



Oxford Cambridge and RSA

Thursday 16 June 2022 – 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

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Candidate number

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First name(s)

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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 the **polarisation** of electromagnetic waves.

- (a) Explain what is meant by the term polarisation and state why all electromagnetic waves can be polarised.

In a polarised wave the oscillations (of the electric field) are in one plane only.
All EM waves are transverse (oscillations perpendicular to the direction of travel), and only transverse waves can be polarised. [2]

- (b) A student looks at light reflected from a glass block through one polarising filter. Explain how they could tell if the reflected light shows any polarisation.

Look at the reflected light through the polarising filter and slowly rotate the filter through 360° .
If the light is (partly) polarised, its brightness changes gradually as the filter is rotated, from a maximum to a minimum.
The angle between the positions of maximum and minimum intensity is 90° .
If the brightness does not change, the light is unpolarised. [3]

- (c) Another student investigates the polarisation of microwaves using apparatus shown in Fig. 1.1.

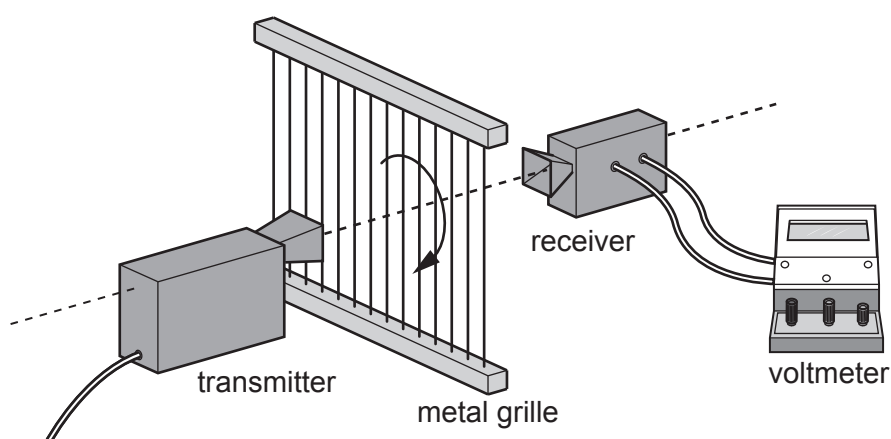


Fig. 1.1

The grille starts in the vertical position as shown and is rotated. The intensity of the microwaves at the receiver is measured at different angles.

- (i) Describe how the angle of rotation could be measured in a school laboratory.

Use a large protractor fixed behind the grille, centred on its axis of rotation.

Measure the angle between the direction of the bars and a vertical plumbline hung in front of the protractor. [2]

- (ii) The results from the investigation are plotted on the graph shown in **Fig. 1.2**. Use data points from the graph below (excluding voltage = 0) to test whether the investigation shows that

$$\text{Intensity} \propto \cos^2 \theta$$

Make your conclusion clear.

