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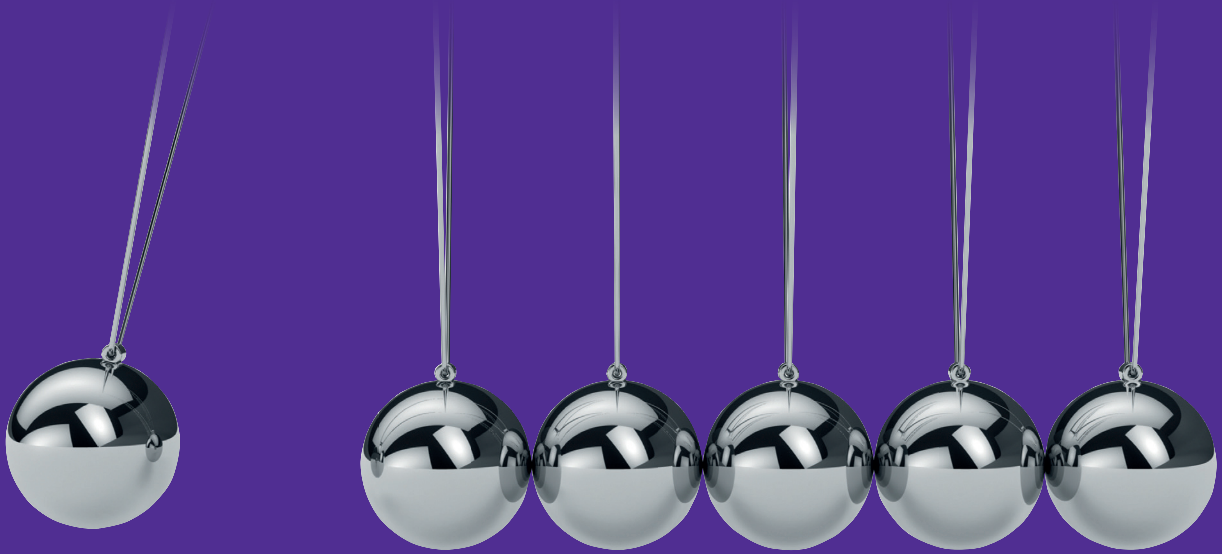
Executive
Preview

Physics

for Cambridge International AS & A Level

MULTI-COMPONENT SAMPLE

David Sang, Graham Jones,
Gurinder Chadha & Richard Woodside



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Brighter Thinking
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At Cambridge University Press, we put you at the heart of our teaching and learning resources. This new series has been developed using extensive research with our exclusive teacher community (the Cambridge Science Panel), as well as teacher interviews and lesson observations around the world. It meets the real needs that we have discovered in our research – solving and supporting the biggest classroom challenges that you have told us about. We want to help you deliver engaging lessons that use the best practical pedagogies to enable your students to achieve their learning goals. In essence, we want to make your teaching time easier and more effective.

At the heart of this new series, our completely revised and expanded teacher's resource helps you to use each of the resources in the series effectively. This includes teaching activity, assessment and homework ideas, suggestions on how to tackle common misconceptions, and support with running practical activities. This resource will inspire and support you while saving much-needed time.

For this new edition of the coursebook, we have added new features. These include reflection opportunities and self-evaluation checklists that develop responsible learners, a broader range of enquiry questions that support practical activities, as well as group work and debate questions that develop 21st century skills. The 'Science in Context' features now include open-ended discussion questions that enable students to practise their English skills, interpret ideas in a real-world context and debate concepts with other learners. There is also extra support to help English as a second language learners successfully engage with their learning (including improved and expanded support for learning the all-important scientific vocabulary) alongside simple definitions of key terms and command words. Active lesson ideas and multi-part exam-style questions ensure student engagement and helps them feel confident approaching assessment.

The workbook is the perfect companion for the coursebook. You can use it to reinforce learning, promote application of theory and help students practise the essential skills of handling data, evaluating information and problem solving. The workbook now includes frequent tips to support students' understanding, alongside a range of formative exercises that map directly onto, and build on, coursebook topics and concepts. Multi-part exam-style questions also provide students with practice in a familiar format.

To support the syllabus focus on practical work and the scientific method, the practical workbook contains step-by-step guided investigations and practice questions. These give students the chance to test their knowledge and help build confidence in preparation for assessment. Practical investigation helps to develop key skills – such as planning, identifying equipment, creating hypotheses, recording results, and analysing and evaluating data. This workbook is ideal for teachers who find running practical experiments difficult due to lack of time, resources or support. It contains help and guidance on setting up and running practical investigations in the classroom, as well as sample data for when students can't do the experiments themselves.

We're very pleased to share with you draft chapters from our forthcoming coursebook, teacher's resource, workbook and practical workbook. We hope you enjoy looking through them and considering how they will support you and your students.

If you would like more information or have any questions, please contact your local sales representative: **cambridge.org/education/find-your-sales-consultant**

Steve Temblett

Head of Publishing – Science, Technology & Maths, Cambridge University Press

Hello, I am Graham Jones and I am part of the author team for this revised *Cambridge International AS & A Level Physics* series. I have taught and been an examiner for physics for more than 40 years. In this time, I have also run online and face-to-face training around the globe to support fellow teachers. I am very pleased to give you some information about the content in the new *Cambridge International AS & A Level Physics* series.

As you may be aware, there have been revisions to the syllabus for first examination in 2022. You will find the full syllabus document online at cambridgeinternational.org.

The series has four components – a coursebook, workbook, practical workbook and teacher resource. We have made sure that they work together to give you and your students full support in every aspect of the course. In order to help prepare you and your students for the syllabus changes, we have made the following changes to our resources:

- We have revised the **coursebook** so that it perfectly covers all of the learning objectives in the revised syllabus. This includes reviewing the language level, to make it more accessible for students whose first language is not English.
- Each chapter begins with context to stimulate discussion. Within the text, questions encourage students to deepen their understanding of topics, and exam-style questions at the end of chapters build learner confidence.
- The number of technical terms in science can be challenging. We have fully explained these when they first appear. They are highlighted in 'Key Words' boxes and can also be found in the glossary. Summaries, a self-evaluation table and a reflection feature encourage learners to reflect and improve.
- While the coursebook covers the *content* of the syllabus, the **workbook** helps learners to develop the many *skills* that they need in order to prepare for examination questions. These include the Assessment Objective 2 skills and also some of the skills that are used in practical work (AO3).
- We know that finding time and facilities for doing practical work can be a challenge, but we also know its importance to help learners reach their full potential. We have therefore provided a **practical workbook** to give detailed guidance in doing practical work. We have trialed all of the experiments in a school laboratory, and provided comprehensive step-by-step instructions.
- We have completely revised the **teacher's resource** to ensure that it provides the teacher with extensive support for all aspects of the course, including sample data for the practicals.

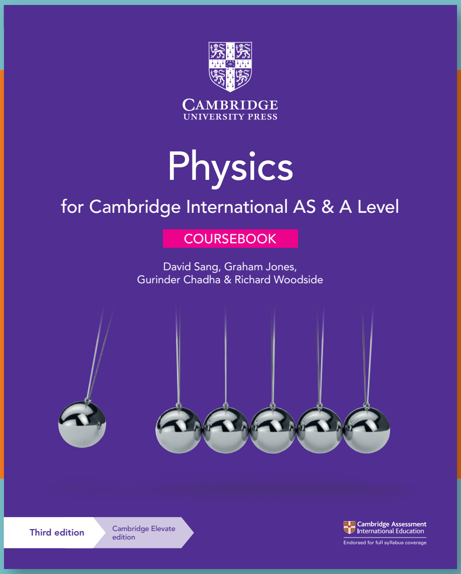
All the authors for this series are experienced teachers of physics. I hope that you and your students will enjoy using these new editions and wish you every success.

Kind regards,
Graham Jones

We are working with Cambridge Assessment International Education towards endorsement of these titles.

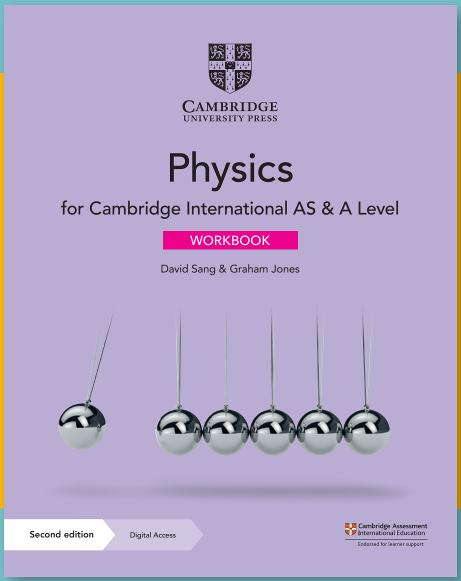
How to use this series

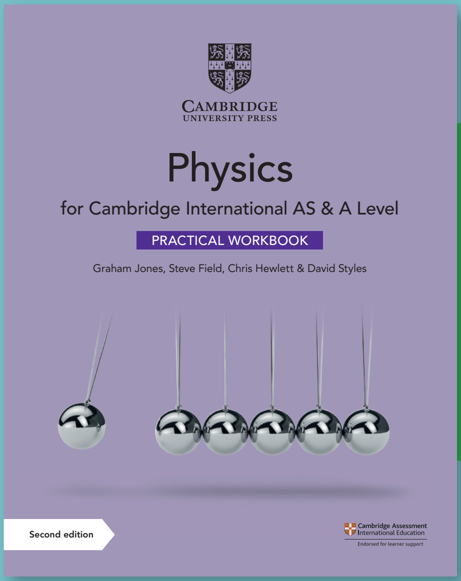
This suite of resources supports students and teachers following the Cambridge International AS & A Level Physics syllabus (9702). All of the books in the series work together to help students develop the necessary knowledge and scientific skills required for this subject.



The coursebook provides comprehensive support for the full Cambridge International AS & A Level Physics syllabus (9702). It clearly explains facts, concepts and practical techniques, and uses real-world examples of scientific principles. Two chapters provide full guidance to help students develop investigative skills. Questions within each chapter help them to develop their understanding, while exam-style questions provide essential practice.

The workbook contains over 100 exercises and exam-style questions, carefully constructed to help learners develop the skills that they need as they progress through their Physics course. The exercises also help students develop understanding of the meaning of various command words used in questions, and provide practice in responding appropriately to these.





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Physics
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PRACTICAL WORKBOOK
Graham Jones, Steve Field, Chris Hewlett & David Styles

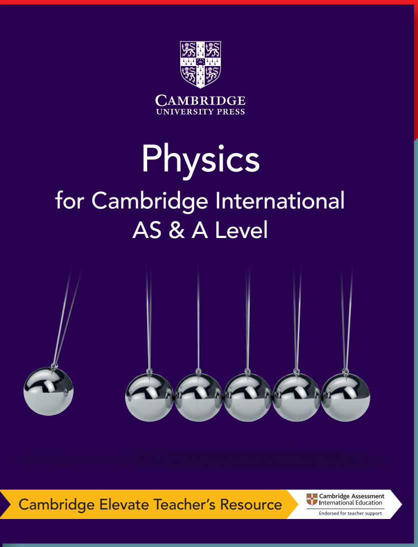
Second edition

Cambridge Assessment International Education
Endorsed for learner support

This write-in book provides students with a wealth of hands-on practical work, giving them full guidance and support that will help them to develop all of the essential investigative skills. These skills include planning investigations, selecting and handling apparatus, creating hypotheses, recording and displaying results, and analysing and evaluating data.

The teacher's resource supports and enhances the questions and practical activities in the coursebook. This resource includes detailed lesson ideas, as well as answers and exemplar data for all questions and activities in the coursebook and workbook. The practical teacher's guide, included with this resource, provides support for the practical activities and experiments in the practical workbook.

Teaching notes for each topic area include a suggested teaching plan, ideas for active learning and formative assessment, links to resources, ideas for lesson starters and plenaries, differentiation, lists of common misconceptions and suggestions for homework activities. Answers are included for every question and exercise in the coursebook, workbook and practical workbook.
Detailed support is provided for preparing and carrying out for all the investigations in the practical workbook, including tips for getting things to work well, and a set of sample results that can be used if students cannot do the experiment, or fail to collect results.



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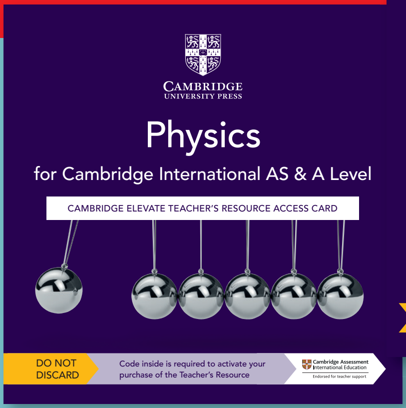

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Physics

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COURSEBOOK

David Sang, Graham Jones,
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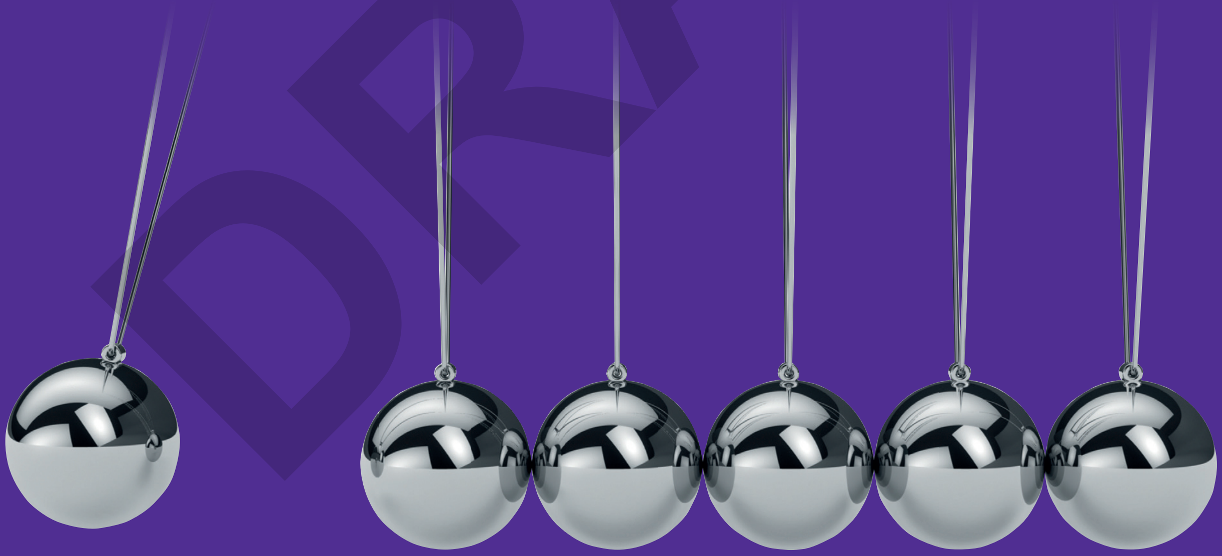

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Contents

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.

BEFORE YOU START

This contains questions and activities on subject knowledge you will need before starting this 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. There are discussion questions at the end that look at some of the benefits and problems of these applications.

PRACTICAL ACTIVITIES

This book does not contain detailed instructions for doing particular experiments, but you will find background information about the practical work you need to do in these boxes. There are also two chapters, P1 and P2, which provide detailed information about the practical skills you need to develop during the course.

Questions

Appearing throughout the text, questions give you a chance to check that you have understood the topic you have just read about. You can find the answers to these questions in the digital Coursebook.

KEY DEFINITION

Key definitions for important scientific principles, laws and theories are given in the margin and highlighted in the text when it is first introduced. You will also find definitions of these in the Glossary at the back of this book.

KEY EQUATIONS

Key equations are highlighted in the text when an equation is first introduced. Definitions for the equation and further information are given in the margin.

KEY WORDS

Key vocabulary is highlighted in the text when it is first introduced. Definitions are then given in the margin, which explain the meanings of these words and phrases.

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 when they are first introduced. In the margin, you will find the Cambridge International definition.

You will also find the same definitions in the Glossary at the back of this book.

*See disclaimer on next page.

WORKED EXAMPLES

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

KEY IDEAS

Important scientific concepts, facts and tips are given in these boxes.

REFLECTION

These activities ask you to look back on the topics covered in the chapter and test how well you understand these topics and encourage you to reflect on your learning.

SUMMARY CHECKLISTS

There is a summary of key points at the end of each chapter.

