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Examiners' report

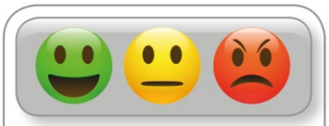
PHYSICS B (ADVANCING PHYSICS)

H557
For first teaching in 2015

H557/03 Summer 2019 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 exam paper can be downloaded from OCR.

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. Most parts of the paper include structured questions, 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 no evidence that candidates had run out of time.

Candidate performance overview

Candidates who performed well on this paper generally:

- Described experimental methods clearly and concisely, using appropriate scientific terminology in the LOR Questions 1(b) and 3(a).
- Rearranged algebraic relationships clearly in questions such as 2(a), 4(a)(ii) and 4(b).
- Demonstrated good understanding of uncertainties in questions such as 1(a)(ii), 2(b)(i), 2(c) and 4(c)(i), as well as the LOR questions.

Candidate who did less well on this paper generally:

- Produced lower quality diagrams and/or graphical work. For example, using less appropriate scales for the graph in Question 2(b)(iii), or a poor circuit diagram in Question 3(a), or the straight line in Question 4(c)(iii) missing one of the error bars.
- Showed limited understanding of technical vocabulary in their explanations of concepts particularly in Questions 3(b)(iii), 4(a)(i) and 4(c).

Note

From this series students have been provided with a fixed number of answer lines and an additional answer space. The additional answer space will be clearly labelled as additional and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their answers. Please follow this link to our SIU (https://www.ocr.org.uk/administration/support-and-tools/siu/alevel-science-538595/)

Question 1 (a) (i)

1 Manufacturers of spectacles (glasses) are keen to develop new materials for lenses. The refractive index of such materials is an important property to consider.

This question is about a method to determine the refractive index of a transparent polymer.

A ray box is used to shine a narrow beam of light through a block of the polymer. Fig. 1 shows the path of the light.

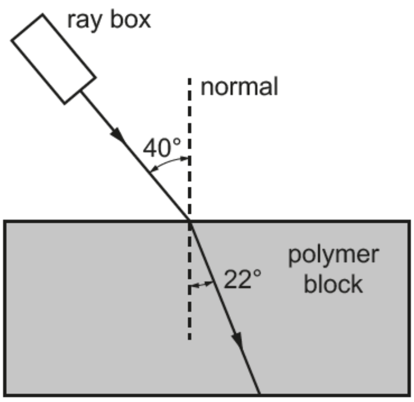


Fig. 1 (not to scale)

The angle of incidence is 40° and the angle of refraction is 22°.

(a) (i) Calculate the refractive index *n* of the polymer.

n = ... **[2]**

This seemed a straightforward start for most candidates. Nearly all got this correct; with only a handful of candidates using their calculator in radians mode and hence getting an incorrect value for refractive index.

Question 1 (a) (ii)

(ii) The absolute uncertainty in the measurement of each angle is ±4°.

Complete the table below with maximum and minimum values of the measured angles, and hence determine the absolute uncertainty in the calculated value of refractive index *n*.

Angle	Maximum value / °	Minimum value / °
angle of incidence, *i*		
angle of refraction, *r*		

absolute uncertainty in *n* = ± .... **[3]**

Nearly all candidates completed the table correctly. Most candidates used the correct combination of angles to find the largest and/or smallest values possible for n and then correctly found the absolute uncertainty. Common errors were to use an incorrect pair of angles, for example the largest value for angle of incidence with the largest value for angle of refraction. Others just tried adding percentage uncertainties of the angles, without any reference to finding the sine of the angle.

Question 1 (b)

(b)* Describe the method which could be used in this experiment to reduce the uncertainty in the calculated value of the refractive index of the polymer.

In your answer, include details of the experimental procedure and the analysis of data.

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.... **[6]**

Many candidates showed little knowledge of practical techniques which could be employed to measure the angles of incidence and refraction in this experiment. Many did suggest using a monochromatic laser and a digital angle measurer, without any reference as to how these would be used in practice. They do still need to record the path of a ray of light whether it is a laser beam or a narrow beam from a ray-box and many candidates omitted any such method. A detailed method which would help someone with some science knowledge to carry out the experiment could achieve Level 3. Some candidates did correctly suggest that a number of different values for angle of incidence should be used, and the corresponding values of refraction recorded, but only some of these went on to suggest that a graph should be plotted. A level 3 response should suggest plotting a graph of sin *i* against sin *r* and calculating a gradient to find refractive index as well as some discussion of how to find uncertainty in the calculated value.

