

Maths Skills

for GCSE Edexcel Biology

Also suitable for GCSE Edexcel Combined Science (1SC0)

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Teacher's Introduction

This GCSE Maths Skills pack will support students studying the Edexcel GCSE Biology specification with the key mathematical skills they need to succeed in their course.

Mathematical skills pose a challenge for many students, with some finding it difficult to see how a skill learned in a Maths lesson is applied in a Biology lesson. This resource has been designed to support students in making this connection, and to build up their confidence in approaching questions that have a mathematical element.

Remember!

Always check the exam board website for new information, including changes to the specification and sample assessment material.

It gives a gentle, conversational review of the skill, with worked examples, and offers students the opportunity to practise the skill in isolation and then also in the context of an examination-style question. By using these resources, students can ensure they have the skills they need for each section of the Biology course. They can work through the chapters independently, or they can be directed to them as support for skills identified in class as in need of some improvement.

There are five chapters covering all the key maths skills needed for GCSE Biology. Each chapter contains the following elements:

- **Specification overview** – this provides an overview of the skills and explains what the exam board requires students to demonstrate in the exam.
- **Topic notes** – a brief summary revising the skills and demonstrating how to apply the skills.
- **Worked examples** – one or more fully worked questions which use the relevant skill, to demonstrate how students should approach them.
- **Practice questions** – each skill is concluded with practice questions that increase in difficulty. All the Biology knowledge needed to complete the question will be provided, and the question focuses on testing students' understanding of the maths skill itself.

The chapters are:

1. Arithmetic and numerical computation
2. Handling data
3. Algebra
4. Graphs
5. Geometry and trigonometry

There are two diagnostic tests for each chapter. The first is provided at the start of the resource and is designed to be used before you work through each chapter, to highlight students' existing strengths and areas for improvement. The second is designed to be used after reviewing the chapter's content and is provided after the main content of the resource, just before the answers. The tests will allow you to identify areas for particular focus before undertaking the work, and then afterwards, to determine whether further work is needed on specific areas.

March 2023

Students' Introduction

In order to do well in your GCSE Biology course, you need to have some maths skills. Some questions will require some mathematics.

Many students are less confident with maths than they would like to be, and it can be difficult to see how what is learned in a Maths lesson is applied in a Biology lesson. This resource has been created to make this connection, and to build up your confidence in approaching questions of this element. It gives a review of the skills you need, with worked examples, and then goes on to show how to use these skills in isolation and then also in the context of an examination-style question.

By using the resources, you can ensure that you have the skills you need for each chapter. You can work through the chapters independently, or your teacher may direct you to the chapters identified in class as in need of some improvement.

There are five chapters covering all the key maths skills needed for GCSE Biology. The chapters cover the following elements:

- **Specification overview** – this provides an overview of the skills and explains what students need to demonstrate in the exam.
- **Topic notes** – a brief summary revising the skills and demonstrating how to use them.
- **Worked examples** – one or more fully worked questions which use the relevant skills. This shows you how you should approach them.
- **Practice questions** – each chapter finishes with practice questions that increase in difficulty. The knowledge needed to complete the question will be provided for you, and then you are asked to apply your understanding of the maths skill itself.

The chapters are:

1. Arithmetic and numerical computation
2. Handling data
3. Algebra
4. Graphs
5. Geometry and trigonometry

There are two **diagnostic tests** for each chapter.

- **Test 1** should be used before you work through each chapter, to show what you need to improve.
- **Test 2** should be used after you have worked through the chapter's content.

The tests will help you to identify areas for particular focus before undertaking the chapters. They will also determine whether you still need to work on specific areas.

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DIAGNOSTIC TEST

1.1 ARITHMETIC AND NUMERICAL COMPUTATION

1. Write 0.4 as a fraction in its simplest terms.
.....
2. Write $\frac{5}{8}$ as a decimal and as a percentage.
.....
3. Write 1 000 in standard form.
.....
4. Write 3.5×10^{-3} as a decimal number.
.....
5. There are 25 students in a class; seven of them have blue eyes. What percentage have blue eyes?
.....
.....
6. A biscuit contains 7.5 grams of carbohydrate and 2.5 grams of fat. What is the total energy value of the biscuit? Give your answer in its simplest terms.
.....
.....
7. A farmer needs to order food for her chickens. She has 48 chickens, and they eat 100g of food each each month. Estimate how much chicken food the farmer needs to order each month.
.....
.....

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DIAGNOSTIC TEST

2.1 HANDLING DATA

1. Write 25198 to three significant figures.

.....

2. A gardener grew some tomatoes in 10 pots. She noted how many tomatoes she got from each pot.

25 28 18 25 26 31 25

- a) Calculate the **mean** number of tomatoes per plant.

.....

- b) Write down the **median** number of tomatoes per plant.

.....

- c) Write down the **modal** number of tomatoes per plant.

.....

3. A wildlife rescue centre kept records of the types of wild mammals that came into the centre for one week.

Hedgehog	Hedgehog	Fox	Hedgehog
Vole	Vole	Badger	Fox
Hedgehog	Hedgehog	Vole	Badger
Fox	Fox	Hedgehog	Vole

- a) Design a frequency table for the data.



- b) Display the data using a suitable chart.



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DIAGNOSTIC TEST

2.1 HANDLING DATA (CONTINUED)

4. There are 120 students in Year 11. The head of year wants to select six students for a planning committee. Suggest a method she could use to choose the students randomly.

.....

.....

.....

5. A bag contains one red ball, two blue balls and five yellow balls. You pick a ball at random. What is the probability that the ball will be:

- a) blue?
- b) not red?

6. The table shows the heights and shoe sizes of a group of adults.

Height (m)	UK shoe size
1.52	4
1.77	10
1.62	6
1.70	7
1.75	9
1.65	6
1.80	12
1.60	5

- a) Draw a graph for these data.
- b) Describe the relationship between height and shoe size for this group of people.

.....

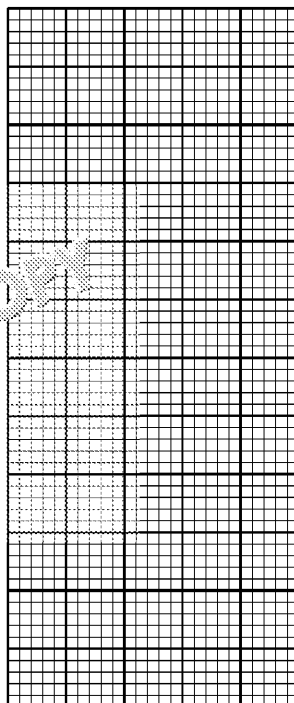
.....

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7. A rectangular field is 150 m wide by 200 m long. What is the order of magnitude in square metres (m^2)?

.....

.....

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DIAGNOSTIC TEST

3.1 ALGEBRA

1. Write the following expressions in words.

- a) $x \gg y$
- b) $\frac{5x-1}{2} = 12$

2. Solve these equations to find the value of x .

- a) $3x + 5 = 44$
- b) $\frac{5x-1}{2} = 12$

3. The formula for the density of an object is

$$\text{density} = \frac{\text{mass}}{\text{volume}} \quad d = \frac{m}{v}$$

- a) Calculate the density of an object that weighs 40 g and has a volume of 10 cm³.
.....
- b) What would be the mass of your answer to part a)?
.....
- c) A different object has a density of 0.5 kg/m³ (kilograms per cubic metre).
Does it weigh? Give the units of your answer.
.....

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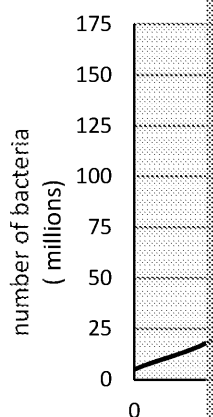
DIAGNOSTIC TEST

4.1 GRAPHS

1. The graph shows the growth of bacteria in a nutrient solution.

a) How many bacteria were present on day 2?

b) Describe what happened to the population of bacteria over the five days.



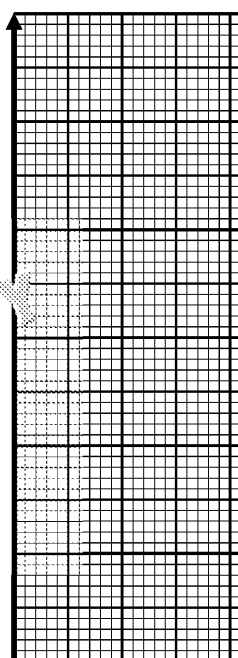
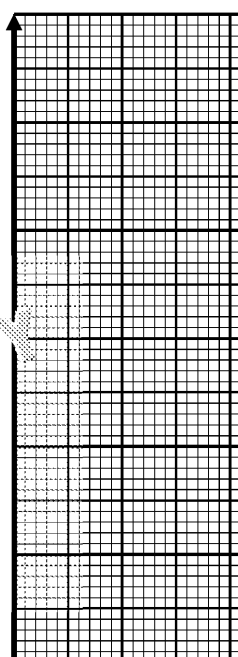
c) Calculate the population growth rate between day 1 and day 3, in millions per day.

2. a) Plot a graph of $y = 2x + 1$ for values of x from 0 to 8.

b) What is the gradient of this graph?

c) What is the y-intercept of this graph?

d) How would the line graph for $y = 4x + 1$ look different from the line you drew in 2a?



3. A wood pigeon can fly at a speed of 60 kilometres per hour. Speed = $\frac{\text{distance}}{\text{time}}$

a) Plot a graph of distance against time for a pigeon flying for six hours. Label both axes of your graph.

b) How far will the pigeon travel in 2.5 hours?



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DIAGNOSTIC TEST

5.1 GEOMETRY AND TRIGONOMETRY

1. Calculate the area of the following shapes:

a) Rectangle $4 \text{ cm} \times 1.5 \text{ cm}$

.....

b) Triangle with base 10 cm , height 4 cm

.....

.....

c) Circle with radius 5 cm

.....

.....

2. This tank measures $2 \text{ m} \times 2 \text{ m} \times 6 \text{ m}$.

Calculate the volume of the tank. Give the units of your answer.

.....

.....

3. This cube measures $2 \text{ cm} \times 2 \text{ cm} \times 2 \text{ cm}$.

Calculate the total surface area of the cube. Give the units of your answer.

.....

.....

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1 ARITHMETIC AND NUMERICAL COMPUTATION

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SPECIFICATION OVERVIEW

- 1a – Recognise and use expressions in decimal form
- 1b – Recognise and use expressions in standard form
- 1c – Use ratios, fractions and percentages
- 1d – Make estimates of the results of simple calculations

THEORETICAL OVERVIEW

Decimals

A decimal number includes amounts which are between 0 and 1 (fractions).

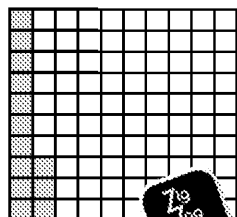
0.25 is a decimal number, and so is 9.25.

You use decimals with money; £3.62 is three pounds sixty-two pence, or three pounds and 62 pence.

The decimal point separates the whole numbers from the fractions, which are tenths, hundredths, thousandths, etc.

- **0.1** is a tenth, $\frac{1}{10}$
- **0.01** is a hundredth, $\frac{1}{100}$
- **0.001** is a thousandth, $\frac{1}{1000}$

Example: In **0.13**, the value of the digit 1 is one tenth, and the value of the digit 3 is three hundredths.



Tip: The large square represents 1, and it is divided into 10 columns and 10 rows. Each small square represents $\frac{1}{100}$.

A full column represents $\frac{1}{10}$, which is the same as $\frac{10}{100}$.

Ordering decimals

Hundreds are bigger than tens, tens are bigger than units, units are bigger than tenths, tenths are bigger than hundredths.

When ordering numbers, you should always compare the digits on the left first; just as you would when putting words into alphabetical order.

WORKED EXAMPLE

Which is greater: 2.701 or 2.71?

Solution

Line up the decimal points like this:

Units	Tenths	Hundredths	Thousandths
2	7	0	1
2	7	1	0

Both numbers have the same units and tenths, but 2.701 has 0 hundredths and 1 thousandth, while 2.71 has 1 hundredth and 0 thousandths. Therefore, 2.71 is greater than 2.701.

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Decimal places (dp)

'Decimal places' means how many digits come after the decimal point.

Examples: 3.985 has three decimal places; 78.0015 has four decimal places.

When you analyse experiment results, your calculator may give you a number with usually need to round your answers to one or two decimal places for your table and

Rule: Count the figures after the decimal point to find the decimal place. If this is 5, it stays as it is. 5 or more, and you round up.

3.42 = 3.4 to one decimal place (1 dp): **one decimal place** is the **first figure after** the decimal point. Now look at the next figure to see if it is 5 or more. It's a 2, so the 4 stays the same.

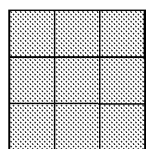
6.58 = 6.6 to 1 dp: the first figure after the decimal point is 5, but because the 5 is followed by an 8, it rounds up to a 6.

47.3942 = 47.39 to 2 dp: the 9 is the second decimal place, followed by a number less than 5, so it stays the same.

3.98 = 4.0 to 1 dp because the 9 is rounded up to a 10, which makes the 3 into a 4. This is the case on this occasion because you need one digit after the decimal point to have one decimal place.

Indices and standard form

A square number is made when you multiply a number by itself.



9 is a square number.

$$3 \times 3 = 9$$

3×3 can also be written as 3^2 (3 squared)

The small 2 (2) is an **index number**, or **power**. It tells you how many times you have to multiply the number by itself.

The opposite of a square number is a **square root**. For example, the square root of 9 is 3.

The mathematical symbol for square root is $\sqrt{\quad}$, so you would write it as $\sqrt{9} = 3$.

WORKED EXAMPLES

a) Calculate 168^2

Solution

Use the x^2 button on your calculator: $168 \ x^2 =$ Or do $168 \times 168 = 28224$

b) Find the square root of 6.25

Solution

Use the $\sqrt{\quad}$ button on your calculator: $\sqrt{6.25} =$ The answer is 2.5

Indices (powers)

A power of a number shows how many times you need to multiply that number by itself.

For example, 3 to the power of $5 = 3 \times 3 \times 3 \times 3 \times 3 = 243$

Your calculator should have a button labelled x^n . To calculate 3^5 it's $3 \ x^n \ 5 =$

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Biology application: multiplying bacteria – the 2ⁿ rule

Bacteria are very simple organisms, and they reproduce by dividing in two.

In warm, moist conditions, such as inside the human body, bacteria can double in number.

If you started with one bacterium, then over two hours it would work like this:

	20 min	40 min	60 min	80 min	100 min
	$\times 2$	$\times 2$	$\times 2$	$\times 2$	$\times 2$
1	2	4	8	16	32

Two hours is 120 minutes. So you would have $1 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 64$

This is the same as 2^6

To work out the number of bacteria in a specified time, you need to know:

- How many there were at the start
- The time period it takes for them to divide

Then the calculation you do is **starting number $\times 2^n$** , where n is the number of times they divide.

WORKED EXAMPLE

If you start with 1000 bacteria and they divide once every two hours, how many will there be after 16 hours?

Solution

16 hours is 8×2 hours, so that's eight time periods ($n = 8$) $\Rightarrow 1000 \times 2^8$

Powers of 10

Numbers such as **one hundred**, **ten thousand** and **1 million** are sometimes written as powers of 10.

Power of 10	Number in figures	Number in words	Word
10^2	100	One hundred	
10^3	1000	One thousand	
10^4	10 000	Ten thousand	
10^5	100 000	One hundred thousand	
10^6	1 000 000	One million	
10^9	1 000 000 000	One billion	

★ Notice that the power of 10 is equal to the number of zeros.

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WORKED EXAMPLE

Write the number one hundred thousand as a power of 10.

Solution

Write the number out in figures, and then count the zeros to get the power of 10.

$$100\,000 = 10^5$$

Negative powers of 10

Negative powers of 10 are **fractions**. In biology we often study very small things, therefore, you need to understand very small measurements.

Very small numbers such as **thousandths** and **millionths** are usually written as negative powers of 10.

Power of 10	Number in figures as a fraction	Number in figures as a decimal	Number in words
10^{-1}	$1/10$	0.1	One tenth
10^{-2}	$1/100$	0.01	One hundredth
10^{-3}	$1/1000$	0.001	One thousandth
10^{-6}	$1/1\,000\,000$	0.000001	One millionth
10^{-9}	$1/1\,000\,000\,000$	0.000000001	One billionth

Biology applications

Cells are usually measured in micrometres. A micrometre is 10^{-6} metres, or one millionth of a metre. The mathematical sign for micrometre is μm .

A human red blood cell is $8\,\mu\text{m}$ in diameter. In metres that's eight millionths of a metre.

Since $1\,\mu\text{m} = 10^{-6}\text{ m}$, $8\,\mu\text{m}$ is often written as $8 \times 10^{-6}\text{ m}$.

Standard index form

Standard index form is also called **standard form**, and it's a way of writing very large or very small numbers using powers of 10. A number written in standard form is made up of:

- A number between 1 and 10, for example 2.5
- multiplied by 10 to the power of something

Very big numbers have positive powers of 10, and very small numbers have negative powers of 10.

The power of 10 you use is how many places you need to move the decimal point.

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WORKED EXAMPLES

1. Write 253 000 000 in standard form.

Solution

Use the digits you have before the zeros start to make a number between 1 and 10. Here the digits are 253, so the number is 2.53.

Work out the power of 10 by counting how many places you have to move the decimal from 253000000 to 2.53, like this:

8 7 6 5 4 3 2 1
2 . 5 0 0 0 0 0 0 0. So $253\ 000\ 000 = 2.53 \times 10^8$

2. Write 0.000067 in standard form.

Solution

Use the digits you have after the zeros finish to make a number between 1 and 10. Here the digits are 67, so the number is 6.7.

Work out the power of 10 by counting how many places you have to move the decimal from 0.000067 to 6.7, like this:

1 2 3 4 5
0 . 0 0 0 0 6 . 7 So $0.000067 = 6.7 \times 10^{-5}$

You will see numbers written in standard form during your Biology course, and you will see how small they are. The words for the powers of 10 will help you.

Examples: You know that 1 000 000 000 is one billion; therefore, 2.5×10^9 is two and a half billion. You know that 1/1000 is one thousandth; therefore, 4×10^{-3} seconds is four milliseconds.

★ **The higher the power of 10, the higher the value of the number.**

If you need to convert a number in standard form back to an ordinary number, you can use a calculator.

Most scientific calculators have a button labelled $\times 10^x$ or $\times 10^n$ for this.

WORKED EXAMPLE

Write 3.75×10^6 as a whole number.

Solution

On your calculator it's $3.75 \times 10^6 =$ the answer is 3 750 000

If your calculator doesn't have a standard form button, use the x^n button instead.

$3.75 \times 10^6 =$

Alternatively, you can move the decimal point in the opposite direction and fill in any empty spaces to make the number, like this:

1 2 3 4 5 6
→ → → → → →
3 . 7 5 0 0 0 0 So $3.75 \times 10^6 = 3\ 750\ 000$

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Multiplying and dividing using standard form

When you multiply numbers in standard form, you **add** the powers of 10, like this:

$$10^3 \times 10^5 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 10^8$$

Example: 2.3×10^5 multiplied by one thousand = $2.3 \times 10^5 \times 10^3 = 2.3 \times 10^8$

Where both numbers are in standard form, you multiply the numbers and add the powers of 10.

$$2 \times 10^{-3} \times 3.4 \times 10^6$$

Multiply the numbers

$$2 \times 3.4 = 6.8$$

Add the powers of 10

$$10^{-3} \times 10^6 = 10^{-3+6} = 10^3$$

Put it together

$$6.8 \times 10^3$$

When you divide numbers in standard form, you **subtract** the powers of 10, like this:

$$10^5 \div 10^3 = \frac{10 \times 10 \times 10 \times 10 \times 10}{10 \times 10 \times 10} = 10^2$$

$$10 \times 10 \times 10$$

★ Use the $\times 10^x$ or x^n button on your calculator for complicated calculations.

