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Cambridge IGCSE®
Physics
Maths Skills Workbook

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Contents

Introduction

This workbook has been written to help you to improve your skills in the mathematical processes that you need in your Cambridge IGCSE Physics course. The exercises will guide you and give you practice in:

- representing values
- working with data
- drawing graphs
- interpreting data
- doing calculations
- working with shape.

Each chapter focuses on several maths skills that you need to master to be successful in your Physics course. It explains why you need these skills. Then, for each skill, it presents a step-by-step worked example of a question that involves the skill. This is followed by practice questions for you to try. These are not like exam questions. They are designed to develop your skills and understanding. They get increasingly challenging. Tips are often given alongside to guide you. Spaces, lines or graph grids are provided for your answers.

[further paragraph to follow from Jane Thompson, e.g. giving more detail of subject-specific skills developed or about the subject contexts in which the maths skills are practised]

Some of the maths concepts and skills are only needed if you are following the Extended syllabus (Core plus Supplement). The headings of these sections are marked 'Supplement'. In other areas just one or two of the practice questions may be based on Supplement syllabus content, and these are also clearly marked.

There are further questions at the end of each chapter that you can try to give you more confidence in using the skills practised in the chapter. At the end of the book there are additional questions that may require any of the maths skills from all of the chapters.

All of the mathematical formulae that you need to know for your IGCSE Physics course are shown at the back of the book.

Important mathematical terms are printed in **bold** type and these are explained in the Glossary at the back of the book.

Chapter 5: Doing calculations

Why do you need to do calculations in physics?

- Equations in physics are mathematical descriptions of relationships between real quantities.
- The equations allow us to calculate unknown values, by using mathematical procedures.
- Physicists use equations to calculate values that otherwise they would have to measure through observation. It is much simpler to use an equation.

We can also use an equation to check that measurements have been accurately made.

Maths focus 1: Understanding equations

Equations are a mathematical way of showing relationships between variables. They are often used to define a variable. For example, the equation $W = mg$ shows how multiplying the mass of an object m by g the gravitational field strength gives the weight W of an object. You will also find the word **formula** used for a physics equation.

TIP

In an equation, two letters together such as mg means $m \times g$. This is called a **product**.

What maths skills do you need to understand equations?

1 Working with equations: the basics	• Know that equations express relationships • Understand the = sign • List the quantities given • Substitute values and units correctly into equations
2 Calculating with percentages	• Change fractions to percentages • Change percentages to fractions

Maths skills practice

How does understanding an equation help you to solve problems in physics?

Physics problems written in words need some skill to decipher, as you need to choose the correct equation to work with. If you want to find speed from information about distance and time, you need to choose the equation:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

and then substitute the known values correctly into the equation. Putting the values in incorrect places can give you completely the wrong answer for speed. If you understand the relationship that the equation is describing, you are less likely to make errors.

> **TIP**
> Remember that whatever you do to one side of an equation, you must do exactly the same to the other side of the equation to maintain the equality.

Maths skill 1: Working with equations: the basics

What is the importance of the symbol '= '? The equals sign means 'the same as'. It shows that both sides of an equation have the same value *and* equivalent units.

This means that if you change one side of an equation in any way, the other side of the equation needs to be changed in the same way.

The simplest way to show this is to use an example with numbers:

$$2 + 4 = 6$$

Then if we add 3 to both sides:

$$2 + 4 + 3 = 6 + 3$$

If we had added 3 to only one side then the equation would no longer be true.

If you understand the equals sign in this way, then you will see that the sides of an equation can be swapped over. For example, the transformer equation which shows you how the number of turns on the primary and secondary affect the way potential differences are stepped (changed) up or stepped (changed) down:

N_p and N_s are the number of turns on the primary and secondary coils.

V_p and V_s are the potential differences across the primary and secondary coils.

> **TIP**
> Be careful when swapping the sides over to check that you have copied each side exactly. Do not try to change the formula as you swap – this often leads to errors.

The equation is:

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

with the sides swapped over becomes

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

An unknown V_p now becomes much easier to calculate, because it is on the left-hand side of the equation at the top. You now just need to multiply both sides by V_s to find the value of V_p.

This swapping over is useful when you want to **rearrange** an equation, for example to make what is on the top line of the right-hand side appear on the top line of the left-hand side. We will consider this in Maths focus 2.

> **TIP**
> Knowing the variable symbol, name and unit can help you to identify the correct values from the sentences of the problem.

> **LINK**
> See Chapter 1, 'Representing values', for more on variable symbols and units.

WORKED EXAMPLE 1

Find the weight of an object of mass 500 g when it experiences a gravitational field strength of 7.0 N/kg.

Step 1: Make a list of the variables in the question and their values with units.

$$W = ?$$

$$m = 500\,g$$

$$g = 7.0\,N/kg$$

Step 2: Convert any inconsistent units. The gravitational field strength is N/kg, so the mass ne eds to be in kilograms.

$$500\,g = 0.5\,kg$$

Step 3: Choose the equation that you need. *Make sure that there is only one unknown value*, because it not possible to work out answers when there are two unknowns. Write down the equation.

$$W = mg$$

Step 4: Substitute the values and units into the equation.

$W = mg$

$W = 0.5\,\text{kg} \times 7.0\,\text{N/kg}$

Step 5: Calculate the unknown value, remembering to include the unit.

$$W = 3.5\ N$$

WATCH OUT

In all your calculations in physics, make sure you use an equation with just one unknown value. Ideally the symbol for this should be on the left-hand side of the equation.

Practice question 1

A group of people stand 85 m away from a cliff face and shout. They hear the echo after 0.5 s.

a Find the total distance travelled by the sound.

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b Calculate the speed of the sound.

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TIP

The answer to a calculation may have more digits than is sensible for a value obtained from measured data. Use the least number of significant figures shown in the data.

Practice question 2

A solid rectangular object has sides 2 cm, 3 cm and 5 cm. Its mass is 270 g.

a Find the density of the object.

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b Will the object float or sink in water?

....

LINK

See Chapter 1, Maths focus 3, 'Determining significant figures'.

WATCH OUT

With all sound calculations, you need to ensure that the distance and time relate to the same part of the journey. Is 'there and back' considered or just one direction?

Practice question 3 (supplement)

A train travelling at 33 m/s has a mass of 8000 kg.

a What is the value of its kinetic energy? Give your answer in standard form to 2 sf.

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b It the speed is doubled, what is the new value of its kinetic energy? Give your answer in standard form to 2 sf.

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> **TIP**
>
> If you cannot remember the equation to use, look it up in the syllabus or in the Equations section at the back of this book. Then make sure that you memorise the formula.

Maths skill 2: Calculating with percentages

Percentages are very useful for comparing values. 'Per cent' means 'out of a hundred', so 18% means $\frac{18}{100}$ or 0.18.

