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ESSENTIAL MATHEMATICS

UNITS 3 & 4

SECOND EDITION

CAMBRIDGE SENIOR MATHEMATICS FOR QUEENSLAND

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First published 2019
Second Edition 2025
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Cover designed by Sardine Design
Text designed by diacriTech
Typeset by diacriTech
Printed in Singapore by C & C Offset Printing Pte Ltd

A catalogue record for this book is available from the National Library of Australia at www.nla.gov.au

ISBN 978-1-009-51624-2

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About the authors

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Leanne Butler is a Mathematics teacher at Downlands College in Toowoomba. She has over 30 years teaching experience across all levels from Years 7 to 12 at various schools across south-east Queensland and NSW. She has a keen interest in helping students overcome their apprehension towards mathematics by exploring how students learn mathematics and finding real-life relevance for simple and complex mathematical concepts.

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The publishers would also like to thank Kimberley Willocks and Goorlil Consulting for their feedback and contributions.

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Introduction and overview

Cambridge Senior Mathematics for Queensland Essential Mathematics Units 3&4 Second Edition has been written to meet the requirements of the QCAA syllabus to be implemented in Year 12 from 2025. Its four components – the print book, downloadable PDF textbook, online Interactive Textbook and Online Teaching Resource – contain a great range of resources, including fully worked solutions, available to schools in a single package at one convenient price. There are no extra subscriptions or per-student charges to pay.

Overview of the print textbook

1. **Syllabus references** are listed at the beginning of each chapter.
2. **Prior knowledge checks** provide a check of requisite knowledge and skills.
3. **Learning goals** based on the syllabus are given for each section.
4. **What you need to know** boxes list important concepts and principles in concise and accessible format.
5. **Worked examples** detail thinking and the solution in a logical sequence, and are linked to exercises. Video versions are provided in the interactive textbook to encourage independent learning.
6. Exercises are divided into:
   - **Fundamentals** – integrating the Fundamental topic: Calculations throughout the topic, as required by the syllabus.
   - **Applications:** questions in real-life contexts, differentiated into degree-of-difficulty categories as indicated by a strip in the margin:

   Simple Familiar SF Complex Familiar CF Complex Unfamiliar CU

   An exercise that covers only complex subject matter has only CF and CU questions; an exercise that covers only simple subject matter has only SF questions. Some exercises cover both simple and complex subject matter, so have questions in all three categories.

   Applications questions are also differentiated into **learning-style** and **assessment-style**, the latter category being marked by a star ⋆.

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Learning-style questions are scaffolded with steps that guide students to the answer, while assessment-style questions are unscaffolded and are suitable models for examinations or other assessment items. Questions requiring technology other than scientific calculators are learning-style.

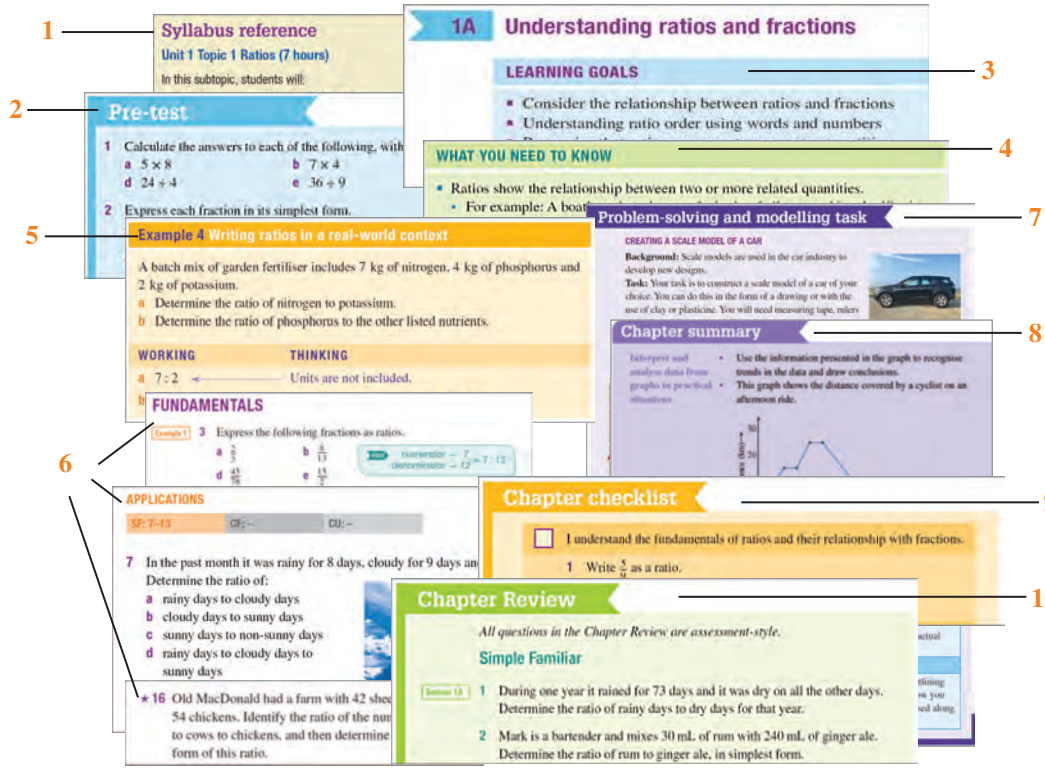
7 **Modelling tasks** are provided for every chapter, set out in stages with a flowchart based on the approach to problem-solving and mathematical modelling used by QCAA.

8 **Chapter summaries** list critical information from the chapter, including important formulas and definitions

9 **Chapter checklists** comprise short questions assessing achievement of learning goals.

10 **Review** exercises contain only assessment-style questions organised under degree-of-difficulty subheadings.

11 Examples and questions using **spreadsheets** are integrated throughout the text, with accompanying Excel files in the Interactive Textbook.



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Downloadable PDF textbook

12 The convenience of a downloadable PDF textbook has been retained for times when users cannot go online.

13 PDF annotation and search features are enabled.

Overview of the Interactive Textbook

The **Interactive Textbook (ITB)** is an online HTML version of the print textbook powered by the HOTmaths platform, included with the print book or available as a separate digital-only product.

14 The material is formatted for on screen use with a convenient and easy-to-use navigation system and links to all resources.

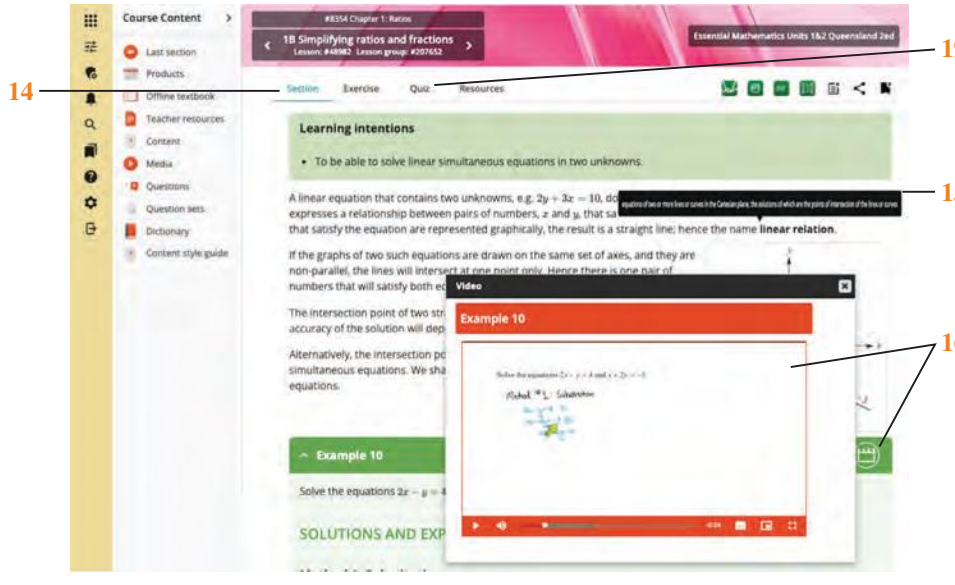
15 **Definitions** pop up for key terms in the text and are also provided in a printable online glossary, while the HOTmaths dictionary is also accessible.

16 Examples have **video versions** to encourage independent learning.

17 The **Desmos scientific calculator**, graphics calculator and geometry tool are also available for students to use for their own calculations and exploration.

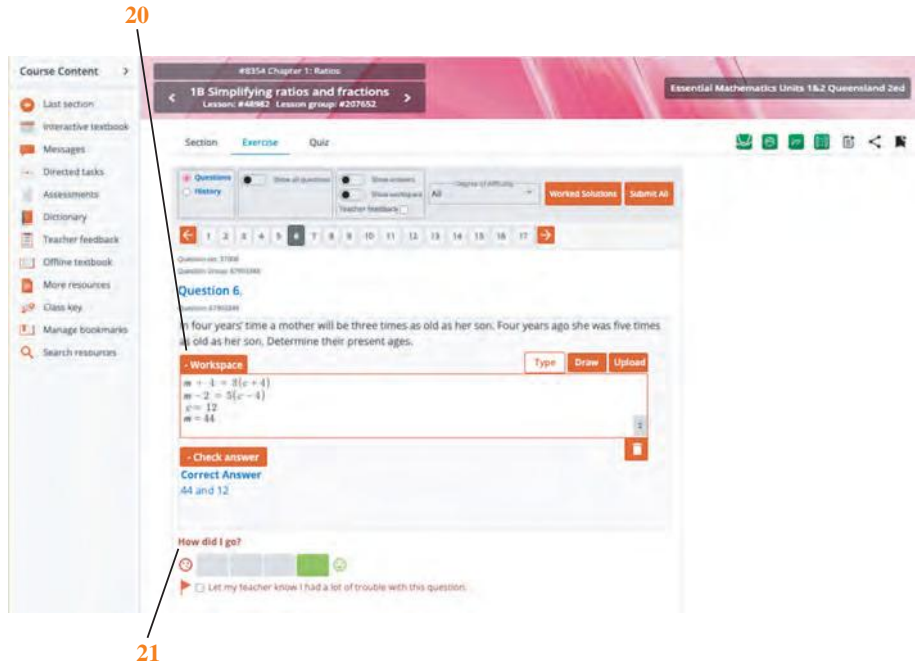
18 **Spreadsheets** are provided in Excel format.

19 **Quick quizzes** containing auto-marked multiple-choice questions enable students to check their understanding.



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20 **Workspaces** enable students to enter working and answers online and to save them. Input is by typing, with the help of a symbol palette, handwriting and drawing on tablets, or by uploading images of writing or drawing.

21 **The self-assessment tools** enable students to check answers, mark their own work, and rate their confidence level in their work. This helps develop responsibility for learning and communicates progress and performance to the teacher. Student accounts can be linked to the learning management system used by the teacher in the Online Teaching Suite.

22 **Worked solutions** are included and can be enabled or disabled in the student accounts by the teacher.

23 **Practice assessment** items are provided in downloadable PDF and Word files.

24 **Online appendices** provide a glossary of terms and cognitive verbs, guides to spreadsheets and the Desmos graphing calculator, links to scientific calculator guides, and guides to problem-solving, modelling and approaching complex unfamiliar problems.

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Online teaching suite

The **Online Teaching Suite (OTS)** is automatically enabled with a teacher account and is integrated with the teacher's copy of the Interactive Textbook. All the assets and resources are in one place for easy access. The features include:

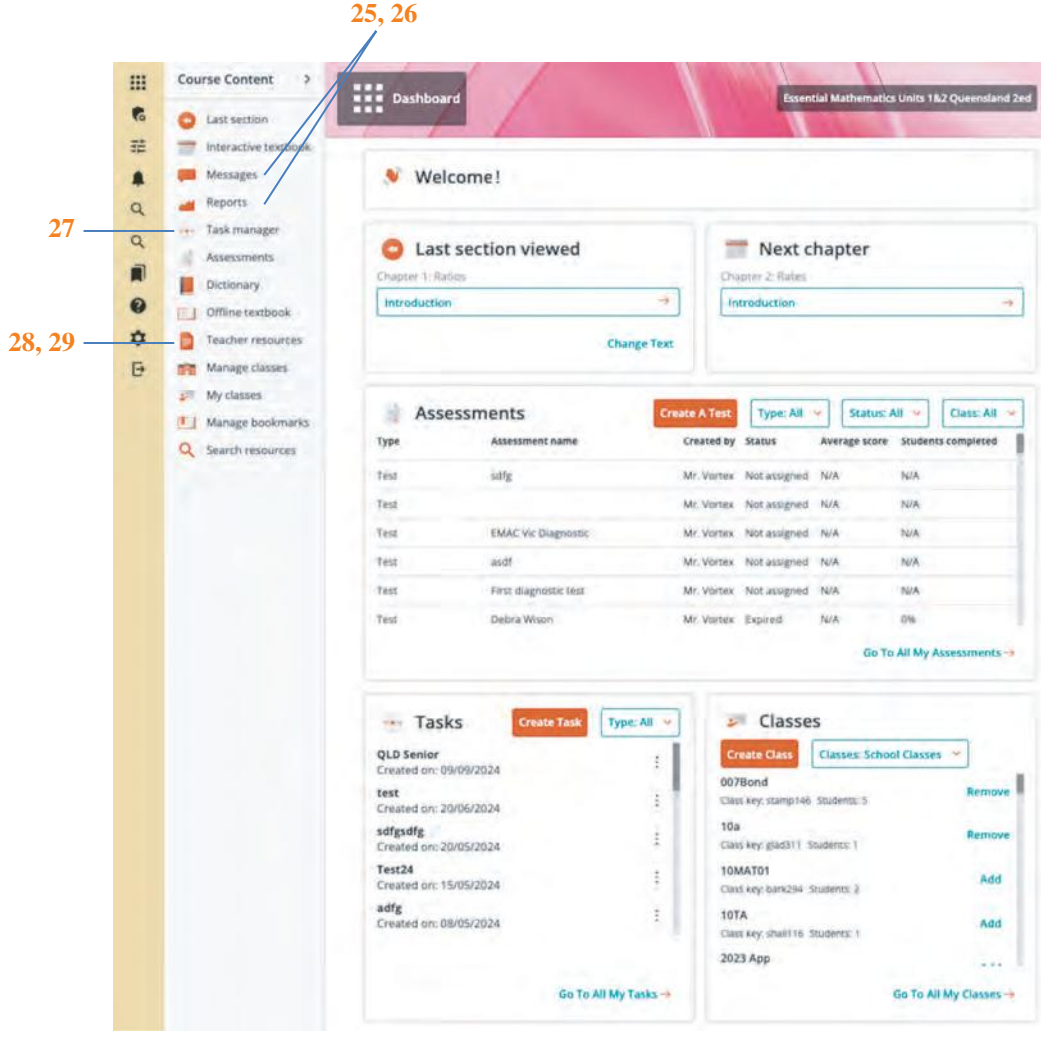
25 **Learning Management System** with class and student analytics, including reports and communication tools

26 Teacher's view of a student's working and self-assessment.

27 **Revamped task manager** allows teachers to incorporate many of the activities and tools listed above into teacher-controlled learning pathways that can be built for individual students, groups of students and whole classes

28 **Chapter test worksheets** as PDFs and editable Word documents.

29 Editable **curriculum grids** and **teaching programs**.



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1 Converting units of measure

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In this chapter

1A Using and converting linear measurements
1B Using and converting between the metric area units
1C Using and converting between metric volume and capacity units
1D Using and converting between units of time
1E Using and converting between metric units of mass
Modelling task
Chapter summary
Chapter checklist
Chapter review

Syllabus reference

Unit 3 Topic 1 Measurement

Converting units of measure (4 hours)

In this sub-topic, students will:

- use metric units of length (millimetres, centimetres, metres, kilometres), their abbreviations (mm, cm, m, km), conversions between them, and appropriate levels of accuracy and choice of units
- use metric units of area (square millimetres, square centimetres, square metres, square kilometres, hectares), their abbreviations (mm^2, cm^2, m^2, km^2, ha), conversions between them and appropriate choices of units
- use metric units of volume (cubic millimetres, cubic centimetres, cubic metres, cubic kilometres), their abbreviations (mm^3, cm^3, m^3, km^3), conversions between them and appropriate choices of units
- understand and use the relationship between volume and capacity, recognising that $1\ cm^3 = 1$ mL (millilitre), $1000\ cm^3 = 1$ L (litre), $1\ m^3 = 1$ kL (kilolitre), 1000 kL $= 1$ ML (megalitre)
- use units of time and convert between fractional, decimal and digital representations
- use metric units of mass (milligrams, grams, kilograms, tonnes), their abbreviations (mg, g, kg, t), conversions between them and appropriate choices of units.

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Prior knowledge check

1 Multiply 2.345 by:

a 10 **b** 100 **c** 1000

2 Divide 369 450 by:

a 10 **b** 100 **c** 1000

3 Write as a normal number without powers:

a 10^2 **b** 1000^2 **c** 100^3

d 10^3 **e** 100^2 **f** 1000^3

4 Evaluate:

a 5×10^2 **b** 0.026×10^3

c $0.000\,124 \times 10^3 \times 100^3$ **d** $875\,000 \div 10^3$

e $0.0545 \div 10^3$ **f** $489\,000\,000 \div 10^3 \div 10^2$

5 State:

a how may minutes are in an hour

b how many seconds are in a minute

c how many weeks are in a year

d how many months are in a year

e how many hours are in a day.

6 Identify the correct unit to measure:

a the weight of a baby (litres, kilogram or hours)

b the time taken to drive from Brisbane to Rockhampton (litres, kilogram or hours)

c the amount of water in a bathtub (litres, kilogram or hours).

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1A Using and converting linear measurements

LEARNING GOALS

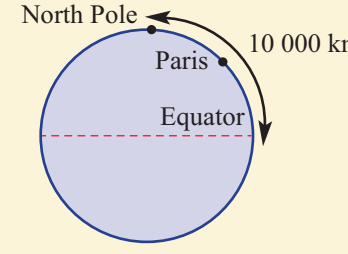
- Use metric units of length (millimetres, centimetres, metres and kilometres).
- Use the abbreviations of mm, cm, m, km to represent units of length.
- Select appropriate units of length.
- Select appropriate units of length for measurement for accuracy.

Why is it essential to understand units of linear measure?

- To assist in purchasing furniture so that it can fit and fill the required space.
- Units of linear measure are used when making clothes, furnishings and cabinetry.

WHAT YOU NEED TO KNOW

- The basic unit used to measure length is the **metre**.
- The **metric system** of measurement originated in France during the French Revolution in the 1790s. Originally, out of a desire to link the measuring system for length with the earth, the **metre** was defined as one ten millionth of the distance between the Equator and the North Pole through Paris i.e. the distance from the Equator to the North Pole was defined as 10 000 000 metres (10 000 km). It took 8 years to measure the distance from the equator to the North Pole.

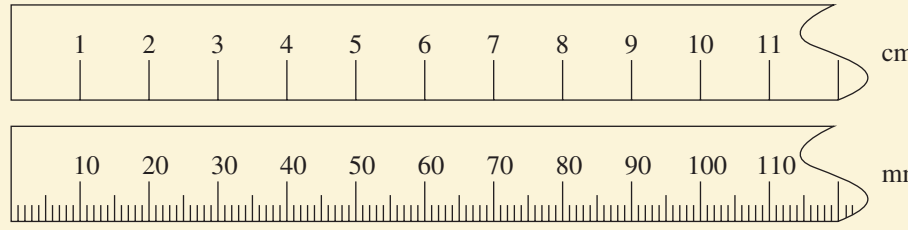


- The common units for measuring length are based on the metre:

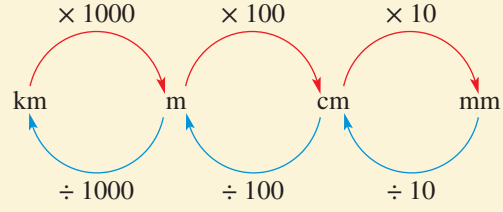
Length unit	Abbreviation	Relationship to 1 m	Best for measuring
Millimetre	mm	1 m = 1000 mm	Small items (e.g. insect or bolt). Millimetres are widely used in the construction industry.
Metre	m	1 m	Large items (e.g. the length of a room)
Centimetre	cm	1 m = 100 cm	Medium sized objects (e.g. height of a child)
Kilometre	km	1 km = 1000 m	Long distances (e.g. distances between towns)

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- When selecting the unit to use for measurement, the degree of accuracy required needs to be considered. For example, for construction, using mm will provide greater accuracy than using cm as shown on these two rulers.



- To convert between linear units:
  - multiply to change from large unit to small unit e.g. km to m
  - divide to change from a small unit to a large unit e.g. cm to m
  - refer to the conversion chart on your formula sheet.



Example 1 Converting between units of measurement

Convert the following measurements into the units given in brackets.

a 6.5 km (m) **b** 25 mm (cm) **c** 0.07 m (mm)

WORKING	THINKING
a $6.5\,\text{km} \times 1000 = 6500\,\text{m}$	Converting from a large unit to a small unit, so multiply by 1000.
b $25\,\text{mm} \div 10 = 2.5\,\text{cm}$	Converting from a small unit to a large unit, so divide by 10.
c $0.07\,\text{m} \times 100 \times 10 = 70\,\text{mm}$	Converting from a large unit to a small unit twice, so multiply by 100 and by 10.

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Example 2 Applying metric units of length

Blake works as a costume designer and he is making costumes for a dance concert. He has worked out that each dancer will need 82 cm of material. There are 8 dancers in the troupe. Determine how many metres of material Blake will need to purchase.

WORKING	THINKING
	Formulate
Required to find total metres of material to make costumes.	What are you required to solve?
Given: 82 cm of material required per dancer, for 8 dancers.	What information do you have?
	Solve
Material = $82 \times 8 = 656$ cm	Multiply material required by the number of dancers.
	Evaluate and verify
Material 656 cm $\div$ 100 = 6.56 m	The answer needs to be in metres. Divide cm by 100.
	Communicate
Blake will need to purchase 6.56 m of material to make 8 costumes.	Write the answer as a sentence.

Exercise 1A

FUNDAMENTALS

Example 1

1 Convert the following measurements into the units given in brackets.

a 5 m (cm)
b 7 cm (mm)
c 20 mm (cm)
d 2 km (m)
e 3.7 m (cm)
f 1.7 km (m)
g 490 cm (m)
h 7 m (mm)
i 1.2 km (mm)
j 3000 cm (km)

Hint If converting from a larger unit to a smaller unit, multiply. If converting from a smaller unit to a larger unit, divide.

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2 Calculate the sum of the following measurements. Express your answer in the units given in the brackets.

a 10 mm, 2 cm (cm)
b 3 m, 200 cm (m)
c 1.5 cm, 10 mm (mm)
d 500 m, 2 km (km)
e 150 cm, 3.5 m (cm)
f 200 m, 1.5 km (m)

3 Determine the most appropriate unit of length (mm, cm, m or km) for the following measurements.

a length of a car
b width of pencil
c length of a ladybeetle
d length of desk
e flight distance from Brisbane to Cairns
f length of fingernail
g length of arm
h height of a giraffe
i distance around the Earth
j distance from London to Cairo

APPLICATIONS

Example 2 ★**4** Jade is an estimator for a building company. A plan shows that a wall in the family room is 5860 mm long. Jade needs the measurement in metres to estimate the cost of the wall panelling. Determine the length of the wall in metres.

★**5** Lachlan is training for a fun run and he runs 4.5 km per day. Determine how many metres Lachlan runs.

★**6** Harrison is looking at house plans to decide which house to build. On one of the house plans, he has measured the length of the master bedroom as 4.2 m. Determine the length of the master bedroom in millimetres.

★**7** At the age of two, Kelly's son is 90 cm. Kelly is told that he will grow to be twice that height. Determine the grown height of Kelly's son in metres.

★**8** Allen is building a garden box for one of his clients. A length of timber is 250 cm long and Allen needs 6 lengths of timber. Determine how many metres of timber in total Allen needs to purchase for the garden box.

SL

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1B Using and converting between the metric area units

LEARNING GOALS

- Understand the use and appropriate choice of the metric units of area including square millimetres, square centimetres, square metres, square kilometres and hectares.
- Use abbreviations such as mm^2, cm^2, m^2, km^2, ha to represent units of area.
- Convert between units of area.

Why is it essential to understand units of area and convert between them?

- Calculating the area of a shape is used in many careers including landscaping, building, painting, clothes making and interior design.
- It is important to convert between units of area so that we can compare sizes of objects that may have been measured in different units.



The floor area may have been calculated in square metres, but the tile size is usually given as dimensions in millimetres, so calculating how many tiles are required will involve conversion of units.

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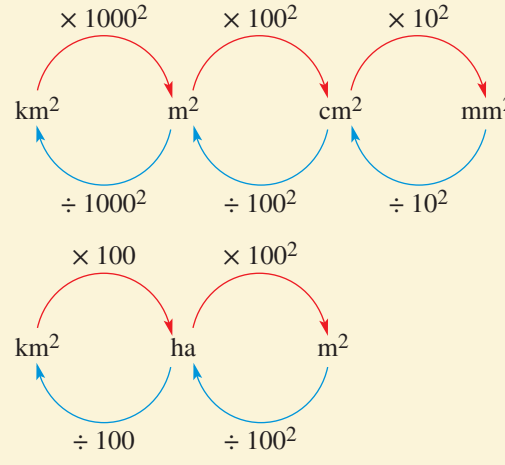
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WHAT YOU NEED TO KNOW

- Area is the measurement of the space enclosed by a two-dimensional shape.
- The common units for measuring area are based on the **square metre**, m^2:

Area unit	Abbreviation	Relationship to 1 m^2	Best for measuring
Square millimetres	mm^2	1 m^2 = 1 000 000 mm^2	Small objects e.g. a precious stone
Square centimetres	cm^2	1 m^2 = 10 000 cm^2	Medium sized objects e.g. the surface of a desk
Square metres	**m^2**	1 m^2	Large areas in a household e.g. floor coverings, walls, house block
Hectares	ha	1 ha = 10 000 m^2	Large parcels of land e.g. a football field is around 1 ha
Square kilometres	km^2	1 km^2 = 1 000 000 m^2	Very large areas of land e.g. area of a city

- To convert between units of area:
  - multiply to change from a large unit to a small unit e.g. m^2 to cm^2
  - divide to change from a smaller unit to a large unit e.g. mm^2 to cm^2
  - refer to the conversion chart of the formula sheet.



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Example 3 Converting between units of area

Convert these area measurements to the units given in brackets.

a $0.72\ \text{km}^2$ (m^2)
b $393\ \text{mm}^2$ (cm^2)
c $34.5\ \text{km}^2$ (ha)
d $800\ \text{m}^2$ (ha)

WORKING	THINKING
a $0.72 \times 1000^2 = 720\,000\ \text{m}^2$	Converting from a large unit to small unit, so multiply by 1000^2.
b $393 \div 10^2 = 3.93\ \text{cm}^2$	Converting from a small unit to large unit, so divide by 10^2.
c $34.5 \times 100 = 3450\ \text{ha}$	Converting from a large unit to small unit, so multiply by 100.
d $800 \div 10\,000 = 0.08\ \text{ha}$	Converting from a small unit to large unit, so divide by 100^2.

Example 4 Converting between units requiring more than one step

Convert these area measurements to the units given in brackets.

a $5\,000\,000\ \text{cm}^2$ (km^2)
b $0.07\ \text{m}^2$ (mm^2)

WORKING	THINKING
a $5\,000\,000 \div 100^2 \div 1000^2$ $= 0.0005\ \text{km}^2$	Converting from a small unit to a large unit, so divide by 100^2 and by 1000^2.
b $0.07 \times 100^2 \times 10^2$ $= 70\,000\ \text{mm}^2$	Converting from a large unit to a small unit, so multiply by 100^2 and by 10^2.

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Example 5 Applying unit conversion to practical problems

Alana has just purchased some new land that is 1.32 ha. Determine the area of Alana's new property in square metres.

WORKING	THINKING
	Formulate
Need to express the area in square metres. Area = 1.32 ha.	What are you required to solve? What information do you have?
	Solve
Area $= 1.32 \times 100^2$ $= 13200\ \text{m}^2$	$\times 100^2$ ha → m^2 from the formula sheet.
	Evaluate and verify
	$1\ \text{ha} = 100^2\ \text{m}^2 = 10\,000\ \text{m}^2$. Answer is more than $10\,000\ \text{m}^2$ so reasonable.
	Communicate
Alana's new property is $13\,200\ \text{m}^2$.	Write your answer in a sentence.

Exercise 1B

FUNDAMENTALS

1 Determine the most appropriate unit of area (mm^2, cm^2, m^2, km^2 or ha) for the following measurements.

a area of a floor rug
b area of a city
c area of a phone screen
d area of a skin cancer
e area of a house block
f area of a farm

Example 3

2 Convert the following measurements to the units given in brackets.

a $5\ \text{m}^2$ (cm^2)
b $7\ \text{cm}^2$ (mm^2)
c $200\ \text{mm}^2$ (cm^2)
d $2\ \text{km}^2$ (m^2)
e $5\ \text{km}^2$ (ha)
f $3.7\ \text{m}^2$ (cm^2)
g $1.7\ \text{km}^2$ (m^2)
h $490\ \text{cm}^2$ (m^2)
i $527\ \text{m}^2$ (ha)
j $5\ \text{mm}^2$ (cm^2)
k $500\ \text{m}^2$ (km^2)
l $3.75\ \text{km}^2$ (ha)

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Example 4 **3** Convert the following measurements to the units given in brackets.

a 7 m^2 (mm^2)
b 0.4 km^2 (cm^2)
c 2800 mm^2 (m^2)
d 1.2 km^2 (mm^2)
e 3000 cm^2 (km^2)

Hint If a length unit is 10 times bigger than another length unit, then its square unit for area is 10^2 times bigger (100 times bigger).

APPLICATIONS

SF

Example 5 ★**4** Anne's property is 2.5 ha. Determine the area of land Anne owns in square kilometres.

★**5** Brisbane covers an area of 15 826 km^2. Determine the area of Brisbane in square metres.



★**6** Molly is making a new dress for her daughter's tiny doll. She has calculated that she needs 19 cm^2 of material. Determine the amount of material that Molly needs in square millimetres.

★**7** Ki is replacing the cover on an old chair. He calculates that he requires 1600 cm^2 of material, which is sold in square metres. Determine the amount of material that Ki needs in square metres.

★**8** Harley's horses each have a paddock of 16 180 m^2 to roam. Determine the total area that her two horses have in hectares.

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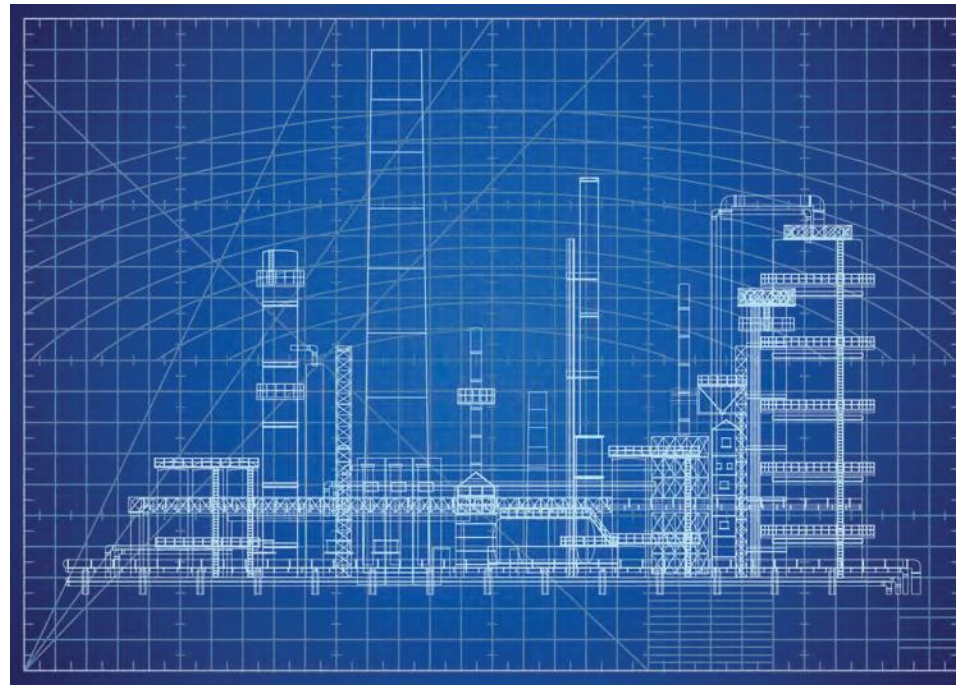
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SF

⋆**9** Kirra works for Surf Life Saving Australia. Part of Kirra's role requires her to wax the rescue boards. She has ten boards in total that have an approximate total surface area of 9200 cm^2 that requires waxing. Determine the total surface area that Kirra will have to wax in square metres.

⋆**10** Jana is laying a small patch of turf in her backyard. She measures the patch to be 3400 mm long by 2100 mm wide, which she calculates to be an area of 7 140 000 mm^2. The turf is sold in square metres. Determine the amount of turf that Jana requires in square metres.

⋆**11** Damien is designing a platform to be able to bear a certain weight and is using a computer program to calculate the strength of the beams he will use. The program requires him to input the area of the cross-section of the beam. He calculated the area of the cross-section of the beam to be 0.018 m^2, but he did not realise that the program requires the area to be in mm^2. Determine the area of the cross-section of the beam in mm^2.



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1C Using and converting between metric volume and capacity units

LEARNING GOALS

- Understand the use and appropriate choice of the metric units of volume including cubic millimetres, cubic centimetres and cubic metres.
- Use abbreviations such as mm^3, cm^3, m^3 and km^3 to represent units of volume.
- Convert between units of volume.
- Understand the relationship between volume and capacity including the conversions between millilitres, litres, kilolitres and megalitres.
- Use abbreviations such as mL, L, KL, ML to represent units of capacity.

Why is it essential to understand units of volume and capacity?

- Many careers, including pool installation, landscaping or storage hire, use volume and capacity.
- The production, storage, distribution and use of materials (whether gas, liquid or solid), require measurement and conversion of volume and capacity.



Measuring volume is a vital skill in laboratories.

WHAT YOU NEED TO KNOW

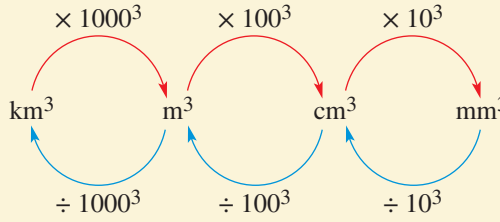
- Volume is the measurement of the amount of space enclosed by a three-dimensional shape.
- The common units for measuring area are based on the **cubic metre**, m^3:

Volume unit	Abbreviation	Relationship to 1 m^3	Best for measuring
Cubic millimetres	mm^3	$1\ m^3 = 1\,000\,000\,000\ mm^3$	Very small solids e.g. the volume of a marble
Cubic centimetres	cm^3	$1\ m^3 = 1\,000\,000\ cm^3$	Small solids e.g. the volume of a candle
Cubic metres	**m^3**	$1\ m^3$	Larger solids e.g. concrete required to pour a house slab
Cubic kilometres	km^3	$1\ km^3 = 1\,000\,000\,000\ m^3$	Very large volumes e.g. the atmosphere or ocean

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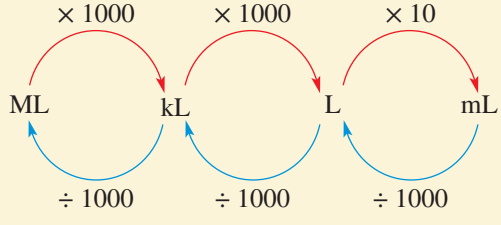
- To convert between units of volume:
  - multiply to change from a large unit to a small unit e.g. m^3 to cm^3
  - divide to change from a small unit to a large unit e.g. mm^3 to cm^3
  - refer to the conversion chart on the formula sheet.



- **Capacity** is the maximum amount that a 3-dimensional container can hold of a substance (solid, liquid or gas).
- The common units for measuring capacity are based on the **litre**:

Capacity unit	Abbreviation	Relationship to 1 L	Best for measuring
Millilitre	mL	1 L = 1000 mL	Very small amounts e.g. sauce in a recipe
Litre	**L**	1 L	Small amounts e.g. water used in a bathtub
Kilolitre	kL	1 kL = 1000 L	Large amounts e.g. water used in a back yard swimming pool
Megalitre	ML	1 ML = 1000 kL = 1 000 000 L	Very large amounts e.g. water released from a dam

- To convert between units of capacity:
  - multiply to change from a large unit to a small unit e.g. L to mL
  - divide to change from a smaller unit to a large unit e.g. mL to kL
  - refer to the conversion chart on the formula sheet.



- To convert between volume and capacity:
  - 1 cm^3 holds 1 mL
  - 1 m^3 holds 1000 L or 1 kL

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Example 6 Converting between units of volume

Convert these volume measurements into the units given in brackets.

a $0.72\ m^3$ (mm^3)
b $10.5\ cm^3$ (mm^3)
c $393\ mm^3$ (cm^3)
d $800\ cm^3$ (m^3)

WORKING	THINKING
a $0.72 \times 100^3 \times 10^3 = 720\,000\,000\ mm^3$	Converting from a large unit to a small unit, so multiply by 100^3 and 10^3.
b $10.5 \times 10^3 = 10\,500\ mm^3$	Converting from large unit to small unit, so multiply by 10^3.
c $393 \div 10^3 = 0.393\ cm^3$	Converting from small unit to large unit, so divide by 10^3.
d $800 \div 100^3 = 0.0008\ m^3$	Converting from small unit to large unit, so divide by 100^3.

Example 7 Converting between units of capacity

Convert these capacity measurements into the units given in brackets.

a 2125 mL (L)
b 0.5 L (mL)
c 2.8 ML (L)

WORKING	THINKING
a $2125\ mL \div 1000 = 2.125\ L$	To convert millilitres to litres, going from a small to a large unit, divide by 1000.
b $0.5 \times 1000 = 500\ mL$	To convert litres to millilitres, going from a large to a small unit, multiply by 1000.
c $2.8 \times 1\,000\,000 = 2\,800\,000\ L$	To convert megalitres to litres, going from a large to a small unit, multiply by 1 000 000.

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Example 8 Converting between units of volume and units of capacity

Convert these volume and capacity measurements into the units given in brackets.

a $325\ cm^3$ (mL) **b** 175 kL (m^3) **c** 2 L (cm^3) **d** $1825\ cm^3$ (L)

WORKING	THINKING
a $325\ cm^3 = 325\ mL$	$1\ cm^3 = 1\ mL$
b $175\ kL = 175\ m^3$	$1\ m^3 = 1\ kL$
c $2\ L \times 1000 = 2000\ mL$ $= 2000\ cm^3$	As there are 1000 mL in a litre, multiply by 1000 to convert to mL, and then use $1\ mL = 1\ cm^3$.
d $1825\ cm^3 = 1825 \div 1000$ $= 1.825\ L$	As there are 1000 cubic centimetres in a litre, divide by 1000 to convert to litres.

Example 9 Applying unit conversion between volume and capacity

Mackenzie works at a plant nursery and has to fill 640 pots with soil. The pots have a capacity of 750 mL. The soil is measured in cubic metres. Determine the approximate amount of soil in cubic metres Mackenzie needs to fill the pots.

WORKING	THINKING
	Formulate
Required to find the volume of soil in m^3. 640 pots Each pot holds 750 mL	What are you required to solve? What information do you have?
	Solve
Total capacity $= 750\ mL \times 640$ $= 480\,000\ mL$	Find total capacity of the pots
Volume $= 480\,000\ cm^3$ $= 480\,000 \div 100^3$ $= 0.48\ m^3$	Convert to required units. $1\ cm^3 = 1\ mL$, and to convert cm^3 to m^3, divide by 100^3.
	Evaluate and verify
	Check the question has been answered. Required answer was to be in m^3 and it is.
	Communicate
Mackenzie needs 0.48 m^3 of soil.	Write your answer in a sentence.

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Exercise 1C

FUNDAMENTALS

1 **a** Determine the most appropriate unit of volume (mm^3, cm^3, m^3 or km^3) for the following measurements.
- **i** amount of soil required for a garden bed
- **ii** size of a grain of rice
- **iii** amount of timber in a chopping board
- **iv** size of an ocean

b Determine the most appropriate unit of capacity (mL, L, kL or ML) for the following measurements.
- **i** size of a car fuel tank
- **ii** amount of water in a town water storage
- **iii** dosage of liquid medicine for a child
- **iv** amount of water in a back yard swimming pool

Example 6

2 Convert these volume measurements to the units given in brackets.

a $0.86\ km^3$ (m^3)

b $18.4\ cm^3$ (mm^3)

c $2.7\ m^3$ (cm^3)

d $276\ mm^3$ (cm^3)

e $1.38\ km^3$ (m^3)

f $68\ cm^3$ (mm^3)

g $129\ cm^3$ (m^3)

h $2.7\ m^3$ (mm^3)

Hint Keep your formula sheet handy.

Example 7, 8

3 Convert these volume and capacity measurements to the units given in brackets.

a $265\ cm^3$ (mL)

b 412 kL (m^3)

c 6 L (cm^3)

d $2128\ cm^3$ (L)

e 27 mL (cm^3)

f 1247 mL (kL)

g 2.7 ML (kL)

h $27.5\ m^3$ (kL)

i 267 kL (ML)

j 0.8 L (mL)

k 628 mL (L)

l 3.2 ML (L)

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APPLICATIONS

Example 9 ★4 Carlene has calculated that to spread mulch to a suitable depth over a garden bed she needs to buy 800 000 cm^3 of mulch. She finds that mulch is sold in cubic metres. Calculate the number of cubic metres of mulch Carlene should order.



★5 Tessa has 1089 m^3 of bitumen that she can use to pave the driveway on her farm. To work out how thick the bitumen layer can be she needs to convert this volume to cubic centimetres. Determine how many cm^3 are in 1089 m^3.

★6 Lee-Ann's pool holds 12 000 L of water. Unfortunately, the pool tiles are damaged, so she has decided to fill the pool in with soil and make a big garden instead. Calculate the number of cubic metres of soil Lee-Ann will need in order to fill the pool.

★7 Jarred works in a factory that makes sugar cubes. A sugar cube with a size of 1 cm^3 is made from 1 mL of liquid sugar. The factory produces 5000 cubes per day. Calculate the number of millilitres of liquid sugar that the factory requires each day.

★8 An Olympic swimming pool has 2.5 megalitres of water. Calculate the number of litres in an Olympic swimming pool.

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★9 A large fuel truck carries around 10 kilolitres of fuel. Calculate how many litres of fuel a large truck can carry.



★10 If all the water in Sydney Harbour was poured into a cubic tank with edges of 1 km, it would fill it to a depth of 562 m. Calculate the number of megalitres of water in Sydney Harbour.



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1D Using and converting between units of time

LEARNING GOALS

- Understand the units of time (milliseconds, seconds, minutes, hours, days, weeks, years).
- Use the abbreviations for units of time (ms, s, min, h, d, wk, mo, yr).
- Convert between fractional, decimal and digital representations of time.
- Recognise appropriate choices for units of time.

Why it is essential to understand units of time

- Humans have been interested in measuring time since the regular cycles of the sun, moon and stars were first noticed.
- Most of our daily activities are measured by time. For example, the duration of a workout, how long a meal will take to cook, how much longer until a show you are watching will finish.
- Converting units of time allows us to plan out our daily activities.

WHAT YOU NEED TO KNOW

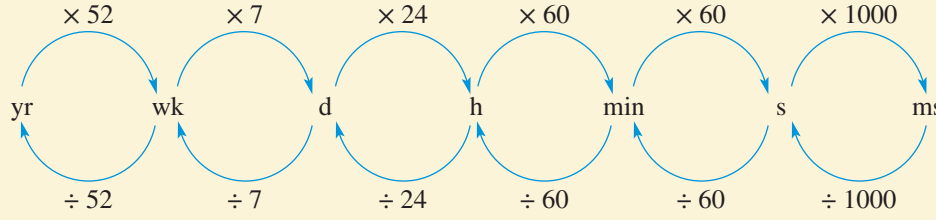
- Time is the measure of the duration to complete an activity. For example, it takes 24 hours for the Earth to complete a full rotation on its axis.
- The SI unit for time is the second (s).
- Common units for measuring time:

Time Unit	Abbreviation	Best for measuring
Millisecond	ms	Very small lengths of time e.g. time to blink
Second	**s**	Small lengths of time e.g. time to run 100 m
Minute	min	Short lengths of time e.g. time to cook a cake
Hour	h	Large parts of a day e.g. work an 8-hours shift
Day	d	Lengths of time greater than 24 hours e.g. a 3-days long weekend
Week	wk	Lengths of time greater than 7 days e.g. a pregnancy takes 40 weeks

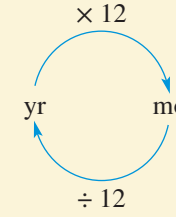
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Time Unit	Abbreviation	Best for measuring
Month	mo	Lengths of time greater than 4 weeks but less than a year e.g. the age of a baby
Year	yr	Long periods of time e.g. a teen can get their Learners permit at 16 years of age

- Use the following conversion chart when solving problems that require conversion of units of time.



- Conversions involving *months* should be converted to a year before converting to the required unit.



- Standard **digital** representation for the time of day uses 2-digit numbers for the hour, minute and second e.g. 7 seconds past 9:15 a.m. is written as 09:15:07.
- Remember from Unit 2: when converting p.m. times to 24-hour time, add 12 hours e.g. 3 seconds past 7:45 p.m. is written 19:45:03.
- To write mixed units of time as a single unit of time with **decimals** involves two steps:

  Step 1: Convert each time unit to the smallest time unit and sum the times together.

  Step 2: Convert to the required unit.

  See Example 11
- To write mixed units of time as a single unit of time with **fractions** involves two steps:

  Step 1: Express each time unit as a fraction of the required time unit.

  Step 2: Sum the fractions together.

  See Example 12

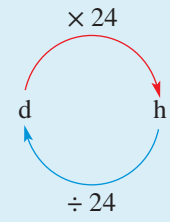
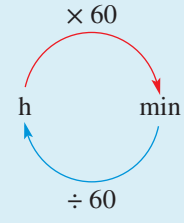
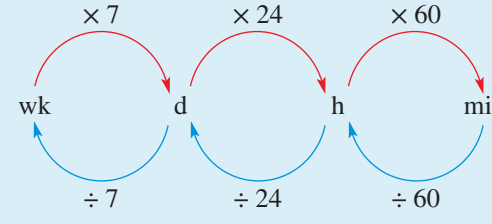
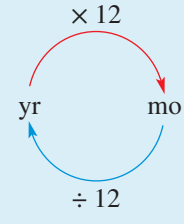
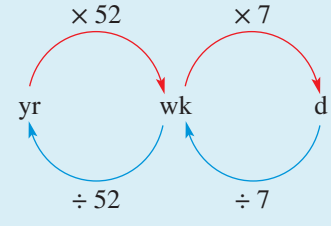
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Example 10 Converting units of time

Convert these time measurements to the units given in brackets

a 3 days (hours)
b 160 min (hours)
c 2 weeks (minutes)
d 36 months (days)

WORKING	THINKING
a $3\text{ d} = 3 \times 24\text{ h} = 72\text{ h}$	
b $160\text{ min} = 160 \div 60 = 2.67\text{ h}$	
c $2\text{ wk} = 2 \times 7 \times 24 \times 60 = 20\,160\text{ min}$	
d $36\text{ mo} = 36 \div 12 = 3\text{ yr}$	
$3\text{ yr} = 3 \times 52 \times 7 = 1092\text{ d}$	

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Example 11 Converting decimal and fraction times to digital representation

Convert the following times to digital representation:

a 1.75 h **b** 3.286 h **c** $7\frac{9}{20}$ h

WORKING	THINKING
a $1.75\text{ h} = 1\text{ h} + 0.75\text{ h}$	Split the whole number and decimal components.
$0.75\text{ h} = 0.75 \times 60\text{ min}$ $= 45\text{ min}$	Convert the decimal component to the next smaller unit.
$1.75\text{ h} = 1\text{ h} + 45\text{ min}$ $= 1{:}45{:}00$	Express the time in digital form.
b $3.68\text{ h} = 3\text{ h} + 0.68\text{ h}$	Split the whole number and decimal components.
$0.68\text{ h} = 0.68 \times 60\text{ min}$ $= 40.8\text{ min}$	Convert the decimal component to the next smaller unit.
$40.8\text{ min} = 40\text{ min} + 0.8\text{ min}$	Still have a decimal → repeat process Split the whole number and decimal components.
$0.8\text{ min} = 0.8 \times 60\text{ s}$ $= 48\text{ s}$	Convert the decimal component to the next smaller unit.
$3.286\text{ h} = 3\text{ h} + 40\text{ min} + 48\text{ s}$ $= 03{:}40{:}48$	Express the time in digital form.
c $7\frac{9}{20}\text{ h} = 7\text{ h} + \frac{9}{20}\text{ h}$	Split the whole number and fraction components.
$\frac{9}{20}\text{ h} = \frac{9}{20} \times 60\text{ min}$ $= 27\text{ min}$	Convert the fraction component to the next smaller unit.
$7\frac{9}{20}\text{ h} = 7\text{ h} + 27\text{ min}$ $= 07{:}27{:}00$	Express the time in digital form.

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Example 12 Expressing time as a decimal

Write 2 h 23 min 12 s in hours using decimals correct to two decimal places.

WORKING	THINKING
$2\text{ h} + 23\text{ min} + 12\text{ s}$ $= (2 \times 60 \times 60)\text{ s} + (23 \times 60)\text{ s} + 12\text{ s}$ $= (7200 + 1380 + 12)\text{ s}$ $= 8592\text{ s}$	Step 1: Convert each time unit to the smallest time unit (seconds) and sum the times together.
$8592\text{ s} = (8592 \div 60 \div 60)\text{ h}$ $= 2.39\text{ h}$	Step 2: Convert to the required unit.

Example 13 Expressing time as a fraction

Write 2 h 23 min 12 s as a fraction of an hour

WORKING	THINKING
$2\text{ h} = 2\text{ h}$ $23\text{ min} = \frac{23}{60}\text{ h}$ $12\text{ s} = \frac{12}{60 \times 60} = \frac{12}{3600}\text{ h}$	Step 1: Express each time unit as a fraction of the required time unit. $1\text{ h} = 60\text{ min}$, therefore $23\text{ min} = \frac{23}{60}\text{ h}$ $1\text{ h} = 60 \times 60\text{ s}$, therefore $12\text{ s} = \frac{12}{60 \times 60}\text{ h}$.
$2\text{ h }23\text{ min }12\text{ s}$ $= \left(2 + \frac{23}{60} + \frac{12}{3600}\right)\text{ h}$ $= \frac{179}{75}\text{ h or } 2\frac{29}{75}\text{ h}$	Step 2: Sum the fraction together. *Use the fraction application on your scientific calculator.

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Example 14 Applications using converting units of time

Calum can maintain a constant walking speed of 5.4 km/h when bushwalking. He is planning a hike that is 17 km long. If he starts the hike at 7:15 a.m., what time is he expected to finish the hike?

WORKING	THINKING
	Formulate
• Need to determine finish time for the hike	What do you need to find?
• Speed = 5.4 km/h Distance = 17 km Start walk at 7:15 a.m.	What information do you have?
• time $= \frac{\text{distance}}{\text{speed}}$ or $\left(t = \frac{d}{s}\right)$	What rules will be useful? *Unit 2.3 Time and motion*
	Solve
$t = \frac{17}{5.4} = 3.148\text{ h}$ $3.148\text{ h} = 3\text{ h} + 0.148\text{ h}$ $0.148\text{ h} = 0.148 \times 60\text{ min}$ $\approx 8.88\text{ min}$ $\approx 9\text{ min}$ Time = 3 h 9 min	Apply the rule $\text{time} = \frac{\text{distance}}{\text{speed}}$. Convert the decimal time to digital time.
Finish time = 7:15 a.m. + 3 h 9 min = 10:24 a.m.	Add time to start time to estimate finish time.
	Evaluate and verify
$5.4\text{ km/h} \approx 5\text{ km/h}$ $d = s \times t$ $d = 3 \times 5 = 15\text{ km}$ At 5 km/h, Calum can walk around 15 km in 3 hours, so answer is reasonable.	Use an estimation technique to check the answer. Apply the rule distance = speed × time.
	Communicate
Calum is expected to finish the walk at 10:24 a.m.	Write the answer in a sentence.

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Exercise 1D

FUNDAMENTALS

Example 10

1 Convert the following times to the units indicated.

a 3 hours (minutes)
b 1 year (minutes)
c 1 week (seconds)
d 28 800 seconds (hours)
e 15 840 minutes (days)
f 140 160 hours (years)

2 Determine the most appropriate unit of time (ms, s, min, h, d, wk, mo, yr) for the following measurements.

a Time to complete a trade qualification
b Time to hear thunder after seeing lighting in the distance
c Time to recover from a broken arm
d Time for a light to turn on once switch is flicked
e Time for a baby to learn to crawl
f Time to boil a kettle

3 State the abbreviation for the following units of time.

a hour
b week
c millisecond
d minute
e month
f second
g year
h day

Example 11

4 Convert the following decimal and fraction times to a digital representation.

a 6.5 h
b 4.33 h
c 28.817 h
d $4\frac{2}{3}$ h
e $6\frac{43}{75}$ h
f $8\frac{38}{100}$ h

Example 12

5 Express the following times in hours as a decimal.

a 2 h 15 min 45 s
b 12 h 0 min 55 s
c 7 h 17 min 20 s
d 19 h 20 min 30 s
e 32 h 40 min 0 s
f 6 h 14 min 38 s

Example 13

6 Express the following times as a fraction of an hour.

a 2 h 15 min 45 s
b 12 h 0 min 15 s
c 7 h 17 min 20 s
d 19 h 20 min 30 s
e 32 h 40 min 0 s
f 6 h 14 min 38 s

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7 Complete the following table

	Time	Digital (h:min:s)	Decimal (h)	Fraction (h)
a	6 h 42 m			
b		03:42:15		
c			5.343 h	
d				$\frac{158}{60}$ h
e	4 h 16 min 12 s			
f		00:07:20		

APPLICATIONS

Example 14

8 Harry can maintain a constant speed of 16 km/h when cycling. He is planning a bike ride that is 45 km long. If he starts the ride at 8:20 a.m., what time is he expected to finish the ride?

Hint $t = \frac{d}{s}$

9 Tom earns $27.40/h. Last week he was paid a gross of $344.78. Determine how many hours he worked. Express your answer in digital format (h:min:s).

10 Jami makes soy candles to sell at the markets. It took 8 h 45 min to make 65 candles. How long does it take to make a single candle? Express your answer in digital format (h:min:s).

Hint Convert time to a single unit.

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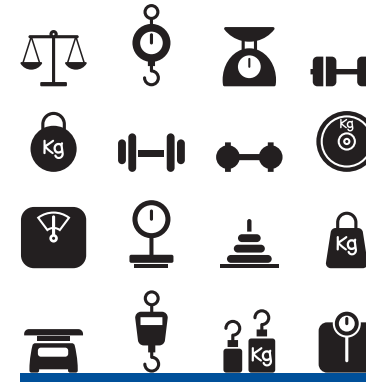
1E Using and converting between metric units of mass

LEARNING GOALS

- Understand the metric units of mass (milligrams, grams, kilograms, metric tonnes).
- Use abbreviations for the metric units of mass (mg, g, kg, t).
- Convert between the metric units of mass.
- Recognise appropriate choices of units.

Why is it essential to use and understand the metric units of mass?

- Understanding how to use and convert mass units is essential in many aspects of life.
- In the transport industry, it is important to know the mass of things being loaded on to trucks and the trucks' maximum load capacity.
- In the health and medical industry, the correct application of metric units of mass is crucial when administering medication.
- In the cooking industry, it is important to be able to convert between mass units in order to follow recipes.



A huge variety of scales for measuring mass are used in everyday life.

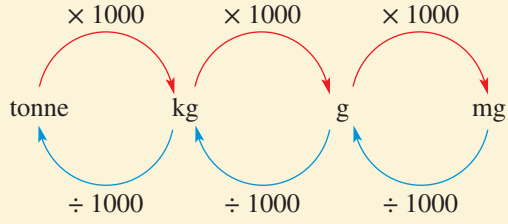
WHAT YOU NEED TO KNOW

- Mass is the amount of matter in an object. In everyday life we measure mass by its weight.
- The common units for measuring mass are based on the **kilogram (kg)**:

Mass unit	Abbreviation	Relationship to 1 kg	Best for measuring
Milligram	mg	1 kg = 1 000 000 mg	Extremely light and small objects e.g. medicine, mosquito, fruit fly
Gram	g	1 kg = 1000 g	Lightweight objects e.g. piece of fruit
Kilogram	**kg**	1 kg	Heavier items e.g. weight of a dog
Tonne	t	1 t = 1000 kg	Very heavy items e.g. a car, truck, whale

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- To convert between units of mass:
  - multiply to change from a large unit to a small unit e.g. tonne to kg
  - divide to change from a small unit to a large unit e.g. grams to kg
  - refer to the conversion chart on the formula sheet.



Example 15 Converting between units of mass

Convert these mass measurements into the units given in brackets.

a 0.7 kg (g)
b 793 500 mg (g)
c 5 t (kg)
d 2.3 kg (mg)
e 6000 mg (kg)

WORKING	THINKING
a $0.7 \times 1000 = 700$ g	Converting from large unit to small unit, multiply by 1000.
b $793\,500 \div 1000 = 793.5$ g	Converting from small unit to large unit, divide by 1000.
c $5 \times 1000 = 5000$ kg	Converting from large unit to small unit, multiply by 1000.
d $2.3 \times 1000 \times 1000$ $= 2\,300\,000$ mg	Converting from large unit to small unit, multiply by 1000 and by 1000.
e $6000 \div 1000 \div 1000$ $= 0.006$ kg	Converting from small unit to large unit, divide by 1000 and by 1000.

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Example 16 Choosing the appropriate unit of mass

Decide on the appropriate mass units that would be used when weighing the following.

a 

b 

c 

d 

WORKING	THINKING
a grams	Grams is a relatively small unit of mass. A teaspoon of sugar would be quite light.
b kilograms	Large dogs look like they could weigh around half what a human weighs. Kilograms would be the most appropriate unit of mass.
c tonnes	Large ships would be extremely heavy; therefore, tonnes would be the most appropriate unit of mass.
d milligrams	Small butterflies are very lightweight; therefore, milligrams would be the best unit of mass.

Example 17 Applying the conversion of units of mass to practical problems

Doug's new caravan weighs 1.93 tonnes.

a Determine the mass of the caravan in kilograms.

b If Doug added 50 kg of food and water plus 35 kg of linen and clothing to his caravan to go away, determine the weight of the caravan now in tonnes.

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WORKING		THINKING
a $1.93 \times 1000 = 1930$ kg	◄	Converting large unit to small unit, multiply by 1000.
Doug's caravan weighs 1930 kilograms.		Communicate your answer in a sentence.
b $1930 + 50 + 35 = 2015$ kg	◄	Use the weight of the caravan in kilograms and add the weight of the food and water and the linen and clothing.
$2015 \div 1000 = 2.015$ t	◄	Converting small unit to larger unit, divide by 1000
Doug's caravan now weighs 2.015 tonnes.	◄	Communicate your answer in a sentence.

Exercise 1E

FUNDAMENTALS

Example 15

1 Convert these mass measurements into the units given in brackets.

a 0.85 kg (g)
b 973 400 mg (g)
c 2300 g (kg)
d 7.5 t (kg)
e 32 g (mg)
f 3570 kg (t)
g 4.7 kg (mg)
h 0.085 t (g)
i 78 000 mg (kg)
j 3 560 000 g (t)

Example 16

2 Decide on the appropriate mass unit (mg, g, kg or t) that would be used when weighing the following objects.

a


b


c


d


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Example 16 ★3 Decide on the appropriate mass units that would be used when weighing the following:

a 

b 

c 

d 

e 

f 

g 

h 

i 

j 

k 

l 

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APPLICATIONS

SF

Example 15 ★4 Shae has had a new baby who weighs 3.45 kg. Determine the weight of Shae's baby in grams.

★5 Jesse works in a food laboratory and needs to know the weight of a steak in milligrams to use in a formula. The supplied steak is labelled as being 450 g. Determine the weight of the steak in milligrams.

★6 The Titanic weighed 52 310 tonnes. Scott needs to know the weight of the ship in kilograms to compare to a table of all the materials used in its construction. Calculate the weight of the Titanic in kilograms.



★7 Esther has an ant farm that has around 420 worker ants inside, and each ant weighs 3 milligrams. Calculate the total weight of the ants in grams.



Example 17 ★8 Jude's caravan weighs 2.9 tonnes.

a Determine the mass of the caravan in kilograms.

b If Jude packs the van with 20 kg of food, 60 kg of water, and 40 kg of linen and clothing, determine the total weight of the caravan in kilograms.

★9 Grace has packed 90 small packets of chips that weigh 45 grams each, ready for a school camp. Determine the total weight of all of the packets of chips in kilograms.



★10 Isaiah has returned from an overseas holiday. When he departed, his bags weighed 25.2 kg. After a three week holiday in Europe, his bags weighed 28.9 kg. Determine the weight in grams of the items that Isaiah purchased overseas.



★11 Ivanna is moving house and has hired a shipping container to store her household items. The shipping container weighs 3.7 tonnes, and she loads it with 9940 kilograms of furniture and homewares. Calculate, in tonnes, the total weight of the shipping container once it has been packed with Ivanna's items.

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Modelling task

Context: A marathon is the ultimate long distance running event. The marathon has been the showcase event at all Olympic games since Athens in 1986. All major cities host annual marathons, and runners come from all around the world to compete in the 42.2 km events.

Task: You are assisting with organising the drinks stations for the Brisbane marathon. You are to calculate how many litres of water you will need for each drink station and how big the storage tanks will be in order to hold enough water for the runners.



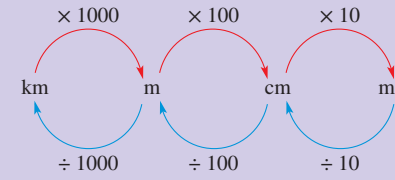
Stage 1: Formulate
Make an assumption of: • the serving size of a drink (in mL) served in a paper cup • how many drink stations will be required. Make an observation of: • the number of competitors who will require a drink.
Stage 2: Solve
• Calculate the amount of water required per drink station in mL and L. • Calculate the volume of the storage tank for each drink station.
Stage 3: Evaluate and verify
Have you answered the question?
Stage 4: Communicate
Write the answer to the problem in a sentence.

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Chapter summary

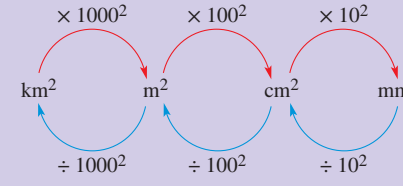
Linear measure

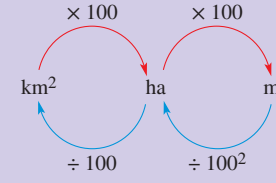
- Linear measure is used to measure length.
- Units and abbreviations:
  - metre (m)
  - kilometre (km)
  - centimetre (cm)
  - millimetre (mm)



Area

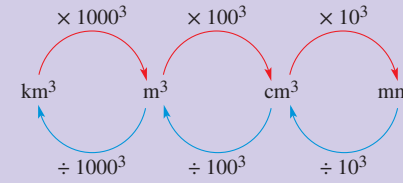
- Area is the measure of the space contained within a 2D shape.
- Units and abbreviations:
  - square metre (m^2)
  - square centimetre (cm^2)
  - square millimetre (mm^2)
  - square kilometre (km^2)
  - hectare (ha)





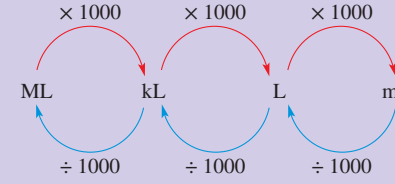
Volume

- Volume is the measure of the space taken up by a 3D shape.
- Units and abbreviations:
  - cubic metre (m^3)
  - cubic centimetre (cm^3)
  - cubic millimetre (mm^3)
  - cubic kilometre (km^3)



Capacity

- Capacity is the maximum amount that a 3-dimensional container can hold of a substance (solid, liquid or gas).
- Units and abbreviations:
  - litre (L)
  - millilitre (mL)
  - kilolitre (kL)
  - megalitre (ML)
- Relationship to volume:
  - 1 cm^3 can hold 1 mL
  - 1 m^3 can hold 1 000 L or 1 kL.

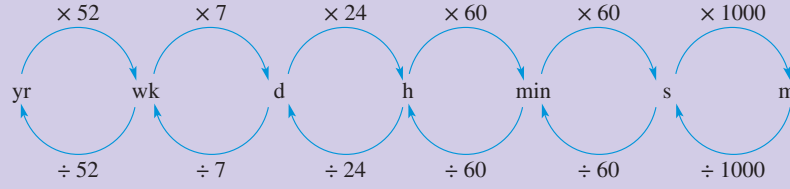


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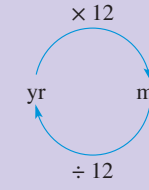
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Time

- Time is the measure of the duration to complete an activity.
- Units and abbreviations:
  - millisecond (ms)
  - second (s)
  - minute (min)
  - hour (h)
  - day (d)
  - week (wk)
  - month (mo)
  - year (yr)

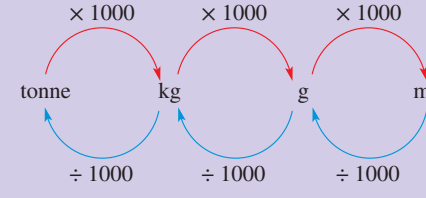


- All conversions involving months need to be converted to years first.
- 24-hour time indicates how much time has passed from midnight.



Mass

- Mass is the amount of matter in an object. We measure mass by its weight.
- Units and abbreviations:
  - milligram (mg)
  - gram (g)
  - kilogram (kg)
  - tonne (t)



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Chapter checklist

1A ☐ I can use the metric units for length and their abbreviations.

1 Write the abbreviation for:
- **a** metres
- **b** millimetres
- **c** centimetres
- **d** kilometres.

☐ I can convert between metric units for length.

2 The length of a queen bed is 203 cm. Write this in metres.

☐ I can choose the appropriate unit of length to use for accuracy.

3 The length of a pencil is closest to 16 ____ (mm/cm/m).

1B ☐ I can use the metric units for area and their abbreviations.

4 Write the abbreviation for:
- **a** square metres
- **b** square millimetres
- **c** hectares
- **d** square centimetres.

☐ I can convert between metric units for area.

5 A house block is 1.5 ha. Convert this to m^2.

☐ I can choose the appropriate unit of area to use for accuracy.

6 The area of a bedroom is closest to 12____ (cm^2, m^2, ha).

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1C

☐ I can use the metric units for volume and their abbreviations.

7 Write the abbreviation for:
- **a** cubic metres
- **b** cubic centimetres
- **c** cubic kilometres.

☐ I can convert between metric units for volume.

8 The volume of a water tank is 12 000 000 cm^3. Write this measurement in m^3.

☐ I can choose the appropriate unit of volume to use for accuracy.

9 The volume of an orange is closest to 300 ____ (mm^3, cm^3, m^3).

☐ I can use the metric units for capacity and their abbreviations.

10 Write the abbreviation for:
- **a** millilitre
- **b** litre
- **c** kilolitre
- **d** megalitre.

☐ I can convert between metric units for capacity.

11 The capacity of a water tank is 12 kL. Convert this to litres.

☐ I can choose the appropriate unit of capacity to use for accuracy.

12 A recipe asks for 2 cups of chicken stock. This is the same as 500 _____ (mL, ML, L).

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1D ☐ I can use the units for time.

13 Write the abbreviation for:
- **a** minute
- **b** hour
- **c** second
- **d** year.

☐ I can convert between the units for time.

14 Convert 250 mins to hours.

1E ☐ I can use the metric units for mass and their abbreviations.

15 Write the abbreviation for:
- **a** gram
- **b** kilogram
- **c** tonne
- **d** milligram.

☐ I can convert between metric units for mass.

16 A baby weighed 3850 g at birth. Convert this to kilograms.

☐ I can choose the appropriate unit of mass to use for accuracy.

17 When weighing ingredients for a recipe, the best units to use are _____ (kilogram, tonne, grams, milligrams).

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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

1A **1** A warehouse receives a shipment of widgets, but they have all been labelled with their lengths in the wrong units for their particular uses. Convert the measurements to the units shown in brackets so that they can be correctly labelled.

a 38 m (cm)
b 15 cm (mm)
c 44 mm (cm)
d 1.79 m (cm)

2 Use abbreviations to identify the most appropriate unit of length to measure each of these:

a length of a guinea pig
b height of a large tree
c length of a bolt
d distance between towns

1B **3** Daniel is painting a 19.2 m^2 feature wall in his house. Determine the area of Daniel's wall in square centimetres.

4 Lyla's horse paddock is 27 190 m^2, where her 3 horses roam. Determine the area of the horse paddock in hectares.

5 Ben has calculated that his front door is 1 810 000 mm^2. Determine the area of the front door in square metres.

1C **6** Brian has spread 2987 cm^3 of soil. Calculate the volume of soil in cubic metres.

7 Ken's spa holds 1400 L of water. Calculate the capacity of the spa in cubic centimetres.

1D **8** Convert the following.

a 3 hours to minutes
b 2 weeks to hours
c 3.87 hours to seconds
d 768 days to years

9 Change the following times in the format shown.

a 6.4 h to digital
b 04:25:30 to decimal hours
c $6\frac{5}{6}$ h to digital
d 07:45:20 to a fraction of an hour

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1E **10** Andrew has a box of 80 bolts that weigh 120 g each. Calculate the total weight of the box of bolts in kilograms.



11 Ronslee is packing for an overseas holiday. She has carry-on luggage that weighs 660 g, plus luggage that goes in the hold that weighs 22.7 kg. Determine the total weight of Ronslee's luggage in kilograms.

12 Decide on the appropriate units for weighing the following living things.

a



b



c



d



13 Select which mass is most likely accurate for the following objects.

a A banana weighs around:

i 1 kg **ii** 130 g **iii** 27 mg

b A grasshopper weighs around:

i 3 g **ii** 1 kg **iii** 60 mg

c A hippopotamus weighs around:

i 3 t **ii** 692 kg **iii** 999 mg

d A blade of grass weighs around:

i 0.5 t **ii** 100 mg **iii** 65 g

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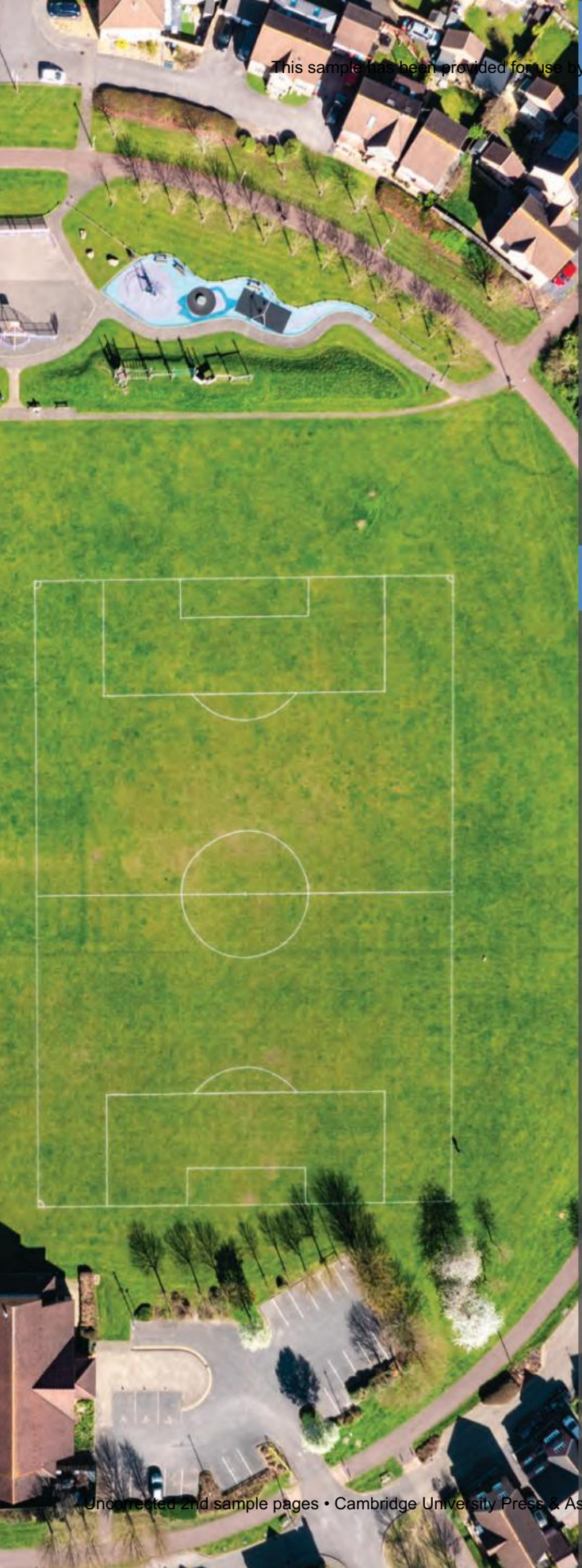
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2 Geometry and linear measure



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In this chapter

2A Recognising common 2D geometric shapes and 3D solids

2B Investigating nets of 3D solids **[complex]**

2C Estimating lengths

2D Calculating perimeters of familiar shapes

2E Calculating perimeters of familiar composite shapes **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 3 Topic 1 Measurement

Geometry (3 hours)

In this sub-topic, students will:

- recognise the properties of standard polygons, e.g. number of vertices, straight edges and angles
- recognise the properties of prisms and pyramids, e.g. number of vertices, straight edges and flat faces
- interpret different forms of two-dimensional representations of three-dimensional objects, including nets of prisms and pyramids [complex].

Linear measure (5 hours)

In this sub-topic, students will:

- estimate lengths
- calculate perimeters of standard polygons, circles and arc lengths
  - circle: $C = 2\pi r$ where C is circumference and r is radius
  - arc length: $l = \frac{\theta}{180}\pi r$ where l is arc length, θ is central angle and r is radius.
- calculate perimeters of composite shapes **[complex]**.

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Prior knowledge check

1 Determine the number of:

a sides in a rectangle

b corners in a rectangle

c edges in a cube

d corners in a cube.

Hint Drawing a diagram may help you to determine the properties or features of a shape or solid.

2 Identify:

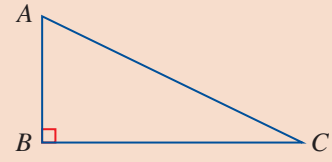
a the unit of measure for angles

b the number of angles in a triangle.

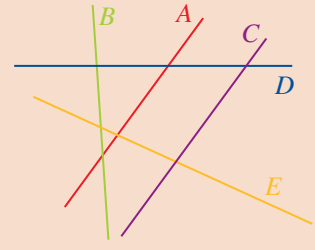
3 Identify:

a the right angle in the diagram shown

b the size of a right angle in degrees.



4 Determine which of the following lines are parallel lines.

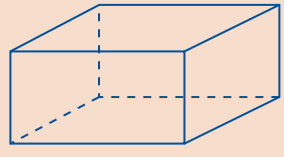


5 For each 3D solid:

i count the number of faces

ii name the 2D shape of each face.

a



b



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2A Recognising common 2D geometric shapes and 3D solids

LEARNING GOALS

- Identify the names and properties of standard polygons including number of:
  - vertices
  - edges
  - angles.
- Identify the names and properties of prisms and pyramids including number of:
  - vertices
  - edges
  - flat faces.

Why is it essential to identify the names and properties of various shapes?

- Shapes and solids are used and seen everywhere.
- It is important to understand the properties of shapes when learning measurement, as the properties can be used to describe and create shapes.
- The properties of shapes can be used in careers such as landscaping, building and engineering.



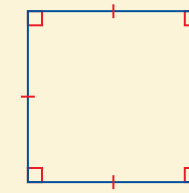
Modern machines can create extremely complex shapes.

WHAT YOU NEED TO KNOW

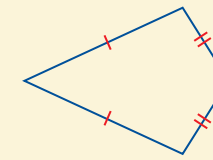
- **Two-dimensional (2D)** shapes are flat. They have only two dimensions, such as length and width. Examples of 2D shapes include square, rectangle, triangle, trapezium, parallelogram, rhombus, kite and hexagon.
- **Three-dimensional (3D)** solids include a third dimension of depth or height. Examples of 3D solids include sphere, cone, cylinder, cube, rectangular prism and triangular prism.

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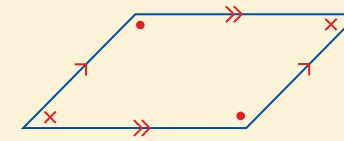
- **Properties** are the description of the shape or solid. The properties of 2D shapes include the number of **sides**, the number of **vertices**, whether the sides are equal, the size of **angles**, whether the angles are equal, and whether the sides are **parallel**. The properties of 3D solids include the number of **faces, edges** and vertices.
- Markings to show properties of 2D shapes
  - Boxed corners represent an angle of 90°. Small ticks on the sides represent equal side lengths.



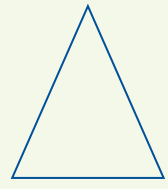
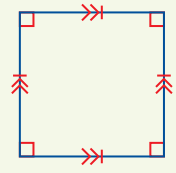
  - Double markings show another set of equal sides. These sides are not the same length as the single marked sides.



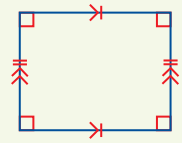
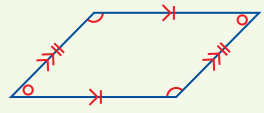
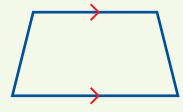
  - Arrows represent parallel lines. Double arrows show another set of parallel lines. Small crosses, dots and arcs can be used to show equal angles.



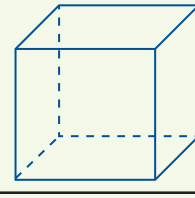
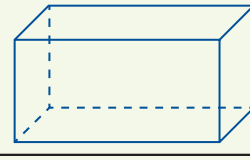
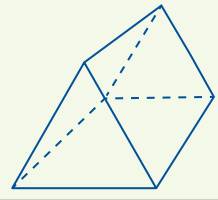
- A **vertex** (plural: vertices) is an angular point on a shape or solid. It is where two or more lines or edges meet.
- 2D shape properties:

Shape	Properties
Triangle 	3 sides 3 vertices All angles add to 180°
Square 	4 sides 4 vertices All sides are equal All angles are 90° All angles add to 360° Two pairs of parallel sides

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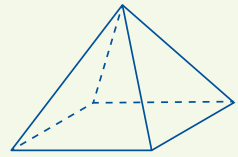
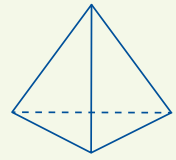
Rectangle 	4 sides 4 vertices All angles are 90° All angles add to 360° Opposite sides are parallel Opposite sides are equal
Parallelogram 	4 sides 4 vertices All angles add to 360° Opposite sides are parallel Opposite sides are equal Opposite angles are equal
Trapezium 	4 sides 4 vertices All angles add to 360° One pair of parallel sides

- A **prism** is a 3D solid with the same shape through its cross section. It is named by the cross-sectional shape.
- Properties of prisms:

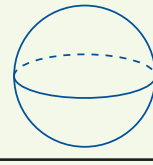
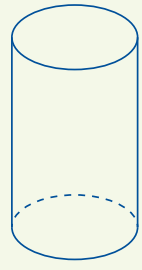
Solid	Properties
Cube 	6 faces 8 vertices 12 edges All faces are squares
Rectangular prism 	6 faces 8 vertices 12 edges All faces are rectangles
Triangular prism 	5 faces 6 vertices 9 edges Three faces are rectangles Two faces are triangles

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- A **pyramid** is a 3D solid that comes to a point.
- Properties of pyramids:

Solid	Properties
Square-based and rectangular-based pyramid 	5 faces 8 edges 5 vertices Base is either a square or a rectangle Four faces are triangles
Triangular-based pyramid (tetrahedron) 	4 faces 4 vertices 6 edges All four faces are triangles

- 3D shapes with curved sides cannot be classified as a prism or pyramid.
- Properties of curved solids:

Solid	Properties
Sphere 	No faces, vertices or edges An evenly curved surface Perfectly symmetrical
Cone 	1 face (circular base) 1 vertex no (straight) edges One curved surface around the circle
Cylinder 	2 faces (top and bottom) No vertices no straight edges One curved surface that flattens to a rectangle

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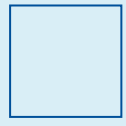
Example 1 Identifying the properties of 2D shapes

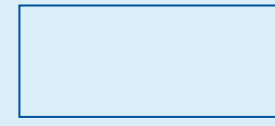
Complete the following for each of the shapes shown.

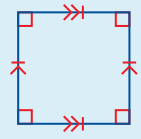
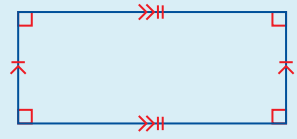
i Identify the name of the shape.

ii Draw the shape.

iii Mark in its properties.

a 

b 

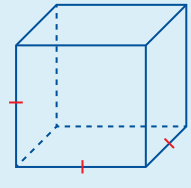
WORKING	THINKING
a i Square	
ii, iii 	All angles are 90 degrees. All sides are equal. Two pairs of parallel sides.
b i Rectangle	
ii, iii 	All angles are 90 degrees. Two pairs of parallel sides. Opposite sides are equal.

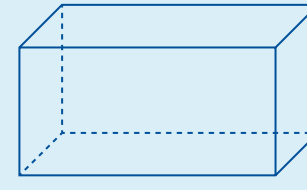
Example 2 Identifying the properties of 3D solids

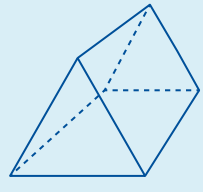
Complete the following for each of the solids shown.

i Identify the name of the solid.

ii Identify the number of faces, edges and vertices.

a 

b 

c 

... Continued

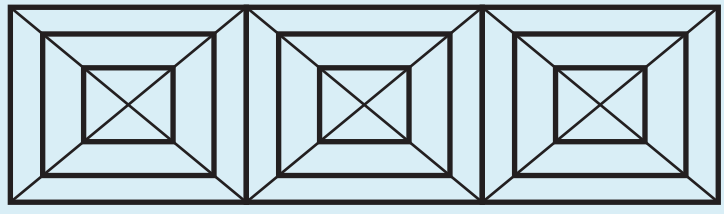
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WORKING	THINKING
a i Cube ii 6 faces, 12 edges and 8 vertices	Faces – count the number of flat sides on each solid.
b i Rectangular prism ii 6 faces, 12 edges and 8 vertices	Edges – count the number of edges (where two faces meet) on each solid.
c i Triangular prism ii 5 faces, 9 edges and 6 vertices	Vertices – count the number of angular points on each solid.

Example 3 Identifying 2D shapes in a real-world context

Valerie has designed a new fence that she would like to place along the front of her house. Identify the 2D shapes in each panel of the fence shown.



WORKING	THINKING
Triangles Trapeziums Rectangles	Look for shapes that are common 2D shapes. Triangles are in the centre of the fence panels. Each panel is a rectangle, and the trapeziums are between the triangles and rectangles in each frame.

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Exercise 2A

FUNDAMENTALS

1 Identify each 2D shape **a–f** with the correct name from the list **A–F**.

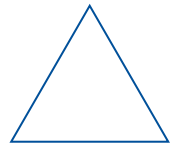
a



b



c



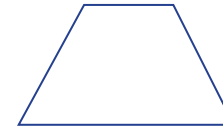
d



e



f



A parallelogram
B trapezium
C triangle
D rectangle
E rhombus
F square

2 Copy the table and tick the boxes to show the correct properties for each of the following shapes.

Property	Square	Rectangle	Parallelogram	Trapezium	Triangle
Four sides					
Three sides					
All sides are equal length					
All angles measure 90°					
Not all angles measure 90°					
Two pairs of parallel sides only					
Two pairs of parallel sides of different lengths					

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Example 1

3 Complete the following for each of the shapes shown.

i Identify the name of the shape.

ii Draw the shape and mark in its properties.

iii Describe the properties of each shape.

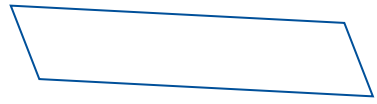
a



b



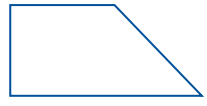
c



d



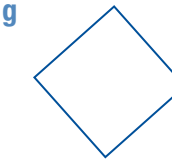
e



f



g

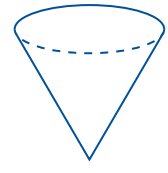


4 Identify each 3D solid **a–g** with the correct name from the list **A–G**.

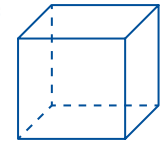
a



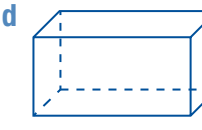
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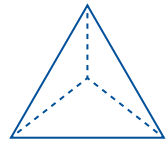
c



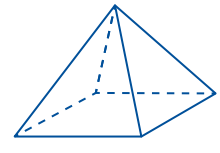
d



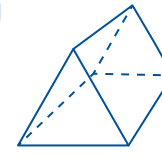
e



f



g



A cube

B triangular prism

C rectangular prism

D triangular-based pyramid (tetrahedron)

E square-based pyramid

F cone

G cylinder

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5 Determine the missing words in the following sentences.

a The flat surface on a 3D solid is called the _____.

b The vertex or vertices describe the _____ of a 3D solid.

c A side of a 3D solid where two faces meet is called the _____.

Example 2

6 Using the properties of 3D solids, determine the blank spaces in the following table.

Name of solid	Faces	Edges	Vertices
	6	12	8
Triangular prism			
	5	8	5
Triangular-based pyramid			

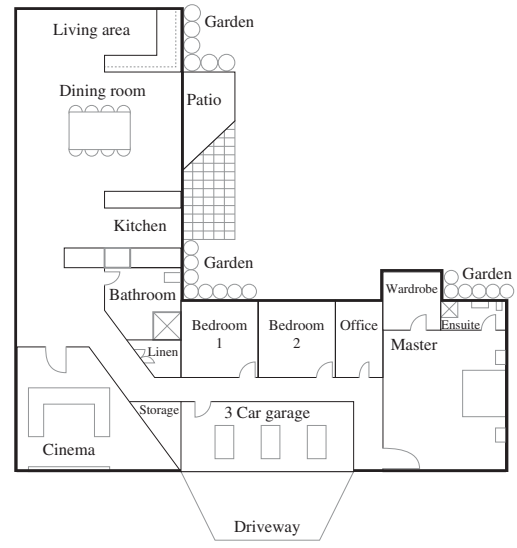
APPLICATIONS

Example 3 ⋆**7** Cubism was a revolutionary style of art that was created by Pablo Picasso and Georges Braque around 1907. It is typically characterised by the use of geometric planes and shapes, similar to the image shown. Identify and create a list of the various 2D shapes within the image.



SF

⋆**8** Sophia has designed the house plan shown. Identify as many 2D shapes as possible and explain what each shape represents in the house.



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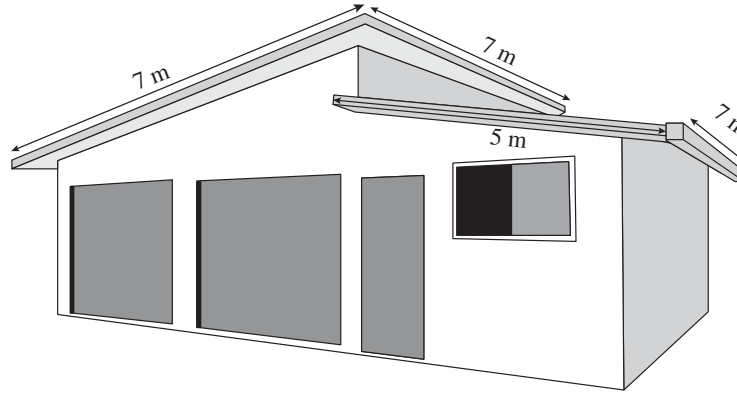
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★9 Ella has just built a new shed for her dance studio.

a Identify the 2D shapes that make up the design of the front of her shed.

b Identify the 2D shapes that make up the design of the sides of her shed.

c Use the roof measurements to identify the 2D shapes that make up the two separate roof designs.



★10 Billy and Alana are looking to buy a block of land in a new housing estate. Each block has been numbered in the plan shown below. Identify which blocks are shaped like a:

a rectangle b parallelogram c trapezium.



Source AV Jennings

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⋆11 Identify the name of the 3D solid that is most similar to the following real-life objects.

a 

b 

c 

d 

e 

f 

g 

h 

i 

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2B Investigating nets of 3D solids

COMPLEX

LEARNING GOALS

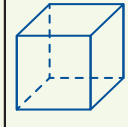
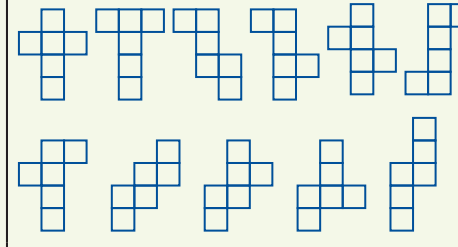
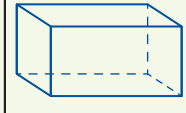
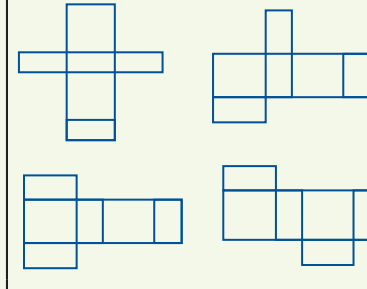
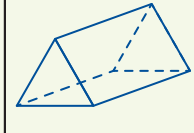
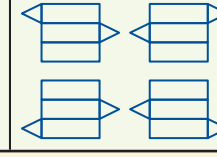
- Interpret various 2D representations of 3D solids in the form of a net, including:
  - prisms
  - pyramids.

Why is it essential to interpret 2D representations of 3D solids?

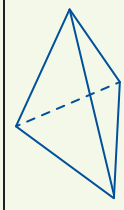
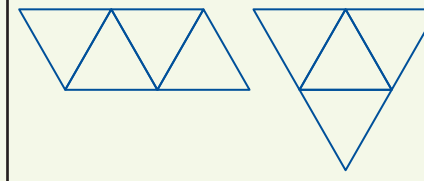
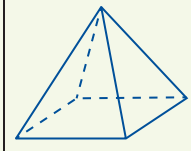
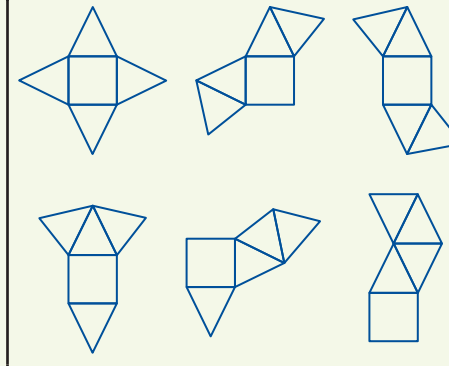
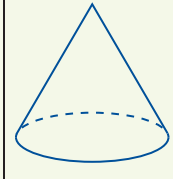
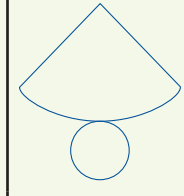
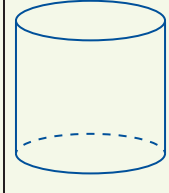
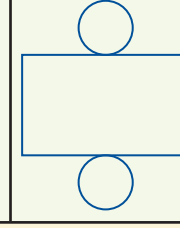
- Creating a 2D form of a 3D solid helps us to communicate the exact dimensions and shapes required to create the solid.
- The concept of designing and creating an object in a solid state requires good communication to the manufacturer, and the best way for this to take place is in the form of a 2D plan.

WHAT YOU NEED TO KNOW

- A **net** is a flat shape (2D) that can be folded up into a 3D solid. A 3D solid can have more than one type of net.

3D solid	3D image	2D net representations
Cube		
Rectangular prism		
Triangular prism		

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3D solid	3D image	2D net representations
Triangular-based pyramid		
Square-based pyramid		
Cone		
Cylinder		



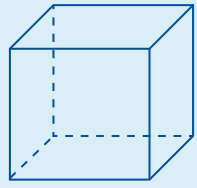


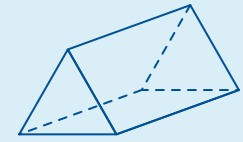
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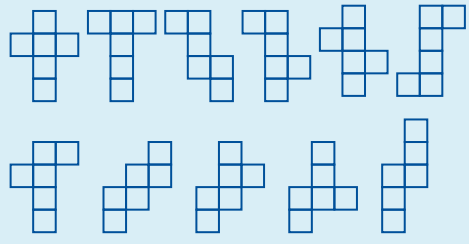
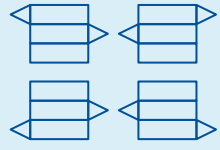
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Example 4 Constructing a 2D net of a 3D solid

Construct a net that represents the following 3D solids.

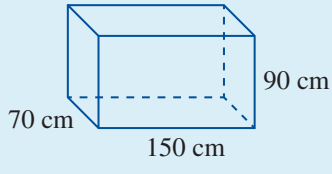
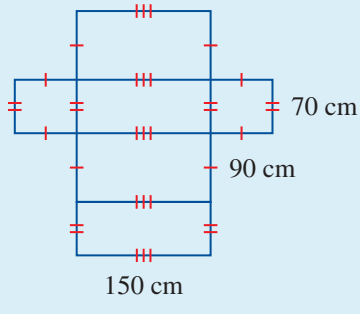
a 

b 

WORKING	THINKING
a 	There are many possible solutions to the design of both nets, all of which are accurate. Check that you have the correct number of faces, edges and vertices to form the solid.
b 	

Example 5 Creating a 2D net from a 3D object

Kenji has purchased a rectangular television cabinet that is 90 cm high, 70 cm deep and 150 cm long. Construct the net of this cabinet, showing the measurements.

WORKING	THINKING
	First draw a sketch of the 3D object with the dimensions.
	Draw the net of a rectangular-based prism. The net includes two rectangles with length 150 cm and width 90 cm. The net includes two rectangles with length 150 cm and width 70 cm. The net also includes two rectangles with length 90 cm and width 70 cm.

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Exercise 2B

FUNDAMENTALS

1 Investigation. Open out some boxes of different shapes to see the net. Draw the box in its original shape and the net required to build it.

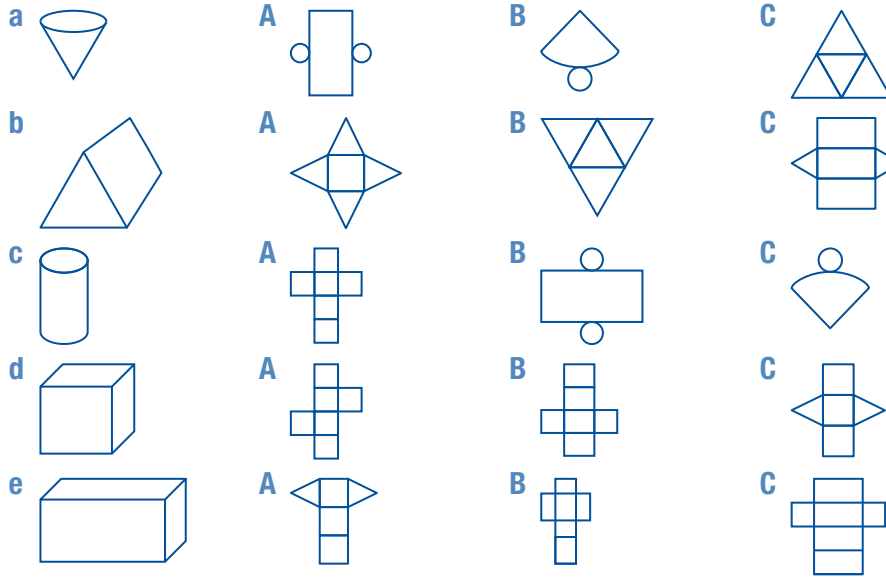
a Toblerone



b Weet-Bix



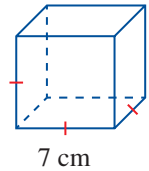
2 Determine the correct net (**A**, **B** or **C**) for each of the following solids.



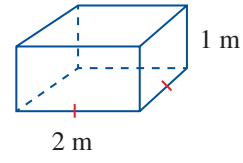
Example 4

3 Draw two different nets for each of the following 3D solids, ensuring that you include the measurements.

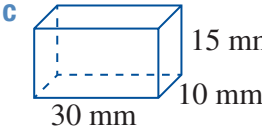
a



b

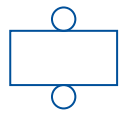


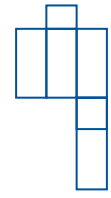
c

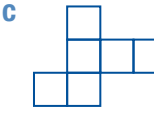


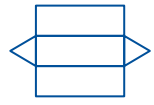
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★4 Match the following nets that are most similar to each of the real-life items in Exercise 2A Question 11 (there may be more than one real-life object per net).

a 

b 

c 

d 

e 

f 

APPLICATIONS

CF

★5 Ahmed is planning to construct a large cube as part of a sculpture that he is creating as a display for the front of a hotel. He will be making the cube out of sheet metal. In order to make the cube, he must first cut out the net of the cube. He will then fold the sheet metal into a cube and weld it together.

a Design and draw a net of the cube.

b Identify how many folds Ahmed will need to make in order to construct the cube.

CU

Example 5 ★6 Josh has just purchased a storage box for his son's bedroom. The box has come in a flat pack. The first step on the assembly instructions is to lay out the timber pieces in the form of a net. Draw the net design, including the measurements of the box.



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2C Estimating lengths

LEARNING GOALS

- Identify the most appropriate unit of length for a measurement.
- Estimate the length of objects.

Why is it essential to be able to estimate lengths?

- Estimation techniques are used to work out a rough measure of lengths required in construction, gardening and dressmaking.
- Sportspeople will also estimate lengths and distances in golf, football and netball.

WHAT YOU NEED TO KNOW

- Units for lengths of linear measure were covered in Section 1A.
- **Estimating** lengths is the application of your knowledge and skills of measuring lengths to approximately guess the length of an object. Estimation mainly takes place through physical, mental and comparative techniques.
  - Physical – knowing the length of a hand span or walking pace length can help to estimate the length of an object. For example, if an adult's pace length is around 1 metre, then the length of a room can be estimated based on the number of paces.
  - Mental – recalling the approximate length of an item and comparing this knowledge to a similar item that is being estimated. For example, recalling the approximate length of a 30 cm ruler can help to estimate the length of a desk.
  - Comparative – knowing the height of a particular item and using this measurement to compare the height to another object nearby. For example, the height of a house may be used to estimate the height of a nearby tree.



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Example 6 Estimating lengths using a physical technique.

Ash is building a new home and wants to estimate the length of a proposed garden bed. She has a 5 m tape measure and measures that she can walk 7 paces in 5 m.

a Calculate the length of a single pace.

b She steps out the length of the proposed garden bed and counts 25 steps. Calculate the estimated length of the proposed garden bed to the nearest metre.

WORKING	THINKING
a 5 m/7 paces 0.714 m/1 pace Each pace is approximately equal to 0.714 m in length.	Write the pace length as a rate. Simplify by dividing both sides by 7. Interpret answer.
b 0.714 m/1 pace 17.85 m/25 paces $\approx$ 17.9 m The proposed garden bed is estimated to be about 18 m long.	Write known rate. Multiply both sides by the number of paces. Interpret the answer and round to nearest whole number.

Example 7 Estimating lengths using a comparative method.

The length of a pen is around 14 cm without a lid. Use a pen to estimate the length and width of this page to the nearest cm.

WORKING	THINKING
Width fits around $1\frac{1}{3}$ pens	Lay pen along base of the page. Count how many 'pens' wide the page is.
Width $= 1\frac{1}{3}$ pens $= 14 + \frac{1}{3} \times 14$ $= 14 + 4.7$ $= 18.7 \approx 19$ cm	
Length fits around $1\frac{5}{6}$ pens	Length fits just short of two pens. Count how many of the 'overhangs' fit along the pen to estimate the fraction.
Length $= 1\frac{5}{6}$ pens $= 14 + \frac{5}{6} \times 14$ $= 14 + 11.7$ $= 25.7 \approx 26$ cm	

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The length of this page is estimated to be 26 cm. ◄····· Write answer in a sentence.

The width of this page is estimated to be 19 cm.

Exercise 2C

FUNDAMENTALS

1 A good way to estimate the length of an object is to compare it to the length of a familiar object. Use a ruler to measure the span of your hand from your thumb to your pinkie (outside finger) in centimetres. Use this measurement to estimate the length of the following items around your classroom.

- **a** length of your desk
- **b** height of your chair
- **c** length of your pen
- **d** width of your book
- **e** length of your eraser
- **f** length of your calculator
- **g** length of your pencil case
- **h** length of the whiteboard

Example 6a

2 Calculate the length of a single pace for the following:

- **a** 9 paces over 10 m
- **b** 4 paces over 3 m
- **c** 19 paces over 20 m
- **d** four and a half paces over 5 m

APPLICATIONS

Example 6b

3 A landscaper has a pace length of 90 cm. Calculate the estimated length in metres when he steps out 7 paces.

4 A tenant has just moved into a new rental home and would like to purchase a floormat for the bedroom. They know they have a pace length of 80 cm. They step out the bedroom and count it to be 5 paces by 4.5 paces. Determine the maximum size floor rug they can purchase.

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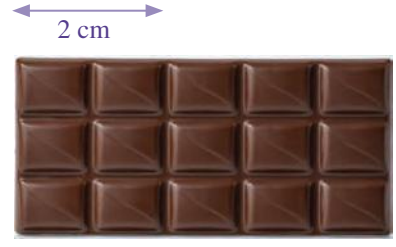
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★5 Choose the correct estimation for each of the measurements shown in the table.

Measurement	Correct estimation		
Length of a diamond in a ring	2.5 cm	6 mm	28 mm
Length of a mobile phone	220 mm	0.4 m	12 cm
Height of an old gum tree	32 m	0.8 km	30 000 cm
Height of a 12-storey high skyscraper	0.1 km	36 m	80 m
Distance from Brisbane to Cairns	368 000 m	2500 km	1700 km

Example 7 ★6 Estimate the length of the following images, given that the blue line is 2 cm long.

a



b



c



★7 Estimate the height of the palm tree near the front door, given that the height of the front rendered wall on the house is 3 m.



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2D Calculating perimeters of familiar shapes

LEARNING GOALS

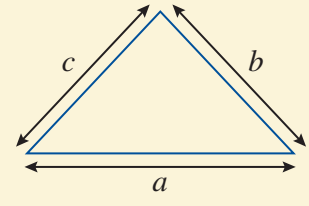
- Define perimeter.
- Name terms associated with circles (radius, diameter, circumference, arc).
- Calculate the perimeter of standard polygons.
- Apply the formula $C = 2\pi r$ to calculate the circumference of a circle.
- Apply the formula $l = \frac{\theta}{180}\pi r$ to calculate the arc length of a circle.

Why is it essential to understand and calculate perimeter?

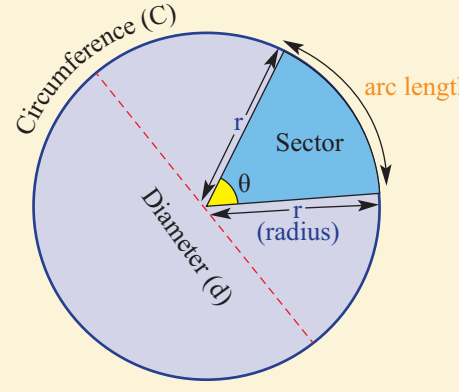
- In construction, perimeter can be used to calculate the total length around the property when building a fence.
- Perimeter is used to calculate the amount of timber required to frame a painting.
- Perimeter can be used in fashion to work out the length of trimming required around the hem of a skirt.

WHAT YOU NEED TO KNOW

- Perimeter is the distance around the outside of a shape. In the triangle shown, Perimeter = a + b + c.



- Parts of a circle:



  - The **radius (r)** is the length from the middle to the outside of a circle.

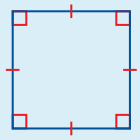
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- The **diameter (d)** is a straight line passing through the centre of the circle and joins both sides of the circle. $D = 2r$ or $r = \frac{D}{2}$.
- The **circumference (C)** is the distance around the outside of a circle.
  - The formula is $C = 2\pi r$.
  - If the diameter is given, find the radius first.
- A **sector** is a section of a circle formed from two radii.
- An **arc length** is the part of the circumference bounded by a sector.
  - The formula is $l = \frac{\theta}{180}\pi r$.

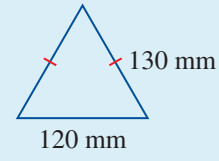
Example 8 Calculating the perimeter of 2D shapes

Calculate the perimeter of the following shapes.

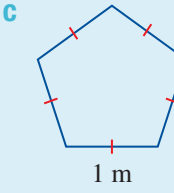
a



b

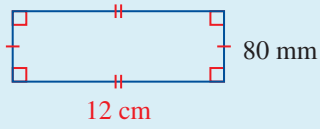


c



For the following question, calculate the perimeter in the units highlighted in red.

d



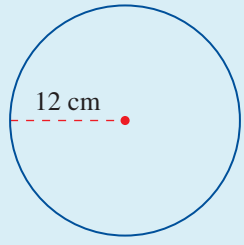
WORKING		THINKING
a	$8 + 8 + 8 + 8 = 32$ cm	Add all the side lengths together.
b	$130 + 130 + 120 = 380$ mm	Add all the side lengths together.
c	$1 + 1 + 1 + 1 + 1 = 5$ m	Add all the side lengths together.
d	$80 \text{ mm} \div 10 = 8$ cm	Convert mm to cm first. There are 10 mm in every 1 cm, so divide 80 by 10.
	$8 + 8 + 12 + 12 = 40$ cm	Add all the side lengths together.

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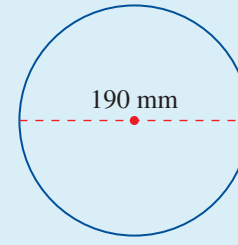
Example 9 Calculating the circumference of a circle

Calculate the circumference of the following circles using the appropriate formula. Round your answers to two decimal places.

a



b



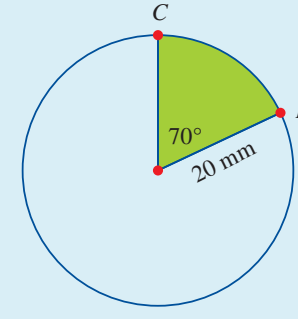
WORKING	THINKING
a $C = 2\pi r$	Given the radius so use $C = 2\pi r$ formula.
$C = 2 \times \pi \times 12$	Substitute $r = 12$ cm.
$C \approx 75.398\,223 \ldots$ $C \approx 75.40$ cm	Round your answer to two decimal places by looking at the 3rd decimal place. Round up as the 3rd number is greater than 5.
b D $= 190$ mm	Given diameter rather than radius.
$r = \frac{D}{2}$	Use relationship to calculate the radius.
$r = \frac{190}{2} = 95$ mm	
$C = 2\pi r$ $= 2 \times \pi \times 95$ $\approx 596.902\,604 \ldots$	Substitute radius into the formula for circumference. Round answer to two decimal places by looking at the third decimal place.
$C \approx 596.90$ mm	

Example 10 Calculating the arc length and perimeter of a sector

Use the appropriate formula to calculate:

a the length of the arc CD, rounding your answer to two decimal places

b the perimeter of the sector



... Continued

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WORKING	THINKING
a $l = \frac{\theta}{180}\pi r$	Use the formula $l = \frac{\theta}{180}\pi r$.
$l = \frac{70}{180} \times \pi \times 20$	Substitute $\theta = 70°$ and $r = 20$ mm.
$l \approx 24.434609$ $l \approx 24.43$ mm	Round your answer to two decimal places by looking at the third decimal place. This number is less than five so we round down, which means we can keep the second decimal place the same.
b Arc length ≈ 24.43 mm $P \approx 24.43 + 20 + 20$ $P \approx 64.43$ mm	Use the arc length found in part **a**. The sides lengths of the sector are the radii of 20 mm. There are two side lengths, so add both to the length of the arc.

Example 11 Applying perimeter to practical problems

Griffin has 30 m of flexible fencing. He would like to use all of the fencing to make the largest circular pen for his pigs. Calculate the diameter of the largest pen that Griffin can make using all of the fencing. A suitable degree of error for this application is up to a centimeter, meaning the fence can have a 1 cm overlap or gap at the end and still be deemed fit for purpose. For this reason the diameter can be rounded to the nearest cm or two decimal places.

WORKING	THINKING
	Formulate
Need to find the diameter. We are given a circumference. $C = 2\pi r$ $D = 2r$	What do we need to find? What information do we have? What rule/s can we use?
	Solve
$C = 2\pi r$ $30 = 2 \times \pi \times r$	Substitute into the circumference formula.
$15 = \pi \times r$	Divide both sides by π.
$4.774648 \ldots = r$	Divide both sides by π. Store this answer for d in your calculator.

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$D = 2r$ ◀ Use the relationship between diameter and radius to calculate the diameter.
$D = 2 \times 4.774648\ldots$
$= 9.54929\ldots$

$D \approx 9.55$ m ◀ Round answer to two decimal places.

Evaluate and verify

$D \approx 9.55$ m ◀ Check the answer by calculating the circumference when $D = 9.55$ m.
$r = 9.55 \div 2 = 4.775$ m
$C \approx 2\pi r$
$C \approx \pi \times 9.55 \approx 30.00$ m

Communicate

The largest diameter possible with 30 m of fencing to make a circular pen is 9.55 m. ◀ Write answer in a sentence.

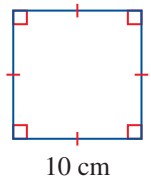
Exercise 2D

FUNDAMENTALS

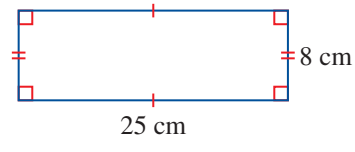
Example 8

1 Calculate the perimeter of the following shapes.

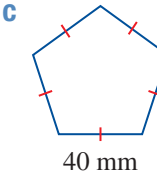
a



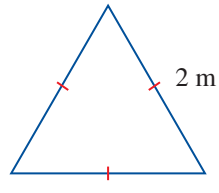
b



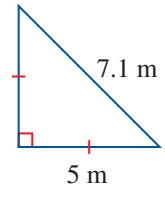
c



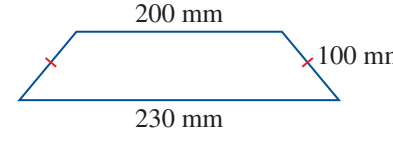
d



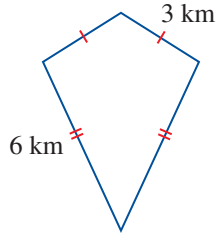
e



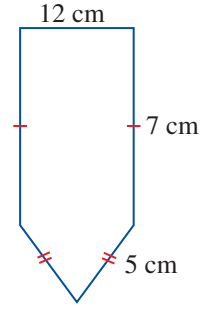
f



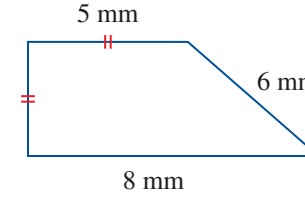
g



h



i

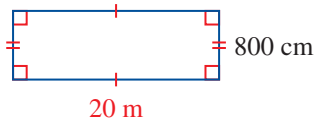


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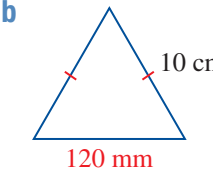
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2 Calculate the perimeter for the following shapes using the units indicated in red.

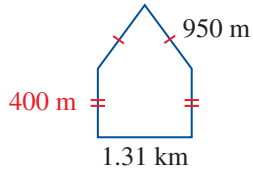
a



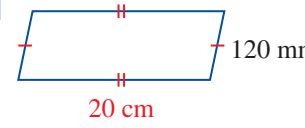
b



c



d

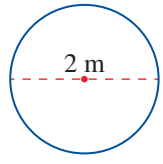


Example 9

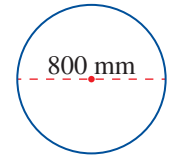
3 Calculate the circumference of the following circles. Round your answer to two decimal places.

Hint Use $C = 2\pi r$.

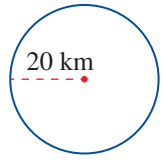
a



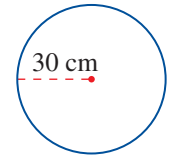
b



c



d

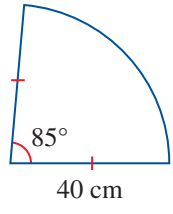


Example 10

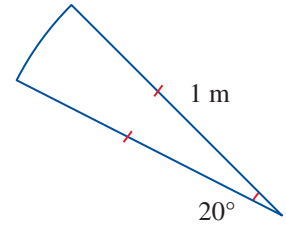
4 Calculate the arc length of the following sectors. Round your answer to two decimal places.

Hint Use $l = \frac{\theta}{180}\pi r$.

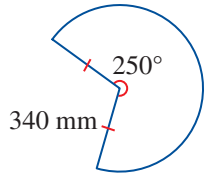
a



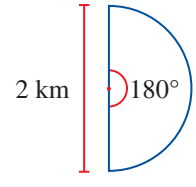
b



c



d



5 Calculate the perimeter for each of the sectors in Question **4**.

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APPLICATIONS

For the following questions, write your answers correct to two decimal places, where appropriate.

Example 12 ★6 Quinn is baking her mother a cake for her birthday. Quinn uses a 20 cm square baking dish and plans on decorating the cake by wrapping a ribbon around it. Determine the minimum amount of ribbon Quinn will require for the cake.

★7 Lyn lives on a large property and has a new dog that has a reputation for running away. She has decided that she will put in an electric dog fence along the perimeter of her property. The shape of the property is a rectangle. It is 80 metres long and 70 metres wide. Determine how many metres of electric dog fencing Lyn will need to purchase.

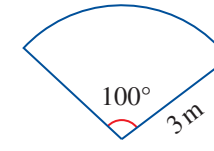
Example 9 ★8 Bethany is planning on upcycling her old lampshade. It has a circular base that has a 38 cm diameter. She wishes to wrap a length of beading along the edge of the base.

a Calculate the radius for a diameter of 38 cm.

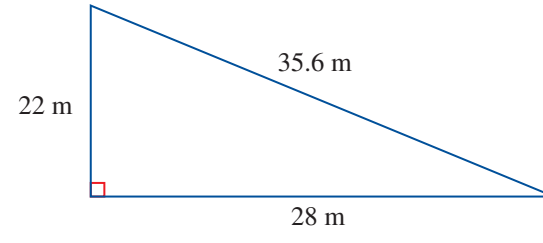
b Determine the length of beading Bethany should purchase.

Example 11 ★9 Josh is renovating his bathroom and has purchased a circular mirror. The measurement on the box states that the mirror has a circumference of 4 m. He would like to determine if the mirror will fit on a particular wall in the bathroom. Calculate the diameter of the mirror.

Example 10 ★10 Stacey is installing a concrete pool in the shape of a sector at her new house. She needs to calculate the perimeter of the pool to work out how many pavers she will need to order. Use the image shown to calculate the perimeter of Stacey's pool.



★11 Jarrah is building a fence for one of his yards to help keep his stock away from the road. The yard is triangular, as per the image shown. The fence design that he is planning has three railings of timber.



a Calculate the perimeter of the yard.

b Determine how many metres of timber Jarrah requires to construct the fence.

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2E Calculating perimeters of familiar composite shapes

COMPLEX

LEARNING GOALS

- Identify composite shapes.
- Calculate perimeters of composite shapes.

Why is it essential to calculate perimeters of composite shapes?

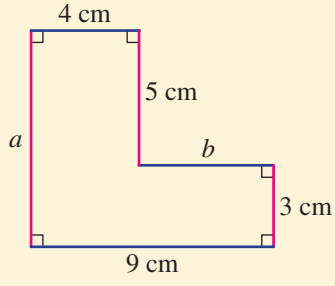
- Often in life, shapes are more intricate in detail, and form a composite shape. They are made by combining two or more familiar shapes.
- Breaking composite shapes into smaller, familiar shapes can help with calculations.



In a quilt, simple shapes can be sewn together to make more complex composite shapes.

WHAT YOU NEED TO KNOW

- A **composite shape** is a shape that is made up of two or more basic shapes.
- Some diagrams of composite shapes do not show the length of every side, as it is possible to calculate these lengths using either addition or subtraction.



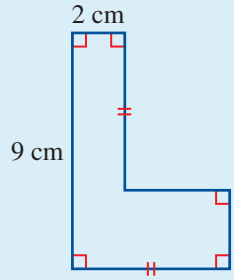
Considering the vertical sides (red), it can be seen that
$a = 5 + 3 = 8$ cm.
Considering the horizontal sides (blue), it can be seen that
$4 + b = 9$ cm.
Take 4 from both sides, which gives
$b = 5$ cm.

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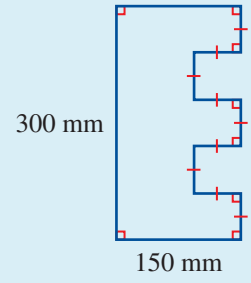
Example 12 Calculating the perimeter of composite shapes

Calculate the perimeter of the following composite shapes.

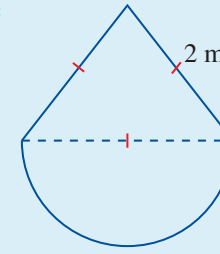
a

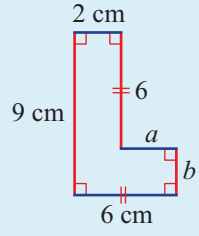


b



c



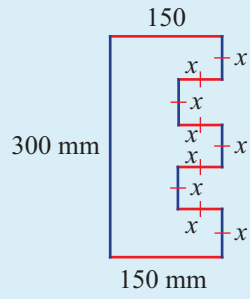
WORKING	THINKING
a 	Copy the diagram. Label missing sides lengths that are marked the same as another length. Label unknown side lengths a and b.
Vertical sides:	
$9 = 6 + b$ $3 = b$	Subtract 6 from both sides.
Horizontal sides:	
$2 + a = 6$ $a = 4$	Subtract 2 from both sides.
Perimeter $= 2 + 6 + a + b + 6 + 9$ $= 2 + 6 + 4 + 3 + 6 + 9$ $= 30$ cm	Add all sides together.

... Continued

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b



◄····· Copy the diagram.

Label missing sides lengths that are marked the same as another length.

Label unknown side lengths that are equal to each other x.

Vertical sides:

$5x = 300$

$x = 60$ mm

◄····· Divide both sides by 5.

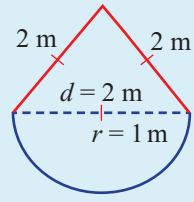
$\text{Perimeter} = 150 + 9x + 150 + 300$

$= 150 + 9 \times 60 + 150 + 300$

$= 1140$ mm

◄····· Add all sides together.

c



◄····· Copy the diagram.

Label missing sides lengths that are marked the same as another length.

Label the diameter and radius for the semi-circle.

$\text{Semi-circle} = \frac{1}{2} \times \text{ circumference}$

$= \frac{1}{2} \times 2\pi r$

$= \frac{1}{2} \times 2 \times \pi \times 1$

$= 3.14$ m

◄····· The curved side at the bottom is half of a circle.
Use half of the circumference formula to find length.

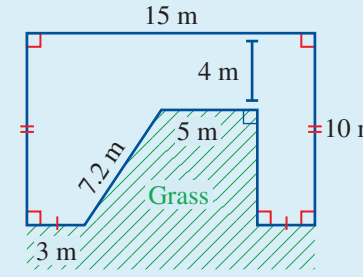
$\text{Perimeter} = 2 + 2 + 3.14 = 7.14$ m

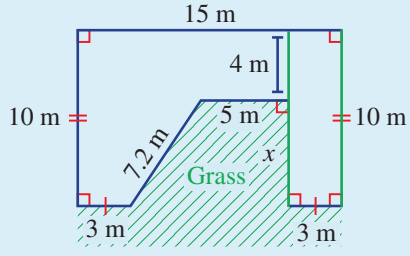
◄····· Add all sides together.

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Example 13 Applying perimeter of composite shapes to practical problems

Noah has designed a garden bed for his new property, as per the image shown. He would like to place timber edging along the entire perimeter to hold the soil in place. Calculate how much timber Noah requires for his garden bed.
Note: The dimensions are measured around the 'outside' of the garden bed after the timber has been added, so you do not have to consider the thickness of the timber.



WORKING	THINKING
	**Formulate** Copy the diagram. Label missing sides lengths that are marked the same as another length. Label unknown side length x.
Vertical sides:	**Solve**
$4 + x = 10$ m $x = 6$ m	Subtract 4 from both sides.
Perimeter $= 15 + 10 + 3 + 6 + 5 + 7.2 + 3 + 10$ $= 59.2$ m	Add all sides together.
	Evaluate and verify
	Check the number of sides (8) matches the number of sides used in the perimeter calculation.
	Communicate
Noah used 59.2 metres of timber to build his garden bed.	Write your answer in a sentence.

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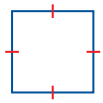
Exercise 2E

FUNDAMENTALS

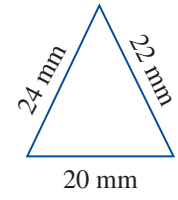
Where appropriate, write your answers to two decimal places.

1 Calculate the perimeter or circumference of the following common shapes.

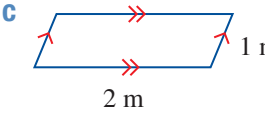
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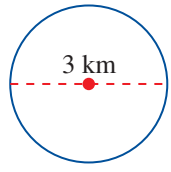
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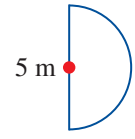
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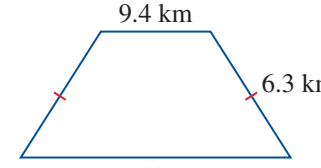
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e



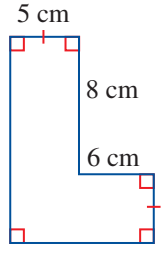
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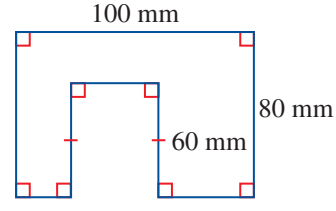
Example 12

2 Calculate the perimeter for the following composite shapes.

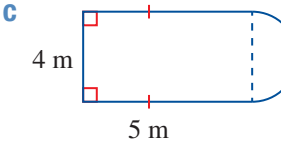
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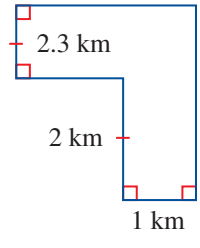
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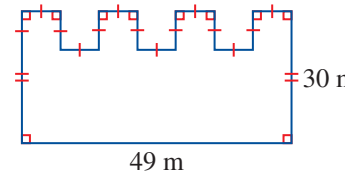
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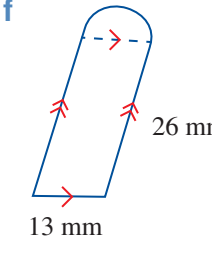
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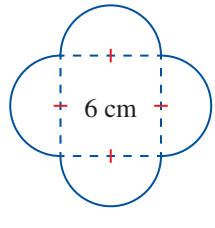
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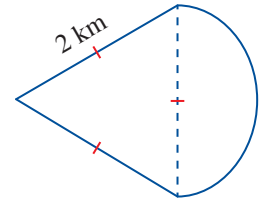
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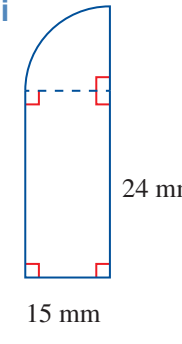
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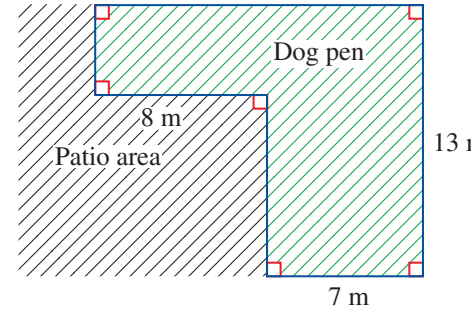
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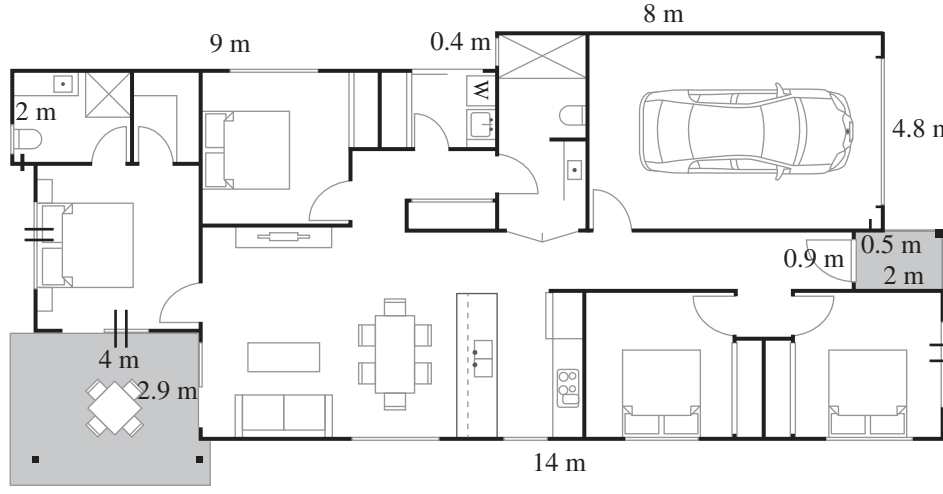
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APPLICATIONS

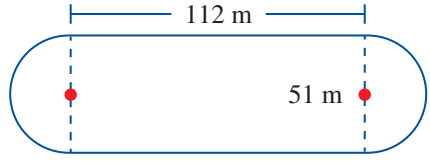
Example 13 ★3 Russell needs to fence a large patch of grass area next to his patio to create a dog pen with the dimensions shown in the diagram. Calculate the total length of fencing that Russell needs to purchase.



★4 Valerie is renovating her house and she would like to purchase some paint to change the colour of the outside of her house. Her local hardware store has asked her for the perimeter and height of the external walls of her house. She knows the external walls are 3 metres high. Valerie is using her house plan to work out the perimeter. Calculate the perimeter of Valerie's house using the image shown.



★5 Mason is building a speed skating rink and he is required to place a railing around the outside of the rink for spectators. Use the diagram shown to calculate the length of the railing that will be required.



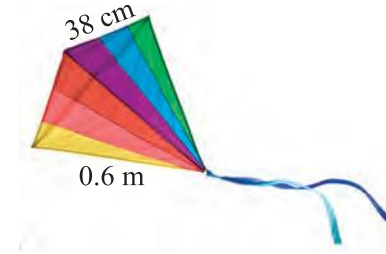


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CF

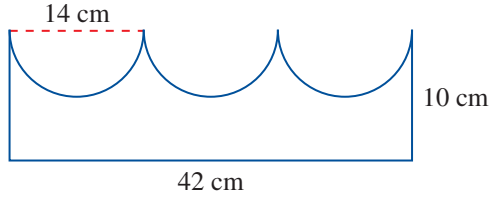
★6 Mathew has cut and sewn a pattern for a kite in the shape of the image shown. He now needs to buy dowel (wooden rod) to insert along the edges of the kite before he can fly it. Calculate how many metres of dowel Mathew must purchase.



Hint A kite has 2 pairs of equal sides.

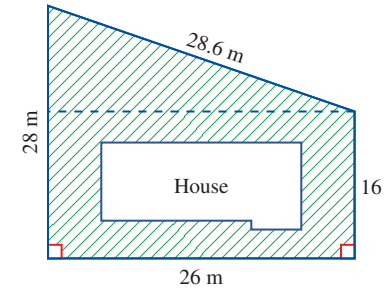
★7 Anaya is making eight crowns for her daughter's fifth birthday party. She plans to cut the crowns out of cardboard and stick decorative washi tape on the top and bottom of the crown to provide strength. The diagram shows an outline for the crown. Calculate how many centimetres of washi tape Anaya will need to purchase to complete the eight crowns.



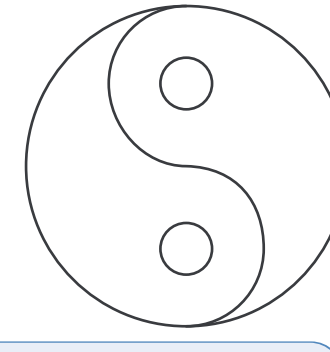


CU

★8 Shekila's property contains her house situated in the front rectangular section of the property as shown in the diagram. She wishes to enclose the back triangular section of her yard with fencing. Calculate the length of fencing that Shekila will require.