WORKED EXAMPLE

Since the start of the COVID-19 pandemic, the cases of infection in the UK are 2.3×10^7 . The number of deaths is estimated as 1.82×10^5 .

Calculate the death rate as a percentage of total infections.

Solution

The calculation is: $\frac{\text{deaths}}{\text{cases of infection}} \times 100$

On your calculator that's $1.82 \times 10^5 \div 2.3 \times 10^7 \times 100 = 0.79\%$ to 2 s.f.

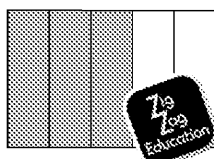
Fractions, ratios and percentages

Fractions

A **fraction** is made up of two parts: the **numerator** (on the top) and the **denominator** (on the bottom).

- ★ The **denominator** tells you how many parts or **fractions** the whole amount has been divided into.
- ★ The **numerator** tells you how many of those fractions we're talking about right now.

Example



This rectangle has been divided into five parts. The parts are divided into five equal parts. Three parts out of five are shaded in; that's $3/5$. Two parts out of five are not shaded; that's $2/5$.

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$$\frac{1}{2} = \frac{2}{4}$$

★ Sometimes you can divide the top and bottom of a fraction by the same number.

An exam question will sometimes ask you for a fraction in its simplest form.

Write $\frac{12}{16}$ in its simplest form.

12 and 16 will both divide by 4, so you cancel it down like this:

You can't divide it any further, so this

Imagine that there are 10 questions in a test and you get seven of them correct.

You would say that you got $\frac{6}{10}$ or $\frac{3}{5}$, or $\frac{7}{10}$. That means that 7 as a fraction of 10 is $\frac{7}{10}$.

In the same way, 12 is $\frac{4}{12}$ or $\frac{1}{3}$ of 36, and 20 is $\frac{10}{48}$ or $\frac{5}{24}$ of 48.

★ You may need to estimate to get an approximate fraction, also called a proportion.

Example: If 293 adults in a group of 910 are obese, then the proportion of obese is **about $\frac{1}{3}$** because 293 is approximately 300 and 910 is approximately 900.

$$300/900 = 1/3$$

These often come up, and you must be **really** careful with the units. Both amounts must be in the same units when you make the fraction.

Example: Write 20p as a fraction of £2.

20p as a fraction of £2 is not $\frac{20}{2}$, it's $\frac{20}{200}$ because £1 = 100p.

$20/200 = 1/10$, so 20p is $1/10$ of £?

What fraction of five metres is 30 centimetres?

There are 100 centimetres in a metre, so $5\text{ m} = 500\text{ cm}$.

30 cm as a fraction of 5 m is $30/500 = 3/50$

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Finding a fraction of a number or an amount

The rule is that whenever you see the word 'of' in maths, it means that you multiply.

Example: What is $\frac{3}{8}$ of 24?

$$\frac{3}{8} \times 24 = \frac{3 \times 24}{8} = \frac{72}{8} = 9 \quad \text{On your calculator that's } 3 \div 8 \times 24 = 9$$

Multiplying fractions

Rule: When you multiply fractions, just multiply the numerators and multiply the denominators.



WORKED EXAMPLE

Calculate $\frac{3}{4} \times \frac{2}{5}$

Solution

$$\frac{3}{4} \times \frac{2}{5} = \frac{3 \times 2}{4 \times 5} = \frac{6}{20} = \frac{3}{10}$$

Ratios

A ratio is a way to compare two or more amounts.

Recipes, for example, are sometimes given as ratios. To make pastry you usually need 2 parts flour to 1 part butter. This means that the ratio of flour to butter is 2 : 1.

If pastry is made with 2 parts flour to one part butter, then there are three parts (2 + 1) altogether. So, one third of the pastry is butter.



flour	flour	butter
-------	-------	--------

- ★ Ratios are similar to fractions; they can both be simplified by cancelling down.
- ★ Always write the ratio in the order that is stated in the question. The ratio of flour to butter is 2 : 1.

Example: There are 15 women and six men working in a health centre. What is the ratio of women to men? Give your answer in its simplest form.

The ratio of women to men is 15 : 6. However, both sides of this ratio will divide by 3. Dividing by 3 gives you 5 : 2.

So, the simplest form of the ratio is 5 : 2.

You may be asked to simplify a ratio to n : 1. In that case, just divide each side by n.

There are 5 times as many women as men.



Remember

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WORKED EXAMPLE

Anjula is 120 cm tall. Fiona is 1.5 m tall. What is the ratio of Anjula's height to Fiona's height in its simplest form?

Solution

★ You can't compare two amounts unless they are in the same units.

One amount is in centimetres, the other is in metres. You must convert Fiona's height to centimetres.

$$1.5 \text{ m} = 150 \text{ cm}$$

Now the ratio is $120 : 150$

Both sides will divide by 10; this makes it $12 : 15$

Both sides will divide by 3; this makes it $4 : 5$

Therefore, the ratio is $4 : 5$.

Ratios are also used when dividing up amounts.

Example: In a population of pea plants, the ratio of pink flowered plants to white flowered plants is 3 : 1. How many plants of each colour would you expect to find in a sample of 500?

1. Add the numbers in the ratio together. $3 + 1 = 4$

pink	pink	pink	white
------	------	------	-------

2. Divide the amount by this number. $500 \div 4 = 125$, so one part is **125 plants**

3. Multiply each of the numbers in the ratio by 125.

Pink flowered plants $3 \times 125 = \underline{375}$

White flowered plants $1 \times 125 = \underline{125}$

Check that the two parts add up to 500.

Sometimes you aren't given the whole amount, and you need to work it out. The numbers in the ratio represent the parts the numbers represent.

WORKED EXAMPLE

The ratio of girls to boys in a school is 13 : 12. There are 572 girls. How many pupils are there in the school altogether?

Solution

1. You know that there are 572 girls – that number represents 13 parts.

Therefore, one part = $572 \div 13 = 44$ pupils.



2. You are given that girls = 13 parts and boys = 12 parts, so that's 25 parts altogether.

$44 \times 25 = 1100$ pupils.

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Percentages and percentage change

- ★ 'Per cent' (%) means 'out of 100', so a percentage is a fraction with 100 as the denominator
- ★ If 70 per cent of the population has a mobile phone, this means that 70 out of every 100 people have a mobile phone

Converting fractions, decimals and percentages

Here are some conversions you should try to remember if you can – it will make life easier!

fraction	decimal	
 $\frac{1}{2}$	0.5	
$\frac{1}{4}$	0.25	
$\frac{1}{10}$	0.1	
$\frac{1}{3}$	0.3333...	
$\frac{1}{100}$	0.01	

- ★ To change a fraction to a percentage, multiply it by 100.

$$\frac{2}{5} \text{ converted to a percentage is } \frac{2}{5} \times 100 = \frac{200}{5} = 40 \%$$

- ★ To change a percentage to a fraction, put 100 as the denominator, then cancel it down.

$$64 \% \text{ expressed as a fraction is } \frac{64}{100} = \frac{32}{50} = \frac{16}{25}$$

- ★ To change a decimal to a percentage, multiply by 100 on your calculator or move the decimal point two places to the right, like this:

$$0.62 \text{ expressed as a percentage is } 62 \%$$

$$0.375 \text{ expressed as a percentage is } 37.5 \%$$

- ★ To change a percentage to a decimal, divide by 100 on your calculator or move the decimal point two places to the left, like this:

$$73.5 \% \text{ expressed as a decimal is } 0.735$$

$$60 \% \text{ expressed as a decimal is } 0.60, \text{ or just } 0.6$$

$$5 \% \text{ expressed as a decimal is } 0.05 - \text{be careful with this one}$$

Finding a percentage of an amount

A percentage is another way of writing a fraction with a bottom number of 100.

$$30 \% = \frac{30}{100}$$

So, to find 30 % of an amount, you must work out $\frac{30}{100}$ of that amount.

Example: 30 % of 90 mm = $30 \div 100 \times 90 = 27 \text{ mm}$

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Writing an amount as a percentage

Test results are often written as percentages because it makes it easier to compare

Example: A student receives the following results:

English	40 out of 50
Maths	45 out of 60
History	27 out of 30

Which is the student's best subject?

To find out, change each result into a percentage, like this:

Student's mark / Total for the subject $\times 100$

English $40 \div 50 \times 100 = 80\%$

Maths $45 \div 60 \times 100 = 75\%$

History $27 \div 30 \times 100 = 90\%$

The percentages allow the results to be compared very easily. In this case the lowest is the best result.

★ Any units of measurement can be used to make the fraction, but they must be the same.

WORKED EXAMPLE

Express 0.5 mm as a percentage of 2500 μm .

Solution

First you must make the units the same, so convert millimetres to micrometres.

$0.5 \text{ mm} \times 1000 = 500 \mu\text{m}$

The calculation is $\frac{500}{2500} \times 100 = 20\%$

Percentage increase or decrease

Often in scientific experiments we are measuring a change. For example:

- How much do plants grow with different amounts of water?

To investigate this, you could take five plants of the same species, give each a different amount of water each day for one or two weeks, and measure the increase in height of each plant.

However, it's very unlikely that your five plants would all be exactly the same height at the start of the investigation, so then how do you compare them?

The solution to this problem is to calculate the **percentage change**. This will tell you how much the plant has grown compared to how tall it was at the start.

To calculate a percentage change, whether it's an increase or a decrease, the formula is:

$\text{percentage change} = \frac{\text{actual change} \times 100}{\text{original amount}}$

- To work out the **actual change**, subtract the original amount from the new amount.
- A positive change is an increase; a negative change (for example -3) is a decrease.

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WORKED EXAMPLE

Three years ago Adam weighed 50 kg; now he weighs 65 kg. What is the percentage increase in Adam's weight?

Solution

1. Work out the actual increase in his weight '35' by subtracting the two amounts
2. Divide by the original weight '50 kg', and then multiply by 100 to

$$15 \div 50 \times 100 = 30\%$$

So, Adam's weight has increased by 30%.

**Estimating the results of simple calculations**

You don't always need an exact value for a number, especially a very long number. You can use a rough or an **approximate** value which gives you a good idea what the true value is.

For example, if you are reporting back on an experiment to investigate whether colour affects how quickly a plant makes food by photosynthesis, saying

The rate of photosynthesis of a plant under blue light is almost double the rate of photosynthesis under yellow light.

might be more relevant than saying

Under blue light the rate of photosynthesis is 33.7 units, whereas under yellow light it is 16.8 units.

If you are asked to **estimate** an answer, they want a sensible idea of how big the answer is, not a precise answer from your calculator.

You round off all the numbers in the problem to **one significant figure** to make 'easy' calculations. You do this in your head.

Example: Give an estimate of the answer to the calculation 608×29

5.8



Round each number to one significant figure, and then do the calculation:

$$\underset{6}{600} \times \underset{6}{30} = \underset{6}{18\,000} = \underset{6}{3000}, \text{ so the answer is } \underset{6}{3000}$$

There is more information about significant figures in the next section.

PRACTICE QUESTIONS

1. a) Copy and complete the table; the first one has been done for you.

Amount in words
Thirteen thousand five hundred and six
Two thousand and six hundred
One million seven hundred and fifty thousand



- b) Arrange the numbers from part a) in order of size, starting with the **smallest**.
2. Put these decimal numbers in order of size, starting with the **largest**.

0.702, 0.072, 0.72, 0.207, 0.27, 0.027

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3. Write these numbers in standard form.
 - a) Three billion
 - b) 250 000 000
 - c) 0.0015
4. Complete these statements using powers of 10.
 - a) A kilogram is _____ grams.
 - b) A millimetre is _____
 - c) A nanosecond is _____ seconds.
 - d) _____ are _____ μm
5. Calculate, giving your answer in standard form.
 - a) 3.6×10^4 multiplied by 5 million
 - b) 8.7×10^7 divided by 10^2
6. Bacteria of species X divides every 1.5 hours. Starting with one bacterium, how many are there after 36 hours?
7. Simplify the following ratios to $n : 1$.
 - a) 240 : 60
 - b) 1 metre : 10 centimetres
 - c) 7000 : 350
8. The ratio of cats to dogs in a rescue centre is 3 : 1. If there are 60 of these animals, how many are dogs?
9. Calculate:
 - a) $\frac{2}{5}$ of 600
 - b) $\frac{5}{9}$ of 450
10. Multiply these fractions, giving your answer in its simplest terms.
 - a) $\frac{3}{7} \times \frac{2}{5}$
 - b) $\frac{2}{5} \times \frac{10}{12}$
11. Three fifths of the trees in a wood are deciduous (lose their leaves in winter). If there are 120 trees in the wood, what is the total number of trees in the wood?
12. Copy and complete the table below. The first one has been done for you.

Fraction	Decimal
$\frac{1}{4}$	0.25
$\frac{3}{8}$	
$\frac{2}{5}$	
	0.04

13. In a school there are 800 students and 70 teachers. 15 % of the students and 20 % of the teachers are left-handed. How many left-handed people are there altogether?
14. Anika is on a diet to lose weight. At the start of the diet, she weighed 85 kg. After 4 weeks she weighed 70 kg. Calculate the percentage change in Anika's weight. Give your answer to 1 decimal place.
15. Estimate the answer to the following calculation. Your estimate should be a simple number.

$$\begin{array}{r} 31\,009 \\ 1926 \end{array}$$

$$\begin{array}{r} 1155 \\ 201 \end{array}$$

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2 HANDLING DATA

SPECIFICATION OVERVIEW

- 2a – Use an appropriate number of significant figures
- 2b – Find arithmetic means
- 2c – Construct and interpret frequency tables and diagrams, bar charts and histograms
- 2d – Understand the principles of sampling as applied to scientific data
- 2e – Understand simple probability
- 2f – Understand the terms mean, median and mode
- 2g – Use a scatter diagram to identify a correlation between two variables
- 2h – Make order of magnitude calculations

THEORETICAL OVERVIEW

Significant figures (sf)

When we get a long decimal answer on a calculator, we could round it off to a certain number of significant figures.

Another method for giving an approximated answer is to round off using **significant figures**.

The word **significant** means important. The closer a digit is to the beginning of a number, the more significant it is.

In the number **368 249**, the **3** is the most significant digit because it tells us that there are **three hundred thousand** and something. It follows that the **6** is the next most significant, and so on.

3 6 8 2 4 9

You may be asked to round off a number using a certain number of significant figures. For example, round off 368 249 to 3 significant figures.

The rules for rounding are:

- Find the digit you want.
- If the next digit is **5 or more**, you **round up**.
- If the next digit is **4 or less**, you **do not round up**.

Use zeros to fill in spaces and to keep the value of the number.

WORKED EXAMPLE

Write the number 368 249 correct to 2 significant figures.

Solution

3 6 8 2 4 9

Identify the first two digits. They are 3 and 6. Therefore, so far, we have **360 000**.

Look at the next digit. It is 8, so you round the 6 up to 7.

Don't forget to put zeros in, so that the number still has the same value.

The final answer is **370 000**.

You can also round off very small numbers in the same way. The first digit after the decimal point is the most significant.

In the number **0.0058763**, the **5** is the most significant digit because it tells us that there are **five thousandths** and something. The **8** is the next most significant, and so on.

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WORKED EXAMPLE

Write the number 0.0058763 correct to 2 significant figures.

Solution

0 . 0 0 5 8 7 6 3

1. Identify the first two numbers after the decimal point that aren't zeros. The far, you have 0.0058.
2. Look at the next digit, which is 7, so you must round the 8 up to 9.
3. To keep the value, you need the zeros between the decimal point and the 5, and the ones after.

The answer is 0.0059

Recording survey data – frequency tables, bar charts and histograms**Categoric, discrete and continuous variables**

- **Categoric** variables are described in words, and the categories are separate. Examples include blood group, and species of animal.
- **Discrete** variables are measured in numbers, but only some numbers have meaning. The number of children in a family is discrete because you can't have half a child.
- **Continuous** variables can cover any value within your range of accuracy. For example, height in centimetres, or mass in kilograms, are possible and have meaning.

Frequency tables

A frequency table is first of all a table – a table that shows how often a particular value occurs.

The data can also be shown in a bar chart or a histogram, depending on whether the variable is discrete or continuous.

Example: Some students were investigating the species of wildflowers in their local area. They counted the numbers of five plant species in a $2\text{ m} \times 2\text{ m}$ square. Their frequency table looks like this:

Plant species	Tally	Frequency
Daisy	- - III	18
Buttercup	III	8
Plantain	II	7
Clover	-	10
Trefoil	II	2

A set of data like this is called a **frequency distribution**.

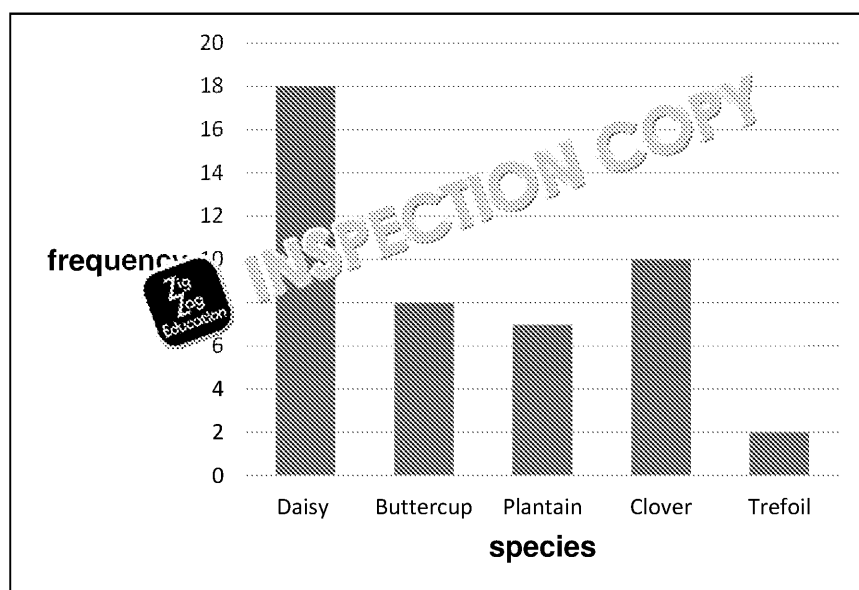
Tally marks are used to count the data in groups of five, so it's easier to read.

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Bar charts

For data where you count the frequencies of categoric or discrete variables, you will get numerical results. The bar chart for this set of data would look like this:



Notice the bars are separate. You can have the same same have pencil

In this example, there are single bars because the researcher was counting only one variable. However, a slightly different type of bar chart can show more than one categoric variable.

Example: A student collected data about the hair colour and eye colour of a group of people. This is a two-way table.

		Hair colour				
		Black	Brown	Blonde	Red	Grey
Eye colour	Brown	20	30	10	4	26
	Blue	2	10	6	2	15
	Green	2	5	3	6	4

The information in the two-way table can also be shown as a multiple bar chart, like this:

Decide which category you are going to put on the horizontal scale – in this case it's hair colour.

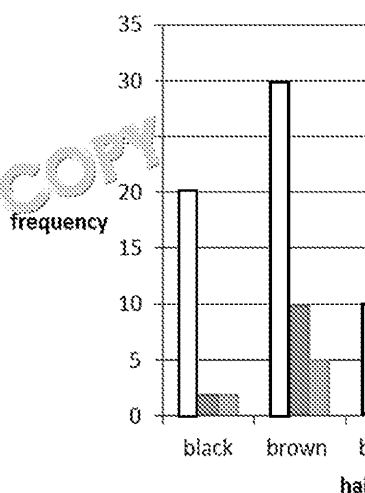
Then for each hair colour you draw a bar for the numbers with brown, blue and green eyes.

Always include a key to show what each bar represents.

Anybody could look at this and draw conclusions.

- Nearly everybody in the sample who has black hair also has brown eyes.
- The least common hair colour is red.

