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Executive Preview

Physics

for Cambridge IGCSE™

MULTI-COMPONENT SAMPLE

Digital Access

Brighter Thinking
Better Learning

Dear Cambridge Teacher,

The new *Cambridge IGCSE™ Physics* series will publish in Spring 2021, updated for the revised Cambridge International syllabuses (0625/0972) for examination from 2023.

This Executive Preview contains sample content from the series, including:

- A guide explaining how to use the series
- A guide explaining how to use each resource
- The table of contents from each resource
- The first chapter from each resource, including the coursebook, workbook, practical workbook, teacher's resource including sample data and practical guidance, English language skills workbook and maths skills workbook

This new series has been designed after extensive research interviews and lesson observations with teachers and students around the world. As well as targeted support in the coursebook, we have produced updated workbooks to address the key challenges we heard from teachers. A new workbook includes exercises for each topic, providing more practice opportunities to consolidate students' learning. The practical workbook includes practical activities to develop students' investigative skills, with extensive support notes and exemplar data provided in the teacher's resource.

A maths skills workbook and an English skills workbook develop students' maths skills (in relation to science) and linguistic skills, in the context of the Cambridge IGCSE Physics syllabus respectively. Both resources publish in 2022.

We have also updated the teacher's resource. With teaching activity, assessment and homework ideas, guidance on how to tackle common misconceptions in each topic and a new feature developing your own teaching skills, we hope this resource will inspire and support you and save you time.

Finally, as we develop new resources, we ensure that we are keeping up to date with best practice in pedagogy. For this new series we have added features to the coursebook, such as engaging projects to develop students' collaborative skills and 'getting started' questions and activities to help you evaluate students' learning starting points. We have developed our differentiated support in this new series, with three-tier exercises in the workbook progressing from 'focus', to 'practice', to 'challenge' and differentiated worksheets for each of the syllabus topics in the teacher's resource, supporting all your learners' different needs.

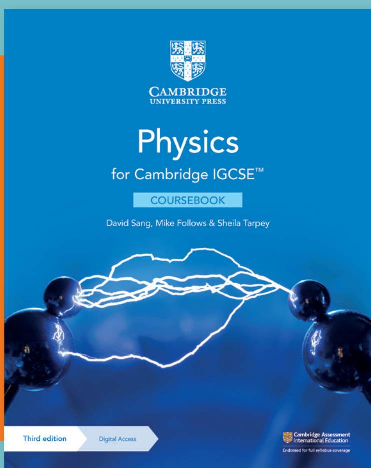
Visit our website to view the full series or speak to your local sales representative.

cambridge.org/education

Priyanka Comar and Gemma Coleman
Commissioning Editors for Cambridge IGCSE™ Sciences, Cambridge University Press

How to use this series

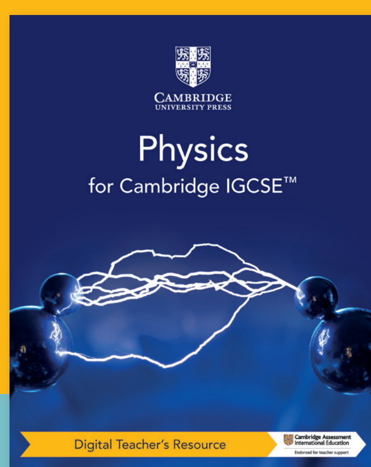
We offer a comprehensive, flexible array of resources for the Cambridge IGCSE™ Physics syllabus. We provide targeted support and practice for the specific challenges we've heard that students face: learning science with English as a second language; learners who find the mathematical content within science difficult; and developing practical skills.

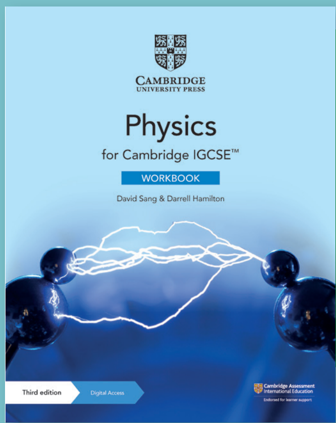


The coursebook provides coverage of the full Cambridge IGCSE Physics syllabus. Each chapter explains facts and concepts, and uses relevant real-world examples of scientific principles to bring the subject to life. Together with a focus on practical work and plenty of active learning opportunities, the coursebook prepares learners for all aspects of their scientific study. At the end of each chapter, examination-style questions offer practice opportunities for learners to apply their learning.

The digital teacher's resource contains detailed guidance for all topics of the syllabus, including common misconceptions identifying areas where learners might need extra support, as well as an engaging bank of lesson ideas for each syllabus topic. Differentiation is emphasised with advice for identification of different learner needs and suggestions of appropriate interventions to support and stretch learners. The teacher's resource also contains support for preparing and carrying out all the investigations in the practical workbook, including a set of sample results for when practicals aren't possible.

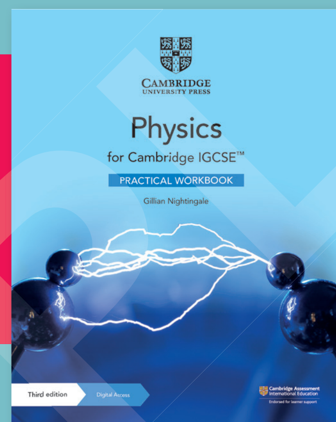
The teacher's resource also contains scaffolded worksheets and unit tests for each chapter. Answers for all components are accessible to teachers for free on the Cambridge GO platform.



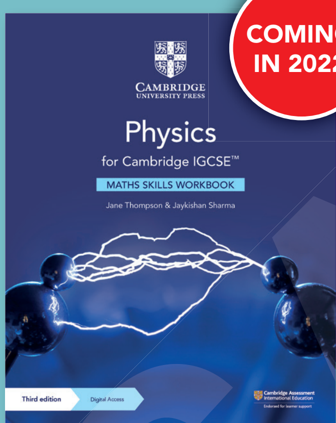


The skills-focused workbook has been carefully constructed to help learners develop the skills that they need as they progress through their Cambridge IGCSE Physics course, providing further practice of all the topics in the coursebook. A three-tier, scaffolded approach to skills development enables learners to gradually progress through 'focus', 'practice' and 'challenge' exercises, ensuring that every learner is supported. The workbook enables independent learning and is ideal for use in class or as homework.

The Cambridge IGCSE Physics practical workbook provides learners with additional opportunities for hands-on practical work, giving them full guidance and support that will help them to develop their investigative skills. These skills include planning investigations, selecting and handling apparatus, creating hypotheses, recording and displaying results, and analysing and evaluating data.



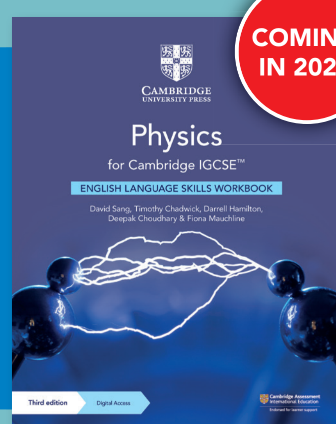
COMING IN 2022



Mathematics is an integral part of scientific study, and one that learners often find a barrier to progression in science. The Maths Skills for Cambridge IGCSE Physics write-in workbook has been written in collaboration with the Association of Science Education, with each chapter focusing on several maths skills that learners need to succeed in their Physics course.

Our research shows that English language skills are the single biggest barrier to learners accessing international science. This write-in workbook contains exercises set within the context of Cambridge IGCSE Physics topics to consolidate understanding and embed practice in aspects of language central to the subject. Activities range from practising using comparative adjectives in the context of measuring density, to writing a set of instructions using the imperative for an experiment investigating frequency and pitch.

COMING IN 2022



CAMBRIDGE
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Physics

for Cambridge IGCSE™

COURSEBOOK

David Sang, Mike Follows & Sheila Tarpey

Third edition

Digital Access

Contents

How to use this book

Throughout this book, you will notice lots of different features that will help your learning. These are explained below.

LEARNING INTENTIONS

These set the scene for each chapter, help with navigation through the coursebook and indicate the important concepts in each topic. These begin with 'In this chapter you will:'.

In the learning intentions table, Supplement content is indicated with a large arrow and a darker background, as in the example here.

GETTING STARTED

This contains questions and activities on subject knowledge you will need before starting the chapter.

SCIENCE IN CONTEXT

This feature presents real-world examples and applications of the content in a chapter, encouraging you to look further into topics that may go beyond the syllabus. There are discussion questions at the end which look at some of the benefits and problems of these applications.

EXPERIMENTAL SKILLS

This feature focuses on developing your practical skills. They include lists of equipment required and any safety issues, step-by-step instructions so you can carry out the experiment, and questions to help you think about what you have learned.

KEY WORDS

Key vocabulary is highlighted in the text when it is first introduced, and definitions are given in boxes near the vocabulary. You will also find definitions of these words in the Glossary at the back of this book.

Supplement content: Where content is intended for learners who are studying the Supplement content of the syllabus as well as the Core, this is indicated in the main text using the arrow and the bar, as on the right here, and the text is in blue. You may also see the blue text with just an arrow (and no bar), in boxed features such as the Key Words or the Getting Started. Symbols in blue are also supplementary content.

Questions

Appearing throughout the text, questions give you a chance to check that you have understood the topic you have just read about. The answers to these questions are accessible to teachers for free on the Cambridge GO site.

ACTIVITY

Activities give you an opportunity to check your understanding throughout the text in a more active way, for example by creating presentations, posters or taking part in role plays. When activities have answers, teachers can find these for free on the Cambridge GO site.

KEY EQUATIONS

Important equations which you will need to learn and remember are given in these boxes.

COMMAND WORDS

Command words that appear in the syllabus and might be used in exams are highlighted in the exam-style questions. In the margin, you will find the Cambridge International definition. You will also find these definitions in the Glossary.

SELF/PEER ASSESSMENT

At the end of some activities and experimental skills boxes, you will find opportunities to help you assess your own work, or that of your classmates, and consider how you can improve the way you learn.

WORKED EXAMPLE

Wherever you need to know how to use an equation to carry out a calculation, there are worked example boxes to show you how to do this.

REFLECTION

These activities ask you to think about the approach that you take to your work, and how you might improve this in the future.

PROJECT

Projects allow you to apply your learning from the whole chapter to group activities such as making posters or presentations, or performing in debates. They may give you the opportunity to extend your learning beyond the syllabus if you want to.

SUMMARY

There is a summary of key points at the end of each chapter.
Supplement content is indicated with a large arrow in the margin and a darker background, as here.

EXAM-STYLE QUESTIONS

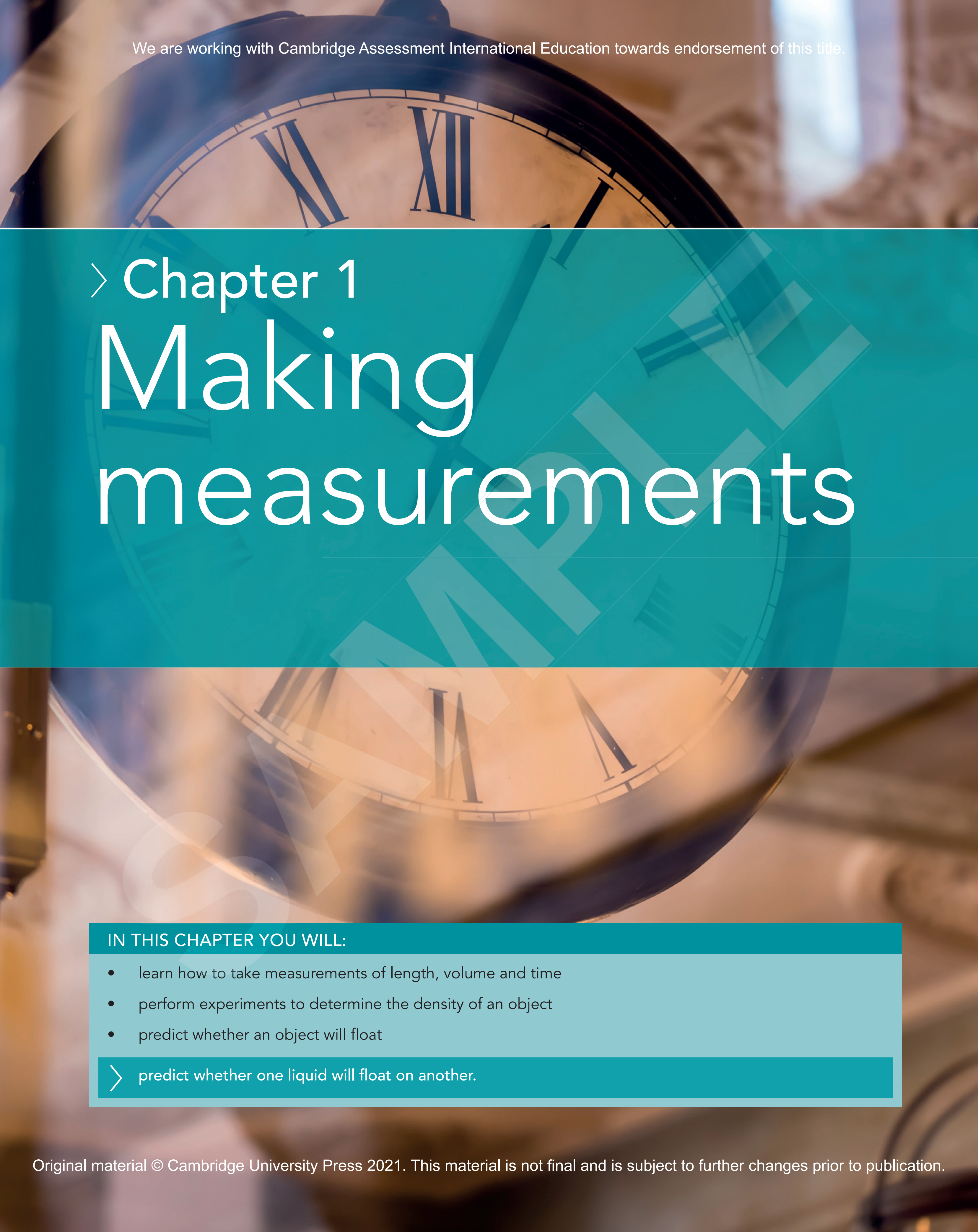
Questions at the end of each chapter provide more demanding exam-style questions, some of which may require use of knowledge from previous chapters. The answers to these questions are accessible to teachers for free on the Cambridge GO site.

Supplement content is indicated with a large arrow in the margin and a darker background, as here.

SELF-EVALUATION CHECKLIST

The summary checklists are followed by 'I can' statements which match the Learning intentions at the beginning of the chapter. You might find it helpful to rate how confident you are for each of these statements when you are revising. You should revisit any topics that you rated 'Needs more work' or 'Almost there'.

I can	See Topic...	Needs more work	Almost there	Confident to move on
Core				
Supplement				



Chapter 1
Making measurements

IN THIS CHAPTER YOU WILL:

- learn how to take measurements of length, volume and time
- perform experiments to determine the density of an object
- predict whether an object will float

› predict whether one liquid will float on another.

GETTING STARTED

In pairs, either take the measurements or write down how you would do the following:

- measure the length, width and thickness of this book and work out its volume
- measure the thickness of a sheet of paper that makes up this book
- measure the length of a journey (for example, on a map) that is not straight.

Now discuss how you would work out the density of:

- a regular-shaped solid
- an irregular-shaped solid
- a liquid.

ARE WE CLEVERER THAN OUR ANCESTORS WERE?

People tend to dismiss people who lived in the past as less intelligent than we are. After all, they used parts of their bodies for measuring distances. A cubit was the length of the forearm from the tip of the middle finger to the elbow. However, the ancient Egyptians knew this varied between people. Therefore, in around 3000 BCE, they invented the royal cubit (Figure 1.1), marked out on a piece of granite and used this as a **standard** to produce cubit rods of equal length.

Figure 1.1: Cubit rod.

The Ancient Egyptians were experts at using very simple tools like the cubit rod. This enabled them to build their pyramids accurately. Eratosthenes, a brilliant scientist who lived in Egypt in about 300 BCE, showed the same care and attention to detail. This allowed him to work out that the Earth has a circumference of 40 000 km (Figure 1.2).

In contrast, there are many recent examples where incorrect measurements have led to problems. Although the Hubble Space Telescope had the most precisely shaped mirror ever made, the original images it produced were not as clear as expected. Tiny mistakes in measuring meant that it had the wrong shape and it took a lot of effort to account for these errors.

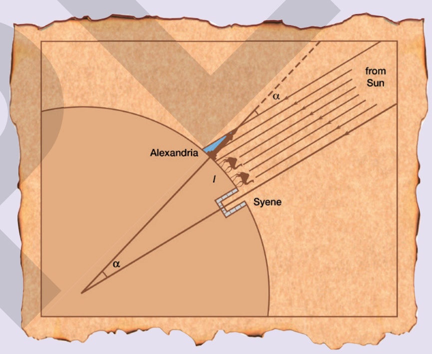


Figure 1.2: Eratosthenes used shadows and geometry to work out the circumference of the Earth.

Discussion questions

1. You cannot always depend on your eyes to judge lengths. Look at Figure 1.3 and decide which line is longer? Check by using a ruler.

Figure 1.3: Which line is longer?

2. Eratosthenes may have hired a man to pace the distance between Alexandria and Syene (present-day Aswan) to calculate the Earth's circumference. People have different stride lengths so some people take longer steps than others. Discuss the possible ways that anyone with any stride length could have measured the distance between these towns accurately.

1.1 Measuring length and volume

In physics, we make measurements of many different lengths, for example, the length of a piece of wire, the height of liquid in a tube, the distance moved by an object, the diameter of a planet or the radius of its orbit. In the laboratory, lengths are often measured using a ruler (such as a metre ruler).

Measuring lengths with a ruler is a familiar task. But when you use a ruler, it is worth thinking about the task and just how reliable your measurements may be. Consider measuring the length of a piece of wire (Figure 1.4).

- The wire must be straight, and laid closely alongside the ruler. (This may be tricky with a bent piece of wire.)
- Look at the ends of the wire. Are they cut neatly, or are they ragged? Is it difficult to judge where the wire begins and ends?
- Look at the markings on the ruler. They are probably 1 mm apart, but they may be quite wide. Line one end of the wire up against the zero on the scale. Because of the width of the mark, this may be awkward to judge.
- Look at the other end of the wire and read the scale. Again, this may be tricky to judge.

Now you have a measurement, with an idea of how **precise** it is. You can probably determine the length of the wire to within a millimetre. But there is something else to think about – the ruler itself. How sure can you be that it is correctly **calibrated**? Are the marks at the ends of a metre ruler separated by exactly one metre? Any error in this will lead to an inaccuracy (probably small) in your result.

The point here is to recognise that it is always important to think critically about the measurements you make, however straightforward they may seem. You have to consider the method you use, as well as the instrument (in this case, the ruler).

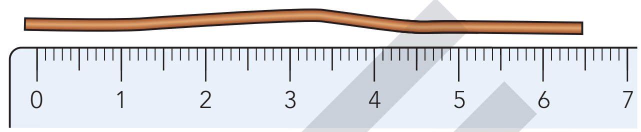


Figure 1.4: Simple measurements still require careful technique, for example, finding the length of a wire.

> **KEY WORDS**
>
> **standard:** is an absolute or primary reference or measurement
>
> **precise:** when several readings are close together when measuring the same value
>
> **calibrated:** should agree closely with a standard or agrees when a correction has been applied

More measurement techniques

If you have to measure a small length, such as the thickness of a wire, it may be better to measure several thicknesses and then calculate the average. You can use the same approach when measuring something very thin, such as a sheet of paper. Take a stack of 500 sheets and measure its thickness with a ruler (Figure 1.5). Then divide by 500 to find the thickness of one sheet.

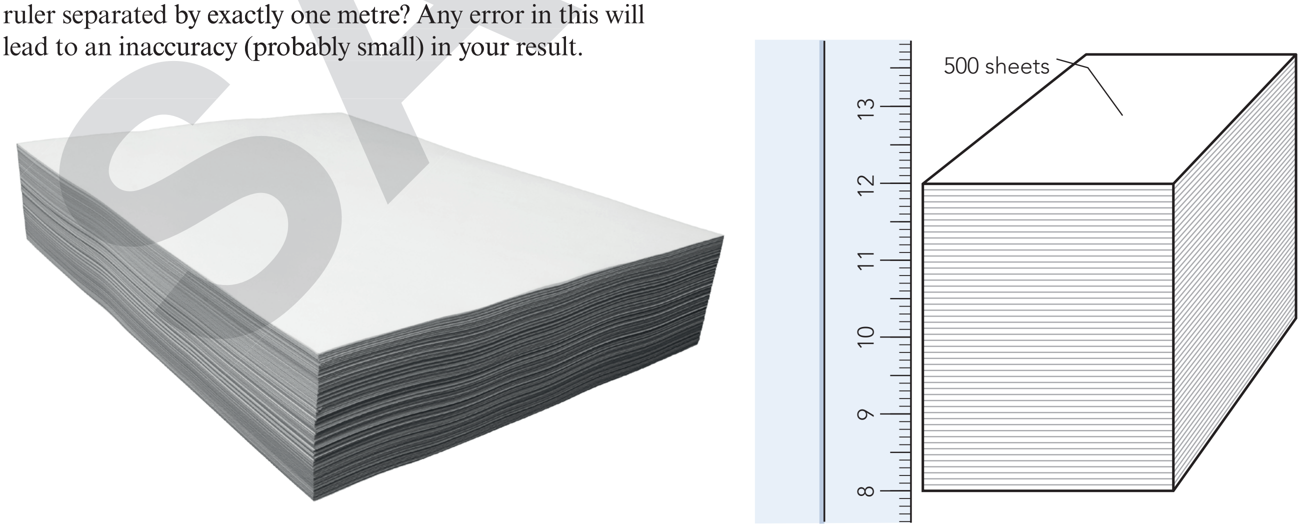


Figure 1.5: Making multiple measurements.

For some measurements of length, such as curved lines, it can help to lay a thread along the line. Mark the thread at either end of the line and then lay it along a ruler to find the length. This technique can also be used for measuring the circumference of a cylindrical object such as a wooden rod or a measuring cylinder.

Measuring volumes

There are two approaches to measuring volumes, depending on whether or not the shape is regular.

For a cube or cuboid, such as a rectangular block, measure the length, width and height of the object and multiply the measurements together. For objects of other regular shapes, such as spheres or cylinders, you may have to make one or two measurements and then look up the equation for the **volume**.

For liquids, measuring cylinders can be used as shown in Figure 1.6. (Recall that these are designed so that you look at the scale horizontally, not at an oblique angle, and read the level of the bottom of the **meniscus**.) The meniscus is the curved upper surface of a liquid, caused by surface tension. It can curve up or down but the surface of water in a measuring cylinder curves downwards. Think carefully about the choice of cylinder. A 1 litre (or a 1 dm^3) cylinder is unlikely to be suitable for measuring a small volume such as 5 cm^3. You will get a more accurate answer using a 10 cm^3 cylinder.

Figure 1.6: A student measuring the volume of a liquid. Her eyes are level with the scale so that she can accurately measure where the meniscus meets the scale.