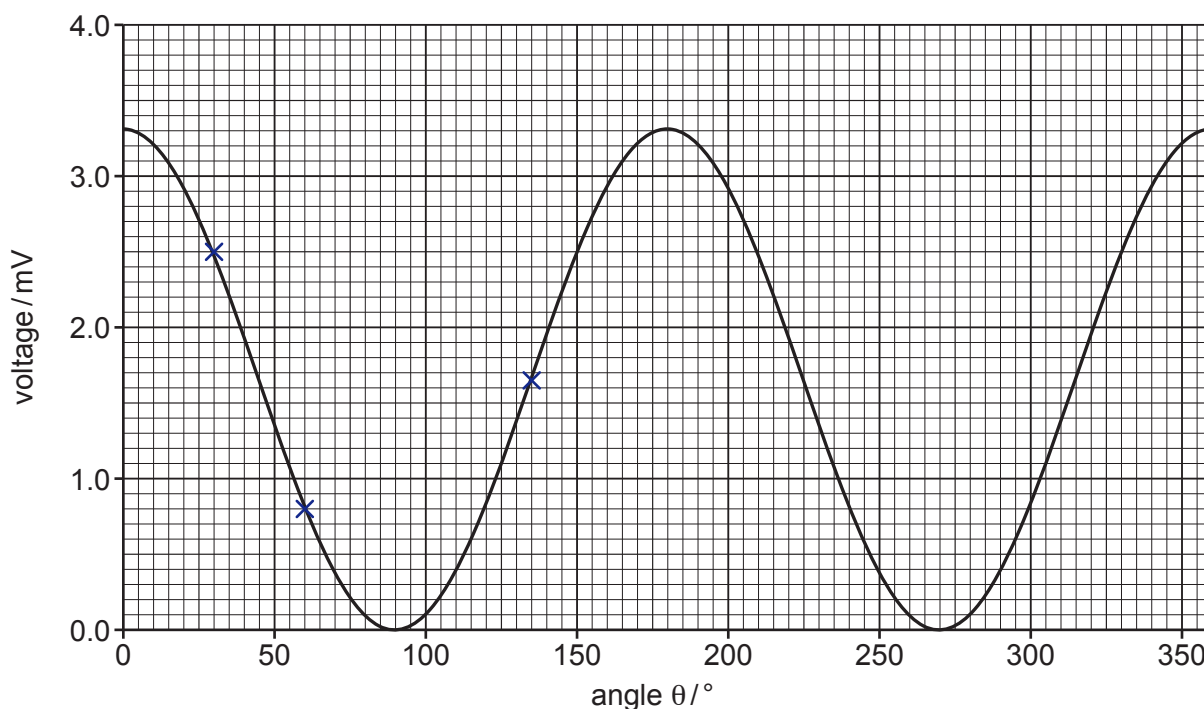


Fig. 1.2

Reading from the graph: (30°, 2.5 mV), (60°, 0.80 mV), (135°, 1.65 mV)

$V/\cos^2\theta$: $2.5/\cos^2 30 = 2.5/0.75 = 3.3$; $0.80/\cos^2 60 = 0.80/0.25 = 3.2$;

$1.65/\cos^2 135 = 1.65/0.50 = 3.3 \text{ mV}$

$V/\cos^2\theta$ is constant (about 3.3 mV) within reading error, so $V \propto \cos^2\theta$:

the investigation does support intensity $\propto \cos^2\theta$.

[3]

Turn over

- 2 This question is about an investigation into the relationship between the pressure and volume of a gas. The relationship is often referred to as Boyle's Law. A student set up the apparatus shown in Fig. 2.1.

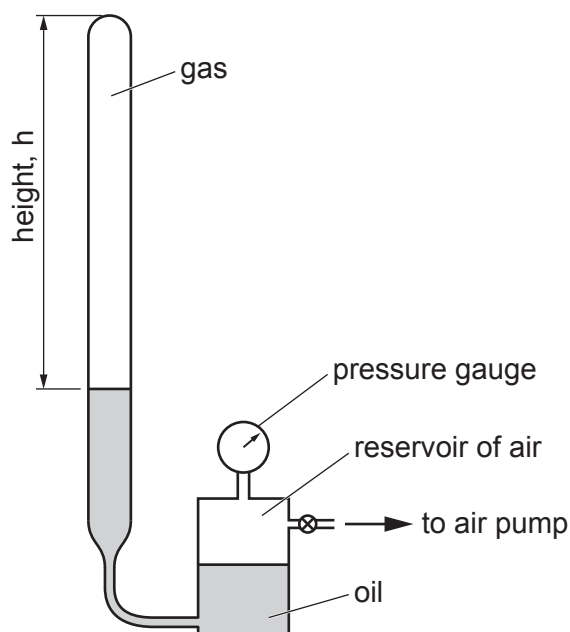


Fig. 2.1

- (a) (i) Identify a variable which needs to be controlled in the investigation.

The temperature of the gas. [1]

- (ii) Before setting up the apparatus, the student took measurements with vernier calipers of the internal diameter of the tube containing the gas. The student created the dot plot of cross-sectional area shown in Fig. 2.2.

Taking into consideration any outliers, calculate a value for the mean and percentage uncertainty of the cross-sectional area of the tube. Give your answers to an appropriate number of significant figures.

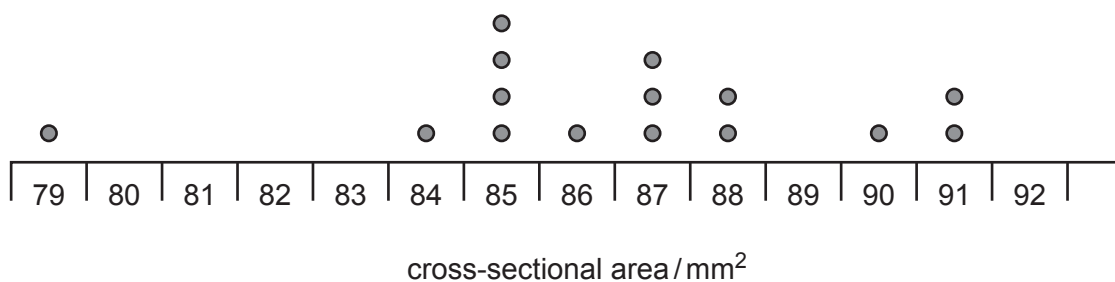


Fig. 2.2

Outlier = 79 mm², excluded. Mean = (84 + 4×85 + 86 + 3×87

+ 2×88 + 90 + 2×91)/14 = 1219/14 = 87.1 mm²

Uncertainty = ½ × range = ½ × (91 – 84) = 3.5 mm²

% uncertainty = 3.5/87.1 × 100 = 4.0 %

Mean cross-sectional area = ... *87* mm² ± *4* % [4]