Again, notice that there is a gap between the groups of bars for each hair colour.



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Continuous data

If you are counting frequencies for a continuous variable such as height or weight, You need to group the data carefully so that every individual is counted just once.

Example: This frequency table shows the *heights* of 25 secondary school pupils.

Height (cm)	120–130	130–140	140–150	150–160
Frequency	4	6	10	5

However, there's a problem with the table because if somebody is exactly 140 cm and, therefore, they will be counted twice.

However, you can't have 120–129, 130–139, etc. because it's possible for a person to be 129.4 cm tall or 129.99 cm tall and, therefore, not be counted at all.

A better way of representing grouped continuous data is to use **inequality signs** to

Symbol	Meaning
<	is less than, so $2 < 5$ is a true statement
>	is more than, so $6 > 4$ is a true statement
\leq	is less than or equal to, so $2 \leq 5$ is true, and so is $5 \leq 5$
\geq	is more than or equal to, so $6 \geq 4$ is true, and so is $5 \geq 5$

So, the table of results for this set of data would look like this:

Height (cm)	Frequency
$120 \leq h < 130$	4
$130 \leq h < 140$	6
$140 \leq h < 150$	10
$150 \leq h < 160$	5

For example, $120 \leq h < 130$ means that

- 120 cm is **less than or equal to** the height of the people in this group, and
- the height of the people in this group is **less than** 130 cm.

People who are **exactly** 120 cm tall will come into this group because of the equals sign.

When you draw a bar chart for this frequency distribution, the bars are joined together because height is a **continuous** variable. A bar chart like this is called a **histogram**.



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WORKED EXAMPLE

A farmer measured the height of 20 young fruit trees in his orchard. These

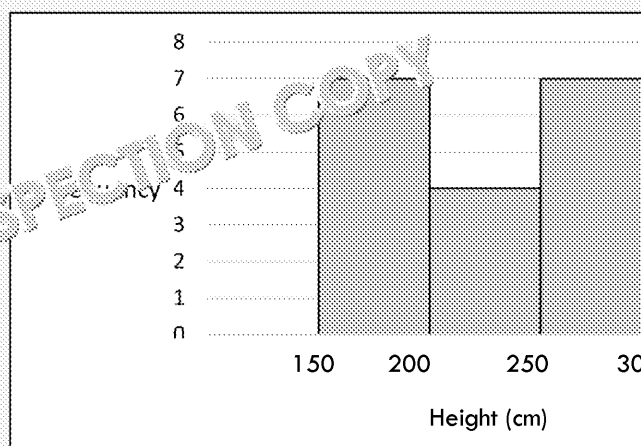
175 cm	230 cm	250 cm	185 cm
281 cm	228 cm	160 cm	260 cm
309 cm	286 cm	290 cm	180 cm
320 cm	210 cm	205 cm	190 cm

Display these results in a grouped frequency table and in a histogram.

Solution

The smallest height is 160 cm, and the largest is 320 cm, so it would make sense to group the data like this:

Height (cm)	Frequency
$150 \leq h < 200$	7
$200 \leq h < 250$	4
$250 \leq h < 300$	7
$300 \leq h < 350$	2



Sampling

If researchers need to carry out a survey, it is not always possible to test a whole 'population'; for example, you couldn't count every single plant in a field, or ask every person in the UK with heart disease about the medication they are on.

In cases such as this, a method of sampling is needed. You need a sample which **represents** the population as a whole and is not **biased**.

Biologists sometimes need to find out what species of plants and animals live in a habitat, and then monitor their numbers to see whether they are changing.

It is usually not possible to count the entire population, so scientists take a **sample** and then use it to **estimate** the total population.

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Scientists usually use **quadrats** to sample plant populations. A quadrat is usually a square. The plants underneath can be identified and counted.

If you know the area of the habitat and the area under the quadrats, you can calculate the numbers of organisms in the habitat.

Example: There are 12 dandelion plants inside a 1 m² quadrat. The whole field is 150 m² in area. The estimated population of dandelions in the field would be:

$$12 \times (150 \div 1) = 12 \times 150 = 1800$$

However, it's important that the quadrats are placed **at random**.

That means the people do not choose where to place them, because they could be biased without realising it.

The best way is to measure out the habitat and divide it up into a numbered grid.

Each square on the grid will have two numbers – one horizontal and one vertical – for example, the shaded square on this grid is 4,12.

Then, you use a computer or a calculator to generate two random numbers between 1 and 20. Use these numbers as coordinates for where you place the quadrat.

- ★ **The validity and reproducibility of the results increase the more quadrats you use.**
- ★ **Random numbers can also be used to choose people to take part in health surveys.**

	1	2
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		

WORKED EXAMPLE

A doctor's surgery has 1600 patients who are over 16 years old. A doctor wants to select 100 of these patients to be interviewed to take part in a health and lifestyle survey. How can the doctor do this?

Solution

The surgery could assign each of the 1600 patients a number, and then use a computer to generate 100 random numbers.

Remember: when carrying out a **random sample**, you must make sure that every patient has a chance of being chosen.

Analysing data – mean, mode, median and range

When you do experiments or surveys, you are collecting results. These are called **raw data**. You can do anything with them yet.

Once raw data has been collected, it needs to be **analysed** to see what it tells the scientist.

This is done by measuring the **range** of the data and the **average** or **middle value** of the data.

The four values used in analysing raw data for GCSE are **mean**, **median**, **mode** and **range**.

- ★ **Mean is the total of all the results divided by the number of results – this is what people find the average, and it's also called the arithmetic mean because you have to do arithmetic.**

Scientists usually repeat their experiments and calculate the mean of their results – the more likely the mean is to be reliable.

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The **mean** gives you an idea of the average value, but it is not always a good measure of any extreme values (those that are a lot bigger or a lot smaller than the others) as

For example, if you are trying to find the average height of a group of 10-year-olds in the group who is unusually tall for their age, this will push the mean up. If you were to park visit for this group, you might find that more children than you expected were too

In the case of experiment results, where there are repeated results, if one result is much better than the others, researchers call this an anomalous result and ignore it when they calculate

★ **Median** is the middle value when the values are arranged in order from smallest to largest.

61 77 83 88

If there is an even number of values, the median is the average of the middle two values.

3.2 3.4 3.6 3.8 3.9

The median will be $\frac{3.6 + 3.8}{2} = 3.7$

The **median** can be used if there are any extreme values because it is not affected by them. The end could be anything as far as the median is concerned; the middle value is still the same. The advantage about the median is that you know exactly half the values are above it and half are below it.

★ **Mode** is the most common value – the value with the highest frequency. The mode is used for categorical variables such as species of plant or animal; for example, it will tell you the most common in a park.

★ **Range** is the difference between the smallest value and the largest value. It tells you how spread out the data is.

The range can be written either as a difference between two numbers or as '... to ...'.

For example, if the highest result in a test is 20 and the lowest is 6, the range of marks is 14 (20 - 6 = 14).

Finding the mean, median, mode and range for a set of data:

WORKED EXAMPLE 1 – discrete distribution with a small number of values

Student A took 11 tests during the term. These were her marks out of 20:

10 14 10 12 10 11 12 10

Work out the mean, median, mode and range of Student A's results.

Solution

- To find her **mean** score, just add up all the marks and then divide by the number of tests.

$$\frac{10 + 14 + 10 + 12 + 10 + 11 + 12 + 10 + 10 + 11 + 12}{11} = \frac{121}{11} = 11$$

- To find her **median** score, first arrange the marks in order.

Put the marks in order: 9 10 10 10 10 11 11 12 12 12 14

Find the middle number: 9 10 10 10 10 11 11 12 12 12 14

The middle number is 11, so the median is 11

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WORKED EXAMPLE 1 (CONTINUED)

- To find the **mode**, also called the **modal score**, you need to identify the number that occurs the most.

Put the numbers in numerical order: 9 10 10 10 10 11 11 12 12

The number 10 occurs most often, so the **mode** is 10.

- To find the **range** of the data:

Find the lowest mark; this is 9

Find the highest mark; this is 14

Subtract the lowest number from the highest number: $14 - 9 = 5$, so the range is 5.

WORKED EXAMPLE 2 – discrete distribution with a larger number of values
frequency table

A group of 25 adults were asked how many children they each have:

Number of children	Frequency
0	3
1	8
2	12
3	1
4	1

Three adults have no children

Eight adults have one child

Twelve adults have two children

One adult has three children

One adult has four children

Work out the mean, median, mode and range of these data.

Solution

- To find the **mean**:

You need to find the mean number of children per adult.

- Find the **total number of children**. To do this you multiply the number of adults that have that number of children (the frequency):

$$3 \text{ adults have } 0 \text{ children each} \quad 3 \times 0 = 0 \text{ children}$$

$$8 \text{ adults have } 1 \text{ child each} \quad 8 \times 1 = 8 \text{ children}$$

$$12 \text{ adults have } 2 \text{ children each} \quad 12 \times 2 = 24 \text{ children}$$

$$1 \text{ adult has } 3 \text{ children} \quad 1 \times 3 = 3 \text{ children}$$

$$1 \text{ adult has } 4 \text{ children} \quad 1 \times 4 = 4 \text{ children}$$

$$\underline{39 \text{ children}}$$

- Find the **total number of adults**. In this case the question tells you, but you can also add the numbers in the frequency column: $3 + 8 + 12 + 1 + 1 = 25$

- Divide the number of children by the number of adults: $39 \div 25 = 1.56$

★ This is the **arithmetic mean**, and it is a theoretical value – you can't have half a child.

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WORKED EXAMPLE 2 (CONTINUED)

- To find the median
 - Find the **total number of adults**. In this case the question tells you, but if not, add the numbers in the frequency column: $3 + 8 + 12 + 1 + 1 = 25$
 - Find the **middle number**. $\frac{25 + 1}{2} = 13$ so the median is the 13th adult
 - Count through the frequency column until you get to the 13th adult – it's the 2nd column, so the frequency is 2
- To find the **mode** just look for the highest frequency – 12 adults have two children
- To find the **range** you subtract the lowest number of children from the highest number of children: $4 - 0 = 4$

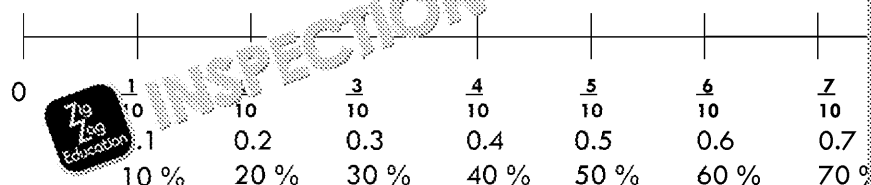
Probability

Probability means how **likely** it is that something will happen.

It is measured on a scale between 0 and 1, or between 0 % and 100 %.

- A probability of zero means that something is **impossible**.
- A probability of 1 or 100 % means it is **definitely going to happen**.
- Unlikely events have a probability between 0 and $\frac{1}{2}$; likely events have a probability between $\frac{1}{2}$ and 1.

Probability can be written as a fraction, as a decimal, or as a percentage, like this:



Calculating probabilities

When different **outcomes** of an event are equally likely to happen, you can use the probabilities of the different outcomes:

$$\text{probability of the outcome} = \frac{\text{number of ways that the outcome can happen}}{\text{total number of possible outcomes}}$$

Example:

When you throw a fair dice there are **six possible outcomes**: 1, 2, 3, 4, 5 or 6.

- What is the probability that you throw a 6?**
There is only **one** way of throwing a 6, so the probability is $\frac{1}{6}$

- What is the probability that you throw an odd number?**
There are **three** odd numbers – 1, 3 and 5 – so the probability is $\frac{3}{6}$

$$\frac{\text{number of ways of throwing an odd number}}{\text{all the possible numbers}} = \frac{3}{6} = \frac{1}{2} \text{ or } 0.5 \text{ or } 50 \%$$

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Finding the probability of something not happening

Any outcome is **either** going to **happen** or **not happen**, so the probability that something will happen is **100 %** minus the probability that it **will** happen.

WORKED EXAMPLE

The probability that it will rain on any day in December is $\frac{1}{5}$. What is the probability that it will not rain on 5th December?

Solution

The probability that it will not rain is $1 - \frac{1}{5} = \frac{4}{5}$

For a set of data from a survey or an experiment, you can calculate the probability of an event occurring by dividing the number of times it occurs in the sample.

Example: If 80 trees in a wood were checked, and 20 of them were found to be diseased, the probability that a tree selected at random is diseased will be

$$\frac{\text{diseased trees}}{\text{total trees}} = \frac{20}{80} = \frac{1}{4} \text{ or } 0.25 \text{ or } 25\%$$

With any data, the bigger the sample the more likely it is to reflect the general population. A sample of 1000 trees would give a more reliable probability than a sample of 80 trees.

The AND/OR rule

If you are asked to find the probability that **outcome A and outcome B both happen**, you add the probabilities together.

WORKED EXAMPLE 1

Every time a baby is born, the probability that it will be a girl is $\frac{1}{2}$. What is the probability that the first three children born will all be girls?

Solution



$$\begin{array}{ccccccc} & \text{Child 1} & & \text{Child 2} & & \text{Child 3} & \\ & \frac{1}{2} & \times & \frac{1}{2} & \times & \frac{1}{2} & = \frac{1}{8} \end{array}$$

If you are asked to find the probability that **either outcome A or outcome B happens**, you add the probabilities together.

WORKED EXAMPLE 2

Mrs Begum buys a pack of 50 mixed flower bulbs to plant in her garden. The bulbs are as follows:

Tulips	10
Daffodils	10
Snowdrops	15
Bluebells	15

She picks a bulb at random. What is the probability that it is a bluebell or a snowdrop?

Solution



$$\frac{\text{bluebells + snowdrops}}{\text{total bulbs}} = \frac{15 + 15}{50} = \frac{30}{50} = \frac{3}{5}$$

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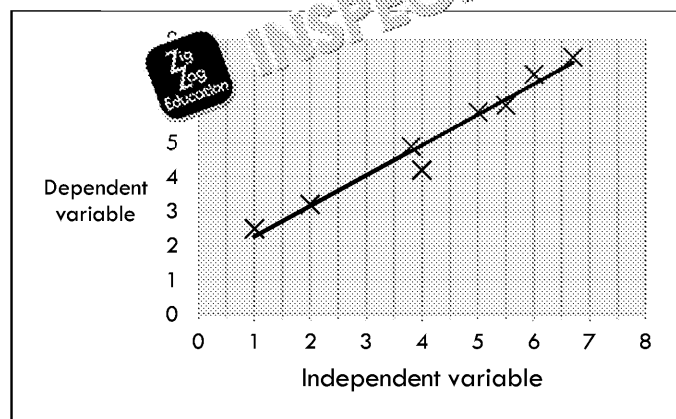
Scattergraphs and correlation

Scattergraphs are a way of plotting two variables against each other to see whether there is a relationship between them. They are often used to record experiment results, and there is more about how to design them in the chapter on graphs.

If the two variables are related, you will be able to draw a **line of best fit** showing the relationship. (You can just use your judgement to do this – it does **not** have to pass through any one point, but it should pass roughly through the middle of them.)

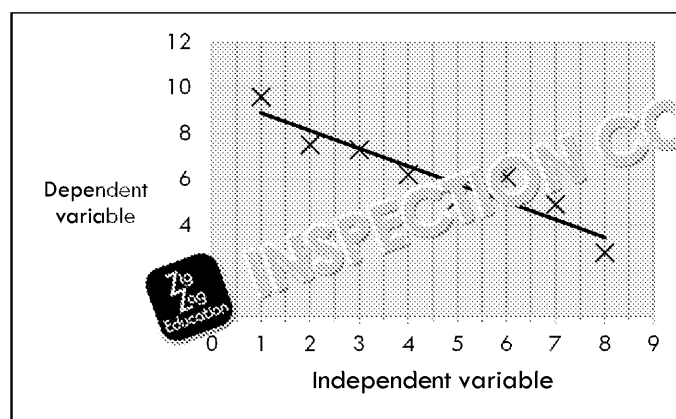
★ If there is a **correlation** between two variables, it means that they are related in some way.

Examples:



Positive correlation
as the independent variable increases, so does the dependent variable.

★ For more information about independent and dependent variables, see Chapter 1.



Negative correlation
as the independent variable increases, the dependent variable decreases.

The closer the crosses are to the line of best fit, the stronger the correlation.

★ Sometimes when you have plotted your results on the graph you can see that they are more like a curve than a straight line.

If you can't get a line or curve of best fit at all, then there is **no correlation** – the two variables are not related.

More information about plotting graphs from experimental data is included in the chapter on graphs.

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WORKED EXAMPLE

A student investigated the effect of exercise on his heart rate.

He measured his heart rate before starting his experiment, using a digital heart rate monitor.

He then pedalled an exercise bike at a constant speed for four minutes, measuring his heart rate every minute. These were his results:

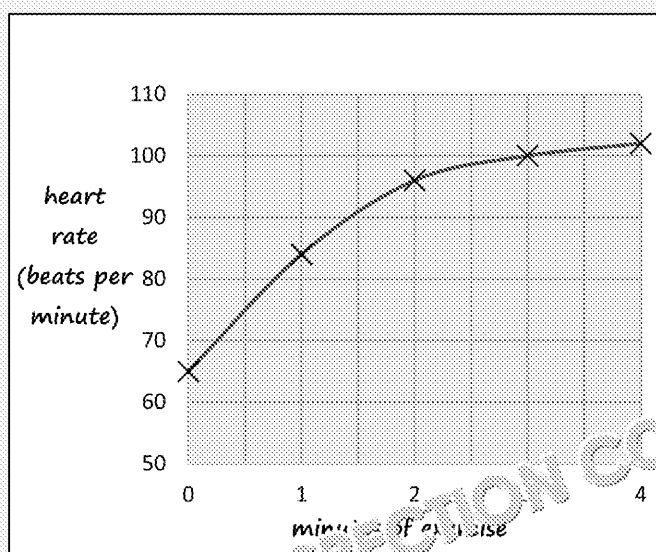
Minutes of exercise	0	1	2	3	4
Heart rate (beats per minute)	65	84	96	100	102

Draw a graph of these results, including a line or curve of best fit.

Solution



Your graph would look like this:



This graph tells you the duration of exercise.

However, it doesn't tell you the heart rate.

You can see that as the duration of exercise increases, the pulse rate increases and then more slowly.

Join up your points with a smooth curve, like the one shown.

This is called a best-fit curve. It is a smooth curve that passes as close as possible to every individual result.



Order of magnitude calculations

Order of magnitude is a way of comparing amounts to the nearest power of 10. It's good for comparing very large or very small numbers.

WORKED EXAMPLE

A cell in the human breathing passages is approximately 16 micrometres long.

A flu virus is approximately 80 nanometres long.

By how many orders of magnitude is the human cell larger than the virus?

Solution

First convert the cell size and the virus size into standard form:

Human cell: 1 micrometre (μm) = 10^{-6}m , therefore, $16\text{ }\mu\text{m} = 16 \times 10^{-6}\text{m}$

Virus: 1 nanometre (nm) = 10^{-9}m , therefore, $80\text{ nm} = 80 \times 10^{-9}\text{m} = 8 \times 10^{-8}\text{m}$

Now do the calculation on your calculator: human cell \div virus

$$1.6 \times 10^{-5} \div 8 \times 10^{-8} = 200$$

$200 = 2 \times 10^2$ so the human cell is two orders of magnitude larger than the virus.

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PRACTICE QUESTIONS

- Write 47 392 to 1 significant figure.
 - Write 0.009854 to 2 significant figures.
 - Calculate 17.5 % of 2390. Give your answer to 2 significant figures.
- Here are seven numbers:

13 6 2 5 4 8

Calculate:

- The mean
 - The median
 - The range
 - The range
- The table shows information about the marks of 30 students in a test.