Measuring volume by displacement

Most objects do not have a regular shape, so we cannot find their volumes simply by measuring the lengths of their sides. Here is how to find the volume of an irregularly shaped object. This technique is known as measuring volume by **displacement**.

- Select a measuring cylinder that is about three or four times larger than the object. Partially fill it with water (Figure 1.7), enough to cover the object. Note the volume of the water.
- **Immerse** the object in the water. The level of water in the cylinder will increase, because the object pushes the water out of the way and the only way it can move is upwards. The increase in its volume is equal to the volume of the object.

Units of length and volume

In physics, we generally use SI units (this is short for Le Système International d'Unités or The International System of Units). The SI unit of length is the metre (m). Table 1.1 shows some alternative units of length, together with some units of volume. Note that the litre and millilitre are not official SI units of volume, and so are not used in this book. One litre (1 l) is the same as 1 dm^3, and one millilitre (1 ml) is the same as 1 cm^3.

KEY WORDS

volume: the space occupied by an object

meniscus: curved upper surface of a liquid

displace: moving something to another place so water is moved out of the way (upwards) when an object is lowered into it

immerse: to cover something in a fluid (usually water) so that the object is submerged

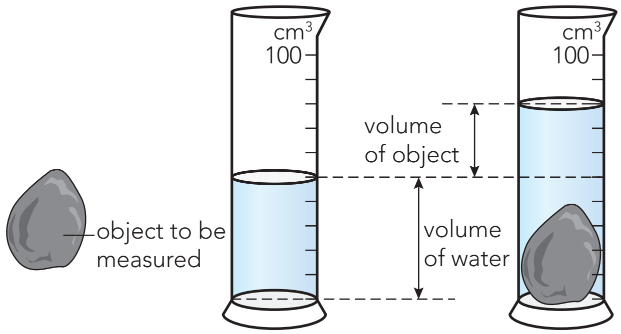


Figure 1.7: Measuring volume by displacement.

Quantity	Units
length	metre (m) 1 decimetre (dm) = 0.1 m 1 centimetre (cm) = 0.01 m 1 millimetre (mm) = 0.001 m 1 micrometre (μm) = 0.000 001 m 1 kilometre (km) = 1000 m
volume	cubic metre (m^3) 1 cubic centimetre (cm^3) = 0.000 001 m^3 1 cubic decimetre (dm^3) = 0.001 m^3

Table 1.1: Some units of length and volume in the SI system.

Questions

1 The volume of a piece of wood which floats in water can be measured as shown in Figure 1.8.
   a Write a paragraph to describe the procedure.
   b State the volume of the wood.

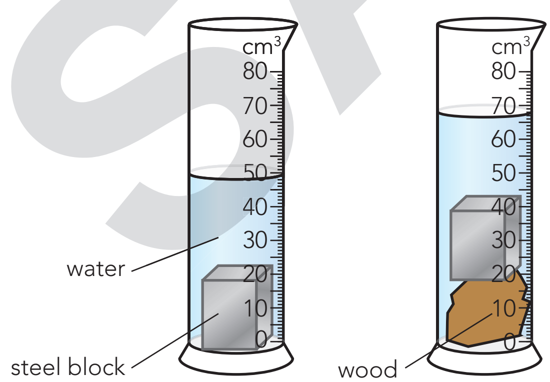


Figure 1.8: Measuring the volume of an object that floats.

2 A stack of paper contains 500 sheets of paper. The stack has dimensions of 0.297 m × 21.0 cm × 50.0 mm.
   a What is the thickness of one sheet of paper?
   b What is the volume of the stack of paper in cm^3?

1.2 Density

Our eyes can deceive us. When we look at an object, we can judge its volume. However, we can only guess its **mass**. We may guess incorrectly, because we misjudge the density. You may offer to carry someone's bag, only to discover that it contains heavy books. A large box of chocolates may have a mass of only 200 g.

The mass of an object is the quantity (amount) of matter it is made of. Mass is measured in kilograms. But **density** is a property of a material. It tells us how concentrated its mass is. You will learn more about the meaning of mass and how it differs from **weight** in Chapter 3.

In everyday speech, we might say that lead is heavier than wood. We mean that, given equal volumes of lead and wood, the lead is heavier. In scientific terms, the density of lead is greater than the density of wood. So we define density as shown, in words and as an equation.

Density is the mass per unit volume for a substance.

KEY EQUATION

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

$$\rho = \frac{m}{V}$$

KEY WORDS

mass: the quantity of matter a body is composed of; mass causes the object to resist changes in its motion and causes it to have a gravitational attraction for other objects

density: the ratio of mass to volume for a substance

weight: the downward force of gravity that acts on an object because of its mass

The symbol for density is ρ, the Greek letter rho. The SI unit of density is kg/m^3 (kilograms per cubic metre). You may come across other units, as shown in Table 1.2.

Unit of mass	Unit of volume	Unit of density	Density of water
kilogram, kg	cubic metre, m^3	kilograms per cubic metre	1000 kg/m^3
kilogram, kg	cubic decimetre, dm^3	kilograms per cubic decimetre	1.0 kg/dm^3
gram, g	cubic centimetre, cm^3	grams per cubic centimetre	1.0 g/cm^3

Table 1.2: Units of density.

Values of density

Some values of density are shown in Table 1.3. Gases have much lower densities than solids or liquids.

An object that is less dense than water will float. Ice is less dense than water which explains why icebergs float in the sea, rather than sinking to the bottom. Only about one tenth of an iceberg is above the water surface. If any part of an object is above the water surface, then it is less dense than water.

	Material	Density / kg/m^3
Gases	air	1.29
	hydrogen	0.09
	helium	0.18
	carbon dioxide	1.98
Liquids	water	1000
	alcohol (ethanol)	790
	mercury	13 600
Solids	ice	920
	wood	400–1200
	polyethene	910–970
	glass	2500–4200
	steel	7500–8100
	lead	11 340
	silver	10 500
	gold	19 300

Table 1.3: Densities of some substances. For gases, these are given at a temperature of 0 °C and a pressure of 1.0×10^5 Pa.

Many materials have a range of densities. Some types of wood, for example, are less dense than water and will float. Other types of wood (such as mahogany) are more dense and will sink. The density depends on the nature of the wood (its composition).

Gold is denser than silver. Pure gold is a soft metal, so jewellers add silver to make it harder. The amount of silver added can be judged by measuring the density.

It is useful to remember that the density of water is 1000 kg/m^3, 1.0 kg/dm^3 or 1.0 g/cm^3.

Calculating density

To calculate the density of a material, we need to know the mass and volume of a sample of the material.

WORKED EXAMPLE 1.1

A sample of ethanol has a volume of 240 cm^3. Its mass is found to be 190.0 g. What is the density of ethanol?

Step 1: Write down what you know and what you want to know.

mass $m = 190.0$ g

volume $V = 240\ cm^3$

density $\rho = ?$

Step 2: Write down the equation for density, substitute values and calculate ρ.

$$\rho = \frac{m}{V}$$

$$= \frac{190\ g}{240\ cm^3}$$

$$= 0.79\ g/cm^3$$

Answer

Density of ethanol = 0.79 g/cm^3

Measuring density

The easiest way to determine the density of a substance is to find the mass and volume of a sample of the substance.

For a solid with a regular shape, find its volume by measurement (see Section 1.1). Find its mass using a balance. Then calculate the density.

Questions

3 A brick is shown in Figure 1.9. It has a mass of 2.8 kg.

Figure 1.9: A brick labelled with its dimensions.

- **a** Give the dimensions of the brick in metres.
- **b** Calculate the volume of the brick.
- **c** Calculate the density of the brick.

4 A box full of 35 matches has a mass of 6.77 g. The box itself has a mass of 3.37 g.

- **a** What is the mass of one match in grams?
- **b** What is the volume (in cm^3) of each match. A match has dimensions of 42 mm × 2.3 mm × 2.3 mm?
- **c** What is the density of the matches?
- **d** How do you know if these matches will float?

5 The Earth has a mass of 6×10^{24} kg and a radius of about 6400 km. What is the density of the Earth (in kg/m^3)? The volume of a sphere is given by the equation $V = \frac{4}{3}\pi r^3$, where r is the radius.

6 40 drawing pins (thumb tacks) like those shown in Figure 1.10 have a mass of 17.55 g. What is the volume (in mm^3) of one pin when they are made of metal with a density of 8.7 g/cm^3?

Figure 1.10: A pair of drawing pins (thumb tacks).

7 A young girl from the Kayan people in northern Thailand wears a neck ring made of brass (Figure 1.11). It looks as if there are 21 individual rings but the ring is actually one continuous length of brass fashioned (bent) into a coil. The height of the brass coil is 12 cm and its average circumference is 40 cm. Neck rings are usually only removed to be replaced with a bigger one as the girl grows. However, we can estimate the mass of this neck ring without removing it.

Figure 1.11: A Kayan girl wearing a neck ring.

a What looks like 21 individual rings around the girl's neck is actually 21 turns of a coil of brass. Each turn has a circumference of 40 cm. Calculate (in cm) the total length of brass used to make the girl's neck ring.

b The coil has a height of 12 cm and the coil has 21 turns. Calculate the radius of the brass in cm.

c If the brass coil is unwound from the girl's neck and straightened out, it would be a long, thin, cylinder. Calculate the volume of this cylinder in cm^3. The volume of a cylinder is given by the equation $V = \pi r^2 h$, where r = radius and h = height.

d Calculate the mass of brass used to make the neck ring and express your answer in kg. The density of brass = 8.73 g/cm^3.

Finding the density of a liquid

Figure 1.12 shows one way to find the density of a liquid. Place a measuring cylinder on a balance. Set the balance to zero. Now pour liquid into the cylinder. Read the volume from the scale on the cylinder. The balance shows the mass.

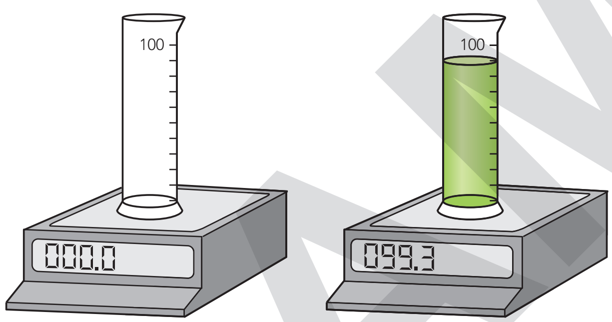


Figure 1.12: Measuring the mass of a liquid.

When liquids with different densities are poured into the same container, they will arrange themselves so that the liquid with the lowest density will be at the top and the ones with the highest density will be at the bottom. This is because the denser liquids displace the less dense liquids. This is easier to see when each liquid is given a different colour. In Figure 1.13, the green liquid is less dense than the red liquid and so on.

When a distinct layer forms in a mixed solution, the liquids are said to be immiscible, which means they do not mix. This is why oil floats on water. However, not all liquids stay separated so you would be disappointed if you tried this at home with squash and water, for example.

When liquids mix, it is usually because one liquid dissolves in the other. For example, orange squash is a concentrated syrup that is diluted by dissolving it in water.

Figure 1.13: Liquid density towers.

Apart from making colourful liquid density towers, do variations in the density of liquids have practical consequence? In Chapter 11, you will learn about convection currents in fluids (liquids and gases), which are driven by differences in density. These convection currents include the thermohaline circulation in the oceans. Colder and saltier water sinks, displacing (pushing up) warmer and less salty water.

ACTIVITY 1.1

Finding the density of a regularly shaped solid

In pairs, create a worksheet on the computer for finding the density of a regularly shaped solid object (for example, a rectangular block) using a ruler and a mass balance. Your worksheet should include:

- a method for measuring the mass and working out the volume
- the equation for calculating density
- a table to record the data.

You could include an optional task to work out the density of a liquid.

After your allotted time, another pair is going to test a copy of your worksheet (perhaps by doing the experiment). They are going to add any steps that are missing or make suggestions to make your worksheet clearer. When you get your worksheet returned, edit and save a new version of it.

CONTINUED

Finding the density of an irregularly shaped solid

Before you start, make a copy of your previous worksheet and save it under a new name. Some of what you included in the previous worksheet can be kept and some will need to be edited.

In pairs, create a worksheet for finding the density of an irregularly shaped solid object using a mass balance, a measuring cylinder, some thread, a pair of scissors and a eureka can (if you have access to one). Your method explaining how to measure the mass and how to calculate the density should be the same. However, you should:

- explain how to measure volume by displacement
- say something about choosing a suitably sized measuring cylinder
- change your previous table

You could include an optional task to work out the density of an irregularly shaped solid object that is less dense than water. Finding its mass and calculating the density is straightforward. The challenging part is explaining how to work out the volume of an object that floats.

Design a flowchart or decision-tree (optional)

Design a flowchart or decision-tree for use by anyone who wants to work out the density of any liquid or any solid object. Ensure that your flowchart includes enough information so that someone could take the measurements. Ask your partner or someone else who has completed the first two parts to check and correct your flowchart.

REFLECTION

Write down one thing that you did really well in this activity.

Write down one thing that you will try to do better next time. How will you do this?

1.3 Measuring time

The athletics coach in Figure 1.14 is using his stopwatch to time a sprinter. For a sprinter, a fraction of a second (perhaps just 0.01 s) can make all the difference between winning and coming second or third. It is different in a marathon, where the race lasts for more than two hours and the runners are timed to the nearest second.

Figure 1.14: An athletics coach uses a stopwatch to time a hurdler, who can then learn whether she has improved.

ACTIVITY 1.2

How dense can you be?

In groups of three, write a method showing how you could work out your own density, or that of a friend or of a younger sibling. Alternatively, plan out your strategy and be prepared to share it with the class. There are at least two methods: a dry method and a wet method. Discuss one or both of them.

You will need to include:

- a method that is detailed enough for someone to follow (this should include advice about how a measurement should be taken)
- any calculations
- possible sources of uncertainty in the measurements
- what you expect your answer to be.

If you actually carried out the experiment, comment on how close your measurement was to what you expected.

In the laboratory, you might need to record the temperature of a container of water every minute, or find out how long an electric current is flowing. For measurements like these, stopclocks and stopwatches can be used. You may come across two types of timing device.

An **analogue** clock (Figure 1.15) is like a traditional clock whose hands move round the clock's face. You find the time by looking at where the hands are pointing on the scale. It can be used to measure time intervals to no better than the nearest second.

Figure 1.15: An analogue clock.

A **digital** clock (Figure 1.16) or stopwatch is one that gives a direct reading of the time in numerals. For example, a digital clock might show a time of 9.58 s. A digital clock records time to a precision of at least one hundredth of a second. You would never see an analogue watch recording times in the Olympic Games.

Figure 1.16: A digital clock started when the gun fired and stopped 9.58 s later when Usain Bolt crossed the finishing line to win the 100 m at the 2009 World Championships in world record time.

KEY WORDS

analogue: display has hands (or a needle) and is often not very precise

digital: display shows numbers and is often precise

When studying motion, you may need to measure the time taken for a rapidly moving object to move between two points. In this case, you might use a device called a light gate connected to an electronic timer. This is similar to the way in which runners are timed in major athletics events. An electronic timer starts when the marshal's gun is fired, and stops as the runner crosses the finishing line.

You will learn more about how to use electronic timing instruments in Chapter 2.

Measuring short intervals of time

Figure 1.17 shows a typical lab pendulum. A mass, called a **plumb bob**, hangs on the end of a string. The string is clamped tightly at the top between two wooden jaws. If you pull the bob gently to one side and release it, the pendulum will swing from side to side.

The time for one **oscillation** of a pendulum (when it swings from left to right and back again) is called its **period**. A single period is usually too short a time to measure accurately. However, because a pendulum swings at a steady rate, you can use a stopwatch to measure the time for a large number of oscillations (perhaps 20 or 50), and calculate the average time per oscillation. Any inaccuracy in the time at which the stopwatch is started and stopped will be much less significant if you measure the total time for a large number of oscillations.

KEY WORDS

plumb bob: a mass (usually lead) hanging from a string to define a vertical line

oscillation: a repetitive motion or vibration

period: the time for one complete oscillation or wave; the time it takes an object to return to its original position

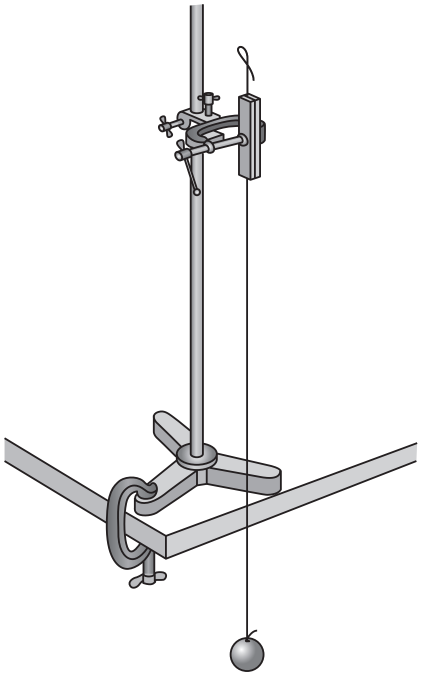


Figure 1.17: A simple pendulum.

Questions

8 High-speed video can record sporting events at a frame rate of 60 frames per second (frame/s).

- **a** What is the time interval between one frame and the next?
- **b** If we can see 24 frame/s as continuous motion, by what factor can the action recorded at 60 frame/s be slowed down and still look continuous?

9 A student was investigating how the period of a pendulum varied with the length of the string and obtained the results in Table 1.4.

Length of string / m	Time for 20 oscillations / s	Time for 1 oscillation / s
0.00	0.0	
0.20	18.1	
0.40	25.1	
0.60	28.3	
0.80	39.4	
1.00	40.5	
1.20	44.4	
1.40	47.9	

Table 1.4

- **a** Why did the student record the time for 20 swings?
- **b** Make a copy of Table 1.4 and, for each length of the pendulum, calculate the time for one oscillation and record the value in the third column of the table.
- **c** Plot a graph of the period of the pendulum against its length (that is, plot the length of the pendulum on the x-axis).
- **d** Use the graph to work out the length of the pendulum when the period is 2 seconds. This is the length of pendulum used in a grandfather clock.

ACTIVITY 1.3

Using a pendulum as a clock

In 1656 the Dutch scientist Christiaan Huygens invented a clock based on a swinging pendulum. Clocks like these were the most precise in the world until the 1930s. One oscillation of a pendulum is defined as the time it takes for a plumb bob at the bottom of the string to return to its original position (Figure 1.18).

You need to develop a worksheet so that students can plot a graph of how the period of oscillation of a pendulum varies with the length of the string. They then need to use the graph to find the length the pendulum needs to be to give a period of one second (useful for a clock). Your worksheet needs to:

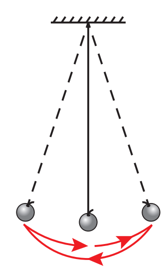


Figure 1.18: One oscillation is when the plumb bob swings one way and then the other and returns back to its original position.

CONTINUED

- define what an oscillation means (so that a student knows when to start and stop the stopwatch)
- explain why we take the time for 10 or 20 oscillations when we only need the time for one oscillation
- provide a labelled diagram of the assembled apparatus (not just a list of equipment) so that students know how to put the equipment together
- a method (step-by-step instructions).

Swap copies of your worksheet with a classmate. Write down suggestions for any improvements on the worksheet you receive before returning it to its owner. Note down any improvements if you have a class discussion.

PROJECT

In groups of three or four, produce a podcast (no more than five minutes long) on one of the following options.

Option 1: Can we build on what we have learned about density?

This is opportunity to revise what you have learned about density and then consolidate that knowledge and understanding by applying it to one of the two examples below.

- You must explain how density is calculated, including the equation.
- You should describe how to measure the mass and volume of both regular and irregular shaped objects.
- You could describe how to work out the density of an object that can float.

1 RSS Titanic

It was claimed that the RSS Titanic was unsinkable. However the ship sank in 1912 on its first voyage.

- You must explain why a ship can float despite being made of material that is denser than water.
- You should explain why a ship can sink, in terms of changes in density.
- Do some research to find out about bulkheads in ships: what are they and what are they for? Why did the RSS Titanic sink despite being fitted with bulkheads?

2 Submarines and scuba divers

You could describe one phenomenon that depends on changes or differences in density. You could think of your own or select one of these:

- Explain how a submarine or scuba diver moves up and down in the water column (or perhaps explain how a Cartesian diver demonstration works).
- Explain how differences in fluid density can lead to convection (something you will meet in Chapter 11). You might want to go on to discuss how this relates to ocean currents or wind.

Option 2: What was the solution to the longitude problem?

A clock based on a pendulum is impractical on the moving deck of a (sailing) ship but knowing the time is important for navigation as this provides your longitude on a spinning Earth. Lines of longitude are the vertical lines on a map. When you move east or west you are changing your longitude; move far enough and you change time zone.

- You must start with a short description of the longitude problem.
- You could describe the various suggested solutions to the longitude problem.
- You could describe the final solution to the longitude problem. For this, you would need to look up John Harrison and his marine chronometer.

Option 3: How did the Ancient Egyptians build their pyramids so accurately?

The pyramids are an incredible feat of engineering, even by today's standards. Using very basic tools, the Egyptians' pyramids are perfectly symmetrical.

- You could start by introducing the dimensions of the Giza pyramid and the number of blocks required to build it.

CONTINUED

- You could explain how the Egyptians managed to get the sides of their pyramids lined up with true north (without a compass) and how they got the base of them absolutely level (flat) without a (spirit) level.

Option 4: How did Eratosthenes work out the circumference of the Earth?

Eratosthenes was a brilliant scientist. He was told that, at the same time every year (12 noon on 21 June), vertical columns in Syene (present day Aswan) cast no shadows while columns where he lived in Alexandria cast shadows. He used this to work out that the Earth is round. Eratosthenes may have hired a man to measure out the distance between Alexandria and Syene.

- You could start with a short biography of Eratosthenes.
- You should explain why the observation with the shadows shows that the Earth is a sphere. You might want to include a diagram like Figure 1.2.
- You should try and show how the man hired by Eratosthenes could have worked out his stride-length (the distance of each step) and kept count of his strides (steps). Think about his possible journey: did he follow a straight line; were there any hills in the way? Could this have introduced errors in measuring the distance between Alexandria and Syene?
- Finally, you could show how Eratosthenes did the calculation.

Option 5: How did Archimedes really work out that the goldsmith had replaced some of the gold in Hiero's crown with silver?

Archimedes was probably the most brilliant scientist of his era. He is supposed to have solved the problem of how to work out the density of the crown while having a bath. Legend has it that he then ran into the streets shouting 'eureka' (I've solved it).

- You could start with a short biography of Archimedes.
- You could then describe the usual explanation of how he worked out that some gold had been stolen. Silver is less dense than gold so the same mass of silver has a bigger volume and will displace a bigger volume of water. However, it would be difficult to measure the difference in volume, especially since bubbles of air could cling to the submerged crown and there could be other sources of error.
- You could describe a better method, which uses a mass balance. You would need to explain why, when the masses are equal, the balance tips towards the denser mass when lowered into water.
- Gold needs some silver impurity or it would be too soft and would be easy to bend out of shape. Perhaps the goldsmith was falsely accused? Perhaps this idea could form part of a piece of creative writing (some prose or a play) but be sure to include the physics.

