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Examiners' report

PHYSICS B (ADVANCING PHYSICS)

H557
For first teaching in 2015

H557/03 Summer 2018 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. 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 can be downloaded from OCR.

Paper H557/03 series overview

This paper is worth 60 marks out of the total 270 marks for the qualification. It can include content from all teaching modules but places emphasis of practical skills. Most parts of the paper include structured questions, problem solving and calculations, as well as Level of Response (LOR) questions. In this paper there were 3 LOR questions giving candidates opportunities to show their understanding of experimental techniques with which they should be familiar.

A large proportion of the questions in this paper covered assessment objective 2(the application of scientific knowledge and understanding), and compared to papers 1 and 2, there was also a significant amount covering assessment objective 3 (analysis, interpretation and evaluation of scientific information, ideas and evidence).

This paper appeared to be accessible to most candidates as there was a wide spread of marks and there was no evidence that candidates had run out of time.

Question 1(a)(i)

1 (a) A student uses the circuit shown in Fig. 1 to investigate the characteristics of a filament bulb.

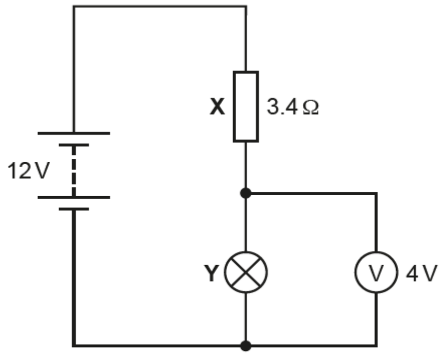


Fig. 1

(i) Show that the resistance R of the filament bulb **Y** in this circuit is approximately 2 Ω.

[2]

Few candidates struggled with this straightforward calculation of resistance in a potential divider circuit. Most used the single step calculation using the ratio of potential difference being equal to the ratio of resistance, whilst a few performed a two-step calculation by first finding the current flowing through resistor X. The actual resistance of the bulb in this question is 1.7Ω

Question 1(a)(ii)

The bulb is broken and the diameter of the filament wire is measured. The diameter is found to be 0.046 ± 0.002 mm.

(ii) Calculate the cross sectional area A of the wire and the uncertainty.

A = ... ± .... m^2 **[3]**

Most candidates were able to correctly calculate the cross-sectional area of the wire. Common errors here included power of ten errors because the diameter was not converted from mm to m and of using the diameter as the radius. There were different methods used to find the uncertainty in the area. Many candidates found the percentage uncertainty in the diameter and then multiplied this by 2 to find the percentage uncertainty in area. Others found the maximum possible area and/or the minimum possible area and then worked out the absolute uncertainty. If candidates had an incorrect value for area it was still possible to gain the two marks available for finding the uncertainty. Common errors in finding uncertainty included squaring the percentage uncertainty in diameter, giving the absolute uncertainty in radius (rather than diameter) to be ±0.002 mm and doubling the absolute uncertainty in diameter instead of the percentage uncertainty.

Question 1(a)(iii)

(iii) The filament is removed from the bulb housing and the length is measured to be 20 cm. Using your answer from **(a)(i)** calculate the conductivity σ of the filament of the bulb stating any assumption(s) that you make.

σ = ... Sm^{-1}

Assumption(s): ....

.... **[3]**

Most candidates were able to calculate conductivity from the data given. Some chose to first find the conductance and then use the equation σ = GL ÷ A, whilst others combined equations and used the relationship σ = L ÷ RA instead. There were some power of ten errors where candidates did not use length and area in consistent units, and a few candidates confused conductance and resistance, or resistivity and conductivity.

The most common assumption given was that the area, diameter or radius was constant along the length of the wire. Few stated that there was no other resistance in the bulb and some commented on the conductivity or resistivity being unaffected by temperature change. Candidates who stated that there was no change in temperature missed the point in this question.

Question 1(b)*

(b)* A new working **identical** bulb is put in the circuit in Fig. 1. The resistor **X** is changed to one with a resistance of 6.9 Ω. A student calculates that the voltage across resistor **X** will now be 6.0 V.
Using ideas about current, temperature and the structure of metals explain whether or not the student is correct.

....

.... **[6]**

There was some misinterpretation in this question as a few candidates thought that there were now 2 working bulbs in the series circuit with the larger 6.9Ω resistor. These candidates were still able to access all the marks in this LOR question.

Most candidates supported their explanation with some simple calculations of potential difference, resistance or current to show that the candidate was incorrect. The potential difference across resistor X should be larger than the 8V in the first circuit, so there was no way it was going to be 6V. Some candidates showed some confusion in their explanations as they attempted to make their correct explanation of how temperature affects resistance in a filament bulb, by then unfortunately stating that this new lower current would cause the temperature in the bulb to increase. There were also a few candidates who described the mechanism for current flow in semiconductors instead of metal wires.

In order to gain Level 3 candidates needed to give clear explanation of the mechanism for conductance in filament wires and to state that the candidate was wrong, and the potential difference across the resistor X is likely to be even larger than the 9V calculated using the bulb's resistance calculated in part (a)(i), due to the now lower current flowing through the filament.