Mark	Frequency
14	2
15	10
16	2
17	3
18	13
	Total = 30

- Calculate the mean mark for this class.
 - Students who scored less than the mean mark are required to retake the test. How many students must retake the test?
- A group of students counted trees of four species in their local park. They obtained the following results:

beech	cherry	beech	beech
sycamore	rowan	cherry	rowan
cherry	beech	rowan	rowan
beech	cherry	beech	rowan

- Design a frequency table for these results.
 - Display the data in a fully labelled bar chart.
- The weights of 30 teenage girls were recorded in this frequency table:

Mass (kg)	Frequency
$40 < x \leq 50$	6
$50 < x \leq 60$	17
$60 < x \leq 70$	5
$70 < x \leq 80$	1
$80 < x \leq 90$	1

- Draw a fully labelled frequency diagram for these data.
- A new girl joins the group. She weighs exactly 60 kg. Which group does she belong to?

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6. Some students were investigating the population of daisy plants in a field. They used this method:

1. Place 10 1 m² quadrat frames in random positions around the field.
2. Count the number of plants in each quadrat.
3. Record the results in a table and calculate the mean.
4. Use this to estimate the total number of plants in the field.

- a) What would be the best way to choose the quadrats to get a valid sample?
- (i) Close their eyes and throw the quadrats.
 - (ii) Use a computer to generate random numbers.
 - (iii) Distribute the quadrats evenly across the field.

- b) The table below shows the students' results:

Quadrat	Number of daisy plants
1	5
2	3
3	7
4	2
5	8
6	5
7	2
8	5
9	3
10	5
Total	

- c) Calculate the mean number of daisy plants per square metre.
- d) The field has an area of 8000 m². Use your answer from part b) to estimate the total number of daisy plants in the field.

7. Staff at an animal rescue centre recorded the colour of 20 cats in their care.

Colour	Frequency
Tabby	8
Black and white	6
Black	3
White	1
Grey	2

A cat is chosen at random. Calculate the probability that:

- a) White
- b) Not grey
- c) Tabby or black

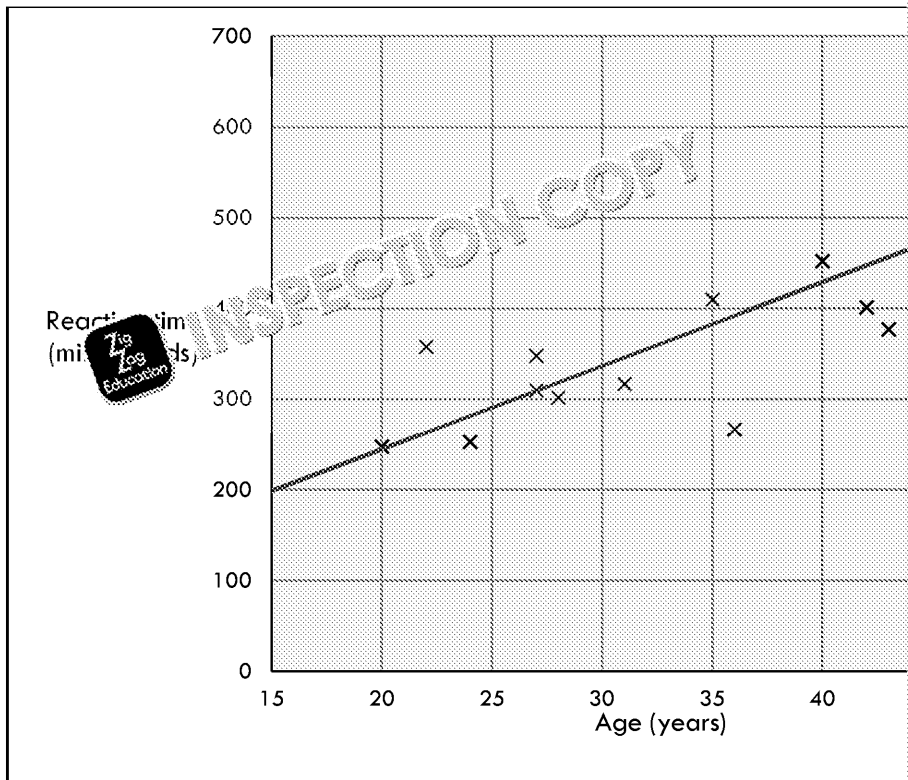
Write each answer as a fraction, in its simplest form.

8. The probability that a patient is carrying *Staphylococcus aureus* bacteria on their skin is about $\frac{1}{100}$. Patients who need to go into hospital are tested to see whether they are carriers. If a hospital tests 3600 patients, estimate how many will **not** be carriers.

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9. A group of adult students investigated the effect of age on their reaction time programme to measure their reaction times in milliseconds and plotted this scatter graph.



- How old was the person whose reaction time was 410 milliseconds?
 - What type of correlation does the graph show?
 - Which of these would be the best conclusion to draw from these results?
 - Younger people always have faster reactions than older people.
 - Younger people always have slower reactions than older people.
 - Younger people tend to have faster reactions than older people, but not all individuals.
 - Younger people tend to have slower reactions than older people, but not all individuals.
10. An egg-laying chicken consumes about 120 g of food per day. Give the order amount of food consumed by 50 chickens in one year, in kilograms.

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3 ALGEBRA

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SPECIFICATION OVERVIEW

3a – Understand and use the symbols =, <, <<, >>, >, \propto , ~

3c – Substitute numerical values into algebraic equations using appropriate units

3d – Solve simple algebraic equations

THEORETICAL OVERVIEW

Symbols

You already know <, > and \geq from your work on handling data. You also need

Symbol	Meaning
<<	< means less than, << means much less than, so 2 mm << 5 km is a true statement
>>	> means more than, >> means much more than, so 600 kg >> 4 g is a true statement

Notice that with these arrow symbols, the bigger quantity goes next to the bigger quantity goes at the 'point' of the arrow.

small < big

big > small

You also need to know these symbols:

=	means exactly equal to; for example, $17.45 + 12.39 = 29.84$
~	means approximately equal to; for example, $17.45 + 12.39 \sim 30$ In maths, the symbol for π (pi) actually works out as 3.141592654... to a long number of places but mostly we just use 3.14 $\pi \sim 3.14$
\propto	means is proportional to . Two variables are in direct proportion when they have the same ratio. For example, when you make pastry, the amount of flour is proportional to the amount of butter, you must also double the amount of flour. If you plot the two variables on a graph, you will always get a straight line through the origin. The mathematical symbol for direct proportion is \propto . $\propto x$ means y is proportional to x.

Working with formulas

A formula is an equation or expression in algebra which describes the **relationship** between variables.

Formulas are used a lot in science; an example is the formula for calculating speed:

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

which means **speed = distance ÷ time**, where d is the actual distance and the actual time taken. The ratio stays the same.

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Solving equations

- In an equation, the number you are trying to find is represented by a letter, so
- Solving** the equation is working out the value of the letter.

An equation works like a balance with an equals sign (=) in the centre.
Both sides of the balance need to be kept equal.

Example: $x + 2 = 6$

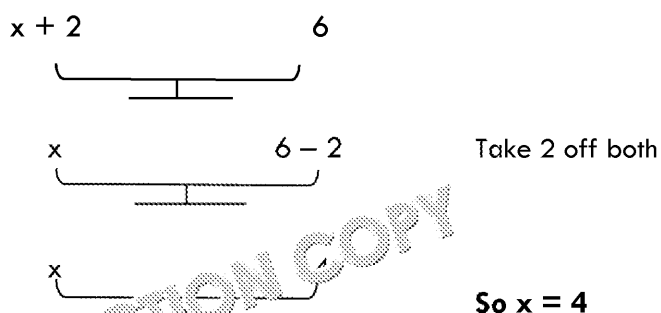
You want to get a simple value, $x =$ a number.

So you take 2 off the left side, leaving x on its own.

Now you must take 2 off the right side to keep the balance.

$$\begin{aligned} x + 2 - 2 &= 6 - 2 \\ x &= 4 \end{aligned}$$

Here is the same problem in diagram form.



You can play around with an equation to get the answer, if you obey one basic rule:

- ★ **Whatever you do to one side of the equals sign, you must do the same thing to the other side.**

The best way to solve an equation is to **get the letter on its own on the left side** of the equals sign.

To do this, you must get rid of everything else from the left side by adding, subtracting, multiplying or dividing.

To get rid of something, you **do the opposite**. For example:

- $x + 2 = 9$ you **subtract 2** from both sides, so $x = 7$
- $y - 2 = 9$ you **add 2** to both sides, so $y = 11$
- $2p = 9$ you **divide** both sides by 2, so $p = 4.5$
- $\frac{a}{2} = 9$ you **multiply** both sides by 2, so $a = 18$
- $m^2 = 9$ you **square root** both sides, so $m = 3$
- $\sqrt{n} = 9$ you **square** both sides, so $n = 81$

Don't forget to **do the same thing to both sides** of the equation, or it won't work.

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Two-step equations

Sometimes you need to do more than one thing to get the letter on its own.

WORKED EXAMPLE

Solve $2x + 3 = 13$

Solution

- First get rid of the things that aren't attached to what's + 3.

The opposite of + is -, so subtract 3 from each side

$$\begin{aligned} 2x + 3 - 3 &= 13 - 3 \\ 2x &= 10 \end{aligned}$$

- You want x on its own, so divide both sides by 2. $\Rightarrow x = 5$

Solving equations with fractions

In algebra, divisions are written as fractions.

$x \div 2$ is written $\frac{x}{2}$ and $3 \div a$ is written $\frac{3}{a}$

If the letter you are trying to find is part of a fraction, you need to get rid of the denominator and you do that by multiplying.

So, if $\frac{x}{2} = 15$ then $\frac{x}{2} \times 2 = 15 \times 2$ so $x = 30$

WORKED EXAMPLE 1

Solve $\frac{2t + 5}{3} = 7$

Solution

- First get rid of the denominator of the fraction on the left. To do this you multiply both sides by 3.

$$\frac{2t + 5}{3} \times 3 = 7 \times 3 \quad \text{so } 2t + 5 = 21$$

- Now get rid of + 5. $2t + 5 - 5 = 21 - 5$ This simplifies to $2t = 16$
- Now divide both sides by 2 to get t on its own. $t = 16 \div 2$, so $t = 8$

WORKED EXAMPLE 2

Solve the equation $\frac{2t}{3} + 5 = 7$

Solution

Notice that in this example the +5 is not part of the fraction, it's just added on away before you multiply:

- First get rid of + 5. The opposite of + is -, so subtract 5 from each side.

$$\frac{2t}{3} + 5 - 5 = 7 - 5 \quad \text{This simplifies to } \frac{2t}{3} = 2$$

- Now get rid of the fraction on the left. To do this you multiply both sides by 3.

$$\frac{2t}{3} \times 3 = 2 \times 3 \quad 2t = 6$$

- Now divide both sides by 2 to get t on its own. $t = 6 \div 2$, so $t = 3$

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Substituting numbers into equations

If you know some of the variables in a formula or an equation, you can find the others if you know instead of the letters.

★ *It's only possible to find one missing number at a time.*

So, in the speed formula, if you know that the distance is 180 miles and the time is 3 hours,

$$s = \frac{d}{t} = \frac{180}{3} = 60 \text{ miles per hour}$$

When you have found the missing value, you have **solved** the equation.

WORKED EXAMPLE

Body mass index (BMI) is a measure of a person's weight relative to their height. The formula is

$$\frac{m}{h^2}$$

where m is the mass (weight) in kilograms and h is the height in metres.

Amina is 1.64 metres tall, and she weighs 60 kilograms. Calculate her BMI.

Solution

1. Substitute 60 for m in the formula, and 1.64 for h
2. Now do the calculation on your calculator $60 \div 1.64^2 = 22.3081...$

Amina's BMI is **22.3**

You will often be able to work out the **units** using the information you have been given.

For example, the **density** of a substance is found using the equation:

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

If the mass is measured in grams (g) and the volume is measured in cubic centimetres (cm³), then the density is measured in **grams per cubic centimetre (g/cm³)**.

★ *Whenever you see the word per, it always means divide. Miles per hour is miles divided by hours.*

Biology application – calculating magnification

A microscope magnifies a small object to give a larger image.

You are dealing with **three** numbers:

- The **actual size** of the object (**A**)
- The **magnification** of the microscope (**M**)
- The **image size** (**I**)

Actual size × Magnification = Image size, or $A \times M = I$

If you know **two** of these numbers you can always work out the other one.

There are two ways of doing this:

Method 1

Just remember that **the image is always the big amount** because that's what you're looking at. So, if you know the actual size and the magnification, you can find the image size by multiplying them together.

$$A \times M = I$$

Therefore, if you are trying to find I , you multiply: $I = A \times M$

If you know I and you are trying to find one of the others, you divide: $A = I \div M$ or $M = I \div A$

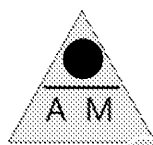
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- **Method 2: use the formula triangle**

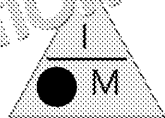
Cover the value you're trying to find with your finger, and the triangle will tell you what sum to do.

To find the **image size**



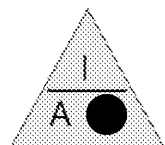
$$I = A \times M$$

To find the **actual size**



$$A = I \div M$$

To find the **magnification**



$$M = I \div A$$

WORKED EXAMPLE

The image shows a cross section of a plant root tip, as seen under the microscope.

The image has been magnified 40 \times .

Calculate the width of the root tip.

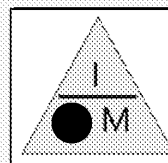
Solution

First write down what you already know

$$I = 25 \text{ mm}$$

$$M = 40 \text{ so you need to find } A$$

$$\text{Actual width of root tip} = I \div M = 25 \div 40 = 0.625 \text{ mm}$$



PRACTICE QUESTIONS

1. Insert one of the following symbols into each space in these expressions to make them true.

=	<	<<	>	>>	\propto	\sim
---	---	----	---	----	-----------	--------

a) $0.375 \text{ } \underline{\hspace{1cm}} \text{ } 1/2$

b) $12 \times 7 \text{ } \underline{\hspace{1cm}} \text{ } 80$

c) One million $\text{ } \underline{\hspace{1cm}} \text{ } 10^6$

d) One nanometre $\text{ } \underline{\hspace{1cm}} \text{ } \text{one millimetre}$

e) $\frac{9778}{503} \times 1.95 \text{ } \underline{\hspace{1cm}} \text{ } 37$

2. Solve the following equations.

a) $7x - 4 = 17$

b) $\frac{2a}{3} + 5 = 25$

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3. The speed at which something moves can be calculated using the equation

$$s = \frac{d}{t} \quad \text{or} \quad \text{speed} = \frac{\text{distance}}{\text{time}}$$

In a human reflex action, such as moving your hand away from a hot object, the impulse travels at 100 metres per second (m/s).

How long would the impulse take to travel 0.9 m? State the **units** of your answer.

4. When you look at cells under the microscope, you see a magnified image.

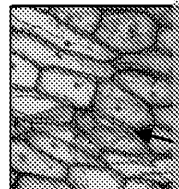
Actual size \times Magnification = Image size

If you know two of these, you can work out the third.

- a) These onion cells have been magnified by 100 \times .

The distance shown on the diagram is 29 millimetres.

Calculate the actual length of the onion cell. 2 marks



- b) This cross section of a young plant root is 1.2 millimetres wide.

The distance shown on the diagram is 48 millimetres.

Calculate the magnification. 2 marks

- c) An *E. coli* bacterium is 0.6 micrometres (μm) long. It is magnified 12 000 times under an electron microscope. How long will the image be? Give your answer in **millimetres** for a third mark. 3 marks

5. Medicines use very small amounts of drugs, and these are usually measured in milligrams (mg). A milligram is one thousandth of a gram.

Sometimes children need to have medicines that are usually prescribed to adults. Working out the appropriate dose.

Young's rule uses this equation:

$$\text{Child dose (mg per day)} = \text{Adult dose (mg per day)} \times \frac{\text{Age of child}}{\text{Age} + 12}$$

Use this rule to work out the correct dose for an eight-year-old child, when the adult dose is 100 mg per day.



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4 GRAPHS

SPECIFICATION OVERVIEW

- 4a – Translate information between graphical and numeric form
- 4b – Understand that $y = mx + c$ represents a linear relationship
- 4c – Plot two variables from experimental or other data
- 4d – Determine the slope and intercept of a line of best fit

THEORETICAL OVERVIEW

When you carry out a scientific experiment, you are trying to answer a question about variables. For example:

What happens to a person's pulse rate when they exercise?

Do young people have faster reactions than older people?

How does light affect plant growth?

You are trying to find out how one variable affects the other. You do this by changing the effect, and then measuring what happens to the other one.

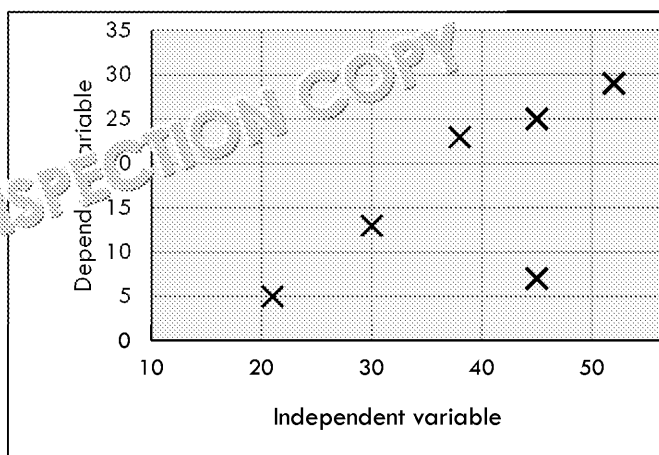
The variable you change on purpose is called the independent variable. You choose its values.

The result that you measure is called the dependent variable. You measure it for each value of the independent variable.

Designing and plotting a graph from a table of results

- The independent variable goes on the horizontal axis; the dependent variable goes on the vertical axis.
- Label each axis and include units of measurement.
- For each axis, use a sensible scale. It doesn't always have to start from zero – for example, 10 to 50. Go from the smallest to the largest value for each variable. Decide how much each square should represent.
- Plot your results onto the graph as small crosses.
- Look for the pattern, and then draw in your line or curve of best fit. Use a sharp pencil. Draw the line or curve beyond the values you are given.
- You may have a result that does not fit the pattern of the others, as shown in the graph below.
- This is called an **anomalous** result.
- Check that you have plotted it correctly and, if you have, draw a circle around it.

If you can't get a line or curve of best fit at all, write **no correlation** on your graph. If the results are **random** and do not show a relationship between the two variables.



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WORKED EXAMPLE

The cell sap in plant cells contains sugar and other substances in solution. Water moves out of cells through the cell membrane.

Some students conducted an experiment to find out what happens to potato sticks in solutions of different concentrations of sugar solution.

They cut five sticks of potato to the same size and weighed them.

Then they placed the potato sticks in beakers containing different concentrations of sugar solution: 0 mol/dm³ (distilled water), 0.25 mol/dm³, 0.5 mol/dm³, 0.75 mol/dm³ and 1.0 mol/dm³ (very strong sugar solution) and left them for two hours.

After two hours they removed the potato sticks, dried them, and weighed them again. They then calculated the percentage change in mass.