★9 Paul has been commissioned to paint a large yin-yang symbol, similar to the image below. The symbol is to have a 2 m diameter, and the small dots are to have a 40 cm diameter. Paul needs to purchase black paint for the outline of the symbol. Calculate the perimeter of the black line so that Paul can purchase enough paint to complete the artwork.



Hint The inside swirl line can be calculated using two semi-circles.

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Modelling task



Context: Landscape and garden design involves dealing with composite shapes and using perimeters to calculate fencing and edging.

Task: Your task is to create a landscape design for a backyard. You must incorporate at least four familiar geometrical shapes, such as squares, triangles, rectangles, trapeziums and circles, to represent aspects of your yard. Use a key to clearly show what they represent. You must incorporate a feature in your landscape design that is a composite shape. Your plans must show measurements. You will then need to calculate the perimeter of your land, the composite-shaped feature and also one other familiar shape.

Stage 1: Formulate
Make an assumption of: • interesting features you may like to include in the design • features that will be needed to be included in your design e.g. clothesline. Make an observation of: • the overall size of the backyard.
Stage 2: Solve

• Sketch the plan of your backyard ensuring that you:
  • incorporate at least four familiar shapes
  • include measurements
  • create a composite-shaped feature
  • use a key.
• Calculate the perimeter of the following:
  • the backyard
  • the composite-shaped feature
  • one other 2D familiar shape.

Stage 3: Evaluate and verify
• Check that you have included as many measurements as possible in your design. • Check that your composite-shaped feature has at least two familiar shapes. • Check that your perimeter calculations are accurate.
Stage 4: Communicate
Write a summary of your design highlighting what your composite-shaped feature represents.

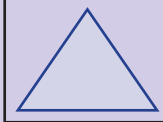
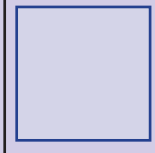
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Chapter summary

Two-dimensional shapes

- Two-dimensional shapes are flat shapes that have two dimensions, such as length and width. Examples include rectangles and triangles.
- 'Polygon' is the general term for 2D shapes with straight sides.
- Properties of standard polygons:

Shape	Number of sides and vertices	Angle properties	Side properties
Triangle 	3	• Angles add to 180°	-
Square 	4	• Angles all 90° • Add to 360°	• All sides equal • Opposite sides parallel
Rectangle 	4	• Angles all 90° • Add to 360°	• Opposite sides equal • Opposite sides parallel
Parallelogram 	4	• Opposite angles equal • Add to 360°	• Opposite sides equal • Opposite sides parallel
Trapezium 	4	• Add to 360°	• 1 pair of opposite sides parallel

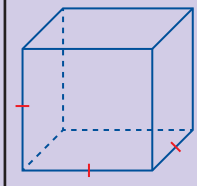
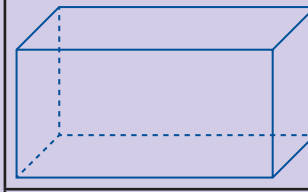
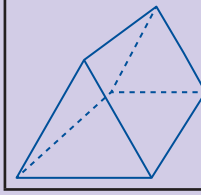
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3D solids

- 3D solids are solid shapes that have three dimensions, such as length, width and height. They fall into three categories: prisms, pyramids and curved solids.

Prism

- A prism is a 3D solid with the same shape through its cross section.
- Prisms are named according to their cross-sectional shape.
- Properties of common prisms:

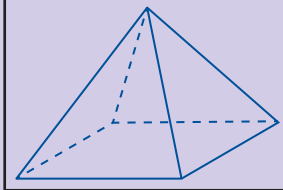
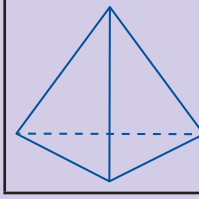
Prism	Faces	Vertices	Edges
Cube 	• 6 • All square	8	12
Rectangular prism 	• 6 • Rectangles (and possibly two squares on sides)	8	12
Triangular prism 	• 5 • Triangles and rectangles	6	9

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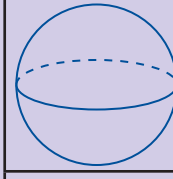
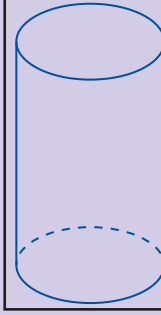
Pyramid

- A pyramid is a 3D solid that comes to a point.
- Pyramids are named by the shape of the base.
- Properties of common pyramids:

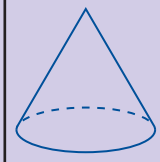
Pyramid	Faces	Vertices	Edges
Square or rectangular based 	• 5 • Square or rectangular base • Triangular sides	5	8
Triangular based pyramid (tetrahedron) 	• 4 • All triangles	4	6

3D shapes with curved surfaces

- Properties:

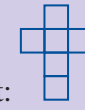
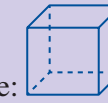
3D shape	Faces	Vertices	Edges
Sphere 	• None with flat sides	0	0
Cylinder 	• None with straight sides • 2 circular faces • 1 curved side that opens out to a rectangle	0	• No straight edges • Circumference around the base

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Cone 	• None with straight sides • 1 circular face • 1 curved side that opens out to a sector	1	• No straight edges • Circumference around the base

Net

- A net is a flat 2D shape that can be folded into a 3D solid.

For example, this net:  folds into this cube: 

Estimating lengths

- Estimating lengths involves an of your knowledge to approximately guess the length of an object. Techniques used include:
  - physical e.g. pace length
  - mental e.g. recalling a known length for comparison
  - comparative e.g. comparing a tree height to a known height of a person.

Perimeter

- The perimeter is the distance around the outside of a shape.
- Perimeter = sum of all sides.
- Perimeter of a circle is called circumference, C
  - $C = 2\pi r$, where r is the radius
  - $D = 2r$ or $r = \frac{D}{2}$ where D is the diameter, r is the radius.
- An arc is part of the circumference. Arc length, $l = \frac{\theta}{180}\pi r$.

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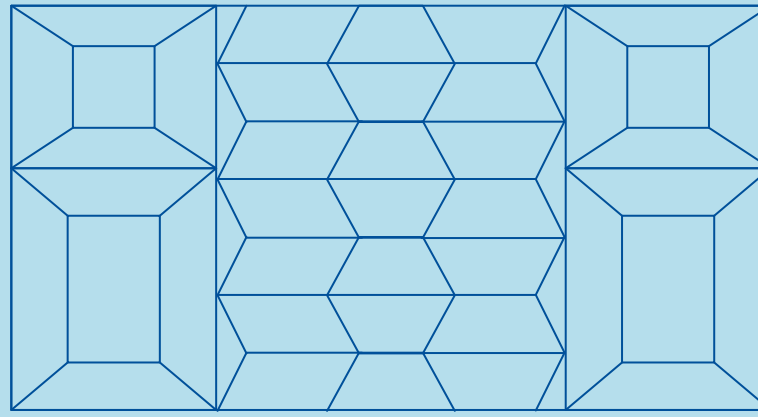
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Chapter checklist

2A ☐ I can identify the names and properties of 2D shapes.

1 List the properties for a square, rectangle and triangle.

2 Identify as many 2D shapes as possible in the following image.

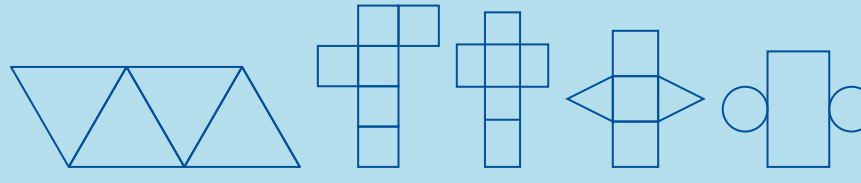


2A ☐ I can identify the names and properties of 3D solids.

3 Construct a table that lists the number of faces, edges and vertices in the following solids: cube, triangular prism, rectangular-based pyramid, triangular-based pyramid, pentagonal prism and hexagonal prism.

2B ☐ I can interpret 2D nets to identify 3D solids. **[complex]**

4 Identify each 3D solid that is formed from the following nets.



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5 Draw nets that best represent each of the following 3D objects.

a



b



c



2C ☐ I can estimate lengths of objects.

6 List some techniques that you can use to help you estimate lengths.

7 Choose the best estimate for the following measurements.

a Thickness of a garden hose
- **i** 12 mm
- **ii** 100 mm
- **iii** 3 cm

b Length of an adult male foot
- **i** 15 cm
- **ii** 30 cm
- **iii** 50 cm

c Perimeter of a house
- **i** 300 m
- **ii** 0.8 km
- **iii** 62 m

d Distance from Gold Coast to Perth
- **i** 10 000 m
- **ii** 2500 km
- **iii** 4000 km

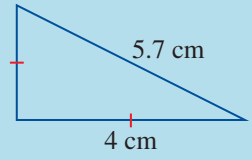
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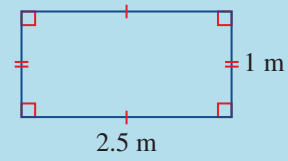
2D ☐ I can calculate the perimeters of familiar shapes.

8 Calculate the perimeter of each of the following familiar 2D shapes.

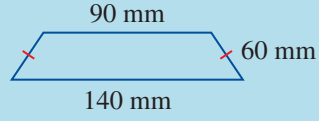
a



b



c



2D ☐ I can calculate the circumference of a circle using the formula $C = 2\pi r$.

9 Calculate the circumference for the following circles, correct to two decimal places.

a 3.7 m radius

b 76 mm diameter

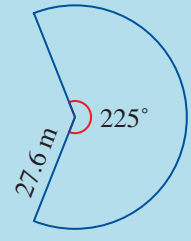
2D ☐ I can calculate arc length and the perimeter of a sector using the formula $l = \frac{\theta}{180}\pi r$.

10 Correct to two decimal places, calculate the:

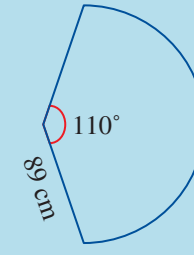
i arc length

ii perimeter of each sector.

a



b

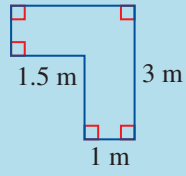


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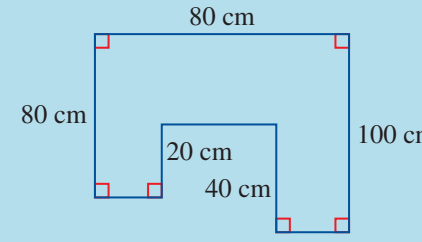
2E ☐ I can calculate perimeters of composite shapes. **[complex]**

11 Calculate the perimeter of the following composite shapes. Where appropriate, write your answers correct to two decimal places.

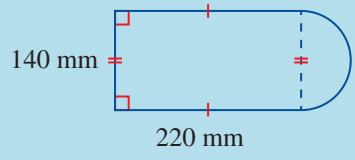
a



b



c



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Chapter review

All questions in the Chapter review are assessment-style.

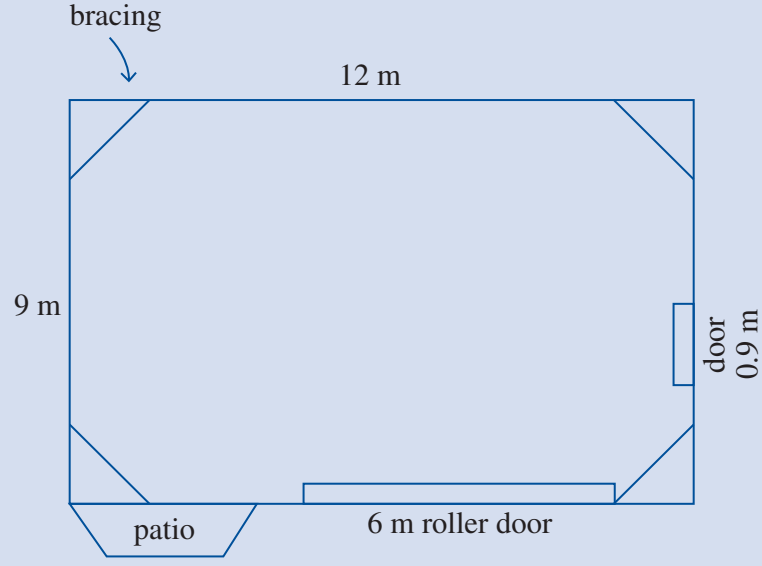
Simple Familiar

Where appropriate, write your answers correct to two decimal places.

2A **1** Ashley is a cattle farmer in Toowoomba. He has a plan for a new hay shed, which is shown in the diagram.

a Identify and list the number of each 2D shape in the hay shed plan.

b List the properties of each of these 2D shapes.



2A **2** Identify which 3D solid is most similar to the following real-life objects.

a



b



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c



d



e



2C **3** Jake measures his pace length over 5 metres. He counts 6 paces over 5 metres.

a Calculate the length of 1 pace.

b Jake steps out 45 paces to estimate the length of a fenceline. Determine the estimated length of the fenceline.

2D **4** Beatrix is planning to sew lace around the perimeter of a 45 cm square cushion that she has just completed. Determine how many metres of lace Beatrix will require.

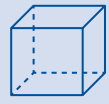
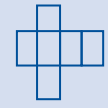
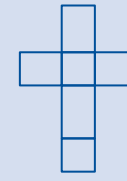
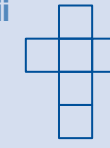
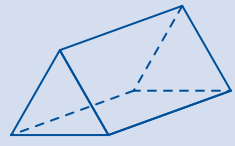
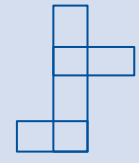
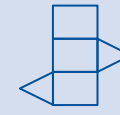
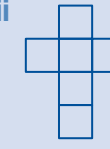
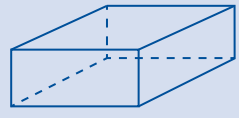
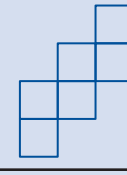
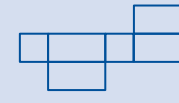
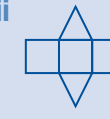
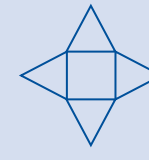
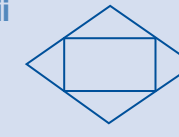
2D **5** Tim works at a school in maintenance. He has been asked to build a new sandpit that requires a 6 m by 8 m rectangular frame (measured around the outside of the timber frame). Determine how many metres of timber Tim needs to order.

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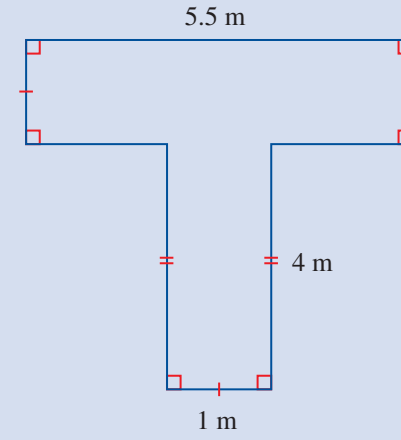
Complex Familiar

2B **6** A workshop makes building blocks from metal sheets. Unfortunately, the diagrams of the building blocks and their nets have been mixed up. Decide which net matches with the 3D solid so that the workshop can continue making the building blocks.

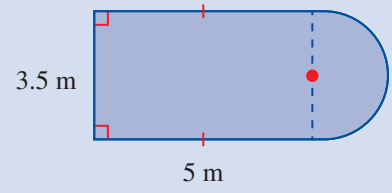
3D solid	Net
a 	i  ii  iii 
b 	i  ii  iii 
c 	i  ii  iii 
d 	i  ii  iii 

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2E **7** Lee-Ann is planning to concrete a path to her front door and underneath her patio. She needs to first construct a timber frame to hold the concrete in place. The diagram at right shows Lee-Ann's plan for the concrete. Calculate how much timber Lee-Ann needs for the timber frame.

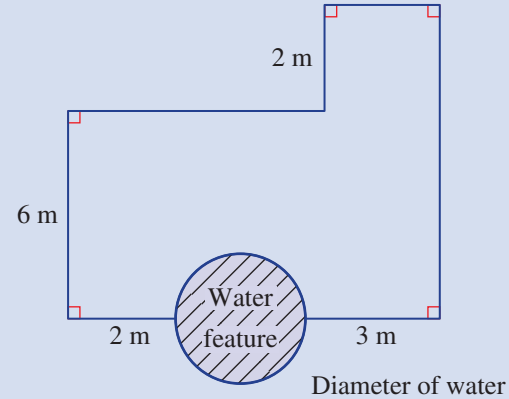


2E **8** Jay is installing some pavers around the edge of his pool, shown in the diagram. Calculate the perimeter of the pool.



Complex Unfamiliar

2E **9** Sara is constructing a new garden bed that wraps around her circular water feature. She has drawn a plan with a red line indicating where she will be placing timber as a border for the garden bed. Determine how many metres of timber Sara will need to purchase.



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3 Area measure



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In this chapter

3A Estimating and calculating areas of triangles, squares, rectangles, parallelograms and circles

3B Calculating the area of trapeziums, sectors and composite figures **[complex]**

3C Calculating the surface areas of cubes, prisms and pyramids **[complex]**

3D Calculating the surface areas of spheres, cones and cylinders **[complex]**

3E Calculating the surface areas of irregular solids **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 3 Topic 1 Measurement

Area measure (9 hours)

In this sub-topic, students will:

- estimate areas of different shapes
- calculate areas of standard shapes, triangles, parallelograms and circles
  - triangle: $A = \frac{1}{2}bh$ where b is base length and h is perpendicular height
  - parallelogram: $A = bh$ where b is base length and h is perpendicular height
  - circle: $A = \pi r^2$ where r is radius.
- calculate areas of trapeziums and sectors **[complex]**
  - trapezium: $A = \frac{1}{2}(a + b)h$ where a and b are parallel lengths and h is perpendicular height
  - sector: $A = \frac{\theta}{360}\pi r^2$ where θ is central angle and r is radius.
- calculate areas of composite figures by decomposing them into standard shapes **[complex]**
- calculate surface areas of prisms and cylinders **[complex]**
  - cylinder: $S = 2\pi rh + 2\pi r^2$ where r is radius and h is perpendicular height.
- calculate surface areas of pyramids and cones **[complex]**.
  - cone: $S = \pi rs + \pi r^2$ where r is radius and s is slant height.
- calculate surface areas of composite shapes and spheres **[complex]**.
  - sphere: $S = 4\pi r^2$ where r is radius.

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Prior knowledge check

1 Convert 344 cm into millimetres (mm), metres (m) and kilometres (km).

2 Calculate how many squares with a side length of 1 m will fit into a rectangle of length 12 m and width 10 m.

3 Without using a calculator, calculate:

a 7×8 **b** $56 \div 8$

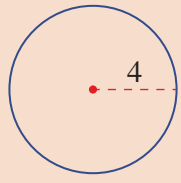
4 Evaluate:

a 1^2 **b** 9^2 **c** 10^2

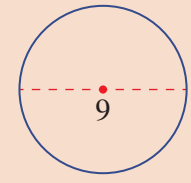
d 100^2 **e** 1000^2 **f** 13^2

5 In the circles below, determine the size of the radius.

a



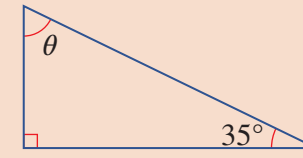
b



6 State the name of the symbol π and explain what it represents in relation to the lengths of the diameter of a circle and its circumference.

7 In this geometry diagram, identify the feature represented by these symbols:

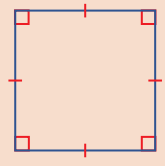
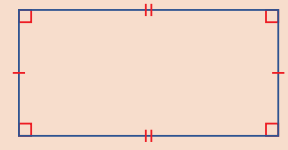
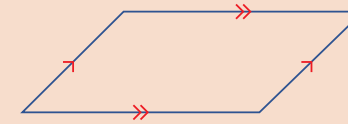
a  **b**  **c** 



8 In these geometry diagrams:

i explain what is meant by the marks on the sides

ii identify the shape.

a  **b**  **c** 

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3A Estimating and calculating areas of triangles, squares, rectangles, parallelograms and circles

LEARNING GOALS

- Calculate the area of various regular shapes including:
  - triangles
  - squares
  - rectangles
  - parallelograms
  - circles.
- Estimate the area of familiar shapes.

Why is it essential to understand how to calculate the area of a shape?

- There are many real-life reasons why you would need to calculate the area of various shapes.
- Calculating the area allows a landscaper to find the amount of turf required or a painter to work out how much paint is needed.
- It is also a good way to compare the sizes of properties when you are looking at buying or leasing (renting) some land.

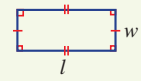
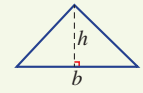
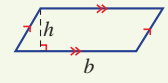


Real estate agents' signs and ads for small-to-medium properties for sale or lease usually state the area in square metres – larger blocks such as farms would be in hectares.

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WHAT YOU NEED TO KNOW

- The **formulas** for the areas of some common shapes are given in the table below.

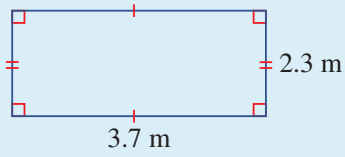
Shape	Area formula
Rectangle 	$A = lw$
Triangle 	$A = \frac{1}{2}bh$
Parallelogram 	$A = bh$
Circle 	$A = \pi r^2$ * Note: if given diameter D, use $r = \frac{D}{2}$ to calculate the radius.

- Abbreviations: A area, l length, w width, b breadth or base, h height, r radius, $\pi\,(\text{pi}) = 3.142$ approximately.
- Units of area include square millimetres, square centimetres, square metres, square kilometres and hectares. These can be abbreviated to mm^2, cm^2, m^2, km^2 and ha. (see Section 1B).

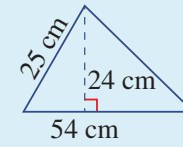
Example 1 Calculating the area of a common 2D shape

Calculate the area of the following common 2D shapes.

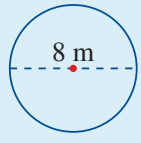
a



b



c



Round your answer to two decimal places.

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WORKING	THINKING
a $A = lw$	Calculate the area of the rectangle using $A = lw$.
$A = 3.7 \times 2.3$ $A = 8.51 \text{ m}^2$	Substitute the values for l and w.
b $A = \frac{1}{2}bh$ $A = \frac{1}{2} \times 54 \times 24$	Calculate the area of the triangle using $A = \frac{1}{2}bh$.
$A = 648 \text{ cm}^2$	Substitute the values for b and h. Note: The height must be the *perpendicular* height, meaning it meets the base at a right angle (i.e. 24 is used here).
c $r = \frac{D}{2}$ $= \frac{8}{2}$ $= 4 \text{ m}$	Calculate the radius using $r = \frac{D}{2}$.
$A = \pi r^2$	Calculate the area of the circle using $A = \pi r^2$.
$A = \pi \times 4^2$	Substitute the value for r.
$A \approx 50.27 \text{ m}^2$	Round your answer to two decimal places.



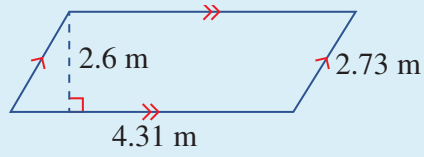
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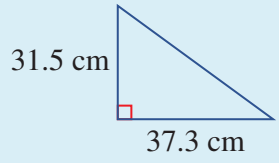
Example 2 Estimating the area of common 2D shapes

Round the dimensions of the following shapes using leading-digit approximation. Use approximation to estimate the area.

a



b



c



Round your answer to two decimal places.

WORKING		THINKING
a	$2.6 \text{ m} \approx 3 \text{ m}$ $4.31 \text{ m} \approx 4 \text{ m}$	Begin by rounding your dimensions to the nearest whole number. Look at the first decimal place; if it is 0.5 or more, then round your whole number up; if it is less than 0.5, then drop the decimal place. Note: the perpendicular height of the parallelogram is used (i.e. 2.6 m from this shape).
	$A = bh$	Calculate the area of the rectangle using $A = bh$.
	$A = 4 \times 3$ $A = 12 \text{ m}^2$	Substitute the values for b and h using the whole numbers to estimate the area of the parallelogram.
b	$37.3 \approx 40 \text{ cm}$ $31.5 \approx 30 \text{ cm}$	Begin by rounding your dimensions using leading-digit approximation.
	$A = \frac{1}{2}bh$	Calculate the area of the triangle using $A = \frac{1}{2}bh$.
	$A = \frac{1}{2} \times 40 \times 30$ $A = 600 \text{ cm}^2$	Substitute the rounded values for b and h.

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c $52.8 \approx 50$ mm ◄ Begin by rounding the dimensions using leading-digit approximation.
$\pi \approx 3$
$A = \pi r^2$ ◄ Calculate the area of the circle using $A = \pi r^2$.
$A = 3 \times 50^2$ ◄ Substitute the rounded values.
$A = 7500 \text{ mm}^2$

Example 3 Applying the area of a shape to practical problems

Michelle is painting the top surface of a circular stage that has a diameter of 2.4 m. Calculate the area that Michelle will be painting, correct to two decimal places.

WORKING	THINKING
	Formulate
Need to find area of a circle. Given $D = 2.4$ m Rules: $A = \pi r^2$ and $r = \frac{D}{2}$	• What are you asked to find? • What information do you have? • What formula could you use?
	Solve
$r = \frac{D}{2}$ $r = \frac{2.4}{2} = 1.2$ m	• Substitute into formula to find the radius.
$A = \pi r^2$ $A = \pi \times 1.2^2$ $A = 4.52 \text{ m}^2$	• Substitute into formula to find the area.
	Evaluate and verify
	• Have you answered the question asked? • Have you included units?
	Communicate
Michelle will be painting an area of 4.52 m^2.	• Write your answer in a sentence.

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Exercise 3A

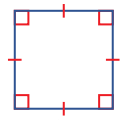
FUNDAMENTALS

Example 1

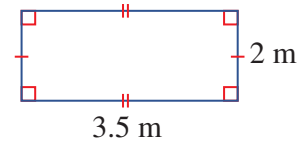
1 Calculate the area of the following common 2D shapes. Round to two decimal places where necessary.

Hint The height must be the perpendicular height for triangles and parallelograms.

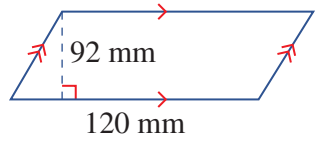
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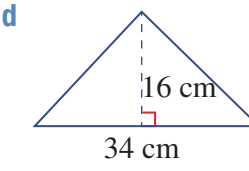
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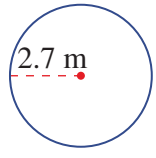
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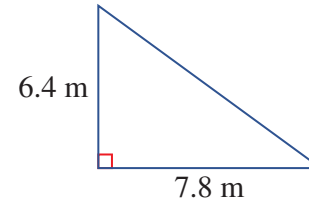
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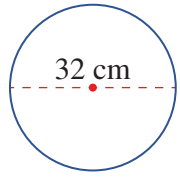
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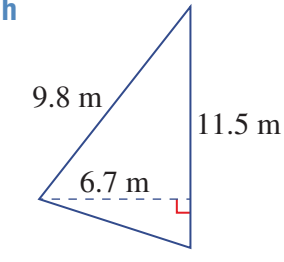
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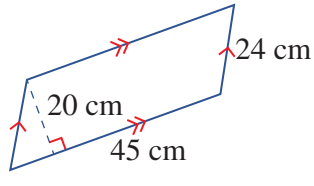
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i



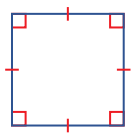
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Example 2

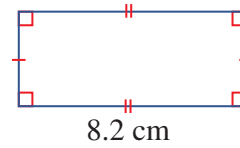
2 Estimate the area of the following common 2D shapes by using leading-digit approximation.

Hint Leading-digit approximation means rounding the number so that only have the first digit is a non-zero.

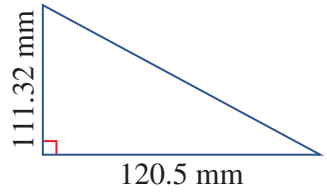
a



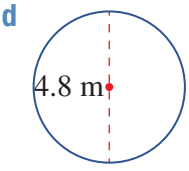
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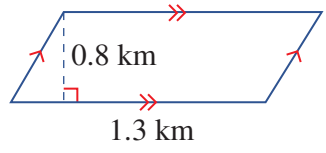
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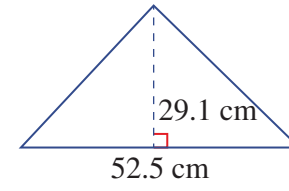
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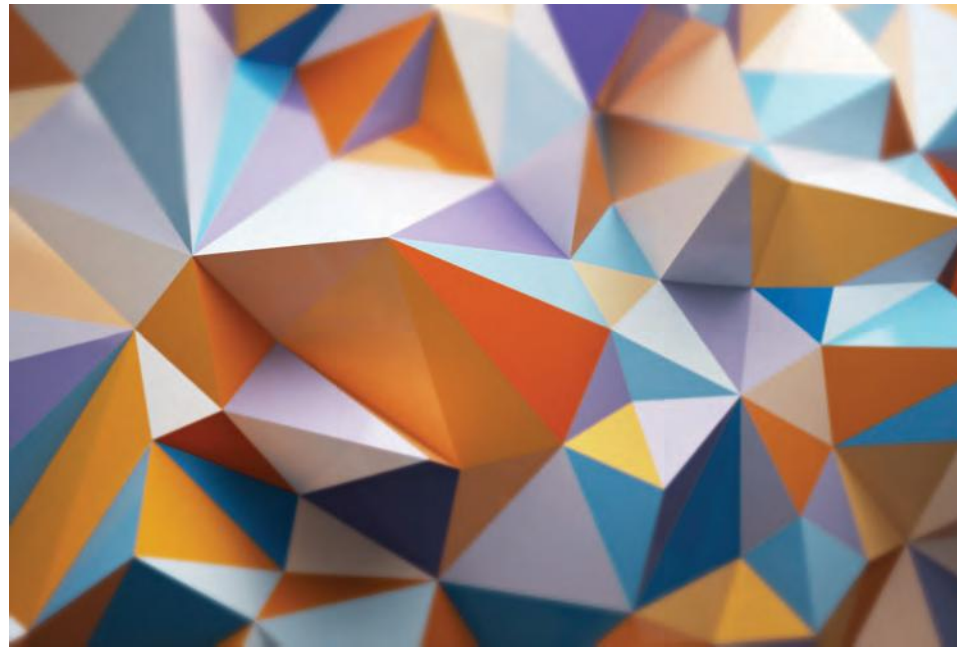


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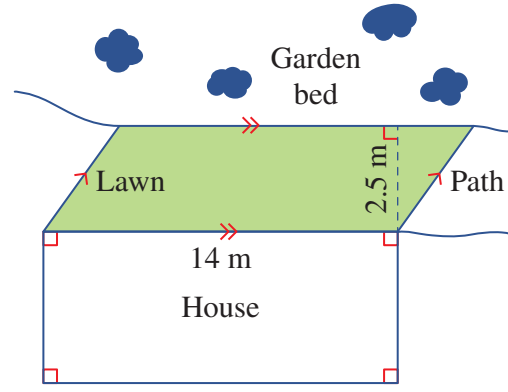
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APPLICATIONS

3 Jarred is covering a display board with blue paper. The board is a rectangle and it has a length of 3.5 m and height of 1.5 m. Calculate the area that Jarred will be covering in blue paper.

★4 Ryan is laying an area of lawn that runs parallel between his house and the garden bed. The image below is the outline of the patch that he is turfing. Calculate the area of the new lawn.



★5 Chelsea is painting the triangular section on the top of her house. The triangle has a base of 8.2 m and a perpendicular height of 3.2 m. Calculate the area that Chelsea is painting so that she can calculate the amount of paint required.



SF

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Example 3 ★6 Nathan is constructing a circular sandpit for his children. The sandpit will have a diameter of 1800 mm. Calculate the area of the sandpit in m^2.

★7 Dane has been commissioned to paint a mural on the side of a building. The mural will be rectangular and has a width of 5.7 m and a height of 3 m. Calculate the area of the mural.



8 Graham has just purchased a rectangular plot of land that is 220 m by 100 m. He knows that he can have 10 sheep per hectare, and he would like to have as many sheep as possible on his land.

a Calculate the area of Graham's land in hectares.

b Determine how many sheep Graham can keep on his new property.

Hint 1 hectare is 10 000 m^2.

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3B Calculating the area of trapeziums, sectors and composite figures

COMPLEX

LEARNING GOALS

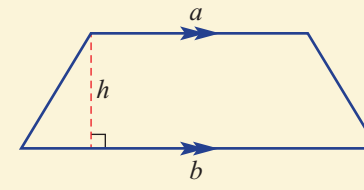
- Apply the formula to calculate the area of trapeziums and sectors.
- Apply knowledge of regular shapes to decompose composite shapes.
- Calculate the area of composite shapes.

Why is it essential to understand how to calculate the area of trapeziums, sectors and composite shapes?

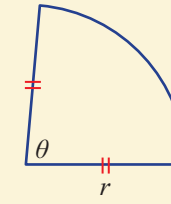
- There are many real-life situations where you would need to calculate the area of these shapes.
- Trapeziums and sectors can be found in construction, painting, town planning, fashion and even cooking.
- The majority of shapes around the home are actually composite shapes.

WHAT YOU NEED TO KNOW

- For a trapezium, $A = \frac{1}{2}(a + b)h$, where a, b are the parallel sides and h is the height between them.



- For a sector, $A = \frac{\theta}{360}\pi r^2$.
  - A sector is part of a circle with radius r and an internal angle of θ.



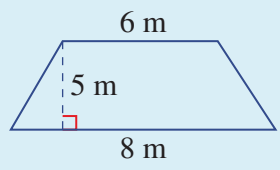
- Like they were in Section 2E, composite shapes are made by joining together standard shapes. We can add/subtract to calculate the area of composite shapes.

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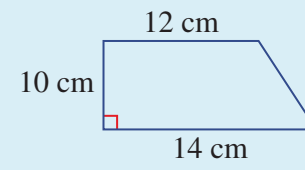
Example 4 Calculating the area of a trapezium

Calculate the area of the following trapeziums.

a



b

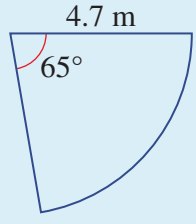


WORKING	THINKING
a $A = \frac{1}{2}(a+b)h$	Calculate the area of the trapezium using $A = \frac{1}{2}(a+b)h$.
$A = \frac{1}{2} \times (6+8) \times 5$ $A = 35 \text{ m}^2$	Substitute the values for a, b and h.
b $A = \frac{1}{2}(a+b)h$	Calculate the area of the trapezium using $A = \frac{1}{2}(a+b)h$.
$A = \frac{1}{2} \times (12+14) \times 10$ $A = 130 \text{ cm}^2$	Substitute the values for a, b and h.

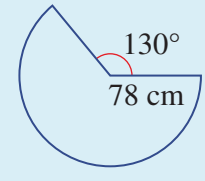
Example 5 Calculating the area of a sector

Calculate the area of the following sectors. Round your answer to two decimal places.

a



b



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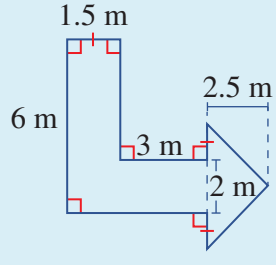
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WORKING	THINKING
a $A = \frac{\theta}{360}\pi r^2$	Calculate the area of the sector using $A = \frac{\theta}{360}\pi r^2$.
$A = \frac{65}{360} \times \pi \times 4.7^2$	Substitute the values for the internal angle (θ) and the radius (r).
$A = 12.53 \text{ m}^2$	Round your answer to two decimal places.
b $360° - 130° = 230°$	As the shape is a sector, calculate the internal angle first by subtracting the external angle from 360°.
$A = \frac{\theta}{360}\pi r^2$	Calculate the area of the sector using $A = \frac{\theta}{360}\pi r^2$.
$A = \frac{230}{360} \times \pi \times 78^2$	Substitute the values for the internal angle (θ) and the radius (r).
$A = 12\,211.37 \text{ cm}^2$	Round your answer to two decimal places.

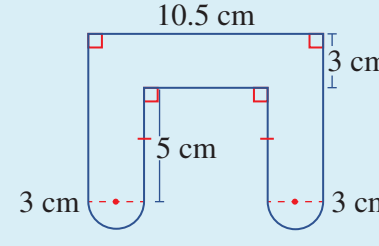
Example 6 Calculating the area of composite shapes with addition

Calculate the area of the following composite shapes, correct to two decimal places if needed.

a



b



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WORKING	THINKING
a There are 2 rectangles and one triangle.	Decompose the composite shape by identifying the regular shapes.
$A = lw$	Calculate the area of the rectangles using the formula.
$A = 6 \times 1.5 = 9 \text{ m}^2$	Substitute the values for l and w.
$A = 3 \times 2 = 6 \text{ m}^2$	
$A = \frac{1}{2}bh$	Calculate the area of the triangle using the formula.
$h = 2.5 \text{ m}, b = 1.5 + 2 + 1.5$ $= 5 \text{ m}$	The unlabelled parts of the base have tick marks indicating they are the same as the side labelled 1.5 m.
$A = \frac{1}{2} \times 5 \times 2.5 = 6.25 \text{ m}^2$	Substitute the values for b and h.
$A = 9 + 6 + 6.25$ $A = 21.25 \text{ m}^2$	Add all the shapes together to find the total area of the composite shape.
b There are 3 rectangles and two semi-circles.	Decompose the composite shape by identifying the regular shapes.
$A = lw$	Calculate the area of all rectangles using the formula.
$A = 10.5 \times 3 = 31.5 \text{ cm}^2$	Substitute the values for l and w.
$A = 5 \times 3 = 15 \text{ cm}^2$	
$A = 5 \times 3 = 15 \text{ cm}^2$	
$r = \frac{D}{2} = \frac{3}{2} = 1.5$	Both semi-circles have a diameter of 3 cm, so they make one whole circle when combined. The radius of the circle is half of the diameter.
$A = \pi r^2$	Calculate area of the circle using the formula.

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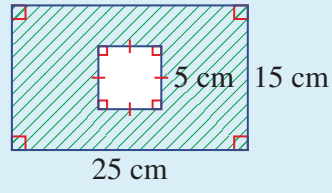
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$A = \pi \times 1.5^2$	◂ Substitute the value for r.
$A = 7.07 \text{ cm}^2$	◂ Round your answer to two decimal places.
$A = 31.5 + 15 + 15 + 7.07$ $A = 68.57 \text{ cm}^2$	◂ Add all the shapes together to find the total area of the composite shape.

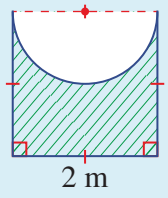
Example 7 Calculating the area of composite shapes with subtraction

For the following composite shapes, calculate the area of the shaded section, correct to two decimal places if needed.

a



b



WORKING	THINKING
a There is one rectangle and one square that is cut out from the centre.	Decompose the composite shape by identifying the regular shapes.
$A = lw$	◂ Calculate the area of the rectangle using $A = lw$.
$A = 25 \times 15 = 375 \text{ cm}^2$	◂ Substitute the values for l and w.
$A = l \times l$	◂ Calculate the area of the square using $A = l \times l$.
$A = 5 \times 5 = 25 \text{ cm}^2$	◂ Substitute the value for l.
$A = 375 - 25 = 350 \text{ cm}^2$	◂ Subtract the square from the rectangle to find the shaded area.

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b There is one square and one semi-circle that is cut out from the top of the square.

Decompose the composite shape by identifying the regular shapes.

$A = l \times l$

◄····· Calculate the area of the square using $A = l \times l$.

$A = 2 \times 2 = 4 \text{ m}^2$

◄····· Substitute the value for l.

$r = \frac{D}{2} = \frac{2}{2} = 1 \text{ m}$

◄····· Find the radius by halving the diameter (divide by 2).

Area of semi-circle

◄····· The shape is half of a circle (semi-circle): $A = \frac{1}{2} \times \text{circle}$
$= \frac{1}{2} \times \pi r^2$.

$A = \frac{1}{2} \times \pi r^2$

◄····· Substitute the value for r.

$A = \frac{1}{2} \times \pi \times 1^2$

$A = 1.57 \text{ m}^2$

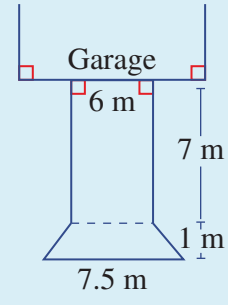
$A = 4 - 1.57$

◄····· Subtract the semi-circle from the square to find the shaded area.

$A = 2.43 \text{ m}^2$

Example 8 Applying the area of composite shapes to practical problems

A driveway, as shown in the diagram, is to be concreted. Calculate the area of the driveway, correct to two decimal places.



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WORKING	THINKING
	Formulate
Need to find area of the driveway. It is made up of a rectangle and a trapezium. Rectangle, $A = lw$ Trapezium, $A = \frac{1}{2}(a + b)h$	• What do you need to find? • Can you break the shape up into smaller, regular shapes? • What rules can you use?
	Solve
 $A = lw$ $A = 6 \times 7$ $A = 42 \text{ m}^2$	• Substitute values to find area of rectangle.
 $A = \frac{1}{2}(a + b)h$ $A = \frac{1}{2}(6 + 7.5) \times 1$ $A = 6.75 \text{ m}^2$	• Substitute values to find area of trapezium.
$A = 42 + 6.75$ $= 48.75 \text{ m}^2$	• Add two areas to find total area.
	Evaluate and verify
	• Have you answered the question? • Have you used the correct units?
	Communicate
The area of the driveway is 48.75 m^2.	• Write the answer in a sentence.

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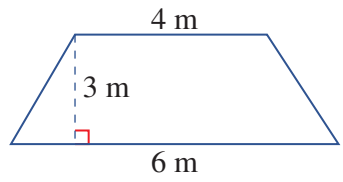
Exercise 3B

FUNDAMENTALS

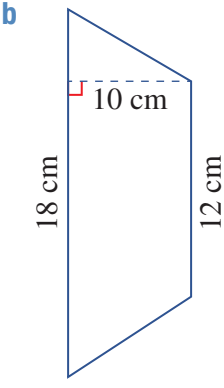
Example 4

1 Calculate the area of the following trapeziums.

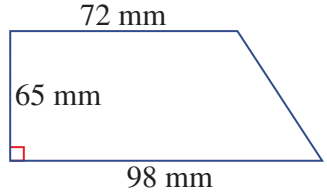
a



b



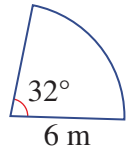
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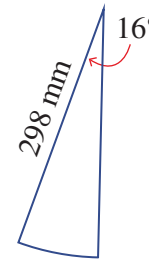
Example 5

2 Calculate the area of the following sectors.

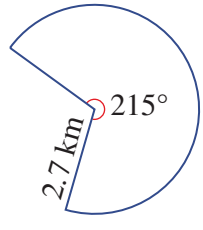
a



b



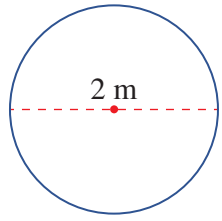
c



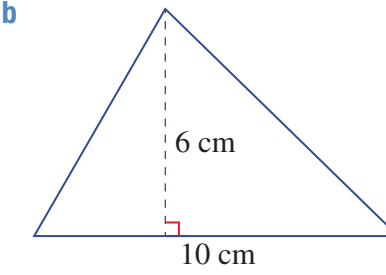
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3 Calculate the area of the following common 2D shapes.

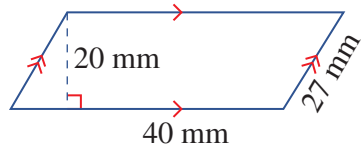
a



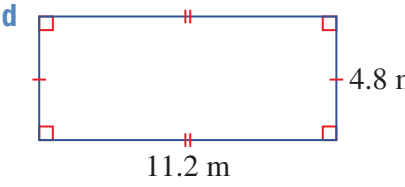
b



c



d

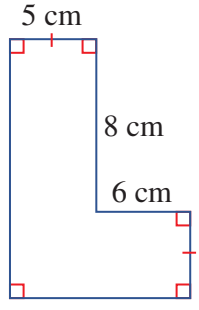


Example 6

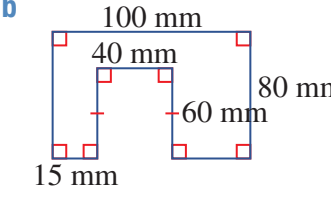
4 Determine the area of the following composite shapes by first decomposing the shapes into regular shapes and then adding the areas of the shapes.

Hint Redraw the shapes into the common shapes to help you calculate the total area.

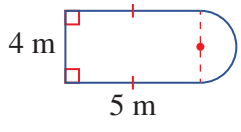
a



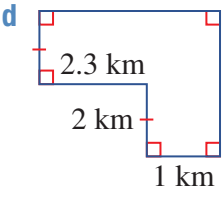
b



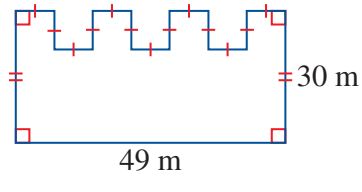
c



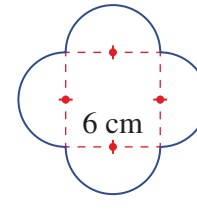
d



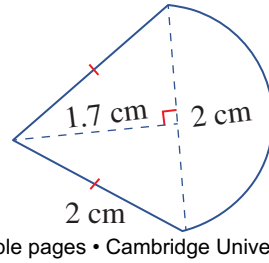
e



f



g

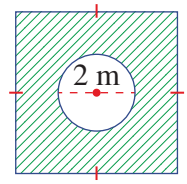


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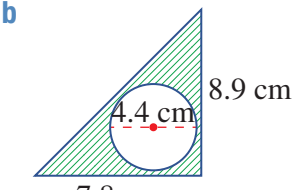
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Example 7 **5** Determine the area of the shaded section in the following composite shapes by first decomposing the shape into regular shapes and then subtracting the sections that are not shaded. All angles that look like right angles are 90°.

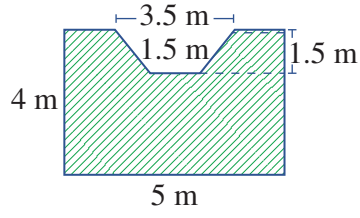
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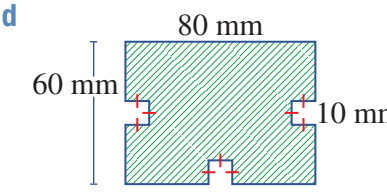
b



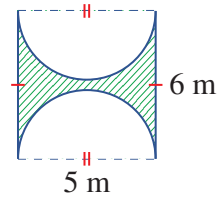
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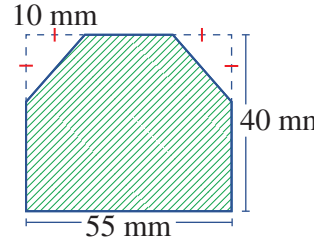
d



e

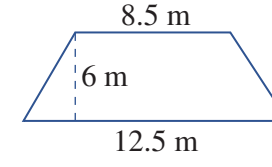


f

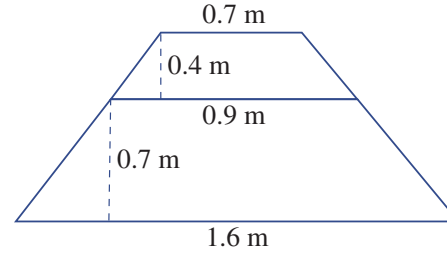


APPLICATIONS

Example 8 ★**6** Ben is planning on making a new shade sail to run from the roof line of his house, across his deck, and on to some posts that are near his pool. The design of the sail is shown. Calculate the area of the material that Ben needs for the sail.



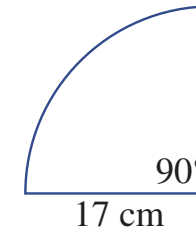
★**7** Hans has been commissioned to re-paint a fading sign of a pizza restaurant. He is calculating how much red paint he will require for the section of the sign shown. He has discovered that the sign makes two trapeziums and has measured the dimensions shown. Calculate the total area that will require red paint.



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CF

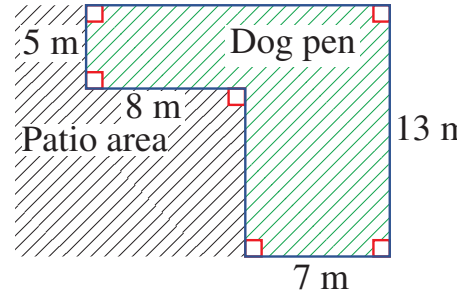
★8 Leonie has ordered a pizza that has a diameter of 34 cm. She has eaten a quarter of the pizza.



a Use the diagram to calculate the area of pizza that Leonie has consumed.

b Determine the area of the pizza that will be left over for Leonie's friends to consume.

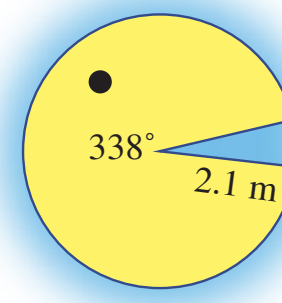
★9 Ruby is laying a large patch of grass area next to her patio, as shown in the diagram, to create a dog pen. Calculate the total area of turf that Ruby needs to purchase.



CU

★10 Randal has been commissioned to paint a large logo on a billboard. He needs to buy the correct amount of yellow paint that covers the area of the logo in the image. Randal will need to multiply the total area by two, as he will need to complete two coats of paint on the logo. If 1 litre of paint covers 15 m^2, determine how many litres of paint Randal will need.

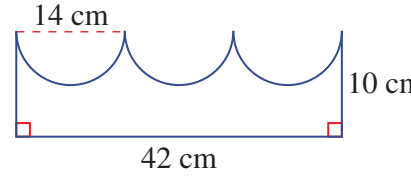
Note: Randal will start with yellow paint and will paint the eye of the icon over the top.



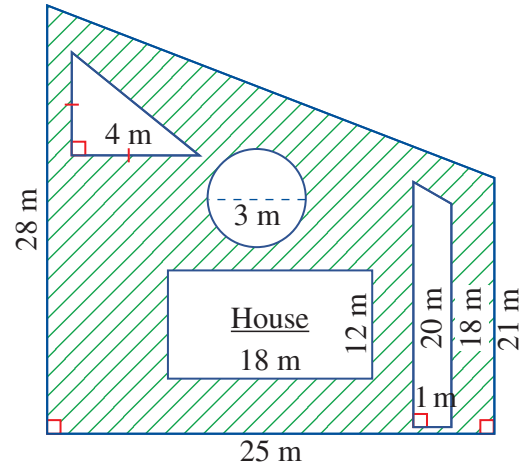
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CU

★11 Anaya is making eight crowns for her daughter's fifth birthday party. She plans on cutting the crowns out of cardboard and covering the outside surface in glitter. The image shown is an outline for the crowns. Calculate the total area that Anaya will need to cover.



★12 Below is an image of Shekila's property. She has outlined her house, water feature and two garden beds. Shekila would like to lay lawn everywhere else on her property. Calculate the total area of Shekila's lawn.



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3C Calculating the surface areas of cubes, prisms and pyramids

COMPLEX

LEARNING GOALS

- Draw 2D representations in the form of a net, to show all faces of a 3D solid.
- Calculate the surface area of prisms.
- Calculate the surface area of pyramids.

Why is it essential to calculate the surface area of 3D solids?

- Calculating the surface area of 3D objects allows us to calculate how much material is needed to construct the surface of the object or to paint, cover or finish it.
- Applying yourself to learning this skill will also help you to develop your spatial awareness.



The amount of paint required to cover the surface area of a composite solid can be found by adding the surface areas of the visible regular shapes.

WHAT YOU NEED TO KNOW

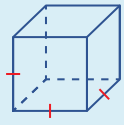
- Surface area is the sum of the area of all faces on a 3D solid shape.
- When calculating the surface area of a prism or pyramid, start by drawing the **net** of the solid to identify all of its faces.
- Nets for 3D shapes are dealt with in Section 2B.
- To calculate the surface area of a 3D solid, calculate the area of all of the **faces** (the 2D shapes) in the net and add them up.
- After drawing the net, you may find it helpful to group identical faces together and to draw each type, with dimensions. This is shown in Examples 10 and 11.
- There are different types of triangular-based pyramids, so be sure to use the correct base and height for each triangle when applying your formula.

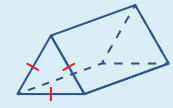
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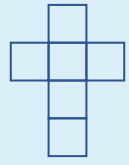
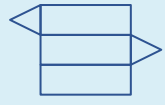
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Example 9 Identifying and drawing the net of a solid

Draw a net to represent the following 3D solids.

a 

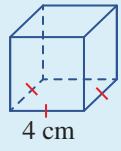
b 

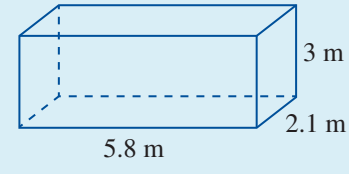
WORKING	THINKING
a 	There are many possible solutions to the design of both nets, all of which are accurate. Check that you have the correct number of faces, edges and vertices to form the solid. This 3D solid is a cube, so all six faces are squares.
b 	This 3D solid is a triangular prism, so there are 2 triangles that are the ends. The other 3 faces are rectangles. The triangle is an equilateral triangle so all rectangles have the same dimensions.

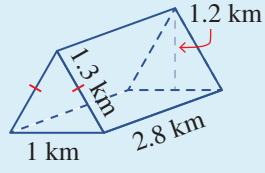
Note: other answers are possible.

Example 10 Calculating the surface area of a cube, rectangular prism and triangular prism

Calculate the surface area of the following 3D solids.

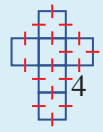
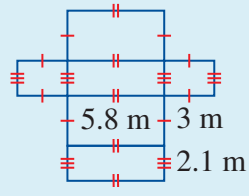
a 

b 

c 

... Continued

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WORKING	THINKING
a 	Draw a net of the cube, including the dimensions.
4 cm 4 cm	There are 6 square faces in a cube.
$A = l \times l$	Calculate the area of one square using $A = l \times l$.
$A = 4 \times 4 = 16 \text{ cm}^2$	Substitute the value for l.
Total surface area $= 16 \times 6$ $= 96 \text{ cm}^2$	There are 6 identical square faces in the cube, so multiply the area of one square by 6.
b 	Draw a net of the rectangular prism, including the dimensions.
	There are three pairs of rectangles.
$A1$ 3 m 5.8 m	Two rectangles are 5.8 m by 3 m.
$A2$ 2.1 m 5.8 m	Two rectangles are 5.8 m by 2.1 m.
$A3$ 2.1 m 3 m	Two ends of the prism make two smaller rectangles that are 3 m by 2.1 m.
$A = lw$	Calculate the area of each rectangle pair using $A = l \times w$.
$A1 = 5.8 \times 3 = 17.4 \text{ m}^2$ $A2 = 5.8 \times 2.1 = 12.18 \text{ m}^2$ $A3 = 2.1 \times 3 = 6.3 \text{ m}^2$	Substitute the values for l and w in each rectangle pair.

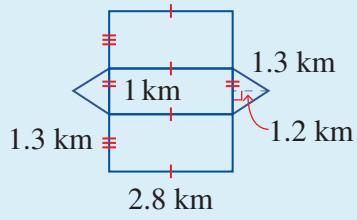
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Total surface area
$= (17.4 \times 2) + (12.18 \times 2) + (6.3 \times 2)$
$= 34.8 + 24.36 + 12.6 = 71.76 \text{ m}^2$

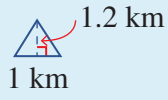
◄····· Double each rectangle area and add all the areas together to find the total surface area of the rectangular prism.

c



◄····· Draw a net of the triangular prism, including the dimensions. There is one pair of triangles, one pair of identical rectangles and one other rectangle.

$A1$



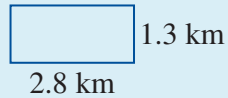
◄····· Two triangles have a base of 1 km and a height of 1.2 km.

$A2$



◄····· Two identical rectangles are 2.8 km by 1 km.

$A3$



◄····· One other rectangle is 2.8 km by 1.3 km.

$A = \frac{1}{2}bh$

◄····· Calculate the area of the triangles using $A = \frac{1}{2} \times b \times h$.

$A1 = \frac{1}{2} \times 1 \times 1.2 = 0.6 \text{ km}^2$

◄····· Substitute the values for b and h.

$A = lw$

◄····· Calculate the area of each rectangle pair using $A = l \times w$.

$A2 = 2.8 \times 1.3 = 3.64 \text{ km}^2$
$A3 = 2.8 \times 1 = 2.8 \text{ km}^2$

◄····· Substitute the values for l and w.

Total surface area
$= (0.6 \times 2) + (3.64 \times 2) + 2.8$
$= 1.2 + 7.28 + 2.8 = 11.28 \text{ km}^2$

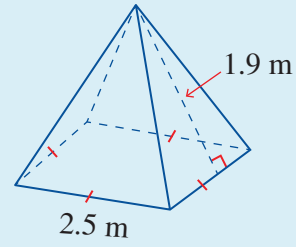
◄····· Double the rectangle area ($A2$) and the triangle area ($A1$). Add all the areas together to calculate the total surface area of the triangular prism.

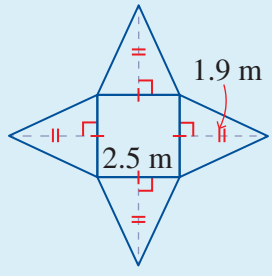
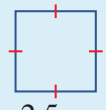
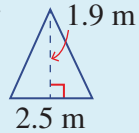
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Example 11 Calculating the surface area of pyramids

Calculate the surface area for the following pyramid.



WORKING	THINKING
	Draw a net of the square-based pyramid, including the dimensions.
$A1$ 	There is one square with a side length of 2.5 m.
$A2$ 	There are four identical triangles with a base of 2.5 m and height of 1.9 m.
$A = l \times l$	Calculate the area of the square ($A1$) using $A = l \times l$.
$A1 = 2.5 \times 2.5$ $= 6.25 \text{ m}^2$	Substitute the values for l.
$A = \frac{1}{2}bh$	Calculate the area of the identical triangles ($A2$) using $A = \frac{1}{2}bh$.

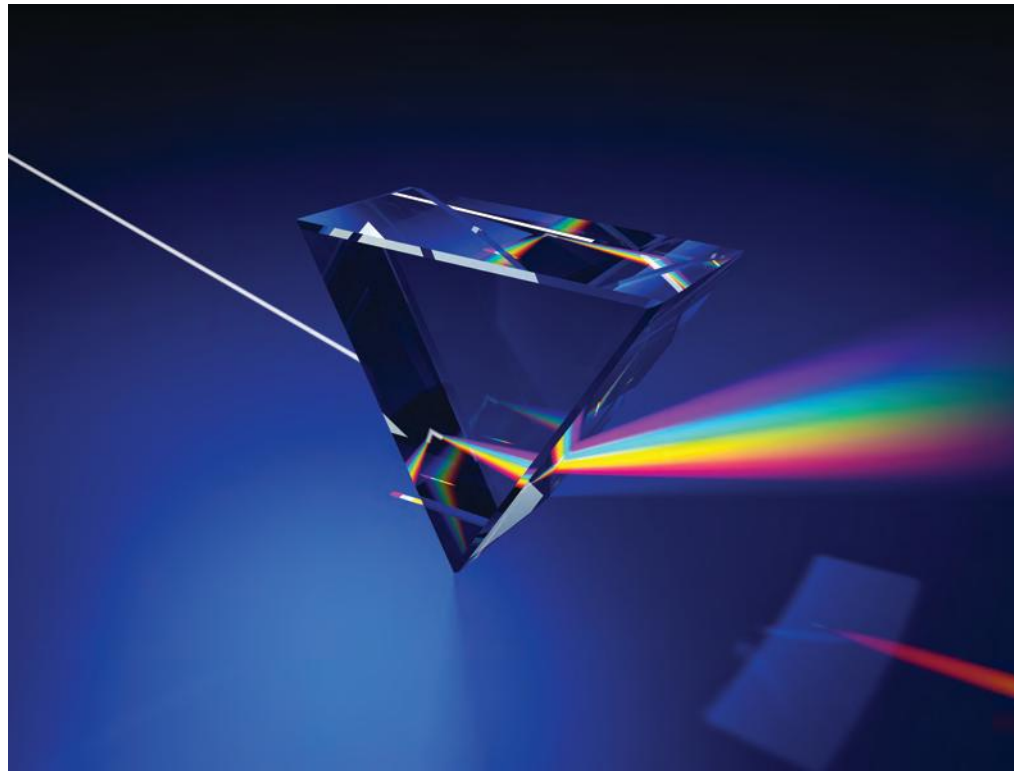
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$A2 = \frac{1}{2} \times 2.5 \times 1.9$
$= 2.375 \text{ m}^2$

◄····· Substitute the values for b and h.

Total surface area
$= 6.25 + (4 \times 2.375)$
$= 6.25 + 9.5$
$= 15.75 \text{ m}^2$

◄····· Multiply the area for the identical triangles by 4. Add the area of the square base to the area of the 4 triangles to calculate the total surface area of the square-based pyramid.



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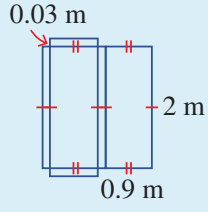
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Example 12 Applying the surface area of 3D solids to practical problems

Cailin is painting the inside of her house. She has 10 doors that she needs to remove from the hinges and paint. The doors are rectangular prisms in shape, as shown in the image. They are 0.9 m wide, 2 m high and 0.03 m thick. Determine the total surface area of all 10 doors that Cailin needs to paint.

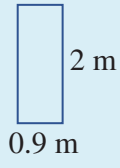


WORKING	THINKING
	Formulate
Need to find surface area of 10 doors.	• What do you need to find?
Net of the prism:	• What information do you have? • What rules could you use?



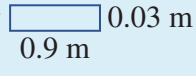
Break net into standard shapes

*A*1



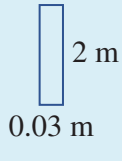
There are three pairs of rectangles. Two rectangles are 0.9 m by 2 m.

*A*2



Two rectangles are 0.9 m by 0.03 m.

*A*3



Two rectangles are 0.03 m by 2 m.

Area, $A = lw$

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Solve

$A1 = lw$
$A1 = 2 \times 0.9 = 1.8 \text{ m}^2$ ◄····· Find $A1$ using $A = lw$.

$A2 = lw$
$A2 = 0.03 \times 0.9 = 0.027 \text{ m}^2$ ◄····· Find $A2$ using $A = lw$.

$A3 = lw$
$A3 = 0.03 \times 2 = 0.06 \text{ m}^2$ ◄····· Find $A3$ using $A = lw$.

$\text{Total} = 2 \times A1 + 2 \times A2 + 2 \times A3$
$= 2 \times 1.8 + 2 \times 0.027 + 2 \times 0.06$
$= 3.774 \text{ m}^2$ ◄····· Find the total surface area of one door by summing the areas together.

For 10 doors, total area $=$
$10 \times 3.774 = 37.74 \text{ m}^2$. ◄····· There are 10 doors.

Evaluate and verify

- Have you answered the questions?
- Have you included correct units?

Communicate

Caitlin will need to paint a surface area of 37.74 m^2. ◄····· Write answer in a sentence.

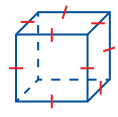
Exercise 3C

FUNDAMENTALS

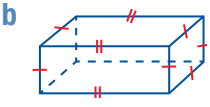
Example 9

1 Draw a net that represents each of the following 3D solids.

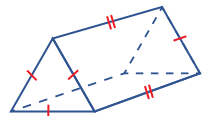
a



b



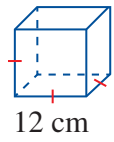
c



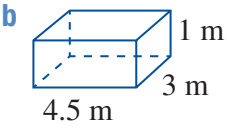
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Example 10 **2** Calculate the surface area of the following cubes and rectangular prisms.

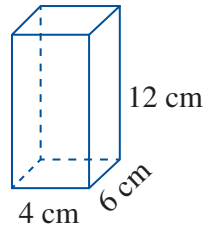
a



b



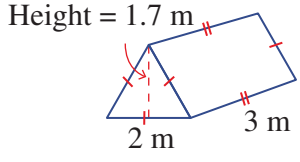
c



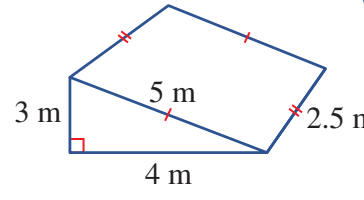
Example 10 **3** Calculate the surface area of the following triangular prisms.

Hint Draw the net of each solid to help you work out the total surface area.

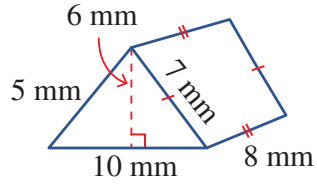
a



b

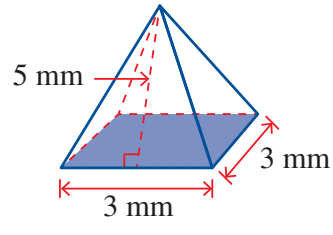


c

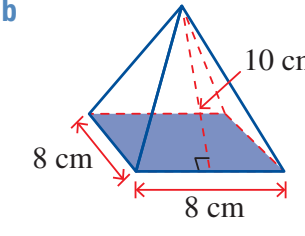


Example 11 **4** Calculate the surface area of the following square-based pyramids.

a

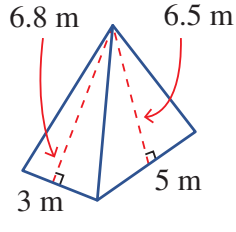


b

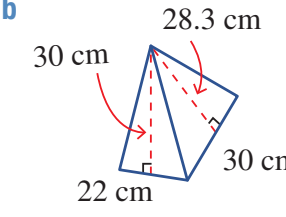


Example 11 **5** Calculate the surface area of the following rectangular-based pyramids.

a



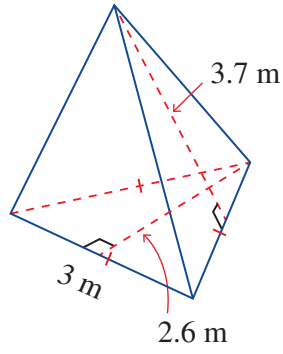
b



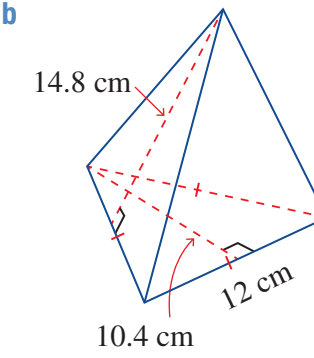
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6 Calculate the surface area of the following triangular-based pyramids.

a



b

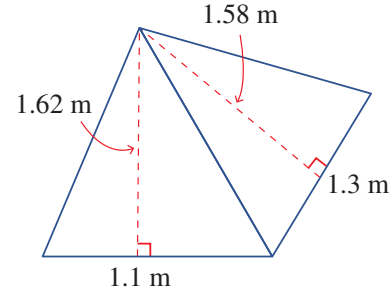


APPLICATIONS

Example 12 ★**7** Scott is sewing together the outer cover of a foot stool that looks like a Rubik's cube. He would like the stool to be 60 cm cube. Calculate the total area of material that Scott will require to cover the outside of the foot stool. CF



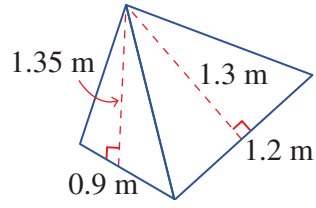
★**8** Michael is making a rectangular-based pyramid out of stainless steel to put on display in his garden. The plan for Michael's pyramid is shown in the diagram. Determine the total area of stainless steel required. CU



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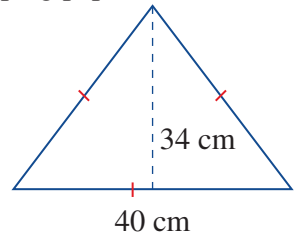
CU

★9 Anika makes children's play teepees and sells them at the markets. The tepees are rectangular-based pyramids as shown in her sewing plan below. At her last market, she sold 8 teepees. Calculate the total area of material that Anika used to make the teepees that were sold at the market on that day.





★10 Madison has won a giant Toblerone. She is planning on wrapping it in paper and giving it to her mum for Christmas. The Toblerone is 1.5 metres long, and the measurements for the equilateral triangle at either end are shown in the diagram below. Determine the minimum total area of wrapping paper that Madison will require, ignoring the need to overlap the edges of the wrapping paper.





★11 Renee is designing and sewing a tent for her husband. She plans on making it in the shape of a rectangular prism. It needs to be big enough that her husband can stand in it, and it also needs to fit their double air mattress. Her husband is 1.8 metres tall, and their air mattress is 1.6 metres wide and 2 metres long. Sketch a plan for Renee's tent and calculate the total area of material that she will require, including the base (groundsheet).

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3D Calculating the surface areas of spheres, cones and cylinders

COMPLEX

LEARNING GOALS

- Apply the formula $S = 4\pi r^2$ to find the surface area of a sphere.
- Apply the formula $S = \pi rs + \pi r^2$ to find the surface area of a cone.
- Apply the formula $S = 2\pi rh + 2\pi r^2$ to find the surface area of a cylinder.

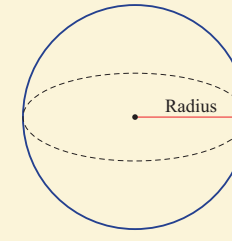
Why is it essential to calculate the surface areas of spheres, cylinders and cones?

- The surface area of a sphere can be used to calculate material required to make a ball for sport.
- The surface area of a cone can be used to calculate area of an ice cream cone.
- The surface area of a cylinder is useful in calculating material required to make a soft drink can.



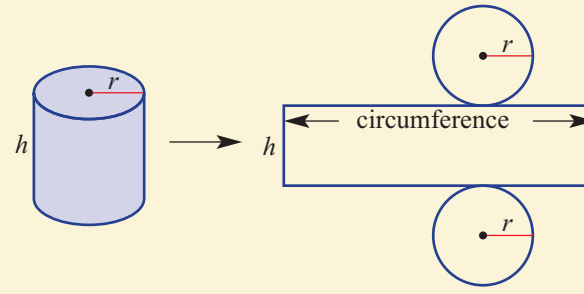
WHAT YOU NEED TO KNOW

- A **sphere** is a perfectly round 3D solid.
- **Radius** is the distance from the centre of the sphere to the outside.
- Surface area is found using $S = 4\pi r^2$.
- A **cylinder** could be considered a 'circular prism', but it does not have straight sides and so does not fall into the prism category.

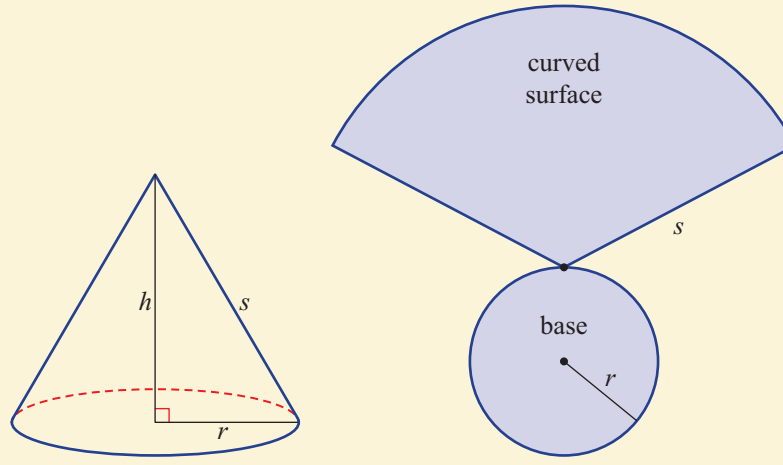


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- The net of a **closed cylinder**, shown in the diagram, is made up of two circles joined by a rectangle. The length of the sides touching the circles is the same as the **circumference** of the circles.



- Surface area $=$ rectangle $+ 2 \times$ circles
  $=$ Circumference $\times$ height $+ 2 \times$ circles
  $= 2\pi r \times h + 2 \times \pi r^2$
  $S = 2\pi rh + 2\pi r^2$
- An **open cylinder** does not include the circular ends, so we only need to use the first part of the formula: $S = 2\pi rh$.
- A **cone** could be considered a 'circular pyramid', but it does not have straight sides and so does not fall into the pyramid category.
- The net of a **closed cone**, shown in the diagram, is made up of a circle joined to a sector.



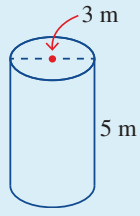
- Surface area $=$ curved surface $+$ base
  $S = \pi rs + \pi r^2$ where $s =$ slant length, $r =$ radius

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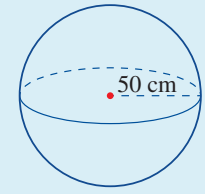
Example 13 Calculating the surface areas of spheres, cylinders and cones

Calculate the surface area of the following solids. Round your answers to two decimal places.

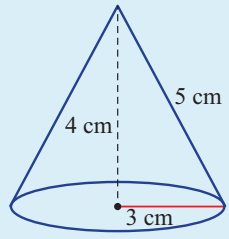
a



b



c



WORKING	THINKING
a Radius $= 3 \div 2 = 1.5$ m	Determine the radius first by halving the diameter.
$S = 2\pi rh + 2\pi r^2$ $S = 2 \times \pi \times 1.5 \times 5 + 2 \times \pi \times 1.5^2$ $S = 47.12 + 14.14$ $S = 61.26$ m^2	Calculate the surface area of a cylinder using the formula $S = 2\pi rh + 2\pi r^2$. Substitute the values for radius (r) and height (h). Round your answer to two decimal places.
b $S = 4\pi r^2$ $S = 4 \times \pi \times 50^2$ $S = 31\,415.93$ cm^2	Calculate the surface area of the sphere using the formula $S = 4\pi r^2$. Substitute the value for the radius (r). Round your answer to two decimal places.
c $S = \pi rs + \pi r^2$ $S = \pi \times 3 \times 5 + \pi \times 3^2$ $= 75.40$ cm^2	Calculate the surface area of a cone using the formula $S = \pi rs + \pi r^2$. Substitute $r = 3$ and $s = 5$. Round answer to two decimal places.

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Example 14 Applying the surface area of a cylinder to a practical problem

Lachlan enjoys four-wheel driving and fishing at the beach. He is making a storage container for his fishing rods to attach to his four-wheel drive ute. He has purchased a 5-metre long PVC pipe and two end caps. The caps and pipe have a diameter of 25 cm. He needs to calculate the surface area of the storage container, including the end caps, so that he can paint it black to match his vehicle. Calculate the surface area of the storage container.

WORKING	THINKING
	Formulate
Need to find the surface area of a cylinder. Height = 5 m Diameter = 25 cm $= 25 \div 100 = 0.25$ m	• What do you need to find? • What information do you have? • What rules can you use?
	Solve
$r = \frac{D}{2}$ For a cylinder $S = 2\pi rh + 2\pi r^2$	• Substitute values to find radius.
$r = \frac{D}{2} = \frac{0.25}{2} = 0.125$ m	• Substitute to find radius
$S = 2\pi rh + 2\pi r^2$ $S = 2 \times \pi \times 0.125 \times 5 + 2 \times \pi \times 0.125^2$ $S = 4.03$ m^2	• Substitute values to find the surface area.
	Evaluate and verify • Have you answered the question? • Have you used the correct units?
	Communicate
Lachlan needs to paint an area of 4.03 m^2.	• Write the answer in a sentence.

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Exercise 3D

FUNDAMENTALS

1 Match the shape with the correct formula to calculate the surface area.

a 

b 

c 

d 

e 

f 

A surface area of a sphere

$$S = 4\pi r^2$$

B total surface area of a cylinder

$$S = 2\pi rh + 2\pi r^2$$

C surface area of a hemisphere

$$S = \frac{1}{2} \times 4\pi r^2$$

D curved surface area of a cone

$$S = \pi rs$$

E curved surface area of a cylinder

$$S = 2\pi rh$$

F total surface area of a cone

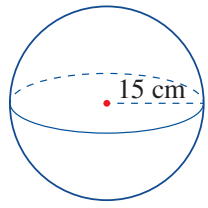
$$S = \pi rs + \pi r^2$$

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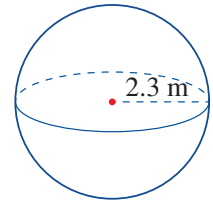
Example 13

2 Calculate the surface area of the following spheres. Round your answer to two decimal places where necessary.

a

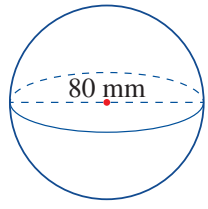


b



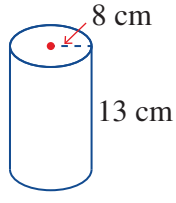
Hint $A = 4\pi r^2$

c

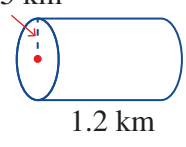


3 Calculate the surface area of the following closed cylinders. Round your answer to two decimal places where necessary.

a

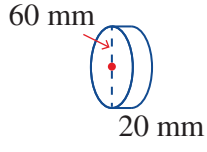


b



Hint $A = 2\pi rh + 2\pi r^2$

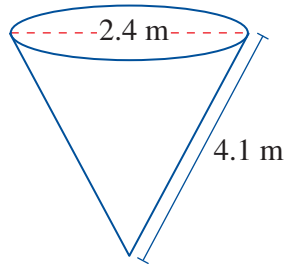
c



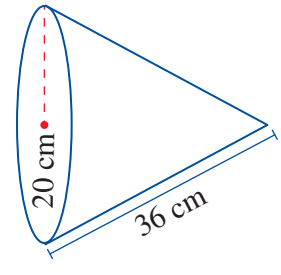
Example 18

4 Calculate the surface area of the following cones.

a

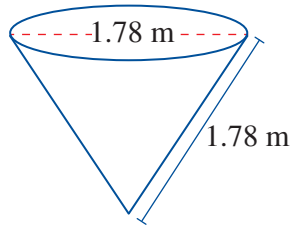


b



Hint $A = \pi rs + \pi r^2$

c



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APPLICATIONS

Example 14 ★5 Georgie has saved a Pringles container that her mum was going to throw out. It has a height of 30 cm and a diameter of 8 cm. She plans on decorating the container so that she can store some craft items in it. Georgie will be covering the container with contact. Calculate the total surface area of the container.



CF

★6 Tanya is powder coating a pole that will be holding up a sail. It has a height of 3 m and a radius of 0.08 m. Calculate the total surface area of the pole.

★7 Asher works in a factory that makes tennis balls. His job is to apply the glue that holds the felt on the ball. An average tennis ball has a diameter of 6.6 cm. Determine the area of glue required for each ball.

★8 In the heart of Adelaide, South Australia, lies Rundle Mall, where a giant sculpture by Bert Flugelman resides, called 'On Further Reflection'. It is two stainless steel spheres, one on top of the other, which were gifted to the city in 1977. The spheres have a diameter of 2.15 metres. Calculate the total surface area of both spheres.



CU

★9 Earth has a diameter of 12 742 km. Determine the total surface area of the Earth, assuming it is a sphere.

★10 Kanku has been given a digeridoo to paint. He will be painting the external curved surface black as a base for his artwork. The digeridoo is a cylinder with a length of 130 cm and a radius of 1.6 cm. Determine the area of the curved surface that Kanku will be painting.



11 This image shows Vietnamese women wearing traditional conical hats. The hat has a diameter of 50 cm and a slant height of 35 cm. Calculate the outer surface area of the hat.



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3E Calculating the surface areas of irregular solids

COMPLEX

LEARNING GOALS

- Identify regular 3D solids with in irregular solids.
- Calculate the surface area of irregular solids.

Why is it essential to calculate the surface areas of irregular solids?

- Not all objects are formed with the use of familiar solids.
- Sometimes we need to identify the familiar shapes within an object so that we can calculate the surface area of an irregular solid.
- This helps in careers such as painting and construction, along with baking.



The main shape of this gingerbread house is made from a triangular prism on top of a rectangular prism.

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WHAT YOU NEED TO KNOW

- For the purposes of this course, an **irregular solid** is either a **composite 3D solid** that consists of two or more of the common solids, or it is part of a common solid, such as half a sphere or half a cylinder cut lengthways.
- We can calculate the surface area of irregular solids if their **nets** are formed from the 2D shapes.

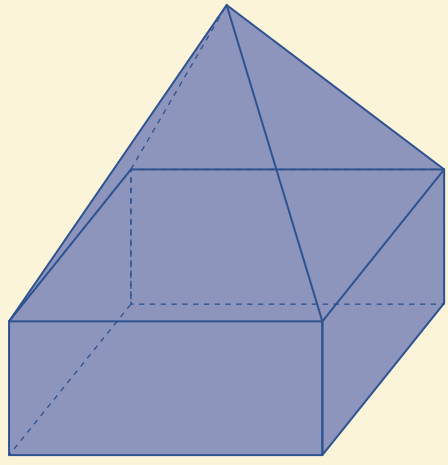
Shape	Formula
Square	$A = l^2$
Rectangle	$A = lw$
Triangle	$A = \frac{1}{2}bh$
Parallelogram	$A = bh$
Trapezium	$A = \frac{1}{2}(a + b)h$
Circle	$A = \pi r^2$
Sector	$A = \frac{\theta}{360}\pi r^2$

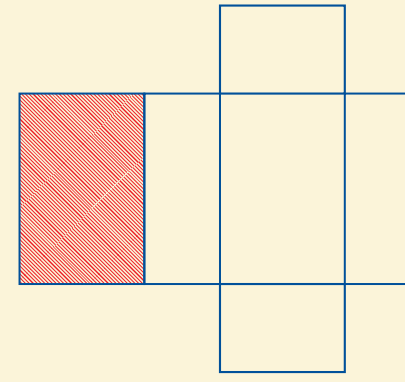
- We may be able to calculate the surface area of irregular solids if they include spheres, cylinders and cones.

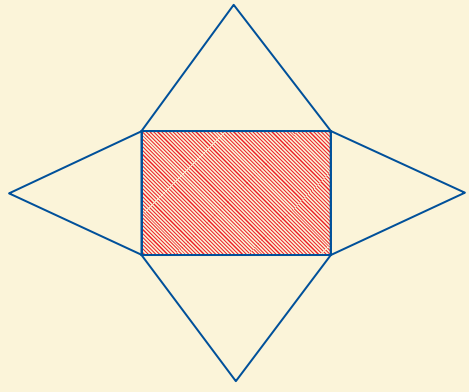
Shape	Formula
Sphere	$S = 4\pi r^2$
Closed cylinder	$S = 2\pi rh + 2\pi r^2$
Cone	$S = \pi rs + \pi r^2$

- For the total surface area of an irregular solid, you need to remember not to include any surfaces that are not visible from the outside of the solid.
  For example, shown below is an irregular solid with a rectangular-based pyramid on top of a rectangular prism. Draw a sketch of the nets for each solid. Think about which parts are not visible in the solid:
  - In the rectangular prism, the top side is not included.
  - In the rectangular-based pyramid, the base rectangle is not included.

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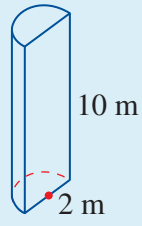




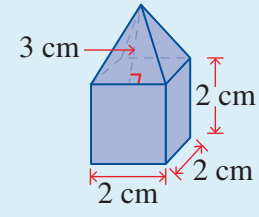
Example 15 Calculating the surface area of irregular solids

Calculate the surface area for each of the following irregular solids.

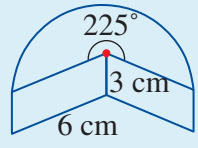
a



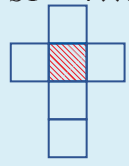
b



c



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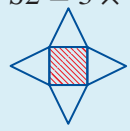
WORKING	THINKING
a Surface area for cylinder $S = 2\pi rh + 2\pi r^2$ $S = 2 \times \pi \times 1 \times 10 + 2 \times \pi \times 1^2$ $S = 69.12 \text{ m}^2$	The formula for finding the surface area of a cylinder is $S = 2\pi rh + 2\pi r^2$. The radius is half the diameter, so radius is 1 m. Substitute $r = 1$ and $h = 10$ into formula.
Surface area for half of cylinder $S1 = 69.12 \div 2$ $S1 = 34.56 \text{ m}^2$	This shape is only half a cylinder so divide your answer by 2.
Area of rectangle face $A = lw$ $S2 = 10 \times 2$ $S2 = 20 \text{ m}^2$	Calculate the area of the rectangular face by using $A = lw$. Substitute $l = 10$ and $w = 2$.
Total surface area $= S1 + S2$ $= 34.56 + 20$ $= 54.56 \text{ m}^2$	Calculate the total surface area by adding the surface areas for half the cylinder and the rectangle.
b Area of square base $A = 2 \times 2 = 4 \text{ cm}^2$	Calculate the area of the square base by using $A = l^2$.
Surface area of bottom cube $S1 = 4 \times 5 = 20 \text{ cm}^2$ 	The top of the cube is not visible (indicated by the shading) so instead of multiplying by 6, multiply by 5.
Surface of the triangle faces $A = \frac{1}{2}bh$ $A = \frac{1}{2} \times 2 \times 3 = 3 \text{ cm}^2$	Calculate the area of each triangle using the formula $A = \frac{1}{2}b \times h$.

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$S2 = 3 \times 4 = 12 \text{ cm}^2$



◄····· There are 4 triangles the same size, so multiply this by 4.

Total surface area
$= S1 + S2$
$= 20 + 12$
$= 32 \text{ cm}^2$

◄····· Add both sections of the irregular solid to calculate total surface area.

c Fraction of a cylinder:

$$S1 = \frac{\theta}{360} \times (2\pi r^2 + 2\pi rh)$$

$$S1 = \frac{225}{360} \times (2 \times \pi \times 6^2 + 2 \times \pi \times 6 \times 3)$$
$$= 212.06$$

◄····· The shape is a fraction of a cylinder plus two flat sides that are rectangles.
SA of a cylinder is given by:
$S = 2\pi r^2 + 2\pi rh$

$2 \times$ Flat rectangular faces:
$S2 = 2 \times lw$
$S2 = 2 \times 6 \times 3$
$S2 = 36$

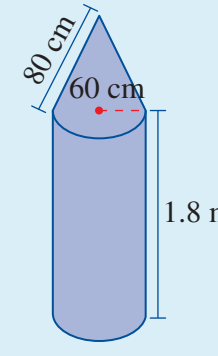
◄····· Area of a rectangle $= lw$

$SA = S1 + S2$
$= 212.06 + 36$
$= 248.06 \text{ cm}^2$

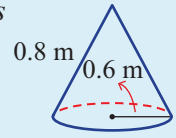
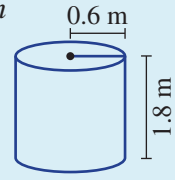
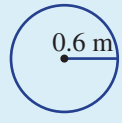
◄····· Calculate total surface area by adding S1 and S2 together.

Example 16 Applying the surface area of an irregular solid to practical problems

Melfred is painting a cardboard rocket that he has made with his son. Calculate the total surface area of the rocket. The 'cap' is a cone and the body is a cylinder. The base of the rocket is closed.



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WORKING	THINKING
	Formulate
Need to find surface area.	• What do you need to find?
S1 Curved surface of a cone	• Can you break the shape up into smaller, regular shapes?
$S = \pi rs$	• What rules can you use?
	
S2 Curved surface of cylinder	
$S = 2\pi rh$	
	
S3 Circle base	
$A = \pi r^2$	
	
	Solve
$S = \pi rs$	Substitute values to find surface area of curved surface of cone.
$S1 = \pi \times 0.6 \times 0.8$	
$S1 = 1.51 \text{ m}^2$	
$S = 2\pi rh$	Substitute values to find surface area of curved surface of a cylinder.
$S2 = 2 \times \pi \times 0.6 \times 1.8$	
$S2 = 6.79 \text{ m}^2$	
$A = \pi r^2$	Substitute values to find surface area of the circular base.
$S3 = \pi \times 0.6^2$	
$S3 = 1.13 \text{ m}^2$	
	Add three areas to find total area.
Total Surface area $= S1 + S2 + S3$	
$= 1.51 + 6.79 + 1.13$	
$= 9.43 \text{ m}^2$	

... Continued

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Evaluate and verify
Have you answered the question?
Have you used the correct units?

Communicate

The total surface area is 9.43 m^2. ◄····· Write the answer in a sentence.

Exercise 3E

FUNDAMENTALS

1 Identify these shapes and provide the formulas required to find their surface areas. (There is no need to calculate surface area.)

a



b



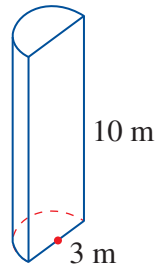
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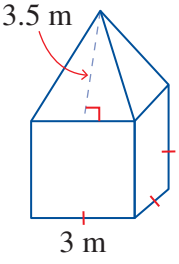
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Example 19 **2** Calculate the surface area of the following irregular solids.

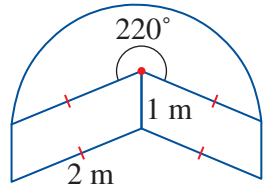
a



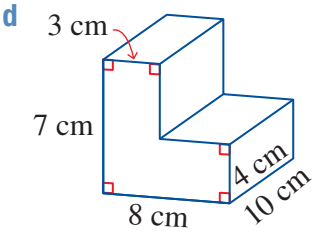
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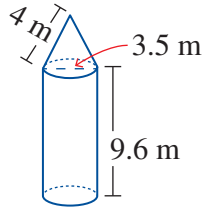
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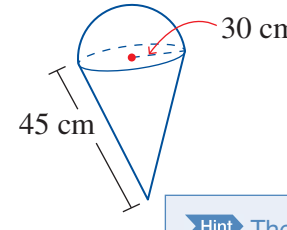
d



e

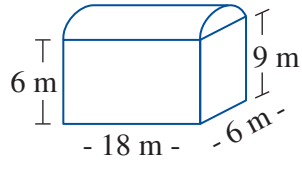


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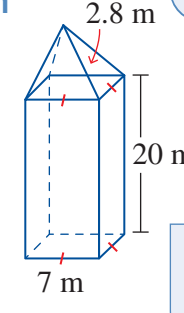


Hint The top is a hemisphere; the bottom is a cone.

g



h



Hint Draw the shapes that make all of the faces of the solid.

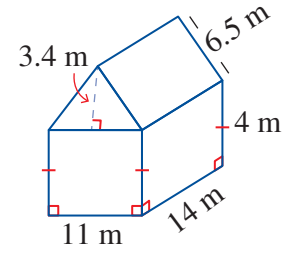
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APPLICATIONS

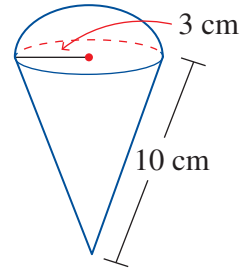
CF

Example 16 ★3 Millie is planning on painting the outside of her house. Use the diagram shown to calculate the total surface area.



★4 Tim has carved a wooden ice-cream for his son's play kitchen, as shown in the diagram. He plans on painting it for him. Determine the total area of paint that Tim will need.

Hint Break shape into smaller regular shapes.

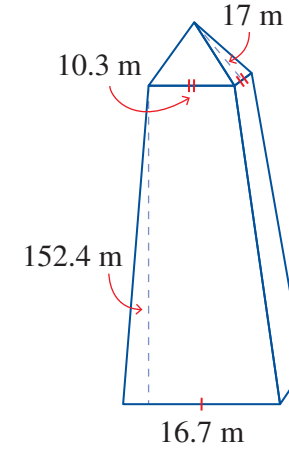


★5 Christine is making a layered sponge cake for her son's birthday. The rectangular tin she is using has a length of 30 cm, a width of 20 cm and a height of 5 cm. She is planning on stacking 3 cakes on top of each other. She will then ice the cake on all 4 sides and the top. Determine the total surface area for the icing.

CU

★6 A monument in Washington is 169.2 m tall in total. The main part has four equal-sized faces, each in the shape of a trapezium, and there is a square-based pyramid on the top. Calculate the total surface area of the monument, using the approximate measurements in the diagram shown.





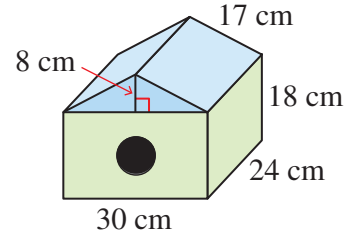
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CU

★7 Jean has some camembert cheese in her fridge that has a radius of 7 cm and a height of 3.2 cm. She has eaten a large slice that is approximately 70° of the total cheese. Determine the remaining surface area of the cheese.



★8 Mason has made a nesting box for his birds. The hole has a diameter of 9 cm. Calculate the external surface area of the nesting box after Mason cuts out the hole for the birds to enter.



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Modelling task



Context: Host cities for the Olympic games typically have a logo to identify with their games. The logo is usually in the same colour theme as the Olympic flag (with the 5 rings) and is made up of composite 2D shapes. This was the logo for when Australia last hosted the Olympic games in Sydney in 2000.

Task: Your task is to design a logo that could be used for the Brisbane 2032 games. The logo needs to fit within a 10×10 cm square and have an area between 40 cm^2 and 70 cm^2. The logo must be composed of at least 4 unique 2D shapes.

Stage 1: Formulate
Make an assumption of: • the shapes you may use for your design. Make an observation of: • the constraints placed upon your design • rules that can be used to calculate area.
Stage 2: Solve

• Sketch your logo ensuring that you:
  • incorporate at least four familiar 2D shapes
  • include measurements
  • create a composite-shaped feature
  • use a key.
• Calculate the area of your logo.

Stage 3: Evaluate and verify

• Check that the area of your logo meets the specifications:
  • fits inside a 10×10 cm square
  • composed of at least 4 unique 2D shapes
  • has an area between 40 cm^2 and 70 cm^2.

Stage 4: Communicate
Write a summary of your design highlighting what your logo represents.

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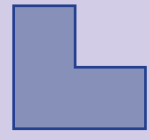
Chapter summary

Area formula

Shape	Example	Formula
Rectangle		$A = lw$
Triangle		$A = \frac{1}{2}bh$
Parallelogram		$A = bh$
Circle		$A = \pi r^2$
Trapezium		$A = \frac{1}{2}(a + b)h$
Sector		$A = \frac{\theta}{360}\pi r^2$

Area of composite shapes

- Shapes made up of two or more regular shapes are known as composite shapes.
- To calculate the area, decompose the shape into smaller shapes and use addition or subtraction.



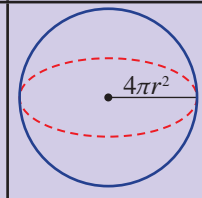
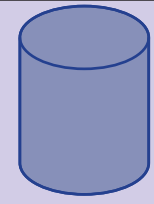
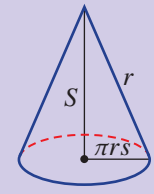

Surface area

- Surface area is the sum of the areas of all faces on a 3D solid shape.
- It is useful to draw a net to be able to decompose the solid shape into the separate face components.

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Surface area with curved surfaces

Shape	Example	Formula
Sphere		$S = 4\pi r^2$
Cylinder		$S = 2\pi rh + 2\pi r^2$ Curved surface $= 2\pi rh$
Cone		$S = \pi rs + \pi r^2$ Curved surface $= \pi rs$

Surface area of composite shapes

- 3D Shapes made up of two or more regular 3D shapes are called composite shapes.
- Decompose the shape into smaller shapes to calculate the area.

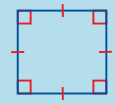
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Chapter checklist

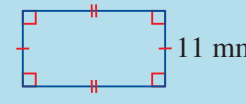
3A ☐ I can calculate and estimate the area of various familiar shapes.

1 Calculate the area of the following common 2D shapes.

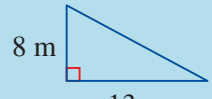
a



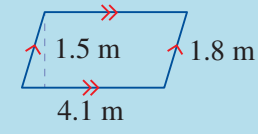
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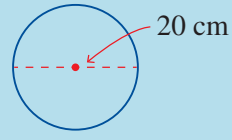
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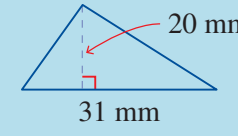
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e

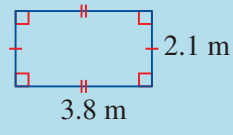


f

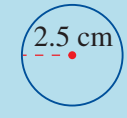


2 Estimate the area of the following common 2D shapes using leading digit approximation.

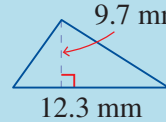
a



b



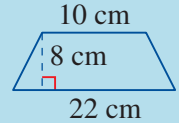
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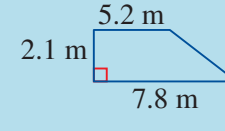
3B ☐ I can calculate the area of trapeziums and sectors.

3 Calculate the area of the following trapeziums.

a



b

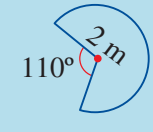


4 Calculate the area of the following sectors. Round your answers to two decimal places.

a



b



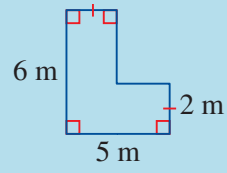
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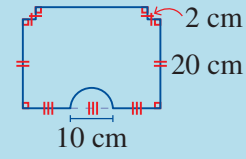
3B ☐ I can calculate the area of composite shapes by decomposing into common shapes.

5 Calculate the area of the following composite shapes.

a



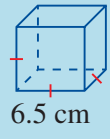
b



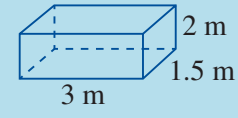
3C ☐ I can calculate the surface area of cubes, rectangular and triangular prisms.

6 Calculate the surface area of the following solids.

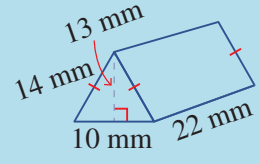
a



b



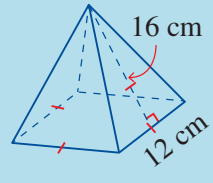
c



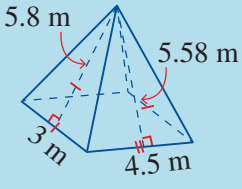
3C ☐ I can calculate the surface area of square-based and rectangular-based pyramids.

7 Calculate the surface area of the following pyramids.

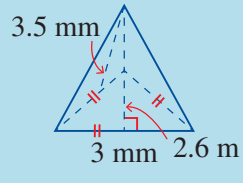
a



b



c

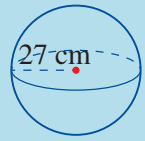


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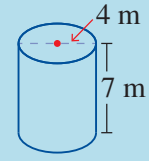
3D ☐ I can calculate the surface area of spheres and cylinders.

8 Calculate the area of the following sphere and cylinder.

a



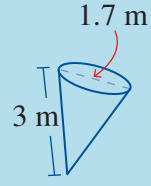
b



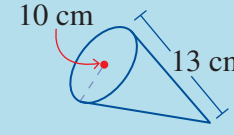
3D ☐ I can calculate the surface area of cones.

9 Calculate the surface area of the following cones.

a



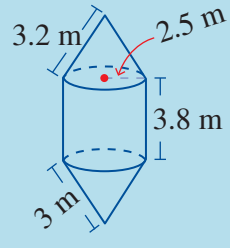
b



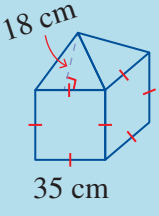
3E ☐ I can calculate the surface area of irregular solids.

10 Calculate the surface area of the following irregular solids.

a



b



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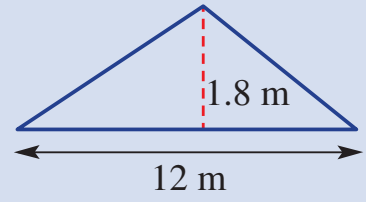
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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

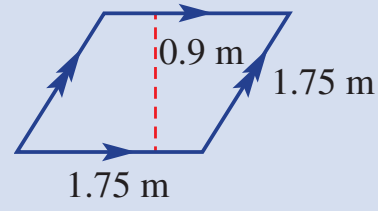
3A **1** The front of a house has a gable as shown.



Calculate the area of the gable.

3A **2** A floor rug measures 150 cm by 220 cm. Calculate the area of the rug.

3A **3** A puppy pushes on the corner of the square pen used to keep the puppy safe. It is now a parallelogram as shown.



a Calculate the area of the pen in its original square state.
b Calculate the area of the pen when pushed into a parallelogram.

3A **4** Thelma has just purchased a new block of land that is 32.7 metres long by 28 metres wide. Calculate the area of Thelma's land.

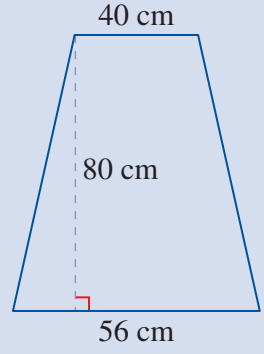
3A **5** James has built a new circular training pen for his horses that has a radius of 2.2 metres. Calculate the area of the training pen.

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Complex Familiar

3B **6** Emily has designed an A-line skirt that she is now planning on sewing. The image below shows the pattern for the front panel of the skirt. Calculate the area of material that Emily will need to make the front of the skirt.

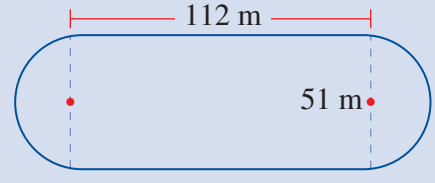




3B **7** Farmer Jo has slashed 310° from one of his circular planted hay crops that has a diameter of 800 metres. Determine the area of land that Jo has slashed for hay.



3B **8** Mason is polishing a speed-skating rink, as shown in the diagram. Calculate the area of the rink that Mason is polishing.

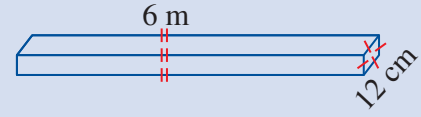


3C **9** Toby's dad has given him a cubed cardboard box that is 70 cm square. Toby is planning on painting the outside of the box red and using it as part of a rocket that he is building. Calculate the total surface area that Toby will be painting.

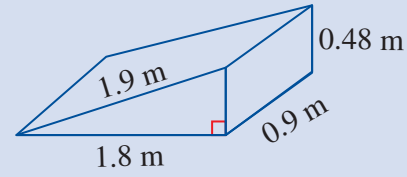
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3C **10** Bronte is varnishing a timber hand rail that is in the shape of a rectangular prism. Calculate the surface area of the prism in square metres.



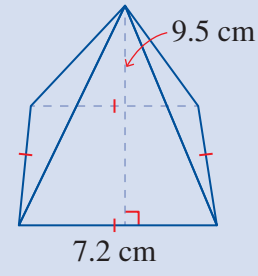
3C **11** Jaz has constructed a triangular prism out of MDF (medium-density fiberboard) to jump his BMX bike. The dimensions are shown in the diagram. Determine the total surface area of the ramp.



3D **12** Mike is a coach for shot put. So that he can easily locate his equipment at sporting events, he paints each shot put yellow. The shot puts have a radius of 60 mm and he has 10 of them. Determine the total surface area that Mike has painted.

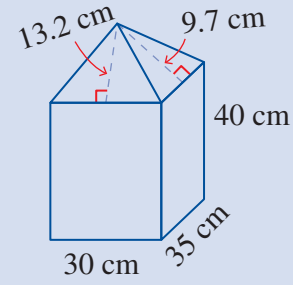
3D **13** Alisha has just finished making a timber table. The table has 4 legs that are shaped like a cylinder, and they have a height of 1.2 m and a diameter of 0.2 m. Before she attaches the legs to the table top, she wishes to varnish them first for protection. Determine the total area that Alisha will be varnishing.

3D **14** Haydn has bought his wife a candle in the shape of a square-based pyramid as shown. He has 160 cm^2 of wrapping paper left over at home. Determine if this will be enough wrapping paper to wrap the candle.



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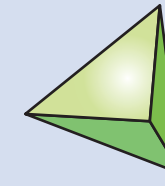
3E **15** James has made a new letterbox from steel that he plans on powder coating. Calculate the total surface area of the letterbox as shown in the diagram below.



Complex Unfamiliar

3B **16** Cooper has ordered a pizza for dinner. There are 8 slices of pizza, so he has calculated that each piece of pizza is 45° of the whole pizza. Cooper eats 4 pieces of pizza and his wife eats 3 pieces. Determine the area of pizza that both Cooper and his wife have consumed, if the pizza has a diameter of 35 cm.

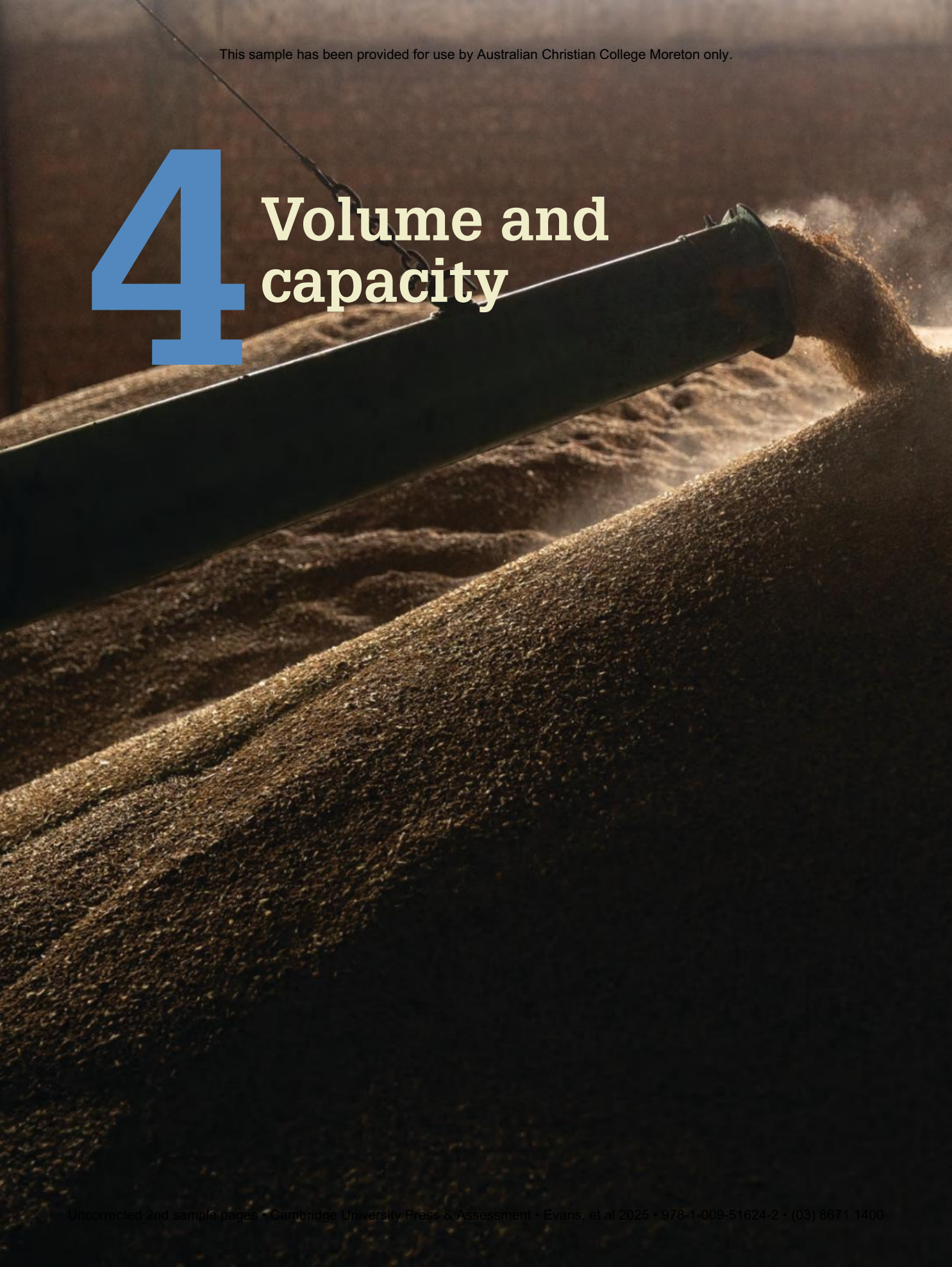
3E **17** A Pyraminx is a puzzle that is similar to the Rubik's cube, but it is the shape of a triangular pyramid with a base that is the same as the sides. (This shape, with all four triangular faces the same, is called a tetrahedron.) The base edge of the Pyraminx is 98 mm and the perpendicular height is 84.9 mm. The company that manufactures the product produces 400 per week and wraps them in plastic. Determine the minimum area of plastic sheet the company would be using each week. Do not include any overlap of the edges of the plastic.



3E **18** Jayden's largest silo on his farm is a cylinder with a cone for the cap. It has a diameter of 7.9 metres and the cylindrical section has a height of 19.7 metres. The slant height of the cone is 5.1 metres. Calculate the surface area of the silo.

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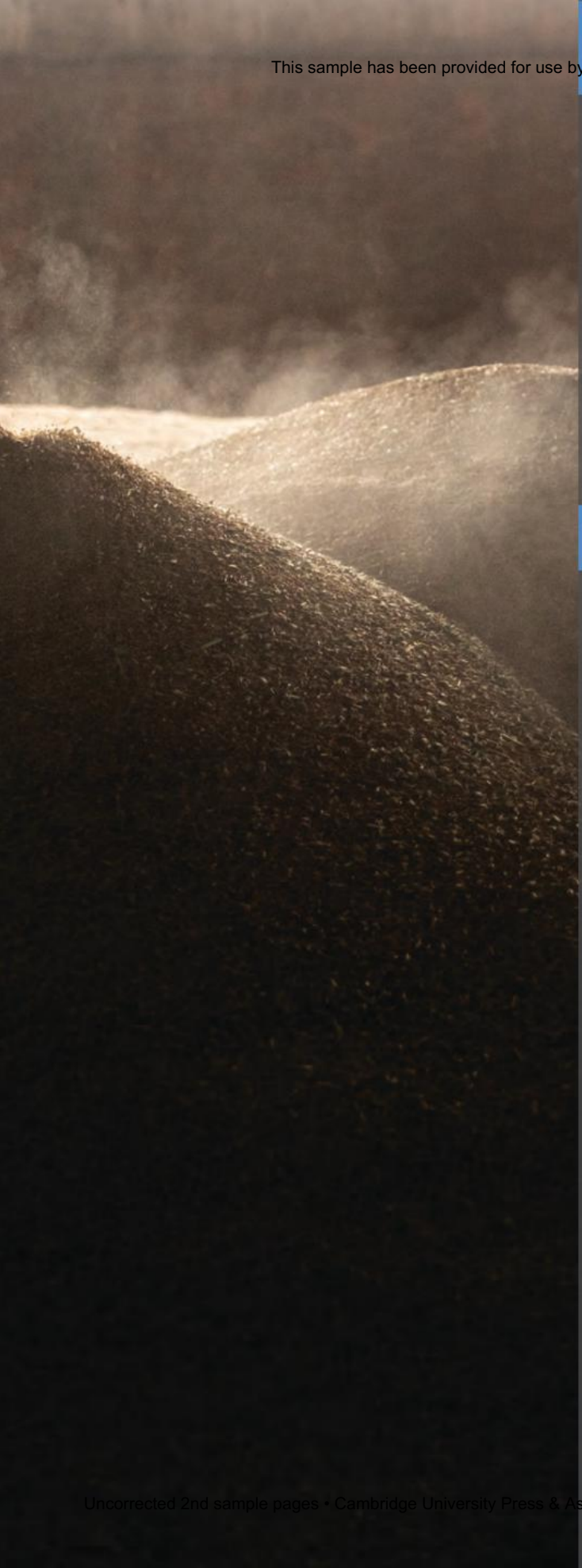
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4 Volume and capacity

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In this chapter

4A Estimating and calculating the volume and capacity of prisms and cylinders

4B Estimating and calculating the volume and capacity of pyramids and cones

4C Estimating and calculating the volume and capacity of spheres and composite shapes **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 3 Topic 1 Measurement

Volume and capacity (6 hours)

In this sub-topic, students will:

- estimate volumes and capacities of various objects
- calculate volumes and capacities of prisms and cylinders
  - prism: $V = Ah$ where A is base area and h is perpendicular height
  - cylinder: $V = \pi r^2 h$ where r is radius and h is perpendicular height.
- calculate volumes and capacities of pyramids and cones
  - pyramid: $V = \frac{1}{3}Ah$ where A is base area and h is perpendicular height
  - cone: $V = \frac{1}{3}\pi r^2 h$ where r is radius and h is perpendicular height.
- calculate volumes and capacities of composite shapes and spheres **[complex]**.
  - sphere: $V = \frac{4}{3}\pi r^3$ where r is radius.

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Prior knowledge check

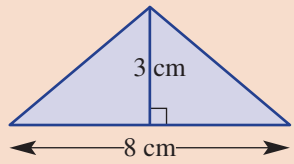
1 Explain the meaning of:

a 'milli-' as used in the unit 'millilitre'

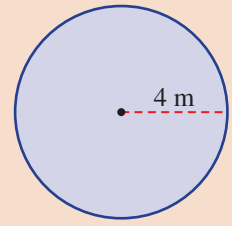
b 'kilo-' as used in the unit 'kilometre'.

2 Calculate the area of the following shapes:

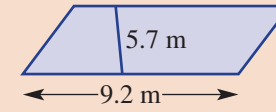
a



b

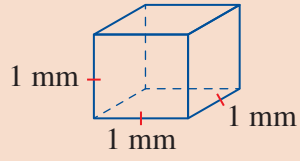


c

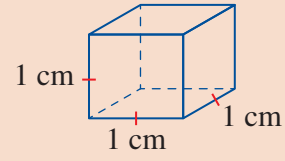


3 Each cube represents a unit of volume. They are not drawn to the same scale. Write down the full name of each unit and its abbreviation.

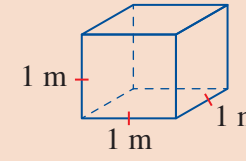
a



b



c



> **Hint** The abbreviation or symbol for these units of volume includes a number as an index (a power) that represents the length, width and depth of the cube (three sides with the same value) being multiplied together.

4 Convert:

a 150 mm to cm

b 2.7 m to mm

c 3.85 m^2 to cm^2

d 450 632 mm^2 to m^2

e 12.45 cm^3 to mm^3

f 6 780 000 mm^3 to cm^3

5 How many millilitres are in a litre?

6 Convert:

a 3 L to mL

b 12 400 mL to L

c 3.7 kL to L

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4A Estimating and calculating the volume and capacity of prisms and cylinders

LEARNING GOALS

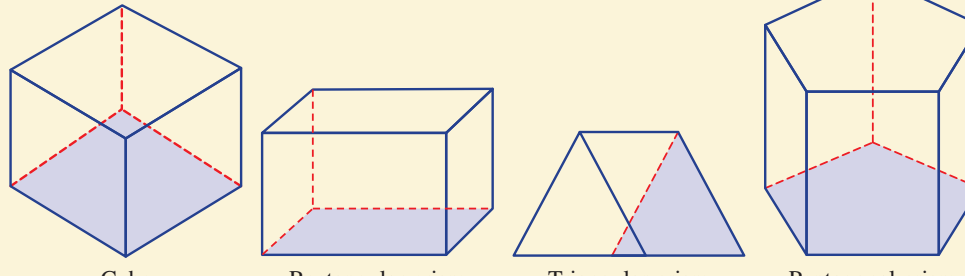
- Estimate the volumes and capacities of various objects.
- Calculate the volume of prisms using the formula $V = Ah$.
- Calculate the volume of a cylinder using the formula $V = \pi r^2 h$.

Why is it essential to estimate and calculate volumes?

- Estimation strategies are useful when doing calculations to have an idea of what the answer will be before doing the calculations. It allows us to check for reasonableness of our answer.
- Volume calculations are useful in construction (e.g. how many cubic metres of concrete are required for a slab), and in landscaping (e.g. how many litres of potting mix is required for a pot).

WHAT YOU NEED TO KNOW

- **Prisms** are 3D solid shapes that have the same shape throughout their cross-section, and that shape maintains the same dimmensions thoughout. Properties of prisms were covered in Section 2A.
- Prisms are named by their cross-sectional shape. This is important to identify as it is used in the calculation of their volume.

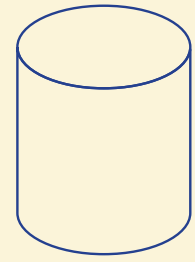


Cube | Rectangular prism | Triangular prism | Pentagonal prism

- **Volume** is a measure of the amount of space enclosed by a 3D shape. Units for Volume were covered in Section 1C.
- For prisms, $V = Ah$, where A = area of cross section (base area) and h = perpendicular height.

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- **Cylinders** are like prisms in that they have the same shape (a circle) throughout their cross-section, but because they have a curved (and not straight) sides, they do not fit into the prism category.



- For cylinders, $V = \pi r^2 h$, where r = radius and h = perpendicular height.
- **Capacity** is the maximum amount that a 3D container can hold of a substance (solid, liquid or gas). Units for capacity were covered in Section 1C.
- To convert between volume and capacity,
  - 1 cm^3 holds 1 mL
  - 1 m^3 holds 1000 L or 1 kL.

Example 1 Converting volume to capacity units

Convert to the capacity units in the brackets. Round to one decimal place if necessary.

a 1.44 m^3 (kL)
b 1000 cm^3 (L)
c 356 720 mm^3 (mL)
d 2 035 752.04 cm^3 (L)

WORKING	THINKING
a 1.44 kL	Use 1 m^3 = 1 kL
b 1000 cm^3 holds 1000 mL 1000 mL ÷ 1000 = 1 L	Given that 1000 cm^3 = 1 L, divide by 1000 to convert mL to L
c 356720 ÷ 10^3 = 356.7 cm^3 = 356.7 mL	To convert to cm^3 divide by 1000. 1 cm^3 = 1 mL. Round to one decimal place.
d 2035752.04 cm^3 holds 2035752.04 mL 2035752.04 mL ÷ 1000 = 2035.8 L	1 cm^3 = 1 mL. To convert to Litres, divide by 1000. Round to one decimal place.

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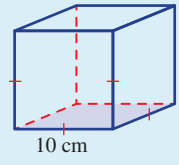


The sizes of packaging cartons may be given in units of capacity or volume; both can easily be estimated from the dimensions of the carton.

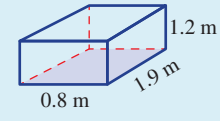
Example 2 Calculating the volume of solids

Calculate the volume of the following solids.

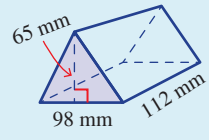
a



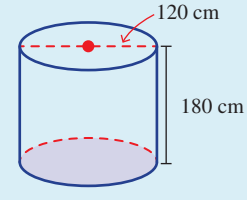
b



c



d



WORKING	THINKING
a Base shape: square, $A = l^2$	Find the area of the base shape.
$A = 10^2 = 100 \text{ cm}^2$	
$V = Ah$	Substitute into $V = Ah$ to calculate the volume.
$V = 100 \times 10 = 1000 \text{ cm}^3$	

... Continued

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b Base shape: rectangle, $A = lw$ ◄ Find the area of the base shape.

$A = 0.8 \times 1.9 = 1.52 \text{ m}^2$

$V = Ah$ ◄ Substitute into $V = Ah$ to calculate the volume.

$V = 1.52 \times 1.2 = 1.824 \text{ m}^3$

c Base shape: triangle, $A = \frac{1}{2}bh$ ◄ Find the area of the base shape.

$A = \frac{1}{2} \times 98 \times 65 = 3\,185 \text{ mm}^2$

$V = Ah$ ◄ Substitute into $V = Ah$ to calculate the volume.

$V = 3\,185 \times 112 = 356\,720 \text{ mm}^3$

$V = \pi r^2 h$ ◄ Substitute into $V = \pi r^2 h$ to calculate the volume of a cylinder.

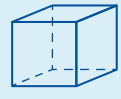
$V = \pi \times 60^2 \times 180$

$= 2\,035\,752.04 \text{ cm}^3$

Example 3 Estimating volume and capacity

Estimate the volume and capacity of the following shapes by first rounding each measurement to the nearest whole number.

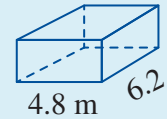
a



3.2 cm

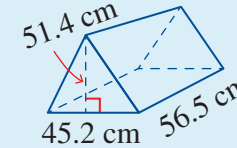
Convert to mL

b

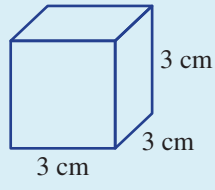


Convert to kL

c



Convert to L

WORKING	THINKING
a 	◄ Redraw shape. Label sides with measurements rounded to nearest whole number.

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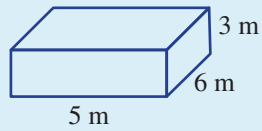
Base shape: square, $A = l^2$ ◄ Find the approximate area of the base shape.

$A \approx 3^2 \approx 9 \text{ cm}^2$

$V \approx Ah$ ◄ Substitute into $V = Ah$ to calculate the approximate volume.

$V \approx 9 \times 3 \approx 27 \text{ cm}^3$

b



◄ Redraw shape. Label sides with measurements rounded to nearest whole number.

Base shape: rectangle, $A = lw$ ◄ Find the approximate area of the base shape.

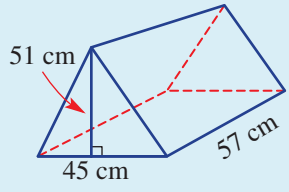
$A \approx 5 \times 6 \approx 30 \text{ m}^2$

$V \approx Ah$ ◄ Substitute into $V = Ah$ to calculate the approximate volume.

$V \approx 30 \times 3 \approx 90 \text{ m}^3$

90 m^3 holds 90 kL ◄ Use the relationship 1 m^3 holds 1000 L or 1 kL.

c



◄ Redraw shape. Label sides with measurements rounded to nearest whole number.

Base shape: triangle, $A = \frac{1}{2}bh$ ◄ Find the approximate area of the base shape.

$A \approx \frac{1}{2} \times 45 \times 51 \approx 1147.5 \text{ cm}^2$

$V = Ah$ ◄ Substitute into $V = Ah$ to calculate the approximate volume.

$V \approx 1147.5 \times 57 \approx 65407.5 \text{ cm}^3$

$65\,407.5 \text{ cm}^3$ holds 65 407.5 mL ◄ Use the relationships 1 cm^3 holds 1 mL and 1000 mL = 1 L.

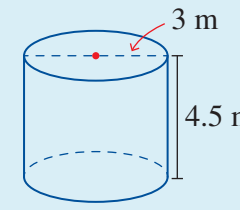
65 407.5 mL = 65.41 L

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Example 4 Applying volume and capacity to practical problems

Joanne has a rainwater tank on her property that has a diameter of 3 metres and a height of 4.5 metres. Calculate the amount of water in litres that her tank can hold to the nearest litre.



WORKING	THINKING
	Formulate
Need to calculate the capacity (amount of water) a tank can hold.	• What do you need to find? • What information do you have? • What rules can you use?
$D = 3$ m, $h = 4.5$ m	
$V = \pi r^2 h$	
$r = \frac{D}{2}$	
1 m^3 holds 1000 L	
	Solve
$r = \frac{D}{2}$	• Substitute values to find radius.
$r = \frac{3}{2} = 1.5$ m	
$V = \pi r^2 h$	• Substitute values to find volume (keep decimal places at this stage).
$V = \pi \times 1.5^2 \times 4.5 = 31.808\,626$ m^3	
31.808 525 m^3 $= 31.808\,626 \times 1000$ $= 31\,809$ L	• Use the relationship 1 m^3 holds 1000 L.
	Evaluate and verify
	• Have you answered the question? • Have you used the correct units?
	Communicate
Joanne's tank can hold 31 809 L of water.	• Write the answer in a sentence.

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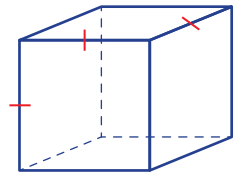
Exercise 4A

FUNDAMENTALS

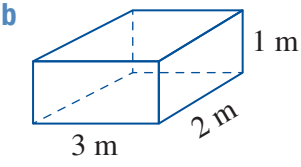
1 For each of the following solids:

i identify the base shape **ii** calculate the volume.

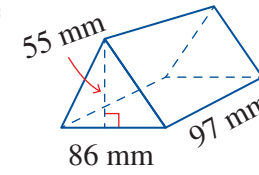
a



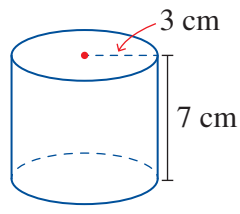
b



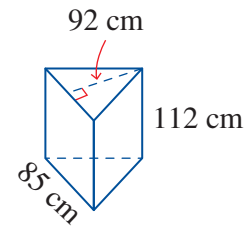
c



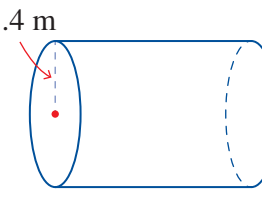
d



e



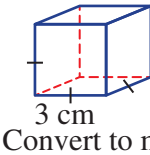
f



Example 1, 2

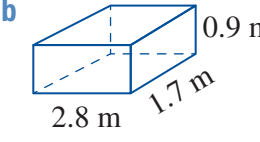
2 Calculate the volume and then the capacity of the following solids.

a



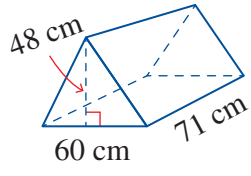
Convert to mL

b



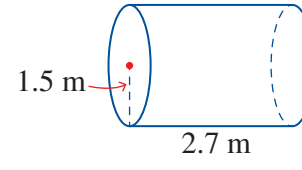
Convert to kL

c



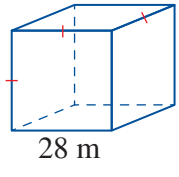
Convert to L

d



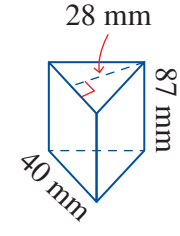
Convert to kL

e



Convert to ML

f



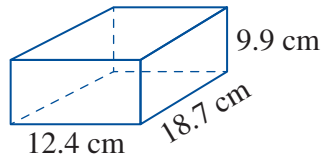
Convert to mL

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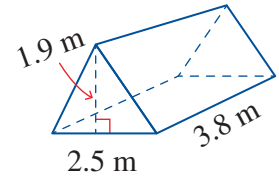
Example 3 **3** Estimate the volume and then the capacity of the following solids.

a



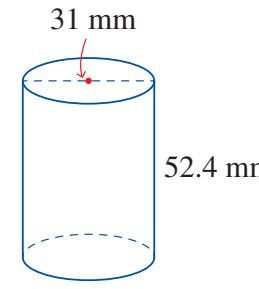
Convert to L

b



Convert to kL

c

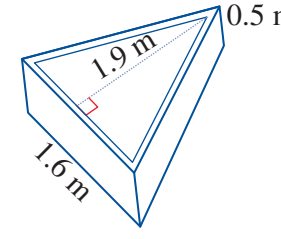


Convert to mL

APPLICATIONS

Example 4 ★**4** Reuben's water tank is a cylinder that has a radius of 1.2 m and a height of 3 m. Calculate the volume of Reuben's water tank.

★**5** Mim has built a triangular garden bed as shown. She plans on filling the garden bed with soil. Determine how many cubic metres of soil Mim will require.



★**6** Lisa has a 45 cm cubic cardboard box. Calculate the volume of the box.

★**7** Michael's can of soft drink is 13 cm tall and has a diameter of 6 cm. Calculate the volume of the can and then the capacity of the can in mL, assuming it is a cylinder.



★**8** A Toblerone box is 30.6 cm long, and the base of the triangle is 5.4 cm with a height of 5 cm. Determine the capacity of the box in millilitres.



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SF

★9 An industrial gas cylinder has a length of 457 cm and a diameter of 124.5 cm. Calculate the capacity of the cylinder in kilolitres, assuming the ends are flat circles, as with a standard geometric cylinder.



★10 Kyösti's box of cereal is shown. Calculate the capacity of the box in litres.



★11 Ken is a truck driver, and his petrol tanker has a length of 5.94 metres and a diameter of 2.2 metres. Calculate the capacity of the petrol tank in kL. Assume it is a cylinder.



★12 Rochelle is installing a new pool in her backyard. It will be a flat-bottomed pool with a depth of 1.4 metres. The length of the pool will be 12 metres and the width will be 8 metres. Calculate how much water Rochelle's pool will hold in kilolitres.



