Example Candidate Responses

Cambridge International AS & A Level

Cambridge International AS and A Level Physics

9702

Paper 3 – Advanced Practical Skills

For examination from 2016

Cambridge Advanced

CAMBRIDGE International Examinations

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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.

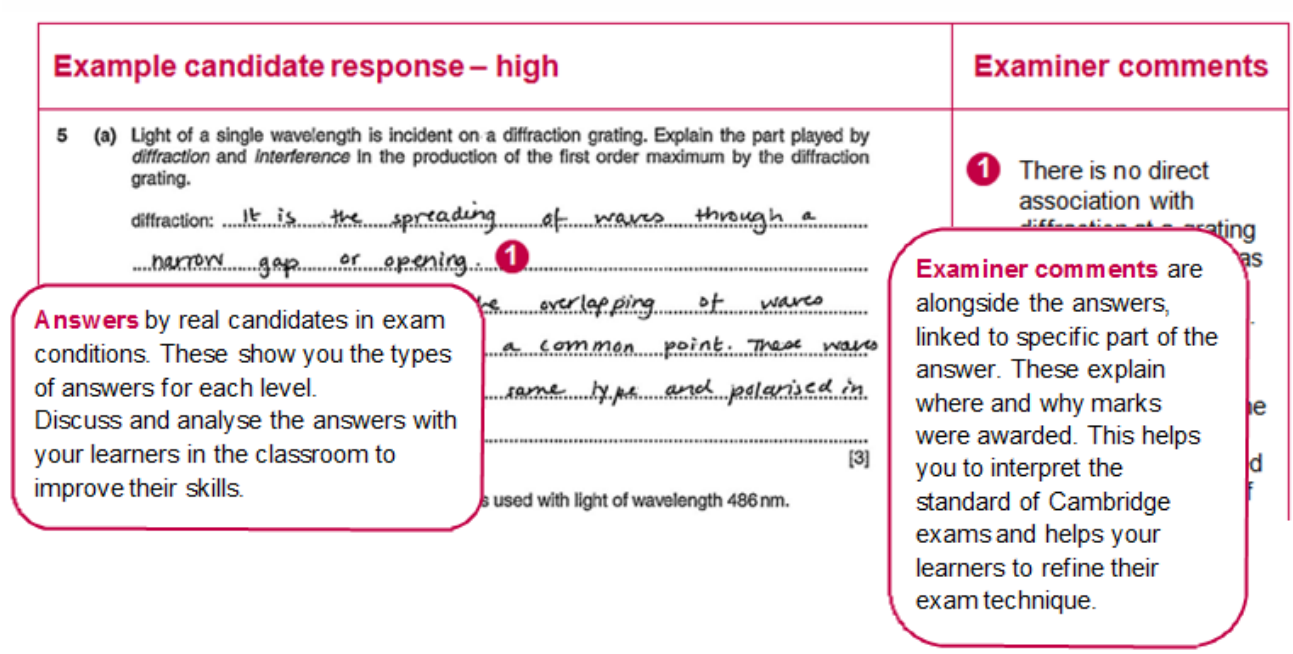
This document provides illustrative examples of candidate work. These help teachers to assess the standard required to achieve marks, beyond the guidance of the mark scheme. Some question types where the answer is clear from the mark scheme, such as short answers and multiple choice, have therefore been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



Example candidate response – high

Examiner comments

5 (a) Light of a single wavelength is incident on a diffraction grating. Explain the part played by *diffraction* and *interference* in the production of the first order maximum by the diffraction grating.

diffraction: It is the spreading of waves through a narrow gap or opening. 1

...overlapping of waves ... a common point. These waves ... same type and polarised in ...

[3]

...s used with light of wavelength 486 nm.

1 There is no direct association with ...grating ...as ...e ...d ...f

Answers by real candidates in exam conditions. These show you the types of answers for each level.
Discuss and analyse the answers with your learners in the classroom to improve their skills.

Examiner comments are alongside the answers, linked to specific part of the answer. These explain where and why marks were awarded. This helps you to interpret the standard of Cambridge exams and helps your learners to refine their exam technique.

How the candidate could have improved their answer

(a) The question was an application of diffraction a... needed to apply their knowledge to the application ... interference needed to be applied to the productior... applications as well as learning basic theory is req...

This explains how the candidate could have improved their answer and helps you to interpret the standard of Cambridge exams and helps your learners to refine exam technique.

(b) The diffraction grating equation was used and the given data interpreted correctly. There was a mathematical error in the calculation and the final answer was not realistic. The candidate needed to be more familiar with likely values for applications of basic theory.

Common mistakes candidates made in this question

(a) Diffraction was described as the bending of light. ... diffraction is a wave property and hence diffraction a... have passed through the diffraction element. The ef... was not described for this specific example.

This lists the common mistakes candidates made in answering each question. This will help your learners to avoid these mistakes at the exam and give them the best chance of achieving a high mark.

(b) The angle given on the diagram was used as the angle θ in the diffraction grating equation. The distance d was quoted as the number of lines per mm N. There were power of ten errors converting d in metres to N in mm^{-1}.

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 3 – Advanced Practical Skills

Question 1

Example candidate response – high	Examiner comments

1 In this experiment, you will investigate a wooden strip acted on by several forces.

(a) (i) Set up the apparatus as shown in Fig. 1.1.

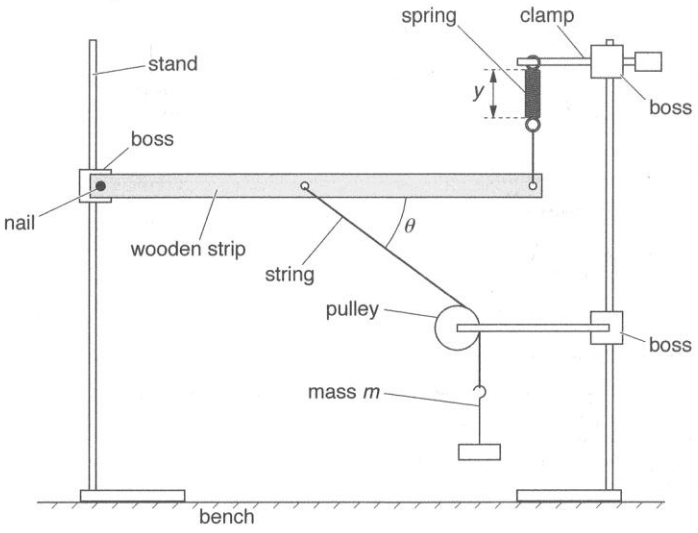


Fig. 1.1

The mass m should be 100 g.

The angle θ between the wooden strip and the string should be approximately 45°.

(ii) Adjust the apparatus so that the spring is vertical and the wooden strip is parallel to the bench.

(b) (i) Record the mass m.

$m =$ 100 g

(ii) Measure and record the length y of the coiled part of the spring.

y_1	y_2	$\langle y \rangle$
4.50	4.50	4.50

$y =$ 4.50 cm [1]

(iii) Measure and record θ.

θ_1	θ_2	$\langle \theta \rangle$
66.0°	68.0°	67.0°

$\theta =$ 67.0 v [1]

1 The candidate gives y to the nearest 0.01 cm, which, although incorrect, is not discredited here as the precision in y looked at in the table. The candidate gives a correct unit and the value is in range so the mark is awarded.

Mark for (b) (ii) = 1/1

2 Angles are read using a protractor that can read to the nearest degree. 66 and 68 would have been enough here.

Mark for (b) (iii) = 0/1

Example candidate response – high, continued	Examiner comments

(c) (i) Add 100 g to the mass hanger.

(ii) Adjust the height of the boss holding the nail until the wooden strip is parallel to the bench.

(iii) Measure and record m, y and θ.

y_1	y_2	$\langle y \rangle$
5.70	5.70	5.70

θ_1	θ_2	$\langle \theta \rangle$
58.0°	59.0°	59.0°

m = 100 g

y = 5.70 cm

θ = 59.0°

Example candidate response – high, continued

(d) Change m and repeat **(c)(ii)** and **(c)(iii)** until you have six sets of values of m, y and θ.

You may include your values from **(b)** and **(c)**.