- To change a % to a fraction, write the value as a fraction with 100 as the *denominator* (the bottom line of a fraction). Example: $63.5\% = \frac{63.5}{100}$
- To change a fraction or decimal to a percentage multiply by 100 and write the % sign next to the number. Example: find $\frac{7}{8} = \frac{7}{8} \times 100$ $\frac{700}{8} = 87.5\%$

WORKED EXAMPLE 2

Find 30% of 2 kg

Step 1: Find 1% of 2 kg.

KEY QUESTION TO ASK YOURSELF:

- How do you find 1% of 2 kg?

  Divide 2 kg by 100: $\frac{2\,kg}{100}$

Step 2: Multiply by 30 to find 30% of 2 kg:

$$\frac{2\,\text{kg}}{100} \times 30 = 0.6\,\text{kg}$$

> **LINK**
>
> See Chapter 6, Maths focus 1, 'Solving problems involving shape' for more on volume.

> **LINK**
>
> See Chapter 1, Maths focus 4, 'Representing very large and very small values' for more on standard form.

Practice question 4

Complete this table. The first one is done for you:

	Percentage	Decimal
4 m as a percentage of 20 m	$\frac{4}{20} \times 100 = 20\%$	0.2
12 minutes as a percentage of 60 minutes		
1250 cm^3 of a liquid as a percentage of 2000 cm^3 of liquid		
35 g as a percentage of 805 g		

> **TIP**
>
> The **percentage** is how many parts of a hundred.
>
> To convert a fraction $\frac{x}{y}$ to a percentage, multiply the fraction by 100.

Practice question 5 (Supplement)

The total amount of input energy of a machine is 180 J. Find the percentage of energy wasted when the useful output energy is 45 J.

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Maths focus 2: Calculating values using equations

Sometimes you have to adjust an equation to work out a value – this is called **rearranging**. You will find it easier to memorise equations if you learn just one version – see the Equations section at the back of the book. Then, if you know how to rearrange equations you can get a different variable on its own on the left-hand side.

Here we will look at techniques for rearranging equations to get the value that you want. We will just look at equations that involve multiplication and division, because these are the ones you see most often in physics; for example, the link between mass and weight $W = mg$, the density equation $P = \frac{m}{V}$, the equation that defines resistance $R = \frac{V}{I}$.

TIP
Rearranging an equation or a formula may be called **changing the subject** of the formula.

What maths skills do you need to calculate values using equations?

1 Using two equations	• Choose the correct equations • Substitute known values • Swap the sides of an equation if necessary • Rearrange if necessary: multiply or divide by a value in order to isolate a variable • Use the 'found' value in the other equation
2 Using an equation of the form: $\frac{y_1}{y_2} = \frac{x_1}{x_2}$	• Know that expressions that are ratios have no unit • Multiply and divide as necessary to isolate a variable
3 Understanding the impact of changing variable size	• Know the impact on answers of multiplying and dividing by larger and smaller numbers

Maths skills practice

How does rearranging an equation help us to find an unknown value?

TIP
Equations are read from left to right.

When working out the value of an unknown variable from an equation, it is best if the unknown is on the left-hand side of the equals sign.

To do this you may need to rearrange an equation. Then it is easier to find its value.

As an example, resistance is a measure of how hard it is for the potential difference to make the current flow. We use the equation:

$$\text{resistance} = \frac{\text{potential difference}}{\text{current}}$$

If you need to find the current, the equation needs rearranging to become:

$$\text{current} = \frac{\text{potential difference}}{\text{resistance}}$$

Once the current has been found, its value can be used to help find other values, such as the current in another part of the circuit.

Methods of rearranging equations are shown in Table 5.1. These work because of some simple mathematical rules:

- Any number or variable multiplied or divided by 1 stays the same, i.e. $\frac{b}{1} = b$
- Any fraction showing a number or a variable divided by itself is equal to 1, i.e. $\frac{b}{b} = 1$

Therefore a fraction such as $\frac{b}{b}$ can be cancelled and hence ignored in multiplication or division.

When rearranging an equation, we choose a value to multiply or divide by so that we can cancel. Read through Table 5.1, and look out for times when this cancelling happens.

TIP

Remember that zx means $z \times x$.

Equation	What do you want to find? (the unknown variable)	How to do it	Example equation
y = zx	y	Multiply z by x	Finding weight from $W = mg$
y = zx	z (one of the two variables that are multiplied together)	Swap sides, then divide both sides by x: $z = \frac{y}{x}$	Finding mass from $W = mg$
y = $\frac{z}{x}$	y	Divide z by x	Finding pressure from $P = \frac{F}{A}$
y = $\frac{z}{x}$	z	Multiply both sides by x to get $yx = z$ Swap sides: $z = yx$	Finding a force from $P = \frac{F}{A}$
y = $\frac{z}{x}$	x	Multiply both sides by x to get $xy = z$ Then divide both sides by y: $x = \frac{z}{y}$	Finding area from $P = \frac{F}{A}$
$\frac{y_1}{y_2} = \frac{x_1}{x_2}$	y_1 (one of the variables on the top line)	Multiply both sides by the variable that y_1 is divided by, i.e. y_2. $\frac{y_1 y_2}{y_2} = \frac{x_1 y_2}{x_2}$ Cancel: $y_1 = \frac{x_1 y_2}{x_2}$	Finding the number of turns on the primary coils of a transformer N_p from $\frac{N_p}{N_s} = \frac{V_p}{V_s}$
$\frac{y_1}{y_2} = \frac{x_1}{x_2}$	y_2 (one of the variables on the bottom line)	Multiply both sides by the unknown variable that you want to find, i.e. y_2. $\frac{y_1 y_2}{y_2} = \frac{x_1 y_2}{x_2}$ Cancel: $y_1 = \frac{x_1 y_2}{x_2}$ Then divide both sides by x_1 and multiply both sides by x_2. $\frac{y_1 x_2}{x_1} = y_2$ Swap sides: $y_2 = \frac{y_1 x_2}{x_1}$	Finding the number of turns on the primary coils of a transformer N_s from $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

Table 5.1 Key methods of rearranging equations

TIP

Alternatively, if you have sufficient information, you can split $\frac{y_1}{y_2} = \frac{x_1}{x_2}$ into two equations, making both sides equal to the same unknown value a: $\frac{y_1}{y_2} = a$ and $\frac{x_1}{x_2} = a$. Then rearrange these equationsasnecessary.

The pattern that you can see in Table 5.1 is:

- If the variable you want is at the top, divide both sides by any variable or number that is preventing the required variable being on its own.
- If the variable you want is at the bottom, multiply both sides by that variable to get it onto the top.

Maths skill 1: Using two equations

You have already seen how to substitute into equations where there is just one equation with one unknown. This section is about how the values found from one equation can be used in another equation. For instance, you can find out how much pressure a weight exerts on an area from knowing its mass. This is by using $W = mg$ to find the weight, then using $P = \frac{F}{A}$, where the weight W is substituted as the force F.

WORKED EXAMPLE 3

Find the pressure, in kg/m^2, exerted by a 1 kg bag of sugar placed on a shelf. The surface area in contact with the shelf is 10 cm by 8 cm. Gravitational field strength is 10 N/kg.

Step 1: Check the units and ensure that they are consistent.

Convert each length into metres.