13 Calculate the amount of water than can be captured over an area of 1 m^2 for every 1 mm of rain that falls.

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4B Estimating and calculating the volume and capacity of pyramids and cones

LEARNING GOALS

- Calculate the volume of pyramids using the formula $V = \frac{1}{3}Ah$.
- Calculate the volume of cones using the formula $V = \frac{1}{3}\pi r^2 h$.
- Estimate the volume of pyramids and cones.
- Calculate the capacity of pyramids and cones.

Why is it essential to know how to calculate the volume of pyramids and cones?

- It is important to be able to measure volume and capacity of pyramids and cones.
- Pyramid and cone shapes are used for ornaments, buildings and artwork as well as other applications.

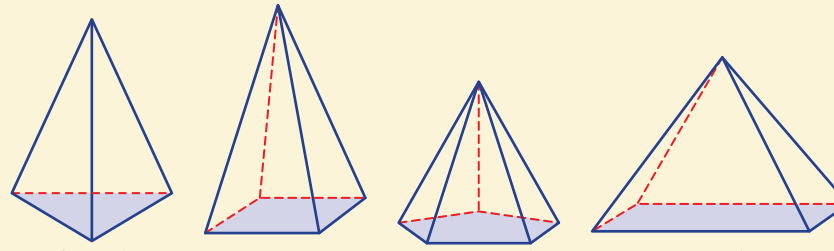


Volume is required to work out how much wax to use to make this candle.

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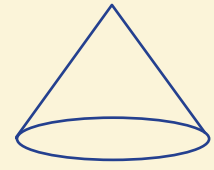
WHAT YOU NEED TO KNOW

- You will need to recall the definitions for volume and capacity, as well as units and conversions from previous sections.
- **Pyramids** are 3D solid shapes that come to a point. Properties of pyramids were covered in Section 2A.
- Pyramids are named by their cross-sectional shape. This is important to identify as it is used in the calculation of their volume.



Triangular pyramid | Square pyramid | Pentagonal pyramid | Rectangular pyramid

- For pyramids, $V = \frac{1}{3}Ah$, where A = area of cross section (base area) and h = perpendicular height.
- **Cones** are like pyramids in that they come to a point, but because they have a curved (and not straight) side, they do not fit into the pyramid category.

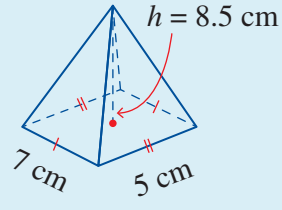


- For cones, $V = \frac{1}{3}\pi r^2 h$, where r = radius and h = perpendicular height.

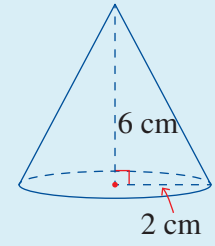
Example 5 Calculating the volume and capacity of pyramids and cones

Calculate the volume and capacity of the following solids. Round your answer to two decimal places.

a



b



... Continued

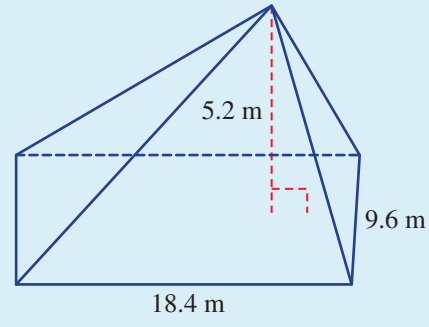
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WORKING	THINKING
a Base shape: rectangle, $A = lw$ $A = 7 \times 5 = 35 \text{ cm}^2$	Find the area of the base shape.
$V = \frac{1}{3}Ah$ $V = \frac{1}{3} \times 35 \times 8.5 = 99.17 \text{ cm}^3$	Substitute into $V = \frac{1}{3}Ah$ to calculate the volume.
Capacity = 99.17 mL	Use the relationship 1 cm^3 holds 1 mL.
b $V = \frac{1}{3}\pi r^2 h$ $V = \frac{1}{3} \times \pi \times 2^2 \times 6$ $= 25.13 \text{ cm}^3$	Substitute into $V = \frac{1}{3}\pi r^2 h$ to calculate the volume of a cone.
Capacity = 25.13 mL	Use the relationship 1 cm^3 holds 1 mL.

Example 6 Estimating the volume and capacity of a pyramid

Estimate the volume and capacity of the oblique pyramid shown by first rounding each measurement to the nearest whole number.



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WORKING	THINKING
Base = 18 m Width = 10 m Perpendicular height = 5 m	Round measurements
Base shape: rectangle, $A = lw$, $A \approx 18 \times 10 \approx 180$ m^2	Find the approximate area of the base shape.
$V \approx \frac{1}{3}Ah$ $V \approx \frac{1}{3} \times 180 \times 5 \approx 300$ m^3	*An oblique pyramid does not have its apex centre over the base. This does not affect the volume calculations as we still use the perpendicular height.* Substitute into $V = \frac{1}{3}Ah$ to calculate the approximate volume.
Capacity = 300×1000 = 30 000 L or 1 kL	Use the relationship 1 m^3 holds 1000 L or 1 kL.

Example 7 Applying volume and capacity to practical problems

Daphne is preparing for her daughter's birthday party. She would like to serve ice cream in a cone as one of the treats. Her daughter's favourite ice cream comes in a 1 L tub, and there will be 16 children in attendance. Calculate the minimum number of ice cream tubs she will need to purchase.



... Continued

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WORKING	THINKING
	Formulate
Need to find the number of ice cream tubs to purchase.	• What do you need to find? • What information do you have? • What assumptions can you make? • What rules can you use?
Diameter = 6 cm, $r = 3$ cm Height = 15 cm	
Assume only filling cone to the top with ice cream.	
$V = \frac{1}{3}\pi r^2 h$	
	Solve
$V = \frac{1}{3}\pi r^2 h$	Substitute values to find volume (keep decimal places at this stage).
$V = \frac{1}{3} \times \pi \times 3^2 \times 15$	
$V \approx 141.37....$ cm^3	Keep the value in your calculator and use it unrounded as you progress
Capacity of 1 cone $\approx 141.37....$ mL.	Use the relationship 1 m^3 holds 1000 L.
Total $\approx 141.37.... \times 16$ ≈ 2261.95 mL.	Multiply by number of children to find total required.
2261.95 mL = 2.26195 L	Use the relationships 1 cm^3 holds 1 mL and 1000 mL = 1 L.
Over 2 litres, under 3 litres	Determine how many tubs of ice cream are required.
Purchase 3 tubs of ice cream.	
	Evaluate and verify
	Have you answered the question? Have you used the correct units?
	Communicate
Daphne will need to purchase 3 tubs of ice cream.	Write the answer in a sentence.

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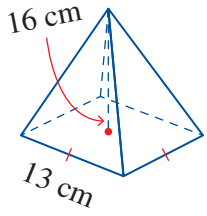
Exercise 4B

FUNDAMENTALS

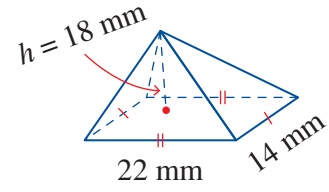
Example 5

1 Calculate the volume of the following solids.

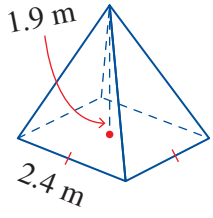
a



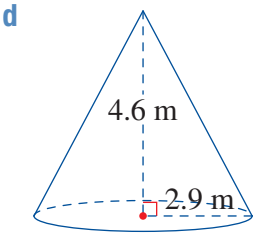
b



c

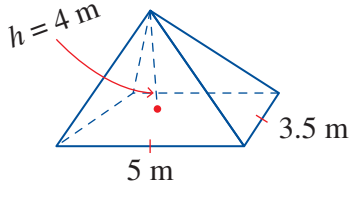


d



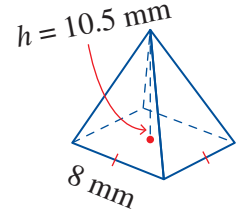
2 Calculate the capacity of the following solids.

a



Convert to kL

b

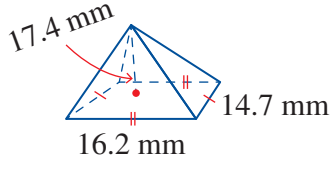


Convert to mL

Example 6

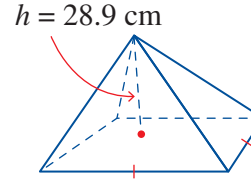
3 Estimate the volume and capacity of the following solids by rounding all dimensions to the nearest whole number.

a



Convert to mL

b



Convert to L

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APPLICATIONS

Example 7 ★4 Bronwyn has designed a rectangular-based pyramid made out of glass that can be used as a paperweight. Calculate the volume if the base has a length of 12 cm and a width of 9 cm, and its height is 8 cm.

★5 Phillip makes pyramid-shaped snow globes that he then sells as souvenirs at his ski resort. The souvenirs have a 68 mm square base and they are 72 mm high. Calculate the volume of the pyramid snow globe.



★6 Neil runs a factory that makes candles. One of the most popular designs is a square-based pyramid. The pyramids have an 8.4 cm square base and a height of 10.5 cm. Calculate the number of litres of wax that Neil would require if his factory made 150 candles in a day.

★7 In 1483, Leonardo da Vinci designed a parachute that was shaped like an upturned square-based pyramid. He claimed that a piece of material with a square base of 7 metres wide and a height of 7 metres would enable a person to throw himself from any height and not suffer any injuries from landing on the ground. Calculate the capacity of the air in litres in the upturned pyramid of da Vinci's design.



★8 If Leonardo had used a cone with a base diameter of 7 m and a height of 7 m, calculate the capacity of the air in litres in his parachute from Question 7.

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4C Estimating and calculating the volume and capacity of spheres and composite shapes

COMPLEX

LEARNING GOALS

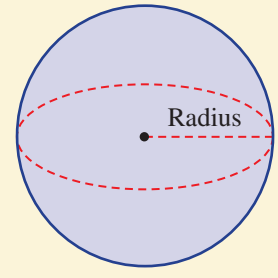
- Calculate the volume of spheres using the formula $V = \frac{4}{3}\pi r^3$.
- Calculate the volume of composite solids.
- Calculate the capacity of spheres and composite shapes.

Why is it essential to know how to calculate the volume of spheres and composite shapes?

- It is important to be able to measure the volume and capacity of spheres and composite shapes.
- Spheres are used in manufacturing balls used in sports and industry.
- Most shapes are made up of a combination of two or more other shapes, so knowing how to identify and make calculations with components is essential to being able to calculate their volume.

WHAT YOU NEED TO KNOW

- You will need to recall the definitions for volume and capacity, as well as units and conversions from previous sections.
- A **sphere** is a perfectly round 3D solid.



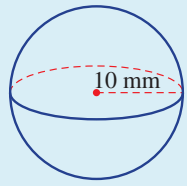
- Radius, r, is the distance from the centre of the sphere to the outside.
- For spheres, $V = \frac{4}{3}\pi r^3$, where r = radius.
- Like they were in sections 2E (perimeter) and 3B (area), **composite shapes** are made by joining together standard shapes. We can add/subtract standard shapes to calculate the volume of composite shapes.

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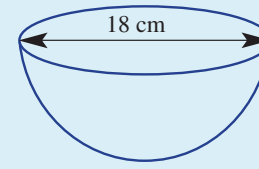
Example 8 Calculating the volume and capacity of spheres

Calculate the volume and capacity of the following solids. Round your answer to two decimal places.

a



b



WORKING	THINKING
a $V = \frac{4}{3}\pi r^3$	Substitute into $V = \frac{4}{3}\pi r^3$ to calculate the volume of the sphere.
$V = \frac{4}{3} \times \pi \times 10^3$	
$V = 4188.79 \text{ mm}^3$	
$4188.79 \text{ mm}^3 = 4188.79 \div 10^3$	Convert mm^3 to cm^3 by dividing by 1000.
$= 4.19 \text{ cm}^3$	
Capacity $= 4.19$ mL	Use the relationship 1 cm^3 holds 1 mL.
b $r = \frac{D}{2} = \frac{18}{2} = 9$ cm	Volume formula requires radius.
$V = \frac{1}{2} \times \frac{4}{3}\pi r^3$	Hemisphere is half a sphere so need to halve the volume.
$V = \frac{1}{2} \times \frac{4}{3} \times \pi \times 9^3$	Substitute into formula to calculate the volume of the sphere.
$V = 1526.81 \text{ cm}^3$	
Capacity $= 1526.81$ mL	Use the relationship 1 cm^3 holds 1 mL.

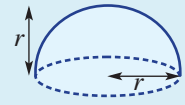
Example 9 Applying volume and capacity to practical problems

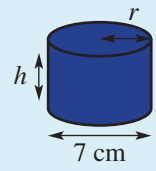
Calculate the capacity of the water bottle shown to the nearest mL.



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WORKING	THINKING
	Formulate
Need to find how much the water bottle can hold.	• What do you need to find?
Hemisphere	• Break the shape up into regular shapes

$V = \frac{1}{2} \times \frac{4}{3}\pi r^3$ 	• What information do you have?
	  • Draw and label the regular shapes.
	  • Diameter $= 2 \times r$.
	  • Radius is also the "height" of the hemisphere.

Cylinder	• What rules can you use?
$V = \pi r^2 h$ 	
1 cm^3 holds 1 mL.	
	Solve
$r = \frac{D}{2} = \frac{7}{2} = 3.5$ cm	Substitute values to find radius.
$r + h = 20$ $3.5 + h = 20$ $h = 16.5$ cm	Find the height of the cylinder.
$V = \frac{1}{2} \times \frac{4}{3} \times \pi \times 3.5^3$ $V = 89.7972$ cm^3	Substitute values to find volume of hemisphere.
$V = \pi r^2 h$ $V = \pi \times 3.5^2 \times 16.5$ $V = 634.9944$ cm^3	Substitute values to find volume of cylinder.
$V = 89.7972 + 634.9944 =$ $724.79 cm^3$	Find total volume.
724.79 cm^3 holds 724.79 mL $\approx$ 725 mL	Use the relationship 1 m^3 holds 1000 L. Round to nearest mL.
	Evaluate and verify
	• Have you answered the question? • Have you used the correct units?
	Communicate
The water bottle holds approximately 725 mL.	Write the answer in a sentence.

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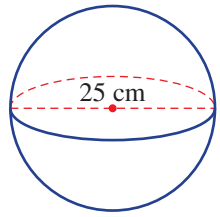
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Exercise 4C

FUNDAMENTALS

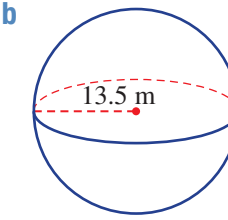
1 Calculate the volume and capacity of the following spheres.

a



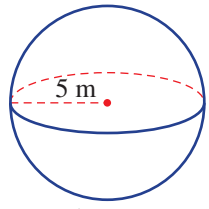
in mL

b



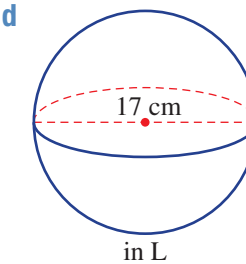
in ML

c



in KL

d



in L

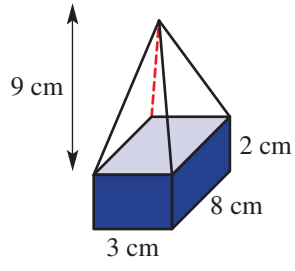
2 For each of the following composite shapes:

i identify the regular shapes they are composed of

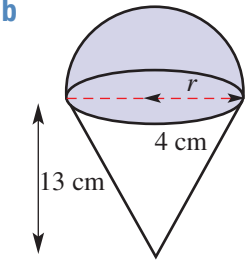
ii select the formula required to calculate each volume

iii calculate the volume.

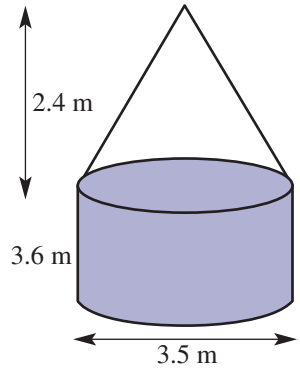
a



b



c



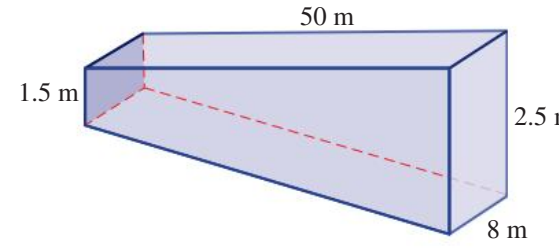
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APPLICATIONS

SF

3 In Richard's barber shop there is a spherical-shaped gumball machine. It has an internal diameter of 0.6 metres. Calculate the volume of the gumball machine.

4 A 50 m swimming pool is 1.5 m at the shallow end and steadily increases to 2.5 m at the deep end. The pool is 8 m across. Calculate the capacity of the pool in litres.



5 Susan makes freshly squeezed orange juice. She is planning on using 12 oranges that each have a radius of 3.2 cm when peeled, and she does not remove the pulp from her juice. Estimate the total number of litres of juice that Susan should get from her oranges.



6 A spherical ice cube is placed in a cylindrical glass. The ice cube has a diameter of 4 cm. The glass has a diameter of 7 cm. The ice cube is left to fully melt. How high up the side of the glass will the water from the melted ice cube rise?

Example 8

7 A portable oxygen tank is used by a sick person to maintain oxygen levels. The silver base has a diameter of 12 cm and a height of 40 cm. By identifying regular solids within the tank, estimate the capacity of the tank (in L).



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Modelling task



Context: In many parts of Queensland water is a valuable resource. Harvesting rainfall from the roof of buildings for storage in water tanks is essential for survival.

Task: Your task is to determine the amount of rainfall that could potentially be harvested from a home over summer, and make a recommendation as to the size of tank required to collect the rainfall.

Stage 1: Formulate
Make an assumption of: • the view (birds-eye) of house to collect measurements • the slope of the roof will have no impact on calculations • all rain that falls on the home will be collected. Make an observation of: • where your home is located • floor plan of a house with measurements • rainfall data for your region http://www.bom.gov.au/qld/observations/map.shtml.
Stage 2: Solve
• Calculate the 'footprint' area of your home. • Calculate the amount of water that can potentially be harvested when 1 mm of rain falls on 1 m^2. • Use weather observations to determine the amount of rainfall received the previous summer in your region. • Calculate the potential amount of water that could be harvested from the home over the summer season. • Determine the size of rainwater tank required to capture the rainwater run-off.
Stage 3: Evaluate and verify
• Have you answered the question? Is your answer reasonable? • How have the assumptions impacted your solution? • How have the observations impacted your solution? • What are the strengths of your solution? • What are the limitations of your solution?
Stage 4: Communicate
Write a summary of your findings and recommendations.

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Chapter summary

Volume
- Volume is a measure of the amount of space enclosed by a 3D shape.
- Units are mm^3, cm^3, m^3 and km^3.

Capacity
- Capacity is the maximum amount that a 3D container can hold of a substance (solid, liquid or gas).
- Units are mL, L, kL and ML.
- To convert between volume and capacity,
  - 1 cm^3 holds 1 mL
  - 1 m^3 holds 1000 L or 1 kL.

Prism
- A prism is a 3D solid shape that has the same shape throughout its cross-section.
- Prisms are named according to their cross sectional (base) shape.
- $V = Ah$, where A = area of cross section (base area) and h = perpendicular height.

Cylinder
- A cylinder is a 'prism' that has a circle as its cross-sectional (base) shape
- $V = \pi r^2 h$, where r = radius and h = perpendicular height.

Pyramid
- A pyramid is a 3D solid shape that comes to a point.
- Pyramids are named according to their cross sectional (base) shape.
- $V = \frac{1}{3}Ah$, where A = area of cross section (base area) and h = perpendicular height.

Cone
- A cone is a 'pyramid' that has a circle as its cross-sectional (base) shape.
- $V = \frac{1}{3}\pi r^2 h$, where r = radius and h = perpendicular height.

Sphere
- A sphere is a perfectly round 3D solid.
- The radius, r, is the distance from the centre of the sphere to the outside.
- $V = \frac{4}{3}\pi r^3$, where r = radius.

Composite shape
- Composite shapes are made by joining together standard shapes.
- Add/subtract standard shapes to calculate the volume of a composite shape.

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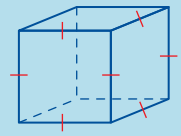
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Chapter checklist

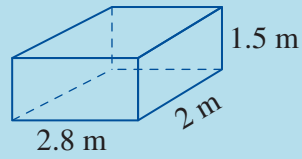
4A ☐ I can calculate the volume and capacity of regular objects.

1 Calculate the volume of the following solids.

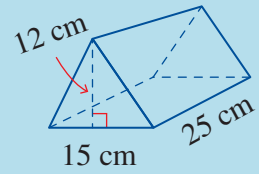
a



b

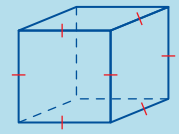


c



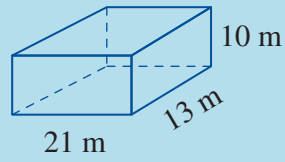
2 Calculate the capacity of the following solids.

a



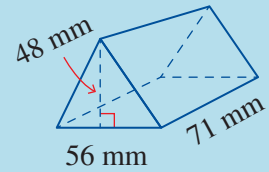
Convert to mL

b



Convert to ML

c



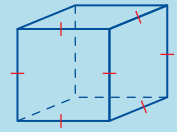
Convert to mL

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4A ☐ I can estimate the volume and capacity of regular objects.

3 Estimate the volume and capacity of the following solids.

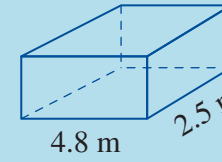
a



13.2 cm

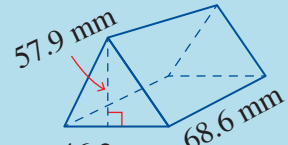
Convert to L

b



Convert to kL

c

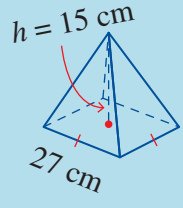


Convert to mL

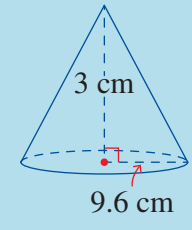
4B ☐ I can calculate the volume and capacity of pyramids and cones.

4 Calculate the volume of the following solids.

a

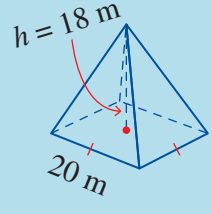


b



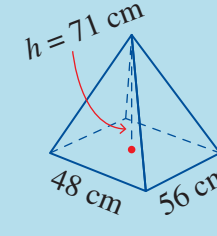
5 Calculate the capacity of the following solids.

a



Convert to ML

b



Convert to L

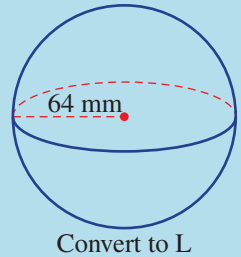
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4C ☐ I can calculate the volume and capacity of spheres.

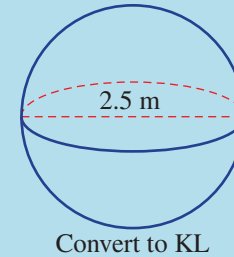
6 Calculate the volume and capacity of the following spheres.

a



Convert to L

b

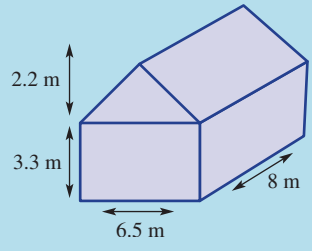


Convert to KL

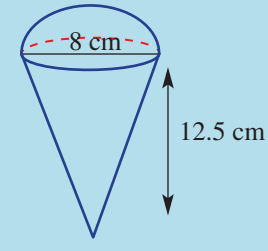
4C ☐ I can calculate the volume of composite shapes.

7 Calculate the volume of the following solids.

a



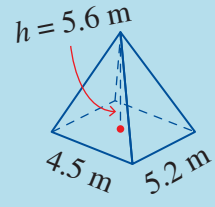
b



4B 4C ☐ I can estimate the volume and capacity of pyramids and spheres.

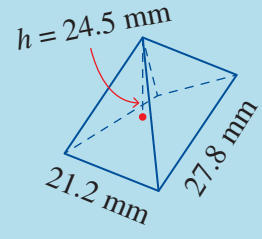
8 Estimate the volume and capacity of the following solids by rounding dimensions to the nearest whole number.

a



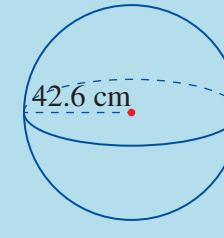
Convert to kL

b



Convert to mL

c



Convert to L

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Chapter review

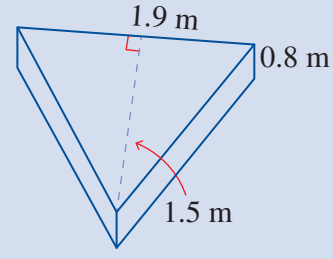
All questions in the Chapter review are assessment-style.

Simple Familiar

4A **1** Daniel has a 50 cm fish tank. Calculate the capacity of the tank in litres.

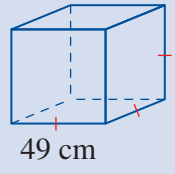
2 Jessica has had a new LPG tank installed in her car. It is a cylinder with a height of 65 cm and a diameter of 27 cm. Calculate the capacity of the tank in litres.

3 William is building a triangular fish pond as shown. Calculate the capacity of the fish pond in kilolitres.

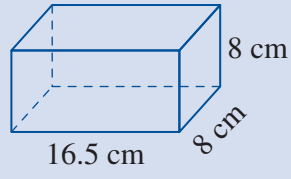


4 Calculate the volume of plastic you would need to make the following solids.

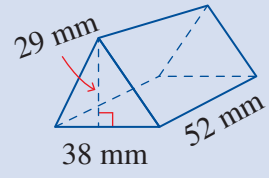
a



b



c



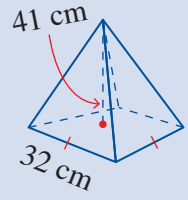
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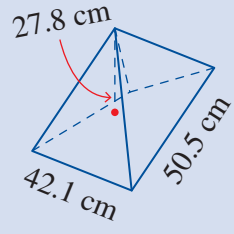
4B **5** Amara has designed a rectangular-based pyramid made out of plastic that can be used as a paperweight. Calculate the volume of the pyramid if it has a length of 10.5 cm, a width of 7.8 cm and a height of 9 cm.

6 Calculate the capacity of melted wax that is needed to make candles of these sizes and shapes, in litres for **a** and **b**, and in millilitres for **c**.

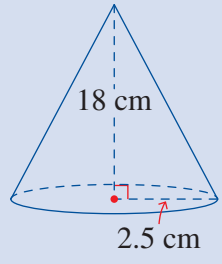
a



b



c



Complex Familiar

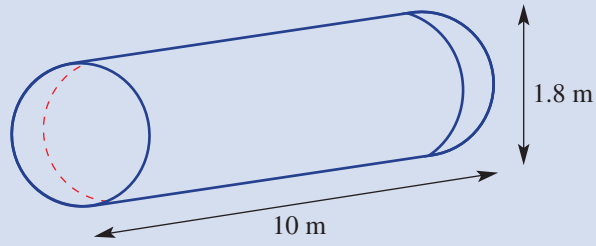
4C **7** Jillian has been given a large beach ball that has a diameter of 900 cm. Calculate the capacity of the beach ball in megalitres.

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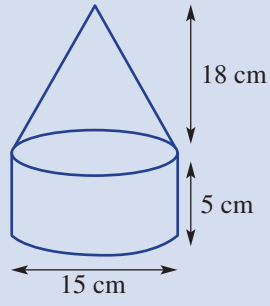
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8 Calculate the volume of these composite solids.

a



b



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5 Scale drawings

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In this chapter

5A Reviewing scales and interpreting scale symbols and abbreviations

5B Calculating length, perimeter and area from scale drawings

5C Estimating and comparing quantities, materials and costs from scale diagrams **[complex]**

5D Understanding and applying drawing conventions of scale drawings **[complex]**

5E Constructing scale diagrams **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 3 Topic 2 Scales, plans and models

Interpret scale drawings (6 hours)

In this sub-topic, students will:

- interpret commonly used symbols and abbreviations in scale drawings
- find actual measurements from scale drawings, including lengths, perimeters and areas
- estimate and compare quantities, materials and costs using actual measurements from scale drawings **[complex]**.

Creating scale drawings (4 hours)

In this sub-topic, students will:

- understand and apply drawing conventions of scale drawings, including scales in ratio, clear indications of dimensions and clear labelling **[complex]**
- construct scale drawings by hand and by using software packages **[complex]**.

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Prior knowledge check

1 Determine the following ratios in simplest form.

a 12 : 144 **b** 25 : 200 **c** 50 : 750

d 14 : 280 **e** 11 : 330

Hint Find a common factor of the two numbers in the ratio, then divide both numbers by the common factor.

2 Convert the following measurements to metres.

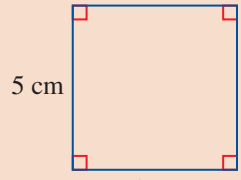
a 2400 cm **b** 1800 mm **c** 14 km

3 Convert the following measurements to millimetres.

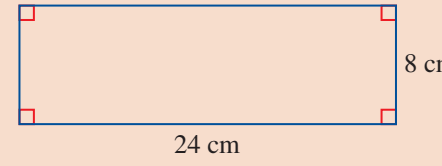
a 2.25 m **b** 1.4 cm **c** 0.279 km

4 Calculate the perimeter of the following shapes.

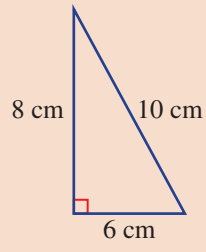
a



b

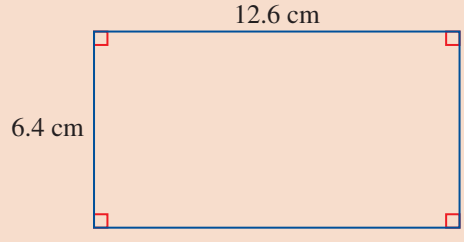


c

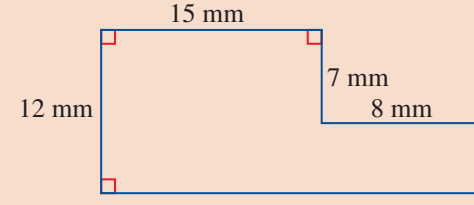


5 Calculate the area of the following shapes.

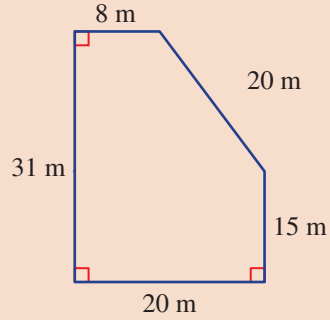
a



b



c



Hint These last two are composite shapes that should be divided up.

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5A Reviewing scales and interpreting scale symbols and abbreviations

LEARNING GOALS

- Review the concept of a scale.
- Convert between units of measure.
- Simplify scales.
- Identify and interpret common symbols and abbreviations in scale diagrams.
- Use the internet to research common symbols and abbreviations.

Why is it essential that we use symbols and abbreviations on a scale diagram?

- Symbols and abbreviations are added to scale diagrams to help users interpret the information in the diagram and identify the use of each space or detail.
- Without symbols and abbreviations, a detailed plan would be difficult to read as there would be too much information written on the plan.



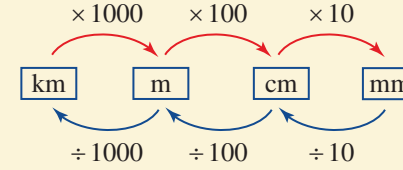
House plans use abbreviations and symbols to represent different parts of the house.

WHAT YOU NEED TO KNOW

- A **scale** is a comparison of like quantities usually expressed as a **ratio** such as 1 : 100. The first number is the size on the diagram or plan; the second number is the actual size in real life. Remember this as **length on page : length in real life**.
- **Simplify** a scale by changing both the diagram and actual measurements to the same units, and then simplifying the ratio using common factors.
- Scales are used in construction and manufacturing industries.
- Scale drawings, scale diagrams and plans are the same thing – the terms are used interchangeably.

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- Plans are drawn to scale by designers, planners and architects prior to construction.
- Builders and manufacturers use **scale drawings** to build at full size.
- To convert between units of length use these calculations:



- **Symbols** and **abbreviations** are used on plans to avoid covering detail with text labels.
- Some special or unfamiliar terms such as **void** may be used on house plans.

Example 1 Simplifying scales in ratio

Simplify the following scales.

a 1 cm : 2 m

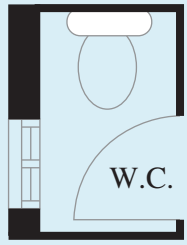
b 5 mm : 2 m

WORKING	THINKING
a 1 cm : 2 m	Convert both sides of the scale to the same units.
1 cm : 200 cm	There are 100 cm in 1 m, so multiply by 100.
	$2 \times 100 = 200$ cm
1 : 200	As both units are the same, remove the cm symbol. Since the scale has 1 as the first number, it doesn't need to be simplified any more.
b 5 mm : 2 m	Convert both sides of the scale to the same units.
5 mm : 2000 mm	There are 1000 mm in 1 m, so multiply by 1000.
	2 m × 1000 = 2000 mm
1 mm : 400 mm	Divide both sides by 5 to simplify.
1 : 400	As both units are the same, remove the mm symbol.

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Example 2 Interpreting abbreviations used on scale drawings

Interpret the meaning of the abbreviation W.C. from the diagram.



WORKING	THINKING
The abbreviation W.C. stands for Water Closet, which is a toilet.	Type 'W.C.' abbreviation into an internet search engine to discover its meaning.

Activity 4A Symbols, abbreviations and special terms used on house plans: See the Interactive Textbook for this activity to research and list abbreviations, symbols and special terms used on house plans.

Example 3 Interpreting symbols used on scale drawings

Interpret the meaning of the symbol  from the diagram.



WORKING	THINKING
It is a cooktop.	As it is in the kitchen, we can use our general knowledge of kitchens to identify that a cooktop would look like this symbol.

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Exercise 5A

FUNDAMENTALS

1 Describe what action is required to:

a convert m to cm
b convert m to km
c convert m to mm
d convert cm to mm.

2 Convert the following measurements into the unit indicated in brackets.

a 5 m (cm)
b 28 cm (mm)
c 3.73 m (cm)
d 2.75 cm (mm)
e 4 m (mm)
f 6.75 m (mm)
g 250 cm (m)
h 1200 mm (m)



Example 1

3 Simplify the following scales.

a 1 cm : 4 m
b 1 mm : 20 cm
c 1 mm : 2 m
d 1 mm : 3.75 m
e 5 cm : 3 m
f 7.5 cm : 3.6 m
g 12 mm : 7.2 m
h 15 mm : 4.5 m

Hint The scales must have the same units for both numbers. Divide both numbers by a common factor.

Example 2

4 Interpret the meaning of each of the following abbreviations by first identifying its position in the scale diagram of the house.



a L'DRY
b SRD
c REF
d ROBE
e ASD
f ASW

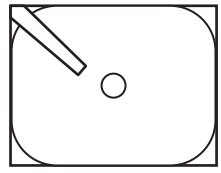
Hint Activity 4A will help set up to answer these questions.

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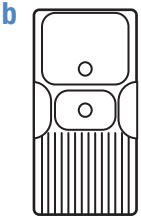
Example 3

5 Interpret the meaning of each of the following symbols by first identifying its position in the scale diagram of the house in Question **4**.

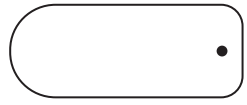
a



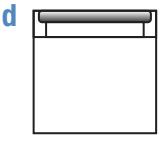
b



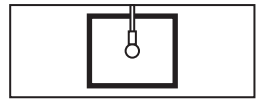
c



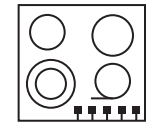
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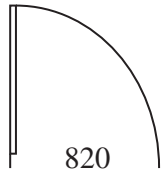
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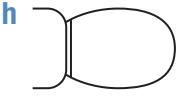
f



g



h



6 This plan is the top floor of a two-storey house. Interpret the meaning of each of the following by first identifying its position in the scale diagram of the house.

a W.I.R

b PDR

c W.I.L.

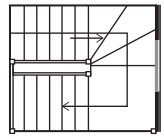


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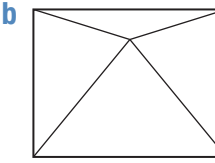
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7 Interpret the meaning of each of the following symbols by first identifying its position in the scale diagram of the house in Question **6**.

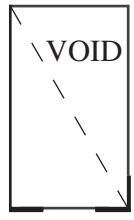
a



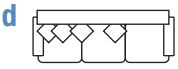
b



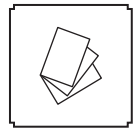
c



d



e



f



APPLICATIONS

★8 Luther was looking over the internal plans for his new house from the builder and discovered some abbreviations that he did not understand. These were AS, U/G and ENS. Determine what the abbreviations represent on the plan by researching their meaning.

★9 Lillian saw the abbreviations of FW, DP and HWS on her house plans and did not understand what they represented. Determine what the abbreviations represent on the plan by researching their meaning.

★10 Lana wants to create a symbol to represent her home gym on her new house plans. Create a symbol for her to use.

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5B Calculating length, perimeter and area from scale drawings

LEARNING GOALS

- Identify a scale from a plan.
- Take precise measurements from drawings.
- Use a scale to calculate actual lengths, perimeter and area from a plan.

Why is it essential that we know how to read and interpret scale plans and diagrams?

- Many professions and occupations use scale diagrams and plans to complete projects such as designing a new car or constructing a building.
- These professions and occupations include planners, architects, landscapers, builders, designers and manufacturers.
- By knowing how to read and interpret scale plans and diagrams, a builder can accurately build the owner's/designer's house to the correct measurements and design.



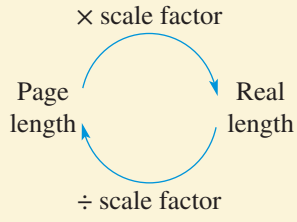
Understanding the symbols, abbreviations and scales of a house plan are important when interpreting the designer's details

WHAT YOU NEED TO KNOW

- A **scale diagram** is a smaller representation of something that is much bigger in real life. Building plans, maps and technical drawings are examples of how we can use a scale diagram. In Unit 1, ratios were discussed to describe scale. In Unit 2, scales were used to find distances on maps.
- A **scale** is expressed as ratio **length on page : length in real life**. For example, a scale 1 : 200 means that a length of 1 cm on the page is 200 cm in real life. Typically, the scale is expressed as 1 : SF, where SF is the scale factor.

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- **Scale factor** is determined using **scale factor** $= \dfrac{\textbf{length in real life}}{\textbf{length on page}}$ and tells us how much bigger the real length is compared to the length on the page.
- To convert between page length and real length:



- Content from Chapters 1, 2 and 3 will be applied to calculate length, perimeter and area in this section.

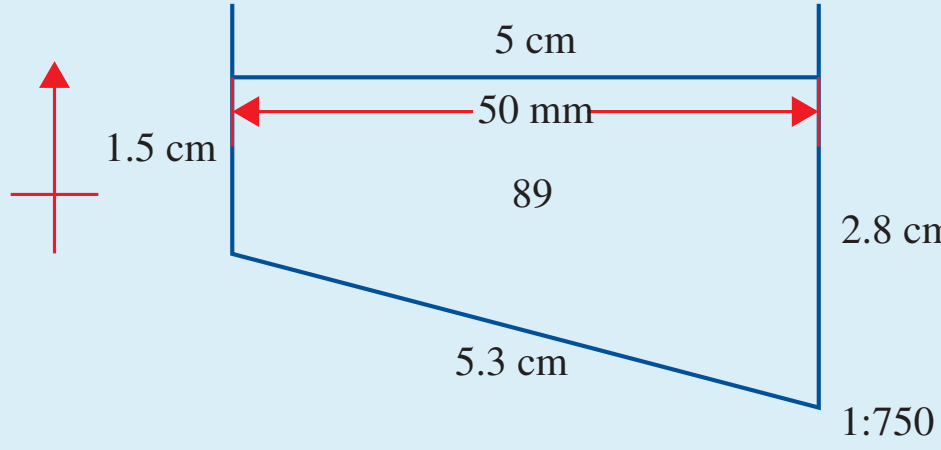
Example 4 Using a scale to calculate length, perimeter and area

The scale drawing below shows lot 89 in a new subdivision. The scale of the site plan is 1 : 750.

a Use the scale to determine the length of each property boundary.

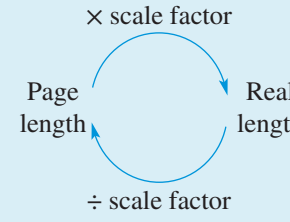
b Calculate the perimeter of the property.

c Calculate the area of the property.



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WORKING	THINKING
a Scale factor = 750	Identify the scale factor.
Northern side Page length = 5 cm Real length = 5×750 $= 3750$ cm or 37.5 m	Measure length to nearest mm. Apply conversion between page length and real length.
Eastern side Page length = 2.8 cm Real length = 2.8×750 $= 2100$ cm or 21 m	
Southern side Page length = 5.3 cm Real length = 5.3×750 $= 3975$ cm or 39.75 m	
Western side Page length = 1.5 cm Real length = 1.5×750 $= 1125$ cm or 11.25 m	
b Perimeter $= 37.5 + 21 + 39.75 + 11.25$ $= 109.5$ m	Perimeter is the sum of all the sides.
c $A = \frac{1}{2}(a + b)h$ $A = \frac{1}{2} \times (21 + 11.25) \times 37.5$ $A = 604.69$ m^2	The property is in the shape of a trapezium. Parallel sides are a and b. Perpendicular distance between a and b is h. Apply formula for area of a trapezium. Substitute into the formula.



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Exercise 5B

FUNDAMENTALS

1 Simplify the following scales to be in the form 1 : SF.

a 5 : 20 **b** 6 : 30

c 4.5 : 18 **d** 7.3 : 146

2 Identify the scale factor in the following scales:

a 1 : 200 **b** 1 : 550

c 2 : 600 **d** 8 : 200

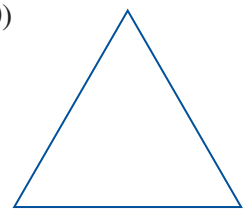
3 The scale of each shape is given in brackets. For each shape:

i measure the side length

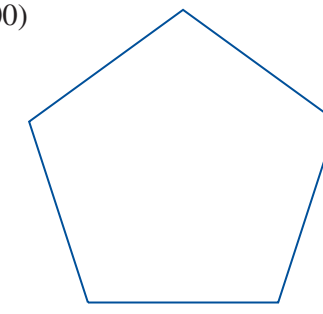
ii use the ratio to determine the real side length

iii calculate the real perimeter.

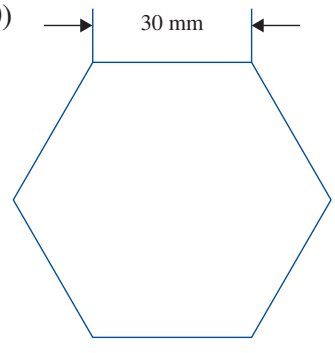
a (1 : 100)



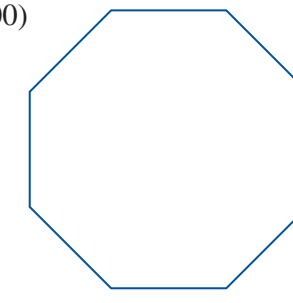
b (1 : 200)



c (1 : 150)



d (1 : 400)



Hint A scale is a ratio of size in diagram to actual size.

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APPLICATIONS

4 The plan below shows a 3-bedroom home. It is drawn to a scale of 1 : 150.

a Use the scale to determine the actual dimensions (in millimetres) of the:

- **i** bedroom 3 (including robe)
- **ii** W.C.
- **iii** laundry
- **iv** family/dining area
- **v** ensuite
- **vi** garage.

b Calculate the real perimeter (in metres) of the garage.

c Calculate the area of the garage.



5 The floor plan below shows a 4-bedroom home. It is drawn to a scale of 1 : 100.

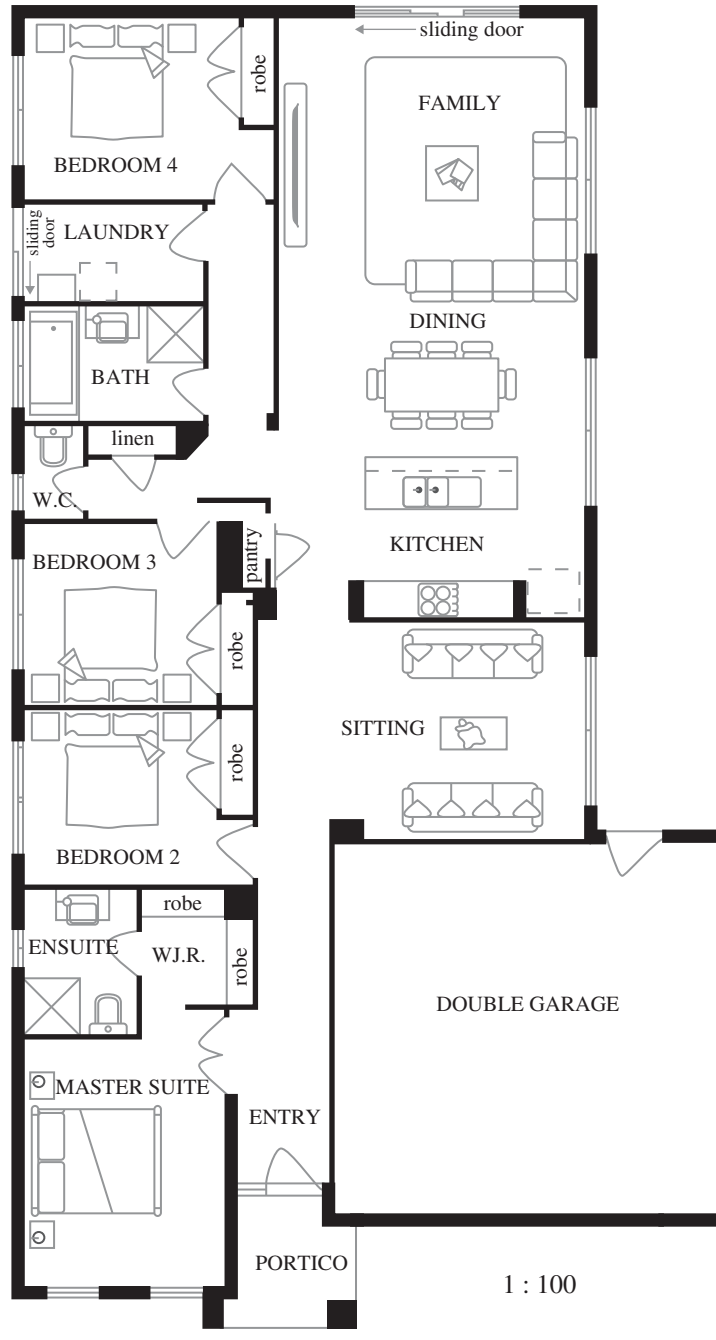
a Calculate the dimensions (in millimetres) of the:

- **i** master suite (not including the ensuite and W.I.R.)
- **ii** garage
- **iii** bathroom
- **iv** ensuite.

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b Calculate the real area of the master suite in square metres.

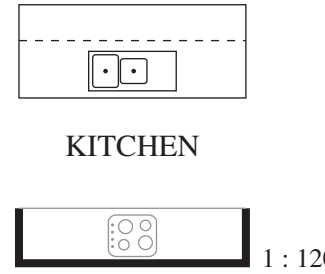
c Calculate the real perimeter of the house.



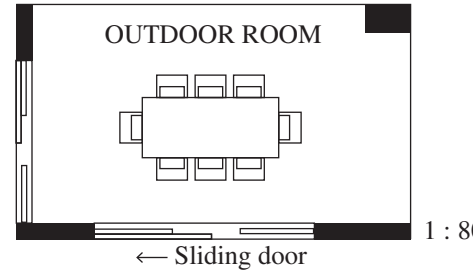
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SF

6 Monica is looking at plans for her new kitchen. The scale is 1 : 120. Calculate the actual length of the island bench.

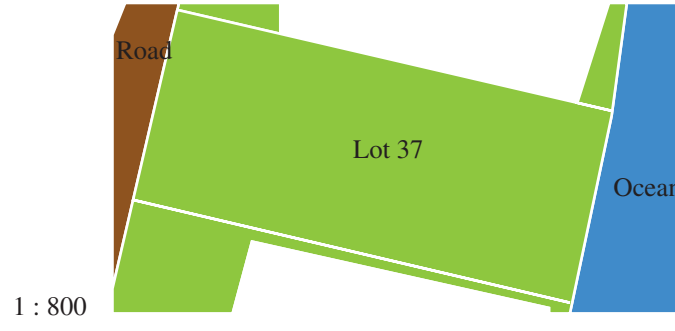


7 Wayne is ordering tiles for the outdoor room of his new home. The plan for the outdoor area is drawn to a scale of 1 : 80.



a Calculate the real length and width of the outdoor room in metres.
b Calculate the real area of the outdoor room in m^2.
c When buying tiles, it is sensible to order an extra 10% to allow for breakage. Calculate the m^2 of tiles Wayne will need to order.

8 The James family has purchased the rectangular Lot 37 to build their dream home overlooking the beach. The site plan below is drawn to a scale 1 : 800.



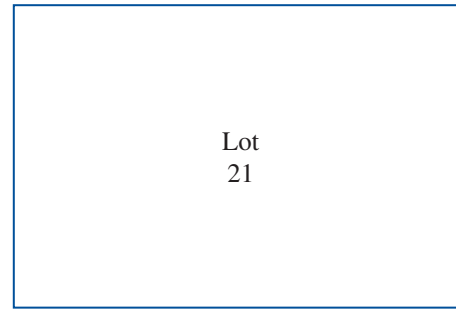
a Use the scale to find the real length and width of the block in metres.
b The family need to build a fence to keep in their pet dog. Calculate the real perimeter of the property.

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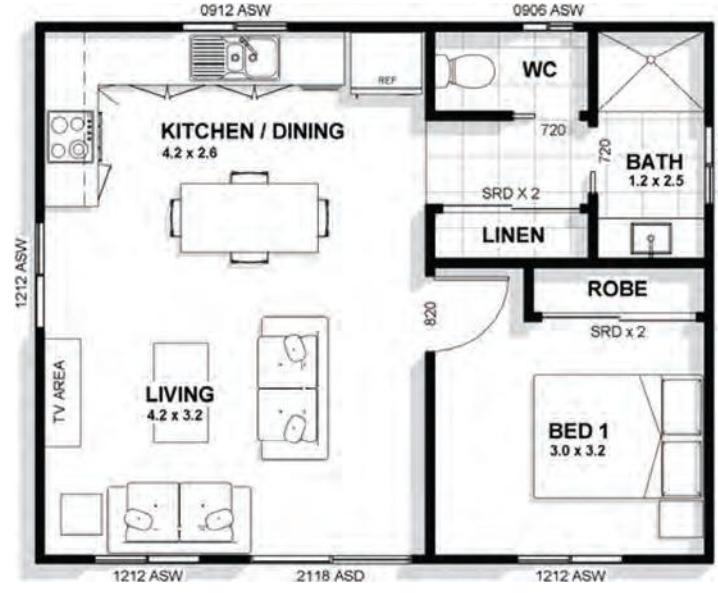
SF

9 Wilma has bought a block of land named Lot 21. The actual length of the shortest side is 20 metres.



a Measure the scale length of the shortest side in mm.
b Convert 20 m to mm.
c Use your answers from parts **a** and **b** to determine the scale for the site plan.
d Use your answer from part **c** to calculate the longest side of the block.
e Calculate the real area of the block in m^2.
f Calculate the real perimeter of the block in m.

10 Henry is building a granny flat in his backyard for his mother. The council allows a maximum area for a granny flat of 60 m^2. The floor plan below is drawn to a scale of 1 : 75.



1 : 75

a Use the scale to determine the real length and width of the granny flat in metres.
b Calculate the real area in m^2 of the granny flat.
c Determine if the granny flat meets council requirements.

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5C Estimating and comparing quantities, materials and costs from scale diagrams

COMPLEX

LEARNING GOALS

- Determine costs from dimensions and areas calculated from scale diagrams.
- Estimate quantities of materials needed.
- Compare costs of materials to determine best values.

Why is it essential to be able to calculate dimensions and areas from plans?

- Homeowners need to budget for building, renovating and landscaping their homes.
- Many commonly used materials are sold by length or area. Skirting boards are sold by length. Stores sell floor coverings such as carpet and tiles by the square metre.
- Knowing how to calculate areas in square metres from a plan helps people to determine what tiles and carpet they can afford.



Tilers are priced in dollars per m^2, and the tiler charges for labour in the same units.

WHAT YOU NEED TO KNOW

- Use a ruler to measure to the nearest millimetre or tenth of a centimetre, and ensure that you start at zero.
- Simplify a scale by changing both the scale and actual measurements to the same units, and then simplifying the ratio using common factors.
- Content from Chapter 3: Area measure will be used in this section.
- Cost is usually calculated as number of units multiplied by price in dollars per the same unit. For example, the cost of 3 m of material sold by length and priced at $5.00 per metre is $15.

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Example 5 Determining costs using calculated areas

Ryan is tiling the floor of his home theatre, which is a rectangle with dimensions 5.5 m by 4 m. The tiles that Ryan has chosen cost $29.95 per square metre, and the tiler charges $45 per square metre to lay the tiles.

a Calculate the area of Ryan's home theatre.

b Determine how much it will cost Ryan to tile his home theatre.

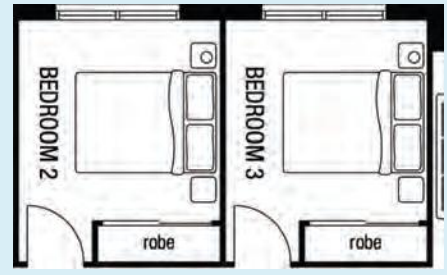
c After tiling, the tiler offers to install a decorative skirting board around the perimeter of the room at a cost of $3.60 per metre. Calculate the extra cost, ignoring the doorway.

WORKING	THINKING
a $A = l \times w$ $A = 5.5 \times 4$ $A = 22\ \text{m}^2$	Write the formula for area of a rectangle. Substitute the values of length and width into the formula. Calculate the area.
b Add cost of tiles and tiler: $\$29.95 + \$45 = \$74.95\ \text{per m}^2$ Total cost $= 22\ \text{m}^2 \times \$74.95$ $= \$1648.90$	Add up the cost per m^2 of the tiles and the labour of the tiler. Calculate the total cost by multiplying the area by the cost per m^2.
c Perimeter = length + width + length + width $= 5.5 + 4 + 5.5 + 4$ $= 19\ \text{m}$	The perimeter is the distance around the edge of the room. Add up the sides.
Cost of skirting $= 19\ \text{m} \times \$3.60/\text{m}$ $= \$68.40$	Calculate the cost by multiplying the perimeter by the cost per m.

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Example 6 Determining costs using areas calculated from a scale diagram

Erin is replacing the carpet in two of her bedrooms as shown in the plan. The carpet that Erin has chosen costs $43.75 per square metre fully laid. The scale drawing shown has a scale 1 : 125.



1 : 125

a Determine the combined area of the bedrooms, including the robes, ignoring the joining wall and robe walls.

b Calculate the cost of the carpet.

WORKING	THINKING
a L : 54 mm W : 26 mm	Measure the length and width of the two rooms together; ignore the joining wall and robe walls in your calculations.
$L = 54 \times 125$ $= 6750$ mm $= 6.75$ m $W = 26 \times 125$ $= 3250$ mm $= 3.25$ m	Determine the actual dimensions of the rooms by multiplying by the scale factor of 125. Convert to metres.
$A = l \times w$ $A = 6.75 \times 3.25$ $A = 21.94$ m^2	Use the area of rectangle formula. Calculate the area of the rooms.
b Cost $= 21.94$ m$^2 \times \$43.75$ $= \$959.88$	Calculate the cost by multiplying the area by the cost per m^2.

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Exercise 5C

FUNDAMENTALS

Example 5

1 Bella has just completed her new rumpus room that she built underneath her house. She wants to buy skirting boards to place around the edge of the rumpus room. Bella's rumpus room is 6 m by 4 m, and the skirting boards cost $20 per metre.

a Calculate the perimeter of the rumpus room.

b Calculate the cost of the skirting boards by multiplying the cost per metre by the perimeter.

2 Tom wants to carpet his bedroom. His bedroom is 3 m by 3.5 m, and the cost of carpet is $52 fully laid per square metre.

a Calculate the area of the bedroom.

b Calculate the cost to carpet the room.

Hint: Total cost is the price per unit times the number of units.

Example 6

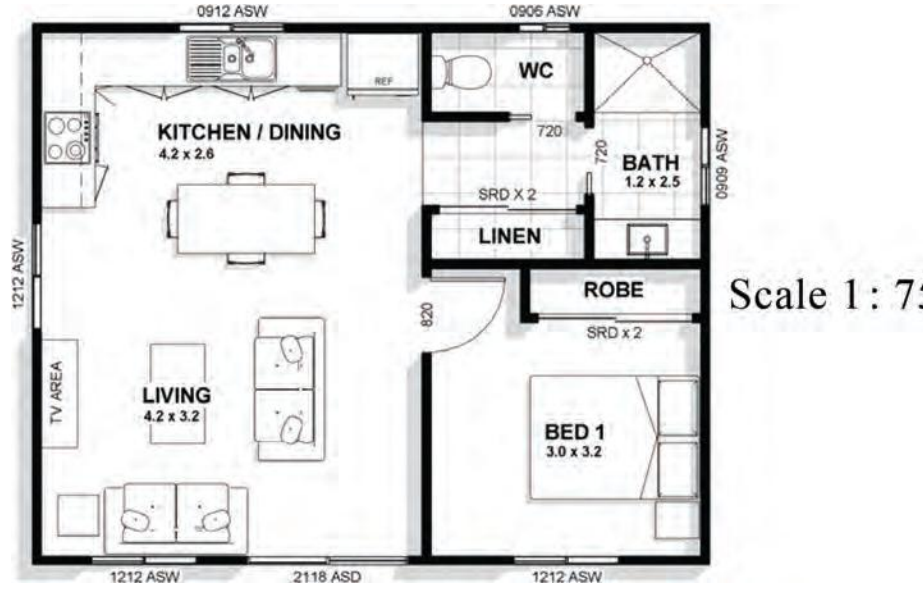
3 Tamika wants to tile her patio. The patio is 6 m by 5.5 m, and the cost of tiling is $65 fully laid per square metre.

a Calculate the area of the patio.

b Calculate the cost to tile the patio.

APPLICATIONS

Henry is working on some extra features for the granny flat for his mother. Use the following scale drawing to answer Questions **4** to **6**.



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4 Henry has decided that he wants to have a concrete mowing strip poured around the edge of the granny flat in his backyard.

- **a** Use the scale to calculate the length and width of the granny flat.
- **b** Calculate the perimeter using the actual length and width of the granny flat.
- **c** The concreting will cost $20 per metre of the perimeter of the flat. Calculate the total cost of the mowing strip.

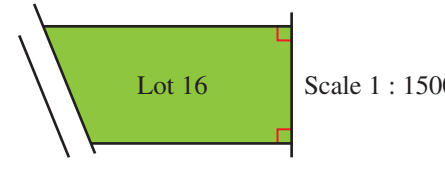
5 Henry's mum Dorethy has decided that she wants a special cornice (a decorative strip to border the ceiling and the walls) in her bedroom. The cost of the cornice is $4.75 per linear metre.

- **a** Measure the length and width of the bedroom on the diagram, ignoring the robe and door.
- **b** Using the scale 1 : 75, determine the actual length and width of the bedroom.
- **c** Calculate the perimeter of the bedroom.
- **d** Calculate the cost of the cornice.

6 Henry wants to lay wooden floorboards in the kitchen, dining and living space. The cost of the floorboards including laying is $62 per square metre.

- **a** Measure the length and width of the kitchen, dining and living area, ignoring the cabinets and furniture.
- **b** Using the scale 1 : 75, determine the actual length and width of the kitchen, dining and living area.
- **c** Calculate the area of the kitchen, dining and living area.
- **d** Calculate the cost of laying the floorboards in the granny flat.

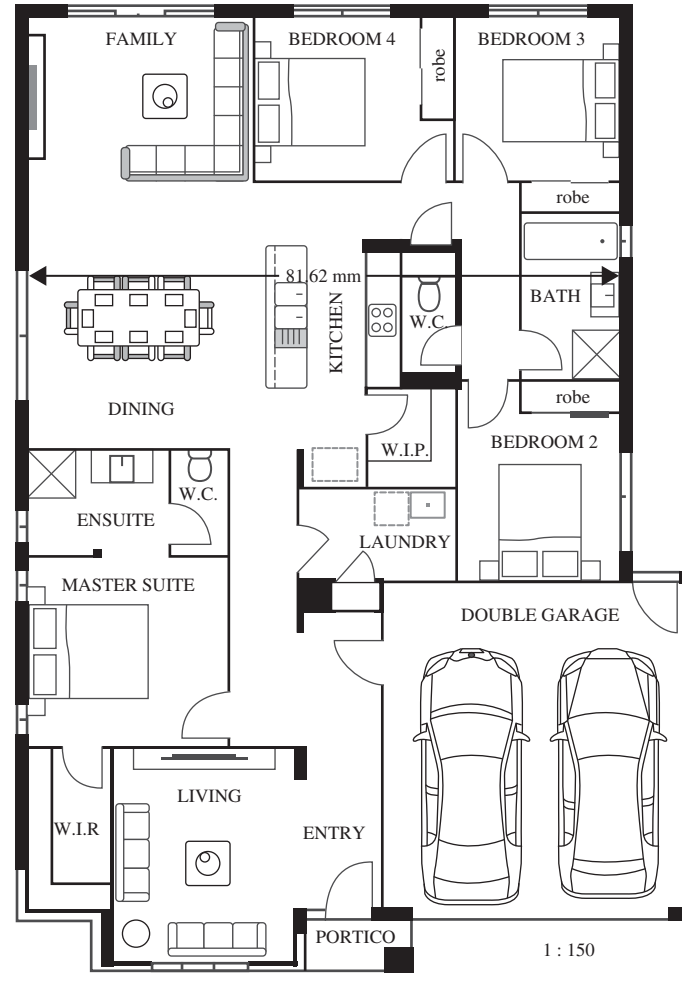
7 Alaskah is buying a block of land as shown in the scale drawing. If she is fencing all 4 sides at a cost of $47.50 a metre, calculate the total cost of fencing Alaskah's property.





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For Questions **8** to **12** use the following house plan drawn to a scale 1 : 150.



★8 Rae is a tiler who is quoting to tile the laundry floor. If Rae charges $70 per square metre to lay the tiles, and the tiles cost $34 per square metre, determine the cost to tile the laundry floor.

★9 Julie wants to carpet the living room, which is beside the entry.

a If the carpet costs $53.75 per square metre, calculate the cost to carpet the living room.

b Julie sees an advertisement for carpeting a lounge area for $600. Determine whether this would be a cheaper way for Julie to carpet her lounge area.

★10 Aaston wants to buy paving paint to paint the floor of his garage. One litre of paint covers 8 m^2 and costs $54.

a Calculate how many tins of paving paint are needed to paint the floor of the garage.

b Determine the total cost for the paint.

CF

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CF

⋆**11** Jang has discovered that the garage does not have any ceiling insulation and she has decided to purchase the insulation and install it herself.

a If it costs $11.50 per square metre, calculate the total cost for Jang to insulate the ceiling herself.

b If the builder offers to insulate the garage for $450, determine which will be the cheapest way for Jang to insulate her garage.

⋆**12** Jii built this house on a 30 metre by 20 metre block and he is going to lay turf at a cost of $7.70 per square metre. He estimates the area of the house to the nearest square metre by measuring its greatest length and width. Determine the approximate cost to turf the block.

Hint
Formulate
Solve
Evaluate
Communicate

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5D Understanding and applying drawing conventions of scale drawings

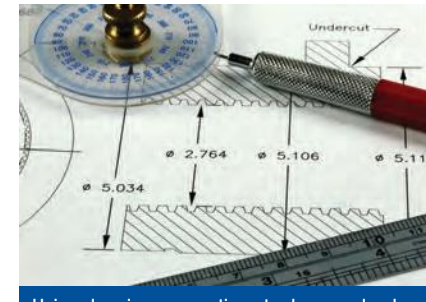
COMPLEX

LEARNING GOALS

- Identify drawing conventions for scale diagrams.
- Identify labelling techniques of ratio in scale diagrams.
- Read measurements from scale diagrams.
- Understand and apply drawing conventions of scale drawings.

Why are drawing conventions essential?

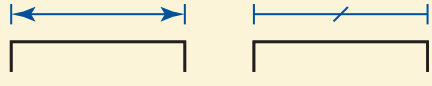
- In order for plans to be used by multiple people in the process of any construction, a universally agreed convention must be used so that there is an understanding of what the plans say.
- Some people create plans and other people need to read the plans to build or construct, so drawing conventions are vital.



Using drawing conventions to draw scale plans helps others interpret the plans for building or manufacturing.

WHAT YOU NEED TO KNOW

- Depending on what types of plans you are reading, the measurements are marked in slightly different ways, either with arrows or with lines marked on a parallel line.

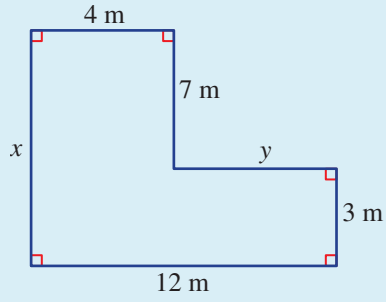


- A very common scale is 1 : 100 for building plans, meaning that 1 centimetre on the plan indicates 100 cm (or 1 metre) in the actual building.
- An engineering scale, where a small part is drawn enlarged on a plan, would be 10 : 1, meaning that 10 millimetres (1 centimetre) on the plan would be 1 millimetre on the actual part.
- Common symbols, as discussed in Section 5A, are used in plans to make them uniform. One such example is the symbol for a shower. ☒
- In order not to crowd the plans, not all measurements are named; however, all the measurements can be found from other markings on the plans.

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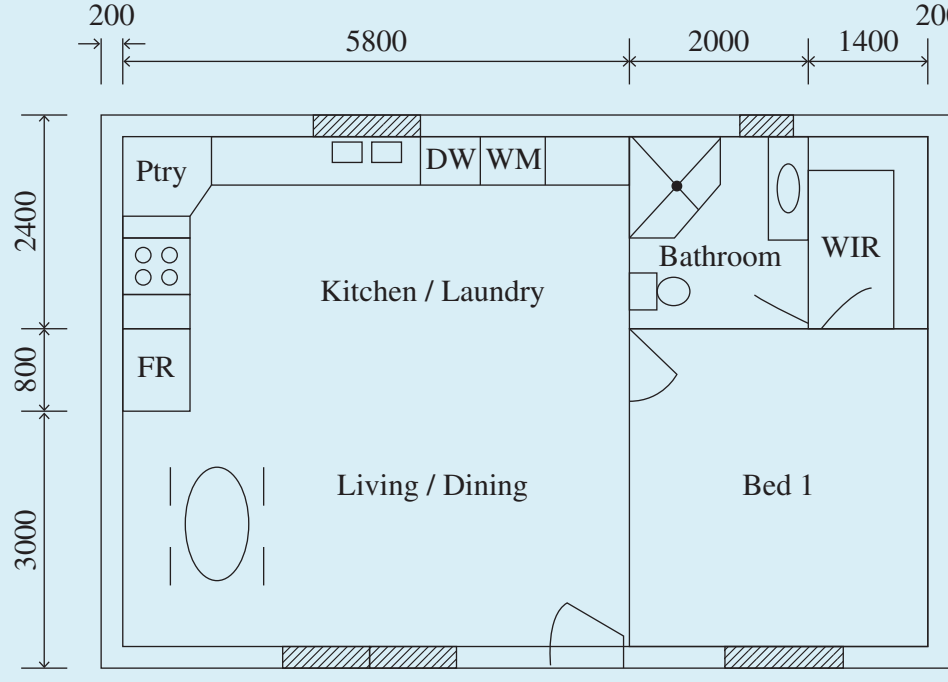
Example 7 Reading measurements from indicated dimensions

Determine the missing side measurements on the following diagram.



WORKING	THINKING
Vertical measurement $x = 7\text{ m} + 3\text{ m} = 10\text{ m}$	Add the two vertical measurements on the right side.
Horizontal measurement $y = 12\text{ m} - 4\text{ m} = 8\text{ m}$	Determine what is left when the 4 m side is subtracted from the 12 m side.

Example 8 Understanding and applying drawing conventions of scale drawings



... Continued

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Use the plan shown to answer the following questions. Measurements are in mm.

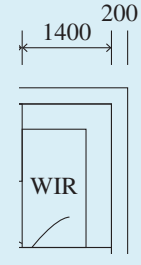
a Identify the width of the external walls.

b Identify the internal dimensions of the kitchen/laundry/living/dining area.

c Determine what the measurement of 2000 mm (found on the top side of the plan) refers to.

d Determine the internal measurements of bedroom 1.

e The council requires a granny flat to be less than 60 m^2. Determine if this granny flat will fit council requirements.

WORKING	THINKING
a 200 mm	The width of the external wall is shown as the first measurement along the length.  Read the dimensions of the kitchen/laundry/living/dining area.
b Length = 5800 mm Width = 3000 + 800 + 2400 − 200 − 200 = 5800 mm Dimensions are 5800 mm by 5800 mm.	Length = 5800 Width = 3000 + 800 + 2400 −200 − 200 (subtracting the external wall from each end)
c The width of the bathroom.	Follow the lines on the measurement to identify the measured section.
d Width = 2000 + 1400 = 3400 mm Length = 3000 + 800 − 200 = 3600 mm Dimensions are 3600 mm by 3400 mm.	Read the dimensions from the plan. Width = 2000 + 1400 Length = 3000 + 800 − 200 (subtract the width of the outer wall)

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e Need to calculate area of the granny flat using area of a rectangle.

$A = lw$

Length $= 200 + 5800 + 2000 + 1400 + 200$

$= 9600$ mm

Width $= 2400 + 800 + 3000$

$= 6200$ mm

Formulate

What are you required to find?
How will you find it?
What rules will you use?
What information do you have?

Solve

Length $= 9600 \div 100 \div 10 = 9.6$ m

Width $= 6200 \div 100 \div 10 = 6.2$ m

$A = lw$

$A = 9.6 \times 6.2 = 59.52$ m^2

This is less than 60 m^2 ✓

Change mm to m before calculating area.

Substitute into formula to calculate area.

Evaluate and verify

Have you answered the question?
Were correct units used?

Communicate

The area will fit within the council requirements as it less than 60 m^2.

Write a sentence to answer the question.

Exercise 5D

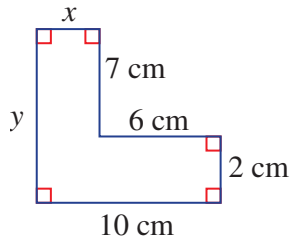
FUNDAMENTALS

Example 7

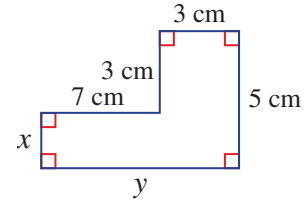
1 Determine the missing side measurements in the following diagrams.

Hint The unknown side lengths are the difference between two or more known side lengths.

a

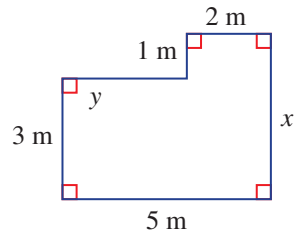


b

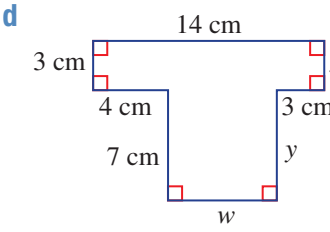


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c

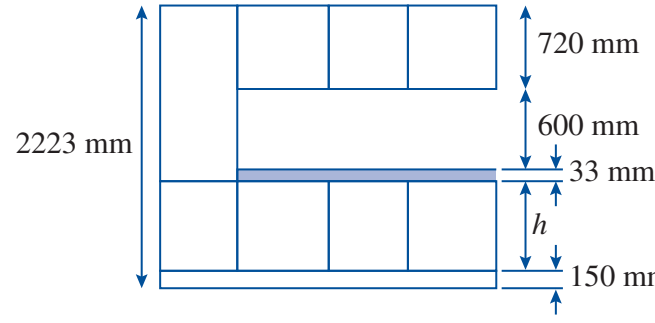


d

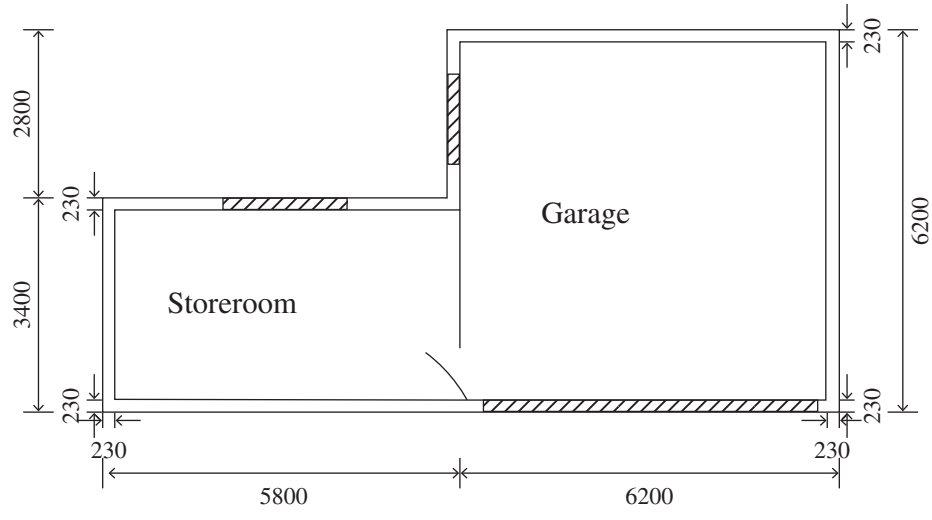


APPLICATIONS

★**2** Janice wants to work out the actual height of the base cabinets from the kitchen plan shown. She realises that 33 mm is the thickness of the benchtop and 150 mm is the height of the kickboards under the bench. Use the measurements from the plan to calculate h, the height of the bottom cabinet doors for Janice.



Example 8 ★**3** Use the plan shown to answer the following questions. The measurements are in millimetres.

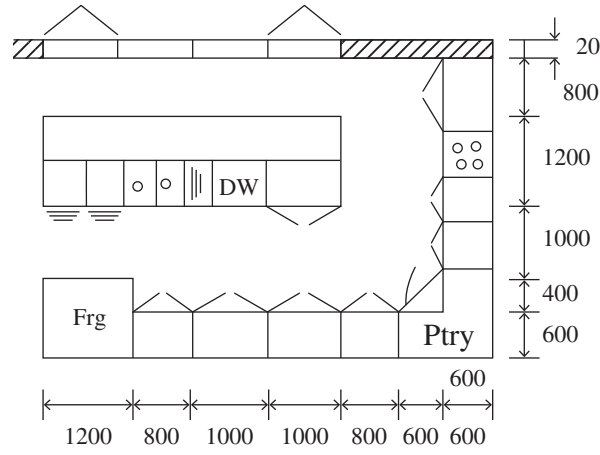


a Determine the actual internal dimensions of the garage, in metres.
b Determine the actual external dimensions of the garage, in metres.
c Determine the actual width of the external walls.
d Identify the internal dimensions of the storeroom.

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CF

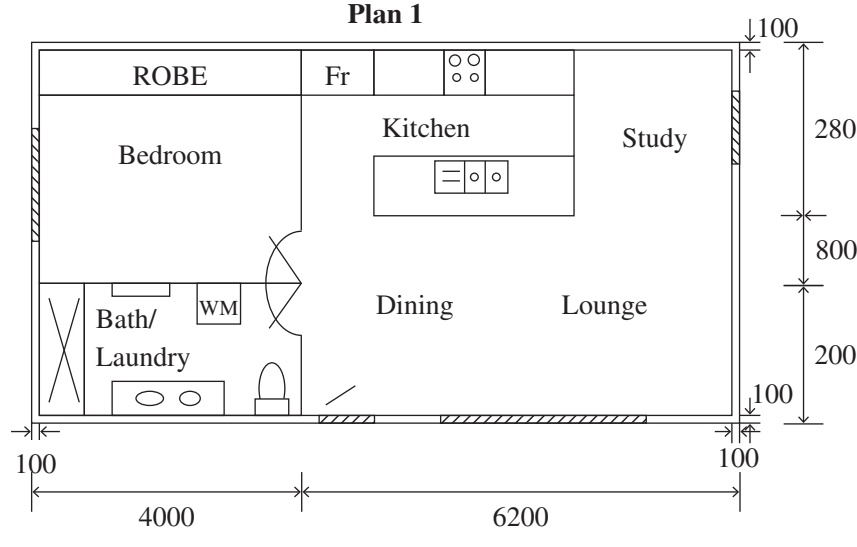
★4 Use the plan shown to answer the following questions. The measurements are in millimetres.



a Identify the window width in the kitchen plan.
b Identify the dimensions of the island bench in the kitchen.
c Determine the walk space distance between the island bench and the external wall/window.

★5 Use the granny flat plan shown to answer the following questions. The measurements are in millimetres.

Plan 1



a Identify the width of the external walls.
b Identify the internal dimensions of the:
i dining/lounge area
ii bathroom/laundry.

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c Determine what these measurements indicate:

i 2000 on the right-hand side of plan

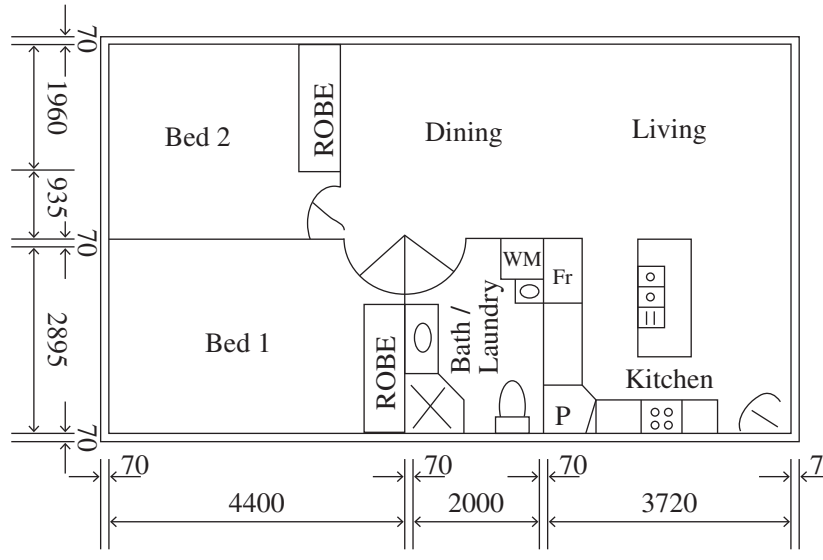
ii 4000 along the bottom of the plan.

d Determine the internal measurements of the bedroom (including the robes).

e The council requires a granny flat to be less than 60 m^2. Determine if the granny flat will meet council requirements.

6 Use the granny flat plan shown to answer the following questions.
The measurements are in millimetres.

Plan 2



a Identify the width of the external walls.

b Identify the internal dimensions of the:

i kitchen

ii bath/laundry.

c Determine what the 1960 measurement on the left-hand side of the plan indicates.

d Determine the internal measurements of Bedroom 1 (including the robes).

e The council requires a granny flat to be less than 60 m^2. Determine if the granny flat will meet council requirements.

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5E Constructing scale diagrams

COMPLEX

LEARNING GOALS

- Construct enlargement scale diagrams by hand.
- Construct reduction scale diagrams by hand.
- Construct scale diagrams using technology.

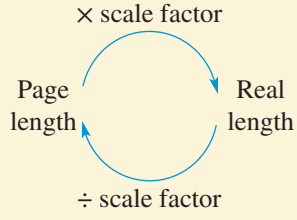
Why is it essential to be able to construct scale diagrams?

- Constructing scale diagrams allows us to create an image to share our vision for renovating or landscaping around our own homes.
- The process allows us to share ideas, visions and inventions with others to help our dreams become a reality.

WHAT YOU NEED TO KNOW

Recall from Section 5B:

- A **scale** is expressed as ratio **length on page : length in real life**. For example, a scale 1 : 200 means that a length of 1 cm on the page is 200 cm in real life. Typically, the scale is expressed as 1 : SF, where SF is the scale factor.
- **Scale factor** is determined using **scale factor** $= \dfrac{\textbf{length in real life}}{\textbf{length on page}}$ and tells us how much bigger the real length is compared to the length on the page.
  - A scale of 1 : 10 would have scale factor, $SF = \dfrac{10}{1} = 10$. This means that the real-life measurement is 10 times **larger** than the length on the page.
  - A scale of 10 : 1 would have scale factor, $SF = \dfrac{1}{10}$. This means that the real-life measurement is $\dfrac{1}{10}$ the length on the page, i.e. it is **smaller**.
- To convert between page length and real length:



- Grid paper is useful for drawing lines and shapes accurately with the help of a ruler.

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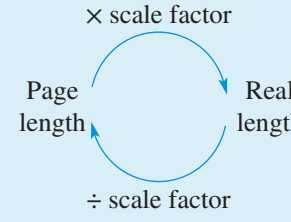
Example 9 Use scale to determine page length for a scale drawing. (SF >1)

A cabinet maker is drawing up plans for a new kitchen. He wants to use a scale of 1 : 20.

a Calculate the scale factor for the scale 1 : 20.

b Determine the length he will draw on the plan to represent an island bench that will be 1800 mm × 900 mm.

WORKING	THINKING
a $\text{scale factor} = \frac{\text{length in real-life}}{\text{length on page}}$ $\text{SF} = \frac{20}{1} = 20$	Apply the rule to find the scale factor.
b Length $= 1800 \div 20 = 90$ mm Width $= 900 \div 20 = 45$ mm	To convert from a real length to a page length, divide by the scale factor.



Example 10 Use scale to determine page length for a scale drawing. (SF <1)

A jeweller is drawing up plans for an engagement ring. He wants to use a scale of 4 : 1.

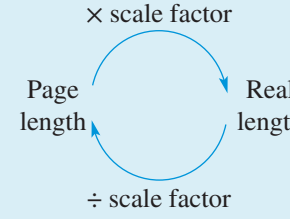
a Calculate the scale factor for the scale 4 : 1.

b Determine the length he will draw on the plan to represent:

i the width of the band, which is 4 mm

ii a stone that has a 6 mm diameter.

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WORKING	THINKING
a scale factor $= \dfrac{\text{length in real-life}}{\text{length on page}}$ $\text{SF} = \dfrac{1}{4} = 0.25$	Apply the rule to find the scale factor.
b i Width $= 4 \div 0.25 = 16$ mm **ii** Diameter $= 6 \div 0.25 = 24$ mm	To convert from a real length to a page length, divide by the scale factor. 

Example 11 Applying a scale to construct a scale drawing

Construct a 1 : 200 scale drawing of a shed that is to be 7.315 m × 8.534 m.

WORKING	THINKING
	Formulate
Construct a scale drawing. Scale is 1 : 200 Dimensions are 7.315 m × 8.534 m Will need scale factor. scale factor $= \dfrac{\text{length in real-life}}{\text{length on page}}$	• What are you required to do? • What information do you have? • What information and materials will you need to do this?
	Solve
$\text{SF} = \dfrac{200}{1} = 2000$ Real length $= 7.315 \times 100 \times 10$ $= 7315$ mm Real width $= 8.534 \times 100 \times 10$ $= 8534$ mm	• Calculate the scale factor. • Will use mm to draw scale diagram, so need to convert dimensions to mm.

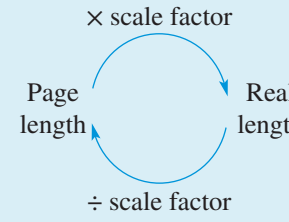
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Page length $= 7315 \div 200$
$= 36.575$ mm
≈ 37 mm
Page width $= 8534 \div 200$
$= 42.67$ mm
≈ 43 mm

Use SF to find page lengths.

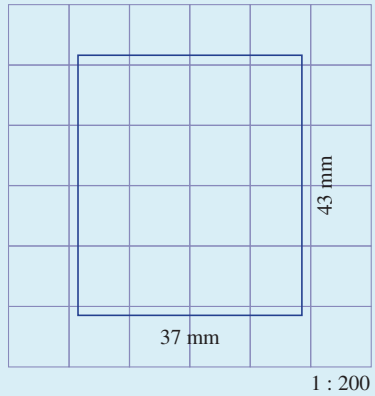


Evaluate and verify

- Have you answered the question?
- Have you used correct units?
- Have you correctly applied the scale factor?

Communicate

- Draw a rectangle using the calculated page length measurements.
- Using a ruler and grid paper will increase your precision and accuracy.
- Indicate the scale used.



Exercise 5E

FUNDAMENTALS

Example 9a

1 Determine the scale factor for the following scales:

a 1 : 500
b 2 : 60
c 20 : 1
d 5 : 4

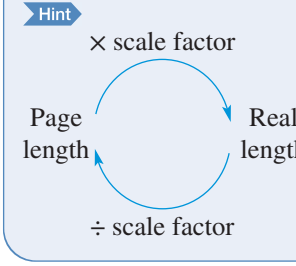
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Example 9, 10

2 Complete the following table.

	Length on page	Scale factor	Real-life length
a	45 mm	5	
b		20	1880 mm
c	58 mm		2900 mm
d	24 mm	0.8	
e		0.2	7 mm
f	120 mm		6 mm

Hint



3 Measure the following lines to the nearest mm.

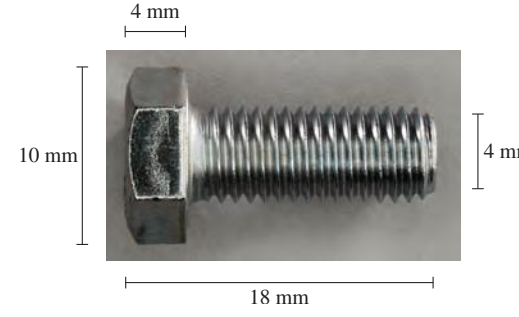
a _____

b _____

c _____

d _____

4 A draftsman needs to make a 5 : 1 scale drawing of this bolt in order to have more manufactured in their workshop. He takes the measurements as shown in the image.

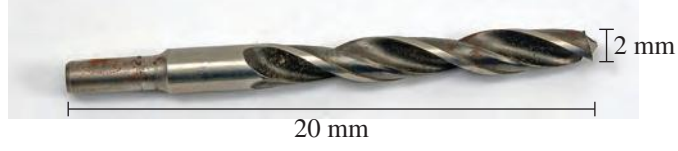


a Determine the scale factor for the 5 : 1 scale.

b Use the scale factor to convert the real-life measurements to the lengths to be drawn on the page.

c Ignoring the threads, draw a scale diagram for the bolt.

5 An apprentice needs to draw a 4 : 1 scale diagram of the following drill bit.



a Determine the scale factor for the 4 : 1 scale.

b Use the scale factor to convert the real-life measurements to the lengths to be drawn on the page.

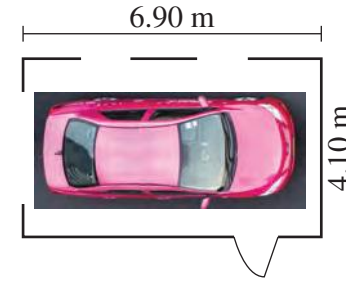
c Ignoring the threads, draw a scale diagram for the drill bit.

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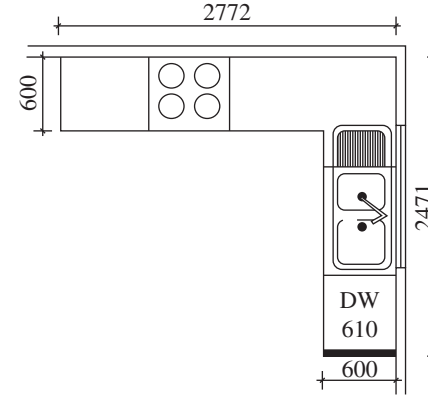
Example 11

6 Use the following steps to construct a scaled diagram of the garage. Use a scale of 1 : 100.



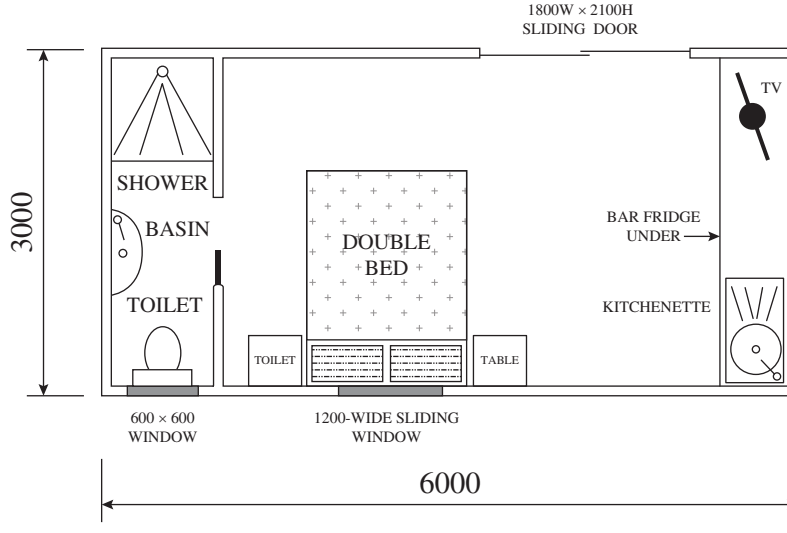
- **a** Convert the actual measurements to millimetres, given the measurements are in metres.
- **b** Calculate the scale factor.
- **c** Apply the scale factor to convert the actual measurements to diagram measurements.
- **d** Draw a rectangle using the scale measurements on grid paper.

7 Use the following steps to construct a scale diagram of the outline of these kitchen cabinets using grid paper and a scale of 1 : 50.



- **a** Calculate the scale factor.
- **b** Apply the scale factor to the actual measurements to convert to diagram measurements.
- **c** Draw the outline using the scale measurements on the grid paper. You do not have to draw the individual kitchen units, just the outline.

★8 Construct a scale diagram of the exterior dimensions of this garage conversion using grid paper and a scale of 1 : 75.



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⋆**9** Construct a 1 : 100 scale drawing showing the boundary of a rectangular block of land and the exterior walls of a rectangular shed placed in the centre of it. The block of land is 26 m × 16.5 m, and the shed is 12.5 m by 9 m. The longer side of the shed runs in the same direction as the longer side of the block. The yard is of equal width on opposite sides of the shed. Label the dimensions of the block of land in metres and the shed in millimetres. Add the scale to the drawing.

10 Use technology to create a kitchen of your own design. Online kitchen programs are available through the internet, and most schools will have a CAD (Computer Aided Design) program that can be useful.



11 Use technology to create a bathroom of your own design. Online bathroom programs are available through the internet, and most schools will have a CAD (Computer Aided Design) program that can be useful.

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Modelling task



Context: Floor plans of dwellings are the most common kind of scale drawing that people will experience in their lives.

Task: The council have rezoned the rules for the construction of granny flats in the Sunshine Coast area. They are now allowing an area of 90 m^2. Your task is to design a granny flat that meets the council requirements. You can either use technology or draw by hand the granny flat plan. Your client wants to have a separate laundry and two toilets in the granny flat, and a spare bedroom for guests and family to stay.

Stage 1: Formulate
Make an assumption of: • the elements you want to include in the granny flat. Make an observation of: • minimum bedroom and bathroom sizing • information given to you for the task.
Stage 2: Solve
• Sketch the outline of your granny flat, ensuring it is less than or equal to 90 m^2. • Sketch the rooms into the outline of the granny flat. • Draw symbols onto the plan to identify fixtures and features. • Use abbreviations to label the smaller rooms on the plan.
Stage 3: Evaluate and verify
Have you answered the question? • Show someone else your work for comment. • Check your area.
Stage 4: Communicate
• Submit your plan along with a paragraph identifying the positive traits of your design and the mathematical expression showing that it will meet council requirements.

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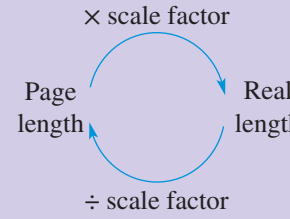
Chapter summary

Scale

- A scale is a comparison of two like quantities that are in the **same** units (mm, cm, m or km).
- Scales are expressed as a ratio of the form:
  length on page : length in real life.

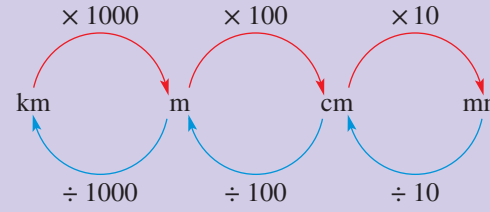
Scale factor

- Scale factor is the relationship between the length on the page of a scale drawing and the real-life measurement.
- **Scale factor** $= \dfrac{\textbf{length in real life}}{\textbf{length on page}}$.
- To convert between page length and real length:



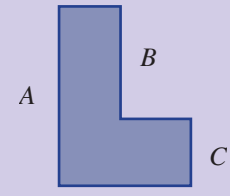
Length

- Length is measured in mm, cm, m or km. See Chapters 1 and 2.
- Conversions



Perimeter

- Perimeter is the distance around the outside of a 2D shape. See Chapter 2.
- Addition or subtraction may be used to find unknown lengths.
  E.g. $A = B + C$ also $B = A - C$ and $C = A - B$



Area

- Area is the space inside a 2D shape. See Chapters 1 and 3.

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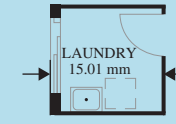
Chapter checklist

5A ☐ I understand and can interpret scale symbols and abbreviations.

1 Convert 3.54 m into mm.
2 Simplify the scale 8 mm : 48 cm.
3 Identify the meaning of the abbreviation ROBE.
4 Identify the  symbol.

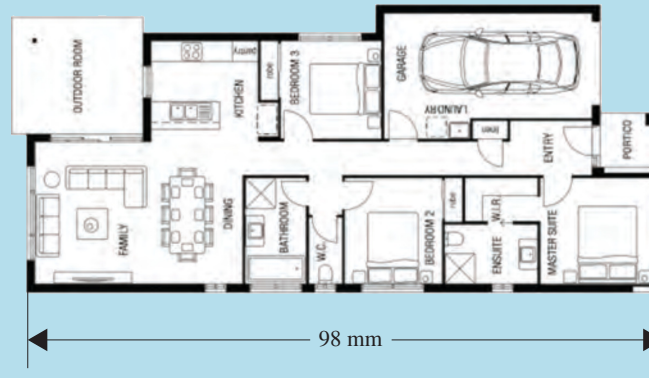
5B ☐ I can identify and calculate measurements of length, perimeter and area from scale diagrams.

5 Calculate the area of a rectangle with a length of 6.4 m and a width of 5.3 m.
6 This laundry is drawn using a scale 1 : 100.
   a Measure the length and width in mm.
   b Calculate the real-life dimensions of the laundry.



5C ☐ I can estimate and compare quantities, materials and costs from scale diagrams. [**complex**]

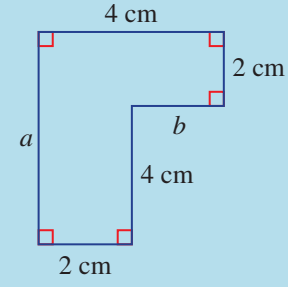
7 Tutu wants to carpet his bedroom. His bedroom has dimensions of 4 m by 4.2 m, and the cost of carpet (fully laid) is $48 per square metre.
   a Calculate the area of the bedroom.
   a Calculate the cost to carpet the room.
8 This house plan is drawn to a 1 : 200 scale. Jonah wants to tile the ensuite. If the tiles and tiling cost $62 per square metre, calculate the cost to tile the ensuite.



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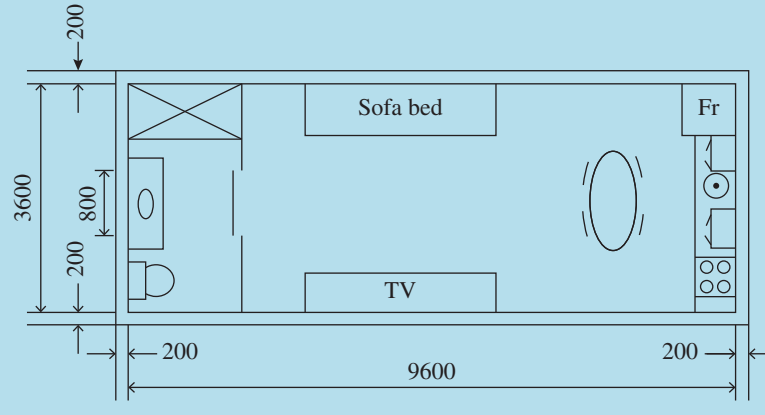
5D ☐ I can understand and apply drawing conventions of scale drawings. **[complex]**

9 Determine the missing side measurements from the following diagram.



10 Use the plan below to complete the following:

- **a** Identify the width of the external walls.
- **b** Identify the internal dimensions of the entire apartment.
- **c** Determine what the measurement of 800 mm found on the left-hand side of the plan refers to.
- **d** Determine the overall area of the building, including external walls.



5E ☐ I can construct a scale diagram. **[complex]**

11 Construct a scale enlargement diagram using grid paper and a scale of 4 : 1 for a bolt. It has a length of 15 mm, a head with dimensions 12.5 mm by 5 mm, and the threaded portion has a diameter of 5 mm. Indicate the scale on the diagram.

12 Construct a scale diagram of a garage with dimensions of 5.8 m by 6 m using grid paper and a scale of 1 : 100.

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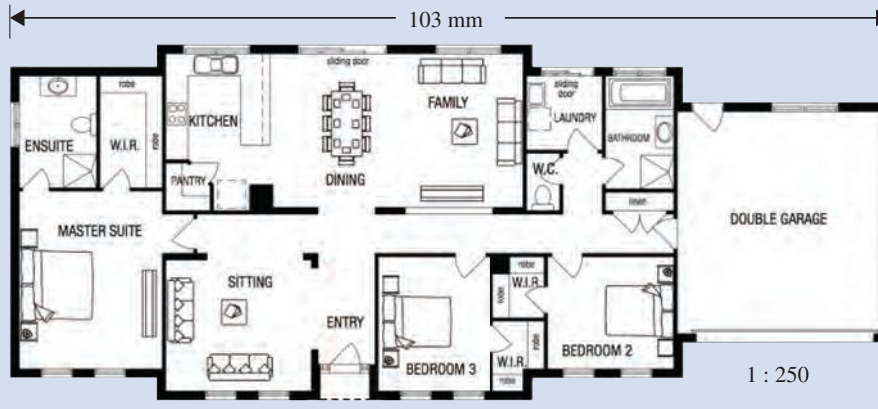
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Chapter review

All questions in the review are assessment style.

Simple Familiar

Refer to this diagram for Questions 1 to 5.



5A **1** Simone is reading the plans of the house she would like to have built on her block of land. She does not know what the abbreviations W.C. and W.I.R. mean. Interpret these abbreviations for Simone.

5B **2** The house is drawn to a scale 1:250

- **a** Determine the scale factor for this scale.
- **b** Calculate the area of the sitting room.
- **c** Calculate the area the master suite (not including the W.I.R. and ensuite).

Complex Familiar

5C **3** Aaron wants to retile the ensuite in his home. The cost of laying the tiles is $35 per square metre, and the tiles cost $42.25 per square metre. Determine the area of the ensuite and calculate the total cost for Aaron to have it retiled.

4 Gina wants to paint the floor of the garage with paving paint. If the paint covers 6 m^2 per litre and she needs to do 2 coats of paving paint, calculate the number of 4-litre tins Gina will need to purchase.

5 Dan is going to carpet bedroom 3 excluding the walk-in robe. Calculate the cost if the carpeting costs $34 per square metre fully laid.

5D **6** Use the plan shown below to answer the following questions, given that the measurements are in millimetres.

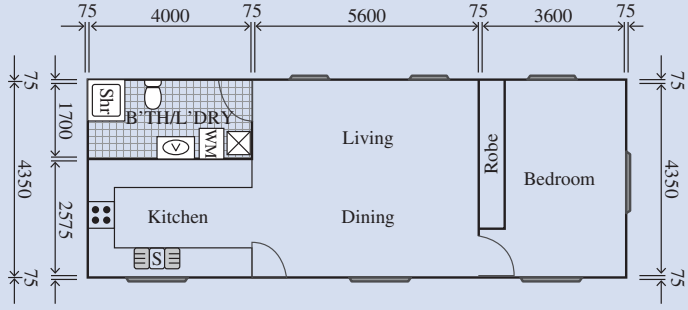
- **a** Identify the width of the external walls.
- **b** Identify the dimensions of the bedroom including the robe.

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c Determine what the measurement of 4000 mm found at the top side of the plan measures.

d Determine the internal measurements of the living/dining area.

e The council requires a granny flat to be less than 60 m^2. Calculate the area of this plan to determine if it will fit council requirements.



5E **7** Construct a scale diagram using grid paper and a scale of 3 : 1 for the U-bolt shown. It has a height of 30 mm, a width of 15 mm and a thickness of 1.5 mm. Indicate the scale on the diagram and label its actual dimensions.



Complex Unfamiliar

5C **8** Construct a 1 : 100 scale diagram of a granny flat on grid paper with the following rectangular dimensions. Draw the first dimension in each pair horizontally on the plan, and the second dimension vertically on the plan.

- External dimensions 8950 mm by 5500 mm, with the longer side horizontal in the plan
- Bedroom 1 located at the top left of the plan, internal dimensions 3000 mm by 3760 mm
- Bathroom located at the top centre of plan, next to bedroom 1, internal dimensions 2400 mm by 2800
- Study located at bottom left of plan, next to bedroom 1, internal dimensions 3000 mm by 1340 mm
- The kitchen/dining and living areas make up the space left over, with the living area at the top right of the plan, and kitchen/dining in the bottom right of the plan.

Show the front door at the top of the plan, and doors to the enclosed rooms. Don't show windows or fixtures and features. Label the plan with the external dimensions and the names of the rooms, and indicate their internal dimensions in a suitable way. Indicate the scale.

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6 Right-angled triangles



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In this chapter

6A Calculating the hypotenuse by applying Pythagoras's theorem

6B Calculating a short side length by applying Pythagoras's theorem

6C Determining unknown side lengths by applying trigonometric rules **[complex]**

6D Determining unknown angles by applying trigonometric rules **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 3 Topic 2 Scales, plans and models

Right-angled triangles (5 hours)

In this sub-topic, students will:

- apply Pythagoras's theorem to solve problems for all side lengths where c is length of hypotenuse and a and b are lengths of the perpendicular sides, using the formulas:
  - $c^2 = a^2 + b^2$
  - $a^2 = c^2 - b^2$
  - $b^2 = c^2 - a^2$
- apply the cosine, sine and tangent ratios to find unknown angles (θ) and sides **[complex]**
  - $\cos\theta = \dfrac{\text{adjacent}}{\text{hypotenuse}}$
  - $\sin\theta = \dfrac{\text{opposite}}{\text{hypotenuse}}$
  - $\tan\theta = \dfrac{\text{opposite}}{\text{adjacent}}$
- use the concepts of angle of elevation and angle of depression to solve practical problems **[complex]**.

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Prior knowledge check

1 Calculate the squares of the following numbers using your calculator.

a 6
b 8
c 11
d 24
e 33

2 Calculate the square roots of the following numbers using your calculator. Round to two decimal places where necessary.

a 169
b 289
c 320
d 3600
e 4336

3 Determine the value of the unknowns in the following problems using your calculator. Round to two decimal places where necessary.

a $c = \sqrt{12^2 + 16^2}$
b $c = \sqrt{10^2 + 24^2}$
c $c = \sqrt{21^2 + 43^2}$
d $a = \sqrt{39^2 - 15^2}$
e $b = \sqrt{23^2 - 17^2}$

4 Determine the value the following problems using your calculator. Round to two decimal places where necessary.

a $15 \times \cos 20°$
b $\sin 62° \times 13$
c $\tan 45° \div 21$
d $78 \div \cos 12°$

Hint If your calculator has a mode for radians ('Rad'), make sure it is in degree mode ('Deg').

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6A Calculating the hypotenuse by applying Pythagoras's theorem

LEARNING GOALS

- Understand Pythagoras's theorem.
- Identify the sides of a right-angle triangle.
- Identify the hypotenuse of a right-angled triangle.
- Calculate the hypotenuse given the other two sides.
- Calculate the hypotenuse in a real-world context.
- Verify square angles in construction by using Pythagoras's theorem.

Why is it essential to understand the use of Pythagoras's theorem?

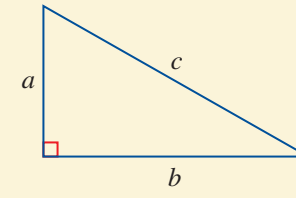
- Pythagoras's theorem is a very practical way to help verify right angles.
- It is one of the most common mathematical theorems used in occupations that require manufacturing and construction, where it is necessary to calculate lengths and verify that the edges of a shape are square.



Pythagoras's theorem can be used to check that the corner of this soccer field is a right angle.

WHAT YOU NEED TO KNOW

- A **right angle** is a 90° angle, as found at the corners of squares and rectangles, and it is also known as a square angle.
- The **hypotenuse** is the longest side of a triangle, which is found opposite the right-angle.
- The formula is known as $c^2 = a^2 + b^2$, where c is the length of the hypotenuse.



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- **Pythagoras's theorem** states that in a right-angled triangle, the square of the longest side is equal to the sum of the squares of the other two sides.
- To find the value of c rearrange the formula to $c = \sqrt{a^2 + b^2}$.
- $c^2 = a^2 + b^2$

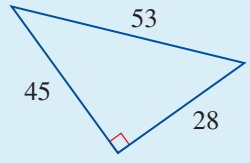
  $a^2 = c^2 - b^2$

  $b^2 = c^2 - a^2$

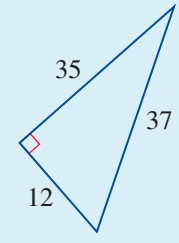
Example 1 Identifying the hypotenuse on a right-angled triangle

Identify the length of the hypotenuse in each of the following triangles.

a



b



WORKING	THINKING
a The hypotenuse is 53.	The hypotenuse is the longest side and is also opposite the right angle.
b The hypotenuse is 37.	The hypotenuse is the longest side and is also opposite the right angle.

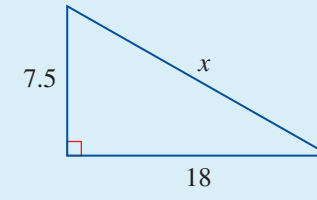
Example 2 Determining the value of the hypotenuse given the other two sides

Complete the following steps to determine the value of the hypotenuse for the triangle shown.

a Identify the values of a, b and c.

b Substitute the values into the formula, $c^2 = a^2 + b^2$.

c Calculate the value of the hypotenuse using your calculator. Round to one decimal place when necessary.

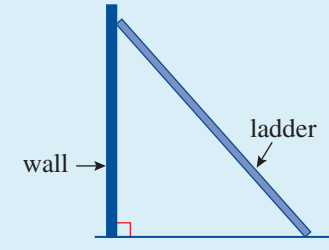


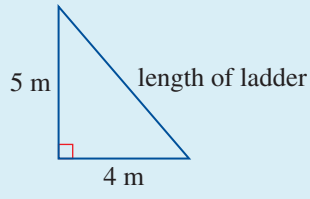
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WORKING	THINKING
a $c = x, a = 7.5, b = 18$	Identify the hypotenuse, which is the longest side opposite the right angle. The other sides are a and b in any order.
b $c^2 = a^2 + b^2$	Write the formula.
$x^2 = 7.5^2 + 18^2$	Substitute the values for a, b, c into the formula.
c $x = \sqrt{7.5^2 + 18^2}$	Calculate the value of the hypotenuse.
$x = \sqrt{380.25}$	
$x = 19.5$	Round the final answer to one decimal place.

Example 3 Determining the value of the hypotenuse in a real-world context

A ladder is leaning against a vertical wall at a height of 5 metres up the wall. If the base of the ladder is 4 metres from the base of the wall, determine the length of the ladder, correct to one decimal place.



WORKING	THINKING
	Formulate
$a = 5$ m, $b = 4$ m, c = length of ladder	Draw your diagram; identify the hypotenuse; substitute the values into the formula.
	
$c^2 = a^2 + b^2$	
$c^2 = 5^2 + 4^2$	

... Continued

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Solve

$c = \sqrt{4^2 + 5^2}$ ◄····· Calculate the value of the hypotenuse.
$c = \sqrt{41}$
$c = 6.403124237$

Evaluate and verify

$c = 6.4\,\text{m}$ ◄····· Round your answer and make sure it is longer than the other two sides.

Communicate

The length of the ladder is 6.4 m. ◄····· Write your answer as a sentence.

Example 4 Determining if an angle is a right angle

Ziza is building a shed in her backyard. She wants to verify that the concrete slab she is having poured has been set out correctly and is at right angles. She starts by measuring two adjoining sides as 5 m and 6 m, and their diagonal as 7.85 m. Verify that the concrete slab will be square (within a 1 cm difference is allowable).

WORKING	THINKING
	Formulate
$A = 5\,\text{cm}, b = 6\,\text{m}, c = 7.8\,\text{m}$	◄····· Identify the two short sides and the hypotenuse (longest side).
$c^2 = a^2 + b^2$	◄····· Identify required formula.
	Solve
$c^2 = a^2 + b^2$ $c^2 = 5^2 + 6^2$ $c = \sqrt{61}$ $c = 7.81\,\text{m}$	◄····· Use the formula to calculate the length of the hypotenuse if a right-angled triangle.
	Evaluate and Verify
Expected length if a right angle = 7.81 m Measured length = 7.85 m	◄····· Compare the expected length of the hypotenuse with the measure value.
	Communicate
The measured length is more than 1 cm different from the expected length. Therefore the slab is not square.	◄····· Write your answer as a sentence.

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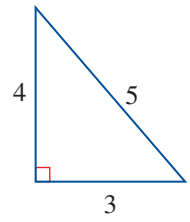
Exercise 6A

FUNDAMENTALS

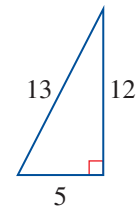
Example 1

1 Identify the length of the hypotenuse in these right-angled triangles.

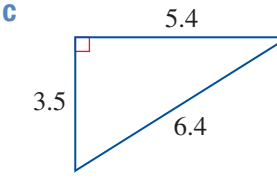
a



b



c



2 Calculate the value of the following expressions using your calculator. Round to one decimal place where necessary.

a $\sqrt{3^2 + 4^2}$

b $\sqrt{5^2 + 12^2}$

c $\sqrt{7^2 + 11^2}$

d $\sqrt{13^2 + 24^2}$

Example 2

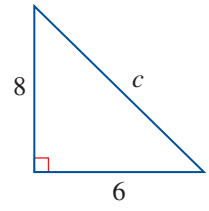
3 Complete the following for each of the triangles shown.

i Identify the values of a, b and c.

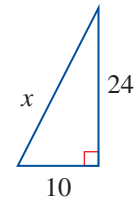
ii Substitute the values of a, b and c into the formula $c^2 = a^2 + b^2$.

iii Calculate the value of the unknown side by using your calculator. Round your answer to one decimal place when necessary.

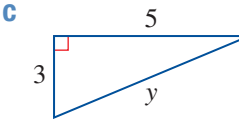
a



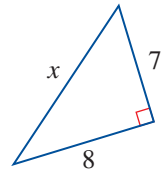
b



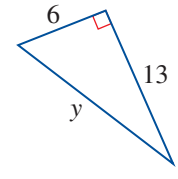
c



d



e



Hint The value of c is important to identify; a and b are just the other two short sides.

Example 4

4 Verify that the triangles with the following side lengths are right-angled triangles. An allowance of 0.1 difference may be applied due to rounding.

a 8, 15, 17

b 7, 24, 25

c 33, 56, 65

d 4.5, 6.3, 7.74

e 12.7, 18.6, 22.52

Hint The hypotenuse is the longest side.

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APPLICATIONS

Example 3 ★5 The ladder rests against a tree 10 m above the ground. The base of the ladder is 3 m away from the base of the tree.
Determine the length of the ladder using your calculator. Round to one decimal place.



ST

Hint
Formulate
Solve
Evaluate
Communicate

★6 Chen is on top of a vertical cliff with a height of 120 m. He is about to ride a flying fox that lands at a horizontal distance of 175 m from the base of the cliff.
Calculate the length the flying fox rope, correct to one decimal place.



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SF

★7 Anmarie is designing a cable-stayed bridge. She needs to calculate the length of a cable that will attach to the bridge pylon (the column) with a vertical distance of 40 metres above the bridge deck. The other end of the cable will attach to the bridge deck at a horizontal distance of 20 metres from the middle of the bridge pylon. Calculate the required length of the cable, correct to one decimal place.



★8 Holly is building a gate in the shape of a rectangle and she needs to add a brace that runs diagonally from the upper corner to the lower corner. If the gate is 1.2 metres high and 2.6 metres wide, calculate the length of the brace needed. Round your answer correct to one decimal place.

★9 Hayden has designed a television that is 140 cm wide and 90 cm high. He is told that to market his television he needs to advertise the length of the screen diagonal. Calculate the length of the television screen diagonal, correct to one decimal place.

Example 4 ★10 Bitta the builder is checking the right angle between two walls in a rectangular room by measuring the lengths of the sides of the rectangle and its diagonal. She measures the sides of the room as 8 metres and 6 metres, and the diagonal as 10 metres. Verify that the walls have been built at a right angle.

★11 Lance is wanting to renovate his kitchen. Before he orders new cabinets, he wants to confirm that the room is actually square. If one wall is 3 m, the adjoining wall is 3.6 m, and the diagonal is approximately 4.69 m, verify that the kitchen is square (within 0.1 m difference is allowable).

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6B Calculating a short side length by applying Pythagoras's theorem

LEARNING GOALS

- Understand Pythagoras's theorem.
- Identify the hypotenuse on a right-angled triangle.
- Calculate a short side given the hypotenuse and the other short side.

Why is calculating side lengths in a right-angled triangle essential?

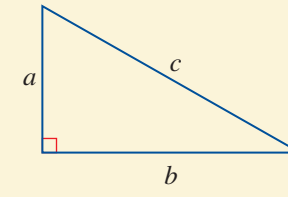
- Allows for problem solving when the length of only one short side and the hypotenuse is known in a right-angle triangle. These two lengths can be used to calculate the length of the unknown side.
- Useful in many industries, such as manufacturing and construction, surveying, landscaping and sewing, as the square angle can be checked using this theorem.



This roof truss is in the shape of two right-angled triangles joined along their shortest sides.

WHAT YOU NEED TO KNOW

- The formula is known as $c^2 = a^2 + b^2$, where c is the length of the hypotenuse.

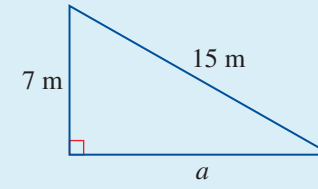


- It does not matter which side is labelled a or b, as long as they are not the hypotenuse.
- To find the value of a, rearrange the formula to $a^2 = c^2 - b^2$.
- To find the value of b, rearrange the formula to $b^2 = c^2 - a^2$.
- Round to a required number of decimal places.

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Example 5 Determining the unknown side given the hypotenuse and one short side

Complete the following steps to determine the unknown side for the triangle shown.



a Identify the values of a, b and c.

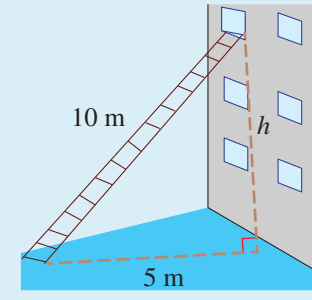
b Substitute the values of a, b and c into the formula $a^2 + b^2 = c^2$ and rearrange it to write it in terms of a.

c Determine the value of the short side using your calculator. Round your answer to one decimal place if necessary.

WORKING	THINKING
a $c = 15\text{ m},\ a = ?,$ $b = 7\text{ m}$	Identify the hypotenuse, which is the longest side opposite the right angle. The other sides are a and b in any order.
b $a^2 + b^2 = c^2$ $a^2 + 7^2 = 15^2$ $a^2 = 15^2 - 7^2$ $a = \sqrt{15^2 - 7^2}$	Write the formula. Substitute the values for a, b and c into the formula and rearrange.
c $a = \sqrt{176}$ $a = 13.26649916$ $a = 13.3$	Calculate the value of the short side. Round the final answer to one decimal place.

Example 6 Calculating the unknown side given the hypotenuse and one short side in a real-world context

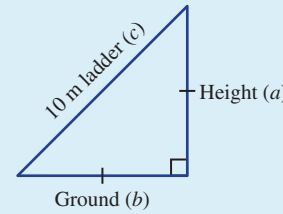
A 10-metre ladder is leaning against a vertical wall at a height of h metres. If the base of the ladder is 5 metres from the base of the wall, calculate the height that the ladder reaches up the wall, correct to one decimal place.



... Continued

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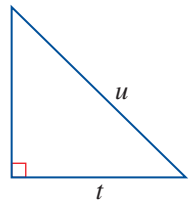
WORKING	THINKING
	Formulate
$a^2 + b^2 = c^2$ $a = h, b = 5$ m, $c = 10$ m $h^2 + 5^2 = 10^2$	Draw a diagram that represents the question.  Write down the formula and substitute the values into the formula.
	Solve
$h^2 = 10^2 - 5^2$ $h = \sqrt{10^2 - 5^2}$ $h \approx 8.7$ m	Rearrange the formula to find the short side Calculate the value of h and round to one decimal place.
	Evaluate and Verify
$a = 8.7$ m, $b = 5$ m, $c = 10$ m	Check that the hypotenuse is the longest length.
	Communicate
The ladder reaches up the wall to a height of approximately 8.7 m.	Write your answer as a sentence.

Exercise 6B

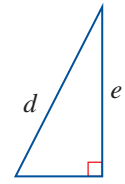
FUNDAMENTALS

1 The unknown side is 'a' in these right-angled triangles. Write the rule to find the value of a using the other values on the triangles.

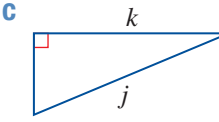
a



b



c



2 Calculate the value of the following expressions using your calculator. Round to one decimal place where necessary.

a $\sqrt{13^2 - 12^2}$ **b** $\sqrt{25^2 - 20^2}$ **c** $\sqrt{17^2 - 14^2}$

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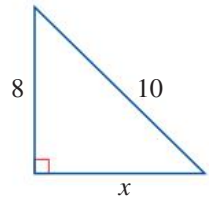
Example 5 **3** Complete the following for each of the triangles shown.

i Identify the values of a, b and c.

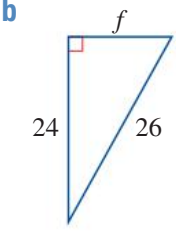
ii Substitute the values of a, b and c into the formula $a^2 + b^2 = c^2$ and rearrange.

iii Calculate the value of the unknown side by using your calculator. Round your answer to one decimal place when necessary.

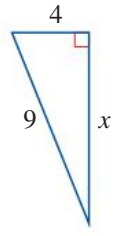
a



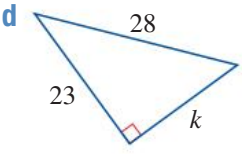
b



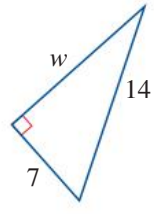
c



d



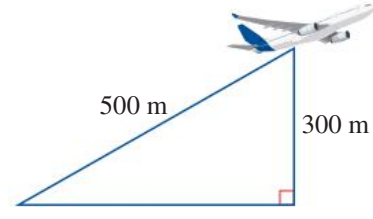
e



Hint $a^2 + b^2 = c^2$ rearranges to $a^2 = c^2 - b^2$.

APPLICATIONS

Example 6 ★**4** A plane has just taken off and has travelled 500 m in a straight line sloping upwards. It is 300 m vertically above the ground.
Determine the horizontal distance the plane has travelled. Round your answer to one decimal place.



SLS

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★5 Paul has been flying a kite but it is now stuck in the top of a tree. He had the full 50 metres of line out and it is pulled tight. The line forms a straight line from where he is standing, which is 29 metres horizontally from the base of the tree. Calculate the height of the tree, correct to one decimal place.

★6 Boyd has a 5 metre ladder to climb onto a roof that is 3 metres high. Calculate how far from the base of the wall the base of the ladder should be placed.

★7 Jonah has a television with a 150 cm screen, which is measured as the length of the diagonal. If the screen is 75 cm high, calculate the width of the screen.



★8 Melanie has bought an odd-shaped block of land in the shape of a right-angled triangle. If the two longest sides are 50 metres and 40 metres respectively, calculate the length of the third side of the triangle.

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6C Determining unknown side lengths by applying trigonometric rules

COMPLEX

LEARNING GOALS

- Understand the concept of a trigonometric ratio.
- Determine the adjacent and opposite sides to an angle in a right-angled triangle.
- Use trigonometric ratios to calculate the unknown sides of a right-angled triangle.
- Calculate unknown sides in right-angled triangles in a real-world context.
- Understand the terms 'angle of depression' and 'angle of elevation'.

Why is it essential to understand the use of trigonometric ratios to find unknown side lengths in right-angled triangles?

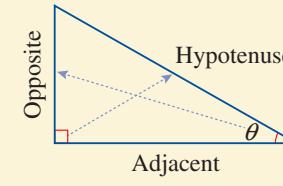
- Allows for problem solving when only one side and an angle are known in a right-angled triangle. These two pieces of information can then be used to calculate the length of the unknown side.
- Trigonometry is useful in many industries. For example, it is essential for mapping and GPS technology, such as determining the distance between two locations when only some measurements are available.



Right-angled triangles have applications in navigation.

WHAT YOU NEED TO KNOW

- For a right-angled triangle with an angle labelled θ, the three sides should be named adjacent (next to the angle), opposite (not touching the angle) and the hypotenuse (the longest side opposite the right angle).



- We use trigonometric ratios to form a relationship between two sides and an angle in a right-angled triangle. The abbreviation SOH CAH TOA is used to help remember the trigonometric formulas shown in the diagram.

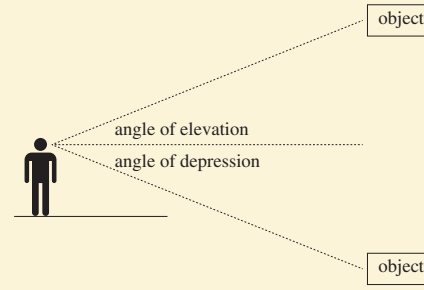
SOH CAH TOA

$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}} \quad \cos\theta = \frac{\text{Adjacent}}{\text{Hypotenuse}} \quad \tan\theta = \frac{\text{Opposite}}{\text{Adjacent}}$$

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- Our calculators must be set to degree mode, often displayed as 'deg' or 'D' on the top of the calculator screen. Sin, cos and tan buttons can be found on all scientific calculators. To calculate the angle, shift or 2nd function sin, cos or tan is used.
- The angle of **elevation** is the angle from the horizontal going up. The angle of **depression** is the angle from the horizontal going down.



Example 7 Rearranging & calculating the unknown value

Solve for the unknown value in the following. Round the answer to two decimal places.

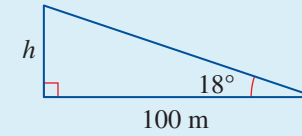
a $\sin 48 = \frac{x}{15}$ **b** $\cos 22 = \frac{19}{y}$

WORKING	THINKING
a $\sin 48 = \frac{x}{15}$	Rewrite the equation.
$15 \times \sin 48 = x$	Move divided by 15 to the other side as multiplied by 15. (If the unknown value is on the top, then multiply.)
$x \approx 11.147\ldots$	Determine the unknown value using your calculator.
$x \approx 11.15$	As the third decimal place is a 5 or greater, round your answer up to two decimal places.
b $\cos 22 = \frac{19}{y}$	Rewrite the equation.
$y = 19 \div \cos 22$	Swap the cos 22 with the y (If the unknown is on the bottom, then swap the values.)
$y \approx 20.492\ldots$	Determine the unknown value using your calculator.
$y \approx 20.49$	As the third decimal place is below 5, your answer stays the same at two decimal places.

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Example 8 Calculating a side length using trigonometric ratios – unknown numerator

Complete the following steps to calculate the unknown side in the triangle shown.



a Identify the known sides on the triangle.
b Determine which trigonometric ratio is required.
c Substitute the values into the ratio.
d Solve the ratio for the unknown value. Round answer to one decimal place.

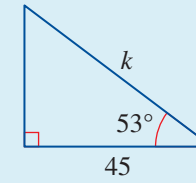
WORKING	THINKING
a The angle is 18°. 100 m is the adjacent side.	The 100 m is next to the angle but is not the hypotenuse, so it is the adjacent side.
h is the opposite side.	The h is opposite the named angle, so it is the opposite side.
b $\tan\theta = \frac{\text{opp}}{\text{adj}}$	The ratio that has the adjacent (A) and opposite (O) sides is the tangent ratio (TOA).
c $\tan 18 = \frac{h}{100}$	Substitute the values into the tangent ratio with $\theta = 18°, \text{O} = h, \text{A} = 100$ m.
d $100 \times \tan 18 = h$ $h \approx 32.491\ldots$	Multiply tan 18 by 100 to solve for h. Calculate the answer using your calculator.
$h \approx 32.5$ m	Round your answer to one decimal place.


Land surveying makes extensive use of trigonometry.

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Example 9 Calculating a side length using trigonometric ratios – unknown denominator

Complete the following steps to calculate the unknown side in the triangle shown.



a Identify the known sides on the triangle.
b Determine which trigonometric ratio is required.
c Substitute the values into the ratio.
d Solve the ratio for the unknown value. Round your answer to one decimal place.

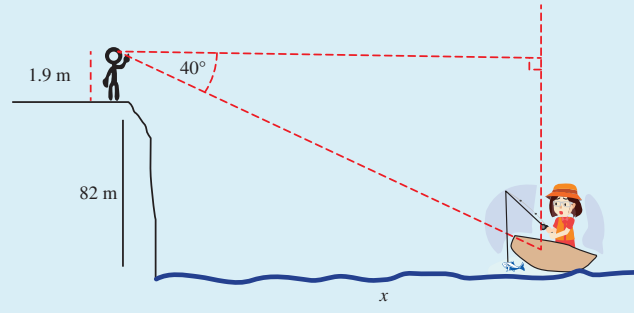
WORKING	THINKING
a The angle is 53°. 45 is the adjacent side. k is the hypotenuse.	The 45 is next to the angle but is not the hypotenuse, so it is the adjacent side. The k is opposite the right angle so is the hypotenuse.
b $\cos\theta = \frac{\text{adj}}{\text{hyp}}$	The ratio that has the adjacent (A) and hypotenuse (H) side is cosine (CAH).
c $\cos 53 = \frac{45}{k}$	Substitute the values into the cosine ratio with $\theta = 53°$, H $= k$, A $= 45$.
d $k = \frac{45}{\cos 53}$ $k \approx 74.77\ldots$ $k \approx 74.8$	Rearrange the ratio by swapping the position of the 45 and the k. Calculate the answer using your calculator. Round the answer to one decimal place.

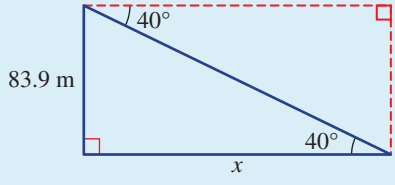

Navigation is based on trigonometry.

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Example 10 Calculating the unknown side using angle of depression

Rex is 1.9 metres tall and is standing on the top of an 82-metre cliff. He looks out to sea and views his wife fishing at a 40° angle of depression. Determine how far away Rex's wife is from the base of the cliff. Round your answer to one decimal place.



WORKING	THINKING
	Formulate
	Draw your diagram and identify which sides are the opposite and adjacent, and then determine the correct ratio from SOH CAH TOA.
$\theta = 40°$ Adj $= x$ Opp $= 82 + 1.9 = 83.9$ $\tan 40° = \frac{83.9}{x}$	The tangent ratio uses opposite divided by adjacent, so substitute the values into the formula.
	Solve
$\tan 40° \times x = 83.9$ $x = \frac{83.9}{\tan 40°}$ $x = 99.98\ldots$ $x \approx 100.0\,\text{m}$	Rearrange the formula to calculate the unknown value.