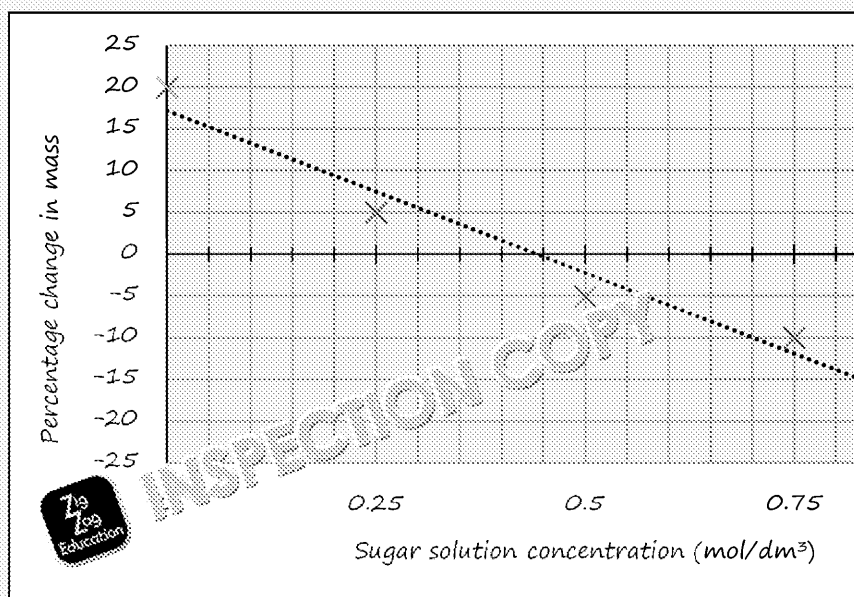
The table shows their results.

Sugar solution concentration (mol/dm ³)	Mass of potato (g)		
	Starting mass	Final mass	Change in mass
0	2.0	2.4	+ 0.4
0.25	2.1	2.2	+ 0.1
0.5	2.1	2.0	- 0.1
0.75	2.0	1.8	- 0.2
1.0	1.9	1.5	- 0.4

- Plot a fully labelled graph of the results.
- Use your line of best fit to estimate the concentration of sugar solution for which there is no change in mass.

Solution

- Your graph would look like this:



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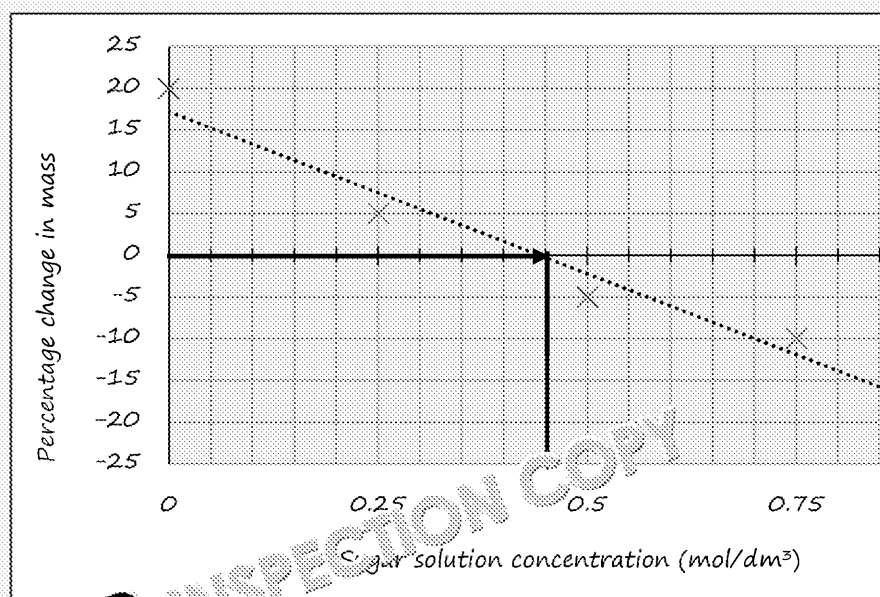
WORKED EXAMPLE (CONTINUED)

You will get marks for:

- independent variable on x-axis, dependent variable on y-axis
- x-axis and y-axis labelled, with correct unit
- even, sensible scales on both axes
- points plotted as 'x's
- a line of best fit that goes through the middle of the results



b) No change in mass would be 0 % on the y-axis.



Draw a vertical line across from 0 until it meets your line of best fit, and then draw a horizontal line to the y-axis. Read the value off the scale – it's 0.4.



Translating information between graphical and numerical data

Reading and understanding graphs

The line on a graph tells you **what happens when you increase the value of the independent variable** from left to right.

The steepness and direction of the line show the changes in the dependent variable.

An upward slope means an increase. The steeper the slope the faster the increase.

A horizontal line means no change in the dependent variable.

A downward slope means a decrease. The steeper the slope the faster the decrease.

The next graph is about enzyme action.

Digestive enzymes break down large molecules in our food into small, soluble molecules that can be used by the body cells.



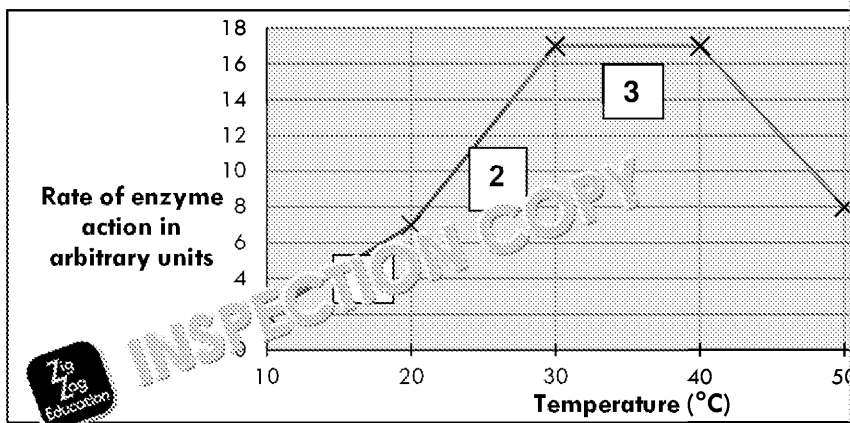
The **rate** of enzyme action means how quickly it works, and it is affected by several factors.

This graph shows the rate of enzyme action at temperatures between 10 °C and 60 °C.

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You can see that the line on the graph shows four definite stages.



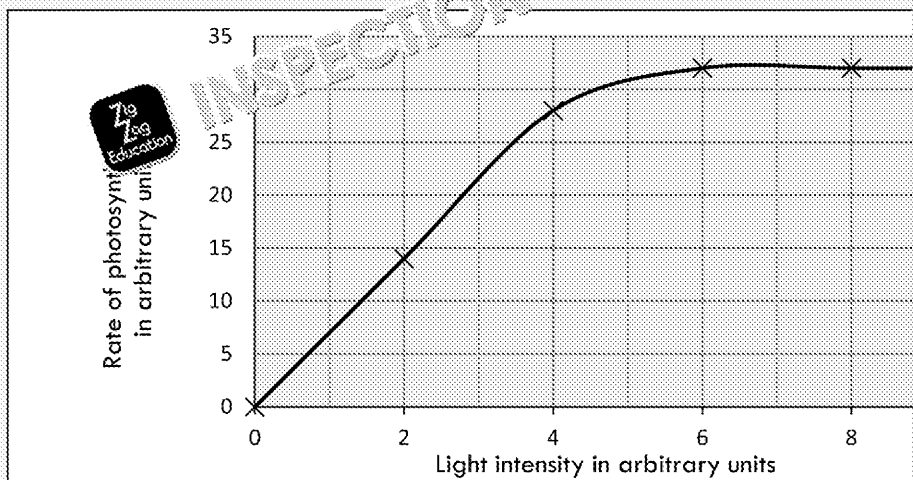
As the temperature increases:

1. from 10 to 20 degrees, the rate of enzyme action increases
2. from 20 to 30 degrees, the rate of enzyme action increases more rapidly (steepest part of the curve)
3. from 30 to 40 degrees, enzyme action stays at a constant high rate
4. from 40 to 60 degrees, the rate of enzyme action decreases, until the enzyme is denatured

Obtaining numerical data from a graph

WORKED EXAMPLE

Plants make food by photosynthesis. They need light to do this. The graph shows the effect of light intensity on the rate of photosynthesis.



- Describe the effect of increasing the light intensity on the rate of photosynthesis.
- Predict the rate of photosynthesis at 14 units of light intensity. Explain your answer.

Solution

- Just describe the line on the graph and give values of the independent variables. Here you can see that it's an upward slope, and then the line goes horizontal. The answer would be:

As the light intensity increases, the rate of photosynthesis increases up to 6 units of light intensity, then it levels off.

- 32, because the rate of photosynthesis reached its maximum at 6 units; increasing light intensity beyond this has no effect.

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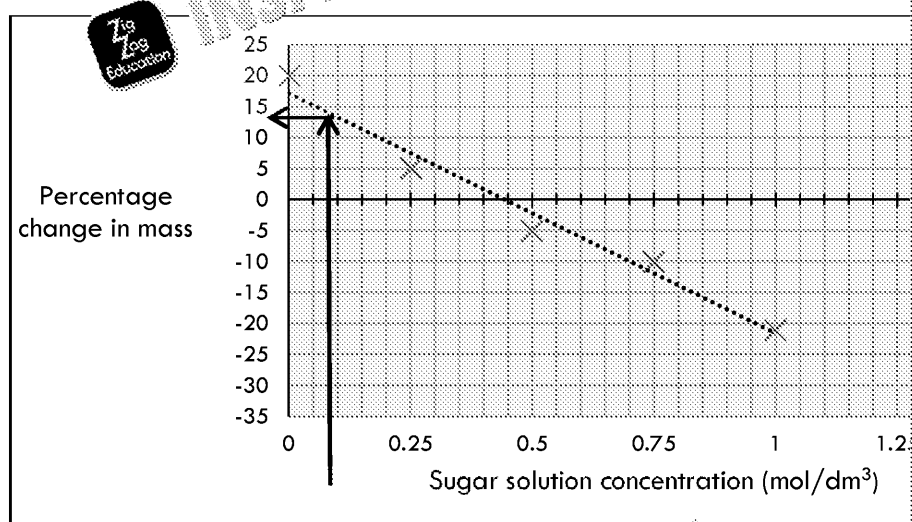
You may be asked to:

- read the graph and give data values using the line on the graph or the line of best fit
- extend the line to predict results outside the data provided (extrapolation)
- use data from the graph for calculations

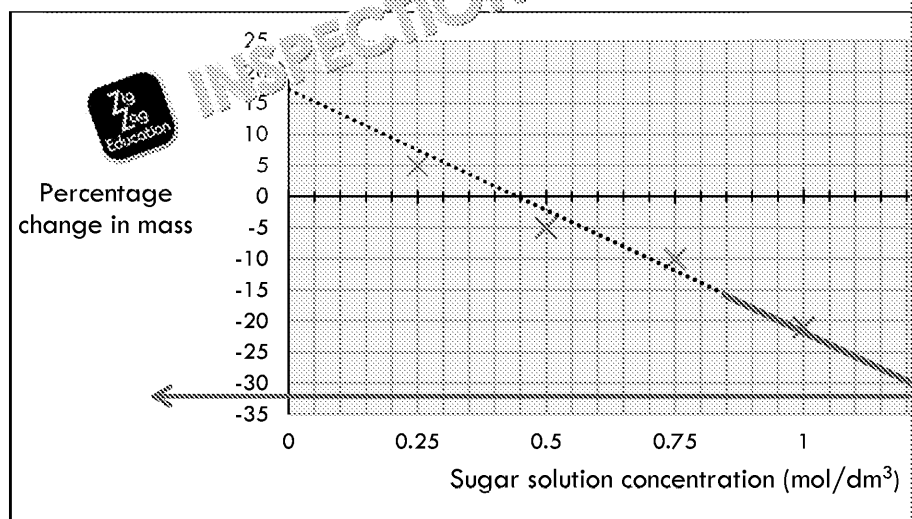
Using the graph on percentage change in mass from earlier in this chapter:

- a) Use the line of best fit to estimate the percentage change in mass of a potato concentration of 0.1 mol/dm^3 .

Find 0.1 on the horizontal axis, then draw a line up to the line of best fit on the graph and across to the percentage change axis to read off the value. The answer is **13 %**.



- b) Predict the percentage decrease in mass of a potato stick placed in a sugar solution of 1.25 mol/dm^3 .



Place your ruler on the line of best fit and extend it until it gets to 1.25 on the x-axis, then draw a line across to the percentage change axis and read off the value. The answer is **30 %**.

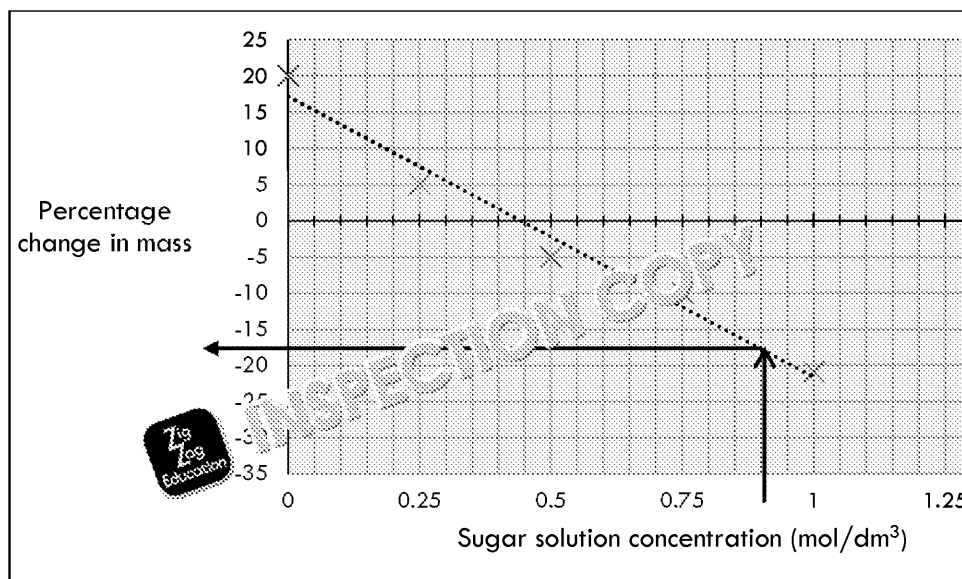
★ You don't need to write the minus sign because the question was about percentage decrease.

- c) A potato stick with a mass of 2.5 g is placed in 0.9 mol/dm^3 sugar solution for two hours. Estimate the mass of the potato after two hours. Give your answer to two significant figures.

Find 0.9 on the horizontal axis, then draw a line up to the line of best fit on the graph and across to the percentage change and read off the value. The answer is **-17.5 %**.

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Your prediction is that the potato will decrease in mass by 17.5 %. The original mass was 2.5 g

Work out 17.5 % of 2.5 g $17.5 \div 100 \times 2.5 = 0.4375$ g

Now subtract that from the starting weight $2.5 - 0.4375 = 2.0625$ g

Round this answer to 2 sf $2.0625 \sim 2.1$ g

Graphs of straight lines

A straight line on a graph shows a relationship between the **x** coordinate and the **y** coordinate. **every point on the line**. It means that the two variables are **proportional** to each other.

This relationship can be described by a **linear equation**, which means no powers of **x** or **y**.

The equation tells you what you must do to **x** to get **y**.

A straight-line graph, which represents a **linear function**, can usually be written in the form

$$y = mx + c$$

where **m** is a **multiple** of **x**, and **m** and **c** are both **constants** (numbers which stay the same).

If you are given a linear function and asked to plot the graph for it, you can make a table of values for **x** and **y** using the equation to work out **y**, like this:

If $y = 2x + 1$, this means that

When $x = -2$, $y = 2 \times -2 + 1 = -3$

When $x = -1$, $y = 2 \times -1 + 1 = -1$

When $x = 0$, $y = 2 \times 0 + 1 = 1$

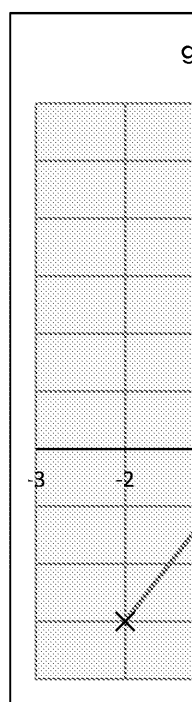
When $x = 1$, $y = 2 \times 1 + 1 = 3$

When $x = 2$, $y = 2 \times 2 + 1 = 5$

x	-2	-1	0	1	2
$y = 2x + 1$	-3	-1	1	3	5

Now you can plot the points and join them up in a straight line.

Notice that the **y** values go up by the same amount each time, so you will soon see the pattern.



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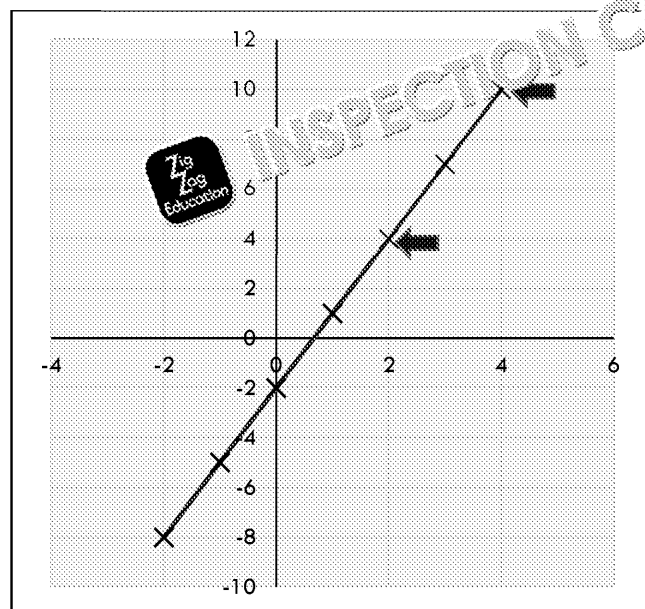
Finding m and c

m is the **gradient or slope of the line**. To work it out, pick two points on your line.

$$m = \frac{\text{change in y values}}{\text{change in x values}}$$

The larger the gradient the steeper the slope.

c is the **place where the line crosses the y-axis**; you can just read it off the graph



Choose any two points on the line, for example (0, -2) and (2, 4)

$$\text{Change in y} = 4 - (-2) = 6$$

$$\text{Change in x} = 2 - 0 = 2$$

$$m = 6 \div 2 = 3$$

The line crosses the y-axis at -2

$$c = -2$$

The equation for this graph is $y = 3x - 2$

WORKED EXAMPLES

a) Draw the graph of $y = 5x - 3$

Solution

a) Make a table of values of x, and then use the equation to get y. You need about 5 values.

If $y = 5x - 3$, that means that every time the x value increases by 1, the y value increases by 5.

$$\text{When } x = -2, y = 5 \times -2 - 3 = -10 - 3 = -13$$

$$\text{When } x = -1, y = 5 \times -1 - 3 = -5 - 3 = -8$$

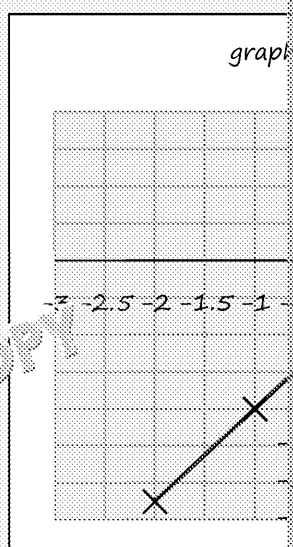
$$\text{When } x = 0, y = 5 \times 0 - 3 = -3$$

$$\text{When } x = 1, y = 5 \times 1 - 3 = 5 - 3 = 2$$

$$\text{When } x = 2, y = 5 \times 2 - 3 = 10 - 3 = 7$$

x	-2	-1	0	1	2
$y = 5x - 3$	-13	-8	-3	2	7

Now plot the points and join them up in a straight line.



