Catholic Junior College
JC2 Mid Year Examinations
Higher 2

CANDIDATE NAME	**MARK SCHEME**
CLASS	2T

PHYSICS

9749/04

Paper 4 Practical

20 May 2024

2 hour 30 minutes

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB or 2B 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 on the 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 assessment, fasten all your work securely together.
The number of marks is given in brackets [ ] at end of each question or part question.

Shift
Laboratory

For Examiner's Use	
1	/ 14
2	/ 8
3	/ 22
4	/ 11
Total	/ 55

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1 In this experiment, you will determine the resistivity of a metal.

(a) Set up the circuit as shown in Fig. 1.1, using the resistor of resistance R = 68 Ω.

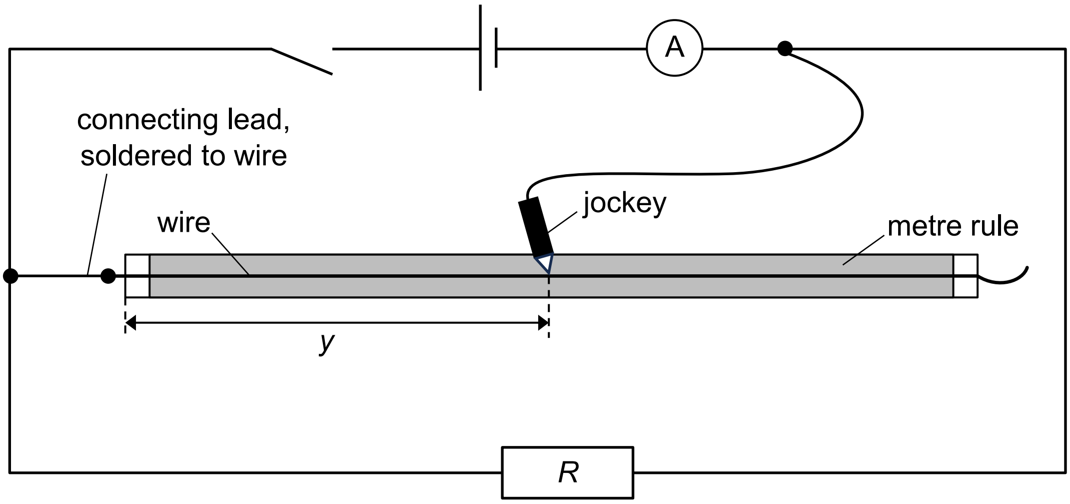


Fig. 1.1

Place the jockey on the wire about half-way along the metre rule. The distance between the end of the wire and the jockey is y, as shown in Fig. 1.1.

Close the switch.

Adjust the position of the jockey until the ammeter reading I is as close as possible to 121 mA.

Record R, I and y.

R = 68 Ω

I = 121.1 mA

y = 53.3 cm

[1]

Open the switch.

1 mark:

- R recorded as **68 Ω exactly without any d.p.**
- Current I to be within **120.6 to 121.4 mA.** (able to **round off to 121 mA**).
- y recorded to **1 d.p. in cm or 3 d.p. in m**.

(b) Vary R and adjust y each time so that I is always as close as possible to 121 mA.

Present your results clearly.

R / Ω	y / cm	$\frac{R}{y}$ / Ω cm^{-1}
56	55.5	1.0
68	53.3	1.3
82	51.0	1.6
100	49.3	2.03
120	48.2	2.49
whole number	1 d.p	follow least s.f. of R & y

[Marking: U, P, V]

1 mark – at least 5 sets of raw data (both IV and DV); (**5 rated resistors are provided and so all 5 should be used. These resistors may also be combined in series or parallel to obtain a 6th set of data**.)

1 mark – **column headers with units** & **no split table** & **correct trend** (as R increases, y decreases)

1 mark – correct computation and sf of calculated quantity (correct d.p. for average y if column is shown).

Do not mark for column of I. If IR column is present, check for correct computation.

[3]

(c) It is suggested that R and y are related by the expression:

$$\frac{R}{y} = \frac{QIR}{F} - Q$$

where I is your value from **(a)** and Q and F are constants.

Plot a suitable graph to determine values of Q and F.

Plot $\frac{R}{y}$ against R to obtain a straight line graph where $\frac{QI}{F}$ is the gradient and −Q is the vertical intercept.

$$\frac{QI}{F} = \text{Gradient} = \frac{2.56 - 1.1}{123 - 60} = 0.023175 \text{ cm}^{-1}$$

Sub (123, 2.56) into Y = mX + c,

−Q = Vertical intercept = 2.56 – 123(0.023175) = −0.29053 Ω cm^{-1}

Q = 0.291 Ω cm^{-1}

$$F = \frac{QI}{\text{gradient}} = \frac{0.29053(121.1)}{0.023175}$$
$$= 1.52 \times 10^{3}\ \Omega\ \text{mA}$$

Q = ...0.291 Ω cm^{-1}........................

F = ...1.52×10^{3} Ω mA........................

[8]

[Marking: gradient/vertical intercept & graph]

1 mark – correct graph plotted (correct linearization of equation implied from the graph plotted) **[If *I* is not kept constant in (b) at the value recorded in (a), do not accept graph of R/y against IR]**

1 mark – Scale/size of graph. Axes correctly labelled with quantity and units.