... Continued

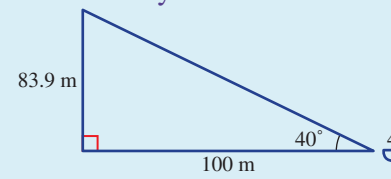
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Angle of depression = 40°
Adjacent = 100 m
Opposite = 83.9 m

Evaluate and Verify

◄····· Check that your answer seems reasonable.



Is it reasonable that Rex's wife is 100 metres away from the cliff given the size of the angle and height of the cliff? What would happen to the distance if the angle of depression was bigger? Or smaller?

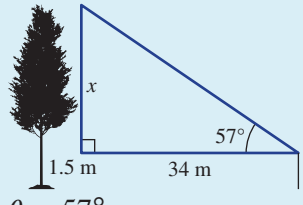
Communicate

The wife is 100 metres away from the base of the cliff.

◄····· Write your answer as a sentence.

Example 11 Calculating the unknown side using angle of elevation

Jane is standing 34 metres from the base of a tree. She uses a clinometer, mounted on a tripod that is 1.5 m high, and discovers the angle of elevation from the clinometer to the top of a tree is 57°. Determine the height of the tree to one decimal place.

WORKING	THINKING
	Formulate
	◄····· Draw your diagram and identify which sides are the opposite and adjacent, and then determine the correct ratio from SOH CAH TOA.
$\theta = 57°$	The tangent ratio uses opposite divided by adjacent, so substitute the values into the formula.
Adj = 34 m	
Opp = x	
$\tan 57° = \frac{x}{34}$	

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Solve

$34 \times \tan 57° = x$ ◄ Rearrange the formula to calculate the unknown value. Add the height of the clinometers stand.
$x \approx 52.35 \approx 52.4$ m
Height of tree $\approx$
52.4 m + 1.5m $\approx$ 53.9 m

Evaluate and Verify

Angle of depression = 57° ◄ Check that your answer seems reasonable.
Adjacent = 34 m
Opposite = 52.34 m

Communicate

The tree is approximately 53.9 metres high. ◄ Write your answer as a sentence.

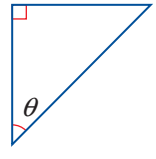


Exercise 6C

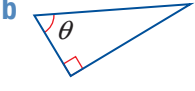
FUNDAMENTALS

1 Label the sides of the triangles below with A (adjacent), O (opposite) and H (hypotenuse).

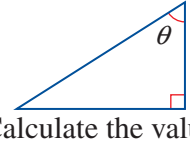
a



b



c



Hint The names relate to the angle θ.

2 Calculate the value of the following, rounding the answer to one decimal place where necessary.

a $24 \times \cos 50°$
b $33 \times \sin 37°$
c $48 \div \tan 82°$
d $67 \div \cos 12°$

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Example 7

3 Solve for the unknown value in the following, rounding to two decimal places.

a $\sin 23 = \frac{x}{17}$

b $\cos 47 = \frac{y}{86}$

c $\tan 12 = \frac{a}{36}$

d $\tan 68 = \frac{23}{x}$

e $\sin 41 = \frac{16}{g}$

f $\cos 62 = \frac{118}{b}$



Estimating the height of tall objects uses angles of elevation and trigonometry.

Example 8 & 9

4 Complete the following steps to calculate the unknown side in the triangle shown.

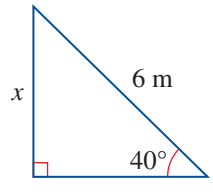
i Identify the known sides of the triangle.

ii Determine which trigonometric ratio is required.

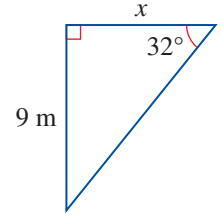
iii Substitute the values into the ratio.

iv Solve the ratio for the unknown value. Round your answer to one decimal place.

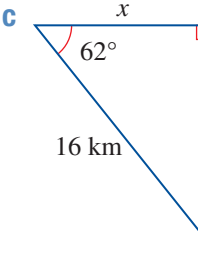
a



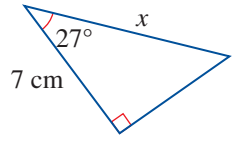
b



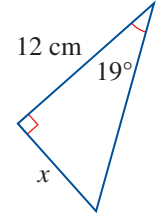
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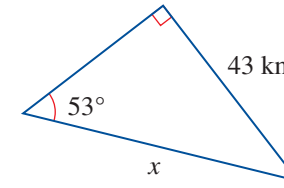
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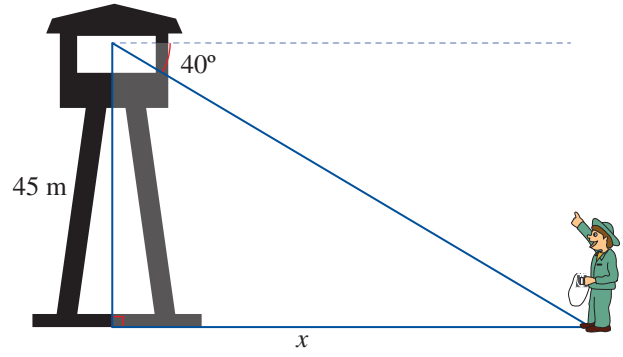
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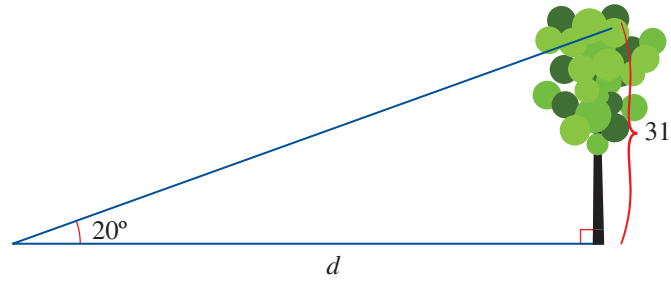
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APPLICATIONS

Example 10 ★5 Bridget is in the tower at an overall height of 45 m above ground (this includes her height). She can see her Aunty Maree on the ground at a 40° angle of depression. Calculate the distance from Aunty Maree to the base of the tower. Round your answer to one decimal place.



Example 11 ★6 Rove can see the top of a tree in the distance at a 20° angle of elevation. The height of the tree is 31 meters. Calculate the distance Rove is standing from the base of the tree. Round your answer to one decimal place.



★7 Karen is looking up to the top of a building at a 60° angle of elevation. The base of the building is 36 metres from her on the ground. Calculate the height of the building.

Hint
Formulate
Solve
Evaluate
Communicate

★8 Heidi is flying her rescue helicopter 1200 m above the ocean and sees a person in trouble at an angle of depression of 38 degrees. Calculate the direct distance from the helicopter to the person in the water.



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CF

★9 A cable is to be attached to the top of a large antenna that is 32 metres tall. If the cable is to have an angle of elevation from the ground to the top of the antenna of 65 degrees, calculate the length of the cable.

★10 Billy is running down a 322-metre slope on the hill. If he found the angle of depression of the hill to be 21 degrees, calculate how high the hill is above ground level.

★11 Pebbles is flying a kite and has let out the entire 55 metres of string. If the angle of the kite string is 44 degrees from the ground, calculate the horizontal distance to the kite.

★12 A straight waterslide has an angle of elevation of 38 degrees and is 12 metres high. Calculate the actual length of the waterslide.



CU

★13 The school flagpole is casting a 4.5-metre shadow. If the angle of depression of the sunlight is 36 degrees, calculate the actual height of the flagpole.

★14 Margret has seen a lighthouse 1350 metres horizontally from her boat. She has measured the angle of elevation from her boat to the top of the lighthouse as 52 degrees. Margret knows that the lighthouse is 50 metres tall on the top of the cliff. Determine the height of the cliff.

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6D Determining unknown angles by applying trigonometric rules

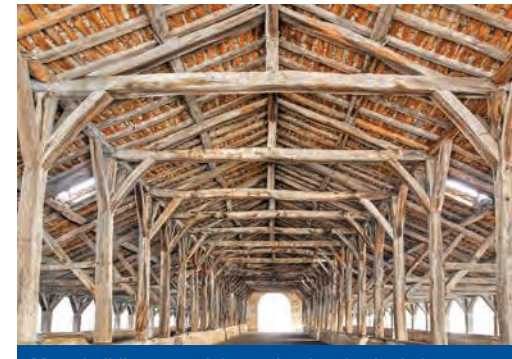
COMPLEX

LEARNING GOALS

- Determine the named sides in relation to the unknown angle in a right-angled triangle.
- Use the rules to calculate the unknown angle of a right-angled triangle.
- Identify which trigonometric rules are required to solve real-world context questions, and hence calculate the unknown angle.
- Applying knowledge of angles of depression and angles of elevation to problems.

Why is it essential to understand the use of trigonometric ratios to find unknown angles in right-angled triangles?

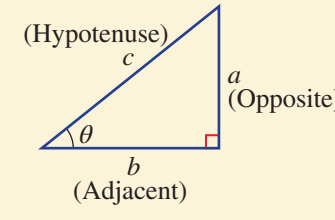
- Allows for problem solving when two side lengths are known in a right-angled triangle. These two pieces of information can then be used to calculate the size of an angle.
- Useful in many industries such as manufacturing and construction, as certain angles create strength.



Many buildings use right-angle triangles in their construction.

WHAT YOU NEED TO KNOW

- Inverse sine ($\sin^{-1}$), inverse cosine ($\cos^{-1}$) and inverse tangent ($\tan^{-1}$) can be used to find angles in right-angled triangles.
  - $\sin\theta = \frac{a}{c}$ means $\theta = \sin^{-1}\left(\frac{a}{c}\right)$
  - $\cos\theta = \frac{b}{c}$ means $\theta = \cos^{-1}\left(\frac{b}{c}\right)$
  - $\tan\theta = \frac{a}{b}$ means $\theta = \tan^{-1}\left(\frac{a}{b}\right)$



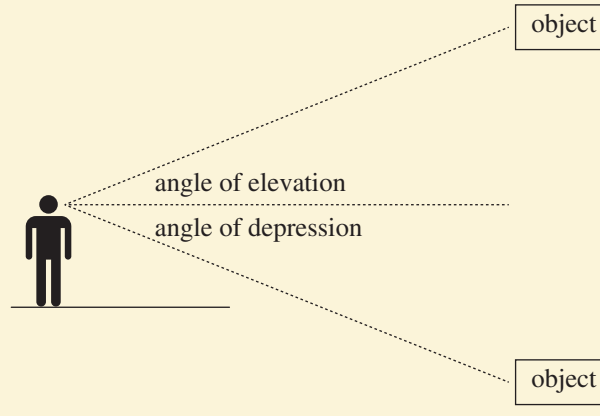
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- We use trigonometric ratios to form a relationship between two sides and an angle in a right-angled triangle. The abbreviation SOH CAH TOA is used to help remember the trigonometric formulas shown in the diagram.

SOH CAH TOA

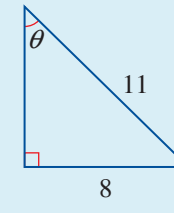
$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}} \qquad \cos\theta = \frac{\text{Adjacent}}{\text{Hypotenuse}} \qquad \tan\theta = \frac{\text{Opposite}}{\text{Adjacent}}$$

- The angle of **elevation** is the angle from the horizontal going up. The angle of **depression** is the angle from the horizontal going down.



Example 12 Calculating the unknown angle using trigonometric ratios

Complete the following steps to calculate the unknown angle in the triangle shown.



a Identify the known sides of the triangle in relation to the angle you want to find.
b Determine which ratio uses the two given sides using SOH CAH TOA.
c Substitute the values into the ratio.
d Calculate the unknown angle in the ratio, rounding to one decimal place.

WORKING	THINKING
a 8 = opposite side 11 = hypotenuse	The 8 is opposite the named angle and 11 is the hypotenuse.
b $\sin\theta = \frac{\text{opp}}{\text{hyp}}$	Identify the correct ratio required from SOH CAH TOA. The sine ratio uses O and H.

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c $\sin\theta = \frac{8}{11}$ ◄ Substitute the values into the sine ratio with $\theta°$, O = 8 and H = 11.

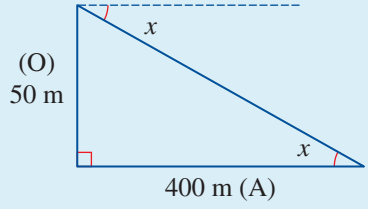
d $\theta = \sin^{-1}\frac{8}{11}$ ◄ Move sin to the other side of the equals sign as $\sin^{-1}$.

$\theta \approx 46.65° \ldots$ Calculate the angle size using your calculator.

$\theta \approx 46.7°$ Round the answer to one decimal place.

Example 13 Calculating the unknown angle using trigonometric ratios in a real-world context

Ranger Yogi wants to build a flying fox (cable glider) to go from the top of the lookout to the ranger station on the ground. The lookout is 50 metres high, and the base of the lookout is 400 metres from the ranger station. Determine the angle of depression of the cable connecting the top of the lookout to the ranger station.

WORKING	THINKING
	Formulate
	◄ Draw a diagram. Identify that the angle of depression equals the angle of elevation at the opposite side of the right-angled triangle. Label the relevant information on the diagram indicating labels for A, O or H when used.
50 m = opposite	
400 m = adjacent	◄ Identify the correct ratio required from SOH CAH TOA. The tangent ratio uses O and A.
$\tan\theta = \frac{\text{opp}}{\text{adj}}$	

... Continued

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Solve

$\tan x = \frac{50}{400}$ ◄ Substitute the values into the tangent ratio with O = 50 and A = 400.

$x = \tan^{-1} \frac{50}{400}$ Move tan to the other side of the equals sign as $\tan^{-1}$.

$x \approx 7.12°$ Calculate the angle size using your calculator.

$x \approx 7.1°$ Round your answer to one decimal place.

Evaluate and verify

◄ Assess whether the angle seems reasonable.

Communicate

The angle of depression is approximately 7.1° ◄ Write your answer as a sentence.

Exercise 6D

FUNDAMENTALS

1 Calculate the following, rounding to two decimal places where necessary.

a $\cos^{-1} \frac{12}{13}$ **b** $\sin^{-1} \frac{37}{61}$

c $\tan^{-1} \frac{7}{38}$ **d** $\tan^{-1} \frac{18}{16}$

2 Solve for the unknown value in the following, rounding to two decimal places.

a $\sin\theta = \frac{12}{13}$ **b** $\cos\theta = \frac{5}{13}$

c $\tan\theta = \frac{14}{17}$ **d** $\sin\theta = \frac{29}{83}$

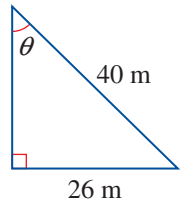
Hint You need the inverse trigonometric ratio buttons ($\sin^{-1}$, etc.) on your calculator to solve these equations. Usually this is the '2nd' or 'shift' button on your calculator.

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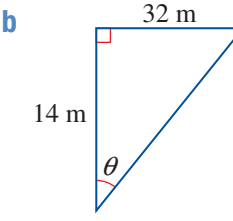
Example 12 **3** Complete the following steps to calculate the unknown side in the triangle shown.

- **i** Identify the known sides of the triangle.
- **ii** Determine which trigonometric ratio is required.
- **iii** Substitute the values into the ratio.
- **iv** Solve the ratio for the unknown value. Round your answer to one decimal place.

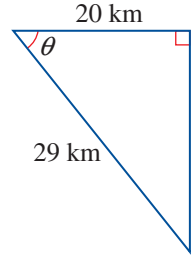
a



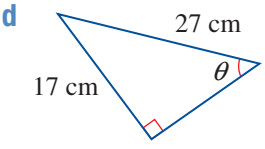
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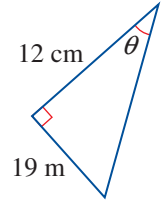
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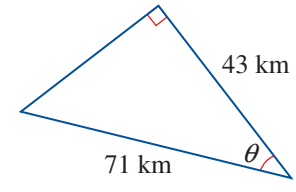
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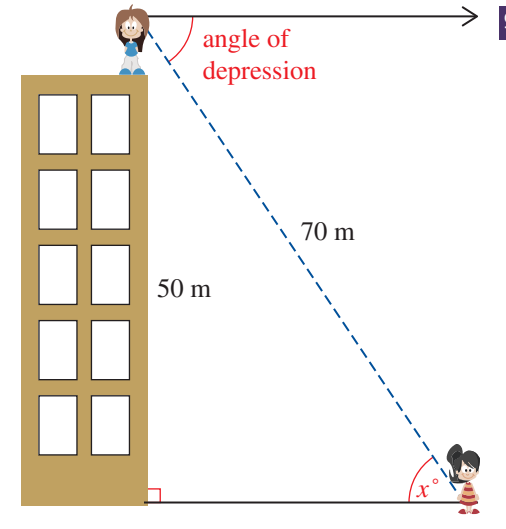


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APPLICATIONS

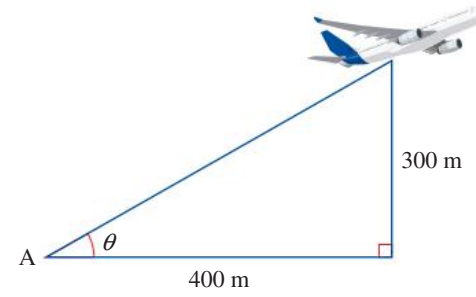
Example 13 ★**4** Charlie is on top of a building that is 50 metres above the ground and she can see her friend Georgie outside the building on the ground. The direct distance between Charlie and Georgie is 70 metres. Calculate the angle of depression from Charlie to Georgie, correct to one decimal place.



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CF

★5 Peta the pilot has just taken off from the runway at point A, as shown in the diagram. Calculate the angle of elevation at which plane was flying.



★6 Douglass has climbed a big tree that is 20 metres high. His father leans a 30-metre ladder against the tree so that he can climb up it and help Douglass down to the ground. Calculate the angle of elevation that the ladder makes with the tree, correct to one decimal place.

★7 Holly has climbed to the top of Mount Coolum, which is 208 metres above sea level. She sees the ocean, which is 1100 metres horizontally from Holly's current position. Determine the angle of depression as Holly looks down towards the ocean.

★8 A ski lift travels 324 metres to the top of a hill that is 212 metres high. Calculate the angle of elevation of the ski lift from the base.



★9 A castle has a 20-metre wall and a 40-metre-wide moat. If an archer wanted to fire an arrow from the top of the wall at someone on the edge of the moat, determine the angle of depression at which the arrow would need to be fired. (Assume the arrow will travel straight.)

★10 A right-angled triangular roof is being built on a house that is 20 metres wide. The roof has a slope length of 28 metres. Calculate the angle of elevation of the roof.

★11 A straight slippery slide has a height at the top of 2.5 metres and the slide itself is 5 metres long. Determine the angle of depression from the top of the slide.

CU

★12 Henry is 1.80 metres tall and sees a 24-metre flagpole while he is standing 20 metres away from the base of the flagpole. Determine the angle of elevation that Henry must raise his eyes to see the top of the flagpole. (Assume his eyes are 1.8 metres above the ground.)

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Modelling task



Context: Developing ways to measure inaccessible objects (like the height of a tree) was the driving force behind the development of many mathematical ideas. Early mathematicians observed that shadows could be used to determine the height of various objects by comparing shadows and known heights at the same time of day.

Task: Using your knowledge of trigonometry, determine the sun's angle of depression at a particular time of the day by measuring a person's height and the length of their shadow. Use this information to determine the height of three different objects by first measuring their shadow lengths and applying trigonometry.

Stage 1: Formulate
Make assumptions regarding: • the accuracy of your measuring tool • the potential impact of movement of the sun over time on the accuracy of your measurements. Make observations of: • the height of the person measured • the length of shadow for the same person • the shadow length of three different objects • the formula you will need to use to determine the sun's angle of depression.
Stage 2: Solve
• Determine the angle of depression of the sun. • Use the calculated angle of depression to determine the height of each object.
Stage 3: Evaluate and verify
• Look at your answers for the height of each object that you found. Does your answer seem reasonable? Justify your belief that your answers are accurate. • Discuss whether your assumptions would impact your findings (i.e. did the sun move positions in the time that it took for you to measure three different shadows?) • Include any recommendations to make your calculations more accurate.
Stage 4: Communicate
Summarise your findings in a short paragraph.

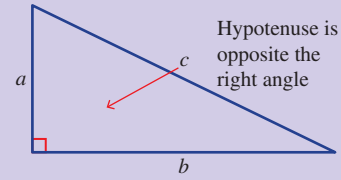
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Chapter summary

Pythagoras's Theory

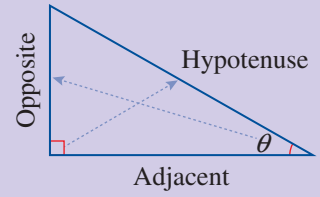
- Pythagoras's theorem is used to find the unknown side lengths of a right-angled triangle using the formula $a^2 + b^2 = c^2$.
  - This theorem can be used to find the length of the short sides (a or b) by rearranging the formula, or the formula can be used to calculate the length of the hypotenuse (c).
    - The hypotenuse of a triangle is the longest side and is directly opposite the right angle.



    - To find the value of c, rearrange the formula to $c = \sqrt{a^2 + b^2}$.
  - To calculate a short side (a or b), rearrange the formula to $a = \sqrt{c^2 - b^2}$.

Trigonometry to find a side length

- For a right-angled triangle with an angle labelled θ, the three sides are named adjacent (next to the angle), opposite (not touching the angle) and hypotenuse (the longest side opposite the right angle).



- We use trigonometric ratios to form a relationship between two sides and an angle in a right-angled triangle. The abbreviation SOH CAH TOA is used to help remember the trigonometric formulas shown in the diagram.

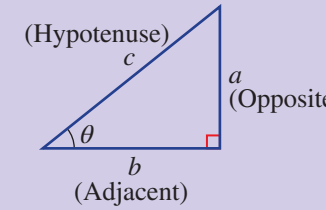
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SOH CAH TOA

$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}}$ $\cos\theta = \frac{\text{Adjacent}}{\text{Hypotenuse}}$ $\tan\theta = \frac{\text{Opposite}}{\text{Adjacent}}$

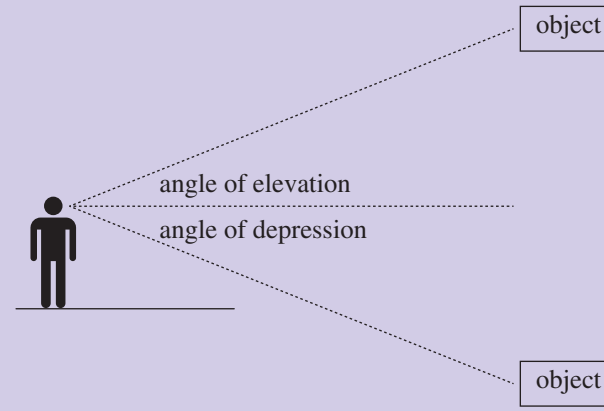
Trigonometry to find an unknown angle

- SOH CAH TOA can also be used to find the unknown angle in a right-angle triangle by using the inverse function on a calculator and the below ratios:
  - $\sin\theta = \frac{a}{c}$
    $\theta = \sin^{-1}\frac{a}{c}$
  - $\cos\theta = \frac{b}{c}$
    $\theta = \cos^{-1}\frac{b}{c}$
  - $\tan\theta = \frac{a}{b}$
    $\theta = \tan^{-1}\frac{a}{b}$



Angle of depression and elevation

- The angle of **elevation** is the angle from the horizontal going up. The angle of **depression** is the angle from the horizontal going down.

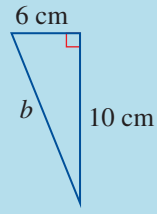


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Chapter checklist

6A ☐ I can calculate the hypotenuse using Pythagoras's theorem.

1 Calculate the value of b in the triangle shown, rounding to one decimal place.

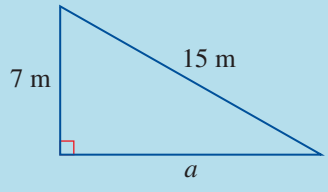


2 Calculate the hypotenuse of a right-angled triangle if its base is 8 m and its height is 18 m. Round your answer to one decimal place.

3 Kristy is making a gate that is 2600 mm by 1800 mm and she needs to build a diagonal brace. Determine the length of the brace that Kristy will need to cut, rounding to the nearest whole number.

6B ☐ I can calculate unknown short sides using Pythagoras's theorem.

4 Solve for a in the diagram shown, rounding to one decimal place.



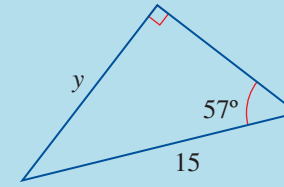
5 Calculate the base of a right-angled triangle if its hypotenuse is 26 metres and its height is 11 metres. Round your answer to one decimal place.

6 Brad ran 2.5 km due west and then ran due north for some distance. If he then ran 4.2 km back to his starting point, determine how far north Brad has run.

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6C ☐ I can apply the tangent, sine and cosine rule to determine unknown side lengths. **[complex]**

7 Calculate the value of y in the triangle shown, rounding to one decimal place.



8 A right-angled triangle has an angle of 30 degrees and an adjacent side of 25 metres.

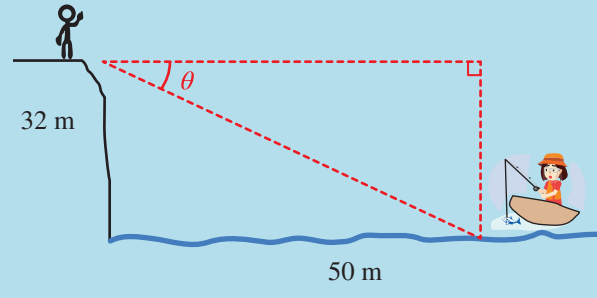
a Calculate the length of the opposite side.

b Calculate the length of the hypotenuse.

9 Terri is walking her puppy with a 2.5 m lead. The puppy is walking ahead and pulling the lead tight, and it makes an angle of elevation from the dog to Terri's hand of 21°. Determine how much higher Terri's hand is than the puppies' collar.

6D ☐ I can apply the tangent, sine and cosine rule to determine unknown angles. **[complex]**

10 Freda is standing on the top of a cliff and can see a person in a boat fishing in the ocean. The person in the boat is 50 m from the base of the 32 m-high cliff. Ignoring the height of Freda, calculate the angle of depression from Freda to the person in the boat.



11 A stunt ramp is 14 metres long and 5 metres high. Determine the angle of elevation of the ramp from the ground.

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Chapter review

All questions in the Chapter review are assessment style.

Simple Familiar

6A 1 A castle drawbridge is 20 metres long and has chains connecting the end of the drawbridge to the top of the castle wall, which is 25 metres high. Determine the length of the chains to one decimal place.

2 An old tree needs a steel cable to help hold it upright. If the cable is attached 2 metres from the base of the tree and 5 metres high on the tree, determine the length of cable between the tree and the ground to the nearest whole number.

3 Esmae walked due north on a 4 km hike and then turned 90 degrees and walked a further 2.5 km due west. Determine how far Esmae is from her starting point, rounding to one decimal place.

6B 4 Tarek has a 3.5-metre ladder and leans it against a wall that is 2.5 metres high. Calculate the distance the base of the ladder is from the base of the wall, rounding to one decimal place.

5 A tent pole that is 2.1 metres high has a rope attached that is 2.6 metres long. Determine how far the peg needs to be hammered into the ground from the base of the pole so that the rope will be tight.

Complex Familiar

6C 6 River is standing 40 metres from the base of a waterfall. If she measures the angle to the top of the waterfall as 52 degrees, calculate the height of the waterfall.



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7 Zek is flying a plane and approaching a runway at 1000 metres above the ground. He notices that the beginning of the runway is at an angle of 28 degrees from the plane. Calculate the distance the plane still needs to travel before reaching the beginning of the runway.

6D **8** Nell slides down a straight slippery slide that is 6.2 metres long and 2.5 metres high. Calculate the angle of the slippery slide from the ground.

9 James hang glides from the top of a 368-metre cliff to land 823 metres away from the base of the cliff. Assuming James travelled in a straight line, determine the angle of depression that he flew.

Complex Unfamiliar

10 The lighthouse keeper looks due east from the top of her lighthouse, 182 metres above sea level, and sees a ship at an angle of depression of 12 degrees. She sees another ship in the same direction at an angle of depression of 18 degrees. Calculate the distance between the two ships.



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7 Simple probabilities and simulations

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In this chapter

7A Express probabilities formally using fractions, decimals, ratios and percentages

7B Performing probability experiments using technology

7C Recognising the repetition of chance events

7D Identifying and calculating relative frequency

7E Identifying complication factors with real-life simulations **[complex]**

7F Constructing a sample space

7G Determining probabilities for an experiment

7H Using tree diagrams to determine probabilities

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 3 Topic 3 Probability and relative frequencies

Simulations (5 hours)

In this sub-topic, students will:

- express probabilities formally using fractions, decimals, ratios and percentages
- perform simulations of probability experiments using technology
- recognise that the repetition of chance events is likely to produce different results
- identify relative frequency as probability
- identify factors that could complicate the simulation of real-world events **[complex]**.

Simple probabilities (8 hours)

In this sub-topic, students will:

- construct a sample space for an experiment
- use a sample space to determine the probability of outcomes for an experiment
- use arrays and tree diagrams to determine the outcomes and the probabilities for experiments
- model and solve problems involving probability experiments.

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Prior knowledge check

1 Round each of the following decimals correct to two decimal places.

a 0.454 **b** 0.438 **c** 0.595

2 Convert the following fractions to decimals correct to two decimal places.

a $\frac{17}{98}$ **b** $\frac{16}{52}$ **c** $\frac{2}{43}$

Hint Use division.

3 Express each fraction in its simplest form.

a $\frac{10}{15}$ **b** $\frac{6}{8}$ **c** $\frac{12}{14}$

4 Convert the following fractions to percentages correct to two decimal places.

a $\frac{16}{81}$ **b** $\frac{5}{36}$ **c** $\frac{4}{18}$

5 Calculate the following correct to two decimal places.

a $\frac{6}{8} \times 65$ **b** $\frac{12}{14} \times 50$ **c** $\frac{7}{12} \times 38$

6 Calculate the following.

a 10% of 45

b 18% of 460

c 1.5% of 120

7 In the past week at a local hospital, 12 babies were born. The babies' genders are tallied in the table below.

a Complete the totals in the frequency table.

b Calculate the fraction of boys based on the table.

c Calculate how many of the 12 babies you would have expected to be boys.

d Reflect on any similarities or differences between your answers to **b** and **c**.

Outcome	Tally	Frequency
Boy	𝍸 III	8
Girl	IIII	4
Total		

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7A Express probabilities formally using fractions, decimals, ratios and percentages

LEARNING GOALS

- Define probability.
- Calculate simple probabilities.
- Express probabilities formally using fractions and decimals.
- Express probabilities formally using percentages.
- Express probabilities formally using ratios.

Why is expressing probability using fractions, decimals, ratios and percentages essential?

- **Clarity of communication:** Different formats can convey probability more effectively depending on the context. For example, a sports analyst might use percentages to show a team's win probability e.g. 75% chance to win.
- **Applicability in various fields:** Different disciplines prefer certain formats for probability. For example, scientists often use decimals (0.85) for statistical results, while marketers might prefer percentages (85%).



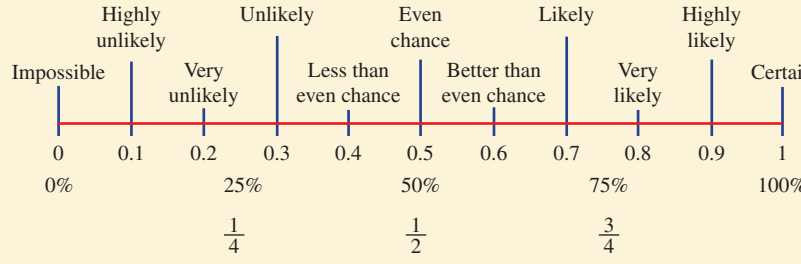
Different expressions allow for easy comparison between probabilities. e.g. Comparing odds of winning a lottery (1 in 10 million).

WHAT YOU NEED TO KNOW

- **Probability** is a numerical indicator of the chance of an event occurring.
  - Probability of an event $= \dfrac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$.
  - Probability ranges in value from 0 (will not happen) to 1 (will happen).
- Probabilities can be expressed as fractions, decimals, percentages or ratios for ease of communicating, and to suit the context.
- The probability fraction can easily be converted to a **decimal** using division to give a value between 0 (impossible) and 1 (certain).
  - For example, $\frac{1}{4} = 1 \div 4 = 0.25$.

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- To express a probability as a percentage, multiply the probability as a decimal by 100.
  - For example, a probability of $0.25 = 0.25 \times 100 = 25\%$ (25 out of 100).
- Expressing the probability as a ratio gives a comparison between **favourable** outcomes and **unfavourable** ones. The wording before the ratio is important to indicate odds for or against,. or ratio losses to wins or vice versa.
  - For example, if the odds are 3 : 1 for an event, there are 3 favourable outcomes and 1 unfavourable outcome for each 4 attempts. This gives a probability of $\frac{3}{4} = 0.75 = 75\%$.
- Theoretical probability is based on chance, so the results are just estimates and may not reflect what actually happens in real life.



Example 1 Expressing probability as fractions, decimals and percentages

The NRL competition currently has 17 teams, each with 30 players in their squad. Of the total players in the NRL, 61 identify as First Nations people.

a Determine the probability of randomly selecting a player from the NRL who is a First Nations player. Express your answer as a fraction and a decimal, correct to two decimal places.

b Calculate the percentage of players in the NRL who identify as First Nations people.

c Estimate how many First Nations players you would expect per team based on your answer to part **b**. Comment on the reality of this answer.

WORKING	THINKING
a Total players $= 17 \times 30$ $= 510$	Calculate the total number of players: There are 17 teams, each with 30 players.

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$$\text{Probability} = \frac{61}{510}$$
$$= 61 \div 510$$
$$\approx 0.119$$

◄····· Probability $= \frac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$
61 First Nations players of a total of 510 players.
Calculate decimal with division using a calculator.

Rounded to two decimal places
≈ 0.12

b $0.12 \times 100 = 12$
Approximately 12% of NRL players are First Nations people.

◄····· To calculate a percentage, start with the fraction or decimal and multiply by 100.

c $0.12 \times 30 = 3.6$
Expect approximately 4 First Nations players per team.

◄····· Apply the percentage from part **b** of 12% to a team of 30 players.
Convert the percentage to a fraction or decimal and multiply by team total.
Round to the nearest whole number.

In reality there may not be an even spread of First Nations players in teams across clubs; some may have more than others.

◄····· Theoretical probability does not always match what exists in real life.



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Example 2 Expressing probability as a ratio

Darcy is betting on horses at a charity event at the races. He receives a tip for a horse with the odds of winning 4 : 1, that means a history of losses to wins as a ratio of 4 : 1.

a Calculate the probability of the horse winning, expressed as a fraction, percentage and in words.

b If another tip indicates a 75% chance of winning, express this probability as a ratio and in words.

WORKING	THINKING
a calculate the total outcomes 4 losses + 1 win = 5 outcomes.	Odds of 4 : 1 mean that it is expected to lose 4 times for every 1 time the horse is expected to win. Calculate the total outcomes.
$P(\text{winning}) = \frac{1}{5}$	Probability $= \frac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$.
$\frac{1}{5} \times 100 = 20\%$	To express the fraction as a percentage, multiple by 100.
20% chance of winning; unlikely chance of winning.	20% is less than $\frac{1}{4}$. Use words such as unlikely.
b $P(\text{win}) = \frac{75}{100}$ $P(\text{loss}) = \frac{25}{100}$ wins : losses = 75 : 25	A 75% chance of winning means 75 wins out of 100. Express as a ratio wins : losses (75 wins and 25 losses out of a total 100).
$\div 25$ (75 : 25) $\div 25$ (3 : 1)	Simplify ratio by dividing each side by HCF of 25.
More likely to win than lose.	75% is between $\frac{1}{2}$ and 1, so use words such as likely.

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Exercise 7A

FUNDAMENTALS

1 Convert the following fractions to percentages, correct to two decimal places.

a $\frac{5}{17}$ **b** $\frac{14}{74}$ **c** $\frac{68}{86}$ **d** $\frac{9}{34}$

2 Convert the following percentages to fractions in their simplest form.

a 45% **b** 92% **c** 16% **d** 62%

3 Describe the following probabilities using words ('impossible', 'unlikely', 'even', 'likely', 'certain').

a One in four chance of being selected for sports captain $\left(\frac{1}{4}\right)$.

b 80% chance of severe storms this afternoon.

c Ratio of winning games to losing games in the last month is 5 : 2.

APPLICATIONS

Example 1

4 Neve is conducting a magic trick that involves drawing a card from a standard pack of cards and returning it. Use the table below showing card deck possibilities to answer the following questions.

Hint A standard deck of cards is 52 cards with 13 of each suit.

Card type	Total number of card type in deck
Number 8	4 (1 in each suit)
Queen	4 (1 in each suit)
King	4 (1 in each suit)
Even numbers (2, 4, 6, 8, 10)	20 (5 in each suit)

For the following events **a**–**d**,

i describe the probability of the outcome in words

ii express the probability of the outcome as a fraction and a decimal (correct to two decimal places).

a Selecting the 8 of hearts

b Selecting a number 8 card of any suit

c Selecting a queen or a king

d Selecting an even numbered card



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5 Sean is playing a board game with a 12-sided die. Each number appears once. The possible results of rolling the die are:

1 2 3 4 5 6 7 8 9 10 11 12

For the following events **a**–**d**,

i describe the probability of the outcome in words

ii calculate the probability of the outcome as a fraction and a decimal.

a Rolling an odd number

b Rolling a two digit number

6 Sarah is using Smarties for a science demonstration and has a total of 10 boxes. Each box is identical and contains 6 blue, 3 green, 5 yellow, 4 brown, 3 pink, and 9 orange Smarties.

a Determine the probability, expressed as a percentage, of randomly selecting:

i an orange Smartie from one box

ii a pink or blue Smartie from one box.

b Determine the percentage of yellow and green Smarties across all boxes, and state whether it is likely or unlikely to select one of these at random.



Example 2

7 Cooper has been playing Mario Kart for a long time and believes that his chances of winning against his younger brother are 8 : 1. Express this probability of Cooper winning as a percentage.

8 The probability of getting a 100% game completion achievement in a new video game is 6%. Express the probability of achieving this as a ratio in its simplest form.

Hint To simplify a ratio, divide each side by the HCF.

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7B Performing probability experiments using technology

LEARNING GOALS

- Perform probability experiments.
- Perform simulations of probability experiments using technology.

Why is simulation of real-life scenarios essential?

- We often wonder, 'What will happen if...?' Understanding potential outcomes aids decision-making.
- Simulations provide a quick way to explore these outcomes. They are cost-effective and efficient. Simulations eliminate the need for time-consuming probability experiments.



Engineers run simulations of traffic flow using computer software when designing new freeways to predict bottlenecks and find ways to eliminate them.

WHAT YOU NEED TO KNOW

- An **experiment** is a procedure undertaken to make a discovery. We can conduct probability experiments to simulate real-life problems.
  - Each repeat of an experiment is called a **trial**.
  - The results of the probability experiment need to be organised into a **frequency** table. Frequency is a count of how often an outcome appears.
- Physical techniques that can be used for simulation include:
  - tossing a coin. For example, the gender of a baby before it is born can be represented as heads = girl, tails = boy.
  - rolling a die. For example: even result = girl, odd result = boy.
  - spinning a spinner. For example: even result = girl, odd result = boy.
  - drawing a selection 'from a hat'
  - drawing cards from a standard pack of playing cards, which has four suits and two Jokers. Red suits: Hearts ♥ and Diamonds ♦; Black suits: Spades ♠ and Clubs ♣. Each suit has 13 cards: A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K.

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- Simple technology that can be used for simulation includes:
  - the random number feature on a scientific calculator, which returns a random decimal number between 0 and 1

    rand .23640104
  - the RandomBetween function in Excel. For example, entering =RANDBETWEEN(1, 2) in a cell returns a random whole number between 1 and 2 that could be allocated to your selection.
  - Online calculators are useful when lots of trials are required.

Example 3 Analysing physical probability experiments

Toss a coin to simulate the gender of 20 babies born at a hospital during a week. Use heads = girl, tails = boy.

a Organise the result of 20 coin tosses in a frequency table.

b Calculate the percentage of girls from your simulation.

c Decide if the simulation results varied from what you expected. Explain how they may differ.

WORKING	THINKING
a Result of 20 coin tosses: T H H H T H H T T H H H H H H H T T H H	You can use tally marks and record as you go or just record each result of the coin toss and count when done.

Result	Frequency
heads/girls	14
tails/boys	6

b Percentage girls $= \frac{14}{20} \times 100 = 70\%$.	Percentage $= \frac{amount}{total} \times 100$.
c The simulation did not produce the expected result. The percentage of girls in the simulation was 70%; you would expect it to be around 50%.	Simulations do not always give the results you would expect. Lots of trials need to be done to get a result that is close to what the expected value might be. **Note:** In real life, the probability of a boy or a girl is not actually equal. 51.2% of babies born in industrialised countries are boys. For the purposes of this chapter, we will assume that it is equal.

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Example 4 Conducting a simulation of a probability experiment using technology

Conduct a simulation to estimate how many students need to be chosen at random for each of the four school houses to be represented.

a Use Excel to generate data for which school house a student is from. Use the numbers 1, 2, 3, 4 to represent the four school houses.

b Copy and complete this frequency table to record which school house the simulation shows the students are from. Stop when all four school houses have been selected at least once.

House	1	2	3	4
Tally				
Frequency				

c Determine how many simulations it took to represent all four school houses.

d Identify which school house was represented more than other houses in the simulation.

e Calculate the probability fraction of students from house 2. Express this probability as a decimal and percentage.

f Explain a way the simulation experiment could be conducted using a physical technique.

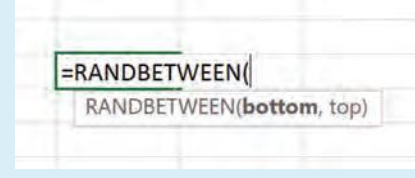
WORKING

a Data: houses of 12 students:

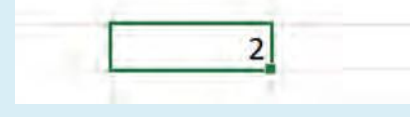
4 2 2 1
1 3 3 1
1 1 4 3

THINKING

=RANDBETWEEN(1, 4) will randomly select a whole number between 1 and 4 to represent the four school houses.



Tip: Grabbing the little box in the bottom right corner and dragging down or across will give you more random numbers within the same range.



... Continued

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b ~~4~~ ~~2~~ ~~2~~ ~~1~~
~~1~~ ~~3~~ 3 1
1 1 4 3

◄····· Cross off each simulated school house and record it in the table. Stop once all the houses have been represented.

Frequency table:

House	1	2	3	4
Tally	||	||	|	|
Frequency	2	2	1	1

c It took 6 simulations for all four school houses to be represented.

◄····· Count the number of houses crossed off or total up the frequencies.

d The first two school houses were both represented twice before the final school house, 3, was selected.

◄····· Look for the highest frequency.

e Probability (house 2)
$= \frac{2}{6} = \frac{1}{3}$
$1 \div 3 = 0.3\dot{3}$
$0.3\dot{3} \times 100 = 33.3\%$

◄····· Fraction of house 2
$P(\text{house2}) = \frac{\text{no. frequency house 2}}{\text{total simulation frequency}}$.
To convert the fraction to a decimal, use division. To convert the decimal to a percentage, multiply by 100.

f Playing cards could be used where each suit represents a school house. The card would need to be replaced after each selection is noted.

◄····· Any technique that has four possible choices would be suitable.
Replacing the card each time keeps the chance of each being selected the same.

Spread-sheet

Spreadsheet activity 7B: See the interactive textbook for this activity using the random number and counting functions in Excel to conduct a simulation for this exercise.

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Exercise 7B

APPLICATIONS

SF

Example 3

1 Complete the following questions based on this simulation.

a Toss two coins twenty times to simulate the gender of children in twenty 2-child families. Use heads = girl, tails = boy. Copy and complete the following frequency table to record your results.

2-child combination	Tally	Frequency
boy + boy		
boy + girl		
girl + girl		

b Calculate the percentage of 2-child families with a boy and a girl combination in your simulation.

c Decide if the results of your simulation differ from what you might have expected. Explain how they may differ.

2 A supermarket runs a promotion where a free collectable toy is given away with each $30 spent in the store. There are 20 different toys to collect. Ashleigh runs a simulation using a spreadsheet to estimate how much money she would need to spend to collect all 20 toys. The simulation below shows which toy she receives after spending $30.

9	7	5	6	2	17	9	11	9	5
6	13	7	5	19	12	19	6	15	15
15	7	11	13	18	11	4	13	4	14
20	18	4	17	2	9	9	10	7	13
19	4	5	10	15	7	14	18	3	8
19	2	12	20	15	18	3	17	11	9
7	18	19	16	9	8	14	9	1	9

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SF

a Copy and complete this frequency table to record which toys the simulation shows she will receive. Stop when all 20 toys have been collected at least once.

Toy number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Tally																				
Frequency																				

b Determine how many simulations it took to collect all 20 toys.

c Calculate how much money she will need to spend to collect all 20 toys using the results of the simulation.

d Determine which toy was collected more than any other in the simulation.

e Calculate the probability of receiving toy number 7, expressed as a fraction.

Hint Look for the highest frequency.

Example 4 ★3 Ben wants to run a simulation to estimate how many people he would need to ask before he finds two with the same birth month.

a Explain why each of the following simulation techniques would or would not be suitable to use:

i Using a standard pack of cards and removing the Kings. The card drawn at random represents the month of birth. i.e. A = Jan, 2 = Feb, 3 = Mar.... J = Nov, Q = Dec. The card is not replaced after being drawn.

ii Using a deck of cards, as in part **i**, but the card is replaced after the selection is noted.

iii Rolling two standard die and adding the two faces to simulate the month of birth.

iv Using Excel and entering the formula =RANDBETWEEN(1, 12).

b Ben decides to use the deck of cards without the Kings and replace the card after each selection. He has the following results after 40 trials:

A	9	10	8	6	Q	J	5
3	5	5	5	3	8	A	7
7	A	A	2	2	3	8	4
J	8	7	3	Q	8	4	10
3	7	8	6	5	A	2	10

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Organise the results of the simulation into a frequency table like the one following. Stop when one of the months has been selected twice.

Card drawn/month	A	2	3	4	5	6	7	8	9	10	J	Q
Tally												
Frequency												

c Determine how many trials Ben needed to conduct to find two people with the same birth month.

d Calculate the probability of drawing a J card, expressed as a fraction.

e Calculate the probability of drawing a numbered card, expressed as a fraction.

★**4** From Question **3b**, Ben notices that not all the months seem to be represented evenly in his trials. He decides to see how big the differences are.

a Organise the results of all 40 trials into a frequency table like the one following.

Card drawn/month	A	2	3	4	5	6	7	8	9	10	J	Q
Tally												
Frequency												

b Decide if Ben was correct: were all the months represented the same amount of times in the 40 trials? Comment on the results.

c Calculate the probability of selecting a Q card in the 40 trials.

★**5** From Question **3b**, repeat Ben's experiment for 40 trials using Excel and the formula =RANDBETWEEN(1, 12).

a Determine how many trials it takes to find two people with the same birth month.

b Decide if all the months were represented evenly over the 40 trials.

c Calculate the probability over the 40 trials of selecting an Ace card.

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SF

⋆**6** Gretel Tippett is the Goal Attack for the QLD Firebirds Netball team. In the 2018 season she scored 283 goals from 315 attempts.



a Show that her success rate for shooting a goal is 90%.

b Use the random number feature on your calculator to simulate 30 attempts at goal. If the last two digits are between 01–90, she successfully shoots the goal; if the last two digits are between 91–00, she misses the goal. Copy and complete the following frequency table to record your results.

Attempt at goal	Tally	Frequency
Successful		
Miss		
Total		

c Calculate the percentage success rate for the 30 trials.

d With a 90% success rate, determine how many of the 30 goals you would expect Gretel to successfully shoot.

e Compare your answer in part **d** to the number of successful attempts found in the simulation in part **b**. Comment on differences or similarities between the two results.

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7C Recognising the repetition of chance events

LEARNING GOALS

- Use technology to perform simulations.
- Recognise how repetition will affect results.

Why is an understanding of repetition of chance essential?

- In games of chance, like lotteries, some numbers come out more often than others. This does not improve the chance of them appearing in the next draw.
- A common misconception is that past results influence future outcomes, contributing to gambling issues.
- Problem gambling can lead to emotional and financial distress.



A common myth is that past results affect future outcomes, which worsens gambling problems.

- Australians lose more than $25 billion a year on legal forms of gambling.

WHAT YOU NEED TO KNOW

- The **outcome** of previous trials has no impact on the chance of the outcome occurring in successive trials. As an example, say you tossed five heads in a row with a single coin. For the 6th toss, the chance of 50% heads remains.
- When conducting **trials** where all outcomes have an equal chance, we would expect the different outcomes to appear approximately the same number of times.
  - The expected number of occurrences of an outcome = trials ÷ number of different outcomes.
- When conducting **simulations**, we can get unusual results when only running a small number of trials. Increasing the number of trials can improve the reliability of our predictions.

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Example 5 Conducting an experiment with repetition of trials

Using a single coin, conduct an experiment where the coin is tossed twice for ten trials.

a Organise the results into a table.

Trial	1	2	3	4	5	6	7	8	9	10
First toss										
Second toss										

b Determine how often the outcome in the second toss was the same as in the first toss.

c Calculate how many heads were recorded in the first toss.

d Calculate how many heads were recorded in the second toss.

e Calculate how many heads you would expect over ten trials.

f Determine the average number of heads observed per toss over the ten trials.

g Decide if the results were as expected.

WORKING | **THINKING**

a

Trial	1	2	3	4	5	6	7	8	9	10
First toss	T	T	H	T	T	H	T	T	T	H
Second toss	T	H	H	T	T	H	H	H	H	H

Insert the results into a table.

b 6 out of the 10 trials had the same result in both tosses.

Since the chance of a head or a tail is equally likely, we would expect about half the time to toss the same result as the previous toss. While we did not get exactly one half, it is very close.

c 3 heads were recorded in the first toss.

d 7 heads were recorded in the second toss.

... Continued

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e Expected number of heads $= 10 \div 2$
$= 5$
Therefore, we would expect to toss 5 heads from the ten trials.
◄····· The two outcomes should appear the same amount of times.

f Average number of heads $= \frac{3+7}{2} = 5$.
◄····· Total number of heads over both sets of 10 tosses.

g While the individual trials did not achieve the expected number of heads (i.e. 5), the average over the two trials was what was expected.
◄····· They were expected because we only did two trials. Repeating trials gives a better result.

Exercise 7C

APPLICATIONS

Example 5 ★1 A coin is tossed 20 times. The results are shown below.



Regardless of previous results, each time a coin is tossed the chance remains the same for tossing a head.

H	T	H	T	H	H	T	H	T	T
T	T	H	H	T	T	T	T	H	H

a Determine how many different outcomes there are when a coin is tossed.
b Calculate how many times you would expect each outcome to appear in the 20 tosses.
c In this experiment, what was the resulting fraction of head outcomes? Express your answer as a percentage.
d Decide if any results appear more/less often than expected.

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⋆**2** A standard die is rolled 30 times. The results are shown below.

4	3	4	5	2	1	5	6	5	6
1	3	1	2	3	5	5	1	4	4
2	4	1	1	4	3	4	4	4	4

a Determine how many different outcomes there are when a die is rolled.
b Calculate how many times you would expect to get the same result as the previous roll in the 30 trials.
c Determine how many times the same result appears in consecutive rolls over the 30 trials. Compare this answer with what you expected from part **b**.
d Calculate how many times you would expect each outcome to appear in the 30 rolls.
e Decide if any results appear more/less often than expected.

3 A lottery website displays data of numbers drawn over time as a way of offering strategy tips for picking numbers to encourage people to participate in the lottery.

HOT NUMBERS statistics show these numbers have been drawn more often	6, 30, 37, 40, 36, 9
COLD NUMBERS statistics show these numbers have been drawn less often	16, 29, 4, 27, 12, 4
MOST PROFITABLE NUMBERS statistics show these numbers have resulted in bigger payouts	36, 10, 39, 25, 24, 21
LEAST PROFITABLE NUMBERS statistics show these numbers have resulted in smaller payouts	28, 37, 25, 6, 9, 15

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a Decide if the 'Hot Numbers' are more likely to come up in the next draw than the 'Cold Numbers'. Explain why or why not.

b Determine how many of the 'Hot Numbers' also appear in the:

i 'Most Profitable Numbers'

ii 'Least Profitable Numbers'.

c Reflect on the results from part **b**. Explain why might this happen.

d The results from the last draw are shown on the right:
Determine how many of the numbers drawn were:

i Hot Numbers

ii Cold Numbers

iii Most Profitable Numbers

iv Least Profitable Numbers.



4 Use an online simulator to investigate tossing a coin with a very large number of repetitions. A suggested site is *http://www.shodor.org/interactivate/activities/Coin/*. Determine what happens to the distribution of Heads/Tails as the number of trials is increased.

5 Use an online simulator to investigate rolling a die with a very large number of repetitions. A suggested site is *https://academo.org/demos/dice-roll-statistics/*. Determine what happens to the distribution of the outcomes as the number of trials is increased for:

a one die **b** two dice.

Spread-sheet

Spreadsheet activity 7C: See the interactive textbook for this activity using Excel to simulate the results of rolling a die 30 times with many repetitions.

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7D Identifying and calculating relative frequency

LEARNING GOALS

- Calculate probability.
- Identify relative frequency as a probability.

Why is calculating relative frequency essential when determining probability?

- In some real-life situations, the outcomes of trials do not have an equal chance of occurring e.g. teams winning a game of sport.
- Relative probability is essential for predicting outcomes when chances are not equal because, it allows for a more accurate assessment of likelihood based on varying conditions or factors.



Past performance is used to estimate the chance of a team winning a match.

WHAT YOU NEED TO KNOW

- **Probability** is a numerical indicator of the chance of an event occurring.
  - Probability of an event $= \frac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$.
  - Probability ranges in value from 0 (will not happen) to 1 (will happen).
- **Relative frequency** can be used to estimate the probability from a simulation or survey.
  - Relative frequency of an event $= \frac{\text{number of favourable outcomes observed}}{\text{total number of trials}}$.
  - Relative frequency ranges from 0 (did not happen) to 1 (happened in every trial).
  - Probability of a coin coming down heads = favourable outcomes 1 (heads); total number of outcomes 2 (heads and tails); probability 0.5.
  - In 6 coin tosses where 4 came down heads, relative frequency of heads is the number of favourable outcomes observed (4); the total number of trials is 6; the relative frequency of heads is 0.67.
  - When increasing the number of trials to a very large amount, the relative frequency approaches the expected (calculated) probability.

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Example 6 Calculating probabilities using relative frequency

A survey asked students how many times they had visited the dentist in the past year. The table below shows the findings:

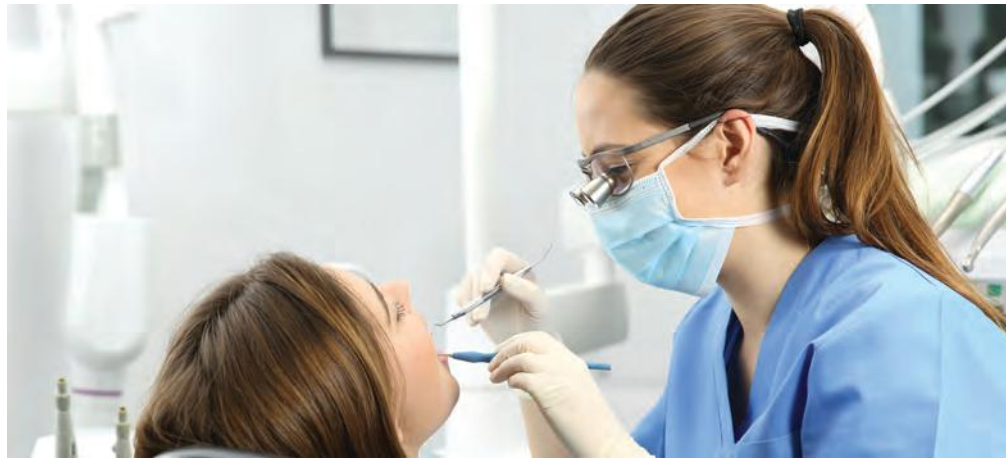
Number of visits	0	1	2	3	4	5
Number of students	2	6	4	2	0	1

Determine the following based on selecting a student at random.

a Calculate the probability that the student has visited the dentist twice in the past year. Round your answer to two decimal places.

b Calculate the probability that the student has been to the dentist more than once. Round your answer to two decimal places.

WORKING	THINKING
a Total number of students $= 2 + 6 + 4 + 2 + 0 + 1$ $= 15$ Probability of 2 visits $= \frac{4}{15}$ $= 4 \div 15 \approx 0.27$	Relative frequency of an event = $\frac{\text{number of favourable outcomes observed}}{\text{total number of trials}}$.
b Probability of more than 1 visit $= \frac{4 + 2 + 0 + 1}{15}$ $= \frac{7}{15}$ $= 7 \div 15 \approx 0.47$	More than once will mean they have visited 2, 3, 4 or more times.



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Example 7 Using relative frequency to make estimations

A deputy principal wants to look at ways of improving traffic congestion around the school by encouraging students to either walk, ride a bike, or catch a bus to school. He does a survey of a group of students and finds the following results:

Transport method	Car	Walk or ride push bike	E-Bike or scooter	Bus
Number of students	56	27	12	43

a Determine how many students were surveyed.
b Calculate the relative frequency of students who travel by car correct to two decimal places.
c The school has a total of 827 students. Use the relative frequency to estimate the number of students in the school who travel to school in a car.

WORKING	THINKING
a Number of students surveyed $= 56 + 27 + 12 + 43 = 138$	Total the number of students.
b Relative frequency of car travel $= \frac{56}{138}$ ≈ 0.41	Relative frequency of an event = $\frac{\text{number of favourable outcomes observed}}{\text{total number of trials}}$.
c Estimate of students in the school who travel by car $= \frac{56}{138} \times 827$	It is better to use the exact value and not a rounded value in subsequent calculations, so use the fraction form of the relative frequency.
$= 336$ students	Round to nearest whole number as this count is discrete.



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Exercise 7D

FUNDAMENTALS

1 Convert the following fractions to decimals. Round your answer to two decimal places.

Hint top (numerator) divided by bottom (denominator)

a $\frac{14}{25}$ **b** $\frac{125}{267}$

c $\frac{54}{87}$ **d** $\frac{17}{693}$

2 Calculate the following. Round your answer to the nearest whole number.

a 0.28×568 **b** 0.79×682

c $\frac{24}{52} \times 467$ **d** $\frac{39}{586} \times 1276$

3 Two regular 6-sided dice are rolled together 8 times, and the faces landing up are added together. The results are shown below:

3 9 12 2 8 7 11 4

For each of the following, give your answer as a fraction, a decimal and a percentage:

a Calculate the relative probability of the total being an even number.

b Calculate the relative probability of the result being a factor of 12.

c Calculate the relative probability that the faces could total less than 10.

SF

APPLICATIONS

Example 6 ★**4** A class is surveyed about how many siblings each student has. The results are:

Number of siblings	0	1	2	3	4	5	6
Number of students	3	6	10	4	2	0	1

a Determine how many students were surveyed.

b Calculate the relative frequency of a student having two siblings. Express your answer as a decimal correct to two decimal places.

c Calculate the relative frequency of a student having more than two siblings.

d Calculate the relative frequency of a student having at least two siblings. Express your answer as a percentage correct to two decimal places.

e Calculate the relative frequency of a student having fewer than two siblings.

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5 According to the latest Census from the Australian Bureau of Statistics, the top six languages other than English spoken at home 2021 are:

Preliminary data - languages other than English spoken at home	Thousands ('000s)
Italian	360
Greek	250
Cantonese	190
Arabic	170
Vietnamese	135
German	100
Total	1205

a If selecting at random a household that speaks a language from the above table, determine the relative probability that they will speak:
i German **ii** Greek or Italian

b Determine the probability ratio of speakers chosen at random being Arabic to those who do not speak Arabic.

c Based on your answers from part **a**, calculate the percentage of individuals you would expect to find in a selection of 50 people from households that speak a language listed above, that speak:
i German **ii** Greek or Italian

★**6** The age of migrants to Queensland over a ten-year period is shown below:

Age (years)	0–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65 and over
Number	31 002	13 945	11 577	21 032	28 107	27 936	23 144	16 306	8392	4209	2640	4292

a Calculate how many migrants arrived in Queensland over the period of study.

b Determine the relative frequency of migrant children who are aged 0–14 years.

c Calculate the relative frequency of migrants who are aged under 20 years.

d Calculate the relative frequency of migrants who are aged 60 years or older.

Example 7 **7** Social media influencers typically have over 10 000 followers and post 3–5 times a week. Influencer A has 61 212 followers, while Influencer B has 11 660 followers. Influencer A's most recent post received 2448 likes, and Influencer B's latest post received 450 likes.

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SF

a If a follower is chosen at random from Influencer A's followers, what is the probability that they liked the most recent post? Express your answer as a percentage to one decimal place.

b If a follower is chosen at random from Influencer B's followers, what is the probability that they liked the most recent post? Express your answer as a percentage to one decimal place.

c Based on the information from part **a** and **b**, estimate the number of likes a post from another influencer, Influencer C, would receive if they have 12 580 followers.

d If none of the influencers share followers, and all their followers are placed in a ballot for a prize, determine the probability that the winner will be a follower of Influencer B. Express your probability as a percentage to one decimal place.



Spread-sheet

Technology Activity 7D: See the Interactive Textbook for this activity on using Excel to simulate rolling 2 dice and calculating relative frequency.

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7E Identifying complication factors with real-life simulations

COMPLEX

LEARNING GOAL

- Identify factors that cause unreliable results when conducting a simulation using techniques other than technology.

Why is identifying complication factors in simulations essential?

- When conducting a simulation, the outcomes need to be completely random in their selection.
- Poor techniques, such as not returning cards to a deck after selection or always tossing a coin with heads facing up, could alter the results achieved.



Poor techniques could complicate the results obtained from a simulation.

WHAT YOU NEED TO KNOW

- Poor techniques could complicate the results obtained from a simulation.
- If selecting from a hat or a pack of cards:
  - always return the item to the hat/deck
  - mix/shuffle thoroughly before making the next selection
  - ensure there are no cards missing, but check there are no Jokers if the simulation doesn't involve them.
- When rolling a die, tossing a coin or spinning a spinner:
  - ensure that it is well tossed/spun so that the same selection does not continue to come up
  - do not always start with the same side up or at the same place
  - check the spinner rotates freely without sticking (e.g. that it does not stop in the same place each time).

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Example 8 Identifying complication factors with real-life simulations

Identify potential problems that could occur with the following simulation experiments:

a simulating the gender of a baby by tossing a coin and always starting on heads

b simulating the month of birth for a person by rolling two dice and adding the faces together

c simulating the meal choice of chicken or beef for wedding guests by selecting a card from the top of a new unshuffled deck of cards, noting the colour of the card, and then not returning the card to the deck before making the next selection.

WORKING	THINKING
a Tossing a coin and always starting on heads could create a bias towards one result, depending on the height and spin of the toss.	Always start at a different position.
b Simulating the month of birth by rolling two dice has the potential problem that the minimum sum is 2, so January would never be selected. February needs both dice to be 1, and December needs both dice to be 6, but June could come from either 3 + 3, 2 + 4 or 1 + 5.	The simulation must be able to produce all results, and each outcome needs to be equally likely to occur.
c A new, unshuffled deck of cards is likely to have the cards grouped by suit, and so the first 13 drawn from the top will be the same colour – the deck should be shuffled, or the card drawn at random. If the card is not returned, then the number of options reduces, so if the first card is red, and not returned, then there are now more black cards than red cards to choose from. A deck has two Jokers, which would not indicate either meal choice if drawn.	Each outcome needs to be equally likely to occur.

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Exercise 7E

APPLICATIONS

Example 8

1 Use a set of standard playing cards to simulate which sport house each member of a group of 20 students is in, from a choice of four houses. Remove both Jokers from the deck, and use these variations on simulation technique to compare the results.

- i Return the selected card to the deck after each selection and shuffle the deck between selections.
- ii Return the selected card to the deck after each selection but do not shuffle the deck between selections.
- iii Do not return the selected card to the deck after each selection but thoroughly shuffle between selections.
- iv Do not return the selected card to the deck after each selection and do not shuffle between selections.

a Copy and complete this frequency table to collate your results.

	Frequency			
Complicating factor	**Hearts**	**Diamonds**	**Clubs**	**Spades**
return/shuffle				
return/no shuffle				
no return/shuffle				
no return/no shuffle				

b Evaluate which of the techniques could have possibly caused a problem with the results collected. Explain how.

2 Use a coin to simulate the gender of 20 babies born in a hospital in one week. Use these variations on simulation technique to compare the results.

- i Always start with heads.
- ii Always start with the previous result up. For instance, if a head is tossed, start with a head facing up next turn.
- iii Always use a high toss.
- iv Always use a low toss.
- v Catch the coin off the toss and reveal the result on the back of your hand.
- vi Allow the coin to fall to the ground from the toss.

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a Copy and complete this frequency table to collate your results.

	Frequency	
Complicating factor	**Heads**	**Tail**
heads up		
previous result up		
high toss		
low toss		
catch and reveal		
fall to the ground		

b Evaluate which of the techniques could have possibly caused a problem with the results collected. Explain how.

3 Use a die to sample the following variations on simulation techniques over 20 trials and compare the results collected.

i Use a cup to shake the die before rolling.

ii Pick up the die and flick straight out of your hand without shaking.

iii Shake the die in your hands before rolling.

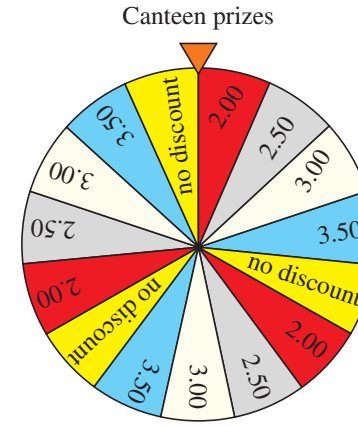
a Copy and complete this frequency table to collate your results.

	Frequency					
Complicating factor	1	2	3	4	5	6
use cup to shake						
no shaking of die						
shake in hands						

b Decide which of the techniques could have possibly caused a problem with the results collected. Explain how.

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4 The principal of a high school holds a weekly competition at assembly where students can win a prize from an assortment of canteen vouchers. Teachers pick a name out of a hat from students who have been entered for good behaviour during the week, and a computerised spinner is used to determine the prize awarded, similar to the picture to the right.



a Use a simulation technique (cards, spinner etc.) to estimate the relative frequency of each outcome over one year (trials = 40).

b The principal notices that the staff re-spin the wheel if a 'no discount' comes up, to keep the students happy.

- **i** In what way does this complicate the simulation that was conducted?
- **ii** Based on your results from part **a**, how often will the wheel need to be re-spun?
- **iii** Use a simulation technique to re-spin the wheel for the 'No discount' outcomes. Calculate the new relative frequency for each of the discounts.

c Whenever the 'no discount' comes up, the staff always re-spin the wheel. Suggest a better simulation method.

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7F Constructing a sample space

LEARNING GOALS

- Determine the size of a sample space.
- Use a table to construct a sample space.
- Use a systematic list to construct a sample space.

Why is the use of sample spaces essential?

- Creating a complete list of outcomes enables the calculation of probabilities for specific events.
- Application in real life: Sample spaces are used in various scenarios, like predicting weather outcomes (sunny, rainy, cloudy) or analysing sports results (win, lose, draw).



A sample space is a list of all possible outcomes. The image shows the sample space for throwing one die.

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WHAT YOU NEED TO KNOW

- A **sample space** is a list of all possible outcomes. The list can be constructed by either using a table or a systematic list.
- A **table** is used when there are two stages in a probability experiment. The outcomes of one stage are listed across the top and the other stage is listed along the side. The table is then infilled with the combinations of the two trials.
- For example, when tossing a coin and rolling a die:

Die outcomes

Coin outcomes	1	2	3	4	5	6
Head	Head, 1	Head, 2	Head, 3	Head, 4	Head, 5	Head, 6
Tail	Tail, 1	Tail, 2	Tail, 3	Tail, 4	Tail, 5	Tail, 6

- The **size of the sample space** is determined by the product of the number of outcomes in each stage.
  - For example: A die has 6 outcomes $\{1, 2, 3, 4, 5, 6\}$ and a coin has two outcomes $\{H, T\}$. Therefore, size of sample space $= 6 \times 2 = 12$.
- A **systematic list** is constructed by systematically listing all the outcomes of the first stage with each of the outcomes of the second stage in turn.
  - For example: A coin is tossed and a spinner is spun with the outcomes A, B, C on each selection. The sample space would be:

Head, A	Head, B	Head, C
Tail, A	Tail, B	Tail, C

- If selecting two items from a list, repeats cannot happen.
  - For example: Colby, Sharlah, Bridget and Tom nominate for the school tennis team. Only two positions are available. The possible team combinations would be:

First person selected

Second person selected	Colby	Sharlah	Bridget	Tom
Colby	X	S, C	B, C	T, C
Sharlah	C, S	X	B, S	T, S
Bridget	C, B	S, B	X	T, B
Tom	C, T	S, T	B, T	X

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Example 9 Using a table to construct a sample space

Nicole is packing for an overseas holiday. She plans on taking:
- three shirts that are blue, white and black
- two pairs of trousers that are tan and black.

a If each combination of shirt/trousers is an outcome, calculate the size of the sample space.

b Use a table to construct a sample space of the different outfit combinations.

WORKING	THINKING
a Sample space size $= 3 \times 2 = 6$	The product of the number of outcomes in each stage determines the size of the sample space.
b Sample space:	Construct a table showing all outcomes.

Trousers \ Shirts	blue	white	black
tan	blue, tan	white, tan	black, tan
black	blue, black	white, black	black, black

Example 10 Using a systematic list to construct a sample space

A pizza restaurant offers two types of base (thin or thick) and two types of sauce (BBQ or tomato). These can be ordered in any combination.

a Calculate the size of the sample space (the number of pizza combinations).

b Make a systematic list of the pizza combinations.

WORKING	THINKING
a Sample space size $= 2 \times 2 = 4$	Sample space size = product of number of outcomes in each stage
b List of combinations: Thin, BBQ; Thin, Tomato Thick, BBQ; Thick, Tomato	Start with the first stage (bases) and add each of the elements from the second stage (sauces).

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Example 11 Using a table without repetition to determine a sample space

Patrick is in the gym and wants to add weights to the bench press to increase the load. He can choose from 2 kg, 5 kg, 10 kg or 20 kg weights. There is only enough space to add two weights to the machine and only one of each of the weights to choose from.

a Calculate the size of the sample space.

b Use a table to construct a sample space of the different weight combinations. (NOTE: 2kg followed by 10kg is considered a different outcome to 10kg followed by 2kg)

WORKING	THINKING
a Sample space size $= 4 \times 3 = 12$	Once a weight has been selected, it cannot be selected again, so the second selection only has three possible outcomes.
b Sample space:	Construct a table without repetition of the outcomes.

Weight No. 1

Weight No. 2	2	5	10	20
2	X	5, 2	10, 2	20, 2
5	2, 5	X	10, 5	20, 5
10	2, 10	5, 10	X	20, 10
20	2, 20	5, 20	10, 20	X

Exercise 7F

FUNDAMENTALS

1 For each of the following probability experiments:

a Determine how many elements are in the sample space.

b List the sample space.

i Rolling two 4-sided die.

ii Tossing a coin and rolling 6-sided die.

iii Selecting a card from a standard deck and noting the colour, then returning and selecting another.

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APPLICATIONS

Example 9 ★2 When buying a car, Zara had the choice of body type (hatch, sedan, SUV) and colour (white, red, grey, blue).



a Calculate the size of the sample space to determine how many different combinations of car choices are possible.

b Use a table to determine the sample space for car choices.

★3 A couple is expecting twin babies.

a Calculate the size of the sample space to determine how many different combinations of Boy/Girl are possible.

b Use a table to determine the sample space for the gender of the two babies.

Example 10 ★4 Ryan is ordering a takeaway meal from the local thai restaurant. He has a choice of:
Meat: Chicken, Beef, Prawns
Accompaniment: Steamed Rice, Fried Rice, Noodles



a Calculate the size of the sample space to determine how many different meal combinations are possible.

b Use a systematic list to determine the sample space for meal choice combinations.

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★5 Grace is organising her 18th birthday celebrations at a local tavern. The menu has the following options for the set menu:
Entrée: Salt & Pepper Calamari, Garlic Prawns, Chicken Satay
Main: Fillet Steak, Chicken Schnitzel, Barramundi, Chicken Parmigiana, Pasta Carbonara

a Calculate the size of the sample space to determine how many different combinations of entrée and main are possible.

b Use a systematic list to determine the sample space for meal choice combinations.

Example 11 ★6 The university rugby committee is selecting a captain and vice-captain for a mixed-nationality exhibition match. Each country—Australia, New Zealand, Japan, and the Philippines—has two nominees in the draw. The committee will randomly select two individuals, and it is permissible for both representatives to be from the same country.

a Calculate the sample size to determine how many different combinations are possible.

b Use a table to determine the number of different combinations possible.



★7 Mike, Darcy, Brooke, Ariel and Yoko all nominate to be the Student Representative for their class. Only two positions are available on the SRC.

a Calculate the sample size to determine how many different SRC combinations are possible.

b Use a table to determine the sample space for SRC combinations.

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7G Determining probabilities for an experiment

LEARNING GOALS

- Use a sample space to determine the probability of outcomes for an experiment.
- Model and solve problems involving probability experiments.

Why is the ability to calculate probabilities essential?

- Theoretical probability can be calculated using a sample space, without experiments.
- Calculating the likelihood of results happening by chance is essential.
- Important fields for calculating probabilities include weather and environmental forecasting, and insurance (e.g. predicting losses and accidents).



Scientists have to calculate the probability that their results arose by chance.

WHAT YOU NEED TO KNOW

- **Probability** is a numerical indicator of the chance of an event occurring.
  - Probability of an event $= \dfrac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$.
- The total number of **outcomes** is the size of the **sample space**.
- **Favourable outcomes** are the elements of the sample space that we are interested in, or which suit our needs.

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Example 12 Calculating probabilities from a simple sample space

A café van sets up at school sports on saturday mornings. Due to high demand, it offers only three types of coffee: latte, cappuccino and flat white. Milk options are also limited to full cream, skim, or oat milk.

a Determine the size of the sample space.

b List the sample space.

c i Calculate the probability of a person ordering a latte with oat milk.

ii Calculate the percentage probability of a person ordering a coffee with full cream milk.

WORKING	THINKING
a 2 elements: coffee type and milk type 3 options for each element.	Consider how many elements there are. Consider how many options for each element.
Sample size: $3 \times 3 = 9$ outcomes.	Size of sample space is the product of the number of elements at each stage.
b Full cream latte, Skim latte, Oat latte Full cream capp, Skim capp, Oat capp Full cream flat, Skim flat, Oat flat	Sample space: include all results possible.
c i Full cream latte, Skim latte, <u>Oat latte</u> Full cream capp, Skim capp, Oat capp Full cream flat, Skim flat, Oat flat $P(\text{Oat latte}) = \frac{1}{9}$	Probability of an event $= \frac{(\text{no.of favourable outcomes})}{(\text{total no.of outcomes})}$ Highlighting, or underlining, favourable outcomes in your sample space is a great exam technique.
ii <u>Full cream latte</u>, Skim latte, Oat latte <u>Full cream capp</u>, Skim capp, Oat capp <u>Full cream flat</u>, Skim flat, Oat flat	
$P(\text{full cream}) = \frac{3}{9} = \frac{1}{3}$ $\frac{1}{3} \times 100 \approx 33.3\%$	Always simplify the fraction if possible. To convert the fraction to a percentage, multiple by 100.

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Example 13 Calculating probabilities from a sample space in a table

Two standard dice are rolled, and the two faces are added together.

a Determine how many elements are in the sample space.
b Use a table to determine the sample space.
c Calculate the probability that a total of 4 is rolled.
d Calculate the probability that a total of more than a 4 is rolled.
e Calculate the probability that a total of at least 4 is rolled.
f Calculate the probability that a total less than 4 is rolled.
g Calculate the percentage probability of rolling an even total.

WORKING	THINKING
a Sample size $= 6 \times 6 = 36$	Sample size is the product of the number of elements in each stage of the experiment.
b Sample space:	Construct a table to show all outcomes.

		Die 1					
	+	1	2	3	4	5	6
Die 2	1	2	3	4	5	6	7
	2	3	4	5	6	7	8
	3	4	5	6	7	8	9
	4	5	6	7	8	9	10
	5	6	7	8	9	10	11
	6	7	8	9	10	11	12

c Number of favourable outcomes $= 3$ Probability of a total of 4 $= \frac{3}{36} = \frac{1}{12}$	Highlighting, or underlining, favourable outcomes in your sample space is a great exam technique.
d Number of favourable outcomes $= 30$ Probability of total more than 4 $= \frac{30}{36}$ or $\frac{5}{6}$	'More than 4' does not include 4.
e Number of favourable outcomes $= 33$ Probability of total of at least 4 $= \frac{33}{36}$ or $\frac{11}{12}$	'At least 4' includes 4.

... Continued

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Die 2 \ Die 1	1	2	3	4	5	6
1	2	3	4	5	6	7
2	3	4	5	6	7	8
3	4	5	6	7	8	9
4	5	6	7	8	9	10
5	6	7	8	9	10	11
6	7	8	9	10	11	12

◄ *The sample space is copied here for convenience.*

f Number of favourable outcomes = 3

Probability of total of less than 4 $= \frac{3}{36}$ or $\frac{1}{12}$

◄ 'Less than 4' does not include 4.

g Number of favourable outcomes = 18

Probability of an even total $= \frac{18}{36}$ or $\frac{1}{2}$

◄ Even numbers are 2, 4, 6, ...

$\frac{1}{2} \times 100 = 50\%$

◄ To convert a fraction to a percentage, multiple by 100.

Exercise 7G

FUNDAMENTALS

Example 12

1 A card is selected from a standard deck of 52 cards.

Hint A standard pack of cards has 4 suits.
Red suits: Hearts ♥ and Diamonds ♦
Black suits: Spades ♠ and Clubs ♣
Each suit has 13 cards:
A, 2, 3, 4, 5, 6, 7, 8, 9, 10, J, Q, K

a If the colour of the card is noted:

- **i** determine the size of the sample space
- **ii** list the sample space
- **iii** calculate the probability of selecting a Red card.

b If the suit of the card is noted:

- **i** determine the size of the sample space
- **ii** list the sample space
- **iii** calculate the percentage probability of selecting a Heart.

c If the face of the card is noted:

- **i** determine the size of the sample space
- **ii** list the sample space
- **iii** calculate the probability of selecting an Ace.

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APPLICATIONS

★2 Two coins are tossed and the result noted.

- **a** Determine the size of the sample space.
- **b** Use a table to list the sample space.
- **c** Calculate the probability of tossing no tails.
- **d** Calculate the probability of tossing one tail.
- **e** Calculate the probability of tossing two tails.
- **f** Calculate the probability of tossing at least one tail.

Example 13 ★3 An ice-cream shop offers two types of cones (Waffle and Sugar) and four different flavours of ice-cream (Chocolate, Vanilla, Strawberry and Salted Caramel).

- **a** Determine the size of the sample space.
- **b** Use a table to list the sample space.
- **c** Calculate the probability of a person ordering Salted Caramel in a Waffle cone. Express your answer as a decimal, correct to two decimal places.
- **d** Calculate the probability of a person ordering Salted Caramel ice-cream.
- **e** Calculate the probability of a person ordering ice-cream in a Waffle cone.
- **f** Calculate the probability of a person ordering Chocolate ice-cream or a Waffle cone. Express your answer as a decimal and percentage.

4 A card is selected from a standard deck of 52 cards. Complete the following if the suit and face of the card is noted.

- **a** Determine the size of the sample space.
- **b** Use a table to list the sample space.
- **c** Calculate the probability of selecting the Ace of Hearts.
- **d** Calculate the probability of selecting a Picture Card (J, Q, K).
- **e** Calculate the probability of selecting an Ace or a Queen. Express your answer as a decimal, correct to two decimal places.
- **f** Calculate the probability of selecting a Spade or a Queen.
- **g** Calculate the percentage probability of selecting a Picture Card or a Club. Answer correct to one decimal places.



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★5 The university rugby committee is selecting a captain and vice-captain for a mixed-nationality exhibition match. Each country—Australia, New Zealand, Japan, and the Philippines—has two nominees in the draw. The committee will randomly select two individuals, and it is permissible for both representatives to be from the same country.

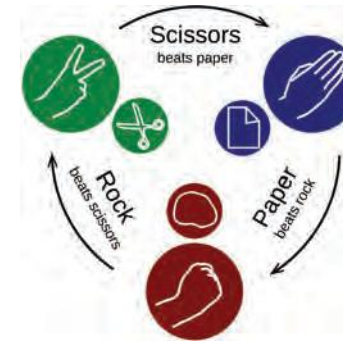
- **a** Calculate the probability that the two selected are both from the same country.
- **b** Calculate the probability that at least one of those chosen is from Australia.
- **c** Calculate the percentage probability that the representatives chosen are from Japan and Philippines.
- **d** Calculate the percentage probability that New Zealand does not have a representative chosen.

★6 A student guesses the answer to two multiple choice questions in a test. Each question has four options, with only one being correct.

- **a** Determine the size of the sample space.
- **b** Use a table to list the sample space.
- **c** Calculate the probability of getting both questions correct. Express the answer as a percentage.
- **d** Calculate the probability of getting one question correct.
- **e** Calculate the probability of getting at least one question correct.
- **f** Calculate the probability of getting no questions correct. Express the answer as a fraction and as a decimal correct to two decimal places.

★7 Hayley and Ben play 'Rock-Paper-Scissors' to decide who will pay for ice-cream. Each player randomly selects to be 'rock' or 'paper' or 'scissors'. The rules are:

- **a** Determine the size of the sample space.
- **b** Use a table to list the sample space.
- **c** Calculate the probability of Ben playing 'Scissors'.
- **d** Calculate the probability of both players playing 'Rock'.
- **e** Calculate the probability of both players playing the same move.
- **f** Calculate the probability of Hayley winning by playing 'Paper'.



Hint If two players play the same move, it is a draw and the game is played again.

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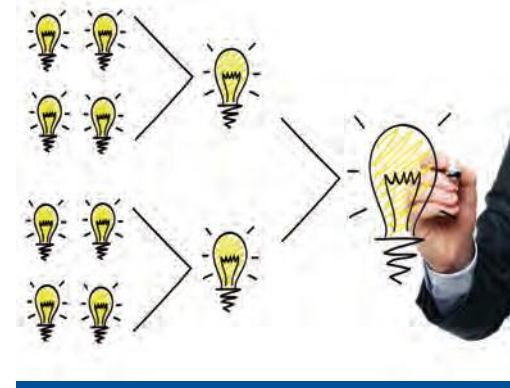
7H Using tree diagrams to determine probabilities

LEARNING GOALS

- Construct a tree diagram for two or more trials.
- Determine a sample space from a tree diagram.
- Determine probabilities for experiments using a tree diagram.
- Model and solve problems involving probability experiments.

Why are tree diagrams essential?

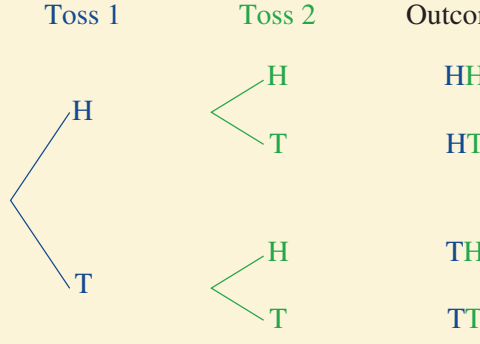
- For experiments with more than two trials, tables and lists become too complex and hard to manage. Instead, we use tree diagrams for these cases.
- Tree diagrams clearly show all possible outcomes and make it easier to calculate probabilities.
- An example of real-life use is a financial analyst who evaluates investment risks and opportunities, modelling various outcomes using tree diagrams.



Tree diagrams can optimise business processes by analysing complex scenarios and probabilities.

WHAT YOU NEED TO KNOW

- **Outcomes** for each **trial** are listed in columns. The sample space is a list of all possible outcomes written in a column at the end of the branches.
  - For example, if a coin is tossed two times, the **tree diagram** would be:



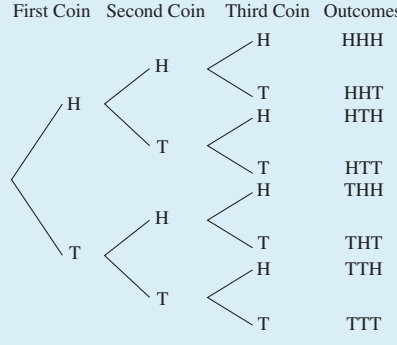
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Example 14 Using a tree diagram to determine probabilities

In order to get approved funding for her project, Lilly has to get a 'Yes' from at least two of the three rounds of approvals. Lilly tosses three coins for a probability experiment, noting the result from each coin as a Head (H) or a Tail (T). Heads represent a 'Yes' for approval, and Tails represent a 'No' for approval.

a Construct a tree diagram showing all possible outcomes of the experiment.
b Determine the number of outcomes.
c Use the tree diagram to list all possible outcomes of the experiment.
d Calculate the probability of getting a 'Yes' for all three rounds.
e Calculate the probability of tossing two heads (two out of three rounds approved).
f Calculate the probability of Lilly's funding not being approved.
g Calculate the probability of Lilly's funding being approved. Express your answer as a percentage.

WORKING	THINKING
a 	Construct a tree diagram ensuring that only the possible outcomes at each stage are included.
b There are 8 outcomes.	Count how many outcomes are in the final column.
c The outcomes are HHH, HHT, HTH, HTT, THH, THT, TTH, TTT.	Read across each branch set to create a list of the outcomes.
d Number of favourable outcomes = 1 Probability of HHH = $\frac{1}{8}$	There is only one outcome of HHH, Representing all rounds giving a YES for funding approval.

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e Number of favourable outcomes = 1.
Probability of TTT = $\frac{1}{8}$.

◄ HHT, HTH and THH are all favourable outcomes.

f Number of favourable outcomes = 4.
Probability of not being approved = P(not HHH or TTT)
= $\frac{6}{8} = \frac{3}{4}$.

◄ It will not be approved if she gets more than one 'No' (T). HHT, HTH, HTT, THH, THT and TTH are all favourable outcomes.

g Number of favourable outcomes = 2.
Probability of at least two head = $\frac{2}{8} = \frac{1}{4}$.
$\frac{1}{4} \times 100 = 25\%$

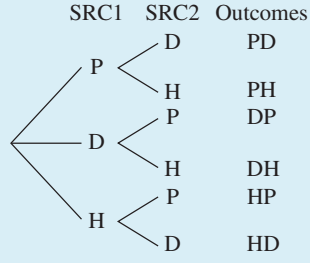
◄ Probability of Lilly's funding being approved is equal to the probability of two or more heads. HHH and TTT are both favourable outcomes.
To convert a fraction to a percentage, multiply by 100.

Example 15 Using a tree diagram without replacement to determine probabilities

Preston, Doug, and Hannah all nominate for the two positions as class SRC representative. They are all equally qualified for the position and have all been deemed equally likely candidates.

a Construct a tree diagram showing all possible outcomes.
b Determine the number of outcomes.
c List all possible outcomes of the experiment from the tree diagram.
d Calculate the probability that Doug and Hannah are the SRC representatives.
e Calculate the probability that Preston is an SRC representative. Express your answer as a percentage.

WORKING	THINKING
a All possible outcomes:	◄ Each person can only be selected once. If selected in the first round, they cannot be selected in the second round.



Continued

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b There are 6 outcomes. ◄····· Count how many outcomes are in the final column.

c The outcomes are PD, PH, DP, DH, HP and HD. ◄····· Read across each branch set to create a list of the outcomes.

d Number of favourable outcomes = 2. ◄····· DH and HD are both favourable outcomes.
Probability that Doug and Hannah are the representatives
$= \frac{2}{6}$ or $\frac{1}{3}$.

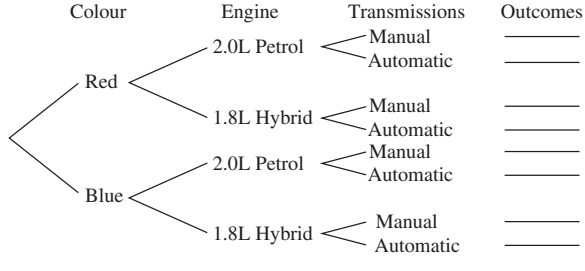
e Number of favourable outcomes = 4. ◄····· Count the outcomes with P.
Probability that Preston is the representative $= \frac{4}{6}$ or $\frac{2}{3}$.
$\frac{2}{3} \times 100 \approx 66.6\%$ To convert a fraction to a percentage, multiply by 100.

Exercise 7H

FUNDAMENTALS

APPLICATIONS

1 Tenille is looking to buy herself a car. The car she has decided on comes with a choice of colour, engine type and transmission. A tree diagram of the possible choices is shown.





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a Complete the Outcomes column.
b Determine how many car combinations are possible.
c Calculate the probability that Tenille selects a Red Hybrid Automatic car.
d Calculate the probability that Tenille selects a Red Automatic car.
e Calculate the probability that Tenille selects a an Automatic car.

Example 14 ★2 Felix conducts a probability experiment by selecting a card at random from a standard deck of cards and noting the colour as Red (R) or Black (B). He conducts three trials of the experiment and returns the card to the deck after each selection.
a Construct a tree diagram showing all possible outcomes of the experiment.
b Determine the number of outcomes.
c Use your tree diagram to list all possible outcomes of the experiment.
d Calculate the probability of Felix selecting exactly three red cards.
e Calculate the probability of Felix selecting exactly two red cards.
f Calculate the probability of Felix selecting less than two red cards.

★3 Will has noticed that the school bus is equally likely to be either on Time (T) or Late (L) each morning. He conducts a probability experiment by rolling a die to determine the likelihood of being late for the next three mornings. If the result on the die is even, then the bus is on Time (T); if the result is odd, then the bus is Late (L).
a Construct a tree diagram showing all possible outcomes of the experiment.
b Determine the number of outcomes.
c List all the possible outcomes.
d Calculate the probability that Will is on time for school all three days.
e Calculate the probability that Will is late for school on one of the three days.
f Calculate the probability that Will is late for school at least once over the three days.

★4 Lochie is enjoying a meal at Murphy's Grill. The menu is shown on the right.
a Construct a tree diagram showing all possible steak meal combinations of:
- Steak: Eye (E), Rib (R) or Rump (P)
- Potato: Chips (C) or Mash (M)
- Side: Vegetables (V) or Salad (S).

Murphy's Grill

200G EYE FILLET ---------- 34
250G RIB FILLET ---------- 35
350G RUMP ---------- 32

OUR GRILLS ARE SERVED WITH
CHIPS OR MASH
VEGETABLES OR SALAD

b Determine the number of meal combinations.
c List all the meal combinations.
d Calculate the probability that Lochie has the Rump steak served with chips and salad.
e Calculate the probability that Lochie has the Rib Fillet steak served with chips.

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5 In a Mario Kart race, you can choose from the following characters, cars, and wheels:

- **Characters:** Mario, Luigi, Peach
- **Cars:** Standard Kart, Sports Coupe
- **Wheels:** Slick, Roller

a Draw a tree diagram to show all possible combinations.
b Calculate the probability that a player chooses Luigi in a Sports Coupe with slick wheels.
c Calculate the probability that a player chooses Peach with any combination of cars and wheels.
d Calculate the probability that a player chooses Mario in the Standard Kart with any wheels.

Example 15 ★**6** Chloe, Gabby, Libby and Michelle all nominate for the two positions in the school tennis team.

a Construct a tree diagram showing all possible outcomes.
b Determine the number of outcomes.
c List all the possible outcomes.
d Calculate the probability that Libby and Gabby are in the tennis team.
e Calculate the probability that Chloe is in the tennis team.

★**7** Cortay wants to have an ice-cream. He can have his choice of Waffle (W) or Sugar Cone (S) and likes to have two scoops of ice-cream with *different* flavours. The flavour choices are: Chocolate (C), Wild Berry (B) and Vanilla (V).

a Construct a tree diagram showing all possible ice-cream outcomes.
b Determine the number of outcomes.
c List all the possible outcomes.
d Calculate the probability that Cortay has a Waffle cone with Wild Berry and Chocolate ice-cream.
e Calculate the probability that Cortay has no Chocolate ice-cream.



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Modelling task

Context: Probability is valuable in many real-world situations, helping us anticipate potential future events. In this task, students will examine how probability and statistics can be applied to predict future occurrences based on historical data.

Task: Select a real-world scenario, such as predicting sports game outcomes, weather conditions, or social media engagement rates. Analyse relevant historical data to identify the chance of the event occurring. Develop a simple predictive model/simulation/experiment to predict future events.

Stage 1: Formulate
Make an observation of: • what you are required to do • what information you have • what other information is needed. Make an assumption of: • how you will gather more information • which models of probability may be suitable • which aspects of real life will need to remain constant to predict future events.
Stage 2: Solve
• Decide on appropriate researching techniques. • Gather more information through research. • Produce the graphs, tables or lists required to help solve the problem. • Conduct probability simulation experiments to model the outcome researched. • Compare experimental and theoretical probability.
Stage 3: Evaluate and verify
Check all information has been included and researched accurately. • Check you have verified the statistics and probability calculations. • Check you have the evidence to back up your report summary. • Include the evidence in the form of statements and calculations. Justify your model of the proposed task in context, by considering your: • assumptions • limitations • observations • strengths.
Stage 4: Communicate
Reflect on your response and solution, outlining the decisions involved in making your response. • State your main point. • Explain the evidence.

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Chapter summary

Probability

- Probability is a numerical indicator of the chance of an event occurring.

  Probability of an event $= \dfrac{\text{number of favourable outcomes}}{\text{total number of outcomes}}$.

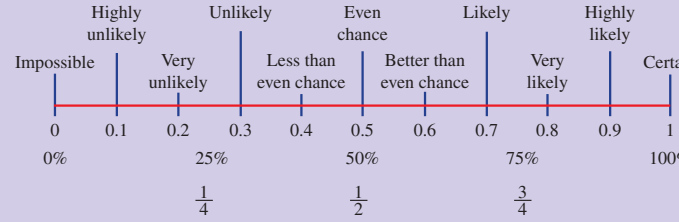
  Probability ranges in value from 0 (will not happen) to 1 (will happen).

Favourable outcome

- Favourable outcomes are the elements of the sample space that we are interested in, or which suit our needs.

Probability number line

- The format of expressing a probability can be converted from the original fraction using the formula above to decimals, ratios or percentages for ease of communicating and to suit the context.



Experiment/simulation

- An experiment, or simulation, is a procedure undertaken to make a discovery.

  We can conduct probability experiments to simulate real-life problems.

Frequency

- Frequency is a count of how often an outcome appears. Usually organised into a frequency table.

Random number feature

- A scientific calculator can produce a random decimal number between 0 and 1.

  Press shift > Ran > =

Trials

- Repetitions of experiments are called trials. The outcome of a previous trial has no impact on the chance of the outcome occurring in successive trials. Expected number of occurrences = trials ÷ number of different outcomes.

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Relative frequency

- Frequency can be used to estimate the probability from a simulation or survey.

  Relative frequency of an event $= \dfrac{\text{number of favourable outcomes observed}}{\text{total number of trials}}$

  When increasing the number of trials to a very large amount, the relative frequency approaches the expected (calculated) probability.

Unreliable results

- Poor techniques could complicate the results obtained from a simulation. For example, if selecting from a hat, always return the item before repeating the trail.

Sample space

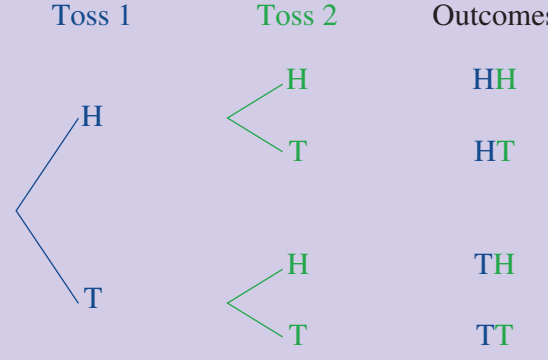
- A sample space is a list of all possible outcomes. The list can be constructed by using either a table or a systematic list.

Sample size

- The sample size is determined by the product of the number of outcomes in each stage. For example, a die has 6 outcomes and a coin has 2, so the sample space: $6 \times 2 = 12$.

Tree diagram

- A tree diagram is a visual representation used to illustrate all possible outcomes of a series of events. It consists of branches that represent different choices or events. The sample space is a list of all possible outcomes written in a column at the end of the branches.



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Chapter checklist

7A ☐ I can express probabilities formally using fractions, decimals, ratios and percentages.

1 A mixed-year homeroom class is made up of:

- 5 Year 7 students
- 8 Year 8 students
- 10 Year 9 students
- 4 seniors (Year 11 & 12)
- 3 Year 10 students.

Calculate the probability of randomly selecting a middle school student (Year 7, Year 8, or Year 9). Express your answer as a fraction, a decimal, and a percentage.

2 Archie's dad is a professional golfer. Despite all his practice and training, the ratio probability of Archie beating his dad in a round of golf are 7 : 1 against him. Calculate the percentage probability that Archie wins.

7B ☐ I can perform simulations of probability experiments using technology.

3 Generate 20 random numbers with a calculator or spreadsheet. Assign a NO vote to odd results and a YES vote to events results. Note the numbers and what they represent.

7C ☐ I can recognise that repetition of chance events is likely to produce different results.

4 If a die is rolled 300 times, calculate how many times you would expect each side to appear.

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7D ☐ I can identify relative frequency as probability.

5 A survey asked students how many sports they currently participate in. The table below shows the findings.

Number of sports	0	1	2	3
Number of students	42	57	24	2

If a student is selected at random:

a calculate the probability that the student plays one sport. Round your answer to two decimal places.

b calculate the probability that the student plays fewer than two sports. Round your answer to two decimal places.

7E ☐ I can identify factors that could complicate the simulation of real-world events [complex].

6 Explain the potential problems of doing a simulation by drawing cards from an unshuffled pack of cards.

7 In a probability simulation, explain if the coin should always be held the same way up before tossing.

7F ☐ I can construct a sample space for an experiment.

8 A coin is tossed twice. Determine the sample space by using:

a a table

b a systematic list

c a tree diagram.

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7G ☐ I can use a sample space to determine the probability of outcomes of an experiment.

9 Use your sample space from the previous question to determine the probability of:

- **a** two tails
- **b** one tail
- **c** at least one tail.

7H ☐ I can use a tree diagram to determine the outcomes and probabilities for experiments.

10 Sam has three shirts: they are blue, red and white. He is packing to go away for the weekend and needs to pack two shirts.

- **a** Construct a tree diagram to show the possible combinations of the shirts he packs.
- **b** Determine the probability that he packs the blue and red shirts.
- **c** Determine the probability that he packs the white shirt.

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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

7A, C, D **1** Sam tosses a coin to simulate the gender of 30 job applicants at a fast food store during a week. Heads = girl, tails = boy. The results of the simulation are:

T	T	T	H	T	T	H	H	T	H
T	H	H	H	T	T	H	T	T	T
H	T	T	T	T	T	H	H	T	T

a Record the results of the simulation in a frequency table.

Result	Frequency
heads/girls	
tails/boys	

b Determine the percentage of boys from your simulation.

c Calculate how many boys would you expect to find in the sample.

d Decide if the simulation varied from what you expected. Explain your answer.

e Calculate the relative probability of a job applicant being a girl. Express your answer as a percentage.

7A, C, D **2** Celeste tosses two coins to simulate the gender of the children in twenty families with two children. Heads = girl, tails = boy. The results of the simulation are:

T H	H H	H T	T H	H T
T T	H T	H H	T T	T H
T T	H T	H H	T H	T H
H T	T T	T T	H H	H T

a Copy and complete the following frequency table to record your results.

2-child combination	Tally	Frequency
boy + boy		
boy + girl		
girl + girl		

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b Calculate the relative frequency of 2-child families with a boy and a girl combination in your simulation. Express your answer as a fraction and a decimal.

c Calculate the relative probability of the 2-child family have at least one girl. Express your answer as a percentage.

7B **3** Connor estimates that his school bus is late once a week.

a Show that P(bus is late) is 0.20.

b Use the random number feature on your calculator to simulate if the bus is late (0.001 – 0.200) or on time (0.201 – 0.999) for the next 4 school weeks.

i Organise your results in a table.

ii Determine the number of times the bus is 'late' in the simulation.

c Connor estimated that the bus was late 20% of the time.

i In four weeks, determine how many times would you expect the bus to be late.

ii Describe any differences or similarities between the simulation in part **b** and the expected answer found in **c i**.

7C **4** In a probability experiment, Ayuen selects a card from a standard deck of cards and notes the suit. He repeats the experiment 20 times. The results are:

H	D	C	S	D	D	H	C	C	D
S	D	S	H	D	C	H	D	S	H

a Identify how many different outcomes there are when a card is selected at random from a deck and the suit noted.

b Determine how many times you would expect to get the same result as the previous selection in the 20 trials.

c Calculate how many times the same result appears in consecutive selections. Compare this answer with what you expected from part **b**.

d Determine how many times you would expect each outcome to appear in the 20 selections.

e Calculate the relative probability of selecting a Hearts card.

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7C **5** Ayuen thinks that some results appear more than others in his probability experiment.

a Using the data from Question **3**, complete a frequency table for the experiment.

b Calculate the relative frequency for each outcome.

c Determine if any results appear more/less often than expected.

d Describe how Ayuen could change the experiment so that each outcome appears the same amount of times.

6 In a recent one month study of traffic infringements in a city, the following data was collected:

- Total drivers observed: 2500
- Speeding violations: 210
- Running red lights: 97
- Provisional driver, driving without a P-plate visible: 32
- Using a mobile phone while driving: 128.

If a driver is selected at random:

a Calculate the percentage of drivers who received any kind of infringement. Express this as a ratio of drivers with and without infringement.

b Calculate the probability that the driver was a Provisional driver not displaying P-plates. Round your answer to two decimal places.

c Determine the probability that the driver is using a mobile phone. Express your answer to the nearest whole percentage.

7F **7** A merchandise promoter is randomly pulling shirts from a bag to give away at a local event. If a shirt in your desired size and colour is pulled, you must race up to receive it. The available shirt colours are blue, green, and red, and the sizes are small, medium, and large.

a Determine the size of the sample space.

b Use a table to list the sample space.

8 Two coins are tossed, and the result noted.

a Determine the size of the sample space.

b Use a systematic list to determine the sample space.

7G **9** Use the sample space from Question **6b** to calculate the probability of:

a a blue small shirt being pulled out of the bag. Express the answer as fraction and decimal rounded to two decimal places.

b any size blue shirt being pulled out of the bag. Express the answer as a percentage, rounded to the nearest whole number.

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c any colour medium or large shirt being pulled out of the bag. Express the answer as a fraction and a decimal rounded to two decimal places.

10 Two coins are tossed, and the result noted. Use the sample space from Question **7b** to:

a calculate the probability of tossing two heads
b calculate the probability of tossing one head
c calculate the probability of tossing no heads
d calculate the probability of tossing at least one head.

7H **11** A die is rolled three times and the outcome is noted as Odd (O) or Even (E).

a Draw a tree diagram showing all possible outcomes of the experiment.
b Determine the number of outcomes.
c From your tree diagram, list all possible outcomes of the experiment.
d Calculate the probability of rolling two even numbers.
e Calculate the probability of rolling three even numbers.
f Calculate the probability of rolling less than two even numbers.

7G **12** Tanya wants to order Chinese takeaway for her family. They have four favourite dishes that she usually orders: Lemon Chicken (C), Mongolian Lamb (L), Sweet and Sour Pork (P) and Satay Beef (B). Tanya only needs to order two *different* meals tonight.

a Determine the size of the sample space.
b Use a table to list the sample space.
c Calculate the probability that Tanya orders Sweet and Sour Pork.
d Calculate the probability that Tanya orders Lemon Chicken and Satay Beef.
e Calculate the probability that Tanya orders Lemon Chicken and Satay Beef or Mongolian Lamb.
f Calculate the probability that Tanya orders Lemon Chicken or Satay Beef.

Complex Familiar

13 A standard deck of cards is used to simulate the probability of scoring a goal (red) or not scoring (black) in a soccer penalty shootout. Explain how not returning a selected card to the deck after each selection, while thoroughly shuffling the remaining cards between selections, could lead to potential problems with the outcomes.

14 Siblings often argue about who gets to sit in the front seat of the car, so they decide to use a coin toss to decide. They assign heads to sibling 1 and tails to sibling 2. Explain how always starting with the coin showing tails when tossing it might lead to problems with the results.

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15 The votes for the best and fairest player across all ages and teams in the club are extremely close, resulting in six players having the same number of votes. To determine the winner, a die will be rolled, with each player assigned a number from 1 to 6. Is it reasonable to place the die in a cup to shake it before rolling?

Complex Unfamiliar

16 As part of a History investigation into the one-child policy once adopted in rural communities in China, Anna wants to conduct a probability experiment to determine the average number of children a family would need to have in order to have at least one son. She decides to toss a coin and say that Head = Girl, Tail = Boy. The results of her tosses are below. She has indicated the number of children required for the first three families to have a boy child by grouping results together until a Tail is tossed.

H	T	H	T	H	H	T	H	H	T
H	T	H	H	T	T	T	T	T	T
H	H	H	H	T	T	T	H	H	H
T	T	T	T	H	H	T	T	T	H

a Continue to identify the size of twenty families in Anna's simulation.

b Organise the results into a frequency table as follows.

Number of children	Tally	Frequency
1		
2		
3		
4		
5		
Total		

c Calculate the relative frequency for:
i 2 children **ii** 1 child

d Calculate the relative probability of having more than 2 children. Express your answer as a percentage.

e Analyse the results of the experiment and comment on the probability of a family being able to have only male. Justify your response with calculations.

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8 Unit 3 Review



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8A Simple Familiar

1A **1** Convert the following measurements into the units given in brackets.

a 4 cm (mm)
b 30 mm (cm)
c 4.5 km (m)
d 7.3 m (cm)

1B **2** Write the abbreviation for:

a square millimetres
b square kilometres.

3 Write the full unit for:

a cm^2
b m^2
c ha.

4 State the most appropriate choice of units to measure the following areas.

a Surface area of a classroom desk
b Suburban block of land
c Horse paddock
d Outback cattle station

1C **5** Express the following metric units of volume to their abbreviated forms.

a Cubic millimetres
b Cubic centimetres
c Cubic metres

6 Convert the following measurements into the units given in brackets.

a 1.74 cm^3 (mm^3)
b 2.67 m^3 (cm^3)
c 2340 mm^3 (cm^3)
d 0.0001 km^3 (cm^3)

7 Convert these volume and capacity measurements into the units given in brackets.

a 75 cm^3 (mL)
b 2.5 L (cm^3)
c 6172 cm^3 (L)
d 3.2 ML (kL)

1D **8** Convert the following time to the units indicated.

a 7.65 h to minutes
b 8 weeks to hours
c 9 h 27 min to hours
d 4.6 days to seconds

9 Express in the required format:

a 4.76 hours in digital format
b $7\frac{4}{5}$ hours in digital format
c 12 : 42 : 15 in decimal format for hours
d 15 : 24 : 36 in a fraction format for hours

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1E **10** Convert the following metric units of mass to their abbreviated forms.

a milligrams
b grams
c kilograms
d tonnes

11 Convert these mass measurements into the units given in brackets.

a 0.027 kg (g)
b 973 400 mg (g)
c 2300 g (kg)
d 7.5 t (kg)
e 3570 kg (t)
f 94 000 mg (kg)

12 Decide on the appropriate mass units that would be used when weighing the following:

a



b



c



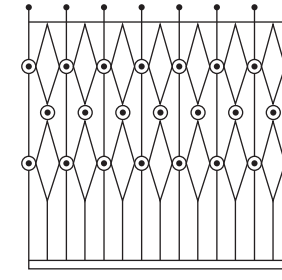
d



2A ⋆**13** Geometric animal art is currently quite popular. It is often used in graphic design as well as in drawings and paintings. This involves using a variety of 2D shapes to create an animal. In the image shown, identify the two main shapes that are used to draw the flamingos.



⋆**14** Lyn has designed a new gate that she would like to have made. Identify the various 2D shapes that she has used.



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★15 Identify the name of the 3D solid that is most similar to these landmarks.


Eiffel Tower in Paris

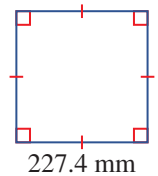

Pyramids in Egypt

2D ★16 Jana has made a circular cake with a radius of 15 cm for her daughter's fifth birthday party. After slicing the cake and serving it to the guests, she notices that there is $\frac{1}{4}$ (90°) of the cake remaining. She divides the cake four ways between her husband, daughter, son and herself. Calculate the arc length of each of these four slices.

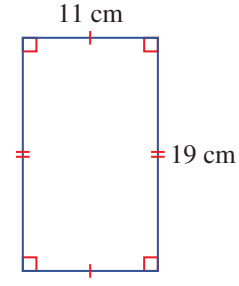


3A 17 Calculate the area of the following common 2D shapes. Round to two decimal places where necessary.

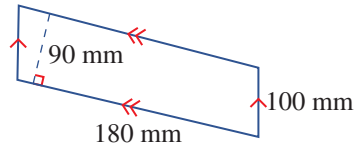
a



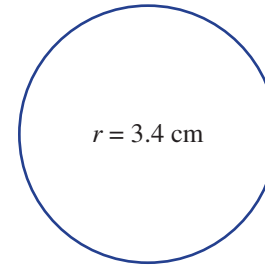
b



c



d



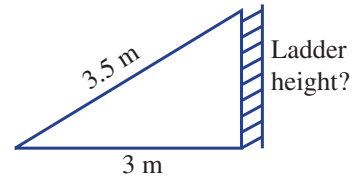
★18 Haley is tiling the floor of her 2.8 metre square bathroom. Calculate the area that Haley is tiling.

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6A **19** Cian has rested a ladder against the wall of his shed that is 6 metres above the ground. The base of the ladder is 2.5 metres away from the base of the shed. Use Pythagoras' theorem to determine the length of the ladder.

6B **20** Imran wants to design a slippery slide to fit in his townhouse courtyard. He only wants it to take up 3 metres across the ground and he has purchased a 3.5 metre slide. Determine the vertical height of the slide from the ground. Round your answer to one decimal place.



7A **21** On Halloween, a basket of lollies and chocolates is presented to children knocking at the door. They are to randomly select one treat from the basket. At the start of the night, the basket contains: 15 chocolate frogs, 8 choc/nut bars, 10 sour lollies, 12 lollipops and 5 mint chews. Calculate the probability expressed as a fraction, decimal and percentage of choosing:

a a lollipop
b any type of chocolate
c a mint chew or a sour lolly.

7B **22** Ian has 7 different ties that he keeps in a box on his desk. He randomly selects a tie from the box each morning when he arrives at work. His workmate, David, uses a spreadsheet to conduct a simulation of which tie Ian will wear each day for the next month. The results are as follows:

Week	Monday	Tuesday	Wednesday	Thursday	Friday
One	5	7	1	1	4
Two	1	3	7	3	7
Three	1	5	7	5	7
Four	7	5	5	3	2

a Copy and complete this frequency table for how many times each tie is worn over the four-week simulation.

Tie number	1	2	3	4	5	6	7
Tally							
Frequency							

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b Determine if any tie is worn more, or less, often than another.
c Calculate how often the simulation shows that Ian wears the same tie more than once in a week.
d Identify how often the simulation shows that Ian wears the same tie on two consecutive days.

7C **23** A standard die is rolled 20 times and the results are recorded. The results of 10 trials are displayed.

	Dice Outcome Frequency						
Trial	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
1	1	2	4	5	5	3	20
2	4	1	4	4	4	3	20
3	4	2	3	4	3	4	20
4	5	3	2	2	5	3	20
5	5	3	3	3	2	4	20
6	5	6	2	4	0	3	20
7	5	2	1	2	6	4	20
8	1	5	3	2	5	4	20
9	4	5	3	4	3	1	20
10	3	3	5	3	3	3	20
Total							



a Calculate how many times you would expect each face of the die to appear in 20 rolls.
b Determine if any outcome appeared more than another in:
  i the first trial
  ii the sixth trial.
c Calculate and complete the totals for each outcome in the bottom row of the table.
d Calculate how many times you would expect each face of the die to appear in 200 rolls, which is the grand total of rolls of the die from the last column of the table.
e Decide if any results from the 200 rolls differ from what you would expect.

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7D **24** A new video game has been released, and in the first two days, 3500 players start the game. Out of these, only 210 achieve 100% game completion. Calculate the probability that a player chosen at random has achieved this level of completion. Express your answer as a percentage.

7F, 7G **25** Alex is forming a representative pairs volleyball team from two different teams. Team A: Josiah, Sara and Mandeep. Team B: Elianna, Josie and Liam.
Alex randomly selects two players, one from each team.

- **a** Calculate the sample size to determine how many different player combinations are possible.
- **b** Use a table to determine the sample space for player choices.
- **c** Determine the probability that Alex choses Josiah and Liam. Express your answer as a fraction and decimal rounded to two decimal places.
- **d** Calculate the probability as a percentage of Alex choosing Elianna or Sara as one of the players. Express your answer to the nearest whole percentage.

7H **26** Daku loves bubble tea and is finding it hard to decide on a flavour choice. The bubble tea shop offers: three fruit flavours (mango, strawberry and lychee) and then two milk bases (classic milk tea and green tea).

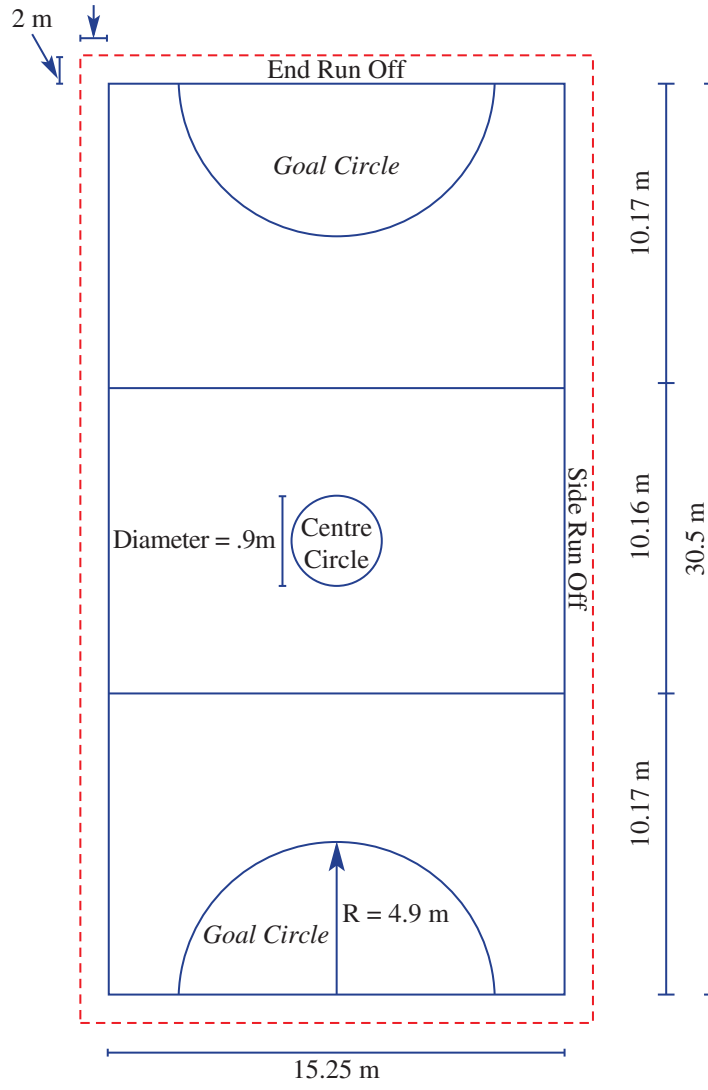
- **a** Draw a tree diagram to represent all the possible combinations Daku could order.
- **b** Calculate the probability that Daku orders a bubble tea with strawberry flavour. Express your answer as a percentage.

8B Complex Familiar

2B ⋆ **27** Sally has purchased a new fridge and it was delivered in a large box. Sally has cut the edges and flattened the box to form a net. Construct a diagram to identify what the net would look like. Ignore the extra flaps that cardboard boxes usually have.

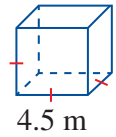
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2E **28** A netball court has the following dimensions and line markings. Calculate the perimeter of the court.

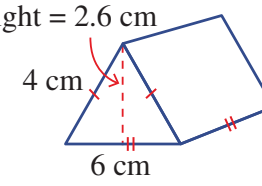


3C **29** Calculate the surface area of the following prisms.

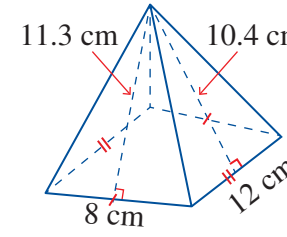
a



b



30 Calculate the surface area for the following pyramid.



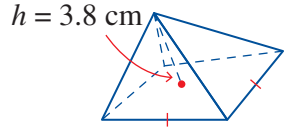
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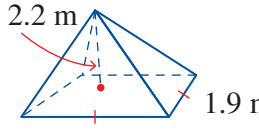
★31 The Eiffel Tower is a monument in Paris, France. It is similar in shape to a square-based pyramid with a base length of 99.9 metres and a height of 304 metres. Suppose a steel square-based pyramid was to be made to transport the Eiffel Tower. Its base length is 100 m and the perpendicular height of the triangles forming the four sides is 308 m. Determine the total surface area of steel required.



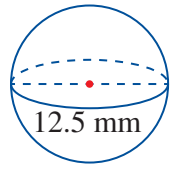
4B, 4C 32 Calculate the capacity of the following solids. Round your answer to two decimal places.

a 

Convert to mL

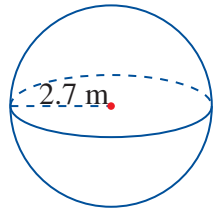
b 

Convert to kL

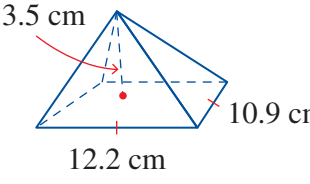
c 

Convert to mL

33 Estimate the volume and capacity of the following solids by first rounding each measurement to the nearest whole number.

a 

Convert to ML

b 

Convert to L

34 Shahida makes large spherical candles. She makes them by pouring melted wax into a spherical mould, which has an internal diameter of 24.3 cm. Calculate the capacity of the mould in litres.

6C 35 Willem has measured the shadow of a tree and found that it is 7.2 metres long. If the angle of depression of the sun rays are 52 degrees, calculate the actual height of the tree.

7E 36 There are only 4 tickets available for a music workshop, but 12 students in the class want to attend. The teacher decides to assign a number to each student and roll a 12-sided die. The student whose number matches the number face up on the die gets a ticket.
Identify potential problems with this simulation if the teacher rolls the die without shaking it first, simply flicking it out of their hand.

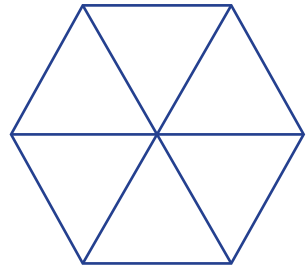
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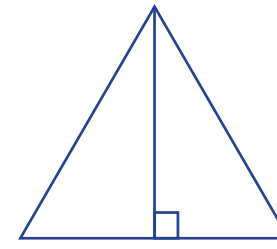
8C Complex Unfamiliar

3A, 5B **37** A regular hexagon has 6 equal sides and 6 equal angles. It contains 6 equilateral triangles within its bounds. The perpendicular height of each triangle is also its axis of symmetry. Calculate the area of a hexagon with side lengths of 10 cm.

a



b



5C ⋆**38** Gerties Guttering is quoting for supplying gutters for the roof of the building shown. Unfortunately, the plan does not have a scale, but the owner knows that the garage is 6.4 m wide. The guttering costs $12 per metre.

a Determine the scale.

b Calculate the perimeter of the building.

c Calculate the overall cost of the guttering assuming that the perimeter of the roof is the same as the perimeter of the building.



6D **39** Eloise has climbed to the top of Mt Beerwah, which is 556 metres high above sea level. She can see the base of Mt Tibrogargan, which is 6400 metres diagonally from Eloise's current position. Eloise is 165 cm tall. Calculate the approximate angle of depression that Eloise is looking down at. Round your answer to the nearest degree.

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9 The Cartesian plane and bivariate scatterplots



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In this chapter

9A Plotting coordinates on the Cartesian plane
9B Generating tables for linear functions, including for negative values of x
9C Graphing linear functions
9D Constructing a scatterplot using a given dataset and describing the association between variables of bivariate data
Modelling task
Chapter summary
Chapter checklist
Chapter review

Syllabus reference

Unit 4 Topic 1 Bivariate graphs

Cartesian plane (6 hours)

In this sub-topic, students will:

- demonstrate familiarity with Cartesian coordinates in two dimensions by identifying and plotting points on the Cartesian plane
- generate a table of values for a given linear function, including for negative values of x
- graph a linear function from a table of values with pencil and paper and with graphing software.

Bivariate scatterplots (4 hours)

In this sub-topic, students will:

- construct a scatterplot using a given dataset
- describe the patterns and features of bivariate data
- describe the association between two numerical variables in terms of direction (positive/negative), form (linear/non-linear) and strength (strong/moderate/weak).

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Prior knowledge check

1 Evaluate:

a $7 + 3 \times 2$

b $5 + 4 \times 2$

c $21 \div (4 + 3) - 2$

2 Find the value of:

a $11 - (4 \times 2) + 7$

b $12 \div (4 - 1) + 8$

c $2(12 + 2) - 3 \times 4$

3 Calculate:

a $9 - (4 \times (-2)) + 7$

b $20 \div (4 + (-1)) - 3$

c $(8 + (-2))^2 - 3 \times (-4)$

4 Carlos earns $22 per hour; calculate how much he will earn for the following job times.

a 3 hours

b 8 hours

c 2.5 hours

d 6 hours 30 minutes

e 4.75 hours

5 Margareta earns $40 per hour plus a $50 call out fee; calculate how much she will earn for the following job times.

a 1 hour

b 3 hours

c 2.5 hours

d 4 hours 30 minutes

e 1.75 hours

6 Determine the next number in the following number patterns.

a 2, 4, 6, …

b 3, 6, 9, …

c 4, 7, 10, …

d 2, 9, 16, …

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9A Plotting coordinates on the Cartesian plane

LEARNING GOALS

- Understand what a Cartesian plane is and the standard convention for naming coordinates.
- Determine the x and y values of a coordinate from a graph.
- Graph coordinates on a Cartesian plane.
- Plot coordinates on a graph based on a Cartesian plane in a real-world context.

Why is it essential to be able to plot coordinates?

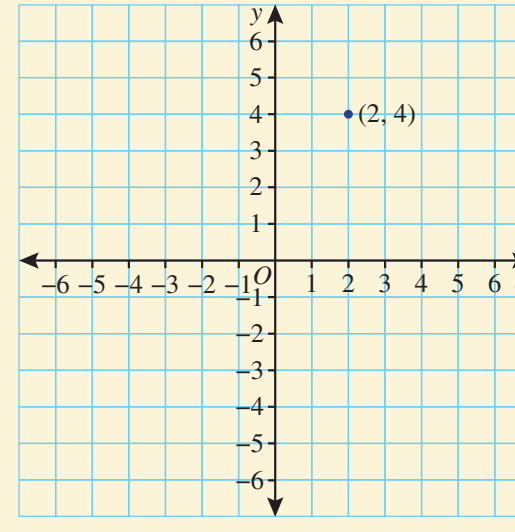
- Plotting coordinates helps you visualise how different pieces of data are related, making it easier to spot trends.
- In business and finance, line graphs and scatterplots are the most widely used way of displaying data.



Linear graphs are used in a variety of areas, particularly in the fields of finance and science.

WHAT YOU NEED TO KNOW

- A **Cartesian plane** is a graph with axes x and y labelled with whole number values, including negative values. In its basic form it is arranged in a square with O at the centre.
- The **x-coordinate** is the horizontal distance on the x-axis.
- The **y-coordinate** is the vertical distance on the y-axis.
- A coordinate is written by convention as the x-coordinate first followed by the y-coordinate, in brackets: (x, y). For example, the point (2, 4) is shown here.



- Line graphs and scatterplots in real-world contexts are usually based on a Cartesian plane displaying only the positive values of x and y.

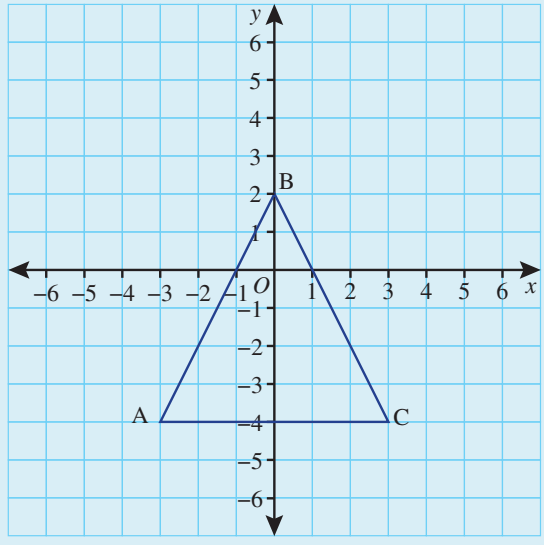
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Example 1 Plotting coordinates on a Cartesian plane

Plot the following set of points, connecting them in order, and name the shape it makes.
A (−3, −4), B (0, 2), C (3, −4)

WORKING

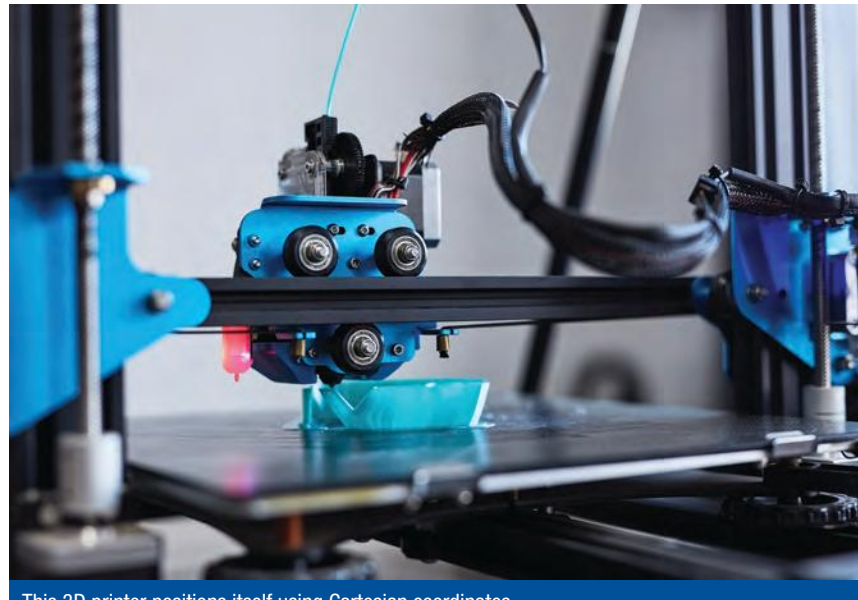


The coordinate points form a triangle.

THINKING

To plot point A, go to −3 on the horizontal axis and then down four places to −4 on the vertical axis.
To plot point B, go to 0 on the horizontal axis and then up two places to 2 on the vertical axis.
To plot point C, go to 3 on the horizontal axis and then down four places to −4 on the vertical axis.
Connect points in order A to B and B to C with three straight lines.

Identify the shape formed.



This 3D printer positions itself using Cartesian coordinates.

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Example 2 Plotting coordinates on a Cartesian plane in a real-world context

Ziah starts a gardening business to make some extra cash. In the first month he earned $15; in the second month he earned $45; in the third month he earned $30; and in the fourth month he earned $40.

a Complete the table using the values identified in the question.

Month	1	2	3	4
Earnings $				

b Plot the coordinates (month, earnings) on a graph.

c Join the coordinates in order of time.

d Determine the month that Ziah earned the most money.

e Calculate the total Ziah earned in the four months.