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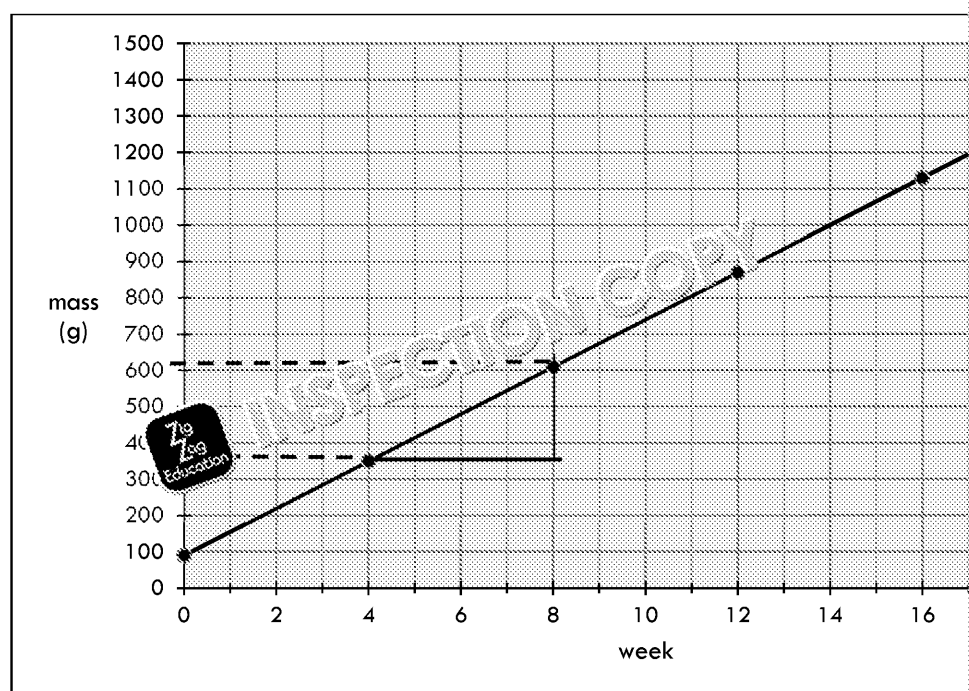


WORKED EXAMPLES (CONTINUED)b) What is the gradient of the line $y = 5x - 3$?**Solution**b) The gradient is the *m* number, which is the multiple of *x*.In $y = 5x - 3$ the multiple of *x* is 5Therefore, the gradient of $y = 5x - 3$ is 5**Rate calculated from graphs**

With some scientific research, data is collected over a period of time; for example with measles, or the number of species that become extinct each year.

If time is on the *x*-axis of a graph, then the **gradient** of the graph represents the rate.

This graph shows the weight of a kitten in the first 20 weeks of its life:



To work out the kitten's growth rate in **grams per week**, find the gradient (*m*) like this:

Choose two convenient points on the line – it's best to pick ones that are easy to read. Here we choose the values for 4 weeks and 8 weeks.

Mass at 4 weeks = 350 g Mass at 8 weeks = 600 g Increase in mass = 250 g

To calculate the growth rate, divide this by the number of weeks between the two points:

$250 \text{ g} \div 4 \text{ weeks} = 62.5 \text{ grams per week}$

★ Notice that the line does not start at 0; it intercepts the *y*-axis at 100 g. That was the kitten's mass at birth.

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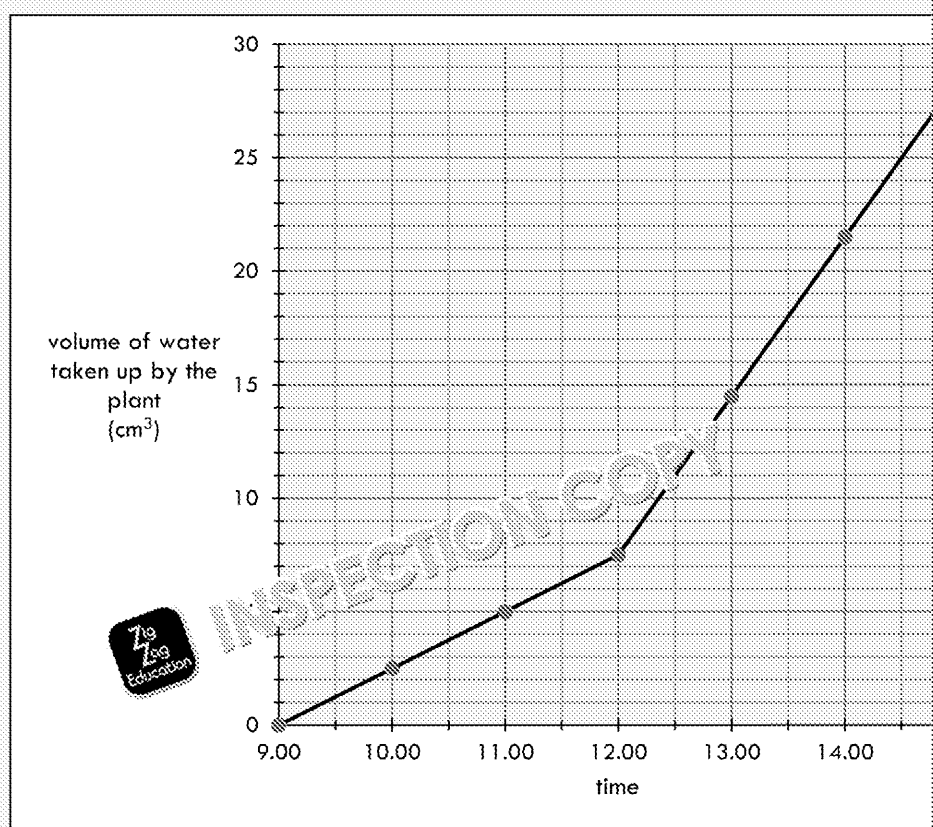
WORKED EXAMPLE

Plants lose water through their leaves in a process called transpiration. The water evaporates through tiny pores on the leaf surface called stomata.

A potometer can be used to measure the amount of water that a plant loses. A leafy plant shoot is placed in the potometer, and it takes up the same volume of water that evaporates through the leaves. This is then measured on a scale on the glass tube.

A student set up a potometer and recorded the reading on the scale at regular intervals for three hours. Then she switched on a fan in front of the plant and continued to take readings for a further three hours. The temperature was kept constant throughout the investigation.

The graph below shows the student's results:

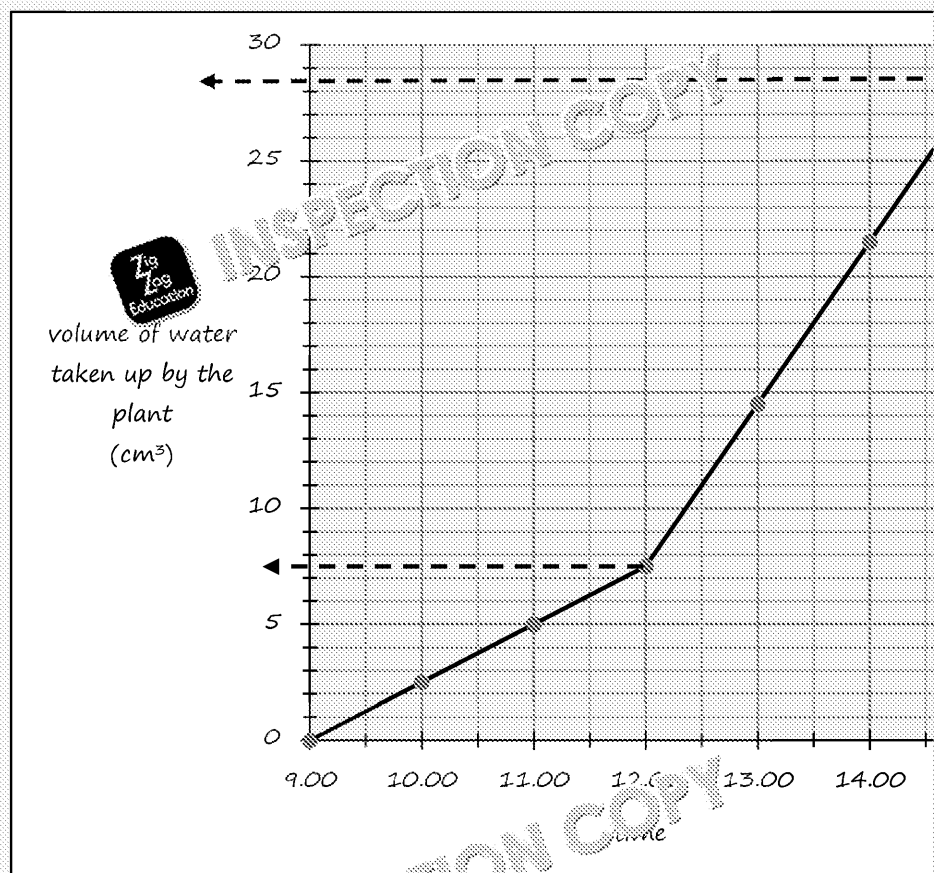


How many times faster was the rate of transpiration after the fan was switched on?

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WORKED EXAMPLE (CONTINUED)

Solution



First work out the rate of transpiration without the fan; that's between 9.00 and 12.00 hours. By drawing a line on the graph you can see that 7.5 cm³ of water was taken up

$$\frac{7.5 - 0}{12.00 - 9.00} = \frac{7.5 \text{ cm}^3}{3 \text{ hours}} = 2.5 \text{ cm}^3 \text{ per hour}$$

Now work out the rate with the fan; that's 12.00 to 15.00

By drawing another line on the graph, you can see that 21 cm³ of water had

$$\frac{21 - 7.5}{15.00 - 12.00} = \frac{13.5 \text{ cm}^3}{3 \text{ hours}} = 4.5 \text{ cm}^3 \text{ per hour}$$

To work out how many times faster the rate of transpiration with the fan is, you

$$4.5 \div 2.5 = 1.8 \text{ times faster}$$

★ If the question had been 'How much faster is the rate of transpiration after you would need to subtract the two rates.

$$4.5 - 2.5 = 2 \text{ cm}^3 \text{ per hour faster}$$

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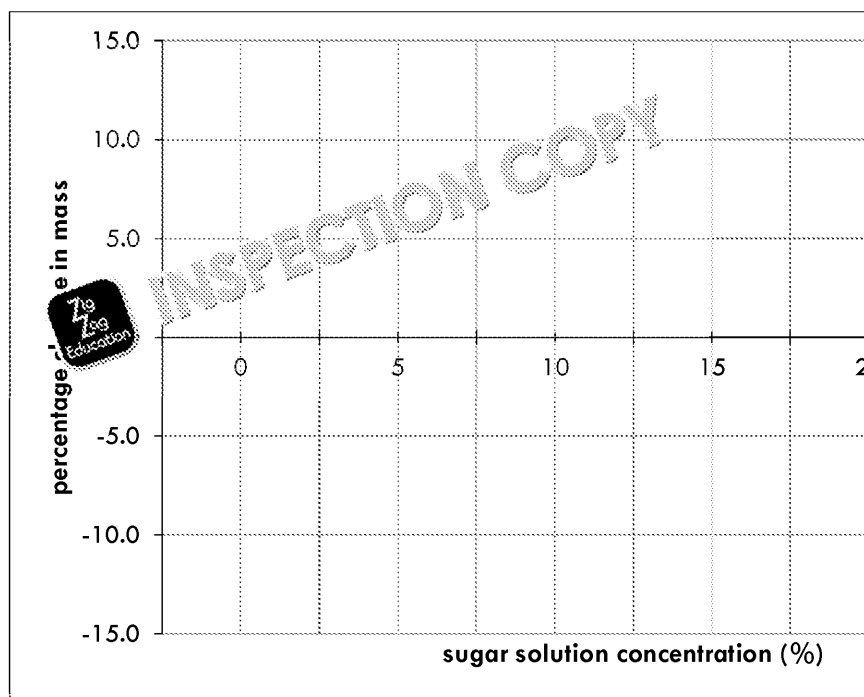
PRACTICE QUESTIONS

1. The cell sap in pumpkin cells contains sugar and other substances in solution. Some students wanted to find out what happens to pumpkin cells when they are placed in different concentrations of sugar solution. They cut sticks of pumpkin to the same size and weighed them, and then placed them in different concentrations of sugar solution from 0 % to 25 %.

After an hour the students removed the sticks of pumpkin from the solutions, dried them, and weighed them again. The table shows their results:

Sugar solution concentration (%)	Mass of pumpkin (g)		
	Initial mass	Final mass	Change in mass
0 (distilled water)	5.0	5.6	
5	5.1	5.4	
10	5.1	5.0	
15	5.0	4.8	
20	4.9	4.6	
25	5.2	4.7	

- a) Copy and complete the table. Give your answers to **one decimal place** if the change is positive or negative.
- b) Copy these axes onto graph paper and plot the percentage change as a line of best fit.



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2. The same group of students completed another experiment. This time they were to investigate the effect of temperature on the action of amylase enzyme. Amylase is a digestive enzyme that breaks down starch molecules into sugar molecules.

The students added 1 cm³ of amylase solution to 10 cm³ of starch solution at different temperatures and waited for the mixture to turn blue to 65 °C.

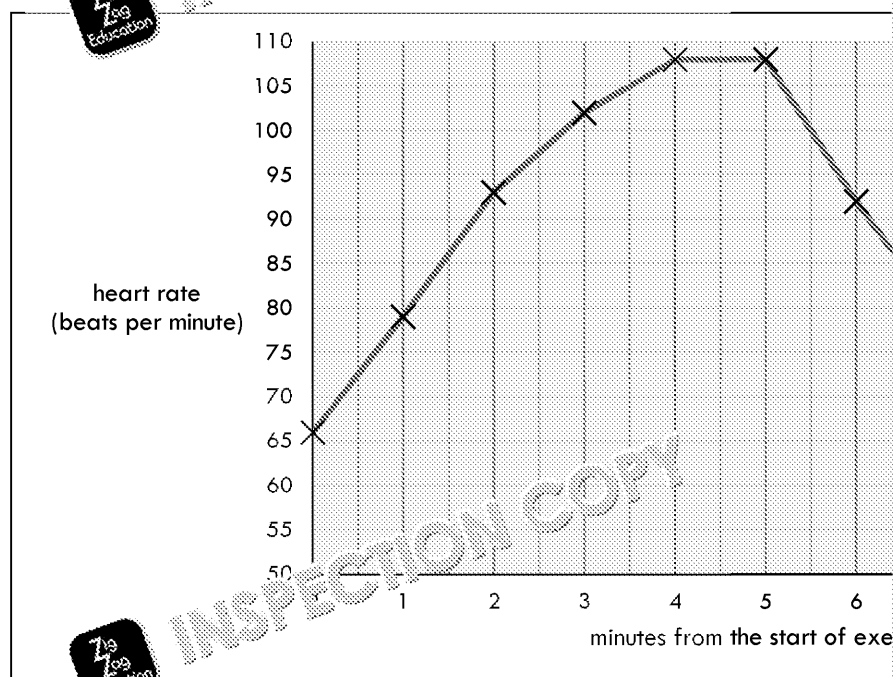
They tested the mixture every 30 seconds for 10 minutes and recorded the time taken for the mixture to turn blue. The time taken for the mixture to be broken down.

The table shows their results:

Temperature (°C)	Time for the starch to be digested (minutes)
15	4.5
25	2.5
35	1.5
45	2.0
55	5.0
65	10.0 (experiment stopped – starch not broken down)

- a) On graph paper, plot a suitable graph for these results.
- Label both axes, including units
 - Use sensible scales on both axes
 - Plot your six points accurately with small crosses
 - Draw a line or curve of best fit
- b) What does your graph tell you about the effect of temperature on starch digestion?
3. A man ran on a treadmill while wearing a digital heart rate monitor.

He measured his heart rate at the start of the exercise and then every minute during the exercise. The graph shows his heart rate readings.

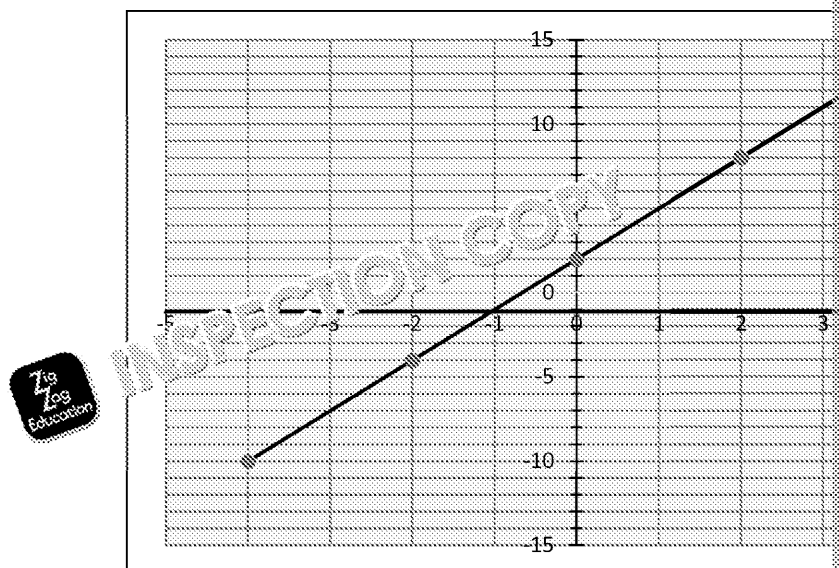


- How long did the exercise last for?
- What was the man's heart rate after 3.5 minutes of exercise?
- After he stopped exercising, how long did it take for the man's heart rate to return to its resting value?
- Describe what happened to the man's heart rate during the 10 minutes.

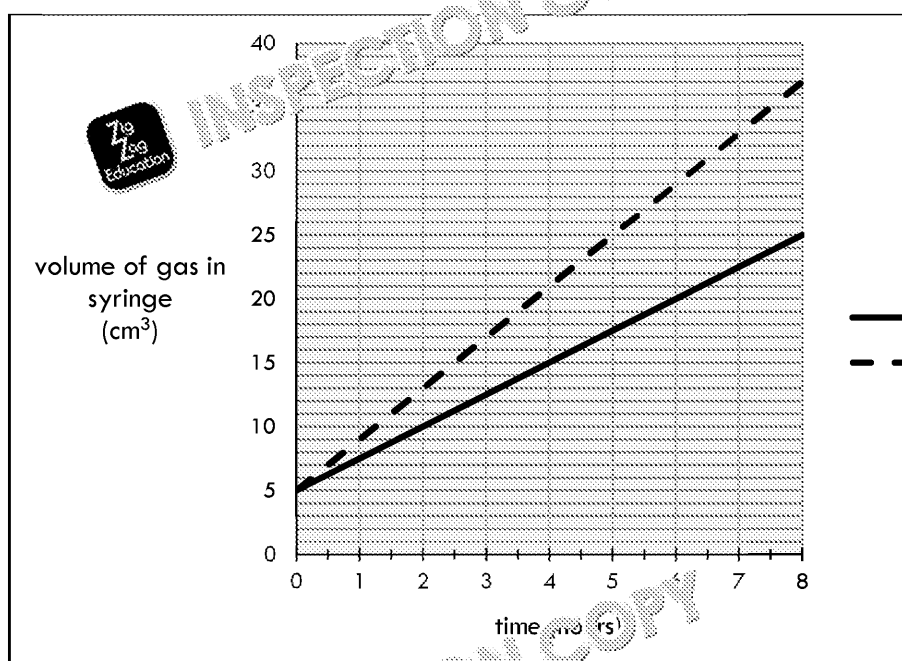
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4. For the straight line graph below:



- Calculate the gradient of the line.
 - Give the equation of the line in the form $y = mx + c$
5. When plants make food by photosynthesis they produce oxygen, which returns to the atmosphere. In the case of underwater plants, the oxygen appears as bubbles coming out of the plant. You can collect the gas in a gas syringe and measure the volume that is produced.
- Ali put two 15 cm pieces of pondweed in water under lights of different colours. He measured the volume of oxygen they produced in eight hours.
- The graph shows his results.



- Without doing any calculations, which colour of light leads to faster photosynthesis?
- When the experiment started, there was already some gas in the syringe. How much?
- How much gas was produced by plant 1 in six hours?
- Calculate the rate of gas production for both plants in cm^3 per hour.