Include values of $m\sin\theta$ in your table.

m/g	y/cm			θ/°			
	y_1	y_2	$\langle y \rangle$	θ_1	θ_2	$\langle\theta\rangle$	$m\sin\theta$/g
100	4.50	4.50	4.50	66.0	68.0	67.0	92.1
200	5.70	5.70	5.70	58.0	59.0	59.0	171.
250	6.50	6.50	6.50	60.0	62.0	61.0	219
300	7.20	7.20	7.20	57.0	59.0	58.0	254
350	7.90	8.00	8.00	56.0	56.0	56.0	290
450	9.30	9.40	9.40	54.0	55.0	55.0	369

[10]

(e) (i) Plot a graph of y on the y-axis against $m\sin\theta$ on the x-axis. [3]

(ii) Draw the straight line of best fit. [1]

(iii) Determine the gradient and y-intercept of this line.

Gradient = $\frac{7.2-5.7}{369-171} = \frac{1}{132} = 7.58\times10^{-3}\ \text{cm g}^{-1}$

c, y-intercept: $y = mx + c$

$3.5 = 50(7.58\times10^{-3}) + c$

$c = 3.12\ \text{cm}$

gradient = $7.58\times10^{-3}\ \text{cm g}^{-1}$

y-intercept = $3.12\ \text{cm}$

[2]

Examiner comments

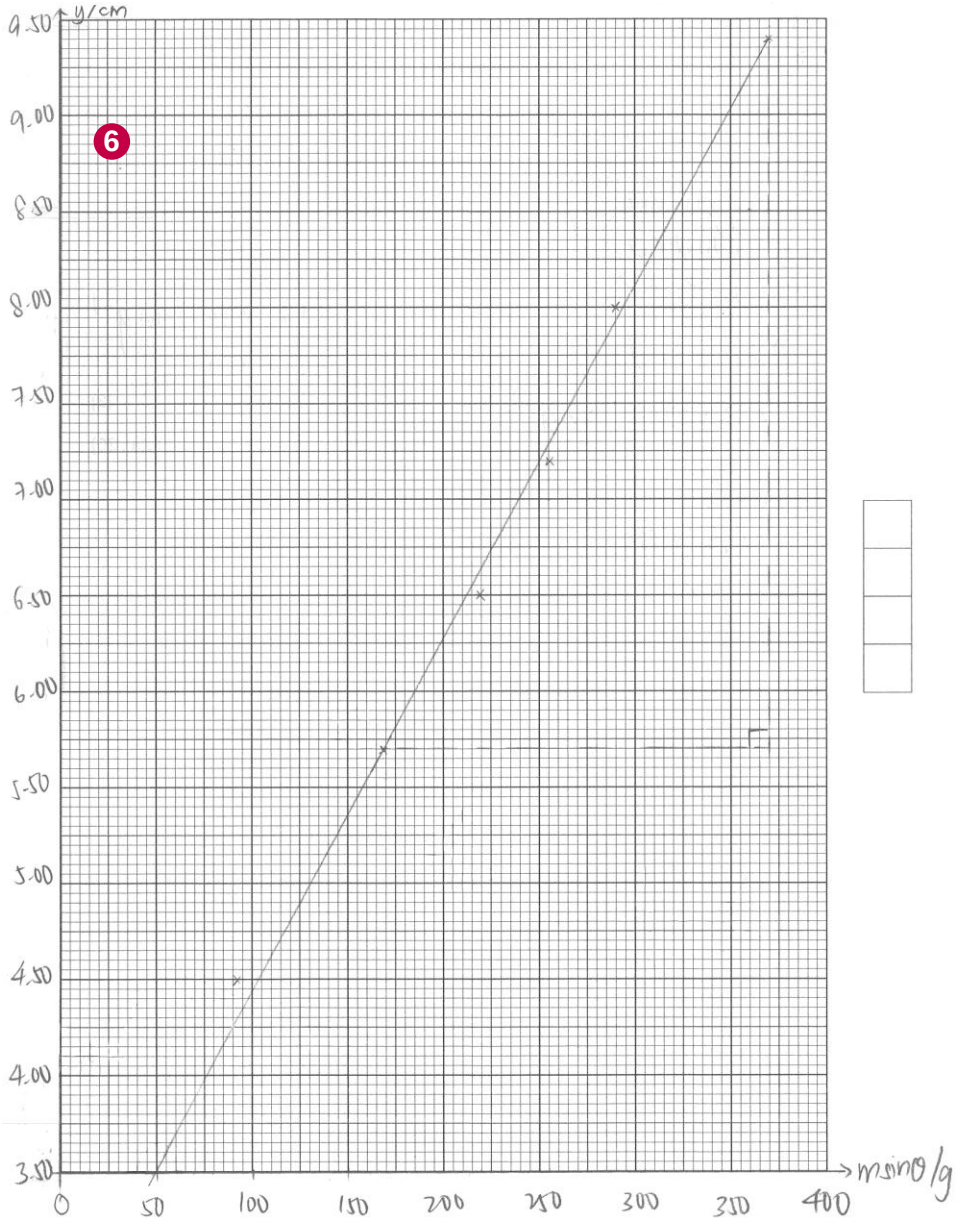
3 The candidate correctly uses the whole range of masses available to them. They use the correct headings and corresponding units separated by a dividing mark, calculate correctly and state the calculated quantity to the correct number of significant figures.

4 Measurement of y is made using a ruler with mm markings so 0.01 cm cannot be measured. Here 4.5, 5.7, 6.5, 7.2, etc., would have sufficed.

Mark for (d) = 5/5 + 4/5
= 9/10

5 The candidate has misread y = 9.4 as y = 7.2, possibly owing to careless reading from the table instead of directly from the graph.

Mark for (e) (i) = 3/3
Mark for (e) (ii) = 1/1
Mark for (e) (iii) = 1/2

Example candidate response – high, continued	Examiner comments
	6 Excellent setting out of the graph, plotting and drawing line of best fit. The axes are easy to read, making the plotting of the points a relatively easy task. Line of best fit cannot be rotated or shifted to give a better fit.

Example candidate response – high, continued	Examiner comments
(f) The quantities y, m and θ are related by the equation $y = Pm\sin\theta + Q$ where P and Q are constants. Using your answers in **(e)(iii)**, determine the values of P and Q. Give appropriate units. $y = P(m\sin\theta) + Q$ $y = mx + c$ $P = m$ = gradient $= 7.58 \times 10^{-3}$ cm g^{-1} $Q = c$ $= 3.12$ cm $P =$ 7.58 x10^{-3}cm g^{-1} $Q =$ 3.12 cm [2] [Total: 20] 7	7 Incorrect read-off has led to the final answer for P being out of range. Mark for (f) = 1/2 **Total marks awarded = 16 out of 20**

How the candidate could have improved their answer

(b) (iii) The candidate's raw value of θ was given to one decimal place when the protractor can measure to the nearest degree only. The candidate could have improved by giving the raw angles as 66° and 68°.

(d) In tabulating their observations, the candidate correctly used a large range to cover the masses provided, as stated in the confidential instructions. They correctly stated a unit alongside each heading, separated by a dividing line (brackets around the units would also have sufficed). The quantity $m \sin\theta$ was correctly calculated to three significant figures. To improve, the candidate should have given the value of y to the nearest mm, as the ruler cannot measure to any greater degree of precision. So y should have been given as 4.5 and not 4.50. Notice that this mistake was also made in (b) (ii) but the examiner only discredited this in one place (in this case, in the table).

(e) (i) The candidate set out and labelled their axes clearly and plotted their points accurately. They placed their line of best fit so that no rotation or shift was needed to get a better line. The quality of the results was also very good as all the points lay within a certain distance of the line. If the plots are a long way from the line, candidates should check over their observations and results and redo them.

(e) (iii) The candidate correctly identified the gradient and y-intercept calculation. Of the six different read-offs used in these calculations one was misread (7.2 should have been read as 9.4). To improve, the candidate needed to take greater care and recheck any read-offs taken.

(f) The candidate used the method correctly and the expected value of Q was of the right order of magnitude with the correct units. Although the units were correct for P, the order of magnitude was too small for that expected (2×10^{-2} cm g^{-1}). This resulted from the incorrect read-off used in the calculation; otherwise the candidate would have reached an answer of 1.9×10^{-2} cm g^{-1}.

Mark awarded = **(b) (ii) 1/1, (iii) 0/1**
Mark awarded = **(d) 5/5, 4/5**
Mark awarded = **(e) (i) 3/3, (ii) 1/1, (iii) 1/2**
Mark awarded = **(f) 1/2**

Total marks awarded = 16 out of 20

Example candidate response – middle

1 In this experiment, you will investigate a wooden strip acted on by several forces.

(a) (i) Set up the apparatus as shown in Fig. 1.1.

