

PHYSICS (9702)

Paper 34 Guide

May/June 2025 Session

Contains Question Paper, Marking Scheme and Specialized Notes



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- 1 In this experiment, you will investigate how the motion of a pendulum whose swing is interrupted depends on its length.
- (a) (i) Lay the pendulum next to the rule and use the pen to make a mark on the string so that the distance L is 0.180 m, as shown in Fig. 1.1.

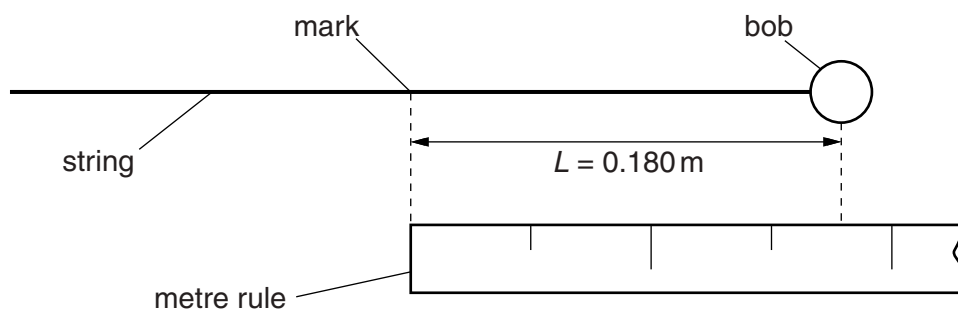


Fig. 1.1



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- (ii) Set up the apparatus, fixing the string in the split bung so that the string is just touching the wooden rod at the mark you have made.

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Fig. 1.2 shows a side view and a front view of the apparatus.

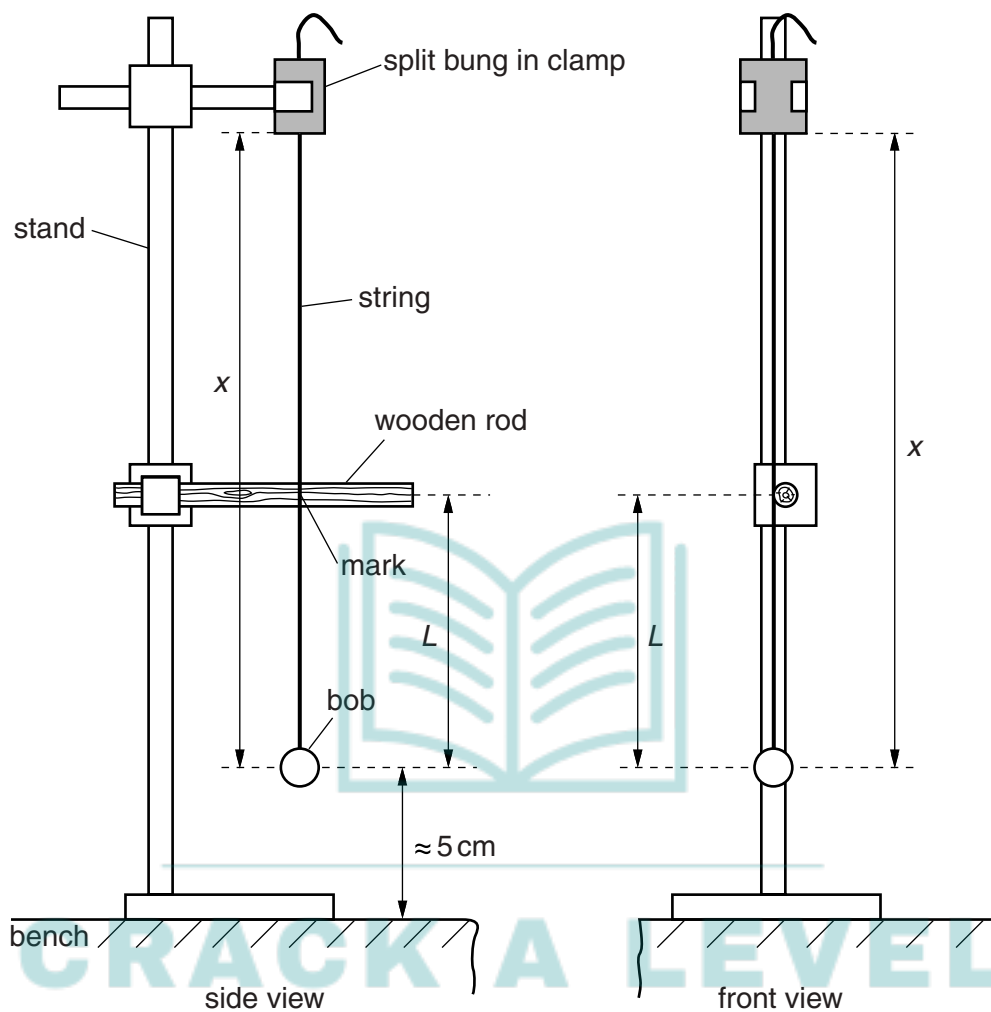


Fig. 1.2

The centre of the bob should be approximately 5 cm above the bench.

The distance x between the bottom of the bung and the centre of the bob should be approximately 55 cm.

The mark on the string should be level with the centre of the rod.

- (iii) Measure and record the distance x .

$x = \dots\dots\dots$ m [1]



- (b) (i) Move the bob sideways through a distance of approximately 5 cm, as shown in Fig. 1.3.

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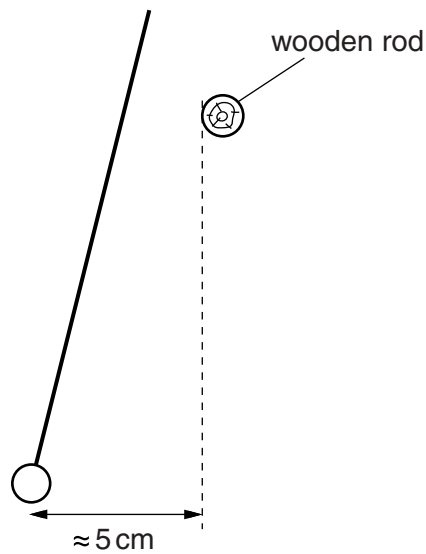


Fig. 1.3

- (ii) Release the bob and watch its movement. The bob will move to the right and then to the left again completing a swing, as shown in Fig. 1.4. Let the pendulum swing to and fro, counting the number of swings.

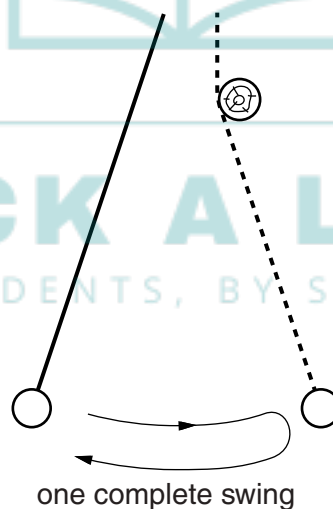


Fig. 1.4

Measure and record the time for at least 10 consecutive swings.

