Example Candidate Responses

Cambridge International AS & A Level

Cambridge International AS and A Level Physics

9702

Paper 5 – Planning, Analysis and Evaluation

Cambridge Advanced

CAMBRIDGE International Examinations

In order to help us develop the highest quality Curriculum Support resources, we are undertaking a continuous programme of review; not only to measure the success of our resources but also to highlight areas for improvement and to identify new development needs.

We invite you to complete our survey by visiting the website below. Your comments on the quality and relevance of Cambridge Curriculum Support resources are very important to us.

https://www.surveymonkey.co.uk/r/GL6ZNJB

Do you want to become a Cambridge consultant and help us develop support materials?

Please follow the link below to register your interest.

http://www.cie.org.uk/cambridge-for/teachers/teacherconsultants/

Contents

Introduction

The main aim of this booklet is to exemplify standards for those teaching Cambridge International AS & A Level Physics (9702), and to show how different levels of candidates' performance (high, middle and low) relate to the subject's curriculum and assessment objectives.

In this booklet candidate responses have been chosen to exemplify a range of answers. Each response is accompanied by a brief commentary explaining the strengths and weaknesses of the answers.

For each question, each response is annotated with a clear explanation of where and why marks were awarded or omitted. This, in turn, is followed by examiner comments on how the answer could have been improved. In this way it is possible for you to understand what candidates have done to gain their marks and what they will have to do to improve their answers. At the end there is a list of common mistakes candidates made in their answers for each question.

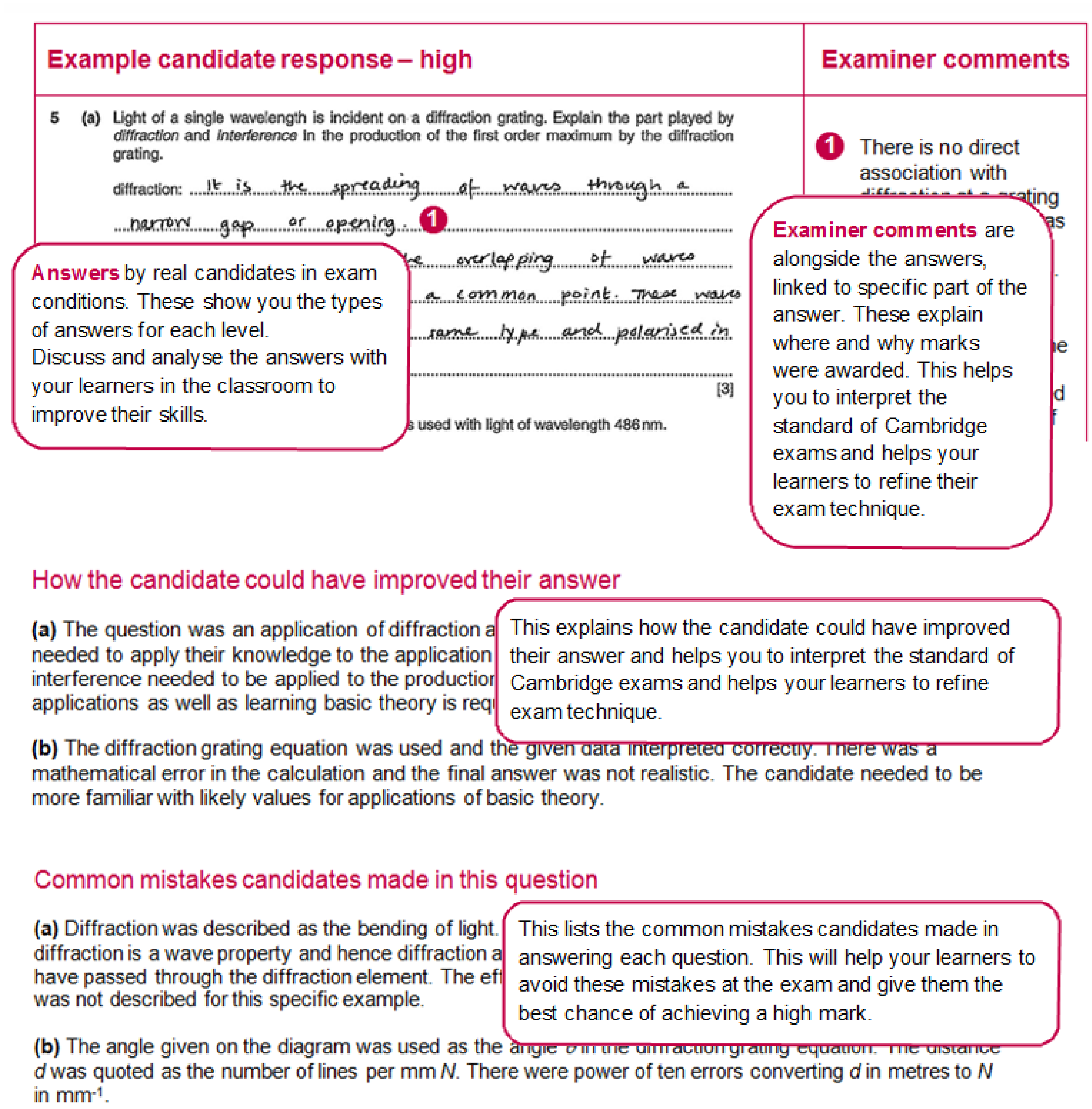
This document provides illustrative examples of candidate work. These help teachers to assess the standard required to achieve marks, beyond the guidance of the mark scheme. Some question types where the answer is clear from the mark scheme, such as short answers and multiple choice, have therefore been omitted.

The questions, mark schemes and pre-release material used here are available to download as a zip file from Teacher Support as the Example Candidate Responses Files. These files are:

Question Paper 22, June 2016	
Question paper	9702_s16_qp_22.pdf
Mark scheme	9702_s16_ms_22.pdf
Question Paper 33, June 2016	
Question paper	9702_s16_qp_33.pdf
Mark scheme	9702_s16_ms_33.pdf
Question Paper 42, June 2016	
Question paper	9702_s16_qp_42.pdf
Mark scheme	9702_s16_ms_42.pdf
Question Paper 52, June 2016	
Question paper	9702_s16_qp_52.pdf
Mark scheme	9702_s16_ms_52.pdf

Past papers, Examiner Reports and other teacher support materials are available on Teacher Support at **https://teachers.cie.org.uk**

How to use this booklet



Assessment at a glance

Candidates for Advanced Subsidiary (AS) certification take Papers 1, 2 and 3 in a single examination series.

Candidates who, having received AS certification, wish to continue their studies to the full Advanced Level qualification may carry their AS marks forward and take Papers 4 and 5 in the examination series in which they require certification.

Candidates taking the full Advanced Level qualification at the end of the course take all five papers in a single examination series.

Candidates may only enter for the papers in the combinations indicated above.

Candidates may not enter for single papers either on the first occasion or for resit purposes.

All components are externally assessed.

Component	Weighting	
	AS Level	A Level
Paper 1 Multiple Choice — **1 hour 15 minutes** This paper consists of 40 multiple choice questions, all with four options. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on an answer sheet. [40 marks]	31%	15.5%
Paper 2 AS Level Structured Questions — **1 hour 15 minutes** This paper consists of a variable number of questions of variable mark value. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on the question paper. [60 marks]	46%	23%
Paper 3 Advanced Practical Skills — **2 hours** This paper requires candidates to carry out practical work in timed conditions. The paper will consist of two experiments drawn from different areas of physics. The experiments may be based on physics not included in the syllabus content, but candidates will be assessed on their practical skills rather than their knowledge of theory. Candidates will answer both questions. Candidates will answer on the question paper. [40 marks]	23%	11.5%
Paper 4 A Level Structured Questions — **2 hours** This paper consists of a variable number of questions of variable mark value. All questions will be based on the A Level syllabus but may require knowledge of material first encountered in the AS Level syllabus. Candidates will answer all questions. Candidates will answer on the question paper. [100 marks]	–	38.5%

