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Oxford Cambridge and RSA

A LEVEL

Examiners' report

PHYSICS B (ADVANCING PHYSICS)

H557

For first teaching in 2015

H557/03 Summer 2022 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers are also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Advance Information for Summer 2022 assessments

To support student revision, advance information was published about the focus of exams for Summer 2022 assessments. Advance information was available for most GCSE, AS and A Level subjects, Core Maths, FSMQ, and Cambridge Nationals Information Technologies. You can find more information on our website.

Paper 3 series overview

This paper is worth 60 marks out of the total 270 marks for the qualification. It includes content from all teaching modules but places emphasis of practical skills. There is quite a lot of emphasis on measuring and calculating uncertainties and graphical work. On the most part the paper consists of structured question covering, problem solving and calculations, as well as LOR questions. This paper appeared to be accessible to most candidates as there was a wide spread of marks and there was little evidence that candidates had run out of time.

Candidates who did well on this paper generally did the following:	Candidates who did less well on this paper generally did the following:
• Demonstrated good understanding of uncertainties. • Wrote explanations clearly and concisely using appropriate terminology. • Interpreted graphs correctly both qualitatively and quantitatively.	• Made some power of ten errors and/or gave responses to inappropriate numbers of significant figures. • Suggested that rubber bands plastically deformed (in Question 4(a)(ii)). • Didn't lay out their mathematical workings clearly.

Section A

Question 1 (a)

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.

....

....

....

.... **[2]**

Most candidates showed understanding of the concept of polarisation but some did not use the correct terminology. Commonly candidates referred to waves only oscillating in one direction rather than plane, or they omitted the word oscillate or vibrate and wrote for example, waves being in one plane.

Misconception

Some candidates referred to the perpendicular variation of a magnetic field and electric field associated with electromagnetic waves. They then explained polarisation as filtering out one or other of these oscillating fields. Whereas in reality both fields pass through the polarising filter but only in one plane each and still perpendicular to one another.

Question 1 (b)

(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.

....

....

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....

....

.... **[3]**

Some candidates missed the point here that only one polarising filter is required to tell if the reflected waves are polarised or not. There is no need for a second polarising filter for this simple observation. Many candidates gained marks for explaining that the light intensity would vary as the polarising filter is rotated if the light was polarised. Some other candidates over complicated the investigation by describing how to use a light sensor to measure the light intensity as the filter was rotated. This was purely meant to be a qualitative investigation.

Exemplar 1

If the light is polarised, when the filter is rotated there will be an angle where little to no light can get through. This is when the filter is perpendicular to the direction of the polarised wave. If the light is unpolarised, there will not be a minimum at any angle. **[3]**

This response starts off well by saying that the polarising filter needs to be rotated and this gets the first marking point. The candidates explains that when the filter is at 90° to the plane of the polarised light, no light would be transmitted which gains a second mark. In order to gain the third mark here, the candidates needed to have clearly stated that the intensity of the light varies continuously as the angle of the filter changes.

Question 1 (c) (i)

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

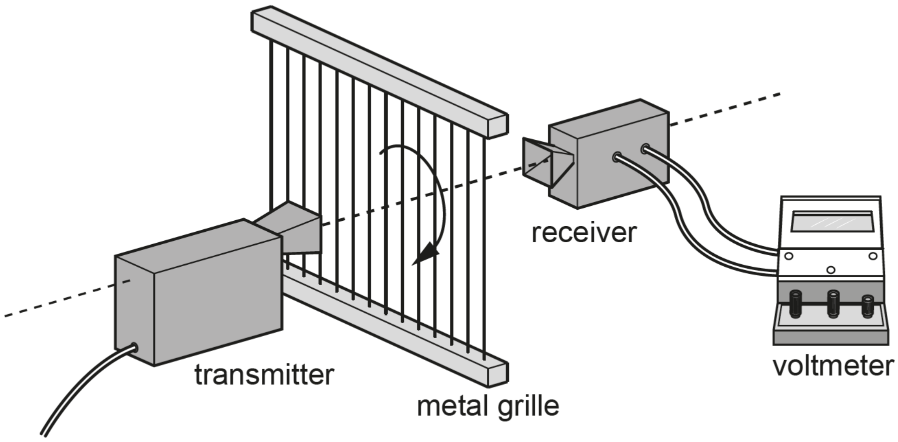


Fig. 1.1

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.