1 mark – all points plotted & 3 points plotted accurately (1^{st} ,middle, last) – if point is outside grid deduct here

1 mark – Line of best fit (need 4 points to judge trend; allow only 1 anomaly)

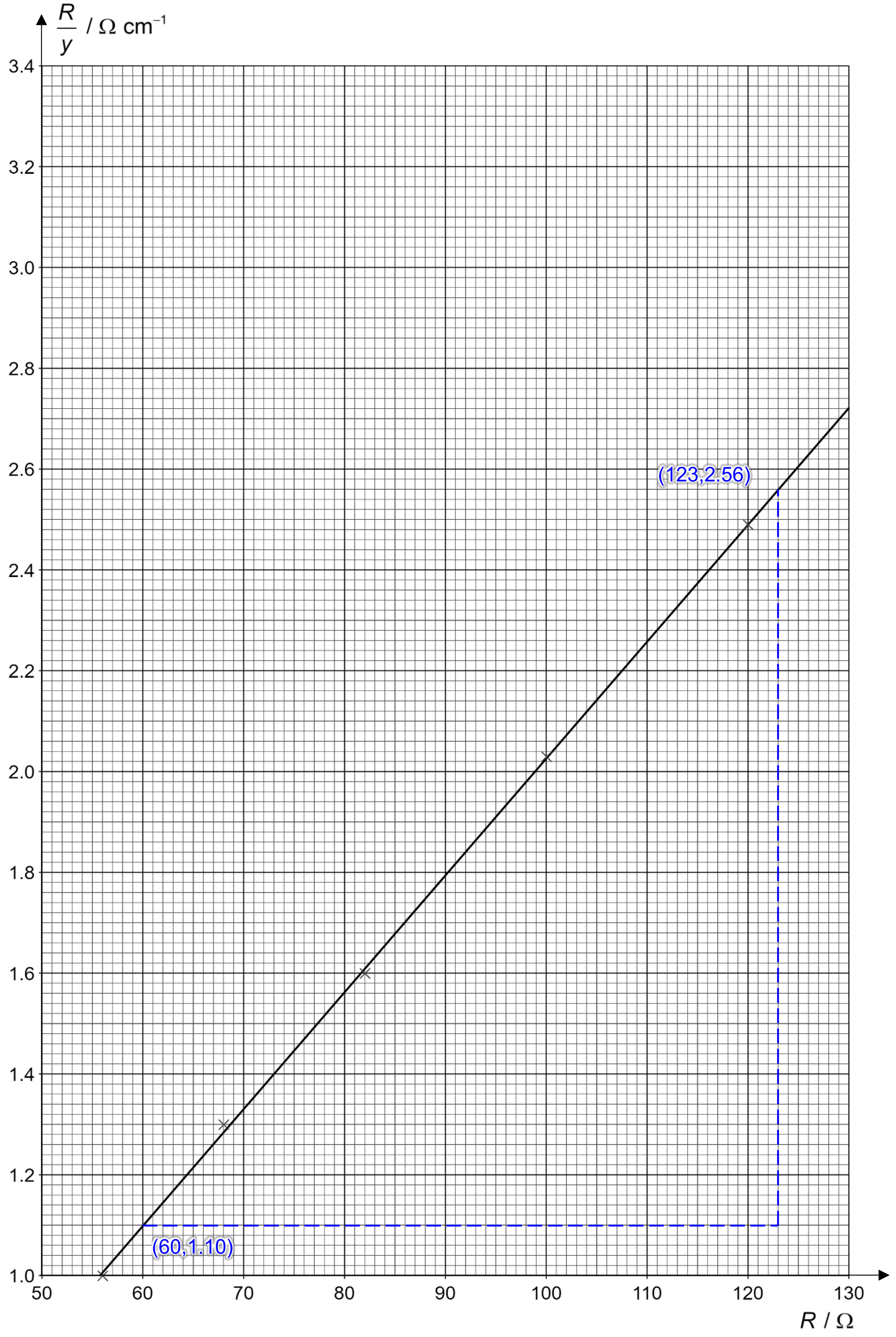
1 mark – Read off co-ordinates accurately, large size of hypotenuse (grad triangle) & method to find gradient

1 mark – Correct **method** to find vertical intercept – by read off or calculation

1 mark – Correctly computed value of *Q* with correct units [Marker has to calculate to verify]

1 mark – Correctly computed value of *F* with correct units [Marker has to calculate to verify]

Only 1 mark is penalized if *I* is not kept constant. Penalise in the first mark.



$\frac{R}{y}$ / Ω cm^{-1}
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
50
60
70
80
90
100
110
120
130
R / Ω
(123,2.56)
(60,1.10)

(d) Theory suggests that:

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

where d is the diameter of the wire and ρ is the resistivity of the metal.

Determine a value for ρ.

$$d = \frac{0.17 + 0.17}{2} = 0.17 \text{ mm}$$ (measured using micrometre screw gauge provided)

$Q = 0.29053\ \Omega\ \text{cm}^{-1} = 0.29053 \times 10^2\ \Omega\ \text{m}^{-1}$

$$\rho = \frac{Q\pi d^2}{4} = \frac{(0.29053 \times 10^2)(\pi)(0.17 \times 10^{-3})^2}{4}$$

$$= 6.59 \times 10^{-7}\ \Omega\ \text{m}$$

ρ = ...6.59×10^{-7}...... Ω m [2]

1 mark - **repeated readings of diameter *d*** and **sensible readings of 0.17 – 0.21 mm. (36 SWG, diameter 0.19 mm)** ***Note that while question did not explicitly instruct candidates to take measurements for d, it is expected that candidates do so since information of d is not given and a suitable apparatus for measuring d is stated in the Apparatus List on the Whiteboard under Q1!***

1 mark - **correct calculation of *ρ*.** Check that **value of *Q* has been converted to SI units**.

[Total:14]

2 In this experiment, you will investigate an oscillating system.

Two bobs A and B are supported by strings. The string supporting A has a mark at its midpoint.

Set up the apparatus as shown in Fig. 2.1.