Exemplar 1

Using ideas about current, temperature and the structure of metals explain whether or not the student is correct.

$I = \frac{V}{R}$ and $V_{out} = V_{in} \times \frac{R_X}{R_X + R_Y}$

If we are to calculate the theoretical voltage across the resistor X, then $V_{out} = 12 \times \frac{6.9}{6.9+1.7} = 9.6\,V$

However, it is assuming therefore no changes due temperature rises. The current carried around the circuit is proportional to the speed of charge carriers. However, As ~~the~~ more current travels through the filament ~~of~~ wire, the more it heats up by. This cause the ions in the metallic structure of the wire to vibrate more which obstructs the movement of charge carriers. This reduces the conductivity of a bulb and as ~~then~~ $G \propto \frac{1}{R}$, the resistance will rise. And as $V = IR$, the rise in R will cause a rise in the V and there will be a higher resistance ratio at the Y bulb and overall reduces the voltage across X.

L2 [6]

This candidate starts by correctly calculating the potential difference across resistor X when R_X = 6.9 Ω and the bulb has a resistance of 1.7 Ω. This is a correct macroscopic explanation. The candidate then goes on to explain that the resistance of a bulb varies with temperature because of the structure of a metal, and that resistance will be larger at higher temperatures. However, there is no mention of the fact that with a larger overall resistance in the circuit the current in the bulb would be lower and therefore the bulb would be at a lower temperature. This would lead to a reduction in resistance of the bulb, so the potential difference across the resistor would be even higher than the originally calculated 9.6 V.

Question 2(a)

2 An experiment is carried out to find the half-life of a solid radioactive isotope **X** which emits beta radiation.

(a) Describe **two** safety precautions necessary for handling such a material in the laboratory.

....

....

....

....

....

.... **[2]**

Most candidates were able to give two appropriate safety precautions for handling radioactive isotopes in the laboratory. Vague statements such as keep a long distance away, or store in a protective container were not credited; neither were inappropriate suggestions such as wear lead body protection.

Question 2(b)(i)

(b) The results obtained from the experiment are given in the table below.

Time t/s	Count rate/Bq	Corrected count rate A/Bq	ln (A/Bq)
25	9.2	8.0	2.08
50	7.5	6.3	1.84
75	6.0	4.8	1.57
100	4.8		1.28
125	4.1	2.9	
150	3.4	2.2	
175	3.0		0.59
200	2.7	1.5	0.41
225	2.4	1.2	0.18

(i) Explain what is meant by "Corrected count rate" **and** complete this column in the table.

....

....

.... **[2]**

This was a straightforward question with most candidates gaining both marks for the correct values for corrected count rate and some implication of subtracting background radiation count to find the corrected count rate. A few candidates confused cosmic microwave radiation for background radiation.

Question 2(b)(ii)

(ii) Complete the fourth column of the table by calculating the missing values for ln (A/Bq). **[1]**

Nearly all candidates correctly calculated the ln(A) and gave their values to 2 decimal places.

Question 2(b)(iii)

(iii) A graph of ln (A/Bq) (y-axis) and t (x-axis) is drawn in Fig. 2. Plot the remaining points on the graph and draw the line of best fit. **[2]**