....

....

....

.... **[2]**

Most candidates gained at least one mark here for suggesting to use a protractor but often did not mention some sort of baseline from which to measure the angle to the edge or the slats. A common error was to suggest that the angle of rotation could be measured using the output read from the voltmeter, somehow missing the point of this investigation.

Question 1 (c) (ii)

(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

Intensity $\propto \cos^2\theta$

Make your conclusion clear.

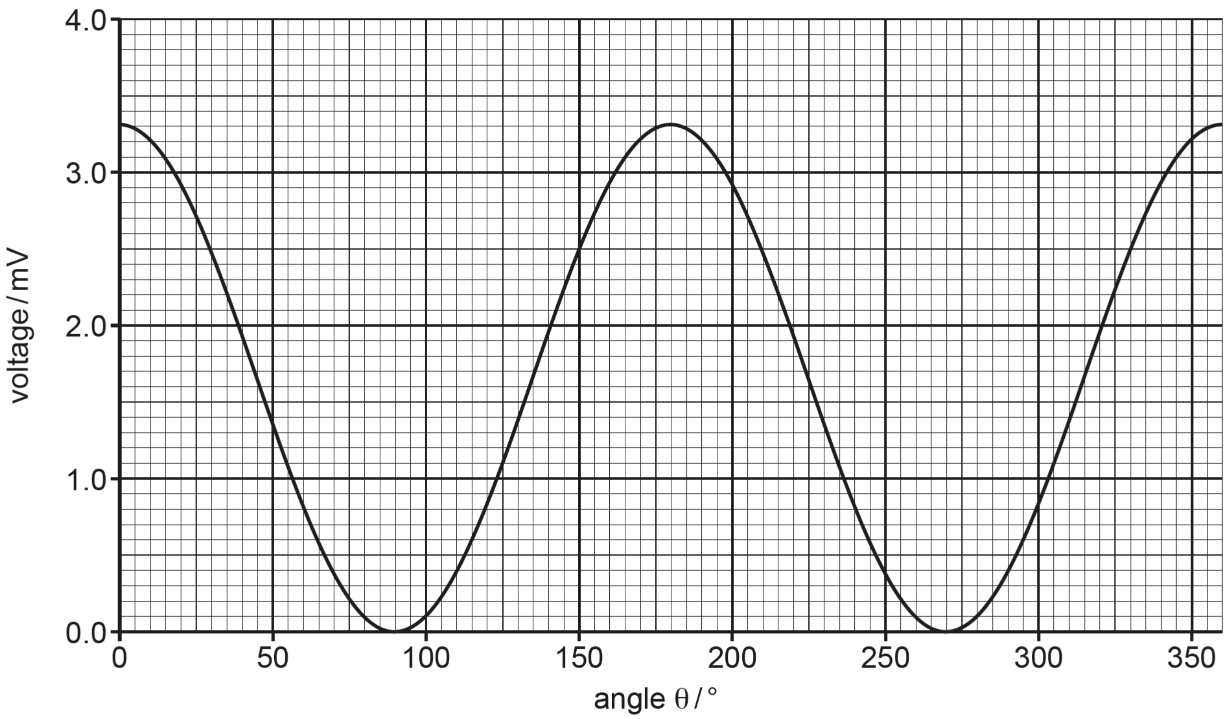


Fig. 1.2

Many candidates followed the correct method here to take pairs of coordinates from the graph and then find a constant of proportionality. Some candidates just stated that it followed the shape of a $\cos^2$ graph so must follow this hypothesis, while others only took coordinates from the same value of voltage. Some candidates erroneously thought that intensity would be proportional to voltage^2.

Question 2 (a) (i)

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**.