EXAM-STYLE QUESTIONS

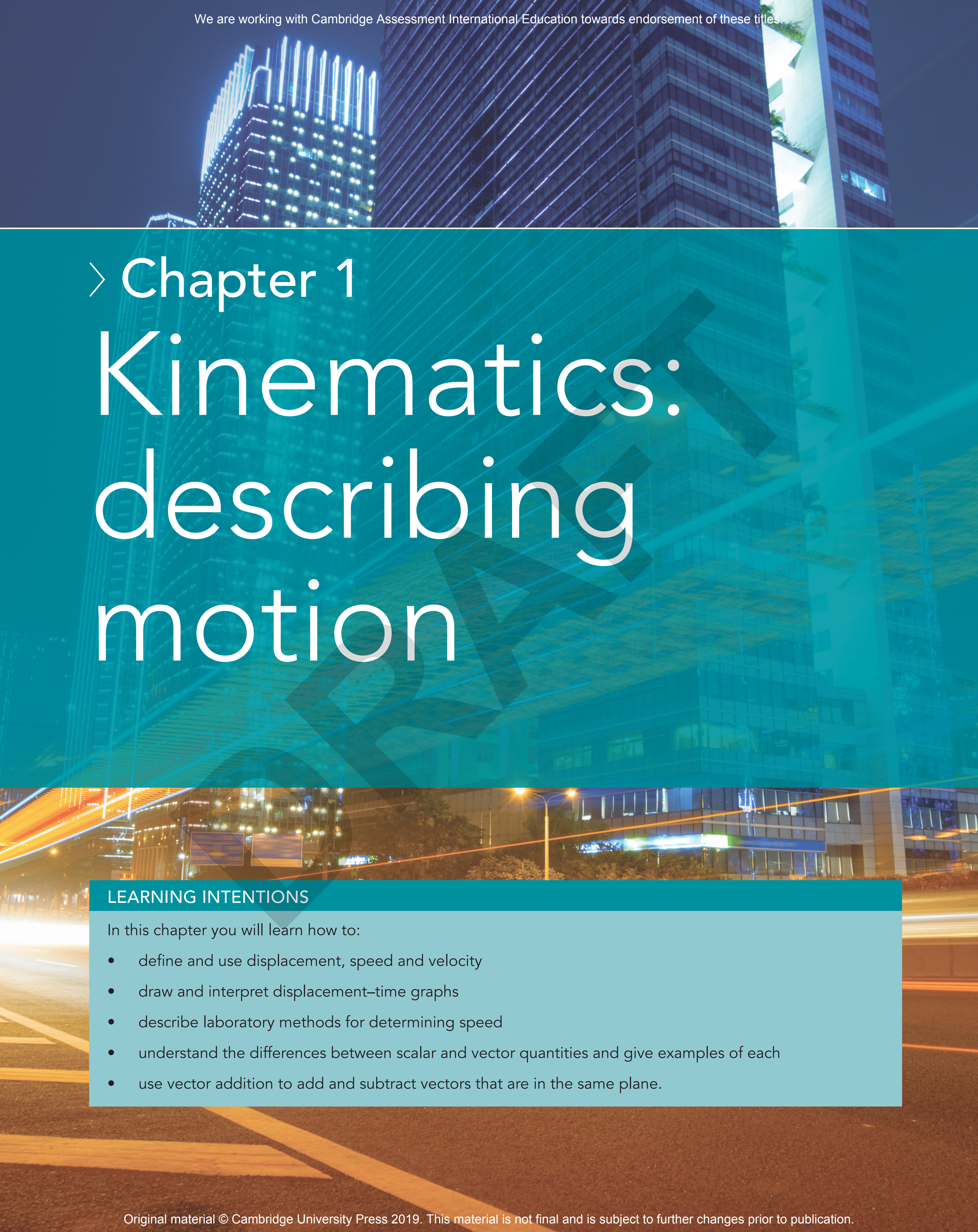
Questions at the end of each chapter provide more demanding exam-style questions, some of which may require use of knowledge from previous chapters. Answers to these questions can be found in the digital Coursebook.

SELF-EVALUATION CHECKLIST

The summary checklists are followed by 'I can' statements that 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	Ready to move on

*The information in this section is taken from the Cambridge International syllabus for examination from 2022. You should always refer to the appropriate syllabus document for the year of your examination to confirm the details and for more information. The syllabus document is available on the Cambridge International website at www.cambridgeinternational.org.



Chapter 1

Kinematics: describing motion

LEARNING INTENTIONS

In this chapter you will learn how to:

- define and use displacement, speed and velocity
- draw and interpret displacement–time graphs
- describe laboratory methods for determining speed
- understand the differences between scalar and vector quantities and give examples of each
- use vector addition to add and subtract vectors that are in the same plane.

BEFORE YOU START

- Do you know how to rearrange an equation that involves fractions? Choose an equation that you know from your previous physics course, such as $P = \frac{V^2}{R}$, and rearrange it to make R or V the subject of the formula.
- Can you write down a direction using compass bearings, for example, as 014°, N14°E or 14° east of north?

DESCRIBING MOVEMENT

Our eyes are good at detecting movement. We notice even quite small movements out of the corners of our eyes. It's important for us to be able to judge movement – think about crossing the road, cycling or driving, or catching a ball.

Figure 1.1 shows a way in which movement can be recorded on a photograph. This is a stroboscopic photograph of a boy juggling three balls. As he juggles, a bright lamp flashes several times a second so that the camera records the positions of the balls at equal intervals of time.

How can the photograph be used to calculate the speed of the upper ball horizontally and vertically as it moves through the air? What other apparatus is needed? You can discuss this with someone else.

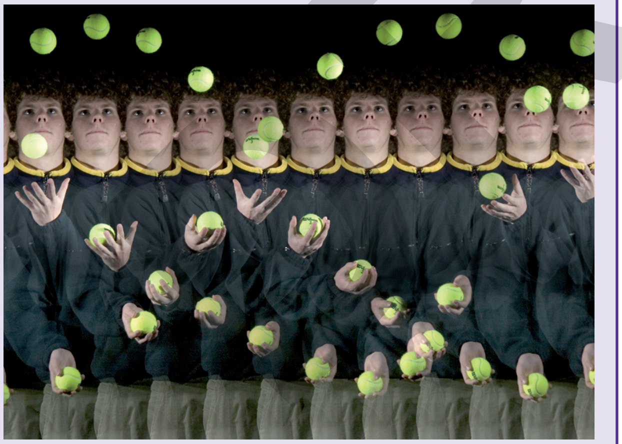


Figure 1.1: This boy is juggling three balls. A stroboscopic lamp flashes at regular intervals; the camera is moved to one side at a steady rate to show separate images of the boy.

1.1 Speed

We can calculate the average speed of something moving if we know the distance it moves and the time it takes:

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

In symbols, this is written as:

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

where v is the average speed and d is the distance travelled in time t.

If an object is moving at a constant speed, this equation will give us its speed during the time taken. If its speed is changing, then the equation gives us its **average speed**. Average speed is calculated over a period of time.

If you look at the speedometer in a car, it doesn't tell you the car's average speed; rather, it tells you its speed at the instant when you look at it. This is the car's **instantaneous speed**.

KEY EQUATION

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

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

KEY WORDS

average speed: the total distance travelled by an object divided by the total time taken

instantaneous speed: the speed of an object measured over a very short period of time

Question

1 Look at Figure 1.2. The runner has just run 10 000 m in a time of 27 minutes 5.17 s. Calculate his average speed during the race.

Figure 1.2: England's Mo Farah winning his second gold medal at the Rio Olympics in 2016.

Units

In the Système Internationale d'Unités (the SI system), distance is measured in metres (m) and time in seconds (s). Therefore, speed is in metres per second. This is written as $m\,s^{-1}$ (or as m/s). Here, s^{-1} is the same as 1/s, or 'per second'.

There are many other units used for speed. The choice of unit depends on the situation. You would probably give the speed of a snail in different units from the speed of a racing car. Table 1.1 includes some alternative units of speed.

Note that in many calculations it is necessary to work in SI units ($m\,s^{-1}$).

$m\,s^{-1}$	metres per second
$cm\,s^{-1}$	centimetres per second
$km\,s^{-1}$	kilometres per second
$km\,h^{-1}$ or km/h	kilometres per hour
mph	miles per hour

Table 1.1: Units of speed.

Questions

2 Here are some units of speed:

$m\,s^{-1}$ $mm\,s^{-1}$ $km\,s^{-1}$ $km\,h^{-1}$

Which of these units would be appropriate when stating the speed of each of the following?

- **a** a tortoise
- **b** a car on a long journey
- **c** light
- **d** a sprinter.

3 A snail crawls 12 cm in one minute. What is its average speed in $mm\,s^{-1}$?

Determining speed

You can find the speed of something moving by measuring the time it takes to travel between two fixed points. For example, some motorways have emergency telephones every 2000 m. Using a stopwatch you can time a car over this distance. Note that this can only tell you the car's average speed between the two points. You cannot tell whether it was increasing its speed, slowing down or moving at a constant speed.

PRACTICAL ACTIVITY 1.1

Laboratory measurements of speed

Here we describe four different ways to measure the speed of a trolley in the laboratory as it travels along a straight line. Each can be adapted to measure the speed of other moving objects, such as a glider on an air track or a falling mass.

Measuring speed using two light gates

The leading edge of the card in Figure 1.3 breaks the light beam as it passes the first light gate. This starts the timer. The timer stops when the front of the card breaks the second beam. The trolley's speed is calculated from the time interval and the distance between the light gates.

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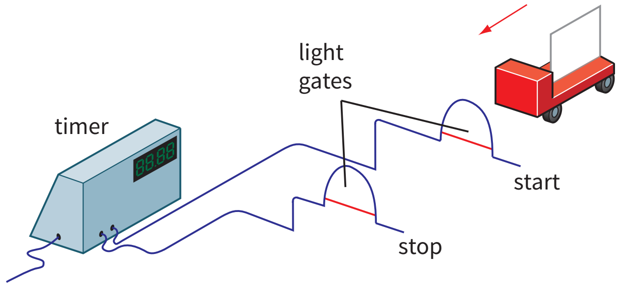


Figure 1.3: Using two light gates to find the average speed of a trolley.

Measuring speed using one light gate

The timer in Figure 1.4 starts when the leading edge of the card breaks the light beam. It stops when the trailing edge passes through. In this case, the time shown is the time taken for the trolley to travel a distance equal to the length of the card. The computer software can calculate the speed directly by dividing the distance by the time taken.

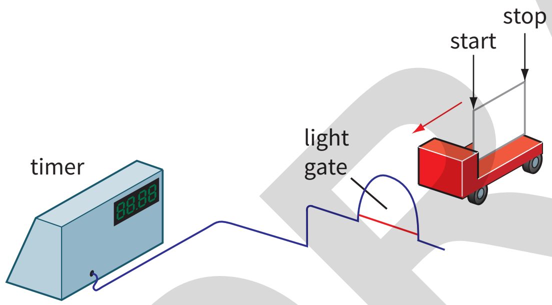


Figure 1.4: Using a single light gate to find the average speed of a trolley.

Measuring speed using a ticker-timer

The ticker-timer (Figure 1.5) marks dots on the tape at regular intervals, usually s (i.e. 0.02 s). (This is because it works with alternating current, and in most countries the frequency of the alternating mains is 50 Hz.) The pattern of dots acts as a record of the trolley's movement.

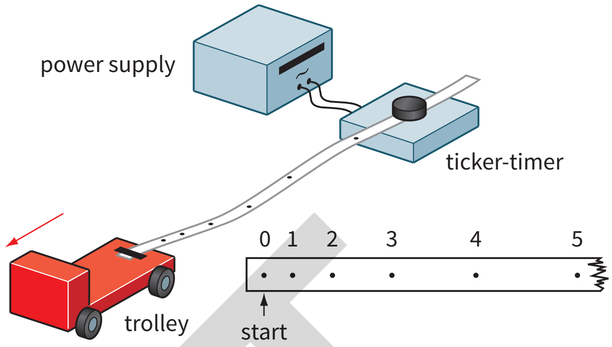


Figure 1.5: Using a ticker-timer to investigate the motion of a trolley.

Start by inspecting the tape. This will give you a description of the trolley's movement. Identify the start of the tape. Then, look at the spacing of the dots:

- even spacing – constant speed
- increasing spacing – increasing speed.

Now you can make some measurements. Measure the distance of every fifth dot from the start of the tape. This will give you the trolley's distance at intervals of 0.10 s. Put the measurements in a table and draw a distance–time graph.

Measuring speed using a motion sensor

The motion sensor (Figure 1.6) transmits regular pulses of ultrasound at the trolley. It detects the reflected waves and determines the time they took for the trip to the trolley and back. From this, the

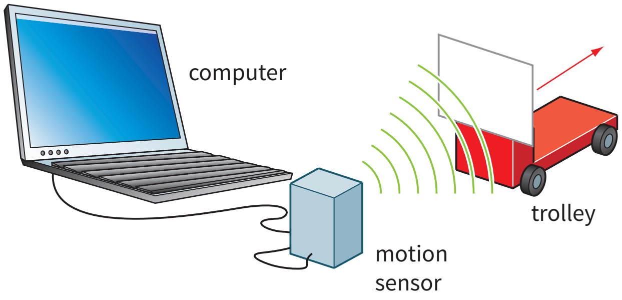


Figure 1.6: Using a motion sensor to investigate the motion of a trolley.

CONTINUED

computer can deduce the distance to the trolley from the motion sensor. It can generate a distance–time graph. You can determine the speed of the trolley from this graph.

Choosing the best method

Each of these methods for finding the speed of a trolley has its merits. In choosing a method, you might think about the following points:

- Does the method give an average value of speed or can it be used to give the speed of the trolley at different points along its journey?
- How precisely does the method measure time–to the nearest millisecond?
- How simple and convenient is the method to set up in the laboratory?

Questions

4 A trolley with a 5.0 cm long card passed through a single light gate. The time recorded by a digital timer was 0.40 s. What was the average speed of the trolley in m s^{-1}?

5 Figure 1.7 shows two ticker-tapes. Describe the motion of the trolleys that produced them.

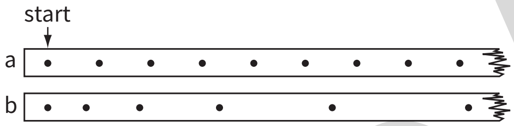


Figure 1.7: Two ticker-tapes. For Question 5.

6 Four methods for determining the speed of a moving trolley have been described. Each could be adapted to investigate the motion of a falling mass. Choose two methods that you think would be suitable, and write a paragraph for each to say how you would adapt it for this purpose.

1.2 Distance and displacement, scalar and vector

In physics, we are often concerned with the distance moved by an object in a particular direction. This is called its **displacement**.

KEY WORD

displacement: the distance travelled in a particular direction; it is a vector quantity

Figure 1.8 illustrates the difference between distance and displacement. It shows the route followed by walkers as they went from town A to town C.

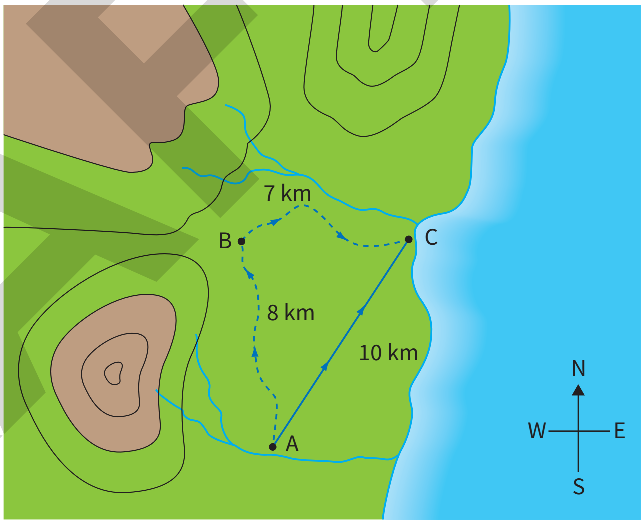


Figure 1.8: If you go on a long walk, the distance you travel will be greater than your displacement. In this example, the walkers travel a distance of 15 km, but their displacement is only 10 km, because this is the distance from the start to the finish of their walk.

Their winding route took them through town B, so that they covered a total distance of 15 km. However, their displacement was much less than this. Their finishing position was just 10 km from where they started. To give a complete statement of their displacement, we need to give both distance and direction:

displacement = 10 km at 030° or 30° E of N

Displacement is an example of a **vector quantity**. A vector quantity has both magnitude (size) and direction. Distance, on the other hand, is a **scalar quantity**. Scalar quantities have magnitude only.