Record enough readings to determine an accurate value for the time T taken for one complete swing.

$T = \dots\dots\dots$ [2]

[Turn over]

- (c) Reduce the distance x . Keep L constant, by adjusting the height of the wooden rod if necessary. Repeat **(a)(iii)** and **(b)** until you have six sets of values of x and T .

Include values of $\sqrt{x}$ in your table.

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[9]

- (d) (i) Plot a graph of T on the y -axis against $\sqrt{x}$ on the x -axis.

[3]

- (ii) Draw the straight line of best fit.

[1]

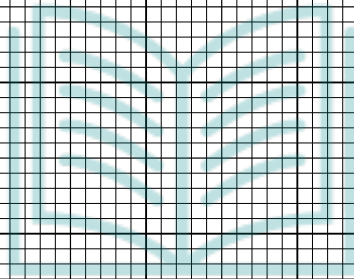
- (iii) Determine the gradient and y -intercept of this line. _____

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gradient = ...

y -intercept = ...

[2]



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- (e) The quantities T and x are related by the equation

$$T = P\sqrt{x} + Q$$

where P and Q are constants.

Using your answers from (d)(iii), determine the values of P and Q .

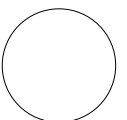
Give appropriate units.

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$P =$

$Q =$ [2]

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- 1 (a) (iii) Value of x in the range 0.50 – 0.60 m. [1]
- (b) (ii) Value of T with unit: $0.9\text{ s} < T < 1.3\text{ s}$. [1]
Evidence of repeats. [1]
- (c) Six sets of readings of x and T scores 4 marks, five sets scores 3 marks etc. [4]
Incorrect trend –1. Minor help from Supervisor –1; major help –2.
- Range of x at least 25 cm. [1]
- Column headings: [1]
Each column heading must contain a quantity and a unit where appropriate.
The unit must conform to accepted scientific convention e.g. x/m or $x(\text{m})$ or x in m.
- Consistency of presentation of raw readings: [1]
All values of x must be given to the nearest mm.
- Significant figures: [1]
Significant figures for $\sqrt{x}$ should be the same as, or one more than, s.f. for x .
- Calculation: $\sqrt{x}$ calculated correctly. [1]
- (d) (i) Axes: [1]
Sensible scales must be used. Awkward scales (e.g. 3:10) are not allowed.
Scales must be chosen so that the plotted points on the grid occupy at least half the graph grid in both x and y directions.
Scales must be labelled with the quantity that is being plotted.
Scale markings should not be greater than three large squares apart.
- Plotting of points: [1]
All the observations in the table must be plotted.
Check the points are plotted correctly.
Work to an accuracy of half a small square.
Do not accept 'blobs' (points with diameter greater than half a small square).
- Quality: [1]
All points in the table must be plotted (at least 5) for this mark to be scored. Judge by the scatter of all the points about a straight line. All points must be within $0.04\text{ m}^{1/2}$ ($0.4\text{ cm}^{1/2}$) on the $\sqrt{x}$ axis from a straight line.
- (ii) Line of best fit: [1]
Judge by the balance of all the points on the grid (at least 5) about the candidate's line.
There must be an even distribution of points either side of the line along the full length.
Allow one anomalous point if clearly indicated (e.g. circled or labelled) by the candidate.
Line must not be kinked or thicker than half a small square.

(iii) Gradient: [1]

The hypotenuse of the triangle must be at least half the length of the drawn line.
Both read-offs must be accurate to half a small square in both the x and y directions.
Do not allow $\Delta x/\Delta y$.

y-intercept: [1]

Either:

Check correct read-off from a point on the line, and substitution into $y = mx + c$. Read-off must be accurate to half a small square in both the x and y directions. Allow ecf of gradient value.

Or:

Check the read-off of the intercept directly from the graph.

(e) Value of P = candidate's gradient and Q = value of candidate's intercept. Do not allow fractions. [1]

Unit for P ($\text{s m}^{-1/2}$ or $\text{s cm}^{-1/2}$ or $\text{s mm}^{-1/2}$) consistent with value, and Q (s). [1]

[Total: 20]

You may not need to use all of the materials provided.

- 1** In this experiment, you will investigate the motion of a Y-shaped pendulum.
- (a)** You have been provided with two pieces of string. The longer piece of string has a loop at each end. The shorter piece of string is attached to a bob.

Set up the apparatus as shown in Fig. 1.1.

Attach the shorter string to the middle of the longer string with a knot.

Ensure the two rods of the clamps are at the same height above the bench.

Position the stands approximately 35 cm apart.

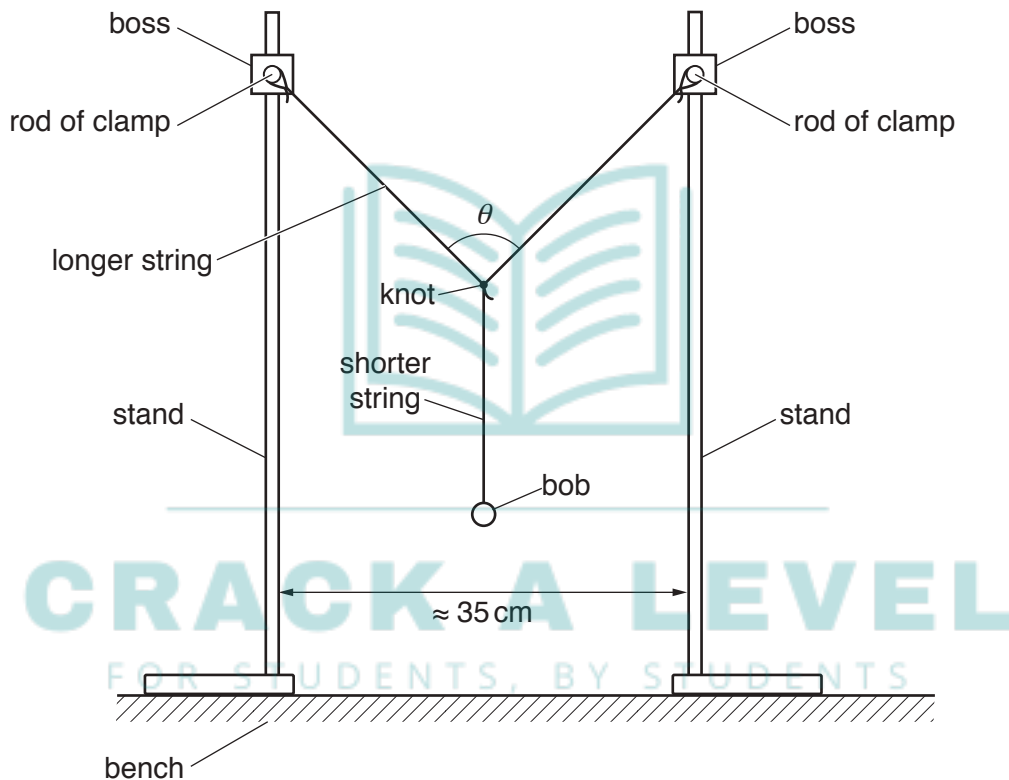


Fig. 1.1

The angle θ is the angle between the two halves of the longer string.

