H

millennia institute

2024 Preliminary Exams

Pre-University 3

H2 PHYSICS **9749 / 04**

Paper 4 Practical **26 August**

Candidates answer on the Question Paper. **2 hours 30 minutes**

Shift
Laboratory

READ THESE INSTRUCTIONS FIRST

Write your name, class and admission number in the spaces provided at the top of this page.

Write in dark blue or black pen on both sides of the papers.

You may use an HB pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions.

Write your answers in the spaces provided in this question paper.

The use of an approved scientific calculator is expected, where appropriate.

You may lose marks if you do not show your working or if you do not use appropriate units.

Give details of the practical shift and laboratory where appropriate in the boxes provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	16
2	8
3	19
4	12
TOTAL	**/ 55**

1 This investigation considers the size of the hole needed in a salt shaker for the salt to flow at a suitable rate.

(a) You have been provided with a beaker labelled **P** containing 100 g of salt as shown in Fig. 1.1.

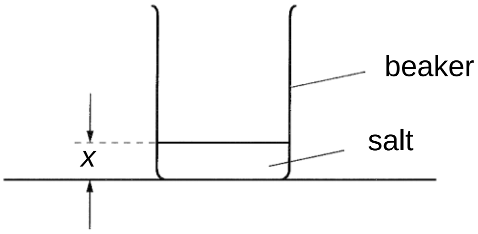


Fig. 1.1

(i) Measure and record the depth *x* of salt in beaker **P** using the vernier calipers.

Zero error = 0.00 cm
x_1 = 2.18 cm , x_2 = 2.20 cm

$x = \frac{2.18+2.20}{2}$ = 2.19 cm

[1] zero error recorded and considered in calculation. correct d.p. of *x*; Repeated readings recorded; and correct unit of *x*

x = 2.19 cm (2 d.p.) [1]

(ii) State a significant source of error in your value of *x*.

It was difficult to level the salt evenly within the beaker OR

It was difficult to ensure that the tail of the vernier calipers was perpendicular to the based of the beaker [1]

[1] A reasonable source of error stated

(iii) Estimate the percentage uncertainty in your value of *x*.

$\Delta x = (0.01 + 0.04)\text{cm}$

$\frac{\Delta x}{x} \times 100\% = \frac{0.05}{2.19} \times 100\%$

percentage uncertainty = 2.3 %

Absolute uncertainty in the range of 2mm to 5mm (1.s.f.).
[-1] either percentage uncertainty more than 2 s.f.
[-1] either absolute uncertainty not 1 s.f.
[-1] either (Δx and *x*) differs in d.p.

percentage uncertainty = 2.3 % (2 s.f.) [1]

(b) You have been provided with two cards. Each card has a hole of a different size.

(i) Measure and record the diameter *d* of the smaller hole.

d_1 = 0.46 cm , d_2 = 0.47 cm

$d = \frac{0.46+0.47}{2} = 0.47\text{cm}$

[1] correct d.p. of *d*; Repeated readings recorded; and correct unit of *d*

d = 0.47 cm (2 d.p.) [1]

(ii) Determine the area *A* of the smaller hole.

$A = \pi(\frac{0.47}{2})^2$

$A = 0.173\ cm^2$ = 0.17 cm^2

[1] *A* calculated correctly, correct s.f. of *A* (following from raw data); and correct unit of *A*.

If Area stated as 1 s.f. no marks given.

A = 0.17 cm^2 (2 s.f.) [1]

(c) **(i)** Fill the boiling-tube, as shown in Fig. 1.2, with salt from beaker **P**.

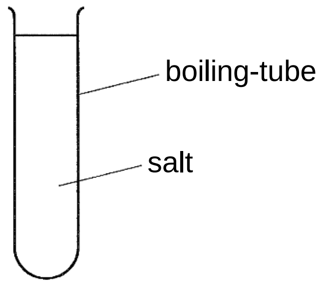


Fig. 1.2

(ii) Cover the open end of the boiling-tube with the card that has the smaller hole.

Use tape to attach the card to the boiling-tube.

The hole should not be covered by tape. When the boiling-tube is inverted, it should not be possible for salt to leave the boiling-tube other than through the hole.

(iii) Cover the hole with your finger.

Invert the boiling-tube over the empty beaker **Q**.

Remove your finger and allow the salt to flow through the hole into beaker **Q** for 50 seconds.