WORKING | **THINKING**

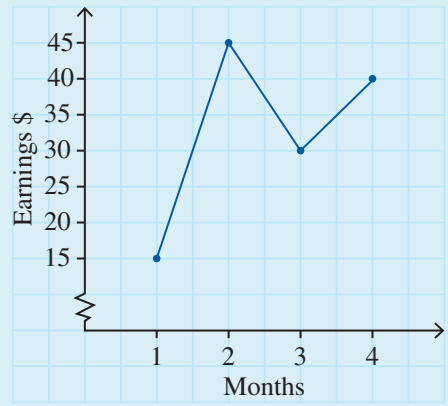
a

Month	1	2	3	4
Earnings $	15	45	30	40

◄····· Complete the table by entering the corresponding amount to the month.

b

c



◄····· Identify that the graph needs to go to at least $45 on the vertical axis and 4 on the horizontal axis.
Draw the axes and label accordingly.
Plot the points as per the table using (month, earning). Join the points.

d Ziah earned the most in the 2nd month.

◄····· Find the highest point in the graph.

e $15 + $45 + $30 + $40 = $130

◄····· Calculate the total earnings by adding the monthly earnings.

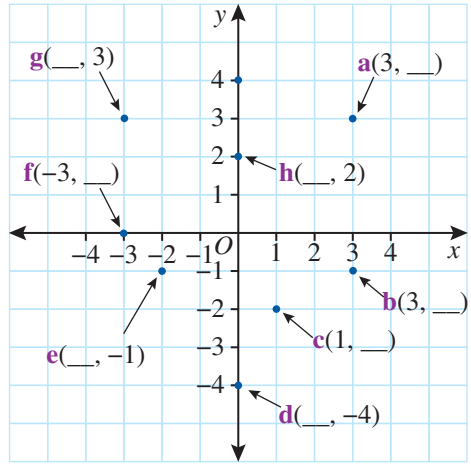
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Exercise 9A

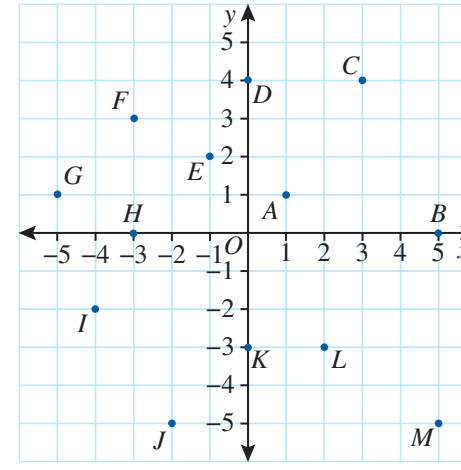
FUNDAMENTALS

1 Determine the missing coordinates labelled **a** to **h** (below, left).

Question 1



Question 2



2 Identify and write the coordinates of the points labelled *A* to *M* (above, right).

Example 1

3 Plot the following sets of points, connecting them in order, and name the shape it makes.

a A (0, 2), B (2, 0), C (0, −4), D (−2, 0), E (0, 2)

b A (−3, 1), B (−1, 2), C (1, 1), D (0, −1), E (−2, −1), F (−3, 1)

c A (−4, −3), B (−4, 2), C (1, 2), D (1, −3), E (−4, −3)

d A (−3, −1), B (−2, 1), C (3, 1), D (2, −1), E (−3, −1)

APPLICATIONS

Example 2

4 Yindi is saving up for a trip, so they decide to do some freelance graphic design work. In the first week they earned $65; in the second week they earned $80; in the third week they earned $105; and in the fourth week they earned $120.



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SF

a Complete the table using the values identified in the question.

Week	1	2	3	4
Earnings ($)				

b Plot the coordinates (week, earnings) on a graph.
c Join the coordinates in order of time.
d Determine the week in which Yindi earned the most money.
e Calculate the total Yindi earned in the four weeks.

5 Darlene starts a mowing business to make some extra cash. In the first month she earned $40; in the second month she earned $60; in the third month she earned $50; and in the fourth month she earned $80.

a Complete the table using the values identified in the question.

Month	1	2	3	4
Earnings $				

b Plot the coordinates (month, earnings) on a graph.
c Join the coordinates in order of time.
d Determine the month that Darlene earned the most money.
e Calculate the total Darlene earned in the four months.

★6 Rionna is making crochet beanies for premature babies to help them stay warm. She made 10 in 2020, 14 in 2021, 18 in 2022 and 20 in 2023.

a Create a table of values for this data.
b Create a graph to display this data.
c Determine the year that Irene made the most beanies.
d Calculate the total number of beanies that Irene knitted in the four years.



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★7 James has 1000 shares he is planning to sell to buy a car worth $28 000. The value of his shares has varied over the years. Originally, they were worth $26.50 per share in 2020, growing to $27.50 per share in 2021, $27.00 per share in 2022, and $26.50 per share in 2023. Draw a graph and determine when James should have sold his shares in order to afford the car. Justify your answer.

★8 Carmer wants to buy her first electric scooter by selling her stocks. Shares of the stock were $3.50 in 2021, $4.75 in 2022, $4.25 in 2023 and $4.00 in 2024. If Carmer has 2000 shares, draw a graph and determine when she should have sold her stock to make the most money.

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9B Generating tables for linear functions, including for negative values of x

LEARNING GOALS

- Substitute values into equations to calculate solutions.
- Work with negative numbers.
- Complete a table of values.

Why is it essential to be able to use a table of values?

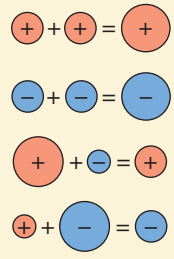
- Tables of values are the starting point for graphing linear functions.
- By having the table of values, you can plot each point accurately and observe any trends or patterns in the data more effectively.
- Tables of values are relevant to many occupations in science, finance and real estate.



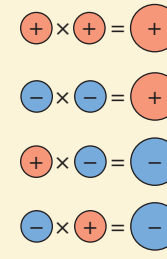
Linear functions can be used in a variety of fields to predict future values.

WHAT YOU NEED TO KNOW

- A **linear function** is an equation of the form $y = mx + c$ where m and c are constants.
- Addition rules of **positive** and **negative** numbers.



- Multiplication rules of **positive** and **negative** numbers.



The size of the circles indicates the size of the number.

- Solve an equation by substituting values for the variables into the equation. For example, for $y = 2x + 3$, if $x = 4$ then $y = 2 \times 4 + 3 = 11$ (calculate using BIDMAS).

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Example 3 Generating tables of values for linear functions including negative values for x

Complete the table of values for the linear equation $y = -5x + 2$.

x	-2	0	2
y			

WORKING	THINKING
When $x = -2$, $y = -5 \times -2 + 2$ $y = 10 + 2 = 12$	Substitute the value of -2 into the equation. Use BIDMAS to simplify.
When $x = 0$, $y = -5 \times 0 + 2$ $y = 0 + 2 = 2$	Substitute the value of 0 into the equation. Use BIDMAS to simplify.
When $x = 0$, $y = -5 \times 2 + 2$ $y = -10 + 2 = -8$	Substitute the value of 2 into the equation. Use BIDMAS to simplify.
	Complete the table using the values for y found above.

x	-2	0	2
y	12	2	-8

Example 4 Generating tables for linear functions in a real-world context

Josiah is an electrician and charges an $80 call out fee and $100 per hour. This can be mapped by the equation $y = 100x + 80$, where x is the number of hours worked and y is the cost for the client.

a Complete the table of values for the cost of hiring Josiah.

x	1	2	3
y			

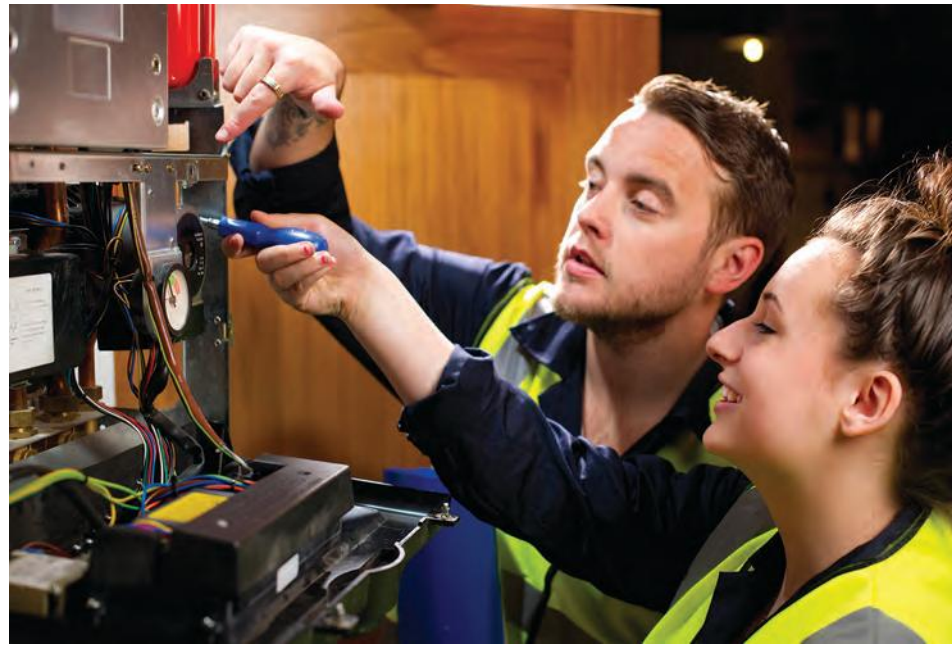
b Calculate the cost of hiring Josiah for $1\frac{1}{2}$ hours.

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WORKING	THINKING
a $y = 100 \times 1 + 80 = 180$ $y = 100 \times 2 + 80 = 280$ $y = 100 \times 3 + 80 = 380$	Substitute the value of 1 into the equation. Use BIDMAS to simplify. Substitute the value of 2 into the equation. Use BIDMAS to simplify. Substitute the value of 3 into the equation. Use BIDMAS to simplify. Use the values calculated to complete the table of values.

x	1	2	3
y	180	280	380

b $y = 100 \times 1\frac{1}{2} + 80$ $= \$230$	Substitute $x = 1\frac{1}{2}$ into the equation to calculate Josiah's pay.



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Exercise 9B

FUNDAMENTALS

1 Substitute $x = 2$ into the following equations to calculate the value of y.

a $y = 3x$
b $y = -5x$
c $y = x + 3$
d $y = x - 4$
e $y = 2x - 4$
f $y = 6 - 5x$

2 Substitute $x = -3$ into the following equations to calculate the value of y.

a $y = 4x$
b $y = -2x$
c $y = x + 4$
d $y = x - 3$
e $y = 2x + 3$
f $y = 3 - 4x$

Hint Use the addition and multiplication rules for positive and negative numbers.

Example 3

3 Complete the table of values for the following linear equations.

a $y = 3x$

x	-2	0	2
y			

b $y = -2x$

x	-3	0	3
y			

c $y = x + 3$

x	-2	0	2
y			

d $y = x - 2$

x	-3	0	3
y			

e $y = 4x + 1$

x	-2	0	2
y			

f $y = -2x - 2$

x	-3	0	3
y			

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APPLICATIONS

Example 4 ★4 Luca builds and repairs keyboards and charges a $100 call out fee and $60 per hour. This can be mapped by the equation $y = 60x + 100$, where x is the number of hours worked and y is the cost for the client.

a Complete the table of values for Luca's repair costs.

x	1	2	3
y			

b Calculate the cost of hiring Luca for $2\frac{1}{2}$ hours.

★5 Mario is a plumber who charges an $85 call out fee and $80 per hour. This can be mapped by the equation $y = 80x + 85$, where x is the number of hours worked and y is the cost for the client.



a Complete the table of values for Mario's plumbing cost.

x	2	4	6
y			

b Calculate the cost of hiring Mario for $4\frac{1}{2}$ hours.

★6 Mira owns a catering business and is preparing for upcoming events and has stocked 30 boxes of disposable paper serving containers. Each event uses 3.5 boxes. This can be represented with the equation $y = 30 - 3.5x$, where x is the number of events and y is the total of boxes of containers remaining in stock. Complete the table of values for Mira's serving containers.

x	1	2	3	7
y				

★7 Lisa won $1000 and spends $150 per week from her winnings. This can be mapped by the equation $y = 1000 - 150x$, where x is the number of weeks and y is the amount Lisa has left. Complete the table of values for Lisa.

x	1	3	5
y			

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SF

8 In Questions **6** and **7**, if the table was extended for more weeks, there would come a point where all the containers were gone, and all the money would be gone. Determine approximately how many weeks it would take for:

a all Mira's containers to be used

b all Lisa's winnings to be gone.

9 Trev's Truck hire costs an initial $120 plus $50 per hour that the truck is rented. Create an equation to map this relationship and then create a table of values to show the cost to hire his truck for the first 5 hours.

Hint In the equation, the initial cost of $120 stays the same, while separately, the time in hours has to be multiplied by the cost per hour.

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9C Graphing linear functions

LEARNING GOALS

- Create graphs based on linear functions with pencil and paper.
- Create graphs based on linear functions using technology.
- Read values from the graphs created.

Why is it essential to graph linear functions?

- Knowing how to draw graphs for linear functions is really useful to help you see how two things are related.
- Many businesses use graphs to show patterns or trends in information.
- Figuring out what might happen next is the most useful application of graphs in everyday life.



The money markets and financial companies use linear graphs to illustrate trends in the stock market.

WHAT YOU NEED TO KNOW

- A linear function is an equation of the form $y = mx + c$, where m and c are constants: m is the slope (gradient) and c is the y-intercept.
- The y-axis is the vertical axis and the x-axis is the horizontal axis.
- A scale for the x- and y-axis is created by reading the range of the x values and y values in the data to be graphed.
- A plotted graph line is simply a series of points joined together.
- A straight line can be drawn using three coordinates to ensure no mistakes have been made.
- Linear graphs can be plotted by hand or using technology such as spreadsheets and online graphing calculators (like Desmos).

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Example 5 Graphing linear equations by hand

Use the equation $y = 2x - 3$ to complete the following.

a Complete a table of values for $x = 0, 2, 4$.

b Determine the range of x and y values needed on the graph.

c Draw the graph axes and labels on graph paper.

d Plot the coordinates and draw a line through the points.

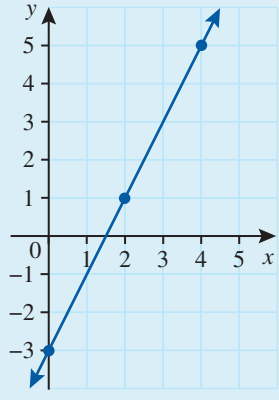
WORKING	THINKING
a	Substitute the values of 0, 2 and 4 into the equation. Use BIDMAS to simplify.

x	0	2	4
y	−3	1	5

b x is from 0 to 4, y is from −3 to 5.

Identify the range of x and y required for the graph.

c
d



Use the range of x and y to draw a graph large enough to display all the coordinates.

Plot the coordinates on the graph and draw a line passing through all three points.



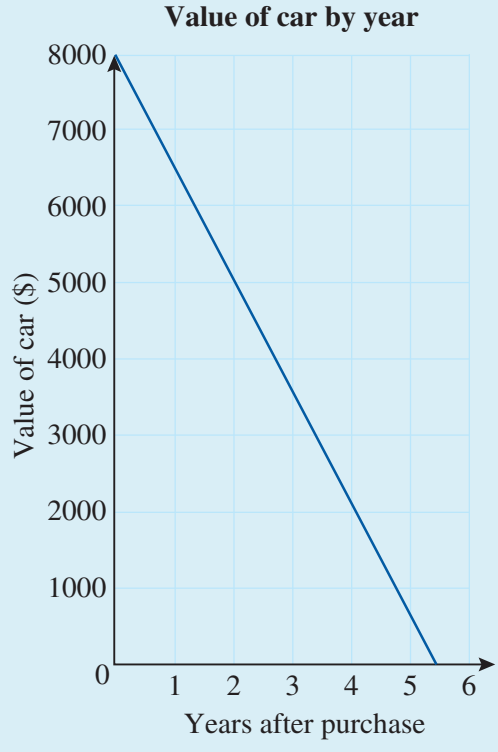
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Example 6 Graphing linear equations in a real-world context

Tamara bought a used car worth $8000. The car depreciates (goes down in value) by $1500 per year. The car's value can be described as $y = 8000 - 1500x$, where y is the car's value and x is the number of years.

a Graph the equation of the value of her car by hand or with technology.

b Determine how many years it will take for the car to be worth under $1000, round to the nearest year.

WORKING	THINKING
a 	The range of y values was from 0 to 8000, so show the car's value decrease with a step of 1000. The range of x values was from 0 to 6 with a step of 1 as the car is worth nothing by the 6th year.
b After 5 years the car will be less than $1000.	Once the line goes below the 1000 mark, the car is worth less than $1000.



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Example 7 Graphing linear equations in a real-world context using graphing software (spreadsheet)

Ruona would like to hire a car so he can take a road trip. The cost of hiring a car is a $100 initial fee plus 50 cents for each kilometre. This information can be represented by the linear equation: $y = 100 + 0.5x$, where y represents the total cost and x is the number of kilometres he drives.

a Create a table of values for x values 0, 5, 10..... 50 and graph the equation with technology.

b Determine the maximum distance Ruona can travel with the budget of $115 for car rental.

WORKING

a

A2 | *fx* Kilometres

	A	B
1		
2	Kilometres	Cost
3	1	
4	5	
5	10	
6	15	
7	20	
8	25	
9	30	
10	35	
11	40	
12	45	
13	50	
14		

B3 | *fx* =100 + 0.5*A3

	A	B
1		
2	Kilometres	Cost
3	1	100.5
4	5	
5	10	
6	15	
7	20	
8	25	
9	30	
10	35	
11	40	
12	45	
13	50	
14		

THINKING

Open the spreadsheet software:
- Open your preferred spreadsheet software on your computer or tablet.

Enter data:
- In the first column, label the cells from A2 downwards as 'X' (representing the x-values or kilometres driven).
- In the second column, label the cells from B2 downwards as 'Y' (representing the y-values or cost of car hire).
- In cells A3 to A13, enter the x-values you want to use. For example, you could use numbers from 1 to 50 in increments of 5 (km).

Enter the linear equation:
- In cell B3, use an equation to represent the linear equation. In this example: = *sum*(100 + 0.5*A3)

(when entering the equation, click on the A3 cell rather than typing).

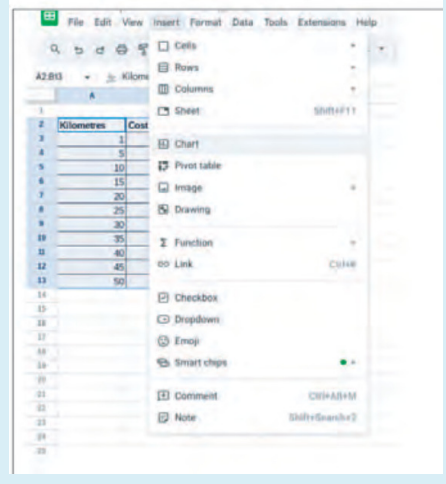
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B3:B13 ▼ | *fx* =100 + 0.5*A3

	A	B	
1			
2	**Kilometres**	**Cost**	
3	1	100.5	
4	5	102.5	
5	10	105	
6	15	107.5	
7	20	110	
8	25	112.5	
9	30	115	
10	35	117.5	
11	40	120	
12	45	122.5	
13	50	125	
14			

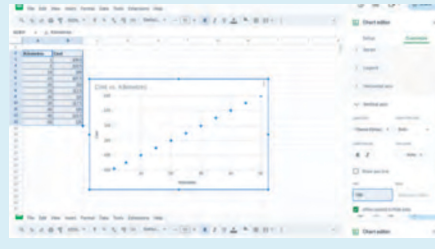
◄··· Calculate remaining *y* values (costs at different kilometres):

- Click on the small dot in the bottom right corner of cell B3, where the first answer is, and drag down to cell B13 (or final *x* value). This will display the resulting costs.



◄··· Create the graph:

- Select the data range from A2 to B13 (including the column headers).
- Go to the 'Insert' tab (in Excel) or 'Insert' menu (in Google Sheets) and select 'Chart' or 'Graph'.
- Choose the 'Scatter' plot type. This will create a scatter plot with your *x* and *y* values.



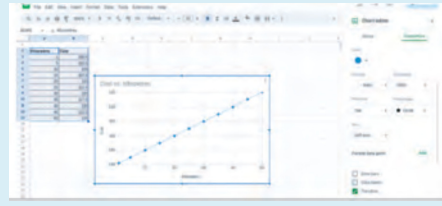
◄··· Customise the Graph:

- Once the scatter plot is inserted, you can customise it to make it easier to read. You can add axis labels, a title, and adjust the axis scales if needed.
  For example, enter min value for *y*-axis as 100.

... Continued

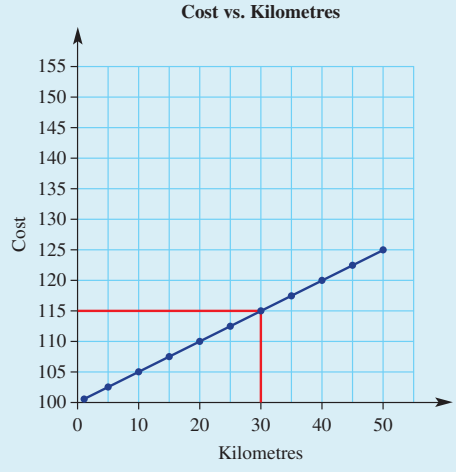
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◄··· Add line to join data points (optional):
- You can add a trendline to your scatter plot to see the overall trend of the data.
- Go to customise, series, and scroll down to find and tick the box called 'trendline'.

b



◄··· Read off the graph created along the y-axis (cost) until you get to the budget \$115. From there, read across the graph until you hit the trendline, and read off the corresponding kilometres (on the x-axis).

Answer: Ruona can travel 30 km on his road trip with a car hire budget of \$115.

Spread-sheet **Desmos activity 9C** See the interactive textbook for this activity on how to graph a linear function using the Desmos online graphing calculator.

Spread-sheet **Spreadsheet activity 9C** See the interactive textbook for this activity on how to graph a linear function using a spreadsheet.

Exercise 9C

FUNDAMENTALS

1 For the following set of points, determine the vertical and horizontal range required for the graph axes.

Hint Remember to extend the axis above and below the range of values given.

a

x	1	2	3
y	−3	2	7

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b

x	-2	0	2
y	-5	-1	3

c

x	-3	0	3
y	-12	2	16

d

x	0	3	4
y	0	13	26

2 Graph the following tables of values on the same graph.

i Plot the coordinates on the graph paper.

ii Connect the three coordinates by drawing a straight line through them.

a

x	-2	0	2
y	-1	3	7

b

x	0	2	4
y	4	1	-2

Example 5

3 For each of the following equations, complete the following.

i Complete a table of values for $x = 0, 2, 4$.

ii Determine the range of x and y values needed on the graph.

iii Draw the graph axes and labels on graph paper.

iv Plot the coordinates and draw the lines.

a $y = x + 3$ **b** $y = 2x$

c $y = 3x - 3$ **d** $y = -2x + 1$

4 Use Desmos to assist you to complete the following.

Hint Follow Desmos example online activity.

a Graph the following equations.

i $y = x$ **ii** $y = 2x$

iii $y = \frac{1}{2}x$ **iv** $y = -2x$

b Identify what the number in front of the x does to each graph in part **a**.

c Graph the following equations.

i $y = x + 1$ **ii** $y = x - 3$

iii $y = x + 4$ **iv** $y = 4$

d Identify what the number at the end (not next to the x) does to each graph in part **b**.

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APPLICATIONS

Example 6 ★5 Davina is a salesperson selling high quality handbags. She receives $100 per week and $50 per handbag that she sells. Her income can be described as $y = 50x + 100$, where y is her income and x is the number of handbags she sells.

a Graph the equation of Davina's income by hand.

b Determine the total income Davina that will receive if she sells 7 handbags.

Example 7 ★6 Charlie is a salesperson who sells jetskis. He receives $500 per week and $250 per jetski he sells. His income can be described as $y = 250x + 500$, where y is his income and x is the number of jetskis he sells.

a Graph the equation of his income with technology.

b Determine the total income Charlie will receive if he sells 3 jetskis.



★7 Bobbie is a farmer who has bought a tractor worth $25 000. The tractor depreciates (goes down in value) by $4500 per year, and the value of the tractor can be described as $y = 25\,000 - 4500x$, where y is the value of the tractor and x is the number of years.

a Graph the equation of the value of the tractor by hand or with technology.

b Determine how many years it will take for the value of the tractor to be under $5000.

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SF

★8 Matteo has bought a coffee van worth $38 000. The coffee van depreciates (goes down in value) by $6000 per year, and the value of the van can be described as $y = 38\,000 - 6000x$, where y is the value of the van and x is the number of years.

a Graph the equation of the value of the van by hand or with technology.

b Determine how many years it will take for the value of the van to be under $15 000.



★9 Taj is a Hummer driver who charges a $150 fee when picking up clients and then charges $2.50 per km travelled. The hire fare can be described as $y = 2.5x + 150$, where y is the total Hummer fare and x is the number of km travelled. If Taj picks up a client at Cairns airport and takes them to Palm Cove, which is 26 km away, create a graph to determine the total fare cost.

10 Kirra has a surfboard shop and it costs her $800 a day in wages and rent to stay open. If she makes $210 per surfboard she sells, write this as an equation and graph the equation to determine the amount of surfboards required to be sold to make a profit each day.



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9D Constructing a scatterplot using a given dataset and describing the association between variables of bivariate data

LEARNING GOALS

- Construct a scatterplot of bivariate data.
- Understand the definition of bivariate data.
- Identify patterns and trends from bivariate data.
- Determine positive/negative data correlations.
- Determine linear/non-linear data correlations.
- Determine strong/moderate/weak/no data correlations.

Why is it essential to identify an association between two variables?

- Statistics helps to understand relationships between two related variables in bivariate data.
- These relationships aid in drawing conclusions and predictions.
- Investigation of cause and effect is key in research across various fields.



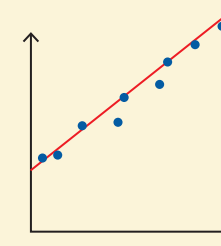
Statistics can help determine whether there is a relationship between heart rate and oxygen intake, and the ages of athletes.

WHAT YOU NEED TO KNOW

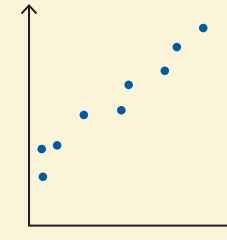
- **Bivariate data** is data for two **variables** that may have an **association**. An example is hours of study in maths and maths test scores.
- The independent variable is the one which is controlled and assumed to have an effect on the other, e.g. hours of study.
- The dependent variable is measured or observed, often being the outcome of changes to the independent variable, e.g. test score.
- The association between them is that the hours of study affects the test scores. An association is also called a relationship or **correlation**.
- A **scatterplot** is the most usual form of a graph of bivariate data, where the data points are represented by individual dots on the graph.

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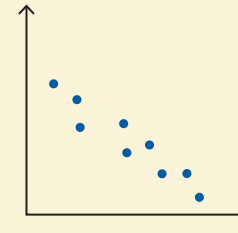
- A scatterplot is constructed with the independent variable drawn on the horizontal x-axis, while the dependent variable is drawn on the vertical y-axis.
- Each pair of bivariate data forms a data point (x, y) on the scatterplot.
- A **linear correlation** is when a graph of the data appears similar to a straight line with a slope, as shown here.



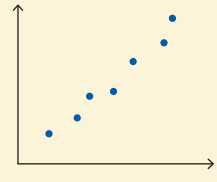
- A **non-linear correlation** is when a graph of the data produces a curve.
- A **positive correlation** means that as one data variable increases so does the other data variable As such, the graph slopes up to the right (e.g. comparing height to shoe size – the taller the person the larger the shoe size).



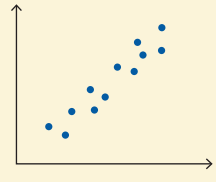
- A **negative correlation** means that as one data variable increases, the other data variable decreases As such, the graph slopes down to the right (e.g. a greater number of days with sunny weather will mean less water left in the dam due to evaporation).
- The correlations can be described as strong, moderate, weak or none depending on the scatter and how close to a straight line the data lies.



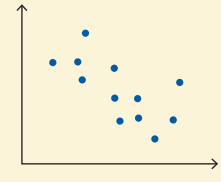
Strong correlation



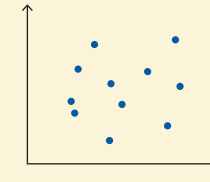
Moderate correlation



Weak correlation



No correlation



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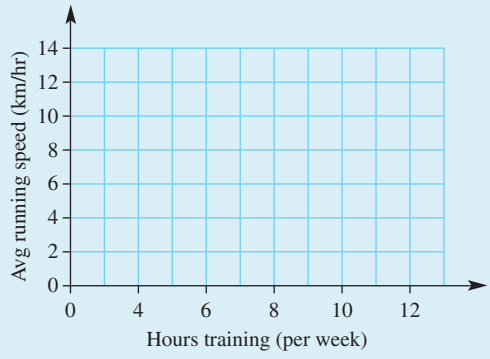
Example 8 Constructing a scatterplot from a given dataset

The following data was collected over a running training program. It collects data about training hours per week and running speed of athletes. The coach would like to analyse this data for trends. Construct a scatter plot to show this data visually.

Hours training (per week)	3	5	7	10	4	6	8	12
Avg running speed (km/h)	8	9.5	11	12	8.5	10.5	12	14.5

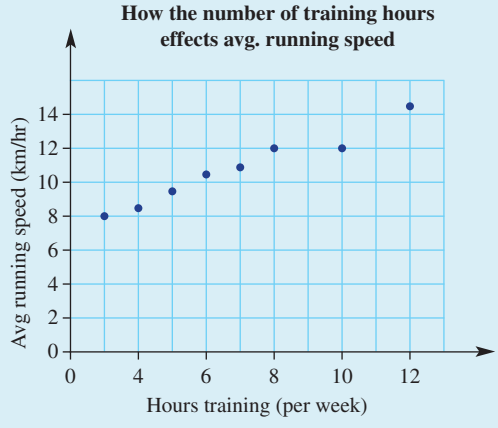
WORKING	THINKING
	Identify the independent and dependent variables to decide on the axis labels.
The independent variable will be the number of training hours and will be the *x*-axis label.	The independent variable is the variable that is set and will affect the results of the dependent variable. This will be drawn on the horizontal *x*-axis
The dependent variable that is affected by training time is the resulting ability to run fast – the average running speed. This will be the *y*-axis label.	The dependent variable will change as the independent variable changes. This will be drawn on the vertical *y*-axis.
	Determine the scale for your axis.
The *x*-axis going up by 2s will make 6 steps. The *y*-axis going up by 2s will make 8 steps.	Each axis needs to fit the range of data given and aim for between 5 and 10 steps. The *x*-axis training hours range from 3 – 12. The *y*-axis average run speed ranges from 8 – 15.

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Draw and label the axis.

Draw two perpendicular lines to represent your axis: x-axis on the horizontal; y-axis on the vertical.
Label your axis with variable data names.



Plot the data points.

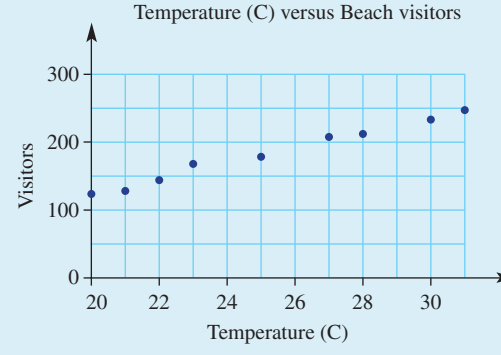
For each pair of data points (x, y), find the corresponding position on the graph and mark a dot e.g. 3 hours training per week with a running speed of 8 km is one data point with coordinates (3, 8). That is, 3 on the x-axis and 8 on the y-axis.
Repeat the process and mark a dot on the graph for each pair of data variables.
Write a descriptive title above the scatterplot to explain what the data represents.

Example 9 Describing the association of variables of bivariate data from a scatterplot

The scatterplot shown maps the temperature and visitors to the beach.

a Describe any correlations in terms of positive or negative, linear or non-linear, and strong, moderate, weak or none.

b Determine what relationship, if any, exists between temperature and the number of visitors to the beach.



... Continued

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WORKING	THINKING
a The scatterplot has a positive, linear and strong correlation.	As the scatterplot goes up from left to right, it is positive. The data is close to a straight line and is therefore linear. It is also close to a line, so it is a strong correlation.
b As the temperature increases the number of visitors to the beach also increases.	As there is a correlation, we can conclude with a statement describing the relationship between the temperature and the number of visitors to the beach.



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Example 10 Creating a scatterplot and describing the association of variables of bivariate data

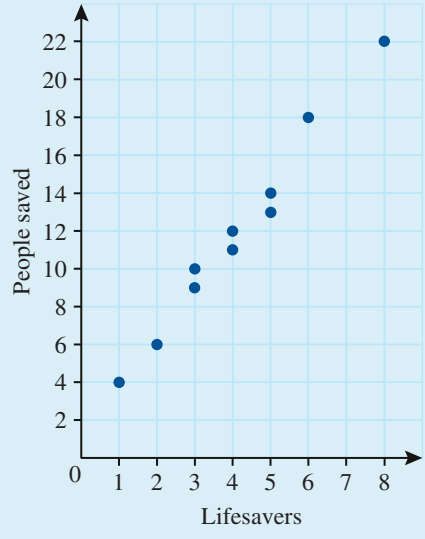
The lifesaver association wants to show that the number of lifesavers patrolling a beach affects the number of people who are saved each year.

Number of lifesavers	4	7	7	1	5	8	4	3	6	5	3
Number of people saved	12	18	6	4	13	22	11	10	19	14	9

a Using the data in the table, create a scatterplot to display the number of lifesavers and the number of people saved.

b Describe any correlation (trend) in the scatterplot in terms of direction, shape and strength of relationship.

c Explain if the number of lifesavers have an effect on the number of people saved each year.

WORKING	THINKING
	Formulate
a 	Identify the range of 'Lifesavers' and 'People saved' required to be graphed. For the graph to be large enough to display all the coordinates, choose to count by 1s on x-axis and 2s on y-axis. Plot the coordinates on the graph from the table of data points to create a scatterplot.

... Continued

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Solve

Analyse the scatterplot.

b As the scatterplot goes uphill, it is positive in direction.

◄····· *Direction:* Looking from left to right, note if the data goes uphill (positive) or downhill (negative).

In this case the shape is linear.

Shape: Looking at the pattern the data dots form, note if they are close to a straight line (linear) or otherwise (non-linear).

In this case the data is close to forming a line; it is a strong correlation.
The correlation is positive, linear and strong.

Relationship: The closer the dots are to a straight line, the stronger the relationship of the variables could be.

Evaluate and verify

We would expect that the busier a beach gets (with more people), the more life savers may need to be supervising which results in more people being saved. This highlights questionable causality. Having more lifesavers on the beach does not lead to more people needing to be rescued. Instead having more visitors on the beach leads to more lifeguards being present.

◄····· Check all data from the original table has been plotted correctly. Use a form of estimation for the data as to the expected trend. Check your resulting answer makes sense.

Communicate

c It appears that more lifesavers on patrol will result in more people being saved, however, further investigation is needed to determine if it is the number of lifeguards on duty that causes the increase in incidents, or the increased number of visitors at the beach.

◄····· As there appears to be a correlation, we can conclude with a statement describing the relationship between the number of lifesavers and the number of people saved while still questioning causality.

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Exercise 9D

FUNDAMENTALS

1 Decide if the data variables are expected to have a relationship.

a weight of cars and fuel consumption
b temperature and the cost of a textbook
c number of flowers and number of bees
d height of a door and size of door handles
e amount of rain and the size of vegetables in the garden
f length of student's hands and the length of student's feet

Hint If two variables are related, one of these should be true:
- When one of them changes, it will produce a change in the other (but not necessarily the other way around).
- When a third thing changes, it causes both of the variables to change.

2 For each part in Question **1**, identify which variable would be considered the independent (x-axis) variable.

Example 8

3 For each of the following sets of data:

i name the independent and dependent variables
ii construct a scatterplot.

a

Practice hours (per week)	Mistakes made in game
2	10
3	8
1	12
4	7
5	5
6	4
4	6
3	8
7	3
5	5
2	9
6	3

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b

Vaping frequency (days/month)	Asthma symptoms severity (out of 10)
30	10
8	5
4	4
0	0
15	6
25	8
1	1
0	1
20	8
30	10

Example 9

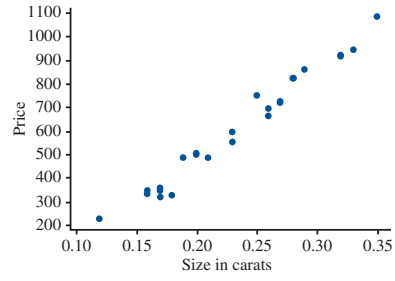
4 Describe the correlations between the variables in these graphs in terms of:

i direction (positive or negative)

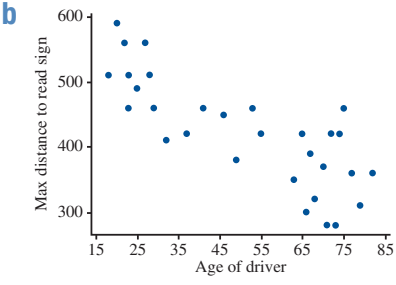
ii shape (linear or non-linear)

iii strength (strong, moderate, weak or none).

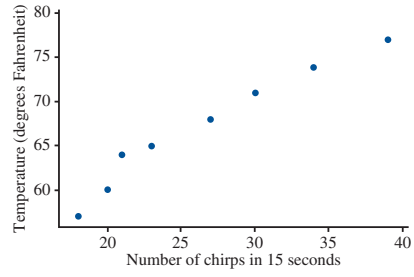
a



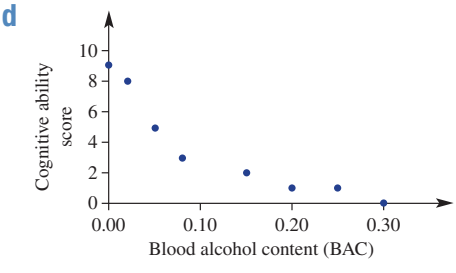
b



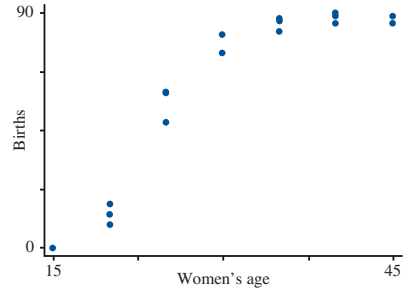
c



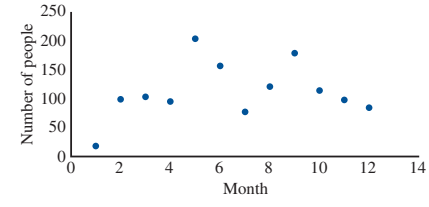
d



e



f



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Example 10

5 Construct a scatterplot using the data below. From this scatterplot determine the correlation between the data variables in terms of:

a direction (positive, negative, none)

b shape (linear or non-linear)

c strength (strong, moderate, weak or none).

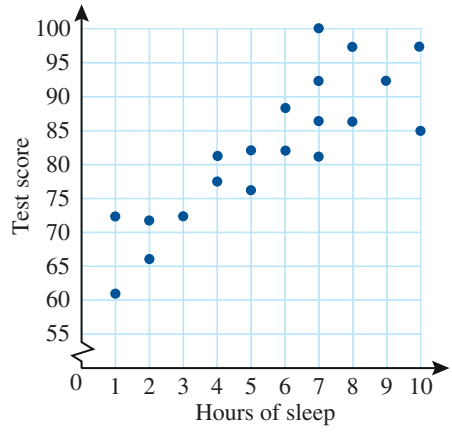
Hours studied	9	1	5	4	3	5	0	1	2
Test score	90	86	84	92	91	100	76	82	85

APPLICATIONS

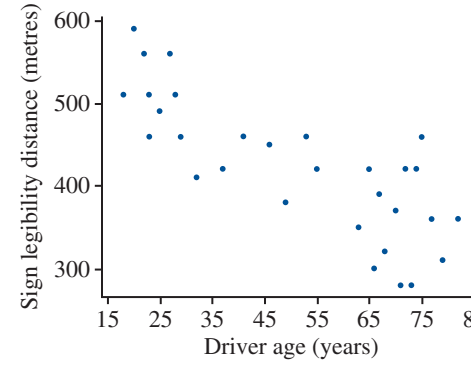
SF

★**6** The scatterplot shown below (left) maps student's test scores against their average hours of sleep per night. Describe any correlations in terms of direction, shape and strength, and determine what effect the hours of sleep have on student's test scores, if any.

Question 6



Question 7



★**7** The scatterplot shown above (right) maps the age of a driver against the distance at which they can read street signs. Describe any correlations in the terms of direction, shape and strength, and determine what effect the age of the driver has on the driver's ability to read distant street signs, if any.

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★8 It has been thought that the number of hours of playing video games per day by teenagers negatively affects their overall number of hours of sleep. Using the data in the table, create a scatterplot by hand or with technology to determine any correlations that exist between the hours per day of playing video games and the amount of sleep. Describe any correlations in terms of direction, shape and strength, and determine if the number of hours playing video games affects the teenagers' sleep.

Number of hours playing video games per day	5	0	3	2.5	6	4	3.5	8	2	5	3	1.5
Number of hours of sleep per day	7	10	8	8.5	6	8	7.5	5	8.5	7.5	8.5	9



★9 The CSIRO are examining the effects of fertiliser on the yield per crop. Using the data in the table, create a scatterplot by hand or with technology to determine any correlations that exist between the amount of fertiliser used and the crop yield. Describe any correlations in terms of direction, shape and strength, and determine if the amount of fertiliser has an effect on the crop yield.

Fertiliser (kilograms)	100	125	180	80	250	140	276	112	211
Crop yield (tonnes)	7.2	7.7	8.4	6.4	12.4	8.0	13.0	7.3	10.9

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⋆10 The police union are wanting to prove that a greater number of police serving in an area correlates with a lower incidence of crime. Using the data in the table, create a scatterplot to determine any correlation between the number of police and the incidence of crime that exists. Describe any correlations in terms of direction, shape and strength, and comment on the reasonableness of the police union's belief.

Number of police	15	21	8	14	19	31	17	12	18	9	12	14
Incidence of crime	28	16	36	24	21	19	21	26	22	31	24	26

⋆11 A survey was conducted with the school basketball team asking players how many hours per week they practised and the average points per game they scored. Using the data in the table, create a scatterplot by hand or with technology to determine any correlations that exist between the hours per week practising and the average points per week. Describe any correlations in terms of direction, shape and strength, and determine if the practice amount affects the points scored.



Hours practising per week	4	10	2	6	3.5	7	9	1	5.5	8
Average points per game	12	18	8	5	9	8	7	14	6	9

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Modelling task



Context: Sport scientists and coaches often seek to understand how accurately individuals perceive the intensity of their physical activity based on their subjective feelings of exertion compared to objective measures like heart rate. Understanding this could contribute to enhancing exercise prescription, monitoring training intensity, and optimising fitness programs for individuals based on their perceived exertion levels.

Task: To explore the correlation (relationship) between heart rate and perceived exercise intensity in individuals during physical activities such as running or rope skipping.

Stage 1: Formulate
Make an observation of: • what you are required to do • what information you will need to collect • how you will collect information • what equipment you will need to record information. Make an assumption of: • how you could gather more information • how many participants are needed for investigation • accuracy of perceived feelings of intensity • accuracy of heart rate collection method.
Stage 2: Solve
• Decide on appropriate method to collect perceived exertion information. • Estimate the expected trend in data. • Conduct necessary activities and collect the two forms of data. • Produce graphs and/or tables required to help solve the problem. • Note any trend or correlation in the data. • Decide how to deal with any outliers in data.

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Stage 3: Evaluate and verify
Check all information has been included and researched accurately. • Check you have verified estimation or expected result. • Check you have the evidence to back up your decision. • Include the evidence in the form of statements, graphs and tables. Justify your response to questions posed in context, by considering your: • assumptions • observations • limitations • strengths.
Stage 4: Communicate
Reflect on your response and solution to the investigation, outlining the decisions involved in making your response. • State your main point. • Explain the evidence.

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Chapter summary

Cartesian plane
- Line graphs and scatterplots in real-world contexts are usually based on a Cartesian plane.
- The x-coordinate is the horizontal distance on the x-axis and typically displays the explanatory (independent) variable.
- The y-coordinate is the vertical distance on the y-axis and typically displays the response (dependent) variable
- A coordinate is written by conventions as the x-coordinate first followed by the y-coordinate, in brackets: (x, y).

Linear function
- A linear function is an equation of the form $y = mx + c$ where m and c are constants.
- Complete a table of values for a linear function by substituting values for the variables into the equation.

Linear graphs
- A plotted linear graph is simply a series of points joined together with a straight line passing through the points.
- Linear graphs can be plotted by hand or using technology.

Bivariate data
- Bivariate data is data for two variables that may have an association.

Scatterplot
- A scatterplot is the most usual form of a graph of bivariate data, where the data are represented by individual dots on the graph.

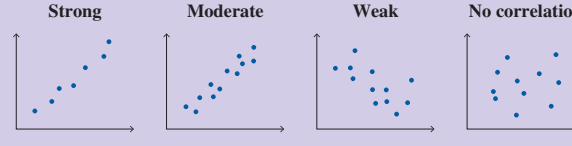
Linear correlation
- In a linear correlation, a graph of the data appears similar to a straight line.

Non-linear correlation
- In a non-linear correlation, a graph of the data produces a curve.

Negative correlation
- A negative correlation means that as one data variable increases, the other data variable decreases, so the graph slopes down to the right.

Positive correlation
- A positive correlation means that as one data variable increases, so does the other data variable, so the graph slopes up to the right.

Strength of correlation
- Correlations can be described as strong, moderate, weak or none, depending on the scatter and how close to a straight line the data lies.



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Chapter checklist

9A ☐ I can plot coordinates on the Cartesian plane in two dimensions.

1 Plot the set of points (2, −2), (1, 1), (−1, 1), (−2, −2) and (2, −2) and connect them in order. Name the shape that is made.

2 Luke starts a car cleaning business to make some extra cash. In the first month he earned $80; in the second month he earned $55; in the third month he earned $100; and in the fourth month he earned $90.

a Complete the table using the values identified in the question.

Month	1	2	3	4
Earnings $				

b Plot the coordinates (month, earnings) on a graph.

c Join the coordinates in order of time.

d Determine the month that Luke earned the most money.

e Calculate the total Luke earned in the 4 months.

9B ☐ I can generate tables for linear functions, including negative values of x.

3 Complete the table of values for the linear equation $y = 3x - 2$.

x	−2	0	2
y			

4 Delta is a fridge mechanic who charges a $40 call out fee and $70 per hour. This can be mapped by the equation $y = 70x + 40$, where x is the number of hours worked and y is the cost for the client.

a Complete the table of values for Delta's fridge repair costs.

x	1	2	3
y			

b Calculate the cost of hiring Delta for $2\frac{1}{2}$ hours.

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9C ☐ I can graph linear functions by hand and using technology.

5 Use the equation $y = 2x + 3$ to complete the following.
- **a** Complete a table of values for, $x = -2, 0, 2$.
- **b** Determine the range of x and y values needed on the graph.
- **c** Draw the graph axes and labels on graph paper.
- **d** Plot the coordinates and draw a line through the points.

6 Graph the equation $y = 2 - 3x$ using technology.

7 John is a helicopter pilot who charges a $120 fee when picking up clients plus $5 per km travelled. The helicopter costs can be described as $y = 5x + 120$, where y is the total helicopter cost and x is the number of kilometres travelled. If John picks up a client at Brisbane airport and takes them to Toowoomba, which is 138 km away, create a graph to determine how much the total fare will be.

9D ☐ I can construct a scatterplot from a given data set.

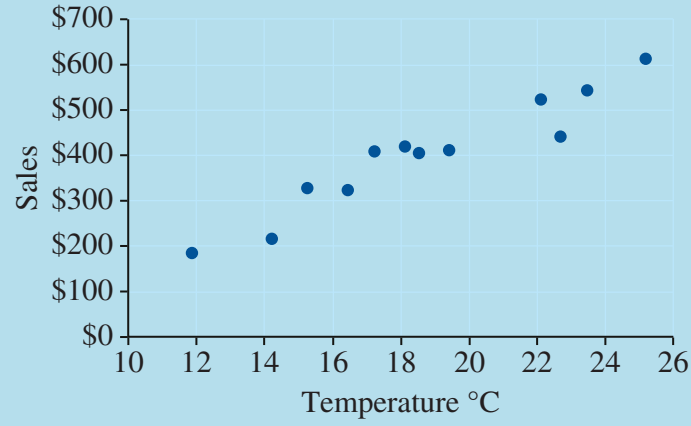
8 Archie observed that older drivers tend to own more valuable cars. To investigate, he surveyed ten drivers at his school, recording their ages and car values. Create a scatterplot using the data below:

Age (years)	22	18	35	47	52	61	49	26	17	28
Car value ($thousand)	21	10	32	33	45	57	38	25	15	27

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9D ☐ I can identify patterns in bivariate data in direction, form and strength.

9 Describe the graph shown in terms of direction, form and strength.



10 Shannon is a music teacher and wants to test the idea that listening to music improves a sense of wellbeing for students. After conducting a survey, the results below were found. Use mathematical techniques to investigate the credibility of this teacher's theory, providing reasons for your conclusion.

Hint Draw a scatterplot and describe the correlation between the data.

Listen to music (hours per week)	0	2	5	1	3	0	4	2	1	6
Sense of wellbeing (rate 1–10)	4	6	8	5	7	5	8	5	6	9

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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

9A **1** Glen has started busking with his guitar to make some extra cash. In the first month he earned $48; in the second month he earned $41; in the third month he earned $63; and in the fourth month he earned $54.



a Complete the table using the values identified in the question.

Month	1	2	3	4
Earnings				

b Plot the coordinates (month, earnings) on a graph.
c Join the coordinates in order of time.
d Determine the month that Glen earned the most money.
e Calculate the total Glen earned in the 4 months.

2 Charlette sells jewellery at the local markets each week. In week 1 she made $112; in week 2 she made $146; in week 3 she made $134; and in week 4 she made $121. Enter Charlette's income into a table of values and draw the graph. Calculate the total Charlette made in the 4 weeks.

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9B **3** Javier is a pool cleaner who charges a $20 call out fee and $38 per hour for cleaning the pool. This can be mapped by the equation $y = 38x + 20$, where x is the number of hours and y is Javier's total fee.

a Complete the table of values for Javier's fee.

x	0	1	2	3
y				

b Determine after how many hours Javier has earned more than $100.

4 Fen made $2000 selling some of their shares. If they spend $300 per week from this money until there is no money left, this can be written by the equation $y = 2000 - 300x$, where x is the number of weeks and y is the amount of money Fen has remaining.

a Complete the table of values for Fen's remaining money.

x	1	3	5
y			

b Calculate how many weeks approximately until all the money is spent.

9C **5** Hugo has purchased a mobile crane for $90 000. The crane depreciates (goes down in value) by $12 500 per year and its value can be described as $y = 90\,000 - 12\,500x$, where y is the crane's value and x is the number of years.

a Graph the equation of his crane's value.

b Determine after how many years the crane will be worth under $16 000.



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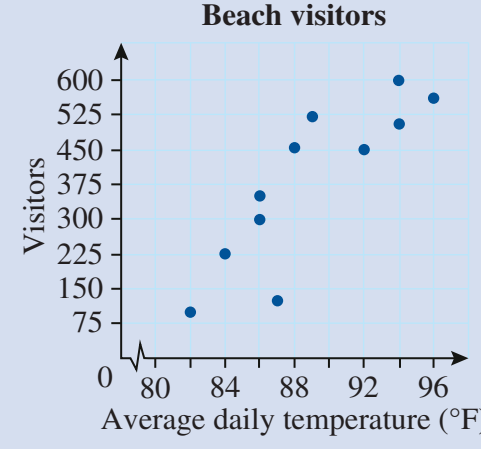
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6 Zac is a taxi driver who charges a $6.50 fee when picking up clients plus $0.90 per km travelled. The taxi fare can be described as $y = 0.9x + 6.50$, where y is the total taxi fare and x is the number of kilometres travelled. If Zac picks up a client at Cairns airport and takes them to the city, which is 8 km away, create a graph and determine the total cost of the fare.

9D **7** Mrs Miotto noticed the moods of her senior students varied from day to day and was curious as to the effect sleep hours may have on their mood. The following set of data is the results of the survey. Construct a scatterplot of the data and comment of the shape, direction and strength of any relationship between mood and sleep hours.

Average sleep (hours per night)	Mood rating (1–10)
7	8
5	5
6	6
8	9
4	4
5	7
6	6
5	5
8	8
9	9

8 The scatterplot shown maps the daily temperature at the beach and the number of visitors to the beach. Determine if any correlation exists in terms of direction, shape and strength. Comment on whether a relationship exists between the number of visitors attending the beach and the daily temperature.



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9 Climate scientists have been mapping the temperatures at Antarctica, and they have recorded the average yearly temperature and the area of the ice. Determine if any correlation exists in terms of direction, shape and strength. Comment on whether a relationship exists between the average yearly temperature and the area of the ice.



Area of Antarctic ice ('000 000 km^2)	14	13.8	13.3	13.5	13.2	12.9	13.1	12.7	12.5
Average yearly temperature (°C)	8.3	8.2	8	7.8	7.9	7.5	8	7.8	7.3

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10 Line of best fit



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In this chapter

10A Identifying the dependent and independent variables

10B Determining the line of best fit **[simple/complex]**

10C Interpreting relationships between variables **[complex]**

10D Calculating the correlation coefficient using technology **[complex]**

10E Making predictions **[complex]**

10F Distinguishing between causality and correlation **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 4 Topic 1 Bivariate graphs

Line of best fit (8 hours)

In this sub-topic, students will:

- identify dependent and independent variables
- draw a line of best fit by eye
- use technology to determine the equation of the line of best fit in the form $y = mx + c$ where m is slope (gradient) and c is y-intercept **[complex]**
- interpret the effect of the parameters m and c from the equation of the line of best fit in the form $y = mx + c$ **[complex]**
- use technology to calculate the correlation coefficient (an indicator of the strength of linear association) **[complex]**
- use the line of best fit to make predictions, both by interpolation and extrapolation **[complex]**
- recognise the dangers of extrapolation **[complex]**
- distinguish between causality and correlation through examples **[complex]**.

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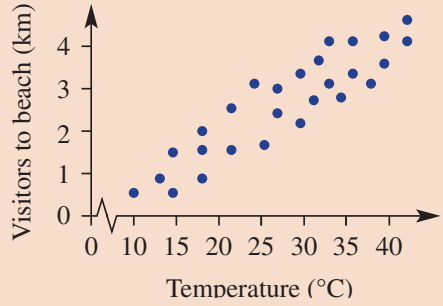
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Prior knowledge check

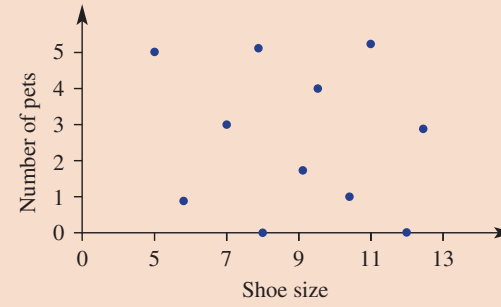
1 For each of the following scatterplots, state whether the variables appear to be related. If the variables appear to be related:

- **a** state whether the association is positive or negative
- **b** classify the association as linear or non-linear
- **c** classify the strength of the association as weak, moderate, strong or no association.

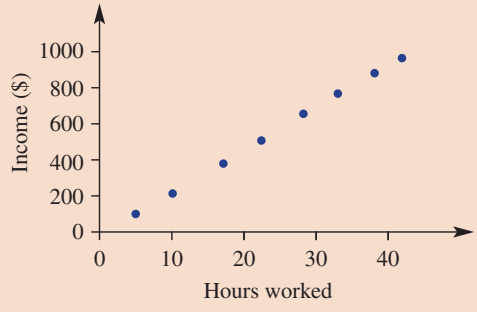
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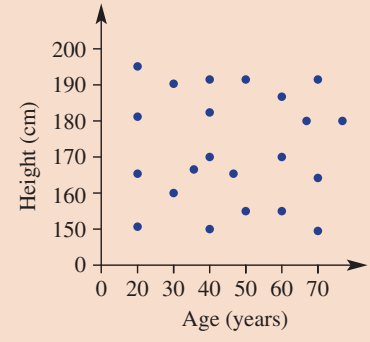
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iii



iv

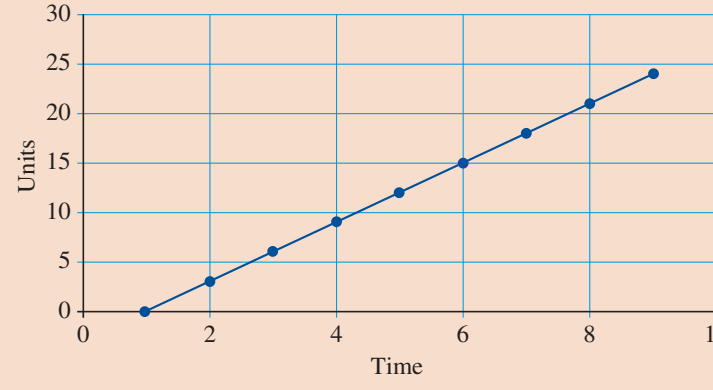


2 Create a scatterplot using the following dataset:

Hours training (per week)	3	5	7	10	4	6	8	12
Avg running speed (km/h)	8	9.5	11	12	8.5	10.5	12	14.5

3 This is a graph of a quantity against time.

- **a** Determine the number of units at time 6.
- **b** For every increase in 1 unit of time, determine the increase in the number of units.



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10A Identifying the dependent and independent variables

LEARNING GOAL

- Identify the dependent and independent variables

Why is understanding the independent and dependent variables essential?

- Bivariate data reveals a connection between two variables, indicating a potential relationship (correlation).
- It is crucial to grasp how changes in one variable (the independent one) can lead to changes in the other (the dependent one).
- This understanding is vital across various fields, including science, health, technology, education, economics and social science.



Investigating the impact of exercise (independent variable) on heart health (dependent variable).

WHAT YOU NEED TO KNOW

- A **variable** is a measure that may change.
- An **independent variable** is the variable in an experiment that we change or select in order to see what effect it has, or which changes naturally, like time or the weather. It is independent of what we are going to measure.
  - 'Independent' here does not mean independent of the researcher, because it is the thing that the researcher changes or allows to change.
- A **dependent variable** 'depends' on the independent variable.
  - It is what we measure because we think it is changed by the independent variable. It could be something that is affected in an experiment or discovered in a survey.
  - The dependent variable reacts to the independent variable.
- The independent variable is the cause and the dependent variable is the effect.
- When graphing, the independent variable is placed on the horizontal (x-axis) and the dependent variable is placed on the vertical (y-axis).
- A line of best fit could be straight (if the relationship is **linear**) or curved (if the relationship is **non-linear**). In this course we will deal mainly with linear relationships.

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Example 1 Identifying the independent and dependent variable

Sigrid is interested in how different types of stress affects a patient's heart rate.

a What is the independent variable?

b What is the dependent variable?



WORKING	THINKING
a The independent variable is the type of stress, as this can be changed by the researcher.	What can be changed by the researcher?
b The dependent variable is the heart rate, as it is dependent on the type of stress.	What will be affected? What will be responding? What will be changed by the independent variable?

Exercise 10A

FUNDAMENTALS

1 For each of the following statements write True (T) or False (F):

a A variable is a measure that may change.

b The independent variable is placed on the y-axis when graphing.

c The dependent variable is what is actually being measured and what is affected during the research.

d An independent variable is changed or allowed to change by the researcher.

e The dependent variable is placed on the x-axis when graphing.

Example 1

2 For each of the pairs of variables below, name the independent variable:

a Temperature and Ice Cream Sales

b Exam Scores and Study Time

c Rainfall and Crop Yield

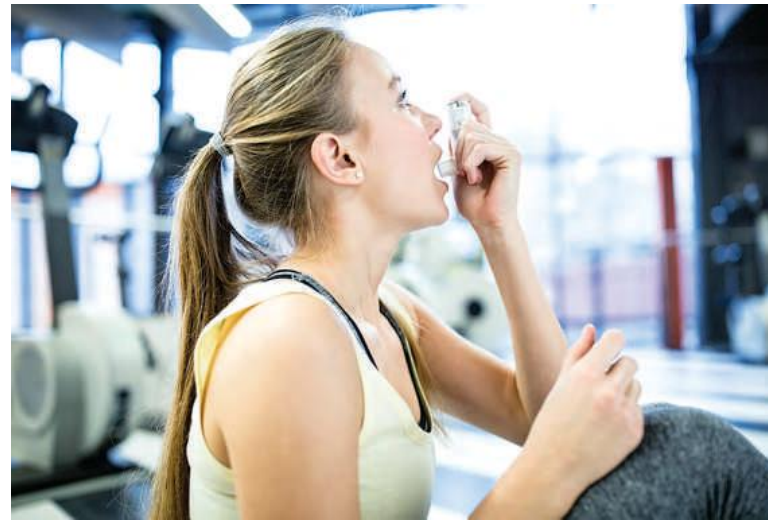
d Athletic Performance and Training Intensity

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APPLICATIONS

SF

★3 Alix is researching a new medication for asthma. She needs to alter the amount of medication given to see if the breathing rate changes.



a What could be the independent variable? Give a reason.
b What could be the dependent variable? Give a reason.

★4 Marnie is keen to see how teamwork can affect a soccer team's performance.
a What could be the independent variable? Give a reason.
b What could be the dependent variable? Give a reason.

Hint The independent variable is the variable that is not affected by the other variable in the experiment.

★5 Mira is studying how rising ocean temperatures are impacting the amount of coral in the Great Barrier Reef.
a What could be the independent variable? Give a reason.
b What could be the dependent variable? Give a reason.

★6 Ari is researching how classical music can increase children's reading ability. He sets a variety of students to listen to classical music for different times and then collects their reading results.
a What could be the independent variable? Give a reason.
b What could be the dependent variable? Give a reason.

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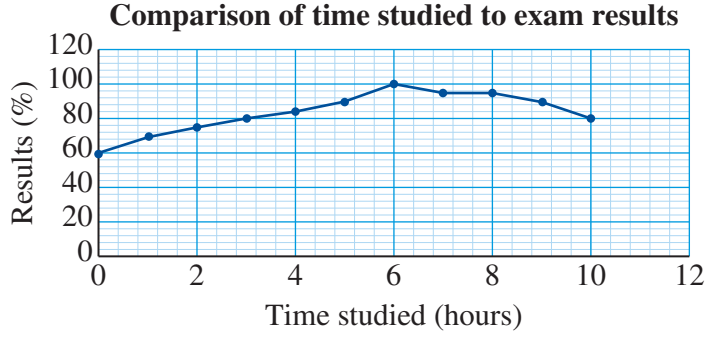
SF

★**7** The graph shows how the number of hours a group of students studied affected their exam results.



a What could be the independent variable? Give a reason. What could be the dependent variable? Give a reason.

b Suggest other independent variables for this investigation.



8 The following table gives the time in minutes it takes for a headache to respond to medication, together with the dose of the medication received by a group of 10 patients.

Dose (mg)	0.5	1.2	4.0	5.3	2.6	3.7	5.1	1.7	0.3	4.0
Response time (mins)	65	35	15	10	22	16	10	18	70	20

a Identify the independent variable. Label the horizontal axis with this variable.

b Construct a scatterplot of this data.

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10B Determining the line of best fit

SIMPLE/COMPLEX

LEARNING GOALS

Note: this section contains both simple and complex subject matter.

- Determine the line of best fit by eye.
- Use technology to create the line of best fit, and determine the equation of the line of best fit in the form $y = mx + c$. [complex]

Why is it essential to be able to determine the line of best fit by eye?

- The line of best fit informs us if the relationship between the variables is proportional; that is, if a change in the independent variable causes a proportional change in the dependent variable.



The line of best fit can help identify trends and patterns in stock price movements.

- The line of best fit is essential because it provides a concise summary of the relationship between variables, facilitates prediction and modelling, and helps identify outliers in the data.

WHAT YOU NEED TO KNOW

- Most bivariate data that is collected results in a **scatterplot** rather than a neat line graph. This is because in the real world it can be hard to get accurate measurements and hard to prevent other factors from affecting your measurements.
- A **line of best fit** (or trend line) is a straight line that best represents the data on a scatterplot.
- The line of best fit shows the general direction of the change in the dependent variable in response to changes in the independent variable. The closer the scatterplot points are to the line of best fit, the stronger the possible relationship (correlation) of the two variables.

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- When drawing a line of best fit by eye, start by placing your ruler on its edge in the position you think the line should be, so you can easily see the dots on either side. Aim to balance an approximately equal number of points above and below the line. It may pass through some of the points or none of the points on the graph.
- The line of best fit can be found with technology using Excel, spreadsheets or Desmos. Using technology also gives you the equation of the resulting line of best fit.
- The equation of the line of best fit is in the form $\boldsymbol{y = mx + c}$, with m being the gradient or slope of the line and c being the y-intercept.

Example 2 Drawing the line of best fit by eye

Liv is working in a café and suspects that there is a relationship between the outside temperature and her sales of hot chocolate. She has recorded the recent data in a table.

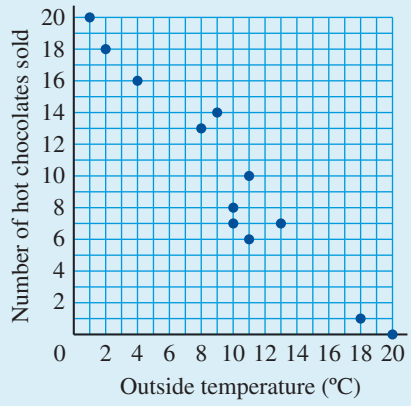
Outside temperature °C	20	18	10	11	13	10	11	8	9	4	2	1
Number of hot chocolates sold	0	1	8	6	7	7	10	13	14	16	18	20

a Determine the independent and dependent variables.
b Draw a scatterplot by hand.
c Draw the line of best fit by eye.

WORKING	THINKING
a Independent variable is Outside temperature, as it is what is changing naturally in the environment and is not affected by sales of hot chocolate. Dependent variable is Number of hot chocolates sold, as that is what is expected to change when the temperature changes.	Determine the independent variable (thing that is controlled by researcher or environment) and the dependent variable (thing that is predicted to change based on the independent variable).

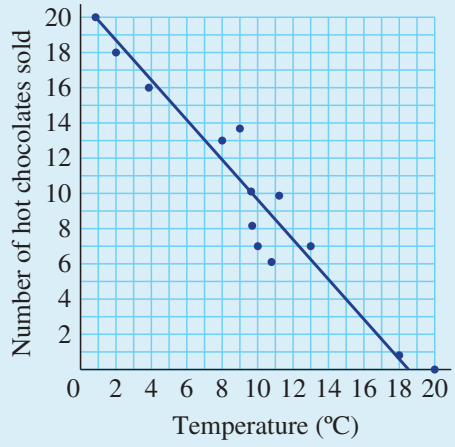
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b



◄···· Use grid paper. Place the independent variable on the *x*-axis. Place the dependent variable on the *y*-axis. Plot the points.

c



◄···· Using your ruler, draw a line through the scatterplot, ensuring that as many data points are above the line as below it and that it follows the trend of the data.

Example 3 Using a spreadsheet to create the line of best fit and determine its equation [complex]

Nate has noticed a relationship between the age of a person and the amount of emails they receive per day.

Age (years)	50	64	23	25	24	72	26	47	60	30	70	28
Number of emails per day	14	10	28	27	24	5	27	15	7	28	7	26

Use a spreadsheet to:

a Graph the data in a scatterplot

b Create the line of best fit

c Determine the equation of the line of best fit.

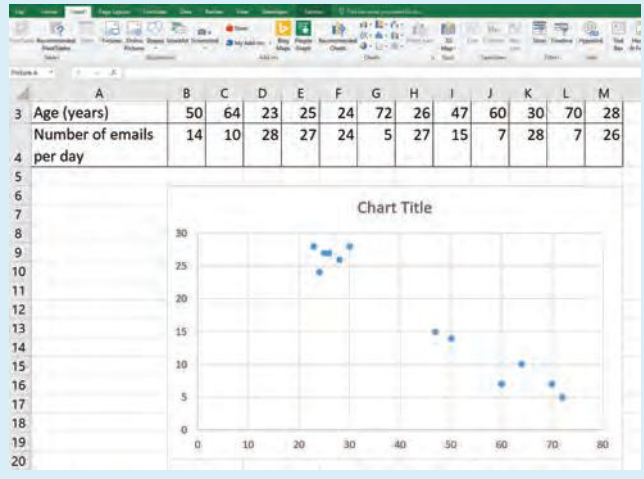
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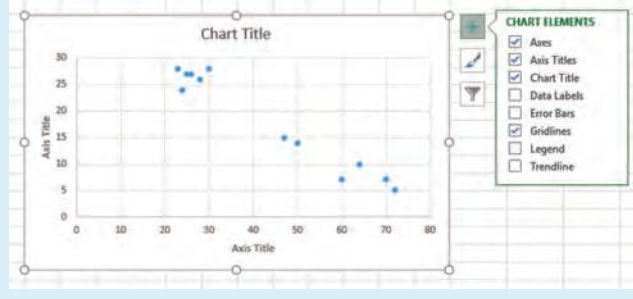
WORKING	THINKING
a	

	A	B	C	D	E	F	G	H	I	J	K	L	M
2													
3	Age (years)	50	64	23	25	24	72	26	47	60	30	70	28
4	Number of emails per day	14	10	28	27	24	5	27	15	7	28	7	26
5													

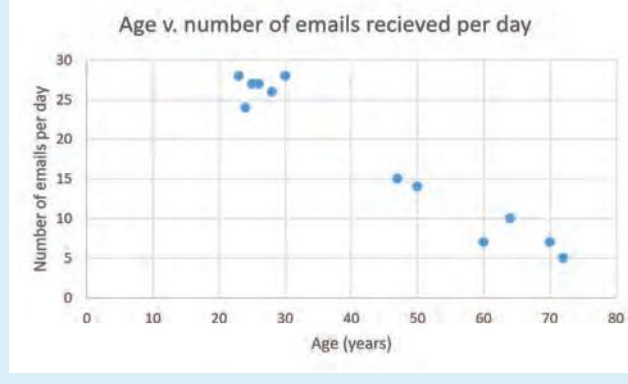
◄··· Type data into spreadsheet cells.



◄··· Select the data. Click on the Insert tab > Charts > Scatter.



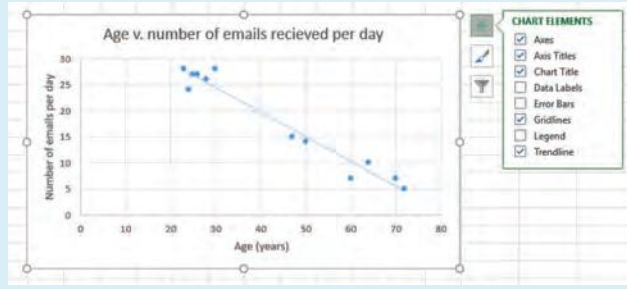
◄··· Click on chart to bring up the + icon. Click Axis Titles.



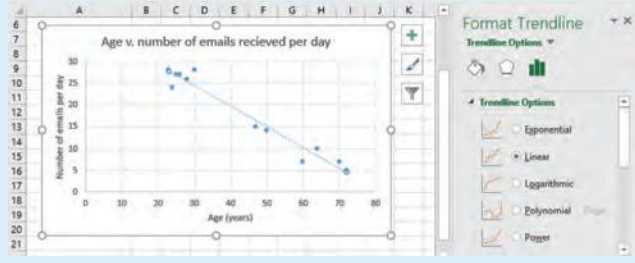
◄··· Insert titles.

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b

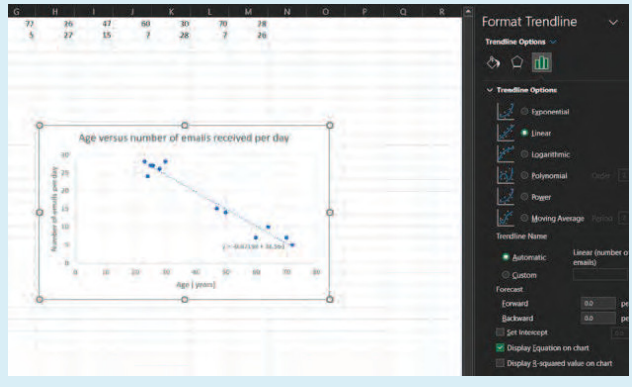


◄··· To find and create the line of best fit, click on the chart to bring up the + icon. Click Trendline.



◄··· Right click the trendline. Format Trendline. Adjust the settings.

c



◄··· To add a label showing the equation of the line of best fit (trendline): in the Format Trendline settings, scroll to click on a box labelled 'Display equation on chart'.

Desmos Activity: See the interactive textbook for an example and activity based on using the Desmos graphing calculator to fit a line to a scatterplot.

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Exercise 10B

Note: *It is suggested in Questions 2–4 that the line of best fit be done by eye. The rest of the questions in the exercise could be done by eye, with a spreadsheet, with Desmos, or with another technology. Check with your teacher.*

FUNDAMENTALS

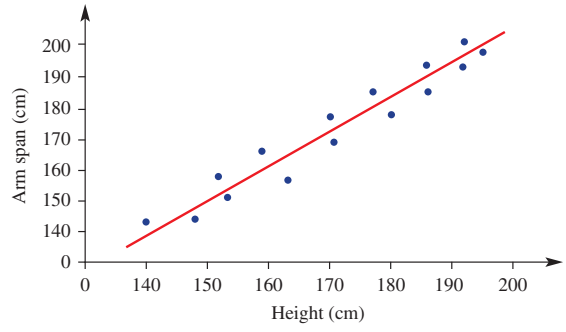
1 Analyse the line of best fit drawn on the following scatterplots and determine:

i the independent and dependent variables

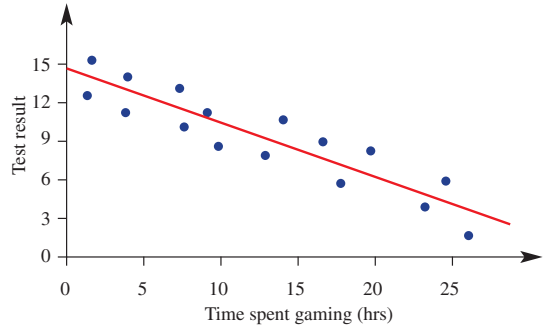
ii the direction of the line of best fit

iii the strength of the relationship between the variables.

a



b



APPLICATIONS

Example 2

2 Felicity is studying a type of soft coral that is often found in cooler waters, and she has collected the following data in an attempt to find out if the coral is more plentiful in cooler southern seas compared to tropical waters.

Ocean temp (°C)	19	18	20	27	30	17	27	31	24
Number of corals per 100 m^2	140	160	122	40	12	154	19	2	80

a Determine the independent and dependent variables.

b Create a scatterplot by hand.

c Draw the line of best fit by eye.



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SF

3 Sonia is training for a marathon and is recording her training times.

Time (min)	25	40	35	37	90	40	115	35	95
Distance (km)	6	10	15	10	20	15	25	10	20

a Determine the independent and dependent variables.
b Create a scatterplot by hand.
c Draw the line of best fit by eye.

4 Blood pressure and age are critical indicators of cardiovascular health. When doctors analyse these variables together, they can gain valuable insights into a patient's risk of various health conditions. The following data has been gathered from 10 patients:

Age	45	60	35	70	50	25	55	40	66	31
Blood pressure-systolic (mmHg)	120	140	110	152	133	117	135	128	148	119

a Determine the independent and dependent variables.
b Create a scatterplot of the data.
c Draw the line of best fit by eye.
d Describe the direction and strength of relationship between the variables.

Hint Remember to have approximately half of the points above and half of the points below the line of best fit.

Spread-sheet

Spreadsheet 10B Q5–6 The data is available in a spreadsheet in the Interactive Textbook.

See the note at the start of this exercise about which method to use for these questions. The data is available in a spreadsheet in the Interactive Textbook.

★**5** Deb wants to see if there is a relationship between a group of people's annual salaries and how many years of work experience they have. She has collected the following data.

Years of experience	15	45	35	25	5	30	30	40	45	20	3	3	5	30	25
Annual salary ('000)	25	80	100	30	80	55	85	110	90	80	25	20	30	100	75

a Create a scatterplot of the data by hand or using technology.
b Create the line of best fit by hand or by using technology.



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Spread-sheet

Spreadsheet 10B Q6–8 The data is available in a spreadsheet in the Interactive Textbook.

Example 3 ★6 Kay has been a nurse at a health centre for over 20 years and has noticed a relationship between children's height at 2 years and at 18 years. She has collected the following data.

a Create a scatterplot of the data using technology.

b Create the line of best fit using technology.

c Determine the equation of the line of best fit using technology.



2 yo height (cm)	85	83	87	81	83	88	84	85	86	83	85	80	88
18 yo height (cm)	157	167	171	160	162	172	167	170	170	164	165	159	171

7 Char volunteers as a surf life saver and has noticed a relationship between the average temperature and the amount of people on the beach. She collects the data below with the thought that it may help in planning how many lifesavers to have on duty according to the temperature forecast for each day. Using technology:

a Create a scatterplot of the data.

b Create the line of best fit.

c Determine the equation of the line of fit best.

Average temperature (°C)	23	28	25	34	29	35	27	37	26	29	28	30	36
Number of people on the beach	70	84	74	98	87	115	80	112	78	88	84	92	109



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Spread-sheet

8 Leanne is writing a report about the relationship between a city's height (m) above sea level and its average yearly rainfall (mm). Using technology: CF

a Create a scatterplot of the data.

b Create the line of best fit.

c Determine the equation of the line of best fit.

City	Average yearly rainfall (mm)	Height above sea level (m)
Armidale	900	80
Orange	800	230
Bathurst	180	670
Goulburn	170	640
Toowoomba	275	600
Canberra	280	580
Alice Springs	300	580
Ballarat	690	450
Tamworth	680	400
Kalgoorlie	265	380

9 Research towns in your local area for similar data to Question **8** and comment on any similarties or differences found. CU

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10C Interpreting relationships between variables

COMPLEX

LEARNING GOALS

- Interpret relationships in terms of the variables.
- Interpret parameters from the equation of the line of best fit.

Why is being able to interpret relationships between variables essential?

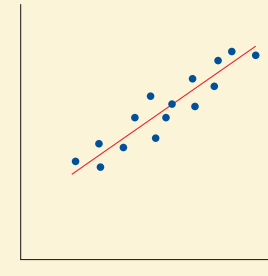
- Graphing bivariate data merely provides a visualisation - it is important to say what that data means.
- Failing to analyse results can lead to misunderstandings, missed opportunities and wasted resources, ultimately diminishing the impact and credibility of your research.
- It could also mean you present the incorrect results from your data.



Bivariate data analysis in a business context can provide valuable insights into marketing expenditure and sales performance.

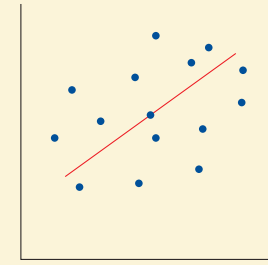
WHAT YOU NEED TO KNOW

- A **correlation** is a measure of the strength of the linear relationship between two variables.
  - The correlations can be described as strong, moderate, weak or none, depending on how close the points are to the line of best fit.
- When looking for a relationship:
  - the closer the points cluster to the line of best fit, the stronger the relationship that exists between the two variables, and there is most likely a correlation (i.e. **strong correlation**)

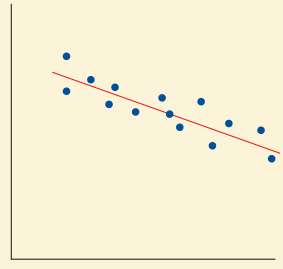


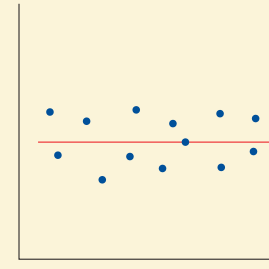
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- the further the points are from the line of best fit, the weaker the relationship that exists between the two variables, and therefore the less likely it is that there is a correlation (i.e. **weak correlation**).



- When the points rise from lower left to upper right, as in the graphs above, there is a **positive correlation** (if x increases, y increases).
- When the points fall from upper left to lower right, there is a **negative correlation** (if x increases, y decreases).
- When the line of best fit is horizontal, there is **no correlation**.





- The **equation of the line of best fit, $y = mx + c$**, has the parameters "m" and "c". Together, these parameters define the slope and position of the line of best fit, which is a representation of the relationship between the variables.
- The **slope m** determines the steepness or gradient of the line. The magnitude of m represents how steep or gradual this change is.
- The ***y*-intercept c** is the point where the line intersects the y-axis. In other words, it is the starting point of the line. It indicates the value of y when no independent variable (x) is present.
- For example, consider $y = 2x + 3$. The line has a slope of 2, meaning it rises 2 units for every 1 unit increase in x. The line intersects the y-axis at $y = 3$, meaning it starts at the point $(0, 3)$ on the graph.

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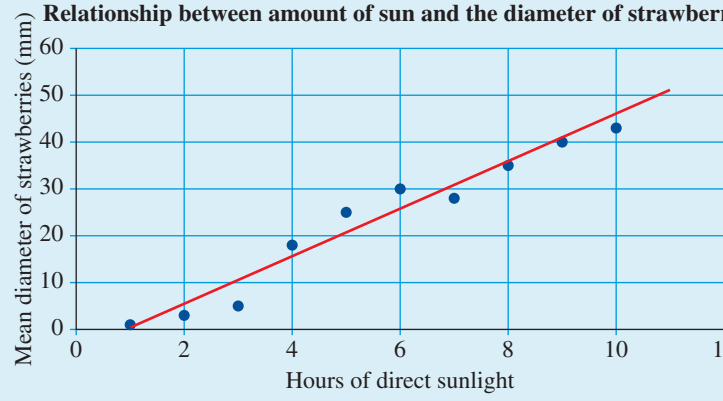
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Example 4 Interpreting relationships in terms of the variables [complex]

Erica owns a strawberry farm. She is collecting data to see if there is a relationship between the amount of direct sun and the diameter of her strawberries. She has exposed different plants to different hours of direct sunlight. All plants are then placed in the same shade to make up to a total of 12 hours of daylight. She gathered the following data after measuring the strawberries and taking the mean diameter.

Amount of direct sunlight per day (hours)	1	2	3	4	5	6	7	8	9	10
Mean diameter of strawberries (mm)	1	3	5	18	25	30	28	35	40	43

This scatterplot and line of best fit for the data has been created.



a Determine which is the independent variable and which is the dependent variable.
b Describe any correlations in terms of positive or negative, linear or non-linear and strong, moderate, weak or none.
c Interpret the relationship between the amount of sunlight and the diameter of the strawberries, and explain what it means for the strawberry farm.

WORKING	THINKING
a The independent variable is the amount of direct sunlight, as Erica changes it for the experiment. The dependent variable is the diameter of the strawberries, as the amount of sunlight can change the growth of the strawberries.	◄···· Which variable possibly causes a change in the other variable?

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b The correlation is positive, linear and strong.

◄···· The line of best fit goes up from left to right; therefore, it is positive.
The points follow a definite line; therefore, it is linear.
The points are close to the line of best fit; therefore, there is a strong correlation.

c There is a strong relationship between the amount of sunlight and the diameter of the strawberries.
As the duration of sunlight increases, the diameter of the strawberries increases. Longer exposure to direct sunlight causes larger strawberries to grow.
If Erica wants larger strawberries, she should expose her strawberries to direct sunlight for longer.

◄···· As there is a strong correlation, there is a relationship between the variables, which can be interpreted as direct sunlight causing larger strawberries to grow.

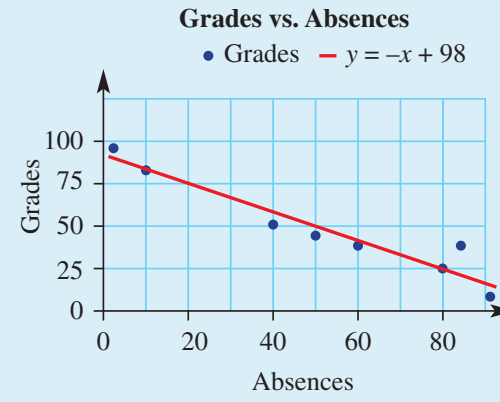


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Example 5 Interpreting relationships using the parameters of the equation of the line of best fit [complex]

Ty is a deputy of a school and is noticing a relationship between student absences and their grades. He has collected data and created the following scatterplot and line of best fit with technology.
Analyse the equation of the line of best fit and use it to interpret the relationship between the number of days absent and the grades achieved.
Explain how the deputy might use this information.



WORKING	THINKING
	Formulate
The independent variable is the number of days absent, as it is not affected by the grades. The dependent variable is the grades. The equation of the line of best fit is given as $y = -x + 98$.	Gather information presented in the question. Identify information from the graph, including the variables and equation of the line of best fit.
	Solve
The correlation is negative, linear and strong.	Interpret the line of best fit. The line of best fit goes down from left to right; therefore, it is negative. The points follow a definite line and is therefore linear. The points are close to the line of best fit; therefore, there is a strong correlation.
The parameters for the line of best fit using $y = mx + c$: m, the slope, is -1, and c, the starting point when x is zero, is 98.	Analyse the parameters for the line of best fit using $y = mx + c$, where m is the slope of the line and c is the intercept of y value when x is zero.

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Evaluate and verify

The slope of the regression line predicts that, on average, the grade decreases by 1% for each additional day absent.
The y-intercept value of 98 predicts that, on average, the grade is 98 when days absent is zero.

◄···· Use logic and an estimation tool to predict outcomes. Check the mathematics with your estimate.

Communicate

The data confirms the suspicion that increased absenteeism negatively affects grades. The deputy principal can use this data and act on it to improve overall academic performance. One example might be a system to flag high absentee students and a tailored program to support them to catch up.

◄···· Use mathematics to verify how this information can assist the deputy principal



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Exercise 10C

FUNDAMENTALS

APPLICATIONS

Example 4

1 Lee organises a rodeo once a year and is wondering if there is a relationship between the age of the rodeo riders and the number of injuries at the rodeo.



Age of riders (years)	35	30	25	15	20	23	32
Number of injuries	18	14	13	8	12	14	16

a Determine which is the dependent variable and which is the independent variable.

b Create a scatterplot.

c Determine the line of best fit.

d Describe any correlations in terms of positive or negative, linear or non-linear, and strong, moderate, weak or none.

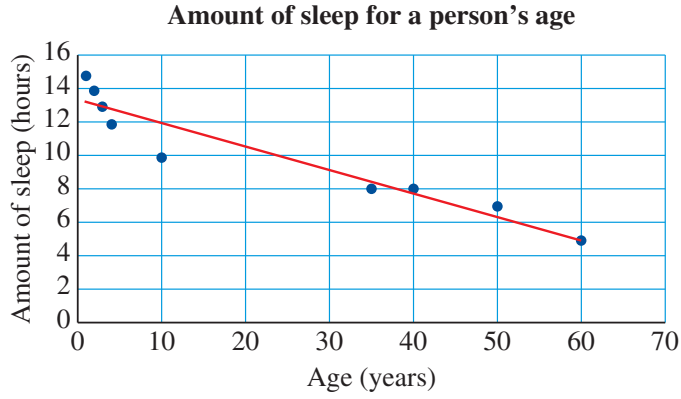
e Interpret relationships between the age of the rider and the injuries sustained.

f Explain how a rodeo rider might use this data.

Hint When the points rise in a line going from lower left to upper right, there is a positive correlation (if x increases, y increases).

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2 Eleanora has collected data to see if there is a relationship between a person's age and the number of hours of sleep they have each day. She has created this scatterplot and line of best fit from the data.



a Determine which is the dependent variable and which is the independent variable.

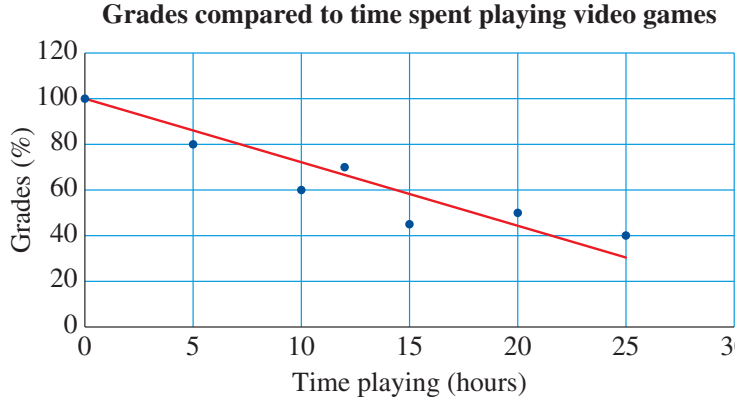
b Describe any correlations in terms of positive or negative, linear or non-linear, and strong, moderate, weak or none.

Hint When the points fall in a line from upper left to lower right, there is a negative correlation (if x increases, y decreases).

c Interpret the relationship between the age and amount of sleep.

d Explain how this information might be used.

3 A teacher is trying to prove to his students that there is a relationship between hours spent playing video games and their grades. She has created this scatterplot and line of best fit from the data.



a Determine which is the dependent variable and which is the independent variable.

b Describe any correlations in terms of positive or negative, linear or non-linear, and strong, moderate, weak or none.

c Interpret relationships between time spent playing games and the grades achieved.

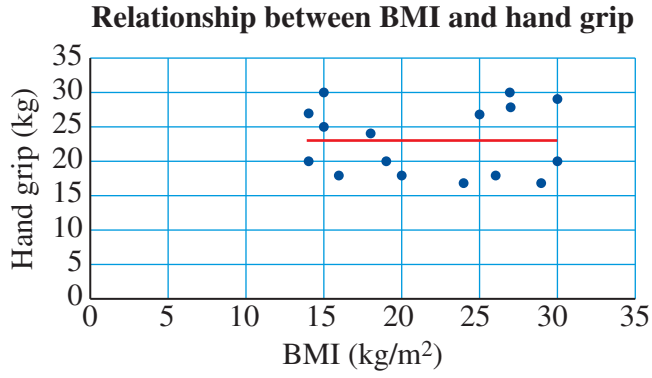
d Explain how the teacher could use this information.

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CF

★**4** A group of people were measured by a researcher to see if there is a relationship between hand grip strength and BMI. She has created this scatterplot and line of best fit from the data.



a Interpret relationships between the BMI and hand grip.

b Explain how this information could be used.



5 Consider the equation of the line of best fit for each graph below and answer these questions:

i Identify the gradient (slope) $\boldsymbol{m}$.

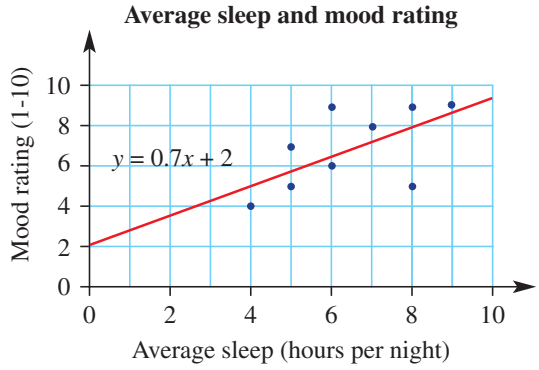
ii Identify whether the gradient is positive or negative and explain what this means for the variables.

iii Identify the y-intercept $\boldsymbol{c}$.

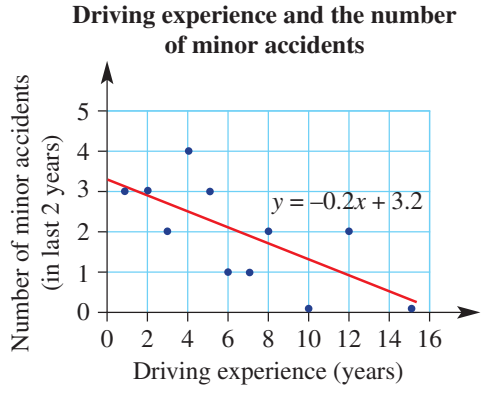
iv Explain, using the variables, the meaning of the value $\boldsymbol{c}$ in part **iii**.

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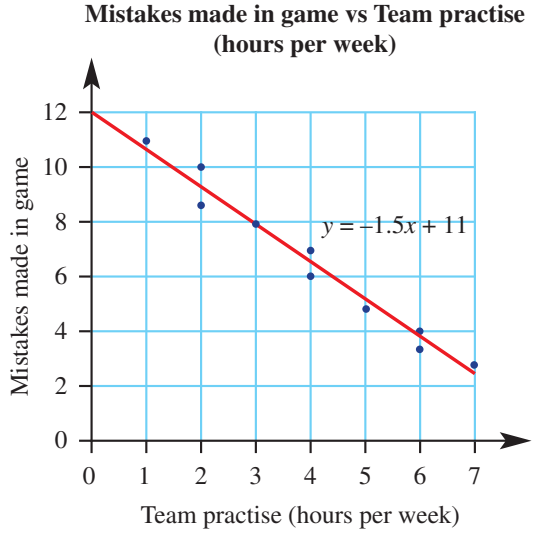
a



b



6 Consider the following scatterplot showing data from a rugby team season.



Hint BMI stands for body mass index and is a measure of weight and height.

a Determine which is the dependent variable and which is the independent variable.

b Describe any correlations in terms of positive or negative, linear or nonlinear, and strong, moderate, weak or none.

c Interpret the parameters of the equation of the line of best fit in terms of relationship between the team's training hours and mistakes made in games.

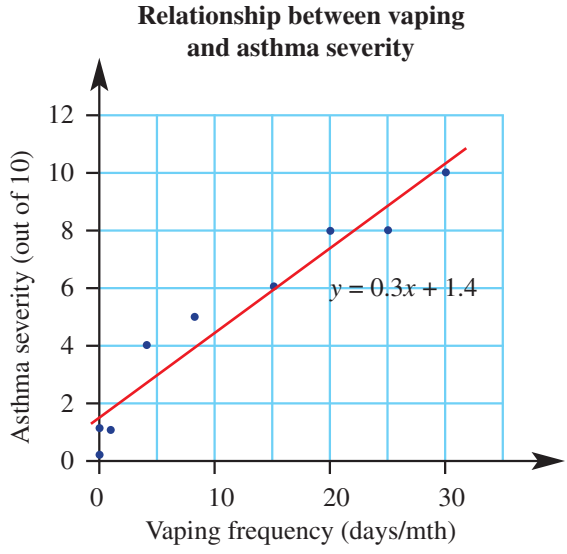
d Explain how the relationship information could be useful.

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CU

★7 Natalie is a sports teacher who wants to teach her students about the effect of vaping on asthma symptoms. After researching the topic, she found data for 10 teenagers diagnosed with asthma who had been surveyed about vaping habits. Natalie created the following scatterplot with line of best fit using spreadsheets.



Analyse the parameters of the equation of the line of best fit, and use them to interpret the relationship between the vaping and asthma severity. Explain how the sports teacher might use this information.



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10D Calculating the correlation coefficient using technology

COMPLEX

LEARNING GOAL

- Use technology to find the correlation coefficient (an indicator of the strength of linear association).

Why is finding the correlation coefficient essential?

- **Provides precision:** Unlike visual inspection of the line of best fit, the correlation coefficient offers an exact measurement of correlation.
- **Supports research and development:** It is crucial in scientific and mathematical work for accurate data analysis and decision-making.
- For example, in science, finding the correlation coefficient between temperature and bacteria growth gives a precise measure of how strongly temperature affects disease-causing bacteria to grow.



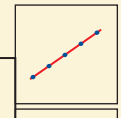
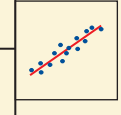
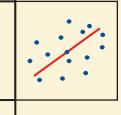
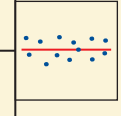
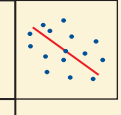
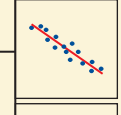
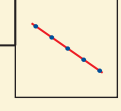
The correlation coefficient shows the degree to which points on a scatterplot lie on a line of best fit.

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WHAT YOU NEED TO KNOW

- Correlation tells us about the strength of the linear relationship between two variables.
  - To measure correlation and the strength of the relationship, we calculate the correlation coefficient.
- The **correlation coefficient** is based on the degree to which points on a scatterplot lie on a line of best fit.
  - The correlation coefficient has the symbol (r), which measures the strength and direction of a linear relationship between variables.
  - The value of r is always between $+1$ and -1.
  - To interpret the correlation coefficient, use the following as a guide:

Value of correlation coefficient	Typical scatterplot	Interpretation
+1		1: perfect positive correlation
0.75		0.75 to 0.99: strong positive correlation
		0.5 to 0.74: moderate positive correlation
0.50		0.25 to 0.49: moderate positive correlation
0.25		
		Above 0 up to 0.24: weak or no positive correlation
0		0: no correlation
		Below 0 down to –0.24: weak or no negative correlation
–0.25		–0.25 to –0.49: moderate negative correlation
–0.50		
		–0.5 to –0.74: moderate negative correlation
–0.75		–0.75 to –0.99: strong negative correlation
–1		–1: perfect negative correlation

- To calculate the correlation coefficient, use a scientific calculator, a spreadsheet or other technology.

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Example 6 Using technology (scientific calculator) to calculate the correlation coefficient [complex]

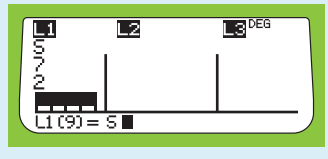
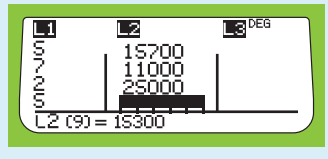
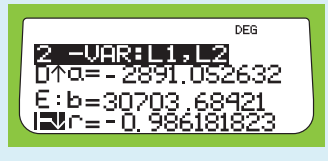
Dan is a used car salesman and needs to understand if there is a relationship between the value of cars and their age. He has collected the following data.

Age (years)	6	3	4	1	8	5	7	2	5
Value	13 000	21 000	18 000	29 800	9 000	15 700	11 000	25 000	15 300

a Use technology (a scientific calculator) to determine the correlation coefficient for the data showing the value of cars with respect to their age in years.

b Interpret the meaning of this value of the correlation coefficient (r).

Note: TI-30XB scientific calculator used for this example. See online resources for steps on other calculators.

WORKING	THINKING
a	Press stat data to get to the tables to enter data. Press stat data 1 to clear away any old data in column 1, press data 2 to clear column 2 etc.
	◄···· Type age of car in L1.
	◄···· Type value of car in L2.
	◄···· Press 2nd stat data 2 to get into 2-Variable Statistics:
The correlation coefficient for this data is $r = -0.986$.	◄···· Arrow down to CALC and press enter Arrow down to find r (correlation).

... Continued

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b $r = -0.986$
The correlation between the age of cars and their value has a very strong, negative relationship. This means that as the age of a car increases, the value of a car decreases.

◄···· Is the correlation positive/negative? Is the correlation strong/moderate/weak/none?
The correlation is very strong, as it is very close to being -1.

Calculator activity 10D Using a scientific calculator to find the correlation coefficient. See the interactive textbook for this activity.

Example 7 Determining and interpreting the correlation coefficient in a real-world context using technology (Excel)

A not-for-profit organisation against gambling advertising is researching the affect that advertising has on the number of gamblers in another country compared to Australia. The following data was researched for that country:

Year	Advertising Expenditure (in millions)	Number of Gamblers (in millions)
2019	450	3.5
2020	500	3.6
2021	550	3.7
2022	620	3.9
2023	600	3.9
2024	670	4.1

Using technology, create a graph to illustrate the relationship between advertising expenditure and the number of gamblers. Use calculations to measure the strength and direction of this relationship, and explain what the results reveal about how advertising spending affects the number of gamblers.

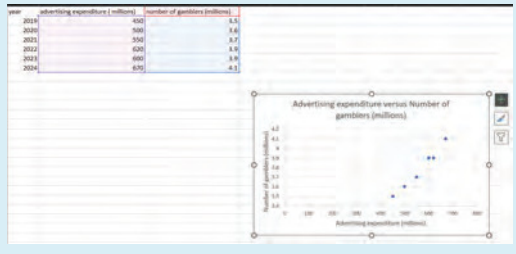
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WORKING	THINKING
	Formulate
Create a graph with technology - a scatter plot using Excel or spreadsheets makes sense with two variables. To investigate the strength and direction of any relationship, find the line of best fit, including the equation and correlation coefficient (r).	Observe what the question asks. Make assumptions of the calculations needed.
	Solve
	Open a new Excel document. Enter Data: use information given in the question to list data in separate columns on spreadsheet.

A	B	C
year	advertising expenditure (millions)	number of gamblers (millions)
2019	450	3.5
2020	500	3.6
2021	550	3.7
2022	620	3.9
2023	600	3.9
2024	670	4.1

A	B	C
year	advertising expenditure (millions)	number of gamblers (millions)
2019	450	3.5
2020	500	3.6
2021	550	3.7
2022	620	3.9
2023	600	3.9
2024	670	4.1

Highlight the columns for expenditure and number of gamblers and click on **Insert**, **Charts**, **Scatter**.



Click on the graph produced and click on + button. Click '***Axis titles***' and insert title names.

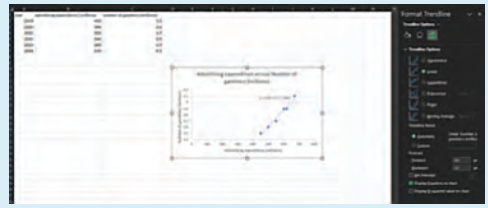


To find and create the line of best fit, click on the chart to bring up + icon. Click box '***Trendline***'.

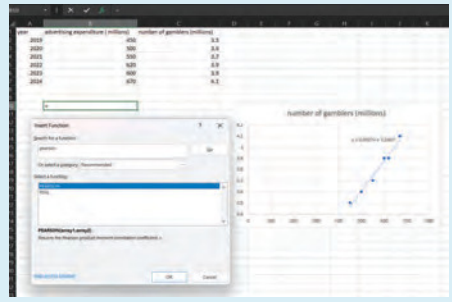
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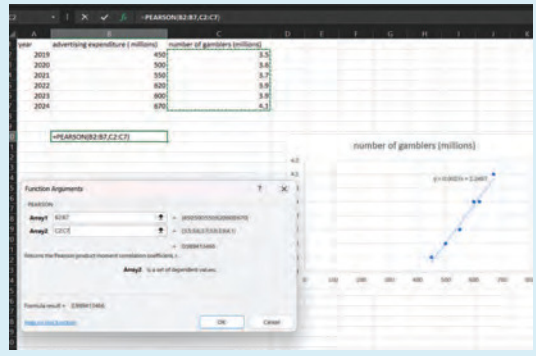
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◄···· To determine and display the equation of the line of best fit, click on the setting of ***trendline*** and scroll to the tick box '***Display equation on chart***'.



◄···· Select another cell. Select ***Formulas***, ***Insert Function***, and write '***Pearson***'. Click OK.



◄···· Select the independent values in ***Array One B2:B7***.
Select the dependent values in ***Array Two C2:C7***.
Click OK and the *r* value will appear in the chosen cell.

advertising expenditure (millions)	number of gamblers (millions)
450	3.5
500	3.6
550	3.7
620	3.9
600	3.9
670	4.1
0.989413466	

◄···· Use an estimating technique to predict the relationship of variables.

$r = 0.989$

Evaluate and verify

Given that both variables increase, one would expect a positive relationship, which is verified by the graphs.

◄···· Strength and relationship of variables:

The line of best fit goes up from left to right, therefore it is positive.

◄···· Consider the direction of the line of best fit from left to right.

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The points follow a definite line; therefore, it is linear.	◄···· Analyse if the data points follow a definite line.
The points are close to the line of best fit, so it is a strong relationship.	◄···· Analyse if the data points are close to the line of best fit.
The equation of the line of best fit (rounded values): $y = 0.003x + 2.2$.	◄···· Interpret the parameters of the equation ('m' and 'c').
$m = 0.003$ so for each increase in x (additional 1 million in advertising expenditure) the y (number of gamblers) goes up, on average, by 0.003 million or 3000 people.	◄···· **slope *m*** determines the steepness or gradient of the line
$c = 2.2$ when x (expenditure) is zero, y (number of gamblers) is 2.2 meaning there are still 2.2 million gamblers when no money is spent on advertising.	◄···· ***y*-intercept *c*** is the point where the line intersects the y-axis. In other words, it is the starting point of the line.
The correlation coefficient of $r = 0.99$ (rounded), which is positive.	◄···· Interpret the correlation coefficient 'r'. Is the correlation positive/ negative?
The correlation is strong, as it is close to being +1.	◄···· Is the correlation strong/ moderate/weak/none?
	Communicate
The equation and the correlation coefficient show that spending more on advertising leads to more gamblers. It highlights how important marketing is in getting people to participate in gambling activities	◄···· Explain your findings and express your answer to the question: Does advertising spending affect the number of gamblers?

Spread-sheet

Spreadsheet activity 10D Using a spreadsheet to find the correlation coefficient. See the Interactive Textbook for this activity.

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Exercise 10D

FUNDAMENTALS

1 Given the correlation coefficient (r), describe the relationship in terms of strength (weak, moderate, strong) and direction (positive, negative), or simply label it as 'no relationship'.

a -0.54 **b** 0.78 **c** 0.97 **d** -0.65
e -0.98 **f** 0.62 **g** 0.21

APPLICATIONS

Example 6

2 Kylie is wondering if there is a relationship between the number of hours worked per week and the average assessment result in their senior class. The following results were collected:

Work (hours per week)	12	6	20	9	24	8	14	27	5	10
Average grade (%)	87	88	75	78	72	92	83	68	80	90

a Use (calculator) to determine the correlation coefficient for the data to three decimal places.
b Interpret the meaning of this value of the correlation coefficient (r).

⋆3 Charlie is wondering if there is a relationship between time spent studying for assessments and the amount of errors she makes in her assessments. She has collected the following data.

Hint A lot of people are confused by the word 'negative', as in 'strong negative relationship'. This just means that as one variable increases, the other decreases. It is not always negative in the sense of being a bad thing.

Assessment study time (min)	52	24	26	45	39	28	60
Assessment errors	3	16	15	7	10	14	1

a Use technology to determine the correlation coefficient for the data to three decimal places.
b Interpret the meaning of this value of the correlation coefficient (r).

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★4 A tailor has been told that there is a relationship between the height and weight of men. He has collected the following data.

Hint Remember when using a scientific calculator to always clear away any old data.

Men's height (m)	1.5	1.2	1.7	2	1.4	1.8	1.3	1.7	1.6
Men's weight (kg)	77	90	82	95	92	106	105	94	68

a Use technology to determine the correlation coefficient for the data.
b Interpret the meaning of this value of the correlation coefficient (r).



Example 7

5 A doctor has collected data on the age of her patients with a certain condition and number of sick days they have been forced to take in the past year.

Age of patients (years)	25	60	38	24	45	58	30	40	65	40
Number of days sick	20	5	15	20	10	7	5	12	8	18

a Use a spreadsheet to create a scatterplot of the data, including a line of best fit.
b Use a spreadsheet to determine the correlation coefficient for the data.
c Interpret the meaning of this value of the correlation coefficient (r).

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Example 7

Spread-sheet

6 Deb has noticed that whenever she goes in the sun, the following day she has a better sense of wellbeing. She has collected the following data to see if there is a relationship. Deb measured wellbeing on a scale from 1 to 10, with 10 being 'feeling excellent' and 1 being 'feeling low'.

CF

Feeling of wellbeing (1–10)	10	2	5	7	4	3	9	8	10	9
Time in the sun each day (min)	20	5	7	15	2	5	18	16	20	18

Create a graph to illustrate the relationship between variables. Use calculations to measure the strength and direction of the relationship, and interpret the meaning.

Spread-sheet

7 Create a graph to illustrate the relationship (if any) between music tempo and running speed data in the given table. Then, use calculations to explain what the results reveal about music tempo and running speed.

CU

Hint
Formulate
Solve
Evaluate
Communicate

Music tempo (BPM)	**Running speed (km/h)**
100	8.5
120	9.2
130	9.8
140	10.5
150	11.2
160	11.8
170	12.5
180	13.2
190	13.8
200	14.5

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10E Making predictions

COMPLEX

LEARNING GOALS

- Use the line of best fit to make predictions, both by interpolation and extrapolation.
- Recognise the dangers of extrapolation.

Why is understanding how to use the line of best fit essential?

- Finding the equation of the line of best fit allows for precise predictions. It enables predictions of values within and beyond the existing data range.
- It is crucial for making informed decisions and advancing research knowledge.



The purpose of creating a line of best fit for data and finding its equation is to be able to make predictions from it.

WHAT YOU NEED TO KNOW

- The **correlation coefficient** is a measurement of the relationship between two variables, as well as the strength of that relationship.
- A **line of best fit** enables a prediction about the data to be formed.
- A **prediction** in this context is a forecast of the value of the dependent variable based on a value of the independent variable, even though neither value was in the original dataset.
- The equation of the line of best fit, in the form $y = mx + c$, can be used to calculate prediction values for y as x changes.
- **Interpolation** is an estimation of a value on the line of best fit. The accuracy of prediction by interpolation generally depends on the strength of the correlation: stronger correlations mean more accurate predictions.

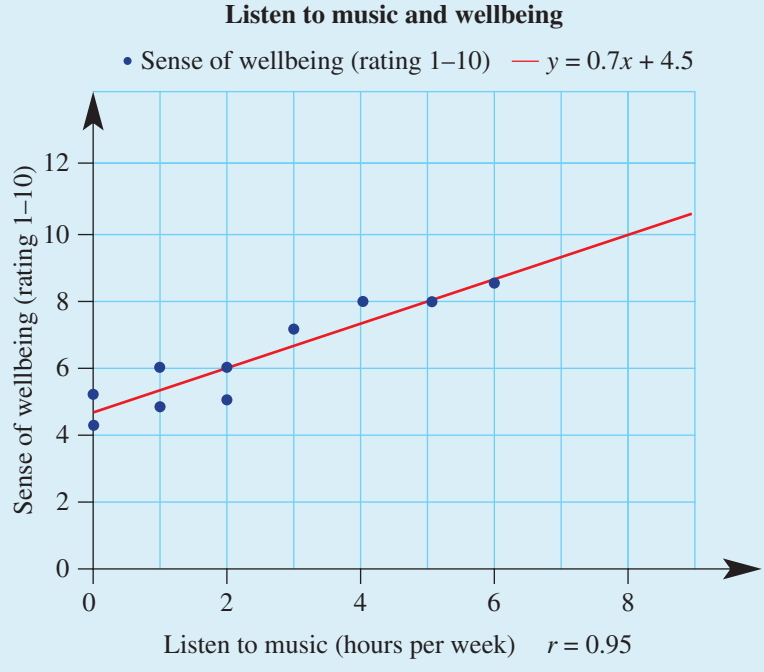
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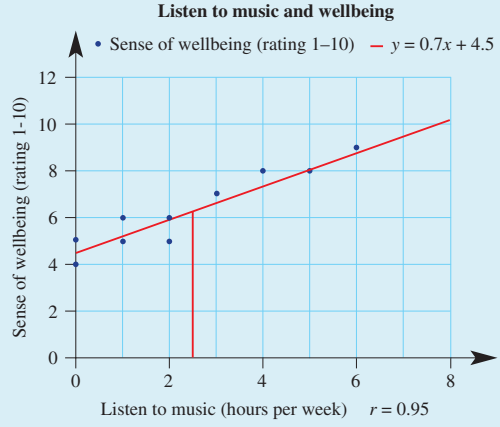
- **Extrapolation** is an estimation of a value based on extending the line of best fit.
  - To extrapolate is to infer something that is not within the range of the particular dataset used to determine the line of best fit.
  - The accuracy of a prediction made by extrapolation is also affected by the strength of the correlation, as with interpolation. In addition, the danger of extrapolation is that there may be natural reasons why the straight line of best fit is not valid beyond the range of the dataset.
- Where the independent variable is time, for example the years when something had a particular monetary value, the main danger of extrapolating is that unknown future events could affect the future value.

Example 8 Using the line of best fit to make predictions, both by interpolation and extrapolation [complex]

Consider the following graph for the variables wellbeing and listening to upbeat music.
Use the equation of the line of best fit to make interpolation and extrapolation statements about the relationship between music and wellbeing.



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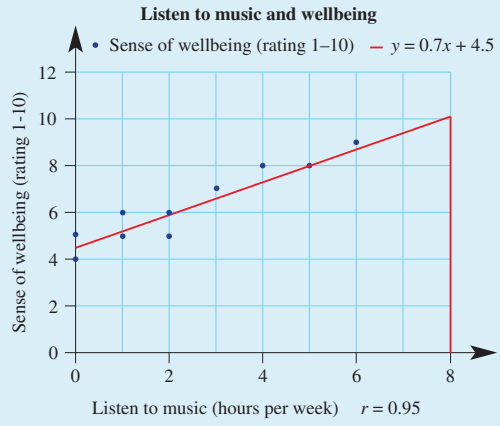
WORKING	THINKING
	Formulate
This is a strong positive relationship, so prediction within the range of data should be reliable.	Note the strength and direction of the relationship, $r = 0.95$, which will affect ability to use it for accurate predictions.
$y = 0.7x + 4.5$.	Note that the equation for line of best fit is given:
	Solve
Using the graph and physical line of best fit:	Interpolation - predicting within the data range. Reading from the graph: follow along the x-axis to choose a value, then go up to the line of best fit and read across off the y-axis.
	
Using substitution into the equation: for 2.5 hours of listening to upbeat music, $x = 2.5$ $y = (0.7 \times 2.5) + 4.5$ $= 1.75 + 4.5$ $= 6.25$	Substitution check: choose a value for x (any number of hours listening to upbeat music not already given) and substitute into the equation for the line of best fit.

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Using the graph and physical line of best fit:



◄···· Extrapolation - predicting outside of data range. That is, using the line of best fit (either the physical line or the equation) to predict a new value outside the given range.

Using substitution into equation:
For 8 hours of listening to upbeat music,
$x = 8$
$y = (0.7 \times 8) + 4.5$
$= 5.6 + 4.5$
$= 10.1$

Substitution check: Choose a value for x any number of hours listening to upbeat music not already given outside of data range and substitute into the equation for the line of best fit.

Evaluate and verify

Interpolation prediction is believable and fairly reliable due to the strong correlation and the range of data researched.

Extrapolation results predict a value for wellbeing above what is possible in a 1−10 rating and thus do not make sense.

◄···· Check calculations are correct. Although the equation allows us to calculate for different values of x, do they always make sense?

Communicate

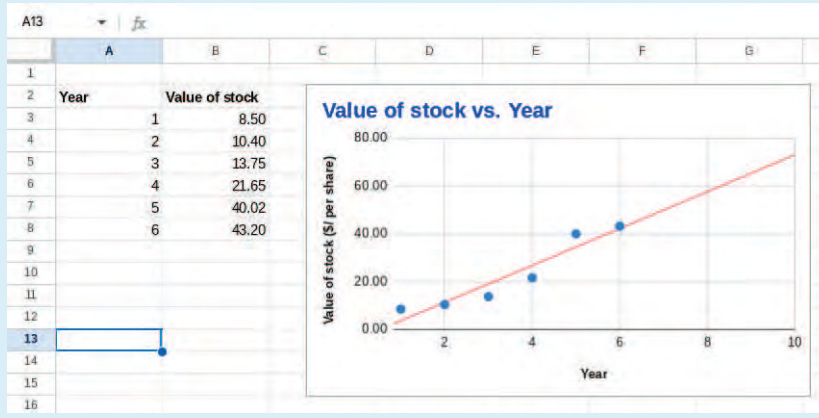
The line of best fit allows us to fairly accurately predict wellbeing ratings with different music listening in the range of 0-6 hours. However, any values above 6 hours could involve other factors that may affect results. This highlights the dangers of extrapolation.

◄···· Give a statement about the predictions available from this data set.

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Example 9 Recognising the dangers of extrapolation [complex]

A stock broker was watching the increase of a particular company's stock. He put the past five year's values in a table and also created a graph.



The broker then predicted the stock values in the next two years. Determine the dangers of the predictions.

WORKING

Although there is a strong positive correlation for the given data, we do not know why the stock has been increasing in value over the past five years, so we cannot be sure that this trend will continue. The stock market is unstable, and future events may differ from the past, meaning stock prices cannot be reliably predicted (extrapolated) outside of given data.

THINKING

Is the stock market stable, i.e. could unknown future events affect the value of the stock in the future?

Note: The actual stock that this example was taken from did fall. Their 8th year value was $2354, and their 9th year was $1840.



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Exercise 10E

FUNDAMENTALS

1 Define using everyday language:
- **a** Interpolation.
- **b** Extrapolation.

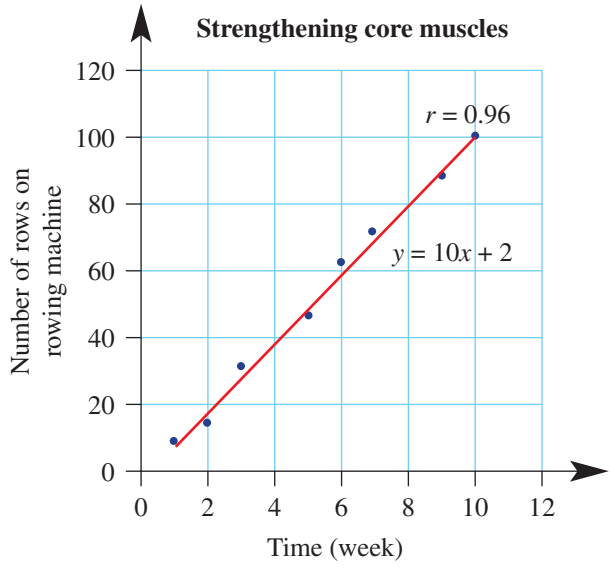
2 Determine which dataset A, B or C would be the most reliable based on the correlations stated. Explain your response.
- **A** $r = -0.94$.
- **B** Moderate positive.
- **C** $r = 0.12$.

3 Determine which dataset A, B or C would be the least reliable based on the correlations stated. Explain your response.
- **A** Weak linear negative.
- **B** $r = 0.75$.
- **C** Strong positive.

APPLICATIONS

Example 8

4 Yvonne has injured her core muscles. To gain strength she has been using a rowing machine. The line of best fit shows her progress after 10 weeks.



CF

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a Using interpolation, estimate the number of rows she was most likely to be able to do in week 4 of her program.

b Yvonne has also forgotten which week she was able to row 80 times. Using interpolation, estimate the week she rowed 80 times.

Hint The closer to ± 1 the correlation coefficient is, the more reliable the predictions using the line of best fit.

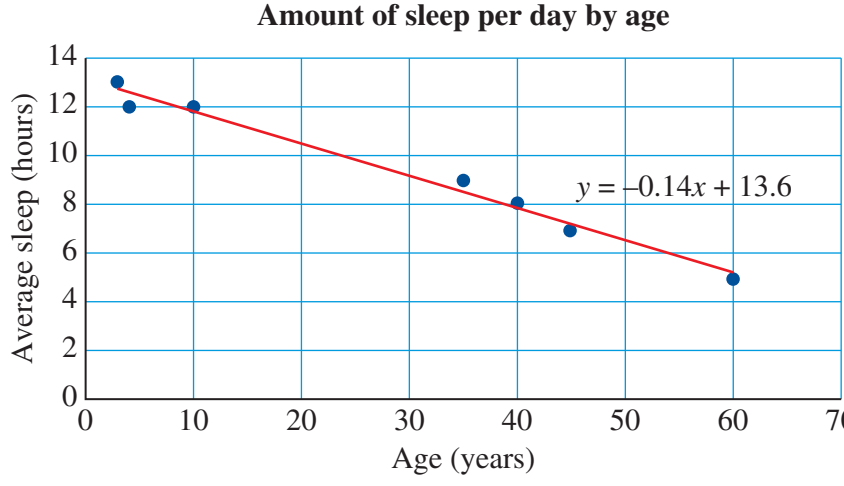
c Using the correlation coefficient, comment on the reliability of your answers in **a**. and **b**.

d Using extrapolation with the equation of the line of best fit, predict how many rows Yvonne will be able to achieve by week 15.

e Comment on the reliability of your answer in **c**.



5 Kent is researching the relationship between sleep and age; however, he has lost a section of his data.



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a Using interpolation, estimate the average amount of sleep required for someone who is 25 years old.

b Using interpolation, estimate on average the age of people who have 6 hours sleep per day.

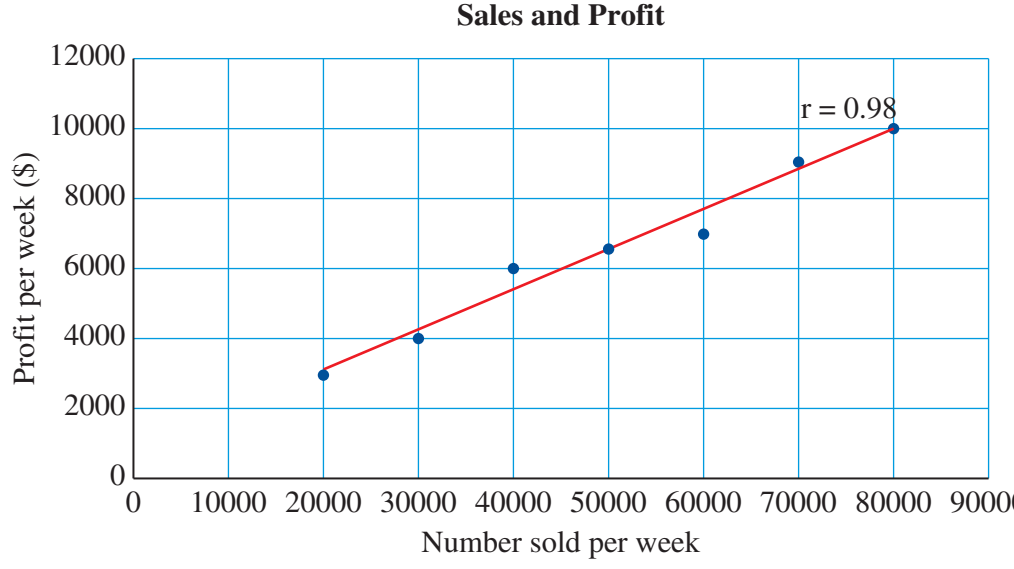
c Use the equation of the line of best fit to predict what how much sleep, on average, an eighty-year-old has.

d Explain how reliable the prediction in part **c** is.



Example 9

6 A business owner is wanting to sell a young couple part of his business and is using extrapolation above 80 000 sales per week from the following chart to enhance his sales pitch. Explain how extrapolation in this situation could be dangerous.



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7 A teacher has collected data and produced this graph to try to convince his students that there is a relationship between the study time for an assessment and the number of errors they make in the assessment.

Study time (hours)	22	27	61	38	52	30	43
Assessment errors	18	16	3	10	5	14	8

Construct an appropriate graph of the data using technology. Then use a method of prediction to give statements of interpolation and extrapolation, including a justification of their reliability.



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10F Distinguishing between causality and correlation COMPLEX

LEARNING GOAL

- Distinguish between causality and correlation through examples.

Why is it essential to understand the difference between causality and correlation?

- Two variables can be related without one causing the other to change. It is essential to understand the difference between causation and correlation.
- Common reasons that correlation does not imply causation include coincidence or the possibility that both variables are influenced by a third variable.



An association between two things does not necessarily mean one caused the other.

WHAT YOU NEED TO KNOW

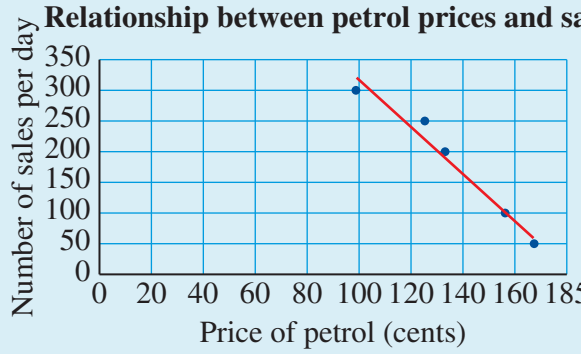
- **Causation**, or causality or a causal relationship, is the ability of one variable to impact another.
  - The first variable may cause the value of the second variable to change.
  - Only when the change in one variable causes the change in another variable is there a causal relationship.
- **Correlation** is a measure of the strength of the relationship between two variables.
- Correlation does not imply causation.
  - Correlation does not explain why and how there is a relationship; it just reveals that a relationship may exist.
  - Causation is also known as cause and effect. Distinguishing between a causal relationship and an association without causation is often a matter of common sense, but sometimes you cannot be certain of the answer and more research is needed.

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Example 10 Distinguishing between causality and correlation (causality) [complex]

Guy works at a petrol station and has noticed a relationship between the price of petrol and the number of sales in a day.





a Determine if there is a correlation between the two variables. Explain your answer.

b Determine if it is likely that there is causality between the two variables. Explain your answer.

WORKING	THINKING
a There is a strong negative correlation between the price of petrol and the number of sales per day. As the price of petrol increases, the number of sales decreases.	Does the graph show a correlation?
b It is likely that there is causality, as people will find another supplier or wait for the petrol prices to go down before they purchase petrol. The price affects the number of sales.	Is there a cause and effect between the two variables?

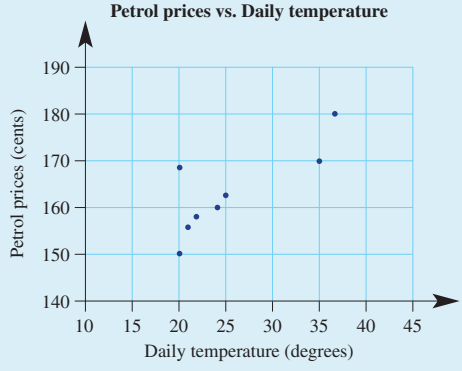
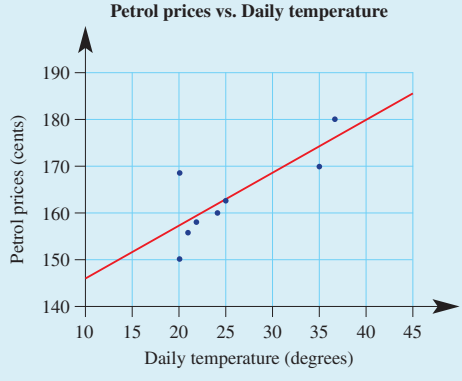
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Example 11 Distinguishing between causation and correlation [complex]

Using the collected data below, comment on with justification if there is a relationship: between the two variables.

Daily temperature	20	21	24	25	20	35	36	22
Petrol prices	150	155	160	162	168	170	180	158

WORKING	THINKING
	Formulate
For bivariate data, use a scatterplot with line of best fit and correlation coefficient to check for a relationship.	Consider the data given. Make assumptions about what graphs and calculations could demonstrate a relationship between two variables.
	Solve
	Produce scatterplot and calculations for the data given. Graph - using technology or by hand, produce a scatterplot with daily temperature on the x-axis and petrol prices on the y-axis.
	Using technology or by hand, produce a line of best fit and note the direction.
Line of best fit shows a positive and linear relationship.	
$r = 0.80$ correlation coefficient shows a strong relationship.	Calculate correlation coefficient using technology and note strength of relationship.

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Evaluate and Verify

The graph and calculation suggest a relationship between the variables, as expected: the data in the table did appear to have two increasing variables. This correlation does not mean there is causation.
There are many other variables that determine the change in petrol prices, for example supply demand, location, and exchange rates.

◄···· Does the graph show a correlation? Is this expected with data?
Is there a cause and effect between the two variables? Is there a mechanism whereby a change in maximum daily temperature can cause the prices to change?

Communicate

While there is a correlation between temperature and petrol prices, we cannot establish causation without further investigation into the underlying factors at play. There are many factors which could influence petrol prices; any observed relationship with temperature might be coincidental.

◄···· Explain your mathematical findings in words and conclude if there is correlation and causation.



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Exercise 10F

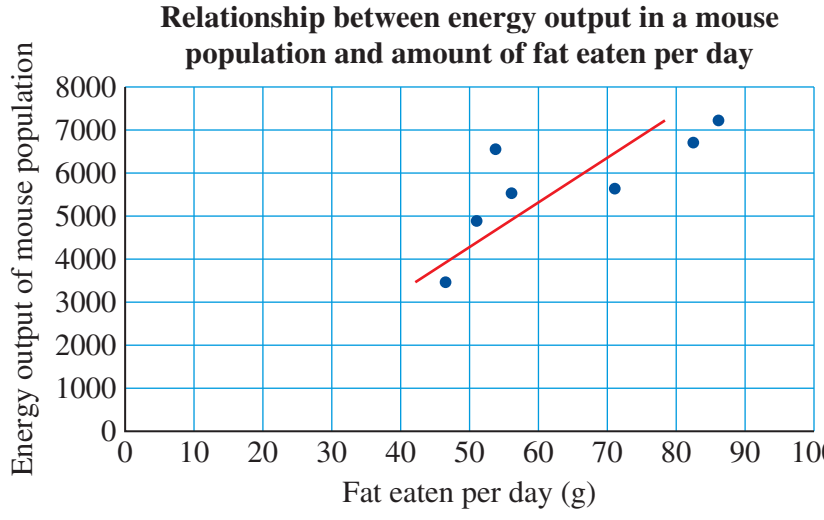
FUNDAMENTALS

1 Define using everyday language:
- **a** Correlation.
- **b** Causation.

APPLICATIONS

Example 10

2 Ella is researching the relationship between fat in the diet of laboratory mice and their energy output. Using laboratory equipment, she has obtained the data shown in the graph.