(b) Measure and record θ .

$\theta = \dots\dots\dots$ [1]

(c) Pull the bob a short distance towards you. Release the bob. The bob will oscillate.

Determine the period T of these oscillations.

$T = \dots\dots\dots$ [1]



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- (d) Vary the distance between the stands and repeat (b) and (c) until you have six sets of values of θ and T .

Record your results in a table. Include values of $\cos\left(\frac{\theta}{2}\right)$ and T^2 in your table.

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[10]

- (e) (i) Plot a graph of T^2 on the y -axis against $\cos\left(\frac{\theta}{2}\right)$ on the x -axis.

[3]

- (ii) Draw the straight line of best fit.

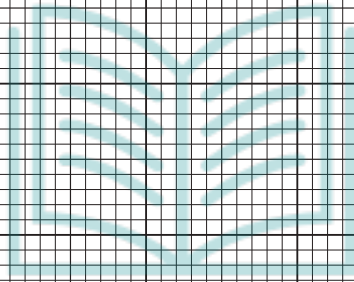
[1]

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

gradient = ...

y -intercept = ...

[2]



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- (f) It is suggested that the quantities T and θ are related by the equation

$$T^2 = P \cos\left(\frac{\theta}{2}\right) + Q$$

where P and Q are constants.

Using your answers in (e)(iii), determine the values of P and Q .

Give appropriate units.

$P =$

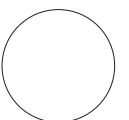
$Q =$

[2]

[Total: 20]



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Question	Answer	Marks
1(b)	Value of θ in range 80–100° with unit.	1
1(c)	Value of T in range 0.80–2.00 s with unit.	1
1(d)	Six sets of readings of θ (different values) and time showing the correct trend (T increases as θ decreases) and without help from the Supervisor scores 5 marks, five sets scores 4 marks etc.	5
	Range: $\theta \geq 120^\circ$ and $\theta \leq 60^\circ$.	1
	Column headings: Each column heading must contain a quantity and a unit where appropriate. The presentation of the quantity and the unit must conform to accepted scientific convention e.g. T^2 / s^2 and $\theta / ^\circ$. No unit for $\cos (\theta / 2)$.	1
	Consistency: All raw values of time must be given to the nearest 0.1 s or all to the nearest 0.01 s.	1
	Significant figures: All values of T^2 must be given to the same number of s.f. as (or one more than) the number of s.f. in raw values of time. If raw times recorded to nearest 0.01 s, allow number of s.f. of T^2 to be one less than the number of s.f. of the raw times.	1
	Values of $\cos (\theta / 2)$ calculated correctly.	1

Cambridge International AS/A Level – Mark Scheme
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Question	Answer	Marks
1(e)(i)	Axes: Sensible scales must be used, no awkward scales (e.g. 3:10 or fractions). Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Scales must be labelled with the quantity that is being plotted. Scale markings should be no more than three large squares apart.	1
	Plotting of points: All observations must be plotted on the grid. Diameter of plotted points must be $\leq$ half a small square (no “blobs”). Points must be plotted to an accuracy of half a small square.	1
	Quality: All points in the table (at least 5) must be plotted on the grid for this mark to be awarded. It must be possible to draw a straight line that is within 0.05 on the $\cos(\theta/2)$ axis (x-axis) of all plotted points.	1
1(e)(ii)	Line of best fit: Judge by balance of all points on the grid about the candidate's line (at least 5). There must be an even distribution of points either side of the line along the full length. Allow one anomalous point only if clearly indicated (i.e. circled or labelled) by the candidate. There must be at least five points left after the anomalous point is disregarded. Lines must not be kinked or thicker than half a small square.	1
1(e)(iii)	Gradient: The hypotenuse of the triangle used should be greater than half the length of the drawn line. Both read-offs must be accurate to half a small square in both the x and y directions. The method of calculation must be correct.	1
	y-intercept: Check correct read-off from a point on the line and substituted into $y = mx + c$. Read-off must be accurate to half a small square in both x and y directions. or Intercept read directly from the graph, with read-off at $x = 0$, accurate to half a small square in the y direction.	1

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Question	Answer	Marks
1(f)	Value of P = candidate's gradient and value of Q = candidate's intercept. The values must not be fractions.	1
	Units for P and Q correct (s^2).	1

- 1 In this experiment you will investigate the oscillations of a pendulum. A rod reduces the length of the pendulum by a distance d for half of each oscillation.

- (a) Clamp the thread using a split cork so that the length of the pendulum is about 70 cm.
- (b) Mount the wooden rod horizontally so that it is halfway down the length of the pendulum. The rod should just touch the string when the pendulum rests in a vertical position, as shown in Fig. 1.1.

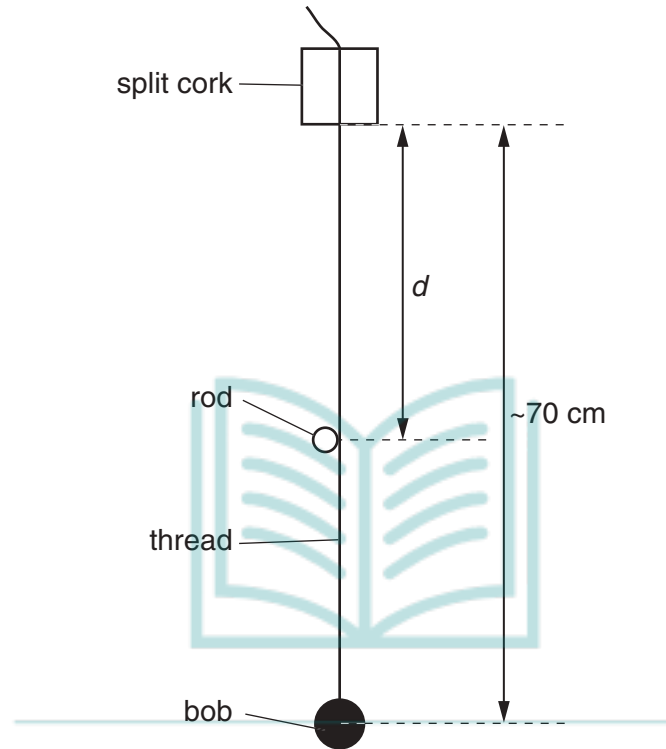


Fig. 1.1

- (c) (i) Measure and record the value of d .

