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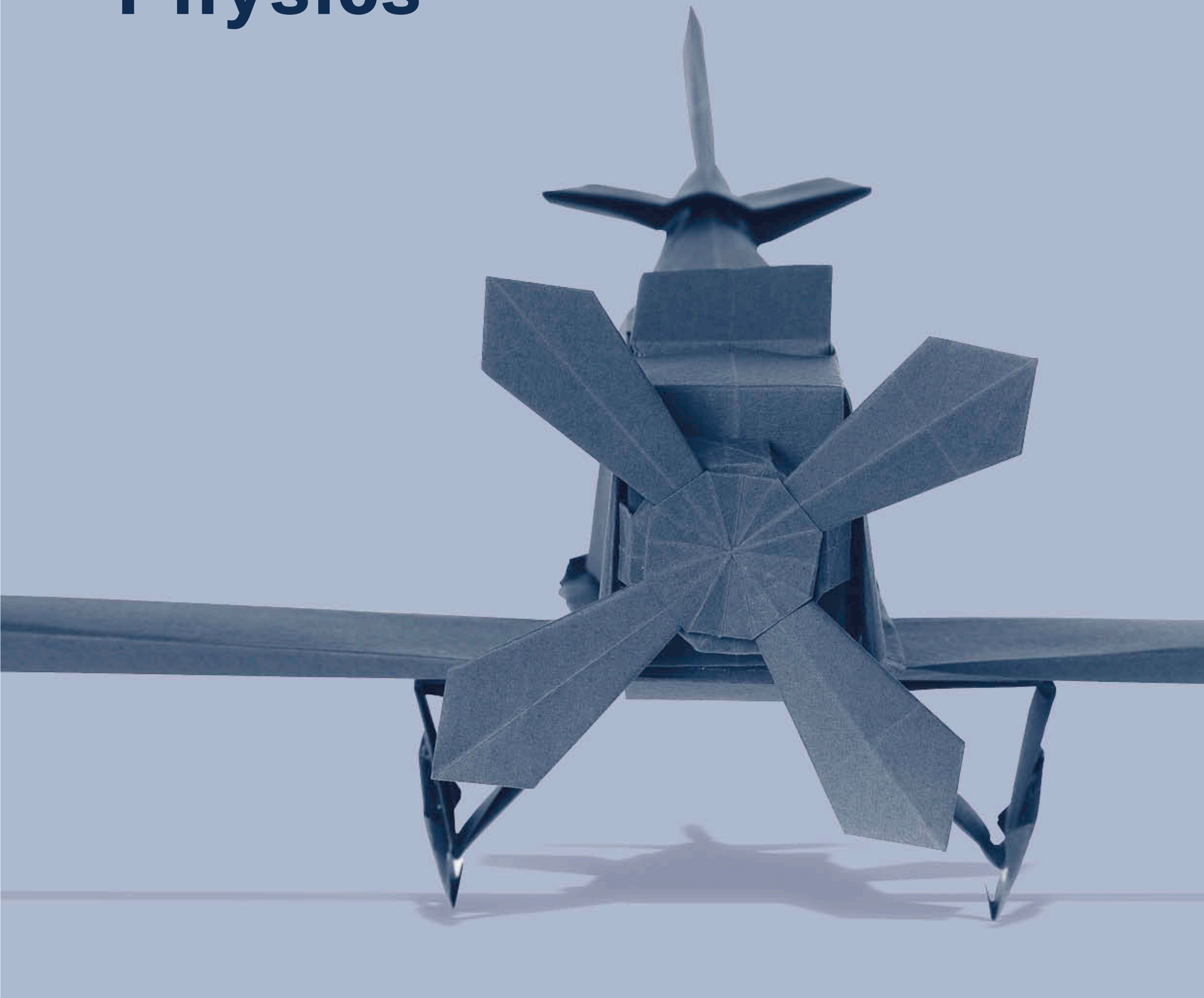
AS and A Level Physics



TRANSITION GUIDE

Reinforcing knowledge, skills and literacy in physics

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Contents

Introduction

Reinforcing knowledge, skills and literacy in physics

The transition from KS4 to KS5 is never entirely easy, and physics throws up its own unique challenges in this regard. It is both helped and hindered by the similarity between the concepts covered at GCSE and A-Level. While familiar topics such as Electrical Circuits and Motion Graphs can be reassuring to year 12 students they can also encourage a false sense of security. Students often do not fully appreciate the additional skillset they need to apply to familiar material; a simple and common example being using speed = distance/time when equations of motion for constant acceleration would be the appropriate way to approach a problem. This guide attempts to revisit familiar topics and re-teach them with direct reference to the skills expected of a KS5 physicist. The skills covered in each lesson are made explicit in the lesson overview.

GCSE Physicists often compartmentalise topics. Many see the study of Motion, Electricity and Waves as entirely separate without appreciating the fundamental skills and logic reasoning that link them together. Therefore this guide covers both Motion and Electricity, the lessons should hopefully demonstrate that the same underlying approach is used when studying both topics. It also offers an opportunity for revision of a topic that might not otherwise be covered until late in the AS year, when GCSE knowledge is all but forgotten.

These transition materials include:

- baseline assessment
- teaching ideas
- practice questions
- examples of student answers with commentary.

This guide can serve two purposes.

1 Learners will feel they are learning something new and will not get bored with over-repetition – particularly true for your most able learners.

2 Learners will be able to discover very early on in the course whether A level chemistry is really a suitable subject choice for them.

You may choose to use this resource in one of several ways.

- After KS4 exams – if your school brings back Yr11 learners after their exams.
- In sixth-form induction weeks.
- As summer homework in preparation for sixth form.
- To establish the level of performance of your students from their range of KS4 qualifications.

Lesson suggestions

The five lessons are designed to touch upon some of the key content at AS level as well as revising ideas from GCSE. Alongside the content they also introduce some of the critical skills for a KS5 physicist such as:

- applying mathematics to graphs
- using positive and negative number to convey direction
- re-arranging equations and logical deduction.

They are designed with customisation in mind – most suggest multiple options for starter, main and plenary activities leaving you to pick the most appropriate activities for your learners and your timeframe. They are also designed to encourage your learners to be independent. By minimising the number of worksheets and handouts we hope to encourage good note-taking and academic resilience, both key attributes of successful KS5 learners in all subjects.

Transition guide overview

Topic	Specification links		Resources
	AS objectives covered	GCSE objectives reviewed	
Motion: Constant Acceleration	12. Understand scalar and vector quantities and know examples of each type of quantity and recognise vector notation. 9. Be able to use the equations for uniformly accelerated motion in one dimension.	3.1 Demonstrate an understanding of the following as vector quantities: **a** displacement **b** velocity **c** acceleration **d** force. 3.3 Recall that velocity is speed in a stated direction. 3.4 Use the equation for speed. 3.5 Use the equation for acceleration.	• Students' strengths and misconceptions • Teaching ideas: Starters, main activities and plenaries • Practice questions • Exam report and discussion
Motion: Motion Graphs	10. Be able to draw and interpret displacement/time, velocity/time and acceleration/time graphs. 11. Know the physical quantities derived from the slopes and areas of displacement/time, velocity/time and acceleration/time graphs, including cases of non-uniform acceleration and understand how to use the quantities.	3.2 Interpret distance/time graphs including determination of speed from the gradient. 3.6 Interpret velocity/time graphs to: **a** compare acceleration from gradients qualitatively **b** calculate the acceleration from the gradient (for uniform acceleration only).	• Students' strengths and misconceptions • Teaching ideas: Starters, main activities and plenaries • Practice questions • Exam report and discussion

Topic	Specification links		Resources
	AS objectives covered	GCSE objectives reviewed	
Forces: Mass and Weight	18. Be able to use the equations for gravitational field strength and weight.	3.14 Use the equation for gravitational field strength. 3.16 Recall that in a vacuum all falling bodies accelerate at the same rate.	• Students' strengths and misconceptions • Teaching ideas: Starters, main activities and plenaries • Practice questions • Exam report and discussion
Electricity: Series Circuits	31. Understand that electric current is the rate of flow of charged particles and be able to use the equation link current charge and time. 32. Understand how to use the equation linking voltage charge and energy. 33. Understand that resistance is defined by $V = IR$ and that Ohm's law is a special case when $I \propto V$ for constant temperature. 35. Understand how the distribution of potential differences in a circuit is a consequence of energy conservation.	1.9 Recall that an electric current is the rate of flow of charge. 2.1 Describe how an ammeter is placed in series with a component to measure the current, in amps, in the component. 2.3 Explain how the current in a circuit depends on the potential difference of the source. 2.5 Demonstrate an understanding that potential difference (voltage) is the energy transferred per unit charge passed and hence that the volt is a joule per coulomb. 2.4 Describe how a voltmeter is placed in parallel with a component to measure the potential difference (voltage), in volts, across it. 2.8 Use the equation $V = IR$. 5.1 Describe current as the rate of flow of charge and voltage as an electrical pressure giving a measure of the energy transferred.	• Students' strengths and misconceptions • Teaching ideas: Starters, main activities and plenaries • Practice questions • Exam report and discussion

<table>
<tr><th rowspan="2">Topic</th><th colspan="2">Specification links</th><th rowspan="2">Resources</th></tr>
<tr><th>AS objectives covered</th><th>GCSE objectives reviewed</th></tr>
<tr><td>Electricity: Parallel Circuits</td><td>34. Understand how the distribution of current in a circuit is a consequence of charge conservation.

36. Be able to derive the equations for combining resistances in series and parallel using the principles of charge and energy conservation, and be able to use these equations.</td><td>1.11 Use the equation Relating charge current and time.

2.2 Explain how current is conserved at a junction.</td><td>● Students' strengths and misconceptions
● Teaching ideas: Starters, main activities and plenaries
● Practice questions
● Exam report and discussion</td></tr>
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The table below outlines the types of resources to be found in each section along with a description of its intended uses.

Type of resource	Description
Baseline assessment	This tests fundamental understanding of understanding from GCSE.
Students' strengths and misconceptions	Students' strengths and common misconceptions.
Teaching ideas	These provide starters, main activities and plenaries for each section.
Practice questions	Checking understanding of key points from Baseline assessment. Checking understanding of new KS5 learning.
Exam practice and Examiners' report	How to answer exam-type questions and KS5 level.

Baseline assessment

Name: ______________________________ Form: ______________

Physics group: ______________________________

GCSE Physics/Science grade: ____________________

Date: ______________________________

Question	Marks
1	/5
2	/6
3	/10
4	/8
Motion total	/29
1	/6
2	/6
3	/12
Electricity total	/24
Grand Total	/53
%	
Grade	

Target grade

- ☐ **OT**
- ☐ **BT**
- ☐ **AT**

Targets for improvement

- ☐
- ☐
- ☐
- ☐
- ☐
- ☐
- ☐

Motion

1 A car is travelling along a level road.

a The car travels at constant velocity. It covers 250 m in 40 s. Calculate the average velocity during this time.

(2 marks)

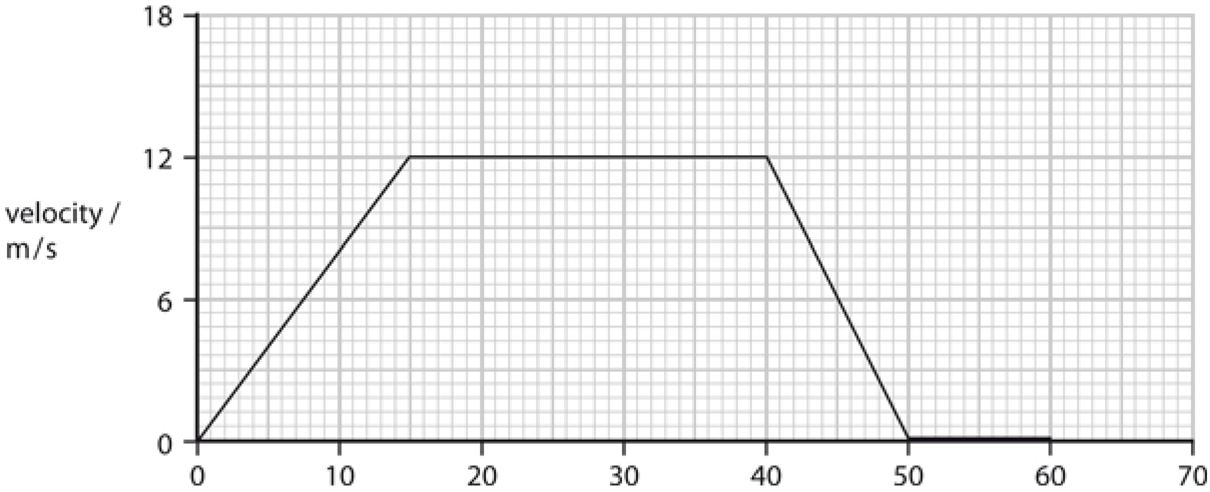
b The car now accelerates in a straight line.