REFLECTION

- For your project, write down some thoughts about what you feel went well and areas where you could improve.
- Give yourself a score out of ten for how much you know and understand the physics you included. If you scored ten, write down how you could have produced a more ambitious project. If you scored less, do you need to thoroughly review the material or are you making careless errors? Write down what concrete steps you need to take to improve for next time.
- Give yourself a score out of ten for the quality of your presentation. Write down what you thought was good about the other presentations or any effective presentation ideas that you might use next time you present.

SUMMARY

Length can be measured using a ruler.
The period of one oscillation can be measured by measuring the time for 20 oscillations and then dividing the time by 20.
The volume of a cube or cuboid can be found by measuring the length of the three sides and multiplying the measurements together.
The volume of a liquid can be measured using a measuring cylinder where the bottom of the meniscus appears on the scale when looked at horizontally.
All objects that sink in water displace their own volume of water.
The volume of an irregularly shaped object can be found from the change in the height of liquid in a measuring cylinder when it is immersed in the liquid.
Density is the ratio of mass to volume for a substance: $\rho = \frac{m}{V}$.
The density of water is $1000\,kg/m^3$ or $1.0\,g/cm^3$.
Anything less dense than water will float in water and anything denser than water will sink in water.
Ice floats because it is less dense than water.
One liquid will float on top of another liquid if it is less dense.
Time can be measured using a clock or watch.
An analogue clock has hands and can only measure time to the nearest second.
A digital clock displays numbers and records time to a precision of at least one hundredth of a second.

EXAM-STYLE QUESTIONS

Use this table to answer questions 1 and 2.

Metal	Density / g/cm^3
gold	19.30
silver	10.49
lead	11.34

1 Three metal cubes have the same volume but are made of different metals. Each one is lowered into a beaker of water. Use the data in the table to decide which one will cause the biggest rise in water level. **[1]**

A gold
B silver
C lead
D all will cause the same rise in water level

CONTINUED

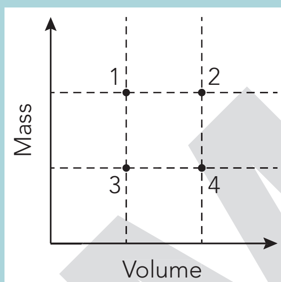
2 Three metal cubes have the same mass but are made of different metals. Each one is lowered into a beaker of water. Use the data in the table to decide which one will cause the biggest rise in water level. **[1]**

A gold
B silver
C lead
D all will cause the same rise in water level

3 Astronauts land on another planet and measure the density of the atmosphere on the planet surface. They measure the mass of a 500 cm^3 conical flask plus stopper as 457.23 g. After removing the air, the mass is 456.43 g (1 m^3 = 1000 litres). What is the best estimate of the density of the air? **[1]**

A 0.000 001 6 kg/m^3
B 0.0016 kg/m^3
C 0.16 kg/m^3
D 1.6 kg/m^3

4 The graph shows the mass and volume of several different objects.



Which two objects have the same density? **[1]**

A 2 and 3 **B** 1 and 4 **C** 2 and 4 **D** 3 and 4

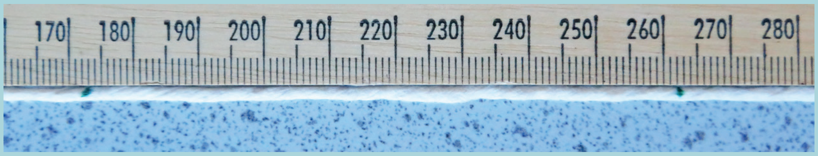
5 A student measures the circumference of a circular copper pipe.

He wraps a length of string four times around the pipe and marks it with ink, as shown in the photograph.

CONTINUED

a The student unwraps the string and holds it against a ruler with a centimetre scale.

The photograph shows the first two ink marks on the string.



i Use the photograph to estimate the circumference of the pipe. **[1]**

ii The student finds that the total length of string for 4 turns is 354 mm. **Calculate** the average (mean) circumference of the pipe using this value. **[1]**

[Total: 2]

6 **Suggest** how you would work out the thickness of a single sheet of paper if the only measuring device available was a ruler and its smallest division was 1 mm. **[1]**

7 What is the mass of a microscope slide that has dimensions of 75 mm × 26 mm × 1 mm and has a density of 2.24 g/cm^3? **[2]**

8 Four different liquids are poured into a 100 cm^3 measuring cylinder that is 10 cm tall. Each liquid has a different density and each has a different colour.

a Calculate the missing values in the table. **[4]**

	Liquid	Mass / g	Volume / cm^3	Density / g/cm^3
clear	ethanol	**i**	20.00	0.79
red	glycerin	20.00	**ii**	1.26
green	olive oil	25.90	28.80	**iii**
blue	turpentine	30.00	35.30	**iv**

b Copy the diagram below. Using the data from the table above, write down the colour of the liquid you would expect to find in each layer and how thick the layer would be. **[2]**

Colour of layer	Thickness of layer / cm

9 Metals are denser than water. **Explain** why a metal ship can float. **[1]**

10 Suggest how you could work out the density of a drawing pin. **[3]**

COMMAND WORDS

calculate: work out from given facts, figures or information

suggest: apply knowledge and understanding to situations where there are a range of valid responses in order to make proposals/ put forward considerations

explain: set out purposes or reasons; make the relationships between things evident; provide why and/or how and support with relevant evidence

SELF-EVALUATION CHECKLIST

After studying this chapter, think about how confident you are with the different topics. This will help you to see any gaps in your knowledge and help you to learn more effectively.

I can	See Topic...	Needs more work	Almost there	Confident to move on
Measure length, volume and time.	1.1, 1.3			
Calculate the volume of a cube or cuboid from measurements using a ruler.	1.1			
Determine the volume of an irregularly shaped object.	1.1			
Measure the size of tiny objects (for example, the thickness of a sheet of paper, the volume of a drawing pin).	1.1			
Calculate density.	1.2			
Predict whether an object will float or sink in water based on its density.	1.2			
Describe an experiment to find the density of a liquid.	1.2			
Predict whether a liquid will float on top of another liquid if their densities are known and they cannot mix.	1.2			
Describe an experiment to find the density of a cube or cuboid.	1.2			
Describe an experiment to find the density of an irregularly shaped object.	1.2			
Describe the differences between analogue and digital watches or clocks.	1.3			

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Contents

How to use this Teacher's Resource

This Teacher's Resource contains both general guidance and teaching notes that help you to deliver the content in our Cambridge resources.

There are **teaching notes** for each unit of the Coursebook. Each set of teaching notes contains the following features to help you deliver the chapter.

At the start of each chapter there is a **teaching plan** (Figure 1). This summarises the topics covered in the chapter, including the number of learning hours recommended for each topic, an outline of the learning content, and the Cambridge resources from this series that can be used to deliver the topic. The topic order generally follows the same sequences as the topics in the syllabus with some exceptions where appropriate.

Sub-chapter	Approximate number of learning hours	Learning content	Resources

Figure 1

Each chapter also includes information on any **background knowledge** that students should have before studying this chapter, advice on helpful **language support**, and a **teaching skills focus** that will help you develop your skills across a number of key pedagogical areas.

At the beginning of the teaching notes for the individual sections there is an outline of the **learning objectives** (Figure 2) for that section, as well as any **common misconceptions** that students may have about the topic and how you can overcome these. Syllabus learning objectives for students who are studying the Supplement are indicated in the table in a darker blue colour, with an arrow on the left.

LEARNING PLAN

Syllabus learning objectives	Learning intentions	Success criteria
Supplement: Determine from given data or the shape of a speed–time graph when an object is moving with: **a** constant acceleration **b** changing acceleration. (Covered here and in Section 2.2.) Calculate acceleration from the gradient of a straight-line section of a speed–time graph (covered here and in Section 2.2).	Distinguish between speed and velocity. Define and calculate acceleration; understand deceleration as a negative acceleration. Use the gradient of a speed–time graph to calculate acceleration.	Learners can describe the difference between speed and velocity. Learners can calculate acceleration from change in speed and time taken.

Figure 2

For each section, there is a selection of **starter ideas**, **main activities** and **plenary ideas**. You can pick out individual ideas and mix and match them depending on the needs of your class. The activities include suggestions for how they can be differentiated or used for assessment.

Homework ideas give suggestions for tasks, along with advice for how to assess students' work.

The Teacher's Resource also includes **practical work guidance** to support you in teaching the exercises in the Practical Workbook, and any **exemplar data** that accompanies the Practical Workbook chapter.

At the end of the teaching notes for each chapter are a selection of useful **links to digital resources**, information on **cross-curricular links** with other subjects, and **project guidance** to support you in teaching the end-of-chapter project in the Coursebook.

You will find **answers** for all components accessible to teachers for free on the 'supporting resources' area of the Cambridge GO platform.

This Teacher's Resource also includes a **differentiation worksheet pack** for each chapter, a **diagnostic test**, a **mid-point test**, three **end-of-course practice tests**, and **end-of-chapter tests**. There's also a lesson plan template and a 'Letter to Parents' and 'How to use this series' presentation you can send to parents to help them understand the Cambridge Approach in our books.

1 Making Measurements

Teaching plan

Sub-chapter	Approximate number of learning hours	Learning content	Resources
1.1 Measuring length and volume	1 hour	Core: Describe the use of rules and measuring cylinders to find a length or a volume. Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of a pendulum).	**Coursebook:** Section 1.1 Measuring length and volume **Workbook:** Chapter 1, Measurements and units, Exercise 1.1 **Practical Workbook**
1.2 Density	2 hours	Core: Define density as mass per unit volume; recall and use the equation $\rho = \frac{m}{V}$ Describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in a liquid (volume by displacement), including appropriate calculations. Determine whether an object floats based on density data. Supplement: Determine whether one liquid will float on another liquid based on density data given that the liquids do not mix.	**Coursebook:** Section 1.2 Density **Workbook:** Chapter 1, Practical applications, Exercise 1.2 **Practical Workbook**
1.3 Measuring time	1 hour	Core: Describe how to measure a variety of time intervals using clocks and digital timers. Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of a pendulum).	**Coursebook:** Section 1.3 Measuring time **Workbook:** Chapter 1, Practical applications, Exercise 1.3 **Practical Workbook**

BACKGROUND KNOWLEDGE

- Learners have seen or used most of the equipment in this chapter, but some learners will need to be supported in order to use the equipment correctly.
- Learners will have drawn results tables and graphs at Primary and Lower Secondary level, but all learners will benefit from a clear reminder of how to do this properly, e.g. units in headings, axis labels, etc.
- Learners have used an equation to calculate the volume of a cube or cuboid before, either in mathematics or in science, but many will need to be reminded of the equation.
- Learners have met ideas about density at Lower Secondary level but only in the context of how density affects whether an object floats and sinks, which will be covered again in this chapter.
- Learners should have found an average of a set of readings before, however some learners will need to be reminded how to do this. The idea of using multiple readings (e.g. many pieces of paper to work out the thickness of one piece of paper) to obtain an average value for a small distance will be new to most learners.

TEACHING SKILLS FOCUS

Area of focus: Cross-curricular links

Specific focus: Working with equations. Learners often lack confidence or find it difficult to transfer their mathematical skills when learning science.

Benefits of working with equations: They will benefit from recapping how to use and manipulate equations in physics, such as the equation to calculate density.

Practise working with equations: Give learners equations with values to substitute and calculate the answer (no rearranging necessary).

Before starting, it would be helpful to discuss with the mathematics department their preferred approach to rearranging equations, particularly for the less confident learners. There are generally two alternative approaches for equations such as $F = ma$ or $\rho = m/v$.

Taking $\rho = m/v$

Approach 1: to make m the subject, multiply both sides by v to 'undo' the division by v:

$\rho \times v = m$

to make v the subject, do the above first and then divide both sides by ρ to 'undo' the multiplication by ρ:

$v = m/\rho$

Approach 2: If two values are known, to find the third, substitute the known values first and solve the equation. For example:

if we have $\rho = 9\,g/cm^3$ and $v = 15\,cm^3$

$9 = m/15$

multiply by 15 to give $m = 135\,g$

There is also another approach, the equation triangle (Figure 1.1), that could be used with less confident learners.

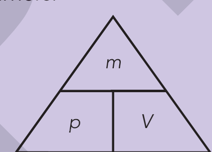


Figure 1.1: The equations triangle.

Ask learners to rearrange other equations which follow this pattern, such as $V = IR$, $F = ma$, distance = speed × time, and do on.

Challenge for learners, can they think of other situations modelled by similar equations?

Examples:

rectangle area = length × width

total cost = cost per item × number of items

If learners are finding this difficult, it can be helpful to consider three related calculations such as:

$20 = 5 \times 4$

$5 = 20/4$

$4 = 20/5$

At the end of the lesson, reflect on which approaches worked well for different learners. What did they find difficult?

Reflection: How can learners of different abilities be supported in future lessons which involve equation work? Would you teach this differently next time? How beneficial is it to work with another department in your school?

LANGUAGE SUPPORT

For definitions of key words, please see the glossary.

Learners often find it difficult to explain the difference between accuracy and precision. Be very careful not to mix these words up when using them:

- Accuracy tells you how close your measurements of the variable are to the true value of the variable. Precise measurements are ones in which there is very little spread about the mean value.
- Precision depends on the extent of random errors – it does not indicate how close results are to the true value.

Use the new scientific words in lessons as much as possible. Ask learners to use the terms correctly in sentences, or provide learners with a sentence that uses a term incorrectly. Learners can then identify the mistake and explain why the sentence is incorrect.

1.1: Measuring length and volume

LEARNING PLAN

Syllabus learning objectives	Learning intentions	Success criteria
Core: Describe the use of rules and measuring cylinders to find a length or a volume. Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of a pendulum).	• Learn how to make measurements of length, volume and time.	Students can use measuring equipment correctly and record measurements of length and volume with appropriate units.

** the above grid demonstrates full syllabus Learning Objectives. Please note that greyed-out content has been covered within a separate sub-chapter.*

Common misconceptions

Misconception	How to identify	How to overcome
Learners may read rules etc from an angle (parallax error).	See Main teaching idea 1: Provide diagrams with an eye drawn at an angle instead of at 90° when reading a ruler, and ask learners why this will not give an accurate reading. Make sure that learners are bending down to read measuring cylinders at 90° and not lifting the measuring cylinder up.	Ask learners to take two measurements on a ruler, one with parallax error and one without. This should enable learners to realise that the two readings are different and why it is important to read the ruler measurement at 90°.

Misconception	How to identify	How to overcome
Learners may read the liquid level from the top of the meniscus.	See Main teaching idea 2: Check for learners who are measuring the liquid level from the top instead of from the bottom of the meniscus.	Use questioning to help learners realise that it should be measured from where the meniscus is flat, i.e. the bottom.

Starter ideas

1 Coursebook 'getting started' activity (10 min)

Resources: Coursebook, Chapter 1 'Getting Started' activity.

Description and purpose: The purpose of this task is to assess learners' prior knowledge of how to take measurements of length accurately and to elicit misconceptions. Organise learners into pairs and ask them to discuss, or carry out, the first three bullet points in the 'Getting started' section of the Coursebook. Move around the learners, listening for misconceptions to address later in the class discussion. Give learners 3 or 4 min of discussion time and then ask them to share their ideas with other learners. Encourage discussion between learners by asking other learners if they agree with the previous comments made.

What to do next: Share any misconceptions that you have heard and ask learners to explain why they are incorrect.

Consolidate ideas using more examples for the less confident learners.

2 Units of measurements (10–15 min)

Resources: PowerPoint slide or worksheet.

Description and purpose: The purpose of this task is to elicit learners' knowledge of the different units of length and volume. In pairs, learners think about different distances (e.g. the length of a book, the volume of a liquid, the speed of a car) and suggest which units they would use to measure them.

Learners might suggest non-SI units, e.g. miles, litres and millilitres so explain why these are not used in this course.

What to do next: Consolidate ideas for less confident learners by providing a worksheet or PowerPoint slide where learners match units for length and units for volume.

Learners can also be stretched by asking them to suggest which units different distances would be measured in; for example, length of your arm (in cm), height of a building (in m), distance between two villages (in km), and so on.

Main teaching ideas

1 Measuring length (20 min)

Learning intention: To be able to measure the length of a piece of wire or string accurately.

Resources: String, wire, electrical leads, 30 cm rulers, Coursebook.

Description and purpose: Learners think that this is a very straightforward task at first. However, to measure the length of a piece of string accurately is more difficult than it looks.

Learners estimate the length of each item before measuring it. Each learner then individually measures the length of each item. Record the results for each item in a table with column headings: predicted length / cm, measured length / cm.

Learners make notes of any difficulties they found in taking the measurements, e.g. the string did not lie straight so their measurement was not exactly the same as their partners.

Safety: Wires may have sharp ends so should be handled carefully. Do not allow learners to put any electrical wires near to sockets.

Differentiation ideas:

Support – some learners may need help to lay the string or wire straight and close enough to the ruler.

Challenge – provide learners with a piece of wire that is more difficult to lie straight, or a piece of wire that is longer than 30 cm and ask learners to measure it.

› **Assessment ideas:** As a class, discuss any difficulties the learners may have had when measuring the items. How close are their predictions to the actual length? Do their measurements agree with their partner's measurements? Why not? How accurate do they think their measurements are? How can a piece of string be used to measure the length of a curved line?

2 Measuring the volume of a liquid (30 min)

Learning intention: To be able to measure the volume of a liquid using a measuring cylinder.

Resources: Different size measuring cylinders with pre-prepared amounts of water in them.

For the assessment section: Pictures of measuring cylinders and beakers showing different volumes of liquids, including some with a curved meniscus and some with an eye correctly or incorrectly placed to demonstrate parallax error.

Description and purpose: The purpose of this task is to assess and improve learners' ability to read a scale accurately, avoiding parallax error. This skill will be needed to determine the density of an irregularly shaped object later on in the chapter.

Practical guidance: Learners determine the volumes of pre-prepared measuring cylinders and beakers of liquids. This could be done with pictures of measuring cylinders if the equipment is not available.

Safety: Mop up any spills of water.

› **Differentiation ideas:**

Support – less confident learners could start by taking measurements from measuring cylinders with straightforward scales.

Challenge – provide more confident learners with a very small amount of water in, e.g. a jug with a pouring spout, and different size measuring cylinders. Learners choose the most appropriate measuring cylinder and explain why they have chosen it.

› **Assessment ideas:** Provide learners with pictures of measuring cylinders containing liquids with the volumes stated (some correct, some incorrect). Individually, learners determine which volumes have been measured correctly. Learners can then work in pairs to discuss their answers.

Learners share their ideas with the whole class. When less able learners are chosen to share their ideas, ask them about the more straightforward measurements, in order to build their confidence when speaking in front of the class.

Ask learners why they agree, or don't agree, with the previous comments made.

3 Measuring the volume of a regularly shaped solid (30 min)

Learning intention: To be able to measure the volume of a regularly shaped object, e.g. a cuboid.

Resources: Coursebook**,** different objects in the shape of a cube or cuboid placed around the classroom, or pictures of objects on a worksheet or on the board (the measurements of the lengths of each side will need to be provided if it is on the board).

Description and purpose: Learners need to be able to calculate the volume of a regularly shaped object using the equation for a cube or cuboid.

Show learners a picture of a cube with the length of a side indicated (2 cm) and a cuboid, with all lengths indicated (2 cm × 3 cm × 2 cm). Alongside this, show that you have (incorrectly) calculated the volume of the cube to be 6 cm^3 and (incorrectly) calculated the volume of the cuboid to be 7 cm^3.

Learners discuss in pairs whether they agree or not with your calculations.

Discuss learners' ideas with the class. They should conclude that each volume has been incorrectly calculated and suggest the correct equation for calculating the volume of a cube or cuboid, such as volume = length × height × depth.

Practical guidance: Learners measure the sides of various cubes and cuboids, record these measurements and calculate their volumes. This could be done on a worksheet or with real objects. Emphasise the need for learners to show ALL of their calculations and not just their final answer.

Answers: The volume of the cube was incorrectly calculated as 6 cm^3 instead of 8 cm^3 by multiplying the length of the side by 3 instead of cubing it.

The volume of the cuboid was incorrectly calculated as 7 cm^3 instead of 12 cm^3 by adding the three lengths together instead of multiplying them.

Differentiation ideas:

Support – provide examples with more scaffolding for less confident learners, e.g. a question with the answer set out clearly, step by step. This is followed by a question with the answer set out as before, but with some gaps for learners to fill in the measurements and then calculate the volume.

Challenge – more confident learners could be asked to calculate the length of a cube when provided with the volume. They could also calculate the length of a missing side of a cuboid when provided with the volume and the two other lengths.

Assessment ideas: Learners peer or self-assess their answers. As learners have written down their measurements and calculations, they will be able to spot where they have made an error if their final answer is incorrect.

Ask learners to reflect on their learning then write a comment on what they did well, e.g. I wrote down all of the calculations clearly, and what errors they made, e.g. I only multiplied two of the sides instead of all three sides, etc.

Plenary ideas

1 Measuring volume (10 min)

Resources: PowerPoint slide or worksheet including the following equipment and objects: cube, cuboid, small stone, glass of water, ruler, metre ruler, measuring cylinder.

Description and purpose: Learners match the items with the correct equipment needed to measure their volume. They also give a brief description of how to work out the volume of each item.

Assessment idea: Discuss the correct answers for learners to self-mark.

2 Matching quantities of length and volume (10 min)

Resources: Coursebook, PowerPoint slide or worksheet with two columns of units. One column will have units with prefixes and the full name; for example, 1 dm (1 decimetre) and the other column has the measurements in metres.

Description and purpose: Learners match up the unit with a prefix to the correct measurement in metres.

Assessment idea: Provide learners with the correct answers to self-mark. They need to make a note of any incorrect answers so that they can refer back to it in future lessons if necessary.

Homework ideas

1 Workbook Exercise 1.1

This homework provides consolidation questions on measuring the thickness of a very thin object using the method where several thicknesses are measured and then an average calculated.

2 Prefixes and standard form

Ask learners to find out the what the following unit prefixes are in standard form. Learners came across most of these prefixes in Plenary Idea 2. They will need to be able to use these prefixes during the course.

M mega, 10^6
k kilo, 10^3
c centi, 10^{-2}
m milli, 10^{-3}

Assessment ideas: As a class, discuss any difficulties the learners may have had when measuring the items. How close are their predictions to the actual length? Do their measurements agree with their partner's measurements? Why not? How accurate do they think their measurements are? How can a piece of string be used to measure the length of a curved line?

2 Measuring the volume of a liquid (30 min)

Learning intention: To be able to measure the volume of a liquid using a measuring cylinder.

Resources: Different size measuring cylinders with pre-prepared amounts of water in them.

For the assessment section: Pictures of measuring cylinders and beakers showing different volumes of liquids, including some with a curved meniscus and some with an eye correctly or incorrectly placed to demonstrate parallax error.

Description and purpose: The purpose of this task is to assess and improve learners' ability to read a scale accurately, avoiding parallax error. This skill will be needed to determine the density of an irregularly shaped object later on in the chapter.

Practical guidance: Learners determine the volumes of pre-prepared measuring cylinders and beakers of liquids. This could be done with pictures of measuring cylinders if the equipment is not available.

Safety: Mop up any spills of water.

Differentiation ideas:

Support – less confident learners could start by taking measurements from measuring cylinders with straightforward scales.