- (iii) The height, h , of the column of air is measured using a standard laboratory metre rule. Estimate the absolute uncertainty in the measurement and justify your answer.

About ± 3 mm, because the metre rule cannot be placed against the gas column: there is parallax when reading through the curved glass tube and the oil meniscus is curved. [2]

- (b) The pressure gauge used in the experiment records excess pressure. The absolute pressure of the gas is given by

absolute pressure = excess pressure + atmospheric pressure

When the pressure gauge reads 255 kPa calculate the value for $\frac{1}{\text{absolute pressure}}$ and state the unit.

Atmospheric pressure = 101 kPa.

$$\text{absolute pressure} = 255 + 101 = 356 \text{ kPa} = 3.56 \times 10^5 \text{ Pa}$$

$$1/p = 1/(3.56 \times 10^5) = 2.81 \times 10^{-6} \text{ Pa}^{-1}$$

$$\frac{1}{\text{absolute pressure}} = 2.81 \times 10^{-6} \text{ unit } \text{Pa}^{-1} \quad [2]$$

Question 2 continues on page 6

The pressure of the gas is changed and the values for absolute pressure and height of the column of gas are recorded. The data are shown in **Table 2.1**. The student plots a graph to show the relationship between height of the column of gas and $1/\text{absolute pressure}$ shown in **Fig. 2.3**.

Height/m	$1/\text{absolute pressure}$
0.150	2.82×10^{-6}
0.200	3.85×10^{-6}
0.250	5.90×10^{-6}
0.300	6.06×10^{-6}
0.350	7.69×10^{-6}
0.400	9.01×10^{-6}

Table 2.1

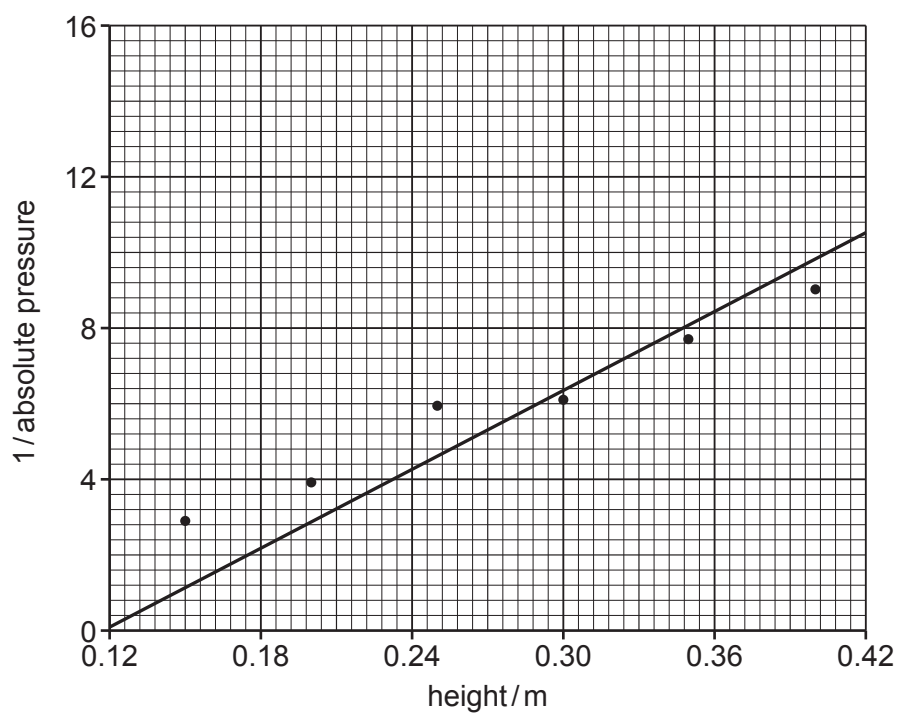


Fig. 2.3

- (c)* Suggest, with reasons, how the presentation of the graph in **Fig. 2.3** could be improved, and identify any anomalous points.