1.3 Speed and velocity

It is often important to know both the speed of an object and the direction in which it is moving.

Speed and direction are combined in another quantity, called **velocity**. The velocity of an object can be thought of as its speed in a particular direction. So, like displacement, velocity is a vector quantity. Speed is the corresponding scalar quantity, because it does not have a direction.

KEY WORDS

vector quantity: a quantity with both magnitude (size) and direction

scalar quantity: a quantity with magnitude only

velocity: an object's speed in a particular direction or the rate of change of an object's displacement; it is a vector quantity

So, to give the velocity of something, we have to state the direction in which it is moving. For example, 'an aircraft flies with a velocity of $300\,\mathrm{m\,s^{-1}}$ due north'.

Since velocity is a vector quantity, it is defined in terms of displacement:

$$\text{velocity} = \frac{\text{change in displacement}}{\text{time taken}}$$

We can write the equation for velocity in symbols:

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

KEY EQUATION

$$\text{velocity} = \frac{\text{change in displacement}}{\text{time taken}}$$

Alternatively, we can say that velocity is the *rate of change* of an object's displacement:

$$v = \frac{\Delta s}{\Delta t}$$

where the symbol Δ (the Greek letter delta) means 'change in'. It does not represent a quantity (in the way that s and t do). Another way to write Δs would be $s_2 - s_1$, but this is more time-consuming and less clear.

From now on, you need to be clear about the distinction between velocity and speed, and between displacement and distance. Table 1.2 shows the standard symbols and units for these quantities.

Quantity	Symbol for quantity	Symbol for unit
distance	d	m
displacement	s, x	m
time	t	s
speed, velocity	v	$\mathrm{m\,s^{-1}}$

Table 1.2: Standard symbols and units. (Take care not to confuse italic s for displacement with s for seconds. Notice also that v is used for both speed and velocity.)

Question

7 Do these statements describe speed, velocity, distance or displacement? (Look back at the definitions of these quantities.)

- **a** The ship sailed south-west for 200 miles.
- **b** I averaged 7 mph during the marathon.
- **c** The snail crawled at $2\,\mathrm{mm\,s^{-1}}$ along the straight edge of a bench.
- **d** The sales representative's round trip was 420 km.

Speed and velocity calculations

The equation for velocity, $v = \frac{\Delta s}{\Delta t}$, can be rearranged as follows, depending on which quantity we want to determine:

$$\text{change in displacement } \Delta s = v \times \Delta t$$

$$\text{change in time } \mathrm{D}t = \frac{\mathrm{D}s}{v}$$

Note that each of these equations is balanced in terms of units. For example, consider the equation for displacement. The units on the right-hand side are $\mathrm{m\,s^{-1}} \times \mathrm{s}$, which simplifies to m, the correct unit for displacement.

We can also rearrange the equation to find distance s and time t:

$$\Delta s = v \times t$$

$$t = \frac{\Delta s}{v}$$

WORKED EXAMPLES

1 A car is travelling at $15\,\mathrm{m\,s^{-1}}$. How far will it travel in 1 hour?

Step 1 It is helpful to start by writing down what you know and what you want to know:

$v = 15\,\mathrm{m\,s^{-1}}$

$t = 1\,\mathrm{h} = 3600\,\mathrm{s}$

$s = ?$

Step 2 Choose the appropriate version of the equation and substitute in the values. Remember to include the units:

$$\begin{aligned} s &= v \times t \\ &= 15 \times 3600 \\ &= 5.4 \times 10^4\,\mathrm{m} \\ &= 54\,\mathrm{km} \end{aligned}$$

The car will travel 54 km in 1 hour.

2 The Earth orbits the Sun at a distance of 150 000 000 km. How long does it take light from the Sun to reach the Earth? (Speed of light in space $= 3.0 \times 10^8\,\mathrm{m\,s^{-1}}$.)

Step 1 Start by writing what you know. Take care with units; it is best to work in m and s. You need to be able to express numbers in scientific notation (using powers of 10) and to work with these on your calculator.

$v = 3.0 \times 10^8\,\mathrm{m\,s^{-1}}$

$$\begin{aligned} s &= 150\,000\,000\,\mathrm{km} \\ &= 150\,000\,000\,000\,\mathrm{m} \\ &= 1.5 \times 10^{11}\,\mathrm{m} \end{aligned}$$

Step 2 Substitute the values in the equation for time:

$$\begin{aligned} t &= \frac{s}{v} \\ &= \frac{1.5 \times 10^{11}}{3.0 \times 10^8} \\ &= 500\,\mathrm{s} \end{aligned}$$

Light takes 500 s (about 8.3 minutes) to travel from the Sun to the Earth.

Hint: *When using a calculator, to calculate the time t, you press the buttons in the following sequence:*

[1.5] [10^n] [11] [÷] [3] [10^n] [8]

Making the most of units

In Worked example 1 and Worked example 2, units have been omitted in intermediate steps in the calculations. However, at times it can be helpful to include units as this can be a way of checking that you have used the correct equation; for example, that you have not divided one quantity by another when you should have multiplied them. The units of an equation must be balanced, just as the numerical values on each side of the equation must be equal.

If you take care with units, you should be able to carry out calculations in non-SI units, such as kilometres per hour, without having to convert to metres and seconds.

For example, how far does a spacecraft travelling at $40\,000\,\mathrm{km\,h^{-1}}$ travel in one day? Since there are 24 hours in one day, we have:

$$\text{distance travelled} = 40\,000\,\mathrm{km\,h^{-1}} \times 24\,\mathrm{h}$$
$$= 960\,000\,\mathrm{km}$$

Questions

8 A submarine uses sonar to measure the depth of water below it. Reflected sound waves are detected 0.40 s after they are transmitted. How deep is the water? (Speed of sound in water = $1500\,\mathrm{m\,s^{-1}}$.)

9 The Earth takes one year to orbit the Sun at a distance of 1.5×10^{11} m. Calculate its speed. Explain why this is its average speed and not its velocity.

1.4 Displacement–time graphs

We can represent the changing position of a moving object by drawing a displacement–time graph. The gradient (slope) of the graph is equal to its velocity (Figure 1.9). The steeper the slope, the greater the velocity. A graph like this can also tell us if an object is moving forwards or backwards. If the gradient is negative, the object's velocity is negative – it is moving backwards.

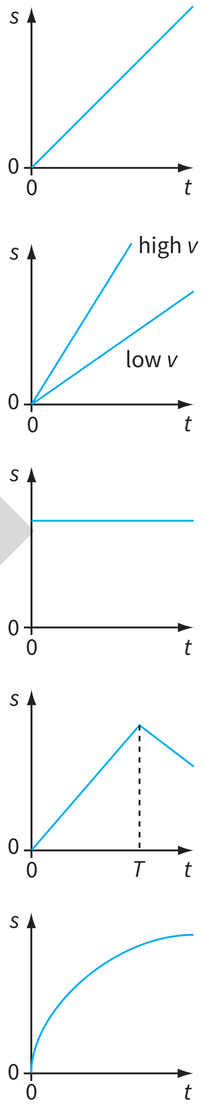
Deducing velocity from a displacement–time graph

A toy car moves along a straight track. Its displacement at different times is shown in Table 1.3. This data can be used to draw a displacement–time graph from which we can deduce the car's velocity.

Displacement *s* / m	1.0	3.0	5.0	7.0	7.0	7.0
Time *t* / s	0.0	1.0	2.0	3.0	4.0	5.0

Table 1.3: Displacement *s* and time *t* data for a toy car.

It is useful to look at the data first, to see the pattern of the car's movement. In this case, the displacement increases steadily at first, but after 3.0 s it becomes constant. In other words, initially the car is moving at a steady velocity, but then it stops.



The straight line shows that the object's velocity is constant.

The slope shows which object is moving faster. The steeper the slope, the greater the velocity.

The slope of this graph is 0.
The displacement *s* is not changing.
Hence the velocity *v* = 0.
The object is stationary.

The slope of this graph suddenly becomes negative. The object is moving back the way it came.
Its velocity *v* is negative after time *T*.

This displacement–time graph is curved. The slope is changing. This means that the object's velocity is changing – this is considered in Chapter 2.

Figure 1.9: The slope of a displacement–time (*s*–*t*) graph tells us how fast an object is moving.

Now we can plot the displacement–time graph (Figure 1.10).

We want to work out the velocity of the car over the first 3.0 seconds. We can do this by working out the gradient of the graph, because:

$$\text{velocity} = \text{gradient of displacement–time graph}$$

We draw a right-angled triangle as shown. To find the car's velocity, we divide the change in displacement by the change in time. These are given by the two sides of the triangle labelled Δs and Δt.

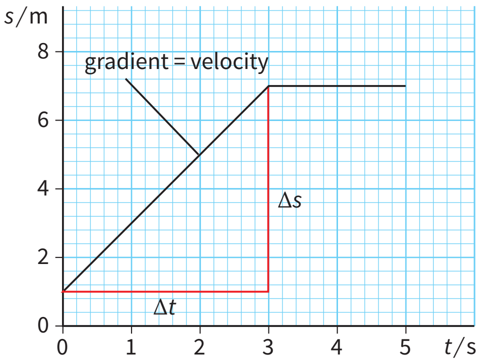


Figure 1.10: Displacement–time graph for a toy car; data as shown in Table 1.3.

$$\begin{aligned}\text{velocity} &= \frac{\text{change in displacement}}{\text{time taken}}\\ &= \frac{\Delta s}{\Delta t}\\ &= \frac{(7.0-1.0)}{(3.0-0)}\\ &= \frac{6.0}{3.0}\\ &= 2.0\,\text{m s}^{-1}\end{aligned}$$

If you are used to finding the gradient of a graph, you may be able to reduce the number of steps in this calculation.

Questions

10 The displacement–time sketch graph in Figure 1.11 represents the journey of a bus. What does the graph tell you about the journey?

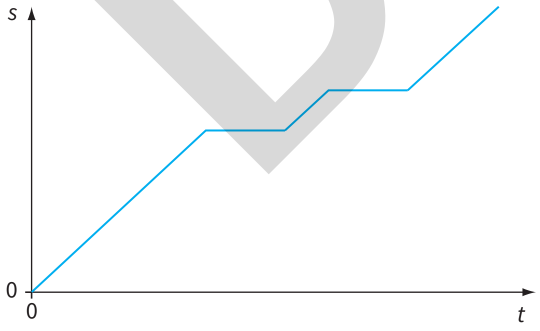


Figure 1.11: For Question 10.

11 Sketch a displacement–time graph to show your motion for the following event. You are walking at a constant speed across a field after jumping off a gate. Suddenly you see a horse and stop. Your friend says there's no danger, so you walk on at a reduced constant speed. The horse neighs, and you run back to the gate. Explain how each section of the walk relates to a section of your graph.

12 Table 1.4 shows the displacement of a racing car at different times as it travels along a straight track during a speed trial.

a Determine the car's velocity.

b Draw a displacement–time graph and use it to find the car's velocity.

Displacement / m	0	85	170	255	340
Time / s	0	1.0	2.0	3.0	4.0

Table 1.4: Displacement *s* and time *t* data for Question 12.

13 An old car travels due south. The distance it travels at hourly intervals is shown in Table 1.5.

a Draw a distance–time graph to represent the car's journey.

b From the graph, deduce the car's speed in km h^{-1} during the first three hours of the journey.

c What is the car's average speed in km h^{-1} during the whole journey?

Time / h	0	1	2	3	4
Distance / km	0	23	46	69	84

Table 1.5: Data for Question 13.

1.5 Combining displacements

The walkers shown in Figure 1.12 are crossing difficult ground. They navigate from one prominent point to the next, travelling in a series of straight lines. From the map, they can work out the distance that they travel and their displacement from their starting point:

distance travelled = 25 km

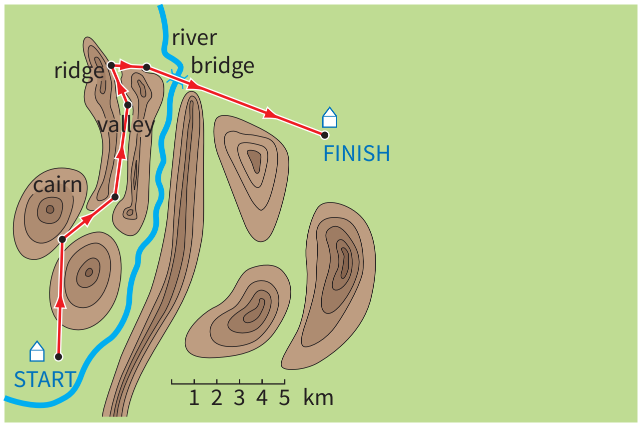


Figure 1.12: In rough terrain, walkers head straight for a prominent landmark.

(Lay thread along route on map; measure thread against map scale.)

displacement = 15 km in the direction 045°, N45° E or north-east

(Join starting and finishing points with straight line; measure line against scale.)

A map is a scale drawing. You can find your displacement by measuring the map. But how can you **calculate** your displacement? You need to use ideas from geometry and trigonometry. Worked examples 3 and 4 show how.

WORKED EXAMPLES

3 A spider runs along two sides of a table (Figure 1.13). Calculate its final displacement.

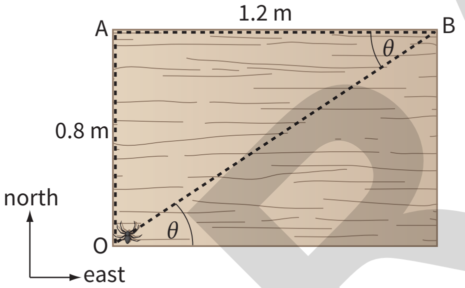


Figure 1.13: The spider runs a distance of 2.0 m. For Worked example 3.

Step 1 Because the two sections of the spider's run (OA and AB) are at right angles, we can **add** the two displacements using Pythagoras's theorem:

$$OB^2 = OA^2 + AB^2$$

$$= 0.8^2 + 1.2^2 = 2.08$$

$$OB = \sqrt{2.08} = 1.44\,\text{m} \approx 1.4\,\text{m}$$

Step 2 Displacement is a vector. We have found the **magnitude** of this vector, but now we have to find its direction. The angle θ is given by:

$$\tan\theta = \frac{\text{opp}}{\text{adj}} = \frac{0.8}{1.2}$$

$$= 0.667$$

$$\theta = \tan^{-1}(0.667)$$

$$= 33.7° \approx 34°$$

So the spider's displacement is 1.4 m at 056° or N56°E or at an angle of 34° north of east.

4 An aircraft flies 30 km due east and then 50 km north-east (Figure 1.14). Calculate the final displacement of the aircraft.

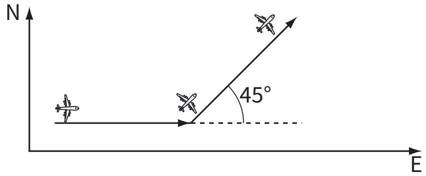


Figure 1.14: For Worked example 4.

Here, the two displacements are not at 90° to one another, so we can't use Pythagoras's theorem. We can solve this problem by making a scale

CONTINUED

drawing, and measuring the final displacement. (However, you could solve the same problem using trigonometry.)

Step 1 Choose a suitable scale. Your diagram should be reasonably large; in this case, a scale of 1 cm to represent 5 km is reasonable.

Step 2 Draw a line to represent the first vector. North is at the top of the page. The line is 6 cm long, towards the east (right).

Step 3 Draw a line to represent the second vector, starting at the end of the first vector. The line is 10 cm long, and at an angle of 45° (Figure 1.15).

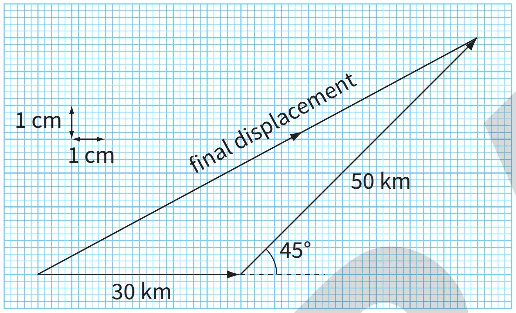


Figure 1.15: Scale drawing for Worked example 4. Using graph paper can help you to show the vectors in the correct directions.

Step 4 To find the final displacement, join the start to the finish. You have created a **vector triangle**. Measure this displacement vector, and use the scale to convert back to kilometres:

length of vector = 14.8 cm

final displacement = 14.8 × 5 = 74 km

KEY WORDS

vector triangle: a triangle drawn to determine the resultant of two vectors

Step 5 Measure the angle of the final displacement vector:

angle = 28° N of E

Therefore the aircraft's final displacement is 74 km at 28° north of east, 062° or N62°E.