10 cm = 0.1 m

8 cm = 0.08 m

Step 2: Use the equation $W = mg$ to find the weight of the bag of sugar

$W = 1\,kg \times 10\,N/kg$

$W = 10\,N$

Step 3: Then using the equation for pressure, $p = \frac{F}{A}$, as weight is the force that acts on the surface $F = W$. The area of contact, A is unknown.

Area = length × breadth

Area = 0.1 m × 0.08 m

Area = 0.008 m²

Step 4: Substitute the values for force and area into the equation $p = \frac{F}{A}$

$$p\ (in\ Pa) = \frac{10\,N}{0.008\,m^2}$$

$$p = 1250\,Pa$$

WORKED EXAMPLE 4 (SUPPLEMENT)

A boy whose weight is 500 N runs up a set of steps which are 4 m high. The average power he develops is 250 W. Which of the following is the time that he takes to run up the steps?

A 2 s **B** 4 s **C** 8 s **D** 20 s

WATCH OUT

F is used to represent force. Weight is a force and so *F* can be used in this case. Weight can be represented by *W* or *F*. Take care, because *W* is also used to represent work done.

Step 1: List the values of the known variables and units. Check the units are consistent with each other.

$$F = 500\,\text{N}$$

$$d = 4\,\text{m}$$

$$t = ?\,\text{s}$$

$$P = 250\,\text{W}$$

In this case the units are consistent.

1 watt = 1 joule per second and 1 joule = 1 newton × 1 metre

There are no prefixes or inconsistent units to take into account.

Step 2: Choose suitable equations and write them down. In this case,

energy transferred, $\Delta E = Fd$

and

power developed, $P = \frac{\Delta E}{t}$

These two equations link all of the information in the question.

TIP

Get into the habit of writing just one equals sign, =, on each line.

Step 3: Firstly, choose the equation where there is only one unknown variable.

$$\Delta E = Fd$$

Substitute the values and find ΔE.

$$\Delta E = 500\,\text{N} \times 4\,\text{m}$$

$$\Delta E = 2000\,\text{N}$$

Step 4: You now have only one unknown in the second equation.

$$\text{P} = \frac{\Delta E}{t}$$

$$250\,\text{W} = \frac{2000\,\text{N}}{t}$$

Step 5: Rearrange to get time t on its own. Multiply both sides of the equation by t.

$$250\,\text{W} \times t = 2000\,\text{N}$$

Then divide both sides by 250 W.

$$t = \frac{2000\,\text{N}}{250\,\text{W}}$$

$$t = 8\,\text{s}$$

The answer is C.

WATCH OUT

Make sure that your final answer has the correct unit.

Practice question 6

A person of mass 60 kg gets into a boat. The surface area of the bottom of the boat in contact with water is 2.5 m². What is the increased pressure on the water when the person gets on board? Gravitational field strength is 10 N/kg.

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TIP

Find the person's weight first.

> **LINK**
> See Chapter 1, Maths focus 3, 'Determining significant figures'.

> **TIP**
> In calculations involving efficiency, it often helps to replace the percentage value with the equivalent decimal or fraction, for example 20% = 0.20.

> **TIP**
> Expressions in the form of $\frac{y_1}{y_2}$ represent a ratio of different values of the same quantity, measured in the same units. The ratio has no unit.

> **LINK**
> See Table 5.1, 'Key methods of rearranging equations'.

Practice question 7 (Supplement)

a When the output potential difference from a power station is 25 000 V, a current of 20 000 A flows. What it the output power?

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b Calculate the input power needed at the power station if the efficiency is 37%. Give your answer to 3 sf.

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Maths skill 2: Using an equation of the form $\frac{y_1}{y_2} = \frac{x_1}{x_2}$

When you use an equation of the form $\frac{y_1}{y_2} = \frac{x_1}{x_2}$ there will be three known values and one unknown.

$\frac{y_1}{y_2}$ is a ratio. A *ratio* is an expression which is a comparison of two numbers with the same unit; the ratio of A to B can be written $A:B$, or expressed as a fraction $\frac{A}{B}$.

If you are calculating the value y_1, then multiply both the left-hand side and the right-hand side by y_2. This isolates y_1.

The same method applies when calculating x_1. Multiply both the left-hand side and the right- hand side by x_2.

A ratio that you often meet in physics is the transformer equation $\frac{V_p}{V_s} = \frac{N_p}{N_s}$ In this equation two ratios are equal to one another.

The following worked example asks you to find the variable x_2. This needs more thought.

WORKED EXAMPLE 5

A transformer has an input voltage of 250 V a.c. and output voltage of 10 V a.c. The number of turns on the primary coils is 3000. How many turns are on the secondary coil?

Step 1: List the known information from the question.

$$V_p = 250\text{ V}$$

$$V_s = 10\text{ V}$$

$$N_p = 3000$$

$$N_s = ?$$

Step 2: Choose the equation that gives only one unknown:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

Step 3: Substitute the values into the equation:

$$\frac{250\text{ V}}{10\text{ V}} = \frac{3000}{N_s}$$

Step 4: Multiply both sides by N_s to make N_s appear on the top line:

$$N_s \times \frac{250\text{ V}}{10\text{ V}} = 3000$$

Step 5: Isolate N_s by multiplying both sides of the equation by 10 and then dividing both sides by 250.

$$N_s \times \frac{250\,\text{V}}{10\,\text{V}} \times 10 = 3000 \times 10$$

$$N_s \times 250 \div 250 = 30\,000 \div 250$$

$$N_s = 120$$

TIP

Alternatively, simplify the fraction on the left-hand side of the equation:

Step 5: Simplify the fraction on the left-hand side of the equation

$N_s \times 25 = 3000$

Step 6: Divide both sides by 25 to isolate N_s

$N_s = 120$

Practice question 8

A transformer is used to change a voltage of 11 000 V to 132 000 V. It has 1000 turns on its primary coil. How many turns does it have on its secondary coil?

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LINK

See Chapter 1, Maths focus 3, 'Determining significant figures'.

Practice question 9 (Supplement)

To find out if a crystal is a diamond, an optical experiment is done to compare its refractive index with that of diamond. Measurements of the angle of incidence, *i*, and the angle of refraction, *r*, are taken, and then compared to similar measurements for a diamond.

	Diamond	Crystal
i /°	20.0	10.0
r /°	8.2	*A*

What value would you expect to find for angle of refraction *A* in the table, if the crystal is a real diamond? Show your working and give your answer to 2 sf.

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WATCH OUT

The formula for refractive index uses sine values.

TIP

Make sure you know how to use your calculator to input a **sine** (sin) value and to evaluate an **inverse sine** ($\sin^{-1}$, giving the angle whose sin is a particular value).

Maths skill 3: Understanding the impact of changing variable size

Changing the size of the values in an equation can have a significant impact on the outcome.