Component	Weighting	
	AS Level	A Level
Paper 5 Planning, Analysis and Evaluation **1 hour 15 minutes** This paper consists of two questions of equal mark value based on the practical skills of planning, analysis and evaluation. The context of the questions may be outside the syllabus content, but candidates will be assessed on their practical skills of planning, analysis and evaluation rather than their knowledge of theory. Candidates will answer both questions. Candidates will answer on the question paper. [30 marks]	–	11.5%

Teachers are reminded that the latest syllabus is available on our public website at **www.cie.org.uk** and Teacher Support at **https://teachers.cie.org.uk**

Paper 5 – Planning, Analysis and Evaluation

Question 1

Example candidate response – high

1 A student is investigating the acceleration of a trolley moving up an inclined plane as shown in Fig. 1.1.

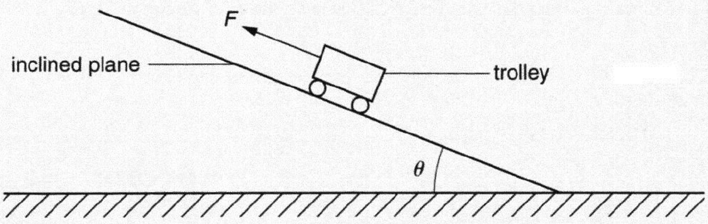


Fig. 1.1

The student is investigating the relationship between the acceleration *a* of the trolley and the angle *θ* of the inclined plane when a force *F* is applied to the trolley.

It is suggested that the relationship is

$$ma = F - (mg\sin\theta + k)$$

where *g* is the acceleration of free fall, *m* is the mass of the trolley and *k* is a constant.

Design a laboratory experiment to test the relationship between *a* and *θ*. Explain how your results could be used to determine a value for *k*. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any safety precautions to be taken.

1

[15]

$F = BIl\sin\theta$

$F =$

$ma = F - mg\sin\theta + k$

$ma = \frac{F}{m} - g\sin\theta + \frac{k}{m}$

$a = -g\sin\theta + \left(\frac{k}{m} - g\right)$

$\frac{k}{m} - g$

$\frac{k}{m}$

$ma = F - mg\sin\theta - k$

$ma = \frac{F}{m} - g\sin\theta - \frac{k}{m}$

$a = -g\sin\theta + \left(\frac{F - k}{m}\right)$

$\frac{F - k}{m} = c$

$mc = F - k$

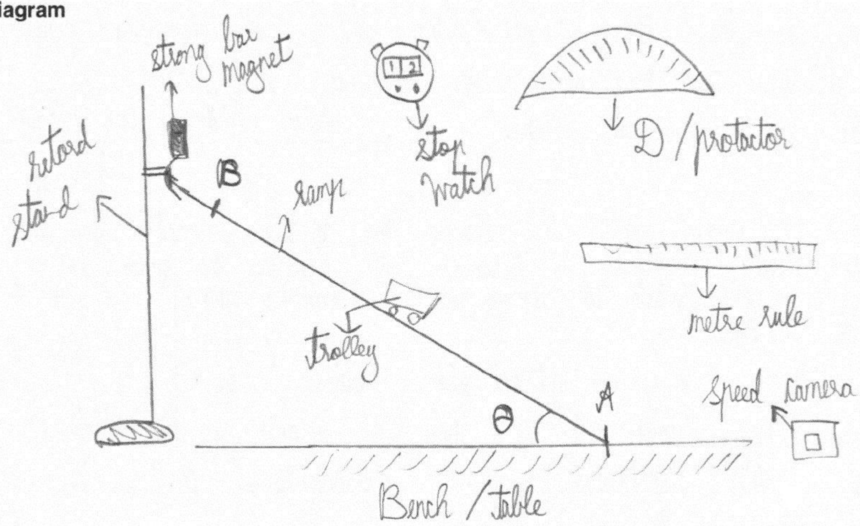
$F - mc = k$

Examiner comments

1 The candidate has used the given relationship to rearrange it so that it matches the equation of a straight line. It is assumed that the candidate is using *c* for the *y*-intercept.

Example candidate response – high, continued

Diagram



2

Defining problem –:
- θ is the independent variable
- a is the dependant variable
- m should be kept constant by using the same trolley.

3

Method of ~~dat~~ data collection –:
- Set up the apparatus as shown in diagram by clamping one end of the ramp with retord stand.
- Measure the angle between the bench and ramp by using a protactor. 4
- Measure the length of the ramp through which the trolley moves.
- Between 2 fixed points on ramp, ~~measure~~ ~~determine~~ record the time taken by the trolley and note the change in

5

Examiner comments

2 The candidate gains the first mark for a clearly labelled diagram which includes a method to support the inclined plane. The drawing of the protractor should indicate the angle being measured. There is no need to draw items such as stopwatches.

3 The candidate clearly indicates the independent and dependent variables for the first P mark. The candidate realises that the mass of the trolley needs to be constant, which gains a D mark, but does not gain the second P mark for keeping the force constant.

4 The method to measure the angle is clearly explained, using an appropriate instrument.

5 The candidate gains a mark for measuring the time with the stop-watch shown in the diagram above, although it would have been better to mention the stopwatch in this sentence. Measuring the length of the ramp is too vague for credit to be given.

Example candidate response – high, continued	Examiner comments
speed at these two points using the speed camera and detector ⑥ • Determine the acceleration by dividing the change of speed by the time taken. $a = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}$. • Attach a magnet with the trolley and another magnet with the retord stand. The force of attraction will provide the force to trolley to move up the inclined ramp. Data analysis –: • Plot a graph of acceleration against Sin θ. • The given relationship is true if graph is a straight line with decreasing gradient. gradient = −g. y - intercept = ~~...~~ $\frac{F - k}{m}$ ⑦ ∴ k = ~~(y intercept + g) m~~ F − m(y - intercept) ⑧ Safety precaution –: • Do not touch the trolley while it is moving on the ramp as it may injure the hands. Wear thick rubber gloves. Additional detail –: • Use a sand tray. The trolley will fall into it rather than falling on the bench. • Use a large protactor to minimize error in measuring θ. • ~~Change the angle θ~~ Make large changes to the angle θ to have noticeable change in acceleration. • Release the trolley from the same point everytime and use the same length of ramp for determining speed changes with time. The distance should be large for greater changes in speed. • Use the same ramp everytime with minimum friction to have smooth movement of trolley. • The force applied should be same and there should be no external forces like wind from fan. ⑨ [Total: 15]	⑥ *Speed camera* is not worthy of credit. The equation does not gain credit on its own; an appropriate, workable method is needed to determine *a*. ⑦ Three marks are awarded for a clear analysis section. An appropriate graph is suggested and the candidate has identified the condition for the relationship to be valid. ⑧ A D mark is awarded for correctly identifying the *y*-intercept or for correctly rearranging the equation on page 2. The third A mark is awarded for correctly identifying *k*. ⑨ A safety precaution is credited in the additional detail section. The candidate also scores the second P mark for the last sentence. **Total marks awarded = 11 out of 15**

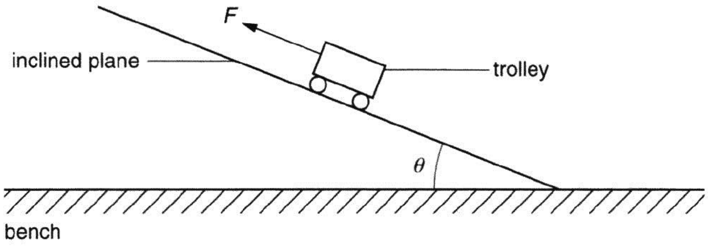
How the candidate could have improved their answer

The candidate could have included more detail on methods of data collection, for example, the mass of the trolley needed to be measured. Furthermore, the determination of the acceleration should have been more detailed and included laboratory measurements, with a relevant equation using the measurements suggested.

There could also have been more additional detail, e.g. an explanation of how the force would be kept constant and detail on repeating the experiment for each angle.