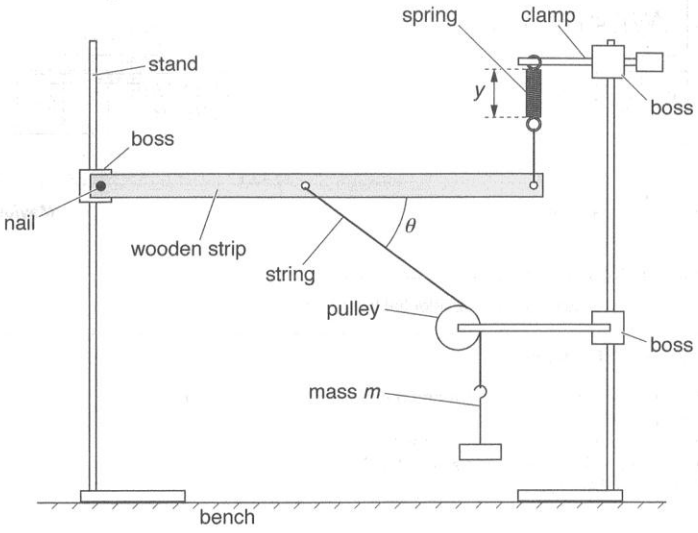


Fig. 1.1

The mass m should be 100 g.

The angle θ between the wooden strip and the string should be approximately 45°.

(ii) Adjust the apparatus so that the spring is vertical and the wooden strip is parallel to the bench.

(b) (i) Record the mass m.

m = 100 g

(ii) Measure and record the length y of the coiled part of the spring.

1

y = 0.035m [1]

(iii) Measure and record θ.

θ = 45° [1]

(c) (i) Add 100 g to the mass hanger.

(ii) Adjust the height of the boss holding the nail until the wooden strip is parallel to the bench.

(iii) Measure and record m, y and θ.

m = 200g

y = 0.045m

θ = 40.4°

Examiner comments

1 The angles are given to the nearest degree with a unit. The length measurement y is given to the millimetre with the correct unit and in range.

Mark for (b) (ii) = 1/1

Mark for (b) (iii) = 0/1

Example candidate response – middle, continued

(d) Change m and repeat **(c)(ii)** and **(c)(iii)** until you have six sets of values of m, y and θ.

You may include your values from **(b)** and **(c)**.

Include values of $m\sin\theta$ in your table.

m/g	y/cm	θ/°	m sin θ
100	3.5	45.0	70.70
150	3.8	44.0	104.2
200	4.5	40.4	129.6
250	4.8	38.0	153.9
300	5.4	41.0	196.8
350	6.0	39.0	220.3

[10]

(e) (i) Plot a graph of y on the y-axis against $m\sin\theta$ on the x-axis. [3]

(ii) Draw the straight line of best fit. [1]

(iii) Determine the gradient and y-intercept of this line.

$m = \frac{6.0 - 3.5}{220.3 - 70.7}$

$= 0.017$

$\frac{220.3 - 70.7}{8} = 187$

$\frac{6 - 3.5}{10} = 0.25$

$y = mx + c$

$6 = 0.017(220.3) + c$

$c = 2.3$

gradient = 0.017

y-intercept = 2.3

[2]

Examiner comments

2 No units are given on calculated quantity.

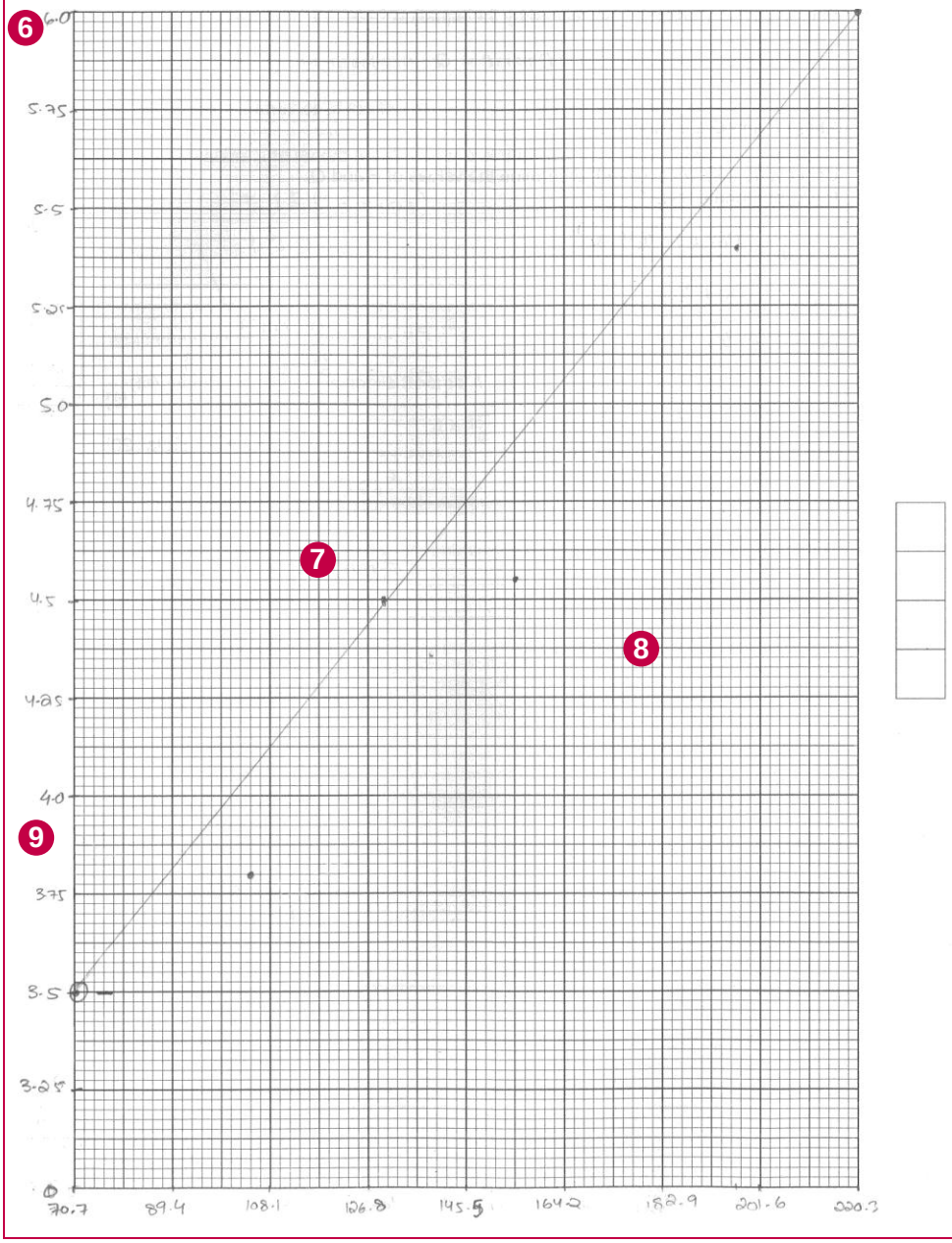
3 The range of masses used does not extend over the whole range supplied.

4 Two or three significant figures are expected in the calculated quantity.

Mark for (d) = 5/5 + 2/5
= 7/10

5 The read-off is correct and is substituted correctly into the gradient and y-intercept calculation.

Mark for (e) (i) = 0/3
Mark for (e) (ii) = 0/1
Mark for (e) (iii) = 2/2

Example candidate response – middle, continued	Examiner comments
	**6** The axes are not labelled and the scale on the *x*-axis is irregular **7** The diameter of the points plotted is greater than half a square, especially the third point up in the *y*-direction. **8** The line of best fit could be rotated clockwise to give a better fit. **9** The position of the points from the line of best fit is greater than that expected for this experiment and so the quality mark is not awarded.

Example candidate response – middle, continued	Examiner comments
(f) The quantities y, m and θ are related by the equation $y = Pm\sin\theta + Q$ where P and Q are constants. Using your answers in **(e)(iii)**, determine the values of P and Q. Give appropriate units. $y = Pm\sin\theta + Q$ $P = 0.017$ $Q = 2.3$ $P =$ 0.017 $Q =$ 2.3 [2] 9 [Total: 20]	9 No units are included in the final answer. Mark for (f) = 1/2 **Total marks awarded = 12 out of 20**

How the candidate could have improved their answer

(d) The table was well presented with six y values correctly stated to the nearest mm and the calculation of $m \sin \theta$ is correct. In the table the candidate needed to give a correct unit for the calculated quantity $m \sin \theta$ and to include a separating mark between the heading and the unit. The number of significant figures used for $m \sin \theta$ should have been two or three (instead of the four used).