The student calculates the gradient to be $25 \times 10^{-6} \text{ kN}^{-1} \text{ m}$. Explain the physical significance of the gradient, state your assumptions, and estimate n , the number of moles of gas that would be present at a temperature of 298 K.

Improvements: the x-axis scale (0.06 m per large square) is awkward; use a sensible scale such as 0.05 m per 2 cm. The y-axis goes to 16 but the data only reach 9.01, so the y-axis should go to 10 so the points cover more than half of the grid.

The y-axis has no unit or power of ten; label it 1/absolute pressure / 10^{-6} Pa^{-1} . Plot the points as small, precise crosses instead of blobs and add error

bars. The drawn best-fit line is too steep and does not pass evenly through the points.

The third point (0.250 m, 5.90×10^{-6}) is anomalous: it lies well above the trend, so it should be circled, rechecked and ignored when drawing the line.

Significance: for an ideal gas $pV = nRT$ and $V = Ah$, so $1/p = (A/nRT) \times h$.

A straight line through the origin shows $1/p \propto h$, i.e. $p \propto 1/V$ (Boyle's law), and the gradient = $A/(nRT)$.

Assumptions: the gas is ideal (particles of negligible volume, no interactions between particles, perfectly elastic collisions, negligible collision time); the

temperature (298 K) and amount of gas are constant; $A = 87 \text{ mm}^2 = 8.7 \times 10^{-5} \text{ m}^2$.

$n = A/(RT \times \text{gradient}) = 8.7 \times 10^{-5} / (8.31 \times 298 \times 25 \times 10^{-6}) = 1.4 \times 10^{-3} \text{ mol}$.

[6]

3 This question is about radioactive decay.

(a) The decay equation is

$$\frac{\Delta N}{\Delta t} = -\lambda N$$

where λ is the decay constant and N is the number of nuclei present. Explain what the decay constant represents for a particular radioisotope and the meaning of the negative sign in the equation.

λ is the probability that a nucleus decays per unit time (per second), i.e. the fraction of nuclei decaying per second.

The negative sign shows that N is decreasing. [2]

(b) The decay equation can be used to make an iterative model of radioactive decay. Initially a radioactive sample has 5000 nuclei. The decay constant is $\lambda = 0.4 \text{ s}^{-1}$. Using $\Delta t = 1 \text{ s}$ generates the model shown in **Table 3.1**.

Time elapsed / s	Number of nuclei, N	Number of nuclei decaying in $\Delta t = 1 \text{ s}$, $\Delta N = \lambda N \Delta t$	Number of remaining nuclei at $t + \Delta t$, $N - \Delta N$
0	5000	2000	3000
1	3000	1200	1800
2	1800	720	1080
3	1080	432	648
4	648	259	389

Table 3.1

(i) Complete the remaining rows of **Table 3.1**.

[2]

- (ii) The decay graph has been started in **Fig. 3.1**. Complete the final three points on the graph using data from **Table 3.1**. [2]

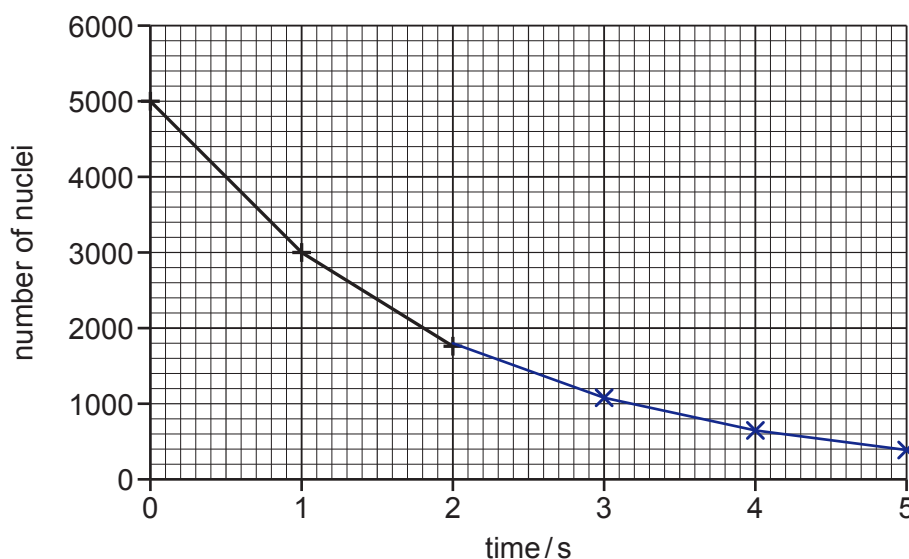


Fig. 3.1

- (iii) How is the activity of the sample represented in this model?

