SECTION A

Answer **all** the questions.

1 This question is about the determination of the specific thermal capacity of aluminium.

An electrical heater is used to raise the temperature of a 1.0 kg aluminium block in the circuit shown in Fig. 1.1.

The switch is closed, switching the heater on for **ten** minutes before the switch is opened, which turns the heater off.

The temperature of the block is recorded at one minute intervals for **fifteen** minutes.

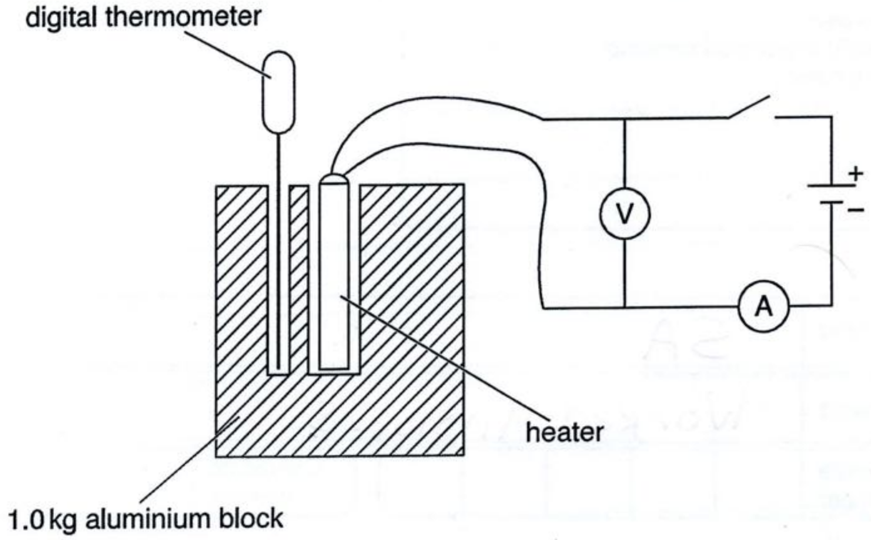


Fig 1.1

Readings are taken of potential difference across the heater and current through the heater every two minutes. The results are shown in the table.

Time t / minutes	Potential difference V / V	Current I /A	Power P / W
0	8.61	2.30	19.8
2	8.67	2.35	20.4
4	8.74	2.32	20.3
6	8.75	2.42	21.0
8	8.69	2.39	20.8
10	8.70	2.41	21.0

$P = IV$

(a) (i) Complete the missing values in the table. **[3]**

(ii) Calculate the mean power. Include the uncertainty in the value.

Mean = 20.6

Uncertainty = range/2 = (21.0 − 19.2)/2 = ±0.6

mean power = 20.6 ± 0.6 W **[2]**

Fig. 1.2 shows a graph of temperature against time.