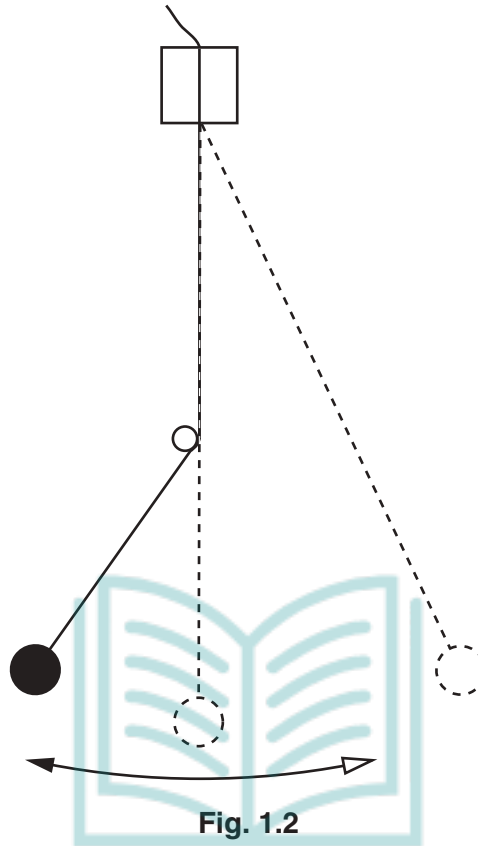
$d = \dots\dots\dots$

- (ii) Estimate the percentage uncertainty in this value of d , showing your working.

% uncertainty in $d = \dots\dots\dots$



- (d) (i) Gently displace the pendulum so that it performs small oscillations in a vertical plane perpendicular to the rod, as shown in Fig. 1.2.



- (ii) Make and record measurements to determine the period T of these oscillations.

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$T = \dots\dots\dots$

- (e) (i) Adjust the position of the rod to give a new value of d and repeat (d) until you have five more sets of readings for d and T where $20.0 \text{ cm} \leq d \leq 60.0 \text{ cm}$. Include all six values of $\frac{d}{T}$ in your table of results below.



- (ii) Justify the number of significant figures that you have given for $\frac{d}{T}$.

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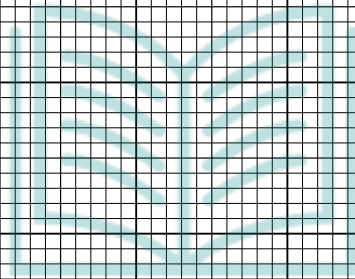
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- (f) (i) Plot a graph of T (y -axis) against $\frac{d}{T}$ (x -axis).

- (ii) Determine the gradient and y -intercept of the line of best fit.

gradient = ...

y -intercept = ...



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- (g) T and d are related by the formula

$$T = -\frac{\pi^2}{g} \left(\frac{d}{T} \right) + T_0$$

where g is the acceleration of free fall and T_0 is a constant.

Use your answers from (f)(ii) to find the values for g and T_0 . Include appropriate units in each case.



$g =$

$T_0 =$

- (h) Suggest **one** possible improvement to your experiment.

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(c) (ii)	Percentage uncertainty in first value of d Uncertainty = 1 mm or 2 mm scores 1 mark. Ratio idea correct scores 1 mark.	2/1/0
(e) (i)	Readings 6 sets of values for d/T scores 1 mark. Check a value for T . Underline checked value. Tick if correct and score 1 mark. Ignore rounding errors. If incorrect, write in correct value and do not award the mark. If there is no record of the number of oscillations then do not award this mark. If there are no raw times do not award this mark. If t for T then do not award this mark and ecf into the calculation for d/T . Check a value for d/T . Underline this value. Tick if correct and score 1 mark. Ignore rounding errors. If incorrect, write in correct value and do not award the mark. ecf for T . Help given by Supervisor, then -1. Excessive help then -2. Misread stopwatch -1.	3/2/1/0
(e) (i)	Repeated readings For each value of d there must be at least two values of t . Do not award this mark if all of the repeats are identical.	1
(e) (i)	Reasonable time used for oscillations At least half of the raw times must be greater than 20 s. If there are no raw times do not award this mark.	1
(e) (i)	Quality of results Judge by scatter of points about the line of best fit. 6 trend plots with little scatter scores 2 marks. 5 trend plots with little scatter scores 1 mark. Wrong trend of plots cannot score these marks (i.e. t increases as d increases)	2/1/0
(e) (i)	Column headings Apply to d/T only.	1
(e) (i)	Consistency Apply to d only. All the values of d must be given to the nearest millimetre.	1
(e) (i)	Significant figures Apply to d/T only. d/T must be given to the same number, or one more than, the number of significant figures as the least accurate data. Check each value by row.	1
(e) (ii)	Justification for sf in d/T Answer must relate sf in d (and t) to sf in d/T . Do not allow answers in terms of decimal places. 'Raw data' ideas or reference to T instead of t can score 1/2 marks.	2/1/0
(f) (i)	Axes Scales must be such that the plotted points occupy at least half the graph grid in both the x and y directions. Scales must be labelled with the quantities plotted. Do not allow awkward scales (e.g. 3:10, 6:10, 7:10 etc.). Ignore unit. Do not allow large gaps in the scale (i.e. 4 large squares or more).	1
(f) (i)	Plotting of points Count the number of plots and write as a ringed number on the grid. All observations must be plotted. There must be at least 5 plots on the grid. Check a suspect plot. Circle and tick if correct. If incorrect, show correct position with arrow, and do not award the mark. Work to half a small square.	1

Page 2	Mark Scheme	Syllabus	Paper
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- (f) (i) Line of best fit 1
 There must be a reasonable balance of points about the line of best fit.
 Only a straight line drawn through a linear trend is allowable.
- (f) (ii) Determination of gradient 1
 Δ used must be greater than half the length of the drawn line.
 $\Delta x/\Delta y$ scores zero. The value must be negative (if the line has a negative gradient).
 Check the read-offs. Work to half a small square.
- (f) (ii) y-intercept 1
 The value may be read directly or calculated using $y = mx + c$ and a point on the line.
- (g₁) Gradient equated with $-\pi^2/g$ 1
- (g₂) Value of g 1
 Accept $9.3 \text{ m s}^{-2} < g < 10.3 \text{ m s}^{-2}$.
 This mark can only be scored if the gradient has been used.
- (g₃) Unit of g 1
 Must be consistent with the working.
- (g₄) Intercept equated with T_0 1
 A numerical value is expected. Allow ecf from candidate's value in (f) (ii).
- (g₅) Unit of T_0 1
- (h) Suggested improvement; e.g. 1
 Measure the time for a greater number of oscillations: Use a thinner rod/knife edge
 for the stop: Use a fiducial marker/projection on screen: Use an electronic
 timing method (e.g. light gates & timer/datalogger & motion sensor/laser & timer)
 Use larger values of d . Do not allow 'repeat readings', 'more sensitive stopwatch',
 'do the experiment in a vacuum', switch the fans off, 'use heavier bob', 'avoid
 parallax error' or 'use a computer'.