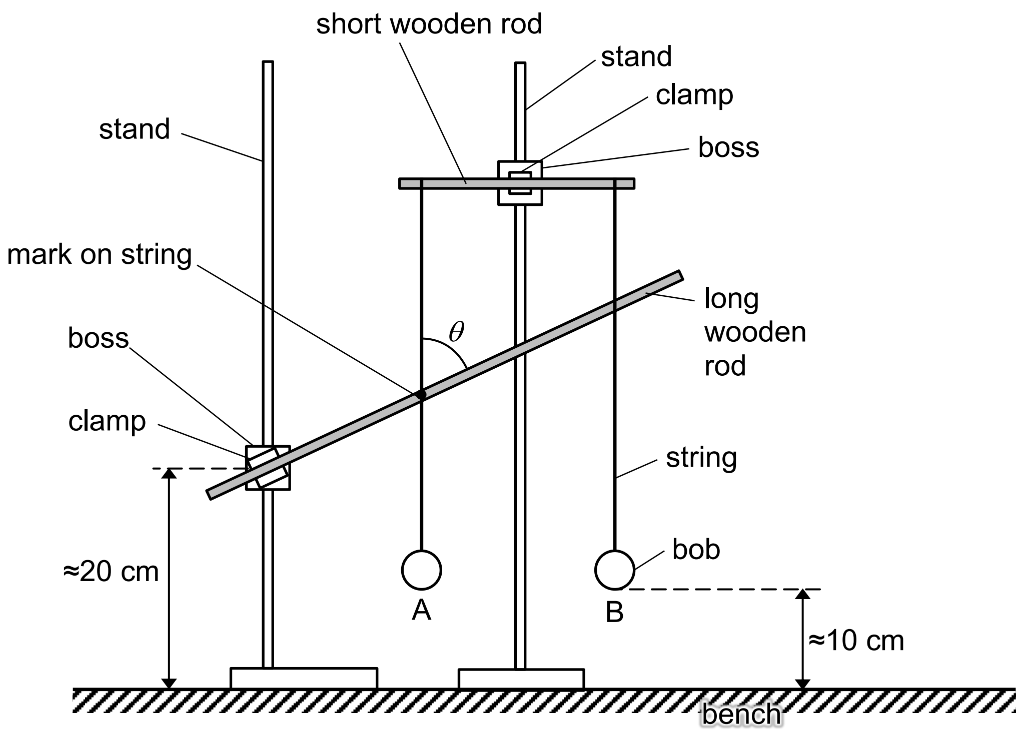


Fig. 2.1

(a) **(i)** The long wooden rod should pass between the stand and the strings.

The angle between the long wooden rod and the string supporting A is θ.

Adjust the position of the long wooden rod so that θ is approximately 60° and the rod is **behind** the mark on the string supporting A. The rod should be just touching both strings, with the strings hanging vertically.

Measure and record θ.

θ = ...60.......... ° [1]

[Marking: V, P]
1 mark – θ **between 56° and 64°** (able to **round off to 60° to the nearest 1°, which is the protractor's precision**). Record to nearest degree (protractor's precision), **no d.p.**

Examiners Comments:

Generally, well done.

Candidates will need to pay attention to the angle that needs to be adjusted. Do not adjust till it is too far off the stated number.

(ii) Pull A and B a short distance away from the long wooden rod. Keep the same separation between A and B.

Release A and B at the same time.

B first oscillates in phase with A, then out of phase, and then back in phase again. This takes n oscillations of B.

Determine n.

$$n = \frac{8+8}{2} = 8$$

n = ...8.......................... [2]

1 mark - **repeated readings** of n. (To do repeat as the uncertainty is high - hard to judge in-phase)

1 mark - value of n within **6 to 11**.

Examiners Comments:

Generally, well done.

Candidates will need to pay attention to number of marks given for this section. Repeated measurements would be required.

(b) It is suggested that:

$$n = k \tan\theta$$

where k is a constant.

Calculate k.

$$k = \frac{n}{\tan\theta} = \frac{8}{\tan 60°}$$
$$= 4.6188 = 4.62$$

k = ...4.62.......................... [2]

1 mark - correct substitution of values.

1 mark - correct calculation (degree not radians mode) and correct number of s.f. to 2 or 3. **[Recap for trigo functions, sine/cosine/tan, value is expressed to 3 s.f.]**

Examiners Comments:

Generally, well done.

Candidates will need to pay attention to use their own values from part **(a).** Take note of the number of significant figures for rounding off.

(c) Determine n and k for two more values of θ.

Tabulate your results.

θ / °	n_1	n_2	n_{avg}	k
50	6	6	6	$\dfrac{6}{\tan 50°} = 5.03$
60	8	8	8	4.62
70	12	12	12	$\dfrac{12}{\tan 70°} = 4.37$

[2]

1 mark - Two more data sets obtained with two more values of k obtained, with **one value of θ <u>lesser than 60°</u> and another value <u>greater than 60°</u>**. Correct calculations of k values. [ignore s.f. of k; ECF.]

1 mark - **Correct trend** (increasing k as θ increases). **Repeated readings for n** (to doublecheck due to high uncertainty in judging pendulum back in-phase).

Examiners Comments:

Generally, well done.

Candidates will need to pay attention to the quantities that need to be calculated. Note that the instruction is to tabulate the results, proper headings and rounding off is to be adhered.

(d) Explain why you would **not** select a value of θ = 90° in **(c)**.

At 90°, the difference in period is very small (and approaches 0) and **the time taken for the bob to go out-of-phase and back in-phase again will be very large** (and approaches an infinite value). So, it is not feasible in terms of time required for measurement.

Accept: Always in-phase, never go out-of-phase [1]

Examiners Comments:

Mixed responses

Candidates will need to pay attention to physics in explaining why we do not choose that specific value for the angle. Reflect back on the experiment performed and understand how the angle specified can affect the oscillations.

[Total: 8]

3 A cantilever beam is a beam that is supported at one end only.

In this experiment, you will investigate how the following properties affect the behaviour of a cantilever beam:

- the length of the beam
- the load on the beam
- the cross-section of the beam
- the stiffness of material from which the beam is made.

(a) Set up the metre rule on a flat surface such as a benchtop or a stool, as shown in Fig. 3.1.

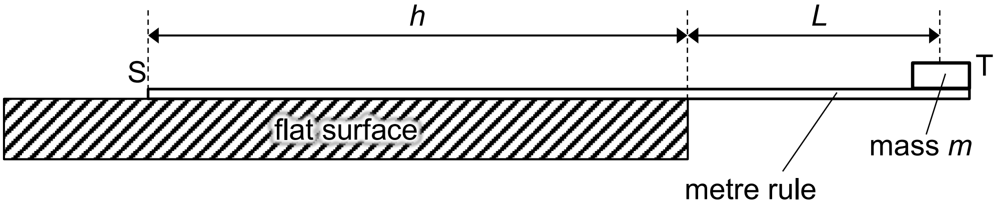


Fig. 3.1

The ends of the rule are S and T.