Its average acceleration is 12 m/s^2.

Calculate the increase in velocity of the car in 4.0 s.

(3 marks)

2 The graph shows a velocity-time graph for a cyclist over a time of 60 s.



a **i** When is the cyclist travelling with greatest velocity?
Place a cross (☒) in the box next to your answer.

A for the first 15 seconds ☐
B between 15 and 40 seconds ☐
C between 40 and 50 seconds ☐
D for the last 10 seconds ☐

(1 mark)

ii Calculate how long the cyclist is stationary for in seconds.

(1 mark)

iii Calculate how far the cyclist travels in metres during the first 40 seconds.

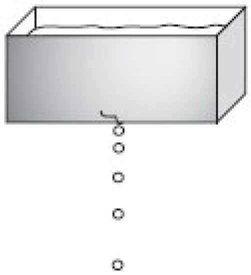
(1 mark)

b A different cyclist accelerates for 8 s. During this time they accelerate from 3 m/s to 14.2 m/s.

Calculate the acceleration during this time.

(3 marks)

3 A water tank drips water.



a Scientists could use four quantities to describe the movement of the water drops.

Three of these quantities are vectors.

The other quantity is a scalar.

acceleration	force	mass	velocity

i Complete the sentence by putting a cross (☒) in the box next to your answer.

The scalar quantity is…

A acceleration ☐

B force ☐

C mass ☐

D velocity ☐

(1 mark)

ii State any vector quantity **not** listed above.

(1 mark)

iii Complete the following sentence using one of the quantities from the word box above.

In a vacuum, all bodies falling towards the Earth's surface have the same

____________________.

(1 mark)

b The mass of one water drop is 0.00008 kg.
Calculate its weight in Newtons.
(Gravitational field strength is 10 N/kg)

(2 marks)

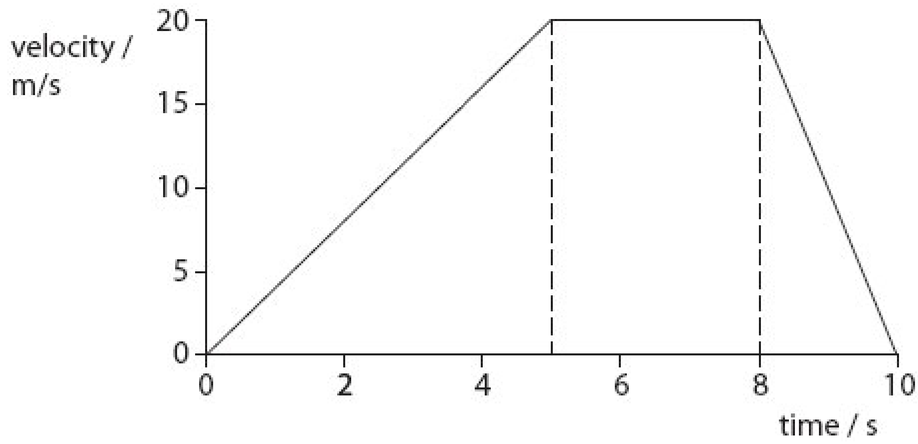
c The water drop falls to the ground, 13 m below, in 1.7 s.
Calculate the average speed in m/s of the drop while it is falling.

(2 marks)

d Assuming the droplet starts at rest calculate the velocity just before it hits the ground. Ignore air resistance.
($g = 10 m/s^2$)

(3 marks)

4 The graph shows how the velocity of a small car changes with time.



a Use the graph to estimate the velocity of the car at three seconds.

(1 mark)

b Calculate the acceleration in m/s^2 of the car when it is speeding up.

(2 marks)

c Explain why the units of acceleration are m/s^2.

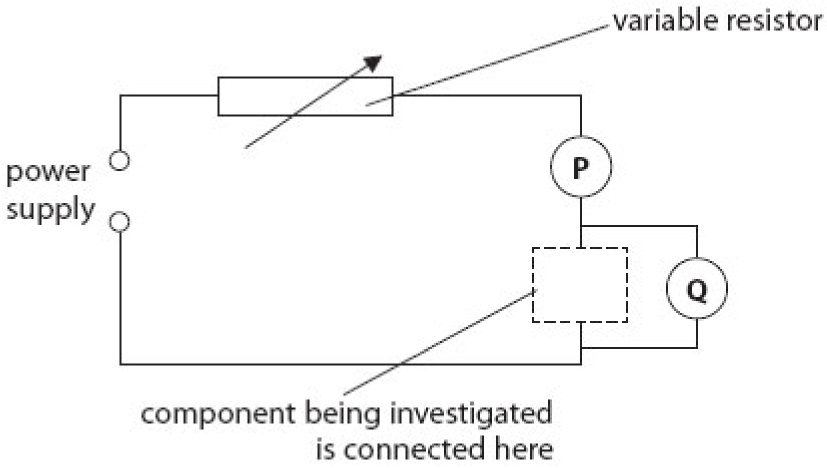
(2 marks)

d Show that the car travels further at a constant velocity than it does when it is slowing down.

(3 marks)

Electricity

1 Some students investigate the electrical resistance of different components using this circuit.



a Which row of the table is correct for both meters P and Q?

Place a cross (☒) in the box next to your answer.

		meter P is	meter Q is
A	☒	an ammeter	an ammeter
B	☒	an ammeter	a voltmeter
C	☒	a voltmeter	a voltmeter
D	☒	a voltmeter	an ammeter

(1 mark)

b One of the components being investigated is a 12 ohm resistor.

When it is in the circuit, the ammeter reading is 0.50 A.

Calculate the voltmeter reading.

(2 marks)

c The students reduce the resistance of the variable resistor.

State what happens to the readings on each of the meters P and Q. Explain what happens to P.

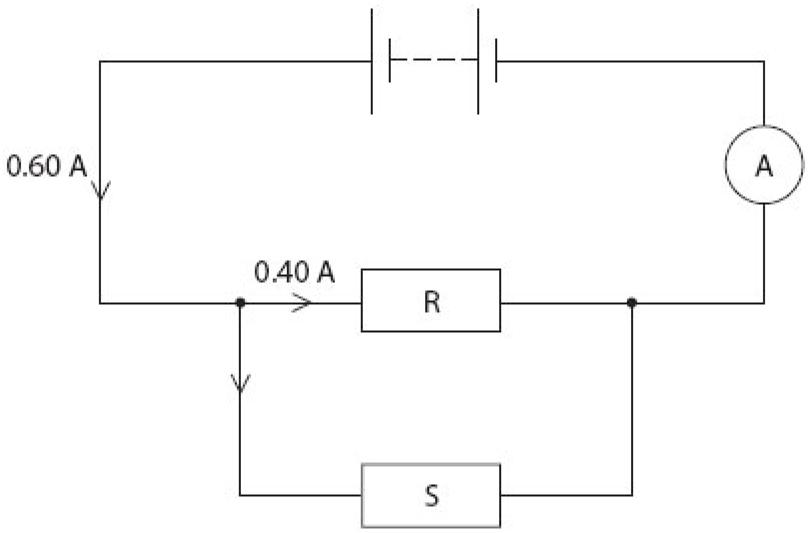
(2 marks)

d The students then reduce the voltage of the power supply.

State what happens to the current in the circuit.

(1 mark)

2 **a** The diagram shows an electric circuit with two resistors, R and S.



i R has a resistance of 11 ohms.

Calculate the potential difference across R.

(2 marks)

ii Use information from the diagram to calculate the current in S.

(1 mark)

iii Calculate the resistance of S.

(2 marks)

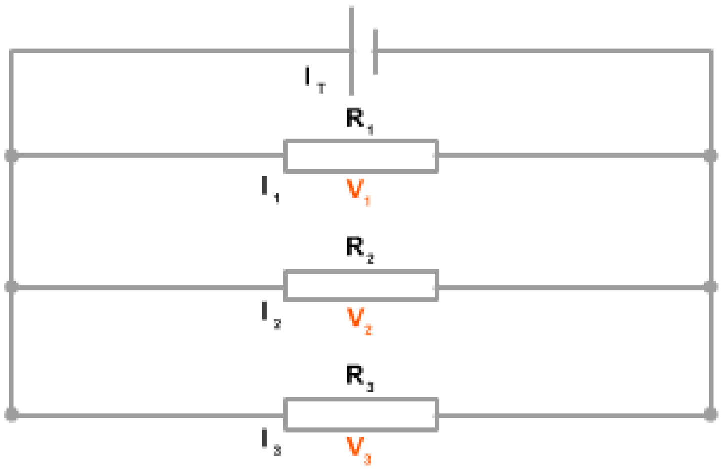
b Complete the sentence by putting a cross (☒) in the box next to your answer.

A student wants to measure the battery voltage with a voltmeter.
The voltmeter should be placed...

A in series with the battery ☒
B in parallel with the battery ☒
C in parallel with the ammeter ☒
D in series with either resistor R or S ☒

(1 mark)

3 The diagram shows an electric circuit with three resistors, R_1, R_2 and R_3.



a **i** R_1 has a resistance of 5 ohms. The current flowing in it is 2A.
Calculate the potential difference across R_1.

(2 marks)

ii State the voltage provided by the battery

(1 mark)

b **i** The resistance of R_2 is 10 ohms and R_3 is 4 ohms. Calculate the combined resistance of R_1, R_2 and R_3 in this arrangement.

(4 marks)

ii Calculate the current being produced by the battery.

(2 marks)

c Calculate the current flowing in:

i R_2

ii R_3

(3 marks for **i** and **ii** combined)

-End of assessment-

Section 1: Constant acceleration

Students' strengths and common misconceptions

The table below outlines the areas in which most students do well and the common mistakes and misconceptions across the topics listed.

	Strengths	**Common mistakes**
Vectors and Scalars	Most students will already be able to state some vectors and scalars and recall the definition of a vector.	At GCSE applying mathematics to vector quantities is taught in a huge variety of ways. Some learners will have covered the topic with full mathematical detail while others will have been given a scaffolded approach that works for GCSE but does not give the full picture. These formulaic methods are often deeply entrenched and must be challenged at KS5.
Using Equations	Students will be familiar with applying equations and know some of the equations being used. Most, but not all, candidates will be confident with re-arranging equations, particularly if your centre requires B grades in GCSE Maths and Physics to take the course. It is probable that students how have chosen the course *like* using equations, as this is one of the major parts of GCSE.	As the equations being used for uniform motion are all similar and contain four rather than three variables the often taught GCSE approach of 'find an equation in the formula sheet that fits and plug in the numbers' tends to fail. Students struggle in particular with distinguishing initial and final velocity. The issues with negative numbers discussed above apply here.

Teaching ideas

Objectives

- Revise vectors and scalars.
- Assign + and – signs to vector quantities, based on direction.
- Perform calculations using the equations for uniformly accelerated motion.

Starter activities

Vectors and scalars

This activity is designed to aid recall of GCSE material and stimulate discussion of the definition of a vector. It should be relatively unchallenging and could be used with weaker learners to build confidence.

Sort the quantities into vectors and scalars.
Explain your reasoning for each one.