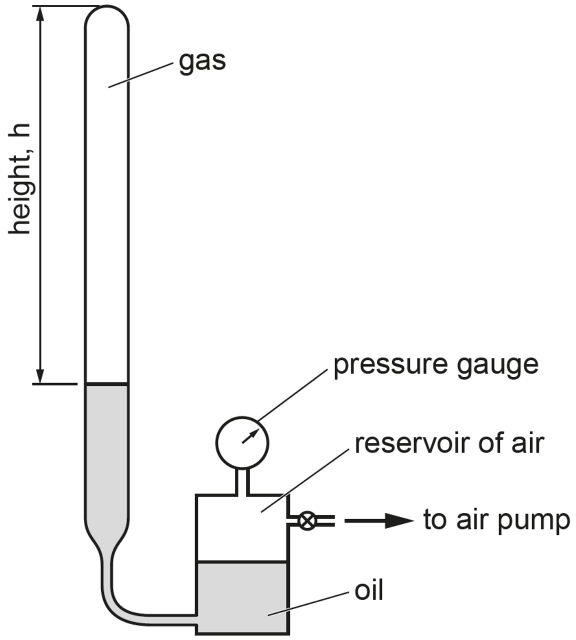


Fig. 2.1

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

.... **[1]**

While most candidates correctly identified that the temperature should remain constant for Boyle's Law to be used, some made impractical suggestions such as the volume of oil. This would be unlikely to change for the duration of this type of investigation.

Question 2 (a) (ii)

(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.

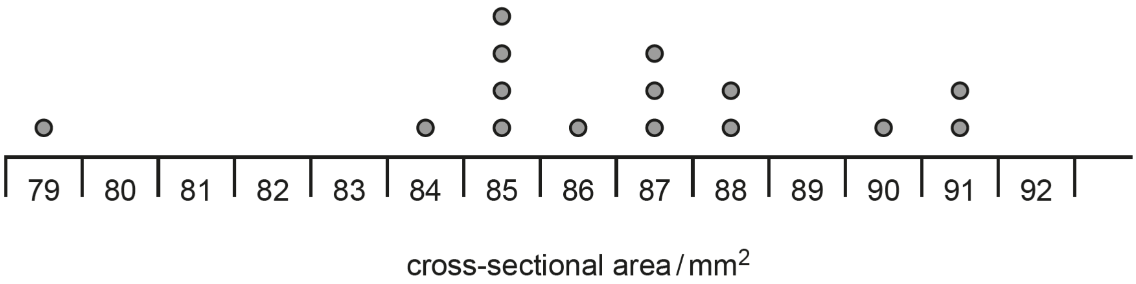


Fig. 2.2

Mean cross-sectional area = ... mm^2 ± .... % **[4]**

Most candidates gained 3 of the 4 marks in this question. For candidates who had completed the calculation correctly, a common error was to use inappropriate significant figures in the final answer. Some candidates either ignored the instruction to identify outliers or decided that there were 4 outliers.

Question 2 (a) (iii)

(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.

....

....

.... **[2]**

Few candidates answered this question correctly. Most candidates refer to the smallest division on a standard laboratory metre rule and suggest that this, or half this will be the absolute uncertainty of the measurement. There is usually no consideration of how difficult it is to measure to the meniscus of oil inside a curved tube to the top of a curved glass tube. Also there were many candidates incorrectly thought that the smallest division on a meter rule is 1cm.

Assessment for learning

Candidates need to be aware that the smallest division on a measuring instrument may determine the precision to which a measurement should be recorded, but this is not necessarily the same as the absolute uncertainty in that measurement. In many cases it is not practically possible to measure to that precision.

Question 2 (b)

(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.

$\frac{1}{\text{absolute pressure}}$ = ... unit .... **[2]**

This was a straightforward question for most candidates, who were able to calculate the value correctly. It was simpler to either stick to using the values as they were given in kPa and then the unit for the reciprocal of absolute pressure will be kPa^{-1}. Alternatively convert everything to Pa first and then the unit will be Pa^{-1}. Where candidates calculated using pressure in Pa and then attempted to convert to kPa^{-1}, it is easy to make a mistake.

Assessment for learning

2.8×10^{-6} Pa^{-1} = 2.8×10^{-3} kPa^{-1} NOT 2.8×10^{-3} mPa^{-1}

Question 2 (c)*

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/absolute pressure shown in **Fig. 2.3**.