Use Blu-Tack to firmly attach a mass m, where m = 100 g, at T.

The distance between S and the edge of the surface is h.

The distance between the centre of mass m and the edge of the surface is L.

(i) Adjust the position of the rule so that S **just** lifts off the surface.

Measure and record h and L.

h = ...71.8 cm..........

L = ...26.2 cm..........

[1]

1 mark - **Sensible reading of *h* between 67 – 77 cm. (*h* + *L*) must be less than 100 cm.**
Correct precision (d.p.): **1 d.p. in cm, or, 3 d.p. in m.**

Examiners Comments:

- Many candidates obtained full credit for this question.
- Some candidates read the measurements wrongly and recorded the value of h as L instead.
- A few candidates recorded the sum of the values of h and L longer than 1 m.
- A few candidates converted the units of the values of h and L wrongly.

(ii) Calculate $\frac{h}{L}$.

$$\frac{h}{L} = \frac{71.8}{26.2} = 2.74$$

$\frac{h}{L}$ = ...2.74.......... [1]

1 mark - Correct calculation of h/L. No unit.

[Turn over

Examiners Comments:

- Many candidates obtained full credit for this question.
- Some candidates were careless in their calculation.
- A few candidates provided unnecessary units in their answers.
- Candidates are reminded to state the final answer to the correct precision.

(iii) Estimate the percentage uncertainty in your value of $\frac{h}{L}$.

$$\frac{\Delta\frac{h}{L}}{\frac{h}{L}}\times 100\% = \left(\frac{\Delta h}{h}+\frac{\Delta L}{L}\right)\times 100\%$$

$$= \left(\frac{0.2}{71.8}+\frac{0.3}{26.2}\right)\times 100\%$$

$$= 1\%$$

Percentage uncertainty in $\frac{h}{L}$ = ...1 %.......................... [2]

1 mark - **Δh and ΔL in the range of 0.2 – 0.5 cm**, and show **$\Delta L > \Delta h$**.
[**Δh and ΔL should be greater than the ruler's precision, so greater than 0.1 cm, since there is uncertainty in judging when S just lifts off the table. Also, since there is the slotted mass on one end of *L* and it is hard to judged where the centre of the slotte mass is, there is additional uncertainty for *L*, so $\Delta L > \Delta h$.**]
1 mark - Correct calculation and **answer to 1 s.f. or 2 s.f.**

Examiners Comments:

- A significant number of candidates found this question challenging.
- Many candidates were unable to state reasonable values of ΔL and Δh.
- Many candidates were unable to show the correct comparison between $\Delta L > \Delta h$.
- A few candidates did not state their final answers to the correct precision.

(b) Vary *m* and repeat **(a)(i)** and **(a)(ii)**.

m / g	*h* / cm	*L* / cm	*h* / *L*
100	71.8	26.2	2.74
200	80.0	18.0	4.44
300	84.5	13.5	6.23
400	87.1	10.9	7.99
500	89.0	9.0	9.9
whole number	1 d.p.	1 d.p	follow least s.f. of *h* & *L*

[Marking: U, V, P]
1 mark – All 5 sets of raw data and correct trend (increasing *m*, increasing *h* / *L*); column headers with units and no split table.
1 mark – *m* recorded to whole number (no d.p.) and correct s.f. of *h* / *L* (least sf).

[2]

Examiners Comments:

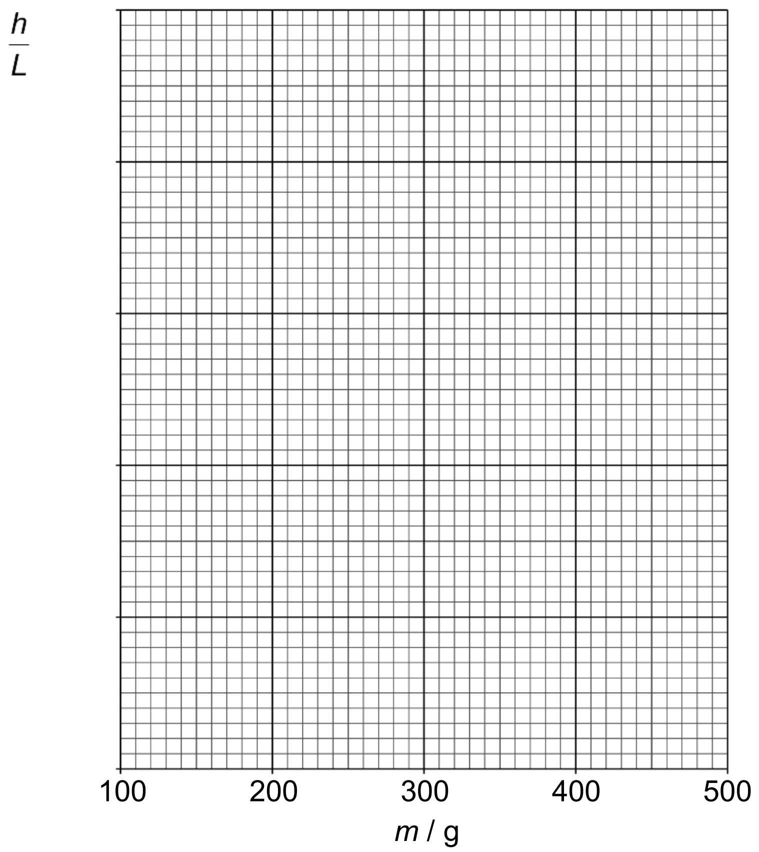
- Many candidates obtained full credit for this question.
- Some candidates did not record five sets of values in their tables.
- There were wrong trends of data evident in some candidates' answers.
- A few candidates presented their answers in two separate different tables.