(e) (i) The candidate could have improved by labelling and setting out regular numerical scales on both axes, as multiples of 18.7 on the x-axis were too awkward and cumbersome to plot and read off points. The drawing of points is expected to be done with a sharp pencil so that the points plotted occupy no more than half a square in either the x or y-direction.

(e) (ii) The drawing of the line of best fit is expected to be done with the use of a sharp pencil and placed so that the line does not need rotating or shifting to give a better fit.

(f) While the read-offs for the gradient and y-intercept in (e) (iii) were correct, when transferring these quantities to determine the values of P and Q, the units also needed to be considered.

Mark awarded = **(b) (ii) 1/1, (b) (iii) 1/1**
Mark awarded = **(d) 5/5, 2/5**
Mark awarded = **(e) (i) 0/3, (ii) 0/1, (iii) 2 /2**
Mark awarded = **(f) 1/2**

Total marks awarded = 12 out of 20

Example candidate response – low	Examiner comments

1 In this experiment, you will investigate a wooden strip acted on by several forces.

(a) (i) Set up the apparatus as shown in Fig. 1.1.

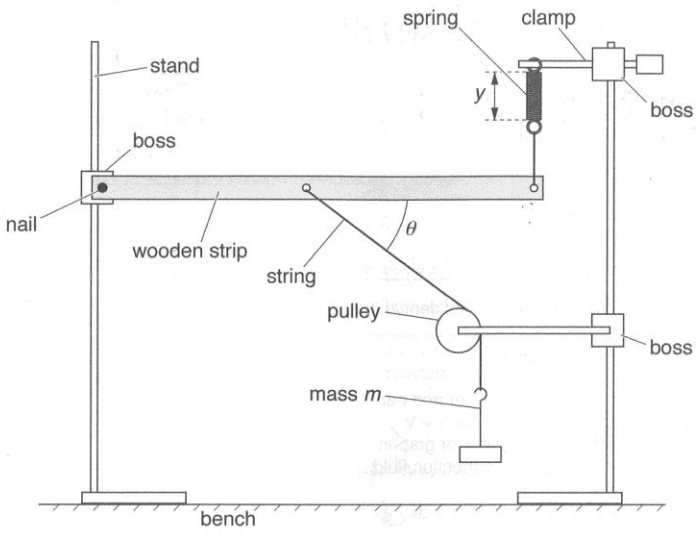


Fig. 1.1

The mass m should be 100 g.

The angle θ between the wooden strip and the string should be approximately 45°.

(ii) Adjust the apparatus so that the spring is vertical and the wooden strip is parallel to the bench.

(b) (i) Record the mass m.

m = 100g [1]

(ii) Measure and record the length y of the coiled part of the spring.

$y = \frac{4.2 + 4.0 + 4.3}{3}$

y = 4.2 cm [1]

Mark for (b) (ii) = 1/1

(iii) Measure and record θ.

θ = 45° [1]

Mark for (b) (iii) = 1/1

(c) (i) Add 100 g to the mass hanger.

(ii) Adjust the height of the boss holding the nail until the wooden strip is parallel to the bench.

(iii) Measure and record m, y and θ.

m = 200g

$y = \frac{4.8 + 4.9 + 5.0}{3}$

y = 4.9 cm

θ = 55°

Example candidate response – low, continued

(d) Change m and repeat **(c)(ii)** and **(c)(iii)** until you have six sets of values of m, y and θ.

You may include your values from **(b)** and **(c)**.

Include values of $m\sin\theta$ in your table.

S.No	m/g	y/cm	θ/°	msinθ/g cm
1	~~100~~ 100	4·20	45	70·7
2	~~100~~ 150	4·6	50	114·9
3	~~150~~ 200	4·9	55	163·8
4	~~250~~ 250	6·0	60	216·5
5	~~350~~ 300	7·0	65	271·9
6	~~350~~ 350	7·8	70	328·9

[10]

(e) **(i)** Plot a graph of y on the y-axis against $m\sin\theta$ on the x-axis. [3]

(ii) Draw the straight line of best fit. [1]

(iii) Determine the gradient and y-intercept of this line.

Taking (80, 3·5) and (356, 8·2)

$$\text{gradient} = \frac{\Delta y}{\Delta m} = \frac{8·2 - 3·5}{356 - 80} = 0·0170$$

Taking (80, 3·5)

$y = mx + c$.

$3·5 = 0·0170 \times 80 + c$

$c = 2·14$

gradient = ... 0·0170 .....

y-intercept = ... 2·14 .....

[2]

Examiner comments

1. Units of degrees are confused with degrees centigrade here. No degrees are expected in the unit for this calculated quantity.

2. The range of masses used does not extend to that supplied.

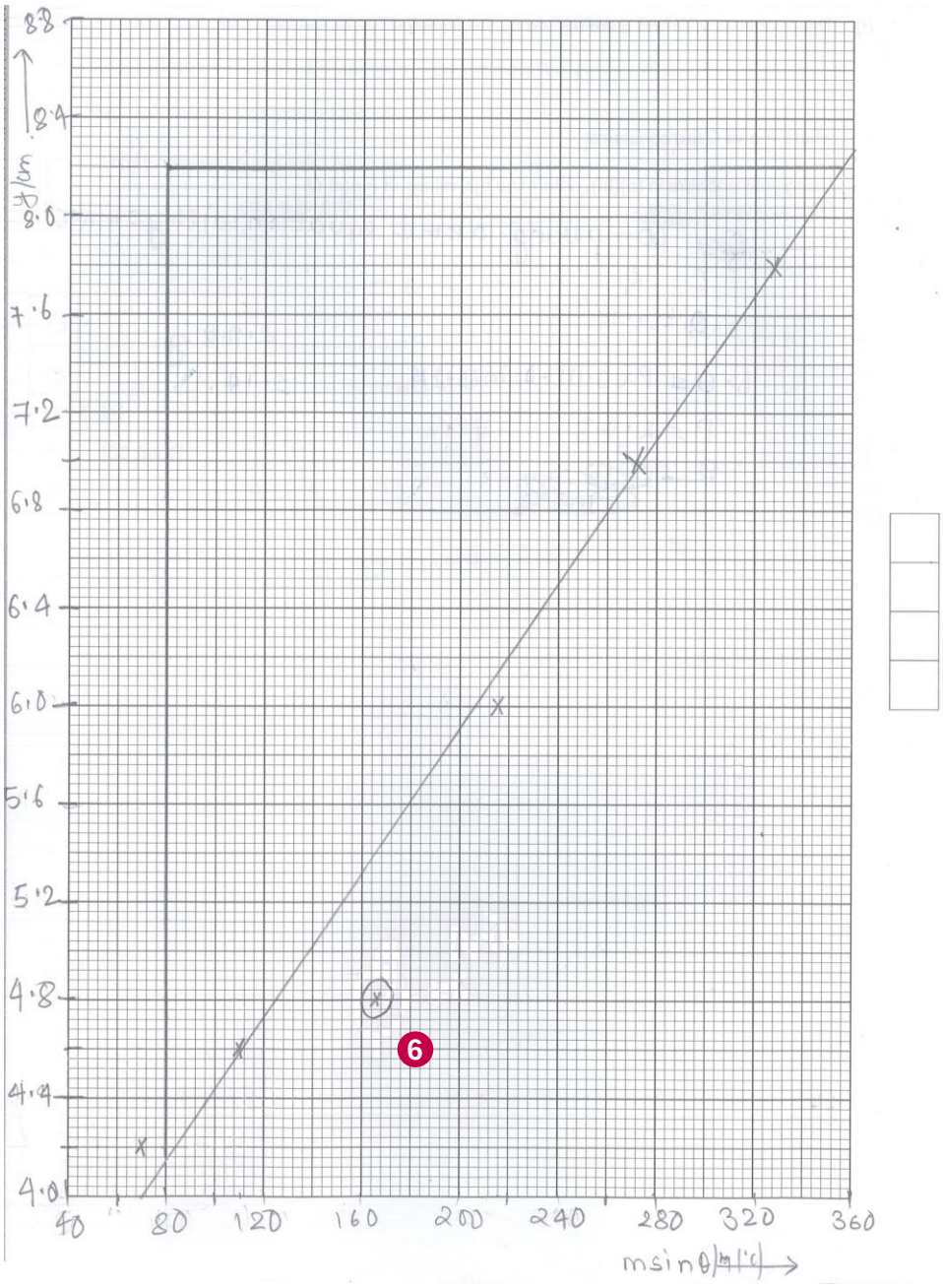
3. y stated to 0.1 cm is correct as the length can be measured to the nearest millimetre.