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5 GEOMETRY AND TRIGONOMETRY

SPECIFICATION OVERVIEW

5c – Calculate areas of triangles and rectangles, surface areas and volumes of cubes and cylinders.
These notes also include area of a circle

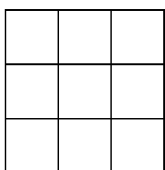
THEORETICAL OVERVIEW

Calculating area and perimeter

Area is the amount of space taken up by a two-dimensional flat shape.

We measure area in **square units**: m^2 , cm^2 , mm^2 , nm^2 , etc. For example, $6 m^2$ means 6 square metres.

It's all about how many squares would fit into the shape, like this:

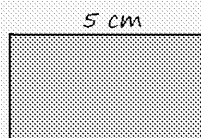


If each small square measures 1 metre long and 1 metre wide, the large square is 9 square metres because nine small squares will fit in it.

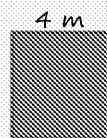
There are formulas for calculating the area of different shapes.

- **Area of a square or rectangle** = length \times width or height

WORKED EXAMPLES



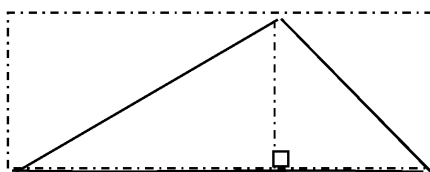
Area = $5 \times 3 = 15 cm^2$



Area = $4 \times 4 = 16 m^2$

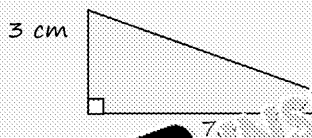
- **Area of a triangle** = $\frac{\text{base} \times \text{perpendicular height}}{2}$

This is because any triangle is half a rectangle, like this:

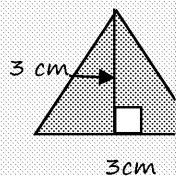


Perpendicular
angles to the base

WORKED EXAMPLES



Area = $\frac{3 \times 7}{2} = \frac{21}{2} = 10.5 cm^2$



Area = $\frac{3 \times 3}{2} = \frac{9}{2} = 4.5 cm^2$

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- **Area of a circle**

You need to know the terms **radius** and **diameter**.

If you are given the diameter of the circle, divide it by 2 to get the radius.

There is only one formula for the area of a circle:

$A = \pi r^2$, where r is the **radius** of the circle

π (pi) is a **constant** which is used to find the **circumference** of circles. Its value is about 3.14.

You can use the π button on a calculator, or else use 3.14.

WORKED EXAMPLE

Find the area of a circle with a diameter of 20 cm.

Solution

The diameter is 20 cm. Therefore, the radius is 10 cm.

$$\text{Area} = \pi r^2 = \pi \times 10 \times 10 = 3.14 \times 10 \times 10 = \underline{314 \text{ cm}^2}$$

Volume is the amount of space taken up by a three-dimensional shape.

We measure volume in **cubic units**: m^3 , cm^3 , mm^3 , nm^3 , etc. For example, 6 m^3

It's about how many cubes would fit into the shape.

This cube is 3 centimetres long, 3 centimetres wide and 3

If you made it up out of 1 cm cubes, you would need three

That's $3 \times 3 \times 3 = 27 = 27$ centimetre cubes

The volume of this cube is **27 cubic centimetres** or **27 cm**

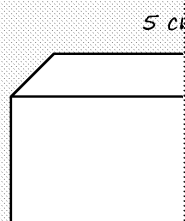
Calculating the volume of a cube or cuboid: – **Volume = length \times width \times height**

WORKED EXAMPLE

Calculate the volume of this cuboid:

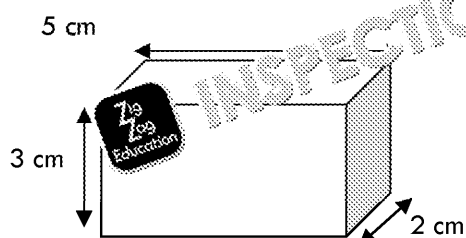
Solution

$$\text{Volume} = 3 \times 5 \times 2 = \underline{30 \text{ cm}^3}$$



The **surface area** of a three-dimensional object is the area of the **outside** of the object.

To find the surface area of a cube or cuboid, find the area of each side, and then



Two sides are $3 \text{ cm} \times 5 \text{ cm} = 15$

Two sides are $2 \text{ cm} \times 5 \text{ cm} = 10$

Two sides are $2 \text{ cm} \times 3 \text{ cm} = 6$

$$\begin{aligned} \text{Surface area} &= (2 \times 15) + (2 \times 10) + (2 \times 6) \\ &= 30 + 20 + 12 \end{aligned}$$

★ The **surface-area-to-volume ratio** of an object is the relationship between the size of the object and the amount it can hold inside it. It's written as **SA : V**.

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This ratio is very important in living organisms. For example, in plants, oxygen and water move in and out through the surface of the leaves; the larger the surface-area-to-volume ratio,

Small objects have a greater SA : V ratio than bigger objects.

This is a 1 cm cube:



It has six sides. Each side has an area of $1 \times 1 = 1 \text{ cm}^2$

So, the total surface area = $6 \times 1 = 6 \text{ cm}^2$

The volume of the cube = $1 \times 1 \times 1 = 1 \text{ cm}^3$

Therefore, $\text{SA} : \text{V} = 6 : 1$

If you put 27 of these cubes together like this:

It has six sides. Each side has an area of $3 \times 3 = 9 \text{ cm}^2$

So, the total surface area = $6 \times 9 = 54 \text{ cm}^2$

The volume of the cube = $3 \times 3 \times 3 = 27 \text{ cm}^3$

Therefore, $\text{SA} : \text{V} = 54 : 27 = 2 : 1$

Notice that you can cancel down the SA : V ratio so that you have $n : 1$

Cancelling to $n : 1$ in the ratio means that you can compare the SA : V ratios for different shapes.

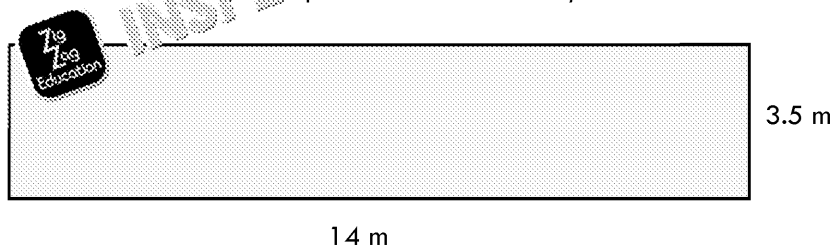
You are comparing how much surface area there is for one unit of volume.

You cancel down to $n : 1$ by dividing the surface area by the volume.

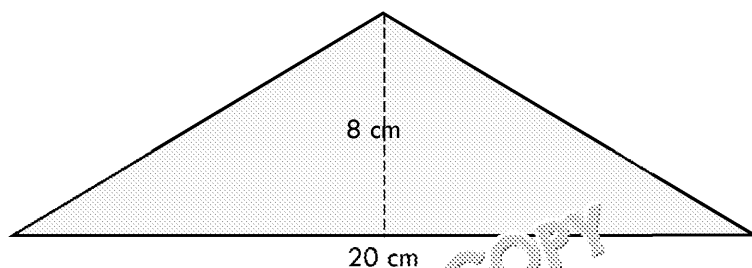
PRACTICE QUESTIONS

1. Calculate the area of each shape. State the units in your answer.

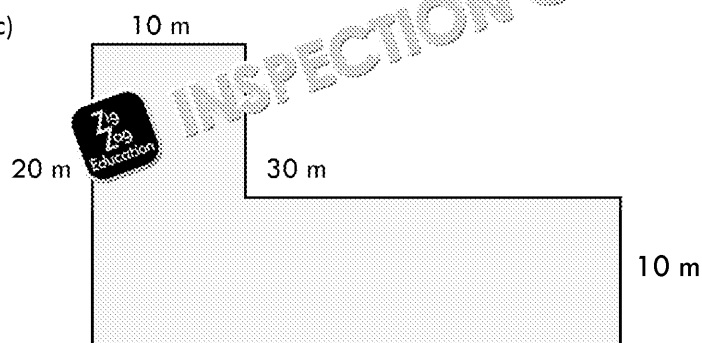
a)



b)



c)



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2. Antibiotics are drugs that kill bacteria.

When bacteria are grown on dishes of nutrient jelly in the laboratory, they will reproduce and eventually cover the jelly completely.

To investigate the effect of an antibiotic on the growth of bacteria, a scientist soaked paper discs in different concentrations of the antibiotic.

They then placed the discs onto a culture of bacteria in a petri dish of nutrient jelly.

After incubating the dish for three days, a scientist measured the diameter of the clear areas around the paper discs, shown in the diagram. Clear areas where no bacteria are growing.

The scientist's results are shown in the table:

Concentration of antibiotic in arbitrary units	Diameter (mm)	Radius (mm)
2	6	
4	12	
6	22	
8	34	

Calculate the radius and the clear areas to complete the table. Give your answers to one decimal place.

3. Two tubes are in the shape of cuboids. They are both one metre long. (1 metre = 100 cm)

Tube 1



Tube 2



- a) Calculate the volume, the surface area and the surface-area-to-volume answers in the table. Write the SA : V ratio in the form $n : 1$.

	Volume (cm ³)	Surface area (cm ²)
Tube 1		
Tube 2		

- b) In humans, nutrients are absorbed into the bloodstream through the surface of the small intestine. Use your answers from part a) to explain why the small intestine is a long tube.

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DIAGNOSTIC TEST

1.2 ARITHMETIC AND NUMERICAL COMPUTATION

1. Write 0.85 as a fraction in its simplest terms.
.....
2. Write $\frac{3}{5}$ as a decimal number and as a percentage.
.....
3. Write 7.5 m in standard form.
.....
4. Write 5.08×10^6 as a decimal number.
.....
5. There are 180 students in Year 11. 45 of them are taking GCSE Biology. What percentage of Year 11 students are taking GCSE Biology?
.....
6. To make up a solution for an experiment, a scientist mixed enzyme with water. The scientist needed 500 cm³ of solution. How much enzyme did she need to make 500 cm³ of solution?
.....
7. Estimate the answer to $\frac{248 \times 5.99}{502}$ Give your answer as a single whole number.
.....
.....

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DIAGNOSTIC TEST

2.2 HANDLING DATA

1. Write 347 585 to two significant figures.

.....

2. A student studied photosynthesis in pondweed. She put a piece of pondweed in a test tube and counted the number of bubbles that the plant produced every minute for 10 minutes.

30 23 28 35 26 41 36

- a) Calculate the **mean** number of bubbles per minute.

.....

- b) Write down the **median** number of bubbles per minute.

.....

- c) Write down the **modal** number of bubbles per minute.

.....

3. The first 24 clients to use a leisure centre one day were taking part in the following activities.

Swimming	Swimming	Badminton	Swimming	Aerobics
Aerobics	Aerobics	Weight training	Badminton	Swimming
Swimming	Swimming	Aerobics	Weight training	Aerobics
Badminton	Badminton	Swimming	Aerobics	Aerobics

- a) Design a frequency table for the data.



- b) Display the data using a suitable chart.



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DIAGNOSTIC TEST

2.2 HANDLING DATA (CONTINUED)

4. 80 patients attend a diabetes clinic. The nurse wants to select 10 patients at exercise questionnaire. Suggest a method she could use to choose the patients.

.....

.....

.....

5. a) A bag contains 12 red balls and three yellow balls. You pick a ball out. What is the probability that the ball will be yellow?

.....

- b) You replace that ball, mix them up and pick again. What is the probability that the ball will be yellow?

.....

6. The table shows the heights and shoe sizes of a group of adults.

Height (m)	UK shoe size
1.52	4
1.77	10
1.62	6
1.70	7
1.75	9
1.65	6
1.80	12
1.60	5

- a) Draw a graph of these data.
- b) Describe the relationship between height and shoe size for this group of people.

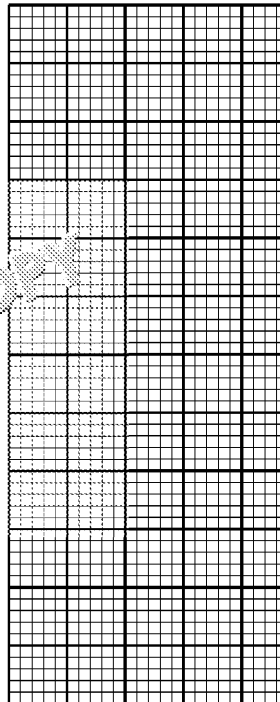
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7. An elephant eats an average of 150 kg of vegetation per day. What is the total mass of food the elephant consumes in a year?

.....

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DIAGNOSTIC TEST

3.2 ALGEBRA

1. Write the following expressions in words.

a) $s > t$

.....

b) $c << d$

.....

c) $x \cdot$

.....

2. Solve these equations to find the value of x .

a) $6x - 3 = 27$

.....

b) $x/2 + 7 = 25$

.....

3. The formula for the speed of a moving object is

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad s = \frac{d}{t}$$

a) Calculate the speed of an object that travels 72 kilometres in 4.5 hours.

.....

.....

b) What would be the units of your answer to part a)?

.....

.....

c) A different object travels at a speed of 52 mph (miles per hour). How long does it take to travel 78 miles? Give the units of your answer.

.....

.....

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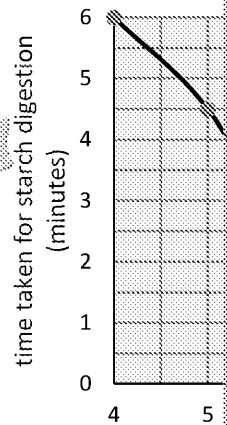
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DIAGNOSTIC TEST

4.2 GRAPHS

1. The pH of a solution measures how acidic or how alkaline it is. It affects how quickly digestive enzymes work to break down the nutrients in our food. The graph shows how long it takes an enzyme to digest 10 cm³ of starch solution at different pH values.



- a) Describe the effect on starch digestion of increasing the pH from 4 to 9.

.....

.....

.....

.....

- b) Estimate the time it would take to digest the starch at pH 7.5.

.....

.....

2. a) Plot a graph of $y = 3x + 2$ for values of x from 0 to 8.

- b) What is the gradient of this graph?

.....

.....

- c) What is the y-intercept of this graph?

.....

.....

- d) How would the line graph for $y = x + 2$ look different from the line you draw in part a)?

.....

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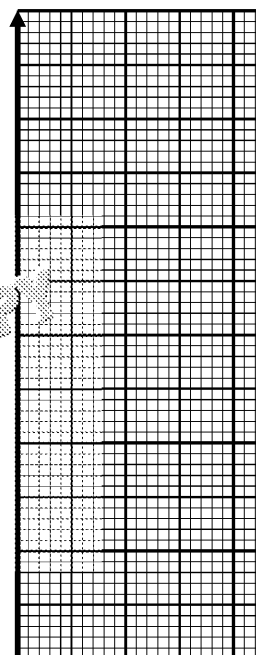
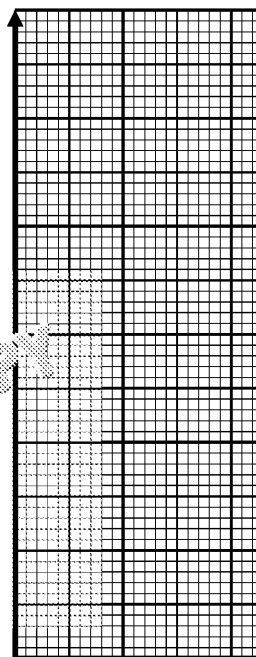
3. A plant weighs 100 g. It is placed outside in hot sunshine, and it loses mass at a steady rate of 6 g per hour.

- a) Plot a graph of the mass of the plant over a period of seven hours. Label both axes on your graph.

- b) How much does the plant weigh after 4.5 hours?

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DIAGNOSTIC TEST

5.2 GEOMETRY AND TRIGONOMETRY

1. Calculate the area of the following shapes:

- a) Rectangle $20\text{ m} \times 12\text{ m}$

.....

.....

- b) Triangle with base 10 cm , height 6 cm

.....

.....

- c) Circle with **diameter** 16 mm

.....

.....

2. This cuboid measures $5\text{ cm} \times 5\text{ cm} \times 8\text{ cm}$.

- a) Calculate the volume of the cuboid. Give the units of your answer.

.....

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- b) Calculate the total surface area of the cuboid. Give the units of your answer.

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SOLUTIONS TO QUES

DIAGNOSTIC TEST 1

1.1 Arithmetic and numerical computation

1. $\frac{2}{5}$
2. 0.625, 62.5 %
3. 1.5×10^4
4. 0.0035
5. 28 %
6. 3 : 1
7. $50 \times 3 = 150$ kg

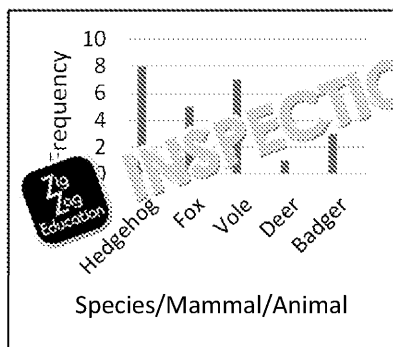
2.1 Hand

1. 25 200
2. a) 25.77777 or 25.8
- b) 25
- c) 25
3. a)

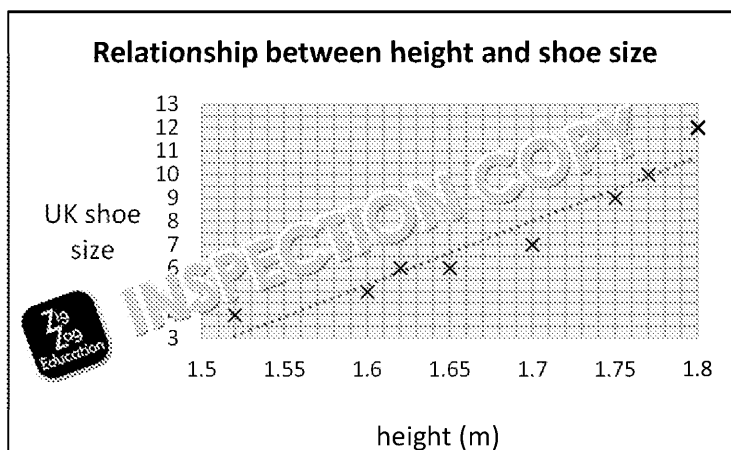
Species/Mammal/Animal	Tally (optional)	Frequency
Hedgehog		8
Fox		5
Vole		7
Deer		1
Badger		3

Categories can be in any order

b)



4. A valid method of achieving randomness; for example, giving each student a computer or a calculator to generate six random numbers between 1 and 12
5. a) $\frac{1}{4}$ or $\frac{2}{8}$
- b) $\frac{7}{8}$
6. a)



- b) Positive correlation, or taller people have bigger feet
7. $150 \times 200 = 30\,000$; that's 3×10^4 – the order of magnitude is 10^4

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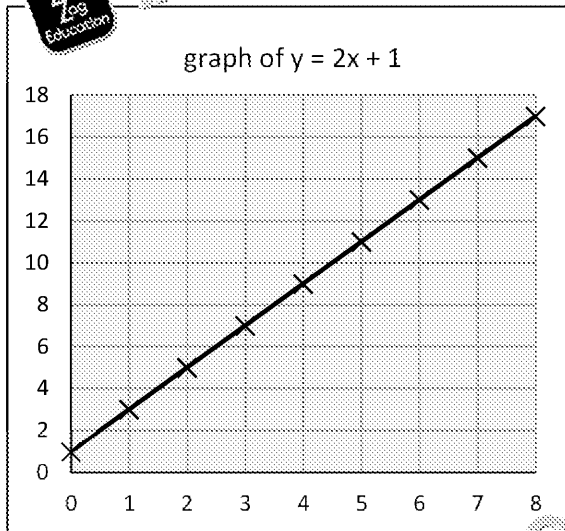