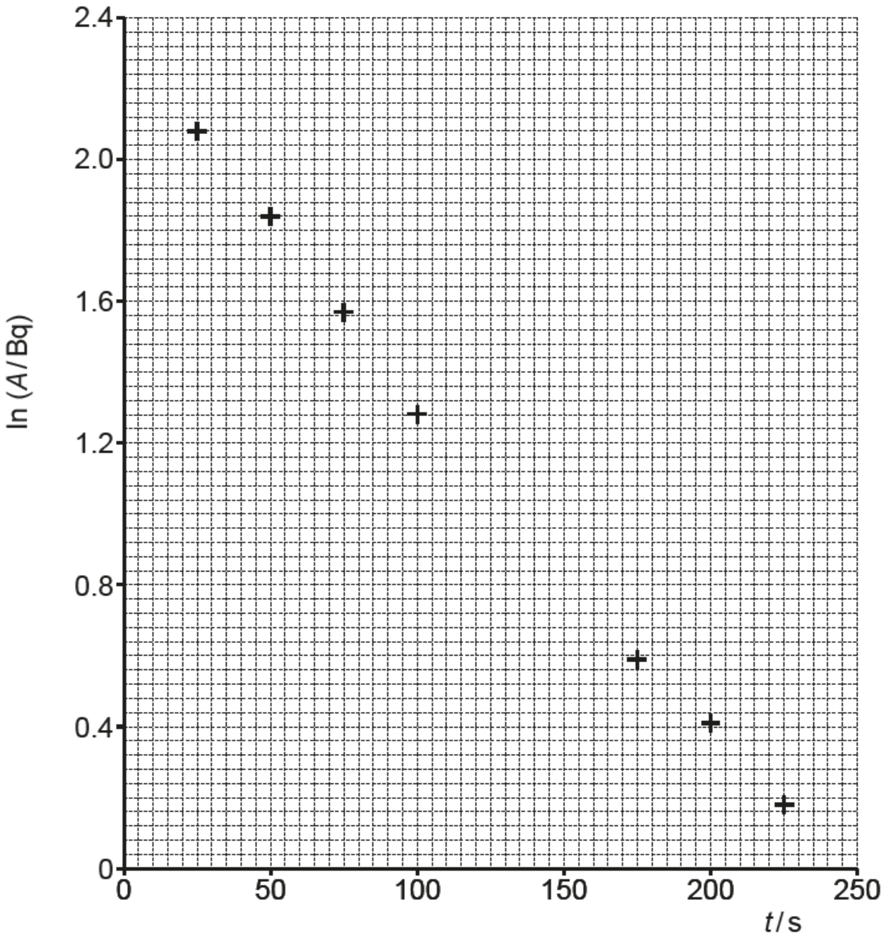


Fig. 2

Nearly all the candidates correctly plotted the two points. The position of the line of best fit is slightly subjective so a range of lines were possible. The mark was credited where it was felt that there was a reasonably balance of plots either side of the line, but those lines which would have looked better if they were rotated slightly did not gain the mark.

Question 2(b)(iv)

(iv)* Use your graph to find the value of half-life for the radioactive isotope **X** and explain the advantages of using ln (*A*/Bq) against *t* over an *A* against *t* graph to find half-life. **[6]**

For the first part of this question, candidates were expected to calculate decay constant (-λ) by finding the gradient of their line and then use that to find the half-life by dividing the gradient into ln2. The value for half-life calculated should have been about 70 s. Although many candidates did use this method, some used other valid methods such as finding the value for A_0 from the y-intercept ($A_0 = e^{\text{y-intercept}}$), calculation half that value, and then reading the time from the graph, or substituting appropriate values into the relationship $A = A_0 e^{-\lambda t}$. Some candidates incorrectly found the time for the value of ln A to halve rather than the time taken for the activity A to halve.

In order to reach Level 3, candidates should have used the gradient method to find half-life, and showed some derivation of the relationship between gradient and decay constant; for example:

$$A = A_0 e^{-\lambda t}$$

$$lnA = \ln A_0 - \lambda t$$

The line drawn has the equation $y = mx + c$; so c = $\ln A_0$ and m = -λ.

Candidates were also expected to compare the logarithmic graph of ln A against t with an exponential decay curve from a plot of A against t. Relevant comments ranged from the simple statement that it was easier to draw a straight line of best fit than a curve through the points on an exponential plot, to some developed arguments relating to the randomness of radioactive decay causing more inaccuracies at low levels of activity. Descriptions of how to calculate the half-life from an exponential curve, and why it was not particularly accurate, were often included and these could have been exemplified by the addition of a sketch graph.

Level 2 responses usually required some correct calculation of the half-life, by any method, and some comparison of the two methods.