Questions

14 You walk 3.0 km due north, and then 4.0 km due east.

- **a** Calculate the total distance in km you have travelled.
- **b** Make a scale drawing of your walk, and use it to find your final displacement. Remember to give both the magnitude and the direction.
- **c** Check your answer to part **b** by calculating your displacement.

15 A student walks 8.0 km south-east and then 12 km due west.

- **a** Draw a vector diagram showing the route. Use your diagram to find the total displacement. Remember to give the scale on your diagram and to give the direction as well as the magnitude of your answer.
- **b** Calculate the resultant displacement. Show your working clearly.

This process of adding two displacements together (or two or more of any type of vector) is known as vector addition. When two or more vectors are added together, their combined effect is known as the **resultant** of the vectors.

KEY WORDS

resultant vector: the single vector formed by adding together two or more vectors

1.6 Combining velocities

Velocity is a vector quantity and so two velocities can be combined by vector addition in the same way that we have seen for two or more displacements.

Imagine that you are attempting to swim across a river. You want to swim directly across to the opposite bank, but the current moves you sideways at the same time as you are swimming forwards. The outcome is that you will end up on the opposite bank, but downstream of your intended landing point. In effect, you have two velocities:

- the velocity due to your swimming, which is directed straight across the river
- the velocity due to the current, which is directed downstream, at right angles to your swimming velocity.

These combine to give a resultant (or net) velocity, which will be diagonally downstream. In order to swim directly across the river, you would have to aim upstream. Then your resultant velocity could be directly across the river.

WORKED EXAMPLE

5 An aircraft is flying due north with a velocity of 200 m s^{-1}. A side wind of velocity 50 m s^{-1} is blowing due east. What is the aircraft's resultant velocity (give the magnitude and direction)?

Here, the two velocities are at 90°. A sketch diagram and Pythagoras's theorem are enough to solve the problem.

Step 1 Draw a sketch of the situation – this is shown in Figure 1.16a.

Step 2 Now sketch a vector triangle. Remember that the second vector starts where the first one ends. This is shown in Figure 1.16b.

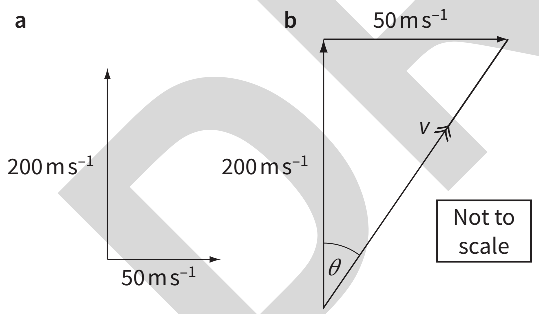


Figure 1.16: Finding the resultant of two velocities. For Worked example 5.

Step 3 Join the start and end points to complete the triangle.

Step 4 Calculate the magnitude of the resultant vector v (the hypotenuse of the right-angled triangle).

$$v^2 = 200^2 + 50^2 = 40\,000 + 2500 = 42\,500$$

$$v = \sqrt{42\,500} \approx 206\,\text{m s}^{-1}$$

Step 5 Calculate the angle θ:

$$\tan\theta = \frac{50}{200}$$

$$= 0.25$$

$$\theta = \tan^{-1}(0.25) \approx 14°$$

So the aircraft's resultant velocity is 206 m s^{-1} at 14° east of north, 076° or N76°E.

Questions

16 A swimmer can swim at 2.0 m s^{-1} in still water. She aims to swim directly across a river that is flowing at 0.80 m s^{-1}. Calculate her resultant velocity. (You must give both the magnitude and the direction.)

17 A stone is thrown from a cliff and strikes the surface of the sea with a vertical velocity of 18 m s^{-1} and a horizontal velocity v. The resultant of these two velocities is 25 m s^{-1}.

a Draw a vector diagram showing the two velocities and the resultant.

b Use your diagram to find the value of v.

c Use your diagram to find the angle between the stone and the vertical as it strikes the water.

1.7 Subtracting vectors

Sometimes, vectors need to be subtracted rather than added. For example, if you are in a car moving at $2.0\,\mathrm{m\,s^{-1}}$ and another car on the same road is moving in the same direction at $5.0\,\mathrm{m\,s^{-1}}$, then you approach the car at $5.0 - 2.0 = 3.0\,\mathrm{m\,s^{-1}}$. You are subtracting two velocity vectors.

Subtraction of vectors can be done using the formula:

$$\mathbf{A} - \mathbf{B} = \mathbf{A} + (-\mathbf{B})$$

where **A** and **B** are vectors.

KEY IDEA

To subtract a vector, add on the vector to be subtracted in the opposite direction.

So, to subtract, just add the negative vector.

But first you have to understand what the negative of vector **B** means. The negative of vector **B** is another vector of the same size as **B** but in the opposite direction.

This is straightforward if the velocities are in the same direction. For example, to subtract a velocity of $4\,\mathrm{m\,s^{-1}}$ north from a velocity of $10\,\mathrm{m\,s^{-1}}$ north, you start by drawing a vector $10\,\mathrm{m\,s^{-1}}$ north and then add a vector of $4\,\mathrm{m\,s^{-1}}$ south. The answer is $6\,\mathrm{m\,s^{-1}}$ north.

It is less straightforward if the velocities are in the opposite direction. For example, to subtract a velocity of $4\,\mathrm{m\,s^{-1}}$ south from a velocity of $10\,\mathrm{m\,s^{-1}}$ north, you start by drawing a vector $10\,\mathrm{m\,s^{-1}}$ north and then add a vector of $4\,\mathrm{m\,s^{-1}}$ north. The answer is $14\,\mathrm{m\,s^{-1}}$ north.

The example in Figure 1.17 shows how to find **A** – **B** and **A** + **B** when the vectors are along different directions.

Question

18 A velocity of $5.0\,\mathrm{m\,s^{-1}}$ is due north. Subtract from this velocity another velocity that is:

a $5.0\,\mathrm{m\,s^{-1}}$ due south

b $5.0\,\mathrm{m\,s^{-1}}$ due north

c $5.0\,\mathrm{m\,s^{-1}}$ due west

d $5.0\,\mathrm{m\,s^{-1}}$ due east

(You can do a scale drawing or make a calculation but remember to give the direction of your answers as well as their size.)

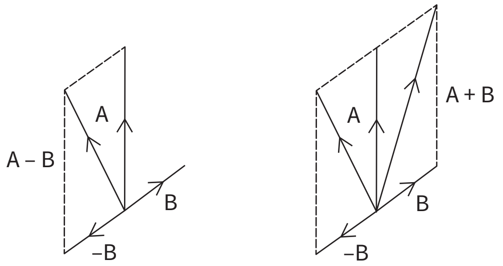


Figure 1.17: Subtracting and adding two vectors **A** and **B** in different directions.

1.8 Other examples of scalar and vector quantities

Direction matters when vectors are combined. You can use this to decide whether a quantity is a vector or a scalar. For example, if you walk for 3 minutes north and then 3 minutes in another direction, the total time taken is 6 minutes whatever direction you choose. A vector of 3 units added to another vector of 3 units can have any value between 0 and 6 but two scalars of 3 units added together always make six units. So, time is a scalar.

Mass and density are also both scalar quantities.

Force and acceleration, as you will see in later chapters, are both vector quantities. This is because, if an object is pushed with the same force in two opposite directions, the forces cancel out.

Work and pressure, which you will also study in later chapters, both involve force. However, work and pressure are both scalar quantities. For example, if you pull a heavy case along the floor north and then the same distance south, the total work done is clearly not zero. You just add scalar quantities even if they are in the opposite direction.

REFLECTION

- Write down anything that you found interesting or challenging in this chapter.
- Look at your notes later when you revise this topic.

SUMMARY

Displacement is the distance travelled in a particular direction.

Velocity is defined by the word equation:

$$\text{velocity} = \frac{\text{change in displacement}}{\text{time taken}}$$

The gradient of a displacement–time graph is equal to velocity:

$$v = \frac{\Delta s}{\Delta t}$$

Distance, speed, mass and time are scalar quantities. A scalar quantity has only magnitude.

Displacement and velocity are vector quantities. A vector quantity has both magnitude and direction.

Vector quantities may be combined by vector addition to find their resultant. The second vector can be subtracted from the first by adding the negative of the second vector, which acts in the opposite direction.

EXAM-STYLE QUESTIONS

1 Which of the following pairs contains one vector and one scalar quantity? **[1]**

A displacement : mass

B displacement : velocity

C distance : speed

D speed : time

2 A vector **P** of magnitude 3.0 N acts towards the right and a vector **Q** of magnitude 4.0 N acts upwards. **[1]**

What is the magnitude and direction of the vector (**P** – **Q**)?

A 1.0 N at an angle of 53° downwards to the direction of **P**

B 1.0 N at an angle of 53° upwards to the direction of **P**

C 5.0 N at an angle of 53° downwards to the direction of **P**

D 5.0 N at an angle of 53° upwards to the direction of **P**

CONTINUED

3 A car travels one complete lap around a circular track at a constant speed of $120\,\mathrm{km\,h^{-1}}$.

a If one lap takes 2.0 minutes, show that the length of the track is 4.0 km. **[2]**

b **Explain** why values for the average speed and average velocity are different. **[1]**

c **Determine** the magnitude of the displacement of the car in a time of 1.0 min. **[2]**

(The circumference of a circle = $2\pi R$, where R is the radius of the circle.) **[Total: 5]**

4 A boat leaves point A and travels in a straight line to point B. The journey takes 60 s.

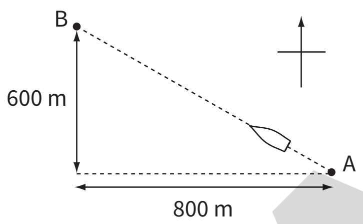


Figure 1.18

Calculate:

a the distance travelled by the boat **[2]**

b the total displacement of the boat **[2]**

c the average velocity of the boat. **[2]**

Remember that each vector quantity must be given a direction as well as a magnitude. **[Total: 6]**

5 A boat travels at $2.0\,\mathrm{m\,s^{-1}}$ east towards a port, 2.2 km away. When the boat reaches the port, the passengers travel in a car due north for 15 minutes at $60\,\mathrm{km\,h^{-1}}$.

Calculate:

a the total distance travelled **[2]**

b the total displacement **[3]**

c the total time taken **[2]**

d the average speed in $\mathrm{m\,s^{-1}}$ **[2]**

e the magnitude of the average velocity. **[2]**

[Total: 11]

6 A river flows from west to east with a constant velocity of $1.0\,\mathrm{m\,s^{-1}}$. A boat leaves the south bank heading due north at $2.4\,\mathrm{m\,s^{-1}}$. Find the resultant velocity of the boat. **[3]**

7 a **Define** displacement. **[1]**

b Use the definition of displacement to explain how it is possible for an athlete to run round a track yet have no displacement. **[2]**

[Total: 6]

COMMAND WORDS

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

determine: establish an answer using the information available

calculate: work out from given facts, figures or information

COMMAND WORD

define: give precise meaning

CONTINUED

8 A girl is riding a bicycle at a constant velocity of 3.0 m s^{-1} along a straight road. At time $t = 0$, she passes her brother sitting on a stationary bicycle. At time $t = 0$, the boy sets off to catch up with his sister. His velocity increases from time $t = 0$ until $t = 5.0$ s, when he has covered a distance of 10 m. He then continues at a constant velocity of 4.0 m s^{-1}.

- **a** Draw the displacement–time graph for the girl from $t = 0$ to $t = 12$ s. **[1]**
- **b** On the same graph axes, draw the displacement–time graph for the boy. **[2]**
- **c** Using your graph, determine the value of t when the boy catches up with his sister. **[1]**

[Total: 4]

9 A student drops a small black sphere alongside a vertical scale marked in centimetres. A number of flash photographs of the sphere are taken at 0.10 s intervals:

This diagram is shown sideways – the first black dot is at 0 cm and the next at 4 cm.

Figure 1.19

The first photograph is taken with the sphere at the top at time $t = 0$ s.

- **a** Explain how Figure 1.19 shows that the sphere reaches a constant speed. **[2]**
- **b** Determine the constant speed reached by the sphere. **[2]**
- **c** Determine the distance that the sphere has fallen when $t = 0.80$ s. **[2]**
- **d** In a real photograph, each image of the sphere appears slightly blurred because each flash is not instantaneous and takes a time of 0.0010 s.

Determine the absolute uncertainty that this gives in the position of each position of the black sphere when it is travelling at the final constant speed.

Suggest whether this should be observable on the diagram. **[2]**

[Total: 8]

10 a State **one** difference between a scalar quantity and a vector quantity and give an example of each. **[3]**

- **b** A plane has an air speed of 500 km h^{-1} due north. A wind blows at 100 km h^{-1} from east to west.

  Draw a vector diagram to calculate the resultant velocity of the plane. Give the direction of travel of the plane with respect to north. **[4]**
- **c** The plane flies for 15 minutes. Calculate the displacement of the plane in this time. **[1]**

[Total: 8]

COMMAND WORDS

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

state: express in clear terms

CONTINUED

11 A small aircraft for one person is used on a short horizontal flight. On its journey from A to B, the resultant velocity of the aircraft is 15 m s^{-1} in a direction 60° east of north and the wind velocity is 7.5 m s^{-1} due north.

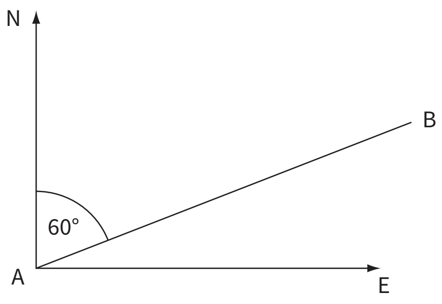


Figure 1.20

a Show that for the aircraft to travel from A to B it should be pointed due east. **[2]**

b After flying 5 km from A to B, the aircraft returns along the same path from B to A with a resultant velocity of 13.5 m s^{-1}. Assuming that the time spent at B is negligible, calculate the average speed for the complete journey from A to B and back to A. **[3]**

[Total: 5]

COMMAND WORD

show (that): provide structured evidence that leads to a given result

SELF-EVALUATION CHECKLIST

After studying the chapter, complete a table like this:

I can	See topic...	Needs more work	Almost there	Ready to move on
define and use displacement, speed and velocity	1.1, 1.2, 1.3			
draw and interpret displacement–time graphs	1.4			
describe laboratory methods for determining speed	1.1			
understand the differences between scalar and vector quantities and give examples of each	1.2			
use vector addition to add and subtract vectors that are in the same plane.	1.6, 1.7			

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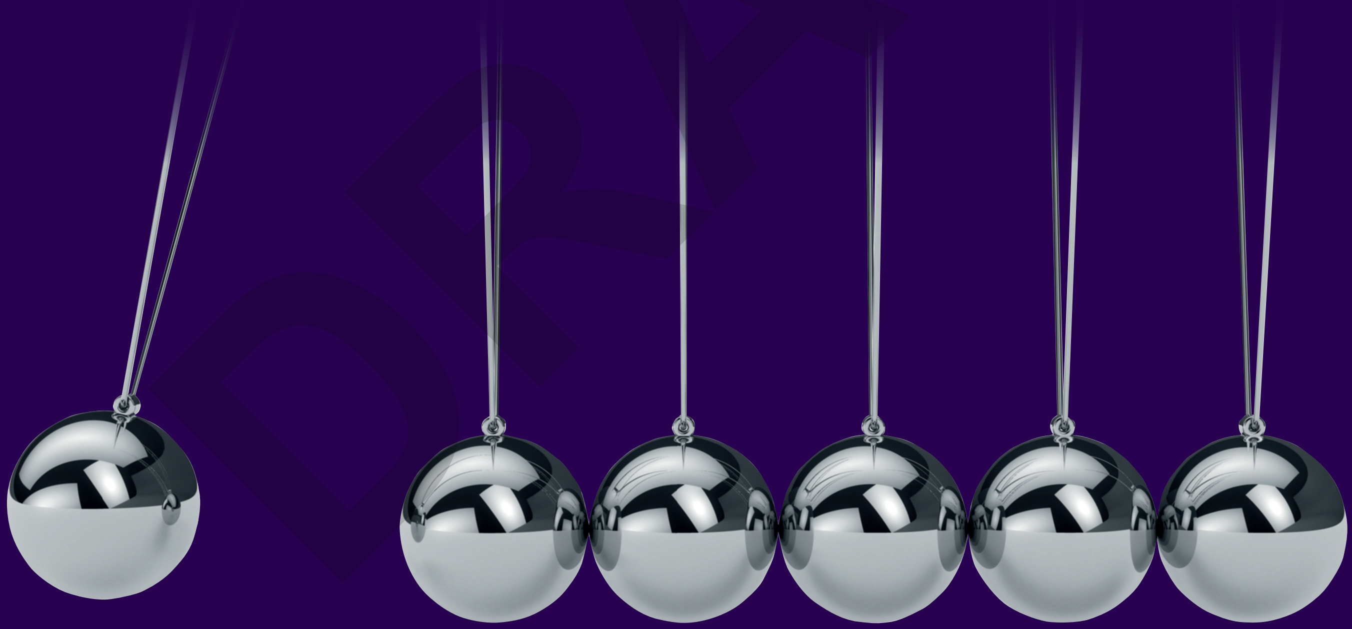

Digital Teacher's Resource

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Contents

Teaching notes

1 Kinematics: describing motion

Syllabus overview

- This section of the syllabus provides learners with a foundation knowledge of speed, velocity, displacement and distance, as well as combining velocities.
- Much of this material is likely to have been covered in previous years. However, the content is important and has links to many other topic areas covered at A Level.
- There are several practical skills included in the first chapter that learners should be familiar with. Many learners need confidence in dealing with practical work and the early, relatively simple, start to the course provides an ideal opportunity to develop practical skills with simple apparatus.
- Some of the mathematical skills listed in the syllabus can be covered, for example geometry and trigonometry, particularly with triangles. You may need to spend time revising these topics before a lesson or to liaise with mathematical teachers to cover the work at an appropriate time.
- There are opportunities to cover all three of the assessment objectives: AO1 (Knowledge and understanding), AO2 (Handling information and solving problems) and AO3 (Experimental skills and investigation).