Mass, Weight, Force, Speed, Velocity, Acceleration,
Distance, Displacement, Energy, Time

A Tale of Two Cities

This is a challenging activity designed to really make learners think about the vector nature of velocity. It should really highlight vectors misconceptions from GCSE. It also provides revision of graphs, which are covered in the next topic.

The cities of Principia and Mathematica are connected by a straight 100km long road.

1. Cars A and B leave Mathematica at the same time. Car A travels at 60 km/hr while car B travels at 40 km/hr. What is the difference in time between their arrivals in Principia?
2. Car C starts in Mathematica, travelling at 60 km/hr. Car D starts in Principia, travelling at 40 km/hr. They leave at the same time.
   - **a** Draw a diagram to show where both cars are after half an hour.
   - **b** When and where do the cars pass each other?
   - **c** There are at least two ways of solving part B. Find another way of getting the solution.
   - **d** Sketch displacement time graphs for both cars on the same axis. Consider their starting points and gradients carefully. What do you notice?
   - **e** Extension – both cars turn around when they reach their respective cities but maintain the same speeds. Have their velocities changed? When will they next pass? When will C **overtake** D (same position travelling in the same direction)?

Main activities

Acceleration and ramps

This is a simple practical to do as it requires very no specialist equipment. It revises the GCSE equation speed = distance/time and introduces the first equation of motion by applying it to students own data. The practical will not give perfect data and can lead to a productive discussion of errors and uncertainties. By reversing the direction of motion it can really illuminate the vector nature of the quantities studied.

Recap the GCSE equation for acceleration and introduce $v = u + at$. Show (or get students to show) that they are the same.

Have students set up ramps at an angle and roll cylinders (old batteries work well) down the ramps a few times. Ask questions such as: What is the initial velocity? Does velocity change? Why does it change? Does it accelerate? How could we calculate final velocity?

Distribute tape or chalk to make a line a short (known) distance from the bottom of the ramp. Using two timers students will then be able to measure the time taken to go down the ramp and the time taken to cover the final part. They can then calculate final velocity and acceleration. By starting at different heights students can investigate if acceleration is constant. There will be systematic errors here which could be discussed.

Once students are comfortable with this have them flick the cylinders up the ramp. They will need to adjust the markings so they can effectively measure initial velocity. By timing how long it takes the cylinder to stop they can calculate acceleration.

Compare the up and down accelerations and discuss whether the values make sense with the theory. Discuss what sign the accelerations and velocities should have. Emphasise the importance of consistency, and opposite directions having opposite signs.

This activity can be extended to explore $s = (u + v)t \div 2$, the average speed equation. Have students measure the distance taken to stop, going up the ramp and compare with the calculated value from u, v and t. Other equations of motion can be explored in a similar manner.

How high can you throw?

This practical is slightly harder than the previous one, both in theory behind it and execution. However it has the additional benefit of investigating free fall, and the data it produces is affected less by systematic errors. The competitive nature of part 2 will appeal to some students.

Part 1

Hang meter rulers vertically using clampstands. Have students practice throwing a ball bearing or marble up so it leaves their hand at 0 on the meter ruler and does not go above the top of the meter ruler.

Once they have the hang of this they can measure time to the top and displacement and use the average velocity equation, re-arranged, to calculate initial velocity. They can then use $v = u + at$ to calculate acceleration. Question why they are getting a negative value.

Once acceleration is known, or assuming it to be g, they can measure the time taken to go up and down again. Question what displacement will be (zero). Calculate initial velocity using $s = ut + \frac{1}{2}at^2$.

Part 2

Take the class outside. Have students throw a tennis ball or similar as high as they can in the air. Time the flight, discussing when best to stop the timer. From measurements calculate initial velocity and distance travelled. Using $a = +g$ will give negative displacements and initial velocities. Discuss why this is.

Plenaries

Choosing equations and setting values

Creating models, the objective of this activity, is in our opinion what physics is really all about. This activity breaks down the modelling process, encouraging students to think logically about which values and equations to use.

In this activity students will set up a 'SUVAT' model of situations and decide which equation of motion needs to be solved. Distribute worksheets with the following repeated several times:

S =   U =   V =   A =   T =   Equation to use:

Or have students write this out several times.

Show a series of SUVAT problems on the board. Students will need to find three of s, u, v, a and t and decide which of the remaining two they are being asked to find. They should fill these in on their blank SUVATS. They then need to decide which equation of motion will give a solution. This should be done relatively quickly – students do not need to then solve the equation to find the value. Pause for discussion of each example, focusing on direction and signs of quantities. The problems could then be solved for homework.

Practice questions

1 Which of the following is a scalar quantity?

Place a cross (☒) in the box next to your answer.

A acceleration ☐

B displacement ☐

C force ☐

D work ☐

(1 mark)

2 A cyclist travelling at a speed of 4.2 m s^{-1} accelerates at 1.1 m s^{-2}. In a time of 7.4 s what is the distance travelled?

Place a cross (☒) in the box next to your answer.

A 30 m ☐

B 35 m ☐

C 61 m ☐

D 91 m ☐

(1 mark)

3 Complete the sentence by putting a cross (☒) in the box next to your answer.

A building has 5 floors. The windows on successive floors are separated by the same vertical distance.

A brick is dropped from a window on each floor at the same time. The bricks should hit the ground at…

A decreasing time intervals ☐

B equal time intervals ☐

C increasing time intervals ☐

D the same time ☐

(1 mark)

4 **a** Explain the difference between scalar and vector quantities.

(1 mark)

b When asked to run one complete lap around a track, a student says, ‘However fast I run, my average velocity for the lap will be zero.’

Comment on his statement.

(3 marks)

5 This photograph shows an athlete performing a long jump.

At take-off his horizontal speed is 8.0 m s^{-1} and his vertical speed is 2.8 m s^{-1}.

a Show that the total time the athlete spends in the air is about 0.6 s.

Assume that his centre of gravity is at the same height at take-off and landing.

(3 marks)

b Calculate the horizontal distance jumped by the athlete.

(2 marks)

c In reality, when the athlete lands his centre of gravity is 50 cm lower than its position at take-off.

Calculate the extra horizontal distance this enables the athlete to jump.

(4 marks)

Examples of students' responses from Results Plus – Examiners' report

Here are some commentaries on and examples of answers to questions used in this section – you may want to print out the answers and ask your students to mark them before sharing the examiners' commentaries.

1 This is a simple recall question: teachers should give students plenty of practice in identifying examples of scalars and vectors in physics.

2 This shouldn't pose a problem to students using the technique presented in this lesson. In the exam from which this question is taken, about two-third of candidates could do this correctly.

3 The most frequent response here was **B**, showing that students are often not clear about the meaning (in terms of the implication for speed and time intervals) of acceleration, especially when it is a 'constant' acceleration. Some time should be spent on examples to consolidate this.

4 **a** The word 'magnitude' causes some problems here. The response 'scalars have size, whereas vectors have size and magnitude' illustrates this. Most knew that a vector involved something extra, but either expressed it poorly or selected the wrong factor for the difference e.g. 'scalar quantity only has direction'.

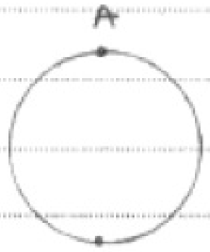
> A scaler quantity has magnitude but no direction, such as mess, a vector quantity has magnitude and direction such a weight.

This good response answer gains the mark for explaining the difference and also includes examples of each.

b This question tests students' ability to apply the idea in **a** so it is surprising how few candidates thought the conclusion was incorrect despite having answered **a** correctly. The clearest answers simply quoted the formula for velocity, stated that the final displacement was zero and drew the appropriate conclusion. Answering in bullet points is an effective strategy.

The student is referring to the fact that his total displacement will equal zero so however fast he went zero divided by any number still equals zero so his statement is true and accurate.

This response gains two marks because it has identified the zero displacement and how it leads to zero velocity, but has not explicitly stated why 'zero divided by any number' is relevant – e.g. by stating the formula for velocity.



Suppose he starts at A. When he completes the journey around the track, his displacement equals to 0 (as he returns to the initial position and displacement is a vector)

$$\text{Velocity} = \frac{\text{displacement}}{\text{time}} = \frac{0}{\text{time}} = 0$$

His statement is correct.

This answer has set out the three required points. Although they are in a different order to the mark scheme, they still show a logical progression from displacement = 0, to velocity = displacement ÷ time to velocity = 0.

5 There is more than one way to approach this but we recommend students calculate the time taken to reach the maximum height and then double that to give the total time of flight; more able mathematicians might put the total displacement at zero and then solve the quadratic equation to find the time. A common problem is to ignore the fact that if the initial velocity is 2.8 m s^{-1} then the value of g is -9.8 m s^{-2}. Ignoring the negative lost a mark.

Students should note the number of marks available and conclude part **b** is a fairly straightforward calculation. In the examination, some mistakenly tried to combine the horizontal and vertical velocities when calculating the horizontal distance travelled.

Part **c** is more challenging; good students substituted the new vertical displacement of -0.50 m into $s = ut + ½at^2$ and solved the quadratic for the total time.

Section 2: Motion graphs

Students' strengths and common misconceptions

The table below outlines the areas in which most students do well and the common mistakes and misconceptions across the topics listed.

	Strengths	**Common mistakes**
Velocity and Displacement Time Graphs	Students will be familiar with the graphs from GCSE and probably already recall the rules for interpreting them.	Students frequently mix up displacement and velocity graphs. Students will be unfamiliar with graphs going below the x-axis
Calculating Areas and Gradients	Has been covered at GCSE and covered in some detail in Maths GCSE.	Most students find this one of the most challenging parts of GCSE. Methods taught are often inconsistent with Maths, leading to confusion and difficulty applying skills learnt.
y= mx + c	Introduced in Maths GCSE	Conceptually very challenging. Requires re-visiting several times before most students grasp it.

Teaching ideas

Objectives

- Use gradients of displacement/time and velocity/time graphs, and the area under velocity time graphs to calculate physical quantities.
- Plot displacement/time and velocity/time graphs and use them to solve problems involving constant acceleration.
- Use y = mx + c to link equations to graphs.

Starter activity

Graphs for a car

This activity revises the equation covered in the last section and invites students to revisit their GCSE knowledge of motion graphs.

A car, travelling at 20 m/s begins to accelerate uniformly, with a = 3 m/s^2. Fill out the following table.

Time (s)	0	1	4	10	20
Velocity (m/s) (use $v = u + at$)	20				
Displacement (m) (There are two equations you can use for this. Pick one.)				350	

Plot two graphs, one of time against displacement, one of time against velocity.

Comment on the shapes of your graphs, using your GCSE knowledge to explain what they mean.

Main activity

Walk the graph

This activity is a real favourite of ours. It gets students on their feet and gives a real physical feel for what the motion graphs mean. The peer assessment at the end is essential, students become more and more confident in analysing graphs when they have to for the purpose of giving feedback.

Display displacement/time and velocity/time graphs on your board (possibly by using a PowerPoint or other electronic aid). Have a volunteer ‘walk’ the graph. The graphs last 10 seconds and the units of distance are irrelevant, the longest clear line in your classroom is best. After each graph have the students rate the walker’s performance (thumbs up, down or in the middle) and pick students to justify their rating. If the walker has got the graph wrong they, or another student, can be invited to do it again. They start easy and get harder.