Exemplar 2

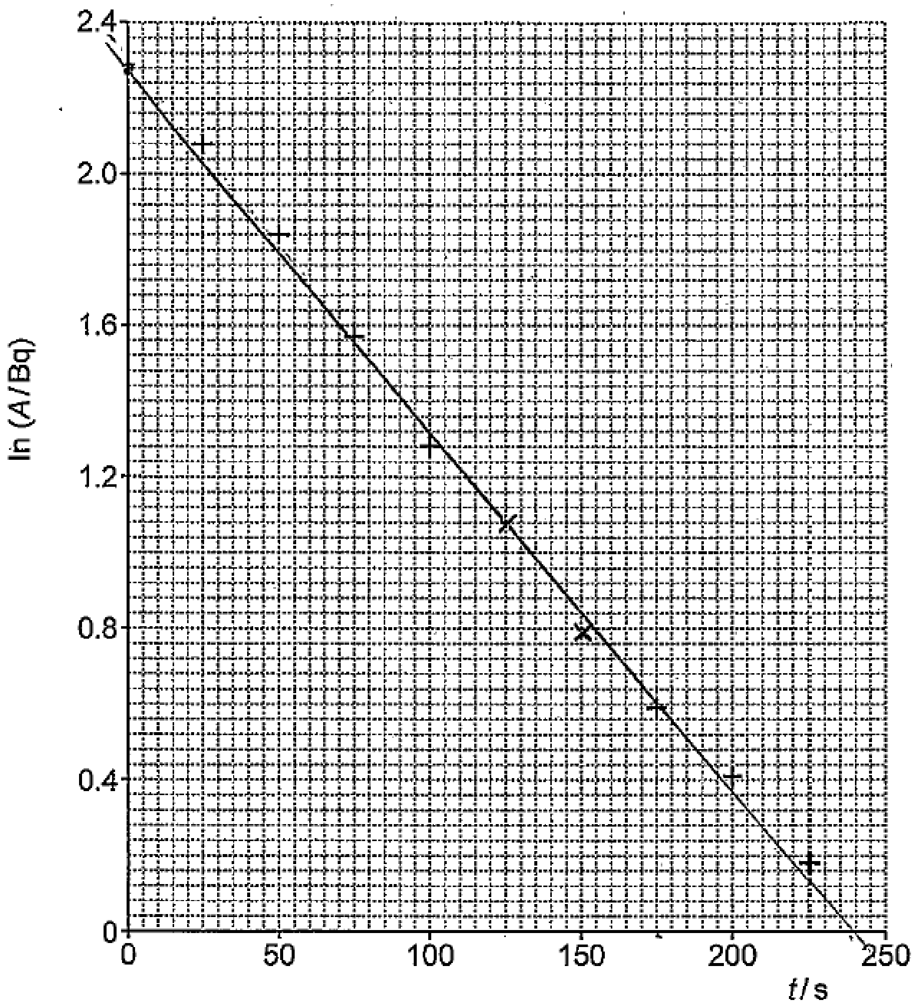


Fig. 2

(iv)* Use your graph to find the value of half-life for the radioactive isotope **X** and explain the advantages of using ln (*A*/Bq) against *t* over an *A* against *t* graph to find half-life. **[6]**

$A = A_0 e^{-\lambda t}$

$\ln A = \ln A_0 + -\lambda t$

intercept   decay constant = gradient

gradient = $\frac{1.75 - 0}{60.6 - 2.22}$ = ~~-108.0~~ $-0.00925 = -\lambda$

$\frac{\ln 2}{\lambda} = T_{\frac{1}{2}} = \frac{\ln 2}{0.00925}$ = half life = 74.9 s

Using an ln(A) graph is more accurate as it reduces the random nature of radioactive decay which is present in the exponential graph of A against t.

The random nature of decay leads to discrepancies in the results from real life to results in the experiment, which decreases the experiment's accuracy.

Furthermore, with the ln graph, only one calculation is needed, which is the gradient to work out the decay constant. With the A against t graph, it is an exponential, so many readings need to be taken to work out an estimate of the half life, which isn't as accurate as the lnA method.

L3 ^

The exponential relationship is clearly converted to logarithmic form and compared to y = mx + c. The half life is then determined from the value calculated for gradient. Two advantages of using a logarithmic graph are explained. There is reference to the random nature of radioactive decay, and the need for taking several readings from an exponential curve to find an estimate of half-life. This response is Level 3.

Question 3(a)

3 In 1917 Robert Millikan investigated the motion of tiny oil drops in an electric field and used this to determine the charge on the electron. He sprayed tiny oil drops between two parallel metal plates connected to a high voltage power supply and observed their motion. The experiment was set up as shown in Fig. 3.

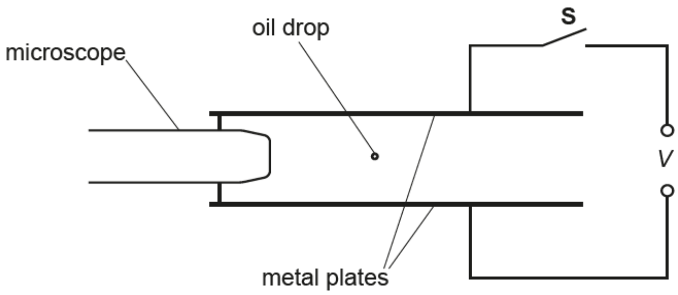


Fig. 3

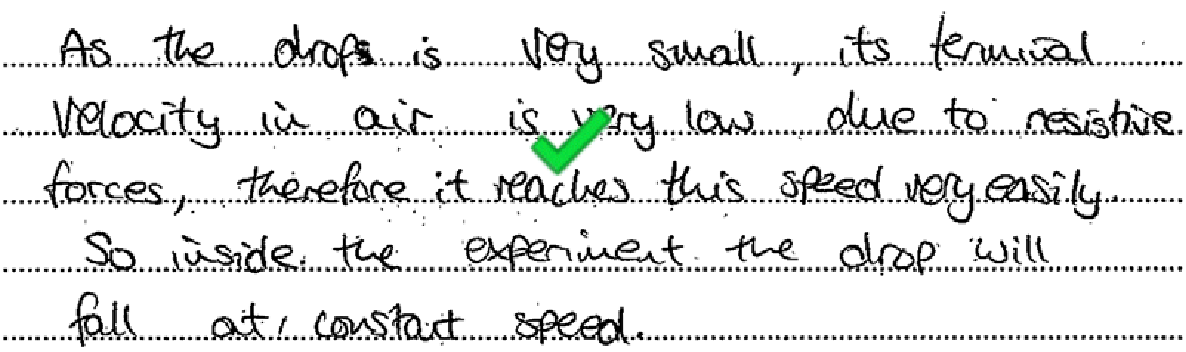
As the oil drops are forced through a spray nozzle they become negatively charged.
With switch **S** open there is no potential difference between the plates and the oil drop is observed to be falling at constant velocity through the air.

(a) Explain why the oil drop falls at constant velocity through the air.

[3]

Most candidates achieved at least one mark here for stating that the oil drop reached terminal velocity. The other two marks were more challenging as it was necessary to state that the force from air resistance was equal and opposite to the weight, so therefore the resultant force is equal to zero. Candidates needed to correctly define the two forces and more often than not, the word 'opposite' was omitted. A few candidates did not realise that there was no electric force at this point.