It may be necessary to shake the boiling-tube gently to achieve constant flow.

(iv) Tap beaker **Q** gently on the bench to ensure that the surface of the salt is level. Measure and record the depth *y* of salt in beaker **Q**.

y_1 = 1.24 cm , y_2 = 1.29 cm

$y = \frac{1.24+1.29}{2}$ = 1.27 cm

Correct d.p. of *y*; Repeated readings recorded; and correct unit of *y*

y = 1.27 cm (2 d.p.)

(v) Estimate the mass *m* of salt in beaker **Q**.

Assuming that the cross-sectional area of both beakers are the same,

$$\frac{\text{mass in Q}}{\text{mass in P}} = \frac{y}{x}$$

$$m = \frac{1.27}{2.19} \times 100$$

$$m = 57.99\text{ g} = 58.0\text{ g}$$

[1] *m* calculated correctly, correct s.f. of *m* (following from raw data); and correct unit of *m*.

m = 58.0 g (3 s.f.) [1]

(d) The recommended daily intake of salt for an adult is 5 g.

Use your data to calculate the time that a shaker, with a hole the same size as that in **(c)(ii)** should be inverted to apply 5 g of salt to food.

Assuming constant flow rate,

$$\frac{58.0\text{ g}}{\text{time needed for 58.0 g to flow}} = \frac{5\text{ g}}{\text{time needed for 5 g to flow}}$$

$$\text{time needed for 5 g to flow} = 5 \times \frac{50}{58.0}$$

$$\text{time needed for 5 g to flow} = 4.3\ s$$

[1] *time* calculated correctly, correct s.f. of *time* (following from raw data); and correct unit of *time*.

time = ...4.3 s (2 s.f.).......... [1]

(e) It is suggested that the rate of flow *R* of salt is proportional to the area *A* of the hole.

Use the card with the larger hole to take further measurements in order to investigate this suggestion. State and explain whether or not you agree with this suggestion.

Present your measurements and calculated results clearly.

For the smaller hole

$$R_1 = \frac{58.0}{50} = 1.16\text{ g s}^{-1}$$

For the bigger hole, d = 0.60 cm

$$A = \pi\left(\frac{d^2}{4}\right) = \pi\left(\frac{0.60^2}{4}\right) = 0.28\text{ cm}^2$$

When t = 10 s, depth z_1 = 0.92 cm , z_2 = 0.98 cm

$$z = \frac{0.92+0.98}{2} = 0.95\text{ cm}$$

$$\frac{m_Q}{100} = \frac{0.95}{2.19}$$

$$m_Q = 43\text{ g}$$

$$R_2 = \frac{43}{10} = 4.30\text{ g s}^{-1}$$

If R = k A, then the two experiment must yield the same k

$$k_1 = \frac{R_1}{A_1} = \frac{1.16}{0.17} = 6.82\text{ g s}^{-1}\text{m}^{-2}$$

$$k_2 = \frac{R_2}{A_2} = \frac{4.30}{0.28} = 15.4\text{ g s}^{-1}\text{m}^{-2}$$

$$\%\text{ k difference} = \frac{k_2-k_1}{\frac{1}{2}(k_1+k_2)}\times 100\% = \frac{8.58}{11.1}\times 100\% = 77.3\%$$

Since % k difference of 77.3% is more than the uncertainty of x (2.3%), the rate of flow of salt is NOT proportional to the area of the hole.

[1] depth of salt, correct d.p. (1 d.p. for mm and 2 d.p. for cm); Repeated readings recorded; and correct unit

[1] Correct calculation of A, correct s.f. of A with correct unit

[1] mass collected calculated correctly, correct s.f. and correct unit

[1] Rate of flow R for both cards calculated correctly, correct s.f. of R (following from raw data); and correct unit of R. R_2 should be larger than. R_1.

Analysis

[1] Both values of k calculated correctly, correct s.f. of k (following from raw data); and correct unit of k

[1] compare % difference with percentage uncertainty of *x* in (a)(iii); conclude correctly OR Draw conclusion based on stated criterion e.g. not obeyed because more than 20% difference in values of *k*.

....

.... [6]

(f) A statement found on the internet says that:

"The salt shaker may be distinguished primarily by the size of the holes, and then by the number of holes. Salt is coarser than pepper, and needs the larger hole. It is also heavier and flows much more freely than pepper, accordingly there are often fewer holes on the salt shaker to help control the flow. However, there is no manufacturing standard."