Activity is the gradient of each straight section of the graph; it is assumed constant during each 1 s interval. [1]

- (iv) Explain why a better model is created if $\Delta t = 0.5$ s.

Twice as many points in the same time give a smoother curve, closer to exponential and more realistic, as activity is assumed constant over a shorter interval, nearer to the continuously changing rate of decay. [2]

- (c) Protactinium-234 is a radioactive isotope which emits beta particles. It is produced in the school laboratory in a bottle containing a solution of a uranium compound. The bottle is shaken, and the protactinium-234 separates out into the top layer of solvent. The radiation is then detected using a Geiger-Muller tube connected to a counter.

The number of counts in consecutive 10-second intervals is recorded over a period of a few minutes. The **count rate** is found by correcting for the background count and then dividing this number of counts by ten.

- (i) Explain why 10-second intervals over a period of a few minutes are suitable for this experiment.

10 s gives a large, measurable count (sample is active) and smooths out randomness. Pa-234 has a short half-life, so the count rate falls a lot in a few minutes; a short time also limits radiation exposure. [2]

- (ii) Fig. 3.2 shows a graph of $\ln(\text{count rate})$ against t from this experiment.

Use the graph to find a value for the decay constant for protactinium-234 and hence the half-life.

Gradient triangle on Fig. 3.2 from (10, 4.28) to (140, 3.03):

$$\text{gradient} = (3.03 - 4.28)/(140 - 10) = -1.25/130$$

$$\text{gradient} = -9.62 \times 10^{-3} \text{ s}^{-1}$$

$$\text{decay constant } \lambda = -\text{gradient} = 9.62 \times 10^{-3} \text{ s}^{-1}$$

$$T_{1/2} = \ln 2 / \lambda = 0.693 / 9.62 \times 10^{-3}$$

$$T_{1/2} = 72 \text{ s}$$

Half-life = ...72.....s [4]