Exemplar 3


As the drops is very small, its terminal velocity in air is very low due to resistive forces, therefore it reaches this speed very easily. So inside the experiment the drop will fall at constant speed.

This response gains one mark for stating that the oil drop reaches terminal velocity. However there is no mention of the weight of the oil drop being equal and opposite to the air resistance force, thereby giving a resultant force equal to zero.

Question 3(b)(i)

(b) The switch **S** is closed and the potential difference is adjusted until the oil drop remains stationary between the two parallel plates.

The following data are recorded:

potential difference $V = 390\,\text{V}$
distance between the plates $d = 6.0\,\text{mm}$
mass of an oil drop $m = 2.15 \times 10^{-15}\,\text{kg}$.

(i) Calculate the electric field strength E between the two parallel plates.
Include a suitable unit.

E = ... unit .... **[2]**

Most candidates were able to perform this relatively straightforward calculation, with a minority giving an incorrect unit or making a power of ten error.

Question 3(b)(ii)

(ii) Calculate the charge q carried by each oil drop.

q = ... C **[3]**

This calculation proved to be slightly more challenging than part (ii). A few candidates attempted to use an incorrect equation, such as the force between two point charges.

Question 3(b)(iii)

(iii) This calculation does not take into account the effect of buoyancy from the displaced air. This effect produces an additional upwards force on the oil drop. Explain what effect this would have on the value calculated for charge.

....

....

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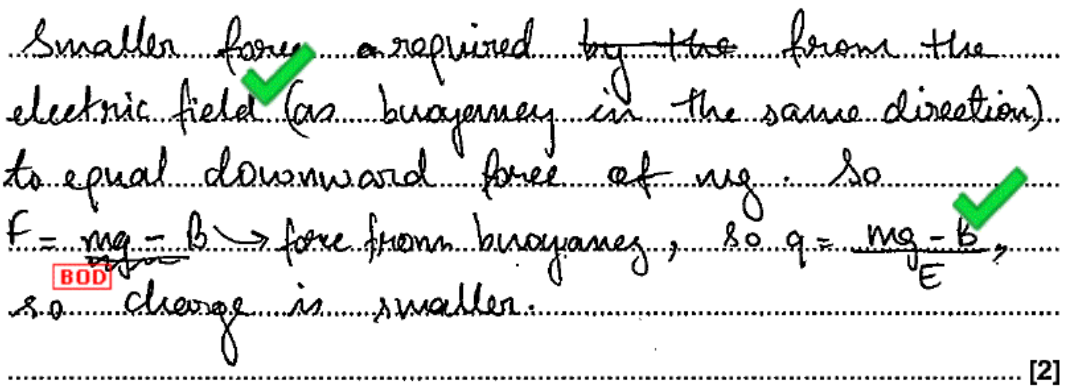
....

....

.... **[2]**

There were several confusing responses to this question. Candidates needed to be precise about which force was which and they needed to be clear about whether they were talking about the calculated value for charge or the actual charge in order to gain the marks.

Exemplar 4


Smaller force ~~a~~ required ~~by the~~ from the electric field (as buoyancy in the same direction) to equal downward force of mg. So $F = mg - B$ → force from buoyancy, so $q = \frac{mg - B}{E}$, so charge is smaller.

BOD

[2]

This response has stated that the electric field strength would be less than that calculated, which is incorrect as the electric field strength is only dependent on the potential difference and the distance between the two plates. It is the electric force which now needs to be smaller, and as the field strength is the same, this means that the value calculated for charge was too large. This response gets one mark.

Question 3(c)

(c) The charge on the parallel metal plates is reversed. Explain the effect this has on the motion of the oil drop.

....

....

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....

....

.... **[2]**

Responses to this question also needed to be specific. Candidates who just stated that the oil drop would move towards the bottom plate were not credited, as it was necessary to state that it would accelerate downwards. The other marking point was for clearly stating that both the electric force and the weight were acting in the same direction, so candidates who just said that the electric force was now downwards did not gain the mark.

Question 4(a)(i)

4 This question is about an experiment to determine the Young modulus of a copper wire. The diameter *D* of the wire was measured using a micrometer screw gauge in several places along the length of the wire. The values obtained are shown in the dot-plot shown in Fig. 4.1. Each dot represents one reading.

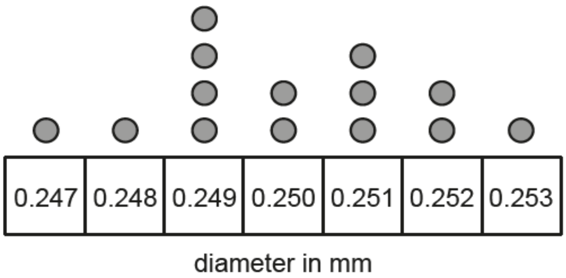

Fig. 4.1

(a) (i) Use the information in the dot-plot to find the mean *D*. Use the spread to determine the percentage uncertainty.

mean *D* = ... mm ± .... % **[3]**

Most candidates correctly calculated the mean value of D as 0.250 mm and the percentage error. A few left the value for D to only 2 significant figures and some candidates used the whole range of values (0.006) rather than the spread (0.003) to calculate the percentage uncertainty.