When two numbers are multiplied together, e.g. $a \times b$:

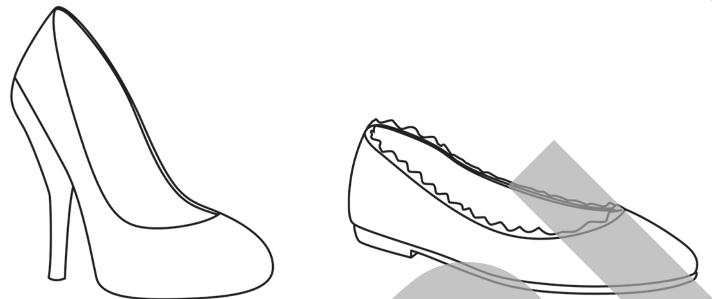
- If one of the numbers a or b gets bigger, the product becomes bigger.
- If one of the numbers is less than 1, the product is smaller than the other number. For example, if $a = 12$ and $b = 0.4$, then the product is: $12 \times 0.4 = 4.8$

When one number is divided by another, e.g. $\frac{a}{b}$:

- If a gets bigger, the answer becomes bigger.

  If b gets bigger, the answer becomes smaller. We will look at this in the next worked example.

WORKED EXAMPLE 6



A woman whose weighs 600 N wears a pair of flat shoes. Each shoe has a surface area of 250 cm² in contact with the ground. What pressure does she exert on the ground? She then changes into stiletto shoes that both have a contact surface area of 75 cm². What is the new pressure?

Step 1: Choose the pressure equation:

$$\text{pressure} = \frac{\text{force}}{\text{area}}$$

Step 2: Substitute the values for the first set of shoes. Don't forget the area needs be multiplied by two as people wear a *pair* of shoes.

$$\text{pressure} = \frac{600\,\text{N}}{2 \times 250\,\text{cm}^2}$$

$$\text{pressure} = 1.2\,\text{N/cm}^2$$

Step 3: The woman has changed the shoes to stilettos, with a narrow heel. Substitute the values for the stilettos.

$$\text{pressure} = \frac{600\,\text{N}}{2 \times 150\,\text{cm}^2}$$

$$\text{pressure} = 2\,\text{N/cm}^2$$

The reduction in the surface area has caused an increase in the pressure.

TIP

Any equation in the form of a fraction with time on the bottom line, as in power = $\frac{\text{energy transferred}}{\text{time}}$, is about the **rate** that something is happening. Power is the rate at which energy is being transferred. If the time is short for a given energy transfer, the power developed is high.

WORKED EXAMPLE 7 (SUPPLEMENT)

A machine transfers 2000 J of energy in 0.1 s. What is the impact of transferring the same amount of energy in 10 s?

Step 1: Choose the equation that links the variables with only one unknown.

$$\text{power} = \frac{\text{change in energy}}{\text{time}}$$

$$\text{power} = \frac{\Delta E}{t}$$

Step 2: Substitute the data into the equation.

$$\text{power} = \frac{2000\,\text{J}}{0.1\,\text{s}}$$

$$\text{power} = 20\,000\,\text{W}$$

This shows that 20 000 J of energy is being transferred every second.

Step 3: Repeat the substitution with the larger value for time.

$$\text{power} = \frac{2000\,\text{J}}{10\,\text{s}}$$

$$\text{power} = 200\ \text{W}$$

By lengthening the time for the transfer, the power is reduced – the rate of energy transfer is reduced.

Practice question 10

An astronaut has a mass of 95 kg.

a Calculate the weight of the astronaut on the Earth where the gravitational field strength is 10 N/kg.

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b Calculate the weight of the astronaut on Pluto where the gravitational field strength is 0.6 N/kg.

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c The astronaut now lands on a new planet and his weight there is 1235 N. What is the gravitational field strength on the new planet? Give your answer to 2 sf.

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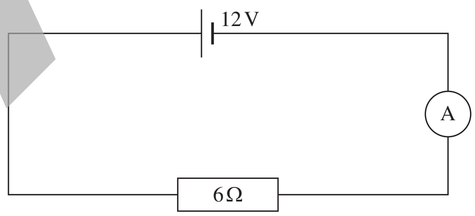
LINK

See Chapter 1, Maths focus 3, 'Determining significant figures'.

Practice question 11

A student is told that the smaller the current caused by a potential difference is, the greater is the circuit resistance.



When the student changes the resistor in the circuit shown, the current changes from 0.02 A to 0.4 mA. What is the value of the new resistance? Was the information told to the student correct?

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Maths focus 3: Doing more complex calculations (supplement)

Many problems in physics are complex and may need more than two equations to solve them. You need to consider how the result of one equation can be used in another. It is helpful to know that the same variable may be in several equations – energy is a good example (see Figure 5.1).

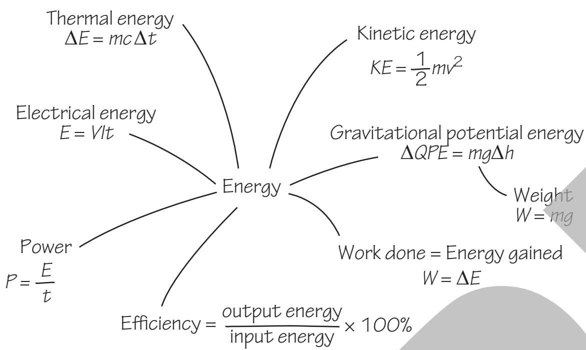

Figure 5.1 The quantity 'energy', symbol E, appears in many equations in physics

With a common variable, equations can be linked together. For example, the work done in lifting an object equals the gravitational potential energy gained by the object. If the time taken for the lifting is known, the power can be calculated. Which equations in Figure 5.1 would be used?

WATCH OUT

Be careful to think about the physics. Check that the variables you are equating are the same physical quantity. The work done lifting a body equals the gravitational potential energy gained. However, it *does not* equal its kinetic energy as it moves upwards.

What maths skills do you need to do more complex calculations?

1 Doing calculations involving several equations	• Record the information that you know and what you need to find • Choose the correct equations to work with • Work out the sequence in which to apply equations • Apply BIDMAS
2 Adding reciprocals	• Add fractions • Find unknown variables

Maths skills practice

How do complex calculations help with problem-solving in physics?

You might need to calculate the efficiency and the power of someone going upstairs, when you are only given the person's weight, change in height and the time taken. This would need a several calculations using equations involving energy.

TIP

Go through the list of formulae in the Equations section at the back of this book. Look out for variables that re-occur. These are the ones that are often used in multi-step calculations.

Maths skill 1: Doing calculations involving several equations

As with all problems, you need to start by writing down values of the variables you know and list the variable you are trying to find. From this you can start with an equation with one unknown. The information gained from this answer can then be used in another equation.

TIP

The symbol Δ means 'change in'.

When you *read* an equation, you read from left to right, just like reading sentences in English. But, when working out the mathematics in an equation such as $\Delta GPE = mg\Delta h$, which can be written $\Delta GPE = mg(h_2 - h_1)$, the *order of calculation* is not always left to right. It is helpful to remember the term **BIDMAS**, which reminds you about which parts of a calculation to do first:

Brackets, **I**ndices (powers), **D**ivision, **M**ultiplication, **A**ddition, **S**ubtraction

TIP

Note that the force needed to lift the object is the object's weight, $mg = 20\,N$.