(c) It is suggested that h, L and m are related by the expression:

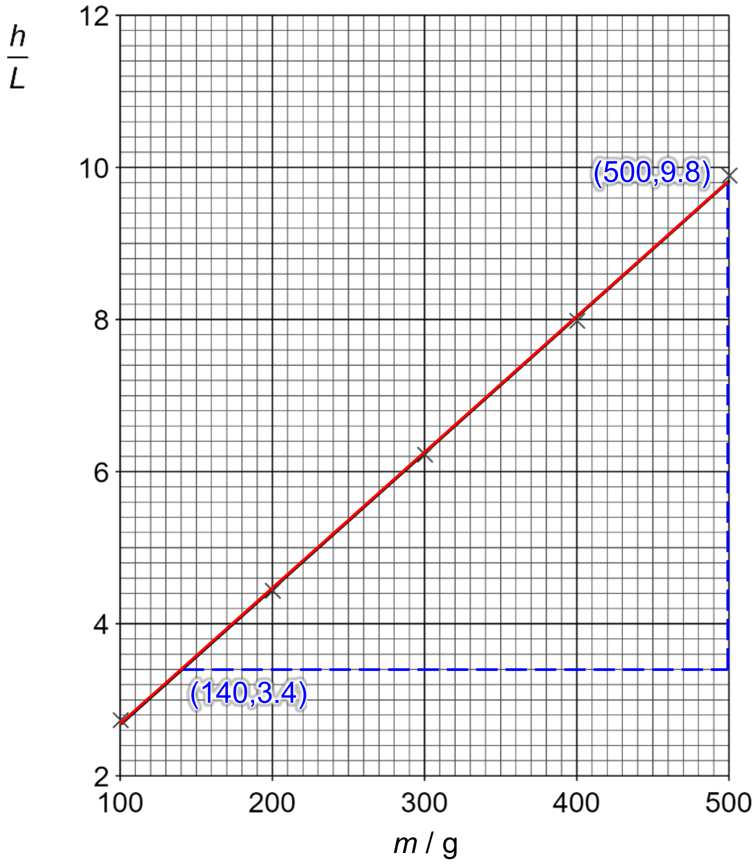
$$\frac{h}{L} = \frac{2m}{X} + 1$$

where X is the mass of the metre rule.

(i) Plot your results on the grid and draw the line of best fit.



[1]



1 mark - All data points plotted; check 3 points plotted correctly (1st, middle, last). Line of best fit. Good vertical scale chosen (at least half the graph vertically).

Examiners Comments:

- A significant number of candidates obtained full credit for this question.
- Some candidates chose inappropriate odd scale when plotting their graphs.
- A few candidates did not plot all their recorded values.
- Candidates are reminded to use small ticks when plotting the points on the graph.

(ii) Use your graph to determine a value for *X*.

$$\frac{2}{X} = \text{gradient} = \frac{9.8 - 3.4}{500 - 140} = 0.017778$$

$$X = \frac{2}{0.017778} = 113 \text{ g}$$

X = ...113............................ g [1]

1 mark - Correct read-off for gradient triangle coordinates. Correct calculation of *X*.

Examiners Comments:

- A significant number of candidates obtained full credit for this question.
- Some candidates were unable to equate the gradient of the graph to the given equation.
- Some candidates calculated the gradient by using only one set of coordinates.
- A few candidates read the coordinates wrongly.

(d) Use a balance to determine the mass X of your metre rule.

X = ...116.10.................. g

Show whether your value in **(a)(iii)** explains the difference between your two values of X.

$$\text{percentage difference} = \frac{X_{actual} - X}{X_{actual}} \times 100\% = \frac{116.10 - 113}{116.10} \times 100\% = 2.67\%$$

Since the **percentage difference between the 2 values of *X*** is 2.67% **more than** the **percentage uncertainty calculated in (a)(iii)** of 1%, the value in (a)(iii) **does not** explain for the difference in the X values.

[1]

1 mark - Correct calculation of percentage difference in X values. Correct conclusion based on Comparison between values. (Students not required to re-state value from **(a)(iii)**)

Examiners Comments:

- Many candidates were able to obtain full credit for this question.
- Some candidates did not show any clear workings to illustrate their answers.
- Some candidates did not convert the units for the mass of the metre rule correctly.
- A few candidates did not make reference to the percentage uncertainty obtained in **(a)(iii)** in their answers.

(e) You will now use a metal hacksaw blade as a cantilever beam.

When one end of the blade is fixed and the other end is loaded, the loaded end will move downwards, as shown in Fig. 3.2.

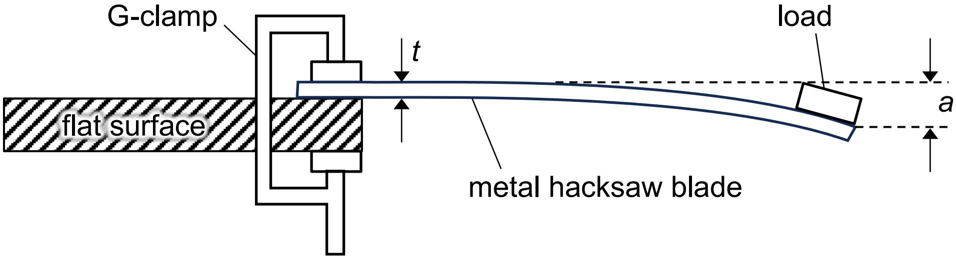


Fig. 3.2

The distance moved down is a, given by:

$$a = \frac{4MgL^3}{Yut^3}$$

where:

- M is the mass of the load
- L is the distance between the centre of the load and the edge of the surface
- u is the width of the blade
- t is the thickness of the blade
- Y is the stiffness of the metal
- g = 9.81 N kg^{-1}.

(i) Wearing safety goggles, set up the apparatus as shown in Fig. 3.2.

Use Blu-Tack to firmly attach a 100 g mass to the metal hacksaw blade.

Take measurements to determine a value for *Y*.