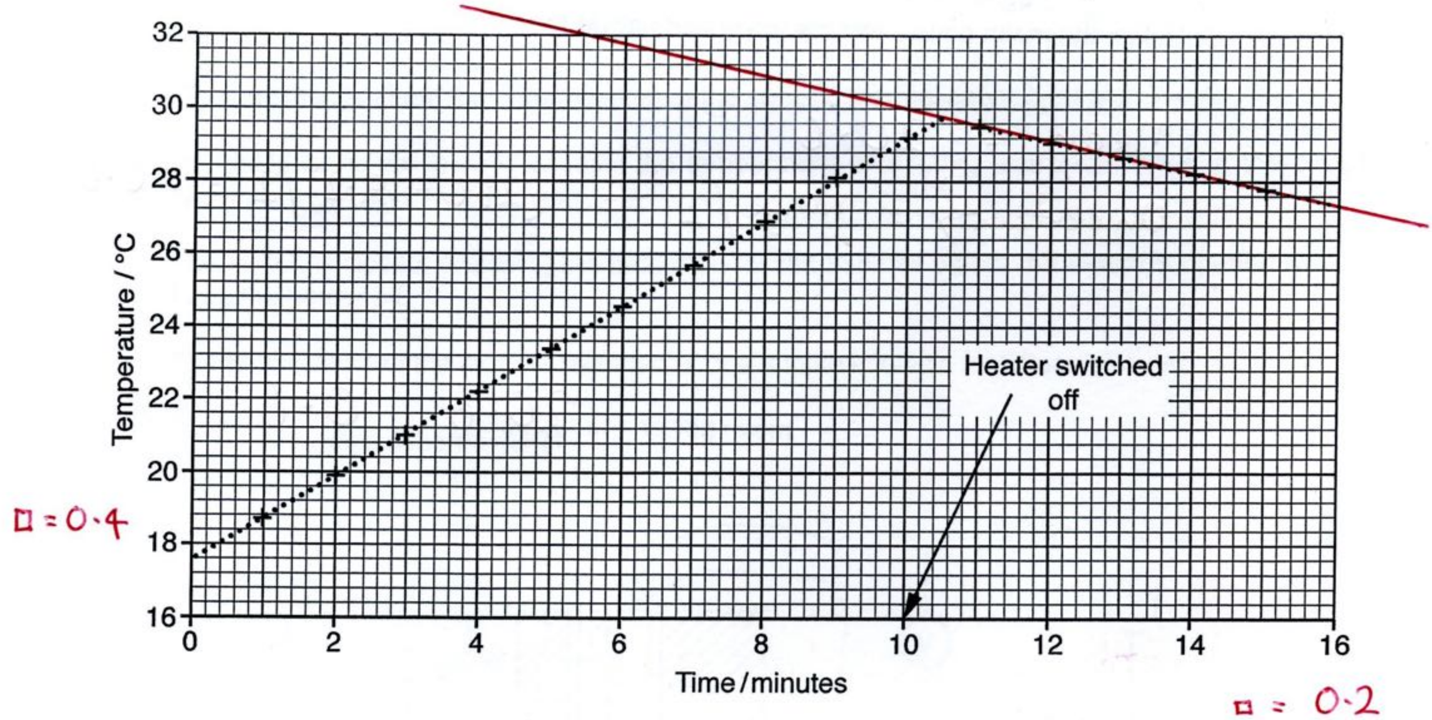


Fig 1.2

(b) **(i)** Use data from the first ten minutes of the graph and your answer to **(a)(ii)** to show that the specific thermal capacity of aluminium is about 1000 $J\,kg^{-1}\,K^{-1}$.

$$E = Pt = mc\Delta\theta$$

$$\therefore \quad c = \frac{Pt}{m\Delta\theta} = \frac{20.6 \times 10 \times 60}{1 \times (29.2 - 17.6)} = 1070 \ J\,kg^{-1}K^{-1}$$

[3]

(ii) Use Fig. 1.2 to estimate the maximum rate of cooling when the switch is opened.

$$\text{Gradient} = \frac{27.3 - 32}{16 - 5.4}$$

maximum rate of cooling = ... -0.44 ...... $K\,min^{-1}$ **[2]**

$(-0.43 \text{ to } -0.47)$

(c) The total percentage uncertainty in the investigation is found to be 5%. The accepted value of the specific thermal capacity of aluminium is 897 $J\,kg^{-1}\,K^{-1}$.

Calculate the percentage difference between your calculated value from **(b)(i)** and the accepted value and use this to comment on the accuracy of the investigation. Suggest reasons for the difference between the investigation value and the accepted value.

Difference = 1070 − 897 = 173

% Difference = 173/897 × 100 = 19 % too high

The block is constantly cooling as soon as it is above room temperature. / The heater may not be 100% efficient as enery is lost heating the leads. etc.

[4]

2 This question is about investigating the terminal velocity of paper cupcake cases.

A paper cupcake case is dropped from a height of 2.0 m and the time taken t to fall to the ground is recorded using a stopwatch.

Fig. 2.1 shows a dot-plot recording the values obtained for t.

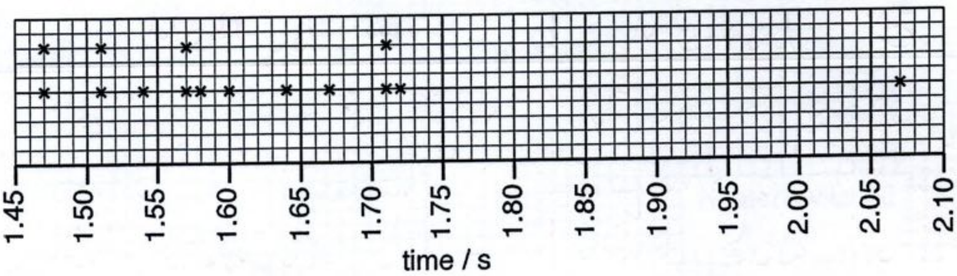


Fig. 2.1

(a) Suggest a practical reason for the outlying result of 2.07 s.