WORKED EXAMPLE 8

A machine uses 300 J of energy to lift a 20 N object from a platform that is 5 m high to a roof that is 17 m high. If it develops a useful power of 600 W, calculate the input power.

Step 1: List the values of the known variables and units.

Input energy = 300 J

Force = 20 N

Starting height = 5 m

Finishing height = 17 m

Input power = ?

Output power = 600 W

KEY QUESTIONS TO ASK YOURSELF:

1 Which equations do you know, relevant to this context, that contain these variables?

$\Delta GPE = mg\Delta h$

$$efficiency = \frac{useful\ energy\ output}{energy\ input} \times 100\,\%$$

$$efficiency = \frac{useful\ power\ output}{power\ input} \times 100\,\%$$

2 Which of these equations has only one unknown value?

We have all the information to calculate the gravitational potential energy, $\Delta GPE = mg\Delta h$.

Step 2: The equation $\Delta GPE = mg\Delta h$ includes the *change in* height, Δh, so you need to work this out first. This is the same as working out the brackets in BIDMAS, since the equation can be written as $\Delta GPE = mg(h_2 - h_1)$. The change in height Δh is $h_2 - h_1$.

Change in height, $\Delta h = 17\,m - 5\,m$

$= 12\,m$

TIP

Remember that moving 1 N through 1 m takes 1 J of work.

Step 3: Then $\Delta GPE = mg\Delta h$

$= 20\,N \times 12\,m$

$= 240\,J$

Step 4: Link ΔGPE to the useful energy transferred.

Energy transferred (output energy) $= \Delta GPE$

$= 240\,J$

Step 5: Link input energy, useful energy transferred (output) and efficiency together. There are two knowns and one unknown.

$$efficiency = \frac{useful\ energy\ output}{energy\ input} \times 100\%$$
$$= \frac{240\,J}{300\,J} \times 100\%$$
$$= 80\%$$

Step 6: We need to find the input power. Link with the efficiency equation expressed in terms of power:

$$efficiency = \frac{useful\ power\ output}{power\ input} \times 100\%$$
$$So,\ 80\,\% = \frac{600\ W}{power\ input} \times 100\%$$

Step 7: Rearrange the equation to give power input.

$$\text{power input} = \frac{600\,\text{W}}{80} \times 100$$
$$\text{power input} = 750\,\text{W}$$

LINK
See Maths focus 2, Table 5.1, 'Key methods of rearranging equations.

Practice question 12

Make a spider diagram, similar to that in Figure 5.1, for either mass or force.

Practice question 13

The power used by a 1.5 V calculator is 1.0×10^{-4} W. When the '=' button is pressed the current flows for 2.6×10^{-7} s.

a Calculate the current from the battery.

....

....

....

....

TIP

In many questions, an answer from an earlier part of the question is needed to complete the next stage. Where this happens, round the numbers at each stage of the calculation but use an extra significant figure. Do the final rounding (to the same number of significant figures as the least number in the question data) at the end of all of the calculations.

TIP

Sometimes multi-step calculations are needed because a change happens in a process, and separate calculations are needed for each stage.

TIP

$\frac{1}{R}$ is called the **reciprocal** of R.

LINK

See Chapter 4, Maths focus 4, Maths skill 2, 'Determining when a relationship is inversely proportional', for more on reciprocals.

b What is the resolution of the circuits in the calculator?

....

....

....

....

c How much energy is transferred in the process?

....

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Maths skill 2: Adding reciprocals

In the design of electric circuits, it is essential to be able to work out the resistance, current and voltages of components in different circuits.

If resistors are in parallel, as in Figure 5.2, the potential difference V across the each one is the same. The total current shown by the symbol I_T equals the *sum* of the current in each of the branches of the circuit.

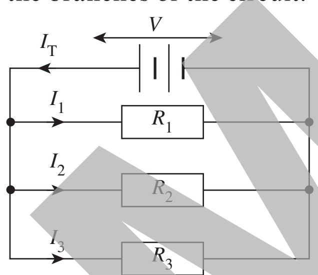


Figure 5.2 Resistors in parallel

$$I_T = I_1 + I_2 + I_3$$

Also $\quad I_1 = \frac{V}{R_1} \quad I_2 = \frac{V}{R_2} \quad I_3 = \frac{V}{R_s}$ and $\quad I_T = \frac{V}{R_T}$

where R_T is the total (effective) resistance of the parallel resistors.

Therefore

$$\frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_s}$$

Dividing both sides of the equation by V:

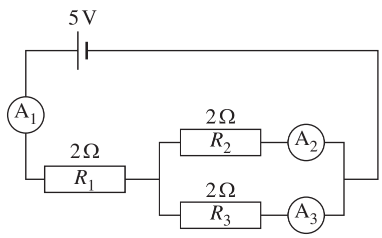
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_s}$$

This allows you to calculate R_T.

TIP

If the resistance values don't allow you to use simple fraction arithmetic, you will need to evaluate the reciprocals using your calculator. The button may be marked $\frac{1}{x}$ or $1/x$ or x^{-1}. You may also need to use a 'shift' or '2nd function' button.

WORKED EXAMPLE 9



A 5 V cell enables a current to flow in this circuit. Find the total resistance of the resistors in parallel, and the total resistance in the circuit.

KEY QUESTIONS TO ASK YOURSELF:

1 Which combination of resistors is in parallel?

R_2 and R_3 are in parallel.

2 How can the total resistance of this parallel section of the circuit be labelled?

R_p is appropriate.

3 Which combination of resistors is in series?

R_1 and R_p are in series.

Step 1: Write down the equation involving R_p.

$$\frac{1}{R_P} = \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_P} = \frac{1}{2} + \frac{1}{8}$$

Using fraction arithmetic:

$$\frac{1}{R_P} = \frac{4+1}{8}$$

$$\frac{1}{R_P} = \frac{5}{8}$$

$$R_p = 1.6\,\Omega$$

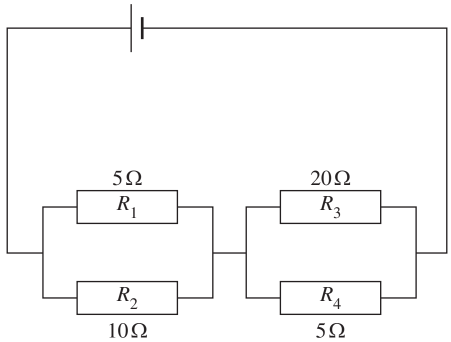
Step 2: As Rp and R_1 are in series, they can be added to find R_T, the total resistance.

$$R_T = 1.6\,\Omega + 2\,\Omega$$

$$R_T = 3.6\,\Omega$$

Practice question 14

Calculate the total resistance in this circuit.