Challenge – provide more confident learners with a very small amount of water in, e.g. a jug with a pouring spout, and different size measuring cylinders. Learners choose the most appropriate measuring cylinder and explain why they have chosen it.

Assessment ideas: Provide learners with pictures of measuring cylinders containing liquids with the volumes stated (some correct, some incorrect). Individually, learners determine which volumes have been measured correctly. Learners can then work in pairs to discuss their answers.

Learners share their ideas with the whole class. When less able learners are chosen to share their ideas, ask them about the more straightforward measurements, in order to build their confidence when speaking in front of the class.

Ask learners why they agree, or don't agree, with the previous comments made.

3 Measuring the volume of a regularly shaped solid (30 min)

Learning intention: To be able to measure the volume of a regularly shaped object, e.g. a cuboid.

Resources: Coursebook, different objects in the shape of a cube or cuboid placed around the classroom, or pictures of objects on a worksheet or on the board (the measurements of the lengths of each side will need to be provided if it is on the board).

Description and purpose: Learners need to be able to calculate the volume of a regularly shaped object using the equation for a cube or cuboid.

Show learners a picture of a cube with the length of a side indicated (2 cm) and a cuboid, with all lengths indicated (2 cm × 3 cm × 2 cm). Alongside this, show that you have (incorrectly) calculated the volume of the cube to be 6 cm^3 and (incorrectly) calculated the volume of the cuboid to be 7 cm^3.

Learners discuss in pairs whether they agree or not with your calculations.

Discuss learners' ideas with the class. They should conclude that each volume has been incorrectly calculated and suggest the correct equation for calculating the volume of a cube or cuboid, such as volume = length × height × depth.

Practical guidance: Learners measure the sides of various cubes and cuboids, record these measurements and calculate their volumes. This could be done on a worksheet or with real objects. Emphasise the need for learners to show ALL of their calculations and not just their final answer.

Answers: The volume of the cube was incorrectly calculated as 6 cm^3 instead of 8 cm^3 by multiplying the length of the side by 3 instead of cubing it.

The volume of the cuboid was incorrectly calculated as 7 cm^3 instead of 12 cm^3 by adding the three lengths together instead of multiplying them.

Differentiation ideas:

Support – provide examples with more scaffolding for less confident learners, e.g. a question with the answer set out clearly, step by step. This is followed by a question with the answer set out as before, but with some gaps for learners to fill in the measurements and then calculate the volume.

Challenge – more confident learners could be asked to calculate the length of a cube when provided with the volume. They could also calculate the length of a missing side of a cuboid when provided with the volume and the two other lengths.

Assessment ideas: Learners peer or self-assess their answers. As learners have written down their measurements and calculations, they will be able to spot where they have made an error if their final answer is incorrect.

Ask learners to reflect on their learning then write a comment on what they did well, e.g. I wrote down all of the calculations clearly, and what errors they made, e.g. I only multiplied two of the sides instead of all three sides, etc.

Plenary ideas

1 Measuring volume (10 min)

Resources: PowerPoint slide or worksheet including the following equipment and objects: cube, cuboid, small stone, glass of water, ruler, metre ruler, measuring cylinder.

Description and purpose: Learners match the items with the correct equipment needed to measure their volume. They also give a brief description of how to work out the volume of each item.

Assessment idea: Discuss the correct answers for learners to self-mark.

2 Matching quantities of length and volume (10 min)

Resources: Coursebook, PowerPoint slide or worksheet with two columns of units. One column will have units with prefixes and the full name; for example, 1 dm (1 decimetre) and the other column has the measurements in metres.

Description and purpose: Learners match up the unit with a prefix to the correct measurement in metres.

Assessment idea: Provide learners with the correct answers to self-mark. They need to make a note of any incorrect answers so that they can refer back to it in future lessons if necessary.

Homework ideas

1 Workbook Exercise 1.1

This homework provides consolidation questions on measuring the thickness of a very thin object using the method where several thicknesses are measured and then an average calculated.

2 Prefixes and standard form

Ask learners to find out the what the following unit prefixes are in standard form. Learners came across most of these prefixes in Plenary Idea 2. They will need to be able to use these prefixes during the course.

M mega, 10^6
k kilo, 10^3
c centi, 10^{-2}
m milli, 10^{-3}

1.2: Density

LEARNING PLAN

Syllabus learning objectives	Learning intentions	Success criteria
Core: Define density as mass per unit volume; recall and use the equation $\rho = \frac{m}{V}$ Describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in a liquid (volume by displacement), including appropriate calculations. Determine whether an object floats based on density data.	• Perform experiments to determine the density of an object. • Predict whether an object will float.	Students can find the densities of regular and irregular solids. Students can use density values to predict whether a solid will float on a liquid.
Supplement: Determine whether one liquid will float on another liquid based on density data given that the liquids do not mix.	Predict whether one liquid will float on another.	Students can predict whether one liquid will float on another given that the two liquids are immiscible and given their densities.

Common misconceptions

Misconception	How to identify	How to overcome
Density is how heavy an object is.	See Starter idea 1: Many learners will think that iron is more dense than paper but for the wrong reason.	Use questioning to help learners realise that density is how much mass there is in a certain volume, and does not only depend on how heavy an object is.
If you cut a piece of wood in half, the density of each piece is half of the original piece If you take a ball of plasticine and add more plasticine to it, the ball will get larger and the density will increase	See Main teaching idea 1: Look at learner's predictions for the densities of different size pieces of (the same type of) wood and plasticine to see if they think the density increases as the size increases.	By doing this activity, learners should understand that the density of a material/substance is fixed and not dependent on the size of the object.

Starter ideas

1 What is the lesson about? (10 min)

Resources: Coursebook**,** image of a density column (you can find something suitable using an internet search; the image should show various liquid such as oil, water, dish soap, and syrup).

Description and purpose: The purpose of this task is to assess learners' prior knowledge of density and to elicit misconceptions.

On the board, show learners the image of a density column. Ask them to explain why the different liquids settle into layers. Move around the learners, listening for misconceptions that could be addressed later in the class discussion.

Give learners 3 or 4 min to discuss in pairs and then ask them to share their ideas with the whole class. Encourage discussion between learners by asking other learners to explain why they agree or do not agree with the previous comments made.

Introduce the term density to the learners if no one has already suggested it. What does density mean? Which is heavier, paper or iron? Which is more dense? How do you know? Some learners may have the misconception that a heavier object is always more dense.

2 Particle diagrams (10–15 min)

Resources: Unlabelled diagrams of the particles in a solid, liquid and gas.

Description and purpose: The purpose of this task is to elicit learners' knowledge of what density means in terms of the particles of the substance.

Show learners unlabelled diagrams of the particles in a solid, liquid and gas. Learners suggest which diagram represents the solid, liquid and gas. How do they know?

What to do next: Use the diagrams to consolidate ideas about the meaning of the term density, i.e. the more dense a substance is, the more particles and therefore mass in a given volume. Then link this definition to the equation for density:

$$\rho = \frac{m}{v}$$

Use the Worked Example 1.1 in the Coursebook.

Main teaching ideas

1 Calculating the density of an irregularly shaped object (1–1.5 hours including peer review)

Learning intention: To be able to measure the volume of an irregularly shaped object and use this to calculate the density of the object.

Resources: Coursebook, irregularly shaped objects that will sink and also fit in a measuring cylinder or a displacement can, (top-pan) balance, paper towels (to dry objects before measuring the mass), beakers, water.

Description and purpose: The purpose of this practical is to be able to use a measuring cylinder and/or a displacement can to measure the volume of an irregularly shaped object and use this to calculate its density.

Show learners a regularly shaped object and ask them to explain how they would find its density. Learners should mention finding the mass, using a (top-pan) balance, the volume, e.g. length × width × height for a cuboid, and then calculate the density using density = mass / volume.

Then show learners some irregularly shaped object, e.g. a stone small enough to fit into a measuring cylinder, and ask them why they could not work out the density in the same way.

In pairs, learners suggest ways of working out the volume of an irregularly shaped object. Discuss a few of their suggestions and then show them a measuring cylinder and a displacement can. Ask learners to improve their ideas by using the two pieces of equipment.

Demonstrate how to find the volume of the small stone using two techniques:

1 Immerse the object in the measuring cylinder and determine the increase in the water level which is equal to the volume of the object.

2 Immerse the object in the displacement can, collect the water that overflows (in a beaker if necessary) and measure its volume in a measuring cylinder.

Practical guidance: Provide learners with measuring cylinders, displacement cans, beakers, a (top-pan) balance and a range of irregularly shaped objects (that will sink in water), including different size pieces of the same type of wood and plasticine in order for learners to see that it is the density of a material and not the density of an object that is being measured.

Learners measure the mass of a (dry) object and then use one, or both, of the techniques to find its volume.

Introduce the equation for density based on how it is defined, i.e. mass per unit volume. Learners calculate the density of each object and record their results in a suitable table. Before measuring the density of each object, ask learners to predict the density.

Safety: Wipe up any spills of water straight away so that floor does not become slippery.

Differentiation ideas:

Support – provide the less confident learners with a pre-drawn results table. Some assistance may be required with measuring the volumes and calculating the density of objects.

Challenge – more confident learners should be able to draw their own results table. They can also be challenged to explain how to find the density of an object that floats (e.g. to find the volume, use a pencil to push the object so that is just under the surface of the water but without putting any of the pencil in the water.)

Assessment ideas: Discuss learners' results with the whole class. Learners to suggest why their results may not be exactly the same as each others. What errors will there be?

2 Floating and sinking (1 hour)

Learning intention: To predict whether an object will float or sink based on its density.

Resources: Different solid objects of known density (in g/cm^3), bowls/containers to put water in which is deep enough for the objects to float/sink.

Description and purpose: The purpose of this task is for learners to analyse data from their experiment and to draw a conclusion relating the density of an object to whether it floats or sinks.

Show learners different small objects, some that will float and some that will sink. Ask learners if they can predict, just by looking, which will float and which will sink. Tell learners that you are not going to tell them if they are correct or not as they will find this out later. This is a useful technique which helps less confident learners express their opinions and ideas in front of a class without the pressure of being told that their answer is wrong. Misconceptions can be referred to later without mentioning learners by name.

Invite learners to pick up an object and say whether they have now changed their mind and, if so, why? Do other learners agree and why? Again, do not tell learners at this stage if their answers are correct or incorrect.

Provide learners with a pre-drawn table with a list of the objects and their densities, and space for their prediction and a float/sink column. Learners complete their predictions before attempting the practical work.

After the practical work, write the value for the density of water, 1 g/cm^3, on the board. Ask learners if they know what value this represents. What pattern can they identify from their results about which objects float and which sink? Learners should be able to identify that:

- objects with a density greater than water will sink
- objects with a density less than water float to the top

Practical guidance: Learners fill their bowls with enough water for objects to be able to float or completely sink.

Learners then complete the practical and fill in their table of results for as many objects as they can.

Safety: Wipe up any spills of water straight away so that floor does not become slippery.

Differentiation ideas:

Support – all learners should be able to do the experiment but some learners will need support to link their results to their knowledge of density. To consolidate less confident learners' knowledge, they could be provided with the density of more objects and asked whether they float or sink.

Challenge – can learners think of any objects that will float even though the material is more dense than water? Can they explain how this can happen? An example you could provide: Why does a boat made of steel float but a lump of steel will not? (Overall density of the boat includes the air inside the boat and is therefore less than the density of the water.)

Assessment ideas: Learners write a conclusion to their practical activity, using the words: objects, float, sink, density. Learners volunteer to share their ideas with the class and other learners can give feedback on how to improve their conclusions if necessary.

More confident learners can also share their answers to the challenge activity and questions.

3 Calculating density (30 min)

Learning intention: To be able to calculate the density of different substances using the equation for density.

Resources: Coursebook Table 1.3, (laminated) cards around the room.

Description and purpose: Make a selection of cards with measurements based on the density of the materials in Table 1.3 in the Coursebook. These could include:

- cuboids with dimensions and mass
- measuring cylinders with volumes and mass of the liquid given
- measuring cylinders with volumes shown before and after a small object is placed in it.
- Learners calculate the density of the material on each card. Encourage learners to show each step of their calculations and then identify which material it is from Table 1.3.

Differentiation ideas:

Support – provide some cards with more scaffolding for less confident learners, e.g. the equation provided and a question with part of the answer set out with gaps to fill in.

Challenge – more confident learners could be given cards with different information so that they have to calculate the mass, volume or length of an object.

Assessment ideas: Learners peer or self-assess their answers. As learners have written down their measurements and calculations, they will be able to spot where they have made an error if their final answer is incorrect.

Learners reflect on their learning and write a comment about what they did well (e.g. I wrote down all of the calculations clearly) and what errors they made (e.g. I used the density equation incorrectly). Exercise 1.2 in the Workbook provides questions on calculating density.

Plenary ideas

1 True or False (10 min)

Resources: PowerPoint slide or worksheet with density facts. Some density facts should be true and some should be false. For example: density is how heavy an object is, provide data for the volume, mass and density of a material (which may be calculated correctly or incorrectly).

Description and purpose: Learners say if the facts are true or false.

Assessment ideas: Discuss correct answers for learners to self-mark. If the facts are false, ask learners to explain why and suggest a correct fact.

2 Density card sort (10 min)

Resources: https://www.tes.com/teaching-resource/density-card-sort-6082470 cut up each sheet into boxes for each pair of learners.

Description and purpose: Learners match up the boxes. There should be three boxes in each group.

Homework ideas

1 Coursebook ideas

Learners write up their method for working out the density of an irregularly shaped object. Encourage learners to use numbers/bullet points for each instruction and to keep the instructions concise. Less confident learners could concentrate on one technique but more confident learners could describe both techniques. As a plenary activity, learners can then peer-assess each other's work.

2 Workbook questions

Learners who are finding the density equation difficult to use can complete Workbook Exercise 1.2 Density data to consolidate ideas. This can then be self- or peer-marked in the lesson.

More confident learners could research the story of Archimedes and the Golden Crown.

Learners could make a poster or PowerPoint presentation and explain the story to the rest of the learners.

CONTRIBUTED TEACHER ACTIVITY

Author name: Tracey Oliver

Title: The relative shape of things

Timing: 30 min

Learning intention: By the end of the activity the students should be able to use a variety of measuring tools, understand how density affects displacement, as well as make estimates as to the quantitative characteristics of items.

Resources: Coursebook pp. 3–9.

A couple of spherical objects (such as ping-pong balls, hockey balls, marbles), as well as a couple of rectangular objects (plastic building blocks, short rulers, etc.), a large beaker with water, callipers, measuring tapes, rulers, an electronic balance, as well as some paper, pens and calculator.

Description: The teacher will have explained in a preceding lesson how various measuring tools are used, as well as how density is calculated. In this lesson, the teacher will divide the students into groups of two. The students will be instructed to first estimate the masses of each object. They will then be instructed to use the balance to record the masses and record these readings in a table. The students will then be asked to determine the approximate density of each object, using the appropriate measuring tools available. During this time the teacher can walk around and assist students with the layout of their tables, how to use/read off the equipment, as well as answer any questions relating to units and recommended methods. By the end of the activity the students should be able to work out volume by displacement and measurement.

The teacher will then call them back to their seats and ask them to compare the relative densities based on the object's size and/or shape. The students can reflect on whether the results were what they expected or estimated.

Reflection opportunity: Students will be able to try to improve their measuring techniques or table set-ups at home during homework activities on this topic.

An activity that both encourages and relates in that it makes students realise how Physics is in all the things they use, and that all the complicated mathematics and applications they hear about start with the basics.

Tracey Oliver

1.3: Measuring time

LEARNING PLAN

Syllabus learning objectives	Learning intentions	Success criteria
Core: Describe how to measure a variety of time intervals using clocks and digital timers. Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of a pendulum).	• Learn how to make measurements of length, volume and time.	Students can use analogue and digital stop clocks and stop watches correctly. Students can measure short time intervals by timing several events and then dividing the time by the number of events.

** the above grid demonstrates full syllabus Learning Objectives. Please note that greyed-out content has been covered within a separate sub-chapter.*

Common misconceptions

Misconception	How to identify	How to overcome
Learners may mix up the hour and minute hand when reading an analogue clock.	See Starter idea 2.	Use questioning to elicit any misconceptions.
Learners may think that there are 100 seconds in a minute, 100 minutes in an hour.	See Main teaching idea 1.	Use questioning to elicit any misconceptions, e.g. there are 100 seconds in a minute, to change seconds into minutes you multiply by 60.

Starter ideas

1 Analogue or digital? (10 min)

Resources: Coursebook, Section 1.4.

Description and purpose: The purpose of this task is for learners to understand the differences between analogue and digital clocks and the advantages of using a digital clock.

Show learners a picture of a runner, an analogue clock and a digital clock. Learners explain which clock would be better to use when timing the runner in a 100 m race.

Give learners about 3 or 4 min to think about ideas individually and then ask them to share their ideas with other learners. Encourage discussion between learners by asking other learners to explain if they agree or not with the previous comments made.

2 Reading analogue clocks (10 min)

Resources: PowerPoint slide or worksheet.

Description and purpose: The purpose of this task is to elicit learners' knowledge of reading the time on analogue clocks correctly.

Show learners different times on analogue clocks, including some with a second hand. Learners write down the times shown on the clocks.

What to do next: Consolidate ideas for less confident learners by providing a worksheet or PowerPoint slide where they determine the times shown on an analogue clock.

Learners can also be stretched by asking them to calculate the difference in the times shown on two analogue clocks.

Main teaching ideas

1 Converting units of time (30 min)

Learning intention: To be able to convert between seconds, minutes and hours.

Resources: Worksheet, e.g. Maths Drill Worksheets.

Description and purpose: Show learners conversions between seconds, minutes and hours, some which are correct and some which are incorrect. Learners work in pairs to explain why some of the conversions are correct and others are not. Use questioning to elicit any misconceptions, e.g. there are 100 seconds in a minute, to change seconds into minutes you multiply by 60. Explain to learners how to convert between the units.

Differentiation ideas:

Support – some learners may need extra practice at converting between units. Provide a worksheet with scaffolding so that learners can work step-by-step through different examples.

Challenge – provide learners with compound units to convert, e.g. km/h into m/s.

2 The simple pendulum (1–1.5 hours including peer review of homework)

Learning intention: To be able to set up equipment and take multiple measurements in order to calculate a mean value for the period of a pendulum.

Resources: Support documents from the Practical Workbook and equipment listed for Practical investigation 1.2: The simple pendulum.

Description and purpose: The purpose of this task is build learners' confidence in setting up equipment and record the period of the oscillations accurately.

Show learners the equipment listed in the Practical Workbook. Learners name the equipment. Demonstrate to learners how to set up the equipment in order to measure the period of a pendulum. Discuss any problems which may occur when taking measurements (e.g. the time for one oscillation is very small), how to make it a fair test (keep the mass of the bob the same and use the same piece of string), and suggest how these problems can be overcome (e.g. measure the time for ten oscillations and divide by 10).

Practical guidance: Learners set up and do the experiment from the Practical Workbook to determine if there is a relationship between the length of a pendulum and its time period. Move around the groups to check that learners have set up and are working through the experiment correctly. Ask questions to check understanding, e.g. why is the time for ten oscillations being measured? (To reduce the effect of human error/ reaction time.) How many different lengths will they use and why? (At least four lengths spread out to get a range of readings.) Why are readings repeated? (To calculate a mean in order to improve precision of results.)

Learners should record their results in the table in the Practical Workbook.

Learners should have an understanding of significant figures and remind them that the results in their table should be recorded to the same number of significant figures, i.e. 2 significant figures.

Safety: Clamp the stands securely to the desk and so that they cannot fall over. Secure the bobs tightly to the string. Secure the string tightly to the boss. Do not pull the pendulum back too far in case the stand falls over.

Differentiation ideas:

Support – all learners should be able to do the experiment, but some may need more support than others, e.g. to know what time to measure, to change the length of the pendulum, to calculate the mean. The homework task will be to plot a graph of their results so less confident learners may need help to draw the axes and scales. Alternatively, less confident learners could be provided with axes and scales already drawn.

Challenge – challenge more confident learners with the Extension work in the Coursebook as the homework task. Learners plot a graph of length, l, against the square of the time period, T^2, and use the gradient to find the acceleration due to gravity, g.

Assessment idea: Peer-assess the graphs set for homework based as a Plenary Activity (2).

3 Testing your body clock (30 min)

Learning intention: To be able to use your pulse to measure an interval of time.

Resources: Workbook Exercise 1.3.

Description and purpose: Learners measure their pulse rate and discuss how good it would be at measuring an interval of time.

Practical guidance Learners find the mean time for one pulse firstly from counting 10 pulses and then 50 pulses. Learners then investigate the effect of exercise on their pulse rate and comment on whether they agree with Galileo that a pendulum is a better time-measuring instrument than your pulse.

Differentiation ideas:

Support – some learners may find it difficult to detect a pulse on their wrist so they could try to find a pulse on their neck instead. Less confident learners might need to be reminded how to calculate a mean from a set of results.

Challenge – more confident learners could extend their learning by comparing how long it takes their pulse rate to return to normal after different types of exercise.

Assessment ideas: Learners share their results with other learners and discuss any difficulties they encountered. Learners could also comment on the suitability of their pulse rate as a time-measuring instrument.

Plenary ideas

1 Matching units (10 mins)

Resources: Slide or worksheet with different units of time, length, volume, mass

Description and purpose: To consolidate learners' knowledge of typical units. Provide learners with a variety of units of time, length, volume and mass. Learners draw a table and put the units in the correct columns.

More able learners could also be given questions which require them to convert units, e.g. 1 cm = 0.01 m.

Assessment idea: Provide learners with the correct answers for them to self-mark.

2 Peer assessment of pendulum graphs (15 mins)

Peer-assess graphs set for homework based on a set of criteria which may include:

- axes drawn and labelled including units
- suitable scales on each axis (no awkward scales such as 3s or 7s)
- points plotted correctly using crosses
- line of best fit
- trend described / value of 'g' calculated using the gradient of the graph.

Learners can also reflect on each other's graphs, by indicating what they did well and what they need to do to improve next time.

Homework ideas

1 Plotting a graph

The homework task will be for learners to plot a graph of their results from Main Activity 2. Remind learners of the main points to remember when plotting graphs and give the set of criteria you will use when marking their graph. Less confident learners may need help drawing the axes and scales or be provided with axes and scales already drawn.

More confident learners could be challenged by plotting a graph of length, l, against the square of the time period, T^2, and then use the gradient to find the acceleration due to gravity, g.

2 Significant figures

Maths skills resources book: Maths focus 3: Determining significant figures.

Learners must use 2 (or more) significant figures in their answers to numerical questions and in practical measurements. Learners can work through Maths skill 2: Practice questions 8, 9 and 10.

Provide learners with the correct answers so they can self-mark their answers and discuss any errors they have made.

Links to digital resources

- Physics and Maths Tutor: past paper question on pendulums. Question 1
- Time period of a pendulum: video of an experiment to investigate how the length of a pendulum affects its time period
- Taking a bath and the Archimedes' principle: video of Archimedes' principle
- Density: video – why does oil float on water?
- Density: resource demonstrating floating and sinking. You will need to create an account – free of charge
- Density: interactive animation where learners can predict whether an object will float or sink

CROSS-CURRICULAR LINKS

Maths: substituting into equation for density; rearranging equation for density; converting units.