The stopwatch operator was momentarily distracted and did not stop the stopwatch in time.

[1]

(b) Fig. 2.2 shows a sketch graph of velocity against time for the cupcake case.

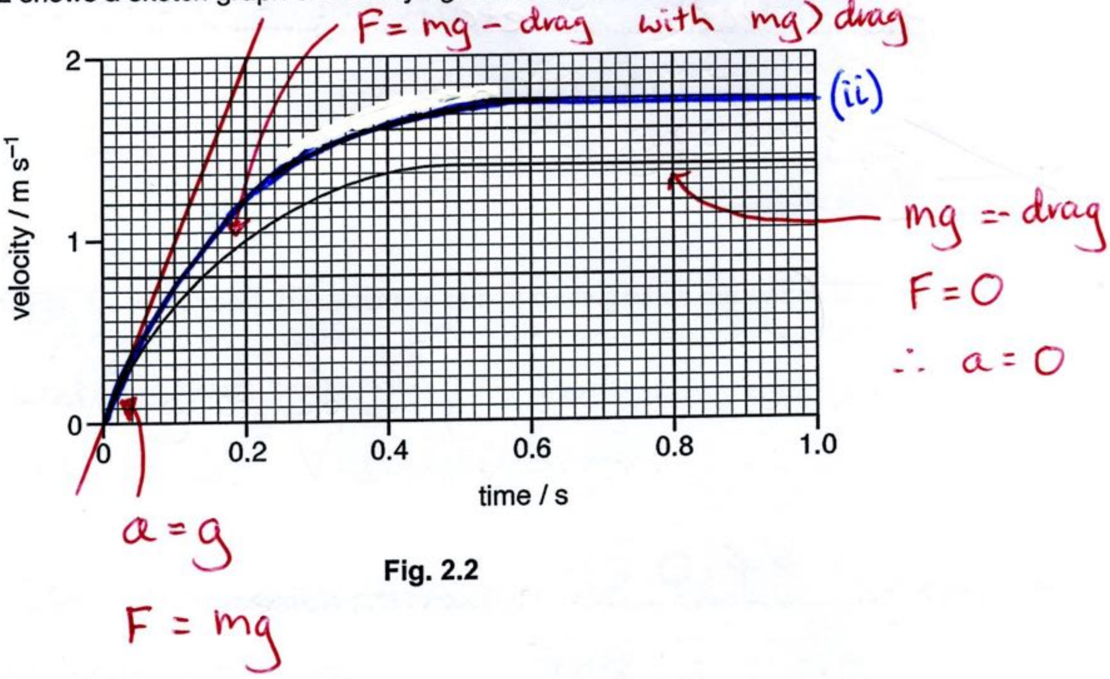


Fig. 2.2

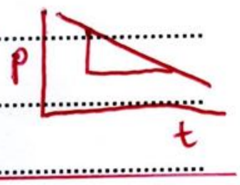
(i) Explain the shape of the graph. Refer to the forces acting on the cupcake case in your answer.

The initial acceleration = $g \approx 10\,ms^{-2}$ as gravity is the only force acting. As velocity increases the upwards air resistance increases reducing the resultant force and hence acceleration. At around 0.5s the air resistance is equal and opposite to the weight so there is no resultant force and the velocity is constant.

[4]

(ii) The mass of the cupcake case is changed by inserting a second case inside the first. Draw a second graph on Fig. 2.2 showing how the velocity of the cupcake cases changes with time. **[2]**

(iii)* A student wishes to investigate how the mass of the cupcake case affects the size of the terminal velocity reached. Describe practical **methods** to find the terminal velocity reached by the cupcake case using standard school laboratory equipment. Include the measurements taken and the calculations required to determine the terminal velocity as well as ways to reduce any sources of uncertainty.