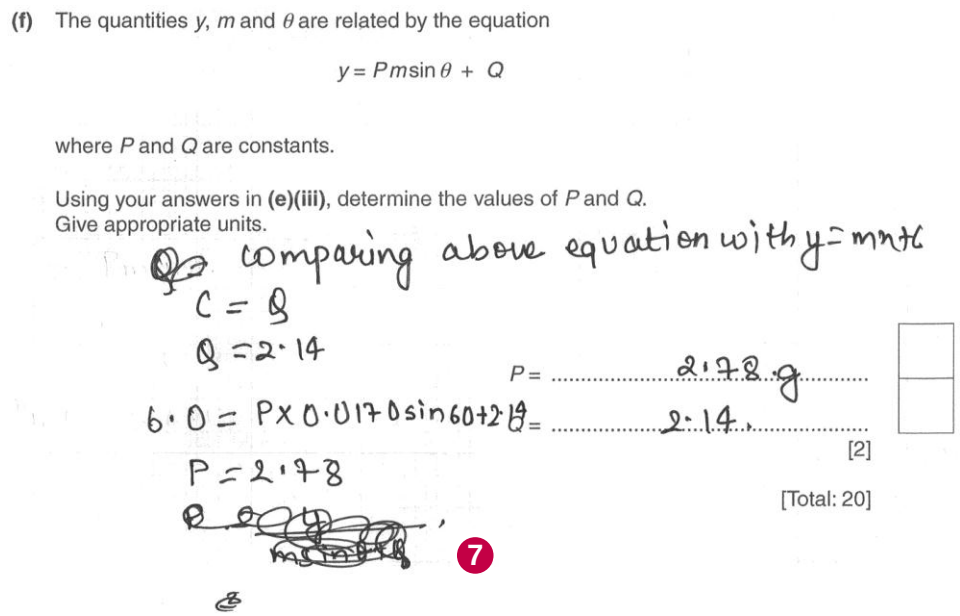
Mark for (d) = 5/5 + 2/5
= 7/10

4. A correct calculation gains credit here. Too many significant figures are used in the calculated quantity. (Two or three only are expected, since the angle is given to two significant figures.)

5. There is a misreading from the graph here. However, since one set of read-offs is correct in the gradient calculation, an error carried forward mark is allowed.

Mark for (e) (i) = 1/3
Mark for (e) (ii) = 0/1
Mark for (e) (iii) = 1/2

Example candidate response – low, continued	Examiner comments
	6 Correctly labelled axes and set-out scales here. The plotted point has been placed at $y = 4.8$ instead of $y = 4.9$. This plot is circled, therefore it has been treated as an anomalous point and ignored for the line of best fit mark. Despite this, the line needed to be rotated anticlockwise to give a better fit on the remaining points.

Example candidate response – low, continued	Examiner comments
	7 A substitution method is used to find *P* and *Q* when the gradient and *y*-intercept were required. Also, the candidate does not use the correct corresponding units. Mark for (f) = 0/2 **Total marks awarded = 11 out of 20**

How the candidate could have improved their answer

(d) The candidate could have extended their range to include *m* = 400 g showing that all the masses available had been used. The units for *m* sin *θ* should have been stated solely as g and without the ° symbol, as sin *θ* is a ratio, and without units. This candidate confused ° with °C, a unit of temperature which does not relate to angles. The calculated quantity should have been given as two or three significant figures (not four) as *θ* is stated to two significant figures.

(e) (i) The candidate could have improved by taking greater care in accurately plotting their points (*y* = 4.8 should have been plotted at *y* = 4.9) and subsequently checking them.

(e) (ii) The line of best fit should have been rotated clockwise to give a better fit, especially since the third point was circled (hence identified as anomalous) and discounted in judging where to place the line.

(e) (iii) When determining the gradient, the candidate read one of the read-offs incorrectly, so they should have taken greater care and checked that any read-offs were within half a square.

(f) When determining the values of *P* and *Q,* consideration of the method and units was needed. The candidate needed to use the *y*-intercept value for determining *Q,* as stated in the question, and not use a substitution method.

Mark awarded = **(b) (ii) 1/1, (b) (iii) 1/1**
Mark awarded = **(d) 5/5, 2/5**
Mark awarded = **(e) (i) 1/3, (ii) 0/1, (iii) 1/2**
Mark awarded = **(f) 0/2**

Total marks awarded = 11 out of 20

Common mistakes candidates made in this question

(b) (iii) Stating the measurements to a greater degree of precision than the measuring instrument.

(e) (i) Not setting out the graph scales in a logical, regular order, which led to incorrect plotting and read-offs.

(e) (ii) Drawing the line so that a better fit could be achieved by further rotation or shifting.

(e) (iii) Incorrectly reading the points to be plotted or read off for the gradient calculation.

(f) & (d) Not considering the unit of the final quantity or calculated quantities.

Question 2

Example candidate response – high	Examiner comments
2 In this experiment, you will investigate the movement of a loaded wire. (a) (i) Take the **shorter** of the two wires. (ii) Measure and record the diameter d of the wire. $0.31 + 0.29 + 0.29$ 3 $= 0.297$ $= 0.30\,mm$ $(0.30 \pm 0.01)\,mm$ $d =$ ~~$(0.3 \pm 1.0)\,mm$~~ [1] (iii) Calculate the cross-sectional area A of the wire using $A = \frac{\pi d^2}{4}$. $A = \frac{\pi (0.30)^2}{4}$ $= 0.07067$ $= 0.071\,mm^2$. 1 $A =$ $0.071\,mm^2$ [1]	1 The diameter is measured correctly to the nearest 0.01 mm, which is as expected from reading a manual micrometer screw gauge. Similarly, length L in (b) (iii) is measured correctly to 1 mm, which is expected from using a ruler with millimetre markings. The area is calculated correctly, as is C in (c) (i). Mark for (a) (ii) = 1/1 Mark for (a) (iii) = 1/1

Example candidate response – high, continued

Examiner comments

(b) (i) Secure the hook of the mass hanger to one end of the wire leaving at least 20 cm of excess wire.
The wire may be wrapped around the hook several times.

(ii) Set up the apparatus as shown in Fig. 2.1.

The length *L* of wire between the clip and the hook of the mass hanger should be approximately 15 cm.

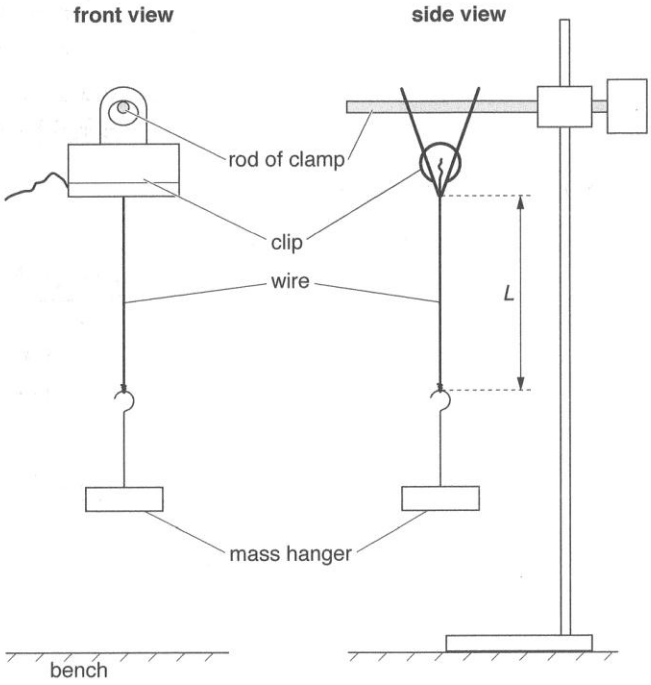


Fig. 2.1

(iii) Measure and record *L*.

$\frac{15.4 + 15.4}{2} = 15.4\text{ cm}$

L = (15.4 ± 0.1) cm [1]

(iv) Estimate the percentage uncertainty in your value of *L*.