Project guidance

Learners will work in groups to produce a podcast on one of the project topics from the Coursebook.

Each group should decide which option they are most interested in – the podcast will only be engaging if the learners are enthusiastic about the content.

Depending on the nature of the class, divide the class into groups of three or four, e.g. groups with learners of similar abilities or mixed abilities. Allocate roles to each member of the group, e.g. time-keeper, team-leader, although this should be rotated so that learners can experience different roles.

One learner should be the facilitator who manages the whole project, coordinating the team members and ensuring that the various tasks are undertaken. The facilitator will also lead discussions with the group to consider the basic structure of the podcast and agree other roles and their allocations with the team.

One or two members of the team should have responsibility for researching and coming up with the basic content, this could be in note form ready to be passed to the script writer.

The script writer takes the rough notes from the researchers to write the text which will be read. The script writer will also work with the facilitator and other members of the team to decide whether various parts of the podcast will be read by different learners.

The learner or learners who will actually make the podcasts can also have the role of proof reading and checking the structure as it is compiled.

Part of the facilitator's job will be to make the most of each individual team member's strengths. For example, the researchers might be those learners with the best scientific knowledge and understanding.

Prepare a list of suitable references, including books and web-links, for each topic that the groups can refer to. Provide more structure for less confident learners/groups in the form of specific questions, 'hint sheets' (with more information on) that could be made available to them at the front of the classroom or a template to fill in.

Encourage learners to start by making a list of what they need to do, e.g. questions that they need to answer and how they will go about doing this.

Assessing individual learners is likely to be difficult but this does not detract from what can be an excellent learning activity.

Assessment will be subjective and should focus on giving constructive feedback that may include responding to:

- depth of research
- relevance of research
- understanding the physics involved
- quality of presentation
- ability to work in a team and individually.

As the podcast will be produced by the whole group, some differentiation will take place from the roles that learners undertake. Also, the very nature of this project will enable some differentiation by outcome, generally reflected in the depth of the research and how well that is put together to create an informative and engaging podcast.

Practical Workbook guidance

Chapter 1: Making measurements

Practical investigation 1.1 Estimating measurements

Planning and setting up the investigation

In this investigation, students will:

- use and describe the use of rulers and measuring cylinders to find a length or a volume
- use and describe the use of clocks and devices, both analogue and digital, for measuring an interval of time.

This practical can be taught in conjunction with the theory.

Duration: 15–20 minutes

Grouping: 2–4 students per group, depending on class size.

Each group will need: metre ruler, stopwatch, Vernier calipers, thermometer, top-pan balance, newton scale, micrometer screw gauge, 30 cm ruler

Review how to use Vernier calipers at the beginning of the practical.

Students may require additional support using Vernier calipers.

Safety considerations

- Keep the classroom door closed when students are measuring its width to prevent fingers being trapped in the hinges.
- Complete a dynamic safety assessment to ensure no risk to students.

Key discussion points for this investigation

- **Precision:** Why use Vernier calipers, rather than a ruler, to measure the diameter of a wire? Why might it be important for an electrician to be more precise with the thickness of cable measurements than an lift engineer, for example?
- **Accuracy:** Why are accurate measurements important? How might an inaccurate measurement affect the outcome of a 100 m race, the value of a diamond, the weight of a gold bar?
- **How can students improve accuracy?** When measuring with a ruler, students should ensure that the ruler is parallel to the object they are measuring, and that their eyes are level with the measurement they are taking, to reduce the effect of a parallax error. When timing events with a short time span, they should record the time for ten events and divide by ten, to find the average time for one.
- **Methods of measurement:** Students should consider alternatives. How many ways could they find the volume of a cube? Which method is more accurate? Why might they choose displacement over length measurement and calculation?

Common errors when conducting this investigation

Set each group a different task, to help avoid congestion around the classroom. They will need to observe the progress of each group to ensure there is no clustering at the more popular tasks.

Supporting your students

Discuss how to use Vernier calipers. Reading the scale might be an issue for some students. Set up Vernier calipers and invite students to read the scale, to ensure that they understand how to do it. If a student is really struggling, provide digital calipers for them to use as an interim measure.

Challenging your students

In the field of medicine, accurate measurement by doctors helps to ensure that patients are diagnosed correctly and treated effectively. Investigate ways in which doctors use technology to make accurate measurements and how inaccurate measurements can affect patient care. Prepare a two-minute presentation for the class.

Practical investigation 1.2 The simple pendulum

Planning and setting up the investigation

In this investigation students will:

- obtain an average value for a small distance and for a short interval of time (including the period of a pendulum) by measuring multiples.

This can be taught after theory.

Duration: 20 minutes

Each group will need: pendulum bob, string, 2 small rectangular pieces of wood or corkboard, clamp stand, clamp, boss, stopwatch, ruler. During the experiment, students should fix the string of the pendulum between the jaws of the clamp.

Use a secondary C-clamp to fix the clamp stand to the bench for safety to prevent toppling.

This investigation considers the relationship between the length of a pendulum and its time period of oscillation. Students are asked to vary the length of the pendulum string and record the time period of oscillation each time. Students will be expected to measure the time taken for ten swings. They will repeat this three times for each length and take an average. Dividing this average by ten will give the time taken for one oscillation.

Safety considerations

- Show students the correct way to swing the pendulum. Demonstrate pulling the pendulum so the string makes a small angle from the vertical and releasing gently, to prevent students releasing the pendulum aggressively. If you have a particularly lively class, suggest goggles should be worn for the practical investigation.
- Fix the clamp stand to the desk or bench with the C-shaped clamp, to prevent it toppling and causing injury.

Key discussion points for this investigation

- **How to measure the time period of one oscillation when the practical equipment is set up:** Discuss why multiple measurements will reduce error in reading.
- **How accuracy in measurements can be improved:** For example, by counting as the bob passes a fixed point or fiducial marker, or passes through its lowest point.
- **The variable that affects the time period:** Graphical representation of these relationships (time period and length) can be presented to the students to discuss the idea of direct proportion when considering $\frac{T^2}{l}$ or what a curve represents if T^2 is plotted against l.

Common errors when conducting the investigation

The pendulum should be released through small amplitudes. If it is released through a large amplitude the swing will not be periodic and will give incorrect readings, which will affect the results. Discuss this with students before starting the investigation.

Students might struggle to remain focused when recording the number of oscillations. Students might count the beginning of the oscillation as 'one', when they need to wait for a complete oscillation, with the pendulum returning to its initial position, before counting. This might cause their results to be smaller than the actual time period.

Supporting your students

Some students might struggle to understand why counting more oscillations reduces error in the final measurements. Use analogies to help the students understand that the error due to human reaction time will remain constant. However, if they count more oscillations, that percentage error will represent a smaller proportion of time than when just recording one oscillation.

Challenging your students

Ask students to investigate the effect of changing the mass of the bob rather than the length of the string. Ask them to consider the potential variables they will need to keep the same.

Practical investigation 1.3 Calculating the density of liquids

Planning and setting up the investigation

In this investigation students will:

- recall and use the equation $\rho = \frac{m}{v}$
- describe an experiment to determine the density of a liquid and of a regular 3d solid and make the necessary calculations
- predict whether an object will float, based on density data.

This practical can be conducted in conjunction with teaching the theory.

Duration: 45–60 minutes including graphical analysis

Grouping: 2–4 depending on class size

Each group will need: 100 ml measuring cylinder, oil, salt-water solution, water, balance 250 ml measuring cylinders can be used, in place of the 100 ml ones.

Any oil that is readily available such as baby oil, cooking oil, rapeseed oil may be used.

Any salt-water solution will have a different density to water, heavily salted water could be used containing food colouring to distinguish it from unsalted water, allow 100 ml per pair.

Equipment should be set out around the classroom, evenly distributed so it is easily accessible and prevents crowding. Dispense the oil and salt-water solution into labelled beakers to prevent students needing to queue for the bottle.

In this investigation the students are asked to record the mass of a fluid for increasing volumes. They will do this for oil, water and a salt-water solution. Students will then be expected to plot their results as a graph of mass against volume. The gradients of the graphs represent the densities of the fluids. From this, students will be asked to determine which solution will float on top of which.

Safety considerations

- Students should wear goggles to ensure no oil or salt-water solution gets into eyes. Rinse immediately if this occurs.
- Clear any spillages immediately to prevent slipping.
- Ask your students if any of them have allergies to rapeseed oil and warn them how important it is that the oil doesn't touch their mouths.

Suggested discussion points for this investigation

- **Taking readings from the bottom of meniscus:** Explain what the meniscus is.
- **Graph skills:** Discuss choosing a scale, drawing the line of best fit, calculating gradient.
- **Discussion:** If students had the same volume of each of the fluids, how could they determine the densities? Why is it important to measure equal volumes?
- **Discussion:** How might temperature affect density? Why would an increase in temperature cause a decrease in density? How is this related to convection?

Common errors when conducting the investigation

Advise students to measure the mass of the water first, then the salt-water solution, then the oil. This is primarily because the water is the easiest to remove from the cylinder, so there will be no residue to affect the mass measurement.

The balance should be tared (zeroised) at the beginning of the experiment to take account of the mass of the measuring cylinder. It should be done again when students start with the next fluid. Students often forget to tare, or continually zero throughout the experiment, which will give them incorrect results.

Students should plot all three graphs on the one grid and should label each line of best fit as they go along so they are clear which line is which.

Supporting your students

Students may struggle with drawing lines of best fit and calculating gradients. Discuss how to calculate a gradient at the beginning of the session and leave a worked example on the board throughout, as a point of reference.

One-to-one help might be required when discussing lines of best fit. It is beneficial to have worksheets with sample plots for students to practise drawing lines of best fit, as an aid.

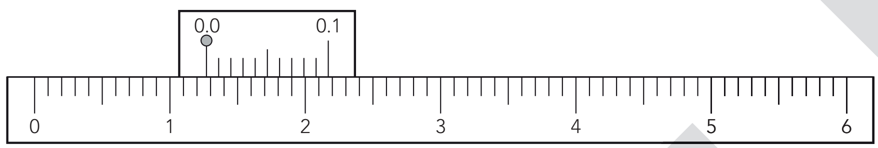
Challenging your students

Give students some additional items, such as a small piece of crayon, a piece of dried pasta, a paperclip and a small piece of wood. Students should layer the fluids they have used, based on their densities, and place the objects in the mix. The objects should settle in different layers. Students should explain, in terms of density, why this has happened and what this implies about the density of the items in comparison to the fluids in which they are suspended.

Exemplar data

Chapter 1: Making measurements

Practical investigation 1.1 Estimating measurements



scale reading = 1.27

Figure 3.1: Diffusion in sweets.

Practical investigation 1.2 The simple pendulum

Length of pendulum / cm	Time taken for 10 oscillations / s				Time taken for 1 oscillation / s
	1	2	3	Average	
10	6.52	6.40	6.49		
20	9.39	9.31	9.38		
30	11.21	11.11	11.90		
40	13.44	13.20	13.19		
50	14.01	14.40	13.99		

Table 1.2

Practical investigation 1.3 Calculating the density of liquids

Water

Mass / g	Volume / cm^3
49.86	50.0
58.22	60.0
69.46	70.0
79.21	80.0
89.90	90.0

Salt-water solution

Mass / g	Volume / cm^3
51.60	50.0
62.21	60.0
72.11	70.0
82.40	80.0
92.69	90.0

Oil

Mass / g	Volume / cm^3
46.21	50.0
55.92	60.0
65.36	70.0
74.99	80.0
83.68	90.0

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Physics

for Cambridge IGCSE™

WORKBOOK

David Sang & Darrell Hamilton

Third edition

Digital Access

Contents

How to use this book

Throughout this book, you will notice lots of different features that will help your learning. These are explained below. Answers are accessible to teachers for free on the 'supporting resources' area of the Cambridge GO website.

KEY WORDS

Definitions for useful vocabulary are given at the start of each section. You will also find definitions for these words in the Glossary at the back of this book.

Supplement content: In the keyword boxes, Supplement content is indicated with a large arrow, as in this example.

LEARNING INTENTIONS

These set the scene for each exercise, beginning with 'In this exercise you will', and indicate the important concepts.

In the learning intentions table, Supplement content is indicated with a large arrow and a darker background, as in the example.

KEY EQUATIONS

Important equations which you will need to learn and remember are given in these boxes.

TIPS

The information in these boxes will help you complete the exercises, and give you support in areas that you might find difficult.

Exercises

These help you to practise skills that are important for studying IGCSE Physics.

Questions within exercises fall into one of three types:

- **Focus** questions will help build your basic skills.
- **Practice** questions provide more opportunities for practice, pushing your skills further.
- **Challenge** questions will stretch and challenge you even further.

SELF/PEER ASSESSMENT

At the end of some exercises, you will find opportunities to help you assess your own work, or that of your classmates, and consider how you can improve the way you learn.

Supplement content

Where content is intended for learners who are studying the Supplement content of the syllabus as well as the Core, this is indicated in the main text using the arrow and the bar, as on the left here.

Chapter 1

Making measurements

Measurements and units

Exercise 1.1

IN THIS EXERCISE YOU WILL:

recall and use the SI units used in physics.

Focus

1 **a** State the SI units (name and symbol) of the following quantities:

length

....

volume

....

b State the name in words and the symbol for the following:

one thousand metres

....

one-thousandth of a metre

....

c How many?

State the number of centimetres there are in a metre. ....

State the number of litres there are in a cubic metre. ....

Practice

2 **a** State how many cm^2 there are in $1\,m^2$.

....

b State how many m^2 there are in $1\,km^2$.

....

Challenge

3 A cube has sides 3.50 m long. Calculate:

a the surface area of the cube in cm^2.

....

....

....

....

....

b the volume of the cube in mm^3.

....

....

....

....

....

Practical applications

KEY WORD

density: the ratio of mass to volume for a substance

KEY EQUATION

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

$$\rho = \frac{m}{V}$$

Exercise 1.2

IN THIS EXERCISE YOU WILL:

- practise converting between units
- practise applying the density formula
- apply your understanding of how density affects the behaviour of materials.

TIP

Don't assume that you know the answer. Always work it out. For example, 1 m^3 in mm^3 is $1000 \times 1000 \times 1000\,mm^3$, since there are 1000 mm in 1 m.

Focus

1 **a** Some data about the density of various solids and liquids are shown in Table 1.1. Complete the fourth column in Table 1.1 by converting each density in kg/m^3 to the equivalent value in g/cm^3. The first two have been done for you.

Material	State / type	Density / kg/m^3	Density / g/cm^3
water	liquid / non-metal	1 000	1.000
ethanol	liquid / non-metal	800	0.800
olive oil	liquid / non-metal	920	
mercury	liquid / metal	13 500	
ice	solid / non-metal	920	
diamond	solid / non-metal	3 500	
cork	solid / non-metal	250	
chalk	solid / non-metal	2 700	
iron	solid / metal	7 900	
tungsten	solid / metal	19 300	
aluminium	solid / metal	2 700	
gold	solid / metal	19 300	

Table 1.1 Densities of various solids and liquids

Two units are used for the densities, kg/m^3 and g/cm^3.

b Use the data to explain why ice floats on water.

....

....

2 A cook mixes equal volumes of water and olive oil in a jar. Predict whether one liquid will float on another liquid based on the data given in Table 1.1. Assume that the liquids do not mix.

....

....

Practice

3 A learner wrote: 'These data show that metals are denser than non-metals.' Do you agree? Explain your answer, using the data in Table 1.1.

....

....

....

....

....

4 Using the data in Table 1.1, calculate the mass of a block of gold that measures 20 cm × 15 cm × 10 cm. State your answer in kg.

....

....

....

....

....

5 A metalworker finds a block of silvery metal, weighs it and measures its volume. Here are their results:

mass of block = 0.270 kg

volume of block = 14.0 cm^3

Calculate the density of the block.

Suggest what metal this might be. ....

Challenge

6 Describe how you could find the density of the metal object in Figure 1.1.

Include:

- the equipment you would use
- how you would use the equipment
- what you would do with the data you collect.

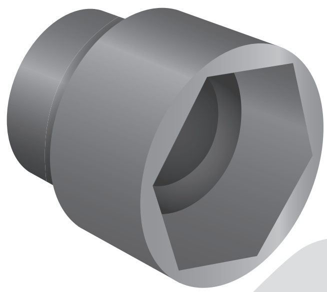

Figure 1.1

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Exercise 1.3

IN THIS EXERCISE YOU WILL:

find out how good your pulse would be as a means of measuring time intervals.

Galileo used the regular pulse of his heart as a means of measuring intervals of time, until he noticed that a swinging pendulum was more reliable.

In this exercise, you need to be able to measure the pulse in your wrist. Place two fingers of one hand gently on the inside of the opposite wrist (see Figure 1.2). Press gently at different points until you find the pulse. Alternatively, press two fingers gently under your jawbone on either side of your neck.

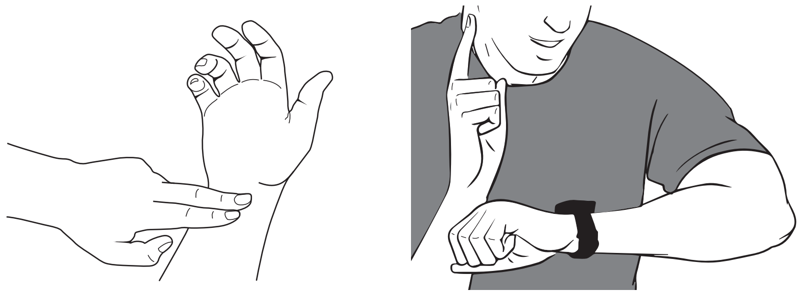

Figure 1.2: Taking a pulse.

You will also need a clock or watch that will allow you to measure intervals of time in seconds.

Focus

1 **a** Start by timing 10 pulses. (Remember to start counting from zero: 0, 1, 2, 3, …, 9, 10.) Repeat this several times and record your results in the table.

b Comment on your results.

i How much do your results vary?

………………………………………………………………………………………………

………………………………………………………………………………………………

ii Give a possible reason for this: is it difficult to time the pulses or is your heart rate varying?

………………………………………………………………………………………………

………………………………………………………………………………………………

c Calculate the average time for one pulse using your results.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

Practice

2 Time how long it takes for 50 pulses. Record your results in the table.

3 Calculate the average time for one pulse.

....

....

....

Challenge

4 Investigate how your pulse changes if you take some gentle exercise, for example, by walking briskly, or by walking up and down stairs.

Write up your investigation in the lined space. Use the following as a guide.

- Briefly describe your gentle exercise.
- State the measurements of pulse rate that you have made.
- Comment on whether you agree with Galileo that a pendulum is a better time-measuring instrument than your pulse.

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SELF-ASSESSMENT

Compare your answers to those of your peers. Do you agree with their points? Are you able to justify yours?

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Physics

for Cambridge IGCSE™

PRACTICAL WORKBOOK

Gillian Nightingale

Third edition

Digital Access

Cambridge Assessment International Education
Endorsed for learner support

Contents

How to use this book

Throughout this book, you will notice lots of different features that will help your learning. These are explained below. Answers are accessible for free for teachers in the supporting resources section of Cambridge GO.

INTRODUCTION

These set the scene for each chapter and indicate the important concepts. These start with the sentence 'The investigations in this chapter will...'

KEY WORDS

Key vocabulary and definitions are given at the start of each investigation. You will also find definitions of these words in the Glossary at the back of this book.

COMMAND WORDS

Command words that appear in the syllabus are highlighted in the exam-style questions and the Cambridge International definition is given. You will also find these definitions in the Glossary at the back of the book.

LEARNING INTENTIONS

These set out the learning intentions for each investigation.

The investigations include information on **equipment**, **safety considerations** and **method**. They also include **questions** to test your understanding on recording data, handling data, analysis and evaluation.

Remember that there is a **Safety section** at the start of this book – you should refer to this often, as it contains general advice that is applicable to many of the investigations.

REFLECTION

These encourage you to reflect on your learning approaches.

TIPS

The information in these boxes will help you complete the questions, and give you support in areas that you might find difficult.

Supplement content:
Where content is intended for students who are studying the Supplement content of the syllabus as well as the Core, this is indicated in the main text using the arrow and the bar, as on the left here.

EXAM-STYLE QUESTIONS

Questions at the end of each chapter provide more demanding exam-style questions, some of which may require use of knowledge from previous chapters. The answers to these questions are accessible to teachers for free on the Cambridge GO site.

Note for teachers:

The teacher's resource in this series includes sample data and support notes for each of the practical investigations in this practical workbook. You can find information about planning and setting up each investigation, further safety guidance, common errors to be aware of, differentiation ideas and additional areas for discussion.

Answers to all questions in this practical workbook are also accessible to teachers at www.cambridge.org/go

Chapter 1

Making measurements

THE INVESTIGATIONS IN THIS CHAPTER WILL:

- allow you to measure length, volume and time using a variety of instruments, as a scientist would do in a lab
- allow you to use techniques to measure short periods of time, or distance and appreciate the methods used to ensure these measurements are accurate. Accurate timing is important in sports such as Formula 1®.

Practical investigation 1.1: Estimating measurements

KEY WORDS

circumference: the distance around the outside of a circle

diameter: the length of a straight line that goes from one side of a circle to the other and passes through the centre of the circle

estimate: use information available to decide on a value that is appropriate

IN THIS INVESTIGATION YOU WILL:

- take accurate measurements of mass, time and distance using appropriate equipment
- calculate average values.

YOU WILL NEED:

- metre ruler
- stopwatch
- top-pan balance
- newton scale
- 30 cm ruler (for analysis section)

Safety

- Before you start recording the time for star jumps, check that the surrounding area is clear of objects.
- Make sure the person performing star jumps is wearing footwear suitable for this task.

Getting started

Familiarise yourself with the names of the equipment and what they measure from the skills section at the start of this book. Fill in the table provided to show which piece of equipment you will use for each type of measurement.

Measurement	Equipment
length	
volume	
mass	
time	

Use this table to help you during your investigation.

Method

1 Look at everything you are going to measure. Estimate each value and record your estimates in the table that has been provided.

2 Take measurements of:
   - the height of the person sitting next to you (in cm)
   - how long it takes a student to perform ten star jumps
   - the length, width and thickness of a glass block
   - the diameter of a piece of wire
   - the mass of a bag of sugar.

   Take each measurement three times.

Recording data

1 Record your measurements in the table. Remember to include the appropriate units.

Measurement type	Estimated value	Measured value			Average measurement
		1	2	3	

TIP

Make sure you record all measurements to the same number of significant figures or decimal places.

Handling data

2 Review your table. Are all of the measurements to the same number of decimal places or significant figures? Correct any that are not.

3 Calculate the average value for each measurement. Write the average values in the table.

Analysis

4 Compare your estimated and measured values. Comment on the values. Make reference to the data in your table to support your comments.

....

....

5 Calculate the volume of the glass block, based on the measurements you have taken.

....

....

Evaluation

6 Were the measuring instruments that you chose suitable in each case? Explain your answer and suggest what other instruments you could have used.

....

....

7 List three of the instruments you used and give the precision of these instruments.

TIP

The precision of an instrument is the smallest scale division on the instrument.

....

....

....