	Method A	Method B
Methods	Set up pair of light gated 1 m apart. vertically. Use data-logger to measure vel.	Video cupcake falling infront of metre rule using slow motion video
Measurements	• distance between gates • time from gate to gate	• position of bottom of case in each frame. • the frame rate of the video
Calculations	velocity = $\frac{\text{distance}}{\text{time}}$	Plot graph of position vs time and calculate the gradient. 
Reducing Uncertainty	• Drop case from well above gates so it has reached V terminal. • Use large separation between gates to reduce uncertainty in time measurement.	• Film from reasonable distance to reduce parallax error. • Use bright lighting so image is sharp and easy to measure. (Fast shutter speed)

[6]

3 This question is about an experiment to determine the Planck constant using LEDs.

Fig. 3.1 shows the circuit which is used in a school laboratory.

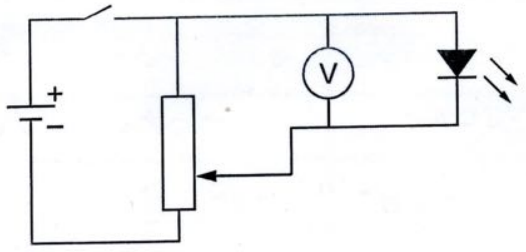


Fig. 3.1

The voltage across each LED is increased until the light emitted from the LED is just visible. This voltage V_t recorded. V_t is found for seven LEDs emitting light of different wavelengths.

(a) V_t for a red LED is measured as 1.35 V. Calculate the energy change of an electron passing through the LED.