Exemplar 1

Place the polymer block on A3 paper. Draw an outline of the block and place it there. Use a thin slit and a ray box to produce as narrow a beam of light as possible. Use a set square to accurately draw ~~an~~ normals from the outline. ~~Remove~~ Turn off the lights of the room in order to remove as much background lighting as possible. Draw over the incident ray of light and the ~~refracte~~ ray leaving the block. Draw normals at these points of intersection. Use a protractor to measure the angles between the lines and the normals. ~~Take~~ Make the angles of incidence as large as possible to reduce the percentage uncertainty of the angles. ~~Calculate the refractive~~ Draw a line between the two intersections to find the angle of refraction Calculate the refractive index using $n_1 \sin\theta_1 = n_2 \sin\theta_2$. Place the polymer block such that the ray will travel along the furthest distance in the block to further reduce uncertainty of the angles. Repeat readings and take readings from a wide range of values. Calculating their respective refractive indices and then find an average.

This candidate has described a practical method for finding the angles. It includes drawing the normal lines using a set square and marking the paths of the rays of light as they travel through the block. The suggestion of dimming the lights will also aid the process. The candidate also explains how to calculate the refractive index and suggests repeating readings and using a range of values for the angle of incidence. This is a Level 2 response. In order to get up to Level 3, it needed to include a graphical method to find refractive index.

Question 2 (a) (i)

2 This question is about determining the acceleration due to gravity *g* using a simple pendulum.

(a) The pendulum bob has mass *m* and the length of the pendulum string is *L*.

Fig. 2.1a shows the pendulum with angle of deflection θ and bob displacement *x*.

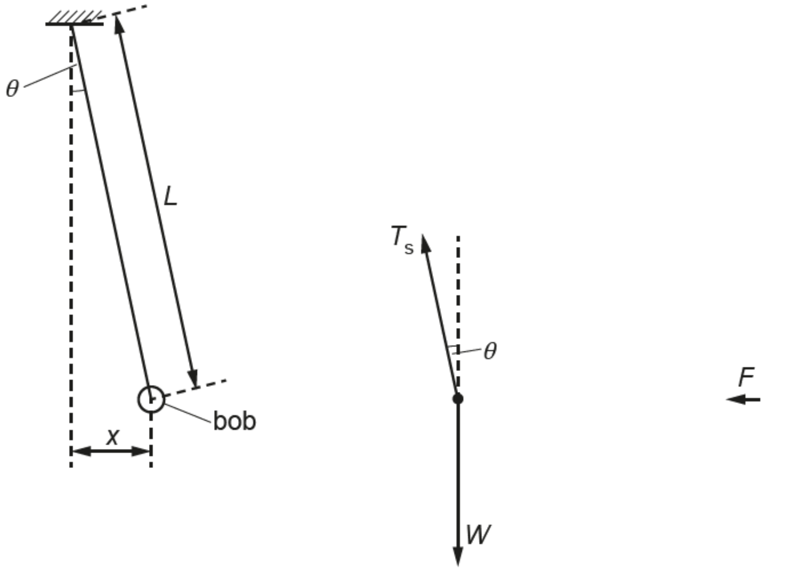

Fig. 2.1a **Fig. 2.1b** **Fig. 2.1c**

Fig. 2.1b shows the free body diagram of the forces on the bob.

Fig. 2.1c shows the restoring (resultant) force *F* on the bob which is horizontal for **small** deflection angle θ.

The weight of the bob is *W* and the tension in the string is T_s.

(i) Explain why, for small angle θ of deflection, *F* can be given by the expression

$$F \approx -\frac{T_s x}{L}.$$

....

....

.... **[2]**

Some candidates were able to show the algebraic relationship equating sin θ to $x \div l$ and $F \div T$ correctly, but only a few explained that the force *F* and the displacement *x* were in opposite directions and that was why there is a minus sign in the relationship. Some candidates were fixated on the small angle approximation or tried using other trigonometric relationships.

Question 2 (a) (ii)

(ii) For small angle θ, $T_s \approx mg$. Therefore, the acceleration a of the bob can be given by the expression

$$a \approx -\frac{gx}{L}.$$

Use the equation for simple harmonic motion, $a = -4\pi^2 f^2 x$, to show that $T^2 = \frac{4\pi^2 L}{g}$, where T is the period of oscillation of the pendulum.

[2]

Most candidates were able to equate the two relationships for acceleration and then simplified it before substituting 1 ÷ T for frequency. A common mistake was to omit one or other of the minus signs in the initial equality.

Question 2 (b) (i)

(b) A student measures the time taken for 10 oscillations of the pendulum bob to determine the period T.

She repeats this for 4 different pendulum lengths.

The results are shown in the table below.