- **a** Determine if there is a correlation between the two variables. Explain your answer.
- **b** Determine if there is causality between the two variables. Explain your answer.

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Example 11

3 A local employer was curious about the effect coffee consumption has on staff. The following results were collected from the seven staff members.

Coffee consumption (cups per day)	2	1	3	4	0	2	3
Levels of productivity (score 1–10)	7	5	8	8	5	6	7

a Use technology to graph the data. Include a line of best fit with the equation and the correlation coefficient for the data.

b Evaluate if there is a correlation between the two variables. Explain your answer.

c Evaluate if there is causality between the two variables. Explain your answer.

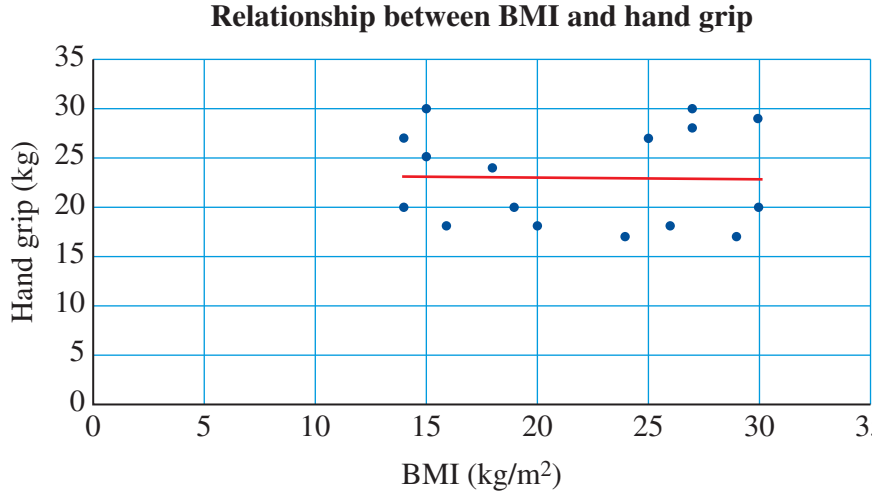
Hint Is there a cause and effect between the two variables?



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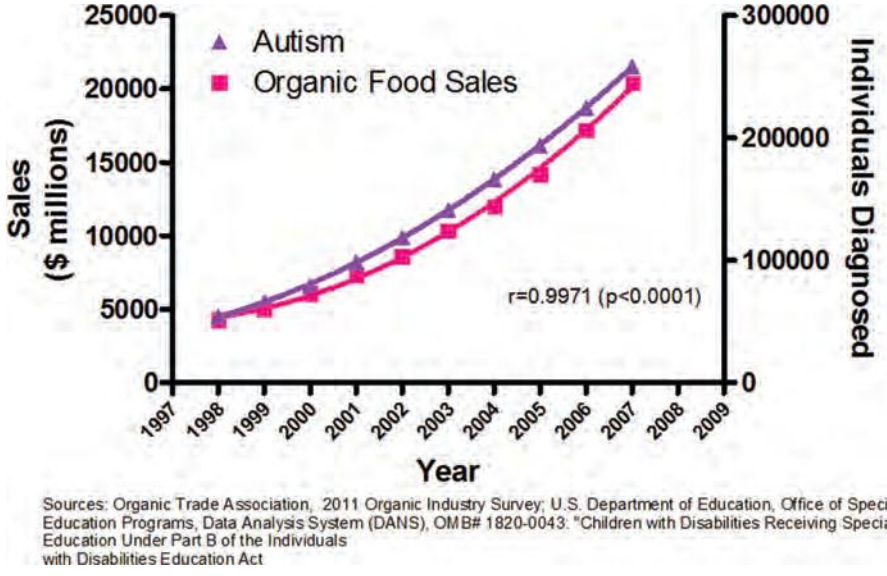
4 Finn is researching to see if there is a relationship between people's BMI and the strength of their hand grip. Her data is shown below.



a Determine if there is a correlation between the two variables. Explain your answer.

b Determine if there is causality between the two variables. Explain your answer.

5 A researcher is studying whether there is a relationship between organic food sales and autism in children. The following graph was presented as evidence.



a Determine if there is a correlation between the two variables. Explain your answer.

b Determine if there is causality between the two variables. Explain your answer.

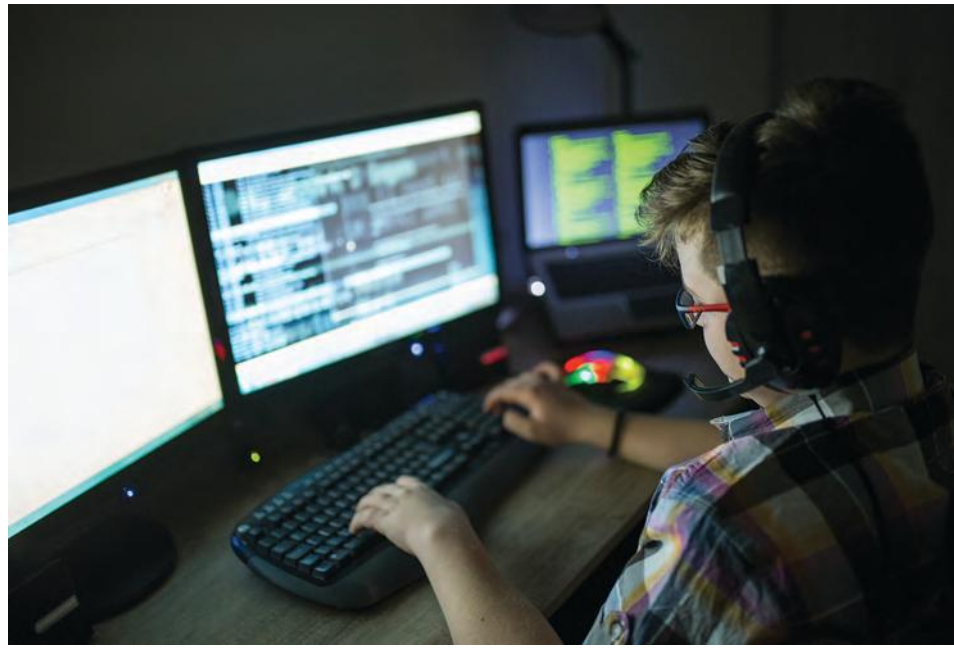
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Spread-sheet

6 A researcher into childhood obesity issues in Australia included a study relating time spent gaming per week and the children's BMI rating. The researcher claims in an article for the media that '***gaming is to blame for our childhood obesity issues***' Using the collected data below, create a suitable graph and comment on the reasonableness of the researchers comment.
A BMI of over 30 is considered to be in the obese range.

Hint
Formulate
Solve
Evaluate and Verify
Communicate

Time spent gaming (hours)	BMI
14	23
10	24
20	29
8	19
15	39
25	35
12	26
30	34
5	25
18	31



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Modelling task



Context: The new principal of your school would like your help in understanding student transportation habits. This could inform initiatives promoting sustainable, healthier travel choices.

Task: Write a brief report for the school principal summarising the findings of your investigation into the relationship between how far students live from school and their main mode of transportation. Collect data for both factors using surveys, measurements or research. In your report, include suggestions for how the results can be used for future projects.

Stage 1: Formulate
Make an observation of: • what you are required to do • what information you will need to collect • how you will collect information • what equipment you will need to record information Make an assumption of: • how you could gather more information • how many participants are needed for investigation • accuracy of students answering their main transport mode • accuracy of results to generalise a larger population of school
Stage 2: Solve
• Decide on an appropriate method to collect information. • Estimate the expected trend in data. • Conduct the necessary activities and collect the two variables of data. • Produce the graphs and/or tables required to help solve the problem. • Note any trend or correlation in the data. • Use spreadsheet program to perform the necessary mathematical steps to verify correlation. • Calculate examples of further predictions using correlation graphs and measures.

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Stage 3: Evaluate and verify
Check all information has been included and researched accurately. • Check that you have verified your estimation or expected result • Check that you have the evidence to back up your decision. • Include the evidence in the form of statements, graphs and tables. • Consider the practical significance of the correlation. Does it make sense based on your understanding of the variables? Justify your response to questions posed in context, by considering your: • assumptions • observations • limitations • strengths.
Stage 4: Communicate
Reflect on your response and solution to the investigation, outlining the decisions involved in making your response. • State your main point. • Explain the evidence. • Discuss any limitations or confounding factors that may have influenced the results. • Suggest potential areas for further research.

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Chapter summary

Independent variable

The independent variables is the variable in an experiment that we change or select in order to see what effect it has. The independent variable is placed on the horizontal (x-axis).

Dependent variable

The dependent variable is what we measure because we think it is changed by the independent variable. The dependent variable is on the vertical (y-axis).

Scatterplot

A scatterplot is a graphical representation of two variables. Each point on the plot represents an observation.

A line of best fit

Also known as a trend line or regression line, a line of best fit is a straight line that best represents the data on a scatter plot. It has an equation in the form $y = mx + c$. It can be drawn by hand or calculated with technology. The line of best fit shows the general direction of the change in the dependent variable in responding to change in the independent variable.

Correlation

Correlation is a measure of the strength of the linear relationship between two variables. It is measured by strength, direction and shape. The closer the points cluster to the line of best fit, the stronger the correlation.

- When the points rise from lower left to upper right, there is a positive correlation (if x increases, y increases).
- When the points fall from upper left to lower right, there is a negative correlation (if x increases, y decreases).
- When the line of best fit is horizontal, there is no correlation.

Correlation coefficient

The correlation coefficient is the degree to which points on a scatterplot lie on a line of best fit. The correlation coefficient has the symbol (r), which measures the strength and direction of a linear relationship between variables.

- r can be calculated using a calculator or spreadsheets.
- The value of r is always between $+1$ and -1.
- The closer the value is to $+1$ or -1, the stronger the correlation of that data.
- A value between 0.2 and -0.2 is said to have no correlation.

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Interpolation	An interpolation is an estimation of a value on the line of best fit. The accuracy of prediction by interpolation generally depends on the strength of the correlation: stronger correlations mean more accurate predictions.
Extrapolation	An extrapolation is an estimation of a value based on extending the line of best fit. To extrapolate is to infer something that is not within the range of the particular dataset used to determine the line of best fit. The danger of extrapolation is that there may be natural reasons why the straight line of best fit is not valid beyond the range of the dataset.
Causation	Correlation does not imply causation. Causation states that any change in one variable will cause a change in another variable. This is also known as cause and effect.

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Chapter checklist

10A ☐ I can identify the dependent and independent variable.

1 Identify both the dependent and independent variable from this data. Give reasons.
The table below shows the number of cups of chai tea sold per hour in the winter recorded against outside air temperature.

Temperature °C	11	8	9	4	20	18	10	11	13	10	2	1
Number of chai teas sold	10	13	14	16	0	1	8	6	7	7	18	20

10B ☐ I can determine the line of best fit by eye.

2 Draw a scatterplot from the previous data, then determine the line of best fit by eye.

10B ☐ I can use technology to determine the equation of the line of best fit in the form $y = mx + c$. **[complex]**

3 Determine the line of best fit from the previous data using a spreadsheet.

10C ☐ I can interpret relationships in terms of the variables. I can interpret the effect of the parameters m and c from the equation of the line of best fit. **[complex]**

4 Interpret and explain the relationships in terms of the two variables from the previous data.

5 Use the parameters m and c from the equation of the line of best fit to further explain the relationship from data in **Questions 1–4**.

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The following data explores whether there is a relationship between the number of minor car accidents and driver years of experience. Use the data to answer **Questions 6–9**.

Driving experience (years)	1	3	5	10	2	7	4	8	6	12
Number of minor accidents (in last 2 years)	2	2	3	0	3	2	2	2	2	1

10D ☐ I can use technology to calculate the correlation coefficient (an indicator of the strength of linear association).

6 Use technology to determine the correlation coefficient from the previous data.

10E ☐ I can use the line of best fit to make predictions, both by interpolation and extrapolation. **[complex]**

7 From the previous data, make both an interpolation and an extrapolation prediction.

10E ☐ I can recognise the dangers of extrapolation.

8 In relation to your previous extrapolation prediction, state whether there are any dangers.

10F ☐ I can distinguish between causality and correlation through examples. **[complex]**

9 In relation to the previous data, distinguish between causality and correlation.

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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

10A **1** Jon is studying how higher summer temperatures are impacting the growth of his crops.

a What could be the dependent variable? Give a reason.

b What could be the independent variable? Give a reason.

10B **2** Natalie is doing a Coast to Coast Walk for charity. During training she has recorded walk distances and times as shown in the table below. Draw a scatter plot and determine the line of best fit by hand.

Time (min)	101	209	140	180	284	195	330	135
Distance (km)	10	19	13	15	21	18	25	12

3 Zek is researching climate change. Identify the dependent variable and list three possible independent variables.

Complex Familiar

10B **4** Jahli has noticed a relationship between the average cost of petrol and the distance from a major city. Consider the following data collected. Draw a scatterplot and determine the line of best fit equation using technology.

Petrol price (cents per L)	165	168	165	170	175	165	182	170	185
Distance from city (km)	0	3	5	6	20	15	45	10	50

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Extension: research your area's petrol prices and distances for comparison, and create a new dataset and graph. Comment on any similarities or differences in correlation (trends).



5 Glenn has been recording the value of his stock over the past five years. Use technology to draw the line of best fit and to determine its equation.

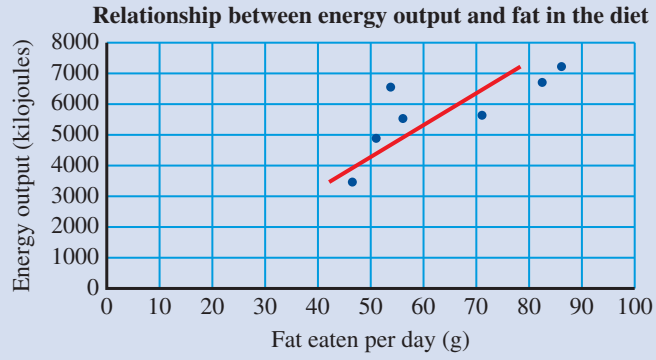
Year	Value of stock $
1	850
2	1037
3	1375
4	2175
5	4002

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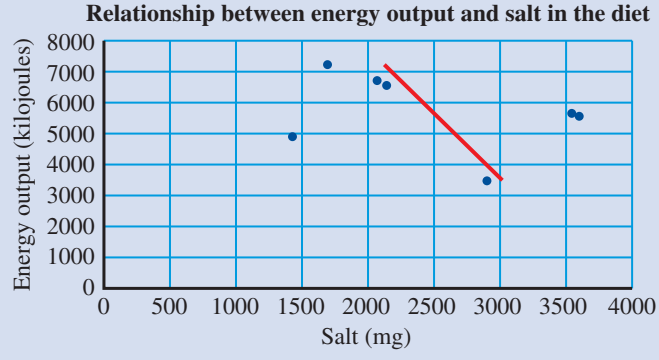
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10C **6** Interpret the relationship in terms of the variables of the following graphs.

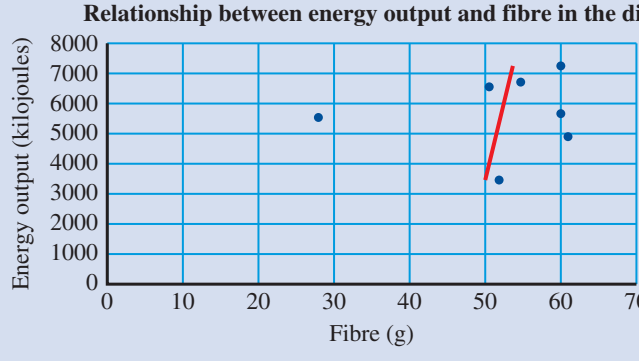
a



b



c



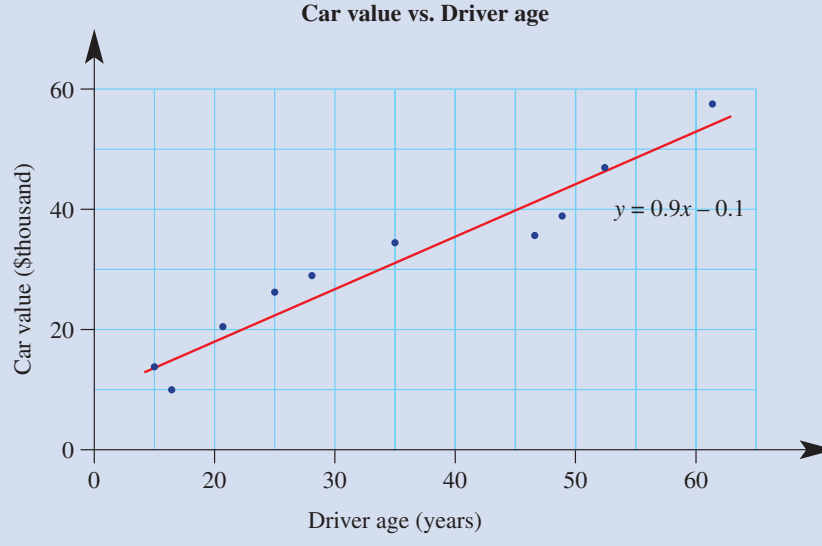
7 Interpret the parameters m and c from the line of best fit from **Questions 5**.

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10D **8** Riley is wondering if there is a relationship between the number of hours of sleep he gets and his mood for the day. Use technology to determine the correlation coefficient for the data.

Average sleep (hours per night)	Mood rating (1–10)
7	8
5	5
6	6
8	9
4	4
5	7
6	6
5	5
8	8
9	9

10E **9** Will noticed that, generally, the older the driver, the more expensive the car they drove, so he put it to the test with mathematics. The following is the scatterplot with the line of best fit produced.



a Using the physical line of best fit and interpolation, estimate the value of a car for a driver aged 40 years.

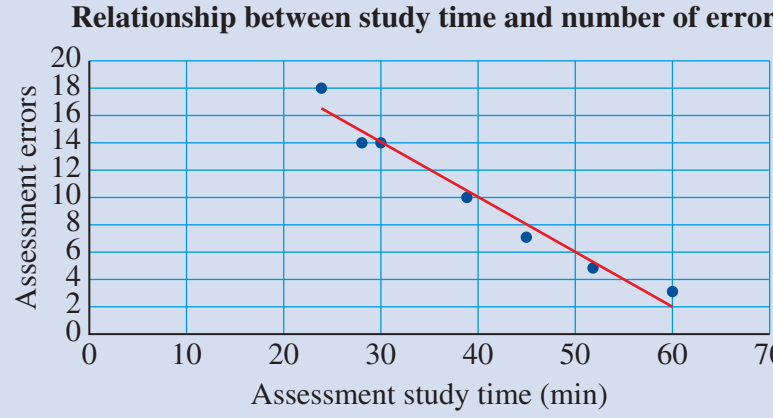
b Use the equation of the line of best fit, $y = 0.9x - 0.1$, to predict the value of a car for a driver aged 70 years.

c Explain the dangers of extrapolation with regards to this graph.

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10F **10** Scarlett has noticed that when she studies more for an assessment, she makes fewer errors in the assessment.

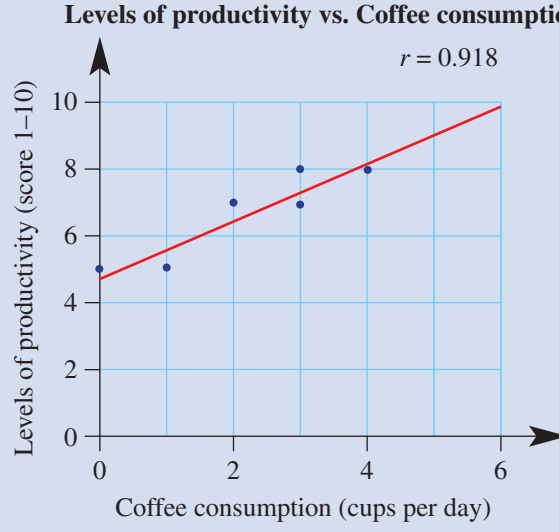


a Determine if there is a correlation between the two variables. Explain your answer.

b Determine if there is causality between the two variables. Explain your answer.

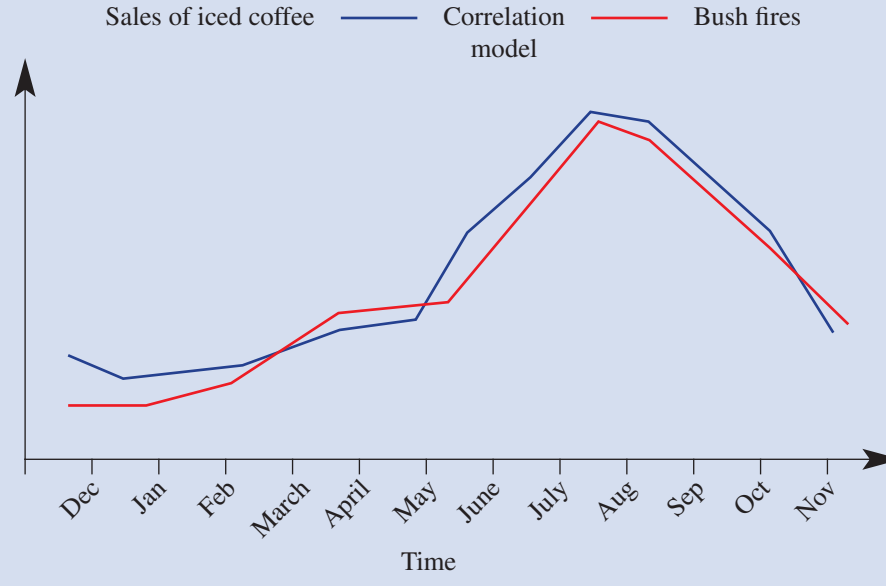
Complex Unfamiliar

11 Use the following graph to comment on with justification any relationship between productivity and coffee consumption and the reliably of any predictions.



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12 Use the following graph to comment on with justification any relationship and between the variables and the nature of any relationship.



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11 Summarising and interpreting data



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In this chapter

11A Identifying and calculating the measures of central tendency

11B Investigating the suitability of measures of central tendency and the effect of outliers **[complex]**

11C Determining quartiles, deciles and percentiles **[complex]**

11D Describing the spread of data

11E Calculating and interpreting measures of spread **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 4 Topic 2 Summarising and comparing data

Summarising and interpreting data (10 hours)

In this sub-topic, students will:

- identify mode from a dataset
- calculate measures of central tendency: median and mean $\bar{x}$ from a dataset of n values
  - mean: $\bar{x} = \frac{\Sigma x}{n}$ where Σx = sum of all data values
- investigate the suitability of measures of central tendency in various real-world contexts **[complex]**
- investigate the effect of outliers on the mean and the median **[complex]**
- calculate quartiles from a dataset
- interpret quartiles, deciles and percentiles from a graph **[complex]**
- use everyday language to describe spread, including spread out, dispersed, tightly packed, clusters, gaps, more/less dense regions and outliers
- calculate and interpret statistical measures of spread, including the range, interquartile range and standard deviation **[complex]**
  - range = highest score − lowest score
  - IQR $= Q_3 - Q_1$
- investigate real-world examples from the media illustrating inappropriate uses of measures of central tendency and spread **[complex]**.

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Prior knowledge check

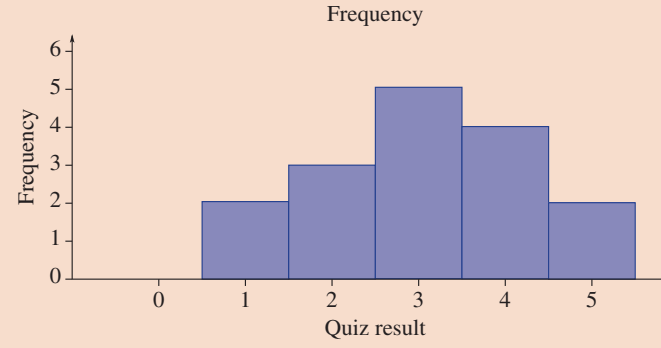
1 Evaluate the following correct to two decimal places.

a $\frac{145}{7}$ **b** $\frac{3}{6}$ **c** $\frac{1}{3}$

2 Consider the following histogram:

a Determine which scores had the lowest frequency.

b Calculate how many people scored 3 marks or less.



3 Evaluate the following.

a $\frac{22+31}{2}$ **b** $\frac{43+45}{2}$ **c** $\frac{56+71}{2}$

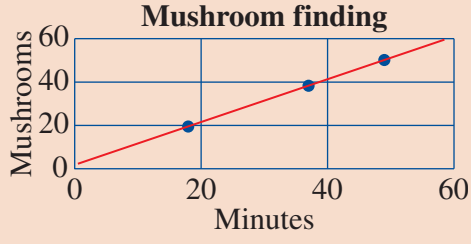
4 Express these fractions as percentages.

a $\frac{4}{16}$ **b** $\frac{7}{16}$

5 Evaluate the following squares.

a 2^2 **b** 7^2 **c** 0.5^2

6 From this graph, estimate how many minutes it took to collect 30 mushrooms.



7 Identify the smallest, largest and most common number in this stem-and-leaf plot.

Stem-and-leaf plot

4	1
5	2 7 8
6	5 6
7	0 5 8 8 8
8	0 0
9	5

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11A Identifying and calculating the measures of central tendency

LEARNING GOALS

- Identify the mode from a dataset.
- Calculate the mean from a dataset.
- Calculate the median from a dataset.

Why is it essential to understand how to determine the measures of central tendency?

- **Shows patterns**: Summarizing data helps us see trends.
- **Aids decisions**: Understanding key measures helps make better choices.
- **Improves clarity**: Simple summaries make complex data easier to share.
- **Leads to better conclusions**: Using these measures ensures conclusions are based on facts.
- **Useful everywhere**: Important for jobs in sales, science, and business for clear insights.



Measures of central tendency help us to make sense of a large data distribution.

WHAT YOU NEED TO KNOW

- A **measure of central tendency** describes a set of data by identifying the central position within that dataset. There are three main measures of central tendency: the mode, the mean and the median.
- The **mode** reveals the most frequent value in the dataset, i.e. the value that occurs most often.
  - A dataset can also have two modes (it is **bimodal**), or no mode at all.
- The **mean** is the average; it is equal to the sum of all the values in the data set divided by the number of values in the data set.
  - The symbol for mean in mathematics is $\bar{x}$.
  - The formula for identifying the mean is $\bar{x} = \frac{\text{sum of all data values}}{\text{number of data values}}$. $\bar{x} = \frac{\sum x}{n}$ where $\sum x$ = sum of all data values.

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- The **median** is the middle value of a dataset, when the dataset is sorted in order from the smallest value to the largest value.
  - The median is the number that falls exactly in the middle of the data.
  - If the dataset has an even number of values, then the median is the **average** of the two middle values.

Odd number of values	Even number of values
4, 6, (7), 9, 11 Median = 7	4, 6, (7, 9), 11, 14 Median $= \frac{7+9}{2}$ $= 8$

Example 1 Identifying the mode from a dataset

Emily is a dressmaker and needs to make some more dresses for her pop-up shop. She recalls the number of dresses she sold at each size over the past three months:
size 6 – 15 dresses
size 8 – 5 dresses
size 10 – 6 dresses
size 12 – 12 dresses
size 14 – 2 dresses
size 16 – 22 dresses.
Identify the mode for the dataset.



WORKING	THINKING
The mode is size 16 at 22 dresses.	The mode is the most common value. The dresses purchased the most are size 16 at 22.

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Example 2 Calculating the mean from a dataset

The following are the term grades for a student's tests.
67%, 78%, 65%, 72%, 64%, 76%, 78%, 80%, 82%, 85%
Calculate the mean for the student's grades.

WORKING	THINKING
$\bar{x} = \frac{67 + 78 + 65 + 72 + 64 + 76 + 78 + 80 + 82 + 85}{10}$ $\bar{x} = 74.7$	Mean $= \bar{x}$ $= \frac{\text{sum of all data values}}{\text{number of data values}}$
The mean of the student's tests for the term is 74.7%.	Add all the values and divide by the number of values (with this dataset, 10).

Example 3 Calculating the median from a dataset

The following are the prices of some apartments in a particular area.
$345 000, $300 000, $450 000, $290 000, $390 000, $670 000, $345 000, $410 000
Calculate the median of the apartments sales.

WORKING	THINKING
290000, 300000, 345000, 345000,	The data must first be ordered from smallest to largest. The median is the middle value.
390000, 410000, 450000, 670000	
The number of scores is 8. So, $n = 8$. The median score will be $\frac{8+1}{2} = \frac{9}{2}$ $= 4.5$th score. The median will lie between the 4th and 5th scores. The 4th score = 345 000. The 5th score = 390 000.	Determine the number of scores. This is an even number of scores, so we need to average the middle two scores.
Median $= (345000 + 390000) \div 2$ $= 367500$	Add the scores and divide by 2.
The median for the apartments prices is $367 500.	Communicate your answer in a sentence.

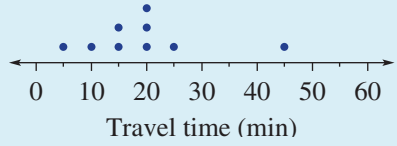
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Example 4 Determine the mean, mode and median from a stem plot and dot plot

Consider the following two graphs of data sets. For each one calculate the:

i mode
ii median
iii mean.

a

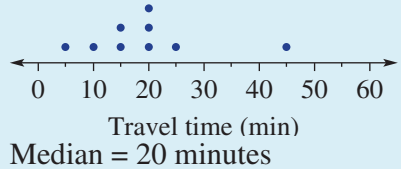


b

Stem	Leaf
6	8
7	
8	7 8 8 9
9	0 6 7 7
10	0

Key: 6|8 means 68

Round to one decimal place if necessary

WORKING	THINKING
a i From the graph, a travel time of 20 mins has the largest number of dots. Mode = 20 minutes	The dot plot is grouped in order from smallest to largest already. The mean is the most occurring number.
ii  Median = 20 minutes	The median is the number in the middle. This can be read off the dot plot. There are 9 dots, so the middle will be between the 5th number.
iii $\bar{x} = \frac{\sum x}{n}$ $\bar{x} = \frac{5+10+15+15+20+20+20+25+45}{9}$ $\bar{x} = \frac{175}{9}$ Mean = 19.4 minutes	The mean uses the formula: mean: $\bar{x} = \frac{\sum x}{n}$ where $\sum x$ = sum of all data values and n = the total number of data.
b i The modes can be read from the graph. Modes = 88 and 97	The stem plot shows data in ascending order already. Mode is the most occurring number. There can be more than one mode.

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ii

Stem	Leaf
6	8
7	
8	7 8 8 9
9	0 6 7 7
10	0

Key: 6|8 means 68

The 5th number is 89 and the 6th number is 90; $(89 + 90) \div 2 = 89.5$.
The median = 89.5.

◄··· The median is the middle number. There are 10 numbers, so the middle is exactly between the 5th and 6th number.

iii $\bar{x} = \dfrac{\sum x}{n}$

$\bar{x} = \dfrac{68 + 87 + 88 + 88 + 89 + 90 + 96 + 97 + 97 + 100}{10}$

$\bar{x} = \dfrac{900}{10}$

Mean = 90

◄··· The mean uses the formula: $\bar{x} = \dfrac{\sum x}{n}$ where $\sum x$ = sum of all data values and n = the total number of data.

Exercise 11A

FUNDAMENTALS

Example 1–3

1 For each dataset, identify:

i the mean
ii the median
iii the mode.

a 6, 4, 3, 5, 6, 2, 7, 6, 5, 9, 5, 4
b 85, 85, 95, 55, 75, 85, 75, 85, 55
c 6.7, 8.5, 8.6, 9.2, 7.4, 7.5, 7.9, 8.0
d 12, 18, 19, 11, 23, 24, 21, 18, 35
e 1, 3, 2, 2, 3, 2, 2, 1, 3, 3, 0, 3, 3, 2

Hint See formula sheet.

Hint The mean is the average. $\bar{x} = \dfrac{\text{sum of all data values}}{\text{number of data values}}$

Hint The median is the middle score. Place all of your data in order from smallest to largest before finding the median.

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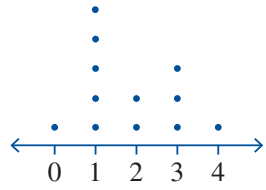
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Example 4

2 Identify the mode for the following datasets.

Hint The mode is the most frequent.

a **Number of children**

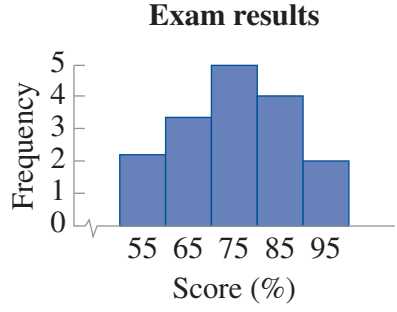


b **Number of goals**

0	9
1	225
2	35
3	0

2|3 = 23

c





APPLICATIONS

3 Dana has been researching the cost of car insurance per month from multiple companies.
The following are the costs per month found:
100, 150, 120, 80, 100, 90, 110.

a Calculate the mean cost of insurance, correct to two decimal places.

b Identify the median cost of insurance.

c Determine the mode cost of insurance.

Hint Mean is the average; median is the middle; mode is the most frequent.



ST

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SF

4 Markus wants to purchase a new gaming console. The following are the amounts recorded from a selection of options.
$700, $900, $200, $1200, $400, $300, $900, $1000, $700, $850, $2600

a Calculate the mean price for a gaming console.

b Identify the median price for a gaming console.

c Determine the mode price for a gaming console.

5 Micaela is a hockey coach and she is preparing for a new season. The following dataset is her team's goal scores for the previous season.
0, 4, 1, 1, 2, 1, 2, 1, 5, 4, 3, 5, 2, 1, 0, 2, 1, 0, 3, 2, 3, 3, 2, 1, 0, 2, 1, 2, 4, 0

a Calculate the mean score.

b Identify the median score.

c Determine the mode.



Example 4

6 For the data in the following stem plots, identify:

i the mean

ii the mode

iii the median.

Hint A stem plot splits each value into a stem (the first digit/s) and a leaf (usually the last digit). For example, 22|5 is 225.

a

0	8 9
1	2 2 3 5 7
2	4 6 9

2 | 4 = 24

b

20	0 0 1 3
21	2 3 4 5 5
22	4 5 5 5 5 8 9
23	6 8
24	0 0 3 4

22 | 5 = 225

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c

4	0 1 3 8
5	2 2 2 3 7 9
6	6 7
7	0 1 3 5

5 | 2 = 52

d

10	0 0 0 0 1 7
11	1 2 2 3 4 5 9
12	1 1 2 2 4 6 8
13	0 0 7

13 | 7 = 137

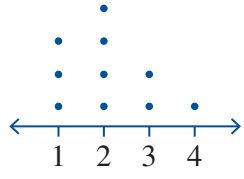
7 For the data in the following dot plots, identify:

i the mean

ii the mode

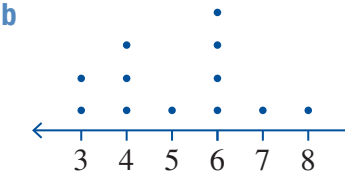
iii the median.

a



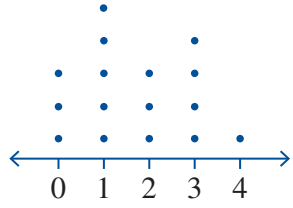
Number of goals

b



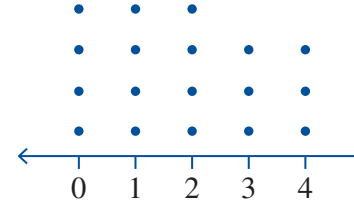
Number of strokes

c



Number of pets

d



Number of musical instruments

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11B Investigating the suitability of measures of central tendency and the effect of outliers

COMPLEX

LEARNING GOALS

- Investigate the suitability of measures of central tendency in various real-world contexts. [complex]
- Investigate the effect of outliers on the mean and median. [complex]

Why is it essential to be able to determine the suitability of the measures of central tendency?

- Depending on what you aim to convey, you might choose one measure over another. Using the most appropriate measure enhances clarity and ensures that the conclusions drawn are supported by the data.
- Outliers can distort the mean but have little effect on the median. Recognising this helps choose a measure that accurately represents central tendency, particularly in data sets with extreme values.



Deciding which measure of central tendency to use can be important when interpreting datasets.

WHAT YOU NEED TO KNOW

- The **mode** reveals the most frequent value in the dataset.
  - Advantages of using the mode:
    - It is simple to understand (the value that occurs most often).
    - It is not affected by extreme values **(outliers)**.
  - Disadvantages of using the mode:
    - It is not based on all the values in a dataset.
    - Sometimes the data has more than one mode, and sometimes there is no mode at all.
- The **mean** is the average of the dataset.
  - Advantages of using the mean:
    - All the data is taken into account.
    - It is easy to understand (the value you would have if all the data points were equal) and easy to calculate.
  - Disadvantages of using the mean:
    - Outliers (extreme values) can distort the results.
    - If the data is in the form of percentages or ratios, it could be challenging to calculate the mean.

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- The **median** is the middle value of a dataset, when the dataset is sorted in order from the smallest value to the largest value. If it is not possible to logically order the data, then don't use the median.
  - Advantages of using the median:
    - It is simple to understand (the data point in the middle, with an equal number of greater and lesser values) and easy to calculate.
    - It is not affected by outliers.
  - Disadvantages of using the median:
    - The median is based only on the middle value of an ordered dataset and does not include values from the other data points at all.
    - Need to remember that if there are an even number of data points, the median is the average of the middle two.
  - An outiler may be due to an inconsistency in the measurement or it may indicate experimental error. They are therefore sometimes removed from the dataset, but this needs to be justified.
  - The mean is usually affected more by the outlier than the median, especially for small datasets. Therefore, it should not be used when outliers are present.

Example 5 Investigating the suitability of measures of central tendency in various real-world contexts [complex]

Juan's goal is to achieve 50% correct on his weekly math test across 10 weeks. Below are his grades out of 20 questions for the past 8 weeks. He has two weeks to go.
4, 6, 9, 11, 8, 10, 12, 6
Investigate and decide which measure of central tendency is best to assist with Juan's preparation to reach his goal. Give a reason.

WORKING	THINKING
	Formulate
Data set given: 4, 6, 9, 11, 8, 10, 12, 6. Juan's goal is 50% correct overall after 10 weeks. This equals 10 out of 20 questions correct overall. There are no outliers. Need to calculate mean, mode and median, and state which is best for Juan to understand where he is towards his goal.	Make observations and assumptions based on the information given. Note any outliers in the data set. Recall the measures of central tendency. Note the main question asked.

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Solve

Mean: $\bar{x} = \frac{\sum x}{n}$

$\bar{x} = \frac{4 + 6 + 9 + 11 + 8 + 10 + 12 + 6}{8}$

$\bar{x} = \frac{66}{8}$

$= 8.25$

◄··· Calculate all measures of central tendency:

Mean: use formula $\bar{x} = \frac{\sum x}{n}$

Median:

4, 6, 6, (8), (9), 10, 11, 12

Median:

◄··· The data must first be ordered from smallest to largest. The median is the middle value.

The number of scores is 8. So $n = 8$.

The median score will be $\frac{8 + 1}{2} = \frac{9}{2} = 4.5$th score.

The median will lie between the 4th and 5th scores.

The 4th score = 8.

The 5th score = 9.

◄··· Determine the number of scores. This is an even number of scores, so we need to average the middle two scores.

Median = $(8 + 9) \div 2$

$= 8.5$

◄··· Add the scores and divide by 2.

The median for the grades is 8.5.

◄··· Communicate your answer in a sentence.

The mode for the grade is 6.

◄··· The mode is the most common value.

Evaluate and Verify

With values in order, the middle is expected to be approximately around 8–9, which verifies the mean and median calculations.

◄··· Use an estimating tool to verify your calculations are correct and make sense in the context.

The mean is the average score of all grades, considering each individual result and giving an overall for all weeks.

The median score does not take into account all grades recorded.

The mode has nothing to do with how well the other grades have contributed to his results and will not fit with a goal of 50% overall.

Consider any pros and cons of each measure of tendency in regards to the main question and Juan's goal.

... Continued

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Central tendency should give a summary of the data and be useful for understanding the data.

◄··· Consider the purpose of the real-world central measure.

Communicate

The mean is the better measure of the central tendency for Juan to have an idea of how he is going towards his goal of 50% over all weeks of exams. It takes all results into consideration, like his overall goal.

◄··· Clarify your answer to the question: Which measure of central tendency is best?

The current mean of 8.25 is below a 50% score of 10 overall and is it helpful to Juan to know that he will need to do better in the last two exams to bring this up to 10 to reach his goal.

◄··· Give reasons for your decision, taking into consideration observations from the question.

Example 6 Identifying an outlier using a formula and demonstrating the effect on the mean and median

The following is a dataset representing the number of wedge-tail eagles spotted each day on a property.

5, 1, 2, 17, 3, 1, 4, 5, 3, 4, 3

a Identify any outliers within the data set.

b Give a possible reason for the outlier.

c Calculate the mean:

- **i** with the outlier
- **ii** without the outlier.

d Compare your answers to **c i** and **ii** and consider if the outlier should be included or removed.

e Calculate the median:

- **i** with the outlier
- **ii** without the outlier.

f Compare your answers to **e i** and **ii** and consider if the outlier should be included or removed.

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WORKING		THINKING
a	17 is an outlier.	◄ 17 is much greater than the rest of the data.
b	There may have been an abundance of prey on the property or a large dead animal on the day of the 17 count.	◄ What possible reason could there be for this larger amount of wedge-tail eagles?
c i	The mean, with the outlier $= \frac{5+1+2+17+3+1+4+5+3+4+3}{11}$ $= 4.36$.	◄ Calculate the mean, including 17.
ii	The mean, without the outlier $= \frac{5+1+2+3+1+4+5+3+4+3}{10}$ $= 3.1$.	◄ Calculate the mean, removing 17 from the dataset.
d	$4.36 - 3.1 = 1.26$ With the difference between the two means being larger than some of the actual observations, it is reasonable to determine that the outlier greatly affects the data and should be removed.	◄ Compare the answers with/without the outlier and determine whether the data is affected.
e i	With the outlier: 1, 1, 2, 3, 3, (3), 4, 4, 5, 5, 17. The median, with the outlier = 3	◄ Calculate the median, including 17.
ii	Without the outlier: 1, 1, 2, 3, (3, 3), 4, 4, 5, 5. The median, without the outlier = 3	◄ Calculate the median, removing 17 from the dataset.
f	Both datasets have a median of 3. Therefore, the outlier does not affect the median and should be included in the dataset.	◄ Compare the answers with/without the outlier and determine whether the data is affected.

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Example 7 Investigating the effect of outliers on suitability of measures of central tendency - mean and median in various real-world contexts [complex]

A development company planning for potential new businesses in a small rural town is considering analysing the yearly salaries of the town, to give an idea of the typical earnings of residents. Determine and justify which measure of central tendency is best to assist the company, considering the potential impact of outliers. Salaries are recorded in thousands.
$62, $55, $50, $60, $45, $300, $65, $75, $70, $80, $68.

WORKING	THINKING
	Formulate
Data set given: $62, $55, $50, $60, $45, $300, $65, $75, $70, $80, $68. Outlier: $300. Assume we need to calculate the mean and median only, as the mode would not consider all salaries and would not be affected by outlier. Need to consider which measure will give the best indication of overall town economic health.	◄··· Make observations and assumptions based on the information given. Note any outliers in the data set. Recall the measures of central tendency. Note the main question asked.
	Solve
Mean: $\bar{x} = \frac{\sum x}{n}$ $\bar{x} = \frac{62+55+50+60+45+300+65+75+70+80+68}{11}$ $\bar{x} = \frac{930}{11}$ $= 84.55$ Mean = $84 550 There is no mode Median: 45, 50, 55, 60, 62, (65), 68, 70, 75, 80, 300 Median = $65 000	◄··· Calculate all measures of central tendency: Mean: use formula $\bar{x} = \frac{\sum x}{n}$ Mode: the most occurring salary. ◄··· Median: rearrange data in ascending order first before finding the middle.
	Evaluate and Verify
There are more salaries in the 60's so estimates suggest the median is here, as verified. The mean is affected by outliers, the value is expected to be larger than the middle, which is verified with calculations.	◄··· Use an estimating tool to verify your calculations are correct and make sense in the context.

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There is a significant outlier in the data of $300 (thousand). Although the mean takes all salaries into consideration, it is affected by the outlier, so the mean salary is not reflective of the whole population. The median takes all data in and is much less affected by the outlier. The median gives an idea of the typical salary of the town.

◄····· Consider any pros and cons of each measure of tendency in regards to the main question. Consider the purpose of the real-world central measure.

Communicate

In this case, the **median** is the better measure of central tendency. The presence of the $300 000 outlier significantly skewed the mean, making it unrepresentative of the typical salaries in the town. The median, however, reflects the middle salary, providing a clearer picture of what most residents earn. Thus, using the median is more appropriate for understanding the economic landscape of the community.

◄····· Clarify your answer to the question: Which measure of central tendency is best?

Give reasons for your decision, taking into consideration observations from the question.

Central tendency should give a summary of the data and be useful for understanding the data.

Worksheet 11B: Investigating a real-world example from the media illustrating inappropriate uses of measures of central tendency: see the Interactive Textbook for this activity

Exercise 11B

FUNDAMENTALS

1 Review the data and the context in which the results will be used, then decide which measure of central tendency – mean, mode, or median—best serves that purpose.

- **a** A teacher looking at class results from a standard exam to get a picture of overall understanding.
- **b** A young couple looking to buy a house and want to know the typical cost of houses in different suburbs to work out where to consider buying.
- **c** A new frozen yoghurt shop looking to see what their customers' favourite flavour is to decide which flavours to continue to stock.

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APPLICATIONS

Example 5

2 Verity is a shoe designer and she is preparing for a new pop-up shop. Verity has recorded the size of shoes purchased over the past week.
12, 7, 7, 7, 7, 8, 6, 7, 7, 10, 10, 5, 9, 9, 10, 9, 11



a Calculate the mean shoe size.
b Identify the median shoe size.
c Determine the mode shoe size.
d Which is a better measure to assist with Verity's preparation? Give a reason.

Hint Mean is the average; median is the middle; mode is the most frequent.

3 Identify which measure of central tendency – mean, median, or mode—should be used to analyse the heights of basketball players in the school team. You may need to consider the potential impact of outliers.

Hint Give examples from your findings in your reasons.

Players	1	2	3	4	5	6	7	8
Height (cm)	185	191	213	186	185	193	188	190



CF

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4 The following back-to-back stem-and-leaf plot displays the homework results over the term of two students.



a For each student, identify:

i the mean

ii the mode

iii the median.

b Compare the performance of the two students using the measures of central tendency.

Hint Include examples of central tendency in your comparison.

Homework scores (%)

Sage		Raoul
85	6	7
64	7	55
552	8	899
865	9	5559

7|5 = 75%

5 Mitchell is a town planner and he needed to determine the number of children in families from two high schools. He chose 300 students from the two local high schools and asked how many siblings each student had. Determine the median number of siblings for all the students surveyed.

Hint Think of a way you could do this without writing out each number.

Number of siblings	Town High School	Rangeville High School
0	118	142
1	82	108
2	59	31
3	31	9
4	10	10

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Example 6

6 Ben and his father were trying to work out a fair way to determine how much per month Ben should have for pocket money. Ben surveyed 13 of his friends and wrote out a list of how much pocket money they received each month.
Calculate the measures of central tendency and decide which is the fairest in this situation, providing your reasoning.

Friend	Monthly pocket money $
1	140
2	50
3	40
4	70
5	2350
6	140
7	120
8	50
9	100
10	50
11	75
12	110
13	50



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CF

★7 Kenzi, a maths teacher, needs to choose who to give the maths award to in her class. She records all the results for her top three students.

Student A	33	45	23	24	47	48	46	25	45
Student B	30	43	20	26	50	50	49	30	47
Student C	30	42	20	23	48	50	48	32	43

Determine which student should win the maths award. Justify your answer, using the measures of central tendency for the students and explaining which of these is the fairest for her class.



CU

Example 7

8 A group of friends were discussing what the typical first car cost is. They surveyed their friends and collected this list of first car values. Use your knowledge of summarizing data to decide which best reflects the typical first car price, use mathematical calculations to justify your answer best reflects a typical first car cost. $9000, $10 000, $18 000, $25 000, $12 000, $15 000, $50 000, $3000, $5000, $7000, $8000

Hint
Formulate
Solve
Evaluate and verify
Communicate

9 A travel company collected data from an online survey to assist in putting together travel holiday packages. Included in the survey was the average amount couples spend on a long weekend holiday. Use your knowledge of summarising data to decide the information most useful to the travel agent, use mathematical calculations to justify your answer.
$1500, $2200, $3000, $3200, $3800, $2500, $2800, $4000, $5000, $14 300, $3500



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11C Determining quartiles, deciles and percentiles

COMPLEX

LEARNING GOALS

- Calculate quartiles from a dataset.
- Interpret quartiles from a graph. [complex]
- Interpret deciles from a graph. [complex]
- Interpret percentiles from a graph. [complex]

Why is understanding quartiles, deciles and percentiles essential?

- Data can be divided into smaller equal parts, such as quartiles, deciles and percentiles.
- These can be used to describe where each data point sits in comparison to the rest of the data.
- Quartiles, deciles and percentiles are used in various industries – such as education, economics, healthcare and marketing – to analyse data distributions and identify performance levels.



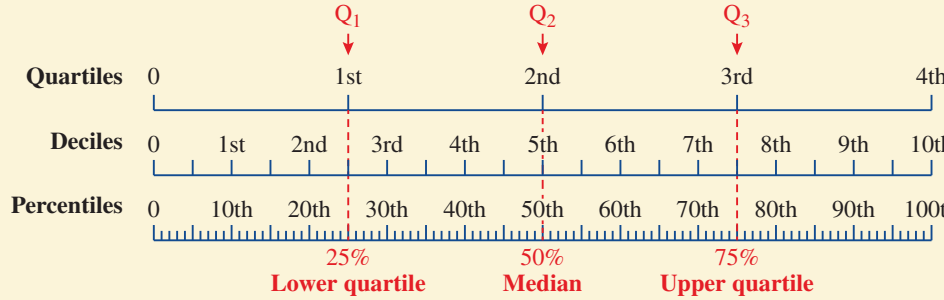
Quartiles, deciles and percentiles are often used to compare performances and analyse information about populations.

WHAT YOU NEED TO KNOW

- Parts or groups in an ordered dataset are divided by values that collectively are known as **quantiles**. ('Ordered' means the dataset is sorted in order from the smallest value to the largest value.)
  - Quantiles that divide ordered data into four equal parts are called **quartiles** (like 'quarters'). There are three quartiles, Q_1, Q_2 and Q_3, shown on the diagram.
  - Dividing ordered data into 10 equal parts are called **deciles** (think of 'decimal', which relates to tenths). There are nine deciles, as shown on the diagram. (They can be called D_1, D_2, D_3 and so on.)
  - Dividing ordered data into 100 equal parts are called **percentiles** (think of 'percentage', which relate to hundredths). There are 99 percentiles, as shown on the diagram. (They can be called P_1, P_2, P_3 and so on.)

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- Quartiles, deciles and percentiles can be compared with this diagram. The first quartile lies between the 2nd and 3rd decile, and it is the same as the 25th percentile. The first decile is the same as the 10th percentile, and so on.



- There are the same number of data points between the quartiles. So, from 0 to Q_1 there are the same number of data points as there are between Q_1 and Q_2, and so on. The same principles apply to the deciles and percentiles: there is an equal number of data points between each one.
- Q_2 is the **median** of the whole dataset, the data point that splits the ordered data into two equally sized groups. It is the same as the 5th decile and the 50th percentile. Then Q_1 is the median of the upper half of the data, and Q_3 is the median of the lower half of the data. Q_1 is also called the lower quartile, and Q_3 is also called the upper quartile. Q_1 is the same as the 25th percentile, and Q_3 is the same as the 75th percentile.
- Cumulative frequency graphs are often used with quartiles, deciles, and percentiles. **Cumulative frequency** is the running total of the **frequency distribution** of the dataset, which is shown in a **frequency table**.

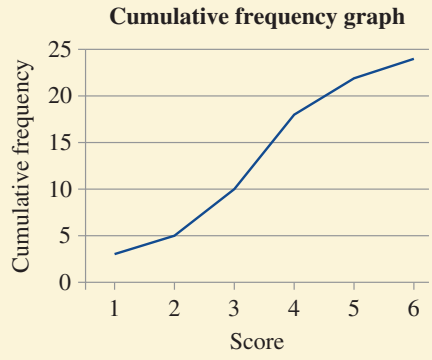
Score	Frequency	Cumulative frequency
1	3	3
2	2	$3 + 2 = 5$
3	5	$5 + 5 = 10$
4	8	$10 + 8 = 18$
5	4	$18 + 4 = 22$
6	2	$22 + 2 = 24$
Total	24	Total

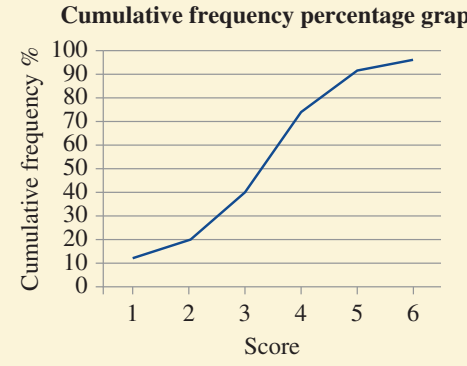
  - The frequency table shows that the dataset contains 24 data points (the total of the frequencies, and the last value of the cumulative frequency). As this is an even number, the median is the average of the two middle values: the 12th and 13th.

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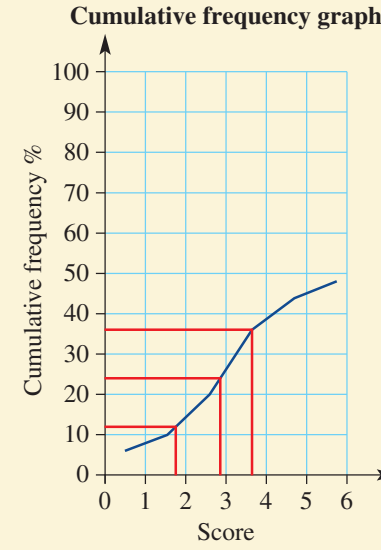
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- Graphs of cumulative frequency
  - The cumulative frequency graph is represented by the cumulative frequency on the vertical axis and scores on the horizontal axis (shown in graph on left).
  - If you plot the cumulative frequency percentage against the score, you get the same graph, but now the vertical axis is in percentages (shown in graph on right).





- A very useful characteristic of a cumulative frequency graph is that the quartiles can be easily marked on both axes, as shown below.
  - For the cumulative frequency graph, the maximum value is 24. On the vertical axis, Q_1 is a quarter (25%) of the maximum value (6), Q_2 is half (50%) the maximum value (12), and Q_3 is three-quarters (75%) the maximum value (18).
  - The same method can be applied to finding deciles and percentiles of the scores.



- Interpretation of quartiles, deciles and percentiles mainly involves determining where a particular value lies in relation to them, and the percentage of scores that are above or below a particular quartile, decile or percentile. For example:
  - 75% of scores are above Q_1 and 25% are below it.
  - 40% of scores are above the sixth decile and 60% are below it.
  - 70% of scores are above the thirtieth percentile and 30% are below it.
- Further interpretation depends on the subject of the data, and whether higher or lower scores are 'better'.

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Example 8 Calculating quartiles from a dataset

Consider this dataset:
9, 10, 7, 7, 8, 6, 12, 28, 6.

a Identify the median (2nd quartile: Q_2).
b Determine the lower quartile (1st quartile: Q_1).
c Determine the upper quartile (3rd quartile: Q_3).
d Interpret what the quartiles mean in relation to the fraction and percentage of scores that lie above and below each one.

WORKING	THINKING
a 6, 6, 7, 7, (8), 9, 10, 12, 28 The number of scores is 9. The middle value is the 5th, which is 8.	The data must first be ordered from smallest to largest.
The median (Q_2) is 8.	The median is the middle value.
b (6, (6, 7), 7), 8, 9, 10, 12, 28 Average of 6 and 7 = $\frac{6+7}{2} = 6.5$	The lower quartile is the middle number of the lower half of the data. Place brackets around the lower half of the dataset, excluding the median, and identify its middle data point or points (ringed). There is an even number of scores, so the middle value is the average of the two middle scores (ringed).
The lower quartile Q_1 is 6.5.	This score is Q_1.
c 6, 6, 7, 7, 8, (9, (10, 12), 28) Average of 10 and 12 = $\frac{10+12}{2} = 11$	The upper quartile is the middle number of the upper half. Place brackets around the upper half of the dataset, excluding the median, and identify its middle data point or points (ringed). There is an even number of scores, so the middle value is the average of the two middle scores (ringed).
The upper quartile Q_3 is 11.	This score is Q_3.

... Continued

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d A quarter or 25% of the data has a value that is less than or equal to 6.5, and three-quarters or 75% of the data has a value that is more than or equal to 6.5.

◄ One quarter is 25%; a half is 50%; three-quarters is 75%.
25% of the data has a value that is less than or equal to Q_1, and 75% of the data has a value that is more than or equal to Q_1.

Half or 50% of the data has a value that is less than or equal to 8, and half or 50% of the data has a value that is more than or equal to 8.

◄ 50% of the data has a value that is less than or equal to Q_2, and 50% of the data has a value that is more than or equal to Q_2.

Three-quarters or 75% of the data has a value that is less than or equal to 11, and a quarter or 25% of the data has a value that is more than or equal to 11.

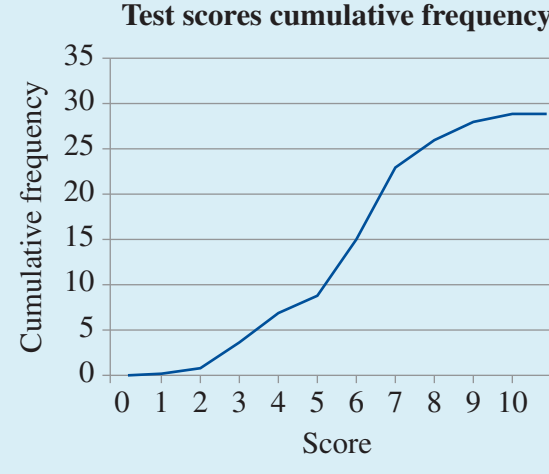
◄ 75% of the data has a value that is less than or equal to Q_3, and 25% of the data has a value that is more than or equal to Q_3.

The middle 50% of the data lie between 6.5 and 11.

◄ The middle 50% of the data lie between Q_1 and Q_3.

Example 9 Determining the quartiles from a cumulative frequency graph

The graph provided shows the cumulative frequency of test scores (out of ten) in a class's test results. Determine the lower quartile Q_1, median Q_2 and upper quartile Q_3 of the test scores.



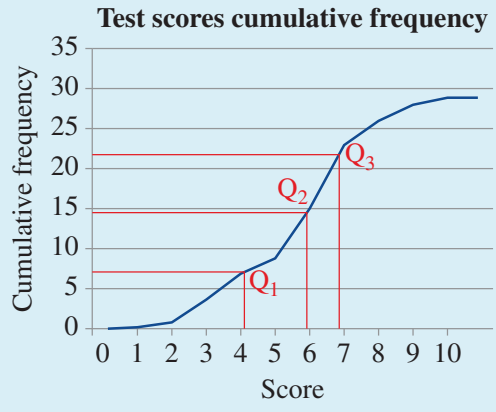
WORKING	THINKING
The cumulative frequency total is 29.	◄ Write down the cumulative frequency total.

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$Q_1 = 7.25$ ◄···· Q_1 (one quarter of the total)

$Q_2 = 14.5$ ◄···· Q_2 (half of the total)

$Q_3 = 21.75$ ◄···· Q_3 (three quarters of the total)



Draw horizontal lines at 7.25, 14.5, and 21.75 on the cumulative frequency axis and label them Q_1, Q_2 and Q_3.
Draw vertical lines from where these horizontal lines meet the graph to the horizontal axis.

Q_1 score = 4
Q_2 score = 6
Q_3 score = 7

◄···· Read off the values of the vertical lines Q_1, Q_2 and Q_3 on the horizontal axis and round to the nearest whole number.

The lower quartile of the test scores is 4.
The median of the test scores is 6
The upper quartile of the test scores is 7.

◄···· Communicate your answers in sentences.

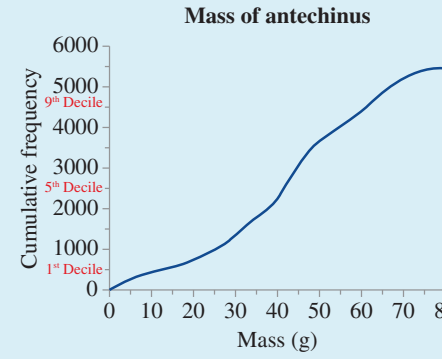


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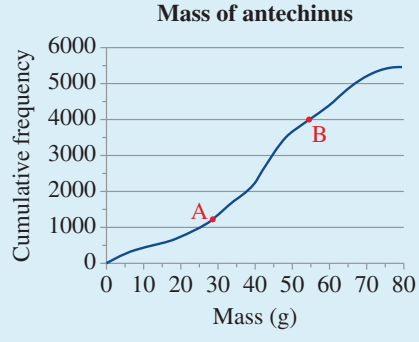
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Example 10 Interpreting the deciles from a cumulative frequency graph

The cumulative frequency graph shows the results of a survey of the mass of marsupial mice (antechinus) in a population.
Two more antechinus specimens have been weighed, with masses of A (30 g) and B (55 g).



a Determine the deciles of mass between which these two specimens lie.
b Interpret what this means in terms of the proportion of the population that are lighter or heavier than the two new specimens.

WORKING	THINKING
a 	Mark the position on the graph for A (30 g) and B (55 g).
Maximum cumulative frequency is 5300	Read the maximum cumulative frequency on the graph.
Position of A on vertical axis is 1250. $1250 \div 5300 = 0.24$.	Determine the position of A on the vertical axis.
A lies between the 2–3 deciles.	Decide between what deciles A lies.
Position of B on the vertical axis is 4000. $4000 \div 5300 = 0.75$	Determine the position of B on the vertical axis.
B lies between the 7–8 deciles.	Decide between what deciles B lies.
Specimen A lies between the second and third deciles, and specimen B lies between the seventh and eighth deciles.	Communicate your solution in words.

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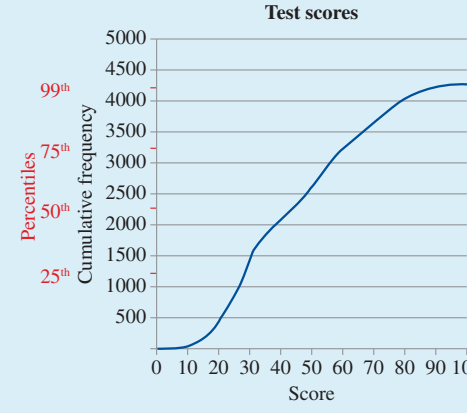
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b Specimen A is heavier than two-tenths of the population and is lighter than seven-tenths of the population. Specimen B is heavier than seven-tenths of the population and is lighter than two-tenths of the population.

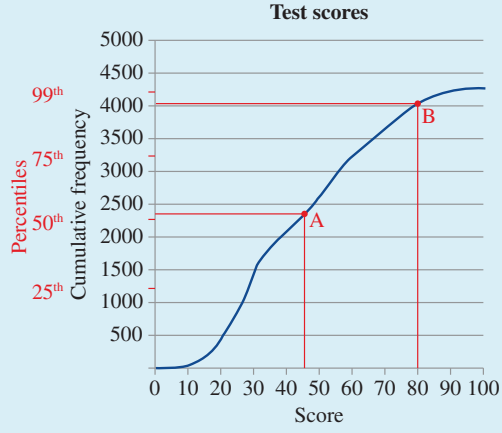
◄····· Two-tenths of the data lies below the second decile, and seven-tenths lies above the third decile ($10 - 3 = 7$). Data lower than a decile are lighter, and data above a decile are heavier.

Example 11 Interpreting the percentiles from a cumulative frequency graph [complex]

The cumulative frequency graph below shows the results of scores in a test. Student A had a score of 44 and Student B had a score of 80. Determine the percentiles for Student A and Student B, and interpret what this means in terms of the percentage of the students who did better or worse on the test than students A and B.



WORKING



THINKING

Formulate

◄··· Use the given information to fill out the graph.
Mark the position on the graph for A at a score of 44.
Draw a vertical line from A to the horizontal axis.
Draw a horizontal line from A to the vertical axis.
Mark the position on the graph for B at a score of 80.
Draw a vertical line from B to the horizontal axis.
Draw a horizontal line from B to the vertical axis.

... Continued

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Solve

Student A's score of 44 lies at approximately 2350 on the *y*-axis.
2350/42.50 ≈ 55.3, therefore it lies between the 55th and 56th percentiles.
Student B's score of 80 lies at approximately 4000 on the *y*-axis.
4000/42.50 ≈ 94.1, therefore it lies between the 94th and 95th percentiles.

◄··· Read off the scores matching the percentiles, using the *y*-axis labels.

Evaluate and verify

The score A appear to be around the halfway point, which verifies the answer of 55th percentile. The score B looks to be in the last 10% of the scores, which aligns with the 95th percentile that was calculated.

◄··· Use an estimating tool to verify your calculations are correct. Look at the graph and estimate how far along the graph the scores A and B.

Communicate

Student A scored better than 55% of students and worse than 44% of students.
Student B scored better than 94% of students and worse than 5% of students.

◄··· Give reasons for your decision, taking into consideration the question.
Percentiles are equivalent to percentage points.

Exercise 11C

FUNDAMENTALS

1 Copy and complete this table to show the cumulative frequency and the totals.

Score	Frequency	Cumulative frequency
1	1	
2	6	
3	25	
4	19	
5	31	
6	12	
Total		

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2 Draw a graph of cumulative frequency against score for the data in Question **2**.

3 On the graph in Question **3**, draw horizontal and vertical lines to show Q_1, Q_2 and Q_3, and determine the approximate value of the score for each of them.

APPLICATIONS

Example 8

4 The dataset below is the number of matches won by teams in a league.
12, 10, 2, 4, 6, 7, 6, 9, 9, 8, 5

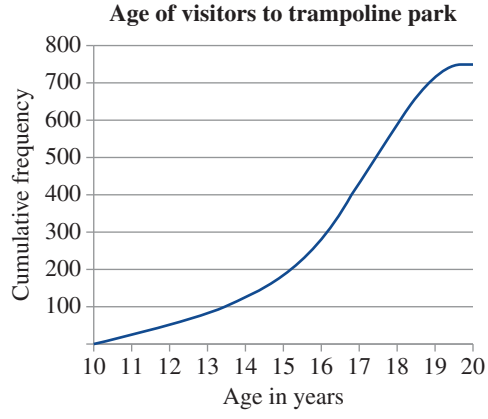
Hint Determine the median, and then the medians for the upper and lower halves of the data.

a Identify the median (2nd Quartile → Q_2).
b Determine the lower quartile (1st Quartile → Q_1).
c Determine the upper quartile (3rd Quartile → Q_3).
d Interpret what the quartiles mean in relation to the fraction of matches won that lie above and below each one.

Example 9

5 Caroline is a trampoline park operator. She has recorded the ages of the visitors to the park to plan new equipment for the following year. Caroline has made a cumulative frequency graph of the results.





a Determine the median of the ages (2nd Quartile → Q_2).
b Determine the lower quartile of the ages (1st Quartile → Q_1).
c Determine the upper quartile of the ages (3rd Quartile → Q_3).

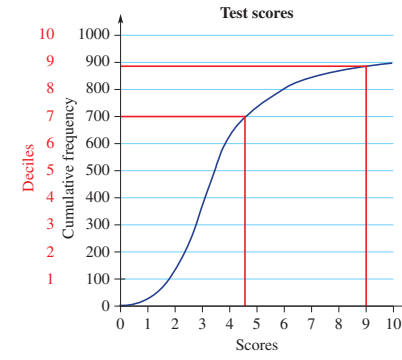
CF

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Example 10

6 This cumulative frequency graph shows the scores of students sitting a science test. Andrew scored $4\frac{1}{2}$ and Brad scored 9.

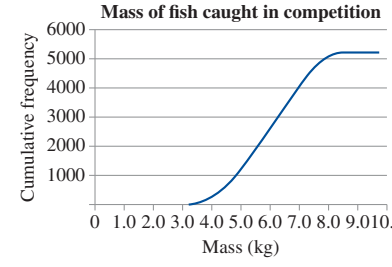


a Determine the deciles of the scores between which these students' scores lie.

b Interpret what this means in terms of the proportion of the students that did better or worse than Andrew and Brad.

Example 11

7 During a huge fishing competition in North Queensland, the mass of individual fish caught were recorded alongside previous competition recordings in the cumulative frequency graph below. Two new competitors wish to compare their fish caught to the rest of the competition. Competitor A's fish weighs 4.2 kg and competitor B's fish weighs 7.5 kg.



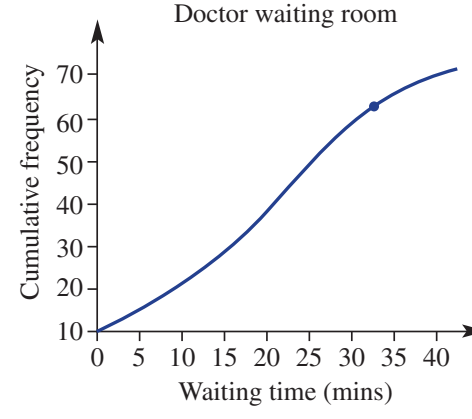
Given that competitor A's fish mass is between the 5th and 6th percentiles and competitor B's fish mass is between the 81st and 82nd percentiles, interpret the meaning of this in comparison to the rest of the competition's fish weights.



★**8** When receiving results for an exam, is it better to receive results in a high or low percentile? Explain your answer.

★**9** Troy is currently in his doctor's waiting room. He has been there for 32 minutes, which is the 85th percentile of waiting times. Is this good or bad? Explain your answer.





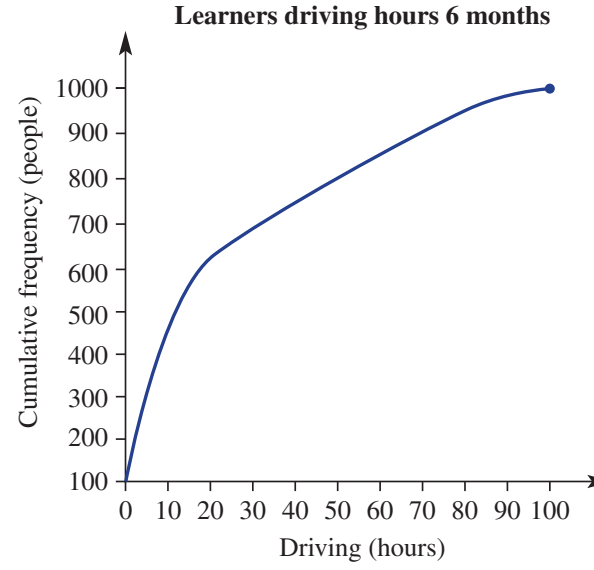
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⋆10 Katrina and Elliot are looking at purchasing a house. Their real estate agent has told them that the most expensive house they can afford is in the 25th percentile. Their research has shown that the 25th percentile of houses in the area that they're looking at is currently $350 000. Use mathematical reasoning to interpret the given information for the potential buyers.



Hint
Formulate
Solve
Evaluate and verify
Communicate

⋆11 The following graph shows the hours driven in the first 6 months of having a licence for 1000 teenagers in the local council area. Elliot has only managed to accumulate 15 hours driving, whilst Syke has 60 hours. Use mathematical reasoning to interpret the progress of Elliot and Skye in comparison to other learner drivers.





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11D Describing the spread of data

LEARNING GOAL

- Use everyday language to describe the spread of the data, including spread out, dispersed, tightly packed, clusters, gaps, more/less dense regions and outliers.

Why is essential to be able to use everyday language to describe spread in data?

- **Clarity:** It simplifies complex statistics for a broader audience.
- **Context:** It provides context to central tendency measures, showing whether they accurately represent the data.
- **Variability:** It highlights how much individual data points differ from the average.
- **Informed decisions:** It aids in making better decisions based on the full data picture.
- **Comparisons:** It enables effective comparisons between different datasets.
- **Outliers:** It helps identify outliers that may skew interpretations.



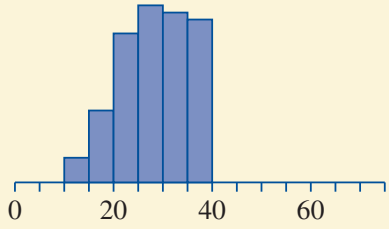
Datasets are easier to understand when you are able to identify and describe the spread.

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WHAT YOU NEED TO KNOW

- Everyday language can be used to describe the spread of data by indicating particular points in the graph.

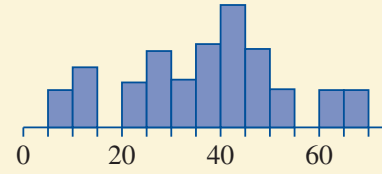
Histogram A



Words describing a distribution that is not spread out:

- not spread out
- tightly packed
- clustered
- more dense
- narrowly (or tightly) distributed
- narrowly dispersed.

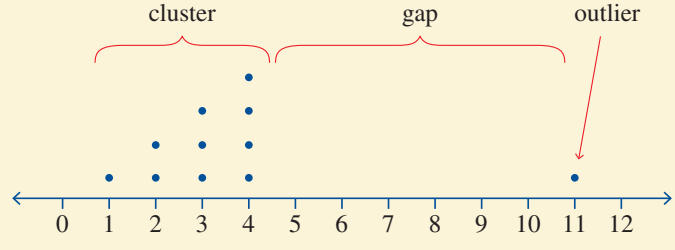
Histogram B



Words describing a distribution that is spread out:

- spread out
- loosely packed
- dispersed
- less dense
- widely distributed
- widely dispersed.

- The spread also describes how a dataset is distributed around the mean or median. The location of the median can be estimated, and when the data is displayed using histograms, the total area of the columns either side of the median will be equal. Looking at the histograms above, we would say 'Histogram A shows data that is tightly packed around the median, whereas histogram B shows data that is loosely packed around the median'.
- A **cluster** is produced when several data points lie in a group.
- A **gap** is a section that contains no data.
- An outlier has a value that is much greater than or much less than other data in the set.



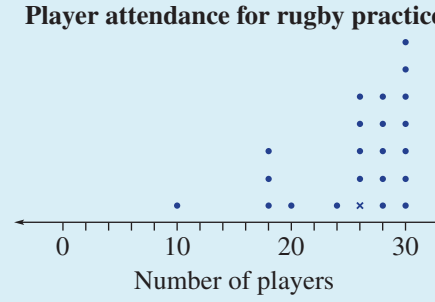
- A large dataset may have a distribution that is mixed, with some parts or regions being tightly packed or clustered and other parts being loosely packed.

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Example 12 Describing the spread from a dot plot

A coach is recording how many players are attending rugby practice.



Describe the distribution, making use of the terms below where possible:

- spread out
- tightly packed
- loosely packed
- dispersed
- more/less dense regions
- clusters
- gap
- outliers.

WORKING	THINKING
The data is tightly packed around the mean. The dot plot has a small dispersion. There are two clusters: one between 18 and 20, and the other between 24 and 30 with the second cluster being more dense. The data has two gaps, one between 14 and 18, the other between 20 and 24. The count of 10 could be considered an outlier due to the gap between it and the other counts.	Go through each term and see if they correspond to the distribution. Where possible include examples from the dataset.

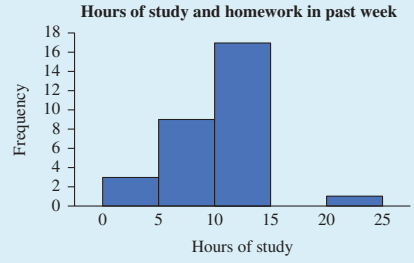


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Example 13 Describe the spread from a graph in real-world contexts [complex]

Use everyday words to describe the following real-world context data sets:

a



b **Student heart rates after doing 1 minute of jumping jacks**

Stem	Leaf
6	1
7	
8	4 6 8
9	2 9 9 9
10	
11	3 4
12	1 2 4 4 7 9
13	8
14	4 7 8
15	1

Key: 6|1 = 61

WORKING	THINKING
a The data is **tightly packed** between 5–15, which is where the majority of the students' answers of hours of study are. The data is most **dense** between 10–15 hours of study, suggesting most students study this number of hours. There is a **gap** in the data between 15–20 hours of study, with a possible **outlier** at 20–25; only one student studies for more than 15 hours.	Describe the distribution, making use of the terms below where possible: • spread out • tightly packed • loosely packed • dispersed • more/less dense regions • clusters • gap • outliers.

... Continued

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b There is a **small cluster** between 80–100 jumping jacks.
There are two **gaps** in the data with no one recording heart rates in the 70's or 100's.
The data is more **dense or clustered** in the 120–130, showing this was the most common range of jumping jacks.
There is a possible **outlier** with the result of 61 beats per minute suggesting a lack of effort or a low resting heart rate for that individual.

◄····· Use the context to make sense of what this description means for summarising data for its purpose. For example, tightly packed/clusters is where most of the data is or the most common result. What does that tell you about the summary of the subject? Gaps and outlines - unusual pieces of data, where no or not many results are. What does this tell you about the subject?



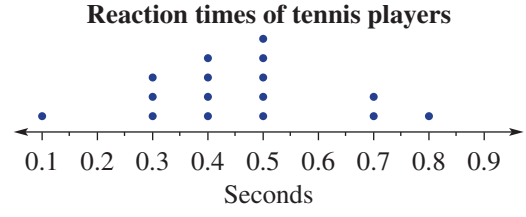
Exercise 11D

FUNDAMENTALS

Example 12

1 Describe the distribution, making use of the terms below where possible:

- spread out
- loosely packed
- more/less dense regions
- gap
- tightly packed
- dispersed
- clusters
- outliers.



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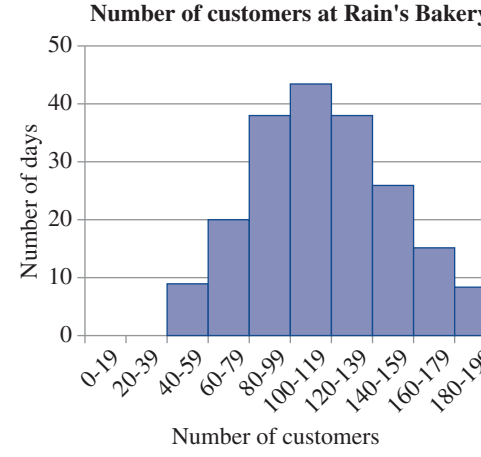
APPLICATIONS

2 Rain has just opened her new bakery and has recorded the number of customers who purchased cakes from her shop.
Expand on each description below in as much detail as you can.

a The distribution has an outlier.

b The distribution has a gap.

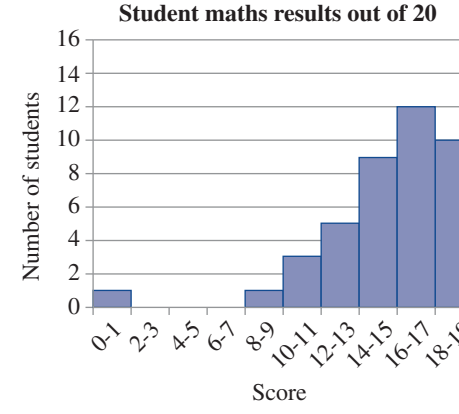
c The data is tightly packed around the mean.





3 A teacher is recording her students' test scores (out of 20). Describe the distribution, making use of the terms below where possible:

- spread out
- widely scattered
- dispersed
- tightly packed
- clusters
- gaps
- more/less dense regions
- outliers.

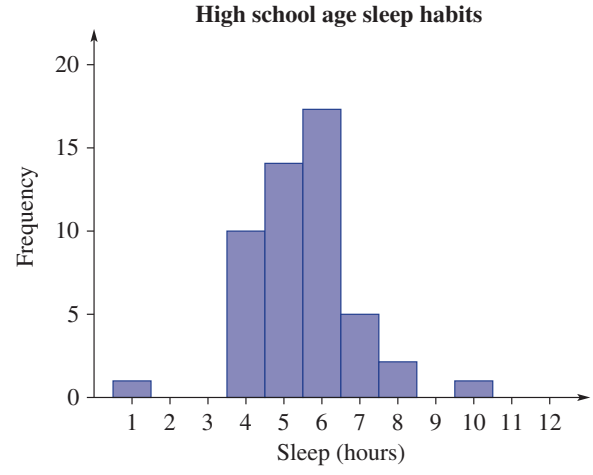


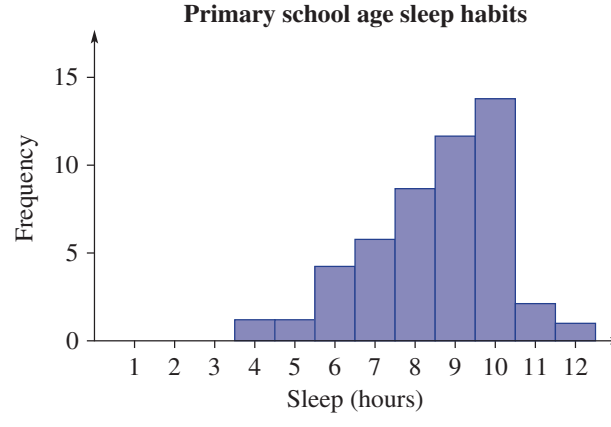
Hint A gap is a section that contains no data.

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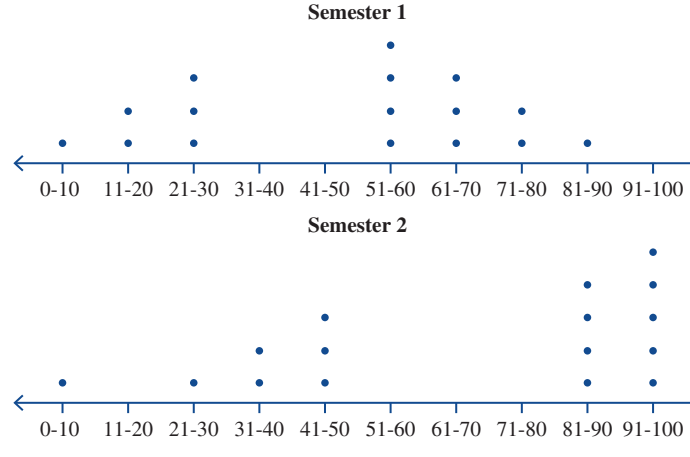
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Example 13 ★4 These two histograms record the average sleep of 50 students from two different age groups – primary and high school ages. Describe and compare the spread for both graphs.





★5 A teacher uses dot plots to display how her students are progressing after each semester. Describe and compare the spread for both semesters.



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⋆6 A combined university study reflecting on the popularity of its multiple open days for high schoolers is shown below. The back-to-back stem plot shows the number of visitors per day to 20 events in two different years *X* and *Y*. Describe and compare the different years.

Open day attendance

Year *X*		Year *Y*
9 5 1	12	0
2	13	
9 8 5 4	14	
9 9 8 5 3 2	15	
7 4 1	16	
6 2	17	5 8
0	18	2 7
	19	5 6 8
	20	1 5 7 9
	21	4 8 9
	22	2 4 7 8 8



Hint A stem-and-leaf plot is like a column graph turned on its side. This is a back-to-back stem-and-leaf plot, so it's like a double column graph, with one dataset on the left and one on the right.



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11E Calculating and interpreting measures of spread COMPLEX

LEARNING GOALS

- Calculate and interpret statistical measures of spread using the range.
- Calculate and interpret statistical measures of spread using interquartile range.
- Calculate and interpret statistical measures of spread using standard deviation.
- Investigate real-world examples from the media illustrating inappropriate uses of central tendency and spread.

Why is it essential to understand how to calculate and interpret statistical measures of spread?

- Measuring spread is essential for mathematical analysis.
- A large spread makes the mean less effective as a data representation. Calculating and interpreting spread using range, interquartile range and standard deviation enables more precise data analysis.



Many industries use measures of spread to assist in explaining the real meaning of results.

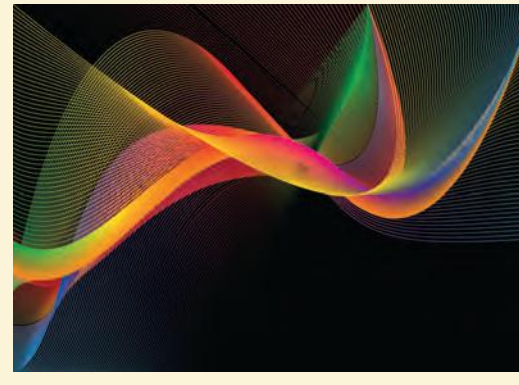
WHAT YOU NEED TO KNOW

- The range, interquartile range and standard deviation are useful measures of spread to compare datasets.
- The simplest measurement of spread is the **range**.
  - The range represents the limits of a dataset and only gives basic detail about the spread.
  - It explains how wide or narrow the spread is, especially when compared to another dataset.
  - The range is found by subtracting the minimum value in a dataset from the maximum value.
  - The range can be distorted by extreme values (outliers), which are values that are very large or very small compared to the rest of the dataset.
- The **interquartile range** (IQR) is the range of the central half of the data, either side of the median. It is calculated by subtracting the lower quartile (Q_1) from the upper quartile (Q_3): $IQR = Q_3 - Q_1$.

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- If the IQR is small compared to the range, the dataset likely contains outliers. In such cases the IQR is often a better measure of spread as it excludes outliers.
- If the IQR is half or more of the value of the range, the data is likely to be evenly spread or tightly packed.

- The most important purpose of **standard deviation** from the mean is to understand how spread out a data set is. It is a measure of the average distance of each data value from the mean.
  - A low standard deviation means that most of the numbers are tightly packed around the mean.
  - A high standard deviation means that the numbers are spread out from the mean.
- The **variability** of a dataset is the amount by which data points differ from the mean and from each other, similar to the spread, and can also be measured by the range, IQR and standard deviation.
- Misuse of measures of spread may arise in the following cases.
  - Standard deviation may be misleading when there are extremes in the data (extremely high or low values), as the average is skewed.
  - The range may be misleading to measure spread when there are outliers or extreme values.
- The **misuse** of measures of central tendency may arise from the following issues:
  - The mean may be misleading when there are outliers or extreme values.
  - The median does not consider the exact value of each observation and is capable of misleading when all information is required.
  - The mode should not be used if the data is continuous, such as the heights of people in a basketball team, as it is not likely to have any one value that is more frequent than any other. It should also not be used if the most frequent value is far away from the rest of the data.

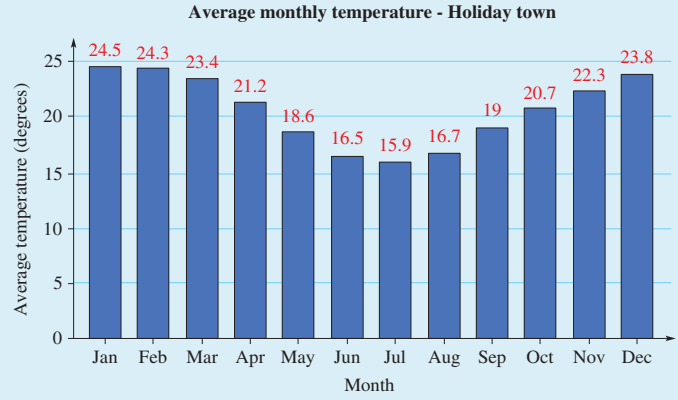


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Example 14 Calculating and interpreting statistical measures of spread using the range

Ali has recorded the average temperature at the same holiday location in Queensland every month for a year.
The results are shown in the following graph:



a Identify the maximum and minimum temperatures recorded in the dataset.
b Calculate the range.
c Interpret the range of the dataset.

WORKING	THINKING
a The maximum temperature is 24.5°C. The minimum temperature is 15.9°C.	Identify the maximum (the highest) and minimum (the lowest) temperatures.
b $24.5 - 15.9 = 8.6°C$	Range = maximum value − minimum value
c The range of the data represents the limits of the dataset. Knowing how cold and how hot a place can get is helpful for planning, especially given the data was collected for a holiday destination. A destination with a very high range in temperature will need more planning as to when to visit. However, with a limited temperature range of 8.6°C, the temperatures at this location are not highly variable across the year and remain consistently temperate. This means that, on average, there is less need to consider the timing of your visit, as the weather is reliably pleasant throughout the year.	Refer to the definition of the range and the context of the data. Consider how the range of average temperatures in a holiday destination is useful.

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Example 15 Calculating and interpreting statistical measures of spread using interquartile range

The test results of ten students are 5, 7, 10, 5, 6, 7, 9, 4, 6, 9.

a Arrange the data in order from the smallest value to the largest value.

b Identify the median (Q_2), lower quartile (Q_1) and upper quartile (Q_3).

c Calculate the interquartile range.

d Interpret the interquartile range.

WORKING	THINKING
a 4 5 5 6 6 7 7 9 9 10	Put values in order from lowest to highest.
b 4 5 5 6 (6 7) 7 9 9 10	To determine the median of a distribution: • The number of scores is 10. • The median will lie between the 5th and 6th scores.
$Q_2 = \frac{6+7}{2}$	
$Q_2 = \frac{13}{2}$	
$Q_2 = 6.5$	
$(4\,5\,(5)\,6\,6)\;7\,7\,9\,9\,10$	The lower quartile is the middle number of the lower half. Place brackets around the lower half of the dataset.
$Q_1 = 5$	
$4\,5\,5\,6\,6\;(7\,7\,(9)\,9\,10)$	Identify the median of the lower half. The upper quartile is the middle number of the upper half. Place brackets around the upper half of the dataset.
$Q_3 = 9$	Identify the median of the upper half.

... Continued

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c $IQR = Q_3 - Q_1$
$IQR = 9 - 5$
$IQR = 4$

◄···· The interquartile range is the difference between Q_3 and Q_1.

d The IQR is the range of the central half of the data. The value of 4 compared to the range of 6 indicates that there are no outliers in the data and it is fairly evenly spread across the range.

◄···· Refer to the definition and usefulness of interquartile range.

Example 16 Calculating and interpreting statistical measures of spread using standard deviation without using technology

Note: In the assessment for this course you will not be asked to calculate standard deviation without using technology. It is done here to help you learn what the standard deviation is. It is suggested that you work through part **a** *in order to see what the technology does when it calculates standard deviation.*

A dog breeder records the number of pups in each of their dogs' litters (2, 4, 4, 4, 5, 5, 7, 9).

a Calculate the standard deviation, without using technology.

b Interpret the standard deviation of the dataset.



WORKING	THINKING
a Step one: the mean for the eight litters is $\bar{x} = \frac{2+4+4+4+5+5+7+9}{8}$ $\bar{x} = 5$	◄···· *Step one*: calculate the mean.

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Step two:

$2 - 5 = -3$ $\quad 5 - 5 = 0$

$4 - 5 = -1$ $\quad 5 - 5 = 0$

$4 - 5 = -1$ $\quad 7 - 5 = 2$

$4 - 5 = -1$ $\quad 9 - 5 = 4$

◄···· *Step two*: find the difference of each number from the mean.

Step three:

$(-3)^2 = 9$ $\quad 0^2 = 0$

$(-1)^2 = 1$ $\quad 0^2 = 0$

$(-1)^2 = 1$ $\quad 2^2 = 4$

$(-1)^2 = 1$ $\quad 4^2 = 16$

◄···· *Step three*: square the difference of each number from the mean. This makes all of them positive, so they don't cancel each other out.

It also magnifies larger differences and minimises smaller differences.

$$\frac{9+1+1+1+0+0+4+16}{8} = 4$$

◄···· *Step four*: calculate the mean of the squared differences.

$$\sqrt{4} = 2$$

◄···· *Step five*: finally, calculate the square root of the answer. This counteracts the squaring from step three and allows the standard deviation to be expressed in the original units.

The standard deviation from the mean for the litter of puppies is 2.

b The standard deviation is 2 from the mean of 5. This indicates that the values in the dataset are spread out around the mean. The standard deviation would be most useful for comparing to another dataset.

◄···· Refer to the definition of standard deviation. Write evaluation in terms of the dog breeding scenario.



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Example 17 Calculating and interpreting statistical measures of spread with technology

Sally recorded the heights of her friends in centimetres:

160, 171, 158, 167, 163.

Calculate the mean, standard deviation, range and IQR using a calculator.

The instructions given below are for a Casio fx 82.



WORKING	THINKING
	Clear any data already in the calculator. Press Mode [setup] > 2 > 1. A table appears. Type individual data values followed by the = key to enter the data, then click AC[off]. For these statistics press these keys:
The mean, $\bar{x}$, is 163.8. The average height of 163.8 cm suggests a typical height for this small group.	**Mean** - this value serves as a central reference point for the group. This is the typical height one could expect in this small group. Mean, $\bar{x}$: Shift > 1 > 4 > 2 > =
Standard deviation for the heights of Sally's friends is 5.26 from the mean. With a **standard deviation of 5.26 cm**, most heights are clustered around this average, indicating a degree of uniformity.	**Standard deviation** - if you take the mean and add or subtract the standard deviation, you get a range, indicating how spread out the data is from the mean. Standard deviation, SX: Shift > 1 > 4 > 4 > =

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Min = 158
Max = 171
Range = 171 − 158
= 13

A **range of 13 cm** shows some diversity but not extreme differences in height.

◄···· **Range** - tells us about the overall spread of heights in the group.
For the range, subtract the minimum value from the maximum value.
Minimum value, minX: Shift > 1 > 5 > 1 > =
Maximum value, maxX: Shift > 1 > 5 > 2 > =

Q1 = 159
Q3 = 169
IQR = 169 − 159
= 10

The **IQR of 10 cm** reinforces that the majority of individuals' heights are within a fairly narrow band, indicating that while there are a few shorter and taller individuals, most people in this group are of similar height.

◄···· **IQR** - represents the middle 50% of the heights, indicating within what range the central half of the group falls.
For the IQR, subtract Q3 from Q1.
Quartile 1, Q1: Shift > 1 > 5 > 3 > =
Quartile 3, Q3: Shift > 1 > 5 > 5 > =

Calculator activity 11E: Calculating statistical measures of spread with scientific calculators.

Spread-sheet

Spreadsheet activity 11E: Calculating statistical measures of spread using a spreadsheet:
These technology activities are in the Interactive Textbook.

Example 18 Investigate real-world examples from the media illustrating inappropriate uses of measures of central tendency and spread [complex]

Headline: '*A brand new small school reports great first ATAR results including a score of 95 and a standard deviation of 18.*'
Investigate if this claim is an accurate picture of the overall results for the school.
The following are the full senior class ATAR results:

80, 45, 65, 50, 75, 95, 80.

Note: The following work is done by hand. Calculations can be done with a calculator or spreadsheet also - check with your teacher which to use in section activities.

... Continued

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WORKING	THINKING
	Formulate
Article states a single score of 95 and standard deviation of 17. Calculate the mean and median to compare to a high result of 95 and decide if it is typical. Calculate the standard deviation to verify the article's claim, and calculate the IQR as a comparison.	Identify which measures of central tendency are being used. Assume which other measures should be calculated to compare. Decide on use of formulas by hand or with technology.
	Solve
Mean: $\bar{x} = \frac{\sum x}{n}$ $\bar{x} = \frac{45 + 50 + 65 + 75 + 80 + 80 + 95}{7}$ $\bar{x} = \frac{490}{7}$ Mean = 70	Calculate the mean using formula: $\bar{x} = \frac{\sum x}{n}$
Median: 45, 50, 65, (75), 80, 80, 95 Median = 75	Calculate the median- place data in ascending order and find the middle. There are 7 pieces of data, so the median is the 4th number.
Standard deviation: 17.8 This verifies the article's claim regarding the standard deviation. However, this may not give a full picture of the distribution/spread of the data.	Calculate the standard deviation using technology of choice. (For calculator steps see previous example or online resources.)
Q1 is middle of first half of data: 45, (50), 65 Q1= 50 Q3 is the middle of the second half of data: 80, (80), 95 Q3 is 80 IQR = Q3 − Q1 = 80 − 50 = 30	Calculate IQR = Q3 − Q1

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	Evaluate and verify
The middle is clear to see in a small data set in order, so the median is verified. The mean would be expected around this value, as at least half the data is between 70–80.	Use an estimating tool for the mean, median and IQR, and verify your calculations make sense within the data context. Evaluate the meaning of the calculations and compare to the question.
Both mean and median are similar and significantly lower than the score of 95, which is therefore a possible outlier and not typical of school results.	Compare the mean and median. If there is a large difference, consider which is a better representation on this dataset.
The standard deviation of approximately 17 indicates a certain level of variability in the dataset. However, without context, it doesn't reveal how the data is distributed, especially if there are outliers. The IQR of 30 indicates a much wider spread of scores, with 50% between 50–80.	The IQR shows that the middle 50% of scores spans a wider range than what the standard deviation suggests. This indicates significant variability among the central scores that the standard deviation alone does not capture.
	Communicate
Stating only the standard deviation is misleading, as the dataset includes spread-out values like 45 and 95. Omitting the IQR of 30 underestimates the variability. Additionally, highlighting a single high score of 95 without mentioning the mean or median in the 70s gives a false impression of overall group performance.	Explain your decision in context of the question. Is the article misleading? Use mathematical reasoning from your calculations in a worded summary.

Spread-sheet **Worksheet 11E** Investigating a real-world example from the media illustrating inappropriate uses of measures of spread: see the interactive textbook for this activity

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Exercise 11E

FUNDAMENTALS

1 For the dataset shown, calculate the range, IQR and standard deviation.
2, 11, 5, 15, 17, 12, 7, 2, 11, 3

2 The following dataset books read this year.
15, 17, 14, 22, 0, 25, 13, 19, 16, 20, 15, 14, 17, 11, 20

a Calculate the range.

b Calculate Q_1, Q_3 and the IQR.

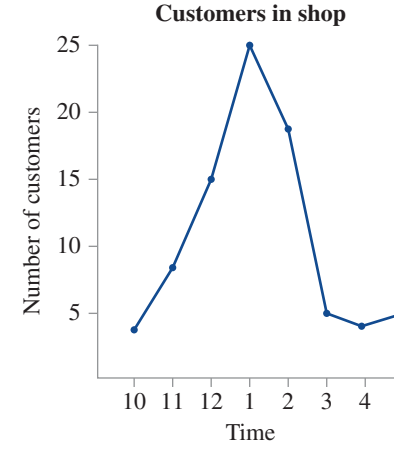
APPLICATIONS

Example 14

3 Ken is deciding whether he needs to hire an assistant and is recording the number of customers in his shop on an hourly basis.

a Identify the maximum and minimum values.

b Calculate the range of the distribution.



Example 15

4 A maths teacher has recorded some of her students' results.

Results	%
Amy	85
Fari	40
Grace	37
Sarah	80
Blake	75
Craig	100
Skye	20



a Arrange the data in order from lowest to highest.

b Identify the median (Q_2), lower quartile (Q_1) and upper quartile (Q_3).

c Calculate the interquartile range of the spread.

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Example 16

5 Obelia and her friends have recorded how many hours of driving practice each friend has done in the last month:
5, 8, 12, 14, 10, 15, 11.
a Calculate the range.
b Calculate the IQR.
c Calculate the mean.
d Calculate the standard deviation (using technology).

6 Rose was trying to explain to her friends the importance of rehydrating. She recorded how much water each of her friends were drinking on average (litres per day):
1, 1.5, 2, 1.7, 2.2, 2.5, 0.8. Use technology to:
a Calculate the mean correct to one decimal point.
b Calculate the standard deviation correct to one decimal point.
c Interpret the answers in a. and b. in the context of the dataset.

7 Sheree has recorded the heights (cm) of some children in her class.
150 140 130 102 105 163 110 152 145 143 147 139 140
Using a calculator:
a calculate the mean
b calculate the standard deviation
c identify the minimum, Q_1, median, Q_3 and the maximum values
d calculate the range
e calculate the IQR.

Spread-sheet

8 Rodney records the weekly weather temperatures for the local area. Calculate the mean and standard deviation using a spreadsheet.
25°C 27°C 32°C 31°C 29°C 32°C 30°C 29°C

Spread-sheet

9 A couple are recording home loan rates in preparation to buying a home. Calculate the mean and standard deviation using a spreadsheet.
4.5% 5% 5.5% 6.5% 4.7% 5.4% 4.7% 5% 6.7% 4.8%
Extension: research current loan interest rates and compare them to these.

10 Cooper has been practising shooting baskets every day in preparation for his basketball tournament. He recorded the number of shots he made each day from 20 shots.
13, 20, 17, 2, 17, 20, 15
a Find the mean of the basketball shots.
b Identify any outliers.
c Explain whether the outliers affect the mean.

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Example 16

11 An online financial blog states: 'Working for company *X* is great with an average salary of $140 000'. Investigate if this claim is an accurate picture of a typical employee's earnings, given the actual dataset of staff salaries below:
$61 000, $75 000, $82 000, $55 000, $97 000, $160 000, $450 000.

Hint
Formulate
Solve
Evaluate and verify
Communicate

CF

12 Media reports on the latest youth crime figures for the last 5 months, quoting that neighbourhood *X* crime levels have increased significantly to 5 times higher than previously. Use calculations to investigate if this claim is an accurate picture of a typical crime rate.
The actual dataset below shows incidents of youth crime per 1000 residence for the last 5 months:

CU

Neighborhood *X*	8	10	13	5	25

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Modelling task

Context: Being able to organise and analyse data to present statistics and describe the data is a highly regarded skill in the workplace and for many interests that people have outside of work.

Task: Use statistics to report on a topic or area that is of interest to you. You will need to gather one dataset (we suggest it should contain 20 values) relevant to your interest. You will need to create a report, including your calculations, to communicate and perhaps promote your interest, demonstrating that statistics promote expertise.

Some ideas for data that you could collect:

Fitness tracking: If you track your workouts, compile data on your exercise performance over a month (e.g., distances run, weights lifted) and analyse trends and improvements.

Reading habits: Collect data on the number of books read by yourself or your friends, including genres and ratings.

Environmental data: Gather statistics on local wildlife sightings or plant species in your area. Analyse seasonal changes, diversity.

Music preferences: Survey friends or family about their favourite music genres and collect data on streaming hours per genre.

Stage 1: Formulate
Make an observation of: • what you are required to do • what information you have • what other information is needed. Make an assumption of: • how you could gather more information • which measures of spread and central tendency will be relevant to your chosen area of interest.
Stage 2: Solve
• Decide on appropriate sampling and/or researching techniques. • Gather more information through research or a survey. • Produce graphs and/or tables required to help solve the problem. • Calculate measures of central tendency and spread relevant to the investigation.

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Stage 3: Evaluate and verify
Check all information has been included and researched accurately. • Check you have verified the statistics. • Check you have the evidence to back up your report summary. • Include the evidence in the form of statements and calculation. Justify your response to questions posed in context, by considering your: • assumptions • observations • limitations • strengths.
Stage 4: Communicate
Reflect on your response and solution to the investigation, outlining the decisions involved in making your response. • State your main point. • Explain the evidence.

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Chapter summary

Measures of central tendency

Measure of central tendency identify the central position within a dataset. There are three main measures of central tendency: the mode, the mean and the median.

Mode

The mode is the most frequent value in the dataset, i.e. the value that occurs most often. A dataset can also have two modes (it is bimodal), or no mode at all.

- Advantages of using the mode:
  simple to understand (the value that occurs most often)
  not affected by extreme values (outliers).
- Disadvantages of using the mode:
  not based on all the values in a dataset
  sometimes the data has more than one mode, or no mode at all.

Mean

The mean is also known as the average. It is found by finding the sum of all the values in the data set and dividing by the number of values in the data set.

The formula for identifying the mean is $\bar{x} = \frac{\sum x}{n}$

where $\sum x$ = sum of all data values, n = number of data values in the dataset.

- Advantages of using the mean:
  all the data is taken into account easy to understand and calculate.
- Disadvantages of using the mean:
  outliers (extreme values) can distort the results
  if the data is in the form of percentages or ratios, it could be challenging to calculate the mean.

Median

The median is the middle value of a dataset when it is sorted in order from the smallest value to the largest value.

- Advantages of using the median:
  simple to understand (the data point in the middle, with an equal number of greater and lesser values) and easy to calculate
  not affected by outliers.
- Disadvantages of using the median:
  the median is based only on the middle value of an ordered dataset and does not include values from the other data points
  at all need to remember that if there is an even number of data points to take the average of the middle two.

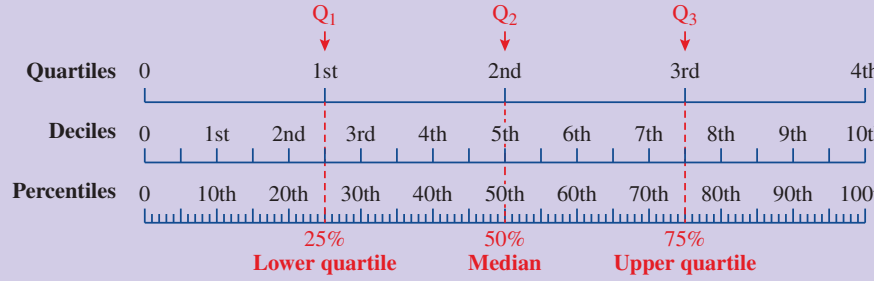
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Quartiles Quartiles divide ordered data into four equal parts.

Deciles Deciles divide ordered data into 10 equal parts.

Percentiles Percentiles divide ordered data into 100 equal parts.



Interpretation of quartiles, deciles and percentiles mainly involves determining where a particular value lies in relation to them, and the percentage of scores that are above or below a particular quartile, decile or percentile.

Cumulative frequency The cumulative frequency is the running total of the frequency distribution of the dataset, which is shown in a frequency table.

Spread The spread describes how a dataset is distributed around the mean or median.

Cluster A cluster is produced when several data points lie in a group.

Outlier An outlier is a value that is much greater than or much less than other data in the set.

Range The range represents the limits of a dataset and only gives basic detail about the spread. The range is found by:
range = highest score − lowest score.

Interquartile range (IQR) Range of the central half of the data, either side of the median. It is calculated by: IQR = $Q_3 - Q_1$.

Standard deviation Measure of the average distance of data away from the mean.
A low standard deviation means that most of the numbers are tightly packed around the mean.
A high standard deviation means that the numbers are spread out from the mean.

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Chapter checklist

11A ☐ I can identify the mode from a dataset.

1 Identify the mode from this dataset.
5, 4, 8, 7, 3, 6, 7, 5, 8, 7, 5, 9, 4, 9, 7, 7, 8, 9, 10, 2

11A ☐ I can calculate the mean and median from a dataset.

2 Calculate the mean and median from the dataset in Question **1**.

11B ☐ I can investigate the suitability of measures of central tendency in various real-world contexts. **[Complex]**

3 **a** List the measures of central tendency that are not much affected by extreme values.
b Explain which measure of central tendency is best to use when you want the value of all the data points in the dataset to be included in its calculation.

4 List the features of datasets that could make the mean, median and mode misleading.

5 Determine the best measure of central tendency for this house price data.
$145 000, $360 000, $1 700 000, $650 000, $170 000, $300 000, $390 000

11B ☐ I can identify outliers and investigate their effect on the mean and the median. **[Complex]**

6 The following is a dataset recording the number of crows found in a field each day.
50, 49, 40, 50, 107, 45, 37, 35, 20, 10, 6, 18
Identify any outliers and then calculate the mean and median with and without the outlier.

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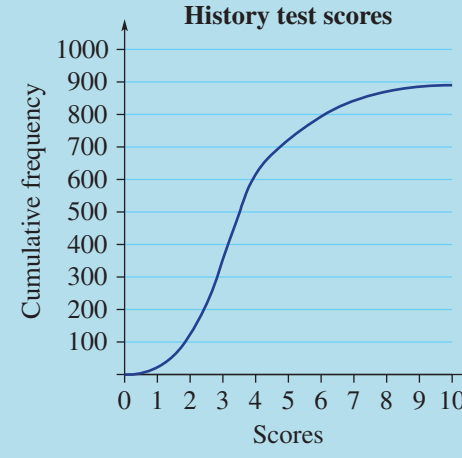
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11C ☐ I can calculate quartiles from a dataset.

7 Calculate the 1st, 2nd and 3rd quartiles for this dataset:
5, 4, 8, 7, 3, 6, 7, 5, 8, 7, 5, 9, 4, 9, 7, 7, 8, 9, 10, 2

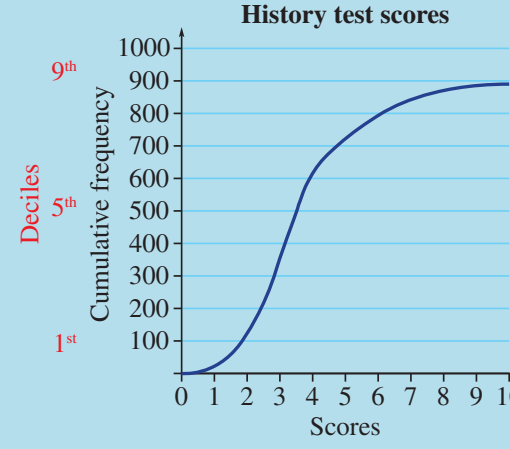
11C ☐ I can interpret quartiles from a graph. **[complex]**

8 From this graph of history test scores, determine the lowest score needed to be in the top quarter of the history class.



11C ☐ I can interpret deciles from a graph. **[complex]**

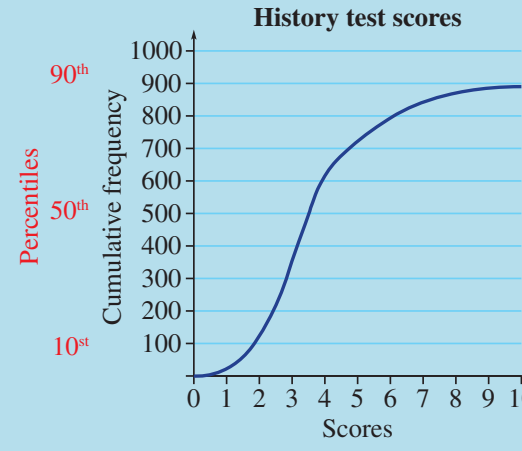
9 On the history test score graph from Question **8**, my score is better than three-tenths of the class. Determine the value of my score.



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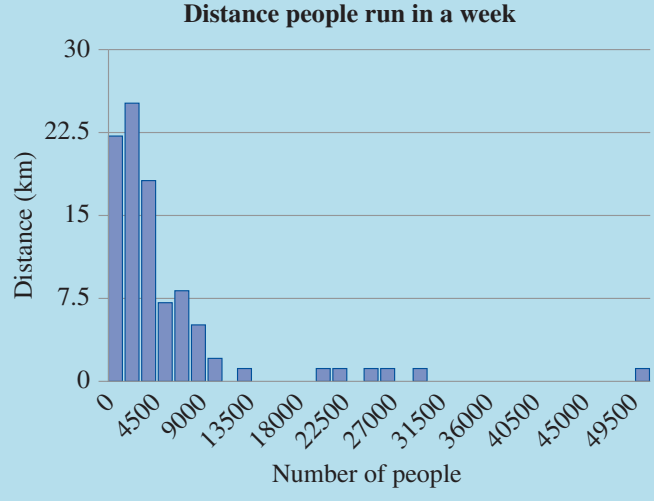
11C ☐ I can interpret percentiles from a graph. **[complex]**

10 On the history test score graph in Question **8**, determine the percentile of a score of 8, and explain what percentage of the class did better than this score.



11D ☐ I can describe the spread of data, including the terms spread out, dispersed, tightly packed, clusters, gaps, more/less dense regions and outliers.

11 Use as many of the terms listed to describe spread of data to describe the spread of the data in this graph.



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11E ☐ I can calculate statistical measures of spread using the range, interquartile range and standard deviation. **[complex]**

12 Calculate the range, interquartile range and standard deviation of the data. This data shows the number of items sold in a retail shop.
6, 7, 5, 24, 25, 27, 3, 0, 0, 1, 45

☐ I can interpret statistical measures of spread using the range, interquartile range and standard deviation.

13 Explain what the range, interquartile range and standard deviation of the dataset in Question **12** tells us about the spread of the data.

11E ☐ I can investigate real-world examples from the media illustrating inappropriate uses of measures of central tendency and spread. **[Complex]**

14 Media reports that most teenagers are spending up to 18 hours gaming on weekends, with little variability with a standard deviation of 2.7.
Raw data collected for survey: 10, 12, 12, 14, 15, 16, 18.
Use other calculations of central tendency and spread to comment on the reasonableness of this media claim.

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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

11A **1** A netball coach was preparing for a new season. The following dataset is her team's goal scores for the previous season.

56 76 45 78 67 48 65 45 65 60 65 59 79

Use the dataset to:

a identify the mode

b calculate the mean

c calculate the median.

11B **2** Explain which measure, or measures, of central tendency are the best to use in the following situations.

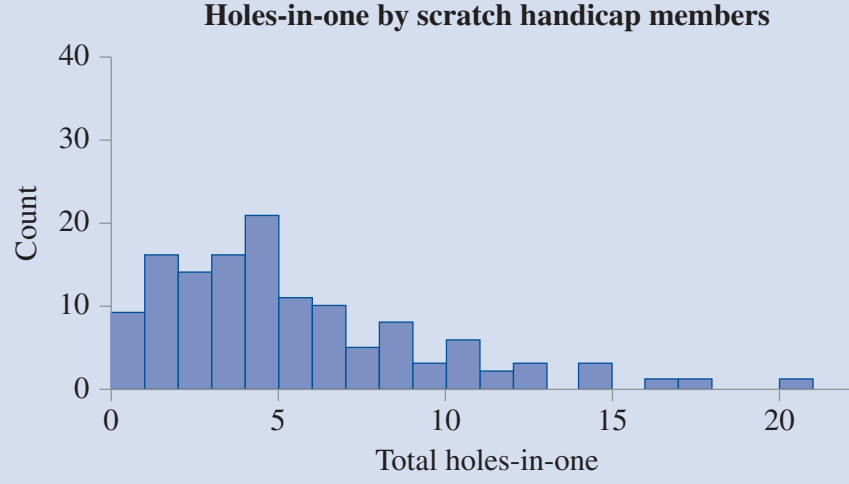
a You don't want the measure of central tendency to be distorted by extreme values.

b You want to include the value of all the points in the measure.

c You want a measure that has an equal number of data points above it as below it.

d You want a measure that tells you which value occurs most often in the dataset.

11D **3** A golf club recorded how many holes-in-one its scratch handicap members achieved during their memberships at the club.

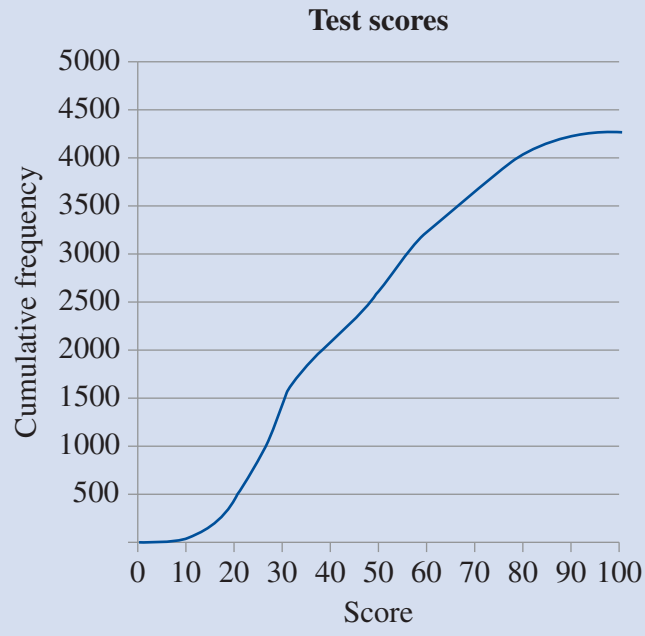


Use everyday language to describe the measure of spread.

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11C **4** The test scores for a class are displayed in the cumulative frequency graph.



a Calculate the median of the test scores (2nd Quartile → Q_2).
b Determine the lower quartile of the test scores (1st Quartile → Q_1).
c Determine the upper quartile of the test scores (3rd Quartile → Q_3).
d Determine below which test score will a quarter of the test scores lie.

Complex Familiar

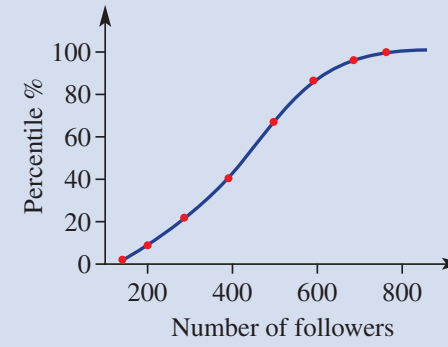
11A, B **5** Abel's goal is to achieve a 50% grade on his mathematics tests. He has recorded his grades out of 20 for the past 8 weeks. He has two weeks to go.

5, 8, 9, 3, 2, 4, 12, 15

a Calculate the mean grade.
b Determine the median grade
c Determine the mode grade.
d Which is a better measure to assist with his preparation to reach his goal? Give a reason.

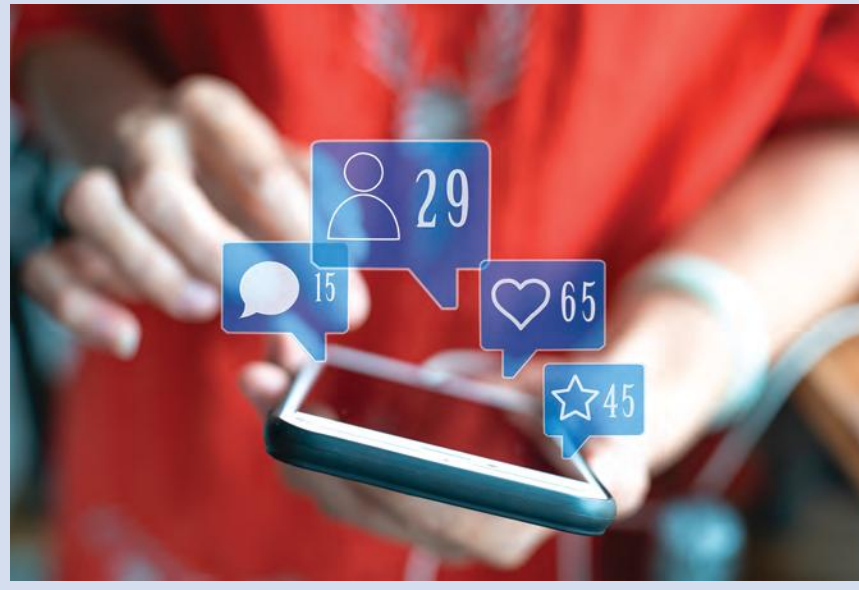
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11C **6** The cumulative frequency graph below shows the results from a suburb survey regarding social media accounts and how many followers they have on these accounts.



a Estimate the number of social media followers in the 90th percentile.

b An individual has 500 followers. Identify from the graph which percentile this lies in and interpret the percentage of these populations that have more followers than this.



11E **7** Tom is recording the following rainfall (mm) for the past number of days. Determine the range, interquartile range and standard deviation.

3, 7, 5, 2, 25, 2, 3, 0, 0, 1, 45

11E **8** Tom has recorded the following maximum temperature (in °C) for the past number of days. Using a calculator, determine the range, interquartile range, mean, and standard deviation.

18, 18, 16, 22, 22, 25, 23, 27, 20, 25, 25, 27

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11E **9** Tom has recorded the following minimum temperatures (in °C) for the past number of days. Using technology determine the range, mean and standard deviation.

4, 7, 4, 7, 8, 5, 5, 7, 8, 7, 5, 7

10 The following is a dataset recording the number of dolphins seen from a cruiseship each day.

35, 49, 36, 50, 107, 43, 37, 34, 20, 10, 6, 7

a For the dataset, determine:
- **i** the median (Q_2)
- **ii** the upper quartile (Q_3)
- **iii** the lower quartile (Q_1)
- **iv** IQR
- **v** mean,

b Determine whether any numbers are outliers.

c Give a possible reason for the outlier.

d Determine whether outliers effect answers in **a**.

e Explain which measure of central tendency is best suited to this dataset, give reasons.



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Complex Unfamiliar

11C **11** Archie works in sport administration and is concerned with their current salary. Archie surveys some colleagues working in administration in other companies and finds that their salary is in the 78th percentile. Should they be concerned? Explain your answer.

11E **12** Consider the three datasets A, B, and C:

$A = \{8, 10, 13, 7, 12\}$

$B = \{10, 10, 10, 10, 10\}$

$C = \{1, 1, 10, 19, 20\}$.

a Calculate the standard deviation of each dataset.

b Determine which dataset has the largest standard deviation.

c Is it possible to answer Question **b** without completing Question **a**?

13 Media posts on social media claim that *'climate change is exaggerated and is not a concern, with a standard deviation of only 0.4 degrees we shouldn't worry'*. Analyse the following temperatures for one area over 7 years, calculate other measures of central tendency and spread, and comment on the reasonableness of this media claim.

Temperatures (°C): 14.2, 14.5, 14.7, 15.0, 15.1, 15.3, 15.4

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12 Comparing datasets



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In this chapter

12A Completing a five-number summary
12B Constructing box plots
12C Comparing datasets **[complex]**
12D Comparing the characteristics of histograms **[complex]**
Modelling task
Chapter summary
Chapter checklist
Chapter review

Syllabus reference

Unit 4 Topic 2 Summarising and comparing data

Comparing datasets (9 hours)

In this sub-topic, students will:

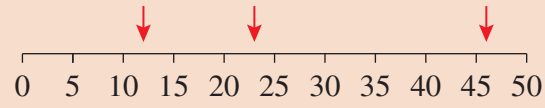
- complete a five-number summary for different datasets
- construct a box plot using a five-number summary
- compare parallel box plots and back-to-back stem plots for different datasets **[complex]**
- compare the characteristics of the shape of histograms using symmetry, skewness and bimodality, where applicable **[complex]**.

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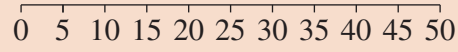
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Prior knowledge check

1 Identify the numbers marked by the arrows on this number line.



2 Given the following group of numbers, determine the range (largest number in the data minus smallest number) of the data and show this on the number line provided.
17, 34, 19, 41, 29



3 Organise the following numbers into a stem plot.
41, 52, 57, 58, 65, 66, 70, 75, 78, 78, 78, 80, 80, 95

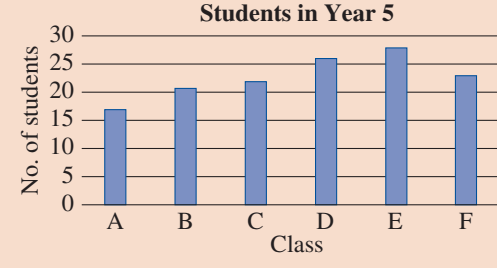
4 The following numbers represent the number of students in every year for a school.

Year	7	8	9	10	11	12
Students	212	225	210	223	195	165

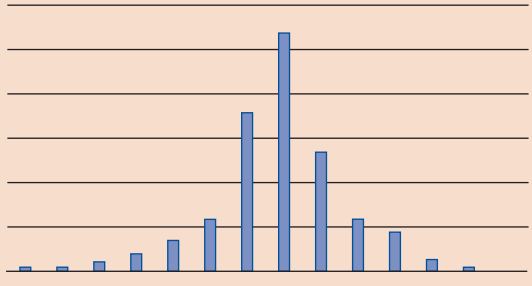
The most useful scale that should be used to plot the data on a histogram is:

A increments of 1
B increments of 0.5
C increments of 10
D increments of 100.

5 The following graph shows the number of Year 5 students in every class. Identify which class has the most students and which has the least.



6 Estimate the position of the median on this column graph.



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12A Completing a five-number summary

LEARNING GOALS

- Explore the structure of a five-number summary.
- Create a five-number summary without using technology for a variety of datasets.
- Create a five-number summary using technology – complex extension only.

Why are five-number summaries essential?

- Data can be overwhelming due to the sheer volume of numbers.
- Creating five-number summaries helps simplify complex datasets, highlighting the five key statistics in a dataset.
- Understanding the structure of data is crucial as we encounter various data sets in everyday life, such as monthly expenses, school grades and weather patterns.



Too many numbers are overwhelming. It is essential to be able to recognise the structure and create five-number summaries.

WHAT YOU NEED TO KNOW

- To find the **five-number summary**, the dataset must first be placed in ascending order.
- The median is the exact middle number of a dataset when ranked in order from smallest to largest. If the dataset has an even number of values, then the median is the average of the two middle values.
- A five-number summary is made up of the:
  1. minimum score (the smallest number in the set of data)
  2. lower quartile, Q_1 (the median of the lower half of the data)
  3. median, Q_2 or M (the number that falls exactly in the middle)
  4. upper quartile, Q_3 (the median of the upper half of the data)
  5. maximum score (the largest number in the set of data).
- The quartiles of a ranked (ordered) set of data values are the three points that divide the dataset into four equal groups.
- When identifying the upper and lower halves of a dataset with an odd number of data points, the upper and lower halves do not include the median.
- The interquartile range (IQR) is another useful measure of spread: $\text{IQR} = Q_3 - Q_1$.

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Example 1 Exploring the structure of a five-number summary

Sally is organising a school sports day and needs to arrange the participants into different events based on their running times. The lists of running times (in seconds) for two different classes are shown below.

Green class: 72 s, 65 s, 80 s, 140 s, 70 s, 100 s, 94 s
Blue class: 65 s, 80 s, 100 s, 105 s, 96 s, 79 s, 90 s, 110 s

Sally requires an idea of the dataset distribution to ensure fair grouping.

a Sort the data in order from smallest to largest for each class.
b Determine the minimum and maximum values for each class.
c Determine the median for each class.
d Determine the lower quartile, Q_1, for each class.
e Determine the upper quartile, Q_3, for each class.
f State the five-number summary for each class.

WORKING	THINKING
a 65, 70, 72, 80, 94, 100, 140 65, 79, 80, 90, 96, 100, 105, 110	Put the numbers in each set in order from smallest to largest.
b $\boxed{65}$, 70, 72, 80, 94, 100, $\boxed{140}$ Minimum = 65 Maximum = 140 $\boxed{65}$, 79, 80, 90, 96, 100, 105 $\boxed{110}$ Minimum = 65 Maximum = 110	Find the minimum and maximum (smallest number and largest number) data values.
c 65, 70, 72, $\boxed{80}$, 94, 100, 140 Median = 80	The median is the middle number. To determine the median of an odd distribution: • The number of scores is 7. • The median score will be 4th score.

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65, 79, 80, [90, 96], 100, 105, 110

Median = (90 + 96) ÷ 2
= 186 ÷ 2
Median = 93

To determine the median of an even distribution:
- The number of scores is 8.
- The median will lie between the 4th and 5th scores.

d (65, 70, 72,) [80], 94, 100, 140
(65, [70], 72,) [80], 94, 100, 140
$Q_1 = 70$

◄····· Put brackets around the numbers below the median (for an odd number do not include the median). This helps in finding Q_1.
Find the median of the lower half.

(65, 79, 80, 90,) 93, 96, 100, 105, 110
(65, 79, 80, 90,) 96, 100, 105, 110

◄····· Put brackets around the numbers below the median. This helps in finding Q_1.
Find the median of the lower half.

$Q_1 = (79 + 80) \div 2$
$Q_1 = 159 \div 2$
$Q_1 = 79.5$

e 65, 70, 72, [80], (94, 100, 140)
65, 70, 72, [80], (94, [100], 140)
$Q_3 = 100$

◄····· Put brackets around the numbers above the median (for an odd number do not include the median). This helps in finding Q_3.
Find the median of the upper half.

65, 79, 80, 90, 93, (96, 100, 105, 110)
65, 79, 80, 90, (96, 100, 105, 110)

◄····· Put brackets around the numbers above the median. This helps in finding Q_3.

$Q_3 = (100 + 105) \div 2$
$Q_3 = 205 \div 2$
$Q_3 = 102.5$

◄····· Find the median of the upper half.

... Continued

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f The five-number summary for the Green class is:
Minimum = 65
$Q_1 = 70$
Median = 80
$Q_3 = 100$
Maximum = 140

The five-number summary for the Blue class is:
Minimum = 65
$Q_1 = 79.5$
Median = 93
$Q_3 = 102.5$
Maximum = 110

◄····· State the five-number summary.