25 marks in total.

You may not need to use all of the materials provided.

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- 2** In this experiment, you will investigate water flow through a hole in a container.

You are provided with a transparent plastic bottle with a small hole drilled in its base and with labels marking two positions P and Q.

The apparatus has been set up for you as shown in Fig. 2.1.

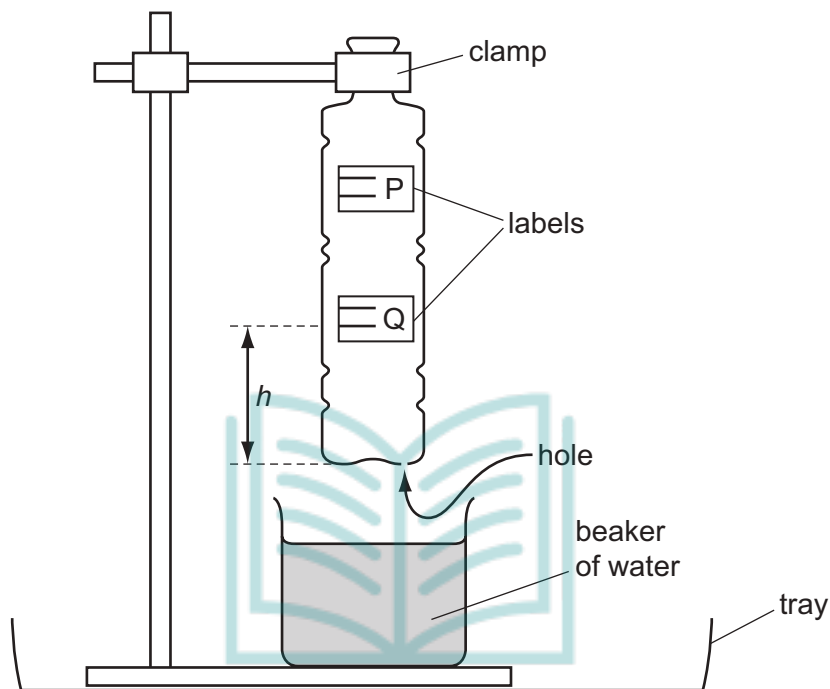


Fig. 2.1

- (a) (i)** Remove the bottle from the clamp and measure the diameter d of the bottle at position Q.

$d = \dots\dots\dots$ cm

- (ii)** Calculate the cross-sectional area A of the bottle at position Q, using the relationship

$$A = \frac{\pi d^2}{4}.$$

$A = \dots\dots\dots$ cm²

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- (b) On the label at position Q, there are two horizontal lines, as shown in Fig. 2.2.

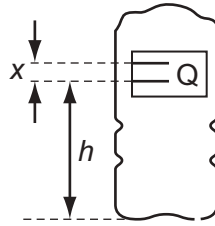


Fig. 2.2

- (i) Measure and record the distance x between the lines at position Q.

$x = \dots\dots\dots$ cm

☐

- (ii) Estimate the percentage uncertainty in x .

percentage uncertainty = $\dots\dots\dots$

☐

- (c) (i) Calculate the volume V of the bottle between the lines at position Q using the relationship $V = Ax$.

$V = \dots\dots\dots$ cm³

- (ii) Measure and record the distance h between the base of the bottle and the lower line at position Q.

$h = \dots\dots\dots$ cm

☐

- (d) (i) Locate the small hole in the base of the bottle.

- (ii) Replace the bottle in the clamp as in Fig. 2.1.

Cover the hole in the base of the bottle with your finger and then add water to the bottle so that the water level is just above the lines at position Q.

Replace the beaker under the bottle.

- (iii) Remove your finger so that water flows into the beaker and measure the time it takes for the water level to drop between the two lines at position Q.

Record this time t .

$t = \dots\dots\dots$ s

☐

- (iv) Calculate the flow rate R , using the relationship $R = \frac{V}{t}$. Give an appropriate unit.

$R = \dots\dots\dots$

☐

- (e) (i) Remove the bottle from the clamp and repeat (b)(i) and (c) for the lines at position P, using your value of cross-sectional area from (a)(ii).

$$x = \dots\dots\dots \text{ cm}$$

$$V = \dots\dots\dots \text{ cm}^3$$

$$h = \dots\dots\dots \text{ cm}$$

- (ii) Repeat (d) for the lines at position P.

$$t = \dots\dots\dots \text{ s}$$

$$R = \dots\dots\dots$$

- (f) (i) It is suggested that the relationship between R and h is

$$R = kh$$

where k is a constant.

Using your data, calculate two values of k .

$$k \text{ for position Q} = \dots\dots\dots$$

$$k \text{ for position P} = \dots\dots\dots$$

- (ii) Explain whether your results support the suggested relationship.

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(g) (i) Describe four sources of uncertainty or limitations of the procedure in this experiment.

1.

.....

2.

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3.

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4.

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(ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1.

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2.

.....

3.

.....

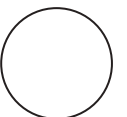
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- 2 (a) (i) Value of d in range 5 cm to 15 cm. [1]
Help from supervisor then –1.
Evidence of repeated measurements of d . [1]
- (ii) Correct calculation of A . [1]
Do not allow a value in terms of π .
- (b) (i) Measurement for x in range $0.8 \text{ cm} < x < 1.0 \text{ cm}$ to nearest mm. [1]
- (ii) Absolute uncertainty 1 or 2 mm (or half the range of repeats), and correct method of calculation. [1]
- (c) (ii) Measurement for h to nearest mm. [1]
- (d) (iii) Value for $t > 1 \text{ s}$ and given to 0.1 s or 0.01 s. [1]
Check raw data if there are repeats.
- (iv) Correct calculation of R , with consistent unit (e.g. $\text{cm}^3 \text{s}^{-1}$). [1]
- (e) (i) Values for x , V and h . [1]
- (ii) Correct trend (R increases with h). [1]
- (f) (i) Values of k calculated correctly. [1]
- (ii) Valid conclusion based on the calculated values of k . Candidate must test against a stated criterion. [1]

(g)

	(i) Problems 4 max	(ii) Improvements 4 max	No credit/not enough
A	Two readings are not enough (to draw a conclusion).	Take more readings, and plot a graph/calculate more k values.	More readings and calculate the average/ only one reading.
B	Bottle not circular/ diameter at P different to that at Q.	Collect water and measure volume/remeasure diameter at P.	
C	Bottle deforms when measuring d .	Use vernier callipers <u>to measure d</u> .	Use string to measure d .
D	Difficult to see water level/meniscus problems/refraction problems.	Use coloured water/liquid.	Use oil.
E	Labels get wet/ink runs	Use waterproof labels/ink	
F	Difficult to judge when to start/stop timing.	Use video, <u>with timing method</u> .	Human reaction time error.
G	Large uncertainty in x .	Use travelling microscope <u>to measure x</u> .	
X	Another valid point E.g. Flowrate calculated is not the flowrate at h .	E.g. Measure h to point midway between marks.	Move marks closer together.