$M = 99.92$ g (either 2 d.p. if measured using the mass balance provided, or, to nearest gram if recorded the calibrated value on the standard mass)

$t = \dfrac{0.75 + 0.74}{2} = 0.75$ mm (*t* measured with Micrometre Screw Gauge; repeat readings)

$u = \dfrac{1.2 + 1.2}{2} = 1.2$ cm (*u, L* and *a* measured with metre rule; repeat readings)

$L = \dfrac{25.5 + 25.4}{2} = 25.5$ cm

$a = \dfrac{13.6 + 13.2}{2} = 13.4$ cm

$$Y = \frac{4MgL^3}{aut^3} = \frac{4\left(99.92\times10^{-3}\right)\left(9.81\right)}{\left(13.4\times10^{-2}\right)\left(1.2\times10^{-2}\right)}\left(\frac{25.5\times10^{-2}}{0.75\times10^{-3}}\right)^3$$

$$= 9.58\times10^{10} \text{ Pa} \quad = 95.8 \text{ GPa}$$

Y = ...95.8.......... GPa [4]

(No mark - Value of M given in the question.)
1 mark - Values of *u*, *L*, *a* recorded to correct d.p. (1 d.p. in cm or 3 d.p. in m); correct units; sensible readings.
1 mark - Value of *t* recorded to correct d.p.(2 d.p. in mm); correct units; sensible reading. **Value of *u* > *t*.**
1 mark - **Repeated readings for u, t & a**.
1 mark - Correct calculation of *Y* and **final answer in GPa.**

Examiners Comments:

- Many students did not repeat measurements for quantities *L, a, u, t*.
- Many students gave weird readings for *t*, implying that they do not know how to read a micrometer screw gauge or they did not use micrometer screw gauge for measuring *t*. (note that all instruments listed as apparatus will be used at least once.)
- Some students made careless mistakes such as omitting the powers for *L* and *t*.
- Many students did not notice the prefix for the final units GPa. The prefix “G” is giga and have a value of 10^9.
- Many students did not convert the values of the quantities to SI units before substituting into the equation, so the final computed value is incorrect.

(ii) Suggest **one** significant source of uncertainty in this experiment.

It is difficult to measure the distance moved down *a* as due to judgement error in measuring the vertical distance between 2 points that are horizontally far apart.

....

.... [1]

1 mark - Identify measuring *a* accurately is the significant source of error. Correct elaboration. Do not accept error from experiment in part (a),(b). Refers to error from (e).

Accept correct use of parallax error (but no marks if student merely explains what parallax error is without explaining how it is an error in context).

Examiners Comments:

- Many students state that thickness of blade is not uniform. It's not a good answer considering that there are errors more significant.

(iii) The value of *Y* for wood is 12 GPa.

Explain why it is **not** possible to perform this experiment using a wooden beam with the same dimensions as the metal hacksaw blade.

For *Y* = 12 GPa, the value of *a* is about 100 cm. This **value of *a* exceeds the length of the blade** and hence is **not practically feasible using the same blade dimensions.**

.... [1]

1 mark - Correct elaboration on impracticality of using wooden beam. Do NOT accept "wooden beam will break" as it does not directly link to stiffness.

Since $a = \dfrac{4MgL^3}{Yut^3}$, and MgL^3/ut^3 is the same for the same dimensions, a is inversely proportional to Y. So by taking ratio of Y values for wood and the metal hacksaw blade, a can be shown to be about 100 cm for wood.

Examiners Comments:

- Most students wrongly mentioned that the wooden beam will break. Note that the information given is only stiffness and not the strength of wooden beam.

(f) A diving board at a swimming pool has length *L*. A person of mass *M* jumps up and down on the end of the diving board.

The frequency of oscillation of the end of the diving board is *f*, given by:

$$f^2 = \frac{Z}{ML^3}$$

where *Z* is a constant.

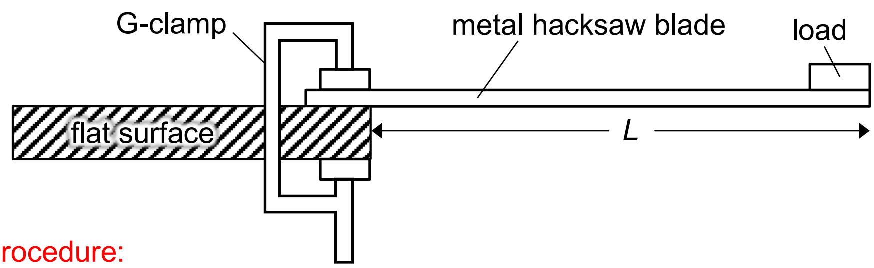
The metal hacksaw blade can be used as a model diving board.

Plan an investigation to find *Z* for the blade.

Your answer should include a diagram, your experimental procedure and a precaution to improve the safety of the experiment.

Wearing safety goggles, use your apparatus to determine **two** values of *Z* for different values of *M* and *L*. Tabulate your results.

Diagram:



Procedure:

1. Use slotted masses for the load in the setup shown above. **Record the total mass *M* of the slotted masses**. (OR, measure the slotted mass with blu-tack using mass balance)
2. Adjust the length *L* of the blade that is extended beyond the edge of the table. **Measure *L* using a metre rule**.
3. Vertically displace the load end of blade by about 2 cm and release it to allow the load to oscillate. Using a **stopwatch**, **record the timing *t*** taken for the load to undergo ***N* oscillations**. *N* should be sufficiently large for *t* to be greater than 20 s. Repeat this step to obtain an average reading of timing *t*.

[7]

[Total: 22]

4. **Repeat** steps (1) to (3) to obtain **6 sets** of data **by varying both *M* and *L*.**
5. **Calculate** $f^2 = \frac{N^2}{t^2}$ **and** $\frac{1}{ML^3}$.
6. **Plot graph of f^2 against** $\frac{1}{ML^3}$. **Gradient of straight line graph will give value of Z.**

Safety: (any one)

- stand a distance away from the setup while it is oscillating
- place a safety screen between experimenter and setup
- use small amplitudes of oscillation to reduce risk of mass detaching from blade
- do a preliminary experiment to ensure the blade does not break

Results (tabulated):

***M* / g**	***L* / cm**	***N***	**t_1 / s**	**t_2 / s**	***T* / s**	***f* / Hz**	**Z / kg m^3 s^{-2}**
100	24.5	36	21.9	22.0	0.610	1.64	3.95×10^{-3}
200	17.8	40	21.8	21.8	0.545	1.83	3.77×10^{-3}
2 d.p.	1 d.p.	whole number	1 d.p	1 d.p	follow least s.f. of *t*	follow least s.f. of *t*	follow least s.f. of *t, L, M*

Short Planning (5 marks):

1st mark – Diagram correctly drawn with load and length *L* labelled.
2nd mark – Method of measuring mass *M* and length *L* (including the instrument used). Method of oscillation and measurement of timing *t* (including stopwatch).
3rd mark – Method to vary *M* and *L*. (**Both *M* and *L* must be different – from 2023 Alevel Examiners' Report.**)
4th mark – Plot a suitable graph and find *Z* from gradient.