Practical investigation 1.2: The simple pendulum

KEY WORDS

mean: the mathematical term for the average of a range of numbers

meniscus: the lowest point of the top of a liquid

oscillation: the movement of an object from its start point to its furthest point and back again to the start

time period: the time taken for one complete oscillation

KEY EQUATION

average: the average of 12, 15 and 16 is 14.3: $\frac{12 + 15 + 16}{3} = 14.3$

IN THIS INVESTIGATION YOU WILL:

- use multiple measurements to calculate the average value for the time period of a pendulum
- determine if there is a relationship between the length of a pendulum and its time period.

YOU WILL NEED:

• pendulum bob • string • two small rectangular pieces of wood or cork board
• clamp stand • clamp • boss • stopwatch • ruler • C-clamp

Safety

Clamp the stand to the bench to ensure it is stable and cannot fall over and cause injury.

Getting started

Take a pendulum. Hold it between your fingers and look at how the pendulum moves.

Think about the things that you will need to consider in order to time the oscillation of the pendulum accurately. Write them down here.

....

....

Now, working with a partner, think of ways in which you could adapt your method to make your measurements more accurate. Write them down here.

....

....

Method

1. Tie the string to the pendulum bob to make a pendulum.
2. Hang the pendulum from the clamp stand and wait for it to come to rest (stop moving).
3. Use the ruler to measure the length of the pendulum from where the pendulum is held to the centre of its bob (its centre of mass).
4. Keeping the string straight, move the pendulum bob to one side and release it, allowing it to swing at a steady pace. Use the stopwatch to time ten complete oscillations.
5. Repeat twice more and take an average of the results.
6. Repeat for four different lengths of pendulum.

Recording data

1 Record your measurements in the table.

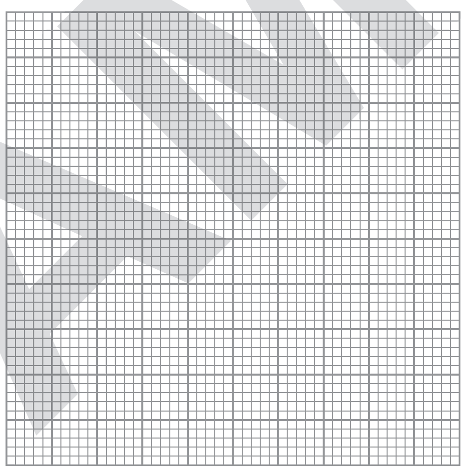
Length of pendulum / cm	Time taken for ten oscillations / s				Time period (time taken for one oscillation) / s
	1	2	3	Average (mean)	

Handling data

2 Calculate the time period for each pendulum length. Write the values in the table.

Analysis

3 Draw a graph of pendulum length against time period.



4 State and explain whether the length of the pendulum has an effect on the time period of an oscillation. Use your results to support your answer.

....

....

....

....

Evaluation

5 Suggest another variable that might affect the time period of an oscillation.

....

....

REFLECTION

How did you find recording the oscillations of your pendulum? With your partner, discuss one way in which you could have improved this investigation to make it easier to record the oscillations.

Practical investigation 1.3: Calculating the density of liquids

IN THIS INVESTIGATION YOU WILL:

- determine the densities of three common liquids by taking measurements of volume and mass.

YOU WILL NEED:

- 100 cm^3 measuring cylinder
- oil
- saltwater solution
- water
- balance
- safety goggles

Safety

- Some of the fluids in this investigation can cause mild irritation to the eyes. Use safety goggles at all times.
- Clear any spills immediately to prevent slipping.

Getting started

With your partner, discuss why knowing the density of a fluid is important. Write some ideas down in the space provided.

TIP

Think about convection and the weather.

....

....

....

....

When you measure the volume of a liquid, it is important to ensure that the reading is taken correctly. The reading should always be taken at eye level, and using the meniscus of the liquid. Look at the example in Figure 1.1 and then try to read off the volume of the remaining three measuring cylinders.

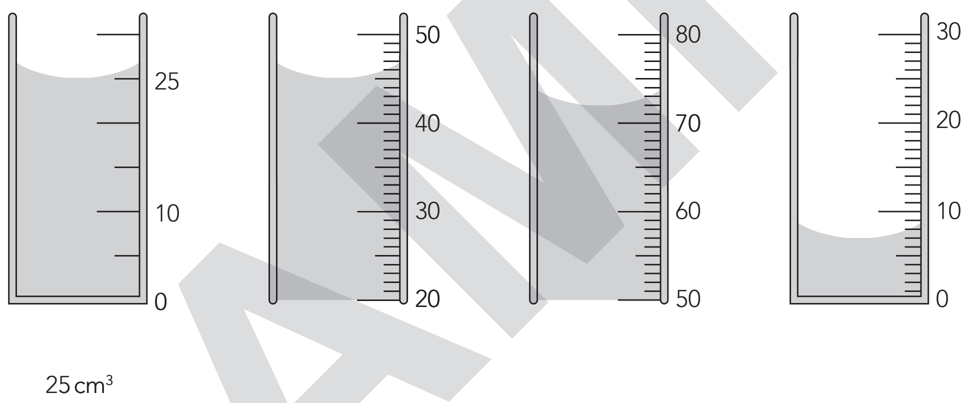


Figure 1.1: Taking a reading from a measuring cylinder.

Method

1. Place the measuring cylinder on the balance. Set the balance to zero.
2. Add 50 cm^3 of water to the measuring cylinder. Record the volume and mass of the water in the table below.
3. Repeat for 60 cm^3, 70 cm^3, 80 cm^3, 90 cm^3 and 100 cm^3. Record the volume and mass of the water in the table below.
4. Empty and dry the measuring cylinder. Repeat steps **1–3** for the saltwater solution and the oil.

Recording data

1 Record your measurements in the tables.

Water	
Volume / cm^3	Mass / g

Saltwater solution	
Volume / cm^3	Mass / g

Oil	
Volume / cm^3	Mass / g

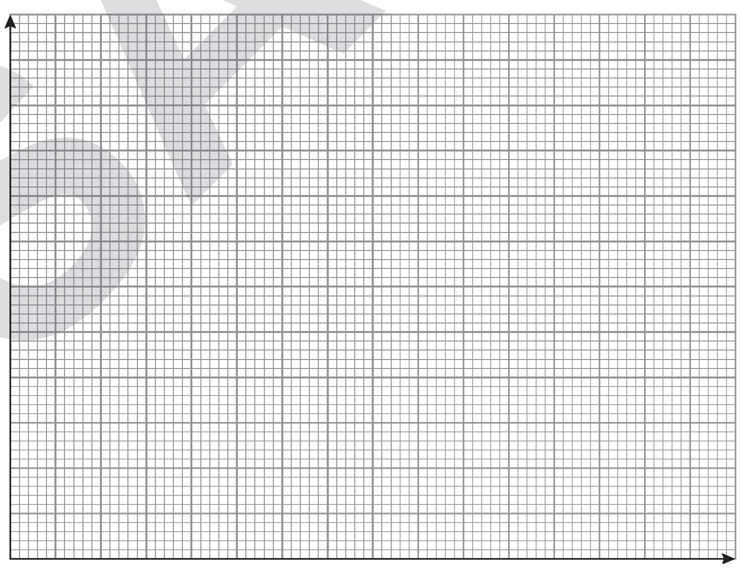
Handling data

2 Use your results to plot a graph of volume against mass for each of the liquids you have measured. Plot all three graphs on the grid provided.

TIP

When you draw the graph, label each axis and include the appropriate unit. For this graph, plot the volume along the horizontal axis and the mass up the vertical axis.

Remember to choose an appropriate scale for each axis.



Analysis

3 Draw a line of best fit for each of the liquids you have tested. Label them clearly.

4 The gradient of the line of best fit in each graph is equal to the density of the liquid. By looking at your graph, predict which liquid has the highest density. In the space below, explain how you can make this assumption by sight alone.

....

....

....

5 Calculate the gradient of each of the lines of best fit. Do your values support your answer to question **4**?

Water ....

....

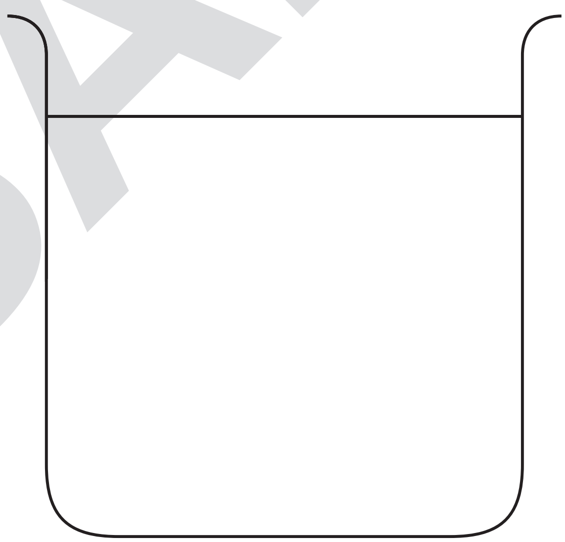
Oil ....

....

Saltwater solution ....

....

6 Liquids that are less dense float on top of more dense substances. The liquids do not mix. In the measuring beaker shown, draw in the order in which the liquids would settle, labelling each one clearly.



Evaluation

7 Your teacher will give you the actual values of density for the liquids you have tested. How do your results compare? Suggest two reasons why your results may be different.

....

....

....

....

8 An oil spill occurs out at sea. A student suggests that a clean-up operation would be impossible because the two substances would mix. Do you think the student is correct? Comment on the student's statement, relating it to the experiment you have conducted here.

....

....

....

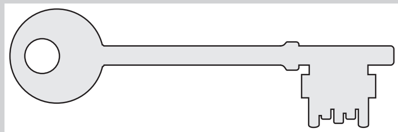
....

REFLECTION

In this investigation you had to calculate the gradient of your line of best fit. Discuss with two other groups the values they calculated. How different were they compared to yours? If you were a scientist trying to evaluate the density of a particular liquid, how would you accommodate the differing results?

EXAM-STYLE QUESTIONS

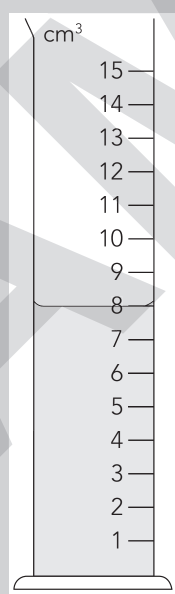
1 A student has been asked to determine the material from which a key is made.



The student has been given a table which lists the densities of a variety of common metals based on measurements taken from 1 cm^3 metal blocks found in the laboratory.

Type of metal	Density / g/cm^3
aluminium	2.7
iron	7.9
lead	11.4
steel	8.4

The student fills a displacement can with water and carefully adds the key, using a measuring cylinder to collect the water that is displaced. The displaced water collected in the measuring cylinder is displayed in the figure.



a **i** Show clearly on the diagram the line of sight you would use to obtain an accurate reading. **[2]**

ii **State** the volume of the key. **[1]**

....

COMMAND WORD

state: express in clear terms

CONTINUED

b i The student then takes the key, dries it and uses a balance to measure its mass. The mass of the key is 65.01 g.
Calculate the density of the material from which the key is made, using the equation for density. **[3]**

....

....

ii Using the table of densities, **determine** the metal from which the key is most likely to be made. **[1]**

....

....

c The density of water is 1 g/cm^3. Which of the metals in the table would you expect to float?

Explain your answer. **[3]**

....

....

[Total: 10]

2 A student has been asked to measure the average speed of a child's toy race car as it goes around a circular track.

a i The student uses the equation for average speed to determine that they need to measure the distance of the track and the time taken for the car to go around the track.

Suggest appropriate equipment for taking these measurements in the table provided. **[2]**

Quantity	Measuring device	Resolution
distance		
time taken		

ii State an appropriate resolution for each of these instruments in the final column of the table. **[2]**

COMMAND WORDS

calculate: work out from given facts, figures or information

determine: establish an answer using the information available

explain: set out purposes or reasons / make the relationships between things evident / provide why and/or how and support with relevant evidence

suggest: apply knowledge and understanding to situations where there are a range of valid responses in order to make proposals / put forward considerations

CONTINUED

b **i** The diagram shows a scale drawing of the circular race track. Use the diagram to calculate the distance travelled by the car in one lap. **[2]**

Scale = 1 cm : 5 cm

....

....

ii The readings for the time taken by the student are given in the table.

Time taken / s	0.48	0.49	0.5

Suggest one way she could improve the tabulation of her data. **[1]**

....

....

iii Calculate the average time taken for one lap. **[1]**

....

....

iv Calculate the average speed for the car around the race track. Include the relevant units in your answer. **[2]**

....

....

c The student notices that the time taken for the car to go around the track is very short. She is worried that the measurements are not accurate enough. Suggest one way in which she could improve the accuracy. **[2]**

....

....

[Total: 12]

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Physics

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ENGLISH LANGUAGE SKILLS WORKBOOK

David Sang, Timothy Chadwick, Darrell Hamilton,
Deepak Choudhary & Fiona Mauchline

Third edition

Digital Access

Contents

Introduction

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- 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.

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This book explains how data and graphs are interpreted by physicists. Once you have learned how to do it, you can apply the same method again and again in lots of different situations. Applying mathematics to physics is very methodical so it is worth learning how to do it.

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, so as 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 Cambridge 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.

How to use this book

Throughout this book, you will notice lots of different features that will help your learning. These are explained below. Answers are accessible to teachers for free on the 'supporting resources' area of the Cambridge GO website.

INTRODUCTION

Important equations which you will need to learn and remember are given in these boxes.

KEY WORDS

Key vocabulary and definitions are given at the start of each investigation. You will also find definitions of these words in the Glossary at the back of this book.

COMMAND WORDS

Command words that appear in the syllabus and might be used in exams are highlighted in the exam-style questions. In the margin, you will find the Cambridge International definition. You will also find these definitions in the Glossary at the back of the book with some further explanation on the meaning of these words.

LEARNING INTENTIONS

These set out the learning intentions for each investigation.

The investigations include information on **equipment**, **safety considerations** and **method**. They also include **questions** to test your understanding on recording data, handling data, analysis and evaluation.

Remember that there is a safety section at the start of this book – you should refer to this often, as it contains general advice that is applicable to many of the investigations.

REFLECTION

These encourage you to reflect on your learning approaches.

KEY EQUATIONS

Important equations which you will need to learn and remember are given in these boxes.

TIPS

The information in these boxes will help you complete the exercises, and give you support in areas that you might find difficult.

Supplement content

Where content is intended for students who are studying the Supplement content of the syllabus as well as the Core, this is indicated using the arrow and the bar, as on the left here.

EXAM-STYLE QUESTIONS

Questions at the end of each chapter provide more demanding exam-style questions, some of which may require use of knowledge from previous chapters. The answers to these questions are accessible to teachers for free on the Cambridge GO site.

Note for teachers:

The Teacher's Resource in this series includes sample data and support notes for each of the practical investigations in this practical workbook. You can find information about planning and setting up each investigation, further safety guidance, common errors to be aware of, differentiation ideas and additional areas for discussion.

Answers to all questions in this practical workbook are also accessible to teachers at www.cambridge.org/go

› Chapter 1

Making measurements

IN THIS CHAPTER YOU WILL:

Science skills:

- use and identify quantity and measurements
- identify quantities and units
- use the concept of density

English skills:

- use words to sequence processes
- use adjectives: comparatives and superlatives
- practice using prefixes
- practice using the past passive tense.

Exercise 1.1 Measuring length and volume

IN THIS EXERCISE YOU WILL:

Science skills:

- understand some of the important concepts (= ideas) and terms (= words) we use when we take measurements in physics

English skills:

- sequence a process using words like first, next, then, after that and finally.

1 John wanted to measure the length of a block of wood. He used a ruler. In his notebook, he wrote:

length of block = 22.4 cm

a Complete the third column in the table using information from John's notebook.

Term	Definition	Example from John's notebook
quantity	an amount that can be measured	
measuring instrument	a tool used to measure a quantity	
value	the result of measuring a quantity	

b The *value* of a quantity has both a number and a unit. What is the unit of length in John's notebook?

....

2 We use different measuring instruments to measure different quantities.

a Match the words to the pictures.

ruler thermometer clock measuring cylinder

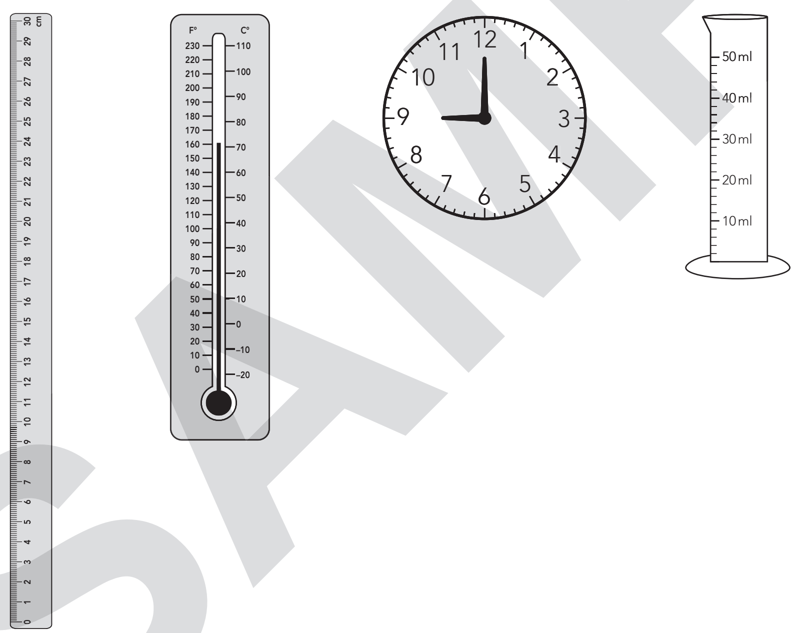

Figure 1.1: A ruler, thermometer, clock and measuring cylinder.

b i Complete the first two columns of the following table using the words from the list. Write the unit name for each quantity in the third column of the table.

ruler **measuring cylinder** **stopwatch** **thermometer**

temperature **volume** **length** **time**

KEY WORDS

temperature: a measure of how hot or cold something is; a measure of the average energy of the particles in a substance

volume: the space occupied by an object

Measuring instrument	Quantity measured	Unit

ii Turn each row of the table into a sentence. One row has been done for you.

1 A ruler is used to measure length in centimetres.

2 ....

3 ....

4 ....

LANGUAGE FOCUS

Sequencers

When you describe an experiment or give instructions, it helps the reader or listener if you use words to show the sequence. These useful words include *First*, *Next*, *Then*, *After that* and *Finally*.

Use *First* or *First of all* to begin your description or instructions.

First read the scale of the pan balance reading when nothing is on it.

Use *Next*, *Then* or *After that* to introduce the steps in your experiment or instructions. In this context, they all mean the same thing.

Then put the stone on the pan balance and read the scale again.

Use *Finally* to introduce the last step in your experiment or instructions.

Finally, to find the mass of the stone, subtract the first reading from the second reading.

3 a Read Siti's description of how she measured the volume of a pebble.

Underline and number (1–7) words that mean the same as the words in the box.

We filled a water cylinder half-way up. We wrote down the amount it said. To find out how big the pebble was, we put it under the water and wrote down the new amount. We worked out the difference between the two amounts.

1 calculated	**2 determine**	**3 half-filled**	**4 immersed**
5 measuring cylinder	**6 recorded**	**7 volume**	

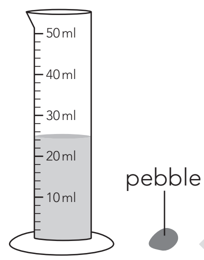

Figure 1.2: Apparatus to find the volume of a pebble.

b When Siti wrote her description, she did not use scientific words. Rewrite Siti's description using words from the box to replace the words you underlined.

First, ...

Next, ...

Then, ...

After that ....

Finally ....

Exercise 1.2 Density

IN THIS EXERCISE YOU WILL:

Science skills:

- use the property of **density** to compare materials

English skills:

- describe and compare things using adjectives.

KEY WORD

density: the ratio of mass to volume for a substance

LANGUAGE TIP

In everyday English we say *heavy*; in science we say *dense*.
In everyday English we say *weight*; in science we say *mass*.

1 The density of water is, in symbols, 1 g/cm^3, and in words, one gram per centimetre cubed. The word 'per' means 'for each'. This is shown by the solidus (/) in the unit.

a Density of water = 1000 kg/m^3. Write this density in words.

....

b The density of water is one kilogram per decimetre cubed. Write this density in symbols.

....

c What quantity is measured in grams?

....

d What quantity is measured in centimetres cubed?

....

e Which of the following is the correct equation for calculating density? Circle it. (Think about the unit of density, g/cm^3. This will help you to see how density is calculated.)

density = **mass** × volume $\quad$ density = $\dfrac{\text{volume}}{\text{mass}}$ $\quad$ density = $\dfrac{\text{mass}}{\text{volume}}$

KEY WORD

mass: the quantity of matter a body is composed of; mass causes the object to resist changes in its motion and causes it to have a gravitational attraction for other objects

LANGUAGE FOCUS

Adjectives

Adjectives are words that describe things. They come before nouns or after *to be*, for example, *dense*, *heavy*, *complex*, *narrow*, *scientific*, *English*, *Chinese*, *small*.

You can use adjectives to compare two things.

To make the comparative form of short adjectives with one syllable (e.g. *small*, *dense*) or with two syllables ending in *-y* or *-w* (e.g. *heavy*, *narrow*), add *-er*: *smaller*, *denser*, *heavier*, *narrower*. (Note: *y* becomes *i*.)

To make the comparative form of other adjectives, put *more* in front of them, for example, *more complex*, *more scientific*.

You then add than:

It's denser than water. Those words are more scientific than these.

To compare more than two things, use the superlative form of the adjective:

-er comparatives → *the -est* superlatives

the densest, the smallest, the narrowest

more comparatives → *the most* superlatives

the most complex, the most scientific.

LANGUAGE TIP

If we know the densities of two or more materials, we can compare them using adjectives.

2 These adjectives are frequently used in physics. Write their comparative and superlative forms.

		Comparative form	Superlative form
a	large	....	....
b	deep	....	....
c	wide	....	....
d	full	....	....

3 Read these short paragraphs. Underline the adjective in the first sentence in each. Then complete the paragraphs using the comparative and superlative forms of the same adjective. Here is an example:

Hydrogen is a light gas. It is *lighter* than helium. It is the *lightest* gas in the Periodic Table.

a John is lifting heavy weights. The red weight is .... than the blue one. The green one is the .... weight of all.

b Today we have had strong winds. The wind today has been .... than yesterday. Tomorrow we will have the .... winds this month.

c The pressure is low today. Tomorrow the pressure is forecast to be .... The .... pressures are usually during the winter.

Exercise 1.3 Measuring time

IN THIS EXERCISE YOU WILL:

Science skills:

- practise using ideas about quantities and units
- understand the difference between units and prefixes in symbols

English skills:

- describe a process using the past passive tense.

In physics, it is important to record measurements correctly. Remember that each value has two parts:

- a number
- a unit.

1 Read the text. (Circle) each value.

It was a hot day – over 30 °C. We had to walk 5 km to get home. It took 2 h because we kept stopping for water. I drank more than 1.5 dm^3 because I was really thirsty, as I had to carry a box with 10 kg of tins of food inside it.

2 Complete the table to show the quantities mentioned in the text and their values. Then write the full name of each unit in the third column. The first row has been done for you.