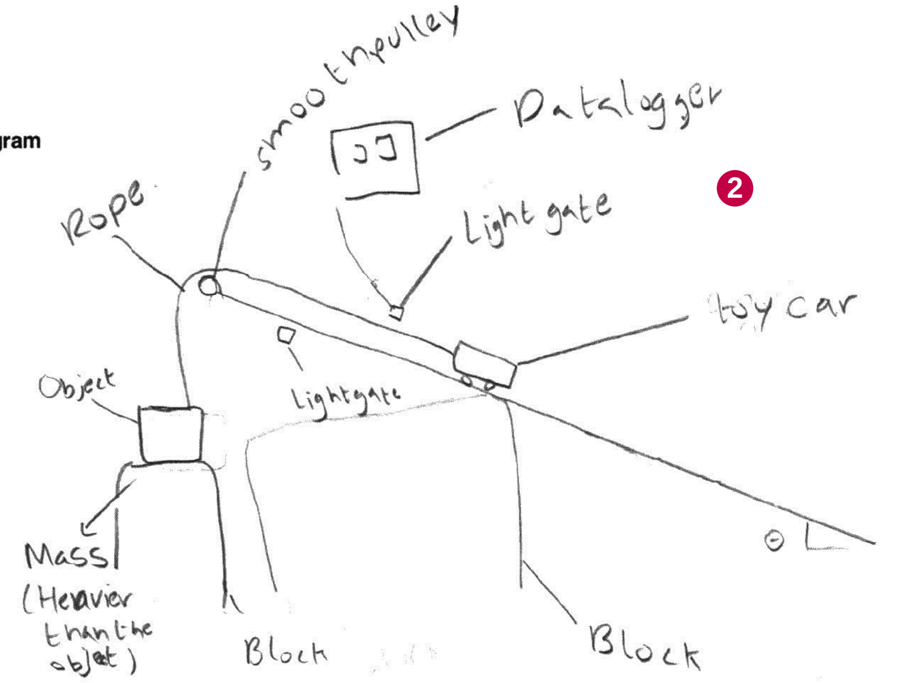
Mark awarded for defining the **P**roblem **(P)** = **2 out of 2**
Mark awarded for **M**ethods of data collection **(M)** = **3 out of 4**
Mark awarded for method of **A**nalysis **(A)** = **3 out of 3**
Mark awarded for additional **D**etail **(D)** = **3 out of 6**

Total marks awarded = 11 out of 15

Example candidate response – middle	Examiner comments
1 A student is investigating the acceleration of a trolley moving up an inclined plane as shown in Fig. 1.1.  **Fig. 1.1** The student is investigating the relationship between the acceleration *a* of the trolley and the angle θ of the inclined plane when a force *F* is applied to the trolley. It is suggested that the relationship is $ma = F - (mg\sin\theta + k)$ where *g* is the acceleration of free fall, *m* is the mass of the trolley and *k* is a constant. Design a laboratory experiment to test the relationship between *a* and θ. Explain how your results could be used to determine a value for *k*. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to • the procedure to be followed, • the measurements to be taken, • the control of variables, • the analysis of the data, • any safety precautions to be taken. [15] 1 $a = \frac{F}{m} - g\sin\theta + \frac{k}{m}$	1 An attempt to rearrange the equation is made here, but it is not in the equation of a straight line. Candidates should be encouraged to put the given relationship into $y = mx + c$ format.

Example candidate response – middle, continued

Diagram



2

3

Independent variable is the angle θ.
Dependent variable is the acceleration.
Control of variable is the force.

The mass will be at rest on the block at first and then the block will be removed so the trolley starts to move. The mass must be atleast twice times heavier than the trolley.
~~Mass of of the object~~ Weight of the object can be measured by a neuton metre and that will be our constant force. 4
To calculate velocity we will use light gates and a data logger 5
We will measure the time using a stopwatch.
Time taken between the two light gates.
6

Examiner comments

2 The diagram lacks care; for example, the block is not level with the bottom of the inclined plane, and the inclined plane is not stable when the trolley reaches the top.

3 The candidate clearly identifies the independent and dependent variables for the first P mark. ‘Control of variable’ does not gain credit for the second mark, as this is repeated from the stem of the question. The mention later on that the force should be constant gains this mark.

4 The second P mark is awarded here.

5 The method for this needs to be clearly explained.

6 The candidate gains the M mark for using light gates and a data logger. Two D marks could have been awarded if the candidate had explained that the length of the card used to interrupt the light gate is measured with a ruler and if an appropriate correct equation had been used to determine the acceleration.

Total marks awarded = 6 out of 15

How the candidate could have improved their answer

More detail could have been given in the methods of data collection. A little more care taken with the diagram would also have helped. The mass of the trolley also needed to be measured.

The candidate sensibly suggested the use of light gates and a data logger, but should have included much more detail about how the light gates were to be used, what lengths would need to be measured, and how these measurements could be used to determine the acceleration.

The candidate could have improved their answer by analysing the data more effectively. Careful rearrangement of the original relationship into the equation of a straight line, $y = mx + c$, would have earned an additional detail mark. This would also have scored the second and third analysis marks by enabling the candidate to realise that the relationship would be valid if the graph was a straight line with a *y*-intercept, allowing *k* to be determined correctly.

There were a number of further additional detail marks that could have been awarded, especially for details about repeating results and how the force should be kept constant. The candidate could also have identified other variables, such as the mass of the trolley, that needed to be kept constant as well.

Mark awarded for defining the **P**roblem **(P)** = **2 out of 2**
Mark awarded for **M**ethods of data collection **(M)** = **2 out of 4**
Mark awarded for method of **A**nalysis **(A)** = **1 out of 3**
Mark awarded for additional **D**etail **(D)** = **1 out of 6**

Total marks awarded = 6 out of 15

Example candidate response – low

1 A student is investigating the acceleration of a trolley moving up an inclined plane as shown in Fig. 1.1.

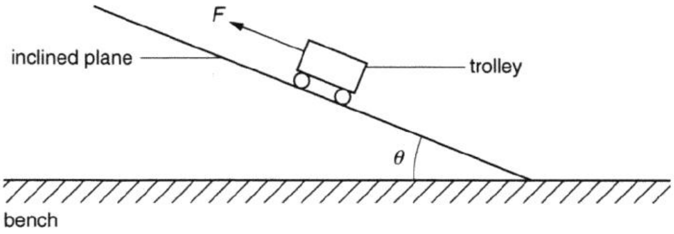


Fig. 1.1

The student is investigating the relationship between the acceleration a of the trolley and the angle θ of the inclined plane when a force F is applied to the trolley.

It is suggested that the relationship is $5 \cdot a = 10 - (5(10)\sin 30° + 1)$ $= 1.8$ $= -0.24.$ $= -19.00$

$$ma = F - (mg\sin\theta + k)$$

where g is the acceleration of free fall, m is the mass of the trolley and k is a constant.

Design a laboratory experiment to test the relationship between a and θ. Explain how your results could be used to determine a value for k. You should draw a diagram, on page 3, showing the arrangement of your equipment. In your account you should pay particular attention to

- the procedure to be followed,
- the measurements to be taken,
- the control of variables,
- the analysis of the data,
- any safety precautions to be taken.

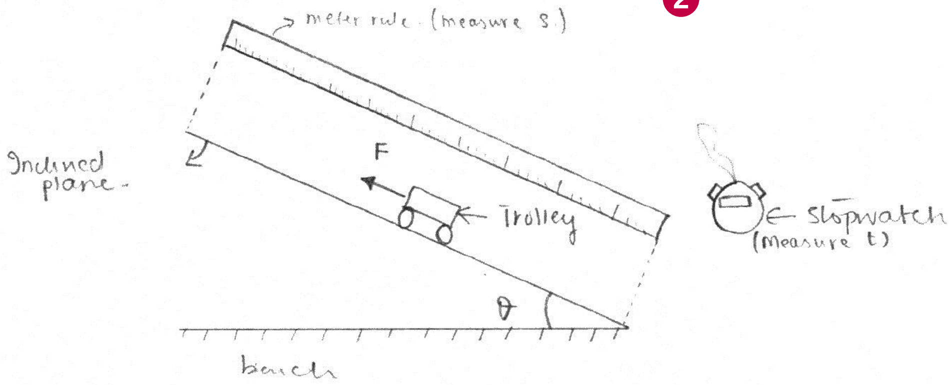
1

[15]