Plenary

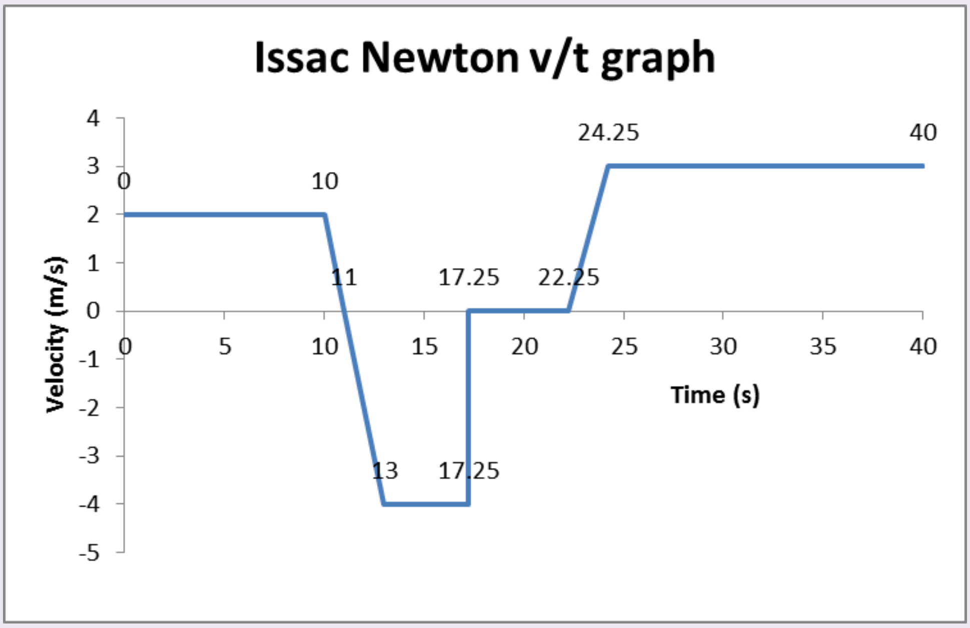
Graph for Isaac Newton

This activity is hard but worthwhile. It asks students to sketch a graph from information given, often overlooked when most (but not all) AS questions ask students to interpret rather than draw. The graph itself is sufficiently complicated to all but ensure mistakes, leading to discussion.

Have students sketch a speed/time graph or a velocity/time graph for this passage.

Isaac set off for the lab one day, walking at a steady pace of 2 m/s. After 10 s he realised he had forgotten the book he was working on. It took him 3 s to change his velocity, after that he sprinted home twice as fast as he had been walking. He stopped instantly and stayed stationary in the house for 5 s while finding his book. Once he had found it he took 2 s to accelerate to a quick walk, then headed to the lab at this slightly faster pace. He reached the lab 15.75 s later.

Have students then swap graphs and critique each other's. They will invariably find mistakes. Then have students compare theirs with the correct graph shown below.



There is all sorts of possible discussion here such as: why is the total time 40 s? why does he sprint backwards for 4.25 s? what does a negative area mean? is stopping instantly realistic? how far away is the lab? what is the total distance travelled? what would a displacement/time or distance/time graph look like? are the speeds realistic?

Practice questions

1 Complete the sentence by putting a cross (☒) in the box next to your answer.

Distance travelled can be found from the...

A area under a velocity-time graph ☐

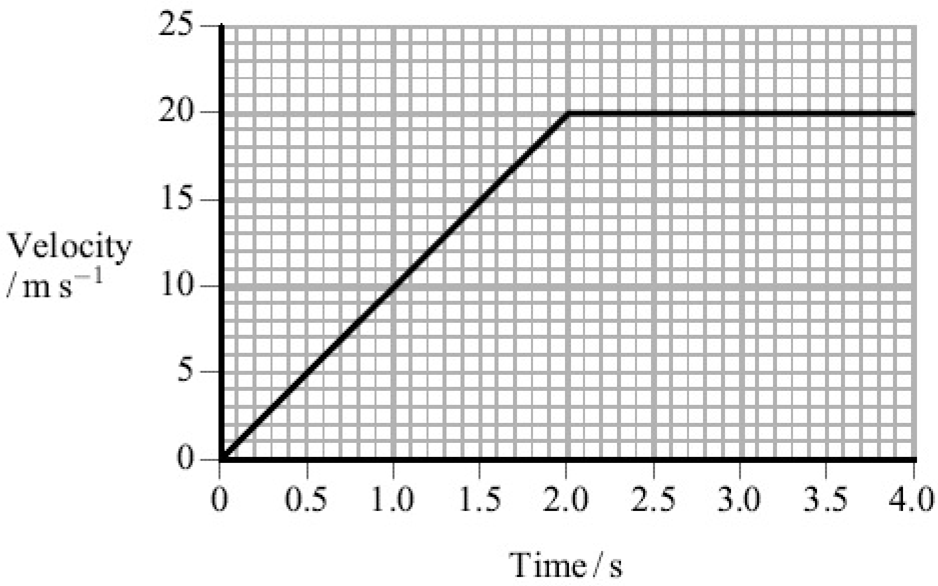
B area under an acceleration-time graph ☐

C gradient of a force-time graph ☐

D gradient of a velocity-time graph ☐

(1 mark)

2 Complete the sentence by putting a cross (☒) in the box next to your answer.



The graph shows how velocity varies with time for an object.

The acceleration at 3 s is...

A 10 $m\ s^{-2}$ ☐

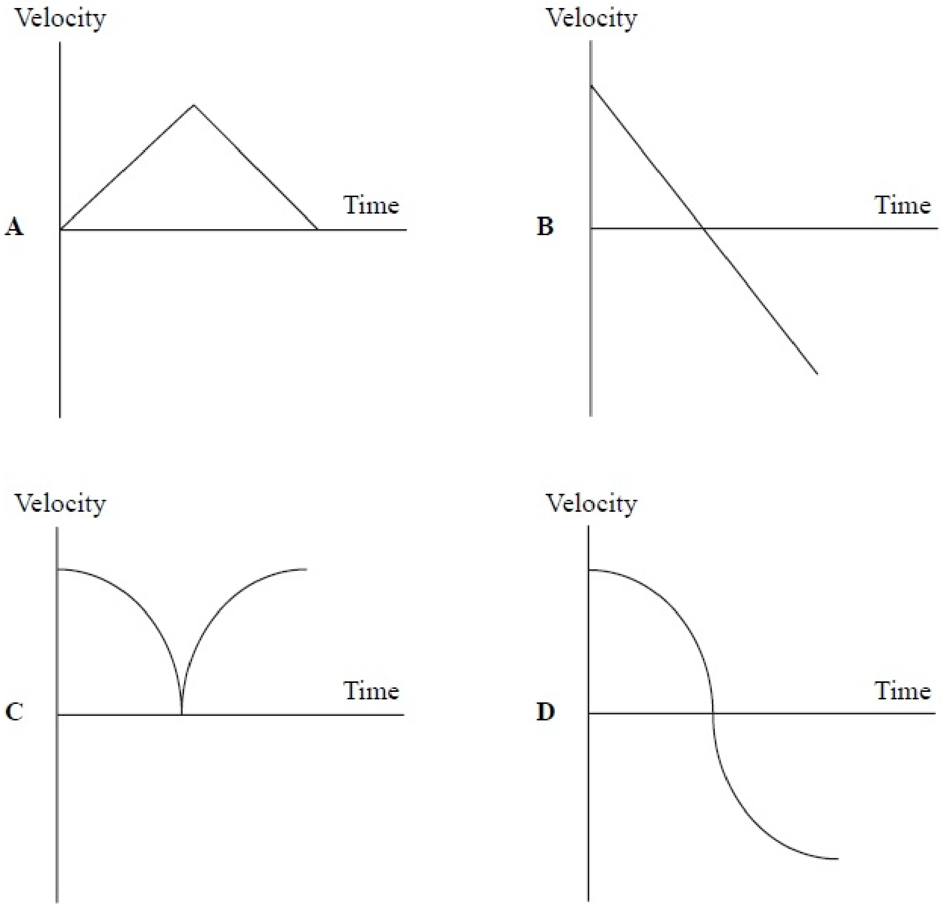
B 7 $m\ s^{-2}$ ☐

C 5 $m\ s^{-2}$ ☐

D 0 $m\ s^{-2}$ ☐

(1 mark)

3 A ball is thrown straight up in the air and caught when it comes down. Which graph best shows the velocity of the ball from the moment it is released until just before it is caught?



Select one answer from A to D and put a cross in the box (☒).

A ☐

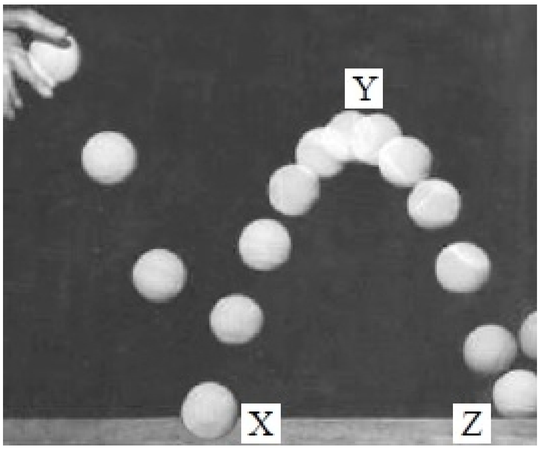
B ☐

C ☐

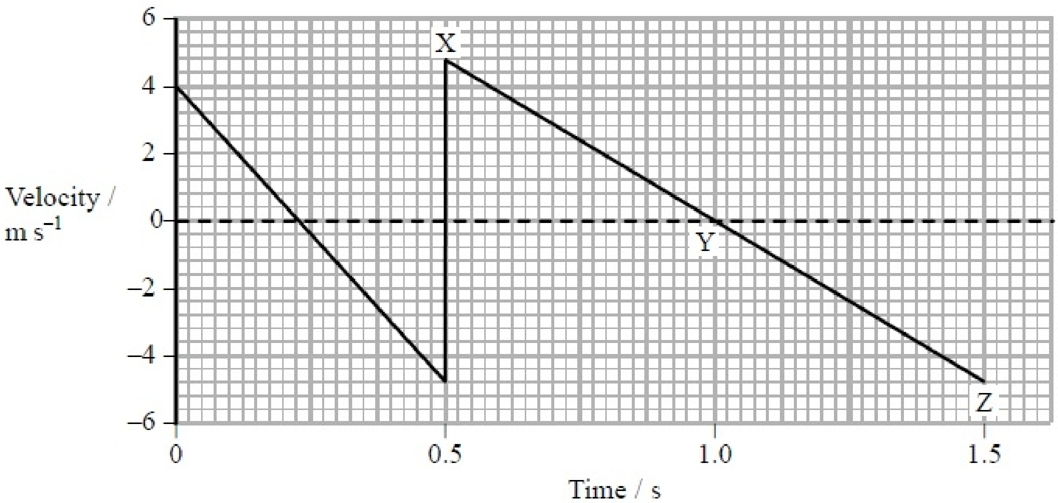
D ☐

(1 mark)

4 The photograph shows a sequence of images of a bouncing tennis ball.



A student plots the following graph and claims that it shows the vertical motion of the ball in the photograph.



a Without carrying out any calculations describe how the following can be found from the graph:

i the vertical distance travelled by the ball between 0.5 s and 1.0 s

ii the acceleration at Y.

(2 marks)

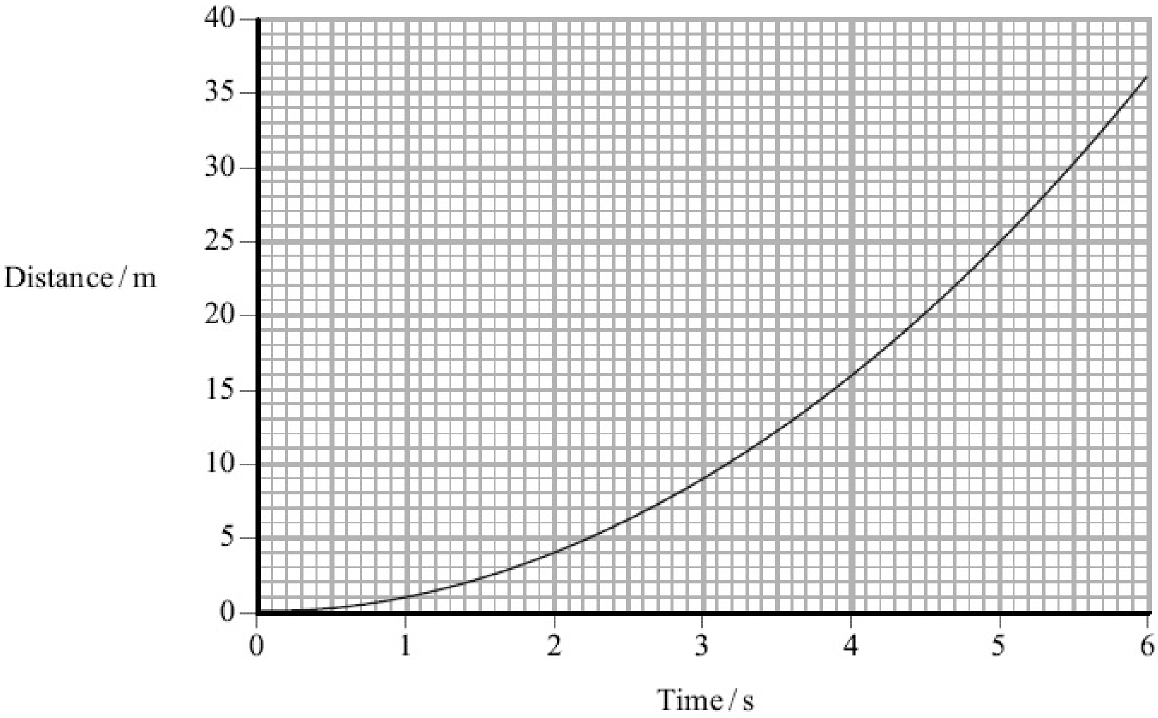
b The graph contains several errors in its representation of the motion of the ball. Explain two of these errors.