Suggest changes that could be made to the salt investigation to study the flow of pepper from a shaker.

Use smaller holes, pepper is finer

Use more holes, does not flow as freely as salt

Use a mass balance to weigh the exact mass of pepper that flows out as pepper can stick to the side of beaker and height of pepper will be inaccurate.

Pour the pepper carefully with the boiling tube lowered into the beaker/ Use a taller beaker /Use a cover to prevent pepper that fly out of beaker and height of pepper will be inaccurate.

Any 3 reasonable changes stated.

1 mark each.

[3]

[Total: 16 marks]

2 In this experiment, you will determine the length of a metal in the form of a wire.

(a) Measure and record the diameter *d* of the wire labelled sample Y that is attached to the cardboard tube.

Zero error = 0.00 mm

d_1 = 0.28 mm , d_2 = 0.28 mm

$$d = \frac{0.28+0.28}{2} = 0.28 \text{ mm}$$

[1] zero error recorded and considered in calculation. correct d.p. of *d*; Repeated readings recorded; and correct unit of *d*

d = 0.28 mm (2 d.p.) [1]

(b) Setup the circuit as shown in Fig. 2.1.

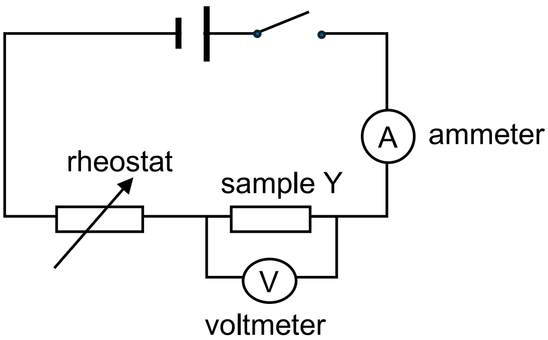


Fig. 2.1

(i) Set the rheostat to its maximum resistance.

(ii) Close the circuit.

Measure the current *I* and the potential difference *V* across sample Y.

I = 43.8 mA (1 d.p.)

[1] correct d.p. of *I* and V(1 d.p. for mA and 3 d.p. for V); correct unit of *I and V*

V = 0.664 V (3 d.p.) [1]

(iii) Open the circuit

(iv) Vary the resistance of the rheostat and repeat **(b)(i)**, **(b)(ii)** until you have 3 more sets of I and V.

I / mA	V / V
43.8	0.664
48.4	0.733
51.8	0.786
64.6	0.977

[1] Each column heading must contain a physical quantity and an appropriate unit.

[1] Consistency in number of decimal places for raw data (***I*** and ***V***).

[2]

(c) Plot your values from **(b)(iv)** on Fig. 2.2.

[1] All collected data points must be plotted correctly on the graph grid. (Accuracy up to half a small square in both the x and y directions).

[1] Best-fit line - Judge by scatter of points about the plotted line. Fair scatter of points on either side of the line. Scales must be chosen such that the plotted points occupy more than half the grid in both x and y directions.