$m\left(\frac{v-u}{t}\right) = F - mg\sin\theta + k$

Examiner comments

1 This is a good page for drafting a possible response to the question.

Example candidate response – low, continued	Examiner comments
Diagram $\theta = \frac{1}{a}$  2 3 In this experiment; Angle θ is the independent variable while acceleration a, is the dependent variable. Keeping length of the plane constant: 4 Measure angle θ using a protector, calculate change in ~~speed~~ velocity ~~over time~~ of the trolley moving up a inclined plane; $v = s/t$, where s is the length of plane and 't' can be measured using a stopwatch. The change in velocity over a period of time will be acceleration; $a = v-u/t$. Take few sets of readings for the variations in acceleration of the trolley on increasing or decreasing the angle θ between bench and a plane. 5	**2** The candidate has just copied the diagram from the question paper. Although they have added labels, there is no indication of how the inclined plane is to be supported. The diagram of the stopwatch is not needed. **3** The candidate starts the question well by identifying the angle and the acceleration as the independent and dependent variables. The candidate then tries to identify variables that need to be kept constant. However, the length of the plane does not gain credit here. **4** M marks are awarded for both the use of the stopwatch and the use of a protractor to measure the angle. **5** The candidate is confused about the method to determine the acceleration. The candidate determines the average velocity of the trolley, not the final velocity, making the method of calculation of acceleration inaccurate. There is just one D mark for measuring the length of the plane with a ruler, as this should have been more clearly expressed. **Total marks awarded = 5 out of 15**

How the candidate could have improved their answer

The candidate should have drawn a diagram to show how the experiment could work in a laboratory, then described the method to determine the acceleration in greater detail, including how measurements would be made and used. The candidate should have described an appropriate graph showing the relationship of *a* against *θ* and explained how *k* could be determined. There were a number of further additional detail marks that could have been awarded, e.g. details about measurements and experimental techniques experienced during their laboratory course.

Mark awarded for defining the **P**roblem **(P)** = **2 out of 2**
Mark awarded for **M**ethods of data collection **(M)** = **2 out of 4**
Mark awarded for method of **A**nalysis **(A)** = **0 out of 3**
Mark awarded for additional **D**etail **(D)** = **1 out of 6**

Total marks awarded = 5 out of 15

Common mistakes candidates made in this question

When defining the problem, candidates often discussed 'controlling' variables rather than stating the variables that need to be kept constant for a fair test. Some candidates did not read the question carefully and designed experiments with the trolley rolling *down* the plane. Others did not show how the inclined plane could be supported or varied.

In general, candidates did not always describe the methods of data collection, in particular the acceleration, in sufficient detail. They also did not mention the relevant measurements and how these measurements would be used. Where candidates suggest data logging procedures, clear explanations were required about the measurements needed. For example, if a piece of card was being used to interrupt a light beam, then the length of the card needed to be measured with a ruler.

When using trigonometry to determine the angle, a clear indication was needed for the lengths to be used as well as a correct relationship.

Many candidates did not describe a graph of *a* against *θ* and, as a consequence, did not gain any further marks in this section. The next mark was awarded for realising that the relationship would be valid if a straight line that did not pass through the origin, in an appropriate graph, was observed. However, many candidates assumed that the straight line *would* pass through the origin. The third mark was for explaining how *k* could be determined. To earn the mark, this required *k* to be the subject of the equation that included the *y*-intercept. Many candidates did not work out the *y*-intercept correctly, with many incorrectly positioned negative signs. One additional detail mark was awarded for the correct rearrangement of the relationship for the graph plotted; this needed to be in the $y = mx + c$ format.

In the additional detail section, vague responses were not awarded marks. The purpose of this section was for candidates to broaden their answers by including appropriate detail based on their practical experience. They were not awarded marks for the statement 'the experiment is repeated and an average is taken'. More detail was required, for example 'for the same angle, the experiment is repeated and *a* is determined again and the average value of *a* is then determined'.

A mark was available for an appropriate safety precaution linked to the trolley falling. Candidates' answers should have given safety detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

Example candidate response – high

2 A student is investigating how the resistance of a wire depends on the diameter of the wire.

The circuit is set up as shown in Fig. 2.1.

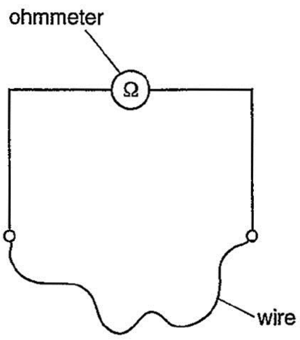


Fig. 2.1

The resistance R of the wire is measured using an ohmmeter.

The experiment is repeated for wires of the same material and same length L but different diameter d.

It is suggested that R and d are related by the equation

$$R = \frac{4\rho L}{\pi d^2}$$

where ρ is a constant.

(a) A graph is plotted of R on the y-axis against $\frac{1}{d^2}$ on the x-axis.

Determine an expression for the gradient.

$$R = \boxed{\frac{4\rho L}{\pi}} \times \frac{1}{d^2}$$

$$m = \frac{4\rho L}{\pi}$$

❶

gradient = $\frac{4\rho L}{\pi}$ [1]

Examiner comments

❶ The candidate has put the given equation into a $y = mx + c$ format. It is useful to encourage candidates to do this for this part.

Mark for (a) = 1/1

Example candidate response – high, continued	Examiner comments
1.2075 ± 0.03 / 3.1387 ± 0.11	

(b) Values of d and R are given in Fig. 2.2.

d/10^{-3} m	R/Ω	$\frac{1}{d^2}$/10^6 m^{-2}
0.91 ± 0.01	1.6	1.21 ± 0.03
0.56 ± 0.01	4.4	3.19 ± 0.1
0.46 ± 0.01	6.6	4.73 ± 0.2
0.38 ± 0.01	9.7	6.93 ± 0.4
0.32 ± 0.01	13.9	9.77 ± 0.6
0.27 ± 0.01	19.5	13.72 ± 1

Fig. 2.2

2

Calculate and record values of $\frac{1}{d^2}$/10^6 m^{-2} in Fig. 2.2.

Include the absolute uncertainties in $\frac{1}{d^2}$. [3]

(c) (i) Plot a graph of R/Ω against $\frac{1}{d^2}$/10^6 m^{-2}

Include error bars for $\frac{1}{d^2}$. [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

Line of best fit
(4.73, 6.6) (13.72, 19.5)
triangle drawn

$\frac{19.5 - 6.6}{(13.72 - 4.73) \times 10^6} = 1.43 \times 10^{-6}$

worst acceptable straight line
(1.18, 1.6) (14.72, 19.5)

$\frac{19.5 - 1.6}{(14.72 - 1.18) 10^6} = 1.32 \times 10^{-6}$

3

absolute uncertainty: $(1.43 - 1.32) 10^{-6}$
$= 0.11 \times 10^{-6}$

$(1.43 \pm 0.1)\ 10^{-6}$

gradient = ~~1.43 ± 0.1~~ [2]