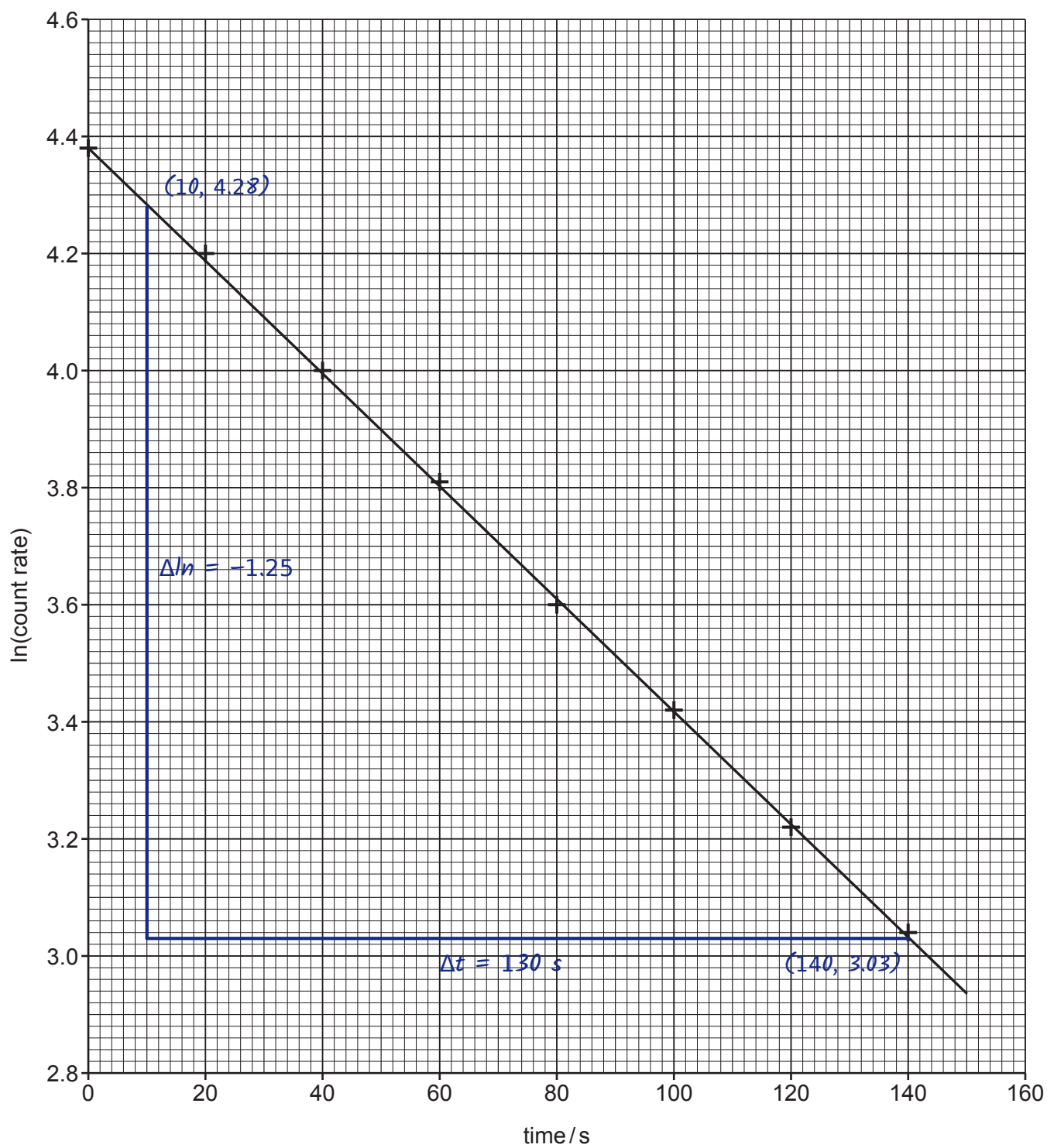


Fig. 3.2

SECTION B

Answer **all** the questions.

- 4 This question is about the behaviour of materials under tension. A student sets up an experiment to investigate the force–extension characteristics of a rubber band and obtains the data shown in Fig. 4.1.

