



Oxford Cambridge and RSA

Wednesday 20 October 2021 – Morning

A Level Physics B (Advancing Physics)

H557/03 Practical skills in physics

Time allowed: 1 hour 30 minutes

You must have:

- the Data, Formulae and Relationships Booklet

You can use:

- a scientific or graphical calculator
- a ruler (cm/mm)



Please write clearly in black ink. **Do not write in the barcodes.**

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

First name(s)

Last name

StemUp Model Solution

INSTRUCTIONS

- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION

- The total mark for this paper is **60**.
- The marks for each question are shown in brackets [].
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **20** pages.

ADVICE

- Read each question carefully before you start your answer.

2

SECTION A

Answer **all** the questions.

1 This question is about measuring the acceleration of free fall.

- (a) Some students use a g-ball to record the time taken to fall from different heights. A g-ball is a ball with a timer inserted. The timer starts automatically when the ball is released from rest and stops when it hits the floor.



The results are recorded in **Table 1.1**.

Height /m ± 0.02	Time to fall, t/s				t^2/s^2
	First attempt	Second attempt	Third attempt	Average time	
2.00	0.64	0.66	0.67	0.66	0.43
3.00	0.78	0.79	0.78	0.78	0.61
4.00	0.90	0.91	0.88	0.90	0.80
5.00	1.01	1.00	1.03	1.01	1.02
6.00	1.11	1.08	1.13	1.11	1.23
7.00	1.20	1.18	1.23	1.20	1.45
8.00	1.28	1.30	1.27	1.28	1.65

Table 1.1

- (i) Complete the last two columns in **Table 1.1**. [2]
- (ii) Plot these **two** points to complete the graph of height against t^2 in **Fig. 1.1**. Add horizontal error bars to **all** the plotted points. [3]

- (iii) Draw the line of best fit on the graph and calculate the gradient.

$$\text{gradient} = \Delta h / \Delta t^2 = (8.50 - 1.50) / (1.750 - 0.305)$$

$$\text{gradient} = 7.00 / 1.445 = 4.84 \text{ m s}^{-2}$$

gradient = ... 4.84 m s⁻² [2]