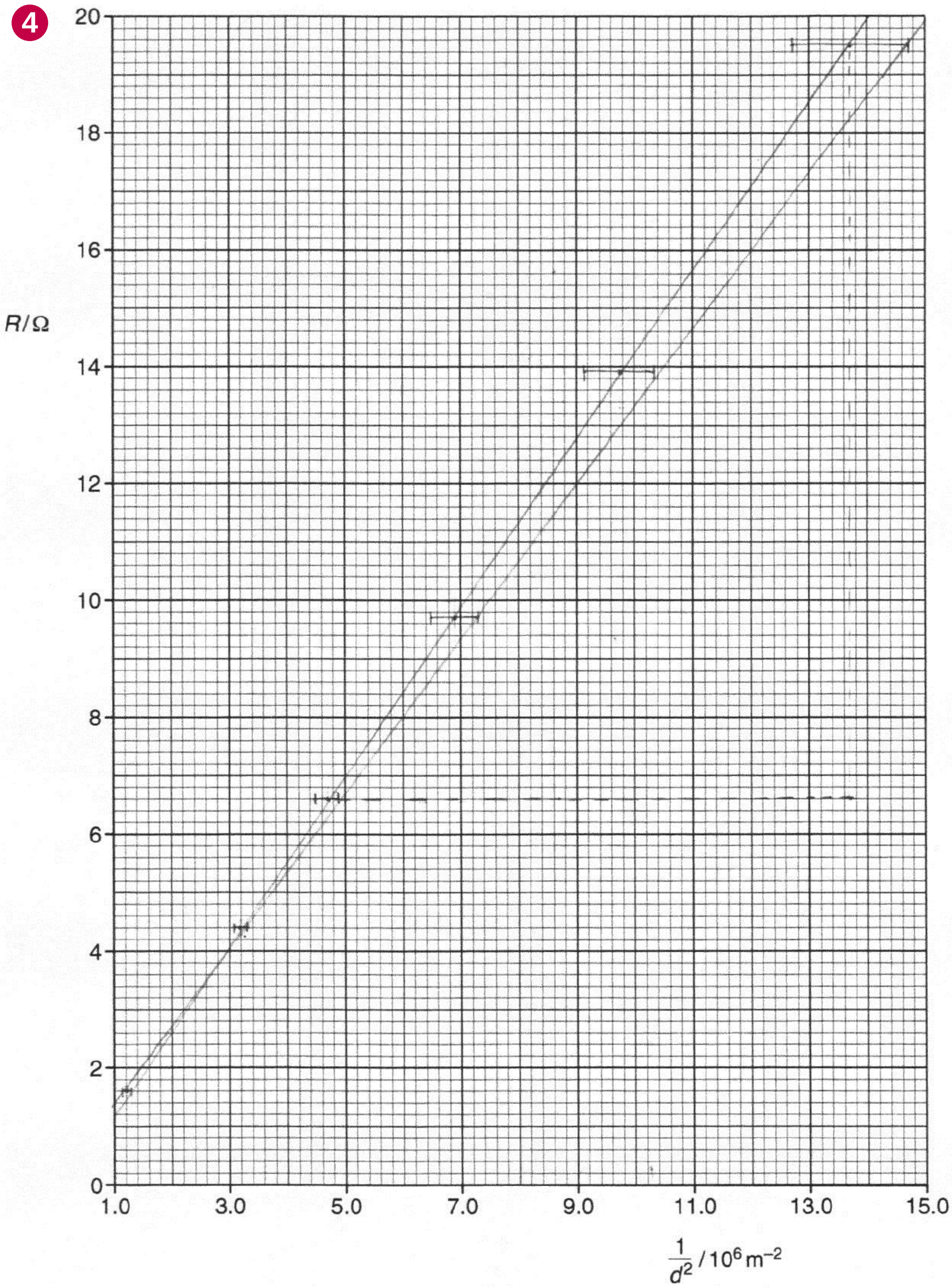
Examiner comments

2 The candidate has labelled the column correctly.
The second mark is not awarded because the last value of $1/d^2$ is given to four significant figures. Since the raw data has been given to two significant figures, then $1/d^2$ should be given to two (or three) significant figures.

Mark for (b) = 2/3

3 The candidate indicates the triangles used on the graph. The hypotenuse is more than half the length of the line.
The calculation shown above allows for the 10^6 on the x-axis. This will assist in part (d). A common mistake is for candidates not to allow for powers of ten on the axes.
The determination of the absolute uncertainty is clearly demonstrated.

Mark for (c) (iii) = 2/2

Example candidate response – high, continued	Examiner comments
4 	**4** The candidate has plotted the data points accurately. Importantly, the dots are not too large. The error bars are also clearly shown. Mark for (c) (i) = 2/2 The candidate does not indicate the best and worst acceptable lines. The lines should either be clearly labelled or the worst acceptable line should be dashed. Technically, the worst acceptable line in this case could have been steeper so that it passed within the second to last error bar. Mark for (c) (ii) = 2/2

Example candidate response – high, continued	Examiner comments
$\Delta \rho = \rho$ $\frac{\Delta\rho}{\rho} = 0$ $\rho = \frac{m \times \pi}{4L}$ 8 $\rho = \frac{m\pi}{4L}$ $\frac{\Omega}{m^{-2}} = \frac{\Omega m^2}{m} = \Omega m$	
(d) (i) Using your answers to **(a)** and **(c)(iii)**, determine the value of ρ. Include an appropriate unit. Data: $L = 1.00 \pm 0.01$ m. $m = \frac{4\rho L}{\pi}$ $\rho = 1.13 \times 10^{-6}\ \Omega m$ $1.43 \times 10^{-6} = \frac{4\rho \times 1}{\pi}$ **5** $4\rho = (1.43 \times 10^{-6})\pi$ $\rho = \frac{(1.43 \times 10^{-6})\pi}{4}$ ρ = $1.13 \times 10^{-6}\ \Omega m$ [2]	**5** The candidate uses the answer from part (a). The method to gain the answer is clearly demonstrated. The answer is correctly evaluated and an appropriate unit given. Mark for (d) (i) = 2/2
(ii) Determine the percentage uncertainty in ρ. $\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + \frac{\Delta L}{L}$ % uncertainty = $0.09 \times 100 = 9\%$ $\frac{\Delta\rho}{\rho} = \frac{0.1 \times 10^{-6}}{1.43 \times 10^{-6}} + \frac{0.01}{1}$ **6** $\frac{\Delta\rho}{\rho} = 0.09$ percentage uncertainty in ρ = 9 % [1]	**6** The candidate clearly demonstrates the determination of the percentage uncertainty using a fractional method. Mark for (d) (ii) = 1/1
7 **(e)** The experiment is repeated with a thinner wire of diameter 0.23 ± 0.01 mm. The wire is of the same material and length. Determine the resistance R of the wire. Include the absolute uncertainty in your answer. $R = \frac{4\rho L}{\pi d^2}$ $R = \frac{4 \times (1.13 \times 10^{-6}) \times 1}{\pi \times 0.23^2} = 2.71 \times 10^{-5}$ $\frac{\Delta R}{R} = \frac{\Delta\rho}{\rho} + \frac{\Delta L}{L} + 2\frac{\Delta d}{d}$ $\Delta R = 5.42 \times 10^{-6}$ $= 0.09 + \frac{0.01}{1} + 2\left(\frac{0.01}{0.23}\right)$ R = $(2.71 \pm 0.5) \times 10^{-5}$ Ω [2] $= 0.2$ [Total: 15]	**7** Unfortunately, the candidate does not allow for *d* being given as 0.23 mm and so is not awarded the first mark due to a power of ten error. The candidate gives the answer to an appropriate number of significant figures. The candidate determines the fractional uncertainty. It would have been helpful to see the working 0.2 × 2.71. The final mark is given because the error is carried forward. Mark for (e) = 1/2 **Total marks awarded = 13 out of 15**

How the candidate could have improved their answer

This candidate clearly demonstrated the methods used to determine the answers. The graph was carefully constructed, although the candidate should have labelled the line of best fit and the worst acceptable line.

Two marks were not awarded: one for giving too many significant figures in the data table in part (b) and the other for not changing millimetres to metres in part (e).

Mark awarded = **(a) 1/1**
Mark awarded = **(b) 2/3**
Mark awarded = **(c) (i) 2/2, (ii) 2/2, (iii) 2/2**
Mark awarded = **(d) (i) 2/2, (ii) 1/1**
Mark awarded = **(e) 1/2**

Total marks awarded = 13 out of 15

Example candidate response – middle

2 A student is investigating how the resistance of a wire depends on the diameter of the wire.

The circuit is set up as shown in Fig. 2.1.

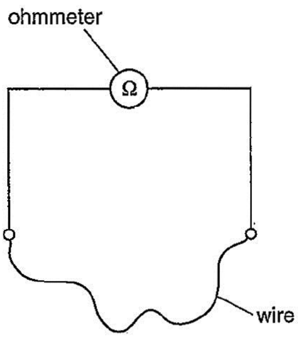


Fig. 2.1

The resistance R of the wire is measured using an ohmmeter.

The experiment is repeated for wires of the same material and same length L but different diameter d.

It is suggested that R and d are related by the equation

$$R = \frac{4\rho L}{\pi d^2}$$

where ρ is a constant.

(a) A graph is plotted of R on the y-axis against $\frac{1}{d^2}$ on the x-axis.