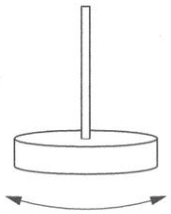
2

$\frac{0.1}{15.4} \times 100 = 0.65\%$

percentage uncertainty = 0.65% [1]

2 Consideration of the inherent difficulties of the experiment in taking the measurement *L* is not factored into working out the uncertainty in *L*.

Mark for (b) (iii) = 1/1
Mark for (b) (iv) = 0/1

Example candidate response – high, continued	Examiner comments
(c) (i) Calculate C where $C = \frac{\sqrt{L}}{A}$. 1 cm = 10 mm 1 cm² = 100 mm² x = 0.071 x = 7.1 × 10⁻⁶ cm² $C = \frac{\sqrt{L}}{A}$ $= \frac{\sqrt{15.4}}{7.1 \times 10^{-6}}$ = 552715.97 = 553,000 C = 553,000 cm⁻¹ [1]	3 Significant figures in C need to relate to all raw readings (d and L). Mark for (c) (i) = 1/1 Mark for (c) (ii) = 0/1
(ii) Justify the number of significant figures that you have given for your value of C. A has two significant figures, so to increase the accuracy, 3 significant figures were used for C. 3 [1]	
(d) (i) Twist the mass hanger through approximately 180°. Release the mass hanger. The mass hanger will oscillate as shown in Fig. 2.2.  Fig. 2.2	
(ii) Take measurements to determine the period T of the oscillations. Record T. 22.0 + 22.7 / 42 = 1.1S. 4 T = (1.1 ± 0.1) s [1]	4 Repeated values of several oscillations, a unit and the final working out of the period ensure the mark here. Mark for (d) (ii) = 1/1
(iii) Remove the wire from the mass hanger.	

Example candidate response – high, continued	Examiner comments
(e) (i) Take the **longer** wire. Repeat **(a)(ii)** and **(a)(iii)**. $\frac{0.11+0.10+0.10}{3} = 0.103 = 0.10\,mm$ $d =$ (0.10 ± 0.01) mm $A =$ 0.0079 mm^2 **(ii)** Secure the hook of the mass hanger to one end of the wire leaving 40 cm of excess wire. Repeat **(b)(ii)**, **(b)(iii)**, **(c)(i)** and **(d)** for a value of L of approximately 30 cm. $\frac{29.9 + 29.9}{2} = 29.9$ $L =$ (29.9 ± 0.1) cm $C =$ ~~7,040,000~~ 6,920,000 cm^{-1} ~~22.97~~ $\frac{26.2+26.2}{16} = 3.35$ $T =$ (3.3 ± 0.1) s [3]	Mark for (e) (ii) = 3/3

Example candidate response – high, continued	Examiner comments
(f) It is suggested that the relationship between T and C is $T = kC$ where k is a constant. **(i)** Using your data, calculate two values of k. $1.1 = k(553,000)$ $k = 1.99 \times 10^{-6}$ $3.3 = k(6,920,000)$ $k = 4.77 \times 10^{-7}$ first value of k = 1.99×10^{-6} ~~Acms~~ second value of k = 4.77×10^{-7} cms [1] ☐ **(ii)** Explain whether your results in **(f)(i)** support the suggested relationship. $\frac{\lvert k_1 - k_2 \rvert}{k_{\text{#1}}} \times 100\% = 76.03\%$ 5 No, as the ~~percentage uncertain~~ uncertainty 76.03% is more than 20%. [1] ☐	5 A percentage difference, a criterion and an opinion based on a comparison ensure that full marks are awarded here. Mark for (f) (i) = 1/1 Mark for (f) (ii) = 1/1

Example candidate response – high, continued	Examiner comments
(g) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment. 1. only two readings were taken to draw a conclusion which is insufficient. 2. The loop of wire around the mass hanger slips. 3. ~~Parallax error in measuring~~ Hard to measure length L as wire not straight. 4. Hard to ~~get accur~~ determine where is one oscillation of the mass hanger. 5. ~~wire is not straight, hard to measure pt to pt~~ Parallax error in measuring L. [4] **(ii)** Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures. 1. More readings should have been taken and a graph plotted to get a more accurate conclusion. 2. Use adhesive tape to stick the wire to the mass hanger. 3. ~~Mark length L on the wire used and measure before attaching wire to clip.~~ Straighten wires by using a motor ~~a~~ and running the wire through the motor. ~~Take a~~ 4. ~~Use~~ Video camera with a timer should be used. 5. Mark length L on wire used and measure before attaching wire to clip. [4] [Total: 20]	**6** An excellent synopsis of possible problems and corresponding improvements. Point two (improvements) is not awarded credit as adhesive tape is not considered to be effective here. Mark for (g) (i) = 4/4 Mark for (g) (ii) = 3/4 **Total marks awarded = 17 out of 20**

How the candidate could have improved their answer

(b) (iv) The candidate could have improved their answer by considering the uncertainty as the smallest division, not taking into account the fact that there are inherent difficulties with taking the measurement (getting the ruler close owing to the fact that the clip and the hanger are in the way). These difficulties should be factored in, despite the measurement being a static one.

(c) (ii) In justifying the number of significant figures used in *C*, the candidate could have improved by referring to the number of significant figures used in the raw values of both *d* and *L* used ultimately to calculate *C*.

(g) (i) & **(ii)** Although the candidate scored very highly in the descriptive evaluation section at the end, they could have improved by stating that the wire that slips 'from the clip' could be 'glued to the clip'. Their suggestion (use of adhesive tape) would still allow the wire to slip in this particular case.

Mark awarded = **(a) (ii) 1/1, (iii) 1/1**
Mark awarded = **(b) (iii) 1/1, (iv) 0/1**
Mark awarded = **(c) (i) 1/1, (ii) 0/1**
Mark awarded = **(d) (ii) 1/1**
Mark awarded = **(e) (ii) 3/3**
Mark awarded = **(f) (i) 1/1, (ii) 1/1**
Mark awarded = **(g) (i) 4/4, (ii) 3/4**

Total marks awarded = 17 out of 20

Example candidate response – middle	Examiner comments
2 In this experiment, you will investigate the movement of a loaded wire. (a) (i) Take the **shorter** of the two wires. (ii) Measure and record the diameter d of the wire. 0.01 × 38 d = 0.38 mm [1] (iii) Calculate the cross-sectional area A of the wire using $A = \frac{\pi d^2}{4}$. $A = \frac{\pi (0.00038)^2}{4} = 1.13 \times 10^{-7}$ 1 m = 1000 mm x = 0.38 0.00038 m. $A = \frac{\pi (0.038)^2}{4}$ = 0.0298 = 1.13 × 10⁻³ A = 1.13 × 10⁻³ cm² [1] 1	1 The diameter is correctly stated to the nearest 0.01 mm, in keeping with the precision of the micrometer screw gauge. Correct calculation of the area. Mark for (a) (ii) = 1/1 Mark for (a) (iii) = 1/1

Example candidate response – middle, continued

Examiner comments

(b) (i) Secure the hook of the mass hanger to one end of the wire leaving at least 20 cm of excess wire.
The wire may be wrapped around the hook several times.

(ii) Set up the apparatus as shown in Fig. 2.1.

The length *L* of wire between the clip and the hook of the mass hanger should be approximately 15 cm.

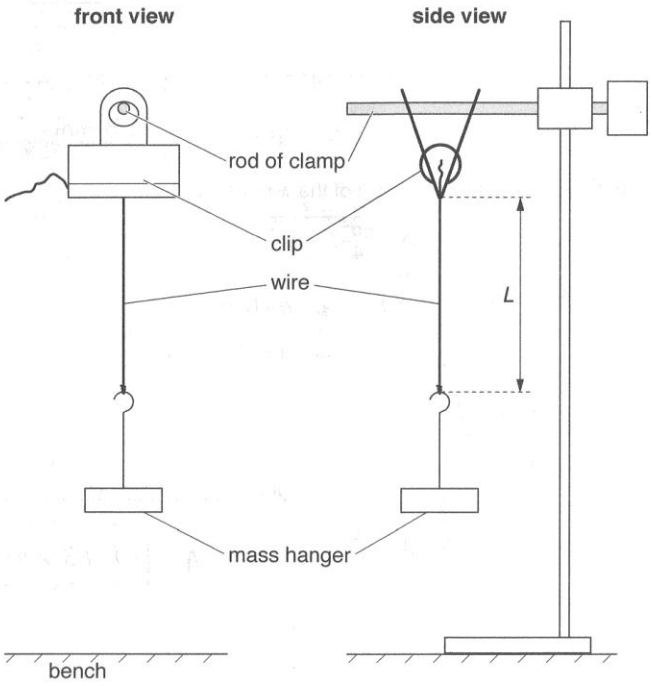


Fig. 2.1

(iii) Measure and record *L*.