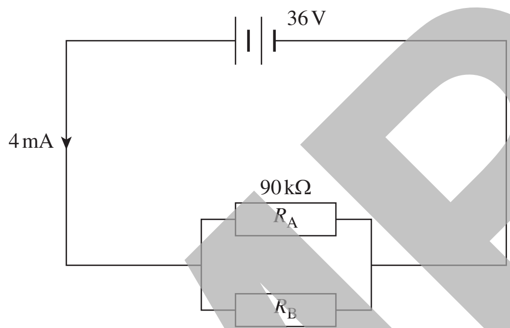


TIP

Calculate the resistance of each set of parallel resistors first.

Practice question 15

What is the resistance of component R_B when a potential difference of 36 V causes a total current of 4 mA to flow? Circle A, B, C or D. Explain your answer.



A 9 mΩ   **B** 10 mΩ   **C** 9 kΩ   **D** 10 kΩ

Explanation:

Maths focus 4: Calculations that involve direction: moments and momentum

The direction in which a force acts is important to the outcome. When a force is causing an object to turn, for example when a weight is put on one end of a beam, then the size of the force and the direction of turning has to be taken into account in any calculations.

What maths skills do you need in calculations that involve direction?

1 Calculating moments	Recognise clockwise ↻ and anticlockwise ↺ directions. Apply the principle of moments : ↺ moment = ↻ moment for objects in equilibrium (balanced) Apply the rule: upwards force is equal and opposite to downwards force for objects in equilibrium
2 Solving momentum problems (Supplement)	Apply direction to momentum calculations Choose and apply the correct momentum equation

Maths skills practice

How is direction important in physics problems?

In many situations the direction of a force or the direction of motion is important to the outcome. Here are just two examples:

- If you are pushing on a door to open it and someone else also pushes it, the *direction* of the push from the other person can make it harder or easier for you to open the door.
- When you are driving a bumper car and are hit by another one, the *direction* in which you are each initially moving affects the impact.

Maths skill 1: Calculating moments

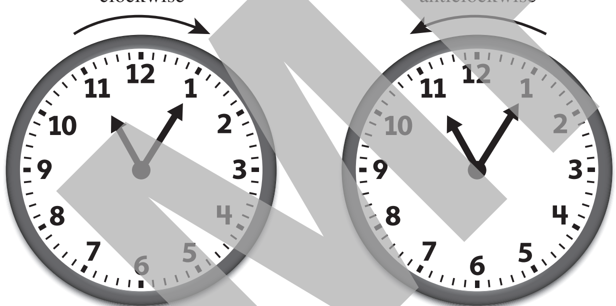
The *moment* of a force is a measure of the turning effect of a force. The direction of the force is important.

When an object is balanced, that is, not turning:

- sum of the anticlockwise moments = sum of the clockwise moments (the principle of moments)

Also, as in any physics problem involving equilibrium:

- sum of the upwards forces = sum of the downwards forces.

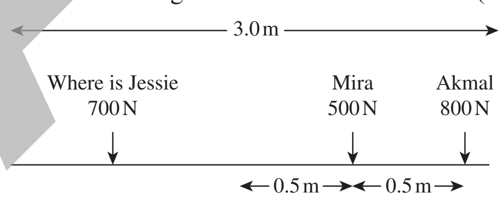


TIP

Make sure you know the difference between anticlockwise and clockwise.

WORKED EXAMPLE 10

Three children are playing on a see-saw which is pivoted in the middle. Where must Jessie be sitting if the see saw is balanced (i.e. in equilibrium)?



KEY QUESTION TO ASK YOURSELF:

- Which forces are tending to turn the see-saw anticlockwise about the pivot, and which are tending to turn it clockwise?

  Jessie's weight causes an anticlockwise moment, while Mira and Akmal contribute to a clockwise moment.

TIP

It is easier to apply the principle of moments if you calculate the anticlockwise moment first. Then keep this on the left-hand side of the equation.

> **TIP**
> The units of moment are Nm, therefore distances in the calculations must be in metres.

> **TIP**
> When describing a distance, always say where you are measuring from. Remember it should always be perpendicular distance from the pivot in moments equations.

Step 1: Work out the total of the anticlockwise moments caused by Jessie.

anticlockwise moment = force × perpendicular distance from the pivot

anticlockwise moment = 700 N × dm

Don't worry that this equation includes an unknown variable. It is the one we want to find: *d* is what we are calling the distance from the pivot to where Jessie sits.

Step 2: Work out the total of the clockwise moments caused by Mira and Akmal.

Mira's clockwise moment = force × perpendicular distance from the pivot

$= 500\,\text{N} \times 0.5\,\text{m}$

$= 250\,\text{Nm}$

Akmal's clockwise moment = force × perpendicular distance from the pivot

$= 800\,\text{N} \times 1.0\,\text{m}$

$= 800\,\text{Nm}$

Total clockwise moment = 250 Nm + 800 Nm

= 1050 Nm

Step 3: Apply the principle of moments:

total anticlockwise moments = total clockwise moments

$700d = 1050$

Step 4: Isolate *d* by dividing both sides of the equation by 700:

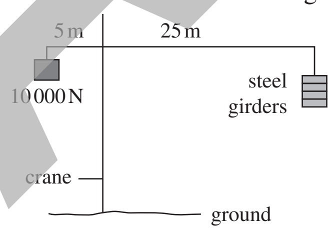
$$d = \frac{1050}{700}$$

$$d = 1.5\text{ m}$$

Jessie sits 1.5 m from the pivot.

Practice question 16

A crane, used to lift heavy steel girders, has a *jib* (arm) 30 m long. There is a concrete balancing weight of 10 000 N positioned at one end of the jib, 5 m from the pivot as shown. What is the maximum weight of girders the crane can lift? Assume the jib has no mass.



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> **LINK**
> See Chapter 6, Maths focus 3, 'Working with vectors'.

Maths skill 2: Solving momentum problems (supplement)

Momentum is defined as the product of the mass and the velocity of a moving object, that is mass multiplied by velocity. It is a **vector** quantity, which means its value includes its direction. Its direction will be that of the velocity.

We only need to consider motion in a straight line. Velocity and momentum values in one direction are positive, and in the opposite direction they are negative.

> **TIP**
> The principle of conservation of momentum is more formally written as: *when two or more bodies act on one another, for example in a collision, the total momentum of the bodies remains constant provided no external forces act.*

> **TIP**
> The impulse equation can be rearranged to:
> $$\text{force} = \frac{\text{change in momentum}}{\text{time}}$$
> This is sometimes called the *rate of change of momentum*.

There are three main equations in which momentum features:

1 momentum = mass × velocity

$$p = mv$$

2 momentum before an event = momentum after the event

This is called the *conservation of momentum*.

For two objects, 1 and 2, involved in a collision:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

where u_1 and u_2 represent the velocity of objects 1 and 2 before the collision, and v_1 and v_2 represent the velocity of each after the collision.

3 impulse on an object = force × time

$$Ft = mv - mu$$

$$\text{force} \times \text{time} = \text{mass} \times \text{final velocity} - \text{mass} \times \text{initial velocity}$$

You can think about impulse in two different ways:

- the force on the object multiplied by the period of time over which it acts.
- the change in momentum of the object.