Error 1

Error 2

(4 marks)

5 The graph shows how displacement varies with time for an object which starts from rest with constant acceleration.



a Use the distance-time graph to determine the speed of the object at a time of 4.0 s.

(3 marks)

b Calculate the acceleration.

(2 marks)

Examples of students' responses from Results Plus – Examiners' report

Here are some commentaries on and examples of answers to questions used in this section – you may want to print out the answers and ask your students to mark them before sharing the examiners' commentaries.

1 & 2 These are standard GCSE-level questions based on graphs of motion and should pose few problems.

3 This question extends GCSE knowledge to include graphs showing negative velocity, testing students' understanding that the sign is used to indicate direction. The graph shapes further test the ability to recognise *g* as a constant acceleration; again, it is worthwhile spending some time ensuring students grasp this key concept.

4 a At A level, students need to be more definite and precise in their answers than at GCSE. Weaker candidates tend to write either too much (becoming either vague or contradictory) or too little (failing to give important detail). The example shown below, while suggesting the student knows the correct procedure, nevertheless scores zero.

(i) the vertical distance travelled by the ball between 0.5 s and 1.0 s

The area under the graph

(ii) the acceleration at Y.

Finding the gradient

> These need to refer explicitly to <u>which</u> area must be calculated and <u>where</u> the gradient should be found.

b This question further illustrates the need to be precise (and to recognise the need to 'explain' and not just identify the errors). For example, candidates commonly noted that the final velocity at Z should be less than at X, but did not say that this would be because of energy losses.

Error 1

The velocity increases after the first bounce. As the area distance increases, this would imply the ball bounded higher, which isn't possible.

> This student should explain why it isn't possible (in terms of energy).

Students also spotted the positive initial velocity rather than zero and an apparent increased velocity at X, if the initial velocity was assumed to be correct.

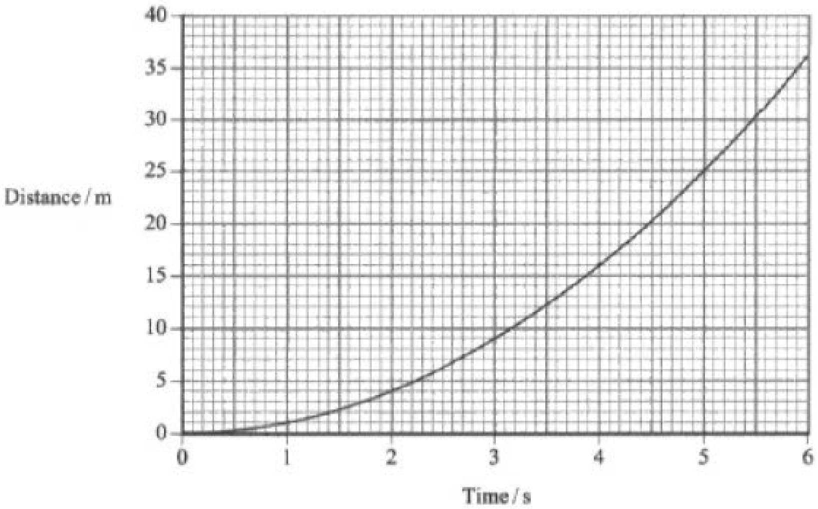
Error 1

One error is that when the ball is released ~~there is not a uniform deceleration~~ ~~out off~~ from a height, after it bounces the ball achieves ~~the~~ greater height whereas it should ~~not~~ be lower.

> This candidate has made a correct observation in terms of the lines on the graph, but thinks it represents height, rather than velocity, and has still not linked it to energy dissipation when saying it should be lower.

5 **a** This question again extends a little beyond GCSE with a curved d-t graph. In the examination few students were successful in this question with many finding the average speed i.e. using the co-ordinates of the 4.0 s point rather than drawing or describing a tangent. This suggests teaching should include more examples of different graph shapes and emphasise the importance of (and technique for finding) gradients of tangents.

b Many students went on to do well here using $v = u + at$ or the GCSE form as the definition of acceleration to obtain marks with 'error carried forward'. Take care to re-emphasise the unit for acceleration as a reminder from GCSE.



(a) Use the distance-time graph to determine the speed of the object at a time of 4.0 s.

(3)

T=4 u=16 ~~S= V=u+at.~~ $S = \frac{u}{t} = \frac{16}{4} = 4ms^{-1}$

Speed = $4ms^{-1}$

(b) Calculate the acceleration.

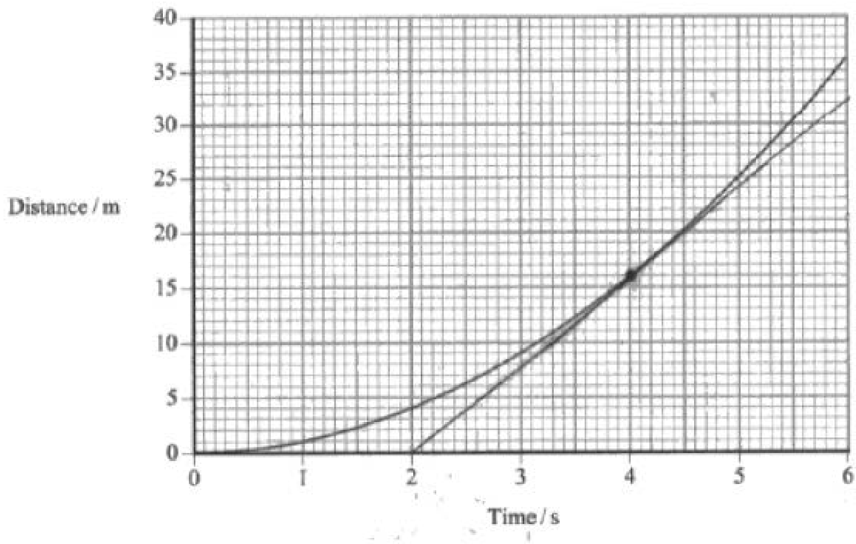
(2)

V=u+at 4=0+4a.

$a = 1ms^{-2}$

Acceleration = $1ms^{-2}$.

This response is typical in failing to use the gradient of a tangent to the curve for part **a**. It gets a single mark for use of speed = distance ÷ time. The method and calculation in part **b** gain both marks, allowing for the error in **a** to be carried forward.



(a) Use the distance-time graph to determine the speed of the object at a time of 4.0 s.

(3)

Speed = $\frac{\text{distance}}{\text{time}}$ (As shown in the diagram the speed at 4.0s is the gradient of the tagent to the curve at 4s)

Speed = $\frac{32.5}{4}$ = 8.125m/s

Speed = 8.125m/s

(b) Calculate the acceleration.

(2)

∵ v=u+at ∴ at=v-u ∴ a= $\frac{v-u}{t}$ = $\frac{8.125}{4}$ ≈ 2.03m/s²

Acceleration = ...

This response correctly draws a tangent and uses its gradient to find the instantaneous speed at 4.0 s and goes on to use this to find the acceleration in part **b** to get full marks.

Section 3: Weight and mass

Students' strengths and common misconceptions

The table below outlines the areas in which most students do well and the common mistakes and misconceptions across the topics listed.

	Strengths	**Common mistakes**
Weight and Mass	Students tend to find using $W = mg$ relatively straightforward as it is a simple three variable equation.	Whilst students are good at using $W = mg$ they often neglect to do so. Through a combination of carelessness and misconception GCSE students mix weight and mass, or forget to convert, with alarming frequency. The added sting in the tail is that the value and unit of g is inconsistent across centres and specifications (10, 9.8 or 9.81 m/s^2 or N/kg).
Use of Graphs	Students will have plotted scatter graphs before and be familiar with drawing lines of best fit.	Finding gradients will be challenging for weaker students. The concept of the gradient revealing a constant will be new.

Teaching ideas

Objectives

- Explain the difference between weight and mass and use units to identify them.
- Use and re-arrange the equation $W = mg$.
- Use graphs to find gravitational field strength.

Starter activities

What is wrong?

This activity challenges the misconceptions surrounding weight and mass and highlights the lack of overlap between everyday language and physics.

Identify the mistake in these statements.

- I've put on weight.
- The object's big mass made it hard to lift.
- I weighed myself today and found I was 80 kg.
- The extra mass of the ballast made the ship sink.

What do you know?

This activity encourages students to extract information from text. It also asks students to interconvert mass and weight.

Extract as much information as you can from these passages a) by reading them and b) by using what you have read to work things out.

The 90 kg rugby player sprinted 50 m in 6 s.

The aeroplane remained at constant height due to an upward pressure of 20 000 N. It covered 450 km in its 2 hr flight.

The fully laden ship displaced 5000 kg of water, whilst when empty it only displaced 300 kg.

A 3 cm long grasshopper can jump 20 times its own body length.
The jump takes 0.35s.

Main activities

Mass and weight

By using different methods to find mass and weight this practical highlights the difference between them. It is of course flawed as the balance is really measuring weight and converting to mass. This can be discussed in the plenary.

> Use Newton meters and electric balances to find the mass and weight of several objects. Plot a graph of mass and weight and use the gradient to find *g*.

Acceleration in free fall

This activity offers plenty of opportunity to develop practical skills but is included here to link the conversion between weight and mass and acceleration due to gravity.

> Drop an object from various heights and record the time taken for it to fall. The issues of timing errors and air resistance should be discussed beforehand.
>
> Bring out the idea that too short a distance will be subject to huge timing errors and too long a distance will underestimate g due to air resistance.
>
> Discuss importance of repeat readings. You could bring in ½ range as an estimate of uncertainty. Plot a graph of distance fallen against *t*. Discuss why it is curved.
>
> Plot a graph of distance fallen against t^2. Explain the link between the equation $s = ut + ½at^2$ and the data.
>
> Find the gradient and discuss its meaning. You may need to provided idealised data here, as the data gathered by students could well be very poor.

Plenary

Graph for Isaac Newton

Rather than a formal plenary we would suggest a discussion here. Some possible talking points are below.

> Have students come up with their own examples of mix ups between mass and weight, as seen in the starter.
>
> Discuss the challenges associated with extracting information from text.
>
> Discuss the flaws in the mass and weight practical, in particular those associated with using an electric balance.
>
> Discuss the errors due to reaction time and air resistance in the acceleration practical.
>
> Examine why acceleration due to gravity also converts mass into weight.

Practice questions

1 Complete the sentence by putting a cross (☒) in the box next to your answer.

On a newly discovered planet, an object of mass 8.0 kg has a weight of 60 N.
The gravitational field strength on this planet is...

A 0.13 N kg^{-1} ☒

B 7.5 N kg^{-1} ☒

C 9.8 N kg^{-1} ☒

D 480 N kg^{-1} ☒

(1 mark)

2 A person weighing 100 N stands on some bathroom scales in a lift. If the scales show a reading of 110 N, which answer could describe the motion of the lift?