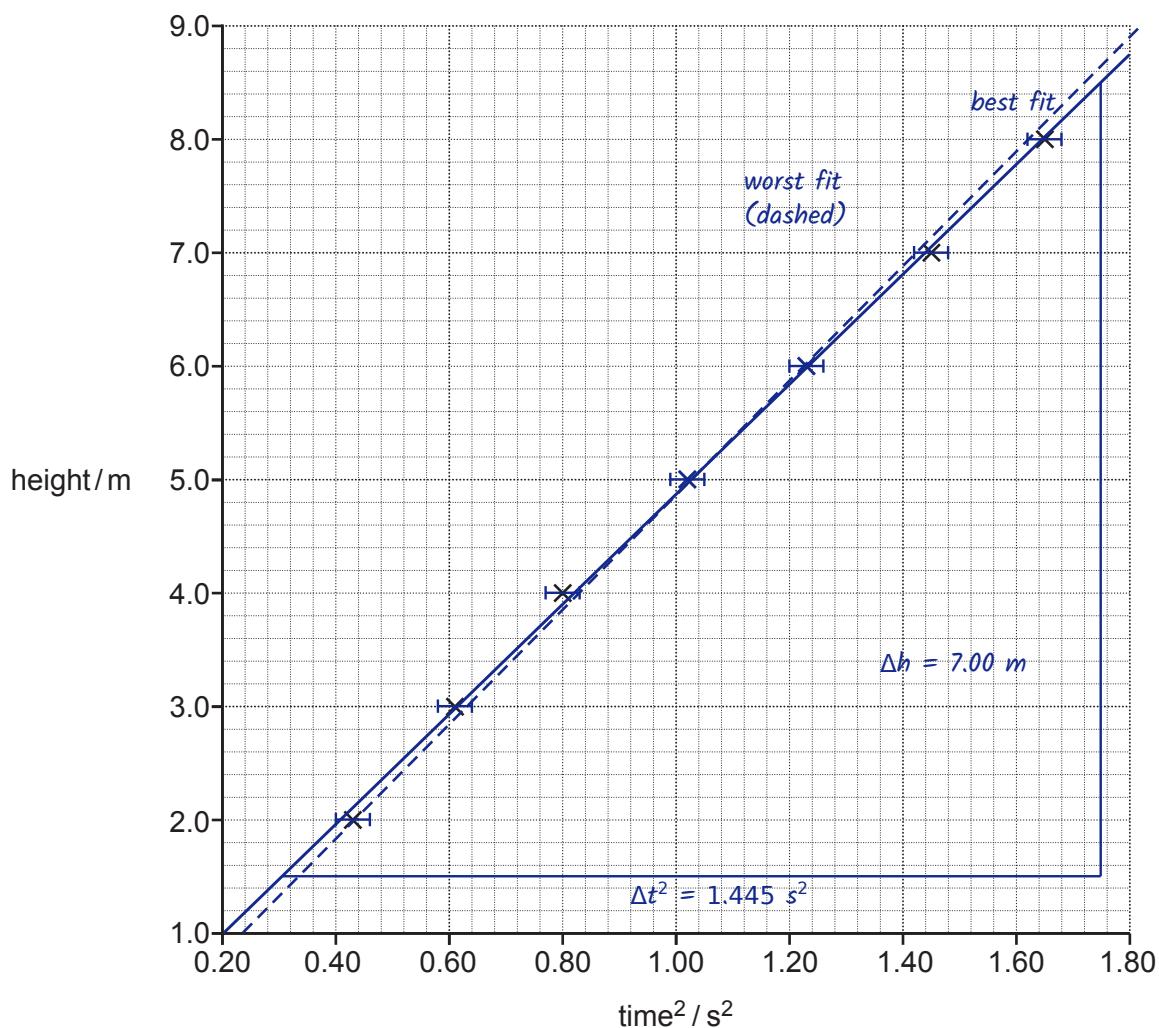


Fig. 1.1

- (iv) Use the gradient to calculate the value for the acceleration of free fall. Include the uncertainty in your answer.

$$s = ut + \frac{1}{2}gt^2 \text{ with } u = 0, \text{ so } h = \frac{1}{2}gt^2 \text{ and gradient} = \frac{1}{2}g$$

$$g = 2 \times \text{gradient} = 2 \times 4.84 = 9.68 \text{ m s}^{-2}$$

$$\text{worst fit gradient} = (8.50 - 1.50) / (1.721 - 0.335) = 5.05, \text{ so } g = 10.1$$

$$\text{uncertainty} = 10.1 - 9.68 = 0.42 \approx 0.4 \text{ m s}^{-2}$$

acceleration of free fall = ... 9.7 $\pm$ 0.4 ms^{-2} [4]

- (b) Another way to calculate the acceleration of free fall is to drop a weighted card through two light gates connected to a datalogger in a laboratory as shown in **Fig. 1.2**.

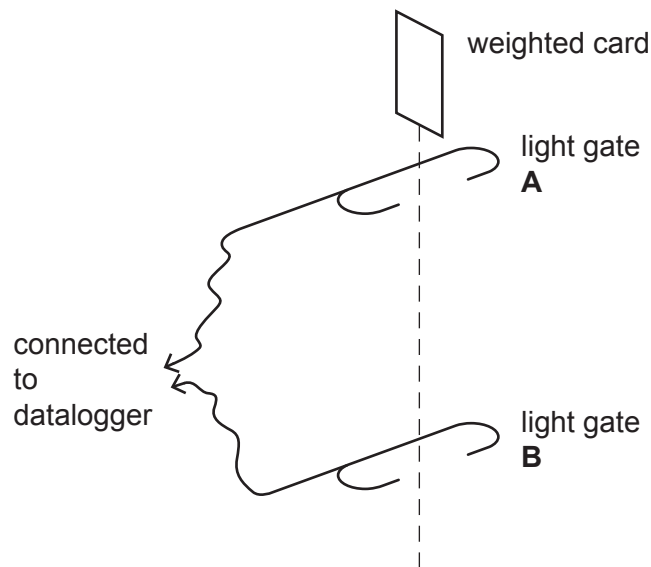


Fig. 1.2

- (i) State the minimum initial data you would need to have in order to obtain a value of g by this method.

The length of the card (only).

..... [1]

- (ii) Describe the sources of error in this method. Discuss whether you consider the g-ball or the light-gate method would give a more accurate value for g , the acceleration of free fall.

Duration of drop: the light gates are only a short distance apart, so the time measured is much shorter than the g-ball fall time, so the percentage (relative) error in the time is greater for the light gates.

Length measurement: the length of the card (a few cm) is much smaller than the drop height (2 to 8 m) measured for the g-ball, so it has a greater percentage error. Also the card may tilt as it falls, so the length of card passing through the beam is inaccurate.

Air resistance: the g-ball falls further and faster, so air resistance has a bigger effect and its acceleration is not constant; the weighted card falls a short distance at low speed. Both methods use electronic timers, so they have similar (absolute) timing uncertainties.

Overall the g-ball method should give a more accurate value of g , because its long drops and large heights give smaller percentage uncertainties, and many heights are combined on a graph.

[3]

- 2 The wavelength of light can be measured using Young's double slit experiment.