Length of pendulum, L / m	Time taken for 10 oscillations, t / s	Period, T / s	T^2 / s^2
0.300	11.33	1.133	1.284
0.400	12.70	1.270	
0.500	14.44	1.444	
0.600	15.41	1.541	

(i) State and explain the advantage of determining the period T by measuring the time for 10 oscillations.

....

....

.... **[2]**

This was not particularly well answered. Many candidates did not mention that the uncertainty is due to reaction time; just mentioning human error is insufficient. Then candidates needed to explain that this reaction time error is a constant absolute uncertainty which has less effect on longer times measured.

Question 2 (b) (ii)

(ii) Complete the table by calculating the three missing values of T^2/s^2. **[1]**

Nearly all candidates correctly calculated T^2 and recorded the values to 4 significant figures, the same as the example given.

Question 2 (b) (iii)

(iii) On Fig. 2.2, plot a graph of T^2 (on the y-axis) against L (on the x-axis) and draw a straight line of best fit through the data points. **[4]**

The graph should occupy at least half the graph grid, so both x- and y- axes needed to be scaled in such a way that the plotted points covered at least six large squares in the y-direction and four large squares in the x-direction. Many candidates chose scales which were too small, maybe because they wanted to include the origin, but this is not necessary. The third marking point was for plotting the points correctly on the grid. Any plots which were outside the graph grid were ignored. Many candidates plotted the third plot (0.500, 2.085) in the incorrect place - usually at about (0.500, 2.008) because they were misreading their y-axis scale. The final mark was for drawing the best fit line through the plotted points. Many candidates incorrectly forced their line through the origin. There should be a balance of points either side of the line without it needed to be rotated slightly.