Select one answer from A to D and put a cross in the box (☒).

A Moving downwards and decelerating. ☒

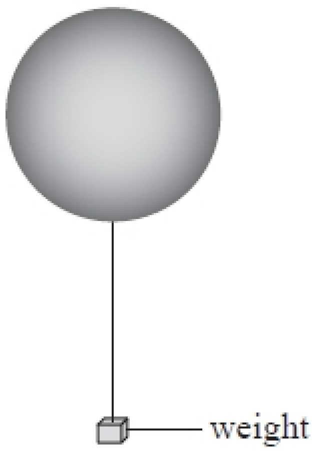
B Moving downwards with a constant velocity. ☒

C Moving upwards and decelerating. ☒

D Moving upwards with a constant velocity. ☒

(1 mark)

3 A student is asked to calculate the magnitude of a weight required to keep a spherical helium filled balloon stationary in the air.



The only measurement taken is the diameter d of the balloon. The student is given the values of the density of air ρ_a, the density of helium ρ_h and gravitational field strength g.

a Using the symbols given, write an expression for:

i the volume V of the balloon

(1 mark)

ii the mass of the helium inside the balloon

(1 mark)

iii the mass of the air displaced by the balloon

(1 mark)

iv the upthrust on the balloon.

(1 mark)

b Assuming the weight of the balloon and string are negligible, write an expression for the magnitude of the required weight.

(1 mark)

4 You are asked to determine the acceleration of free fall at the surface of the Earth, *g*, using a free fall method in the laboratory.

a Describe the apparatus you would use, the measurements you would take and explain how you would use them to determine *g*.

(6 marks)

b Give **one** precaution you would take to ensure the accuracy of your measurements.

(1 mark)

Examples of students’ responses from Results Plus – Examiners’ report

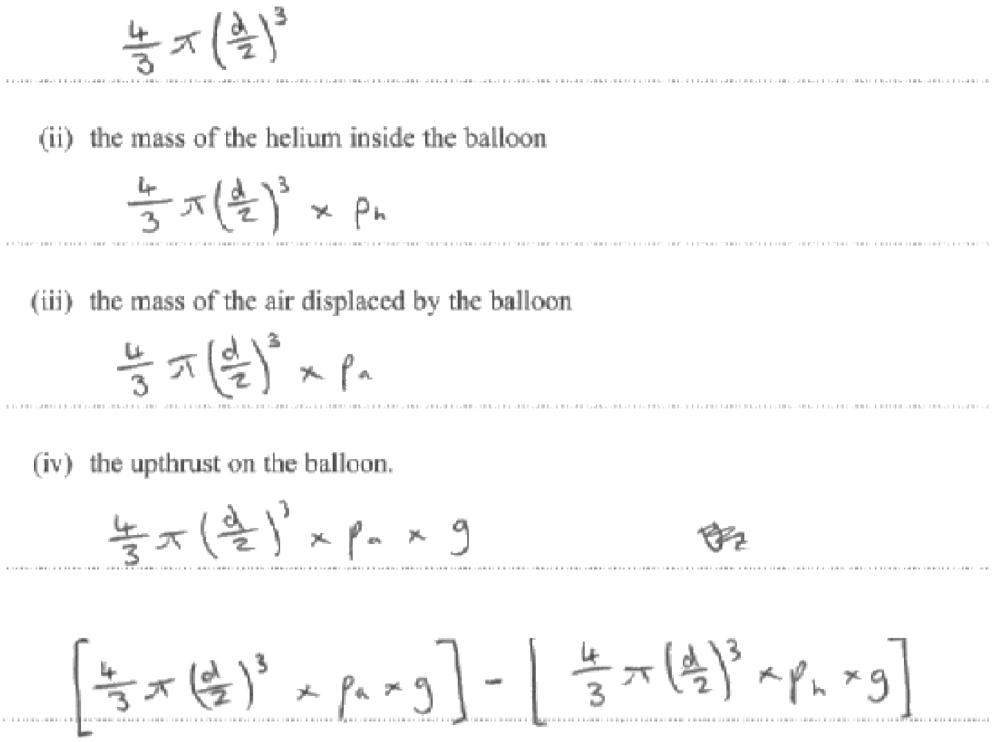
Here are some commentaries on and examples of answers to questions used in this section – you may want to print out the answers and ask your students to mark them before sharing the examiners’ commentaries.

1 Almost all students could do this, with a few not recognising that *g* is different on different planets therefore incorrectly choosing *C*.

2 Many students incorrectly answered **D**. Students should be encouraged to draw free body diagrams even for such seemingly simple questions to ensure that they appreciate the link between acceleration and resultant force.

3 This question is well-scaffolded, broken into small steps, each requiring understanding of some simple words: volume, mass, upthrust, weight, and the formulae involved with them. These are often neglected at A level as they are met sometimes even in KS3 schemes of work and familiarity is tacitly assumed. Use of density, the volume of a sphere and the idea of upthrust are worth re-visiting.

For part **b**, the answer we were originally expecting was that the required weight would be equal to the upthrust minus the weight of the helium. However, the majority of responses did not include the second term, the weight of the helium, and we made the assumption that they considered that weight to be included in the weight of the balloon. We therefore did not penalise those who said that the required weight was equal to the upthrust.


$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3$

(ii) the mass of the helium inside the balloon

$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_h$

(iii) the mass of the air displaced by the balloon

$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_a$

(iv) the upthrust on the balloon.

$\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_a \times g$

$\left[\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_a \times g\right] - \left[\frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \times \rho_h \times g\right]$

This is an example of the ideal answer we were hoping for. The candidate has written the formulae using the symbols given in the question, and fully understood their meaning. Part **b** is the full statement we were expecting.

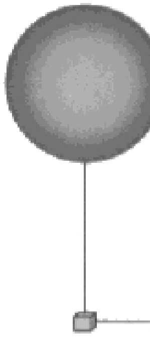
Results Plus: Examiner Tip

Where possible, use the symbols given in the question.

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

$V\rho = m$

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



The only measurement taken is the diameter d of the balloon. The student is given the values of the density of air ρ_a, the density of helium ρ_h and gravitational field strength g.

(a) Using the symbols given, write an expression for

(i) the volume V of the balloon

~~$V = \frac{4}{3}\pi r^3$~~ $V = \frac{4}{3}\pi \frac{d}{2}^3$

(ii) the mass of the helium inside the balloon

$m = V\rho_h$

(iii) the mass of the air displaced by the balloon

$m = V\rho_a$

(iv) the upthrust on the balloon. = weight of fluid displaced

Upthrust = $M_{air} \times g$.

Weight = $M_{air} \times g$.

This response showed the minimum that could achieve full marks. In fact the first mark, for **a i**, was not awarded as the equation showed ½mv^2 rather than $(d \div 2)^3$. This candidate did not use the given symbols all the way through the question, but was considered to fully understand the physics involved. We did insist on the use of d ÷ 2 and not *r* in **a i**.

Results Plus: Examiner Tip

Careless writing of mathematical equations is likely to be penalised as it leads to ambiguous answers.

(b) Assuming the weight of the balloon and string are negligible, write an expression for the magnitude of the required weight.

(1)

weight = drag + upthrust.

There were various forms of response, like this one, which included viscous friction of some kind in the equation. It would be an equation remembered from terminal velocity situations. Any such mention, of course, lost the mark.

Results Plus: Examiner Tip

Always consider the context in which the question is set. In this case the balloon is stationary.

4 Describing experimental procedures is a common examination question and this is an experiment that we expect all students to have some experience of. The simplest example uses a magnetic starter and ‘trapdoor’ switch to stop an electronic timer.

The most common descriptions given involved electromagnets, magnetic gates and timers, or light gates and data loggers and sometimes a confused mixture of the two. Those using the electromagnets and timers tended to score more highly.

Many said they would measure the height and time, or a speed at the end and a time or distance, but the answers tended to be less clear for the latter. Candidates describing the measurement of two speeds and a time between them were the least successful in describing their method.

Too many treated light gate and data logger arrangements as a 'black box'. They sometimes therefore gained credit for describing the measurement of time and little else. Overall, relatively simple methods which could be fully described gained more credit than complex methods which relied on computers producing an answer without describing the actual inputs and how they were processed.

A common error was not to mention a means to measure distance. This was even when the height of a fall was being used, but especially so with the use of light gates to measure speed where the length of the interrupt card was rarely mentioned. Candidates usually mentioned repeating measurements, although they did not always say which measurements or what they would do with the repeats.

The descriptions of how to determine g from the measurements were rarely given in sufficient detail. A common error was to use the height of a fall divided by the time as the final speed and to use this divided by the time for their acceleration result. Others stated the equation they would use, but did not make g the subject.

The suggested precautions in part **b** were often vague and not always about the accuracy of specific measurements, as asked by the question, but about reliability. Repeating and averaging was often given in this part. Some were unrealistic for the laboratory, like carrying out the experiment in a vacuum.

Section 4: Series circuits

Students' strengths and common misconceptions

The table below outlines the areas in which most students do well and the common mistakes and misconceptions across the topics listed.

	Strengths	**Common mistakes**
Definitions	Students will have met current, voltage and resistance before.	Electricity contains a plethora of variables, symbols, units and equations, some of which are counterintuitive. Mixing up units and symbols (plenty of GCSE students seem to think the unit of current is **I**) is common.
$\boldsymbol{V = IR}$	Students will be familiar with this equation applied in simple situations from GCSE	Mixing variables as mentioned above. Students are more used to applying $V = IR$ to whole circuits, rather than individual components.

Teaching ideas

Objectives

- Define Current, Voltage and Resistance.
- Discover/Prove the rules for voltage, current and resistance in series.
- Use the equation $V = IR$.

Starter activities

Quantities, units and symbols

This activity is designed to provide students with a clear reference for electricity, to aid them in not getting things mixed up. It can be used in future lessons, and learning it could be set for homework.

Use your GCSE knowledge, or a textbook, to fill out this table.

Quantity	**Symbol**	**Unit**	**Unit Symbol**	**Relevant Equations**	**SI Base Units (Optional)**
	Q		C		
Current					Amps
		Volt			
	R				
Power					

Electric metaphors

This task will improve students explanation skills, and get them thinking about what electricity really is.

Without using any technical language, how would you explain what electricity is to a five year old?

Main activities

Proving $V = IR$

This activity revisits the use of graphs to derive equations and gives students an opportunity to make measurements in a familiar, unintimidating circuit.

Define Current, Resistance and Voltage in terms of their units.

Distribute cells or DC powerpacks, resistors, wires, Voltmeters and Ammeters. The students should first set up a series circuit passing current through one resistor. Have them vary the voltage from the powerpack/add cells to the circuit and measure the current generated at each voltage.

They should then plot a graph of I and V. The data should give a straight line.

Ask them to consider what the gradient means. They may need help – you could have them calculate the gradient and compare it with the known resistance of the resistor.

Discuss why a graphical method is better for this than simply calculating R from one reading.

Using $V = IR$

This activity follows on naturally from the previous one. It re-enforces the concept of constant current in series circuits and gives the opportunity to investigate the splitting of voltage across components.

Have the students set up a circuit with three or more different resistors in series. They should then use an ammeter to measure the current in as many points as possible.

Discuss why the current is constant and discuss why it is lower than for a single resistor.

They should then use a voltmeter to measure the voltage across as many combinations of resistors as they can.

They should use $V = IR$ and the constant current to calculate the resistance of each resistor and the combinations of resistors. Comparing these with known values should enable students to derive a rule for resistance in series.

They should then measure the voltage across each resistor and the voltage coming from the battery. Compare these values.

Discuss how the voltage is being divided. Use the known resistances to recalculate current. Why does the value make sense? Bring in the idea of ratios and discuss in terms of conservation of energy.

Plenaries

Electrical metaphors

Gives students an opportunity to reflect on what they have learnt and returns to the start point of the lesson.

> Discuss how your metaphor for explaining electricity would change in light of the lesson with the person next to you. Changes could then be shared with the class as a whole.