$E = VQ = 1.35 \times 1.6 \times 10^{-19}$

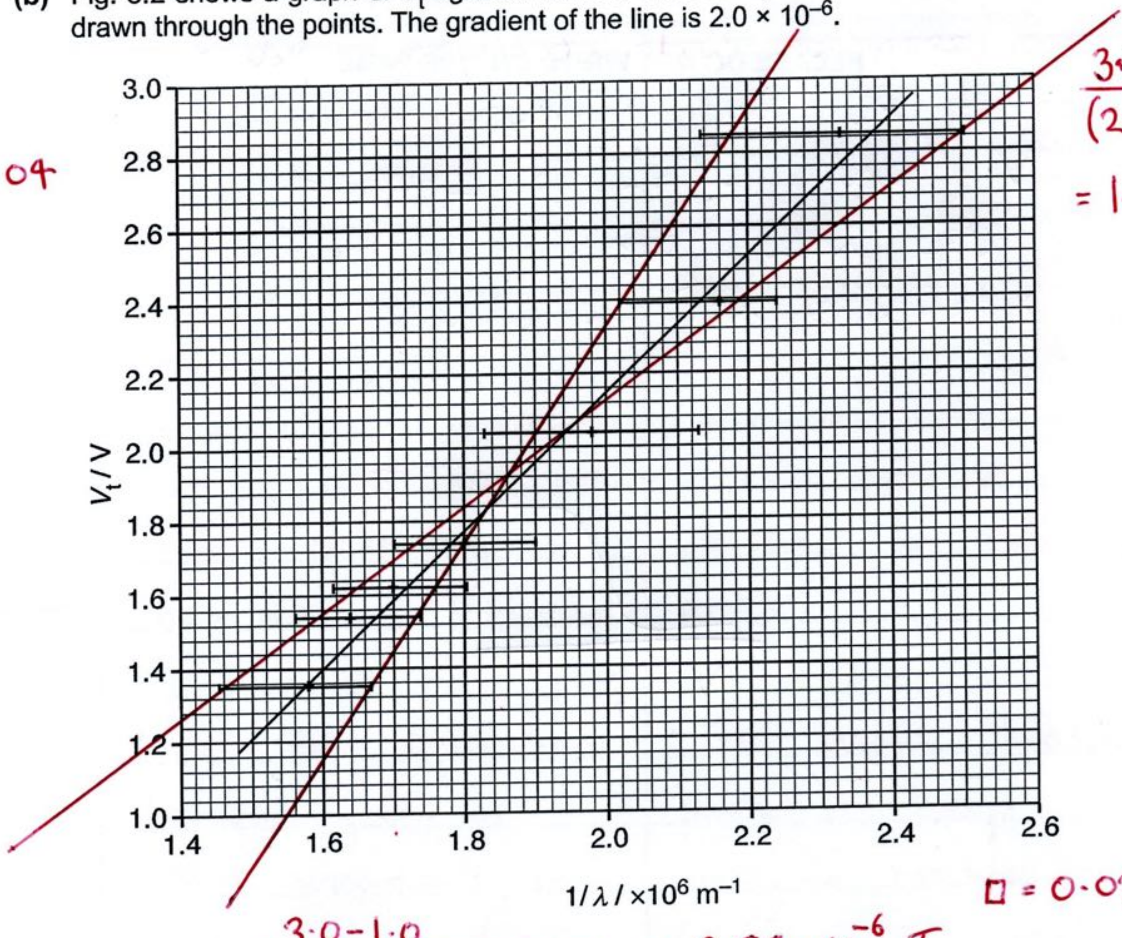
energy change = 2.16×10^{-19} J **[1]**

(b) Fig. 3.2 shows a graph of V_t against $1/\lambda$ with uncertainty bars. The line of best fit has been drawn through the points. The gradient of the line is 2.0×10^{-6}.

$\square = 0.04$

$\frac{3.0 - 1.28}{(2.6 - 1.4) \times 10^{6}}$

$= 1.43 \times 10^{-6}$ J



$\square = 0.02$

$\frac{3.0 - 1.0}{(2.22 - 1.55) \times 10^{6}} = 2.99 \times 10^{-6}$ J

Fig. 3.2

(i) Using the energy-frequency relationship for photons show that the gradient of the line represents

$$\frac{hc}{q}$$

where h is the Planck constant, c is the speed of light in a vacuum and q is the charge on the electron.

$E = Vq$ & $E = hf$ & $f = c/\lambda$

$\therefore Vq = \frac{hc}{\lambda}$ & $V = \frac{hc}{q} \times \frac{1}{\lambda}$

(c.f.) $y = m \quad x$

[2]

(ii) Hence show that h is found to be about 1.1×10^{-33} J s.

gradient $= \frac{hc}{q}$ $\therefore h = \frac{\text{grad} \times q}{c}$

$h = \frac{2.0 \times 10^{-6} \times 1.6 \times 10^{-19}}{3 \times 10^{8}} = 1.1 \times 10^{-33}$ Js

[1]

(iii) A *worst-fit* straight line is one which represents the steepest or least steep possible straight line to pass through all the uncertainty bars. Draw a worst-fit straight line on the graph and calculate a second value for the Planck constant.

$\frac{1.43 \times 10^{-6} \times 1.6 \times 10^{-19}}{3 \times 10^{8}} = 7.6 \times 10^{-34}$ Js

OR

$\frac{2.99 \times 10^{-6} \times 1.6 \times 10^{-19}}{3 \times 10^{8}} = 1.6 \times 10^{-33}$ Js

[3]

(iv)* Compare the calculated values for h with the accepted value (6.6×10^{-34} J s) and comment on the accuracy of the experiment. Describe the sources of uncertainty in the experiment and suggest improvements.

[6]

The error bars give a range of 7.6 to 16 $\times 10^{-34}$ Js giving an uncertainty of ± 4 Js $\times 10^{-34}$

The accepted value of 6.6×10^{-34} Js is just outside the uncertainty $11 \pm 4 \times 10^{-34}$ Js.

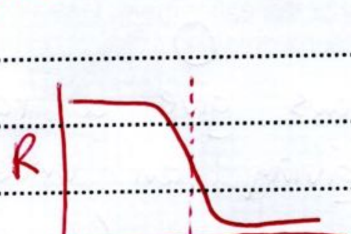
The % difference $= \frac{11 - 6.6 \times 10^{-34}}{6.6 \times 10^{-34}} \times 100 = 67\%$ too high.

PTO

67% too high is larger than can be accounted for due to the uncertainty in $1/\lambda$ which is around $\pm 7.5\%$. There is only a tiny uncertainty in V.

The sources of error may include
- hard to tell when LED lights up
- eye more sensitive to green light
- LED produces a range of wavelengths

To improve the method
- Use blackout blinds to make room dark
- Measure current and use to calculate resistance of LED. Use V vs R graph to measure when LED starts to conduct. This eliminates judging by eye.