5th mark – Safety (1 significant safety consideration): stand a distance away from the setup while it is oscillating / place a safety screen between experimenter and setup / use small amplitudes of oscillation to reduce risk of mass detaching from blade / do a preliminary experiment to ensure the blade doesn't break. (**Do not accept safety goggles since this was stated in the question already.**)

Two measurements tabulated (2 marks):

6th mark – **2 sets** of data ***M, L, N, t*** must be recorded **in a table** as instructed.
Raw timings *t* must be more than 20 s.
Column headings with correct units. Period *T* must be shown.
Both *M* and *L* values to be varied across 2 sets of data. (From 2023 Alevel Examiners' Report.)
7th mark – Correct computation of *Z* values for both sets and correct units for Z.

Examiners Comments:

- Most students did not state the instruments to measure length *L* and time *t*.
- Some students wrongly understand the question and describe an experiment of man jumping on diving board.
- Note the command word "tabulate", a table to organize your data is expected.
- Many students did not record total time *t* in the table. Note that raw data (reading that is directly from stopwatch) must be recorded.
- Many students did not notice the requirement of the question for BOTH *M* and *L* to be different in the 2 sets of data.

4 Two of the sources of naturally-occurring background radiation are from buildings and from soil.

The amount of background radiation detected depends on the distance b from a building and the distance s from the soil.

The background count rate C is given by the equation:

$$C = Kb^p s^q$$

where K, p and q are constants.

Design an experiment to determine the values of p and q.

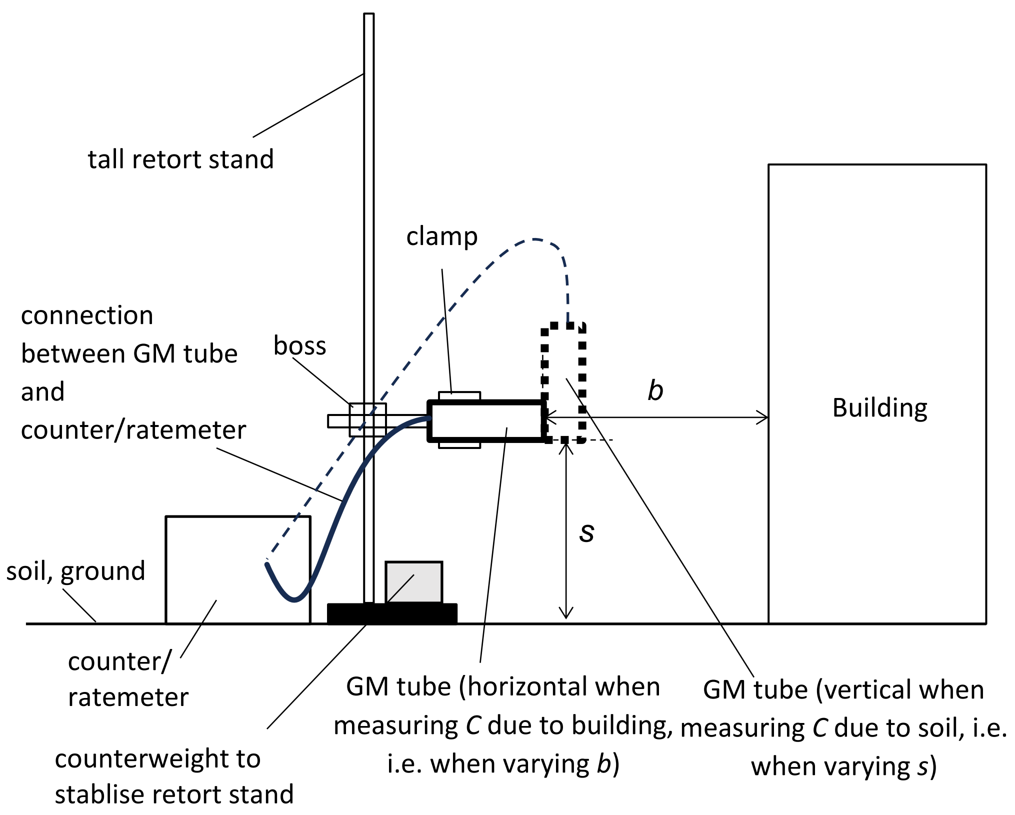
Assume that the investigation takes place outdoors close to a building and that you have a Geiger-Müller (GM) tube which counts individual particles.

Draw a diagram to show the arrangement of your apparatus. You should pay particular attention to:

(a) the equipment you would use
(b) the procedure to be followed
(c) the control of variables
(d) any precautions that should be taken to improve the accuracy of the experiment.

No 'safety' mentioned in this question in 2023 (likely because tested already in Q3 Short Planning). Focus on Accuracy details.

Diagram



[D] – Well labelled diagram (especially relevant to IV & DV/ context of experiment) & including **distances *b* and *s*.** **GM tube and counter with connection between them**

Orientations of GM tube shown in diagram (*or* described clearly under Procedure) for measuring C due to building & soil respectively.