A filament lamp is used to illuminate the double slits in the centre of a square section drainpipe as shown in **Fig. 2.1**. Interference fringes are observed on a ground glass screen at the other end of the drainpipe. The distance between the slits and the screen is measured using a tape measure as 1.50 m.

The double slits are manufactured to have a separation of $8.5 \times 10^{-5} \text{ m}$ with an uncertainty of $\pm 10\%$.

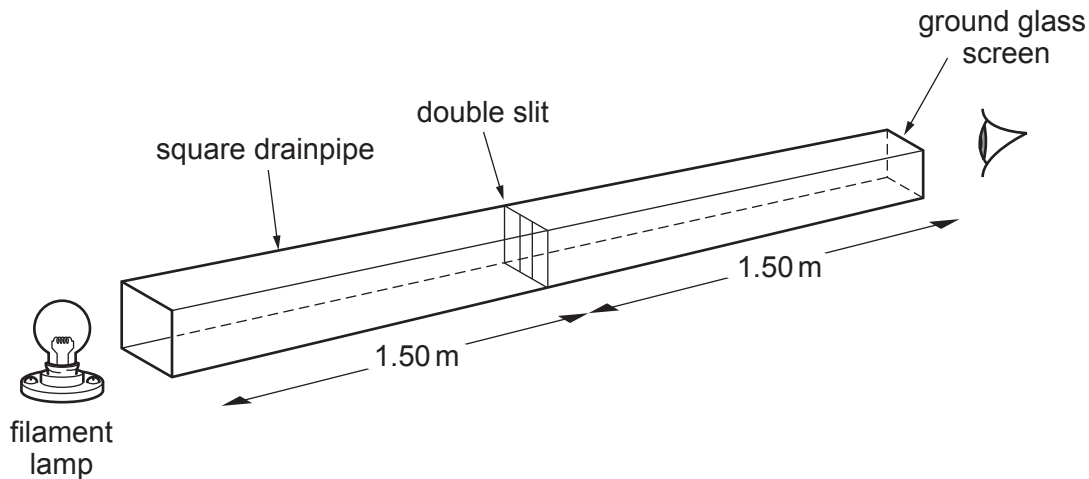


Fig. 2.1

- (a) Describe how the fringe separation could be measured in a school laboratory.

Use a ruler (or travelling microscope) on the screen to measure across as many fringes as possible, e.g. 10 fringe spacings. Divide this distance by the number of fringe spacings to find the mean fringe separation.

..... [2]

- (b) The distance between neighbouring fringes is measured as $1.02 \text{ cm} \pm 2\%$.

- (i) Calculate the wavelength of the light.

$$\lambda = ax / D$$

$$\lambda = (8.5 \times 10^{-5} \times 1.02 \times 10^{-2}) / 1.50$$

$$\lambda = 5.78 \times 10^{-7} \text{ m}$$

wavelength = ... 5.8×10^{-7} m [3]

- (ii) Estimate the uncertainty in the measurement of the distance between the slits and the screen and hence calculate the absolute uncertainty in the calculated value of wavelength.

$$\text{uncertainty in } D \text{ (tape measure)} = \pm 1 \text{ cm} = \pm 0.01 \text{ m}$$

$$\% \text{ uncertainty in } D = (0.01 / 1.50) \times 100 = 0.7 \%$$

$$\% \text{ uncertainty in } \lambda = 10 \% + 2 \% + 0.7 \% = 12.7 \%$$

$$\text{absolute uncertainty} = 0.127 \times 5.8 \times 10^{-7}$$

$$\text{absolute uncertainty} = 7.4 \times 10^{-8} \text{ m}$$

$$\text{absolute uncertainty} = \dots\dots\dots 7.4 \times 10^{-8} \dots\dots\dots \text{ m [3]}$$

- (c) The experiment is repeated using a red laser light instead of a filament bulb.

Describe and explain the effect this will have on the experimental **uncertainties**.

Red laser light has a longer wavelength than the average wavelength of the white light, so the fringes are more widely spaced and the relative (percentage) uncertainty in the fringe spacing x is less.

The laser is monochromatic (one wavelength) so the fringes are sharper and more clearly defined, and it is more intense so the fringes are brighter and easier to see.

The relative uncertainties in D and λ remain the same. [3]

3 This question is about the oscillations of hacksaw blades.

(a) **Table 3.1** shows how the period varies with the length of a hacksaw blade.

Length/cm	Period/s
28.0	0.734
26.0	0.677
24.0	0.623
22.0	0.569
20.0	0.511

Table 3.1

(i) Apply a test to the data to show that length is proportional to period. Explain the method.