Determine an expression for the gradient.

1

$$R = \frac{4\rho L}{\pi d^2}$$

$$R = \left(\frac{4\rho L}{\pi}\right)\frac{1}{d^2}$$

gradient = $\frac{4\rho L}{\pi}$ ....[1]

Examiner comments

1 The candidate has clearly put the equation into a straight line format.

Mark for (a) = 1/1

Example candidate response – middle, continued

(b) Values of d and R are given in Fig. 2.2.

d / 10^{-3} m	R / Ω	$\frac{1}{d^2}$ / 10^6 m^{-2}
0.91 ± 0.01	1.6	~~1.21 ± 0.03~~ 1.20 ± 0.03
0.56 ± 0.01	4.4	~~3.19 ± 0.11~~ 3.20 ± 0.10
0.46 ± 0.01	6.6	~~4.73 ± 0.20~~ 4.70 ± 0.20
0.38 ± 0.01	9.7	~~6.93 ± 0.35~~ 6.90 ± 0.40
0.32 ± 0.01	13.9	~~9.77 ± 0.58~~ 9.80 ± 0.60
0.27 ± 0.01	19.5	~~13.70 ± 0.96~~ 13.70 ± 1.00

Fig. 2.2 ❷

Calculate and record values of $\frac{1}{d^2}$ / 10^6 m^{-2} in Fig. 2.2.

Include the absolute uncertainties in $\frac{1}{d^2}$. [3]

(c) (i) Plot a graph of R / Ω against $\frac{1}{d^2}$ / 10^6 m^{-2}.

Include error bars for $\frac{1}{d^2}$. [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

Gradient of best fit = $\frac{19-5}{(13.4-3.6)\times10^6}$

$= \frac{14}{9.8\times10^6}$

$= 1.43\times10^{-6}$ Ω m^{-2}

Gradient of the worst fit :

$= \frac{18.6-2}{(14-1.4)\times10^6}$

$= \frac{16.6}{1.26\times10^7}$

$= 1.32\times10^{-6}$ Ω m^{-2}

Absolute uncertainty = $(1.43-1.32)\times10^{-6}$

$= 0.11\times10^{-6}$

❸

gradient = $(1.43 \pm 0.11)\times10^{-6}$ Ω m^{-2} [2]

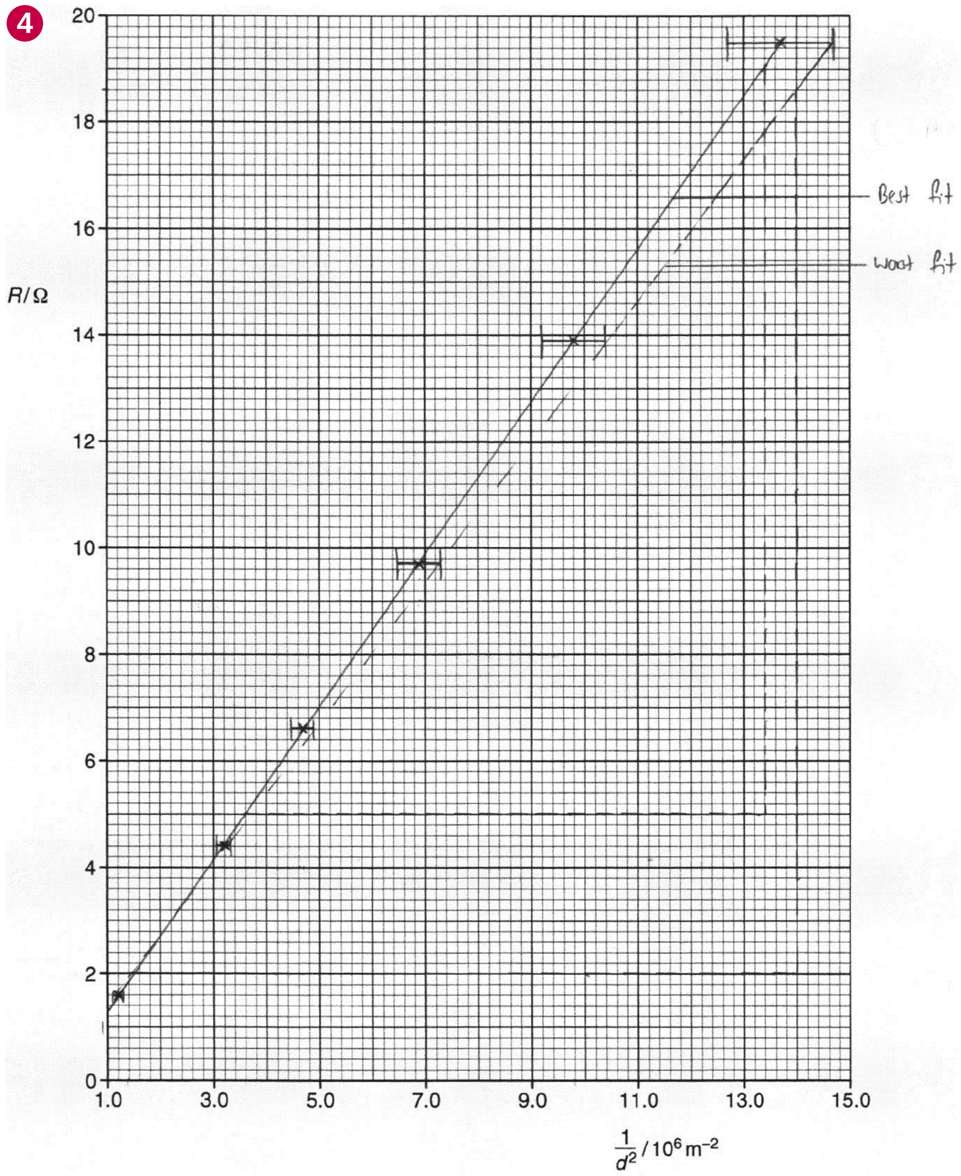
Examiner comments

❷ The candidate has labelled the column correctly.
The second mark is not awarded because the last row has too many significant figures. Furthermore, the candidate does not appear to have understood the calculation of values since they have determined the first five rows correctly to two significant figures and then incorrectly added a zero.
The uncertainties have been determined correctly.

Mark for (b) = 2/3

❸ The candidate clearly demonstrates the methods to determine both the gradient and the absolute uncertainty in the gradient. They have correctly allowed for the power of ten on the x-axis. It is useful that the candidate has included a unit as this will help in the next part.

Mark for (c) (iii) = 2/2

Example candidate response – middle, continued	Examiner comments
4 	**4** The points are clearly plotted and the error bars carefully drawn. Mark for (c) (i) = 2/2 The worst acceptable line is indicated by a dashed line. It is important that 'gaps' are not present in the vicinity of error bars. Mark for (c) (ii) = 2/2

Example candidate response – middle, continued	Examiner comments
(d) (i) Using your answers to (a) and (c)(iii), determine the value of ρ. Include an appropriate unit. Data: $L = 1.00 \pm 0.01$ m. Gradient $= \frac{4\rho L}{\pi}$ $\frac{4\rho L}{\pi} = 1.43 \times 10^{-6}$ $\frac{\rho(4)(1)}{\pi} = 1.43 \times 10^{-6}$ $\rho = \frac{(1.43\times10^{-6})(\pi)}{4}$ $= 1.12 \times 10^{-6}$ **5** $\rho =$ 1.12×10^{-6} .... [2] **(ii)** Determine the percentage uncertainty in ρ. **6** $\frac{\Delta\rho}{\rho} = \frac{\Delta G}{G} + \frac{\Delta L}{L}$ $= \frac{0.11\times10^{-6}}{1.43\times10^{-6}} + \frac{0.01}{1.00}$ $\approx$ ~~0.0769~~ $= 0.087$ $\% = \frac{\Delta\rho}{\rho} \times 100$ $= 0.087 \times 100$ $= 8.7\%$ percentage uncertainty in $\rho =$ 8.7 .... % [1] **(e)** The experiment is repeated with a thinner wire of diameter 0.23 ± 0.01 mm. The wire is of the same material and length. Determine the resistance R of the wire. Include the absolute uncertainty in your answer. **7** $R = \left(\frac{4\rho L}{\pi}\right)\frac{1}{d^2}$ $R = (G_B)\frac{1}{d^2}$ $= (1.43\times10^{-6})\left(\frac{1}{(0.23\times10^{-3})^2}\right)$ $= 27.03$ $R = (G_w)\frac{1}{d^2}$ $= (1.32\times10^{-6})\left(\frac{1}{(0.23\times10^{-3})^2}\right)$ ≈ 24.95 Absolute uncertainty $= 27.03 - 24.95$ $= 2.08$ $R =$ 27.03 ± 2.08 .... Ω [2] **8** [Total: 15]	**5** The determination of resistivity using the gradient is clearly demonstrated. Unfortunately, the unit has been omitted. Mark for (d) (i) = 1/2 **6** The candidate clearly demonstrates the determination of percentage uncertainty. It is helpful to see the substitution of values. Mark for (d) (ii) = 1/1 **7** The candidate recognises that *R* may be calculated using the gradient. However, a mark is not awarded because the value of *d* is given to two significant figures and so the answer should be given to two (or three) significant figures. **8** The candidate incorrectly attempts a worst value calculation here. Since the smaller gradient has been used, the candidate should have used 0.24 mm for the value of *d*. This answer very clearly demonstrates the need for candidates to show their working. Mark for (e) = 0/2 **Total marks awarded = 11 out of 15**