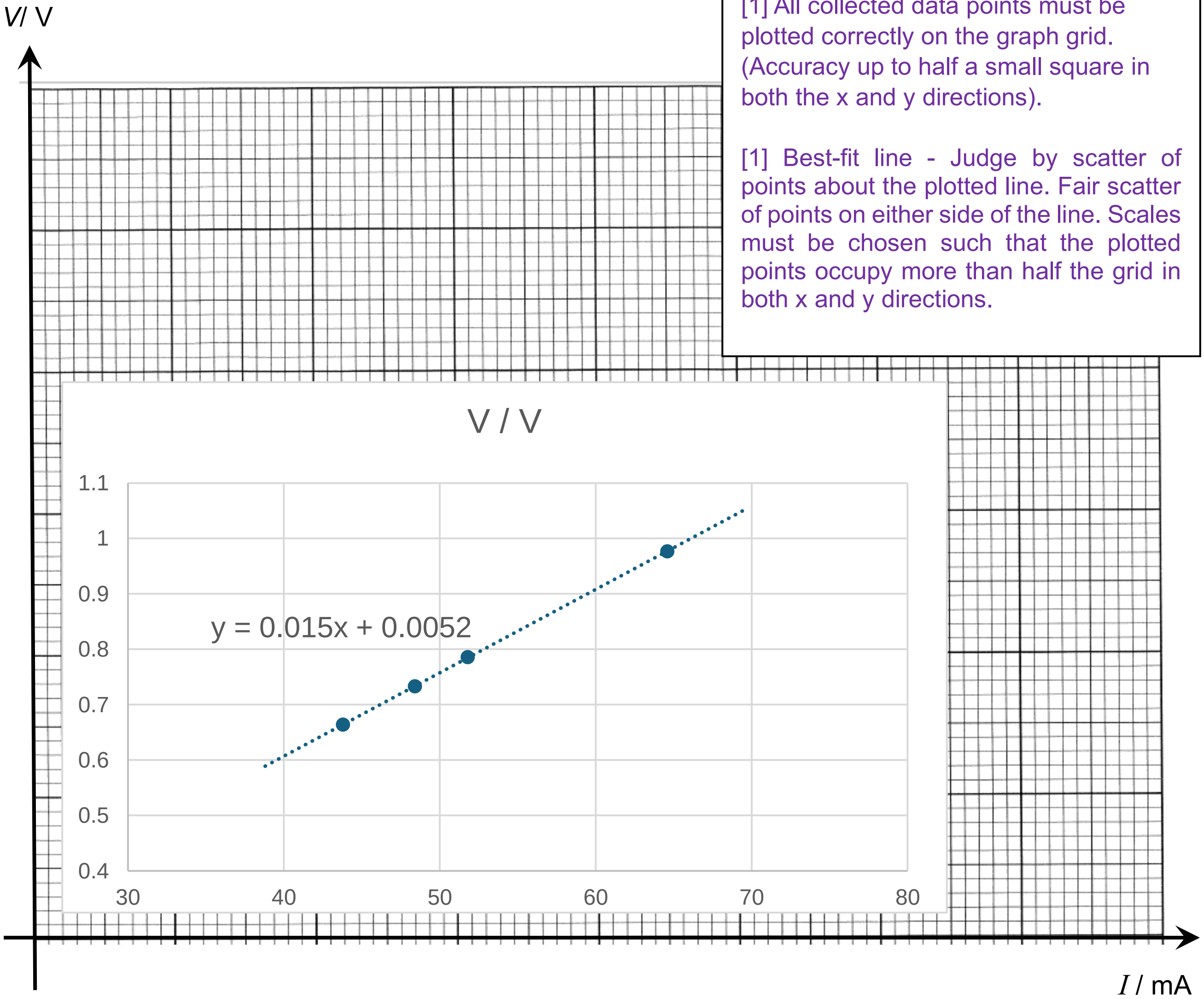


Fig. 2.2

[2]

(d) The gradient of the graph represent the resistance of the sample Y. Given that the resistance is given by

$$R=\frac{\rho L}{A}$$

where ρ is the resistivity of the metal from which the wire is made, L is the length of the wire and A is its cross-sectional area.
The resistivity of the given wire is 4.50×10^{-7} Ω m.

Estimate the length of the sample.

Since the vertical intercept of R is not through the origin, there could be systematic errors. R can be determined from the gradient instead.

Gradient = R = 0.015×10^{3} Ω

$$L=\frac{RA}{\rho}=\frac{(0.015 \times 10^{3})(\pi)(0.14 \times 10^{-3})^{2}}{4.50 \times 10^{-7}}=2.1\ m$$

[1] Determination of ratio of V/I or Gradient

Recording of the coordinates accurate to half a small square
Hypotenuse of triangle > half-length of line drawn. Correct calculation of ratio or gradient
[Note if the intercept of bfl is far from origin, student can use gradient for determination of R, result for use of gradient instead of ratio should be provided.

[1] *L* calculated correctly, correct s.f. of *L* (following from raw data); and correct unit of *L*.
Value to be between 180 cm and 220 cm.

L = 2.1 m (2 s.f.) [2]

[Total: 8 marks]

3 In this experiment, you will investigate how the motion of an oscillating system depends on the mass attached to the system.

(a) **(i)** Set up the apparatus as shown in Fig. 3.1.