Height/m	1/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

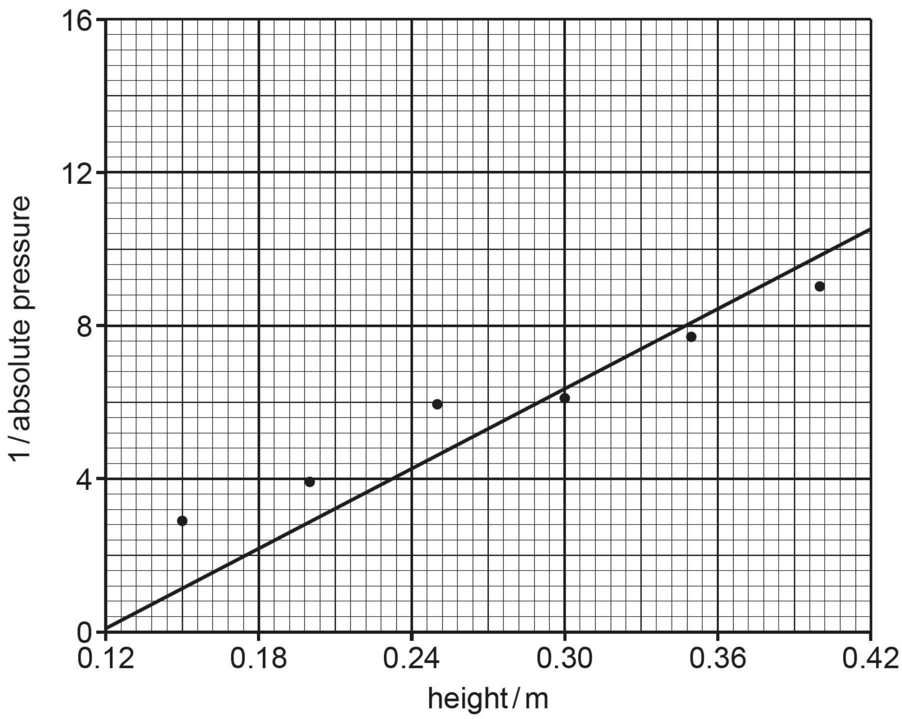


Fig. 2.3

(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 $25 \times 10^{-6}\,\mathrm{kN^{-1}\,m}$. 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.

....

....

....

....

....

.... **[6]**

Considering how much was wrong with the graph, it was disappointing that most candidates only made one or two suggestions for improvements. Some candidates did suggest changing the scales on the axes and adding units to the y-axis, but few wanted to re-draw a better line of best fit. So, they thought that the first plot (0.15, 2.28) was an outlier, rather than the third plot (0.25, 5.90) which is much further from the correct best line. The calculation was quite complex and some candidates did not lay out their working in a logical manner. Many candidates omitted any reference to the area of the tube which had been calculated in part (a), and there were a multitude of different power of ten errors.

Erratum Notice

Turn to **page 7** of the **question paper** and look at **question 2c**.

In the third line, cross out the letter 'k' in '25 x 10^{-6} kN^{-1}m'

The sentence should now read:

'The student calculates the gradient to be 25 x 10^{-6} N^{-1}m'

Exemplar 2

$PV = nRT$

$V = ha$

(h = height,
a = cross-sectional area)

$a = 87 mm^2$

$R = 8.31 J mol^{-1} K^{-1}$

$T = 298 K$

gradient $= 25 \times 10^{-6} N^{-1} m$

$\therefore Pha = nRT$

$\frac{1}{P} = \frac{ha}{nRT}$

$\frac{1}{P} = \boxed{\frac{a}{nRT}} \times h$

↑ gradient

gradient $= \frac{a}{nRT}$

$\therefore n = \frac{a}{RT \times \text{gradient}}$

$n = \frac{~~87mm^2~~ \; 87 \times 10^{-3} m^2}{8.31 J mol^{-1} K^{-1} \times 298 K \times 25 \times 10^{-6} N^{-1} m}$

$n = 1.41 mol$

The graph could be improved by drawing a new line of best fit because the line the student has drawn is too steep. ~~for the it app~~