Quantity	Value	Unit
temperature	30	degrees Celsius (°C)

3 Scientists usually use standard units called SI units. Metres, kilograms and seconds are examples of SI units.

LANGUAGE FOCUS

The use of units and prefixes in symbols

Each unit has a symbol, for example 'g' means grams.

The size of a unit can be changed by adding a prefix in front of the symbol, for example, 'k' stands for the prefix 'kilo-', which means one thousand. A kilogram (kg) is one thousand grams.

Take care! The letter 'm' can stand for a unit *or* a prefix.

a In the unit cm, what prefix does 'c' stand for?

....

b What unit is represented by 'm'?

....

c What prefix does 'm' stand for in a symbol, for example in 'ms'?

....

d What does the symbol 'mm' stand for?

....

e Give the names and symbols for two units of mass.

....

f Give the names and symbols for two units of length which are smaller than a metre.

....

g What does the symbol 'ms' stand for?

....

h Which is bigger, 1 ms or 1 μs?

....

i What quantity can be measured in m^3 and cm^3?

....

4 a

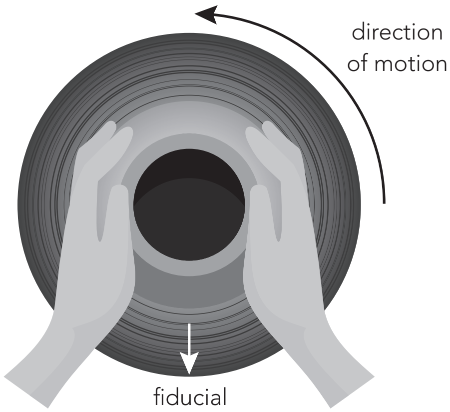

Figure 1.3: A potter's wheel experimental setup.

KEY WORDS

time period: the time taken to complete one lap or one revolution

fiducial marker: any mark on a system which is used as a reference point of measurement

Below are instructions for measuring the **time period** of the potter's wheel in Figure 1.3.

- Use a **fiducial marker** to mark the edge of the wheel.
- Switch on the wheel.
- Start the stopwatch.
- Time how long it takes for 20 rotations.
- Repeat for accuracy.
- Find the time it takes for one complete rotation.

Imagine that you have done this experiment. Rewrite the instructions as a paragraph describing what you did in the past tense. Remember to use words to sequence the steps. The first sentence has been done for you.

First, we used a fiducial marker to mark the edge of the wheel. Next,

....

....

....

....

....

....

LANGUAGE FOCUS

The past passive tense

When we write about experiments we have done, we often need to use the past passive tense. We use it because we don't always know who is doing the action and because 'who' is not always important; we are only interested in the action itself. For example:

Past tense: We recorded the volume of water again.

Past passive: The volume of water was recorded again.

To change an active (normal) past sentence into the passive, we:

1. move the object to the front of the sentence to make it important (here = *The volume of water*)
2. decide if the word at the front (*volume*) is singular or plural and choose the correct part of the past form of *be*: *was* or *were*? (here = *was*)
3. use the past participle of the main verb (here = *recorded*). With regular verbs, add *-ed* to the verb (here = *record* → *recorded*). With irregular verbs, you need a verb table; the past participle is the third part, for example:

   bring brought **brought**   give gave **given**   make made **made**

   put put **put**

Here's another example:

We **half-filled** the measuring cylinder.

The measuring cylinder **was** half-filled.

b Look at the verbs in the potter's wheel experiment. Write their past participles.

i use ....

ii switch ....

iii start ....

iv time ....

v repeat ....

vi find ....

c Rewrite the paragraph you wrote for question **4a**. This time, use the past passive tense, including the past participles you wrote in **4b.** The first sentence has been done for you.

First, we used a fiducial marker to mark the edge of the wheel. Next

....

....

....

....

....

....

....

....

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Jane Thompson & Jaykishan Sharma

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This book explains how data and graphs are interpreted by physicists. Once you have learned how to do it, you can apply the same method again and again in lots of different situations. Applying mathematics to physics is very methodical so it is worth learning how to do it.

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, so as 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 Cambridge 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.

How to use this book

Throughout this book, you will notice lots of different features that will help your learning. These are explained below. Answers are accessible to teachers for free on the 'supporting resources' area of the Cambridge GO website.

KEY WORDS

Definitions for useful vocabulary are given at the start of each section. You will also find definitions for these words in the Glossary at the back of this book.

Supplement content: In the keyword boxes, Supplement content is indicated with a large arrow, as in this example.

LEARNING INTENTIONS

These set the scene for each exercise, beginning with 'In this exercise you will', and indicate the important concepts.

In the learning intentions table, Supplement content is indicated with a large arrow and a darker background, as in the example.

KEY EQUATIONS

Important equations which you will need to learn and remember are given in these boxes.

TIPS

The information in these boxes will help you complete the exercises, and give you support in areas that you might find difficult.

Exercises

These help you to practise skills that are important for studying Cambridge IGCSE Physics.

Questions within exercises fall into one of three types:

- **Focus** questions will help build your basic skills.
- **Practice** questions provide more opportunities for practice, pushing your skills further.
- **Challenge** questions will stretch and challenge you even further.

SELF/PEER ASSESSMENT

At the end of some exercises, you will find opportunities to help you assess your own work, or that of your classmates, and consider how you can improve the way you learn.

Supplement content

Where content is intended for learners who are studying the Supplement content of the syllabus as well as the Core, this is indicated in the main text using the arrow and the bar, as on the left here.

Chapter 1

Representing values

WHY DO YOU NEED TO REPRESENT VALUES IN PHYSICS?

- In physics, numbers are used to give values to measurable characteristics. We use the word **variable** for such a characteristic. Length, time and mass are just some of the variables whose values help us to describe features of the real world. For example, the time sunlight takes to reach the Earth is 8 minutes and 20 seconds, the mass of the of the moon is 7.3×10^{22} kg, the speed of a bullet train is 500 km/h, the mass of a 1 litre bottle of water is 1 kg.
- Each variable has a **unit** linked to it. The unit allows us to understand the size of the variable. Examples of units are: metres, seconds, kilograms and amps.

KEY WORDS

variable: the word used for any measurable quantity; its value can vary or change

unit: a standard used in measuring a variable, for example the metre or the volt

Maths focus 1: Using units

A measured value in physics means nothing without a unit. Scientists have agreed a set of standard units. Wherever you are in the world, scientists use the same set of standard units called SI units (*Système Internationale*). Imagine if you have only numbers in your life, without units. What would your life be like? Does it make sense if you ask a shopkeeper to give you 10 salts?

What maths skills do you need to be able to use units?

1 Choosing the correct unit for a variable	• Identify the variable • Recall the correct unit to match the variable • Use the correct symbol for the unit • Convert units

Maths skills practice

How does using the correct units help when working with equations?

Using same units means that we can compare the size of variables and calculations very easily. This is why the international SI system was agreed. Table 1.1 shows the basic SI units for some variables. Each unit has a symbol, which makes the unit easier to recognise and write quickly.

Variable	FPS unit	CGS unit	SI unit	SI unit symbol
length (or distance)	foot	centimetre	metre	m
mass	pound	gram	kilogram	kg
time	second	second	second	s

Table 1.1: Units for length, time and mass.

Sometimes you will see different units used (see Table 1.2).

Variable	Unit
length (or distance)	kilometre, millimetre
time	hour

Table 1.2: Different units can be used for the same variable.

The unit metres per second (m/s) for speed is a 'derived unit', which means it is based on a calculation. It is the number of metres travelled in each second. The / symbol is read as 'per' and indicates division.

You can read more about SI units in Chapter 1 of the Coursebook.

Other SI units that you need to be familiar with are shown in Table 1.3.

Variable	SI unit
force	newton (N)
energy	joule (J)
power	watt (W)
temperature	degrees Celsius (°C)
frequency	hertz (Hz)
potential difference	volt (V)
electric current	ampere (A)
resistance	ohm (Ω)
electric charge	coulomb (C)

Table 1.3: SI units.

LOOK OUT

Be careful with units when using equations. For example, when distance and time are measured in metres and seconds, the speed that you calculate will be a value in m/s (metres per second), not in km/h (kilometres per hour).

Maths skill 1: Choosing the correct unit for a variable

In a calculation, the units you use must match (be consistent) with one another. For example, when calculating an area using the equation area = length × width

the length and width must have the same units. When the length measurement is in centimetres (cm) and the width is in millimetres (mm), one must be converted so they are consistent.

In Figure 1.1, the width measurement has been converted from millimetres to centimetres.

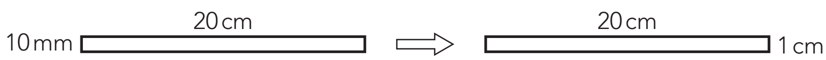


Figure 1.1: Converting millimetres to centimetres.

The area is then 20 cm × 1 cm = 20 cm^2.

See Chapter 6, Maths focus 1, '*Solving problems involving shape*' for more on calculating area.

To convert from cm to m, from cm^2 to m^2, or from cm^3 to m^3, remember:

- there are 100 cm in 1 m
- there are 10 000 cm^2 in 1 m^2
- there are 1 000 000 cm^3 in 1 m^3.

The conversion factors are shown in Table 1.4.

Original unit	New unit	Process	Example
cm	m	Divide by 100	500 cm = 5 m
cm^2	m^2	Divide by 10 000	5000 cm^2 = 0.5 m^2
cm^3	m^3	Divide by 1 000 000	50 000 cm = 0.05 m^3

Table 1.4: Converting units of length, area and volume.

WORKED EXAMPLE 1.1

Find the volume of the block of material in Figure 1.2.

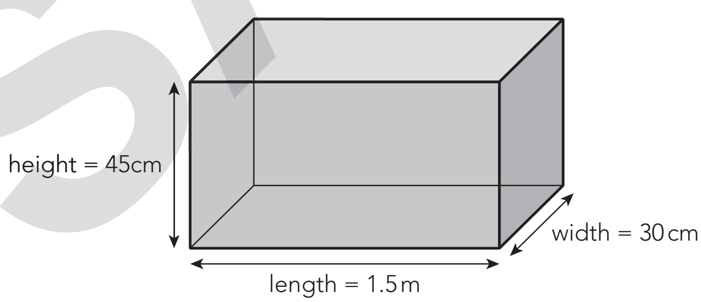


Figure 1.2: Block of material.

Step 1: Remind yourself of the equation for volume.

Volume = length × width × height

Step 2: List each variable with its units.

Length = 1.5 m

Width = 30 cm

Height = 45 cm

Volume = ?

Step 3: Check for consistency and decide which unit you are going work in. Here we will work in metres (remember that 1 cm = 0.01 m).

Length = 1.5 m

Width = 0.3 m

Height = 0.45 m

Volume = ?

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

Volume = 1.5 m × 0.3 m × 0.45 m

Volume = 0.20 m^3

Questions

1 **a** A student releases a trolley down a long ramp, as shown in Figure 1.3. As the front of the trolley passes marker 1, she starts a stopwatch and stops it as the trolley reaches marker 2.

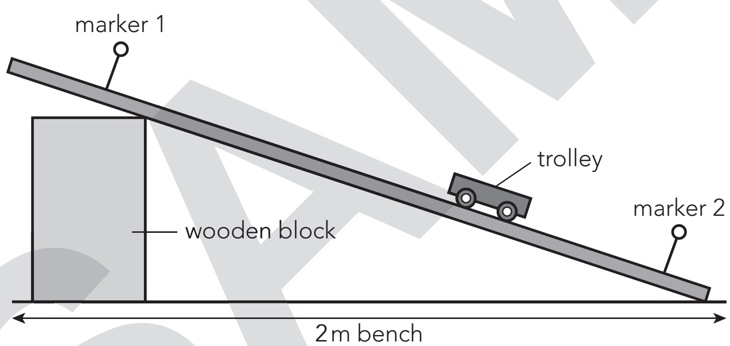


Figure 1.3: Trolley rolling down a ramp.

Write down suitable units, in symbols, for the following variables:

i The time taken to travel down the ramp is measured in ....

ii The length of the ramp is measured in ....

iii The mass of the trolley is measured in ....

b The distance between marker 1 and marker 2 is 10 cm and it takes 2 s to cover this distance. Calculate the speed of the trolley. Give your answer in m/s.

....

....

....

2

Figure 1.4: Horizontal cylinder.

A horizontal cylinder has a cross-sectional area of 30 cm^2 and a length of 3 m. What is its volume?

Use the equation volume = cross-sectional area × length

....

....

....

PEER ASSESSMENT

Do you need to convert the units? Why? Discuss with your classmate.

Maths focus 2: Using symbols for variables

A *variable* is a measurable characteristic. It has a value, expressed as a number with a unit. Scientists use symbols instead of the variables names and units to help find and work with relationships between variables. Then they can express the relationship as a mathematical equation.

What maths skills do you need to use symbols for variables?

1 Using the symbol for each variable and its unit	• Learn the symbol for each variable • Know that the symbol stands for the variable and its unit

Maths skills practice

How does using the correct units help when working with equations?

Look at this equation that shows how the gravitational field strength impacts on mass to give the weight of an object:

weight (in N) = mass (in kg) × gravitational field strength (in N/kg)

Writing equations like this is slow and inefficient. Using symbols, this becomes faster and much easier:

$W = mg$

W stands for 'weight in N'. For example the value of *W* might be 10 N. The symbol includes the numerical value *and* the unit.

In symbol equations, the multiplication sign is often omitted: $mg = m \times g$

Maths skill 1: Using the symbol for each variable and its unit

Most variables in physics have symbols, which are single letters. You need to learn them. A few variables, such as a moment, have no symbol.

Practise your knowledge of symbols. Make yourself a set of flash cards with the variable name and symbol on one side, and the unit name and symbol on the other (Figure 1.5). Practise until you know them all.

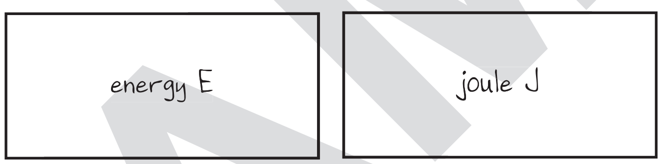


Figure 1.5: Each side of one flashcard, used to help you remember variable symbols and units.

There are only 26 letters in the alphabet, so sometimes the same letter is used more than once.

- Sometimes lower case (small) letters are used and sometimes upper case (CAPITALS):
  - m represents both metre and milli (the prefix for 10^{-3}); *m* represents mass.
  - V represents volt; *V* represents both volume and potential difference.
- In print, *italic* single letters are always variables; units are shown in ordinary type. For example, *A* means area but A means amp.
- Sometimes Greek letters are used. For example, θ for temperature in °C.

WORKED EXAMPLE 1.2

Read this paragraph about heating water and fill the gaps by writing the correct symbols after each **bold** term.

A 1 **kilogram** .... mass of water is heated from a temperature of

5 **degrees Celsius** .... to 100 **degrees Celsius**.

The heater has a **power** .... of 50 **watts** .... i.e. it delivers

50 **joules per second** ....

The heater has to be connected to a 24-**volt** .... supply.

An amount of **energy** .... is used to heat the water.

The temperature rise of the water depends on the **specific heat capacity**

.... of water, measured in **joules per kilogram degree Celsius**.

Step 1: Make sure you know the proper symbols. Never make up symbols.

Step 2: Take care to use lower and upper case letters correctly.

Step 3: Make sure you know when you need a / symbol.

Check your answers below.

A 1 **kilogram** kg mass of water is heated from a temperature of 5 **degrees Celsius** °C to 100 **degrees Celsius** °C.

The heater has a **power** *P* of 50 **watts** W i.e. it delivers 50 **joules per second** J/s.

The heater has to be connected to a 24-**volt** V supply.

An amount of **energy** *E* is used to heat the water.

The temperature rise of the water depends on the **specific heat capacity** *c* of water, measured in **joules per kilogram degree Celsius** J/(kg °C).

LOOK OUT

The brackets in J/(kg °C) show that joules are divided by both kg and °C, that is $\frac{1}{\text{kg °C}}$.

Questions

3 The electric power needed for a kettle can be found by using the equation:

power = potential difference × current

Complete the table to show the correct symbols for the variables and units.

Variable	Symbol for the variable	Name of unit	Symbol for unit
power			
potential difference			
current			

4

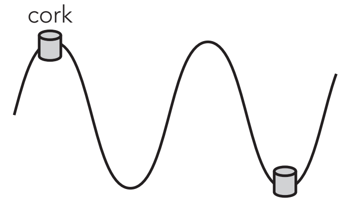


Figure 1.6: Corks on a water wave.

A student places two corks in a bowl of water. The student uses a ruler and a stopwatch to take measurements as a water wave moves across the surface (Figure 1.6). Which line in Table 1.5 gives the correct variable symbols and units for the measurements and average speed calculations?

Circle A, B, C or D.

	Speed		Distance		Time	
	Variable symbol	Unit symbol	Variable symbol	Unit symbol	Variable symbol	Unit symbol
A	*v*	cm/s	*d*	cm	*t*	s
B	*s*	m/s	*D*	m	*t*	s
C	*s*	cm/s	*d*	m	*T*	s
D	*v*	m/s	*s*	m	*T*	s

Table 1.5: Measurements on a water wave for Question 4.

5 A digital radio using solar energy is 90% efficient. It has solar cells to convert light energy to electrical energy. It uses 30% more power than an old analogue radio set.

a Write the correct variable symbol, unit symbols and unit names in the table.

Variable	Symbol for the variable	Symbol for unit	Name of unit
power			
energy			

b An equation for efficiency is:

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{energy input}} \times 100\%$$

Explain why efficiency has a % sign rather than units.

....

....

....

Maths focus 3: Determining significant figures

Some figures (digits) in a number are more important than others. This section is about how to decide which parts of a number are most significant in calculations and when estimating.

What maths skills do you need to determine significant figures?

1	Understanding place value	• Compare the size of different numbers • Relate place value to the size of common measurements
2	Determining a correct number of significant figures	• Identify and count significant figures • Change numbers into a required number of significant figures

Maths skills practice

How are significant figures useful in physics measurements?

The number of **significant figures** in a value indicates how precisely you know the number. For example, a measurement given as 2.34 m has three significant figures and means the measurement is known to the nearest 0.01 m (1 cm).

KEY WORDS

significant figures: the number of digits in a number, not including any zeros at the beginning; for example, the number of significant figures in 0.0682 is three

See Chapter 2 for more on precision and accuracy.

Maths skill 1: Understanding place value

When we write numbers, the position (place) of each digit is important (see Figure 1.7).

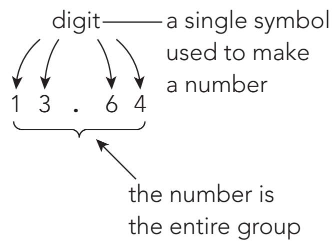


Figure 1.7: Digits in a decimal number.

The positions of the digits give you information about the value represented by the digits. Each place represents ten times the place to the right (Figure 1.8).

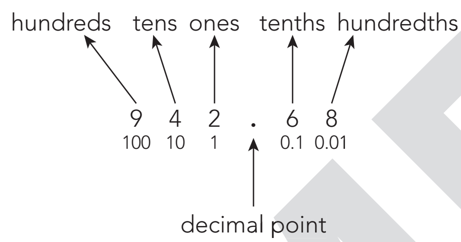


Figure 1.8: How place values are shown in decimal numbers.

Place values in measurements are very important because they indicate value in hundreds, tens and ones of each digit in a measurement. You can see in Figure 1.8 that the 4 in the number really means *4 tens,* or *40,* because of its position.

KEY WORDS

decimal place: the place-value position of a number after a decimal point; the number 6.357 has three decimal places

The number of digits after the decimal point indicates the number of **decimal places** in the number. In Figure 1.8, the number is given to two decimal places (2 d.p.).

WORKED EXAMPLE 1.3

A student must decide which resistor to use in his circuit. He has a box containing resistors with their resistance values marked (Figure 1.9).

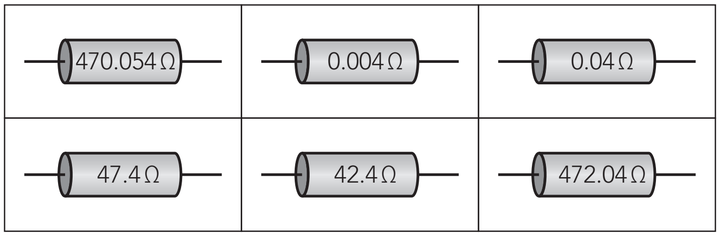


Figure 1.9: Box of fuses given to a student.

The student needs a resistor that is close to four hundredths of an ohm.
Which one should he choose? Be clear of the difference between *thousands* (1000) and *thousandths* $\left(\frac{1}{1000}\right)$.

Step 1: Check that all of the resistances are expressed in the same unit, Ω or kΩ. In this case, they are all in Ω. Comparisons are easier to make if the same units are used.

Step 2: Prepare a grid to hold the numbers.

100s	10s	1s	Decimal point	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
			.			

Step 3: Always keeping the decimal points directly below one another, fill in the grid with all the values.

100s	10s	1s	Decimal point	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
4	7	0	.	0	5	4
		0	.	0	0	4
		0	.	0	4	
	4	7	.	4		
	4	2	.	4		
4	7	2	.	0	4	

Step 4: Now that you can compare values, choose the one that is equal or closest to the value four hundredths of an ohm.

This is 0.04 Ω.

You can read more about resistors in Chapter 19 of the Coursebook.

Questions

6 A student is writing down the power of appliances used in her home. Her results are shown in Figure 1.10.

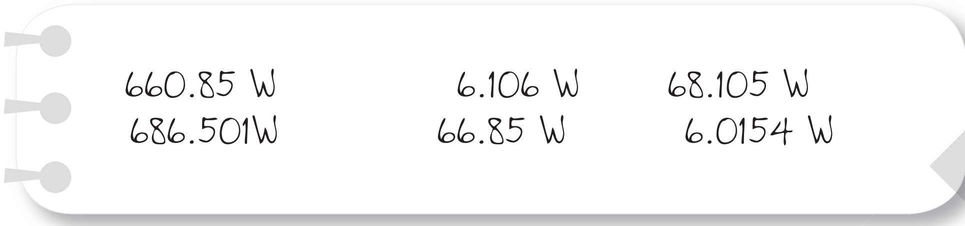


Figure 1.10: Horizontal cylinder.

a Which line shows increasing power from smallest to largest? Circle A, B, C or D.

It may help to draw a place value grid like that in Worked Example 1.3. There is an example below that you may like to use.

A	686.501 W	660.85 W	66.851 W	68.105 W	6.0154 W	6.106 W
B	6.0154 W	6.106 W	66.851 W	68.105 W	660.85 W	686.501 W
C	68.105 W	6.106 W	660.85 W	66.851 W	686.501 W	6.0154 W
D	6.106 W	6.0154 W	68.105 W	66.851 W	660.85 W	686.501 W

100s	10s	1s	Decimal point	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
			.			
			.			
			.			
			.			
			.			
			.			

b State which of the power figures could belong to a microwave cooker. There may be more than one answer.

....

c State which of the power figures could belong to a mobile phone charger. There may be more than one answer.

....

7 The melting point of mercury is stated to be −38.8290 °C. What fraction of a degree Celsius is this value precise to?

....