Example 2 Creating a five-number summary from a stem plot

A charity has collected the following amounts of donations in the first hour of an event. Their collector placed the amounts in a stem plot.

First hour donations

0	5 5 5 6 8 9
1	0 0 5 5
2	0 5 5 7
3	0 5

1 | 5 = $15

a Decide if the data is in order.
b Determine the minimum and maximum scores.
c Determine the median.
d Determine lower quartile, Q_1.
e Determine the upper quartile, Q_3.
f State the five-number summary.

WORKING	THINKING
a Yes, the stem plot has the data in order.	◄····· Does this stem plot display the data in order?

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b **First hour takings**

◄····· Find the minimum and maximum (first number and last number) data value.

0	(5) 5 5 6 8 9
1	0 0 5 5
2	0 5 5 7
3	0 (5)

Minimum = $5
Maximum = $35

c **First hour takings**

◄····· Find the median. The median is the middle number.
- There are 16 terms.
- The median will lie between the 8th and 9th scores.

0	5 5 5 6 8 9
1	0 (0) (5) 5
2	0 5 5 7
3	0 5

The 8th score = 10.
The 9th score = 15.
Median = (10 + 15) ÷ 2
Median = $12.50

d **First hour takings**

◄····· Find lower quartile, Q_1.
- There are 8 terms in the bottom half.
- The lower quartile will lie between the 4th and 5th scores.

0	5 5 5 (6) (8) 9
1	0 0 |5 5
2	0 5 5 7
3	0 5

Find the median of the lower half.

The 4th score = 6.
The 5th score = 8.
Q_1 = (6 + 8) ÷ 2
Q_1 = $7

... Continued

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e **First hour takings**

0	5 5 5 6 8 9
1	0 0 |5 5
2	0 (5) (5) 7
3	0 5

◄····· Find upper quartile, Q_3.
- There are also 8 terms in the top half.
- The upper quartile will lie between the 4th and 5th scores after the median.

The 4th score after the median = 25.
The 5th score after the median = 25.
$Q_3 = (25 + 25) \div 2$
$Q_3 = \$25$

Find the median of the upper half.

f The five-number summary for the data is:
Minimum = \$5
Q_1 = \$7
Median = \$12.50
Q_3 = \$25
Maximum = \$35

◄····· State the five-number summary.

Example 3 Creating a five-number summary using a calculator

Tom recorded the height of his friends in centimetres.
160, 171, 158, 167, 163
Create the five-number summary, using a calculator.
Note: this example is based on a Casio fx-82. For examples using a TI-30XB and Sharp EL531TH see the interactive textbook (a link is below this example).
Creating a five-number summary using technology is not a curriculum requirement; use as an optional extension on calculator skills learnt in previous chapter.



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WORKING	THINKING
Reset All Press [AC] key	Reset your calculator to remove all past data records. To clear, press: SHIFT CLR 9 3 =
Clear? 1 : Setup 2 : Memory 3 : All	
X 1 160 2 171 3 158	Press Mode [setup] > 2 > 1. A table appears. Type individual data values followed by the = key to enter the data. After entering the five data points click AC[off].
minX 158	Press Shift > 1 > 5 > 1 > = for the minimum value.
Q1 159	Press shift > 1 > 5 > 3 > = for quartile 1.
med 163	Press shift > 1 > 5 > 4 > = for the median value.
Q3 169	Press shift > 1 > 5 > 5 > = for quartile 3.
max X 171	Press Shift > 1 > 5 > 2 > = for the maximum value.
The five-number summary is: Minimum = 158 Q_1 = 159 Median = 163 Q_3 = 169 Maximum = 171	State the five-number summary.

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Note: Extension only. Technology not required for five-number summary.

Calculator activity 12A for TI and Sharp calculators: see the interactive textbook for this activity on using a TI-30XB and Sharp EL531TH to create a five-number summary.

Spread-sheet

Spreadsheet activity 12A: see the interactive textbook for this activity on using a spreadsheet to create a five-number summary.

Exercise 12A

FUNDAMENTALS

1 Write each dataset in order from smallest to largest and determine:
- **i** the minimum and maximum scores
- **ii** the median.

a 2, 1, 0, 5, 2, 2, 0, 7, 4, 2, 9, 1, 0, 2, 3, 3
b 8.9, 8.7, 9, 7.7, 8.6, 9.6, 8.7, 8.5, 7.9, 9.2
c 45, 65, 46, 43, 42, 48, 46, 42, 49, 41, 47, 45
d $45.90, $34.70, $35.80, $36.50, $36.00, $36.30

2 For the following datasets:
- **i** determine the minimum and maximum scores in each dataset
- **ii** determine the median.

a 7, 5, 9, 4, 6, 8, 5, 4, 7, 8, 6, 9, 6, 4, 7, 3, 7, 8, 5
b 8.9, 8.0, 8.7, 8.6, 8.6, 8.8, 8.6, 8.9, 8.5, 8.2
c 23, 26, 26, 21, 26, 27, 23, 21, 15, 28, 26, 24, 21

3 The following stem plot records the ages of people in the local library on a Sunday morning.
Note: Re-create the stem plot so it is ordered from smallest to largest and determine:
- **i** the minimum and maximum ages
- **ii** the median age.

Stem	Leaf
0	4 6 7 7
1	2 3 3 6 6 7
2	7 9
3	
4	5 6 8
5	0 4
6	7
7	2
8	3 4 6

8|6 = 86

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APPLICATIONS

Example 1

4 A group of students was asked to record the number of pets each student owned. The data below shows the results.

0, 7, 4, 2, 0, 1, 0, 2, 3, 3, 0, 2, 1, 0, 3, 2, 2

a Sort the data into order.

b Determine the minimum and maximum values.

c Determine the median.

d Determine the lower quartile, Q_1.

e Determine the upper quartile, Q_3.

f State the five-number summary.

Hint
- Minimum (smallest number)
- Q_1 (median of lower half)
- Q_2 (middle value)
- Q_3 (median of upper half)
- Maximum (largest number)

5 Tony collects data on wedge-tail eagles in Highfields. Below are the number of eagles he spotted over the past 12 days.

6, 4, 3, 5, 6, 2, 7, 6, 5, 9, 5, 4

a Sort the data into order.

b Determine the minimum and maximum values.

c Determine the median.

d Determine the lower quartile, Q_1.

e Determine the upper quartile, Q_3.

f State the five-number summary.



6 The following number of bikes were recorded over 20 days on a street where the residents were asking for a bike path.

12, 9, 15, 19, 12, 21, 8, 12, 11, 10, 29, 12, 17, 28, 10, 15, 16, 34, 12, 18

a Sort the data into order.

b Determine the minimum and maximum values.

c Determine the median.

d Determine the lower quartile, Q_1.

e Determine the upper quartile, Q_3.

f State the five-number summary.

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SF

Example 2

7 An apple farmer recorded the number of apples picked, per hour, by a new group of pickers.



Number of apples picked

9	8
10	1 3 5 7 9
11	2 4 6 8 9
12	7 7 7 8
13	4 5 5 7 8 9
14	5 5 6 7 8 9
15	0 0 0 5 5 5 7

11|4 = 114

a Determine the minimum and maximum values.
b Determine the median.
c Determine the lower quartile, Q_1.
d Determine the upper quartile, Q_3.
e State the five-number summary.

8 A doctor is researching diabetes and she has recorded the following systolic blood pressure numbers from a group of patients. Create a five-number summary, without the use of technology, to assist with her research.
128, 122, 113, 108, 115, 115, 107, 130, 115, 107, 120, 106

9 A student was wanting to purchase a refurbished smartphone. The following dataset is the amounts recorded from a selection of options. Create a five-number summary, without the use of technology, to assist with the student's decision.
$200, $1200, $400, $300, $900, $700, $900, $1000, $700, $850

10 A soccer coach was preparing for a new season. The following dataset is his team's scores for the previous season. Create a five-number summary, without the use of technology, to assist with his preparation.
1, 5, 4, 3, 5, 2, 1, 0, 2, 1, 0, 3, 2, 0, 4, 1, 1, 2, 1, 2, 3, 3, 2, 1, 0, 2, 1, 2, 4, 0



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SF

11 A couple were deciding on a bank for a loan to purchase a tiny house. The following dataset is the various interest rates on offer by different banks.
3.5%, 6.4%, 4.6%, 3.7%, 3.7%, 5.8%, 7.3%, 5.3%, 7%, 5.4%, 4%, 3.2%, 6%, 6.5%, 6.4%, 3.6%, 7%, 8.4%, 6%, 7%, 4.5%, 5.6%, 7%, 5.4%



a Organise the data into a stem plot.

b Create a five-number summary, with or without the use of technology, to assist with their decision.

12 The following datasets are the scores from quizzes in a mathematics class. Determine the dataset that the following five-number summary corresponds to.
Minimum = 15
$Q_1 = 20$
Median = 22
$Q_3 = 27$
Maximum = 32

A 15, 20, 21, 32, 27, 16, 30

B 28, 15, 21, 32, 26, 22, 19

C 22, 27, 20, 23, 24, 32, 15

D 32, 20, 15, 22, 20, 22, 27

13 The following datasets are the scores from quizzes in a science class. Determine the dataset that the following five-number summary corresponds to.
Minimum = 23
$Q_1 = 31$
Median = 36
$Q_3 = 45$
Maximum = 51

A 22, 21, 45, 47, 52, 45, 36, 23, 51, 40, 45, 36, 45, 30, 46, 46, 23

B 36, 37, 40, 42, 33, 33, 32, 45, 32, 23, 23, 51, 45, 24, 30, 46, 50

C 51, 50, 42, 34, 22, 27, 20, 23, 24, 32, 15, 50, 51, 51, 37, 45, 23

D 36, 23, 32, 36, 45, 32, 20, 15, 22, 20, 22, 27, 51, 50, 50, 51, 36

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EXTENSION

Example 3

14 State the five-number summary for each of the following datasets, using technology (Extension-optional question).

- **a** Runs per game for cricket team: 24, 67, 54, 87, 56, 32, 76, 45, 31, 53
- **b** Daily website visits for 12 days: 78, 65, 98, 68, 98, 65, 105, 45, 32, 48, 27, 41
- **c** Rainfall in mm for different areas: 84, 99, 48, 34, 93, 27, 12, 36, 73, 112, 117, 38, 96

15 Will is recording the number of cars passing per 20 minutes.
20, 20, 19, 27, 45, 30, 34, 45, 36, 44, 28, 26, 45, 45, 40, 46, 25, 28

- **a** Arrange the data into a stem plot.
- **b** State the five-number summary, with the use of technology.



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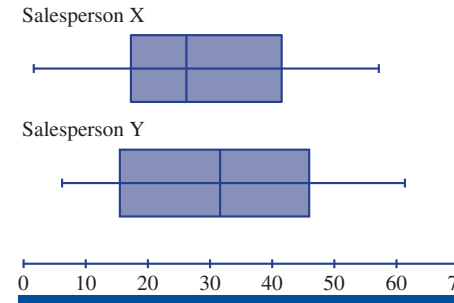
12B Constructing box plots

LEARNING GOAL

- Construct box plots using a five-number summary.

Why are box plots essential?

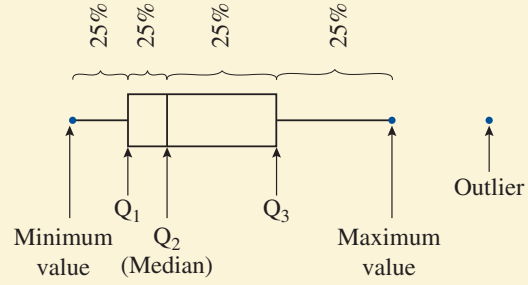
- Box plots visually represent the five-number summary of a dataset. They simplify the presentation of large datasets.
- Knowing how to construct box plots is essential for effective data visualisation.
- Box plots are commonly used for summarising data in many industries, including education, research, finance, marketing and healthcare.



Box plot are helpful to show a quick visual summary to compare data.

WHAT YOU NEED TO KNOW

- **Box plots** are the visual representation of the five-number summary of a dataset.
- They are drawn against a scale.
- Box plots can be drawn vertically or horizontally.
- They are divided into four sections with a quarter (25%) of the data in each section.



- Box plots are also known as box-and-whisker plots, with a box surrounding the Q_1, median and Q_3, and whiskers extending to the minimum and maximum scores.
- Outliers are also used in box plots. They are observations that appear to be inconsistent with the remainder of that set of data - a surprising observations.

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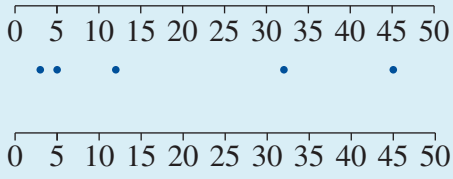
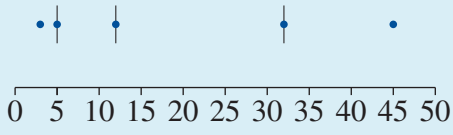
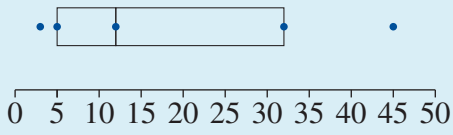
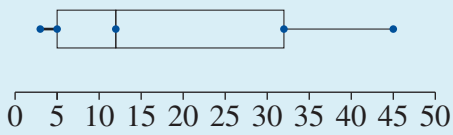
Example 4 Constructing box plots using a five-number summary

Giovani records how many players from each club were selected in representative teams.

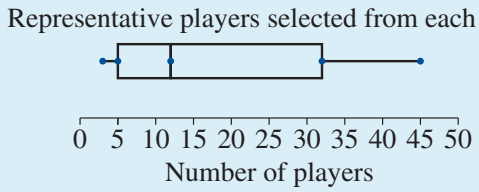
3, 6, 8, 4, 12, 20, 45, 36, 28

a State the five-number summary for the dataset.

b Construct a box plot using the five-number summary, without the use of technology.

WORKING	THINKING
a $(\boxed{3}, 4 \overset{5}{\uparrow} 6, 8) \boxed{12} (20, 28, \overset{32}{\uparrow} 36, \boxed{45})$ Minimum = 3 $Q_1 = 5$ Median = 12 $Q_3 = 32$ Maximum = 45	Write the dataset in ascending order. Find the minimum and maximum values. Find the median. Put the remaining numbers either side in brackets. Find the Q_1 and Q_3.
b 	Choose an appropriate scale to represent the data (e.g. go up only by 1s, 2s or 5s). Draw a number line representing the data. Place a dot above each of the five numbers.
	Extend the dots to small lines for the median, Q_1 and Q_3.
	Create the 'box'.
	Draw lines (whiskers) out to the minimum and maximum values.

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Give your box plot a title.

Exercise 12B

FUNDAMENTALS

1 Choose an appropriate scale for the following data.

a 0, 5, 3, 1, 5, 4, 2, 4, 0, 1, 3, 3, 4, 7, 3, 4, 2

b 14, 14, 21, 16, 15, 17, 14, 18, 14, 23, 19, 16, 16, 17, 18, 14

Hint Do increments of 2, 5 or 10 suit the data best?

c 29, 12, 17, 28, 10, 15, 16, 34, 12, 18, 34, 43, 32, 46, 34, 32, 39, 34, 32, 19

d 0, 52, 4, 11, 0, 0, 7, 8, 0, 2, 18, 0, 0, 4, 0, 0, 5, 13, 2, 13, 1, 1, 14, 1, 12

2 Draw a number line for each dataset. Represent each data value using a dot above the line.

a 5, 8, 7, 9, 6

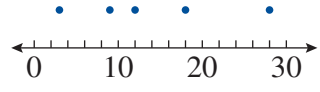
b 0.7, 0.4, 0.8, 0.2, 0.6

c 95, 56, 32, 67, 75

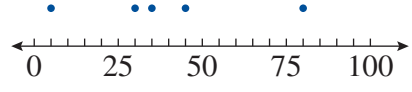
3 Record the numbers represented on the following number lines.

Hint To work out the value of the interval between the tick marks, divide the difference between two labelled values by the number of tick mark intervals between them.

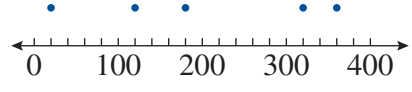
a



b



c



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APPLICATIONS

Example 4

4 A group of students were asked to record the number of hours of homework they completed each week. The data below shows the results.
0, 5, 3, 1, 5, 4, 2, 4, 0, 1, 3, 3, 4, 7, 3, 4, 2

a Create a five-number summary.

b Construct a box plot.

Hint Remember to put the data in order from smallest to largest.

5 A takeaway store recorded the ages of their staff.
14, 14, 21, 16, 15, 17, 14, 18, 14, 23, 19, 16, 16, 17, 18, 14

a Create a five-number summary.

b Construct a box plot.

Hint Organise your scale and number line first.



6 The following number of cars were recorded on a residential street over 20 days where the residents were requesting a traffic calming speed hump.
29, 12, 17, 28, 10, 15, 16, 34, 12, 18, 34, 43, 32, 46, 34, 32, 39, 34, 32, 19

a Create a five-number summary.

b Construct a box plot.

7 A librarian is interested in the number of books teenagers borrow from a library. She selected a sample of 25 teenagers and recorded the number of books each person had borrowed in the previous year. Here are her results:
0, 52, 4, 11, 0, 0, 7, 8, 0, 2, 18, 0, 0, 4, 0, 0, 5, 13, 2, 13, 1, 1, 14, 1, 12

a Identify any possible outliers and write down their values.

b Construct a box plot of the data, showing outliers.

Hint Outliers are observations that appear to be inconsistent with the remainder of that set of data.



SF

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SF

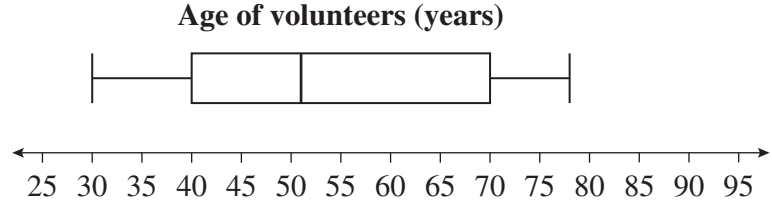
8 The following dataset is the number of social media posts per week from a survey of students in math class.
10, 8, 60, 6, 6, 14, 15, 6, 7, 6, 5, 7, 8, 6, 18, 9, 7, 10, 5, 8, 6, 14, 11, 5

a Identify any possible outliers and write down their values.

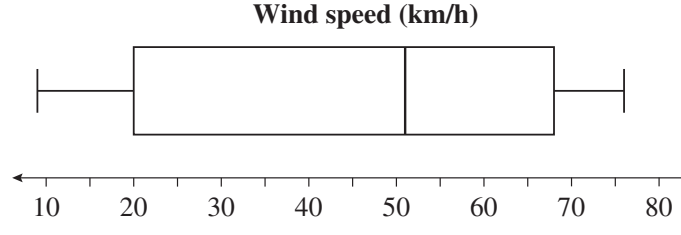
b Construct a box plot of the data, showing outliers.



9 The box plot below shows the age of people volunteering for a particular charity. Create a five-number summary.



10 A group of drone enthusiasts meet at a park every day. To monitor wind speed, they have recorded the wind speed (in km/h) over a month. Create a five-number summary of their recorded data.

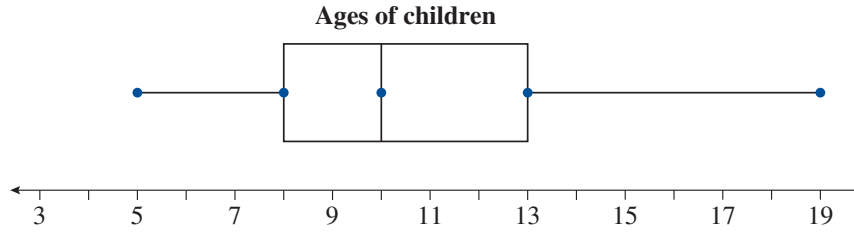




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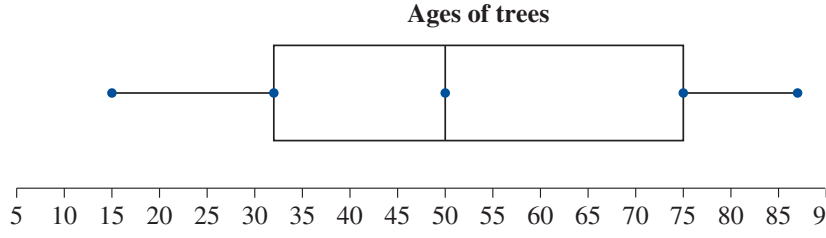
SF

11 The following box plot represents the ages of children who are cousins in a large extended family.



a What age are 75% of the children older than?
b Is it possible to determine how many children there are from this data?
c What percentage of the children are between 13 and 19?
d How old is the youngest child?
e The family are going to the agricultural show. Child tickets are for children up to 13 years old. What percentage of the children qualify for a child ticket?

12 A local arborist determined the age of 100 trees in his suburb.



a What age are 75% of the trees older than?
b What is the range of the data?
c What percentage of the trees are between 15 and 32?
d How old is the oldest tree?

13 The stem plot represents a sample of 50 scores in a golf tournament.



Golf scores

5	8 9 9 9
6	2 3 3 4 4 7 7 8 9 9 9 9
7	0 0 0 0 1 2 2 2 5 7 8 8 8 8
8	0 1 1 1 3 4 6 6 7 8 9 9 9
9	2 3 3 4 8 8 9

7|0 represents a score of 70

a Create a five-number summary of the dataset.
b Construct a box plot.

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SF

14 A group of students throw one dart each at a dart board and their scores are recorded.

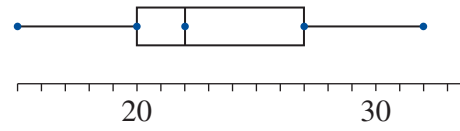
Name	Scores
Tony	8
Isla	22
Steve	28
Ava	14
Coen	30
Tomas	13
Nick	20
Mia	24
David	18
Riama	15
Mitch	7



a Create a five-number summary.

b Construct a box plot.

15 The following datasets are the scores from quizzes in a Biology class. Determine the dataset that the following box plot corresponds to.



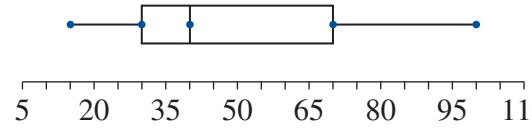
A 22, 27, 20, 23, 24, 32, 15

B 15, 20, 21, 32, 27, 16, 30

C 32, 20, 15, 22, 20, 22, 27

D 15, 32, 26, 28, 20, 20, 22

16 The following datasets are the scores from quizzes in a business class. Determine the dataset that the following box plot corresponds to.



A 95, 63, 15, 76, 45, 57, 31

B 20, 43, 67, 32, 69, 110, 100

C 71, 45, 50, 100, 34, 17, 36

D 58, 53, 80, 100, 43, 41, 79

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12C Comparing datasets

COMPLEX

LEARNING GOALS

- Compare parallel box plots for different datasets.
- Compare back-to-back stem plots for different datasets.

Why is comparing datasets essential?

- In today's world, we encounter vast amounts of data daily, from social media statistics to financial reports.
- Visual tools like box plots and stem plots help convey complex data in an easily digestible format.
- Making informed decisions requires comparing and evaluating different data sets. For example, a business might compare customer satisfaction ratings before and after a product launch to assess the impact of changes.

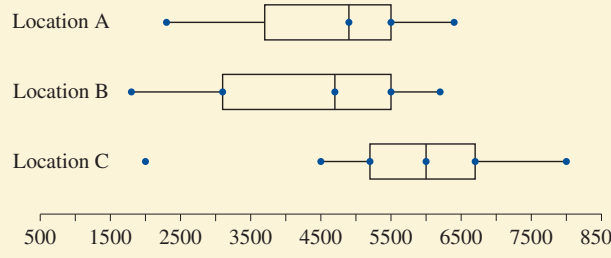


Comparing data is an essential skill to help us make better decisions.

WHAT YOU NEED TO KNOW

- Parallel box plots can be used to compare two or more groups.
- When comparing box plots, they must always be placed against the same axis. This enables the median, spread and possible outliers of the data to be easily identified and compared.
- The range can be used as a measure of spread in a dataset, but it is extremely sensitive to the presence of outliers and should only be used with care.
- The IQR should be compared and contrasted to the range.
- The variability of a dataset is the amount by which data points differ from the mean and from each other, similar to the spread, and which can also be measured by the range, and IQR.

Comparison of the prices paid at auction at three different locations



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- **Back-to-back stem plots** have a single stem with two sets of leaves. Each set of leaves is separated for the two groups being compared. The leaves for one set of data are on one side, and the leaves for the second set of data are on the other side.
- When comparing back-to-back stem plots, the leaves must always be placed against the corresponding stem. This enables the shape, median, spread and possible outliers of the data to be easily identified and compared.
  - The shape of a back-to-back stem plot can be seen by looking at the shape and length of the leaves. This shows whether a dataset is symmetric (roughly the same on each side when cut down the middle) or skewed (lopsided).
  - A symmetric back-to-back stem plot shows the median roughly in the middle of the spread.

Title

Visitors to the park

Jan (Leaf column)	Stem column	Feb (Leaf column)
1 1 0 0	10	0 1
	11	0 1
5 3 3 2 1 0 0 0	12	0 1 3 4
9 8 8 7 3 2 0 0 0	13	1 7 8 9
9 8 6 5 4 2 1 1 0	14	1 2 3 3
	15	
	16	1 3 5 5 5 6
	9 17	0 2 2 3 3 4

16 | 5 = 165

Key for Feb data



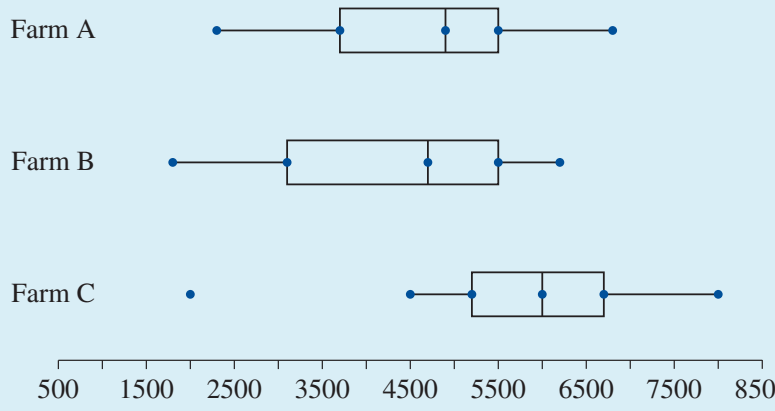
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Example 5 Comparing parallel box plots for different datasets [complex]

The parallel box plots represent the weights (kg) of produce from three different farms.

Comparison of the weights (kg) of produce from three different farms



a Compare the medians of all datasets.
b Compare the range of all datasets.
c Compare the spread using the IQR, which can be read directly from the box plot (the width of the boxes).
d Locate any outliers.
e Write a paragraph comparing the farms.

WORKING	THINKING
a Median for Farm A = 4900 Median for Farm B = 4700 Median for Farm C = 6000 The farm with the highest median is Farm C with 6000 kg of produce. This was, on average, 1100 kg higher than Farm A and 1300 kg higher than Farm B.	Locate the median (middle value) for each dataset by comparing the vertical line in the middle of the boxes.
b Farm A 6800 – 2300 = 4500 Farm B 6200 – 1800 = 4400 Farm C 8000 – 4500 = 3500 Farm A has the largest range with 4500 kg of produce, and Farm C has the smallest range of 3500 kg of produce.	To calculate the range, find the difference between the minimum and maximum of each dataset.

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c Farm A
$5500 - 3700 = 1800$
Farm B
$5500 - 3100 = 2400$
Farm C
$6700 - 5200 = 1500$
The farm with the largest spread between the interquartile range is Farm B, whereas the smallest spread is Farm C with 1500 kg of produce.

◄···· Compare the spread by reading the width of the boxes.
$IQR = Q_3 - Q_1$

d There are no outliers for Farms A and B; however, Farm C has an outlier at 2000 kg of produce.

◄···· Record any marks beyond the 'whiskers'.

e Farm C has the highest median yield of 6000 kg, indicating it generally produces more than Farms A and B. Farm A shows the greatest variability with a range of 4500 kg, while Farm C is the most consistent with a range of 3500 kg. Farm B has the largest interquartile range (IQR) of 2400 kg, indicating more variability within the middle 50% of its data, whereas Farm C has the smallest IQR of 1500 kg. Farm C also has an outlier at 2000 kg. Overall, Farm C is the most reliable in terms of produce consistency, while Farm A shows the most variability and Farm B falls in between.

◄···· Compare and contrast the median, spread and outliers of each farm.

Example 6 Comparing back-to-back stem plots for different datasets [complex]

The back-to-back stem plot compares the number of hours per year spent volunteering at a large charity from two different age groups:

Ages 18–55 years		Ages 56+ years
	Volunteer hours per year	
9 9	4	8
9 9 5 3	5	9
5 5 2 1 1 1 0	6	8 9
5 5	7	2 3 4 5 5 9
	8	2 3 3 8
	9	0

7|2 = 72 years

Compare the range and measures of central tendency of the datasets.

... Continued
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WORKING	THINKING
	Formulate
Central tendency includes measures of median, mean and mode. The median will be effective to compare central tendency with no obvious outliers. Spread calculations include range and IQR.	Observe and list the calculations which will be needed to answer the questions and compare datasets effectively. Make an assumption of the measure of central tendency for comparing this data set.
	Solve
Volunteer hours per year **Ages 18–55 years** | **Ages 56+ years** 9 9 | 4 | 8 9 9 5 3 | 5 | 9 5 5 2 1 1 | 1 | 0 | 6 | 8 9 5 5 | 7 | 2 3 4 | 5 | 5 9 8 | 2 3 3 8 9 | 0 7|2 = 72 years	Locate the median (middle value) for each dataset.
Ages 18–55 years Ages 18–55 years = 8th number Median for Ages 18–55 yrs = 61 hours Ages 56+ years = 8th number Median for Ages 56+ yrs = 75 hours The median hours of volunteering for age group 56+ years is 14 hours higher than age group 18–55 years.	
Ages 18–55 years 75 – 49 = 26 Ages 56+ years 90 – 48 = 42 Ages 56+ years has the wider range with 42 hours compared to 26 hours.	To calculate the range, find the difference between the minimum and maximum of each dataset.

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Volunteer hours per year

Ages 18 – 55 years		Ages 56+ years
9 9	4	8
9 [9] 5 3	5	9
5 [5] 2 1 1 [1] 0	6	8 [9]
5 5	7	2 3 4 [5] 5 9
	8	2 [3] 3 8
	9	0

7|2 = 72 years

◄····· To compare the spread, find the quartiles.
Quartiles are found by finding the median of the lower half of the data and the median of the upper half of the data.

Ages 18–55 years
65 – 55 = 10
Ages 56+ years
83 – 69 = 14
The spread of volunteer hours in Ages 18–55 years (IQR = 10 hours) is smaller than the spread in Ages 56+ years (IQR = 14 years).

Then find IQR: IQR = $Q_3 - Q_1$.

Evaluate and verify

The age group with the lowest volunteer hours is 18–55 years; however, this was only by 1 hour. The age group with the highest volunteer hours was 56+ years by 15 hours. The median volunteer hours differed by 14 hours, with ages 56+ years having contributed more. The variability in the older age group is larger than the younger group as the IQR was larger.

◄····· Compare and contrast the median, range and spread summaries of each year.

Communicate

Overall the older age group 56+ years had a larger variability but overall tended to contribute more volunteer hours per year than the 18–56 years group. This may be due to work commitments and stages of life.
Understanding these patterns and trends will help the charity organisation plan for future projects and cater training to age group needs.

◄····· Summarise in words the comparison and its possible uses or relevance.

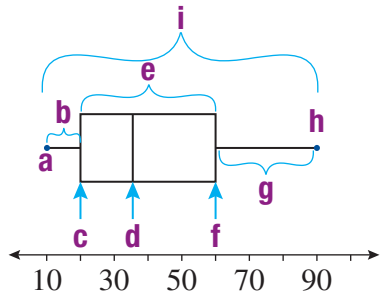
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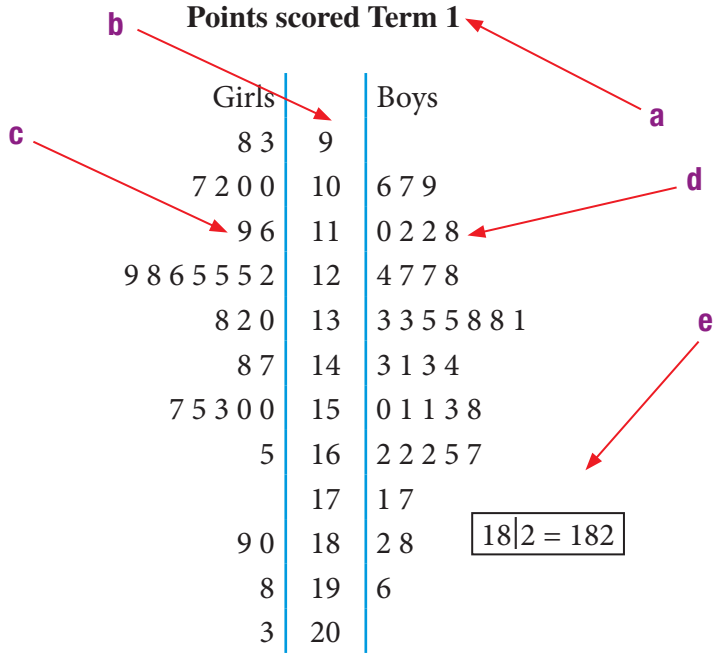
Exercise 12C

FUNDAMENTALS

1 Label the parts of this box plot:



2 Label the parts of this back-to-back stem plot.

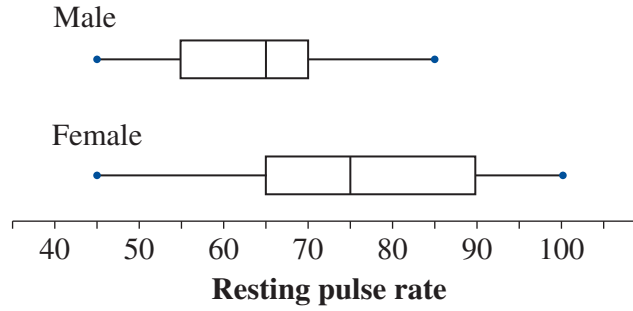


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APPLICATIONS

Example 5

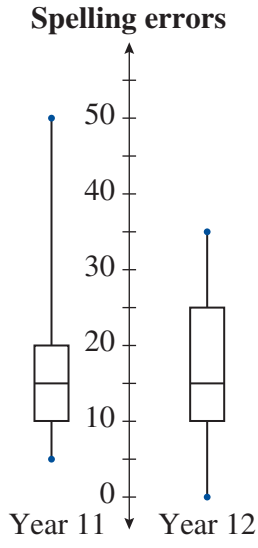
3 A group of 50 male and 50 female students were asked to record their resting pulse rates. The datasets below show the results.



a Compare the medians of both datasets.
b Compare the range of both datasets.
c Compare the spread using the interquartile range.
d Write a statement comparing both datasets.

Hint Q_1 is the median of the lower half of the data; Q_3 is the median of the upper half of the data.

4 One hundred Year 11 students and one hundred Year 12 students sit the same writing task with their spelling errors being recorded.
The datasets below show the results.





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a Compare the medians of both datasets.
b Compare the range of both datasets.
c Compare the spread using the IQR.
d Write a statement comparing both datasets.

Hint: IQR = $Q_3 - Q_1$

CF

Example 6

5 A sample of Year 7 and Year 12 students were asked to record the amount of homework they completed in hours each week. The datasets below show the results.

Homework time (hours per week)

Year 7		Year 12
9 8 6 6 5 4 3 3	0	5 5 7 9
5 5 5 4 4 0 0	1	0 0 2 4 7 8 9
	2	0 1 1 1

0|3 = 3 hours per week

1|0 = 10 hours per week

a Compare the medians of both datasets.
b Compare the range of both datasets.
c Compare the spread using the interquartile range.
d Write a statement comparing both datasets.

6 The back-to-back stem plot displays the number of burpees a group of Year 12 students could do in a minute at the beginning of a netball season and at the end of the season.



Burpees per minute

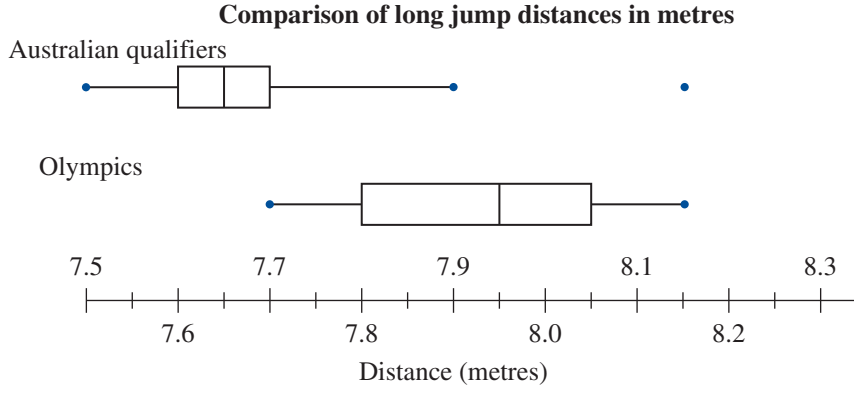
Beginning of Netball season		End of Netball season
	0	
9 8	1	
8 3 1 0 0	2	0 5 5 7
6 5 5 3 2 2	3	0 1 3 7 9 9 9
5 0	4	9 9
	5	0 0

5|0 = 50 burpees per min

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a Compare the medians of both datasets.
b Compare the range of both datasets.
c Compare the spread of the two datasets using the interquartile range.
d Write a statement comparing the two datasets.

7 The following parallel box plots show the long jump distances of the Australian qualifiers compared to the distances achieved at the Olympic games.



Compare the median and IQR of each box plot and explain how the following conclusions can be made from this data.
a The Australian qualifiers' long jumps were generally shorter than the Olympic long jumps.
b The Olympic jumps are spread out more than the Australian qualifiers' jumps.
c Most of the Olympic long jumps were longer than all of the Australian qualifiers' jumps.

8 A popular café is currently concerned by a new café in town stating that they have the fastest service around. The following datasets are the delivery times (in minutes) for both cafés. Compare the range and measures of central tendency of the datasets for the two cafés.



Comparison of delivery times (in minutes)

Popular café		New café
9 8	0	
9 8 6 5 4 3 3 2	1	0 0 1 2 4 5 6 6 8 9
8 3 3 1	2	0 1 2 5
0	3	0
		2|5 = 25 min

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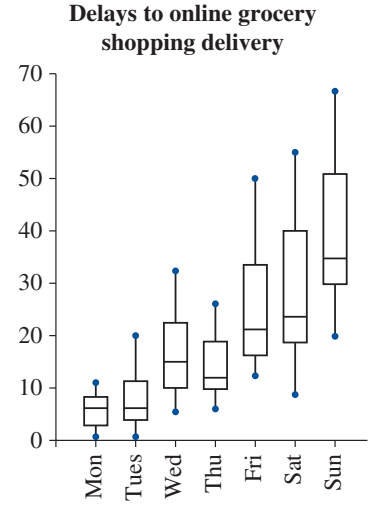
9 Toowoomba High School had their annual 10-pin bowling championships. The back-to-back stem plot shows the highest score of each player, by year level. The mean of the Year 10 highest scores was 143.3 and the mean of the Year 12 scores was 137.4. Compare the range and measures of central tendency of the datasets for the Year 10 and Year 12.

Toowoomba U18 bowling scores

Year 12		Year 10
8 3	9	
7 2 0 0	10	6 7 9
9 6	11	0 2 2 8
9 8 6 5 5 5 2	12	4 7 7 8
8 2 0	13	3 3 5 5 8 8
8 7	14	3 3 4
7 5 3 0 0 0	15	0 1 1 3 8
5	16	2 2 2 5 7
	17	1 7
9 0	18	2 8
8	19	6
3	20	

19|6 = 196 score

10 The following set of box plots were used to compare the delay in delivery times for online groceries orders over a busy week in the lead up to Christmas. Analyse and compare the delay times for each day of the week.



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12D Comparing the characteristics of histograms

COMPLEX

LEARNING GOALS

- Compare the characteristics of the shape of histograms using symmetry.
- Compare the characteristics of the shape of histograms using skewness.
- Compare the characteristics of the shape of histograms using bimodality.

Why is comparing the characteristics of the shape of histograms essential?

- Essential skills for quickly interpreting histograms include understanding symmetry, skewness, and bimodality.
- Interpreting histograms facilitates quick communication for informed decision-making and is used in many fields such as science financial advising, marketing and sales.



Market research analysts utilise histograms to understand consumer behaviour and trends from survey data.

WHAT YOU NEED TO KNOW

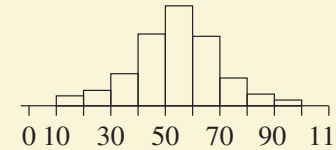
- Recall a **histogram** is a special type of column graph:
  - The data scores are shown on the horizontal x-axis and are organised into groups. The y-axis is the frequency. There are no gaps between the columns.
  - Usually a histogram has vertical columns, but they may be horizontal.
- The distribution is characterised by the shape and spread of the columns. The main ways to describe shape are symmetry, skewedness, number and height of peaks, and whether it is uniform.

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- **Symmetric** shape is when the columns form a mirror image (see Histogram 1).
  - The **centre**, or half-way mark, of the shape is found by eye. This acts as the axis of symmetry where approximately half of the data is on one side and the rest on the other.

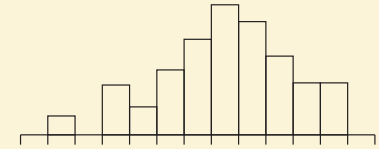
Histogram ①



Symmetric

- **Approximately symmetric** is identified where the shape is approximately the same on both sides (see Histogram 2).
- The mode of a distribution is the value that is most likely to be recorded, having the largest frequency.

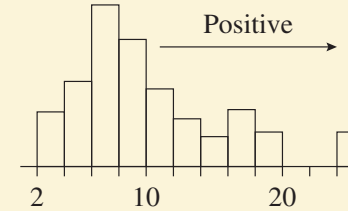
Histogram ②



Approximately Symmetric

- **Positively skewed** is when the distribution's peak is higher on the left, with the tail stretching to the right. Column heights decrease when looking from left to right (see Histogram 3).

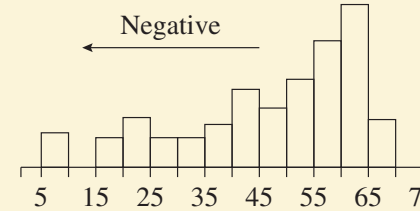
Histogram ③



Skewed

- **Negatively skewed** is when the distribution's peak is higher on the right, with the tail stretching to the left. Column heights increase in size when looking from left to right (see Histogram 4).

Histogram ④



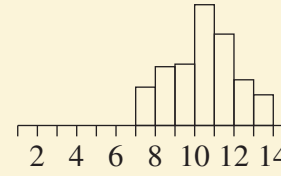
Skewed

- **Comparing location**: Histograms 5 and 6 are similar in shape; however, they are in different locations on the axis.

Histogram ⑤



Histogram ⑥

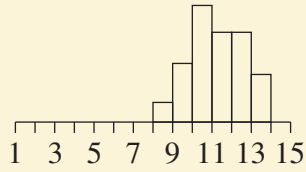


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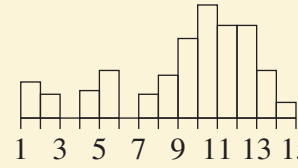
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- **Comparing spread**: Histograms 7 and 8 are both centred in a similar location; however, Histogram 8 is more spread out than Histogram 7.

Histogram ⑦

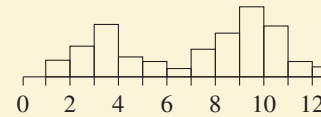


Histogram ⑧



- **Bimodal** is when there are two modes, which means there are two data values have high frequencies (see Histogram 9).

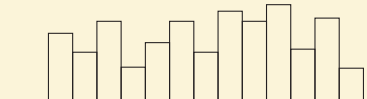
Histogram ⑨



Bimodal

- **Uniform**: Histogram 10, also known as 'multimodal distribution', has a fairly constant or even frequency distribution.

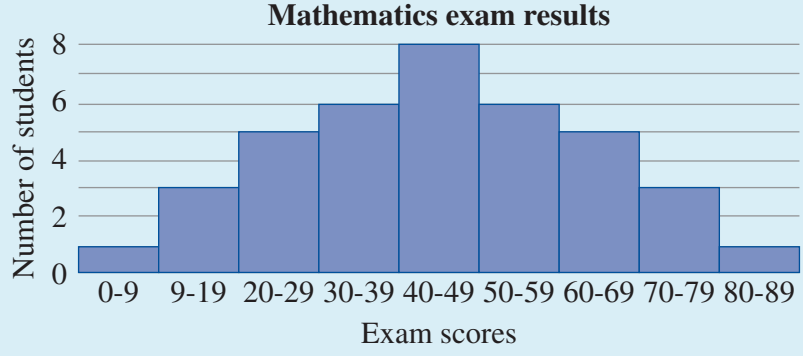
Histogram ⑩



Uniform

Example 7 Comparing the characteristics of the shape of histograms using symmetry

The histograms display the results from a class of their Maths (/89) and English (/32) exams.

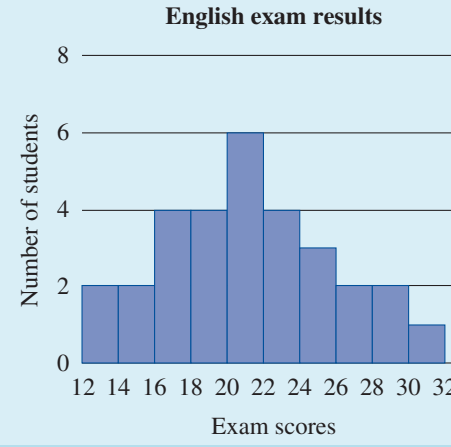


... Continued

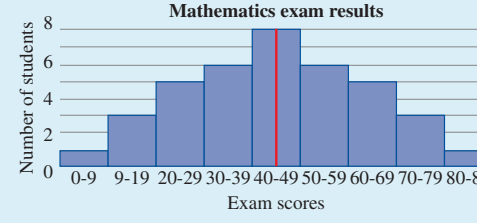
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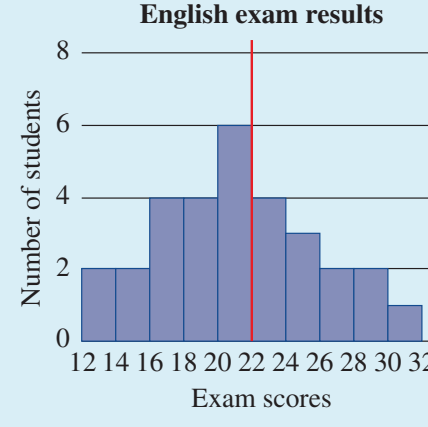
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a Compare the shape of the histograms.
b Compare the centre of both histograms.
c Compare the spread of both histograms.



WORKING	THINKING
a The Maths exam histogram is a symmetric shape, whereas the English exam histogram is approximately symmetric.	◄··· Which shape best describes each histogram?
b The Maths exam histogram has a centre of 44.5 out of 89. $\frac{44.5}{89} \times 100 = 50\%$	◄··· Where is the centre column?
The English exam histogram has a centre of 22 out of 32.	Use your eye to find the centre.





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$\frac{22}{32} \times 100 = 68.75\%$
Therefore, the English exam has a higher centre.

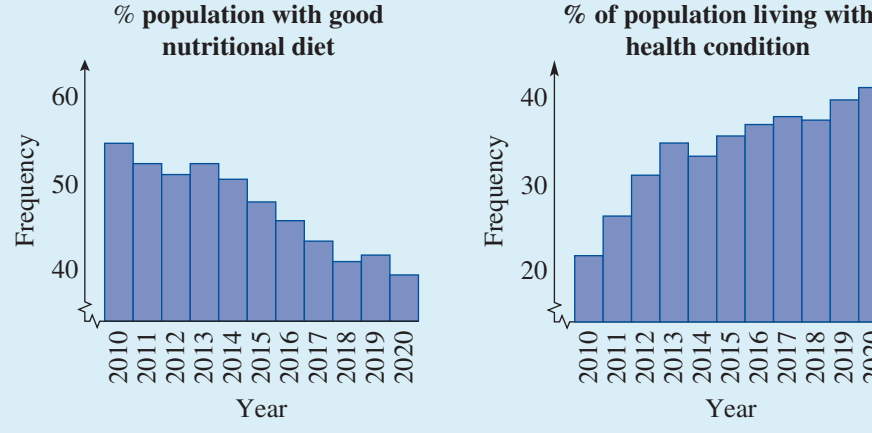
To be able to compare fairly, convert both histograms' centres to a percentage.

c The spread for the Maths exam histogram is
$89 - 0 = 89$
The spread for the English exam histogram $32 - 12 = 20$
Therefore, the spread for the Maths exam histogram is greater than for the English exam histogram.

How are the columns spread across the *x*-axis?
Spread is measured by the range of the distribution.
Find the range of the distributions: maximum value – minimum value.

Example 8 Comparing the characteristics of the shape of histograms using skewness [complex]

The two histograms from a university student study compare the percentage of the Australian population living with health conditions and those reportedly having good diet and nutrition for the 10-year period 2010–2020.



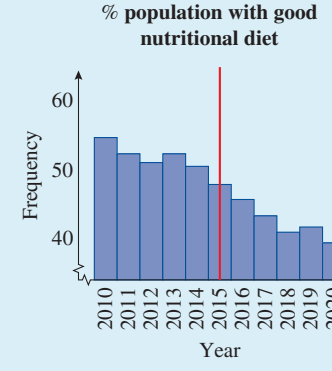
a Compare the shape of the histograms.
b Compare the centre of both histograms.
c Compare the spread of both histograms.

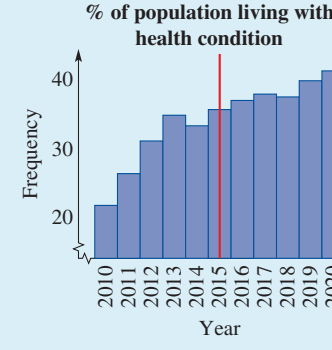
... Continued

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WORKING	THINKING
a The % of population with good nutritional diet histogram is positively skewed, as the distribution's peak is higher on the left, with the tail stretching to the right. The % of population living with health conditions histogram is negatively skewed, as the distribution's peak is higher on the right, with the tail stretching to the left. This is because the shorter columns are towards the left of the distribution.	◄···· Which shape best describes each histogram?
b The % of population with good nutritional diet histogram has a centre of 2015. The centre for both histograms is the 6th year of 11 years. Therefore, the centre is the same for both histograms.	◄···· Where is the centre column? Use your eye to find halfway along the horizontal axis.





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c The spread for the % of population with a good nutritional diet histogram is across the whole axis (11 years).

The spread for the % of population living with health conditions histogram is across the whole axis (11 years).

◄···· How are the columns spread across the *x*-axis?
Spread is the measure of the range of the distribution.
Find the range of the distributions.

Therefore, the spread of both histograms are the same.

◄···· It is worth comparing the spread of frequency for both histograms: for the % of population with a good nutritional diet histogram, it is across the whole *y*-axis. Frequency range is approximately:

$$\begin{aligned}\text{Range} &= \text{max} - \text{min}\\ &= 55 - 42\\ &= 13\end{aligned}$$

The spread for the % of population living with health conditions histogram. Frequency range is approximately:

$$\begin{aligned}\text{Range} &= \text{max} - \text{min}\\ &= 40 - 22\\ &= 18\end{aligned}$$

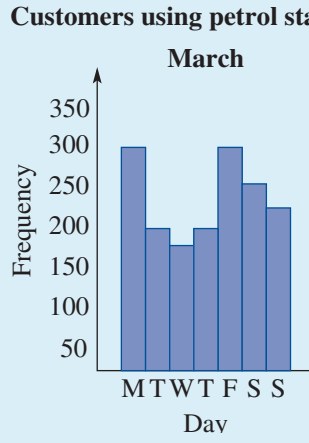
Therefore, the spread of % of population with a good nutritional diet histogram is larger over the 11 years surveyed.

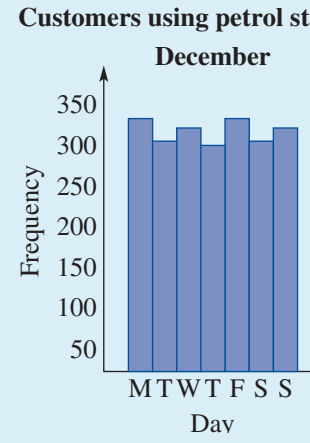
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Example 9 Comparing the characteristics of the shape of histograms using bimodality

The two histograms are comparing the frequency of people visiting the same petrol station in different months.



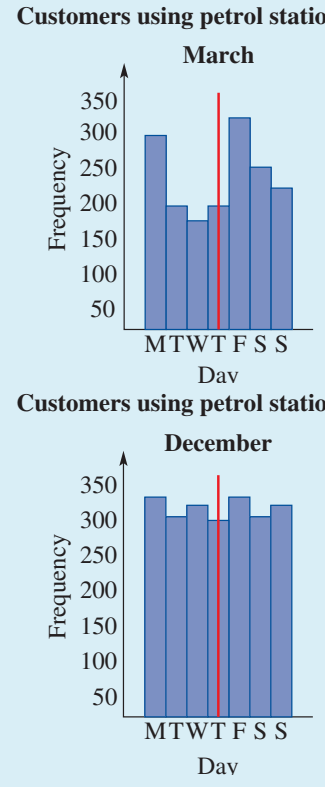


a Compare the shape of the histograms.
b Compare the centre of both histograms.
c Compare the spread of both histograms.

WORKING	THINKING
a The March histogram's shape is bimodal as it is double-peaked at Monday and Friday. The December histogram's shape has an approximately uniform distribution.	Which shape best describes each histogram?
b The March histogram has a centre of Thursday. The December histogram has a centre of Thursday.	Where is the centre column? Use your eye to find halfway along the horizontal axis.

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Therefore, both histograms have the same centre.



c The spread for the March histogram is across the whole axis (1 week).
The spread for the December histogram is across the whole axis (1 week).
Therefore, the spread of both histograms is the same.

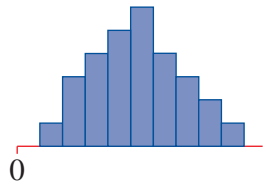
◄···· How are the columns spread across the *x*-axis?
Spread is the measure of the range of the distribution.
Find the range of the distributions.

Exercise 12D

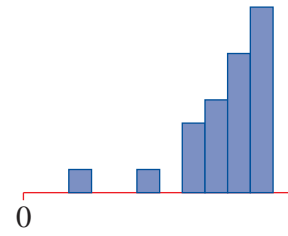
FUNDAMENTALS

1 Describe the shape of each of the following histograms.

a

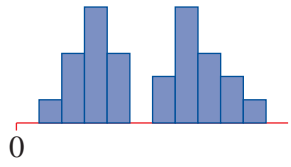


b

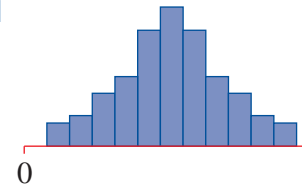


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c



d



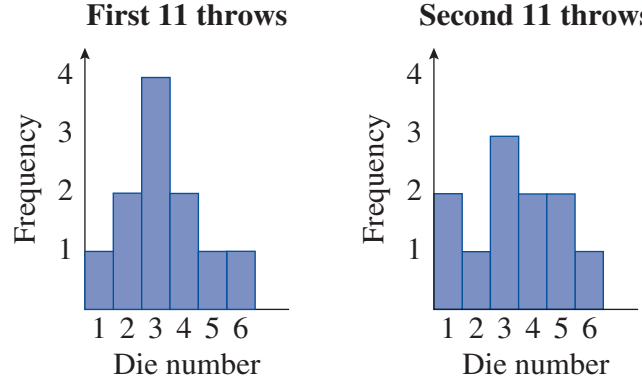
2 Draw a sketch of histogram that is:

- **a** symmetric
- **b** approximately symmetric
- **c** positively skewed
- **d** negatively skewed
- **e** bimodal
- **f** uniform.

APPLICATIONS

Example 7

3 The scores of the first 11 throws and the second 11 throws of a die are shown in the histograms.



- **a** Compare the shape of the histograms.
- **b** Compare the centre and spread of both histograms.

Hint When finding the centre, use your eye to find halfway along the horizontal axis.

Example 8

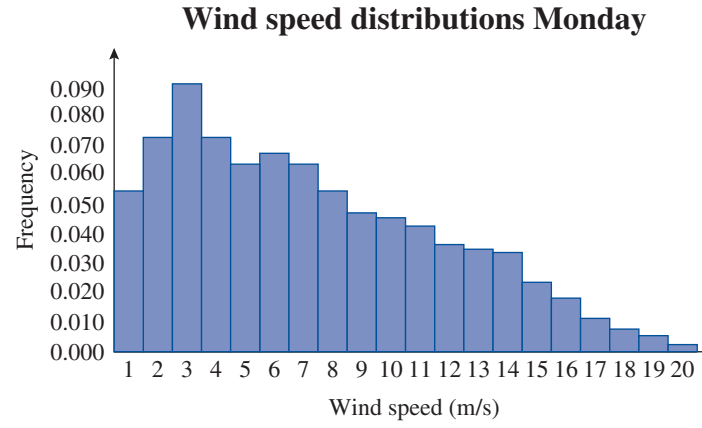
4 A wind farm compared their wind speed over two days. The histograms on the next page show the results.

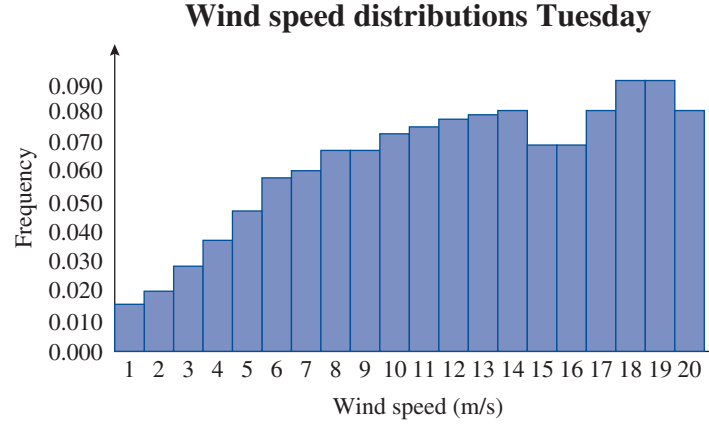


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a Compare the shape of the histograms.
b Compare the centre and spread of both histograms.

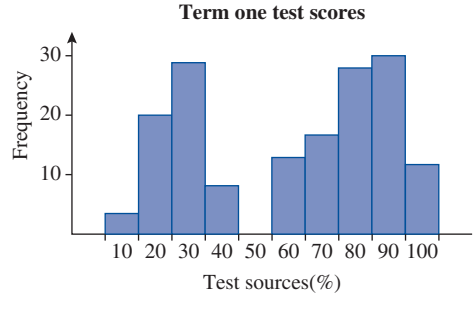
Hint The spread describes the distribution.

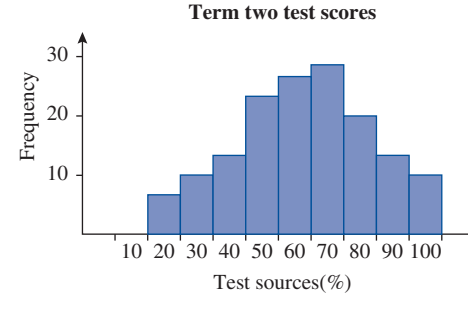




Example 9

5 A teacher uses histograms to display the results of her students' mathematics test scores. The histograms below show the results.





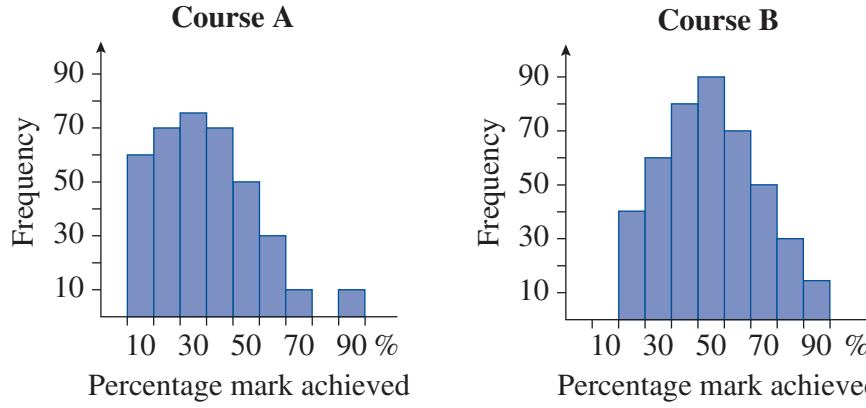
a Compare the shape of the histograms.
b Compare the centre and spread of both histograms.

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Example 10

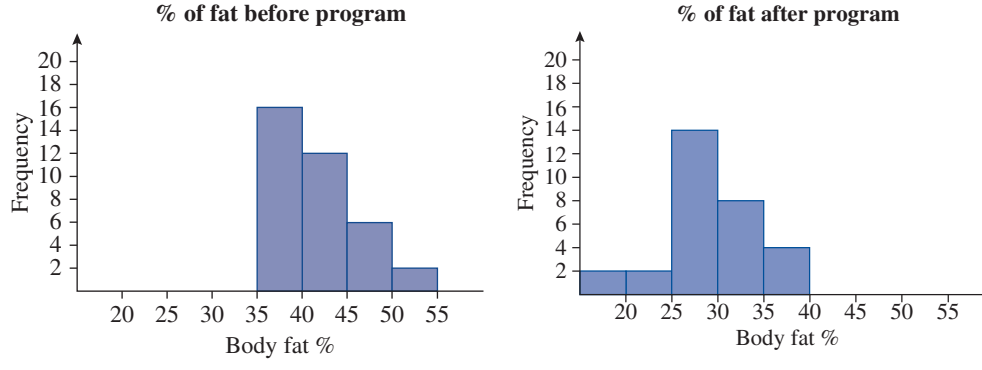
6 A Year 12 student is trying to choose between two TAFE courses. She is using the following histograms to help her decision. CF



a Write a statement comparing the shape of the histograms.

b Explain which course would give the student a greater chance of passing. Justify your answer.

7 A personal trainer is advertising their new program using the following histograms, which compare body composition. Analyse the histograms, and comment on the success of the program, justifying with mathematical reasoning. CU

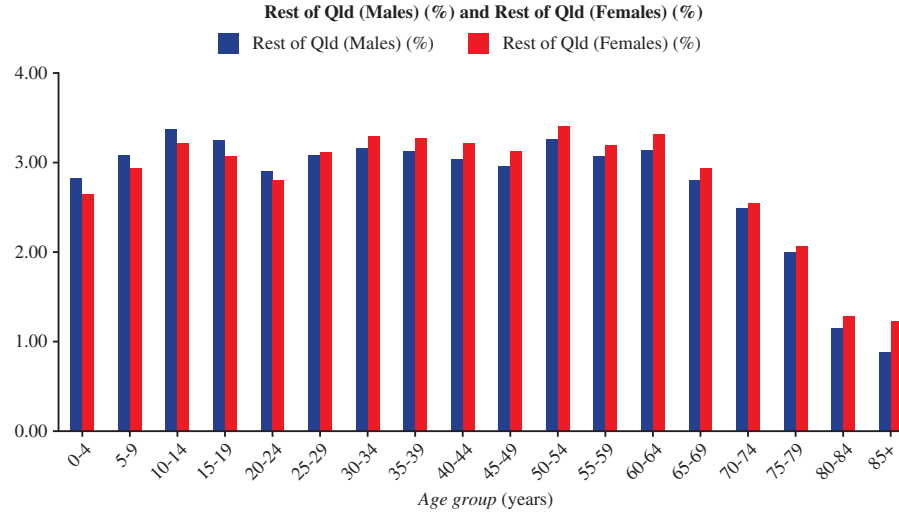


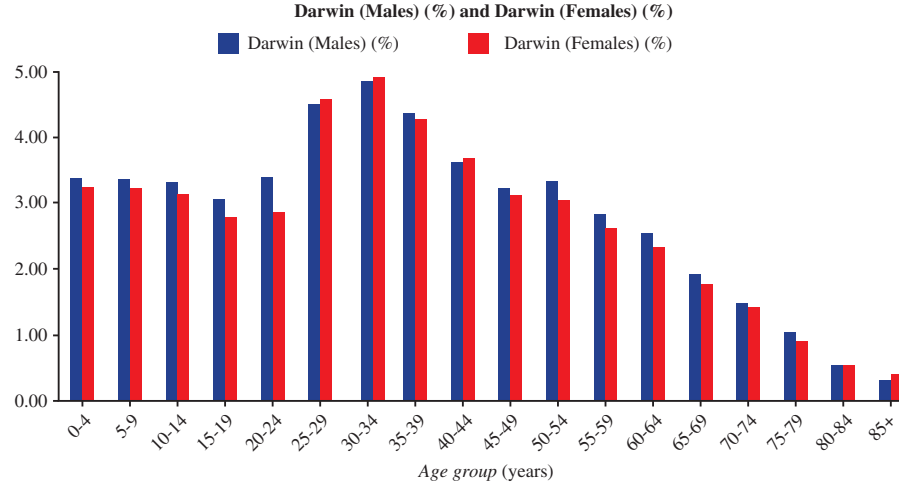


Hint
- Formulate
- Solve
- Evaluate and verify
- Communicate

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8 Analyse and compare the histograms showing population distribution by age and sex for the whole Queensland population and the population of Darwin in the Northern Territory. Comment on how the histograms may be useful, given the context of the data.





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Modelling task

Context: Various articles have been published about the difference in total earnings between males and females in professional sport in Australia.

Task: Find and compare income datasets for male and female professional sportspeople in Australia. Compile the datasets and display them in an appropriate way. Write a short report comparing the datasets.

Extension: Analyse if the difference in income between genders in professional sport has changed in the last 20 years.

Stage 1: Formulate
Make an observation of: • what you are required to do • what information you have • what other information is needed. Make an assumption of: • how you could gather more information • which measures of describing and comparing data will be relevant.
Stage 2: Solve
• Decide on appropriate researching techniques. • Gather more information through research. • Produce graphs and/or tables required to help solve the problem. • Calculate comparison characteristics for your chosen datasets and graphs.
Stage 3: Evaluate and verify
Check all information has been included and researched accurately. • Check you have verified the statistics and calculations. • Check you have the evidence to back up your report summary. • Include the evidence in the form of statements and calculation. Justify your response to questions posed in context, by considering your: • assumptions • limitations • observations • strengths.
Stage 4: Communicate
Reflect on your response and solution to the investigation, outlining the decisions involved in making your response. • State your main point. • Explain the evidence.

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Chapter summary

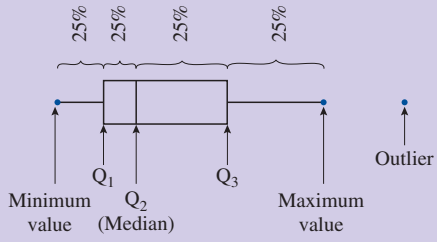
Five-number summary

- Five number summary:
  - minimum score (the smallest number in the set of data)
  - lower quartile, Q1 (the median of the lower half of the data)
  - median, Q2 (the number that falls exactly in the middle)
  - upper quartile, Q3 (the median of the upper half of the data)
  - maximum score (the largest number in the set of data).

Interquartile range

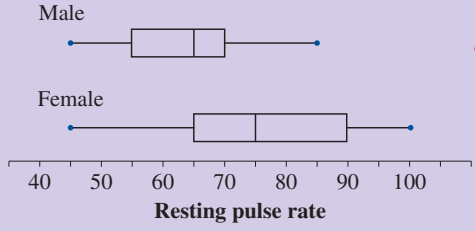
- The interquartile range (IQR) is another useful measure of spread for comparing datasets: IQR = Q3 − Q1.

Box plots



- Box plots are visual representations of the five-number summary of a dataset, drawn against a scale.
- Box plots can be drawn vertically or horizontally.
- They are divided into four sections with a quarter (25%) of the data in each section.

Parallel box plots



- Parallel box plots can be used to compare two or more datasets.
- When comparing box plots, they must always be placed against the same axis. This enables the median, spread and possible outliers of the data to be easily identified and compared. The graph below shows an example.

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Back-to-back stem plots

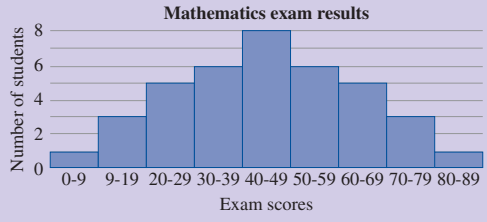
Home work time (hours per week)

Year 7		Year 12
9 8 6 6 5 4 3 3	0	5 5 7 9
5 5 5 4 4 0 0	1	0 0 2 4 7 8 9
	2	0 1 1 1

1|0 = 10 **hours per week**

- Back-to-back stem plots are used to compare two sets of data. They have a single stem with two sets of leaves. Each set of leaves is separated for the two groups being compared. The leaves for one set of data are on one side and the leaves for the second set of data are on the other side.
- When comparing back-to-back stem plots, the leaves must always be placed against the corresponding stem. This enables the shape, median, spread and possible outliers of the data to be easily identified and compared. An example is shown below.

Histogram



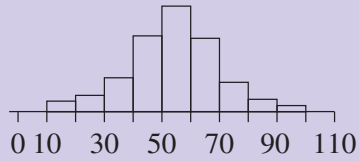
- A histogram is a special type of column graph.
- The data scores are shown on the horizontal x-axis.
- The y-axis is the frequency (it may also be labelled as the number of things being measured or scored, as this is equivalent to frequency).
- There are no gaps between the columns. Usually a histogram has vertical columns, but they may be horizontal. The histogram below provides an example.

Comparing histograms

- Comparing histograms is best done by comparing the shape (symmetry), center (modality) and spread (range).

Symmetric

Histogram ①

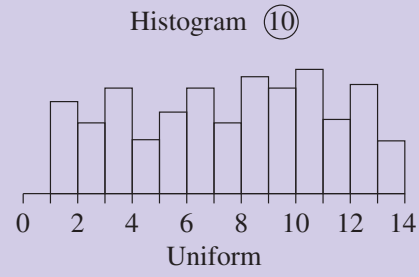


Symmetric

- The shape of a graph can be described as symmetric when the columns form a mirror image.
- The axis is the line through the distribution showing each half.
- The centre, or halfway mark, of the shape is found by eye, where approximately half of the data is on one side and the rest on the other.

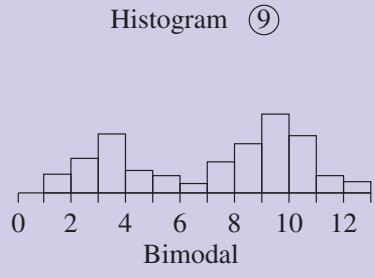
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Uniform



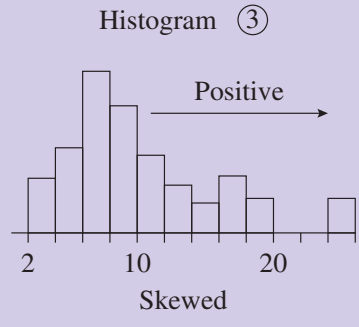
- A uniform distribution, or 'multimodal distribution', has a fairly constant, or even, frequency distribution.

Bimodal



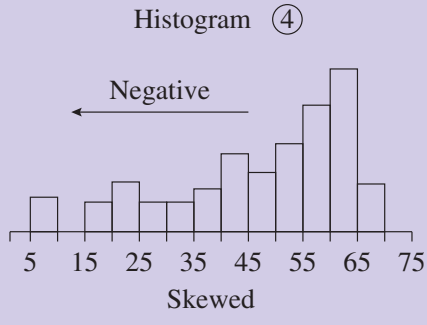
- A bimodal distribution has two modes. This means two data values have high frequencies.

Positively skewed



- A distribution is positively skewed when the distribution's peak is higher on the left, with the tail stretching to the right.

Negatively skewed



- A distribution is negatively skewed when the distribution's peak is higher on the right, with the tail stretching to the left.

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Chapter checklist

12A ☐ I can recognise the structure of a five-number summary.

1 After research into the number of guests people invite to 18th birthday parties, the following five-number summary was calculated:
10 22 35 47 61
Label the names of each of the numbers in the five-number summary.

12A ☐ I am able to create a five-number summary.

2 Create a five-number summary of the following data.
4, 8, 7, 4, 9, 13, 9, 8, 7

12A ☐ I can create a five-number summary with the use of technology. (extension only-optional question)

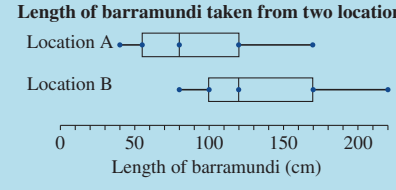
3 Create a five-number summary of the data from Question **3**, using technology.

12B ☐ I can construct box plots using a five-number summary.

4 Create a five-number summary and construct a box plot for the following dataset.
3, 4, 2, 5, 3, 2, 1, 6, 5

12C ☐ I can compare datasets using parallel box plots. **[complex]**

5 Compare the length of barramundi found in location A and B from these parallel box plots.



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12C ☐ I can compare datasets using back-to-back stem plots. **[complex]**

6 The back-to-back stem plot below shows the number of cookies sold per day at a market in April and December.

a Determine the five-number summary, IQR and range for both April and December.

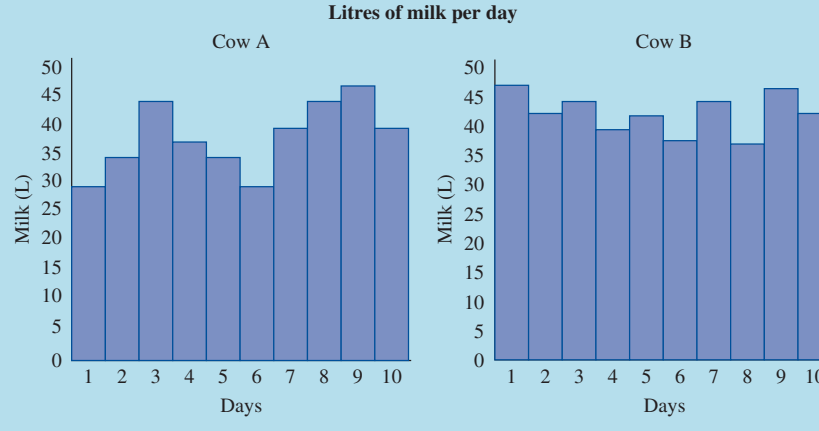
b Compare the differences and similarities in the number of cookies sold each day of markets for April and December.

April		December
9 8	0	
9 9 7 5 2	1	9
3 2 1 1	2	2 2 4 5 8 9
3 1 0	3	5 6 8 8
1	4	1 3 4
	5	2

12D ☐ I can compare the characteristics of the shape of histograms. **[complex]**

7 Compare the shape of the following histograms using symmetry, skewness or bimodality as appropriate.

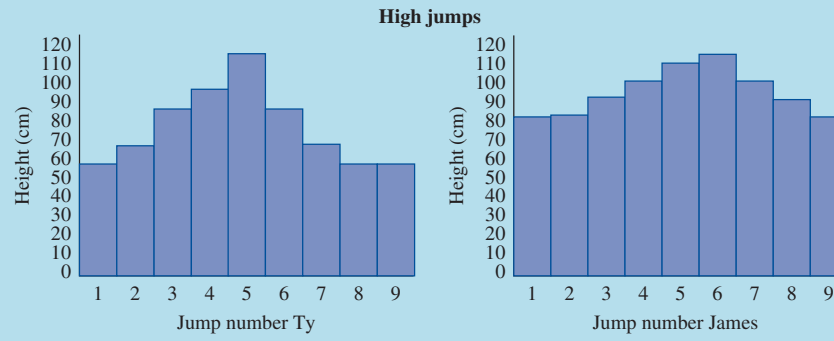
a



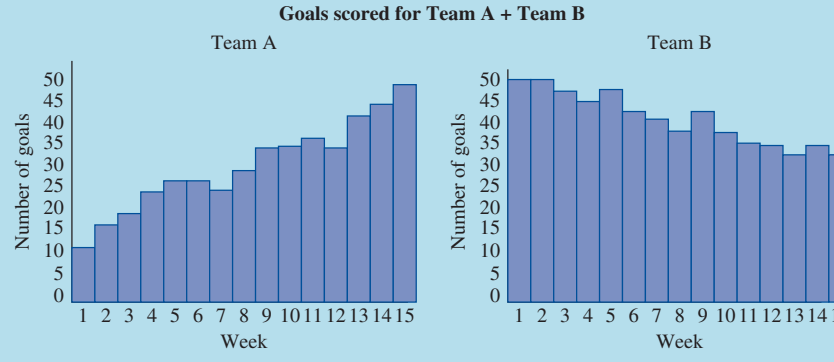
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b



c



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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

12A **1** Christine owns a dog shelter and has recorded the current weights of the dogs in her care. Determine the minimum, Q_1, median, Q_3 and maximum of her current dataset below.

7 kg, 5 kg, 8 kg, 14 kg, 7 kg, 10 kg, 4 kg, 5 kg, 3 kg, 4 kg, 7 kg, 5 kg, 4 kg

2 A soccer coach is preparing for a new season. The following dataset is her team's scores for the previous season. Create a five-number summary, without technology, to assist with their preparation.

2, 1, 0, 3, 2, 0, 4, 1, 1, 2, 1, 2, 3

3 Fajalla has diabetes. Her blood glucose levels are recorded in mmol/L.

4, 8, 7, 4, 9, 13, 9, 8, 7

Create a five-number summary of her latest results using technology. (extension only)

12B **4** A group of Year 12 students were asked to record the number of hours of homework they completed each week. The data below shows the results.

8, 9, 11, 4, 2, 4, 1, 3, 3, 6, 10, 10

a Create a five-number summary.

b Construct a box plot.

5 Sam records the number of players from each football team who are selected to play in the Queensland representative team. Construct a box plot from Sam's dataset.

3, 4, 2, 5, 3, 2, 1, 6, 5



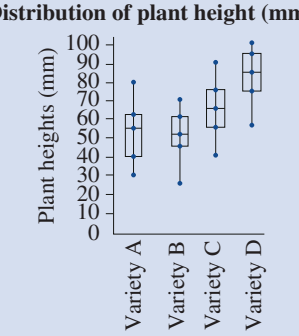
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Complex Familiar

12C **6** The following set of box plots were used to compare the heights of different varieties of a plant.





Compare the distributions of the plant varieties' heights, concluding which is tallest and comment on the variability.

7 The following back-to-back stem plots represent the distribution of the average age of women when marrying from two different 20-year periods in the history of Australia.

Average ages of women at marriage

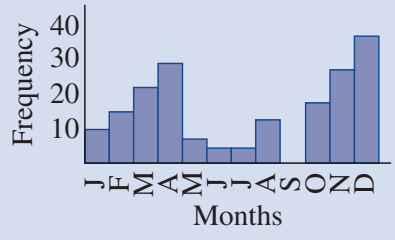
1950–1970									1980–2020						
							0								
						9	9	1							
5	4	2	2	1	1	1	0	2	3	4	5	7	8	8	9
								3	0	1	1				

a Compare these distributions in terms of median, range and IQR.

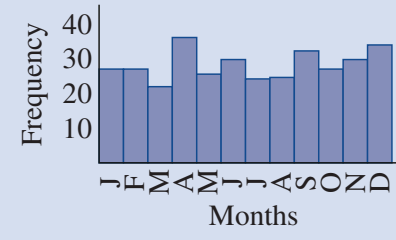
b Write a paragraph concluding whether the average age of women at marriage has changed between the two periods.

12D **8** An avid bird watcher has been recording wedge-tail eagle sightings at two particular locations in each month. Compare the shape of the two histograms.

Eagle sightings at location A



Eagle sightings at location B

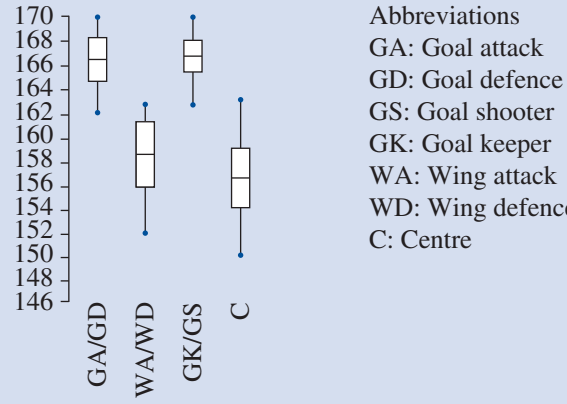


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Complex Unfamiliar

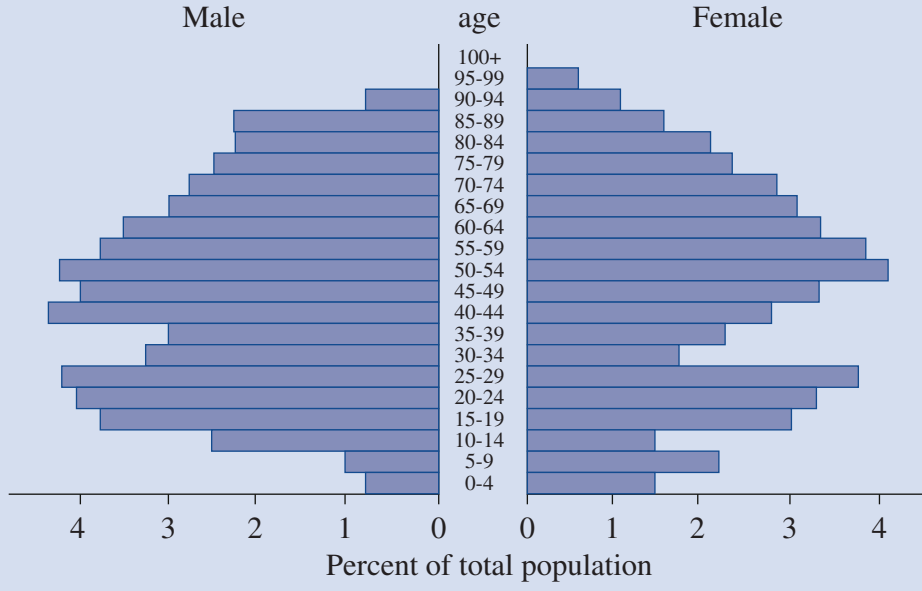
9 The following set of box plots show the heights (in cm) of 100 netball players grouped according to their positions on their teams. Compare the heights for the grouped positions that involve goal and those that do not.

Height (in cm) by position for netball teams



10 The following histograms were used to display the distribution of age by sex from the data supplied by a recent census. Compare and comment on the histograms.

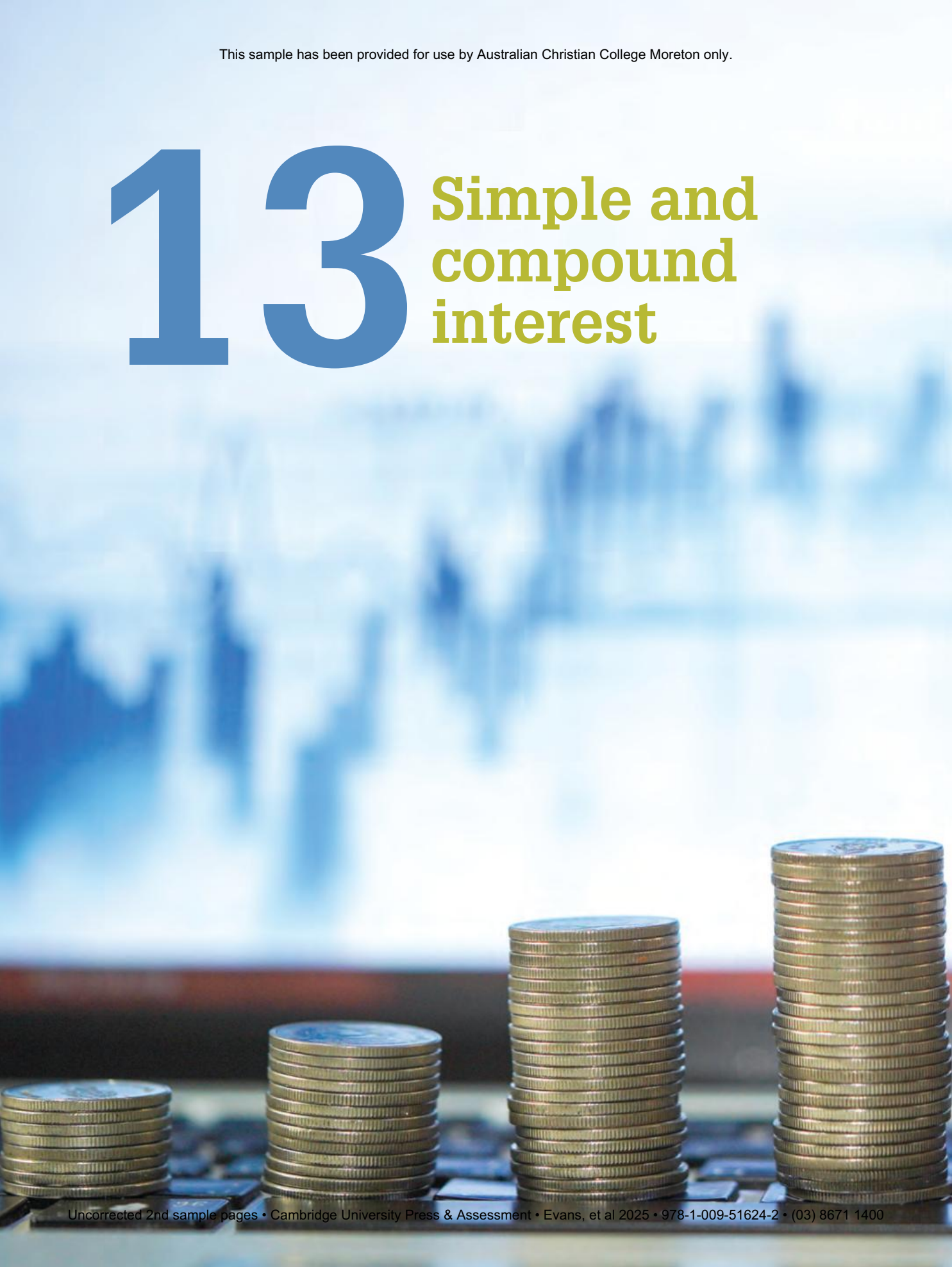
Population distribution by age and sex



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13 Simple and compound interest



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In this chapter

13A Understanding and calculating simple interest

13B Understanding and calculating annual compound interest

13C Understanding and calculating compound interest (non-annual periods) **[complex]**

13D Using technology with investment problems **[complex]**

13E Investigating the effects of changing interest rates and compounding periods using technology **[complex]**

Modelling task

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 4 Topic 3 Loans and compoundinterest

Compound interest (10 hours)

In this sub-topic, students will:

- understand the concept of simple interest where I is simple interest, P is principal, i is interest rate per period and n is total number of periods, to find unknown values using the formulas:
  - $I = Pin$
  - $P = \dfrac{I}{in}$
  - $i = \dfrac{I}{Pn}$
  - $n = \dfrac{I}{Pi}$
- understand the concept of compound interest as a recurrence relation
- use an online calculator to determine the future value of a compound interest loan or investment
- calculate the future value of a compound interest loan or investment with annual periods using the formula $A = P(1 + i)^n$, where A is future value, P is principal, i is interest rate per annum and n is total number of years
- calculate the total interest paid or earned for compound interest loan or investment
- use a spreadsheet to determine the future value of a compound interest loan or investment and the total interest paid or earned **[complex]**
- compare, numerically and graphically, the growth of simple interest and compound interest loans and investments **[complex]**
- investigate the effect of the principal, the interest rate and the number of compounding periods on the future value of a loan or investment **[complex]**.

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Prior knowledge check

1 Convert the following percentages to fractions.

a 15%
b 6%
c 2.4%
d 11.25%

2 Calculate the following amounts correct to two decimal places.

a 12% of $45
b 8% of $1590
c 1.8% of $24 900
d 3.1% of $800

3 Change the following amounts by the given percentage.

a Increase $5750 by 12%
b Increase $600 by 3%
c Decrease $2120 by 4%
d Decrease $30 000 by 15%

4 Convert the following time periods.

a 5 years to months
b 3 years to weeks
c 1 year to days
d 7 years to fortnights

5 Use a calculator to the following. Express your answer correct to two decimal places.

a 2.01^5
b 1.025^3
c 0.85^7
d 0.55^3

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13A Understanding and calculating simple interest

LEARNING GOALS

- Understand contexts where simple interest is appropriate.
- Use the simple interest formula to calculate interest.
- Apply simple interest to real life applications.

Why is understanding simple interest essential?

- Interest is the cost of borrowing money, or the reward for investing money. It is quoted using percentages.
- When investigating loans, or investments, it is important to use the potential costs of interest on a loan, or the interest earned on an investment, to help make good decisions.



Interest is the reward for investing, or the cost of borrowing money.

WHAT YOU NEED TO KNOW

- **Simple interest** is calculated using an interest rate on the same amount of money each **time period**.
- The formula to calculate simple interest is $\boldsymbol{I = Pin}$ (or $I = P \times i \times n$).
  - I = interest calculated.
  - P = **Principal** (the money borrowed or invested).
  - i = interest rate as a decimal per a time period, for example, 0.04 p.a. (p.a. means '**per annum**' which is 'per year'). However, we are usually given the interest rate as a percentage, r %, so it needs to be written as a fraction, $\frac{r}{100}$ when substituting into the formula.
  - n = number of time periods for which interest is calculated.
  - The time units of the time period and the interest rate MUST be the same, e.g. $i = \frac{4}{100}$ p.a and $n = 3$ years; or $i = \frac{4}{100}$ per month and $n = 6$ months.

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- The formula for simple interest can be rearranged to calculate the value of the principal, the percentage interest or the number of time periods for which interest is calculated. The rearranged formulas are:
  $P = \frac{I}{in}$
  $i = \frac{I}{Pn}$
  $n = \frac{I}{Pi}$.
- Loans using simple interest require the borrowed amount and the interest to be repaid.
  - Total to repay = amount borrowed + interest.
  - Regular repayment = total to repay ÷ number of repayments.

Example 1 Calculating simple interest for yearly time periods

Maxine deposits $600 into her bank account. The account offers an interest rate of 3.2% p.a. simple interest. She leaves the money in the bank for four years.

a Calculate the total interest she would earn over four years.

b Determine how much money Maxine will have after the four years.

WORKING	THINKING
	Formulate
a $P = \$600$ $i = \frac{3.2}{100}$ $n = 4$	Identify the values that need to be substituted into the formula $I = Pin$.
	Solve
$I = Pin$ $I = 600 \times \frac{3.2}{100} \times 4$ $I = \$76.80$	Substitute the values into the formula. Keystrokes on scientific calculator: 6 0 0 × 3 . 2 ÷ 1 0 0 × 4 enter Money always has two decimal places because of the cents.
b Balance $= \$600 + \$76.80$ $= \$676.80$	Add the interest to the original amount.

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Evaluate and verify

Check the reasonableness of your answer, given that the deposit was initially $600 and the interest rate was 3.2%.

Communicate

After 4 years, Maxine will have a total of $676.80 in her bank account.

◄····· Write your answer as a sentence.

Example 2 Calculating simple interest for time periods other than a year

Maxine deposits $600 into her bank account. The account offers an interest rate of 3.2% p.a. simple interest. Calculate the total interest she would earn if the money is invested for:

a 10 months
b 15 weeks
c 3 years and 6 months
d 60 days.

WORKING	THINKING
a $P = \$600$ $i = \frac{3.2}{100}$ $n = \frac{10}{12}$	◄····· Identify the values that need to be substituted into the formula $I = Pin$. To change months to years, divide *number of months* by 12.
$I = Pin$ $I = 600 \times \frac{3.2}{100} \times \frac{10}{12}$ $I = \$16.00$	◄····· Substitute the values into the formula. Keystrokes on scientific calculator: 6 0 0 × 3 . 2 ÷ 1 0 0 × 1 0 ÷ 1 2 enter
b $P = \$600$ $i = \frac{3.2}{100}$ $n = \frac{15}{52}$	◄····· Identify the values that need to be substituted into the formula $I = Pin$. To change weeks to years, divide *number of weeks* by 52.

... Continued

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$$I = 600 \times \frac{3.2}{100} \times \frac{15}{52}$$
$$I = \$5.54$$

◄····· Substitute the values into the formula.

c $P = \$600$

$$i = \frac{3.2}{100}$$
$$n = 3 + \frac{6}{12} = 3\frac{6}{12}$$

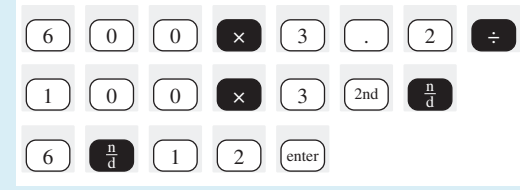
◄····· Identify the values that need to be substituted into the formula $I = Pin$.

To change months to years, divide *number of months* by 12.

$$I = 600 \times \frac{3.2}{100} \times 3\frac{6}{12}$$
$$I = \$67.20$$

◄····· Substitute the values into the formula.

Keystrokes on scientific calculator:



d $P = \$600$

$$i = \frac{3.2}{100}$$
$$n = \frac{60}{365}$$

◄····· Identify the values to substitute into $I = Pin$.

To change days to years, divide *number of days* by 365.

$$I = 600 \times \frac{3.2}{100} \times \frac{60}{365}$$
$$I = \$3.16$$

◄····· Substitute the values into the formula.

Example 3 Calculating the principal in a simple interest loan

Shae borrowed money from her aunty for a holiday. The aunty charged 4% simple interest over 3 years, which meant Shae ended up paying $138 in interest. Calculate the principal amount that Shae initially borrowed for her holiday.

WORKING	THINKING
$P = \frac{I}{in}$ $I = \$138$ $i = \frac{4}{100} = 0.04$ $n = 3$	◄····· Identify the values that need to be substituted into the formula $P = \frac{I}{in}$. Hint: see formula sheet.

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$$P = \frac{138}{0.04 \times 3}$$
$$= \$1150$$

◄····· Substitute the values into the formula and use your calculator to solve.

Shae initially borrowed $1150 from her aunty.

◄····· Write your answer as a sentence.

Example 4 Calculating the interest and number of repayments on a simple interest loan

Jude deposited $5800 into his bank account which earns simple interest.

a After 5 years he logs into the account and sees that he now has a total of $6900 available. Calculate the percentage interest rate on the account.

b Jude accessed the account again and discovered there was $7118.96 in the account. Determine the total number of years (n) that Jude has held the account.

WORKING	THINKING
	Formulate
a $i = \frac{I}{Pn}$	◄···· Identify the values to be substituted into the formula $i = \frac{I}{Pn}$. Be sure to subtract the principal amount from the total amount in the account to calculate I.
$I = \$6900 - \$5800 = \$1100$	
$P = \$5800$	
$n = 5$	
	Solve
$i = \frac{I}{Pn}$	◄···· Substitute the values into the formula and use your calculator to solve.
$i = \frac{1100}{5800 \times 5}$	
$i = 0.0379 \times 100$	
$= 3.79\%$	
	Evaluate and verify
	Check the reasonableness of your answer given the amount of interest charged and the percentage interest.
	Communicate
The interest rate for Jude's account was 3.79% p.a.	◄···· Write your answer as a sentence

... Continued

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b $n = \dfrac{I}{Pi}$

$I = \$7118.96 - \$5800$

$= \$1318.96$

$P = \$5800$

$i = \dfrac{3.79}{100} = 0.0379$

Formulate

◄···· Identify the values to be substituted into the formula $n = \dfrac{I}{Pi}$. Be sure to subtract the principal amount from the total amount in the account to calculate I.

Solve

$n = \dfrac{I}{Pi}$

$n = \dfrac{1318.96}{5800 \times 0.0379}$

$n = 6$

◄···· Substitute the values into the formula and use your calculator to solve.

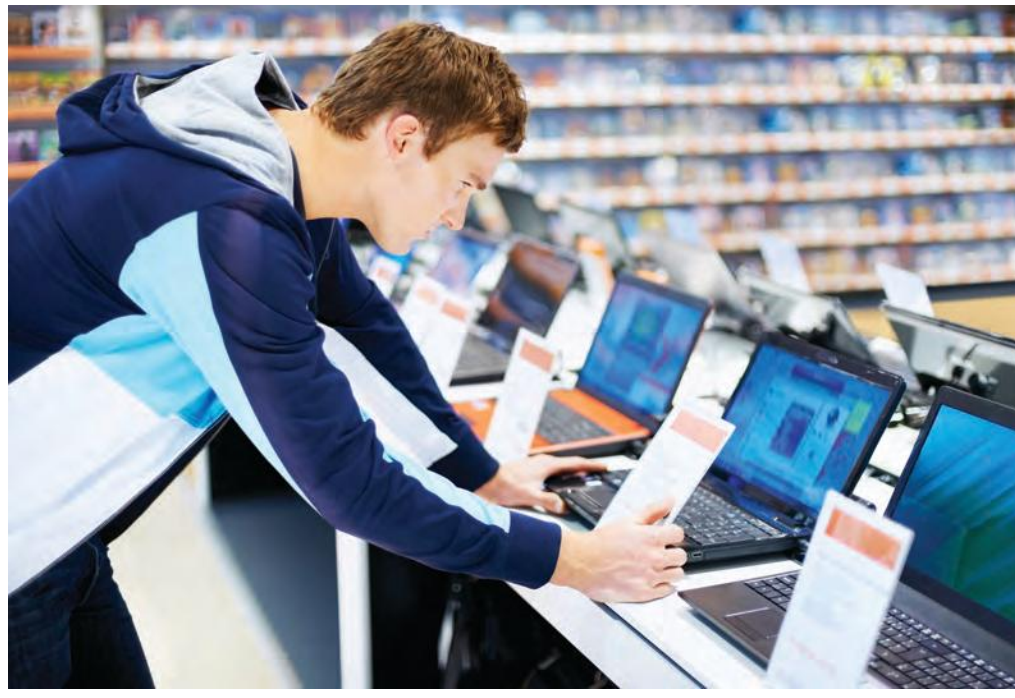
Evaluate and verify

Check the reasonableness of your answer given the amount of interest charged and the percentage interest.

Communicate

Jude has had the account for 6 years.

◄···· Write your answer as a sentence.



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Exercise 13A

FUNDAMENTALS

1 Express the following time periods as a fraction of a year.

a 7 months = _____ year
b 31 weeks = _____ year
c 25 days = _____ year
d 18 months = _____ year
e 270 days = _____ year
f 9 weeks = _____ year

Hint: 1 Year = 12 months
= 52 weeks
= 26 fortnights
= 365 days

2 Calculate the value of the following percentages.

a 30% of $23.70
b 10% of $80.90
c 5% of $126.45
d 3.45% of $456.21
e 1.05% of $364.85
f 0.65% of $63.90

Hint: First divide the percentage by 100 to make it a decimal.

APPLICATIONS

Example 1

3 Calculate the simple interest earned on the following investments.

a $780 is invested at 4.57% p.a. for 4 years.
b $4260 is invested at 6.32% p.a. for 3 years.
c $2030 is invested at 9.05% p.a. for 5 years.
d $625 is invested at 5.9% p.a. for 2 years.
e $1650 is invested at 4.2% p.a. for 5 years.
f $5050 is invested at 3.9% p.a. for 7 years.
g $8880 is invested at 5.79% p.a. for 6 years.
h $7280 is invested at 5.36% p.a. for 2 years.

★4 Angus invested $10 000 in a fixed-term account for 4 years paying a simple interest rate of 3.65% p.a.

a Calculate the total amount of interest earned over the 4 years.
b Calculate the total value of the investment after 4 years.

Example 2

5 Calculate the simple interest earned on the following investments.

a $6200 is invested at 6.8% p.a. for 4 months.
b $590 is invested at 5.11% p.a. for 20 weeks.
c $8290 is invested at 4.48% p.a. for 15 days.
d $6700 is invested at 2.26% p.a. for 2 weeks.
e $7740 is invested at 5.35% p.a. for 14 days.
f $858 is invested at 7.07% p.a. for 7 months.
g $3700 is invested at 6.1% p.a. for 9 years and 6 months.
h $6160 is invested at 5.3% p.a. for 8 years and 3 months.

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★**6** A company invested $2 000 000 in the short-term money market at 8% p.a. simple interest for 30 days.

Hint The short-term money market is used for borrowing and investing money for up to one year.

a Calculate the total amount of interest earned over the 30 days.

b Calculate the total value of the investment after 30 days.

Example 3

7 Calculate the principal amount on the following debts.

Hint $P = \frac{I}{in}$

a 5% interest rate over 3 years, which charges $408 in interest.

b 4.3% interest rate over 2 years, which charges $404.63 in interest.

c 6.8% interest rate over 5 years, which charges $2239.58 in interest.

d 3.8% interest rate over 8 years, which charges $17 601.60 in interest.

e 4.2% interest rate over 12 years, which charges $63 000 in interest.

8 Luna borrowed money from her friend 15 years ago. She was charged a simple interest rate of 2.8% p.a. and she ended up paying $9870 in interest. Calculate the principal amount that Luna initially borrowed from her friend.

9 Kai was left some inheritance from his grandmother. The account showed that the money was invested 20 years ago at a simple interest rate of 4.3% p.a. The account had earnt $15 480 in interest over that time. Calculate the initial amount of money that Kai's grandmother invested.

Example 4

10 Calculate the amount of time (n) the following investments have been accruing simple interest.

Hint $n = \frac{I}{Pi}$

a $5000 at 4.5% interest rate accrues $1350 in interest.

b $16 500 at 3.8% interest rate accrues $4389 in interest.

c $56 000 at 5.1% interest rate accrues $14 280 in interest.

d $200 000 at 6.2% interest rate accrues $186 000 in interest.

e $350 000 at 5.5% interest rate accrues $481 250 in interest.

11 Thomas invested $15 000 into an account for his son. The chosen account paid 5.7% p.a. simple interest, and he planned on leaving the money in the account until it had accrued $17 400 in interest. Determine how long Thomas would need to leave the money in the account.

12 Kirra borrowed $7800 to purchase her first car.

Hint $i = \frac{I}{Pn}$

a After two years she begins to pay back her mum, but now her debt is $9048. Calculate the percentage interest rate that the loan charges.

b A few years later, Kirra has finished paying off her car and she calculates that the car cost her a total of $11544 including interest. Determine how long it took Kirra to pay off her car loan.

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★13 Caleb borrowed $3000 with a simple interest rate of 9.7% p.a. over 18 months to buy a new lounge.



a Calculate the total amount of interest owed after 18 months.

b Calculate the total amount Caleb will need to repay after 18 months.

c Calculate the monthly repayment.

Hint Total to repay = amount borrowed + interest Regular repayment = total to repay ÷ number of repayments

★14 A bank offers the following simple interest rates on fixed-term deposits.

Term	Interest rate for $10 000 to $49 999	Interest rate for $50 000 to $1 999 999
60 months	2.65% p.a.	2.75% p.a.
24–33 months	2.60% p.a.	2.70% p.a.
12 months	2.20% p.a.	2.30% p.a.
6 months	2.05% p.a.	2.05% p.a.
3 months	2.00% p.a.	2.00% p.a.

a Ezikiel wins $15 000 in a lottery. He decides to invest it for two years to use as a home loan deposit.
- i Determine what interest rate the bank will offer.
- ii Calculate how much interest he will earn in two years.
- iii Determine how much his investment will be worth after the two years.

b Georgia inherits $65 000. She decides to invest it for one year while she considers what to do with the money.
- i Determine what interest rate the bank will offer.
- ii Calculate how much interest will she earn in one year.
- iii Determine how much her investment will be worth after one year.

★c Jason has saved $11 400 from his part-time job. He decides to invest it for six months while he hunts for a car to buy.
- i Determine what interest rate the bank will offer.
- ii Calculate how much interest he will earn.
- iii Determine how much his investment will be worth after six months.

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13B Understanding and calculating annual compound interest

LEARNING GOALS

- Understand that compound interest is repeated interest calculations (recurrence relation).
- Apply the compound interest formula to annual compounding periods.
- Calculate the total interest earned or paid.

Why is understanding compound interest essential?

- Compound interest is more common than simple interest, especially with a mortgage or personal loan. Compound interest accounts can also be a great investment option, as the interest accrues on top of the previous interest earnt.

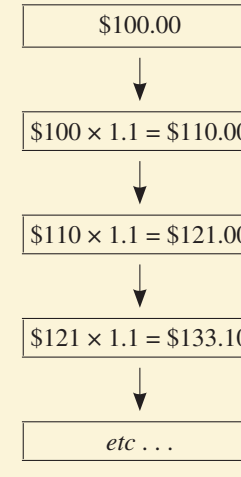


With compound interest, interest is earned on the amount including the interest already earned, so the investment will grow more quickly.

- The interest is added on to the principal at the end of each compounding period, and the future interest calculations are then made on the new balance that includes previous interest payments. For this reason, it's crucial to understand compound interest so that wise investments can be made or loans can be paid off promptly to avoid big interest debts.

WHAT YOU NEED TO KNOW

- At the end of each time period, the same interest calculation rule is applied to the amount of money in the account. The calculation 'recurs' (is repeated) each time. If no money is withdrawn or paid in, and the interest rate remains the same, this produces a sequence where each amount depends only on the previous amount. For example: \$100 is increased by 10% (which means it is multiplied by 1.1) and the result is multiplied by 1.1, and the result of that is multiplied by 1.1, and so on, as shown in the diagram.



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- This is called a **recurrence relation**, of which compound interest is just one type. In this course, we will show this recurrence as successive lines in a table or spreadsheet.
- Consider an investment of $2000 placed in an account paying 4% p.a. for three years, with interest added to the account at the end of each year. We can use a table to find the balance at the end of every year as follows:

Year	Principal	Interest	Balance
1	$2000.00	$2000.00 \times \frac{4}{100} = \$80.00$	$2000.00 + \$80.00 = \$2080.00$
2	$2080.00	$2080.00 \times \frac{4}{100} = \$83.20$	$2080.00 + \$83.20 = \$2163.20$
3	$2163.20	$2163.20 \times \frac{4}{100} = \$86.53$	$2163.20 + \$86.53 = \$2249.73$

- Notice how the balance becomes the principal in the next line, and that the principal is multiplied by the same amount each time $\left(\frac{4}{100} \text{ in this case}\right)$. This is what is meant by a recurrence relation.
- We can also use indices to write repeated, or recurring, multiplication. Hence after three years:

  $\text{Balance} = 2000 \times \left(1 + \frac{4}{100}\right)^3 = \$2249.73$
- A formula for **compound interest** can now be developed.

  $\boldsymbol{A = P(1 + i)^n}$, where:
  - A = the *accumulated* amount at the end of the investment
  - P = the *principal* amount that you started with
  - i = the *interest* rate as a decimal per a time period. Using the example with 4% above, $\frac{4}{100} = 0.04$, so $i = 0.04$ p.a. However, we are usually given the interest rate as a percentage, such as r% p.a. This needs to be written as $\frac{r}{100}$ when put into the formula.
  - n = the *number* of time periods (compounding periods).
  - The time units of the compounding period and the interest rate **must** be the same, e.g. $i = \frac{4}{100}$ p.a and $n = 3$ years; or $i = \frac{4}{100}$ per month and $n = 6$ months. In Exercise 13B we will only look at annual compounding periods.

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Example 5 Calculating annual compound interest using a table

Titan invests $900 into an account paying 3% p.a. interest for four years.

a Complete the following table to calculate Titan's interest and balance at the end of each year.

Year	Principal	Interest	Balance
1	$900		
2			
3			
4			

b Determine how much interest he earned in four years.

WORKING

a

Year	Principal	Interest	Balance
1	$900.00	$900.00 \times \frac{3}{100} = \$27.00$	$900.00 + 27.00 = \$927.00$
2	$927.00	$927.00 \times \frac{3}{100} = \$27.81$	$927.00 + 27.81 = \$954.81$
3	$954.81	$954.81 \times \frac{3}{100} = \$28.64$	$954.81 + 28.64 = \$983.45$
4	$983.45	$983.45 \times \frac{3}{100} = \$29.50$	$983.45 + 29.50 = \$1012.95$

b Interest earned $= 1012.95 - 900.00 = \$112.95$

THINKING

The interest is added to the principal at the end of each year.

The balance becomes the principal in the next year.

Money should always have two decimal places because of the cents.

Subtract the starting principal from the final balance to calculate the interest earned.

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Example 6 Calculating compound interest with yearly compounding periods using the formula

Riley invests $2800 into an account paying 2.5% p.a. interest that compounds annually.

a Use the compound interest formula to find what Riley's investment will be worth after five years.

b Determine how much interest he earned in five years.

WORKING	THINKING
a $P = \$2800$ $i = \frac{2.5}{100}$ $n = 5$	Identify the values that need to be substituted into the formula $A = P(1 + i)^n$.
$A = P(1 + i)^n$ $A = 2800\left(1 + \frac{2.5}{100}\right)^5$ $A = \$3167.94$	Substitute the values into the formula. To enter the power, use the ^ or $x^{\sqrt{}}$ button on your calculator. Keystrokes on scientific calculator: 2 8 0 0 × (1 + 2 . 5 ÷ 1 0 0) ^ 5 enter
b Interest earned $= 3167.94 - 2800$ $= \$367.94$	Subtract the starting principal from the final balance to calculate the interest earned.



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Exercise 13B

APPLICATIONS

Example 5 ★1 Kate invests $2480 into an account that pays 3.2% p.a. compound interest for three years. Interest is compounded yearly.

a Copy and complete the following table to calculate her interest and balance at the end of each year.

Year	Principal	Interest	Balance
1	$2480		
2			
3			

b Determine how much interest she earned in three years.

★2 Jasper invests $3850 into an account that pays 2.10% p.a. compound interest for four years. Interest is compounded yearly.

a Copy and complete the following table to calculate his interest and balance at the end of each year.

Year	Principal	Interest	Balance
1			
2			
3			
4			

b Determine how much interest he earned in four years.

★3 Jedda borrowed $8500 for a holiday. The bank charged 8.2% p.a. compounded interest for three years. The interest was compounded yearly. He planned on paying off the loan in one lump sum at the end of the three years.

a Copy and complete the following table to calculate his interest and balance owing at the end of each year

Year	Principal	Interest	Balance
1			
2			
3			

b Determine the total amount Jedda had to pay at the end of the loan and the interest he was charged.

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★4 Aisha borrowed $16 000 for a new horse. The personal loan terms were charged at 9% p.a. compounded interest for four years. The interest was compounded yearly, and she wanted to pay off the loan in one lump sum at the end of the four years. Create a table to show the compounding calculations for each year and determine the total amount that Aisha owes for her horse.

Example 6 ★5 Abby has saved $9600 from her part-time job. She invests it for two years at 3.20% p.a. until she gets her P's and can buy a car. Interest is compounded yearly.

a Use the compound interest formula to calculate the balance of her account after two years.

b Determine how much interest she earned over the two years.

Hint To enter the power, use the ^ or X^n button on your calculator.

★6 Ben invests the $4500 he earned from the sale of cattle for four years at 2.20% p.a. to save for a trip at the end of school. Interest is compounded yearly.

a Use the compound interest formula to calculate the balance of his account after four years.

b Determine how much interest he earned over the four years.

★7 Chun borrowed $38 000 for a new car. The loan terms are 11.5% p.a. compounded yearly for five years. The interest is charged yearly, and Chun will repay the loan plus interest at the end of the five years.

a Use the compound interest formula to calculate the balance of her loan after five years.

b Determine how much interest she was charged over five years.

8 Calculate the final balance of the following investments.

a $680 invested at 5% p.a. compounded annually for three years

b $275 invested at 3% p.a. compounded annually for six years

c $682 invested at 4% p.a. compounded annually for five years

d $1240 invested at 2.2% p.a. compounded annually for four years

e $5760 invested at 1.8% p.a. compounded annually for seven years

f $4030 invested at 2.15% p.a. compounded annually for five years.

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9 Charlie invests $3500 in an account that pays 4% p.a. interest compounded every year.

★a Use a spreadsheet to calculate the interest and balance each year for five years. A sample set is shown:

> **Hint**
> - All formulas begin with =
> - Multiplication is *
> - Divide is /

	A	B	C	D
1	Year	Principal	Interest	Balance
2	1			
3	2			
4	3			
5	4			
6	5			

i Identify which cell you will need to enter the $3500 principal.

ii Determine the formula will you need to enter in cell C2.

iii Determine the formula will you need to enter in cell D2.

iv Determine the formula will you need to enter in cell B3.

b i Fill down to complete the spreadsheet.

ii Use your spreadsheet to calculate the value of Charlie's investment after five years.

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13C Understanding and calculating compound interest (non-annual periods)

COMPLEX

LEARNING GOALS

- Apply a recurrence relation to non-annual compounding periods.
- Apply the compound interest formula to non-annual compounding periods.
- Calculate the total interest earned or paid.

Why is understanding non-annual compounding periods essential?

- The majority of loans and investments have various non-annual compounding periods.
- Non-annual compounding periods mean that interest can compound daily, weekly, fortnightly, monthly, quarterly or half-yearly. This means that the interest can build rapidly, so it is important to understand how to use this to benefit an investment or to reduce the interest costs in a loan.



Compound interest is a great investment option, as interest is earned on top of interest, so the investment can grow quickly.

WHAT YOU NEED TO KNOW

- Non-annual compounding periods can be daily, weekly, fortnightly, monthly, quarterly or half-yearly.
- You must recall the number of days, weeks, fortnights and months in a year in order to calculate various compounding periods.
  - Days: 365
  - Weeks: 52
  - Fortnights: 26
  - Months: 12
  - Half yearly: 2
- As per Section 13B, we can still use a recurrence relation in the form of a table to display the concept of compounding interest. However, the number of compounding periods will not be yearly but will show the number of compounding periods, which will vary depending on the terms of the investment or loan. A $5000 investment with a 4% p.a. compound interest rate that is compounding monthly will have a recurrence relation table that looks like this.

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Month	Principal	Interest	Balance
1	\$5000	$5000 \times \frac{4}{12 \times 100}$ = \$16.67	5000 + 16.67 = \$5016.67
2	\$5016.67	$5016.67 \times \frac{4}{12 \times 100}$ = \$16.72	5016.67 + 16.72 = \$5033.39
3	\$5033.39	$5033.39 \times \frac{4}{12 \times 100}$ = \$16.78	5033.39 + 16.78 = \$5050.17

- With a non-annual compounding table like this, your compounding periods (first column) will change depending on the number of compounding periods.
- Note that in the above table this only shows the balance after three months. If the term of the investment was 2 years, you would need to have 24 rows (2 years × 12 months = 24 compounding periods) to display all the calculations. Unless using a spreadsheet for these calculations, it is unlikely you would do this by calculator for the full term of the loan. This is why it is important to use the compounding formula.

- The compounding formula that was used in Section 13B can also be used with non-annual compounding periods; however, the interest rate (i) must be divided by the number of compounding periods. Also, the number of compounding periods (n) will no longer be in years but rather 'the number of years × the number of compounding periods each year'. For example, using the investment terms from above where \$5000 is invested at 4% p.a. compounding monthly for 2 years, we can calculate the total balance of the investment at the end of the 2 years with the following formula:

  $A = P(1 + i)^n$

  $P = \$5000$ (principal)

  $i = \frac{4 \div 12}{100} = \frac{4}{12 \times 100} = \frac{4}{1200}$

  $n = 2$ years × 12 compounding periods per year = 24

  Therefore, substitute these values into the given formula:

  $A = P(1 + i)^n$

  $A = 5000\left(1 + \frac{4}{1200}\right)^{24}$

  $A = \$5415.71$

- The total interest paid can be determined by subtracting the original investment (P) from the total amount (A).

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Example 7 Non-annual compounding interest using a recurrence relation [complex]

Annika invests $17 500 into an account paying 4.5% p.a. compounding interest for two years, with monthly compounding periods. Complete the following table to show the balance of Annika's investment after the first four months and determine how much interest her investment has earnt in that time.

Month	Principal	Interest	Balance
1			
2			
3			
4			

WORKING

Month	Principal	Interest	Balance
1	$17 500	$17\,500 \times \frac{4.5 \div 12}{100} = \$65.63$	$17\,500 + 65.63 = \$17\,565.63$
2	$17 565.63	$17\,565.63 \times \frac{4.5 \div 12}{100} = \$65.87$	$17\,565.63 + 65.87 = \$17\,631.50$
3	$17 631.50	$17\,631.50 \times \frac{4.5 \div 12}{100} = \$66.19$	$17\,631.50 + 66.19 = \$17\,697.62$
4	$17 697.62	$17\,697.62 \times \frac{4.5 \div 12}{100} = \$66.37$	$17\,697.62 + 66.37 = \$17\,763.99$

THINKING

The interest is divided by 12 because the compounding periods are monthly.
The interest is added to the principal at the end of each month.
The balance then becomes the principal in the following month

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After four months, Annika's balance is \$17 763.99
Interest earnt after four months:
\$17 763.99 − \$17 500 = \$263.99

◄··· To calculate the interest earnt on the investment, subtract the original principal amount from the new balance at the end of the 4 months.

Example 8 Calculating compound interest with various compounding periods using the formula

Joshua invests \$1600 into an account paying 2.5% p.a. interest for three years. Use the compound interest formula to find what his investment will be worth after three years if interest compounds:

a yearly **b** half-yearly **c** monthly
d weekly **e** daily

WORKING	THINKING
a $P = \$1600$ $i = \frac{2.5}{100}$ $n = 3$	◄··· Identify the values that need to be substituted into the formula $A = P(1 + i)^n$.
$A = P(1 + i)^n$ $A = 1600\left(1 + \frac{2.5}{100}\right)^3$ $A = \$1723.03$	◄··· Substitute into the formula and evaluate with a calculator. Money should always have two decimal places because of the cents.
b $P = \$1600$ $i = \frac{2.5 \div 2}{100} = \frac{2.5}{200}$ per half-year $n = 3 \times 2 = 6$ half-years	◄··· The interest rate will need to be divided by 2 (and 100) since there are 2 half-years in a year. Leaving as a fraction will give a more exact answer. If interest compounds twice per year, then it will compound 6 times in three years.

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$A = P(1 + i)^n$

$A = 1600\left(1 + \frac{2.5}{100}\right)^6$

$A = \$1723.81$

◄··· Substitute into the formula and evaluate with a calculator.

c $P = \$1600$

$i = \frac{2.5 \div 12}{100} = \frac{2.5}{1200}$ per month

$n = 3 \times 12 = 36$ months

◄··· The interest rate will need to be divided by 12 (and 100) since there are 12 months in a year. Leaving as a fraction will give a more exact answer.
If interest compounds every month, then it will compound 36 times in three years.

$A = P(1 + i)^n$

$A = 1600\left(1 + \frac{2.5}{1200}\right)^{36}$

$A = \$1724.28$

◄··· Substitute into the formula and evaluate with a calculator.

d $P = \$1600$

$i = \frac{2.5 \div 52}{100} = \frac{2.5}{5200}$ per week

$n = 3 \times 52 = 156$ weeks

◄··· The interest rate will need to be divided by 52 (and 100) since there are 52 weeks in a year. Leaving as a fraction will give a more exact answer.
If interest compounds every week, then it will compound 156 times in three years.

$A = P(1 + i)^n$

$A = 1600\left(1 + \frac{2.5}{5200}\right)^{156}$

$A = \$1724.58$

◄··· Substitute into the formula and evaluate with a calculator.

... Continued

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e $P = \$1600$

$$i = \frac{2.5 \div 365}{100} = \frac{2.5}{36\,500} \text{ per day}$$

$$n = 3 \times 365 = 1095 \text{ days}$$

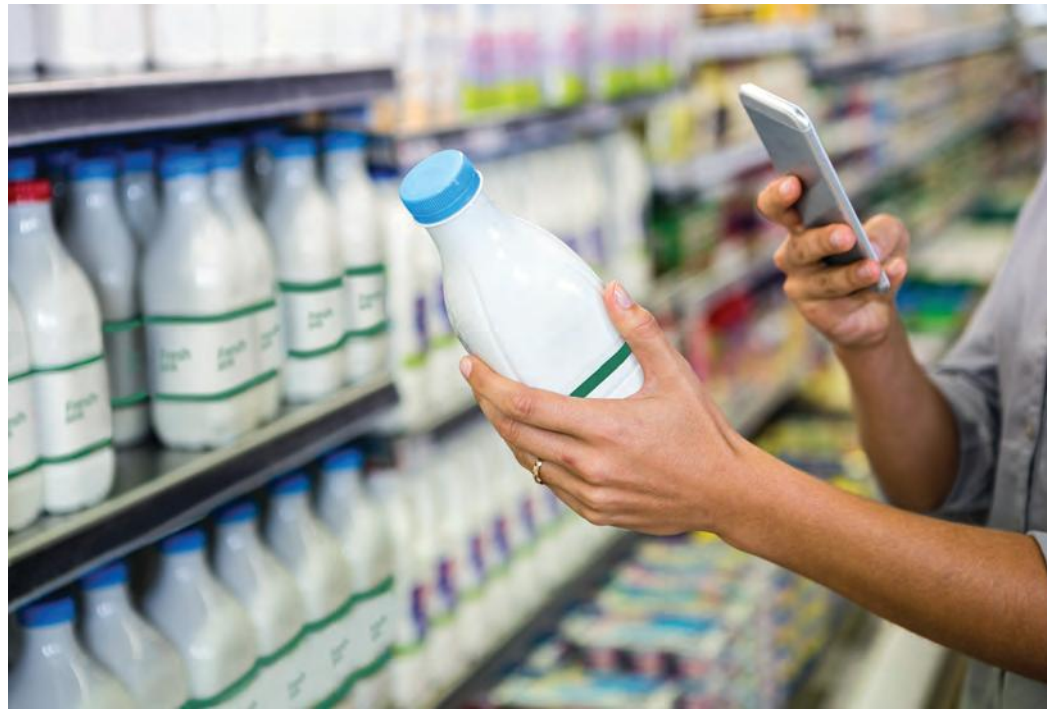
◄··· The interest rate will need to be divided by 365 (and 100) since there are 365 days in a year. Leaving as a fraction will give a more exact answer.
If interest compounds every day, then it will compound 1095 times in three years.

$$A = P(1 + i)^n$$

$$A = 1600\left(1 + \frac{2.5}{36\,500}\right)^{1095}$$

$$A = \$1724.61$$

◄··· Substitute into the formula and evaluate with a calculator.



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Exercise 13C

FUNDAMENTALS

1 Convert one year to:

a months
b weeks
c half-years
d days
e quarters
f fortnights.

2 A bank advertises interest rates of 2.4% p.a. Express this as a:

a half-yearly rate
b quarterly rate
c monthly rate
d fortnightly rate
e weekly rate
f daily rate.

APPLICATIONS

Example 7 ★**3** Ahmed invests $13 000 into an account paying 4.8% p.a. compounding interest for five years, with monthly compounding periods. Complete the following table to show the balance of Ahmed's investment after the first four months and determine how much interest his investment has earnt in that time.

Month	Principal	Interest	Balance
1			
2			
3			
4			

★**4** Coen invests $10 000 into an account paying 5.2% p.a. compounding interest for five years, with quarterly compounding periods. Complete the following table to show the balance of Coen's investment after the first year and determine how much interest his investment has earnt during that time.

Quarter	Principal	Interest	Balance
1			
2			
3			
4			

CF

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CP

★5 Samantha borrows $15 000 to purchase a car. The loan terms are 9.8% p.a. compounding interest for five years, with weekly compounding periods. She agrees to begin repaying the loan after four weeks as she will be away on a holiday. Complete a table to show the balance owing on Samantha's loan after the first four weeks and determine how much interest her debt has accrued during this time.

Weeks	Principal	Interest	Balance
1			
2			
3			
4			

★6 Arthur borrows $220 000 to purchase a unit. The loan terms are 5.8% p.a. compounding interest for 20 years, with monthly compounding periods. He will not begin his repayments on his loan until he has sold his other property in three months' time. Complete a table to show the balance owing on Arthur's loan after the first three months and determine how much interest his debt has accrued during this time.

Month	Principal	Interest	Balance
1			
2			
3			



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CF

★7 Nicola invests $10 000 into an account paying 5.2% p.a. compounding interest for five years, with daily compounding periods. Complete the following table to show the balance of Nicola's investment after the first seven days and determine how much interest investment has earnt in the first week.

Day	Principal	Interest	Balance
1			
2			
3			
4			
5			
6			
7			

Example 8 ★8 Calculate the final balance of the following investments.

a $1370 invested at 8.85% p.a. compounded monthly for three years.

b $54 600 invested at 1.20% p.a. compounded half-yearly for eight years.

Hint The compound interest formula is $A = P(1 + i)^n$.

c $4300 invested at 5.07% p.a. compounded weekly for two years.

d $3350 invested at 6.1% p.a. compounded monthly for three years.

e $7960 invested at 4.92% p.a. compounded fortnightly for two years.

f $4220 invested at 4.66% p.a. compounded quarterly for four years.

★9 Natalie borrows $5000 from a bank that charges interest at the rate of 3.6% p.a. compounding monthly. Use the compound interest formula to calculate how much is owing in her account after five years.

★10 Georgia invests $3800 in an account that charge interest at the rate of 2.4% p.a. compounding weekly. Use the compound interest formula to calculate how much is owing in her account after two years.

CU

★11 Ezekiel is planning on borrowing $8000 to purchase her first car. Her grandad has offered her a loan under the following terms: 9.5% p.a. simple interest and she must repay the loan in 4 years. The bank has offered her a loan under the following terms: 8.5% p.a. compounding monthly interest, with the loan also being paid back after 4 years. In both cases, she must repay the loan in one lump sum at the end of the contract. Calculate the amount of interest paid under both options and help Ezekiel decide which loan she should accept.



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13D Using technology with investment problems

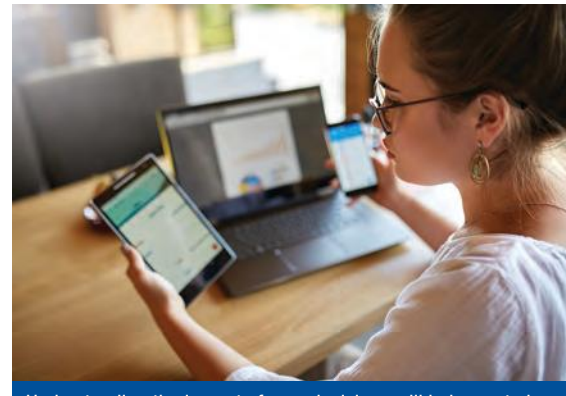
COMPLEX

LEARNING GOALS

- Calculate the future value of a compound interest investment and the total interest earned using:
  - an online calculator
  - a spreadsheet.
- Compare the growth of simple interest and compound interest investments using:
  - an online calculator
  - a spreadsheet.

Why is using technology essential when investigating investments?

- Using technology allows for easier future planning, so that savings can be achieved for things like holidays, cars and homes.
- Technology allows for a simplified tool to help decide which investments will provide the greatest returns or which loans will cost the least.



Understanding the impact of your decisions will help you to be more successful in achieving your financial goals.

WHAT YOU NEED TO KNOW

- There are many places online where you can go to calculate future value of investments. It is the core business of all the banks, so they all have calculators on their websites. The Australian Securities and Investment Commission (ASIC) Moneysmart website is free from bias, is a useful place to find information about savings and loans, and has lots of calculators to help you (*https://www.moneysmart.gov.au/*).

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- For example: with the Moneysmart compound interest calculator, you can easily find the total interest and savings if you save $100 every month for five years at 4% p.a.



- A spreadsheet can also be used to calculate this information:

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
2	1	$ -	0	100	$ 100.00
3	2	$ 100.00	0.333333	100	$ 200.33
4	3	$ 200.33	0.667778	100	$ 301.00
5	4	$ 301.00	1.003337	100	$ 402.00

Scrolling down to the 60th month (five years), we can see that the balance, total interest and regular deposits match the figures from the Moneysmart website:

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
59	58	$ 6,266.03	20.88676	100	$ 6,386.91
60	59	$ 6,386.91	21.28971	100	$ 6,508.20
61	60	$ 6,508.20	21.69401	100	$ 6,629.90
62					
63			$ 629.90	$ 6,000.00	

We will develop this spreadsheet in Example 10.

- Simple interest investments earn the same amount of interest every time period. Compound interest investments have the interest added after each time period, and the amount of interest earned increases over time.