Ignore 'parallax problems' unless there is a convincing diagram.

Ignore 'use assistant'.

Ignore 'use distance sensor' unless there is a convincing diagram.

Ignore 'use a computer/datalogger/light gates'.

Ignore 'bottle not vertical'.

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[Total: 20]

You may not need to use all of the materials provided.

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- 2 In this experiment, you will investigate how the speed of a glass ball falling through oil depends on its size.

The apparatus has been set out for you as shown in Fig. 2.1.

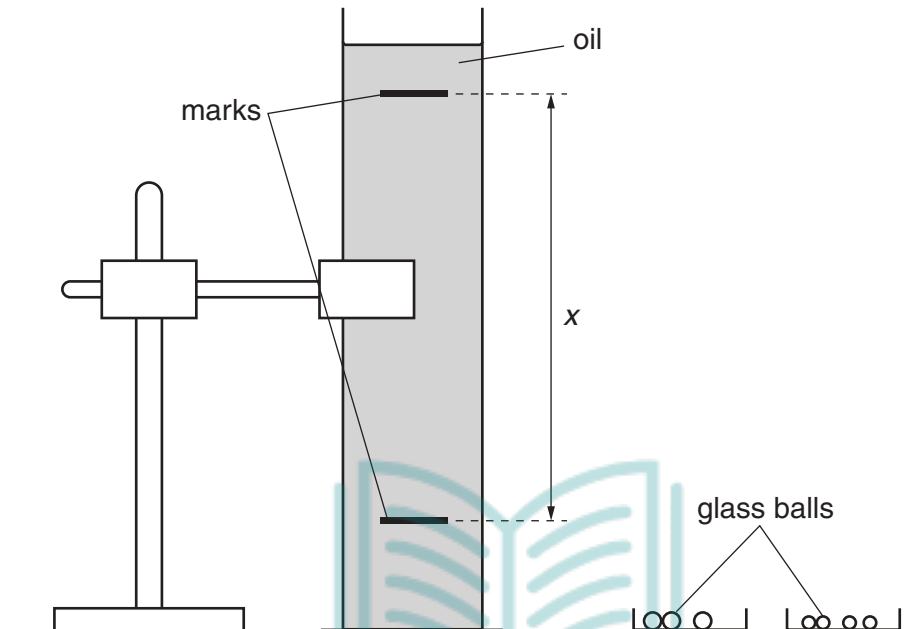


Fig. 2.1

- (a) Measure and record the distance x between the upper and lower marks on the measuring cylinder.

CRACK A LEVEL
FOR STUDENTS, BY STUDENTS

$x =$

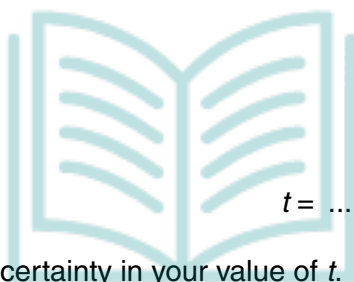


- (b) (i) You have been provided with two different sizes of glass ball: large and small. Take measurements to determine the diameter d of the small glass balls.

For
Examiner's
Use

$d = \dots\dots\dots$ mm

- (ii) Take measurements to determine the time t for a small glass ball to fall distance x through the oil.
Do not remove any balls from the oil. You may ask for more glass balls if needed.



$t = \dots\dots\dots$ s

- (c) Estimate the percentage uncertainty in your value of t .

CRACK A LEVEL

FOR STUDENTS BY STUDENTS

percentage uncertainty = $\dots\dots\dots$

- (d) Calculate the speed v of a small glass ball falling distance x through the oil.

$$(v = \frac{x}{t})$$

$v = \dots\dots\dots$

- (e) Repeat (b) and (d) for the large glass balls.

For
Examiner's
Use

$d = \dots\dots\dots$ mm

$t = \dots\dots\dots$ s

$v = \dots\dots\dots$

- (f) It is suggested that the relationship between v and d is

$$v = kd^2$$

where k is a constant.

- (i) Using your data, calculate two values of k .

CRACK A LEVEL

FOR STUDENTS, BY STUDENTS

first value of $k = \dots\dots\dots$

second value of $k = \dots\dots\dots$

- (ii) Explain whether your results support the suggested relationship.

.....
.....
.....

- (iii) Justify the number of significant figures that you have given for your values of k in (i).

.....
.....
.....

- (g) (i) Describe four sources of uncertainty or limitations of the procedure in this experiment.

For
Examiner's
Use

1.

.....

2.

.....

3.

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4.

.....

- (ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1.

.....

2.

.....

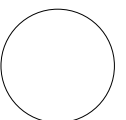
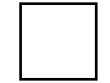
3.

.....

4.

.....

CRACK A LEVEL
FOR STUDENTS, BY STUDENTS



- 2 (a) Raw value(s) of x : $25.0 \text{ cm} \leq x \leq 35.0 \text{ cm}$ with unit to nearest mm. [1]
- (b) (i) Evidence of repeated measurements of d in (b)(i) or (e) [1]
 Value of $d = 3.0 \text{ mm} \pm 1.0 \text{ mm}$ or $SV \pm 1.0 \text{ mm}$ [1]
 Raw values of d to at least 0.1 mm
- (ii) Value of t in range 1 s to 10 s unless SV indicates otherwise. Allow $SV \pm 5 \text{ s}$ [1]
- (c) Absolute uncertainty in t_1 in the range 0.1 to 0.6 s [1]
 If repeated readings have been taken, then the uncertainty could be half the range.
 Correct calculation to get % uncertainty. _____
- (d) v calculated correctly with consistent units. [1]
- (e) Second value for d . [1]
 Second value for t . [1]
 Quality: t_2 less than t_1 . (d increases, t decreases) [1]
- (f) (i) Calculation of two values of k . [1]
- (ii) Valid conclusion based on the calculated values. [1]
 Candidate must test against a specified criterion.
- (iii) Relate raw values of x , t and d . Any decimal place arguments score zero. [1]

	Limitations (4)	Improvements (4)	Ignore
A	A_p Two readings not enough (to support conclusion)/too few readings.	A_s Take more (sets of) readings <u>and</u> plot a graph/compare values of k.	Repeat readings.
B	B_p Time too short/reaction time large compared to measured time/parallax error in judging start/stop.	B_s Increase x/lengthen tube/smaller balls/video with timer (playback) in slow motion.	Light gates, motion sensors, data loggers, computers, helpers, solution for parallax error. Set squares, rulers, etc.
C	C_p Difficult to see glass balls.	C_s Use coloured balls/shine light through.	Use ball bearings (type of ball and oil stays fixed).
D	D_p Terminal velocity not reached (by the first marker).	D_s A valid method to check reached TV, e.g. <u>time constant</u> over three markers/video with timer (playback) in slow motion, multi-flash photography/stroboscope.	References to starting point. Do not accept 'move x down' on its own. Change viscosity of oil (oil and glass must remain fixed).
E	E_p Balls not all the same diameter/size/shape/mass	E_s Use micrometer screwgauge/top pan balance	
X	X_p Balls had a hole in/air bubbles on ball or oil.	X_s Clean balls/immerse in oil	

You may not need to use all of the materials provided.