Test: if $l \propto T$ then l / T should be constant.

l / T in cm s^{-1} : $28.0/0.734 = 38.1$, $26.0/0.677 = 38.4$, $24.0/0.623 = 38.5$,

$22.0/0.569 = 38.7$, $20.0/0.511 = 39.1$

l / T is (approximately) constant, within about 3 %, so length is proportional to period.

[2]

(ii) Calculate the natural frequency for a blade with a length of 24.0 cm.

$$f = 1 / T = 1 / 0.623$$

$$f = 1.61 \text{ Hz}$$

frequency = ...1.61..... Hz [1]

- (b) The same hacksaw blade is then used in an experiment to investigate resonance. The hacksaw blade is connected by a string to a vibration generator which is attached to a signal generator as shown in **Fig. 3.1**.

(i) What is resonance?

Resonance occurs when the driving (forced) frequency is equal to the natural frequency of the oscillating system.
The amplitude of the oscillations is then at a maximum (very large), as energy is transferred most efficiently. [2]

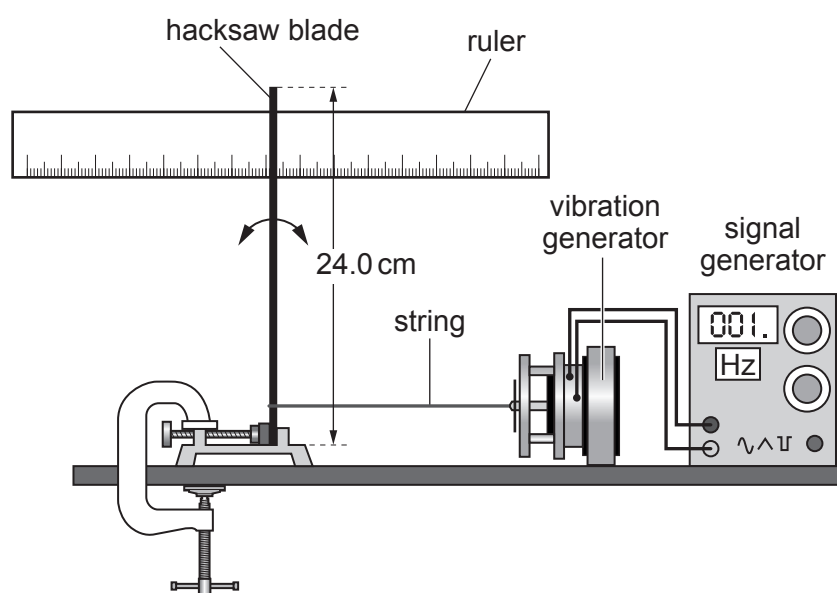


Fig. 3.1

- (ii) On the axes in **Fig. 3.2** sketch the frequency-amplitude graph you would expect to achieve. Label the significant features of your graph.

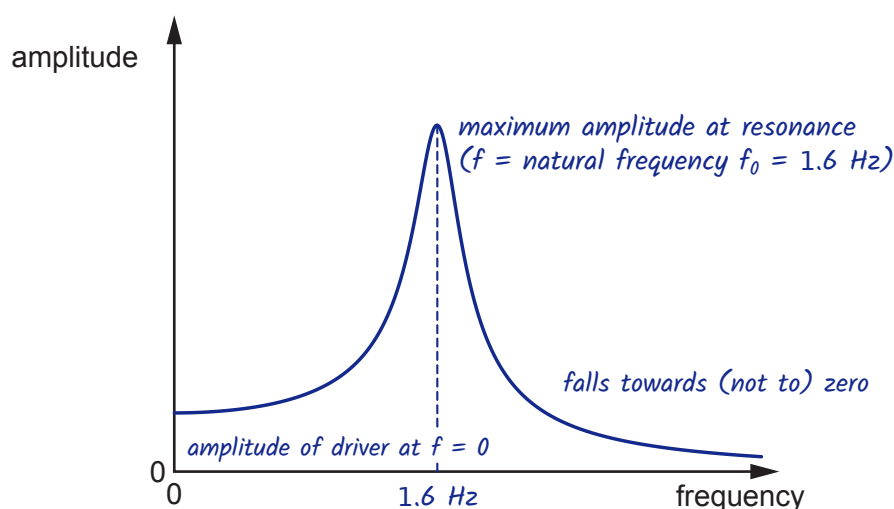


Fig. 3.2

[3]

- (iii)* To investigate how damping affects resonance, two different sized pieces of card can be stuck on the vibrating end of the hacksaw blade as shown in **Fig. 3.3**.