Exemplar 2

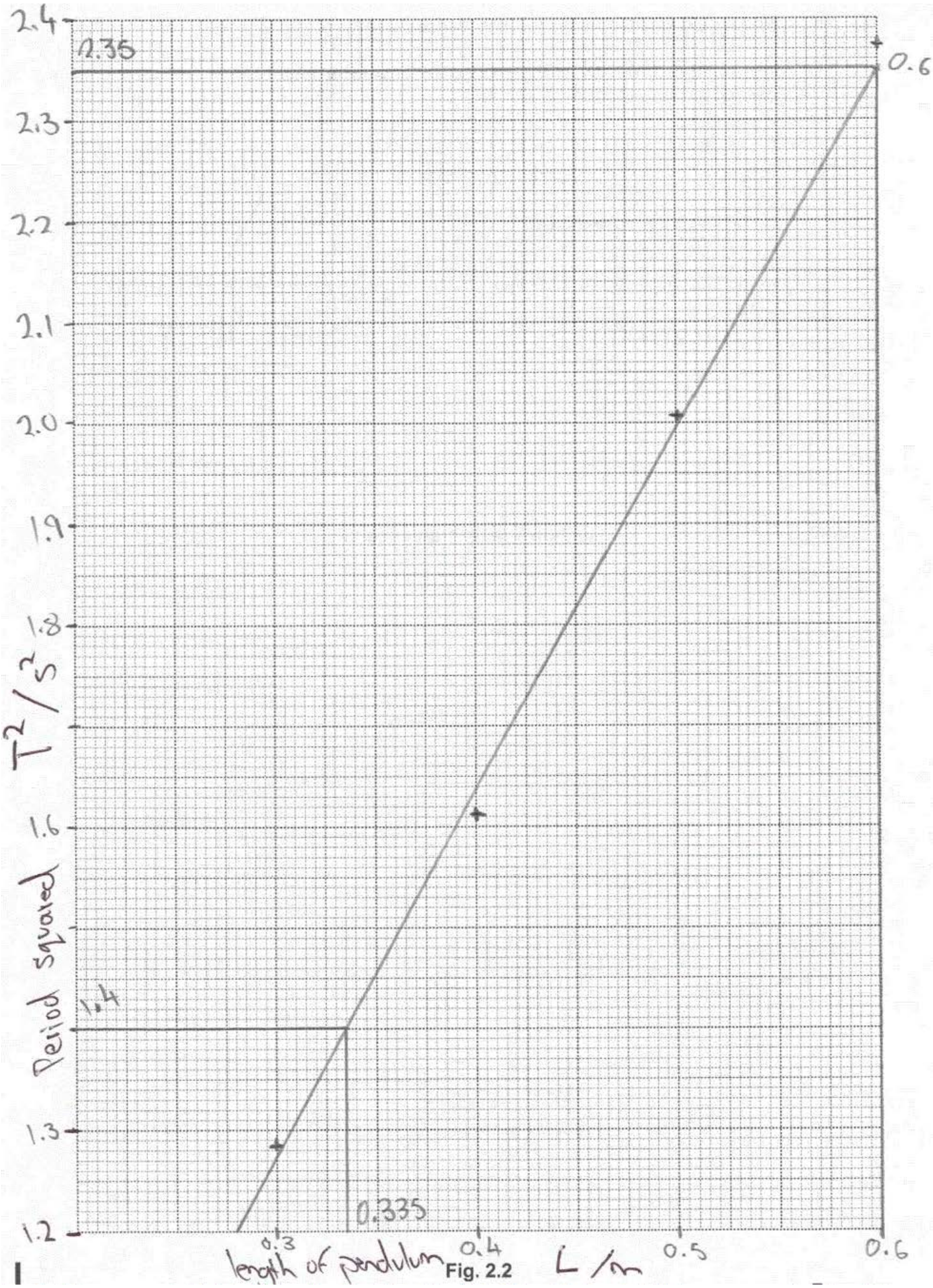

Fig. 2.2

In this example both the x- and y-axis are at a large enough scale. The plotted points occupy six large squares in the x-direction and 12 large squares in the y-direction so both the axes marks were given.

The third plot is incorrectly drawn at (0.500, 2.01) so the plot mark is lost and the line of best fit is just acceptable. The top plot is just to the left and the second plot is just to the right and the line almost passes through the other two plots.

This example gains 3 marks.

Question 2 (b) (iv)

(iv) Use the graph to determine a value for the acceleration due to gravity *g*.

Show your working.

g = ... m s^{-2} **[2]**

Most candidates were able to calculate the gradient of the line, and then found acceleration of gravity by calculating 4 π^2 ÷ gradient. Some candidates mis-read the coordinates of points on the line in their gradient calculation and just gave the value of gradient as their answer for acceleration of gravity.

Question 2 (c)

(c) The student is considering the uncertainty in her value for *g*.

She thinks that data collected for the shorter pendulums have greater percentage uncertainty than those for the longer ones.

Explain her reasoning.

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....

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.... **[2]**

This question was intended for candidates to think about the uncertainty in time values, as any percentage uncertainty in time would be doubled in the uncertainty in the value for acceleration of gravity. Some candidates only referred to the fact that the length measurement would be less, but they were still able to gain a mark for stating that the absolute uncertainty would be the same for all values of length, so for a shorter length this would mean a greater percentage uncertainty.

Question 3 (a)

3 This question is about the electrical conductivity of a metal.

(a)* Describe a suitable experimental procedure which could be used to determine the electrical conductivity σ of the metal.

The following apparatus is available.

Length of metal wire
Meter rule
Micrometer screw gauge
Ammeter
High resistance voltmeter
Battery
Variable resistor
Connecting wires and crocodile clips

You should include details of the measurements to be taken and how they are used to accurately determine the electrical conductivity σ of the metal. You should also consider the uncertainties present in the investigation.

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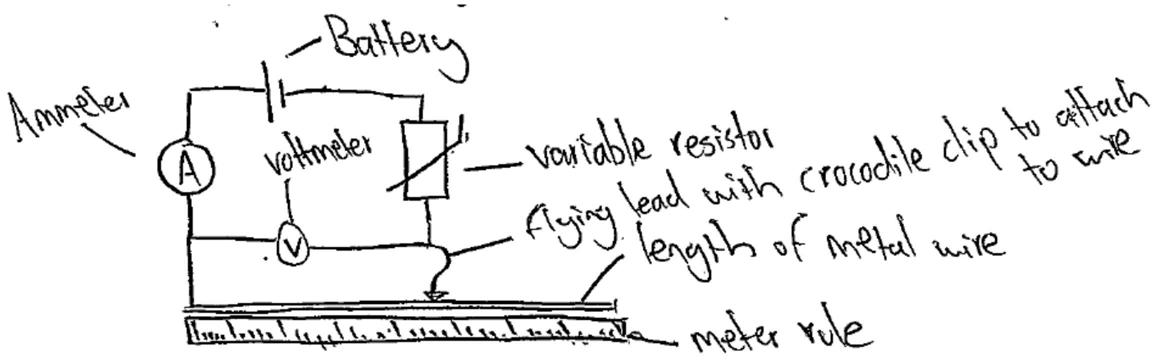
.... **[6]**

This experiment seemed more familiar to candidates than the one in Question 1b. Nearly all candidates explained how to find the area of the wire using the micrometer screw gauge by measuring diameter in several places along the wire. Most candidates were able to draw a workable circuit to measure the current in the wire, but some candidates decided to place the voltmeter across the variable resistor which was in series with the wire and then use a potential divider method to calculate the potential difference across the wire. However, few of these candidates explained how they would know the resistance of the variable resistor or the output voltage from the cell. Some candidates gave a very good description of the method to find conductivity by changing the length of the wire and obtaining a straight line graph. A few candidates even suggested refinements to the experiment such as using the variable resistor to make sure the current was the same through each length of wire, as increasing the current could have affected the conductivity of the wire. A common error was to only take measurements of current and potential difference across a fixed length of wire, which is not such a good experimental technique.