For
Examiner's
Use

- 2 In this experiment, you will investigate how the speed of water flowing through a tube depends on the tube length.

- (a) (i) Take measurements to determine the internal diameter D of the flexible tube, as shown in Fig. 2.1.



Fig. 2.1

$D =$ cm [2]

- (ii) Estimate the percentage uncertainty in your value of D .

percentage uncertainty = ... [1]

- (b) Remove the plunger from the syringe body.

- (c) (i) Measure the length l of the flexible tube.

$l =$ [1]

- (ii) Push the nozzle of the syringe body securely into one end of the flexible tube and then assemble the apparatus as shown in Fig. 2.2. Attach enough modelling clay near the bottom of the tube to make it hang vertically.

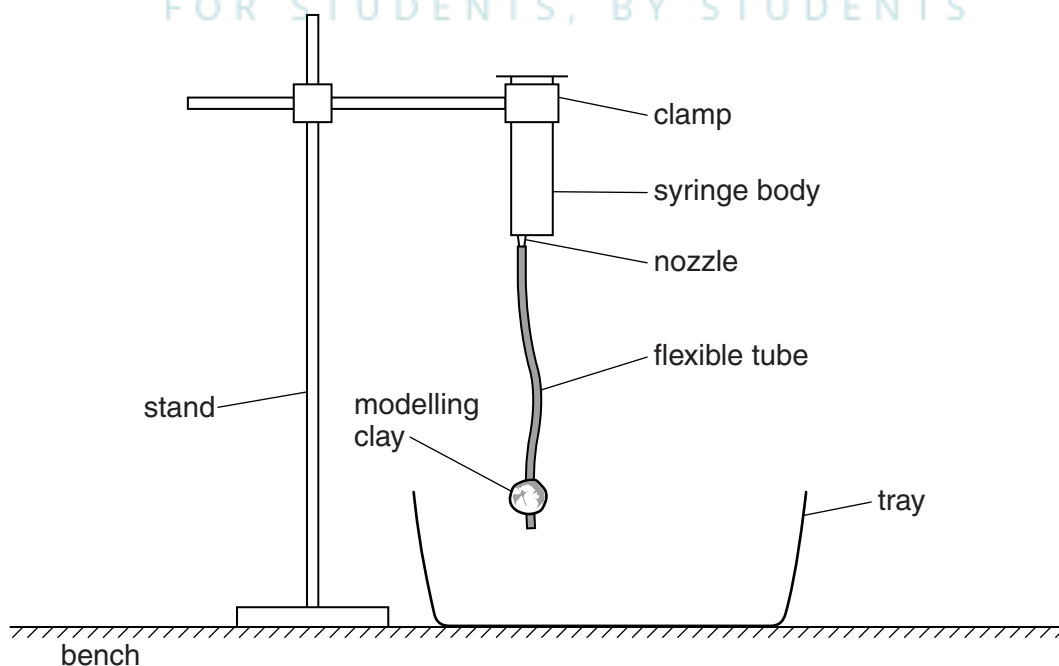


Fig. 2.2

[Turn over]

- (iii) Fill the syringe body to the top with water.

As the water level falls in the syringe body, take measurements to find the time t for the level to fall from the 40 cm^3 graduation to the 10 cm^3 graduation. (Note that $1\text{ ml} = 1\text{ cm}^3$.)

For
Examiner's
Use

$t = \dots\dots\dots \text{ s}$ [1]

- (iv) Calculate the average speed v of the water in the tube using the relationship

$$v = \frac{120}{\pi D^2 t}.$$

$v = \dots\dots\dots \text{ cm s}^{-1}$ [1]

- (d) Justify the number of significant figures that you have given for your value of v .

.....
.....
..... [1]

- (e) (i) Detach the tube from the syringe body and reduce its length by cutting it in half.
(ii) Repeat (c) with one of the shorter tubes.

$l = \dots\dots\dots$

$t = \dots\dots\dots \text{ s}$

$v = \dots\dots\dots \text{ cm s}^{-1}$
[3]

- (f) It is suggested that the relationship between v and l is

$$v^2 = kl$$

where k is a constant.

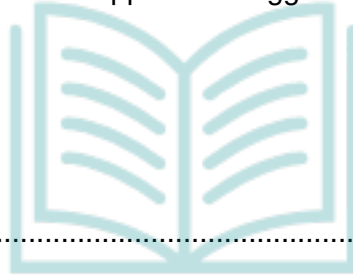
- (i) Using your data, calculate two values of k .

first value of k = ...

second value of k = ...

[1]

- (ii) Explain whether your results support the suggested relationship.



.....

CRACK A LEVEL [1]

FOR STUDENTS, BY STUDENTS

For
Examiner's
Use

☐
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- (g) (i) Describe four sources of uncertainty or limitations of the procedure for this experiment.

For
Examiner's
Use

1.

.....

2.

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3.

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4.

.....

[4]

- (ii) Describe four improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1.

.....

2.

.....

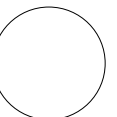
3.

.....

4.

.....

[4]



- 2 (a) (i) All values of D to nearest 0.01 cm or all to nearest 0.001 cm, and in range 3.0 to 5.0 mm. [1]
- Evidence of repeat readings of D . [1]
- (ii) Absolute uncertainty in D in range 0.02 to 0.05 cm and correct method of calculation to obtain percentage uncertainty. [1]
If repeated readings have been taken, then the absolute uncertainty can be half the range (but not zero if values are equal).
- (c) (i) l in range 19.0 to 21.0 cm, with unit, to nearest mm. [1]
- (iii) t in range 2.0 to 10.0 s and value(s) to nearest 0.1 s or 0.01 s. [1]
- (iv) Correct calculation of v . [1]
- (d) Justification for s.f. in v linked to s.f. in D and t . [1]
- (e) (ii) Second value of l . [1]
Second value of t . [1]
Second value of $t >$ first value of t . [1]
- (f) (i) Two values of k calculated correctly. [1]
- (ii) Sensible comment relating to the calculated values of k , testing against a criterion specified by the candidate. [1]

(g)