3.1 Algebra

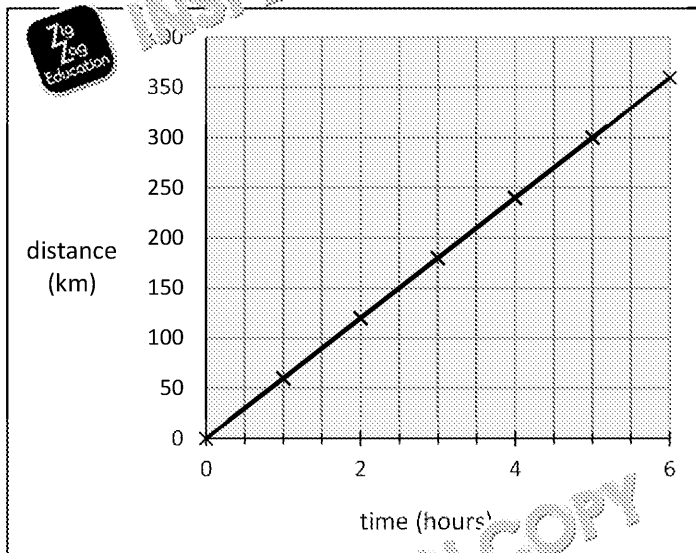
1. a) x is much greater than y
b) a is proportional to b
2. a) $x = 13$
b) $x = 5$
3. a) 0.25
b) g/cm^3 , or
c) 1.5 kg

4.1 Graphs

1. a) 75 million
b) The population is constant until day 4, and then stayed the same at 150
c) 50 million
2. a)



- b) 2
c) 1
d) The slope/line was a steeper
3. a)



- b) 150 kilometres

5.1 Geometry and Trigonometry

1. a) 6 cm^2
b) 20 cm^2
c) $\pi \times 5^2 = 78.5$ or 78.54 cm^2
2. 24 cubic metres (m^3)
3. Surface area = $6 \times (2 \times 2) = 24 \text{ cm}^2$

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PRACTICE QUESTIONS

Arithmetic and numerical computation

1. a)

Amount in words	Amount in figure
Thirteen thousand five hundred and six	13 506
Two thousand and sixty-four	2064
One million seven hundred and fifty thousand	1 750 000
Three thousand and seven	3007
Twenty-five thousand three hundred and sixty	25 360

b) 20 007, 13 506, 25 360, 1 750 000

2. 0.72, 0.072, 0.27, 0.207, 0.072, 0.027

3. a) 3×10^9

b) 2.5×10^8

c) 1.5×10^{-3}

d) 2×10^{-8}

4. a) A kilogram is 10^3 grams

b) A millimetre is 10^{-3} metres

c) A nanosecond is 10^{-9} seconds

d) There are 10^6 μm in a metre

5. a) $3.6 \times 10^4 \times 10^6 = 3.6 \times 10^{10}$

b) $8.7 \times 10^7 \div 10^2 = 8.7 \times 10^5$

6. Division time = 36 hours \div 1.5 hours = 24

$2^{24} \rightarrow 2 \times 2^4 = 16\ 777\ 216$

7. a) 4 : 1

b) 10 : 1

c) 20 : 1

d) $9 : 2 = 4.5 : 1$

8. 15

9. a) 2

b) $\frac{25}{8}$

10. a) $\frac{6}{35}$

b) $\frac{1}{3}$

11. 75

12.

Fraction	Decimal
$\frac{1}{4}$	0.25
$\frac{3}{8}$	0.375
$\frac{2}{5}$	0.4
$\frac{3}{10}$	0.3
$\frac{8}{10}$ Or $\frac{4}{5}$	0.8
$\frac{4}{100}$ Or $\frac{1}{25}$	0.04

13. 120 students + 14 teachers = 134

14. $15 \div 85 \times 100 = 17.65\%$

15. $\frac{30\ 000}{1926} \rightarrow \frac{1200}{78} = 15.38$ or $\frac{31\ 009}{2000} \rightarrow \frac{1000}{200} = 5$

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Handling data

1. a) 50 000
b) 0.0099
c) $17.5 \div 100 \times 2390 = 418.25$ to 2 sf – that's 420 or 420.0
2. a) $13 + 6 + 12 + 7 + 6 + 4 + 8 = 56$ $56 \div 7 = 8$
b) 4 6 6 7 8 12 13 median = 7
c) 4 6 6 7 8 12 13 mode = 6
d) range = 4 to 13 or $13 - 4 = 9$
3. a)

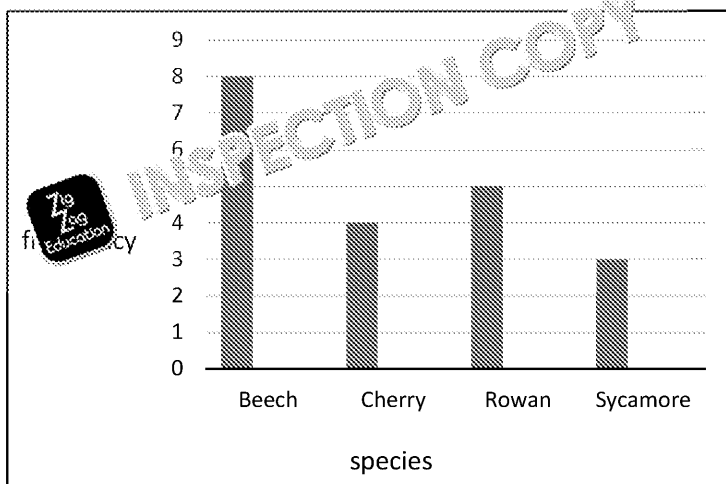
Mark	Frequency	
14	2	$14 \times 2 = 28$
15	10	$15 \times 10 = 150$
16	2	$16 \times 2 = 32$
17	3	$17 \times 3 = 51$
18	13	$18 \times 13 = 234$

Mean mark = $495 \div 30 = 16.5$

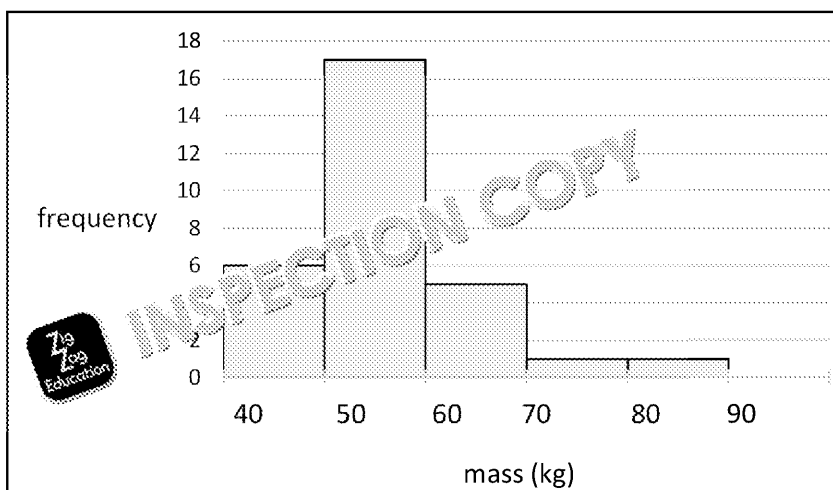
- b) Everyone who got 14, 15 or 16 marks needs to retake $2 + 10 + 2 = 14$ s
4. a)

Species	Frequency
Beech	8
Cherry	4
Rowan	5
Sycamore	3

b)



5. a)



b) $50 < x \leq 60$

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6. a) ii. Use a grid with random numbers
b) 4
c) $8000 \times 4 = 32\,000$
7. a) $\frac{1}{20}$, 0.05, 5 %
b) $\frac{18}{20} = \frac{9}{10}$, 0.9, 90 %
c) $\frac{11}{20}$, 0.55, 55 %
8. $\frac{2}{3} \times 3600 = 2400$
9. a) 35
b) (weak or moderate) **positive** correlation
c) iii. Younger people are likely to have faster reactions than older people, but there is a difference in reaction times between individuals
10. $120 \times 1825 = 219\,000$ g
Divide by 100 to get your answer in kilograms = 2190
To 1 sf that's 2000, or 2×10^3
Therefore, the order of magnitude is 10^3

Algebra

1. a) $0.375 < \frac{1}{2}$
b) $12 \times 7 > 80$
c) One million = 10^6
d) One nanometre \ll one millimetre
e) $\frac{9778}{503} \times 1.95 \sim 40$ < is also a correct answer
2. a) $7x = 17 + 4 \rightarrow 7x = 21 \rightarrow x = 21 \div 7 \rightarrow x = 3$
b) $\frac{2a}{3} = 25 - 5 \rightarrow \frac{2a}{3} = 20 \rightarrow 2a = 20 \times 3 \rightarrow 2a = 60 \rightarrow a = 60 \div 2 \rightarrow a = 30$
3. $100 = \frac{0.9}{t} \rightarrow t = \frac{0.9}{100} \rightarrow t = 0.009$ seconds
4. a) $A = \frac{I}{M} = \frac{290}{1000} = 0.29$ mm or 290 μm
b) $M = \frac{A}{1.2} = \frac{48}{1.2} = 40 \times$
c) $I = A \times M = 0.6 \times 15\,000 = 7200$ μm
 $7200 \div 1000 = 7.2$ mm
5. Child dose = $1500 \times \frac{8}{20} = 600$ mg per day

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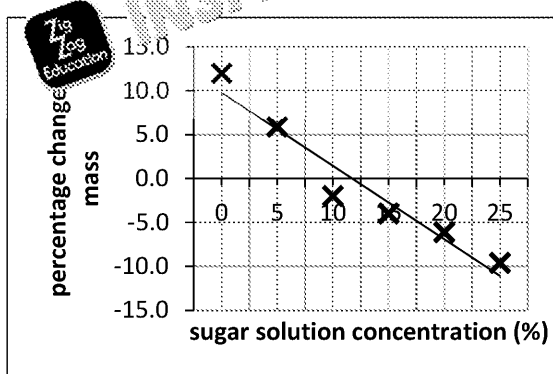


Graphs

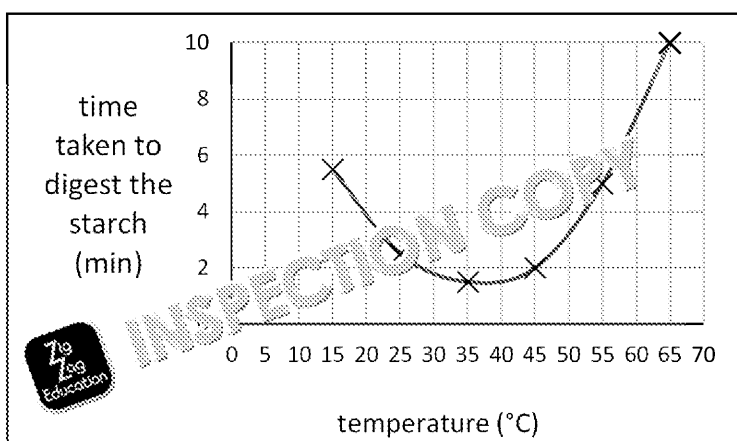
1. a)

Sugar solution concentration (%)	Percentage change in mass
0	+12.0
5	+5.9
10	-2.0
15	-4.0
20	-6.1
25	-9.6

b)



2. a)



- ★ The starch was not digested at 65 °C.
- ★ It was digested at 35 °C.

b) As the temperature increases the time needed for the starch to be digested decreases until it reaches its minimum at 35 °C. Then it increases again. The starch is not digested at all at 65 °C.

3. a) 5 minutes

b) 105 bpm

c) 3 minutes

d) During the five minutes of exercise, the man's heart rate increased from 65 bpm to 108 bpm after four minutes. It stayed level for one minute, and then was decreased at a steady rate for three minutes, until it was back to 65 bpm.

4. a) gradient = 3

b) y-intercept is at 2, so the equation is $y = 3x + 2$

5. a) blue

b) 5 cm^3

c) $20 - 5 = 15 \text{ cm}^3$

d) Plant 1 $(25 - 5) \text{ cm}^3 / 10 \text{ hours} = 2.5 \text{ cm}^3 \text{ per hour (cm}^3/\text{h)}$

Plant 2 $(30 - 10) \text{ cm}^3 / 7.5 \text{ hours} = 4 \text{ cm}^3 \text{ per hour (cm}^3/\text{h)}$

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Geometry and trigonometry

1. a) $14 \times 3.5 = 49 \text{ m}^2$
b) $\frac{8 \times 20}{2} = 80 \text{ cm}^2$
c) Divide the L shape into two rectangles
A $\rightarrow 10 \times 20 = 200 \text{ m}^2$
B $\rightarrow 10 \times 30 = 300 \text{ m}^2$
Total area = $200 + 300 = 500 \text{ m}^2$

2.

Concentration of antibiotic (units/mm ³)	Diameter (mm)	Radius (mm) <i>Divide the diameter</i>
2	6	3
4	12	6
6	22	11
8	34	17

If you used 3.14 for π , then the clear areas for 4, 6 and 8 units of antibiotic are 907.5 mm²

3. a)

	Volume (cm ³)	Surface area (cm ²)
Tube 1	$100 \times 2.5 \times 2.5 = 625$	$4 \times (100 \times 2.5) = 1000$ $2 \times (2.5 \times 2.5) = 12.5$ $1000 + 12.5 = 1012.5$
Tube 2	$100 \times 5 \times 5 = 2500$	$4 \times (100 \times 5) = 2000$ $2 \times (5 \times 5) = 50$ $2000 + 50 = 2050$

- b) Tube 1 is thinner than Tube 2, and it has a much higher surface-area-to-volume ratio, which helps nutrients to be absorbed more rapidly and efficiently through the surface.

DIAGNOSTIC TEST 2

1.2 Arithmetic and numerical computation

1. $\frac{17}{20}$
2. 0.6, 60 %
3. 2.75×10^{-4}
4. 5 080 000
5. 25 %
6. 25 cm³
7. $250 \times 6 \div 500 = 3$

2.2 Handling data

1. 350 000
2. a) 32.3
b) 31
c) 28
3. a)

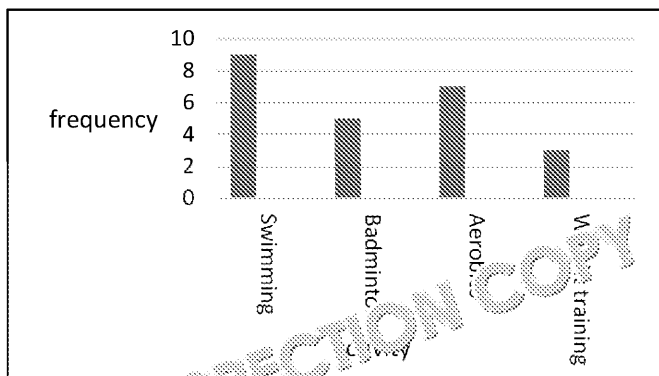
Activity	Frequency
Swimming	9
Badminton	5
Aerobics	7
Weightlifting	3

Categories can be in any order

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b)

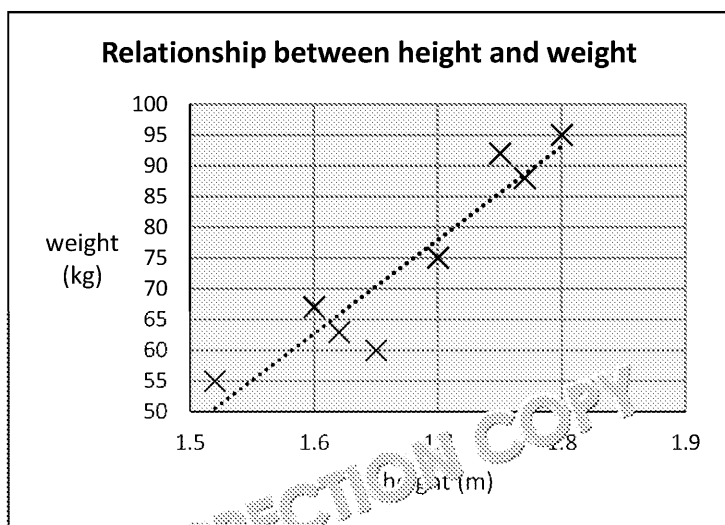


4. A valid method of achieving randomness; for example, giving each patient a computer and calculator to generate 10 random numbers between 1 and 80

5. a) $\frac{1}{5}$ or $\frac{3}{15}$

b) $\frac{1}{25}$ or $\frac{9}{225}$

6. a)



b) Positive correlation, or taller people tend to be heavier

7. $150 \times 3.7 \times 10^4 = 5.55 \times 10^6$; that's 5.475×10^4

The order of magnitude is 10^4

3.2 Algebra

1. a) s is greater/more than t

b) c is much less than d

c) x is approximately equal to y

2. a) $x = 5$

b) $x = 36$

3. a) 16

b) km/h, or kilometres per hour

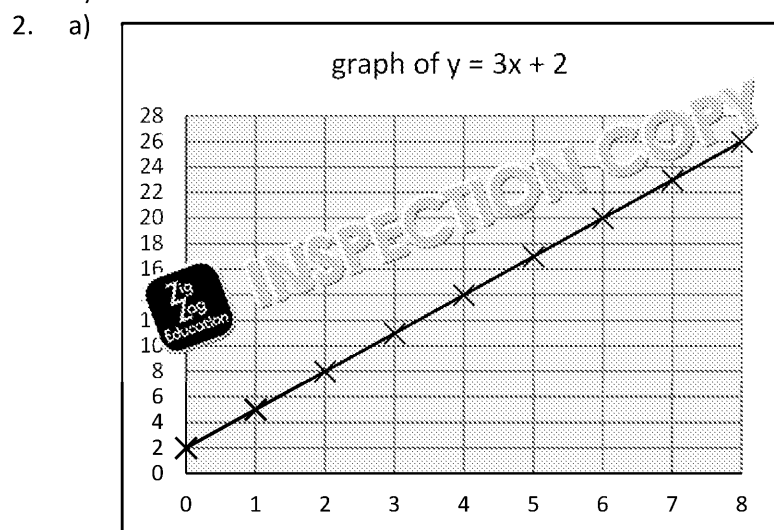
c) 1.5 hours / 90 minutes / 1 hour 30 minutes

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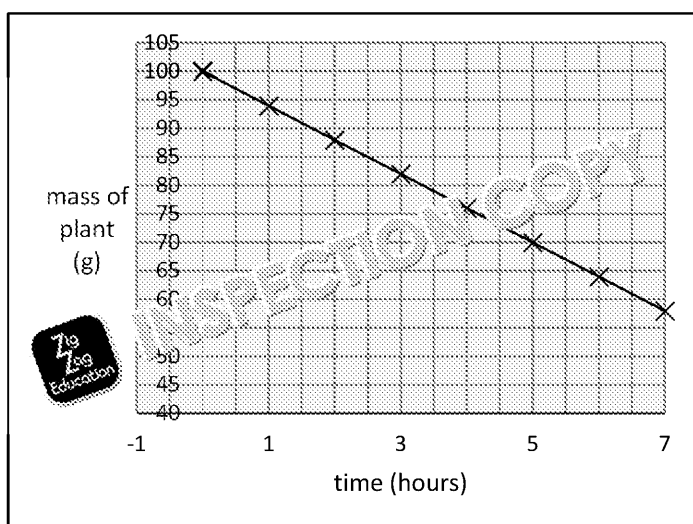


4.2 Graphs

1. a) The time it took to digest the starch decreased from 3 to 7, and then in
b) Answers between 2.2 and 2.4 minutes



- b) 3
 - c) 2
 - d) The slope/line would be less steep
3. a)



- b) 73 g

5.2 Geometry and trigonometry

1. a) 240 m^2
b) 24 cm^2
c) $\pi \times 8^2 = 200.96$ (if $\pi = 3.14$) or 201.06 mm^2
2. a) 200 cubic centimetres (cm^3)
b) Surface area = $2 \times (5 \times 5) + 4 \times (5 \times 8) = 10 + 160 = 170 \text{ cm}^2$

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