[6]

SECTION B

Answer **all** the questions.

4 This question is about the attenuation of gamma radiation as it passes through lead.

Fig. 4.1 shows the experimental set up using a Geiger-Müller tube to detect gamma radiation emitted from a sample of cobalt-60. Different thicknesses of lead sheet are placed between the source and the Geiger-Müller tube and a counter is used to measure the number of counts per minute (cpm).

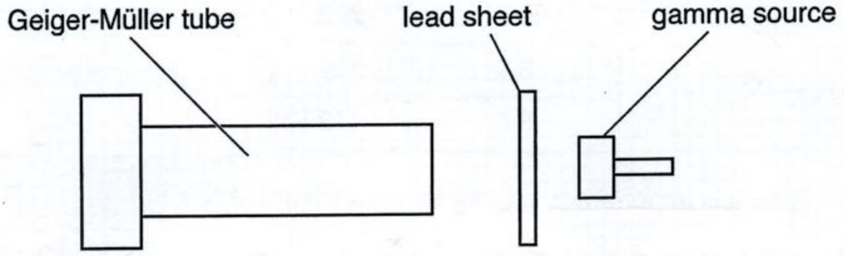


Fig. 4.1

(a) Describe the safety precautions necessary for handling the gamma source.

Handle the gamma source with tongs.
Keep source in lead container
OR Point source away from body
OR Keep exposure time short.

[2]

(b) The values in the table below have been corrected for background radiation.

thickness of lead x / cm	Intensity I / cpm
0.5	890
1.0	651
1.5	442
2.0	310
2.5	222
3.0	154
3.5	112

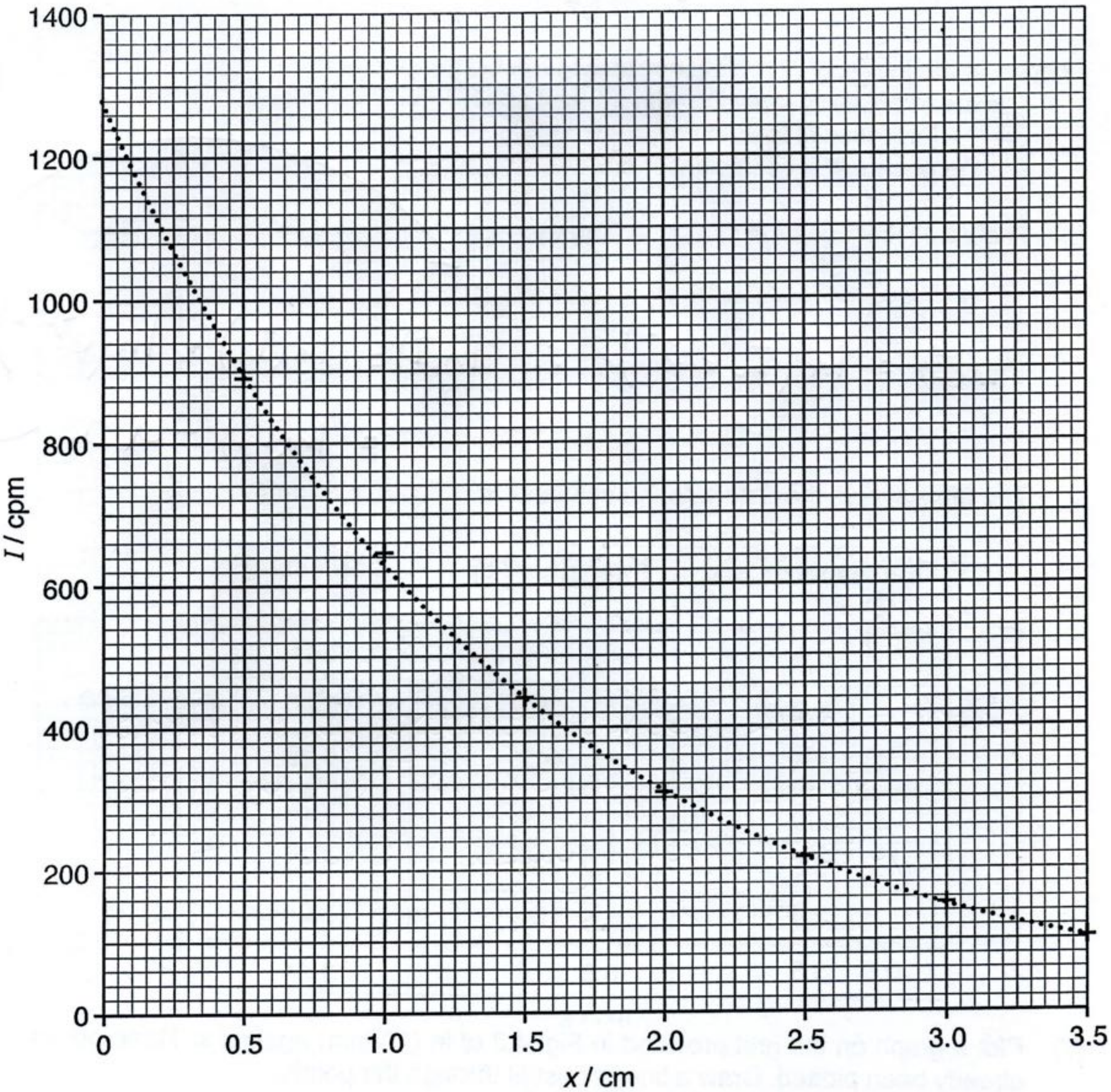
(i) Explain why it is important to correct for background radiation.