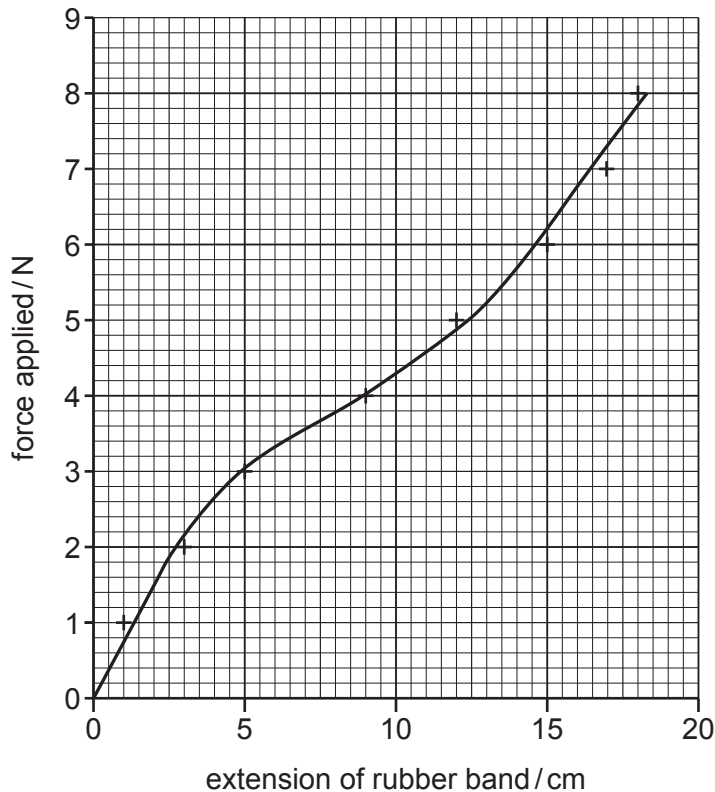


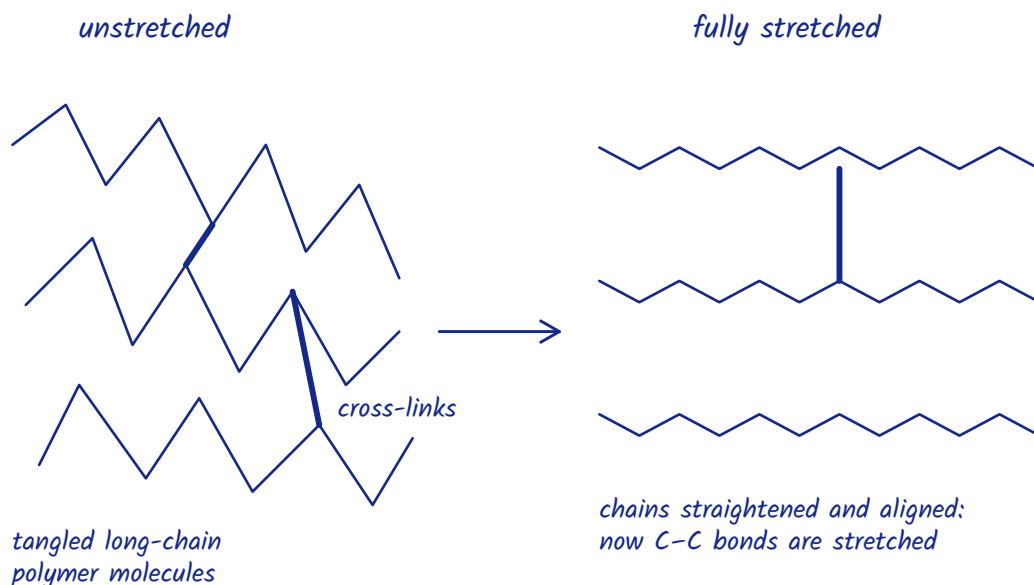
Fig. 4.1

- (a) (i) Describe the experimental technique the student could use to gather reliable data. Include in your answer how BOTH experimental uncertainties and risks can be minimised. Suggest the greatest source of uncertainty in the experiment.

Hang the band from a clamp stand, add 100 g masses one at a time
and measure the extension each time with a vertical metre rule.
Greatest uncertainty: measuring the extension. Reduce it with a pointer
on the band to avoid parallax, and repeat readings averaged.
Risks: wear safety glasses in case the band snaps; keep feet out of the
drop zone.

[4]

- (ii)* Describe the relationship shown by the graph in **Fig. 4.1** and explain how this relates to the behaviour of the band under tension and its microscopic structure. You may use diagrams in your answer.



The graph is non-linear: extension increases with force but the gradient $\Delta F/\Delta x$ (the stiffness) changes. Up to about 3 cm the band is fairly stiff (large force for small extension); from 3 cm to 12 cm the stiffness is much lower (larger extension for a small force); above 12 cm it becomes stiffer again.

Rubber is a polymer: long-chain molecules arranged randomly and tangled, with (sulphur) cross-links between chains.

At first the tangled chains and cross-links resist untangling, so a large force gives a small extension. In the middle section the chains simply uncoil and straighten, sliding over one another, so a small force gives a large extension. Once straight, further extension stretches the C-C bonds within the chains, needing a large force for a small extension. The deformation is elastic, not plastic.

- (b) Metals behave differently from rubber under tension. **Fig. 4.2** shows data the student collected whilst performing an experiment to extend a metal wire with diameter 0.5 mm, original length 4 m.

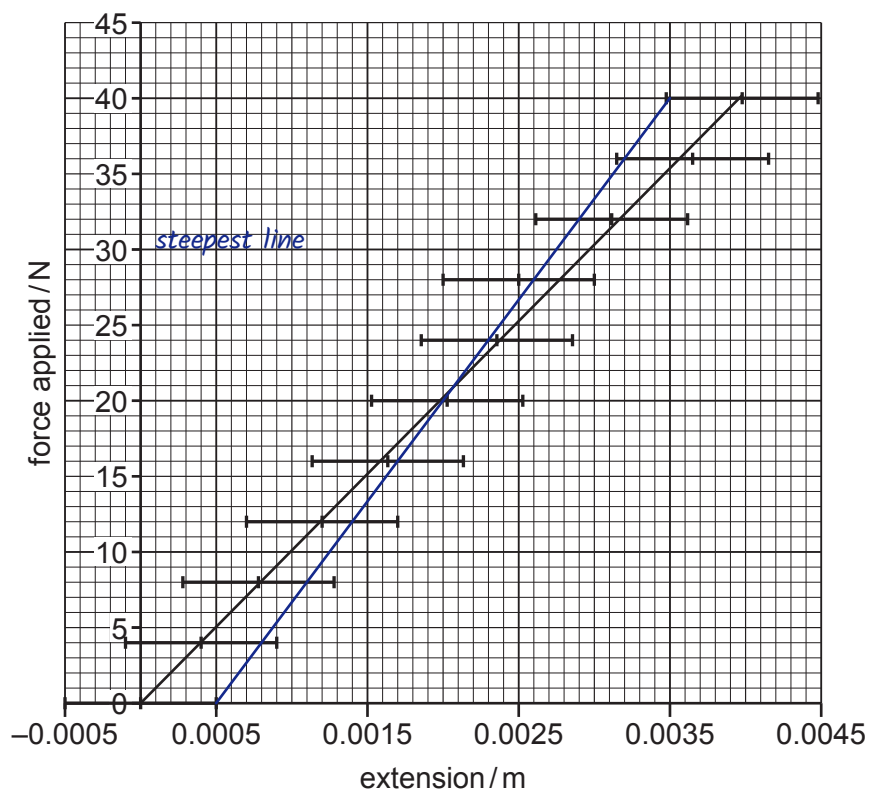


Fig. 4.2

- (i) The line of best fit has been drawn on **Fig. 4.2**. Draw another line within the error bars shown, which has the greatest difference in gradient to the first line. [1]