<u>Part 1: To determine p, vary b and keep s constant</u>

Independent variable (IV): b

Dependent variable (DV): C

Controlled Variables (CV): *s* and orientation of GM tube	
Procedure: 1. Set up the experiment as shown in the diagram above, with the GM tube oriented horizontal and facing the building squarely (CV). **2.** Adjust the distance *s* of the GM tube above soil level to about 50 cm. Ensure that this distance is constant throughout the experiment for part 1 **by clamping the GM tube at this fixed distance *s* (CV).** **3.** Adjust the distance *b* from the building wall to about 50 cm. **4. Measure and record *b* using a measuring tape, from the opening of the GM tube to the building.** **5. To measure *C*:** [Using a Counter] Start the stopwatch while recording down the initial count N_i on the counter connected to GM tube. After 60.0 s has passed on the stopwatch time, record down the count N_f on the counter. Calculate the count rate $C = (N_f - N_i)/60$. OR [Using a Ratemeter] Record the count rate C from the ratemeter. 6. Increase *b* by 50 cm by **moving the retort stand away from the building to vary *b***. Repeat steps 4-6 until **at least 6 sets** of data are obtained. **7. Plot a straight line graph of lg *C* against lg *b*.** 8. Calculate the **gradient** of the graph, which gives the **value of *p***.	[CV1] – Method to keep control variable (*s*) constant for part 1; other CV marked under AD. [IV1] Method of measuring *b* [DV] Method of measuring *C* [VIV1] Varying IV – procedure & suitable number of data sets [A1] Analysis – Suitable graph to plot and feature of graph to use to find *p*
<u>Part 2: To determine *q*, vary *s* and keep *b* constant</u> **IV**: *s* **DV**: *C* **CV**: *b* and orientation of GM tube	
Procedure: 9. Set up the experiment as shown in the diagram above, with the GM tube oriented vertical and facing the soil squarely (CV). **10. Fix distance *b* using a counterweight to stabilise the retort stand and prevent it from shifting easily (CV).** 11. Adjust the distance *s* of the GM tube above soil level to about 10 cm. **12. Measure and record *s* using a metre rule, from the opening of the GM tube to the soil.** 13. Repeat step 5 to measure *C*. 14. Increase *s* by 10 cm by **shifting the GM tube further up the retort stand to vary *s***. Repeat steps 12-14 until **at least 6 sets** of data are obtained. **15. Plot a straight line graph of lg *C* against lg *s*.** 16. Calculate the **gradient** of the graph, which gives the **value of *q***.	[CV2] Method to keep control variable (*b*) constant for part 2; other CV marked under AD. [IV,VIV2] Method of measuring *s* and procedure for varying *s* [A2] Analysis – Suitable graph to plot and feature of graph to use to find *q*

Additional Details:

1. **For accurate determination of how *b* and *s* affect *C*: Face the GM tube squarely towards the building when measuring effect of *C* due to *b* so that most radiation measured is from the building. Face the GM tube squarely towards the soil when measuring the effect of *C* due to *s* so that most radiation measured is from the soil. Keep the orientation of the GM tube fixed throughout part 1 and part 2 respectively (CV).**
2. Perform a preliminary experiment to ensure that the count rate *C* is varying sufficiently when distance *s* and *b* is varied to decide the suitable range of the distances to be used.
3. Using the GM tube, check for objects in the vicinity that are causing a significant high count rate. Remove the objects from the experimental area.
4. Collect data from a sufficiently large amount of soil and big enough building so that count rates are not too low to reduce percentage uncertainty due to random error.
5. Repeat part 1 and part 2 of the experiment by directing GM tube to different points of the building and soil respectively. Calculate average value of *C* to reduce the effects of random error.

[AD1] – Orientation of GM tube in order to measure effect of *b* and *s* on *C* accurately. Also a CV.

[AD2] Any other accuracy detail with reason given.

Marks	
D	Well-labelled diagram that is sensible. Distances *b* and *s* labelled. GM tube connected to a counter/ratemeter.
DV	Method of measuring *C*
CV1	Method to keep control variable *s* constant for part 1; other CV marked under AD.
IV1	Method of measuring *b*
VIV1	Varying IV – procedure & suitable number of data sets
A1	Analysis – Suitable graph to plot and feature of graph to use to find *p*
CV2	Method to keep control variable *b* constant for part 2; other CV marked under AD.
IV,VIV2	Method of measuring *s* & procedure for varying *s*
A2	Analysis – Suitable graph to plot and feature of graph to use to find *q*
AD1	Orientation of GM tube in order to measure effect of *b* and *s* on *C* accurately.
AD2	Any reliability detail to enhance accuracy.

Safety: (not assessed for this year – see phrasing in question part 4(d). Safety assessed in 3(f).)

Examiners Comments:

Common mistakes include:

- Some students drew a pile of soil on one side of the GM tube and the building on the opposite side, without mentioning what constitutes the 'ground' on which the setup is placed.
- Amongst students who drew a pile of soil on one side of the GM tube, they used a shovel to dig up the pile of soil. These students did not consider that usually we try not to cause 'damage' to the environment to conduct such an experiment. Other students used only a small sample of soil for their data collection which

would mean a very low count rate obtained and so higher percentage uncertainty due to statistical random error. • Some students did not read the question carefully that the experiment is assumed to be conducted outdoors and proposed an indoor setting. • Diagrams do not always show the GM tube connected to a ratemeter/counter/datalogger. These usually showed only a GM tube on its own. • Incomplete method to determine *C* which is the count <u>rate</u>, **not** total number of counts. / Lack clarity as to whether data obtained is the total counts or the count rate. Note that *C* is defined as the count rate. • Generic statements like "keep *s* (or *b*) constant at X metres" / "vary *s* (or *b*) using a measuring tape" without specific description of a method and/or instrument to achieve these reliably. Also, students should note that the mere act of measuring *b* or *s* does **not** vary *b* or *s*, or keep *b* or *s* constant. A specific method/procedure must be included as well. • Orientation of the GM tube for accurate measurements of *C* not shown in diagram or described thoroughly in words in the procedure. GM tube should face the building and soil squarely when measuring *C* due to *b* and s respectively. • Some students placed the GM tube on a table with the tube facing the building and with the soil ground below, but then did not explain how the GM tube should be adjusted when measuring *C* due to the soil without the table blocking. • Some students thought *s* is underground. • Providing excessive details not required by this planning question e.g. finding *K* or providing a safety consideration. • Wrong linearisation and/or wrong graph plotted was seen in some scripts e.g. "Plot ln *C* against *p*(ln *b*)" which is not feasible since *p* is unknown.	

[11]