Background radiation* is always present and is subtracted to remove a systematic error.

*(e.g from cosmic rays) **[2]**

Fig. 4.2 shows a plot of I against x.

□ = 20



□ = 0.05

Fig. 4.2

(ii) The *half-thickness* is the thickness of a shielding material required to halve the intensity received by the Geiger-Müller tube. Use the graph to calculate a reliable value for the half-thickness of lead.

1200 to 600 = 1.05 − 0.10 = 0.95 cm

800 to 400 = 1.65 − 0.65 = 1.00 cm

600 to 300 = 2.05 − 1.05 = 1.00 cm

mean = 0.98 cm

half-thickness = ...0.98...... cm **[3]**

(c) The attenuation of gamma radiation in lead can be described by the equation:

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

where: I is the intensity of radiation reaching the Geiger-Müller tube
I_0 is the intensity of radiation with no lead sheet
x is the thickness of lead in cm
μ is the attenuation coefficient in cm^{-1}.

(i) Show that this equation can be written as

$$\ln(I) = -\mu x + \ln(I_0).$$

$\ln(I) = \ln(I_0 e^{-\mu x}) \quad \therefore \quad \ln(I) = \ln(I_0) + \ln(e^{-\mu x})$

$= \ln(I_0) - \mu x$

[1]

The table shows the data with the values of ln (I / cpm) calculated.

thickness of lead x / cm	Intensity I / cpm	ln (I / cpm)
0.5	890	6.79
1.0	651	6.48
1.5	442	6.09
2.0	310	5.74
2.5	222	5.40
3.0	154	5.04
3.5	112	4.72

(ii) Plot a graph on the grid provided in Fig. 4.3 of ln (I / cpm) against x. Three points have already been plotted. Draw a line of best fit through the points. **[2]**

(iii) Calculate the gradient and intercept of the line of best fit and use your answer to **(c)(i)** to determine I_0 and μ.

gradient $= \dfrac{4.35 - 7.13}{4.0} = -0.70$

Intercept = 7.13 = ln(Io)

Io = $e^{7.13}$

I_0 = 1250 cpm

μ = 0.70 cm^{-1}

[4]