Question 4(a)(ii)

(ii) Calculate the cross sectional area *A* of the wire and include the uncertainty.

A .... ± .... m^2 **[3]**

Most candidates were able to correctly calculate the area from the diameter, but there were a number who either forgot to convert to metres, or used the value for diameter as the radius. Similarly to question 1(a)(ii) a number of methods were used to find the absolute uncertainty and similar mistakes occurred.

Question 4(b)

(b) A marker is placed to give an original length of the wire as 4.00 ± 0.02 m.
Fig. 4.2 shows the extension *x* of a metal wire at different applied loads *F*. *x* is measured to ± 0.5 mm and *F* is measured to ± 0.2 N. Fig. 4.2 shows the force-extension graph for the wire.

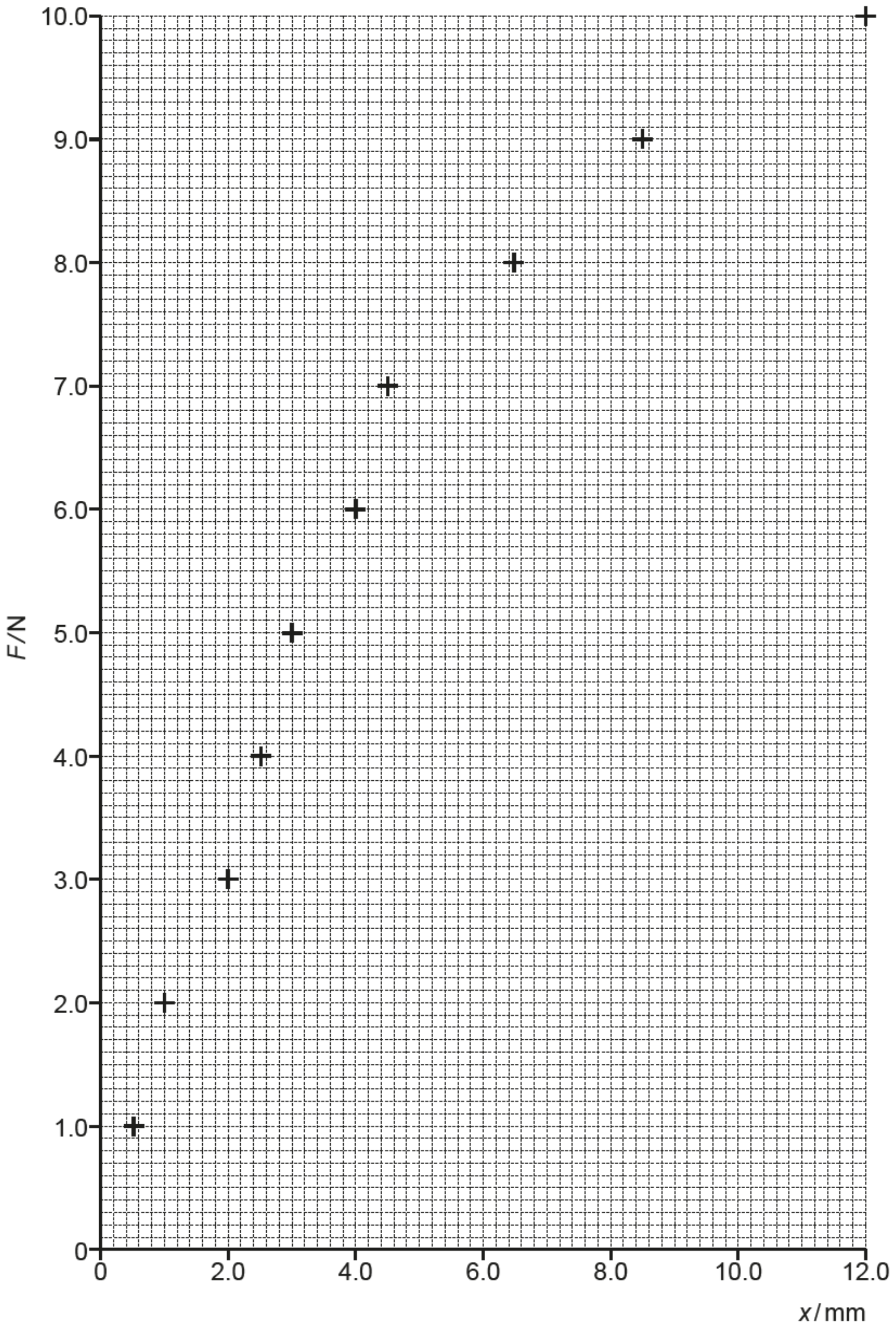

Fig. 4.2

Question 4(b)(i)

(i) On Fig. 4.2
1 complete vertical and horizontal error bars on each of the plots
2 label the regions of elastic and plastic deformation
3 draw a line of best fit through the straight section of the graph. **[4]**

Nearly all the candidates correctly identified the elastic and plastic deformations regions of the graph, and many correctly added error bars in both x and y directions. There were more mistakes in the horizontal error bars than vertical bars. Many candidates incorrectly and unnecessarily forced the line of best fit through the origin and ended up with too many plots to the left of the line. In practice it would be rare for the graph obtained from this experiment in a school laboratory would pass through the origin as it is difficult to eliminate all the kinks in the wire before loading.