- (ii) The gradient of the line of best fit in **Fig. 4.2** is $10\,100\text{ NM}^{-1}$. Use this to calculate a value for the Young modulus of the wire. Use the line you have drawn to calculate its absolute uncertainty.

$$E = \text{stress/strain} = (F/A)/(x/L) = \text{gradient} \times L / A$$

$$A = \pi d^2/4 = \pi \times (0.5 \times 10^{-3})^2/4 = 1.96 \times 10^{-7} \text{ m}^2$$

$$E = 10100 \times 4 / 1.96 \times 10^{-7} = 2.06 \times 10^{11} \text{ Pa} \approx 210 \text{ GPa}$$

$$\text{Gradient of my line} = 40 / (0.0035 - 0.0005) = 13300 \text{ N m}^{-1}$$

$$\% \text{ difference} = (13300 - 10100)/10100 \times 100 = 32 \%$$

$$\text{uncertainty} = 0.32 \times 206 \text{ GPa} = 66 \text{ GPa}$$

Young modulus = ...**210**..... GPa $\pm$ **66**..... GPa [3]

Question 4(c) begins on page 16

- (c) The diameter of the wire is measured with a screw-gauge micrometer, as shown in **Fig. 4.3**. The circumference of the rotating thimble is divided into 50 equal steps and for each full rotation of the thimble it moves a further 0.5 mm along the shaft.

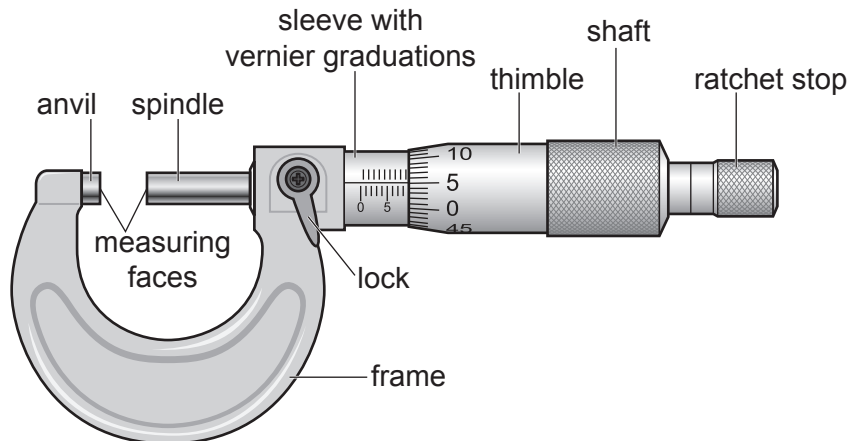


Fig. 4.3

- (i) Give the resolution of the micrometer with the correct unit.

Resolution = ... 0.01 unit mm [1]

- (ii) Suggest how the student could use multiple measurements to find the uncertainty of the diameter of the wire.

Measure the diameter at several different places along the wire and in
different directions (rotating the micrometer around the wire), then
calculate the mean.

The uncertainty is $\pm$ half the range of the readings. [2]

- (iii) The student measures the diameter of another wire to be 0.35 ± 0.02 mm.

Calculate the cross-sectional area of the wire along with the absolute uncertainty.

$$A = \pi d^2/4 = \pi \times (0.35 \times 10^{-3})^2/4 = 9.62 \times 10^{-8} \text{ m}^2$$

$$\% \text{ uncertainty in } d = 0.02/0.35 \times 100 = 5.7 \%$$

$$\% \text{ uncertainty in } A = 2 \times 5.7 = 11.4 \%$$

$$\Delta A = 0.114 \times 9.62 \times 10^{-8} = 1.1 \times 10^{-8} \text{ m}^2$$

$$\text{Area} = \underline{9.6 \times 10^{-8}} \text{ m}^2 \pm \underline{1.1 \times 10^{-8}} \text{ m}^2 \text{ [3]}$$

END OF QUESTION PAPER

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

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