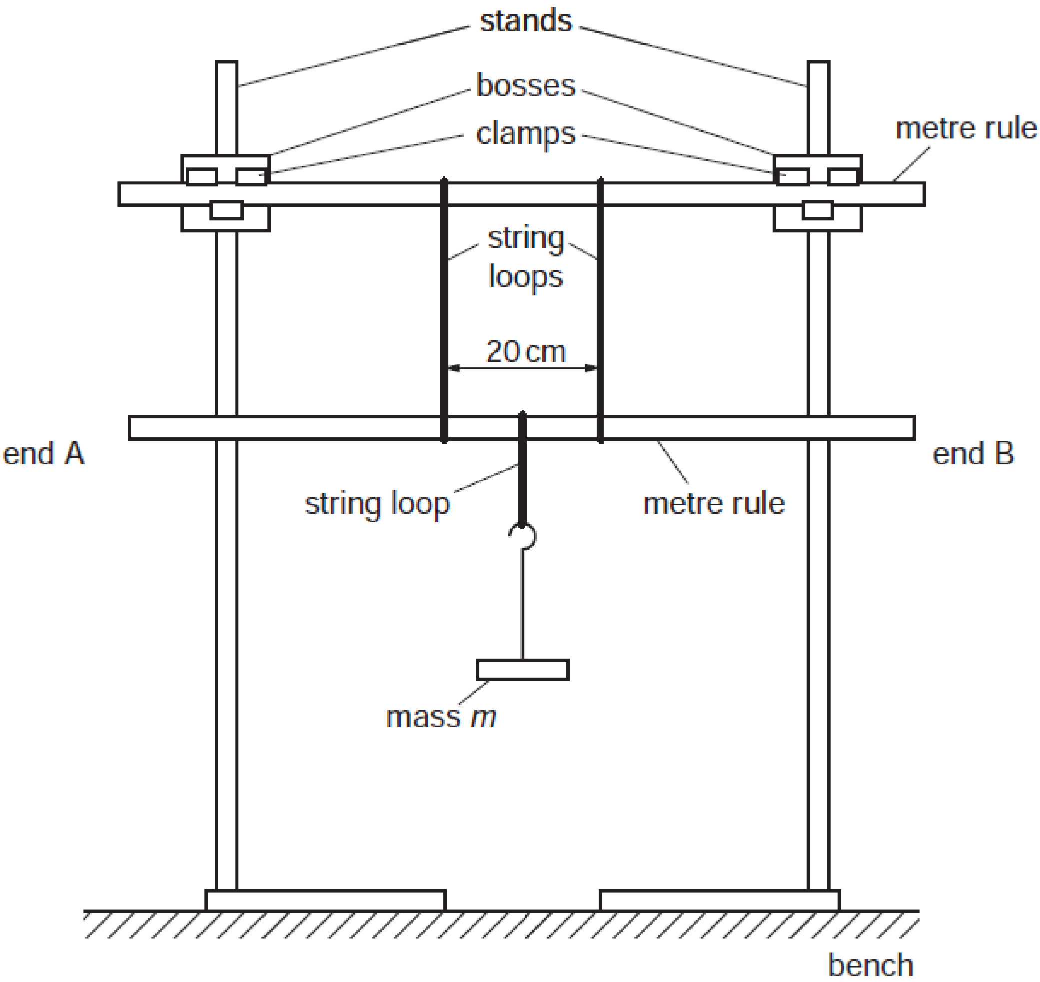


Fig. 3.1

Slide the two loops of string onto a rule and fix this rule in the clamps.

Adjust the clamps until the rule is parallel to the bench.

Using the string provided, make a loop of circumference 20 cm. Slide this shorter loop onto the second rule and use the longer loops to support this second rule.

Both rules should have their markings facing you. The strings should be vertical, 20 cm apart and at equal distances from the centre of the second rule.

Use the shorter loop of string to suspend a mass m at the 50 cm mark on the second rule, where m = 0.500 kg.

(ii) Move the end A of the lower rule towards you and the end B away from you.

Release the rule and watch the movement.