LOOK OUT

When reading negative numbers, as in a temperature of −7 °C, it is better to use the phrase 'a temperature of *negative* 7 °C'. Avoid using the word 'minus'; just use 'minus' for subtractions.

Maths skill 2: Determining a correct number of significant figures

When reading a number from left to right, the first *significant figure* is the first digit *other than zero*.

0.065 00

The first significant figure is 6, which has the value $\frac{6}{100}$.

700 560

The first significant figure is 7, which has the value 700 000.

Counting significant figures in numbers less than 1

To find the total number of significant figures, count the digits from left to right starting from the first significant figure.

0.089 04

The number 0.089 04 has four significant figures (4 s.f.).

Counting significant figures in large numbers

The zeros are written to give place value but are ignored when counting significant figures, unless they come between two other digits. The counting is again from left to right.

900 560 000

The number 900 560 000 has three significant figures (3 s.f.)

Changing to a specified number of significant figures

Changing a number to a specified number of significant figures involves **rounding** (see Figure 1.11). For example, 546 520 written to two significant figures is 550 000.

> **KEY WORD**
>
> **rounding:** expressing a number as an approximation, with fewer significant figures; for example, 7.436 rounded to two significant figures is 7.4, or rounded to three significant figures it is 7.44

To decide the value of the *final significant figure* you either round the next digit up or down. Consider the value of the next digit. Is it greater or less than 5?	
If greater than or equal to 5: Increase the final significant figure by 1.	**If less than 5:** Keep the final significant figure the same.
Example 546 520 rounded to two significant figures is 550 000. The third figure, 6, has been rounded up to 10.	**Example** 542 480 rounded to two significant figures is 540 000. The third figure, 2, has been rounded down to 0.

Figure 1.11: Key steps when rounding.

WORKED EXAMPLE 1.4

In a density experiment, the volume of 12 marbles is found to be 6.2832 cm^3. What is the volume of one marble to two significant figures?

Step 1: Divide 6.2832 cm^3 by 12 = 0.5236 cm^3

Step 2: In the number 0.5236, count from the left. Keep the zero before the decimal point; this is not counted as a significant figure.

1st 2nd
↓ ↓
0 . 5 2 3 6

Consider the value of the third significant figure. As 3 is below 5, it and all following numbers can be ignored.

Volume of one marble = 0.52 cm^3 to 2 s.f.

Questions

8 Which of these energy values has been given to three significant figures? Circle A, B, C or D.

A 4065 J **B** 0.40 J **C** 4060 J **D** 0.41 J

9 Light travels at a constant speed of $2.99\,792 \times 10^3 \frac{m}{s}$ in a vacuum.

Round this value to:

a two significant figures ....

b four significant figure ....

10 Which is the correct result for rounding 14.58 to three significant figures? Circle A, B, C or D.

A 1.458 **B** 14.580 **C** 14.5 **D** 14.6

Maths focus 4: Representing very large and very small values

KEY WORDS
standard form/scientific notation: notation in which a number is written as a number between 1 and 10 multiplied by a power of 10; for example, 4.78×10^9; also called scientific notation, or standard index form, or standard notation

Working with very large and very small numbers can be difficult. It is easy to make errors. Using **standard form (scientific notation)** helps reduce the number of mistakes and also makes it easier to write and compare numbers. For example, the mass of the Earth is:

5 972 000 000 000 000 000 000 000 kg

This number is more simply expressed as 5.972×10^{24} kg and is also much easier to compare with, say, the mass of the Sun: 1.989×10^{30} kg.

The mass of a single hydrogen atom is:

0.000 000 000 000 000 000 000 000 001 672 7 kg

This is much more easily expressed as 1.6727×10^{-27} kg.

KEY WORDS
unit prefix: a prefix (term added to the front of a word) added to a unit name to indicate a power of 10 of that unit, e.g. 1 *millimetre* = 10^{-3} metre

Unit prefixes are another way of making it easier to show large and small values:

- The thickness of a piece of wire is easier to understand in millimetres, mm, than in metres.
- The length of an electricity cable between a power station and a town might be given in kilometres, km, rather than metres.

What maths skills do you need to represent very large and very small values?

1 Converting numbers to and from standard form	• Choose when to use standard form • Write large numbers in terms of a positive power of 10 • Write small numbers in terms of a negative power of 10

2	Interpreting and converting values with unit prefixes to and from standard form	• Convert between unit prefix form and standard form
3	Carrying out arithmetic operations in standard form	• Know how to add, subtract, multiply and divide in standard form

Maths skills practice

How does using standard form help in describing the properties of electromagnetic waves?

The typical wavelength of ultraviolet light is 3.8×10^{-7} m. The typical wavelength of gamma rays is 5.7×10^{-11} m. When you are confident in interpreting standard form using negative powers of 10, it is easy to see that the wavelength of ultraviolet is longer than that of gamma rays. If these wavelengths were written as ordinary decimal numbers, it would be hard to count all those zeros.

The speed of all electromagnetic waves in a vacuum is 3.0×10^8 m/s. Using standard form for the speed v and the wavelength λ helps in applying the equation:

wave velocity = frequency × wavelength

$v = f \times \lambda$

It would be very easy to make an error if you write zeros.

Maths skill 1: Converting numbers to and from standard form

Standard form is used to express very large and very small numbers in a simpler format. This can help to highlight the significant figures:

543 520 in standard form becomes $5.435\,20 \times 10^5$
or 5.4×10^5 to two significant figures.

In standard form, *the decimal point is always placed after the first significant figure*.

Large numbers in standard form

KEY WORDS

power of ten: a number such as 10^3 or 10^{-3}

A number larger than 10 is written with a positive **power of ten** in the standard form. How does 500 become 5×10^2 in standard form?

$500 = 5 \times 100$
$100 = 10 \times 10$ ← multiply by 10 twice
$100 = 10^2$
so $500 = 5 \times 10^2$

500 and 5×10^2 are the same value, shown in different ways.

Numbers less than 1 in standard form

A number smaller than 1 is written with a negative power of 10 in the standard form. How does 0.006 become 6×10^{-3} in standard form?

$0.006 = 6 \times 0.001$

$0.001 = \dfrac{1}{10 \times 10 \times 10}$

$= 10^{-3}$ ← divide by 10 three times

so $0.006 = 6 \times 10^{-3}$

0.006 and 6×10^{-3} are the same value, shown in different ways.

KEY WORDS

index: a small number that indicates the power; for example, the index 4 here shows that the 2 is raised to the power 4, which means four 2s multiplied together: $2^4 = 2 \times 2 \times 2 \times 2$

power: a number raised to the power 2 is squared (e.g. x^2); a number raised to the power 3 is cubed (e.g. x^3); and so on

The **index** or **power** of 10 tells you how many times to use 10 in a multiplication or division (see Table 1.6).

10^2 is $\mathbf{10} \times \mathbf{10} = 100$	10^{-2} is $\dfrac{1}{\mathbf{10} \times \mathbf{10}} = \dfrac{1}{100}$ Expressed in decimal form as 0.01
10^5 is $\mathbf{10} \times \mathbf{10} \times \mathbf{10} \times \mathbf{10} \times \mathbf{10}$ $= 100\,000$	10^{-5} is $\dfrac{1}{\mathbf{10} \times \mathbf{10} \times \mathbf{10} \times \mathbf{10} \times \mathbf{10}} = \dfrac{1}{100\,000}$ Expressed in decimal form as 0.000 01

Table 1.6: Different powers of ten

WORKED EXAMPLE 1.5

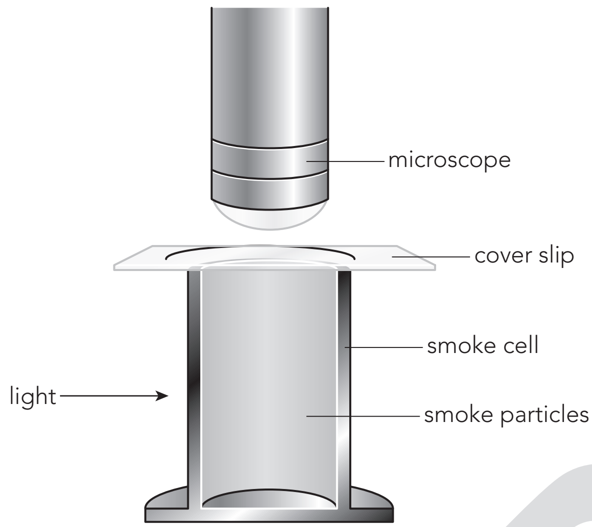


Figure 1.12: Observing Brownian motion.

In an experimental arrangement for observing Brownian motion (Figure 1.12), the particles of smoke are just large enough to show up under the microscope.

KEY WORD

diameter: a straight line connecting two points on a circle (or sphere) that passes through the centre

The **diameter** of a smoke particle is 0.000 000 035 m. Express this in standard form.

Key question to ask yourself:

Does the process involve dividing or multiplying by 10 to get the power?

This depends on whether you are working with very large or very small numbers. In this case, the number is very small and therefore division by 10 is involved.

Step 1: Look at the groups of three digits in the number 0.000 000 035. Reading from right to left, find the first digit that is non-zero.

↓
0.000 000 035

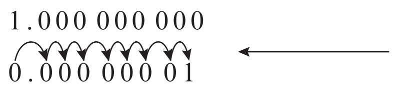
The decimal point goes after this digit:

3.5

Step 2: Work out the decimal number you need to multiply 3.5 by to equal 0.000 000 035.

$$0.000\,000\,035 = 3.5 \times 0.000\,000\,01$$

Step 3: Find the power of 10 to be used when 0.000 000 01 is expressed in standard form, by finding how many times 1 has to be divided by 10 to become 0.000 000 01. Imagine moving the 1 to the right, place by place:



This shows that 1.0 has been divided by 10 eight times to become 0.000 000 01

It has to be divided by 10 a total of 8 times, so:

$$0.000\,000\,01 = 10^{-8}$$

Step 4: Substitute the power of 10 value into the equation in Step 3, to give the answer in standard form:

$$0.000\,000\,035\text{ m} = 3.5 \times 10^{-8}\text{ m}$$

LOOK OUT

Don't forget the unit in your final answer.

You can read more about Brownian motion in Chapter 9 of the Coursebook.

Questions

1 **a** What is a standard form? Circle A, B, C or D.

A Writing numbers as decimals

B Writing numbers with zeroes

A Writing numbers in fractions

D A system of writing very large and very small values in simpler format

b Convert these numbers to standard form.

i 56 752

....

ii 253.312

....

iii 1000.5

....

iv 0.06

....

v 0.000 446

....

12 Convert these values from standard form to numbers with zeros.

a Length of a year: 3.156×10^7 seconds.

....

b The ratio of proton to electron mass: 1.8362×10^3.

....

c The wavelength of red light: 6.5×10^{-11} m.

....

d The distance from the Earth to the Sun: 1.496×10^9 m
Give your answer in kilometres.

....

Maths skill 2: Interpreting and converting values with unit prefixes to and from standard form

In physics, unit prefixes are often used to make measurement values easier to understand. A prefix is an addition to the beginning of a word to change its meaning. In the case of units, the prefix represents a multiple of 10. Look at the examples in Table 1.7. The prefix goes in front of the unit's name. The symbol for the prefix goes in front of the unit symbol.

Multiplying factor	Prefix	Standard form	Example
1 000 000 000	giga G	1×10^9	gigawatt GW
1 000 000	mega M	1×10^6	megajoule MJ
1000	kilo k	1×10^3	kilogram kg
1	*No prefix*	1×10^0	amp A
0.1	deci d	1×10^{-1}	decimetre dm
0.01	centi c	1×10^{-2}	centimetre cm
0.001	milli m	1×10^{-3}	millilitre ml
0.000 001	micro µ	1×10^{-6}	microcoulomb µC
0.000 000 001	nano n	1×10^{-9}	nanosecond ns

Table 1.7: The meanings of unit prefixes used in physics.

WORKED EXAMPLE 1.6

The smallest distance a micrometer screw gauge can measure is 0.01 mm.

a Convert this value to metres, m.

b Give this value in standard form.

Step 1: Find the prefix k in Table 1.4, and look up the power of 10 in the standard form column: 1×10^{-3}.

Step 2: Remove the m in 0.01 mm and write a multiplication sign followed by 10 to the given power.

a 0.01 mm becomes 0.01×10^{-3} m.

b This is 1.0×10^{-5} m in standard form.

LOOK OUT

In standard form the decimal point always goes after the first significant figure.

Questions

13 The sun releases 3.85×1020 MW energy per second. How many watts (W) is this, in standard form?

....

14 How many nanometres are there in 1 μm?

....

15 Convert the following values into the units given. Give your answers in standard form.

a 0.7 kW = ... W

b 14 ms = ... s

c 23 MΩ = ... Ω

d 1.8 μC = ... C

e 475 NM = ... m

Maths skill 3: Carrying out arithmetic operations in standard form

Adding and subtracting standard form numbers

Take care when adding and subtracting numbers expressed in standard form. Unless you use a calculator with care, you can only easily add or subtract numbers with the same power of 10. Often the best method is to change the expression into ordinary numbers and add or subtract as normal.

Multiplying and dividing standard form numbers

- The significant figures in a number follow normal multiplying and dividing rules.
- Powers follow these rules:

  Multiplication of powers of 10: $10^a \times 10^b = 10^{a+b}$

  Division of powers of 10: $\frac{10^a}{10^b} = 10^{a-b}$

  Raising a power to a power: $(10^a)^b = 10^a10^b$
- A negative power indicates that the power is in the denominator: $10^{-a} = \frac{1}{10^a}$.
- Identity rule: Any non-zero number raised to the power of zero is equal to 1, for example: $10^0 = 1$.

Using standard form on a calculator

Take care when you put standard form into your calculator. What you press is not what you see! The EXP button on your calculator means '×10 to the power of'.

What would you press to enter 3.27×10^4 in your calculator?

You would press 3.27 then EXP (the exponent key) then 4.

Try it and see!

WORKED EXAMPLE 1.7

In the Solar System, Venus is 1.08×10^8 km away from the Sun. How long does sunlight take to reach the surface of Venus? The speed of light in a vacuum is 3.0×10^8 m/s. Give your answer in standard form.

Use the equation time = $\frac{\text{distance}}{\text{speed}}$

Step 1: Substitute the values into the equation.

$$\text{Time} = \frac{1.08 \times 1011\text{ m}}{3.0 \times 10^8\text{ m/s}}$$

Key questions to ask yourself:

- Does this question involve addition or subtraction?
- Does this question involve multiplication or division of powers of 10?

Step 2: First divide 1.08 by 3.0.

$$\frac{1.08}{3.0} = 0.36$$

So you have

$$\text{time} = \frac{0.36 \times 10^{11}}{10^8}$$

Step 3: Use the division of powers rule: $\frac{10^a}{10^b} = 10^{a-b}$

Time = $0.36 \times 10^{11-8}$

density = 0.36×10^3 s

Step 4: Change to standard form (one figure before the decimal point).

Time = 3.6×10^2 s

See Maths focus 3, Maths skill 2 for more on significant figures and rounding.

Questions

16 a Express 1 millimetre (mm) in metre (m) in standard form.

1 mm = ...

b Proxima Centauri b is an exoplanet orbiting in the habitable zone of the red dwarf star Proxima Centauri, which is the closest star to the Sun and part of a triple star system. It is located approximately 4.2 light-years from Earth. (1 light-year = 9.5×10^{15} m)

Express the distance in kilometres, in standard form.

....

....

....

17 An air conditioner draws 6900 mA current when connected to a 2.4×10^2 V mains supply. Calculate the power consumed by the air conditioner. Use the equation: $P = V \times I$

....

....

18 A TV station transmits a signal at a frequency of 500 MHz. The speed of transmitted waves in air is 3.0×10^8 m/s. Find the wavelength of the signal.

Use the equation:

wave speed = frequency x wavelength

rearranged as:

$$\text{wavelength} = \frac{\text{wave speed}}{\text{wave frequency}}$$

Give your answer in standard form.

....

....

....

LOOK OUT

Do not forget to replace the unit prefix with the correct multiple of 10 before you substitute the values into the equation.

Maths focus 5: Estimating values

KEY WORDS

estimate: (find) an approximate value

order of magnitude: the approximate size of a number, often given as a power of 10; for example, the order of magnitude of 2700 is 10^3

An important aspect of physics is being able to tell if the numbers shown on a calculator are giving you roughly the right answer. **Estimating** is a technique for checking.

Imagine you get an answer for a car's speed as 70 km/s. Should a car travel at 70 km/s? If it did, the driver would be in trouble because this is equivalent to 2237 miles per hour!

Being able to make an **order of magnitude** estimate of a value such as a car's speed helps you to recognise when an answer is not sensible.

What maths skills do you need to make sensible estimates?

1 Knowing if a value is of the right order of magnitude	• Write the value in standard form • Make an estimate, to one significant figure in standard form, of the expected value • Work out whether the value is sensible by comparing its order of magnitude with the estimate

Maths skills practice

How is estimating useful in checking experimental values?

If you have determined a density value by experiment, you can check if your answer is 'about right' by estimating.

Maths skill 1: Knowing if a number is of the right order of magnitude

The order of magnitude is an approximate measure of the size of a number. If the number is expressed in standard form, the order of magnitude is found by looking at the power to which the power 10 is raised. For example, the order of magnitude of 2700 is 10^3, because $2700 = 2.7 \times 10^3$. The order of magnitude of 8700 is 10^4, because it is nearer to 10 000 than to 1000.

Practical Investigation 3.1 in the Practical Workbook uses estimation in investigating the acceleration of free fall.

WORKED EXAMPLE 1.8

Experimental determinations of the density of water are:

a 1033 kg/m³

b 0.97 kg/m³

c 0.095 kg/m³

Which one is the correct order of magnitude?

Key question to ask yourself:
Are all of the units the same? To compare orders of magnitude, the values must all be in the same unit.

Step 1: Round the values to one significant figure to make it easier to compare their orders of magnitude.

a 1000 kg/m³

b 1 kg/m³

c 0.1 kg/m³

Step 2: Consider whether the values are sensible. 1 m³ is a large cube with each side 1 m long. Considering the likely mass of a volume of water this size, we can conclude that answer A is the only one that makes sense.

Questions

19 Which is the correct order of magnitude for the maximum speed of a cheetah (Figure 1.13)? Circle A, B, C or D.

Figure 1.13: A cheetah.

A 3 m/s **B** 30 m/s **C** 0.3 m/s **D** 300 m/s

20 The double-decker bus (a bus with two levels) in Figure 1.14 has a mass of 1.4×10^4 kg. The area of contact of its tyres with the road is 1490 cm^2. Estimate the pressure exerted on the road.

Figure 1.14: A double-decker bus.

Use the equation pressure = $\frac{\text{force}}{\text{area}}$

The force is the weight = mass × g, and g = 9.8 m/s^2. Give your answer in pascals to 2 s.f.

21

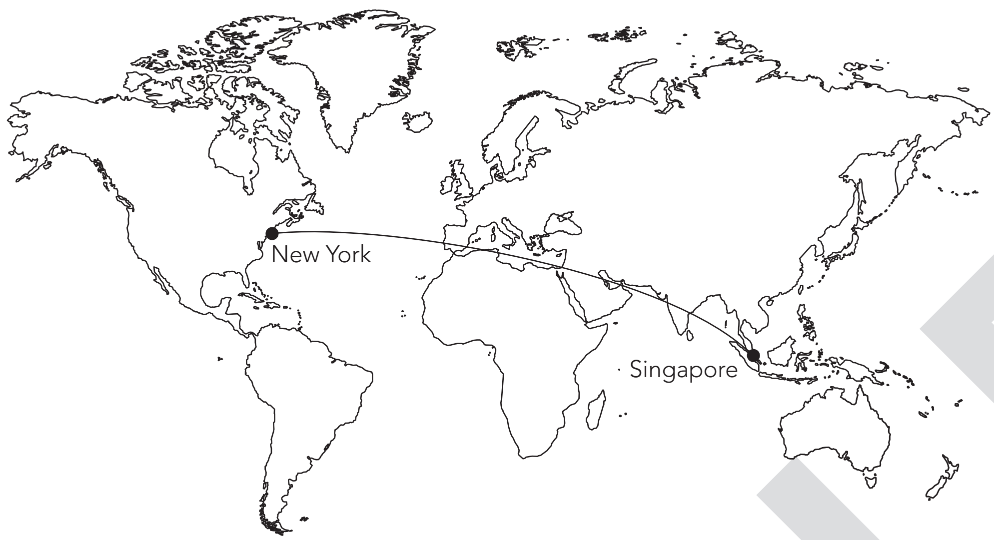


Figure 1.15: Route taken by an aeroplane.

An aeroplane flying at 840 km/hour takes 17 hours 22 minutes to get from New York to Singapore (Figure 1.15). Estimate how far it is in kilometres from New York to Singapore, without using a calculator.

Use the equation: speed $= \frac{\text{distance}}{\text{time}}$

....

....

....

....

....

22 Which row of Table 1.8 gives realistic values for the frequency and speed of the wave type given? Circle A, B, C or D.

	Type of wave	Frequency	Speed in air
A	sound	1.0×10^3 Hz	310 m/s
B	sound	10 Hz	300 mm/s
C	microwaves	1.0×10^{10} kHz	3.0×10^8 m/s
D	microwaves	1.0×10^{-10} Hz	2.9×10^8 km/s

Table 1.8: Which row gives the realistic values?

23 a Calculate the total resistance in the circuit in Figure 1.16.

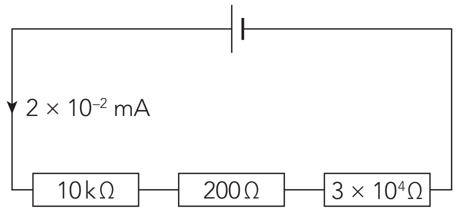


Figure 1.16: Circuit with three resistors.

Give your answer in ohms (Ω) to three significant figures, in standard form.

....

....

....

....

....

b What is the value of the potential difference supplied by the cell? Use the equation for potential difference in terms of current and resistance: $V = IR$

Give your answer to 2 s.f.

....

....

....

....

....

EXAM-STYLE QUESTIONS

1 A tank on the roof of the building is filled with water.

a A student uses the equation

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

to calculate the pressure.

Complete the table to show the correct symbols for the variables and units. **[3]**

Variable	Symbol for the variable	Name of unit	Symbol for unit
Pressure			
Force			
Area			

The water exerts a force of 2700 kN on the bottom of the tank.

b Express the force in standard form.

.... **[1]**

c The cross-sectional area of the bottom of the tank is 90 cm^2. Convert the area from cm^2 to m^2

.... **[2]**

d Calculate the pressure. Give your answer in KPa.

Pressure = ... KPa **[3]**

[Total: 9]

2 Light takes 500 seconds to travel from the sun to the Earth. Light travels 300 000 kilometres per second.

a Convert the speed of light to standard form.

.... **[1]**

b Calculate the distance between the Sun and the Earth to three significant figures.

Use the equation: distance = speed × time

....

....

Distance = ... km **[2]**

[Total: 3]

CONTINUED

3 It takes 4 hours to recharge a battery fully. The average current supplied by the charger is 300 mA.

Use the equation: charge = current × time

a In the space provided, write down this equation using symbols. **[1]**

b Calculate the amount of charge needed to recharge the battery fully, and give the unit.

....

....

Charge = ... **[3]**

[Total: 4]