~~The poin~~ ~~From~~ The line of best fit suggests the points at heights 0.15m, 0.20m and 0.25m are outliers.

in order to get volume from the height, you multiply it by the cross-sectional area (which is constant). ~~Therefore,~~ Therefore, ~~due to height~~ volume ∝ height. The graph shows that height ∝ $\frac{1}{\text{absolute pressure}}$. Therefore, volume is proportional to $\frac{1}{\text{absolute pressure}}$

This candidate has laid out some algebra to show clearly that the gradient of the line is equal to "area ÷ (RT × gradient)", and then substituted the correct numbers to work out the number of moles of gas present. Unfortunately there is a power of ten error in the final value as the area of 87 mm^2 should be $87 \times 10^{-6} m^2$. This is quite a good calculation part of the response.

There is an awful lot of things which can be improved on the presentation of the graph, but this candidate has only mentioned that the line drawn is too shallow for the plotted points. If the candidate had actually drawn a better line through the plots on the graph, they may have noticed that only one of the plots can really be considered as an outlier, not the three which this candidate describes.

This response is worthy of Level 2, but if more of the issues with the graph were mentioned, then because of the good calculation this could have got up to Level 3. There are plenty of other suggestions to try to improve the graph, for example, to change the scales on both the x-axis and y-axis.

Question 3 (a)

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.

....

....

.... **[2]**

Most candidates demonstrated some understanding of the decay constant but their responses were often let down by language. The use of particle, isotope or atom decaying was a common error, as was suggesting that the decay constant was the rate of decay rather than the probability.

Question 3 (b) (i) and (ii)

(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 $\lambda = 0.4\,s^{-1}$. Using $\Delta t = 1\,s$ generates the model shown in **Table 3.1**.

Time elapsed / s	Number of nuclei, N	Number of nuclei decaying in $\Delta t = 1\,s$, $\Delta N = \lambda N \Delta t$	Number of remaining nuclei at $t + \Delta t$, $N - \Delta N$
0	5000	2000	3000
1	3000	1200	1800
2	1800		
3			
4			

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]**

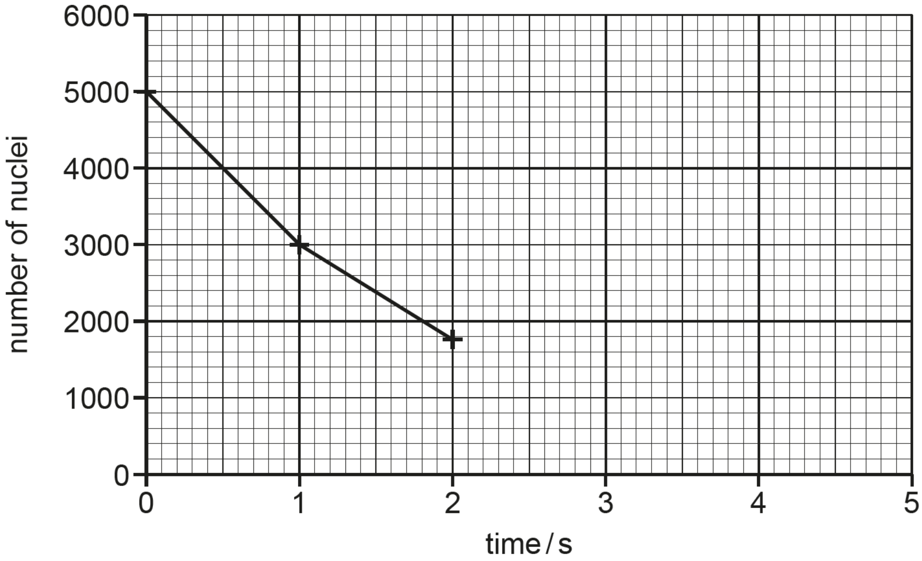


Fig. 3.1

This question was straightforward and most candidates got full marks on both parts (i) and (ii).

Question 3 (b) (iii) and (iv)

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

....

.... **[1]**

(iv) Explain why a better model is created if Δt = 0.5 s.

....

....