Setting questions

What better way to apply and test learning than to come up with questions! This is not the only lesson in which this plenary is useful.

> Draw a series circuit. Decide on the Voltage of the battery and the resistance of the resistors.
>
> Calculate the current.
>
> Give some but not all of the information to another student and see if they can work out the missing value(s).

Practice questions

1 Complete the sentence by putting a cross (☒) in the box next to your answer.

The unit of potential difference can be expressed as…

A $C\ s^{-1}$ ☒

B $J\ C^{-1}$ ☒

C $A\ \Omega^{-1}$ ☒

D $J\ A^{-1}$ ☒

(1 mark)

2 Complete the sentence by putting a cross (☒) in the box next to your answer.

A rechargeable cell stores a maximum energy of 4200 J. The cell has an e.m.f. of 1.5 V and after 2.0 hours use the cell is completely discharged.

Assuming the e.m.f. stays constant, the charge passing through the cell during this time is…

A 1400 C ☒

B 2800 C ☒

C 5600 C ☒

D 6300 C ☒

(1 mark)

3 An electric torch uses two 1.5 V cells. The torch bulb is marked 2.4 V, 270 mA.

What is the resistance of the torch bulb?

Put a cross (☒) in the box next to your answer.

A 0.81 Ω ☒

B 0.65 Ω ☒

C 8.9 Ω ☒

D 11 Ω ☒

(1 mark)

4 A student is taking measurements in order to determine the resistance of a component in a circuit. He connects a voltmeter in parallel with the component and an ammeter in series with the component.

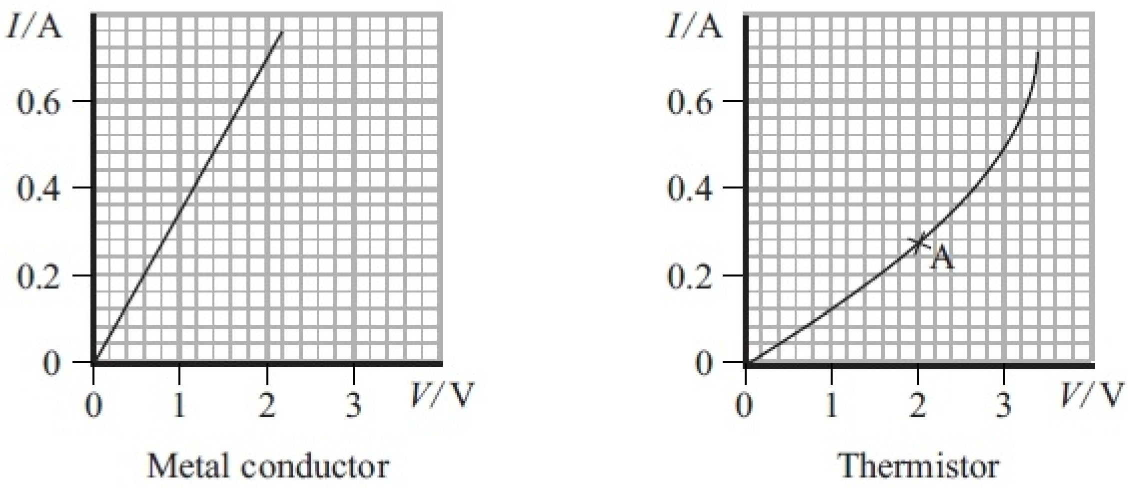
Explain why the voltmeter should have a very high resistance.

(2 marks)

5 **a** Show how the ohm is derived.

(1 mark)

b The graphs show the current-potential difference (I-V) characteristics for a metal conductor and for a thermistor.



i Calculate the resistance of the thermistor at point A.

(2 marks)

ii Use the graphs to describe how the resistance varies with potential difference for each component.

(2 marks)

iii Explain, in terms of electrons, why the thermistor behaves in this way.

(2 marks)

Examples of students' responses from Results Plus – Examiners' report

Here are some commentaries on and examples of answers to questions used in this section – you may want to print out the answers and ask your students to mark them before sharing the examiners' commentaries.

1 & 2 It is useful for students to practise the use of the defining equations (loosely $I = Q \div t$ and $V = E \div Q$) and the link between these equations and units. Combined with Ohm's law and the idea of power this lends itself to a simple card sort activity that can be revisited several times over the course of a topic to consolidate understanding.

3 Students should examine bulbs such as the MES bulbs in common use, ideally without holders. This allows them to see the markings showing the designed power rating as well as the location of the bulb contacts. In this question students confused the rated values with the applied p.d. (leading to the common incorrect response **D**).

4 Students should develop their GCSE knowledge to explain the characteristics of familiar meters, both to develop their knowledge of electricity and more widely of measurement. For a voltmeter this can be approached by way of the potential divider (where adding a small load significantly changes the current in the divider).

A common answer here was that the current should pass through the component rather than the voltmeter, as if there was a fixed current in the circuit. As the question mentioned the voltmeter and not the ammeter, many discussed the effect on potential difference, quite a few mentioning 'voltage through the component', language which should be avoided.

A few candidates discussed total resistance but could rarely express their answers clearly enough to gain credit, usually saying little more than that $1 \div R$ would be very small.

Some candidates failed to score a mark through lack of detail, such as stating that the ammeter reading would not be accurate without saying why or just saying the voltmeter current should be low rather than very small.

Explain why the voltmeter should have a very high resistance.

(2)

the voltmeter should have a very high resistance, so that it does not disrupt how the circuit works when it is connected in parallel with a component. If the voltmeter had a low resistance, the entire resistance of the circuit would be changed as parallel resistances add using $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$, and if both R_1 and R_2 are similar, the total R will be half of these values.

(Total for Question 12 = 2 marks)

This response is awarded 1 mark for describing the possible effect on the resistance of the parallel section of the circuit, but it does not say how this would affect the measurement of the resistance of the component, i.e. by causing a greater current in the ammeter than the current in the component.

Results Plus: Examiner Tip

You need to be able to describe the reasons for the resistance of meters in terms of current and potential difference in series and parallel circuits.

Explain why the voltmeter should have a very high resistance.

(2)

If the voltmeter has a high resistance this will stop any current from passing through the voltmeter. This ensures all current passes through the component its in parallel with and theres only a negligible amount through voltmeter.

This candidate achieves one mark for saying (twice) that the current in the voltmeter is negligible. In an explanation this needs to be linked to the final outcome, which is a correct determination of the resistance of the component. The response says that all current passes through the component, but the key missing effect of the negligible voltmeter current here is that the current measured by the ammeter is the same as the current in the component.

5 a A large majority correctly gave Ohm’s law or the relevant units.

$V = IR \rightarrow R = \frac{V}{I}$ $R = \frac{J/C}{C/s^{-1}}$ $R = Js^{-1}$

$R = \Omega$ // (ohm)

This response gets the mark by identifying the starting point for the derivation, but it is notable that a number of candidates seemed content, after incorrectly dividing fractions, to say that an ohm is the same as a watt.

a.

(1)

$R\ (\Omega) = \frac{\rho(\Omega m) \times l(m)}{A\ (m^2)} = \frac{\Omega m^2}{m^2}$

$= \Omega$ ohm

This response attempts to use a unit already containing ohms to derive ohms.

Results Plus: Examiner Tip

A unit cannot be used to derive itself.

b i Students must be cautioned that scales are unlikely to be '1 small square = 1 unit' at A level. Many went wrong here by reading the scale incorrectly. Also note that Ohm's law applies to each point on the curve and that the gradient of these *V*-*I* characteristics is not significant. AS level students will often bring this misconception with them from GCSE. It is stated that the gradient equals resistance in some GCSE text books with reference to the straight line *V*-*I* graph for a resistor; students should be cautioned that this is only the case because the ratio is the same for all points on the line and that resistance is not like speed, a rate of change of something.

$R = V / I$

$2 / 0.22$

$= 9.09\ \Omega$

Resistance = $9.09\ \Omega$

This candidate has misread the current scale, apparently taking each small square after 0.2 A as 0.01 A, and just gets the first mark for use of the correct equation.

Results Plus: Examiner Tip

Read graph scales carefully, looking at the marked values above and below the relevant point to establish the value of each square.

(2)

$R = \frac{V}{I}$ $\quad \frac{1}{\text{gradient}} = \frac{1}{R} = \frac{3-2}{0.44-0.28}$

$\frac{1}{R} = 0.16 \therefore$

$R = 6.25\ \Omega$

Resistance = $6.25\ \Omega$

This is a clear example, fortunately rare, of the gradient being calculated.

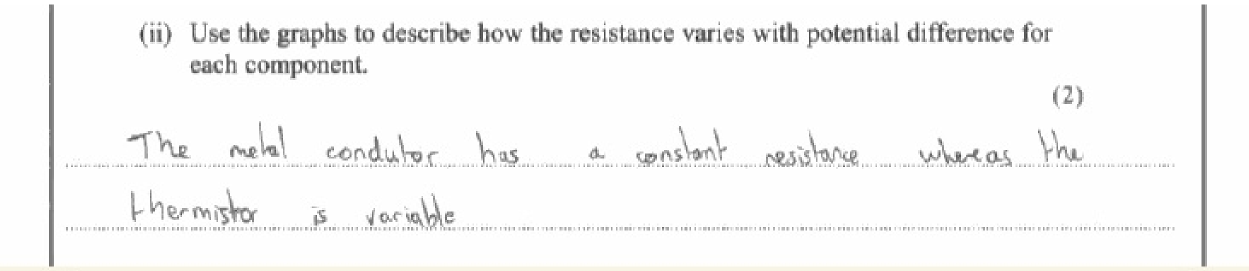
Results Plus: Examiner Tip

Resistance is defined using $R = V \div I$. It is not the gradient of a graph of p.d. against current, and must be calculated using the single values of p.d. and current at the relevant point.

ii Most candidates in the examination knew that resistance is constant for the metal and changes for the thermistor, although they were not all specific enough in stating that the change was a decrease.

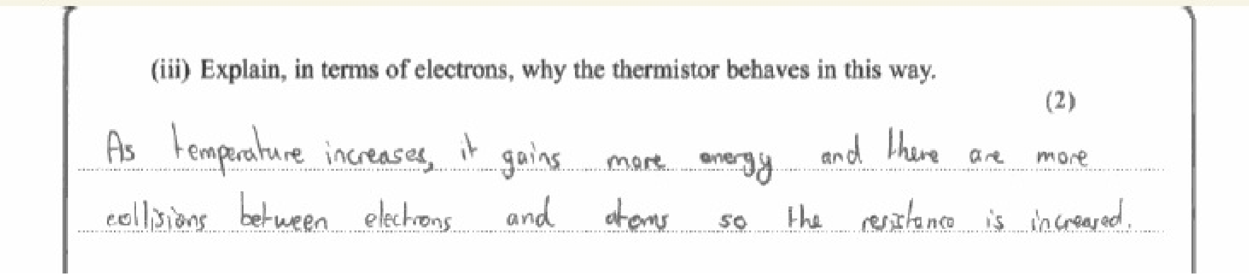
There were more references to gradient in this part than attempts to use a tangent in part **b i**.

iii This was more difficult; many students had clearly learned the model answer for the metal (showing increasing resistance with temperature) and consequently scored nothing. Teaching should include some detail about the properties of semiconductors: while this may be beyond the specification it would be useful in helping students to understand their behaviour.


(ii) Use the graphs to describe how the resistance varies with potential difference for each component.

(2)

The metal condutor has a constant resistance whereas the thermistor is variable


(iii) Explain, in terms of electrons, why the thermistor behaves in this way.

(2)

As temperature increases, it gains more energy and there are more collisions between electrons and atoms so the resistance is increased.

In **b ii** the constant resistance for the metal is identified. The resistance of the thermistor is described as variable, but the candidate needs to say how it varies, i.e. whether it increases or decreases.

In **b iii** the candidate is describing the effect of temperature on a metallic conductor rather than a thermistor.