15.40 cm.

~~0.152m~~
~~24.2 cm~~ ~~15.20cm~~
15.40 cm

L = ...[1]

(iv) Estimate the percentage uncertainty in your value of *L*.

2 $\frac{0.2}{24.2} \times 100 = 1.3$
$= 1\%$

percentage uncertainty = 1 % .....[1]

2 Correct consideration is given to the smallest reading of 1 mm and the inherent difficulty in placing the ruler close is also factored in to give an uncertainty in the length of 2 mm.

Mark for (b) (iii) = 1/1
Mark for (b) (iv) = 1/1

Example candidate response – middle, continued

(c) (i) Calculate C where

$C = \frac{\sqrt{L}}{A}$

$C = \frac{\sqrt{15.24}}{0.00113}$ $\quad C = \sqrt{15.240}$

$0.113 - mm^2$
$0.00113 - cm$

1.13×10^{-3}

$= 3472.8$

$C =$ 3472.8 [1]

(ii) Justify the number of significant figures that you have given for your value of C.

The raw value of L and A are given to 3 significant figures so [1]

(d) (i) Twist the mass hanger through approximately 180°.

Release the mass hanger. The mass hanger will oscillate as shown in Fig. 2.2.

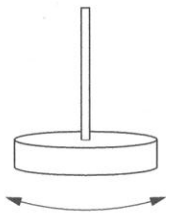


Fig. 2.2

(ii) Take measurements to determine the period T of the oscillations.

Record T.

T_1/s	T_2/s	T_3/s	T_{ava}/s
0.97	1.0	0.96	0.98

$T =$ 0.985 [1]

(iii) Remove the wire from the mass hanger.

Examiner comments

3 The number of significant figures used in C needs to relate to the raw readings used (d and L here).

Mark for (c) (i) = 1/1
Mark for (c) (ii) = 0/1

Mark for (d) (ii) = 1/1

Example candidate response – middle, continued	Examiner comments

(e) (i) Take the **longer** wire. Repeat **(a)(ii)** and **(a)(iii)**.

$15 \times 0.01 = 0.15$

$d =$ ~~0.38 mm~~ 0.15 mm

$= \frac{\pi (1.5 \times 10^{-3})}{4} = 1.77 \times 10^{-6}$

$A =$ 1.77×10^{-6} cm^2

1.77×10^{-6}

(ii) Secure the hook of the mass hanger to one end of the wire leaving 40 cm of excess wire.
Repeat **(b)(ii)**, **(b)(iii)**, **(c)(i)** and **(d)** for a value of L of approximately 30 cm.

$L =$ 15.90 cm

15.20

$c = \frac{\sqrt{15.20}}{1.13 \times 10^{-3}}$

$c =$ 3450

T_1/s	T_2/s	T_3/s	T_{avg}/s
3.67	3.65	3.66	3.66

$T =$ 3.66 s.

[3]

Mark for (e) (ii) = 3/3

Example candidate response – middle, continued	Examiner comments
(f) It is suggested that the relationship between T and C is $T = kC$ where k is a constant. 4 **(i)** Using your data, calculate two values of k. $k_1 = \frac{C}{T}$ $k_1 = \frac{3470}{0.98}$ $= 3540$ $k_2 = \frac{C}{T}$ $= \frac{3450}{3.66}$ $= 943$ first value of k = 3540 second value of k = 943 [1] **(ii)** Explain whether your results in **(f)(i)** support the suggested relationship. $\frac{3540 - 943}{3540} \times 100 = 73\%$. 73% results of my investigation shows that it does not support the suggested relationship as it is greater than 30%. 5 [1]	4 This has been rearranged incorrectly ($k = T/C$). Mark for (f) (i) = 0/1 5 Although the candidate identifies a percentage difference and a criterion and gives an opinion, there is no justification of why the criterion should be as high as 30% for this particular experiment. Mark for (f) (ii) = 0/1

Example candidate response – middle, continued	Examiner comments
(g) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment. 1. Two sets of readings are not enough to arrive at a valid conclusion. 2. Difficult to measure ~~the~~ T ~~because~~ for shorter wire. because it stops rotation very quickly and speed of rotation was high 3. The fans in the room affected rotation because wire is thin and light weight so it moved by wind as well. 4. The longer wire was very thin. It breaks when the clip ~~was~~ is tight. or ~~et~~ if it is clipped several times. [4] **6** **(ii)** Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures. 1. Take more readings and ~~plot~~ plot a graph or compare K values with more readings. 2. use a ~~red~~ play back camera or a slow motion Camera to find T. 3. Turn off the fans while doing the experiment. 4. ~~use a small ball of clay~~ use a cork and a small ball of clay to hang the wire instead of the clip. [4] [Total: 20]	**6** A really good synopsis of the problems encountered. However, in the improvements, greater detail is needed to explain how the equipment is used (points 2 and 4). Mark for (g) (i) = 3/4 Mark for (g) (ii) = 1/4 **Total marks awarded = 13 out of 20**

How the candidate could have improved their answer

(c) (ii) The candidate justified the number of significant figures used in *C* by relating them to that used in *L* and *A.* To improve, the candidate also needed to consider the raw value used to calculate *A,* (that is *d*).

(f) (i) In calculating *k* the candidate could have improved by rearranging the equation correctly ($k = C/T$).

(f) (ii) When explaining whether the results support the relationship, the candidate calculated a percentage difference, stated a criterion and gave an opinion. However, the stated criterion was judged to be too high for this experiment; the candidate needed to state where the idea of 30% came from.

(g) (ii) The candidate scored highly on describing the limitations. To improve, the candidate could have explained the improvements in greater depth, for example, using a video camera with a timer (in shot) to record the period. Although credit was awarded to the fact that there is more than one plane of motion going on, turning off the fans was not considered to be a major factor, as the mass and the wire are compact, compared to using a table tennis ball for example. The thinness of the wire and therefore the likelihood of it breaking when constantly loaded into the clip were not considered creditworthy, nor was the idea of using a cork and a small ball of clay, as there was no detailed explanation of how these could be used to secure the wire.

Mark awarded = **(a) (ii) 1/1, (iii) 1/1**
Mark awarded = **(b) (iii) 1/1, (iv) 1/1**
Mark awarded = **(c) (i) 1/1, (ii) 0/1**
Mark awarded = **(d) (ii) 1/1**
Mark awarded = **(e) (ii) 3/3**
Mark awarded = **(f) (i) 0/1, (ii) 0/1**
Mark awarded = **(g) (i) 3/4, (ii) 1/4**

Total marks awarded = 13 out of 20

Example candidate response – low	Examiner comments
2 In this experiment, you will investigate the movement of a loaded wire. (a) (i) Take the **shorter** of the two wires. (ii) Measure and record the diameter d of the wire. diameter = $\frac{0.2+0.3+0.4}{3}$ = 0.3 d = 0.03 mm [1]	1 There is a diameter misreading from the micrometer screw gauge here. Mark for (a) (ii) = 0/1
(iii) Calculate the cross-sectional area A of the wire using $A = \frac{\pi d^2}{4}$. $A = \frac{\pi (0.03)^2}{4}$ = 7.07×10^{-4} A = 7.07×10^{-4} mm^2 [1]	Mark for (a) (iii) = 1/1

Example candidate response – low, continued

(b) (i) Secure the hook of the mass hanger to one end of the wire leaving at least 20 cm of excess wire.
The wire may be wrapped around the hook several times.

(ii) Set up the apparatus as shown in Fig. 2.1.

The length *L* of wire between the clip and the hook of the mass hanger should be approximately 15 cm.