Topic teaching plan

Topic	Number of lessons	Outline	Resources
1.1	2	Learners: • are reminded of the definition of speed, the various units for speed, conversions, estimates and typical values • measure speed with light gates or ticker-timers	Coursebook: Chapter 1 • Section on speed • Questions 1–6 • Exam-style Question 1a • Laboratory measurements of speed • Displacement–time graphs Workbook: Exercises 1.1 and 1.2 Practical Workbook: Investigations 1.4 and 3.1. Other investigations in Chapters 1 and 2 can be carried out at various times.
1.2	1	Learners produce and interpret displacement–time graphs	Coursebook: Chapter 1 • Displacement–time graphs Workbook: Exercise 1.3
1.3	2	Learners: • combine displacements • combine vectors	Workbook: Exercise 1.4

Topic 1.1

Learners:

- should be given a brief reminder of the meaning of speed and how to rearrange the equation. This should aim to reinforce learning from previous years. It should start the teaching on a familiar and friendly level.
- suggest possible units for speed and estimate various speeds in a variety of units
- are shown light gates or a ticker-timer or have these explained to them
- make a measurement of a speed, either using light gates, ticker-timers or with stopwatch and metre rule or trundle wheel. For those learners who are already good at using the equation, this practical can be used to introduce the idea of uncertainty.

Suggested teaching time

2 hours (2 lessons). Extra lessons will be needed if practical investigations from the Workbook are used.

- 1 lesson for Topic 1.1 and introduction to measurement
- 1 lesson for Topic 1.2 and determination of uncertainty in the time and the distance.

Links to other components in this series

Component	Resource	Description
Coursebook	Chapter 1 *1.1 Speed* and *Determining speed*	• Questions 1–6: laboratory measurements of speed • Exam-style Question 7: laboratory measurements of speed • Practical Activity 1.1: Laboratory measurements of speed • Figure 1.1: stroboscopic images of a boy juggling
	Chapter 2	• Figure 2.1: running cheetah
Teacher's resource	Not applicable	Not applicable
Workbook	Exercises 1.1 and 1.2	• provide simple calculations for the start of the course on speed and measuring speed in the laboratory
Practical Workbook	Practical Investigation 1.4	• involves simple practice with a stopwatch and a measurement of average speed
	Chapters 1 and 2	• improve learners' understanding of how apparatus is used and the limitations and improvements to be expected in practical work

Common misconceptions

- Learners may use inappropriate units for speed, such as m.p.h. or mps (metres per second). At this stage they will learn to use negative indices, such as $\mathrm{m\,s^{-1}}$, rather than m/s. They can still use m/s in their answers.
- The symbol s should **not** be used for speed. This is because s is the symbol used for distance in the equations of motion. Symbols u and v are the recommended symbols for speed at IGCSE and O Level. They are also used as speed in the equations of motion. The symbol s, rather than d, should be used for distance. Symbols v or u should be used for speed.

Lesson starters

This topic could be the first of the course. Learners will almost certainly have covered most of the subject matter at IGCSE/O Level. Depending on the class, you can assume some prior knowledge. Much of the topic can be treated as a recall exercise.

Two suggestions are given here. The choice between activities will depend on what resources are available, the time available and how the class is progressing with this topic.

1 Idea A (20–25 minutes)

Show a number of photographs, pictures or videos from the internet of animals (such as Figure 2.1 in the Coursebook), runners, cars, aeroplanes, the Earth moving round the Sun, and so on. Ask learners to place them in order, from slowest to fastest. In groups, learners can suggest values for the top speed of each object. Groups can then compare their results. As learners discuss results, it should become clear that speeds can be measured in different units. Write some typical results on the board so that learners can self-assess their estimates. Do they understand the different units that you use?

Learners can be challenged to come up with as many different units for speed as they can. What units might an astronomer use to measure the speed of a galaxy moving away from us?

› **Assessment ideas:** Learners can record in their books the estimates from their group of the various speeds. They can record how close they were to the average of the class and to the actual values you gave them. Learners can calculate the percentage difference between their value and your value. They can self-assess whether they were consistently too high or low in their estimates. They can self-assess whether they understand the different units used, such as km/h and m/s.

2 Idea B (15–20 minutes)

Give learners a quick verbal quiz to check their understanding of the terms *speed*, *distance* and *time*. Find out if they remember how to calculate speed. Show Figure 1.1 from the Coursebook or a video of a projectile. Ask learners, in groups, to discuss the figure or video. Ask them to suggest how a stroboscopic picture can be used to find speed. Do the horizontal and vertical speeds change as a ball flies through the air?

› **Assessment ideas:** At the very start, give learners 5 seconds to write down a formula that relates *speed*, *distance* and *time*. They show their formula to the person in front of them. That person ticks or corrects the formula. Discuss variations of the formula with speed, distance or time as the subject of the formula. More confident pupils can be encouraged to give harder variations, such as time = … They can be given even harder formulae to rearrange. For example, if $a = (v - u) / t$ what does v or u equal? During the rest of the lesson, you can see whether each learner had actually remembered the basic idea of speed from previous years.

Listen to different groups discussing the stroboscopic picture. Invite one group to present their suggestions to the whole class.

Main activities

1 Using the formula (20–25 minutes)

Briefly explain the equation for speed. Point out that average speed is calculated from $\frac{\text{total distance}}{\text{total time}}$

Introduce the SI system of units. Explain the need for an international system. Ensure that all learners can rearrange this equation successfully. Do they understand how to convert between different units of distance, such as mm, cm, km? Do they understand how to convert between seconds, minutes and hours?

Teach learners how to set out their answers clearly, with a formula, a substitution, a calculation and unit all being shown. For example

$$\begin{aligned}\text{distance} &= \text{speed} \times \text{time}\\ &= 3.6 \times 5.2\\ &= 18.72\\ &= 19\,\text{m (to 2 significant figures)}\end{aligned}$$

You should make this essential. Learners should be asked to add the necessary detail if they do not show their working in homework or class exercises. The aim is for learners to give this detail automatically. Note: using the same number of significant figures for the answer as in the data is not always necessary at this stage. But you might like to introduce it so learners get into a good habit.

Learners can use Questions 1–4 from the Coursebook to practise using these definitions. You could use Questions 1–4 in a question sheet prepared for learners.

› **Assessment ideas:** Learners can mark each other's work. They can explain in their own words to each other why an answer is incorrect.

Hinge-point question: Two cyclists travel to a town by different routes. Cyclist P covers 27 km in 1 hour 15 minutes, while cyclist Q travels 33 km at an average speed of 5.0 m s^{-1}. What is the average speed of P? How long did Q take to cover the journey? Choose the correct results from Table 1.1.

	Average speed of P / m s^{-1}	Time taken by Q / minutes
A	6.0	110
B	6.0	6600
C	6.5	110
D	6.5	6600

Table 1.1

A is the correct response. If learners answered **B** or **D**, they probably did not notice or realise that the answer needs to be in minutes. The direct calculation gives the distance as 6600 s, rather than minutes. If learners answered **C** or **D**, they probably used the time as 1.15 hours rather than 1.25 hours. They did not understand that there are 60 minutes rather than 100 minutes in 1 hour.

2 Measuring speed in the laboratory (at least 20–25 minutes and up to 1 hour with Practical Investigation 1.4)

Learners are introduced to a single light gate and timer. They investigate speed using a single light gate timer or motion sensor. You could use a demonstration if a light gate is available. Or you could show a video. If you search the internet for 'measuring speed or velocity with light gates or motion sensors' you will find a useful video. Readings can be taken from the video.

Give learners a simple task. An example is using a light gate to measure how fast can they move their hand. Or they could measure how fast a ball travels after it has fallen 1.0 m from rest in air.

If timers are not available, give learners a prepared ticker-timer trace showing dots on a piece of paper (photocopy). Ask them to measure the average speed between various specified points on the paper. Measurements should be repeated. The ideas of average and uncertainty can be introduced using the readings of time that are taken. This uncertainty can be compared with the uncertainty when using a stopwatch.

After they have made measurements of average speed, learners discuss the difficulties in using the apparatus. Learners should suggest possible causes of error and how they may be reduced.

Alternatively, or in addition, learners can measure their reaction time and determine an average speed of a ball rolling down a slope. This can be extended as in Practical Investigation 1.4 in the Practical Workbook to measure the average speed for different angles of slope.

› **Assessment ideas:** Learners should write a report of their method, make a table their readings and show their calculations. Groups of learners can look at each other's accounts. They can suggest which is the best from their group. They share it with you or the class. A good report should state clearly the experimental procedure used. It should state specifically which measurements were made. The best report might talk about the specific difficulties faced in the experiment. From time to time, you can check the account of each learner and the progress shown in their books.

› **Practical guidance:** Learners should use the first two chapters of the Practical Workbook to improve their understanding of how apparatus is used and the limitations and improvements to be expected in practical work. This can be done as appropriate during the first few months of the course.

Differentiation

Stretch and challenge

- Learners can use any uncertainty in time and distance measurements to calculate the maximum and minimum values of speed that are possible with their readings.
- Learners can practise using µm and nm as well as using prefixes for time measurements.

Support

Some learners prefer to use a formula triangle to display the relationship between speed, distance and time. This may be helpful at the start. But learners will eventually need to be able to rearrange simple formulae without aids. Encourage learners to stop using aids as soon as they can.

WRAP UP AND REFLECTION IDEAS

- Play a simple game with groups of students sitting in lines or rows. Read out a problem or display it on the screen. For example, 'a car travels at 50 km/h for 10 minutes, how far does it travel?' Each group member copies and completes the problem in their books. The person at the back writes the solution out on a piece of file paper.

  When their answer is complete, the person sitting at the back passes the answer to the person in front. That person looks at the completed problem. If they agree with the answer, they pass it to the person in front of them. If the answer is incorrect in any way, including lack of equation or a lack of unit, they pass the answer back. This should all take place in silence. If a learner is handed a problem back, they must correct it and pass it forward again.
- Points can be awarded for the team where the person at the front raises a hand to show that the answer has been checked and is correct for all the learners in their team. For the next problem, each learner moves one seat forward. The learner at the front moves to the back and is the one next to answer on file paper.
- Use Coursebook Question 6 for learners to write a paragraph on the best method for measuring speed in the laboratory.

Topic 1.2

Learners:

- discuss different motions shown by distance–time or displacement–time graphs
- carry out at least one experiment and possibly a planning exercise to obtain a distance–time graph
- are reminded of the good features of tabulation and how to plot a graph.

Suggested teaching time

At least 1 hour (1 lesson) depending on how many experiments are carried out.

Links to other components in this series

Component	Resource	Description
Coursebook	Chapter 1 *1.4 Displacement–time graphs*	• Figures 1.9: the slope of a displacement–time graph tells us how fast an object is moving • Figure 1.11 • Questions 10–12 • Exam-style Question 2: consolidate the skills of tabulation, drawing and finding a gradient • Exam-style Question 6
	Chapter P1	• correct tabulation and graph drawing
Teacher's resource	Practical Teacher's Guide, Practicals 1.1 and 1.2	• ensures correct tabulation and graph drawing at the start of the course
Workbook	Exercise 1.3	• provides some simple examples and Exam-style Questions 2 and 3 give further practice.
Practical Workbook	Practical Investigation 3.1	• can be used to consolidate the skills of tabulation, drawing and finding a gradient

Common misconceptions

- Learners often think that they do not need to write down a 0 if it is the only digit to follow a full stop. They will often have values such as 3.6 s, 5 s, 6.3 s. All readings should be to the same precision in one column of a table.
- Learners may believe that the reading of time on a stopwatch can be made to the nearest 0.001 s. An initial experiment where they all measure the same time between two taps on a bench can be used to establish the uncertainty in any reading. The uncertainty is unlikely to be better than 0.1 s.

Lesson starters

Learners may have used displacement–time graphs before their A Level studies. But they are likely to need more experience of using such graphs. The need to develop their ability to plot these graphs. They will also need to build confidence in experimental work. They need to consolidate practical skills.

Two suggestions are given here. The choice between activities will depend on what resources are available, the time available and how the class is progressing with this topic.

1 Idea A (15–20 minutes)

Show learners the range of graphs that show the relationship between distance and time, such as the ones in the Coursebook, Figure 1.9 (without the explanations). Ask them to describe what each graph shows about the velocity.

› **Assessment ideas:** Learners discuss the graphs in groups. They copy them into their books with explanations. They then review one another's work. Each learner can suggest what is good in the explanation from another learner, and how it might be improved. You can listen to the discussions to decide whether they really have understood that the slope is velocity and it can be positive or negative.

2 Idea B (15–20 minutes)

Sketch a displacement–time graph on the board, as in Figure 1.9 in the Coursebook. Invite a learner to walk around the room showing the movement indicated by the graph. Repeat for other graphs.

› **Assessment ideas:** You can see from the learner's movement around the room (and from comments from other learners) whether they have understood the graph.

Main activities

In these activities learners obtain displacement–time graphs from short practical experiments. At this stage, such graphs can be introduced as distance–time graphs to avoid the problems of the difference between displacement and distance.

At this stage, learners can be introduced to the necessary skills of tabulation and plotting a graph. The early experiments in the Practical Workbook provide a useful introduction.

1 Planning and obtaining a distance–time graph (about 40 minutes)

Learners can plan how to obtain a distance–time graph as in Practical 1.2 of the Practical Teacher's Guide. They have only one stopwatch for each learner and a few metre rules. They must plan how they, as a group, can obtain a distance–time graph for someone walking along a path. A possible solution is for learners to be placed 2.0 m apart in a line. As a walker passes you at the start of the line, you shout 'start'. All the learners start their stopwatches. They stop their stopwatches as the walker passes them. Repeat for different motions.

This is a good exercise to practise the use of a stopwatch. Before doing the practical it is worthwhile checking that all learners can time a simple event adequately. One possible way to do this is to tap a bench twice (out of sight of the learners). Compare the times obtained. Repeat until all learners have values within 0.2 s of each other.

› Assessment ideas: Learners can compare the graphs they have obtained. Ask them to look at another learner's graph. Ask them to indicate on the graph whether

- the graph is of a suitable size (the points cover more than half the axes, both horizontal and vertical)
- the axes are labelled with units
- the points are plotted in the right place (within half a square)
- the points are plotted as crosses or dots with circles (plotting a point as a dot is not recommended).

› Practical guidance: Instead of learners doing the practical immediately, you might ask learners to plan the experiment beforehand. Learners find planning difficult. An early start to the processes involved in planning may be beneficial.