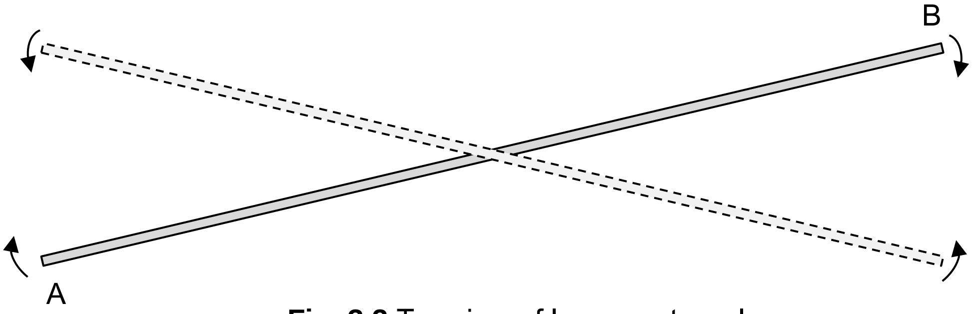


Fig. 3.2 Top view of lower metre rule

End A will move away from you and back towards you, completing a swing.

The time taken for one complete swing is *T*.

Determine an accurate value for *T*.

m = 100 g

N = 15

t_1 = 22.9 s

t_2 = 22.3 s

$T = \frac{22.9+22.3}{2(15)}$ = 1.51 s

[1] *NT* ≥ 20 s; correct d.p. of *t* (1 d.p.); correct s.f. and units of *T*. Readings are recorded clearly; repeat readings taken.

T = ...1.51 s..........[1]

(b) Change *m* and repeat **(a)(ii)** until you have six sets of values of *m* and *T*.

m/kg	N	t_1/s	t_2/s	T/s	T^{-2}/s^{-2}
0.100	15	22.9	22.3	1.51	2.27
0.200	17	21.2	21.2	1.25	1.56
0.300	20	21.5	21.6	1.08	1.17
0.500	26	22.9	22.8	0.879	0.772
0.600	30	23.6	24.4	0.800	0.640
0.700	30	23.2	22.9	0.768	0.590

[1] 6 sets of readings (without assistance), 0 mark if collect 5 sets or less (without assistance)
[-1] if candidate requires some assistance/intervention but has been able to do more of the work independently.
[1] Largest range of mass used (100 g to 700 g)
[1] repeated readings for t
[1] Each column heading must contain a physical quantity and an appropriate unit.
[1] Consistency in number of decimal places for raw data:[3 dp for kg, 1dp for seconds]
[1] T and T^2 calculated correctly, significant figures for each of the calculated value should reflect the number of significant figures in the raw data.

[6]

(c) The quantities *m* and *T* are related by the equation

$$\frac{1}{T^2} = P\,m + Q$$

where *P* and *Q* are constants.

Plot a suitable graph to determine the values of *P* and *Q*.

Plot a graph of $\frac{1}{T^2}$ against m, where P is the gradient and q is the y-intercept

$$\text{gradient} = \frac{2.20 - 0.60}{0.770 - 0.140}$$
$$= \frac{1.60}{0.630}$$
$$= 2.54$$
$$P = 2.54$$

$$\text{y-intercept} = Y - (\text{gradient})\,X$$
$$= 2.20 - 2.54\,(0.770)$$
$$= 2.20 - 1.96$$
$$= 0.24$$
$$Q = 0.24$$

[1] Linearising equation and deriving expressions that equate gradient of graph to P and y-intercept of graph to Q.

[1] Determination of Gradient and hence P
Recording of the 4 coordinates accurate to half a small square
Hypotenuse of triangle > half-length of line drawn

[1] correct calculation of y intercept using a point on the line {not from the table} or read off the graph to accuracy within half a small square;

[1] Correct units of P and Q

P = 2.54 $kg^{-1}\,s^{-2}$

Q = 0.24 s^{-2} [4]

[1] Sensible scales must be used. No awkward scale allowed.
Scales must be chosen such that the plotted points occupy more than half the grid in both x and y directions.
Axes must be labelled with correct quantity and appropriate unit.

[1] All collected data points must be plotted correctly on the graph grid.
(Accuracy up to half a small square in both the x and y directions).

[1] Assessed best fit line if and only if at least 5 out of 6 of the plotted points are non-anomalous.
Judge by scatter of points about the plotted line. Fair scatter of points on either side of the line

[3]

(d) Comment on any anomalous data or results that you may have obtained.

There are no anomalous points as all the plotted points are close to and follows well the trend of the best fit line.
OR
The point (x, y) is an anomalous point because it is far away from the best fit line and does not follow the trend of best fit [1]

(e) State two significant sources of errors in this experiment.

Possible Errors (relevant points with appropriate elaboration):

1 It is difficult to judge visually the position of the start and stop of a complete oscillation, thus affecting the accuracy of the values of t and T obtained.