.... **[2]**

Most candidates missed the point in part (iii) that the activity is assumed to be constant in the model, but did appreciate that it is represented by the gradient of the lines between the plotted points. Most candidates appreciated that shortening the time between the steps would make a more realistic curve which was closer to the true exponential decay.

Question 3 (c) (i)

(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.

....

....

.... **[2]**

Many candidates struggled with this question and tried to explain it in terms of repeating readings to reduce uncertainties. Some candidates did not appreciate that for this experiment that there should be noticeable change of count-rate over the duration of the experiment and this is related to the half-life of the sample. Also the recorded counts in the 10 second periods should be measurable and this relates to the activity of the sample.

Question 3 (c) (ii)

(ii) **Fig. 3.2** shows a graph of ln(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.

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

Many candidates managed to correctly calculate the gradient of the line and equate this with the negative decay constant. Most of them used coordinates of points at least half the length of the drawn line apart. Some candidates misread the y-axis and thought that they had to find the log or the exponential of 4.38 and some were confused by the exponential function.

Section B

Question 4 (a) (i)

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**.

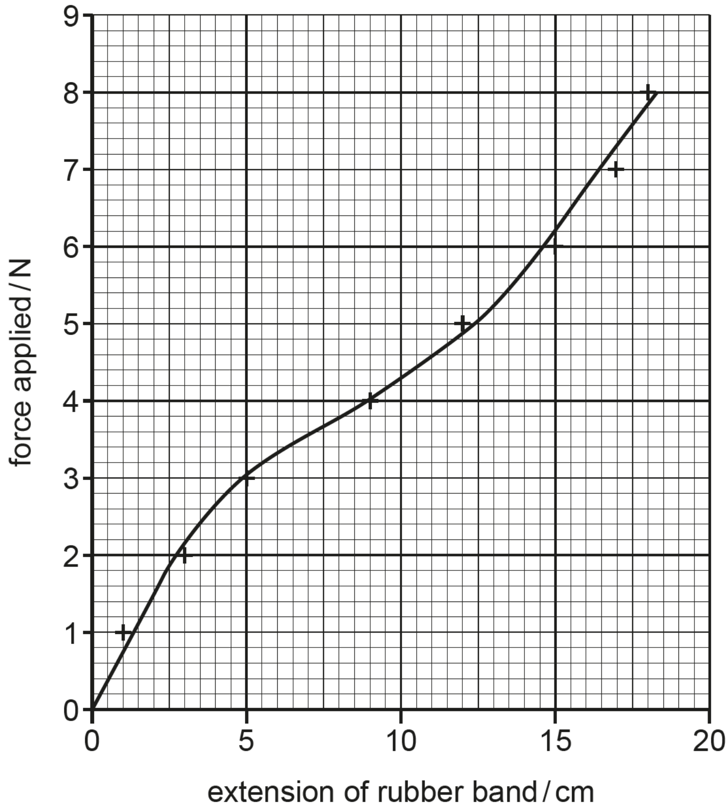


Fig. 4.1

(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.

....

....

....

....

....

.... **[4]**

Many candidates were able to describe a suitable method for this investigation, and most did identify the largest source of uncertainty as the measurement of length or extension of the rubber band. Explanations of how to mitigate such uncertainty often lacked sufficient detail. For example some candidates mentioned a 'fiducial' marker without any indication of where or what this would be used for. Most candidates appreciated that there was a risk that the band might break and that safety goggles would be advisable.

Question 4 (a) (ii)*

(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.

[6]