Question 4(b)(ii)

(ii) Use the graph and the data given to calculate the value of the Young Modulus *E*. Include the appropriate unit.

E = ……………………….. unit .... **[5]**

In order to gain full marks in the question candidates need to use the gradient of the line rather than a single data point. Most candidates gave the correct unit and used the correct relationship to find Young Modulus. A few candidates mis-read the data from the graph or used two points on the line which were too close together.

Question 4(c)*

(c)* Use Fig. 4.2 and your answer to part **(b)(ii)** to estimate the percentage uncertainty in the calculated value of the Young Modulus and describe the main sources of error in the experiment. Suggest and explain possible improvements to the experiment. **[6]**

Several approaches to finding the percentage uncertainty in the value for Young Modulus were used, but a number were not well set out and identified. Many candidates added the individual percentage uncertainty in the four variables – force, area, extension and length, whilst others found the gradient of a steep and/or shallow worst fit line, and then used that to find a maximum and/or minimum value for E.

Whilst many candidates did realise that the variable with by far the greatest uncertainty was the extension, not all of them were able to describe appropriate mitigation in sufficient detail to gain Level 3. Many candidates' explanations made vague suggestions about using more precise measuring instruments without naming suitable ones. Candidates need to realise that rulers with smaller divisions would be unusable, and that using larger forces would result in plastic deformation, so this type of suggestions were not credited. The most obvious solution of increasing the length of the wire causes practical problems to do with space in the laboratory, which needed to be mentioned to gain higher level marks.

Other valid suggested improvements included increasing the area of the wire, but again candidates needed to mention that this would actually cause less extension so probably not worth doing in practice. Weighing any masses used with digital balance or using a digital Newton-meter were acceptable suggestions. Some candidates suggested using a different material wire, but this would defeat the object if they needed to find the properties of a particular material.

As it was clear from part (a), that a micrometer screw gauge was used to find several readings of the diameter of the wire, this was not credited in this question. If further details such as measuring diameter in different planes or directions to check that the wire was cylindrical, then credit could be given. Suggesting repeat readings also needed clear description to gain credit here. Candidates could suggest recording values of extension whilst loading and unloading the wire, or repeat the whole experiment on a new piece of the same wire and finding an average value for E, but not repeating readings of extension and finding the average as each wire will behave in a slightly different manner.

Exemplar 5

improve on this, a longer length of wire could be used. This would increase the value of the ~~percentage error~~ extension, and so the ±0.05mm uncertainty would be proportionally ~~significantly~~ lower, reducing overall uncertainty. To reduce uncertainty from the force, weigh each weight on a digital balance before adding onto the end of the wire. Percentage error would decrease as ~~force is a small~~ high resolution of the digital balance (±0.05g).

To improve experiment further, the extension can be measured by using a tracking microscope and a vernier scale which would reduce uncertainty to ±0.01 mm, ~~halving~~ a fifth of the current technique. Alongside longer length of wire, a ~~two~~ thinner wire would also increase the extension – this may reduce percentage ~~error~~ uncertainty from x, but may increase the uncertainty of A. To reduce the uncertainty from Area, ~~using~~ area could be calculated from density, ~~as~~ length and mass – density will be a given value, length and mass have smaller percentage uncertainties.

*Highest uncertainty → lowest: Extension, Area, Force, Length. ($x \Rightarrow \frac{\pm 0.05}{6.6} \times 100 = \pm 8\%$, $F = \frac{\pm 0.2}{10} \times 100 = \pm 2\%$)

This candidate has used the graph to find a lowest possible gradient and thence to a percentage uncertainty for the gradient. This is then combined with the percentage uncertainties of the length and the area. The list of uncertainties at the end of the text clearly identifies extension as having the largest uncertainty. In order to mitigate the uncertainties several suggestions are made; using a longer length of wire, weighing the individual masses on a digital balance and using a thinner wire. The latter suggestion is analysed in terms of increasing the uncertainty of the area, but as this is lower than the uncertainty in the extension it is still beneficial. This gains Level 3.