	(i) Limitations 4 max.	(ii) Improvements 4 max.	Do not credit
A	two readings are not enough (to draw a conclusion)	take more readings <u>and</u> plot a graph / take more readings and calculate more k values and <u>compare</u>	“repeat readings” on its own / few readings / only one reading / take more readings and (calculate) average k
B1	large uncertainty in D <u>because D is small</u>	measure outside diameter and wall thickness / measure an image showing the cross-section and a scale	use micrometer
B2	tube distorts when measuring D	use travelling microscope / measure volume and calculate D	
C	tube not straight so difficult to make tube vertical / tube not straight so difficult to measure length	tape to a straight rod / increase attached mass	use stiffer tube
D	difficult to judge moment (or operate stopwatch) <u>when level reaches syringe graduations</u>	use video with timer / view video frame by frame / collect water for a timed interval and measure volume / use light gates and timer <u>with practical detail</u> / use different diameter syringe <u>with reason</u> / use position sensor above water surface	‘reaction time’ on its own / human error / ‘light gates’ on its own / slow motion (or high speed) camera
E	difficult to see water level	use coloured water (or dye) / use clear syringe / view against black background	
F	clay stretches (or squashes) tube	measure length after attaching clay	

References to parallax error are ignored for this experiment.

[Total: 20]

Expected Table

$\theta / ^\circ$	t_1 / s	t_2 / s	$\frac{(t_1+t_2)}{2} / \text{s}$	T / s	$\cos \theta / \text{no unit}$



Important Tips

- The degree measured using the protractor must be to 0 decimal places. For example, 35° is correct but 35.5° is wrong
- The time measured in the stopwatch should be to 2 decimal places (unless you have been provided with one that is precise to only 1 decimal place)
- Make sure that throughout the calculations of time period and average time of 5 or 10 or 20 number of oscillation has same decimal places as the raw measured values of t_1 and t_2 .
- Make sure for calculations of $\cos \theta$, $\sin \theta$, T^2 and others have significant figures equal to n (n = least amount of significant figures from raw measured data) or $n+1$
- Make sure to keep significant figures for calculations and decimal places for average or measured values consistent in a column
- To calculate time period (T), we divide the average time of 5 or 10 or 20 oscillations by the number of oscillations taken to get time period of one oscillation.
 - Cos and sin are ratios so have no units

Marks Breakdown for Table

Criteria	Marks
6 readings collected with correct trend	5
80% or more range of independent variable should be covered	1
Headings in table with correct format (Symbol/Unit)	1
Calculations being correct	1
Decimal points of measured values are same and consistent with the instrument used	1
Significant Figures of Calculated Values should be correct (same or +1 of the calculated values)	1

Marks Breakdown for Graph

Criteria	Marks
Axes must be labelled with the required quantities. Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. Scale markings are no more than 2 cm (one large square) apart. Sensible scales must be used. Scales must not be awkward (e.g. 3:10 or fractions).	1
All observations on the table must be plotted on the grid. Diameter of plotted points must be $\leq$ half a small square. Points must be plotted to an accuracy of half a small square in both the x and y directions	1
All points in the table (at least 5) must be plotted on the grid. Trend must be correct.	1
For Line of Best fit, it is judged by balance of all points on the grid (at least 5 points) about the candidate's line. There must be an even distribution of points either side of the line along the full length. Line must not be kinked or thicker than half a small square.	1

Least Count and Uncertainties of Instruments

Instrument	Least Count	Absolute Uncertainty
Stopwatch	0.01 s	± 0.5 s
Vernier Caliper	0.1 mm	± 0.2 mm
Vernier Caliper	0.01 cm	± 0.02 cm
Protractor	1°	$\pm 2^\circ$
Meter Rule	1 millimeters	± 2 millimeter
Meter Rule	0.1 centimeter	± 0.2 centimeter
Meter Rule	0.001 meter	± 0.002 meter
Syringe	1 cm ³	± 2 cm ³

How to calculate percentage uncertainty?

$$\frac{\text{Absolute Uncertainty} \times 100}{\text{Absolute Value}}$$

Justify number of significant figures used for k

For example, if:

Time is to 3 significant figures and diameter is to 3 significant figures. Our justification would be **“The measured quantities which is the raw data of the experiment has time to 3 significant figures and diameter to 3 significant figures. Hence, the calculation of k is given in 3 or 4 significant figures.”**

For example, if:

Time is to 2 significant figures, diameter is to 3 significant figures and length is to 3 significant figures. Our justification would be **“The measured quantities which is the raw data of the experiment has time to 3 significant figures, diameter to 3 significant figures and length is to 3 significant figures. Hence, the calculation of k is given in 2 or 3 significant figures.”**

Note:

The **significant figures of k will be equal to n or n+1**. Where n is number of significant figures of the raw data that has least significant figures.

Explain whether your results support the suggested relationship

$$\text{Percentage Accuracy of } k = \frac{\text{large } k - \text{smaller } k}{\text{large } k} \times 100$$

OR

$$\text{Percentage Accuracy of } k = \frac{\text{large } k - \text{smaller } k}{k \text{ average}} \times 100$$

If the percentage calculated is greater (for example: 13.5%) then given percentage of being within experimental accuracy in question (for example: 10%), then **results do not support the suggested relationship according to our calculations**. As calculated percentage accuracy of k greater than experimental percentage accuracy.

If the percentage calculated is lower (for example: 7.6%) then given percentage of being within experimental accuracy in question (for example: 10%), then **results support the suggested relationship according to our calculations**. As calculated percentage accuracy of k less than experimental percentage accuracy.

Expected Errors and Improvements

Errors:

1. Two sets of readings are not enough to make a valid conclusion
2. Difficult to release the ball without applying force
3. Large uncertainty to measure diameter of ball
4. Tube gets distorted when measuring internal diameter of tube
5. Difficult to judge the moment when the ball reaches or passes the mark
6. Terminal velocity not reached
7. Time too short to judge
8. Volume measured not accurate as syringe is not precise
9. Difficult to judge water level due to meniscus problem
10. Tube not vertical or straight after being fixed
11. Large uncertainty in diameter as diameter of tube is small
12. Wooden strip not vertical with tube
13. Difficult to measure diameter of tube and it is being pressed by vernier caliper
14. Difficult to pull out ball from tube as attraction between ball and magnet not high

Improvements:

1. Take six or more readings and plot a graph to check the relationship
2. Use electromagnet clamp to release ball
3. Use micrometer to measure diameter of ball
4. Use travelling microscope to measure diameter
5. Use video playback with timer to judge when ball reaches the final distance
6. Increase the distance
7. Increase the distance
8. Use measuring cylinder to measure volume
9. Use colored water or dye
10. Use transparent plastic pipe instead of tube
11. Measure out diameter along the sides and measure the wall thickness
12. Use of set square with ruler to ensure the strip is vertical
13. Use travelling microscope to measure diameter
14. Use magnet that has higher attraction to the ball