Describe in detail the data you would collect to perform the investigation, and describe and explain what you would expect the results to show. [6]

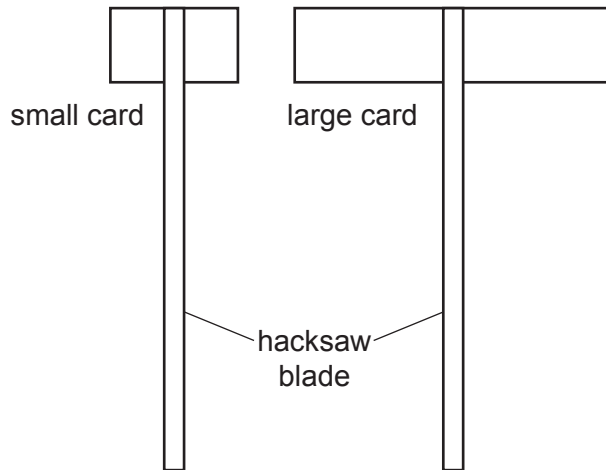


Fig. 3.3

Data: first find the natural frequency of the undamped blade (about 1.6 Hz) from its period. With the string attached, set the signal generator to frequencies either side of the natural frequency, e.g. 0.5 Hz to 3.0 Hz, using small increments (e.g. 0.05 Hz) close to the resonant frequency. At each frequency let the oscillations settle, then record the amplitude of the blade tip against the ruler; repeat three times and find a mean amplitude. Do this for the undamped blade, then with the small card and then the large card, keeping the driver amplitude constant, and plot graphs of amplitude against frequency for all three on the same axes.

Expected results: the card causes damping due to air resistance, which removes energy from the oscillating system. So the damped blade has a smaller amplitude at all frequencies, and the large card causes more damping than the small card. The amplitude at resonance depends only on the amount of damping, so the resonance peak is lower and broader (flatter) for the large card. The resonant frequency decreases slightly as damping increases. At very low frequency all three oscillate with the amplitude of the driver.

SECTION B

Answer **all** the questions.

- 4 This is a question about the properties of different types of radiation.

Fig. 4.1 shows parts of the tracks of three different types of radiation (moving from left to right) directed at various types of shielding.

(a)

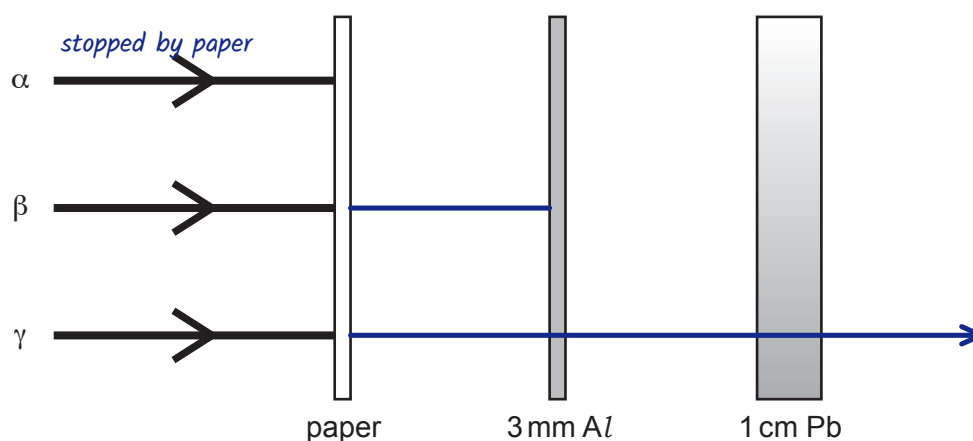


Fig. 4.1

- (i) Complete the tracks by drawing on **Fig. 4.1** continuing the lines through each material unless a material absorbs 100% of the incident radiation. [1]

Table 4.1 shows some properties of two isotopes of Xenon.

Radioisotope	Radiation emitted
xenon-133m	gamma
xenon-135	beta

Table 4.1

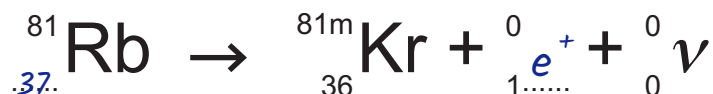
- (ii) Using the information in **Table 4.1** suggest and explain which isotope of xenon should be used as a medical imaging tracer. Consider the effect on the patient of each isotope in your answer.

Xenon-133m. Gamma is weakly ionising and very penetrating, so it passes out of the body and can be detected outside. Beta would be absorbed in the body so could not be detected, and being more ionising it causes more damage (a larger dose) to the patient. [2]

Another noble gas that is used as a medical tracer is Krypton-81m.

- (iii) The parent isotope of krypton-81m is rubidium-81.

Complete the following decay equation for the production of krypton-81m. [2]



- (iv) Krypton-81m has a half-life of only 13 seconds, whilst rubidium-81 has a half-life of 4 hours.

Suggest why hospital stocks do not lose their activity before patients can be seen.