2 The loops of string of 30 cm circumference are not exactly the same size, affecting the accuracy of the values of t and T obtained.

3 The rulers are not exactly horizontal, affecting the accuracy of the values of t and T obtained.

4 The loops slide on the rules during oscillations, affecting the accuracy of the values of t and T obtained.

Any 2 sources of error in the list.

1 mark each. [2]

(f) Suggest improvements that could be made to the experiment to address the sources of error identified in **(e)**. You may suggest the use of other apparatus or different procedures.

Possible Improvements (relevant points with appropriate elaboration):

1 Using a third retort stand, clamp a 30 cm ruler so that it points horizontally at the equilibrium position of end A of the lower ruler, to act fiducial marker for the oscillation.

2 Instead of tying a knot with the string itself, tie the knot at the correct length with a thin thread or tape at the correct length.

3 Use a spirit level to check that both rulers are horizontal, by placing the level on top of each ruler, before commencing each set of readings.

4 Tape or glue the strings to the lower rule so that they remain in the same position on the rule.

2 improvements that are tied to the sources mention in (e) stated.

1 mark each. [2]

[Total: 19 marks]

4 A student wishes to investigate projectile motion.

A small ball is rolled with velocity v along a horizontal surface. When the ball reaches the end of the horizontal surface, it falls and lands on a lower horizontal surface. The vertical displacement of the ball is h and the horizontal displacement of the ball is d, as shown in Fig. 4.1.

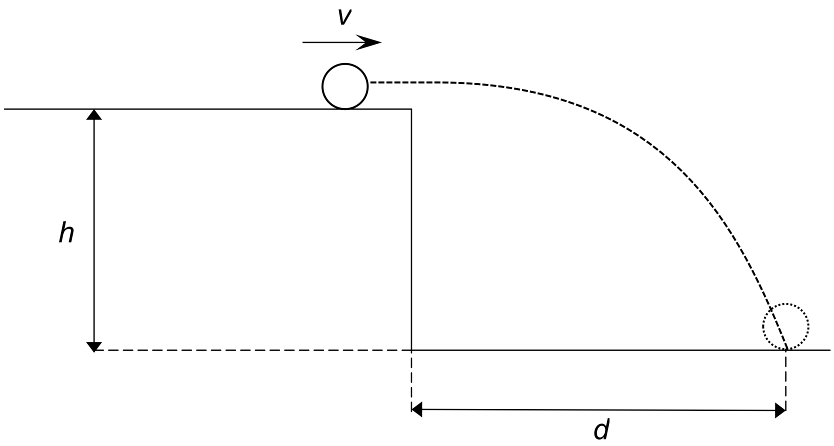


Fig. 4.1

The student suggests that d is dependent on h and v according to the equation

$$d = k\,h^{p}\,v^{q}$$

where k, p and q are constants to be determined.

Design a laboratory experiment to determine the values of k, p and q.

You should draw a diagram showing the arrangement of your equipment. In your account you should pay particular attention to

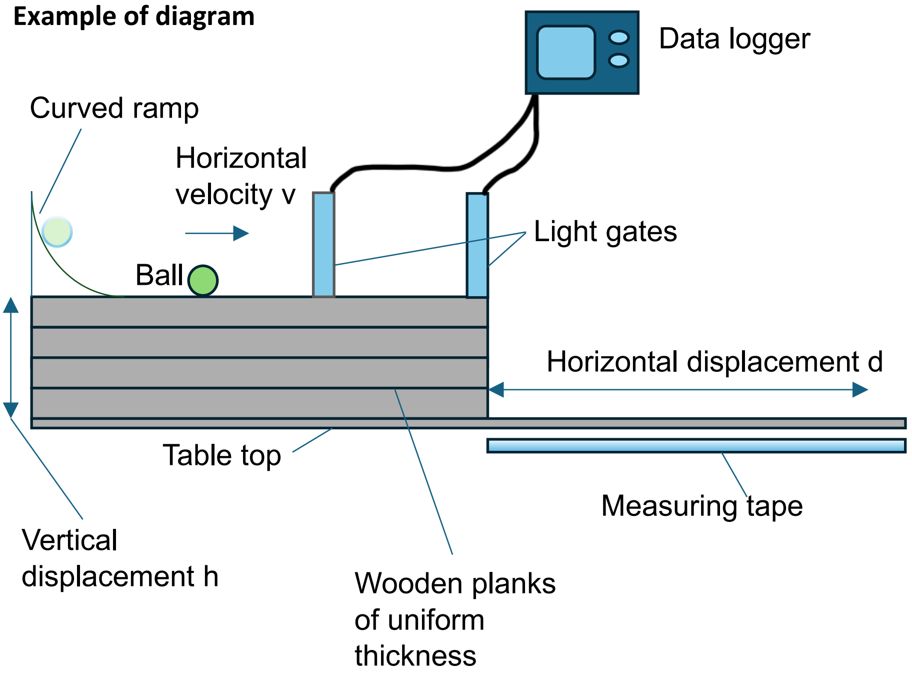
(a) the identification and control of variables,