How the candidate could have improved their answer

(b) The candidate needed to understand significant figures in calculated quantities for this question. The calculated quantity should be given to the same number of significant figures (or one more significant figure) as the least accurate raw data. In this case, the raw data in the last row was given to two significant figures so the calculated data should have been given to two (or three) significant figures. Furthermore, the candidate did not appear to have understood the calculation of values, since they determined the first five rows correctly to two significant figures and then incorrectly added a zero; these values were then incorrectly calculated to three significant figures.

(d) (i) Here the candidate clearly demonstrated their method and gained an answer with the correct power of ten. Unfortunately, the candidate omitted a unit.

(e) Here the candidate gave the value of *R* to too many significant figures. Since the least accurate data is *d*, which is given to two significant figures, *R* should have been given to two or three significant figures. To determine the absolute uncertainty in *R*, the candidate used a maximum/minimum method. In this case, the candidate attempted to find the minimum *R* value but did not use the maximum value of *d*.

Mark awarded = **(a) 1/1**
Mark awarded = **(b) 2/3**
Mark awarded = **(c) (i) 2/2, (ii) 2/2, (iii) 2/2**
Mark awarded = **(d) (i) 1/2, (ii) 1/1**
Mark awarded = **(e) 0/2**

Total marks awarded = 11 out of 15

Example candidate response – low	Examiner comments

2 A student is investigating how the resistance of a wire depends on the diameter of the wire.

The circuit is set up as shown in Fig. 2.1.

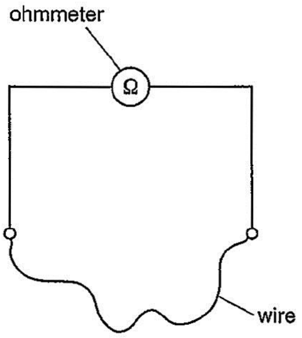


Fig. 2.1

The resistance R of the wire is measured using an ohmmeter.

The experiment is repeated for wires of the same material and same length L but different diameter d.

It is suggested that R and d are related by the equation

$$R = \frac{4\rho L}{\pi d^2}$$

where ρ is a constant.

(a) A graph is plotted of R on the y-axis against $\frac{1}{d^2}$ on the x-axis.

Determine an expression for the gradient.

$R = \frac{4PL}{\pi d^2}$

$y = mx + c$

$R = \frac{4P}{\pi} = \frac{1}{d^2} + c$

$y = mx + c$

$R = \frac{4PL}{\pi} \frac{1}{d2}$ **1**

gradient = $\frac{4P}{\pi}$ ....[1]

1 The candidate has attempted to put the given equation into $y = mx + c$ format but has omitted the ‘L’.

Mark for (a) = 0/1

Example candidate response – low, continued

(b) Values of d and R are given in Fig. 2.2.

$d/10^{-3}$m	R/Ω	$\frac{1}{d^2}/10^6$ $^{-2}$
0.91 ± 0.01	1.6	1.21 ± 0.02
0.56 ± 0.01	4.4	3.18 ± 0.11
0.46 ± 0.01	6.6	4.73 ± 0.29
0.38 ± 0.01	9.7	6.93 ± 0.316
0.32 ± 0.01	13.9	9.77 ± 0.61
0.27 ± 0.01	19.5	13.72 ± 1.02

Fig. 2.2

Calculate and record values of $\frac{1}{d^2}/10^6\,\text{m}^{-2}$ in Fig. 2.2.

Include the absolute uncertainties in $\frac{1}{d^2}$. [3]

(c) (i) Plot a graph of R/Ω against $\frac{1}{d^2}/10^6\,\text{m}^{-2}$.

Include error bars for $\frac{1}{d^2}$. [2]

(ii) Draw the straight line of best fit and a worst acceptable straight line on your graph. Both lines should be clearly labelled. [2]

(iii) Determine the gradient of the line of best fit. Include the absolute uncertainty in your answer.

best fit

$$\frac{y^2-y^1}{x^2-x^1} = \frac{19-4}{(13.4-3.6)\times10^6} = \frac{15}{9.4\times10^6}$$

$$= 1.60\times10^{-6}$$

$$= 1.60 - 1.7$$

$$= 1\times10^{-7}$$

$$\frac{y^2-y^1}{x^2-x^1} = \frac{19-5}{(12.4-4.2)\times10^6} = \frac{14}{8.2\times10^6}$$

$$= 1.7\times10^{-6}$$

gradient = ~~1.60~~ $(1.60 \pm 0.1)\times10^{-6}$ [2]