WORKED EXAMPLE 11

A person jumps from a small stationary boat onto the shore, with a velocity of 2 m/s. The boat moves away from the shore. What is the velocity of the boat as the person leaves it?

The person's mass is 75 kg and the boat's mass is 200 kg.

KEY QUESTION TO ASK YOURSELF:

- Which of the momentum equations are relevant?

  The conservation of momentum equation is the relevant one here:

  $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Step 1: Apply the conservation of momentum.

Before the jump the combined momentum $m_1u_1 + m_2u_2$ of the person and the boat was zero. Therefore the total momentum $m_1v_1 + m_2v_2$ after the jump must be zero.

$$0 = m_1v_1 + m_2v_2$$

where m_1 is the mass of the person, m_2 is the mass of the boat, v_1 is the velocity of the person, and v_2 is the velocity of the boat.

LINK

See Maths focus 1, 'Understanding equations' for more on rearranging equations.

Step 2: Rearrange the equation.

$$v_2 = -\frac{m_1 v_1}{m_2}$$

The minus sign means that the boat is moving in the opposite direction to the person.

Step 3: Substitute values.

$$v_2 = -\frac{m_1 v_1}{m_2}$$

$$v_2 = -\frac{75 \times 2}{200}$$

$$v_2 = -10.75\,\text{m/s}$$

$$= -11\,\text{m/s rounded to the 2 sf of the data in the question}$$

TIP

Decide which object is moving in the positive direction and which one in the negative direction. It does not matter which you choose to be positive, but keep these directions consistently positive and negative throughout the problem. It may help to sketch a diagram.

Practice question 17

Two objects with masses of 10 kg and 11 kg move towards each other with velocities of 20 m/s and 5 m/s respectively. They join together and move as one body.

a What is the common speed of the objects just after the collision? Give your answer to 2 sf.

....

....

....

b In which direction do they move?

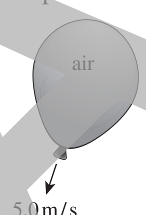
....

LINK

See Chapter 1, Maths focus 3, 'Determining significant figures'.

Practice question 18

A person releases the air, of mass 1.6 g, from an inflated balloon. The air escapes from the balloon at 5.0 m/s. The balloon deflates at a steady rate for 2.0 s. What is the forward impulsive force exerted on the neck of the balloon?



WATCH OUT

You need to convert the mass unit.

....

....

....

Maths focus 5: Radioactive decay calculations

In mathematics you cannot add two different things together and come out with a total, unless you carefully define what you are adding. You need to be really careful with the wording you use. For example, adding 6 protons to 11 neutrons and coming out with 17 as an answer does not make sense. Are they protons or neutrons?

However, if you add 6 'particles with mass' (nucleons) in the nucleus to 11 other 'particles with mass' (nucleons) in the same nucleus then the *total number of particles with mass* (nucleons) is 17. The *wording* really matters.

What maths skills do you need when you do radioactive decay calculations?

1 Doing particle calculations	• Know when particles can be added together • Balance radioactive decay equations (supplement)
2 Interpreting half-life information	• Choose correctly between halving values or doubling values as time goes forwards or backwards • Count the number of half-lives elapsed

Maths skills practice

How does knowing the decay pattern and the half-life of a radioactive material affect choices?

Applications of radioactive decay are an important part of the modern world. As a society we need to understand the processes involved so that safe decisions can be taken. In medicine, radioactive materials can be low-risk if used appropriately. Radioactive tracers, for example, used in diagnosis, need to have short half-lives, emissions that will cause minimum harm, and decay products that are safe inside the human body.

Maths skill 1: Doing particle calculations

Radioactive decay can be represented by equations that use special notation. For example:

$$^{241}_{94}\text{Am} \rightarrow {}^{237}_{92}\text{U} + {}^{4}_{2}\text{He}$$

- The chemical symbol represents the nucleus of a particular element.
- The number at the top left of the chemical symbol represents the total mass of the nucleus. It is the total number of nucleons (protons plus neutrons).
- The number at the bottom left of the chemical symbol is the number of protons in the nucleus. See Figure 5.3.

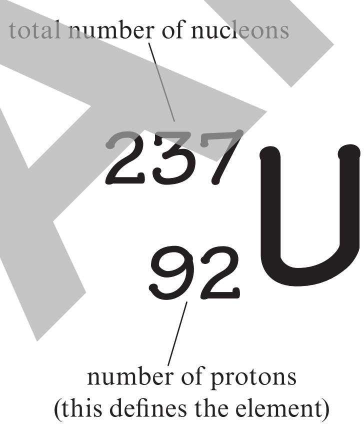


Figure 5.3 Nuclide notation used in decay equations

If the element produced in a decay is unknown, X is used for the chemical symbol. The proton number defines the element.

TIP

Radioactive decay equations have an arrow, not an equals sign. The arrow is read aloud as *becomes.*

TIP

The symbols we use for alpha and beta particles in decay equations are:

Particle	Symbol
alpha	${}^{4}_{2}\mathrm{He}$
beta	${}^{0}_{-1}\mathrm{e}$

The lower number –1 for the beta particle refers to its charge: one proton has charge +1 and one electron has charge –1.

An electron is not a nucleon, so its nucleon number is zero. You cannot add electrons and nucleons. Only the charges can be added.

TIP

Use an arrow, not an equals sign.

TIP

It helps to think of the lower numbers as charges which must balance.

WORKED EXAMPLE 12 (SUPPLEMENT)

When thorium ${}^{232}_{90}\mathrm{Th}$ decays, an alpha particle is emitted. Write the equation which describes this process.

Step 1: Identify the particle that is emitted and its associated symbol. It is an alpha (α) particle, which is ${}^{4}_{2}\mathrm{He}$.

Step 2: Decide whether the information given relates to the element that decays, or to the element that is produced.

Thorium is the starting element that decays.

Step 3: reate the equation using X as the unknown element.

Work out the number of nucleons (upper number) of the new element X, and then the number of protons (lower number).

Do this by ensuring the numbers are the same on both sides.

$$\text{Nucleons: } 232 \rightarrow \mathbf{228} + 4$$

$$\text{Protons: } 90 \rightarrow \mathbf{88} + 2$$

$${}^{232}_{90}\mathrm{Th} \rightarrow {}^{228}_{88}\mathrm{X} + {}^{4}_{2}\mathrm{He}$$

Step 4: On a Periodic Table find the chemical symbol of the element with this number of protons. Replace the X with this chemical symbol.

$${}^{232}_{90}\mathrm{Th} \rightarrow {}^{228}_{88}\mathrm{Ra} + {}^{4}_{2}\mathrm{He}$$

Practice question 19 (Supplement)

The nucleus of the radioactive isotope of radon, ${}^{222}_{86}\mathrm{Rn}$, emits an alpha particle. Write the equation that represents this event.

....

Practice question 20 (Supplement)

When carbon ${}^{14}_{6}\mathrm{C}$ decays, a β-particle is emitted. Work out the equation which represents the process.

....

Practice question 21

These symbols represent different radioactive nuclides.