(b) the equipment you would use and measurements to be taken,

(c) procedure to be followed,

(d) the analysis of the data,

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

Annotation	Rubrics	Max	Actual
Diagram (D)	**(D1)** Clearly labelled diagram showing way of launching ball and determining speed that the ball leaves the edge.	1	
	Example of diagram 		
Identifying the Variables and method of Measurements	**(M1)** Dependent variable is horizontal displacement of ball d, measured with a measuring tape. Two Independent variables: **(M2)** Vertical displacement of ball, *h* measured with a metre rule. **(M3)** Horizontal velocity of the ball *v with workable method to* measure *v* (e.g. using video analysis, light gates with distance and method, motion sensor etc) or determine *v* by calculation (see step 4)	1 1 1	
Control (C)	**(C1)** Method to ensure that the surfaces remain horizontal, e.g. spirit level/check height at different places. (Student should try to have at least 2 points for control variables)	Max 1	
	1. Set up apparatus as shown. 2. Measure and record *h* using a metre rule. 3. Release the ball on the curve track from a height of 20 cm (measured with a metre rule) from the tabletop. 4. Measure the time taken t, for it to travel through the last 10 cm just before it drops off the table. Calculate the average velocity of the ball using v = (0.10/t) and record this value in a table. 5. Measure d horizontal displacement of ball d and record this value in a table.		
Methods of Vary (V)	6. **(V1)** Keeping velocity of v constant, repeat steps 2 to 5 and vary height *h* by stacking of multiple planks to raise the height of ground (or any workable method) to get 6 sets of *v* and *d*. 7. **(V2)** Keeping h constant, repeat steps 2 to 5 and vary velocity v by rolling the ball down a slope of varying height / ball launched from spring compressed to different extent (any workable method) to get 6 sets of *d* and *v*.	1 1	

[Turn over

Analysis (A)	8. **(A1)** $\lg d = p \lg h + \lg (k v^q)$ Plot a suitable graph of lg *d* vs lg *h* (keeping *v* constant). gradient = *p*; y-intercept = $\lg (k v^q)$ $\lg d = q \lg v + \lg (k h^p)$ Plot a suitable graph of lg *d* vs lg *v* (keeping *h* constant). gradient = *q*; y-intercept = $\lg (k h^p)$ 9. **(A2)** If linear graphs are plotted for both equations, p and q can be calculated from the gradients. Using the values of p and q, value of k can be determined from both y intercepts. Average the 2 values to find the value of k.	1 1	
Reliability of Experiment (R) **Method** and **reason**	Any **two** of the following design details to improve Accuracy of DV and IV: **(R1)** Detail on method of improving precision of measurement of d e.g. slow motion playback including scale / marking on A4 using a carbon paper / sand. **(R2)** Method to ensure d is measured from just below edge of upper surface e.g. use set square, plumb line. **(R3)** Show understanding of random error in experiment: Take many readings of d for each h and v and average **(R4)** Method to ensure that velocity of ball is horizontal when it leaves the table, e.g. curved track with horizontal portion on table **(R5)** Ensure that the ball leaves the table at 90°, e.g. use set square/protractor on upper surface to ensure that track that ball is moving within is 90° to the edge of the table. **(R6)** Detail on measuring *d* – location of landing position e.g. centre of crater/start of track.	Max 2	
Safety of Experiment (S)	Any **one** safety consideration. **(S1)** Reasoned method to prevent ball rolling on floor e.g. box below / storage box for balls / sand box. **(S2)** Reasoned method to prevent ball causing injury e.g. goggles / safety screen.	Max 1	
	Total	**12**	