*The krypton-81m is generated at the point of use; rubidium-81
(half-life 4 h) decays to produce krypton-81m.* [1]

- (b) A student is working on an experiment to find effective shielding for a radioactive isotope. They are using the apparatus as shown in Fig. 4.2.

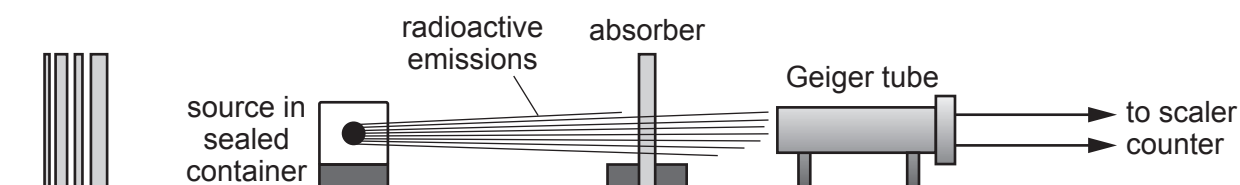


Fig. 4.2

- (i) Suggest and explain **one** safety precaution required when handling a source of ionising radiation.

*Handle the source with long tongs, never with the hands, and point it
away from the body.
This increases the distance from the source, so reduces the dose of
ionising radiation received (and avoids contamination).* [2]

- (ii) Before taking any measurements with the absorber and source in place, the student takes several readings of the count rate.

Explain why they do this.

*To measure the background radiation count rate (a mean of several
readings, as decay is random).
This background value is then subtracted from all the readings taken
with the source to give the corrected count rate.* [2]

(c) The student gathers the following data.

Shielding thickness, x/cm	Count rate/ s^{-1}	Corrected count rate $/\text{s}^{-1}$
0	1250	1240
1	915	905
2	636	626
3	475	465
4	353	343
5	240	230
6	182	172
7	130	120
8	94	84
9	70	60
10	48	38

Table 4.2

Question 4(c) continues on page 14

The student plots a graph of the data.