${}^{98}_{52}\mathrm{P}$ ${}^{99}_{52}\mathrm{Q}$ ${}^{94}_{50}\mathrm{S}$ ${}^{99}_{51}\mathrm{T}$

a Which nuclide has the smallest mass? ....

b Which nuclide has the largest number of neutrons? ....

c (Supplement) Write an equation using two of these nuclides, where one decays to the other by alpha emission.

....

d (Supplement) Write an equation using two of these nuclides, where one decays to the other by beta emission.

....

Maths skill 2: Interpreting half-life information

The half-life of a radioactive element is the average length of time it takes for half of the nuclei in a sample to decay.

It is also the length of time it takes for the activity (number of decays per second) to fall to half.

WORKED EXAMPLE 13

The half-life of Americium-242 is 16 hours. Complete the missing figures in the table.

Time / hours	Count rate counts / s
0	800
16	
	200
48	100
80	25

Step 1: In the first column, look for the pattern showing how time increases.

The time increases by 16 hours for each reading. Therefore the pattern should be: 0, 16, 32, 48, 64, 80.

Step 2: Knowing that the count rate decreases by half every 16 hours (because this is the half-life), work out each missing count rate value from its preceding one.

At 16 hours, the count rate will be half the value of the count rate at the beginning:

$$\frac{800}{2} = 400 \text{ counts /s}$$

At 64 hours, the count rate will be half the value of the count rate at the beginning:

$$\frac{100}{2} = 50 \text{ counts /s}$$

The final table should read:

Time / hours	Count rate counts / s
0	800
16	**400**
32	200
48	100
64	**50**
80	25

WORKED EXAMPLE 14 (SUPPLEMENT)

Carbon $^{14}_{6}C$ has a half-life of 5730 years. The $^{14}_{6}C$ is produced in the upper atmosphere and becomes part of the carbon cycle: when living organisms interact with the atmosphere they absorb $^{14}_{6}C$. The proportion of $^{14}_{6}C$ in living organisms is constant. When the organism dies, no more $^{14}_{6}C$ is absorbed and the known amount of $^{14}_{6}C$ begins to decay. When a tree died it had 240 units of $^{14}_{6}C$ and as a fossil, it has 15 units. How old is the fossil? Give you answer to 3 sf.

KEY QUESTION TO ASK YOURSELF IN HALF-LIFE PROBLEMS:

Which is the better choice – to work from the most recent value and work backwards in time, or to work forwards in time?

In this case there is sufficient information to work either way.

Step 1: Look for the information given – the known amount of material or known count rate. *In this case we know the starting amount and the final amount of $^{14}_{6}C$: 240 units and 15 units.*

Step 2: Decide whether to count forwards or backwards in time.

We will count forwards from the start.

Step 3: Work out the number of units of $^{14}_{6}C$ after each half-life, by repeatedly halving the amount of material, until the final, known value is reached.

240 120 60 30 15

----------5730 y------- -------5730 y------ -------5730 y------ ------5730 y---------

Step 4: Add up the number of years:

4×5730 years = 22 920 years

The fossil is 22 900 years old, to 3sf.

TIP
If you write the time for the half-life between the numbers, then add them, you are less likely to make mistakes.

Practice question 22

Radioactive iodine, which has a half-life of 8 days, is used in hospitals to treat people with tumours in the thyroid gland. The initial count rate is 5.0×10^6 counts / s. Which answer shows the activity after 16 days? Circle A, B, C or D.

A 12.5×10^6 counts / s

B 10.0×10^6 counts / s

C 2.5×10^6 counts / s

D 5.0×10^3 counts / s

Practice question 23

An isotope called technetium-99 is used for bone scanning. Its half-life is 6.0 hours. At 7.00 pm in the hospital's bone scanning department the activity of a sample of technetium-99 is 30 counts / s. What was the activity when the sample left the hospital's storage unit at 7.00 am that morning?

....

....

Practice question 24

An isotope of a radioactive material has a half-life of 7.5 hours. After what period of time is the amount of radioactive material reduced by 75% of its initial value? Circle A, B, C or D.

A $\frac{3}{4}$ hours

B $\frac{1}{4}$ hours

C 15 hours

D 22.5 hours

WATCH OUT

The phrase *reduce by* has a different meaning to *reduce to*. Take care to read every single word in the question.

Further questions (Supplement)

1 An electron of mass 9.1×10^{-31} kg is made to move from rest to a speed of 2.3×10^{-5} m/s. It takes 1.0×10^{-14} s. What is the size of the force acting on it?

....

....

....

2 The producers of a film want to make two identical bullets have a head-on collision and melt. They need to ensure that the kinetic energy of the bullets is sufficient to melt the metal (lead) when they collide.

The melting point of lead is 327 °C. The specific heat of lead is 130 J/kg °C.

The temperature of the bullets before impact is 23 °C.

What speed will the bullets need to reach?

Assume all of the kinetic energy is turned into heat energy. Give your answer to 3 sf .

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3 A 120 cm fluorescent light fitting is suspended from a ceiling by two chains F_1 and F_2 as in the diagram.

F_1 positioned 10 cm from the end. F_2 is positioned 15 cm from the other end. The weight of the light is 15 N.

Calculate the tension forces in the chains.

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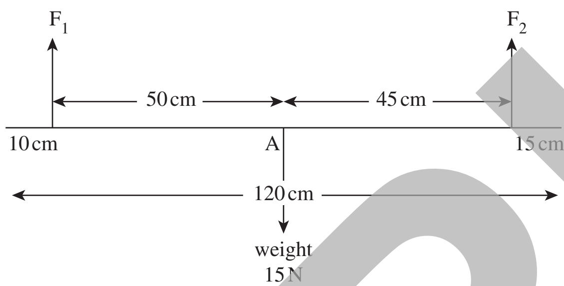
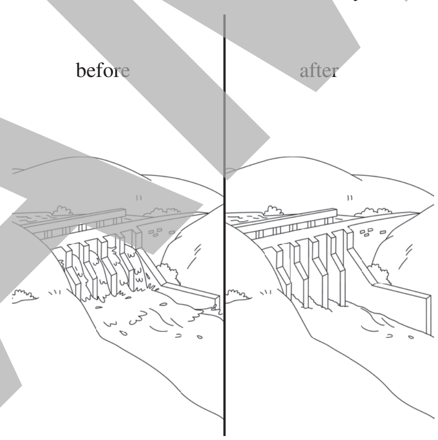


4 An electron of mass 9.1×10^{-31} kg is made to move from rest to a speed of 2.3×10^{-5} m/s. It takes 1.0×10^{-14} s. What is the size of the force acting on it?

5 The water in a dam is 50 m deep. The pressure at the bottom of the dam is 5.6×10^{5} Pa. During a drought the reservoir begins to dry out. What is the new pressure if the depth of the water becomes 35 m? Give your answer to 2 sf.



6 A mass of 20 kg has a constant force acting on it for 5 s. This produces an increase in momentum of 30 Ns. If the same force acts for 35 s on a mass of 10 kg, what is the increase in momentum of this mass?