2 Using light gates or a ticker-timer to obtain a distance–time graph (about 30 minutes)

If a ticker-timer is available, learners can do the experiment in Practical 1.1 of the Practical Teacher's Guide. Otherwise they can use a stopwatch or light gates to time a ball rolling down a slope. Such as a marble rolling from rest down the gap between two metre rules. They can measure the time taken to roll a certain distance. They can repeat the experiment for different distances. They can produce tables and graphs of the results.

› Assessment ideas: Learners can write an account of their method. The table and graphs that learners draw can be used to assess them. Each learner can look at the table and graph of another learner. You can ask questions such as:

- has each column of the table got a unit
- has each column got a consistent number of decimal places?
- does the graph cover more than half the page?

The necessary details for tables and graphs are given in the Practical Workbook and Chapter P1. The main aim of the assessment is that each learner will learn how to draw up a table and draw a graph. You can see what features are being missed so you can teach the need for these features.

Hinge-point question: What are the important things to remember when drawing a graph?

What are the most important things to remember when drawing a table of readings?

See the bullet points in Assessment Ideas. Learners should remember each of these points. If one of them is omitted the learner should realise that they have not understood the importance.

Differentiation

Stretch and challenge

- More confident learners can experiment to see whether a larger or heavier ball travels further in the same time.
- More confident learners can be taught about displacement at this stage. Or they can attempt to use their readings or graphs to find values of speed at various stages in the motion.

Support

If learners find planning difficult you can give them help. You should remind all learners of the good features for a table and a graph.

WRAP UP AND REFLECTION IDEAS

- You can provide sets of displacement or distance graphs. Ask learners to describe each motion. One learner sketches a distance–time graph. They come to the front and describe the motion to the class but do not show the graph. All the other learners sketch the graph from the description. They compare their graphs with the initial graph.
- One learner sketches a distance–time graph. They come to the front and describe the motion to the class but do not show the graph. All the other learners sketch the graph from the description. They compare their graphs with the initial graph.
- Learners can be asked how they can find the speed from a distance–time graph. They should realise that this is the gradient of the graph. You might explain the good features of obtaining a gradient from a graph. Learners can suggest ways in which they can improve their graphs or remember how to draw a good graph.

Topic 1.3

- Activities start by reminding learners of the concept of scalar and vector quantities. They continue with a simple practical, in a large space, to combine displacements and to establish the rule for combining vectors.
- Practise using vector addition and subtraction.
- Establish that velocity can also be added as a vector quantity.

Suggested teaching time

2 hours (2 lessons)

Links to other components in this series

Component	Resource	Description
Coursebook	Chapter 1 *1.5 Combining displacements* and *1.6 Combining velocities*	• Worked Examples 3 and 4: combining displacements • Questions 14 and 15: combining displacements • Questions 16–18: practise adding velocities • Exam-style Question 4: vector addition
Teacher's resource	Chapter 2	• Components of vectors. This is in essence the reverse of the addition of vectors.
Workbook	Exercise 1.4:	• Questions 4 and 5: more examples on vector addition
Practical book	Not applicable	Not applicable

Common misconceptions

- Many learners fail to give a direction when quoting the value of a vector.
- There are often problems in establishing a direction for a vector. For example, N45°E is the same as 045° or 45° east of north. Learners will almost certainly need to be reminded of these conventions for specifying a bearing.

Lesson starters

Most learners will have learnt about scalar and vector quantities before. You can adapt to the previous knowledge of their students by incorporating more difficult quantities. Remind learners of quantities such as work and energy.

Two suggestions are given here. The choice between activities will depend on what resources are available, the time available and how the class is progressing with this topic.

1 Idea A (15 minutes)

Start by showing a video clip of a plane landing in a wind. Start a discussion to lead to a definition of vector and scalar quantities. Ask learners, in small groups, to write down all the quantities in physics that they know about. Ask the learners to sort the quantities into either scalar or vector quantities. This will involve many of the quantities met in previous years. Each group then has to provide an explanation to the class of some of the quantities and why they are a scalar or a vector.

› **Assessment ideas:** You can determine from the group work whether learners can remember what these quantities actually are. This may involve you revising such quantities as displacement, velocity, work, and so on. Learners can write their list down with their own summary of the discussion. You can reference their writing later to confirm understanding.

2 Idea B (15 minutes)

The learners attempt to pull a block of wood along the bench with strings. They pull in a variety of directions at the same time. This could be a large-scale activity. In groups, learners can discuss why direction is important in some quantities. They can suggest a list of such quantities. This list can be shared with the whole class. The reasons why some quantities involve direction and others do not can lead to considerable discussion. For example, why is pressure a scalar?

The main idea to establish during discussion is that some quantities, when added, do so according to ordinary rules such as $1 + 1 = 2$. Others, when added, produce a range of values. For example, $1 + 1$ can be any value between 0 and 2.

› **Assessment ideas:** From the quantities suggested by each group or individual you can see their previous understanding of vector and scalar quantities. You can adapt your teaching appropriately.

Main activities

Ensure that each learner has a list of the quantities from previous years, such as IGCSE or O Level, that are scalars and vectors. Make sure that each learner knows the difference between a scalar and a vector. You need to clearly establish the differences between displacement and distance, and between speed and velocity. Learners also need to know that any vector quantity should be given a direction as well as a magnitude (size).

1 Adding displacements – a simple practical (30 minutes)

In a large space, for example outdoors or in a hall, walk 40 m north in one direction. Then walk 30 m at right angles. Learners measure the resultant displacement with a tape measure or trundle wheel. They measure the angle with a compass. Learners should record the two displacements and the resultant. They should include all bearings relative to north. This can be repeated for other distances and angles. Learners then draw a scale diagram to verify the measurements. The scale diagram method has more general applications. Any pair of vectors, representing, for example, velocity, could be scaled in this way and added by the triangle method.

Learners can also be asked to estimate the percentage uncertainty in their measurements of distance and bearing. They can compare the percentage difference between their measurement of the resultant displacement (size and bearing) with the 'correct' answers from the scale drawing. They can see whether any differences are within the percentage uncertainty in the actual use of the equipment.

› **Assessment ideas:** You can see whether learners are using a compass to provide a direction and the tape measure to measure distance adequately. Such practice with equipment helps in practical assessment. When compared with the values from the scale diagram, the final value of distance and bearing obtained should show whether learners have understood.

› **Practical guidance:** The size of the distances moved can be adapted to the space available and to the measuring devices available.

Hinge-point question: Which diagram in Figure 1.1 shows the resultant R of adding a displacement of 6 m north and a displacement of 10 m east?

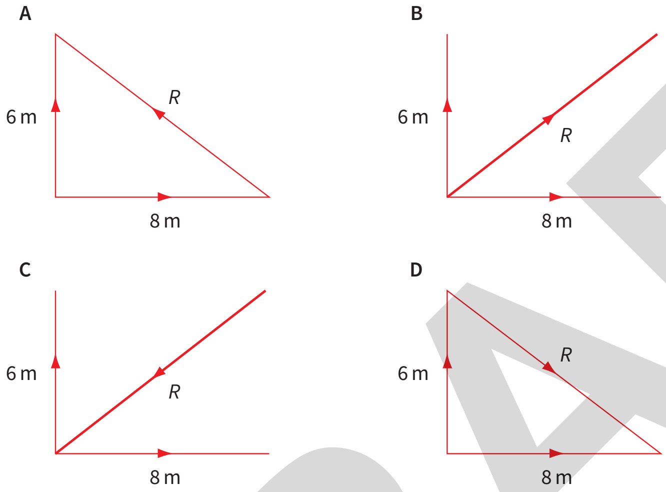

Figure 1.1

B is the correct answer. **A** and **D** show that the learner does not realise that vectors must add head to tail. **C** shows that the learner does not realise that a displacement starts from the initial position.

2 Drawing vector addition accurately (20 minutes)

Show learners the Worked Examples 3 and 4 from *1.1 Combining displacements* in the Coursebook. Alternatively, show a video clip of vector addition by drawing a triangle. Search the internet for something suitable.

Learners should use these ideas to practise adding displacement and velocity using a variety of questions; for example, Questions 14–17 in Chapter 1 and Exercise 1.4 in the Workbook, as well as the Exam-style Questions in this chapter.

› **Assessment ideas:** You may provide a model answer for one of the questions answered by learners. Stress the need for accuracy and the use of an angle at each stage. Learners mark each other's work. If any necessary stage is missing, such as a missing angle or if the result is inaccurate (for example, if the angle is more than 1° wrong) ask the learner to write, in their own words, *why* the answer is wrong. For example: 'used protractor wrongly', 'pencil line was too thick' or 'forgot to reference angle to north properly'. This will help the learner to assess their work. It will provide a reference for the learner to use with their future work.

Hinge-point question: See 'Adding displacements – a simple practical'.

3 Vector addition of velocity and vector subtraction (10 minutes)

Some learners find it difficult to move from addition of displacement to addition of velocity. The importance of addition of velocity can be demonstrated with a video clip of a plane landing in a wind. Learners will find it interesting.

Subtraction of velocity can be explained simply as the addition of a negative velocity.

› **Assessment ideas:** Learners can be given different velocity vector diagrams to draw and calculate, such as Questions 16–18 in the Coursebook or Questions 4 and 5 in Exercise 1.4 in the Workbook. The final results should indicate whether learners have been able to move from a displacement vector diagram to a velocity vector diagram.

Differentiation

Stretch and challenge

- Learners can be challenged to explain why pressure and work are scalar quantities.
- At some stage, all learners should be introduced to the subtraction of vectors. Confident learners can be asked to think about what it means to subtract two vectors.

Support

The components of a vector are met in Chapter 2 but can be introduced at this stage as the reverse of combining two vectors (that is, the process of splitting a single vector into two vectors at right angles that will add up to the single vector).

WRAP UP AND REFLECTION IDEAS

- Ask learners whether it is easier to (a) calculate a resultant vector after sketching the relevant or triangle, or (b) draw the triangle accurately and then calculate the resultant using mathematics. Can they assess when each method is better than the other?
- Give groups of learners a final problem. For example, 'An aircraft wishes to fly due north in a wind of 30 m s^{-1} at 045°'. Ask learners to find the direction in which a plane should steer if its speed in still air is 200 m s^{-1}. Ask learners to describe what they found difficult about constructing the diagram. How will they overcome this in future?

CROSS-CURRICULAR LINKS

- Algebra. You may wish to organise suitable teaching of rearrangement of formulae with the mathematics teacher.
- Graphical work and obtaining gradients.
- Trigonometry and the sine rule, cosine rule and Pythagoras' theorem.

You may wish to consult with mathematics teachers to ensure these topics have been taught previously. It is sometimes possible to teach the same topics in mathematics and physics at the same time. Physics involves more measurement and introduces more concepts such as uncertainty and the use of apparatus.

Coursebook answers

Workbook answers

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Physics

for Cambridge International AS & A Level

WORKBOOK

David Sang & Graham Jones

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Contents

Chapter 1

Kinematics: describing motion

CHAPTER OUTLINE

- define and use distance, displacement, speed and velocity
- draw and interpret displacement–time graphs
- describe laboratory methods for determining speed
- understand the differences between scalar and vector quantities, and give examples of each
- use vector addition to add and subtract vector quantities that are in the same plane

KEY EQUATIONS

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

$$\text{average speed} = \frac{\Delta d}{\Delta t}$$

$$\text{velocity} = \frac{\text{change in displacement}}{\text{time taken}}$$

$$\text{velocity} = \frac{\Delta s}{\Delta t}$$

Exercise 1.1 Speed calculations

These questions will help you to revise calculations involving speed, distance and time. You will also practise converting units. The SI unit of time is the second (s). It is usually best to work in seconds and convert to minutes or hours as the last step in a calculation. The correct scientific notation for metres per second is m s^{-1}.

1 A train travels 4000 m in 125 s. The measurement of the time is not exact and the uncertainty in the time is ±1 s. The uncertainty in the distance is negligible.

- **a** Calculate the average speed of the train.
- **b** Calculate the percentage uncertainty in the time.
- **c** Using the time as $125 - 1 = 124$ s, calculate the maximum value of the average speed given by these values. Give your answer to a sensible number of significant figures.
- **d** Using your answers to parts **c** and **a**, calculate the percentage uncertainty in the average speed of the train.

TIP

When multiplying or dividing quantities, the percentage uncertainty in the final result is found by adding together the percentage uncertainty in each of the quantities.

This means your answer to **d** should be the same as the answer to **b** to one significant figure.

2 A spacecraft is orbiting the Earth with a constant speed of 8100 m s^{-1}. The radius of its orbit is 6750 km.

- **a** Explain what is meant by the term *constant speed*.
- **b** Calculate how far it will travel in 1.0 hour.
- **c** Calculate how long it will take to complete one orbit of the Earth. Give your answer in minutes.

3 A police patrol driver sees a car that seems to be travelling too fast on a motorway (freeway). He times the car over a distance of 3.0 km. The car takes 96 s to travel this distance.

- **a** The speed limit on the motorway is 120 km h^{-1}. Calculate the distance a car would travel at 120 km h^{-1} in one minute.
- **b** Calculate the distance a car would travel at 120 km h^{-1} in 1 s.
- **c** Calculate the average speed of the car, in m s^{-1}.
- **d** Compare the car's actual speed with the speed limit. Was the car travelling above or below the speed limit?

4 It is useful to be able to compare the speeds of different objects. To do this, the speeds must all be given in the same units.

- **a** Calculate the speed, in m s^{-1}, of the objects in each scenario, **i**–**vi**. Give your answers in standard form (also known as *scientific notation*), with one figure before the decimal point.
  - **i** Light travels at 300 000 000 m s^{-1} in empty space.
  - **ii** A spacecraft travelling to the Moon moves at 11 km s^{-1}.
  - **iii** An athlete runs 100 m in 10.41 s.
  - **iv** An alpha-particle travels 5.0 cm in 0.043×10^{-6} s.
  - **v** The Earth's speed in its orbit around the Sun is 107 000 km h^{-1}.
  - **vi** A truck travels 150 km along a motorway in 1.75 h.
- **b** List the objects in order, from slowest to fastest.

Exercise 1.2 Measuring speed in the laboratory

You can measure the speed of a moving trolley in the laboratory using a ruler and a stopwatch. However, you are likely to get better results using light gates and an electronic timer. In this exercise, you will compare data from these different methods and practise analysing data.

1 A student used a stopwatch to measure the time taken by a trolley to travel a measured distance of 1.0 m.

- **a** Explain why it can be difficult to obtain an accurate measurement of time in this way.
- **b** Explain why the problem is more likely to be greater if the trolley is moving more quickly.

2 This diagram shows how the speed of a trolley can be measured using two light gates connected to an electronic timer. An interrupt card is fixed to the trolley:

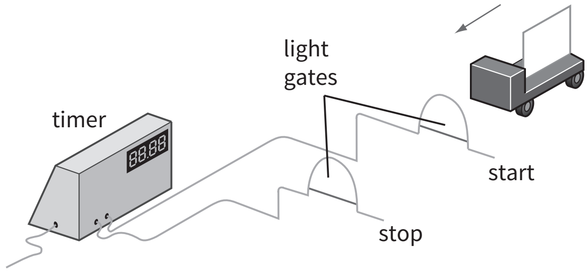

Figure 1.1: For Question 2. Determining acceleration using two light gates.

- **a** Describe what happens as the trolley passes through the light gates.
- **b** Name the quantity shown on the timer.
- **c** What other measurement must be made to determine the trolley's speed? Describe how you would make this measurement.
- **d** Explain how you would calculate the trolley's speed from these measurements.
- **e** Explain why this method gives the trolley's *average* speed.

3 It is possible to determine the average speed of a trolley using a single light gate.

- **a** Draw a diagram to show how you would do this.
- **b** Describe what happens as the trolley passes through the light gate.
- **c** Explain how you would find the trolley's average speed using this arrangement.

4 A ticker-timer can be used to record the movement of a trolley. The ticker-timer makes marks (dots) on paper tape at equal intervals of time.

- **a** Sketch the pattern of dots you would expect to see for a trolley travelling at constant speed.
- **b** A ticker-timer makes 50 dots each second on a paper tape. State the time interval between consecutive dots.
- **c** A student measures a section of tape. The distance from the first dot to the sixth dot is 12 cm. Calculate the trolley's average speed in this time interval. Give your answer in $\mathrm{m\,s^{-1}}$.

TIP

When using ticker-timers, think about whether to count the dots or the spaces between the dots.