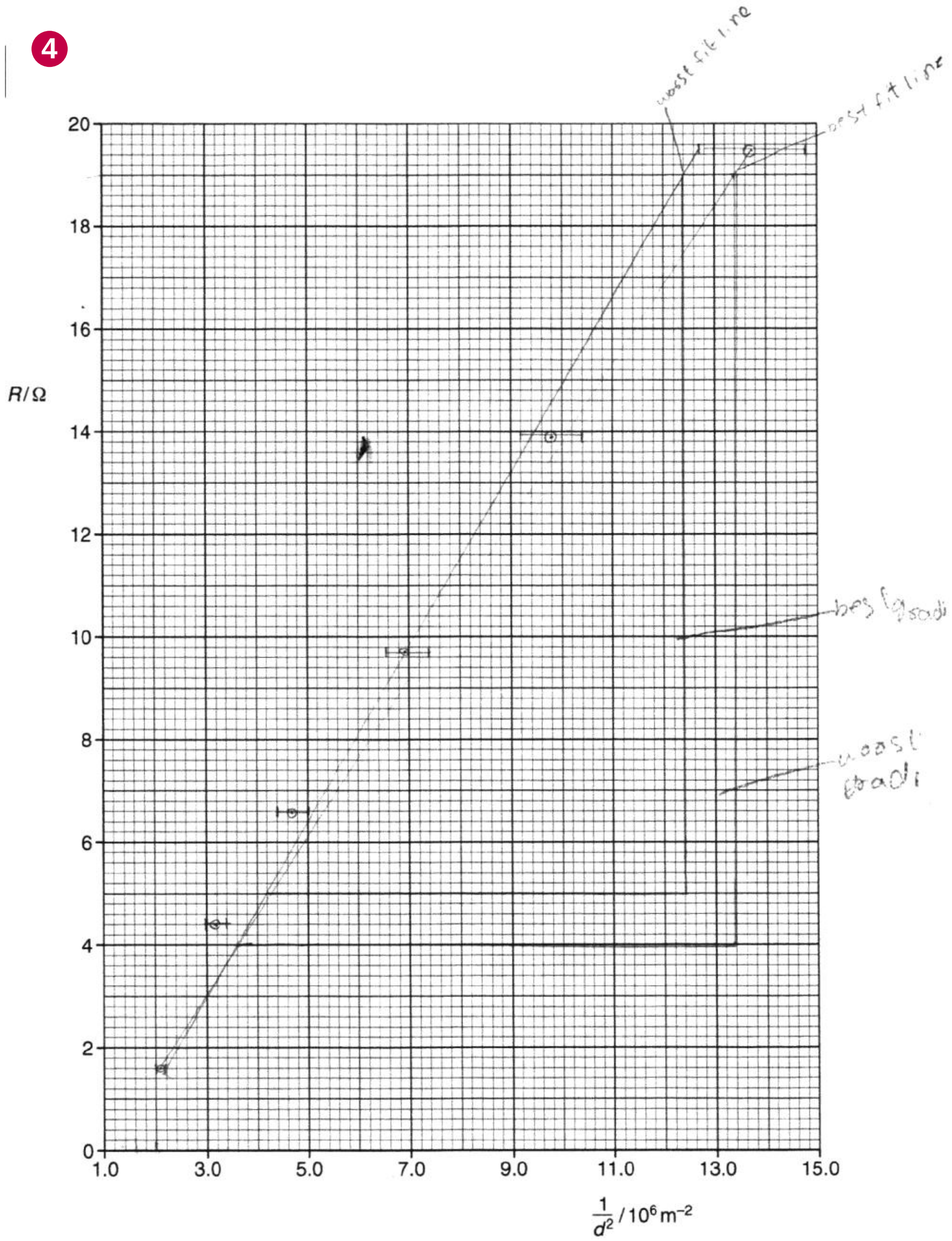
Examiner comments

2 The candidate has omitted the *m* from the column heading and is therefore not awarded the first mark.
Row two is also incorrect; it should be 2.19.
The candidate also gives the last value in the table to four significant figures. Since the raw data is given to two significant figures, the calculated data should also be given to two (or three) significant figures.

Mark for (b) = 1/3

3 The candidate indicates clearly the points used to determine the gradient. They also correctly use the power of ten from the *x*-axis.
The determination of the uncertainty is clearly demonstrated.

Mark for (c) (iii) = 2/2

Example candidate response – low, continued	Examiner comments
4 	**4** The points are plotted correctly. The error bar for the third plot should be one small square in each direction, making the total length two small squares. The candidate has drawn an error bar which is three small squares in length. Mark for (c) (i) = 1/2 Since the first point was incorrectly plotted (2.1 instead of 1.2) from the *x*-axis, the line of best fit is not within tolerance. Mark for (c) (ii) = 1/2

Example candidate response – low, continued	Examiner comments
(d) (i) Using your answers to **(a)** and **(c)(iii)**, determine the value of ρ. Include an appropriate unit. Data: $L = 1.00 \pm 0.01$ m. **5** $R = \frac{4\rho L}{\pi d^2}$ $g = \frac{4\rho}{\pi}$ $(1.6\times10^{-6}) = \frac{4\rho}{\pi}$ $5.03\times10^{-6} = 4\rho$ $\rho = \frac{5.03\times10^{-6}}{4}$ $\rho = 1.25\times10^{-6}$ ρ = 1.26×10^{-6} [2]	**5** The candidate earns a benefit of the doubt mark, having omitted *L* from the relationship reading the gradient to the resistivity. Since *L* has a value of 1, the correct method has, in effect, been used. The candidate is not awarded the second mark since the unit has been omitted. Mark for (d) (i) = 1/2
(ii) Determine the percentage uncertainty in ρ. $\frac{\Delta L}{L} = \frac{2\Delta L}{L}$ $\frac{\Delta L}{1.26\times10^{-6}} = \frac{2\times0.01}{1.00}$ 0.025×10^{-6} $\frac{0.025}{1.26}\times100$ **6** percentage uncertainty in ρ = 1.98 % [1]	**6** No clear method is shown here. Using the candidate's answer to (c) (iii) and a fractional method, the answer should have been about 7%. Mark for (d) (ii) = 0/1
(e) The experiment is repeated with a thinner wire of diameter 0.23 ± 0.01 mm. The wire is of the same material and length. Determine the resistance *R* of the wire. Include the absolute uncertainty in your answer. **7** $R = \frac{4\rho L}{\pi d^2}$ $= \frac{4(1.26\times10^{-6})(1.00)}{\pi\ 0.23}$ $= \frac{5.04\times10^{-6}}{\pi\ 0.23}$ $= 6.97\times10^{-6}$ $\frac{\Delta L}{L} = \frac{2\Delta L}{L}$ $\frac{\Delta L}{6.97\times10^{-6}} = \frac{2\times0.01}{1.00}$ $= 1.39\times10^{-7}$ R = $(6.97 \pm 0.1)\times10^{-6}$ Ω [2] [Total: 15]	**7** The candidate does not change the millimetres to metres for the calculation. The determination of the absolute uncertainty is again incorrect. Mark for (e) = 0/2 **Total marks awarded = 6 out of 15**

How the candidate could have improved their answer

The candidate needed to take more care with the calculation of quantities in the table in **(b)**.

When plotting graphs that should produce a linear trend, it is useful to recheck the plotting of points that do not lie on the trend line. This candidate plotted 2.1 instead of 1.2 from the *x*-axis. As a consequence, the line of best-fit was not within tolerance.

The candidate also appeared to have been confused about the determination of uncertainties. They needed to understand the difference between absolute and percentage uncertainties as well as the methods of combining uncertainties either by fractional methods or maximum/minimum methods.

Mark awarded = **(a) 0/1**
Mark awarded = **(b) 1/3**
Mark awarded = **(c) (i) 1/2, (ii) 1/2, (iii) 2/2**
Mark awarded = **(d) (i) 1/2, (ii) 0/1**
Mark awarded = **(e) 0/2**

Total marks awarded = 6 out of 15

Common mistakes candidates made in this question

To gain the highest marks, the presentation of mathematical working requires a clear statement of the equation used, substitution of numbers, leading to the correct answer. Furthermore, the working has to be logical and readable.

(b) The common mistake in the $1/d^2$ column was stating the last value to four significant figures. Since the raw data was given to two significant figures, it was expected that $1/d^2$ would be given to two or three significant figures. The majority of candidates calculated the absolute uncertainty correctly; a common error was not doubling the percentage uncertainty for d^2.

The two main reasons for not being awarded marks in **(c) (i)** were vertical error bars and drawing large blobs for the plotted points. In **(c) (ii)** some candidates were careless in drawing the worst acceptable line. Some candidates were not awarded the mark for the worst acceptable line because they used a dashed line and allowed a gap in the dash at the error bar.

(c) (iii) required candidates to determine the gradient of the line of best-fit. When selecting points for the gradient they must lie on the line of best fit. Candidates were not awarded this mark either for misreading their graphs or for quoting values from the table. Some candidates did not use a large enough triangle. A significant number of candidates made a power of ten error, having not used the data from the axes correctly; this was not penalised in this part but in **(d) (i).**

When determining the resistivity ρ in **(d) (i)** it is vital that the working for the answer is clearly shown. The equation should be quoted followed by correct substitution of numerical values, one of which must be the value of the gradient calculated in **(c) (iii)**. Many candidates were not awarded the unit mark and several candidates did not give any unit. A number of candidates were not awarded the second mark due to a power of ten error from determining the gradient.

(d) (ii) There was wide recognition that the percentage uncertainty of ρ was the sum of the two percentage uncertainties of the two necessary components in the equation, where clear indication of the data used needed to be shown. Those candidates attempting to use a 'maximum/minimum' method were invariably not awarded this mark due to not showing clearly where the data used had originated from or to using incorrect combinations of maximum and minimum values. Some candidates incorrectly subtracted percentage uncertainties.

(e) Here the calculated value of *R* needed to be quoted to two or three significant figures and to be given in a specific range. Again, clear logical working was required. A number of candidates did not allow for *d* being measured in millimetres. To gain the mark for the absolute uncertainty in *R*, candidates who could not demonstrate their understanding by showing the method used were not awarded this mark. It was expected that appropriate equations would be used with substitution of data.

Cambridge International Examinations
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
t: +44 1223 553554   f: +44 1223 553558
e: **info@cie.org.uk**   **www.cie.org.uk**

Version 1.0