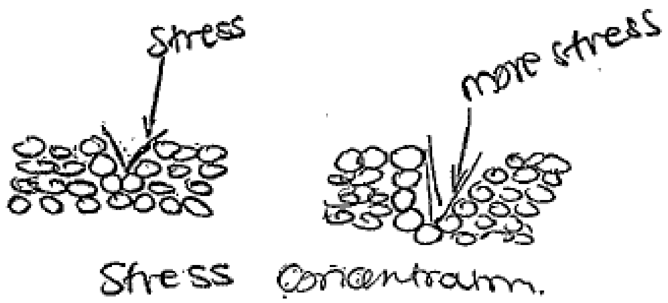
Responses to this second LOR question were disappointing. Most candidates suggested that the rubber band would be deforming plastically and attempted to describe its behaviour to be similar to that of a metal. Many candidates did attempt to describe the microstructure of rubber as being long chain molecules which were initially coiled up, would then straighten out and start to move past one another, breaking any cross links between the molecules, but they did not relate this back to the graph correctly. The graph showed how the force on the band and its extension were related; and showed that the stiffness of the rubber varied as more force is applied. Few candidates even mentioned stiffness in their responses. Candidates seemed very familiar with Hooke's Law and stated that the rubber band followed Hooke's Law for small forces and then plastically deformed. Candidates confused proportionality between force and extension with elastic behaviour. There is no indication of whether the material is elastically or plastically deforming from the force-extension graph. Despite candidates maybe not having carried out such an investigation they should be familiar with rubber bands and realise that they do not plastically deform; after all, they are often referred to as 'elastic' bands.

Misconception

A straight line on a force-extension graph is not an indication of elastic behaviour. In fact the limit of proportionality between force and extension is not exactly coincident with the elastic limit for a metal. It is usually quite close but there is usually a slight curve just before a metal begins to deform plastically.

The force-extension graph cannot indicate whether a material is elastically or plastically deforming unless both loading and unloading lines are plotted. The gradient of the force-extension graph gives a value for stiffness. A steep line indicates that a large force is needed for small extension and vice-versa.

Exemplar 3



The rubber band was extending elastically until around 4cm of extension where it reached it's elastic limit hence it stopped following Hooke's law and force and extension are ~~pr~~ directly proportional. Then it extended plastically where the rotational bonds in the rubber band line up and now starting to break. So as force increases, the stress increased but some areas stress concentration occur where the stress it builded up at rip apart the bones, one layer at the time as shown in the diagram above & This can be seen on the graph as the ~~the~~ gradient decreases ~~stress overall decreased~~. Until the rubber band reaches it fracture point and breaks at 16.5cm extension. **[6]**

This response starts off with some simple diagrams showing that the rubber band is made up of coiled up polymer chains which straighten when loaded and then return to their original positions when the load is removed.

The candidate's writing also states that the rubber band is deforming plastically and that it does not follow Hooke's Law. The candidate refers to the rubber band being relatively strong as it does not plastically deform at high stresses, but there is no description of the shape of the curve. This is only a Level 1 response. In order to achieve Level 2, there should be some description of the gradient of the curve and how it relates to the stiffness of the material. The stiffness can then be related clearly to the movement of the polymer chains in order to get up to Level 3.

Question 4 (b) (i)

(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.