Exemplar 6

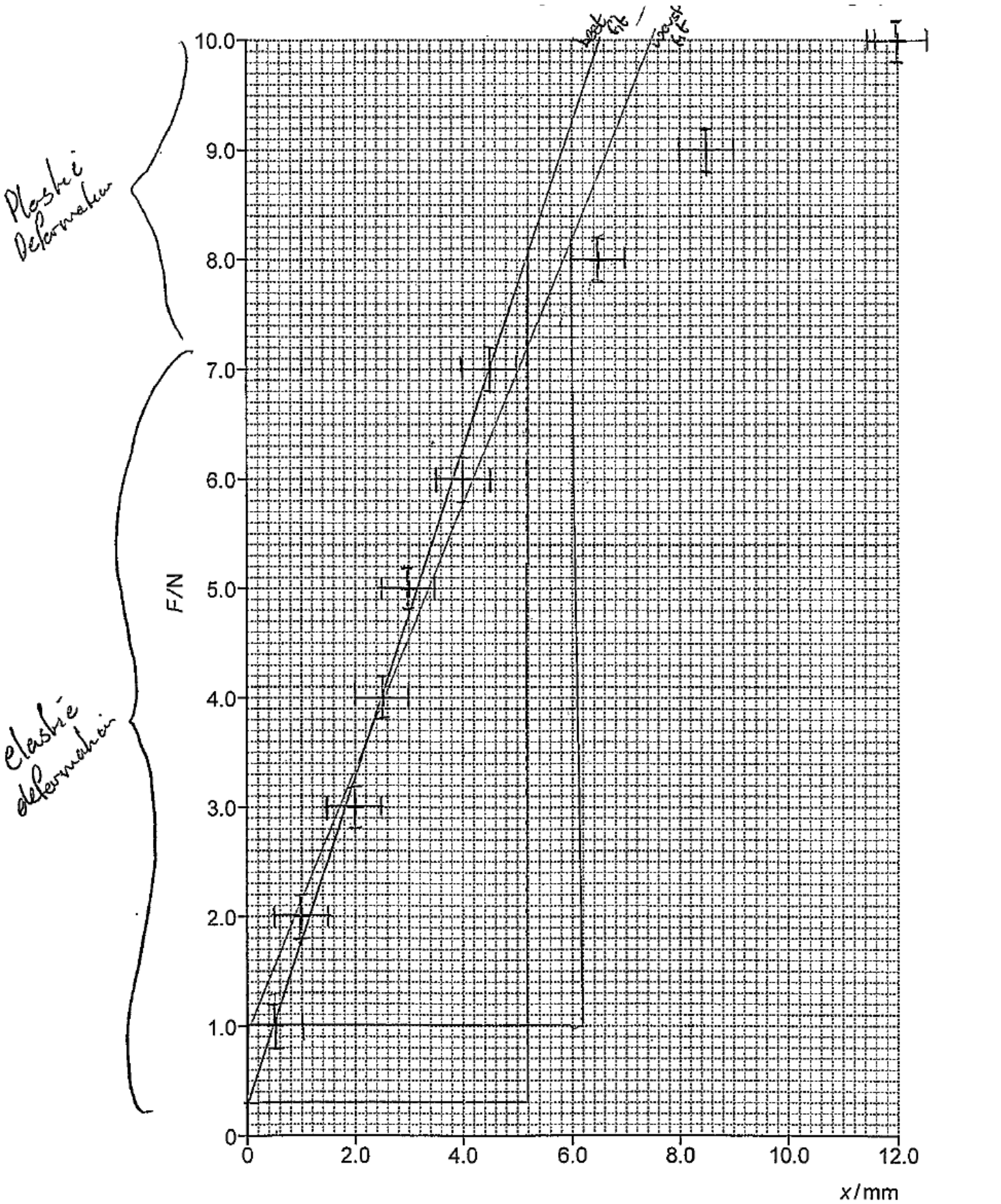

Fig. 4.2

~~% uncertainty (x) =~~
~~m~~ worst gradient = $\frac{\Delta y}{\Delta x} = \frac{8.2-1}{6.2\times10^{-3}}$ = 1161...
∴ % uncertainty in gradient = $\frac{1500-1161}{1500}\times100$ = ~~22~~.23 %
% uncertainty in L = $\frac{0.02}{4}\times100$ = 0.5%
% uncertainty in A = 1.2% ≈
∴ Overall % uncertainty = 22.6 + 0.5 + 1.2 = 24.3 %
≈ 24 %

~~% uncertainty in ...~~

The largest uncertainty comes from the gradient which is made from the extension and the force so these are the areas that we aim to improve. For the extension, we can ~~improve~~ reduce the % uncertainty by either using a more precise measuring device like a ~~digital vernier~~ digital vernier calliper or by increasing by we increase the values for x for a certain force and so we decrease the % uncertainty. In relation to the force, we can decrease the % uncertainty by using a more precise digital top-pan balance. The worst % uncertainty in the extension is $\frac{0.5}{0.5} \times 100 = 100\%$ in comparison to that of the force: $\frac{0.2}{1} \times 100 = 20\%$ ∴ The main source of uncertainty that is needed to be improved upon is the extension.

L3 ^

This response is Level 3. The percentage uncertainty in the gradient is calculated from an acceptable line of worst fit drawn on the graph in Fig 4.2. The percentage uncertainty for length is correctly determined, but the candidate has used the percentage uncertainty in diameter instead of the percentage uncertainty in area. Nevertheless, all the percentage uncertainties are correctly combined and the largest ones clearly identified. Appropriate suggestions for mitigating the uncertainty in both extension and force are explained.

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