Results Plus: Examiner Tip

You are advised to learn standard descriptions, such as the effect of temperature on resistance, but make sure you are applying these to the situation described in the question and not just thinking of a previous question you have used for practice.

(ii) Use the graphs to describe how the resistance varies with potential difference for each component.

(2)

The resistance is constant for the metal conductor because it has a constant gradient. the thermistor's resistance is constant to begin with, but after point A the graph begin's to curve and the resistance begin's to decrease.

(iii) Explain, in terms of electrons, why the thermistor behaves in this way.

(2)

because as the current heats up the metal, the metal releases more charge-carriers (electrons) which means that the current rises for a little rise in potential difference. Since $R = \Delta \frac{V}{I}$, as I increases, R will get smaller if V stays the same.

Although this answer to **b ii** is in terms of gradient rather than the ratio of *V* to *I*, the marks were awarded for the correct description of the resistance in each case.

The answer to **b iii** correctly identifies the current causing a temperature rise and the release of charge carriers, even though some of the other details are not quite correct.

Section 5: Parallel circuits

Students' strengths and common misconceptions

The table below outlines the areas in which most students do well and the common mistakes and misconceptions across the topics listed.

	Strengths	Common mistakes
Parallel Circuits	Students will instantly recognise parallel circuits as they have met them at GCSE	Concepts such as increased current with more resistors are counterintuitive. Students frequently mix up the rules for series and parallel
Resistance in Parallel Equation	Some simple checks can be taught for answers, such as is R_t smaller than any of the resistances used.	Consistently one of the most misapplied equations in GCSE and A-Level Physics.

Teaching ideas

Objectives

- Further develop use of $V = IR$.
- Prove/discover the rules for current and voltage in parallel circuits.
- Analyse circuits to find unknown quantities.

Starter activity

Christmas trees

This starter adds mathematical detail to a well known example of series and parallel circuits used in GCSE teaching. You may want to give a hint for part **b** as power is not covered in this lesson or the lesson before.

A set of Christmas tree lights are powered from a 20V source. There are 10 bulbs in series. Each light needs a power of 10W.

a What is the voltage across each bulb? (2 V)

b What is the current be in each bulb? (use Power = IV) (5 A)

c What must the total resistance of the lights be? (4 Ω)

d What is the resistance of each light? There are two ways of working this out… (0.4 Ω)

e If one light was to be powered from a 20 V source what would the current need to be in the bulb? It still needs a power of 10 W. What would the resistance of this new bulb need to be? (0.5 A, 4 Ω)

f What is the advantage of **i)** lower current **ii)** higher resistance? (Less heating in circuit and lower current safer, component easier to make and less fragile.)

g Is there a practical way of giving the full voltage to each bulb? (Parallel)

h What is the additional advantage of this? (One bulb blowing won't put all the lights out.)

Either of the two starters from the last section (whichever wasn't used) would also work here.

Main activities

Christmas tree lights

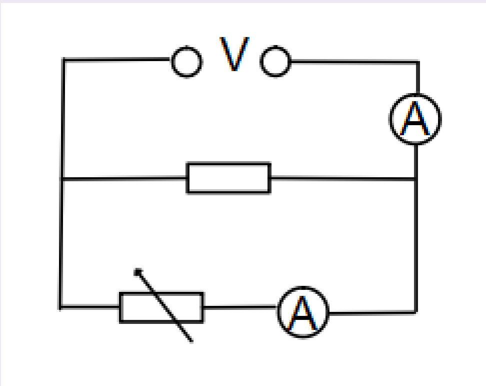
This activity expands on the starter. It gives students an opportunity to grasp the somewhat counterintuitive concept that adding more components to a parallel circuit makes the resistance go down. The more bulbs you have the better, it may be worth combining groups together to make circuits with up to 20 bulbs.

> Have the students set up a circuit with a bulb, cell, ammeter and voltmeter recording the emf from the cell. Students should record the current and emf and use these to work out the resistance of the entire circuit. They should then add bulbs in parallel to the first bulb, recording current each time. Having worked out resistance they should plot a graph of number of bulbs against *R*. Discuss the relationship and the curved graph achieved.

$\frac{1}{\textit{Variable resistance}}$

Parallel circuits

This activity gives students the opportunity to derive the resistance in parallel equation with some guidance.

> Have students set up a parallel circuit as follows, with voltmeters across both resistors.
>
> 
>
>
> Students should then vary the resistance of the variable resistor and observe what happens to the voltage on both voltmeters and the current in both ammeters. Once this has been discussed they should record both currents and the voltage for a range of variable resistor settings and work out the resistance of the variable resistor and total resistance of the circuit. They should then plot graphs of:
>
> *Variable resistance against Total resistance* – this graph will initially seem unintelligible to students. A discussion of what happens when variable resistance is very big and variable resistance is very small will however prove useful.
>
> $\frac{1}{\textit{Variable resistance}}$ against $\frac{1}{\textit{Total resistance}}$. – this graph should be a straight line.
>
> Find the gradient. Discuss why the gradient is one and the meaning of the y-intercept ($\frac{1}{\textit{Reistance of other resistor}}$).
>
> *Current leaving battery against current in variable resistor* – this graph will elicit the idea of current splitting at junctions.

Plenaries

Electrical metaphors 2

Expands on the starter from the previous section, asking students to design metaphors or models for electricity.

> Use the analogy of either pipes, roads or ski-runs to explain how parallel circuits behave. Must include issues with the model, what it does not explain and other flaws.

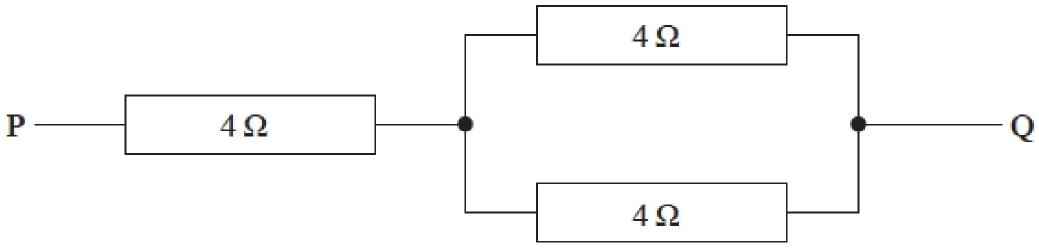
Setting questions

As before, but with parallel circuits.

> Draw a parallel circuit.
>
> Decide on the Voltage of the battery and the resistance of the resistors.
>
> Calculate the current.
>
> Give some but not all of the information to another student and see if they can work out the missing value(s).

Practice questions

1 The diagram shows a combination of three identical resistors.



What is the combined resistance between P and Q?

Put a cross (☒) in the box next to your answer.

A 4 Ω ☐

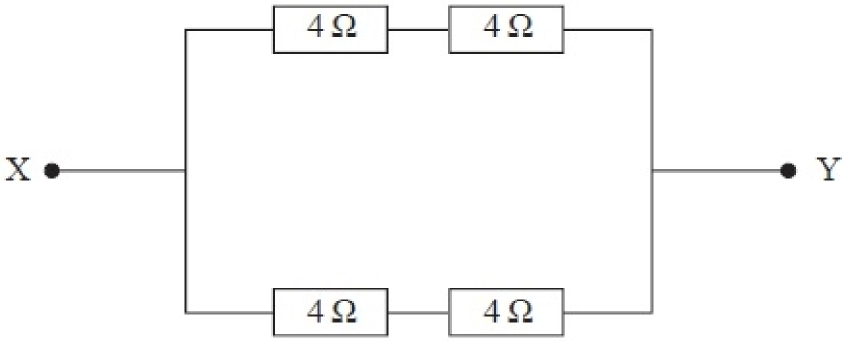
B 6 Ω ☐

C 8 Ω ☐

D 12 Ω ☐

(1 mark)

2 The diagram shows a resistor network.



Complete the sentence by putting a cross (☒) in the box next to your answer.

The total resistance between points X and Y is...

A 0.25 Ω ☐

B 1.0 Ω ☐

C 4.0 Ω ☐

D 16 Ω ☐

(1 mark)

3 Complete the sentence by putting a cross (☒) in the box next to your answer.

Two identical resistors connected in series have a total resistance of 8 Ω.
The same two resistors when connected in parallel have a total resistance of…

A 0.5 Ω ☐

B 2 Ω ☐

C 4 Ω ☐

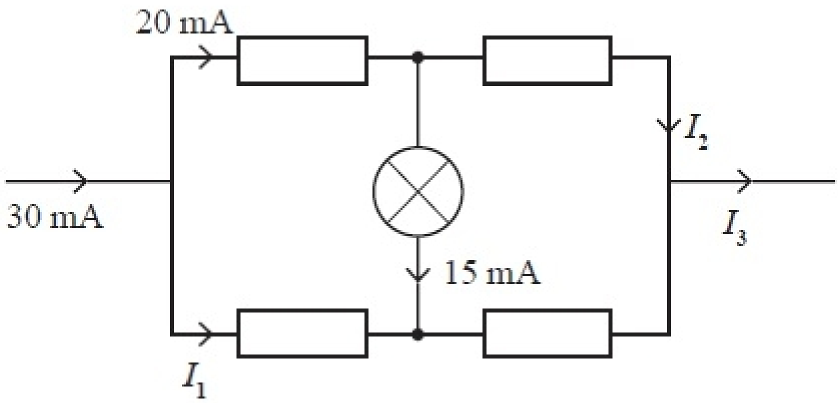
D 8 Ω ☐

(1 mark)

4 **a** What is the coulomb in base units?

(1 mark)

b The diagram shows part of an electrical circuit.



Determine the magnitudes of the currents I_1, I_2 and I_3.

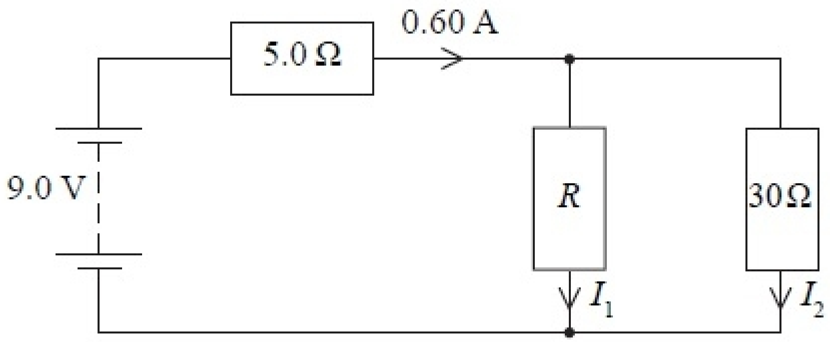
I_1 =

I_2 =

I_3 =

(3 marks)

5 The circuit diagram shows a battery of negligible internal resistance connected to three resistors.



a Calculate the potential difference across the 5 Ω resistor.

(2 marks)

b Calculate the current I_2.

(2 marks)

c Calculate the resistance R.

(2 marks)

Examples of students’ responses from Results Plus – Examiners’ report

Here are some commentaries on questions used in this section – you may want to print out the answers and ask your students to mark them before sharing the examiners’ commentaries.

1, 2 &3 Straightforward questions which most students will be able to answer following the lesson outlined above.

4 This question (part **b**) tested students’ ability to go beyond the simple circuit rules learned at GCSE to using Kirchhoff’s laws accurately. Students should have practise using both laws in increasingly complex scenarios so they can see the point in being disciplined in simple problems which they can answer ‘in their head’.

5 Many candidates scored poorly here precisely because of an inability to apply their knowledge of circuit rules to a more complex circuit.

a Most candidates were able to correctly find the potential difference across the 5 Ω resistor by simple application of Ohm’s law.

b A large percentage of candidates then used 9 V as the p.d. here. Students should be taught never to write Ohm’s law without stating what they are applying it to. ‘Ohm’s law for 30 Ω resistor: $I_{30} = V_{30} \div R_{30}$ so $I_2 = V_{30} \div 30$’ mitigates the risk of error by forcing students to think about what V30 is, rather than blindly plumping for the only available *V* value in the question.

c Most students could apply Kirchhoff’s law to get the current (allowing error carried forward) although many thought it divided equally.

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