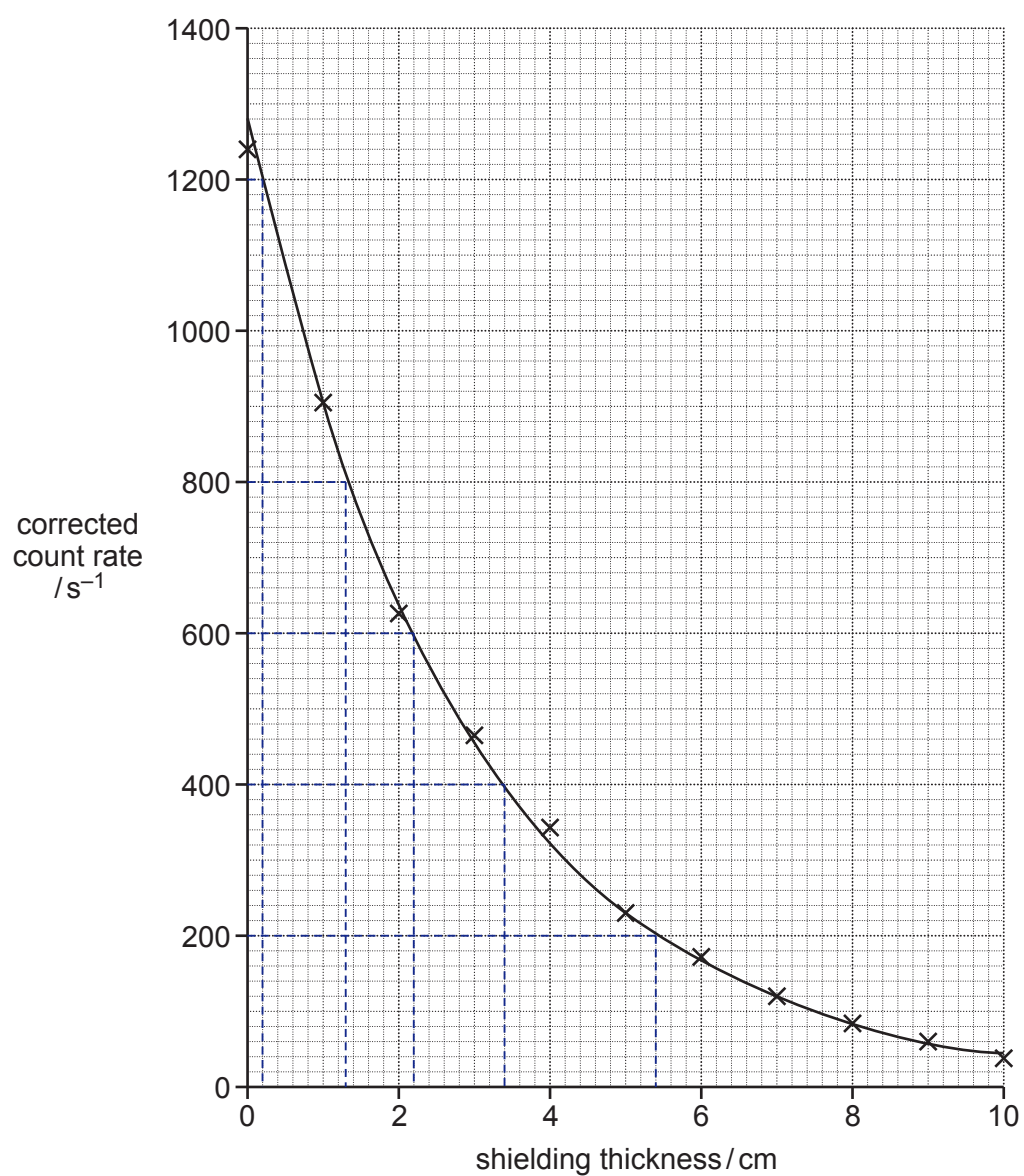


Fig. 4.3

The “half thickness value”, $x_{\frac{1}{2}}$ for a particular shielding material and type of radiation is often used in industry, and is the value of the thickness of the shielding required to reduce the incident intensity of the radiation by half.

- (i)* The student thinks that the relationship shown by the data of corrected count rate versus shielding thickness is exponential.

Using the information provided in **Fig. 4.3** opposite and **Table 4.2** on page 13, describe and perform a mathematical test to support their conclusion. Calculate the half-thickness $x_{\frac{1}{2}}$, describing also the method you use to ensure you obtain a reliable value. [6]

Test 1: for an exponential decrease, equal steps in thickness reduce the count rate by the same factor. From Table 4.2: $905/1240 = 0.730$, $626/905 = 0.692$, $465/626 = 0.743$, $343/465 = 0.738$, $230/343 = 0.671$, $172/230 = 0.748$. The ratios are approximately constant (mean ratio 0.72), so the decrease is exponential.

Test 2: $\ln$ of the count rates are 7.12, 6.81, 6.44, 6.14, 5.84, 5.44, 5.15; the differences between successive values (0.31, 0.37, 0.30, 0.30, 0.40, 0.29) are roughly constant, mean 0.33 per cm, which also shows exponential decay.

Half-thickness from Fig. 4.3: the count rate halves over the same thickness each time. 1200 s^{-1} at 0.2 cm and 600 s^{-1} at 2.2 cm gives 2.0 cm; 1000 at 0.7 cm and 500 at 2.7 cm gives 2.0 cm; 800 at 1.3 cm and 400 at 3.4 cm gives 2.1 cm; 600 at 2.2 cm and 300 at 4.2 cm gives 2.0 cm; 400 at 3.4 cm and 200 at 5.4 cm gives 2.0 cm.

For a reliable value I took several readings starting from different count rates and found the mean: $x_{\frac{1}{2}} = (2.0 + 2.0 + 2.1 + 2.0 + 2.0) / 5 = 2.0 \text{ cm}$.

Additional answer space if required.

This agrees with $x_{\frac{1}{2}} = \ln 2 / 0.33 = 2.1 \text{ cm}$, so the half-thickness is about 2 cm.

The relationship for the variation of intensity of radiation with shielding thickness is given by the equation:

$$I = I_0 e^{-\mu x}$$

where I_0 is the incident radiation intensity, I is the intensity after shielding thickness, x , and μ is the linear attenuation coefficient.

After further analysis the student plots the graph shown in **Fig. 4.4** on page 17.

- (ii) Using the equation $I = I_0 e^{-\mu x}$, and the information in **Fig. 4.4**, determine the value of the attenuation coefficient, μ .

$$I = I_0 e^{-\mu x} \quad \text{so} \quad \ln I = \ln I_0 - \mu x$$

so the graph of $\ln I$ against x is a straight line of gradient $-\mu$

from the line: (1.0 cm, 6.78) and (9.0 cm, 3.99)

$$\text{gradient} = (3.99 - 6.78) / (9.0 - 1.0) = -0.349 \text{ cm}^{-1}$$

$$\mu = 0.349 \text{ cm}^{-1} = 34.9 \text{ m}^{-1}$$

attenuation coefficient = ...35..... unit .. m^{-1} [4]