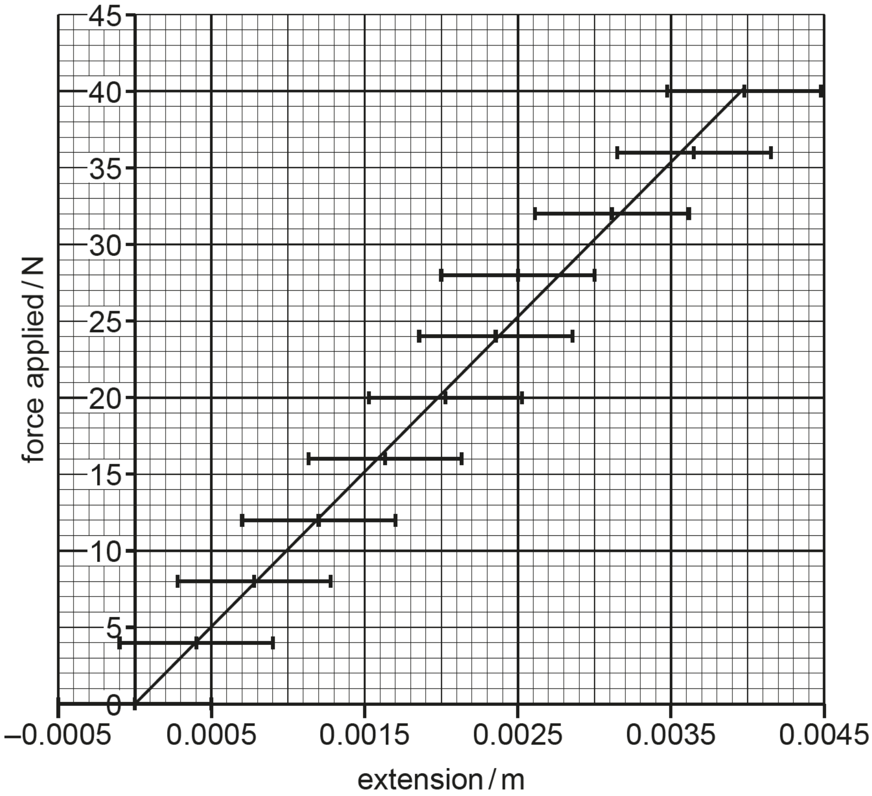


Fig. 4.2

(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]**

Most candidates were able to draw either the least steep or the most steep line within the error bars. A common error was to force the new line through the origin.

Question 4 (b) (ii)

(ii) The gradient of the line of best fit in **Fig. 4.2** is 10 100 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.

Young modulus = ... GPa ± .... GPa **[3]**

Most candidates realised how to use the gradient to find a value for Young Modulus, although some made more work for themselves by calculating their own value and not using the one given in the question. There were some power of ten errors in the calculation of the area and some used diameter as radius in the calculation. Many candidates correctly found a gradient for their worst-fit line and used that to work out the uncertainty on their value for Young Modulus. There was a lot to do in this question so candidates were not penalised for using too many significant figures in their uncertainty values in this question. This had been penalised in a Question 2(a)(ii) earlier in the paper.

Erratum notice

Turn to **page 15** of the **question paper** and look at **question 4bii**.

In the first line, cross out the unit 'M' and change to 'm'

The sentence should now read:

'The gradient of the line of best fit in **Fig. 4.2** is 10 100 Nm^{-1}'

Question 4 (c) (i)

(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.

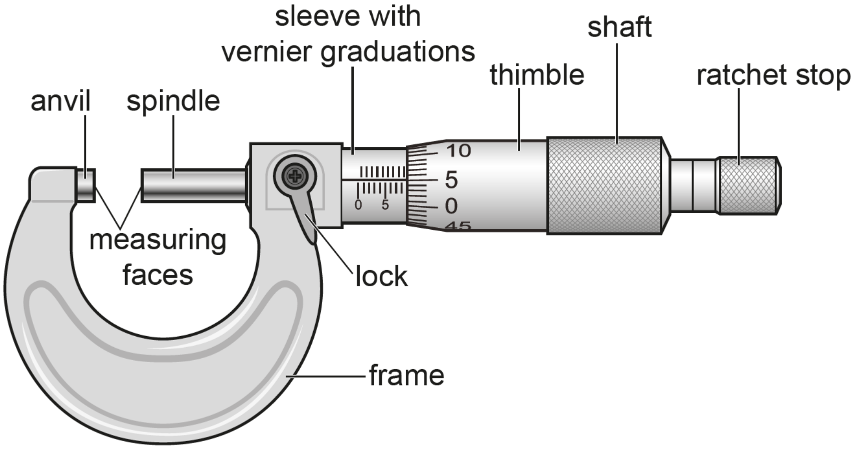


Fig. 4.3

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

Resolution = ... unit .... **[1]**

There was a wide variety of responses here, but many did get the correct value of 0.01 mm. A few candidates misread the question and gave an answer relating to the value read from the diagram.

Question 4 (c) (ii)

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

....

....

....

.... **[2]**

Many candidates repeated part of the question stem about taking multiple measurements but did not mention that they should be in different planes or places along the wire. Most candidates did explain that half the range would give the uncertainty but there is some confusion with the terms "range" and "spread".

Question 4 (c) (iii)

(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.

Area = ... m^2 ± .... m^2 **[3]**

Generally the value for area was correct, with a few candidates getting a power of ten error or using diameter as radius in the calculation. Candidates used different methods for finding the absolute uncertainty in the calculated value. Some of those who used the percentage uncertainty method forgot to double the % uncertainty in the diameter to find the % uncertainty in the area.

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