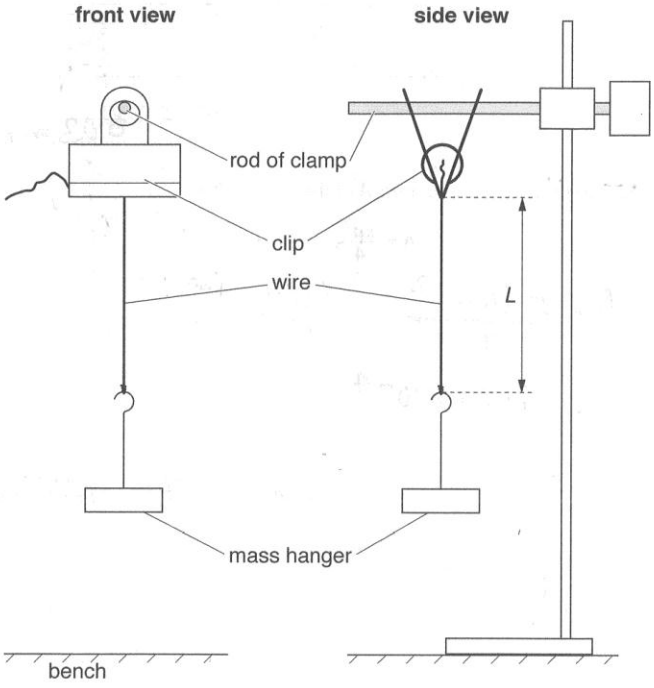


Fig. 2.1

(iii) Measure and record *L*.

$L = \frac{14 + 15 + 14.5}{3}$

$L =$ 14.5cm. [1]

(iv) Estimate the percentage uncertainty in your value of *L*.

2

$\text{Percentage Uncertainty} = \frac{\Delta L}{L} \times 100\%$

$= \frac{0.1}{14.5} \times 100\%$

percentage uncertainty = 0.689% [1]

Examiner comments

2 There is consideration of uncertainty equal to the smallest division of the length measurement here, but no factoring in of the difficulty of actually taking the measurement. It is difficult to bring the ruler up close because the clip is in the way.

Mark for (b) (iii) = 1/1
Mark for (b) (iv) = 0/1

Example candidate response – low, continued

(c) (i) Calculate C where

$$C = \frac{\sqrt{L}}{A}.$$

3

$C = \frac{\sqrt{14.5 \times 10^{-1}}}{7.07 \times 10^{-4}}$

$= 1.70 \times 10^{3}$

$C =$ 1.70×10^{3} [1]

(ii) Justify the number of significant figures that you have given for your value of C.

I've used three significant figure As all my value of L and A are in three significant figure. [1]

4

(d) (i) Twist the mass hanger through approximately 180°.

Release the mass hanger. The mass hanger will oscillate as shown in Fig. 2.2.

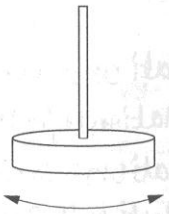


Fig. 2.2

(ii) Take measurements to determine the period T of the oscillations.

Record T.

Time taken for 10 oscillation (t_2) = 10.63.

Time taken for 1 oscillation (t_1) = 1.063.

Time taken for 10 oscillation = 12.78

Time taken for 1 oscillation (t_2) = 1.278

$T = \frac{t_1 + t_2}{2}$

$= 1.17\dot{1}$

$T =$ 1.171 s. [1]

5

(iii) Remove the wire from the mass hanger.

Examiner comments

3 Correct calculation of C (and A in (a) (iii)) despite missing out the units in this case.

Mark for (c) (i) = 1/1

4 The number of significant figures used needs to relate to the raw data used (d and L).

Mark for (c) (ii) = 0/1

5 Repeats in the time taken, calculation of the period and period in range.

Mark for (d) (ii) = 1/1

Example candidate response – low, continued	Examiner comments
(e) (i) Take the **longer** wire. Repeat **(a)(ii)** and **(a)(iii)**. $d = \frac{0.1 + 0.2}{2}$ $d =$ 0.015 mm $A = \frac{\pi (0.015)^2}{4}$ $A =$ 1.76×10^{-4} mm^2 (ii) Secure the hook of the mass hanger to one end of the wire leaving 40 cm of excess wire. Repeat **(b)(ii)**, **(b)(iii)**, **(c)(i)** and **(d)** for a value of L of approximately 30 cm. $L = \frac{29.5 + 30 + 29}{3}$ $L =$ 29.5 cm $C = \frac{\sqrt{29.5 \times 10^{-1}}}{1.76 \times 10^{-4}}$ $= 9.76 \times 10^{3}$ $C =$ 9.76×10^{3} Time taken for 10 oscillation = 13.78 Time taken for 1 oscillation (t_1) = 1.378 Time taken for 10 oscillation = 13.22 Time taken for 1 oscillation (t_2) = 1.322 $T = \frac{t_1 + t_2}{2}$ 6 $T =$ 1.35 s [3]	6 Second values of length and period provided, with an expected trend given that the longer length is used here. Mark for (e) (ii) = 3/3

Example candidate response – low, continued	Examiner comments
(f) It is suggested that the relationship between T and C is $T = kC$ where k is a constant. **(i)** Using your data, calculate two values of k. For first value. $T = KC$ $1.17 = K \times 1.70 \times 10^{3}$ $K = 6.88 \times 10^{-4}$ For second value. $T = KC$. $1.35 = K \times 9.76 \times 10^{3}$ $K = 1.38 \times 10^{-4}$ first value of k = 6.88×10^{-4} second value of k = 1.38×10^{-4} [1]	Mark for (f) (i) = 1/1
(ii) Explain whether your results in **(f)(i)** support the suggested relationship. The result does not supports the relationship because as the value of K increases the value of T also increases with it. [1]	7 No consideration of the percentage difference or a criterion to compare the percentage difference with. Mark for (f) (ii) = 0/1

Example candidate response – low, continued	Examiner comments
(g) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment. 8 1. Two sets of of data are not enough to draw conclusion. 2. Parall. Error while seeing the oscillation. 3. The angle of rotation might not be approximately 180°. 4. The wire at the clip ~~wrong~~ brings error while rotating. [4]	8 The problems listed are vague and do not show how they might affect any measurements. Mark for (g) (i) = 1/4
(ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures. 9 1. Aleast six sets of reading is required and plot its graph. 2. ~~No~~ Sensor must be used for viewing the wire while it goes back and forth. 3. Protractor must be used to while rotating. 4. The wire must be glued at the top so that it doesnot move while rotating. [4] [Total: 20]	9 Two good solutions are identified here. The other two are too vague. Mark for (g) (ii) = 2/4 **Total marks awarded = 11 out of 20**

How the candidate could have improved their answer

(a) (ii) To improve in measuring the diameter of the wire, the candidate needed to have done more practice in reading the micrometer screw gauge accurately, as they gave a value of 0.03 mm when the supervisor gave 0.26 mm.

(b) (iv) To improve in estimating the percentage uncertainty in *L*, the candidate should have thought about the difficulties in measuring *L* and factored these into the uncertainty in *L* so that they did not just consider the smallest possible reading from the ruler in this particular case.

(c) (ii) To improve in justifying the number of significant figures used in their value of *C,* reference should also have been made to the number of significant figures used in *d*.

(f) (ii) To improve the explanation of whether the results supported the relationship, the candidate should have worked out the percentage difference and compared this to a criterion, then formulated an opinion.

(g) (i) & **(ii)** The candidate could have described real problems and solutions in greater detail and linked the problems to specific quantities. For example, the candidate stated 'error in seeing the oscillation'. Here the examiner would expect the candidate to relate this either to the oscillation being in more than one plane or to the fact that the end of an oscillation is difficult to judge, thereby affecting the period.

Mark awarded = **(a) (ii) 0/1, (iii) 1/1**
Mark awarded = **(b) (iii) 1/1, (iv) 0/1**
Mark awarded = **(c) (i) 1/1, (ii) 0/1**
Mark awarded = **(d) (ii) 1/1**
Mark awarded = **(e) (ii) 3/3**
Mark awarded = **(f) (i) 1/1, (ii) 0/1**
Mark awarded = **(g) (i) 1/4, (ii) 2/4**

Total marks awarded = 11 out of 20

Common mistakes candidates made in this question

(a) (ii) Misreading measuring devices such as the micrometer screw gauge.

(b) (iv) Estimating the uncertainty as equal to the smallest division of the ruler (1 mm). Candidates needed to factor in the inherent difficulties of the experiment (getting the ruler close to the wire owing to the clip being in the way), leading to a larger uncertainty in the length reading.

(c) (ii) When justifying the significant figures used in *C,* candidates often referred to the significant figures used in area *A,* which were not a raw value but an intermediate calculated value.

(g) (i) & **(ii)** Descriptions of problems and solutions were often too vague and not specific to a particular measurement.

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