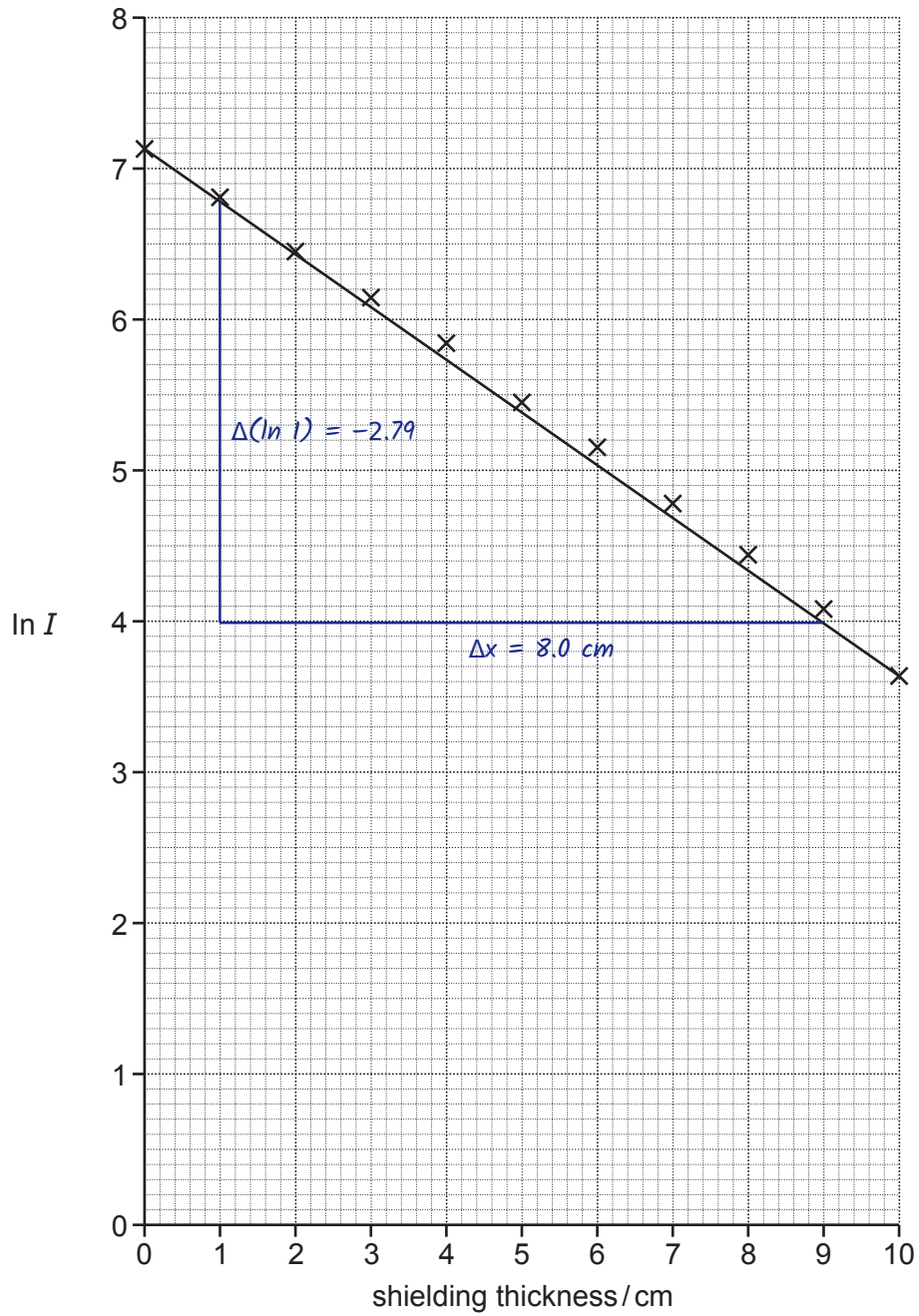


Fig. 4.4

END OF QUESTION PAPER

This image shows a blank sheet of white paper designed for handwriting practice. It features a solid vertical line on the left side, creating a narrow margin. The rest of the page is filled with evenly spaced horizontal dashed lines, providing a guide for letter height and placement. There are no other markings or text on the page.

Oxford Cambridge and RSA

Copyright Information

OCR is committed to seeking permission to reproduce all third-party content that it uses in its assessment materials. OCR has attempted to identify and contact all copyright holders whose work is used in this paper. To avoid the issue of disclosure of answer-related information to candidates, all copyright acknowledgements are reproduced in the OCR Copyright Acknowledgements Booklet. This is produced for each series of examinations and is freely available to download from our public website (www.ocr.org.uk) after the live examination series. If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.

For queries or further information please contact The OCR Copyright Team, The Triangle Building, Shaftesbury Road, Cambridge CB2 8EA.

OCR is part of the Cambridge Assessment Group; Cambridge Assessment is the brand name of University of Cambridge Local Examinations Syndicate (UCLES), which is itself a department of the University of Cambridge.