Exercise 1.3 Displacement–time graphs

A **displacement**–time graph is used to represent an object's motion. The gradient of the graph is the object's velocity. These questions provide practice in drawing, interpreting and using data from displacement–time graphs.

KEY WORD

displacement: the distance travelled in a particular direction

1 Velocity is defined by the equation:

$$\text{velocity} = \frac{\Delta s}{\Delta t}$$

- **a** State what the symbols s and t stand for.
- **b** State what the symbols Δs and Δt stand for.
- **c** Sketch a straight-line displacement–time graph and indicate how you would find Δs and Δt from this graph.

TIP

Remember to label your graph axes with the correct quantities.

2 This sketch graph represents the motion of a car:

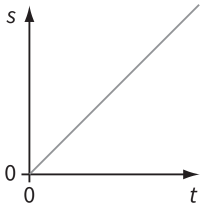

Figure 1.2: For Question 2. Distance–time graph of a car in motion.

a Explain how you can tell that the car was moving with constant velocity.

b Copy the sketch graph and add a second line to the graph representing the motion of a car moving with a higher constant velocity. Label this 'faster'.

c On your graph, add a third line representing the motion of a car which is stationary. Label this 'not moving'.

3 This graph represents the motion of a runner in a race along a long, straight road:

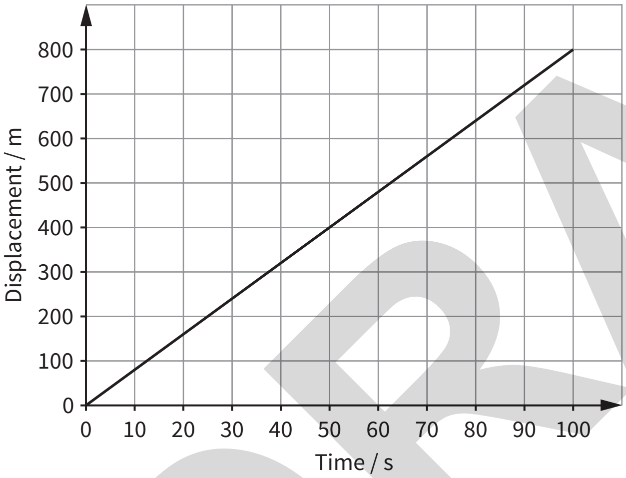

Figure 1.3: For Question 3. Displacement–time graph for a runner.

Use the graph to deduce:

a the displacement of the runner after 75 s

b the time taken by the runner to complete the first 200 m of the race

c the runner's velocity.

4 This table gives values of displacement and time during a short cycle journey:

Displacement / m	0	80	240	400	560	680
Time / s	0	10	20	30	40	50

Table 1.1: Data for a cyclist.

a Draw a displacement–time graph for the journey.

b From your graph, deduce the cyclist's greatest speed during the journey.

Exercise 1.4 Adding and subtracting vectors

These questions involve thinking about displacement and velocity. These are vector quantities – they have direction as well as magnitude. Every quantity in physics can be classified as either a **scalar** or a **vector** quantity. A vector quantity can be represented by an arrow.

KEY WORDS

scalar: a quantity with magnitude only

vector: a quantity with both magnitude and direction

1 A scalar quantity has magnitude only.

- **a** Name the scalar quantity that corresponds to displacement.
- **b** Name the scalar quantity that corresponds to velocity.
- **c** For each of the following quantities, state whether it is a scalar or a vector quantity: mass, force, acceleration, density, energy, weight.

2 This drawing shows a piece of squared paper. Each square measures 1 cm × 1 cm. The track shows the movement of a spider that ran around on the paper for a short while:

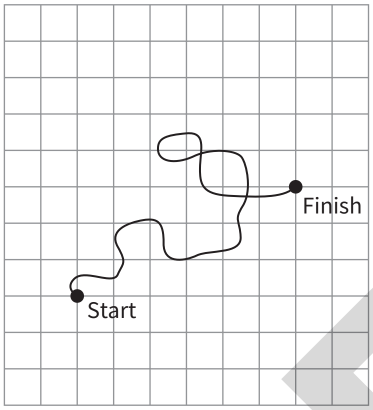

Figure 1.4: For Question 2. Movement of a spider.

- **a** How many squares did the spider move *to the right*, from start to finish?
- **b** How many squares did the spider move *up the paper*?
- **c** Calculate the spider's displacement between start and finish.

  Make sure that you give the distance (in cm) and the angle of its displacement relative to the horizontal.
- **d** Estimate the distance travelled by the spider. Describe your method.

3 A yacht sails 20 km due north. It then turns 45° to the west and travels a further 12 km.

- **a** Calculate the distance, in km, travelled by the yacht.
- **b** Draw a scale diagram of the yacht's journey. Include a note of the scale you are using.
- **c** By measuring the diagram, determine the yacht's displacement relative to its starting point.

4 A passenger jet aircraft can fly at 950 km h^{-1} relative to the air it is flying through. In still air it will therefore fly at 950 km h^{-1} relative to the ground.

- **a** A wind of speed 100 km h^{-1} blows head-on to the aircraft, slowing it down. What will its speed relative to the ground be?
- **b** If the aircraft was flying in the opposite direction, what would its speed be relative to the ground?
- **c** The aircraft flies in a direction such that the wind is blowing at it sideways (in other words, at 90°).
  - **i** Draw a diagram to show how these two velocities add together to give the resultant velocity of the aircraft.
  - **ii** Calculate the aircraft's speed relative to the ground.

5 Subtract a displacement of 5.0 m in a direction 030° (N30°E) from a displacement of 10 m in a northerly direction.

TIP

To subtract a vector, add on a vector equal in size but in the opposite direction, i.e. add on a 5.0 m vector at 210°.

EXAM-STYLE QUESTIONS

1 **a** **Define** speed. **[1]**

This diagram shows a laboratory trolley with an interrupt card mounted on it. The trolley will pass through a single light gate:

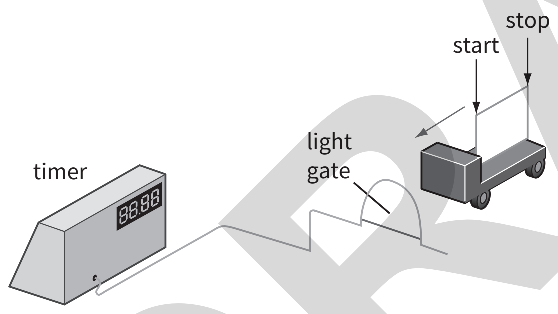

Figure 1.5

b **Explain** how the card causes the timer to start and stop. **[3]**

c The card is 10 cm wide. The timer indicates a time of 0.76 s. **Calculate** the average speed of the trolley. **[2]**

d Explain why the speed you calculated in **c** is the trolley's *average* speed. **[1]**

[Total: 7]

2 A slow goods train is travelling at a speed of 50 km h^{-1} along a track. A passenger express train that travels at 120 km h^{-1} sets off along the same track two hours after the goods train.

a Draw a displacement–time graph to represent the motion of the two trains. **[4]**

b Use your graph to **determine** the time at which the express train will catch up with the goods train. **[1]**

[Total: 5]

COMMAND WORDS

Define: give precise meaning

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

Calculate: work out from given facts, figures or information

Determine: establish an answer using the information available

CONTINUED

3 This graph represents the motion of a car along a straight road:

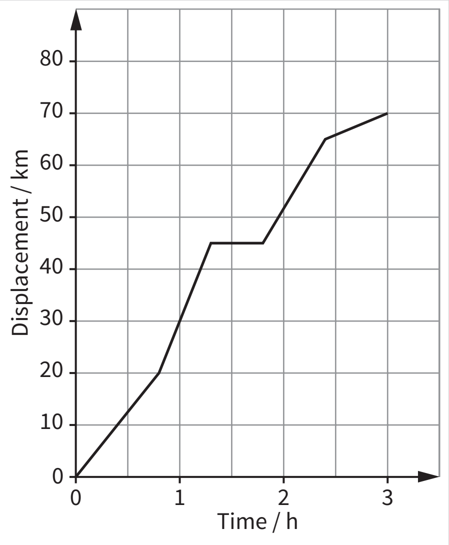

Figure 1.6

From the graph, deduce the following:

a the time taken for the car's journey **[1]**

b the distance travelled by the car during its journey **[1]**

c the car's average speed during its journey **[1]**

d the car's greatest speed during its journey **[1]**

e the amount of time the car spent travelling at the speed you calculated in **d** **[1]**

f the distance it travelled at this speed. **[1]**

[Total: 6]

4 A physical quantity can be described as either 'scalar' or 'vector'.

a **State** the difference between a *scalar quantity* and a *vector quantity*. **[2]**

b Define *displacement*. **[1]**

A light aircraft flies due east at 80 km h^{-1} for 1.5 h. It then flies due north at 90 km h^{-1} for 0.8 h.

c Calculate the distance travelled by the aircraft in each stage of its journey. **[2]**

d Draw a scale diagram to represent the aircraft's journey. **[2]**

e Use your diagram to determine the aircraft's final displacement relative to its starting point. **[2]**

[Total: 9]

COMMAND WORD

State: express in clear terms

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Physics

for Cambridge International AS & A Level

PRACTICAL WORKBOOK

Graham Jones, Steve Field, Chris Hewlett & David Styles

Second edition

Cambridge Assessment
International Education
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Contents

6 Electric current, potential difference and resistance

7 Resistance and resistivity

8 Waves

9 Planning and data analysis

10 Circular motion and gravitational fields

11 Oscillations

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13 Coulomb’s law and capacitance

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15 Electromagnetic induction and alternating currents

16 Quantum physics, nuclear physics and medical imaging

17 Astronomy and cosmology

Chapter 1

Using apparatus

CHAPTER OUTLINE

This chapter relates to Chapter 1: Kinematics: describing motion, Chapter 7: Matter and materials and Chapter 8: Electric current, potential difference and resistance, in the coursebook.

In this chapter, you will complete investigations on:

- 1.1 Determining the density of water
- 1.2 Determining the spring constant of a spring
- 1.3 Determining the resistance of a metal wire
- 1.4 Determining the average speed of a cylinder rolling down a ramp.

Practical investigation 1.1: Determining the density of water

Density is defined as mass ÷ volume or, expressed in symbols:

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

The standard unit for density in the SI system of units is kg m^{-3}. 1000 kg m^{-3} = 1 g cm^{-3}.

KEY EQUATION

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

YOU WILL NEED

Equipment:

• metre rule • 30 cm ruler • 250 cm^3 beaker • Vernier or digital callipers.

Access to:

• jug of water • top-pan balance.

Safety considerations

- Make sure you have read the Safety advice at the beginning of this book and listen to any advice from your teacher before carrying out this investigation.
- Clear any spillages of water.

Part 1: Determining density from single mass and volume measurements

Method

1 Place an empty 250 $\mathrm{cm^3}$ beaker on a top-pan balance. Record the reading on the balance.

Mass of empty beaker = ... g

2 Pour some water into the beaker until the water level is approximately 180 $\mathrm{cm^3}$.

Estimate the volume of the water.

Estimated volume of water V = ... $\mathrm{cm^3}$

3 Record the new reading on the balance.

Mass of beaker and water = ... g

Data analysis

a Calculate m using:

m = mass of beaker and water – mass of beaker

m = ... g

b Calculate the density ρ of water using your measurements.

ρ = ... $\mathrm{g\ cm^{-3}}$

Part 2: Using a graph to find density

Method

1 Place an empty 250 $\mathrm{cm^3}$ beaker on a balance. Record the reading on the balance in the Results section.

2 Pour some water into the beaker until the water level is approximately 50 $\mathrm{cm^3}$.

3 Record the new balance reading in Table 1.1 in the Results section.

4 The water in the beaker has a diameter d and height h.

- **i** Measure d using the 30 cm ruler and record your measurement in the Results section.
- **ii** Measure h using the metre rule and record your measurement in Table 1.1.

5 Change the amount of water in the beaker and take a series of readings of the mass of the beaker and the water and the height h. Record your results in Table 1.1.

Results

Mass of beaker = ... g d = ... cm

Mass of beaker and water / g	*m* / g	*h* / cm

Table 1.1: Results table.

Analysis, conclusion and evaluation

a Calculate m for each of your readings using

m = mass of beaker and water – mass of beaker

Record your values for m in Table 1.1.

b Plot a graph of m on the y-axis against h on the x-axis using the graph grid.

c Draw the straight **line of best fit**.

d Determine the **gradient** of this line.

KEY EQUATION

$$\textbf{gradient} = \frac{\text{change in } y}{\text{change in } x} = \frac{\Delta y}{\Delta x}$$

Gradient = ...

e Extension question. The volume v of a cylinder with diameter d and height h as shown in Figure 1.1 is given by:

$$V = \frac{\pi d^2 h}{4}$$

Using $\rho = \frac{m}{V}$ and $V = \frac{\pi d^2 h}{4}$, show that $m = \frac{\rho \pi d^2 h}{4}$

....

....

....

f Extension question. Show that the gradient of the graph will be $\frac{\rho \pi d^2}{4}$

....

....

....

KEY WORDS

line of best fit: straight line drawn as closely as possible to the points of a graph so that similar numbers of points lie above and below the line

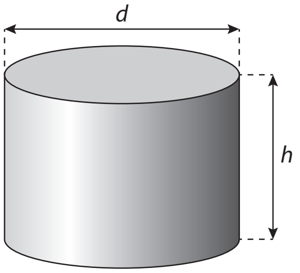

Figure 1.1: A cylinder.

TIP

π, ρ, d and 4 are all constant.

g Determine ρ using:

$$\rho = \frac{4 \times \text{gradient}}{\pi d^2}$$

$\rho =$ .... g cm^{-3}

h Suggest two advantages of using digital callipers instead of a ruler to measure *d*.

....

....

Practical investigation 1.2: Determining the spring constant of a spring

The **spring constant** is defined as force per unit extension, or expressed in symbols:

$$k = \frac{F}{e}$$

The stiffness of a spring is its resistance to deformation when a load is applied. The stiffer the spring, the greater the value of *k*.

The standard unit for spring constant in the SI system of units is N m^{-1}. 100 N m^{-1} = 1 N cm^{-1}.

KEY EQUATION

spring constant $k = \frac{F}{e}$

YOU WILL NEED

Equipment:

- expendable steel spring
- 100 g mass hanger
- 0–10 N newton-meter
- 30 cm ruler
- four 100 g slotted masses
- two stands
- two bosses
- two clamps
- G-clamp.

Safety considerations

- Make sure you have read the Safety advice at the beginning of this book and listen to any advice from your teacher before carrying out this investigation.
- If the stand moves or tilts it may be necessary to secure it to the bench using the G-clamp.

Part 1: Determining the spring constant from the measurement of an extension and the calculation of a load

Method

1 Measure the length x_0 of the coiled section of an unextended spring as shown in Figure 1.2 and write your answer in the Results section.

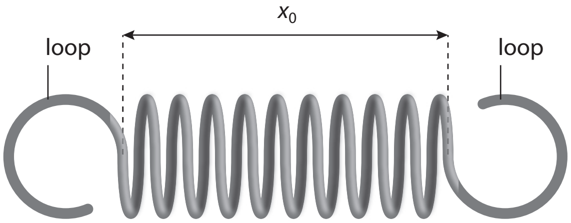

Figure 1.2: Spring with loops at ends.

2 Suspend the spring from the rod of a clamp.

Attach 500 g from the bottom of the spring as shown in Figure 1.3.

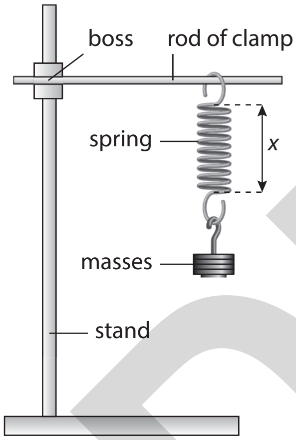

Figure 1.3: Spring suspended from rod with weights.

3 Measure the length of the coiled section x of the extended spring as shown in Figure 1.3 and write your answer in the Results section.

4 Record the masses of the mass hanger and each of the slotted masses separately to the nearest 0.1 g in Table 1.2 in the Results section.

Results

x_0 = …………… cm x = …………… cm

Mass / g				
mass hanger	mass 1	mass 2	mass 3	mass 4

Table 1.2: Results table.

Analysis, conclusion and evaluation

a Calculate the extension e of the spring using:

$e = x - x_0$

Give your answer in metres.

e = ... m

b Calculate the total value m of the mass hanger and the 100 g slotted masses.