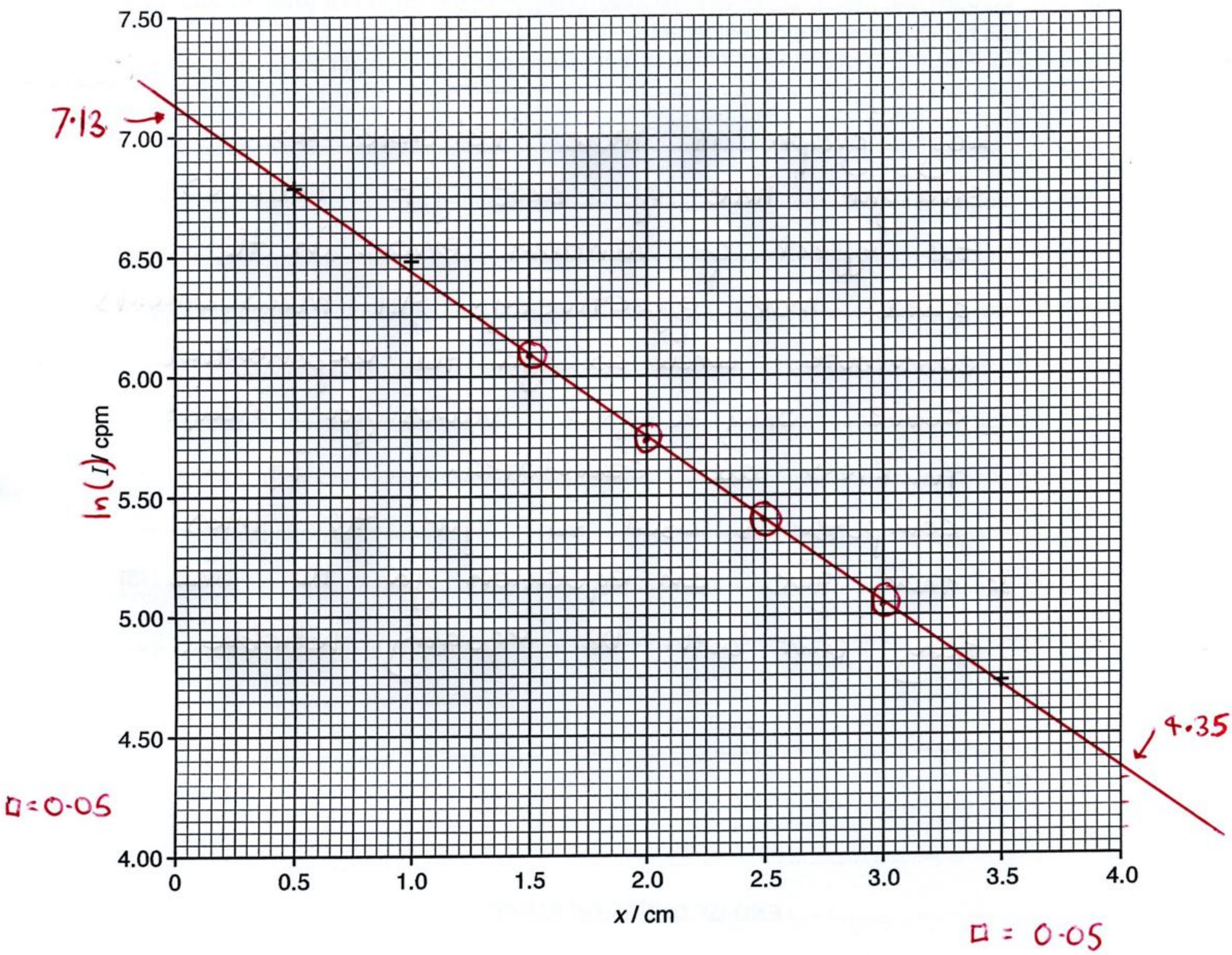


Fig. 4.3

(d) **(i)** Use the value of μ calculated in **(c)(iii)** to calculate the half-thickness of lead.

$$\mu = \frac{\ln 2}{x_{\frac{1}{2}}} = \frac{\ln 2}{0.70} = 0.990 \text{ cm}$$

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

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

$\ln(\tfrac{1}{2}) = -\mu x$

$\ln 2 = \mu x$

half-thickness = 0.99 cm **[3]** ?

(d) (ii) Suggest and explain which of the methods used, in parts **(b)(ii)** and **(d)(i)**, to determine the half-thickness is the most reliable.

Log graph is more reliable as straight line of best fit reduces the effect of random errors in the data more effectively. All measurements contribute where as for the exponential curve only a few values for half-thickness are calculated. If a computer is used to fit the lines & then give an equation for the line **[3]** they will both be equally reliable.

END OF QUESTION PAPER