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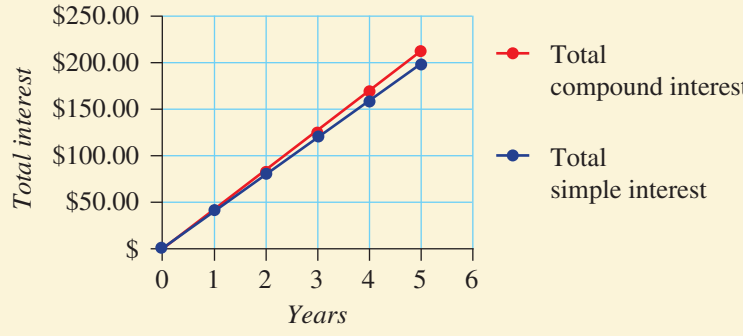
- For example: $1000 is invested at 4% p.a. for five years.

Year	Simple interest	Total simple interest
1	$ 40.00	$40.00
2	$ 40.00	$80.00
3	$ 40.00	$120.00
4	$ 40.00	$160.00
5	$ 40.00	$200.00

Year	Compound interest	Total compound interest
1	$ 40.00	$40.00
2	$ 41.60	$81.60
3	$ 43.26	$124.86
4	$ 44.99	$169.86
5	$ 46.79	$216.65

Graphically, the difference between total interest earned is:

Simple interest vs Compound interest on $1000 @ 4% p.a.



Notice how the simple interest generates a straight line and the compound interest generates a curved line. We will develop this table and graph as a technology activity in the interactive textbook for Exercise 13D.

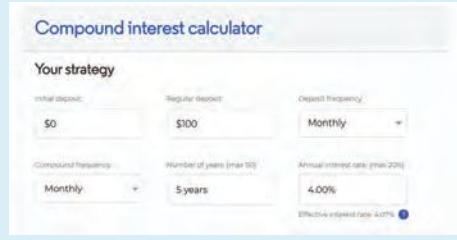
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Example 9 Using an online calculator to find future value and interest for a compound interest investment

Chris has saved $1500 from his part-time job. He deposits it into an account that pays 2.6% p.a., compounding monthly. He continues to deposit $100 into the account every month for the next four years. Use an online calculator to find:

a the future value of Chris's account after four years

b the total interest Chris earned with his account.

WORKING	THINKING
a 	Identify the values to enter in the Moneysmart compound interest calculator.
	Read the total savings from the online calculator.
Chris will have $6717 in his account after four years.	Communicate your answer in a sentence.
b Chris will have earned $417 interest over the four years.	Read the total interest from the online calculator.

Example 10 Using a spreadsheet to find future value and interest for a compound interest investment

Emma has already saved $2500 from her online business selling handbags. She deposits it into an account that pays 2.15% p.a., compounding monthly. She continues to deposit $200 into the account every month for the next two years. Use a spreadsheet to find:

a the future value of Emma's account after two years

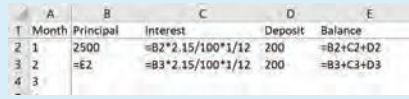
b the total interest Emma earned with her account.

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WORKING	THINKING
a Set up the spreadsheet with the following headings and formulas:	Interest for one month = Pin $= P \times \frac{2.15}{100} \times \frac{1}{12}$



	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
2	1	2500	=B2*2.15/100*1/12	200	=B2+C2+D2
3	2	=E2	=B3*2.15/100*1/12	200	=B3+C3+D3
4	3				

Fill down for 2 years (24 months).

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
22	21	$6,659.95	$ 11.93	200	$6,871.88
23	22	$6,871.88	$ 12.31	200	$7,084.19
24	23	$7,084.19	$ 12.69	200	$7,296.88
25	24	$7,296.88	$ 13.07	200	$7,509.96
26					

The time period, n, needs to be in years to match the interest rate.
Balance = principal + interest + deposit.
Principal next month = balance of last month.
Make sure the deposit stays as 200 for every month.
Tip: freeze the top row so the headings are still visible when you scroll down. See Excel Help.

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
23	22	$6,871.88	$ 12.31	200	$7,084.19
24	23	$7,084.19	$ 12.69	200	$7,296.88
25	24	$7,296.88	$ 13.07	200	$7,509.96
26					
27			=SUM(C2:C25)		
28					

The formula = sum(cell range) will find the total interest and deposits made.

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
23	22	$6,871.88	$ 12.31	200	$7,084.19
24	23	$7,084.19	$ 12.69	200	$7,296.88
25	24	$7,296.88	$ 13.07	200	$7,509.96
26					
27			$ 209.96	$4,800.00	

Read the value in the final Balance cell.

Emma will have $7509.96 after the two years.

Communicate your answer in a sentence.

b Emma will have earned $209.96 interest over the two years.

Read the sum from the interest column.

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Exercise 13D

APPLICATIONS

Use the Moneysmart compound interest calculator to answer the following questions (*https://www.moneysmart.gov.au/tools-and-resources/calculators-and-apps/compound-interest-calculator*).

Example 9

1 Greg saves $250 each fortnight into his superannuation account for 20 years. It earns 6% p.a. interest compounded monthly.



- **a** Select the values that will need to be entered for the:
  - **i** initial deposit
  - **ii** regular deposit
  - **iii** deposit frequency
  - **iv** compound frequency
  - **v** number of years
  - **vi** interest rate.
- **b** Use the Moneysmart compound interest calculator to determine how much he will have in his superannuation account after 20 years.
- **c** Use the Moneysmart compound interest calculator to determine how much he will have earned in interest.

2 Hao wants to retire with a million dollars in his superannuation fund. He is currently 18 and has just finished school. He dreams of retiring when he is 55. His superannuation fund pays 5.6% p.a. compounded yearly and he plans on making a deposit every fortnight into the fund.

- **a** Select the values that will need to be entered for the:
  - **i** initial deposit
  - **ii** deposit frequency
  - **iii** compound frequency
  - **iv** number of years
  - **v** interest rate.
- **b** Use the Moneysmart compound interest calculator to determine how much he will need to deposit each fortnight to reach his millionaire retirement dream.
- **c** Use the Moneysmart compound interest calculator to determine how much he will need to earn in interest.

CF

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3 Shirley is president of her local sports club. The committee have decided that they need to plan for refurbishments of the club house that they think will need to be done in two years' time. They already have $12 000 in the bank; they can save $500 each month and the bank offers them 3.2% p.a. interest compounding monthly.



a Select the values that will need to be entered for the:
- **i** initial deposit
- **ii** regular deposit
- **iii** deposit frequency
- **iv** compound frequency
- **v** number of years
- **vi** interest rate.

b Use the Moneysmart compound interest calculator to determine how much the committee will have in their account after two years.

c Use the Moneysmart compound interest calculator to determine how much they will have earned in interest.

d The committee estimate that they will need to have at least $30 000 for the refurbishments. Use the online calculator to find how long it will take to reach their goal.

e The committee do not think that they can wait more than two years for the refurbishments. Use the Moneysmart compound interest calculator to determine how much they would need to save each month to reach the $30 000 goal in two years.

4 Arika is saving for a deposit on a house. She saves $150 from her pay every fortnight into an account that pays 3.5% p.a. with interest compounding monthly.

a Use the Moneysmart compound interest calculator to calculate how much Arika will have in her house deposit account after five years.

b Use the Moneysmart compound interest calculator to calculate how much Arika will have in her house deposit account after 10 years.

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5 Phill is Arika's friend. After learning about how much Arika had saved in five years, he decides he had better do the same thing to buy his own house. Since he is starting five years later, he doubles his regular payment, to catch up to Arika. He also earns 3.5% p.a. interest that compounds monthly.



a Determine the size of Phill's regular fortnightly deposit.

b Use the Moneysmart compound interest calculator to calculate how much Phill will have in his house deposit account after five years.

c Decide whether Phill will be able to catch up to Arika by doubling the size of his regular deposit. Explain why or why not.

Use a spreadsheet to answer the following questions.

Example 10

6 Allyson is planning an overseas holiday. She has just received her tax return, which was $1256, and she will use this towards her holiday. She budgets to save $210 each month and can earn 3.15% p.a. compound interest that compounds each month.

a Set up a spreadsheet with the following headings:

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
2					
3					
4					

b Decide what will need to be entered in the following cells:

i A2

ii B2

iii C2

iv D2

v E2

vi A3

c Fill down to determine how much she has saved after 12 months.

d Sum the values in the interest column by using =SUM(C2:C13) in any cell to the right of the table. Determine how much interest Allyson earned in the 12 months.

e Allyson believes she will need to save $5000 for her holiday. Continue to fill down your table to determine how many months it will take to reach her goal.

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7 Lirah is saving to buy a car. She already has $3460 saved from her part-time job and can save $500 per month. Her bank account pays 2.8% p.a. interest compounding monthly.

a Set up a spreadsheet with the following headings:

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
2					
3					
4					

b Decide what will need to be entered in the following cells:

i A2 **ii** B2 **iii** C2
iv D2 **v** E2 **vi** A3

c Fill down to determine how much she has saved after 24 months.

d Sum the values in the interest column by using =SUM(C2:C25) in any cell to the right of the table. Determine how much interest Lirah earned in the 24 months.

e Lirah believes she will need to save $20 000 for her car. Continue to fill down your table to determine how many months it will take to reach her goal.

Spread-sheet **Spreadsheet activity 13D:** See the interactive textbook for this activity using a spreadsheet to compare the growth of simple interest and compound interest investments.

Desmos activity 13D: See the interactive textbook for this activity using the Desmos graphing calculator to compare the growth of simple interest and compound interest investments.



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13E Investigating the effects of changing interest rates and compounding periods using technology

COMPLEX

LEARNING GOALS

- Investigate the effect of the interest rate and the number of compounding periods on the future value of an investment using:
  - an online calculator
  - a spreadsheet.

Why is understanding the impact of interest rates and number of compounding periods essential?

- Knowing how to invest our money wisely to earn the maximum possible amount of interest is essential to ensuring a comfortable financial future.
- The interest rate and compounding periods can significantly impact the financial return on an investment or the overall cost of a loan.



The dollar amount of interest paid or earned can be affected by changes to interest rates and frequency of compounds.

WHAT YOU NEED TO KNOW

- Making changes to the interest rate and frequency of compounds will have an impact on the amount of interest earned.
- Compound interest was covered in Section 13B. The formula for compound interest is $A = P(1 + i)^n$.

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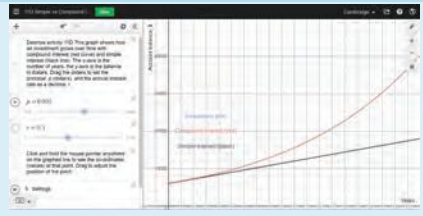
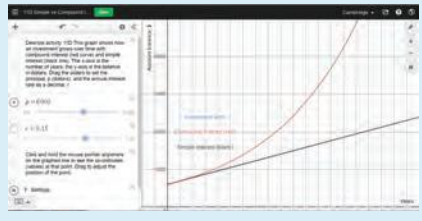
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Example 11 Determining the impact of interest rate changes using an online calculator

a Use Desmos activity 13D from Exercise 13D in the interactive textbook to calculate the value of $6000 after 15 years when it is invested at:
- **i** 10% p.a. compounded yearly
- **ii** 15% p.a. compounding yearly.

b Calculate the difference in the amount of interest earned.

c Describe the changes to the shape of the compound interest curve when the interest rate increased.

WORKING	THINKING
a 	
i After 15 years, investment = $25 063.49.	
	
ii After 15 years, investment = $48 822.37.	
	◄··· Use the sliders for p and r to change to required value. Track along the red line with the mouse, then click and hold to find the value of the investment after 15 years.
b Difference = 48822.37 − 25063.49 = $23758.88	◄··· The amount of interest earned almost doubled over the same time period when the interest rate was increased by half.
c The curve for the compound interest investment (red line) became a lot steeper.	◄··· View the graph to describe the change when the interest increased.

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Example 12 Using an online calculator to determine the impact of frequency of compounding periods

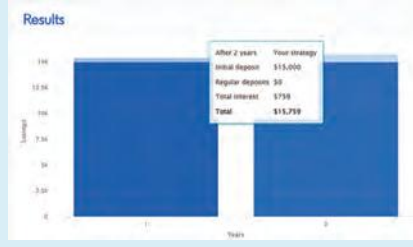
Baxter has $15 000 to invest for two years. The bank offers a 2.5% p.a. interest rate.

a Use the Moneysmart compound interest calculator (*https://www.moneysmart.gov.au/tools-and-resources/calculators-and-apps/compound-interest-calculator*) to calculate the interest earned if interest compounds:
   i annually
   ii monthly.

b Describe the impact of increasing the frequency of the compounds on the amount of interest earned.

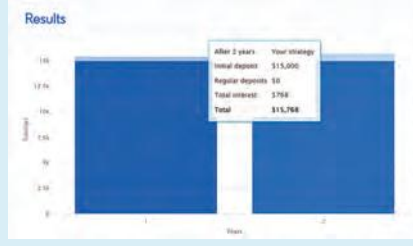
WORKING

a i



Total interest is $759 when compounded annually.

ii



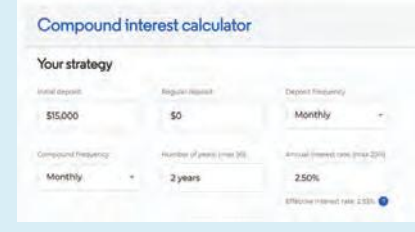
Total interest is $768 when compounded monthly.

b Extra interest was earned (768 − 759 = $9.00) over the same time period with the same interest rate.

THINKING



Change the compound frequency to monthly.



Subtract the total interest from each time period.

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Example 13 Using a spreadsheet to calculate impact of changes to interest on investments

Set up a spreadsheet that will allow you to enter the variables for principal, interest rate, years and compounds per year, and then calculate the final amount when compounding at different time periods. A sample set up is:

	A	B
1	Principal, P	
2	Interest %p.a.	
3	Years	
4	Compounds per year	
5	Amount $A	

a The formula for compound interest is $A = P(1 + i)^n$. Determine which cell has the value for:
- **i** P
- **ii** i.

b i Determine what is in cell B4.
- **ii** Determine how to find the value of n required for the formula $A = P(1 + i)^n$.
- **iii** Explain what will need to happen to the interest rate in the formula $A = P(1 + i)^n$ when compounding at intervals other than a year.

c Use the information above to construct a formula in cell B5 that will calculate the amount, $A, of the investment.

d Use the spreadsheet to calculate the final amount in an account for $5000 deposited at 7% p.a. for four years compounding:
- **i** weekly
- **ii** monthly
- **iii** quarterly.

e Describe the impact of increasing the number of compounding periods over the same time period.

WORKING	THINKING
a i Principal = B1	◄··· Cell referencing uses the column letter followed by the row number.
ii Interest rate = B2	
b i B4 is how many compounds occur per year.	◄··· Number of compounds = number of compounds per year × years. Divide interest rate by number of compounds per year, then by 100 because it is a percentage.
ii n=B4∗B3	
iii i/B4/100	

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c $A = P(1 + i)^n$
P is in cell B1.
i is in cell B2 and needs to be divided by B4 and 100 (i.e. B2/B4/100).

◄··· Number of compounds = number of compounds per year × years.

n will be the product of B4 and B3.
So, the formula for
$A = P(1 + i)^n$ in cell B5 is
= B1 ∗ (1 + B2/B4/100)(B3 ∗ B4).

◄··· The interest rate will need to be divided by the number of compounds per year and then by 100 because it is a percentage. Note that powers are entered in a spreadsheet using ^.

d i

	A	B
1	Principal, P	5000
2	Interest %p.a.	7
3	Years	4
4	Compounds per year	52
5	Amount $A	$ 6,614.40
6		

◄··· There are 52 weeks in a year.

ii

	A	B
1	Principal, P	5000
2	Interest %p.a.	7
3	Years	4
4	Compounds per year	12
5	Amount $A	$ 6,610.27

◄··· There are 12 months in a year.

iii

	A	B
1	Principal, P	5000
2	Interest %p.a.	7
3	Years	4
4	Compounds per year	4
5	Amount $A	$ 6,599.65

◄··· There are 4 quarters in a year.

e The more frequently interest is compounded, the greater the amount of interest earned over the same period.

◄··· The highest final amount was with 52 compounds per year.



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Exercise 13E

FUNDAMENTALS

1 Complete the following conversions.

a 1 year = _____ months.

b 1 year = _____ weeks.

c 1 year = _____ days.

d 1 year = _____ fortnights.

e 1 year = _____ 6 months.

f 1 year = _____ 4 weeks.

g 1 year = _____ quarters.

Use this table to answer questions in the exercise that follow on the next page.

Interest Rates on Term Deposits and Investment Accounts

Interest Rates current as at 28 September 2018 (Interest rates are subject to change at the Bank's discretion)

Term Deposit Interest Payment Options	
4 Weekly or Compound 4 weekly	Interest is paid every 28 days and/or at maturity.
6 Monthly or Compound 6 Monthly	Interest is paid every 6 months and/or at maturity. For terms of 6 months or less, interest is paid at maturity.
Annual or Compound Annually	Interest is paid every 12 months and/or at maturity. For terms of 12 months or less, interest is paid at maturity.

Term Deposit Rates/Headline Rates[#]

	$1,000 – $4,999	$5,000 – $9,999	$10,000 – $49,999			$50,000 – $1,999,999		
Interest Frequencies	Not available to new investments. All Interest Payment Options	All Interest Payment Options	4 Weekly	6 Monthly	Annual	4 Weekly	6 Monthly	Annual
Term in Months*	%pa	%pa	%pa	%pa	%pa	%pa	%pa	%pa
60	1.90	1.90	2.45	2.55	2.65	2.55	2.65	2.75
48-59	1.90	1.90	2.30	2.40	2.50	2.40	2.50	2.60
36-47	1.90	1.90	2.20	2.30	2.40	2.30	2.40	2.50
34-35	1.90	1.90	2.10	2.20	2.30	2.20	2.30	2.40
24-33	1.90	1.90	2.40	2.50	2.60	2.50	2.60	2.70
18-23	1.90	1.90	2.10	2.20	2.30	2.20	2.30	2.40
13-17	1.90	1.90	2.10	2.20	2.30	2.20	2.30	2.40
12	1.90	1.90	2.00	2.10	2.20	2.10	2.20	2.30
11	1.80	1.80	1.80	1.80	1.80	1.90	1.90	1.90
10	1.80	1.80	1.80	1.80	1.80	1.90	1.90	1.90
9	1.80	1.80	1.80	1.80	1.80	1.90	1.90	1.90
8	1.80	1.80	2.50	2.60	2.60	2.50	2.60	2.60
7	1.75	1.75	2.40	2.50	2.50	2.40	2.50	2.50
6	1.75	1.75	2.00	2.05	2.05	2.00	2.05	2.05
5	1.75	1.75	1.75	1.75	1.75	1.85	1.85	1.85
4	1.75	1.75	1.75	1.75	1.75	1.85	1.85	1.85
3	1.75	1.75	1.95	2.00	2.00	1.95	2.00	2.00
2	1.65	1.65	1.65	1.65	1.65	1.75	1.75	1.75
1	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

Source: http://www.commbank.com.au

★2 Harry has $20 000 to invest for two years.

a Determine the number of months in two years.

b Use the table on page 44 to determine the interest rate if interest is compounded:

i annually **ii** 6 monthly **iii** 4 weekly.

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c Determine how many times the interest will compound in a year if it compounds:
i annually **ii** 6 monthly **iii** 4 weekly.

d Use the compound interest formula to calculate the value of the investment after two years if the interest is compounded:
i annually **ii** 6 monthly **iii** 4 weekly.

e Decide which investment option is best for the $20 000 over two years.

APPLICATIONS

Example 11

3 Use the Desmos activity 13D in the interactive textbook to answer the following questions.

a Calculate the value of $8500 after 15 years when it is invested at:
i 5% p.a. compounded yearly
ii 10% p.a. compounding yearly.

b Calculate the difference in the amount of interest earned.

c Comment on the difference in the amount of interest earned between the two rates.

d Describe the changes to the shape of the compound interest curve when the interest rate increased.

4 Use the Desmos activity from Exercise 13D in the interactive textbook to answer the following questions.

a Calculate the value of $10 000 after 20 years when it is invested at:
i 9% p.a. compounded yearly
ii 12% p.a. compounding yearly.

b Calculate the difference in the amount of interest earned.

c Comment on the difference in the amount of interest earned between the two rates.

d Describe the changes to the shape of the compound interest curve when the interest rate increased.

Use the compound interest calculator on the Moneysmart website to answer the following questions.

Example 12

5 Baxter has $8000 to invest for four years. The bank offers a 2.7% p.a. interest rate.

a Use the Moneysmart compound interest calculator to find the interest earned if interest compounds:
i annually **ii** monthly.

b Describe the impact of increasing the frequency of the compounds on the amount of interest earned.

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6 Cherokee has $5000 to invest for three years. The bank is offering two different types of accounts:

i 2.4% p.a. compounding annually

ii 2.2% p.a. compounding monthly.

a Use the Moneysmart compound interest calculator to determine how much she will have in her account if she goes with the first option.

b Use the Moneysmart compound interest calculator to determine how much she will have in her account if she goes with the second option.

c Decide which account option Cherokee should go with.

7 Use a spreadsheet to answer the following question.

	A	B
1	Principal $, P	1000
2	Interest %, i	5
3	Compounds, n	3
4	Amount $ A	

a Set up a spreadsheet that will allow you to enter the variables for principal, interest rate and number of compounds, and calculate the final amount when compounding yearly, as shown above.

b The formula for compound interest is $A = P(1 + i)^n$. Select the cell that has the value for:

Hint Powers are entered using ^

i P **ii** i **iii** n

★**c** Construct the formula that will need to be entered in cell B4 to find the accumulated amount.

d Use the spreadsheet to calculate the amount in an account after $1000 is deposited for three years at:

i 5% p.a. compounding annually **ii** 10% p.a. compounding annually

iii 2% p.a. compounding annually.

e Use the spreadsheet to calculate the amount in an account after $65 000 is deposited for six years at:

i 3.25% p.a. compounding annually **ii** 6.15% p.a. compounding annually

iii 2.01% p.a. compounding annually.

f Describe the impact that changing the interest rate has on the amount of interest earned.

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Example 13

8 Use a spreadsheet to answer the following question.

a Set up a spreadsheet that will allow you to enter the variables for principal, interest rate and compounds per year, and then calculate the final amount when compounding at different time periods. A sample set is shown for $1000 deposited at 6% p.a. for three years compounding monthly:

	A	B
1	Principal, P	1000
2	Interest %p.a. i	6
3	Years	3
4	Compounds per year	12
5	Amount $A	=B1*(1+B2/B4/100)^(B3*B4)

★**b** The formula for compound interest is $A = P(1 + i)^n$. Select the cell that has the value for:

i P **ii** i.

★**c** Use the spreadsheet to answer the following questions.

i Identify what is shown in cell B4.

ii Explain why the power needs to be $(B3 * B4)$ for the formula to work in cell B5.

iii Explain why B2 is divided by B4 and 100 in cell B5.

d Use the spreadsheet to calculate the amount in an account after $1000 is deposited at 6% p.a. for three years compounding:

i weekly **ii** monthly **iii** quarterly.

e Use the spreadsheet to calculate the amount in an account after $65 000 is deposited at 3.25% p.a. for six years compounding:

i weekly **ii** monthly **iii** quarterly.

f Describe the impact of increasing how often interest is compounded on the amount of interest earned.

9 William is treasurer of his local sports club. The club has $120 000 that they want to invest for two years.

★**a** Use the table on page 544 to select the interest rate if interest is compounded:

i 4 weekly **ii** 6 monthly **iii** annually.

b Use the spreadsheet from Question **8** to calculate the amount in an account if interest is compounded:

i 4 weekly **ii** 6 monthly **iii** annually.

c The bank offered different interest rates over different time periods. Describe what impact this may have on any advantage that is usually gained from more frequent compounds.

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Modelling task

Context: Buying your own home is a goal for most young people, but coming up with a deposit for a home loan is a challenge for many.

Task: In this task, you are to design a budget and savings plan to work towards gaining a deposit for your first home. You will need to make assumptions about your income, living expenses and potential regular savings that are achievable. Research some savings account options with various banks and decide on the best account that will provide the greatest gains in compounding interest. Clearly identify and justify the size of the deposit required and outline how this goal will be achieved.



Stage 1: Formulate
Make assumptions regarding: • your income, living expenses, possible savings • interest rate changes. Make observations of: • purchase price of home • size of deposit required • savings account options.
Stage 2: Solve
• Produce graphs/tables required to create a monthly budget and based on this, calculate how much you can afford to save each month. • Show your calculations for your regular savings and the interest earnt from your compounding savings account. • Determine the number of years it would take to save the deposit required for your first home.

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Stage 3: Evaluate and verify

- Check the reasonableness of your answers and consider if these answers account for the increase in housing market prices and inflation/cost of living increases.
- Discuss what the strength and limitations are of your findings.

Stage 4: Communicate

Summarise your findings in a short paragraph:

- Justify whether you believe your answers are accurate and why.
- Discuss whether your assumptions would impact your findings (i.e. what could happen if your income was reduced, or you weren't able to save as much as your budget allowed).
- Include any recommendations to make your calculations more accurate.

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Chapter summary

Simple interest (simple familiar)

- Simple interest is calculated using an interest rate on the same amount of money (principal) each time period.
- The formula for calculating the amount of interest accrued is $I = Pin$ where:
  - I = Interest, the amount of interest in dollars
  - P = Principal, the money borrowed or invested
  - i = interest rate as a decimal per time period $\frac{\%}{100}$
  - n = number of time periods for which interest is calculated in years. For example, if the time period is 9 months, the value must be converted by dividing by 12 to bring it back to years. $\frac{9}{12} = 0.75$ years (leave this value as a fraction if rounding is ever required).
- The formula for simple interest can be rearranged to calculate the value of the principal, the percentage interest or the number of time periods. These formulas are:
  - $P = \frac{I}{in}$
  - $i = \frac{I}{Pn}$
  - $n = \frac{I}{Pi}$.
- Loans using simple interest require the borrowed amount and the interest to be repaid.
  Total to repay = amount borrowed + interest.

Annual compound interest (simple familiar)

- Compound interest is calculated using an interest rate on the previous time period's balance. Therefore, it accrues interest on top of the interest earned each compounding period.
- Compound interest can be calculated using a recurrence relation. In this course, we will show this as successive lines in a table or spreadsheet. For example, an investment with a principal of $16 000 with a 9% compounding annual rate after 2 years is shown below.

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Year	Principal	Interest	Balance
1	\$16 000	$16\,000 \times \frac{9}{100} = \$1440$	$16\,000 + 1440 = \$17\,440$
2	\$17 440	$17\,440 \times \frac{9}{100} = \$1569.60$	$17\,440 + 1569.60 = \$19\,009.60$

- A formula for compounding interest can also be used, $A = P(1 + i)^n$ where:
  - A = the accumulated amount at the end of the investment (this includes the principal and the accrued interest).
  - P = the principal amount that you started with.
  - i = the interest rate as a decimal per a time period; in this case it is annual, so the percentage per annum does not need to be divided by the compounding period.
  - n = the number of compounding periods, in this case the number of years.

Non-annual compound interest (complex)

- The key difference between annual and non-annual compounding periods is with the i and n in the formula calculations. In non-annual compounding interest, the compounding periods are less than one year. They can be daily (365), weekly (52), fortnightly (26), monthly (12) or half-yearly (2).
- As per above with **annual compounding interest**, a recurrence relation can be used by creating a table with successive lines. The main difference is that the compounding periods are shorter than a year, and so more frequent. For example, an investment with a principal of \$16 000 with a 9% compounding monthly rate after two months is shown below:

Month	Principal	Interest	Balance
1	\$16 000	$16\,000 \times \frac{9 \div 12}{100} = \$120$	$16\,000 + 120 = \$16\,120$
2	\$16 120	$16\,120 \times \frac{9 \div 12}{100} = \$120.90$	$16\,120 + 120.90 = \$16\,240.90$

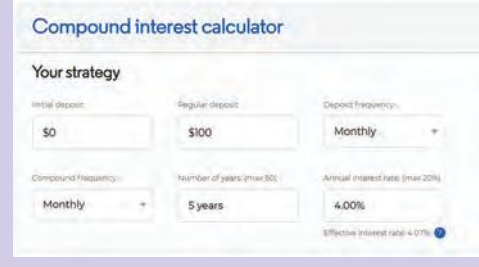
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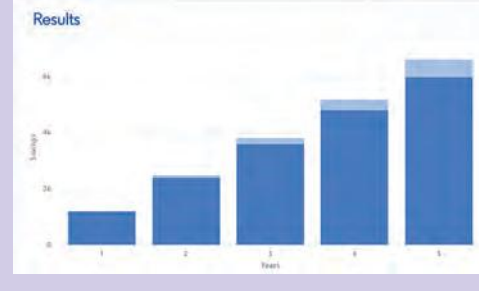
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- The same formula as annual compounding interest can be used; however, the key difference is in the i and n calculations;
  - $A = P(1 + i)^n$ where:
  - A = the accumulated amount at the end of the investment (this includes the Principal and the accrued interest).
  - P = the principal amount that you started with.
  - i = the interest rate as a decimal per a time period; in this case it is a non-annual time period, so the percentage per annum needs to be divided by the compounding period. For example, if it is compounding fortnightly, divide by 26.
  - n = the number of compounding periods, in this case the number of years multiplied by the number of compounding periods. For example, if it is compounding fortnightly over two years, multiply $2 \times 26 = 52$ compounding periods.

Future value of a compound interest investment (complex)

- You can use the Moneysmart to find the future value of an investment . For example, the image below calculates a case where $100 is saved every month for five years at a rate of 4% p.a.







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- A spreadsheet was also used to calculate this information, for example:

	A	B	C	D	E
1	Month	Principal	Interest	Deposit	Balance
2	1	$ -	0	100	$ 100.00
3	2	$ 100.00	0.333333	100	$ 200.33
4	3	$ 200.33	0.667778	100	$ 301.00
5	4	$ 301.00	1.003337	100	$ 402.00

Effects of changing interest rates and compounding periods

- Making changes to the interest rate and frequency of compounding periods will impact the amount of interest earned
- The Moneysmart website and Desmos can be used to determine the effect of the fluctuations in interest rates. The higher the interest rate, the more interest earned on an investment or the greater the charge in interest on a loan.
- Spreadsheets can also be used to demonstrate the change, as it allows for the interest rate or compounding periods to be easily altered.

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Chapter checklist

13A ☐ I can calculate simple interest.

1 $2682 invested at 4.2% p.a. for three years.
- **a** Calculate the total interest earned over three years.
- **b** Determine how much money will be in the account after the three years.

13B ☐ I can calculate annual compound interest.

2 $3540 invested at 2.7% p.a. compounded annually for four years.
- **a** Determine how much money will be in the account after the four years.
- **b** Calculate the total interest earned over four years.

13C ☐ I can calculate non-annual compound interest.

3 Harit invests $15 000 into an account paying 3.9% p.a. compounding interest for seven years, with quarterly compounding periods. Complete the following table to show the balance of Harit's investment after the first year and determine how much interest the investment has earnt in that time.

Quarter	Principal	Interest	Balance
1			
2			
3			
4			

4 Danika invests $7000 in an account that earns interest at the rate of 5.6% p.a. compounding monthly. Use the compound interest formula to calculate how much is in the account after five years.

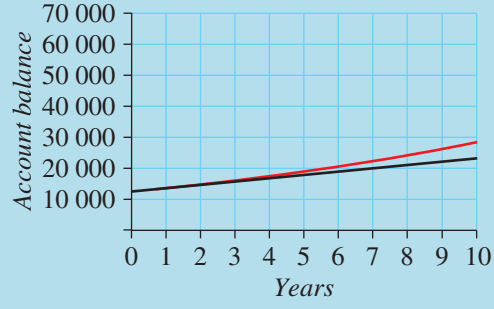
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13D ☐ I can use the Moneysmart compound interest calculator to find the future value of an investment. **[complex]**

5 Anson is saving to buy a car. He already has $8760 saved from his part-time job and can save $400 per month. His bank account pays 2.7% p.a. interest compounding monthly. Use the Moneysmart compound interest calculator to calculate how much he has in his account after two years.

13D ☐ I can compare numerically and graphically the difference between simple and compound interest. **[complex]**

6 Harriet is deciding between two investment options. Option A is a compounding yearly bank account and Option B is a simple interest investment. She has a principal amount of $12 500 to invest. Both options have an interest rate of 8%. Below is a graphical image of both investment options.



a Identify which investment option is shown by the:
i red Line **ii** black line.

b Describe the difference between the shape of the graphs between the for the simple interest and compound interest investments.

c Determine how many years it would take for Harriets investment to reach more than $20 000, if she chose the compounding interest investment?

d Determine how many years it would take for Harriets investment to reach more than $20 000 if she chose the simple interest investment.

e Explain which option Harriet should choose to invest her savings and why.

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13D ☐ I can use a spreadsheet to show growth of a compound interest investment. **[complex]**

7 Cody invests $500 in an account that pays 4% p.a. interest compounded every year. A spreadsheet is used to calculate the interest and balance each year.

	A	B	C	D
1	Year	Principal	Interest	Balance
2	1			
3	2			
4	3			
5	4			
6	5			

a Identify the value that will be entered in cell B2.
b Decide which formula you will need to enter in cell C2.
c Determine the formula you will need to enter in cell D2.
d Determine the formula will you need to enter in cell B3.

13E ☐ I can identify the effect of interest rate changes on investments. **[complex]**

8 $7500 is deposited in an account for five years.
a Calculate the amount in the account after the five years if the interest rate is:
i 3.75% p.a. compounding annually
ii 5.15% p.a. compounding annually.
b Describe the effect of the interest rate change.

13E ☐ I can identify the effect of the number of compounding periods on an investment. **[complex]**

9 $7500 is deposited in an account for five years at 5% p.a. compounding interest.
a Calculate the amount in the account after five years if the interest is compounding:
i annually **ii** fortnightly.
b Describe the effect of the change in compounding frequency.

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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

13A **1** Riley invested $60 000 in a fixed term account for three years paying a simple interest rate of 2.65% p.a.

a Calculate the total amount of interest earned over the three years.

b Calculate the total value of the investment after three years.

2 A company invested $5 000 000 in the short-term money market at 6.7% p.a. simple interest for 90 days.

a Calculate the total amount of interest earned over the 90 days.

b Calculate the total value of the investment after 90 days.

3 Kareela borrowed money from her mother 10 years ago. She was charged a 5% p.a. simple interest rate and she ended up paying $6000 in interest. Calculate the principal amount that Kareela initially borrowed from her mother.

13B **4** Electra invests $1400 into an account that pays 3.8% p.a. compound interest for three years. Interest is compounded yearly.

a Copy and complete the following table to calculate her interest and balance at the end of each year.

Year	Principal	Interest	Balance
1	$1400		
2			
3			

b Determine how much interest she earned in three years.

5 Smithy has saved $5200 from his part-time job. He invests it for two years at 3.20% p.a. so he can buy a car when he turns 18. Interest is compounded yearly.

a Use the compound interest formula to calculate the balance of his account after two years.

b Calculate how much interest he earned over the two years.

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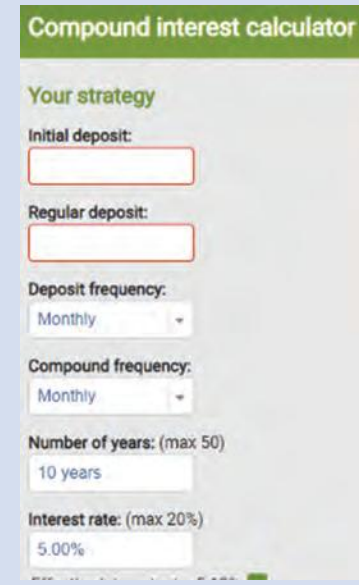
Complex Familiar

13C **6** Shae-Leah invests $2000 in an account that earns interest at the rate of 4.6% p.a. compounding monthly. Use the compound interest formula to determine how much is in her account after four years.

7 Maisie invests $20 000 into an account paying 3.8% p.a. compounding interest for five years, with monthly compounding periods. Complete the following table to show the balance of Maisie's investment after the first three months and determine how much interest her investment has earnt in that time.

Month	Principal	Interest	Balance
1			
2			
3			

13D **8** Tom is saving for a deposit on a house. He saves $450 from his pay every fortnight into an account that pays 3.6% p.a. with interest compounding monthly. He uses the Moneysmart compound interest calculator to determine how much he will have saved after five years.



a Decide what he will need to enter on the online calculator at:
- **i** initial deposit
- **ii** regular deposit
- **iii** deposit frequency
- **iv** compound frequency
- **v** number of years
- **vi** interest rate.

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b The calculator returns the following values:



i Determine how much he will have in his account after five years.

ii Identify how much interest he has earned.

13E 9 $3500 is deposited for three years in an account.

a Calculate the amount in the account after three years at:

i 4.75% p.a. compounding annually

ii 5.25% p.a. compounding annually.

b Describe the effect of the interest rate change.

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10 $3500 is deposited for five years in an account at 4.5% p.a. compounding interest.

- **a** Calculate the amount in the account after five years if the interest compounds:
  - **i** every 6 months
  - **ii** weekly.
- **b** Describe the effect of the change in compounding frequency.

13D **11** The following table shows the interest and balance earned on a $5000 investment earning 5% p.a. for five years when interest is calculated using simple interest versus compound interest.

	Simple interest			Compound interest		
Year	**Principal**	**Interest**	**Balance**	**Principal**	**Interest**	**Balance**
1	$5000.00	$250.00	$5250.00	$5000.00	$250.00	$5250.00
2	$5000.00	$250.00	$5500.00	$5250.00	$262.50	$5512.50
3	$5000.00	$250.00	$5750.00	$5512.50	$275.63	$5788.13
4	$5000.00	$250.00	$6000.00	$5788.13	$289.41	$6077.53
5	$5000.00	$250.00	$6250.00	$6077.53	$303.88	$6381.41

- **a** Calculate the total interest earned in the:
  - **i** simple interest account
  - **ii** compound interest account.
- **b** Explain why the balance is the same at the end of the first year.
- **c** Explain the key difference in how simple interest and compound interest is calculated.

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Complex Unfamiliar

13D **12** Amy is planning an overseas holiday. She has just inherited $3400, which she will use towards her holiday. She budgets to save $360 each month and can earn 4.25% p.a. compound interest that compounds each month. She sets up a spreadsheet as follows.

	A	B	C	D
1	Year	Principal	Interest	Balance
2	1			
3	2			
4	3			
5	4			
6	5			

Determine what needs to be entered in the following cells.

a A2 **b** B2

c C2 **d** D2

e E2 **f** B3

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14 Reducing balance loans



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In this chapter

14A Understanding and modelling reducing balance loans

14B Modelling reducing balance loans using spreadsheets **[complex]**

14C Investigating the effect of the repayment amount, changing interest rates and compounding periods using a calculator **[complex]**

14D Investigating the effect of the repayment amount, changing interest rates and compounding periods using spreadsheets **[complex]**

Modelling

Chapter summary

Chapter checklist

Chapter review

Syllabus reference

Unit 4 Topic 3 Loans and compound interest

Reducing balance loans (8 hours)

In this sub-topic, students will:

- understand that reducing balance loans are compound interest loans with periodic repayments
- use a calculator or an online calculator to model a reducing balance loan with annual repayments
- use a spreadsheet to model a reducing balance loan with non-annual repayments **[complex]**
- investigate the effect of the repayment amount, the interest rate and the number of compounding periods on the time taken to repay a loan **[complex]**.

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Prior knowledge check

1 Calculate the simple interest on the following investments.

Hint 'p.a.' means per annum, i.e. per year.

- **a** $450 at 6% p.a. for one month
- **b** $980 at 5% p.a. for one week
- **c** $387 at 4% p.a. for one fortnight
- **d** $1345 at 5% p.a. for one quarter
- **e** $350 at 6% p.a. for 6 months

2 $4000 is borrowed at 6% p.a. simple interest for 2 years.

- **a** Calculate the interest for the two years.
- **b** Calculate the total amount repaid over the two years.
- **c** Calculate the size of the monthly repayment.

3 Convert the following time periods to years and months.

- **a** 48 months
- **b** 260 weeks
- **c** 78 fortnights
- **d** 42 months
- **e** 338 weeks
- **f** 91 fortnights
- **g** 200 months
- **h** 200 weeks
- **i** 200 fortnights



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14A Understanding and modelling reducing balance loans

LEARNING GOALS

- Understand that reducing balance loans are compound interest loans with periodic repayments.
- Model a reducing balance loan with annual repayments by using technology (online calculator).
- Calculate the future value of a compound interest loan and the total interest paid by using technology (online calculator).
- Compare the growth of simple interest and compound interest loans by using technology (online calculator).

Why is understanding and modelling reducing balance loans essential?

- Reducing balance loans are used when borrowing money for something like a house or a car.
- The interest is normally calculated on the remaining balance.
- Understanding how a loan works can help an individual to save money.



A home loan is the biggest expense you will ever have, so it is wise to look for ways to make savings.

WHAT YOU NEED TO KNOW

- Reducing balance loans have the interest calculated on the *remaining balance* each interest period. This is because a repayment amount is made to pay off the loan and the new interest is charged on the remaining principal.
- Interest periods can be calculated daily, weekly, fortnightly, monthly, quarterly, half-yearly or yearly. Only the annual repayment periods are calculated in Exercise 14A.
- The simple interest formula $I = Pin$ is used to calculate the amount of interest charged after each repayment. In Exercise 14A, $n = 1$.

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- The remaining balance at the end of each interest period is found by adding the principal and interest and subtracting the repayment.
  - *Principal + interest − repayment = balance.*
  - The balance from the previous year becomes the principal for the next year.
- Online calculators such as the one found on the Moneysmart website allow you to calculate the repayment amount and even produce a graph that shows you how much interest is charged over the time of the loan.

Example 1 Calculating a reducing balance loan with annual repayment

Tait has borrowed $235 000 from his parents to buy a unit. The terms of his loan are 6.55% p.a. reducible interest over 20 years, and his yearly repayments are $25 073 p.a.

a Complete this table to determine how much Tait will owe on his loan after the first three years.

Year	Principal	Interest	Repayment	Balance
1				
2				
3				

b Determine the total of Tait's yearly repayments over the first three years.

c Calculate the total of the interest charges over the first three years.

d Calculate the difference between the amount repaid and the interest charges over the first three years.

e Determine how much Tait reduced his debt by in the first three years.

WORKING | **THINKING**

a Year 1

Principal = 235 000

$$\text{Interest} = 235\,000 \times \frac{6.55}{100} \times 1$$

$$= 15\,392.50$$

Repayment = $25 073

◄··· Interest is calculated using the simple interest formula $I = Pin$.
Put the percentage interest rate over 100 to convert to a decimal.
$n = 1$ year

Balance = 235 000 + 15 392.50 − 25 073

= $225 319.50

◄··· Balance = starting principal
+interest
−repayment made

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Year 2
Principal = \$225 319.50

◄··· Previous year's balance becomes this year's principal.

$$\text{Interest} = \$225\,319.50 \times \frac{6.55}{100} \times 1$$
$$= 14\,758.43$$
Repayment = \$25 073
Balance = \$225 319.50 + 14 758.43 − 25 073
= \$215 004.93

◄··· Interest formula $I = Pin$

Year 3
Principal = \$215 004.93

◄··· Previous year's balance becomes this year's principal.

$$\text{Interest} = \$215\,004.93 \times \frac{6.55}{100} \times 1$$
$$= 14\,082.82$$
Repayment = \$25 073
Balance = \$215 004.93 + 14 082.82 − 25 073
= \$204 014.75

◄··· Interest formula $I = Pin$

Complete the values in the table.

Year	Principal	Interest	Repay	Balance
1	\$235 000.00	\$15 392.50	\$25 073	\$225 319.50
2	\$225 319.50	\$14 758.43	\$25 073	\$215 004.73
3	\$215 004.93	\$14 082.82	\$25 073	\$204 014.75

b Total repayments = 25 073 × 3
= \$75 219

◄··· Three equal repayments were made.

c Total interest
= 15 392.50 + 14 758.43 + 14 082.82
= \$44 233.75

◄··· The interest is reducing each year.

... Continued

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d Difference = 75 219 − 44 233.75
= $30 985.25

◄··· Difference = total repaid − total interest

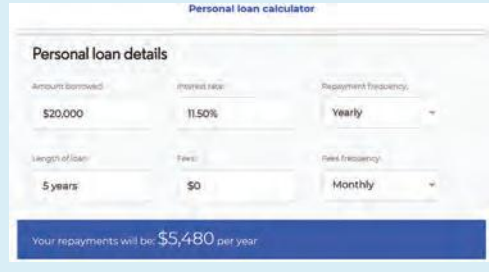
e Difference = 235 000 − 204 014.75
= $30 985.25

◄··· Difference = original loan − debt remaining

Example 2 Using an online calculator for a compound interest loan with annual repayments

Alexander has borrowed $20 000 over 5 years at 11.5% p.a. with reducible (compound) interest to buy a car. Use the Moneysmart personal loan calculator to determine:

a the yearly repayment required
b the total repaid
c the total interest.

WORKING	THINKING
a  The yearly repayment will be $5480.	◄····· *https://www.moneysmart.gov.au/tools-and-resources/calculators-and-apps/personal-loan-calculator#!how-much-will-my-repayments-be* Enter values into an online calculator.
b Total repaid = $5480 × 5 = $27 400 	◄····· This is different to the value on the graph ($27 398) because the yearly repayment has been rounded to the nearest dollar.

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c Total interest = 27 400 − 20 000
= $7400

◄····· Total interest = total repaid − amount borrowed
You can also hover over the light blue section of the graph to find the interest.

Exercise 14A

FUNDAMENTALS

APPLICATIONS

SF

★**1** Lana has borrowed $27 000 to purchase a new car. She has agreed to pay off the loan in 8 years with reducible interest calculated at 12.2% p.a. Her yearly repayments are $5473 p.a. Lana is given a table for her loan schedule as follows.

Year	Principal	Interest	Repayment	Balance
1	$27 000	$3294	$5473	$24 821
2	$24 821	$3028.16	$5473	$22 376.16
3	$22 376.16	$2729.89	$5473	$19 633.05
4	$19 633.05	$2395.23	$5473	$16 555.28
5	$16 555.28	$2019.74	$5473	$13 102.02
6	$13 102.02	$1598.45	$5473	$9227.47
7	$9227.47	$1125.75	$5473	$4880.22
8	$4880.22	$595.39	$5473	$2.61

a Decide if Lana will completely pay off the loan in 8 years. Why will this happen?

Hint Consider the final balance.

b Explain how much Lana should pay in the last year to completely pay off the loan.

c Determine how much Lana will still owe on her loan after 4 years.

d Describe what happens to the interest each year.

e Calculate the total interest Lana pays on the loan.

f Calculate the loan using simple interest at 12.2% of $27 000 per year. Explain why this is different to your answer in **e**.

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SF

Example 1 ★2 Lochy has borrowed $14 700 to buy a car. The terms of his loan are 11.45% p.a. reducible interest over five years, and his repayments are $4023 per year.

a Copy and complete this table to find how much Lochy will owe on his loan after the first three years.

Year	Principal	Interest	Repay	Balance
1	14 700	$147\,00 \times \frac{11.45}{100} \times 1 = 1683.15$	$4023	$\$14\,700 + \$1683.15 - \$4023 = \$12\,360.15$
2	$12 360.15			
3				

b Calculate the total of Lochy's repayments over the first three years.

c Calculate the total of the interest charges over the first three years.

d Determine the difference between the amount repaid and the interest charges over the first three years.

e Determine how much Lochy will reduce his debt by in the first three years.

★3 Stephanie has borrowed $16 500 to fund a trip overseas. The terms of her loan are 12.10% p.a. reducible interest over three years, and her yearly repayments are $6882 per year.

a Copy and complete this table to determine the cost of Stephanie's loan.

Year	Principal	Interest	Repay	Balance
1				
2				
3				

b Determine how much interest Stephanie will pay in the first year.

c Calculate how much Stephanie will reduce her debt by in the first year.

d Determine Stephanie's accurate final repayment at the end of the third year. Explain why it is less.

★4 Gus has borrowed $28 000 to start up a business. He has agreed to repay the loan in four years with 4.35% p.a. reducible interest. He will repay the loan with payments of $7777 p.a.

a Construct a loan schedule for Gus with the headings: Principal, Interest, Repayment, Balance.

b **i** Determine how much will be left owing after four years.

ii Explain why this will happen.

iii Describe how can Gus fix this issue.

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c Calculate the total interest if this had been a simple interest loan.

d Calculate how much interest Gus will pay on his reducible interest loan.

Hint The simple interest formula is $I = Pin$.

SF

Use the calculators on the Moneysmart website (*https://www.moneysmart.gov.au/tools-and-resources/calculators-and-apps/loan-credit-and-debt-calculators*) to answer the following questions:

Example 2

5 Lakeisha has borrowed $18 000 to buy a car. Interest is calculated at 9.85% p.a. on the reducing balance (compound interest), and she will repay the loan over four years. Use the Moneysmart personal loan calculator to determine:

a the yearly repayment required

b the total repaid

c the total interest.

6 Tilly has borrowed $12 000 to pay for an overseas holiday. Interest is calculated at 10.85% p.a. on the reducing balance (compound interest), and she will repay the loan over three years. Use the Moneysmart personal loan calculator to determine:

a the yearly repayment required

b the total repaid

c the total interest.



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SF

7 Charles has borrowed $250 000 from his grandparents to buy a home. Interest is calculated at 5.85% p.a. with yearly repayments on the reducing balance (compound interest), and he will repay the loan over 15 years.

a Use the Moneysmart Mortgage Calculator to determine:

- **i** the yearly repayment required
- **ii** the total repaid
- **iii** the total interest.

b Charles thinks he could afford to repay $28 000 each year.

- **i** Use the 'How can I repay my loan sooner?' tab to determine how long it would now take Charles to repay the loan.
- **ii** Determine how much Charles will now repay in total.
- **iii** Determine how much Charles will now pay in interest.
- **iv** Calculate the saving in interest by paying more each year.
- **v** Determine how much extra Charles will repay each year.
- **vi** Explain what recommendations you would make about paying extra in repayments.



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14B Modelling reducing balance loans using spreadsheets

COMPLEX

LEARNING GOALS

- Model a reducing balance loan by using technology (spreadsheet).
- Calculate the future value of a compound interest loan and the total interest paid by using a spreadsheet.
- Compare the growth of simple interest and compound interest loans by using a spreadsheet.

Why is it essential to use technology for reducing balance loans?

- Most home loans from a bank have non-annual repayments. For example: weekly, fortnightly or monthly.
- Using a spreadsheet allows for quicker calculation, especially when using non-annual repayments.



Using computer spreadsheets to do reducing balance loan calculations saves time.

WHAT YOU NEED TO KNOW

- We can use a spreadsheet to perform the table calculations we did in the last section; however, in this spreadsheet, the repayments are monthly.
  - For example, if $200 000 was borrowed at 5.6% p.a. reducible interest over 25 years, a suitable set up for the debt remaining would be:

	A	B	C	D	E
1	Month	Principal	Interest	Repayment	Balance
2	1	200000	=B2*5.6/100*1/12	1241	=B2+C2-D2
3	2	=E2	=B3*5.6/100*1/12	1241	=B3+C3-D3
4	3	=E3	=B4*5.6/100*1/12	1241	=B4+C4-D4

  For a 25-year home loan, we would need to fill down $(25 \times 12) = 300$ rows to fully pay off the loan.
- Excel can calculate the size of a loan repayment using the formula: =PMT(rate, nper, pv, [fv], [type])

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where:

rate	The interest rate for the loan as a fraction or decimal
nper	The total number of payments to pay off the loan
pv	The present value of the principal; the amount of money borrowed
fv	The future value of the loan. As we will pay off our loans, this will be 0.
type	0 means the payment is made at the end of the period, 1 means the payment is made at the beginning of the period. It is usual to pay at the end of the time period, so we will enter 0 for type.

Example 3 Using a spreadsheet for a compound interest loan

Spread-sheet

Note: the spreadsheet in this example can be accessed in the Interactive Textbook by clicking on the icon at left.

Georgina has borrowed $335 000 over 20 years at 6.2% p.a. with reducible (compound) interest to buy a house. Use a spreadsheet to determine:

a the monthly repayment required
b the total repaid
c the total interest.

WORKING

a

	A	B
1	Principal	335000
2	Rate	6.2
3	Years	20
4	Repayments/year	12
5		
6	Number of Payments	=B4*B3
7		
8	Repayment	=(PMT((B2/(100*B4)),B6,-B1,0,0))
9	Total Repaid	=B8*B6
10	Total Interest	=B9-B1

	A	B
1	Principal	335000
2	Rate	6.2
3	Years	20
4	Repayments/year	12
5		
6	Number of Payments	240
7		
8	Repayment	$2,438.86

The monthly repayment is $2439.

THINKING

The Excel formula needs to know the rate, number of payments and principal.
= **PMT(rate, nper, pv,[fv],[type])**

The rate will need to be divided by number of payments per year and 100 to make it a decimal.

Number of payments = payments per year × number of years
As a formula this is = **B4*B3**

The principal is entered as a negative value in the formula since it is a debt.
For [fv] and [type] we need to enter 0.
Set up spreadsheet as shown.
Round answer to nearest dollar amount.

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b For the total amount repaid:

	A	B
1	Principal	335000
2	Rate	6.2
3	Years	20
4	Repayments/year	12
5		
6	Number of Payments	=B4*B3
7		
8	Repayment	=(PMT((B2/(100*B4)),B6,-B1,0,0))
9	Total Repaid	=B8*B6
10	Total Interest	=B9-B1

Total repaid = repayment × number of payments
As a formula this is = **B8*B6**

Total repaid = $585 325.58

c For the total interest:

	A	B
1	Principal	335000
2	Rate	6.2
3	Years	20
4	Repayments/yea	12
5		
6	Number of Paym	240
7		
8	Repayment	$2,438.86
9	Total Repaid	$585,325.58
10	Total Interest	$250,325.58

Total interest = total repaid − amount borrowed
As a formula this is = **B9 − B1**

Total interest = $250 325.58

Example 4 Using a spreadsheet to model a reducing balance loan

Spread-sheet

Note: the spreadsheet in this example can be accessed in the Interactive Textbook by clicking on the icon at left.

Josh has borrowed $25 000 to buy a car. He will repay the loan with monthly repayments over four years with 13.9% p.a. reducible interest.

a Use a spreadsheet to calculate the size of the monthly repayment to the nearest dollar.
b Set up a spreadsheet to model the loan schedule over four years.
c Determine the amount left owing after 48 months.
d Calculate the size of the last repayment to fix the overpayment.
e Determine how many months it takes to pay off half the loan.

... Continued

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WORKING	THINKING
a Monthly repayment = $682	◄··· Use the spreadsheet from Example 4.

	A	B
1	**Principal**	25000
2	**Rate**	13.9
3	**Years**	4
4	**Repayments/year**	12
5		
6	**Number of Payments**	48
7		
8	**Repayment**	$681.91

	A	B
1	**Principal**	25000
2	**Rate**	13.9
3	**Years**	4
4	**Repayments/year**	12
5		
6	**Number of Payments**	=B4*B3
7		
8	**Repayment**	=(PMT((B2/(100*B4)),B6,-B1,0,0))

b

◄··· All formulas need to start with =. Use the same method as used in Exercise 12A to calculate values in cells.
Fill down for 48 months.

	A	B	C	D	E
1	Month	Principal	Interest	Repayment	Balance
2	1	25000	=B2*13.9/100*1/12	682	=B2+C2-D2
3	2	=E2	=B3*13.9/100*1/12	682	=B3+C3-D3
4	3	=E3	=B4*13.9/100*1/12	682	=B4+C4-D4

c −$5.83 is left owing after 48 months.
The loan has been overpaid by $5.83.

◄··· Scroll to the bottom to find answer.

	A	B	C	D	E
1	Month	Principal	Interest	Repayment	Balance
47	46	$ 1,993.87	$ 23.10	$ 682.00	$ 1,334.96
48	47	$ 1,334.96	$ 15.46	$ 682.00	$ 668.43
49	48	$ 668.43	$ 7.74	$ 682.00	-$ 5.83

Tip: freeze the top row so that the headings stay visible when scrolling.

d Final payment = 682 − 5.83
= $676.17

◄··· Reduce final payment to finish with a $0 balance.

	A	B	C	D	E
1	Month	Principal	Interest	Repayment	Balance
47	46	$ 1,993.87	$ 23.10	$ 682.00	$ 1,334.96
48	47	$ 1,334.96	$ 15.46	$ 682.00	$ 668.43
49	48	$ 668.43	$ 7.74	$ 676.17	-$ 0.00

e Half the loan = 25 000 ÷ 2
= $12 500
It takes 28 months to repay half the loan.

◄··· Scroll until you first find a balance that is less than $12 500.

	A	B	C	D	E	F
1	Month	Principal	Interest	Repayment	Balance	
27	26	$13,696.73	$ 158.65	$ 682.00	$13,173.38	
28	27	$13,173.38	$ 152.59	$ 682.00	$12,643.98	
29	28	$12,643.98	$ 146.46	$ 682.00	$12,108.44	
30	29	$12,108.44	$ 140.26	$ 682.00	$11,566.69	
31	30	$11,566.69	$ 133.98	$ 682.00	$11,018.67	

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Exercise 14B

FUNDAMENTALS

APPLICATIONS

Spreadsheet Example 3 applies to Question 1.

Spread-sheet

Example 3

1 Ayla has borrowed $17 000 to buy a car. She will repay the loan with monthly repayments over 3 years with 6.9% p.a. reducible interest.

- **a** Use a spreadsheet to calculate the size of each repayment to the nearest dollar.
- **b** Calculate the total loan repayments.
- **c** Calculate the total interest charges.

Spreadsheet Example 4 applies to Questions 2–7

Spread-sheet

Example 4

2 Use the information in Question 1 to complete the following.

- **a** Set up the spreadsheet to model the loan schedule over three years.
- **b** Determine how much is left owing after 36 months.
- **c** Calculate the size of the last repayment to fix the underpayment.
- **d** Determine how many months it will take to pay off half the loan.

3 Clayton has borrowed $6000 to fund an overseas holiday. He will repay the loan with fortnightly repayments over two years with 9.73% p.a. reducible interest.

Hint There are 26 fortnights in a year.

- **a** Use a spreadsheet to calculate the size of the repayment to the nearest dollar.
- **b** Determine the total number of payments.
- **c** Calculate the total loan repayments.
- **d** Calculate the total interest charges.

4 Use the information in Question 3 to complete the following.



- **a** Set up a spreadsheet to model the loan schedule over two years.
- **b** Calculate the interest for the first fortnight.
- **c** Determine how much is left owing after two years.
- **d** Calculate the size of the last repayment to fix the underpayment.
- **e** Determine how many fortnights it will take to pay off half the loan.

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Note: a spreadsheet for Questions 5–7 can be accessed in the interactive textbook by clicking on the icon at left.

5 Lexi has borrowed $20 000 to buy a car. Simple interest is charged at 11.5% p.a., and she will repay the loan over five years in equal monthly repayments.

★**a** Calculate:

- **i** the total interest
- **ii** the total to repay
- **iii** the number of repayments
- **iv** how much she will need to repay each month.

★**b** Use a spreadsheet to show the amount still owing over the life of the loan. Use the following headings and formulas and fill down for 60 months.

	A	B	C	D
1			Simple Interest	
2	Month	Simple Interest	Repayment	SI Balance
3	0			20000
4	1	=20000*11.5/100*1/12	525	=D3+B4-C4
5	2	=20000*11.5/100*1/12	525	=D4+B5-C5

★**i** Explain the formula used in cell B4.

★**ii** Explain the formula in cell D4.

★**iii** Explain why the formula in B5 the same as B4.

Hint Adding month 0 (start of the loan) will assist later when we want to graph the loans schedules.

c In cell B65 enter the formula =SUM(B4:B63). Decide if the answer matches your answer from part **a i**.

d In cell C65 enter the formula =SUM(C4:C63). Decide if the answer matches your answer from part **a ii**.

e Describe the values in the Simple Interest column (column B).

6 Daniel is a friend of Lexi. He also has borrowed $20 000 to buy a car. Reducing balance (compound) interest is charged at 11.5% p.a., and he also decides he will repay the loan over five years in equal monthly repayments.

a Use a spreadsheet to calculate:

- **i** the monthly repayment to the nearest dollar
- **ii** the total to repay
- **iii** the total interest.

★**b** Use the same spreadsheet as in Question **6**, and add the following headings and formulas and fill down for 60 months.

	E	F	G	H
1		Compound Interest		
2	Principal	Compound Interest	Repayment	CI Balance
3				20000
4	20000	=E4*11.5/100*1/12	440	=E4+F4-G4
5	=H4	=E5*11.5/100*1/12	440	=E5+F5-G5

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CP

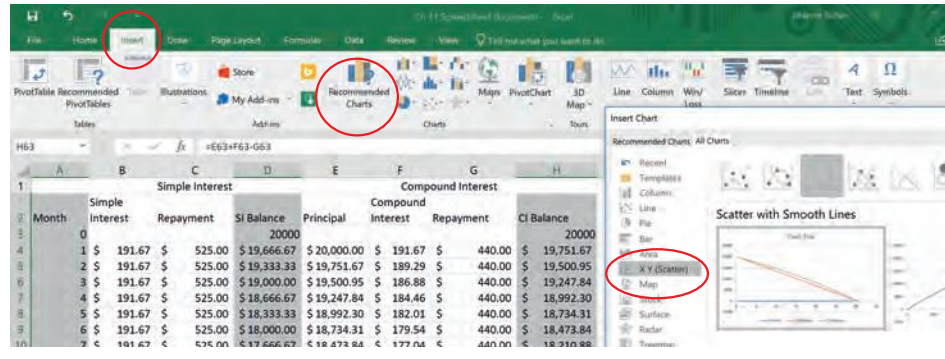
i Explain the formula used in cell F4.
ii Explain the formula in cell H4.
iii Explain the formula in cell E5.

c Describe what is happening to the values in the Compound Interest column (column F).

d In cell F65 enter the formula =SUM(F4:F63).
i Decide if the answer matches your answer from part **a iii**.
ii Calculate the difference in the interest paid in the compound interest loan to the interest paid in the simple interest loan in Question **6**.

e In cell G65 enter the formula =SUM(G4:G63).
i Decide if the answer matches your answer from part **a ii**.
ii Calculate the difference in the total paid in the compound interest loan to the total paid in the simple interest loan in Question **6**.

7 **a** Produce a graph to compare the balance owing on the loans from Questions **5** and **6** over the five years. Hold down the Ctrl key and highlight the month, SI Balance and CI Balance columns. From the Insert Tab>Recommended Charts>All Charts>XY Scatter>Scatter with Smooth Lines as below.



b Add axis labels and a title to your graph.

c Comment on the difference between the graphs of the two loans.

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14C Investigating the effect of the repayment amount, changing interest rates and compounding periods using a calculator

COMPLEX

LEARNING GOALS

- Investigate the effect of the interest rate and the number of compounding periods on the future value of a loan using technology (online calculator).
- Investigate the effect of the interest rate and repayment amount on the time taken to repay a loan using technology (online calculator).

Why is understanding interest rate changes and compounding periods essential?

- Interest rates can significantly impact the repayment amount and the overall cost of a loan.
- Loans can have fixed or variable interest rates. Variable interest rates can change monthly, and this impacts the repayment amount and overall cost of the loan.
- Compounding periods can vary for each loan. They can be daily, weekly, fortnightly, monthly, quarterly or yearly. This impacts the repayment amount and the overall cost of the loan.



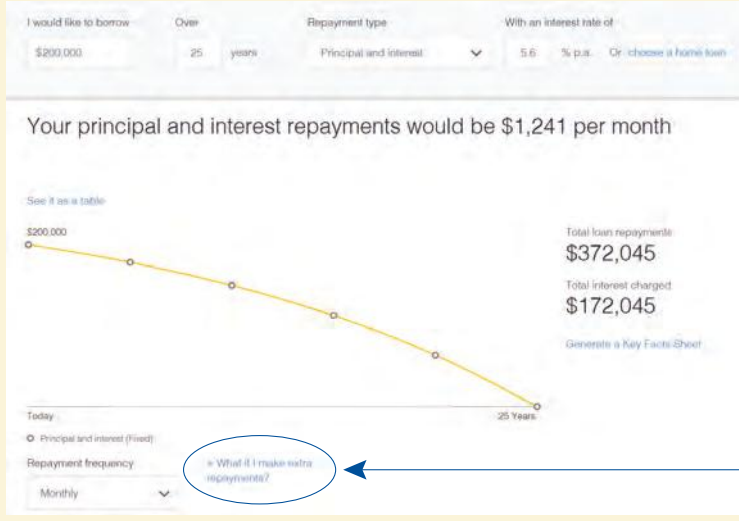
The dollar amount of interest paid or earned can be affected by changes to rates and frequency of compounds.

WHAT YOU NEED TO KNOW

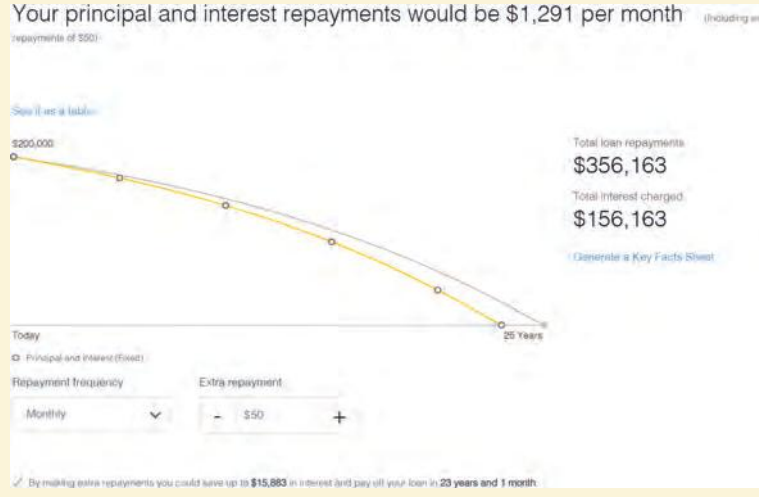
- Changes to the size of repayments, frequency of repayments and interest rate changes all have an impact on the time taken to repay a loan and the amount of interest that will be paid. We will use the Commonwealth Bank home loan calculator and the Moneysmart Mortgage Calculator to further explore these effects:

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- For example, a $200 000 loan over 25 years at 5.6% p.a. reducible interest generated the following results for monthly repayments on the Commonwealth Bank online calculator.



  - If we pay an extra $50 per month, we would pay off the loan faster and make savings on the amount of interest we need to pay.



- A common method used to save time and money on a home loan is to pay half the monthly repayment each fortnight. The Moneysmart Mortgage Calculator has a tab 'How can I repay my home loan sooner?' for this calculation.
- For example, if half of the $1241 monthly repayment is paid each fortnight (Repayment = $1241 \div 2 \approx \$621$), we can see that the loan has been paid off in 21 years and 2 months at a total cost of $341 478, or $30 567 less than our original loan cost!

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- Interest rates go up and down all the time. Rate changes can make a big difference to the size of the loan repayments. The Moneysmart calculator also covers this, so you can plan for worst case scenarios.

Example 5 Using an online calculator to investigate the effect of the interest rate, payment frequency and repayment amount

Clayton borrows $200 000 to buy a small unit. Bank interest rates are 5.95% p.a. reducible interest, and he wants to pay his loan off in 25 years.

a Use the Commonwealth Bank home loan calculator, *https://www.commbank.com.au/digital/home-buying/calculator/home-loan-repayments?ei=calculator-inter-calc-tab-home-loan-repayments*, to determine:

i the monthly repayment

ii the interest charges if the loan is paid monthly.

b Clayton has heard that he can save money by paying fortnightly. Determine:

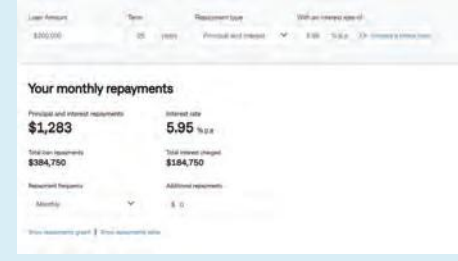
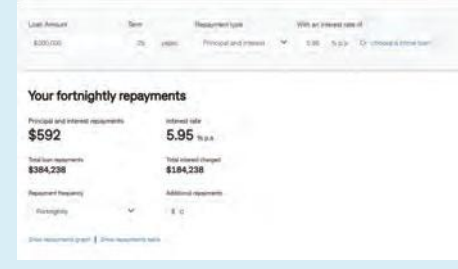
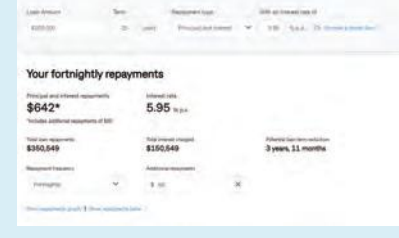
i the fortnightly repayment

ii the savings over 25 years.

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c Clayton decides to pay an extra $50 each fortnight. Calculate the amount he would save in interest costs and determine the time he would save on his loan.

d Clayton is worried about what might happen if interest rates go up. Use the online calculator to determine how much more Clayton would need to pay each fortnight if rates go up 1% p.a.

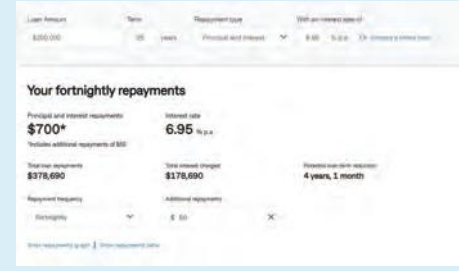
WORKING	THINKING
a i Monthly repayment = $1283	◄··· Input values into the online calculator and read off the answers.
	
ii Total interest charges = $184 750	
b i Fortnightly repayment = $592 Total interest = $184 238	◄··· Change the repayment frequency to fortnightly.
	
ii Savings = 184 750 − 184 238 = $515 Note: still takes 25 years to repay the loan.	
c By paying an extra $50 per fortnight: **i** Interest = $150 549 Savings = 184 750 − 150 549 = $34 201	◄··· Add extra repayment (next to, 'Repayment frequency').
	
ii Savings = 3 years 11 months	

... Continued

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d If rates increase by 1%, the new fortnightly repayment would be $700.
Increased amount = $700 − $642 = $58 each fortnight.

◄··· Change the interest from 5.95% to 6.95 %.





Example 6 Using an online calculator to investigate the effect of the interest rate, payment frequency and repayment amount

Hannah has borrowed $275 000 to buy a home in Mt Isa. Bank interest rates are 5.49% p.a. reducible interest, and she wants to pay her loan off in 25 years. Use the Moneysmart Mortgage Calculator, *https://moneysmart.gov.au/home-loans/mortgage-calculator* to answer the following questions.

a Determine:
- **i** the monthly repayment
- **ii** the interest charges if the loan is paid monthly.

b Hannah has heard that she can save money by paying approximately half the monthly repayment each fortnight.
- **i** Calculate her fortnightly repayment to the nearest dollar.
- **ii** Use the 'How can I repay my home loan sooner?' tab to determine the interest and time savings on her loan.

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c Hannah is worried about what might happen if interest rates go up. Use the online calculator to determine how much more Hannah would need to pay each fortnight if rates go up 0.5% p.a.

WORKING	THINKING
	Enter values in the Moneysmart Mortgage Calculator. Hover over the light blue of the bar to read off the total interest charges.

a **i** Monthly repayment = $1687

ii Total interest = $231 130

b **i** Fortnightly payment $= 1687 \div 2$
$= 843.5$
$= \$844$

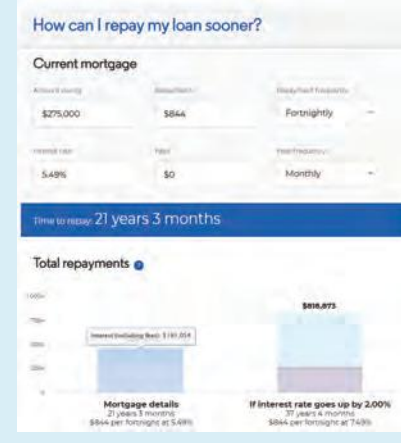
Round up to the next whole dollar amount as website will only accept whole numbers. Also need to pay at least the same amount per month.

ii Interest when paid fortnightly = $191 054

Savings $= 231\,130 - 191\,054$
$= \$40\,076$

Time to repay = 21 years 3 months

Saving = 25 years − 21 years 3 month
= 3 years 9 months

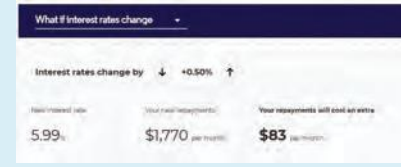


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c New rate = 5.49 + 0.5
= 5.99% p.a.
New monthly repayment = $1770
New fortnightly payment = 1770 ÷ 2
= $885
Increase per fortnight = 885 − 844
= $41
Hannah would need to pay an extra $41 per fortnight to repay her loan. Due to rounding, she would also pay it off 2 months sooner in 21 years 1 month

◄··· Go back to 'How much will my mortgage payments be?' Under the graph in the 'What if my interest rates change' tab, add 0.5%. The new repayment is per month, so calculate the fortnightly repayment by dividing by 2.





Exercise 14C

FUNDAMENTALS

APPLICATIONS

Use the Commonwealth Bank home loan calculator to answer the following questions: *https://www.commbank.com.au/digital/home-buying/calculator/home-loan-repayments?ei=calculator-inter-calc-tab-home-loan-repayments*.

Example 5

1 Preston has borrowed $287 000 to buy a home. Bank interest rates are 5.37% p.a. reducible interest, and he wants to pay his loan off in 25 years.

a Use the Commonwealth Bank home loan calculator to determine:

i the monthly repayment

ii the interest charges if the loan is paid monthly.

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b Preston has heard that he can save money by paying fortnightly. Determine:
- **i** his fortnightly repayment
- **ii** the savings over 25 years.

c Preston decides to pay an extra $50 each fortnight. Calculate:
- **i** the amount he would save in interest costs
- **ii** the time he would save on his loan.

d Preston is worried about what might happen if interest rates go up. Use the online calculator to determine how much more Preston would need to pay each fortnight if rates go up 0.5% p.a.

2 Bella has borrowed $185 000 to buy a townhouse. Bank interest rates are 6.24% p.a. reducible interest, and she wants to pay her loan off in 20 years.

a Use the Commonwealth Bank home loan calculator to find the following:
- **i** the monthly repayment
- **ii** the interest charges if the loan is monthly.

b Bella has heard that she can save money by paying fortnightly. Determine:
- **i** her fortnightly repayment
- **ii** the savings over 20 years.

c Bella decides to pay an extra $40 each fortnight. Calculate:
- **i** the amount she would save in interest costs
- **ii** the time she would save on her loan.

d Bella has heard that interest rates may go down with a new government. Use the online calculator to determine how much less Bella would need to pay each fortnight if rates go down by 0.5% p.a.

Use the Moneysmart Mortgage Calculator to answer the following questions.
https://moneysmart.gov.au/home-loans/mortgage-calculator

Example 6

3 Sianta has borrowed $180 000 to buy a home over 20 years with a reducible interest rate of 6.2% p.a.

a Use the Moneysmart Mortgage Calculator to determine the size of her monthly repayment.

b Calculate the amount of interest will she pay.

c Interest rates drop to 6.05% p.a.; calculate her new monthly repayment.

d Calculate the amount of interest she will save because of the rate drop.

4 Michael has borrowed $40 000 to set up a small business over five years with a reducible interest rate of 8.2% p.a.

a Use the Moneysmart Mortgage Calculator to determine the size of his monthly repayment.

b Calculate the amount of interest will he pay.

c Interest rates increase to 8.5% p.a.; calculate his new monthly repayment.

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d Discuss the impact the new interest rate might have on Michael's small business.
e Calculate the amount of extra interest he will need to pay because of the rate increase.

5 Botrus is investigating borrowing $265 000 to buy a transportable tiny home. The bank is offering 6.15% p.a. reducible rates, and he thinks he will take 25 years to repay the loan.
a Use the Moneysmart Mortgage Calculator to determine the size of his monthly repayment.
b Determine the total cost of the loan over 25 years.
c When Botrus applies for the loan, he is advised to pay half the monthly repayment each fortnight. Determine his fortnightly repayment.
d Use the 'How can I repay my home loan sooner?' tab to determine how long it will take Botrus to repay his loan by paying half the monthly repayment each fortnight.
e Calculate the total cost of the loan if he pays half the monthly repayment each fortnight.
f Discuss the advice you would give Botrus about his home loan.

6 Maddie borrows $315 000 to buy a home. Bank interest rates are 6.19% p.a. reducible interest, and she wants to pay her loan off in 25 years.



a Use the Moneysmart Mortgage Calculator to determine:
i the monthly repayment
ii the interest charges if the loan is paid monthly.
b Maddie has heard that she can save money by paying half the monthly repayment each fortnight.
i Calculate her fortnightly repayment to the nearest dollar.
ii Use the 'How can I repay my home loan sooner?' tab to determine the interest and time savings on her loan.
c Maddie is worried about what might happen if interest rates go up. Use the online calculator to determine how much more Maddie would need to pay each fortnight if rates go up 0.5% p.a.

Hint The fortnightly payment will continue to be half of the monthly repayment.

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7 Ben has borrowed $286 000 to buy a home. Bank interest rates are 5.99% p.a. reducible interest, and he wants to pay his loan off in 20 years.

a Use the Moneysmart Mortgage Calculator to determine:

i the monthly repayment

ii the interest charges if the loan is paid monthly.

b Ben is not sure if he can afford to pay the monthly loan repayment over 20 years. If he opts to pay over 25 years, calculate:

i the monthly repayment

ii the interest charges

iii the additional interest charges from taking longer to repay the loan.

c Ben wants to take advantage of the savings to be made by paying half the monthly repayment each fortnight.

i Calculate his fortnightly repayment to the nearest dollar.

ii Use the 'How can I repay my home loan sooner?' tab to determine the interest and time savings on his loan.

d Ben has heard that interest rates may go down with a new government. Use the online calculator to determine how much less Ben would need to pay each fortnight if rates go down 0.25% p.a.

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14D Investigating the effect of the repayment amount, changing interest rates and compounding periods using spreadsheets

COMPLEX

LEARNING GOALS

- Investigate the effect of the interest rate and the number of compounding periods on the future value of a loan by using technology (spreadsheet).
- Investigate the effect of the interest rate and repayment amount on the time taken to repay a loan by using technology (spreadsheet).

Why is using spreadsheets to investigate changes to a loan essential?

- As we saw in the previous section, when dealing with compound interest, changes to rates, compounding frequency and the amount regularly paid can influence the outcome of a loan.
- Using spreadsheets to investigate how you can make small changes to a loan has the potential to save you a lot of money.



Being well informed about loans has the potential to save you lots in interest charges.

WHAT YOU NEED TO KNOW

- Making changes to the interest rate and frequency of compounds will have an impact on interest charges, the size of repayments required to pay off a loan and the total cost of a loan.
- Making changes to the size of the repayment will change the length of time taken to repay the loan and the amount of interest charged.
- We can use spreadsheets in a similar way to what we have done in previous sections to determine the impact of changes to interest rates, compounding frequency and repayments.

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Example 7 Calculating the impact of changes to interest on loans using a spreadsheet

Spread-sheet

Ned has recently taken out a $320 000 home loan. Interest rates are currently 5.7% p.a., and he is planning to repay the loan in 25 years.

a Use a spreadsheet (like the one used in Section 14B) to determine the monthly repayment.
b Calculate the total amount he will repay.
c Calculate the total amount of interest he will pay.
d Interest rates are increased to 5.85% p.a.; calculate his new monthly repayment.
e Determine how much extra will he pay each month.
f Determine how much extra will he now pay in total for the loan.
g Discuss the impact of the increased interest rate.

WORKING	THINKING
a	Set up spreadsheet as done in Section 14B, example 4.

	A	B
1	Principal	320000
2	Rate	5.7
3	Years	25
4	Repayments/year	12
5		
6	Number of Payments	300
7		
8	Repayment	$2,003.48
9	Total Repaid	$601,044.90
10	Total Interest	$281,044.90

	A	B
1	Principal	320000
2	Rate	5.7
3	Years	25
4	Repayments/year	12
5		
6	Number of Payments	=B4*B3
7		
8	Repayment	=(PMT((B2/(100*B4)),B6,-B1,0,0))
9	Total Repaid	=B8*B6
10	Total Interest	=B9-B1

Monthly repayment = $2003.48 — While the spreadsheet shows you this value as $2003.48, it actually stores and uses 2003.4829915572 to avoid rounding errors.

b Amount repaid = $601 044.90 — Read from spreadsheet.

c Total interest = $281 044.90 — Read from spreadsheet.

... Continued

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d

	A	B
1	Principal	320000
2	Rate	5.85
3	Years	25
4	Repayments/year	12
5		
6	Number of Payments	300
7		
8	Repayment	$2,032.52
9	Total Repaid	$609,756.91
10	Total Interest	$289,756.91

Monthly repayment = $2032.52

◄····· Adjust spreadsheet for new interest rate.

e Extra payment = 2032.52 − 2003.48
= $29.04 per month

◄····· Subtract monthly repayments.

f Extra paid in total
= 609 756.91 − 601 044.90
= $8712.01

◄····· Subtract total paid.

g At an interest rate of 5.7%, the monthly payment would be approximately $2003.48. However, with the slight increase to 5.85%, the monthly payment rises to about $2032.52. This means an additional $29.04 per month.

Over the entire 25-year period, the total payment at 5.7% would be $601 044.90, while at 5.85%, it would be $609 756.91. This results in a difference of $8712.01. Even though the change in interest rate is only 0.15%, it leads to a substantial increase in the total cost of the loan, highlighting how sensitive long-term loans are to interest rate fluctuations.

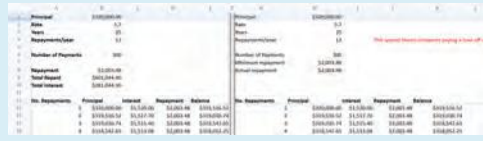
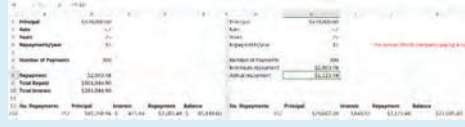
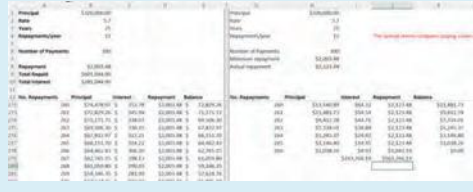
◄····· How does increasing the interest rate impact the loan?

Example 8 Calculating the impact of changes to the minimum payment amount on loans using a spreadsheet.

Spread-sheet

Ned decides he can actually afford to pay an extra $120 per month off his home loan. How much time and interest will Ned save by doing this?

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WORKING	THINKING
 On the right-hand side change the actual payment by making the H8 cell = B8 + 120	Open the comparison spreadsheet for example 8 and fill in the left hand side as done in previous examples
 Fill down until the principal becomes a negative	Change the regular payment
 Sum the interest values to get the total interest paid Savings = 601	The spreadsheet indicates that Ned has paid back $1080.29 too much. To compensate for this, make the final repayment = 2123.48 − 1080.29 = $1043.19
	Cell I279 = sum(I13 : I278) Cell J279 = sum(J13 : J278)
Savings = 601 044.90 − 563 766.19 = $37 278.71	Calculate the amount of money Ned saved
Time saved = 300 months − 266 months = 34 months = 2 years and 10 months	Calculate the time saved

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Example 9 Investigating the effect of the repayment frequency on the time taken to repay a loan using a spreadsheet

Spread-sheet

Daniel borrows $315 000 to buy a home. Bank rates are 5.56% p.a. reducible interest, and he will make monthly repayments over 25 years.

a Use the spreadsheet from Example 8 to find the size of the monthly repayment to the nearest dollar.

b Set up a new spreadsheet (like the one used in Section 14B, Example 4) to model his loan with the following headings:

	A	B	C	D	E
1	Principal	315000			
2	Rate	5.56			
3	Years	25			
4	Repayment	1946			
5	Repayments/year	12			
6					
7	No. Repayments	Principal	Interest	Repayment	Balance
8	1				
9	2				
10	3				

c Use the spreadsheet to calculate the amount of interest he will pay over the 25 years.

d Daniel wants to pay half his monthly repayment each fortnight to save interest. Calculate the amount he will need to repay each fortnight.

e Change the repayment amount and the number of repayments per year to determine how long it would take to repay the loan if paid fortnightly.

f Use the spreadsheet to determine the total amount of interest if he pays half the monthly repayment each fortnight. Calculate how the amount he will save in interest and time.

WORKING

a The monthly repayment is $1946.

	A	B
1	Principal	315000
2	Rate	5.56
3	Years	25
4	Repayments/year	12
5		
6	Number of Payments	300
7		
8	Repayment	$1,945.68

THINKING

◄···· Set up spreadsheet as in Section 14B, Example 4 to find the repayment.

	A	B
1	Principal	315000
2	Rate	5.56
3	Years	25
4	Repayments/year	12
5		
6	Number of Payments	=B4*B3
7		
8	Repayment	=PMT((B2/(100*B4)),(B4*B3),-B1,0,0)

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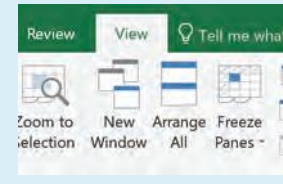
b Set up a new spreadsheet as follows:

	A	B	C	D	E
1	Principal	315000			
2	Rate	5.56			
3	Years	25			
4	Repayment	1946			
5	Repayments/year	12			
6					
7	No. Repayments	Principal	Interest	Repayment	Balance
8	1	=B1	=B8*$B$2/100*1/$B$5	=$B$4	=B8+C8-D8
9	2	=E8	=B9*$B$2/100*1/$B$5	=$B$4	=B9+C9-D9
10	3	=E9	=B10*$B$2/100*1/$B$5	=$B$4	=B10+C10-D10

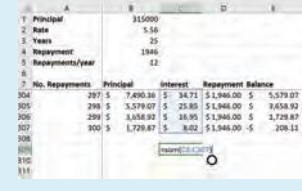
◄···· Interest = *Pin*
Using the dollar sign in the cell reference means we always use the interest value in cell B2 even when we fill down.
Cell B5 has the number of payments made per year. We want to use that to adjust time, n, in the interest calculation.
The repayment is in cell B4
Balance = principal + interest
− repayment

c 25 years = 25 × 12 = 300 months
Total interest = $268 591.89

◄···· Tip: to continue to show the table headings when you scroll down. Click in cell B8 > View >Freeze Panes



Fill the table down for 300 months to model the entire loan.
Type = SUM(C8:C307) into a cell below the interest column.



d Fortnightly repayment = 1946 ÷ 2
= $973

◄···· Halve the monthly repayment.

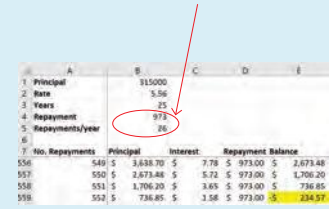
... *Continued*

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e Repayment = $973
Repayments/year = 26 (fortnights)

Time to repay loan = 552 fortnights
= 552 ÷ 26
= 21.23 years
= 21 years 3 months

◄···· Change values at the top only and fill down until the balance falls below $0 for the first time.



	A	B	C	D	E
1	Principal	315000			
2	Rate	5.56			
3	Years	25			
4	Repayment	973			
5	Repayments/year	26			
6					
7	No. Repayments	Principal	Interest	Repayment	Balance
556	549	$ 3,638.70	$ 7.78	$ 973.00	$ 2,673.48
557	550	$ 2,673.48	$ 5.72	$ 973.00	$ 1,706.20
558	551	$ 1,706.20	$ 3.65	$ 973.00	$ 736.85
559	552	$ 736.85	$ 1.58	$ 973.00	-$ 234.57

To change years from a decimal to months:
21.23 − 21 = 0.23
0.23 × 12 = 2.76 (or 3 months to nearest month), so
21.23 years = 21 years 3 months.

f

Interest = $221 861.43
Saving = 268 591.89 − 221 861.43
= $46 730.46

Time saving = 25 years
−21 years 3 months
= 3 years 9 months

By paying half the monthly payment each fortnight, Daniel repays the loan 3 years and 9 months sooner and saves $46 730.46 in interest.

◄···· Type = SUM(C8 : 559) into a cell below the interest column to find total interest.



	A	B	C	D	E
1	Principal	315000			
2	Rate	5.56			
3	Years	25			
4	Repayment	973			
5	Repayments/year	26			
6					
7	No. Repayments	Principal	Interest	Repayment	Balance
556	549	$ 3,638.70	$ 7.78	$ 973.00	$ 2,673.48
557	550	$ 2,673.48	$ 5.72	$ 973.00	$ 1,706.20
558	551	$ 1,706.20	$ 3.65	$ 973.00	$ 736.85
559	552	$ 736.85	$ 1.58	$ 973.00	-$ 234.57
560					
561			=SUM(C8:C559)		
562			SUM(number1, [number2],...)		
563					

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Exercise 14D

FUNDAMENTALS

1 Complete the following conversions.

a 1 year = _____ months

b 1 year = _____ weeks

c 1 year = _____ days

d 1 year = _____ fortnights

e 1 year = _____ 6 months

f 1 year = _____ 4 weeks

g 1 year = _____ quarters

APPLICATIONS

Spread-sheet **Spreadsheet Example 7** applies to Question **2**.

Example 7 **2** Primrose borrows $296 000 to buy a home. She agrees to repay the loan in monthly repayments over 25 years. Reducible interest is calculated at 6.35% p.a.

a Use a spreadsheet to calculate the:

i size of her monthly repayment

ii total amount repaid

iii total interest paid.

b Another bank offers her a loan with only 6.25% p.a. interest. Adjust your spreadsheet to calculate:

i size of her monthly repayment

ii total amount repaid

iii total interest paid.

c Calculate the savings to be made by taking the loan with the smaller interest rate.

Spread-sheet **Spreadsheet Example** 8 applies to the following questions.

3 Lachlan borrows $305 000 to buy a home. Bank interest rates are 5.16% p.a. reducible interest and he will repay the loan with monthly repayments for 20 years.

a Use a spreadsheet to calculate the size of the monthly repayment. Round up to the next dollar.

b Set up the spreadsheet to model his loan with the same headings used in Question **3b**. Fill down until the loan is repaid.

c Use the spreadsheet to calculate how much he will pay in interest.

d Lachlan wants to pay $40 extra each month. Determine how long it will take him now to pay off the loan.

CF

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e **i** Use the spreadsheet to calculate the total amount of interest if he repays an extra $40 each month.

ii Determine how much he will save in interest and time.

4 Bella borrows $450 000 to buy a home. The bank interest rate is 4.75% p.a. reducible interest, and she will repay the loan with fortnightly repayments for 25 years.

a Use a spreadsheet to calculate the size of the fortnightly repayment.

b Set up the Example 8 spreadsheet to model her loan. Fill down until the loan is repaid.

c Use the spreadsheet to calculate how much she will pay in interest.

d Bella wants to pay $50 extra each fortnight. Determine how long it will take her now to pay off the loan.

e Use the spreadsheet to calculate the total amount of interest she pays if she repays an extra $50 each month.

f Determine how much she will save in interest and time.

5 New wants to borrow $350 000 to buy a home. He has two loan options:

1 **Loan A:** Monthly repayments at 5.15% p.a. reducible interest for 25 years.

2 **Loan B:** Fortnightly repayments at 5.21% p.a. reducible interest for 25 years.

a Use the left hand side of the spreadsheet from example 8 to calculate the size of the monthly repayment for Loan A.

b Use the right hand side of the same spreadsheet to calculate the size of the fortnightly repayment for Loan B.

c Now that you have set up spreadsheets to model both loans, fill down until each loan is repaid.

d Compare how much New will pay in interest for each loan.

e Determine which loan is the better offer and explain why.

6 Jordan borrows $450 000 to buy a home. The bank interest rate is 5.85% p.a. reducible interest, and he will repay the loan with monthly repayments for 25 years.

a Use the spreadsheet from example 8 to calculate the size of the monthly repayment.

b Now that the spreadsheet is set up, fill down until the loan is repaid.

c Use the spreadsheet to calculate how much he will pay in interest.

d Jordan wants to make two changes to his payment schedule. Firstly, he wants to pay the loan back fortnightly, and secondly, he can afford to increase each of his fortnightly payments by $30. Determine how long it will take him now to pay off the loan (use the right hand side of the spreadsheet).

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e Use the spreadsheet to calculate the total amount of interest he pays under these new conditions.

f Determine how much he will save in interest and time when compared to the original schedule.

Example 8

7 Jewel borrows $265 000 to buy a home. Bank interest rates are 5.45% p.a. reducible interest, and she will repay the loan with monthly repayments over 20 years.

a Use a spreadsheet to determine the size of the monthly repayment. Round up to the next dollar.

b Set up the spreadsheet to model her loan by adding values to B1, B2, B3 and B4. The rest will auto fill.

	A	B	C	D	E
1	**Principal**	265000			
2	**Rate**	5.45			
3	**Years**	20			
4	**Repayments/year**	12			
5	**Repayment**	1816			
6					
7	**No. Repayments**	**Principal**	**Interest**	**Repayment**	**Balance**
8	1	=B1	=B8*$B$2/100*1/$B$4	=$B$5	=B8+C8-D8
9	2	=E8	=B9*$B$2/100*1/$B$4	=$B$5	=B9+C9-D9
10	3	=E9	=B10*$B$2/100*1/$B$4	=$B$5	=B10+C10-D10

c Fill down until the loan is repaid. Use the spreadsheet to calculate how much she will pay in interest.

d Jewell wants to pay half her monthly repayment each fortnight to save interest. Using the comparison side of the spreadsheet (right), calculate how much will she will now pay each fortnight (Actual repayment = (B8/2)).

e Fill down the comparison side (right) of the spreadsheet to determine how long it would take to repay the loan if paid fortnightly.

f **i** Use the spreadsheet to calculate the total amount of interest if she pays half the monthly repayment each fortnight.

ii Determine how much she will save in interest and time.

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Modelling task

Context: The Great Australian Dream is to own your own home. But is it really the best financial decision?



Task: Compare the costs of buying and maintaining your own home over 10 years against the cost of renting a similar property over the same time and having a regular savings plan. After 10 years, the house will have increased in value, but so will the renter's savings. Investigate who is better off.

Stage 1: Formulate
Make assumptions regarding: • your interest rate changes • future home values (for buying and renting) • expenses involved in owning a house versus renting • frequency of savings. Make observations of: • cost of purchasing a home and home loan options • cost of renting a home • compounding periods and current loan options.
Stage 2: Solve
Purchasing a home: • Use an online calculator or a spreadsheet to determine the monthly repayment. • Use the monthly repayment to calculate the cost in interest and total cost of repaying the home. • Based on house prices 10 years ago, determine a future value for the house. • Consider the total cost of the loan versus the future value. Renting a home: • Calculate the total cost of renting a house over a 10 year period. • Calculate the total savings available by renting. • Produce graphs/tables required to solve the problem. • Determine the variation in the values of the savings account (when renting) versus the house value.

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Stage 3: Evaluate and verify
Check the reasonableness of your answers by comparing to previous house prices 10 years ago (for both renting and buying).
Stage 4: Communicate
Summarise your findings in a short paragraph: • Justify whether you believe your answers are accurate and why. • Discuss whether your assumptions would impact your findings (i.e. what could happen if interest rates change, rent increases, or house prices come down). • Include any recommendations to make your calculations more accurate.

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Chapter summary

Reducing balance loans

- Reducing balance loans are compound interest loans with periodic repayments
- Periodic repayment periods can vary depending on the loan terms, but they can be weekly, fortnightly, monthly (most common), quarterly and annually (yearly).
- Reducing balance loans can be calculated manually using a repayment schedule or by using online calculators and spreadsheets.
- Changes in interest rate, number of repayments and repayment amounts can significantly impact the overall cost of the loan or the length of time it takes to repay the loan.

Modelling reducing balance loans

- Reducing balance loans can be modelled using simple interest and a table as below:

Year	Principal	Interest	Repayment	Balance

  - In Chapter 14, these tables were used to calculate annual repayments only.
  - The principal is the amount owed at the end of each interest period, so it reduces each period (it is the same as the balance from the previous period).
  - The repayment amount stays the same each year (unless the terms of the loan are changed).
  - To calculate the interest, we can use the simple interest formula $I = Pin$.
- Reducing balance loans can also be modelled using a spreadsheet as per the example below:

	A	B	C	D	E
1	Month	Principal	Interest	Repayment	Balance
2	1	200000	=B2*5.6/100*1/12	1241	=B2+C2-D2
3	2	=E2	=B3*5.6/100*1/12	1241	=B3+C3-D3
4	3	=E3	=B4*5.6/100*1/12	1241	=B4+C4-D4

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- In Chapter 14, spreadsheeting was used to calculate non-annual repayments.

Calculating the size of a repayment amount using technology

- Online calculators such as the Moneysmart or Commbank website can calculate the repayment amount for the loan, or Excel can also be used.
- Excel can calculate the size of a loan repayment using the formula: =PMT (rate, nper, pv, [fv], [type])

where;

rate	The interest rate for the loan as a fraction or decimal
nper	The total number of payments to pay off the loan
pv	The present value of the principal; the amount of money borrowed
fv	The future value of the loan. As we aim to pay off the loan, this will be 0
type	0 means the payment is made at the end of the period, 1 means the payment is made at the beginning of the period. It is usual to pay at the end of the time period, so we will enter 0 for this type.

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Chapter checklist

14A ☐ I understand that reducing balance loans are compound interest loans with periodic repayments.

1 Brooke borrowed $16 000 to buy a car. The terms of her loan were 11.56% p.a. reducible interest over four years and her yearly repayments are $5219 per year.

a Complete this table to determine how much Brooke will owe on her loan after the first three years.

Year	Principal	Interest	Repay	Balance
1				
2				
3				

b Determine how much interest Brooke paid in the first year.

c Calculate how much Brooke reduced her debt by in the first year.

d Determine how much interest Brooke paid in the third year.

e Calculate how much Brooke reduced her debt by in the third year.

f Interpret your answers to parts **c** and **e**.

14B ☐ I can use technology (spreadsheet) to model a reducing balance loan. **[complex]**

2 Lachlan borrows $23 000 to buy a car. He repays the loan with monthly repayments of $596 over four years with 11.15% p.a. reducible interest.

a Set up a spreadsheet to model the loan schedule over four years.

b Determine how much is left owing after 48 months.

c Calculate the size of the last repayment to fix the underpayment.

d Calculate the total loan repayments.

e Calculate the total interest charges.

f Determine how many months will it take to pay off half the loan.

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14C ☐ I can use technology (online calculator) to model a reducing balance loan. **[complex]**

3 Megan borrows $24 000 to buy a car. Interest is calculated at 10.85% p.a. on the reducing balance (compound interest), and she will repay the loan over four years. Use an online calculator to calculate:

a the monthly repayment required

b the total repaid

c the total interest.

13A 14C ☐ I can compare simple and compound interest loans. **[complex]**

4 Joe borrows $24 000 to buy a car. Simple interest is calculated at 10.85% p.a. and he will repay the loan over four years. Calculate:

a the total interest

b the total to repay

c the number of repayments

d how much he will need to repay each month

e the difference in monthly repayments and total cost of Joe's simple interest loan and Megan's compound interest loan in Question **3**.

14C ☐ I can use technology (online calculator) to investigate the effect of the interest rate and repayment amount on the time taken to repay a loan. **[complex]**

5 Isabelle borrows $213 000 to buy a townhouse. Bank interest rates are 5.82% p.a. reducible interest, and she wants to pay her loan off in 20 years.

a Use the Commonwealth Bank home loan calculator to determine:

i her monthly repayment

ii interest charges if she pays her loan monthly.

b Isabelle decides to pay an extra $50 each month:

i determine how much she would save in interest costs

ii calculate how much time will she save on her loan.

c Isabelle has heard that interest rates may go down with a new government. Use the online calculator to determine how much less she would need to pay each month if rates go down by 0.5% p.a.

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14D ☐ I can use technology (spreadsheet) to investigate the effect of the interest rate and repayment amount on the time taken to repay a loan. **[complex]**

6 Primrose borrows $365 000 to buy a home. Bank interest rates are 5.02% p.a. reducible interest and her monthly repayments will be $2138.

a Set up a spreadsheet to model her loan with the following headings:

	A	B	C	D	E
1	**Principal**	365000			
2	**Rate**	5.02			
3	**Years**				
4	**Repayment**	2138			
5	**Repayments/year**	12			
6					
7	**No. Repayments**	**Principal**	**Interest**	**Repayment**	**Balance**
8	1	=B1	=B8*$B$2/100*1/$B$5	=$B$4	=B8+C8-D8
9	2	=E8	=B9*$B$2/100*1/$B$5	=$B$4	=B9+C9-D9
10	3	=E9	=B10*$B$2/100*1/$B$5	=$B$4	=B10+C10-D10

b Fill the spreadsheet down to determine how long it will take Primrose to repay the loan.

c Use the spreadsheet to calculate how much she will pay in interest.

d Primrose wants to pay half her monthly repayment each fortnight to save interest. Calculate how much she will need to repay each fortnight.

e Change the repayment amount and the number of repayments per year to determine how long it would take to repay the loan if she paid half the monthly amount each fortnight.

f Use the spreadsheet to find the total amount of interest if she pays half the monthly repayment each fortnight. Calculate how much she will save in interest and time.

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Chapter review

All questions in the Chapter review are assessment-style.

Simple Familiar

14A **1** Betty borrowed $4600 to purchase a new laptop. She agreed to pay off the loan in 3 years with reducible interest calculated at 9.85% p.a. Her yearly repayments are $1844. Betty is given a table of her loan schedule as follows.

Yearly	Principal	Interest	Repayment	Balance
1	$4600	$453.10	$1844	$3209.10
2	$3209.10	$316.10	$1844	$1681.20
3	$1681.20	$165.60	$1844	$2.80

a Determine if Betty will completely pay off the loan in three years. Explain why this will happen.
b Calculate how much she should pay in the last year to completely pay off the loan.
c Determine how much Betty still owes on her loan after two years.
d Determine how much interest Betty paid in the first year.
e Calculate how much Betty reduced her debt in the first year.
f Determine how much interest Betty paid in the third year.
g Calculate how much Betty reduced her debt by in the third year.
h Describe the difference in your answers to parts **e** and **g**.
i Explain why the interest reduces each year.
j Calculate how much interest Betty paid on the total loan.
k Calculate 9.85% of $4600. Explain why this is different to your answer in part **j**.

14A **2** Braydon repays $6132 each year for four years on his $19 500 loan to buy a car.
a Determine how many repayments he will make.
b Calculate how much he repaid in total.
c Calculate how much he paid in interest.

14A **3** Joseph repays $29 729 each year for twenty-five years on his $285 000 home loan.
a Determine how many repayments he will make.
b Calculate how much he repays in total.
c Calculate how much he paid in interest.

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14A **4** Jasper borrowed $18 500 to buy a car. The terms of his loan were 11.12% p.a. reducible interest over four years and his yearly repayments are $5978 per year.

a Complete this table to determine how much Jasper will owe on his loan after the first three years.

Year	Principal	Interest	Repay	Balance
1				
2				
3				

b Calculate the total of Jasper's yearly repayments over the first three years.

c Calculate the total of the interest charges over the first three years.

d Determine the difference between the amount repaid and the interest charges over the first three years.

e Determine how much Jasper reduced his debt by in the first three years.

Note: The following questions require technology beyond a scientific calculator and are not considered exam style questions. They do, however, cover the syllabus content for this topic.

Complex Familiar

14B **5** Libby borrows $318 000 to buy a home. She repays the loan monthly over 25 years with 5.58% p.a. reducible interest. Use an online calculator from a bank website to calculate the:

a size of the monthly repayments

b total loan repayments

c total interest charges

d amount left owing after 20 years

e number of years it takes to pay off half the loan.

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14C **6** Ben borrows $31 000 to buy a car. He repays the loan with monthly repayments of $790 over 4 years with 10.25% p.a. reducible interest.

- **a** Set up a spreadsheet to model the loan schedule over four years.
- **b** Determine how much is left owing after 48 months.
- **c** Calculate the size of the last repayment to fix the overpayment.
- **d** Calculate the total loan repayments.
- **e** Calculate the total interest charges.
- **f** Determine how many months it will take to pay off half the loan.

14C **7** Nick borrows $247 000 to buy a home. Bank interest rates are 5.63% p.a. reducible interest, and he wants to pay his loan off in 25 years.

- **a** Use the Commonwealth Bank home loan calculator to calculate:
  - **i** his monthly repayment
  - **ii** the interest charges if he pays his loan monthly.
- **b** Nick has heard there are savings to be made by paying fortnightly; calculate his fortnightly repayment and savings over 25 years.
- **c** Nick decides to pay an extra $50 each fortnight, calculate:
  - **i** how much he would save in interest costs
  - **ii** how much time he would save on his loan.
- **d** Nick is worried about what might happen if interest rates go up. Use the online calculator to determine how much more Nick would need to pay each fortnight if rates go up 1% p.a.

14C **8** Frank borrows $386 000 to buy a home. Bank interest rates are 5.17% p.a. reducible interest, and he wants to pay his loan off in 20 years.

- **a** Use the Moneysmart Mortgage Calculator to determine:
  - **i** his monthly repayment
  - **ii** the interest charges if he pays his loan monthly.
- **b** Frank is not sure he can afford to pay the monthly loan repayment over 20 years. If he opts to pay over 25 years, calculate:
  - **i** his monthly repayment
  - **ii** the interest charges
  - **iii** his additional interest charges from taking longer to repay the loan.

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c Frank wants to take advantage of the savings to be made by paying half the monthly repayment each fortnight.

i Calculate his fortnightly repayment to the nearest dollar.

ii Use the 'How can I repay my home loan sooner?' tab to determine interest and time savings on his loan.

d Frank has heard that interest rates may go down with a new government. Use the online calculator to determine how much less Frank would need to pay each fortnight if rates go down 0.15% p.a.

Complex Unfamiliar

14D 9 Harry borrows $245 000 to buy a home. Bank interest rates are 6.15% p.a. reducible interest and his monthly repayments will be $1601.

a Set up a spreadsheet to model his loan with the following headings:

	A	B	C	D	E
1	**Principal**	245000			
2	**Rate**	6.15			
3	**Years**				
4	**Repayment**	1601			
5	**Repayments/year**	12			
6					
7	**No. Repayments**	**Principal**	**Interest**	**Repayment**	**Balance**
8	1	=B1	=B8*$B$2/100*1/$B$5	=$B$4	=B8+C8-D8
9	2	=E8	=B9*$B$2/100*1/$B$5	=$B$4	=B9+C9-D9
10	3	=E9	=B10*$B$2/100*1/$B$5	=$B$4	=B10+C10-D10

b Use the spreadsheet to determine how long it will take Harry to repay the loan.

c Use the spreadsheet to calculate how much he will pay in interest.

d Harry wants to pay half his monthly repayment each fortnight to save interest. Calculate how much he will need to repay each fortnight.

e Use the spreadsheet to calculate how long it would take to repay the loan if paid fortnightly.

f Use the spreadsheet to calculate the total amount of interest if he pays half the monthly repayment each fortnight. Determine how much she will save in interest and time.

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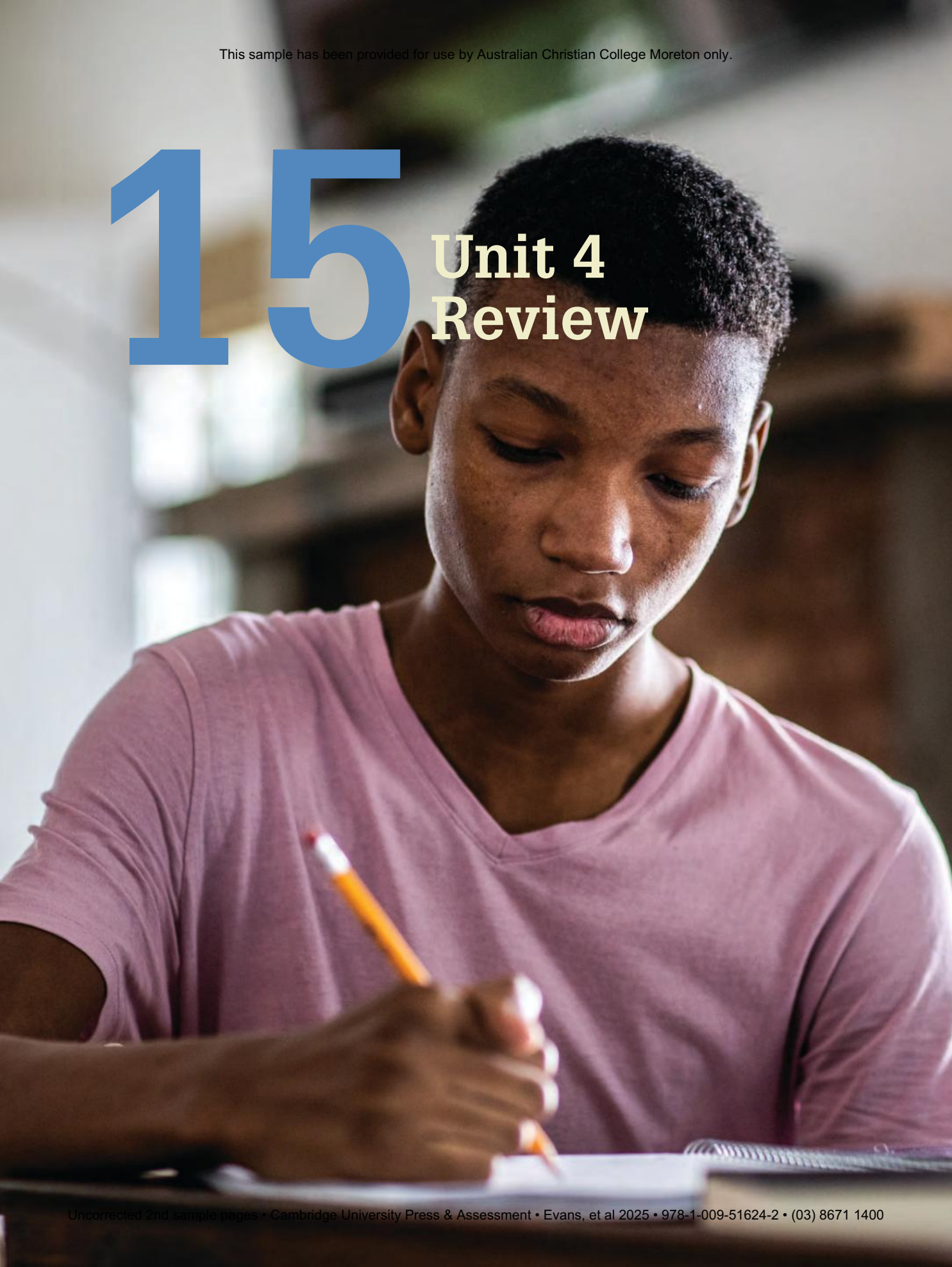
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14D **10** Tom borrows $335 000 to buy a home. Bank interest rates are 6.20% p.a. reducible interest and his monthly repayments will be $2200.

- **a** Set up a spreadsheet to model his loan with the same headings used in Question **10**.
- **b** Use the spreadsheet to determine how long it will take Tom to repay the loan.
- **c** Use the spreadsheet to calculate how much he will pay in interest.
- **d** Tom wants to pay $50 extra each month. Use the spreadsheet to determine how long it will take him now to pay off the loan.
- **e** Use the spreadsheet to calculate the total amount of interest if he repays an extra $50 each month. Determine how much he will save in interest and time.

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15 Unit 4 Review

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15A Simple Familiar

9A **1** Plot the following set of points on a Cartesian plane:
$(-2, 2)$, $(-3, -4)$, $(3, -4)$, $(2, 2)$ and $(-2, 2)$. Connect them in order and name the shape that is formed.

9B **2** Given the linear equation $y = 2x + 5$, complete the table for values of y.

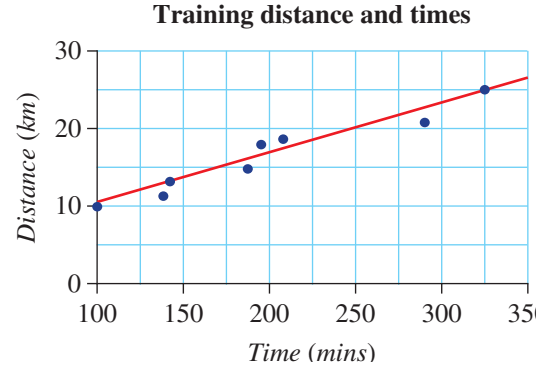
x	-2	-1	0	1	2
y					

9C **3** Akuna purchased a car for $25 000. The car depreciates (loses value) by $3000 per year. The value of the car can be described by the equation $y = 25\,000 - 3000x$, where y is the value of the car and x is the number of years. Graph the equation representing the value of the car by hand or with the help of technology.

9D **4** For the following data, create a scatter plot and describe the relationship in terms of shape, direction and strength.

Coffee consumption (cups per day)	2	1	3	4	0	2	3
Level of productivity (score 1–10)	7	5	8	8	5	6	7

9D **5** The following graph displays the training efforts of a participant in a charity walk in the lead up to the event. In order to see how consistent they are with speed, a scatterplot of the data was created. Comment on the shape, direction and strength of any relationship between distance walked and times.



10A **6** For each of the pairs of variables below name the dependent variable.

a Practice frequency and Tennis serve accuracy

b Player height and Basketball rebounding

c Education level and Income

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11A **7** A doctor is researching anaemia and he has recorded the following systolic pressure values from a group of patients' blood pressure readings.
115, 115, 107, 128, 122, 113, 108, 130, 115, 170, 120, 106

a Calculate the mean number of systolic pressure values.

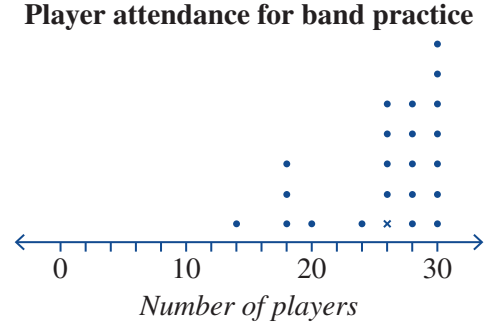
b Identify the median number of systolic pressure values.

c Determine the mode.



Hint Mean is average; median is the middle; mode is the most frequent.

11D **8** A coach is recording how many players are attending band practice over the semester.

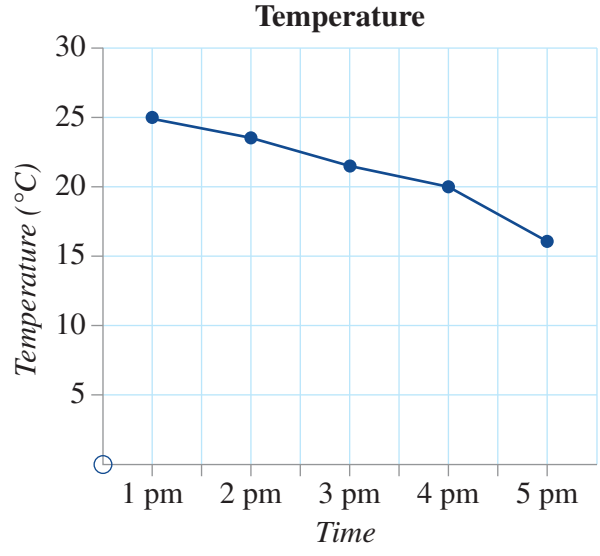


Describe the distribution, making use of the terms below where possible.

- spread out
- tightly packed
- loosely packed
- dispersed
- more/less dense regions
- clusters
- gap
- outliers.

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11E **9** Kari has measured some of today's temperature.





a Identify the maximum and minimum temperatures recorded in the dataset.
b Calculate the range.
c Interpret the range of the dataset.

12A **10** On a recent trip to Tasmania's Maria Island, tour groups were asked to record the number of wombat sightings. The following is the number spotted over 12 days:
4 5 7 3 6 4 2 5 8 2 4 4
a Sort the data into order.
b Determine the minimum and maximum values.
c Determine the median.
d Determine the lower quartile, Q1.
e Determine the upper quartile, Q3.
f State the five-number summary.

12B **11** Interested in the capacity of using an electric vehicle for a road trip around Australia, Jamie researched the number of superfast charging stations in each state. The following are the results without states labelled:
3 43 0 16 9 5 32 12
a Create a five-number summary.
b Construct a box plot.

13A **12** Bindi deposited $15 000 into his bank account which earns simple interest.
a After 5 years he logs into the account and sees that she now has a total of $18 870 available. Calculate the percentage interest rate on the account.
b A few years later, Bindi accessed the account again and discovered there was $22 740 in the account. Determine the total number of years (n) that Bindi has held the account.

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13B **13** Roslyn borrowed $4000 for a new laptop. The personal loan terms were charged at 11.5% p.a. compounded interest for three years. The interest was compounded yearly, and she was paying off the loan in one lump sum at the end of the three years. Create a table to show the compounding calculations for each year and determine the total amount that Roslyn owes for her laptop.

14A **14** Maisie has borrowed $470 000 from her grandparents to buy a house. The terms of her loan are 4% p.a. reducible interest over 20 years and her yearly repayments are $34 583 p.a.

a Complete the table to determine how much Maisie will owe on her loan after three years.

Year	Principal	Interest	Repayment	Balance

b Determine the total of Maisie's yearly repayments over the first three years.

c Calculate the total interest charges that Maisie paid over the first three years.

d Determine how much Maisie reduced her debt by in the first three years.

15B Complex Familiar

10B **15** Consider the following data regarding the mood and sleep patterns of Mrs Carlyle's senior HPE class.

a Determine the independent and dependent variables.

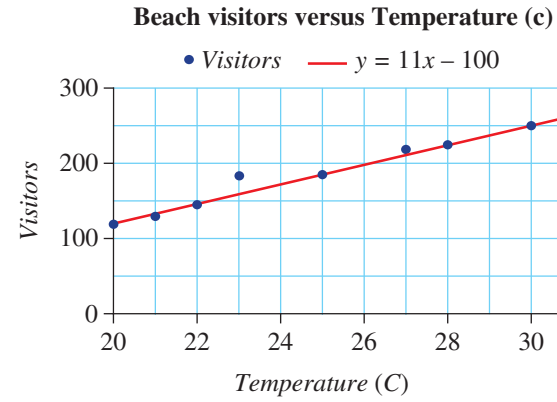
b Create a scatterplot of the data using technology.

c With the use of technology, draw the line of best fit and determine the equation of the line.

Average sleep (hours per night)	Mood rating (1–10)
7	8
5	5
6	6
8	9
4	4
5	7
6	6
5	4

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10C **16** Consider the equation of the line of best fit for the graph below and answer these questions.



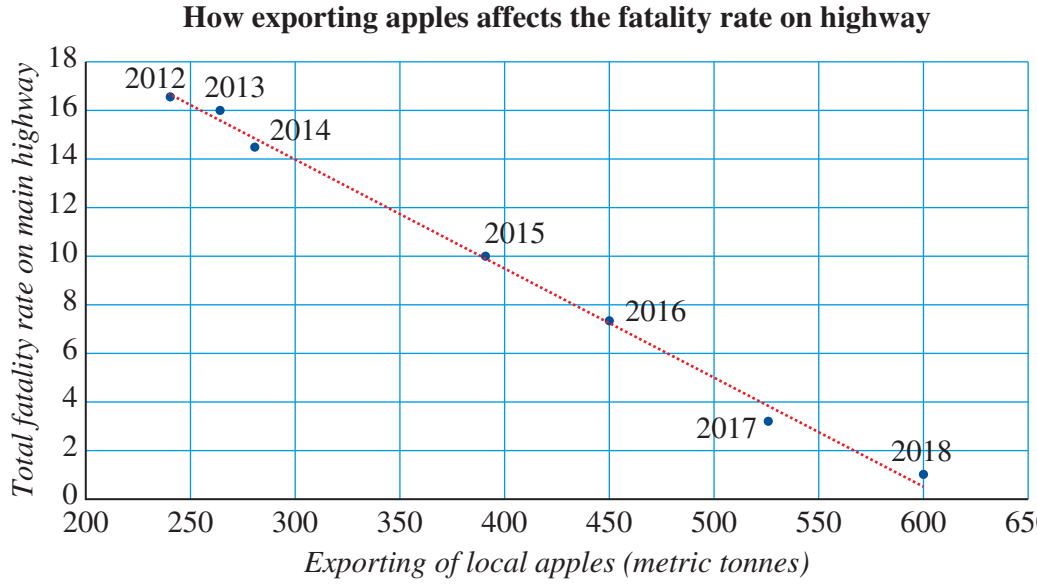
- **a** Identify the gradient (slope) m.
- **b** Identify whether the gradient is positive or negative and explain what this means for the variables.
- **c** Identify the y-intercept c.
- **d** Explain using the variables the meaning of the value c in part **c**.

10D **17** Investigating how levels of Blood Alcohol Concentration (BAC) correlate with cognitive ability using the provided data.

- **a** Create a scatterplot using technology to analyse the relationship between BAC levels and cognitive ability.
- **b** Describe any correlations observed, and calculate the correlation coefficient to justify your findings.

Blood alcohol content (BAC)	0.00	0.02	0.05	0.08	0.3	0.15	0.20	0.25
Cognitive ability (rating out of 10)	9	8	5	3	0	2	1	1

10F **18** A Queensland farmer has informed his local newspaper that he has discovered a relationship between exporting local apples and the fatality rate on their main highway each year. He has collected the following data to illustrate his theory.



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a Determine if there is a correlation between the two variables. Explain your answer.

b Determine if there is causality between the two variables. Explain your answer.

11B **19** Noah is trying to improve his test scores and has been recording his results out of 40 questions in preparation for passing the term.

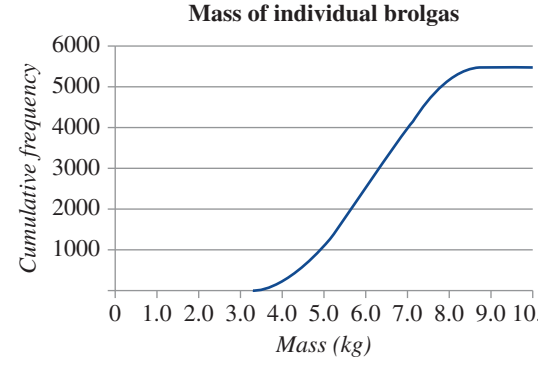
26, 13, 8, 2, 30, 17

Hint Give examples from your findings in your reasons.

a Calculate measures of central tendency for the results.

b Clarify which measure would best assist Noah with his preparation to improve his test scores. Give a reason.

11C **20** The mass of individual brolgas arriving at a site in North Queensland has been recorded, and the results are shown in the cumulative frequency graph. Two new brolgas visit. Brolga A weighs 4.2 kg and Brolga B weighs 7.5 kg.



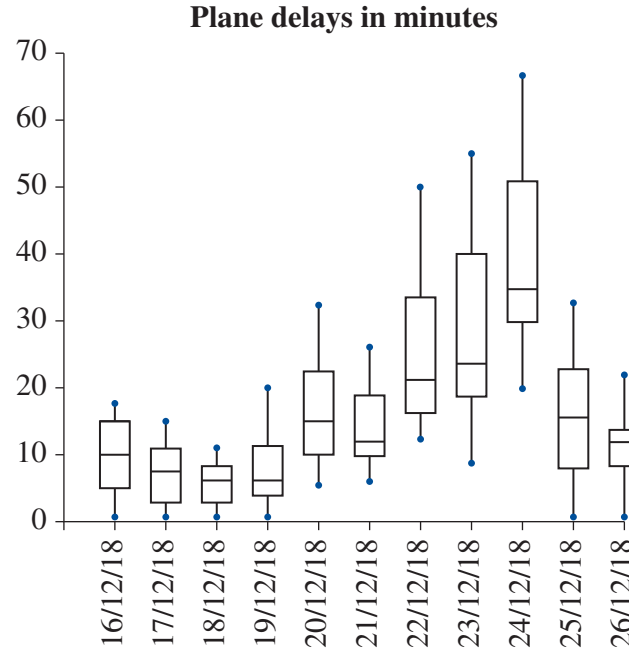


Given that Brolga A's mass is between the 5th and 6th percentiles and Brolga B's mass is between the 81st and 82nd percentiles, interpret the meaning of this in comparison to the rest of the population weights.

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12C **21** The following set of box plots were used to compare the delay times of plane flights (in minutes) during the 2018 Christmas holidays. Compare the delay times for each dataset.



13C **22** Omeon invests $8500 into an account paying 4.9% p.a. compounding interest for 10 years, with fortnightly compounding periods. Use the compound interest formula to calculate how much is in his account at the end of the 10 years.

15C Complex Unfamiliar

10E **23** The given data is from a group of golf players, showing the number of weeks they have been training on driving distance skills and the average distance they can drive the ball. Using technology, construct an appropriate graph. Then, use a method of prediction to comment on their reliability.

Number of weeks training	4	8	12	6	10	14	3	5
Average golf drive distance (m)	210	229	242	219	232	250	201	215

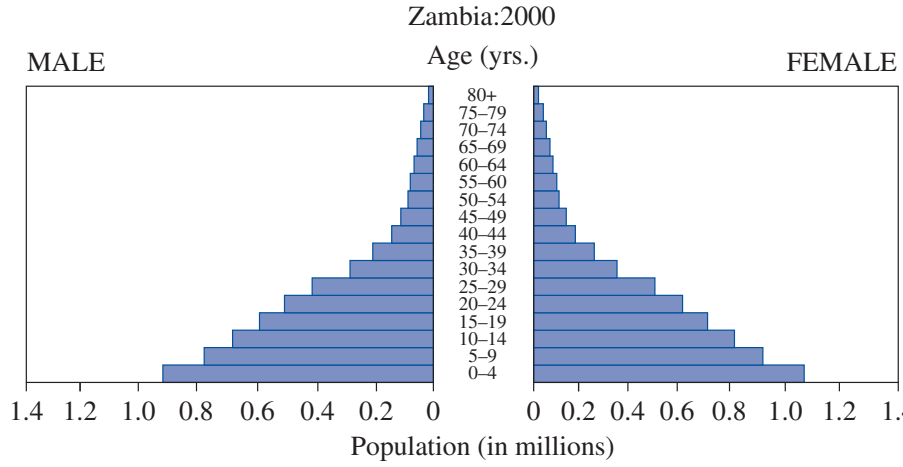
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11E **24** Concerned that her students are working too many hours at casual jobs to focus on final exams, Mrs Nate collects the following data of the total hours worked by their senior students in the last fortnight:
12, 6, 20, 9, 24, 8, 14, 27, 5, 10
Using appropriate calculations, summarise the variability of the data and interpret its meaning in regards to Mrs Nate's claim.

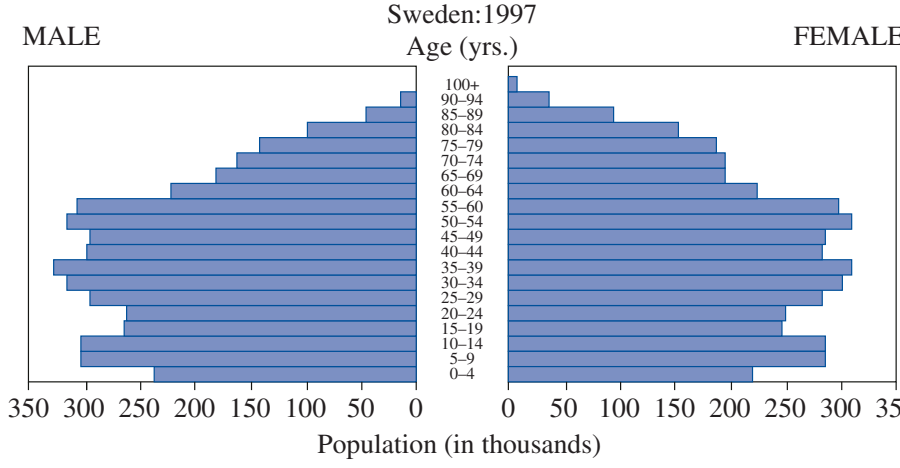
12D **25** The two population distribution histograms below display the distribution of the population by age and sex in Zambia and Sweden.

Population Distribution of Zambia by Age and Sex, 2000



Source: U.S. Census Bureau [Internet]. Washington, DC: IDB Population Pyramids [cited 2004 Sep 10]. Available from http://www.census.gov/ipc/www/idb/.

Population Distribution of Sweden by Age and Sex, 1997



Source: U.S. Census Bureau [Internet]. Washington, DC: IDB Population Pyramids [cited 2004 Sep 10]. Available from http://www.census.gov/ipc/www/idbpyr.html.

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Comment on how the histograms may be useful given the context of the data.

13C, 13E **26** Josephine is borrowing $80 000 to purchase a new tiny home. Bank ABC is offering a loan under the terms of 3.5% p.a. compounding monthly over 5 years. Bank XYZ is offering a loan under the terms of 4.2% compounding monthly over 5 years. She plans on paying out the loan in one lump sum at the end of the 5 years. Determine how much interest Josephine will save by choosing to go with Bank ABC.