Give your answer in kg.

m = ... kg

c $F = m \times g$, where g is acceleration of free fall equal to 9.81 m s^{-2}.

Calculate the spring constant k using $k = \frac{F}{e}$

k = ... N m^{-1}

d The following will contribute to the **uncertainty** in x:

- both ends of the rule must be viewed at the same time
- the exact positions where the coiled section starts and ends may be unclear.

List *two* further sources of uncertainty.

....

....

e Calculate the mean value of a 100 g slotted mass using the values in Table 1.2.

Mean value = ... g

f Calculate the uncertainty in the value of a 100 g mass from the half **range** given by:

$$\frac{\text{largest value of mass} - \text{smallest value of mass}}{2}$$

Uncertainty = ... g

KEY WORDS

uncertainty (also absolute uncertainty): an estimate of the spread of values around a measured quantity within which the true value will be found

KEY EQUATION

uncertainty = $\frac{1}{2}$ (maximum reading – minimum reading)

KEY WORD

range: the difference between the largest value and the smallest value of a measurement

Part 2: Using a newton-meter to measure force

Safety considerations

- Make sure you have read the Safety advice at the beginning of this book and listen to any advice from your teacher before carrying out this investigation.
- Take care when moving the bottom clamp because the spring balance and/or the spring could slide off the end of the rod.

Method

1 Set up the apparatus as shown in Figure 1.4. Use the same spring as you used in Part 1.

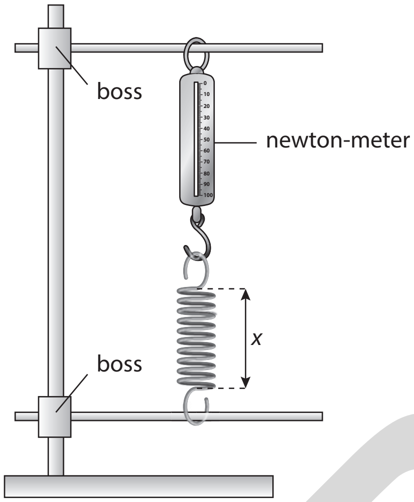

Figure 1.4: Spring between two rods, with newton-meter.

TIP

The newton-meter will record a reading of force F in newtons.

2 Move the bottom clamp vertically to different positions. Take a series of readings of F and x.

Record your data in Table 1.3 in the Results section.

Results

F / N	x / cm	e / cm

Table 1.3: Results table.

Analysis, conclusion and evaluation

a Calculate the extension e of the spring and add these values to Table 1.3.

b Plot a graph of e on the y-axis against F on the x-axis using the graph grid on the next page.

c Draw the straight line of best fit.

d Determine the gradient of this line.

Gradient = ...

e Extension question. Show that:

$$k = \frac{1}{\text{gradient}}$$

....

....

f Extension question. Determine k from your gradient.

k = ... N m^{-1}

g Measure x_0 again. Has it changed? If so, how does this affect your value of k?

....

....

h Suppose you repeated the experiment with a stiffer spring. Draw a dotted line on the graph grid to show the expected result.

i In Table 1.4, list the advantages and disadvantages of using a newton-meter compared to a number of slotted masses.

Advantages	Disadvantages

Table 1.4: Advantages and disadvantages.

Practical investigation 1.3: Determining the resistance of a metal wire

KEY EQUATION

resistance $R = \frac{V}{I}$

The **resistance** of a resistor is defined by:

$$\frac{\text{potential difference across the resistor}}{\text{current in the resistor}}$$

or, expressed in symbols:

$$R = \frac{V}{I}$$

The standard unit for resistance in the SI system of units is the ohm (Ω).

YOU WILL NEED

Equipment:

• 1.5 V cell • connecting leads • crocodile clips • power supply • two digital multimeters • rheostat • metre rule • switch.

Access to:

• reel of wire • scissors • adhesive tape • wire cutters • micrometer.

Safety considerations

- Make sure you have read the Safety advice at the beginning of this book and listen to any advice from your teacher before carrying out this investigation.
- There are no other specific safety issues with this investigation.

Part 1: Using digital multimeters

Method

1 Switch on one of the multimeters. When the dial is moved from the OFF position there are several possible ranges.

These could include:

- direct voltage
- alternating voltage
- direct current
- resistance.

Some of these ranges are shown in Table 1.5.

	Range from zero to:	Precision to the nearest:
direct voltage	600 V	1 V
	200 V	0.1 V
	20 V	0.01 V
	2000 mV (2 V)	1 mV (0.001 V)
	200 mV	0.1 mV
alternating voltage	600 V	1 V
	200 V	0.1 V
direct current	10 A	0.001 A
	200 mA	0.1 mA
	20 mA	0.01 mA
	2000 μA	1 μA
	200 μA	0.1 μA
resistance	2000 kΩ	
	200 kΩ	
	20 kΩ	
	2000 Ω	
	200 Ω	

Table 1.5: Different ranges of multimeters.

Check each range on your multimeter. They should all read zero. You can check the precision by noting where the decimal point is. If you have different ranges to those shown in Table 1.5, add them to the empty rows in this table.

The resistance ranges will all read '1'. This does *not* mean there is a reading of 1 Ω. It means the resistance that is being measured is off the top of the scale. Since no resistor is attached between the terminals of the multimeter, it is measuring a resistance of infinity on all the scales.

2 Connect the multimeter to the cell. If the reading is negative, reverse the connections to the meter.

i Go through the scales.

ii For each scale, record the reading on the multimeter in Table 1.6.

Scale	Reading
600 V	
200 V	
20 V	
2000 mV	
200 mV	

Table 1.6: Results table.

3 Choose the most suitable scale and give reasons for your choice.

…………………………………………………………………………………………

…………………………………………………………………………………………

Part 2: Determining resistance from a single ammeter and voltmeter reading

Method

1 Use the wire cutters to cut a wire of length 110 cm.

2 Use the scissors to cut sufficient tape to attach the wire to the metre rule as shown in Figure 1.5.

Figure 1.5: Wire attached with tape to ends on a metre rule.

3 Connect the circuit as shown in Figure 1.6.

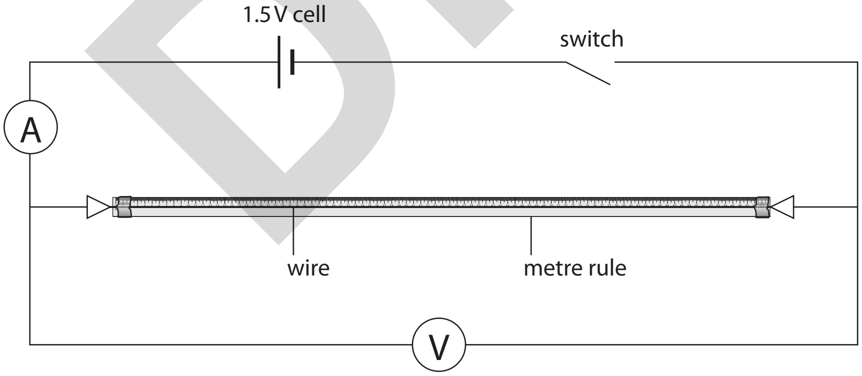

Figure 1.6: Circuit diagram for Part 2.

i How many connecting leads do you need? ……………

ii How many crocodile clips do you need? ……………

4 Switch both meters to suitable scales and record the readings in Table 1.7 in the Results section.

Results

Voltmeter reading *V* / V	Ammeter reading I / mA	I / A

Table 1.7: Results table.

TIP

If *I* in mA is 40, then *I* in amps is 0.040.

Analysis, conclusion and evaluation

a Calculate *R*.

R = …………… Ω

Part 3: Using a rheostat

Method

The rheostat has three terminals, A, B and C, as shown in Figure 1.7.

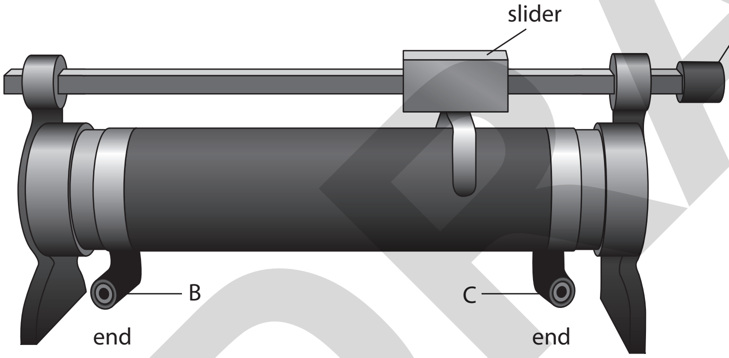

Figure 1.7: Rheostat showing three terminals, A, B and C.

1 Switch the multimeter to the 200 Ω range.

Connect the rheostat to the multimeter and complete Table 1.8.

Connections	Does the resistance reading change when the slider is moved?
A and B	yes / no
B and C	yes / no
A and C	yes / no

Table 1.8: Results table.

Part 4: Determining resistance using a graph

Method

1 Connect the rheostat into the circuit as shown in Figure 1.8.

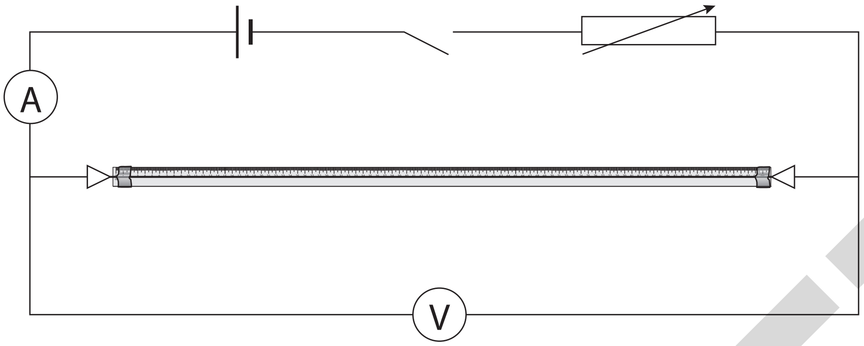

Figure 1.8: Circuit diagram for Part 4.

2 Move the slider on the rheostat and take a series of readings of *V* and *I*.

Record these readings in Table 1.9 in the Results section.

3 Open the switch between readings to prevent discharging the battery.

Results

V / V	*I* / A

Table 1.9: Results table.

Analysis, conclusion and evaluation

a Plot a graph of *I* on the *y*-axis against *V* on the *x*-axis using the graph grid on the next page.

b Draw the straight line of best fit.

c Determine the gradient of this line.

Gradient = ...

d Determine *R* using $R = \frac{1}{\text{gradient}}$

R = ... Ω

e How could you use the rheostat to take a wide range of equally spaced readings?

………………………………………………………………………………………………

………………………………………………………………………………………………

Part 5: Using a micrometer

Resistance per unit length (resistance of 100 cm length of wire) depends on the diameter of the wire. Table 1.10 shows the properties of some wires A, B, C, D and E.

Wire	Diameter / mm	Resistance per unit length / Ω m^{-1}
A	0.38	4.4
B	0.27	8.3
C	0.19	16.8
D	0.15	27.0
E	0.10	60.0

Table 1.10: Properties of wires A, B, C, D and E.

Method

1 Use the micrometer to measure the diameter of your wire.

Diameter = …………… mm

Analysis, conclusion and evaluation

a Use the data in Table 1.10 and your value of *R* to identify the most similar wire.

………………………………………………………………………………………………

b Give a reason(s) for your choice.

………………………………………………………………………………………………

………………………………………………………………………………………………

c Theory suggests that the graph line in Part 4 should go through the point (0, 0).

Suppose you repeated the experiment with a wire of smaller diameter. Draw a dotted line on the graph grid in Part 4 to show the expected result.

Practical investigation 1.4: Determining the average speed of a cylinder rolling down a ramp

The **average speed** of an object is defined by:

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

or, expressed in symbols:

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

The standard unit for speed in the SI system of units is m s^{-1}.

KEY EQUATION

average speed $v = \frac{d}{t}$

YOU WILL NEED

Equipment:

- cylinder
- wooden board
- stand
- boss
- clamp
- metre rule
- protractor
- stopwatch
- book or pencil case to act as a barrier at the bottom of the ramp.

Safety considerations

- Make sure you have read the Safety advice at the beginning of this book and listen to any advice from your teacher before carrying out this investigation.
- Use a book or a pencil case to stop the cylinder after it has reached the bottom of the wooden board.

Part 1: Investigating reaction time

Method

1 Set your stopwatch to zero.

2 Switch the stopwatch on and off as quickly as you can and record the reading.

3 Repeat this reading twice more and record the three values in Table 1.11 in the Results section.

Results

t_1 / s	t_2 / s	t_3 / s

Table 1.11: Results table.

Analysis, conclusion and evaluation

a Calculate the mean value of t.

t = ... s

b Figure 1.9 shows a reading of 1.44 seconds on a stopwatch.

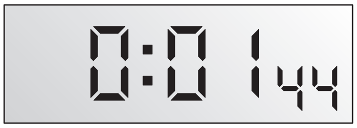

Figure 1.9: Digital display reading 0:01(44).

Use your result in Table 1.11 to calculate the **percentage uncertainty** in the reading in Figure 1.9. You may assume that the absolute uncertainty in the reading on the stopwatch is the same as the absolute uncertainty in your readings in Table 1.1.

Percentage uncertainty = ...%

KEY EQUATION

$$\textbf{percentage uncertainty} = \frac{\text{uncertainty}}{\text{mean value}} \times 100\%$$

KEY WORDS

percentage uncertainty: the absolute uncertainty as a fraction of the measured value

Part 2: Determining average speed

Method

1 Set up the apparatus as shown in Figure 1.10.

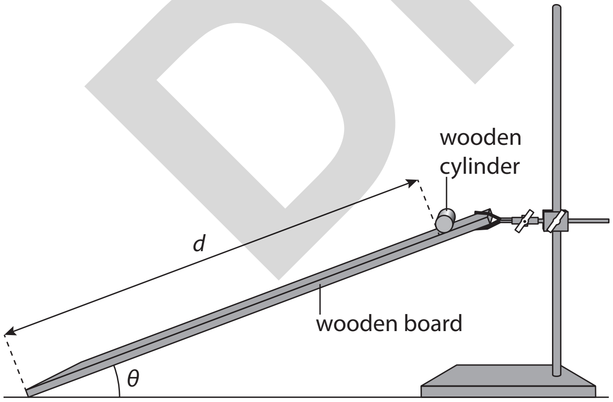

Figure 1.10: Wooden cylinder on sloping board.

2 Place the cylinder near the top of the wooden board.

Measure the distance *d* that the cylinder will travel down the wooden board when it is released. Write this value in the Results section.

3 Release the cylinder and measure the time t_1 for the cylinder to travel the distance *d* down the slope.

4 Repeat this reading and record the three values in Table 1.12 in the Results section.

Results

d = ... cm

t_1 / s	t_2 / s	t_3 / s

Table 1.12: Results table.

Analysis, conclusion and evaluation

a Calculate the mean value of *t* from your results in Table 1.12.

Mean value of t = ... s

b Calculate the average speed *v*.

v = ... cm s^{-1}

Part 3: Investigating how the average speed depends on the angle of the plane

Method

1 Use the protractor to measure the angle θ between the plane and the bench as shown in Figure 1.10.

2 Take a series of readings of θ and *t*.

Record your data in Table 1.13 in the Results section.

Results

	t / s			
θ / °	1st value	2nd value	3rd value	Mean

Table 1.13: Results table.

Analysis, conclusion and evaluation

a Use Table 1.14 to record calculated values of sin θ, t sin θ and v.

sin θ	t sin θ / s	v / cm s^{-1}

Table 1.14: Results table.

b Plot a graph of v on the y-axis against t sin θ on the x-axis using the graph grid on the next page.

c Draw the straight line of best fit.

d Determine the gradient of this line.

Gradient = ……………

e The relationship between v, t and θ is:

$$v = \left(\frac{gt}{3}\right)\sin\theta$$

where g is the acceleration of free fall.

Use your gradient to determine a value for g.

g = …………… m s^{-2}

f The accepted value for *g* is 9.81 m s^{-2} (or 981 cm s^{-2}) and the theory predicts that the *y*-intercept is zero.

Does your value for *g* differ from the accepted value?

……………………………………………………………………………………………

……………………………………………………………………………………………

g Does your straight line of best fit go through (0, 0)?

……………………………………………………………………………………………

……………………………………………………………………………………………

h Are there any anomalous point(s) that you did not include in your straight line of best fit?

……………………………………………………………………………………………

……………………………………………………………………………………………