Exemplar 3



Consider the conductivity equation ~~or~~ $G = \frac{\sigma A}{L}$
From this we can deduce the variables that need to be found and how we can consider all the uncertainties to find the overall uncertainty.
First of all, find the cross sectional area of the wire by putting it under tension and using a micrometer screw gauge to measure the diameter in multiple different places and find an average. A thicker wire can be used to ~~a~~ reduce the % uncertainty as this uncertainty is doubled when using ~~A~~ $\pi d^2/4$ to find the area. Keep the wire under tension when taking readings to avoid it from bending and to reduce uncertainty in length. Connect the wire to the circuit ~~and record~~ recording its length for each reading and record the corresponding current and voltage. Repeat at multiple values of L for the wire and record 3 values of voltage and current and voltage to eliminate anomalies and reduce the percentage error. Draw a table with your recorded values of L, current and Voltage ~~and add an extra~~ make an extra column for conductance (I/V) and plot a graph of conductance G against $1/L$ with each value of

G corresponding to a unique value of L. Find the gradient of this graph. $G / \frac{1}{L} = GL$ the gradient = conductivity x area so to find conductivity divide the gradient by the cross

Additional answer space if required

Sectional area of the wire.

This response starts with a clear circuit diagram using a flying lead, and includes the equation needed to find the conductance of the wire. It explains how to measure the wire in several different places to find an average and suggests that a thicker wire would reduce percentage uncertainty in this measurement, which is helpful as the percentage uncertainty would be doubled in the calculation of area. The length of the wire is changed and values for both current and potential difference are repeated for each length of wire. A suitable graph is plotted which give the gradient equal to *GL,* so conductivity equals the gradient ÷ cross sectional area. This response could be used as a set of instructions to carry out this experiment so this is a Level 3 response which achieved 6 marks.

Question 3 (b) (i)

(b) The conductivity σ of the metal wire in **(a)** at room temperature is $2.1 \times 10^6\,\Omega^{-1}\,m^{-1}$. The cross-section area, *A*, of the wire is $0.166\,mm^2$.

The potential difference across 0.330 m of the wire is 2.0 V.

(i) Calculate the current I in the wire.

I = ... A **[3]**

Most candidates were able to calculate the current in the wire. Common errors included using an incorrect power of ten to convert mm^2 to m^2, or squaring 0.166 mm^2 for area.

Question 3 (b) (ii)

(ii) Use the relationship $I = nAvq$ and the data below to estimate the mean drift velocity, *v*, of electrons in the wire.

number density of free electrons in the metal $n \approx 10^{28}\,m^{-3}$
charge on one electron $q = 1.6 \times 10^{-19}\,C$

v = ... $m\,s^{-1}$ **[1]**

This question was well answered; if a candidate used a consistently incorrect value for area they would still get the same correct answer.

Question 3 (b) (iii)

(iii) The temperature of the metal wire is now increased.

State and explain qualitatively the change, if any, to the mean drift velocity *v* of the electrons in the wire.

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.... **[3]**

Some candidates recalled that as the resistance of a metal wire would increase with increasing temperature and then stated that this would mean a lower mean drift velocity and were able to obtain one mark. A better approach was to think about the temperature of the structure of the wire, and many candidates did refer to more energetic particles, both electrons and metal ions, but few stated that all particles would have more <u>kinetic</u> energy. Many candidates did imply that these more energetic particles would impede the path of the current carrying electrons. A common error was to only think about the more energetic electrons which would therefore be moving faster and hence incorrectly stating that they have a greater mean drift velocity.

Question 4 (a) (i)

4 This question is about the behaviour of gases.

(a) The pressure p and volume V of an ideal gas are related by the equation $pV = \frac{1}{3}Nm\overline{c^2}$.

(i) Explain what is meant by an *ideal gas*.

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.... **[3]**

Many candidates recalled the assumptions regarding ideal gases, but some of the explanations were weak. For example, some stated that the gas occupied negligible volume rather than the particles, or they contradicted themselves by stating that the particles did not interact or collide, but then went on to say that the collisions were elastic. A few candidates incorrectly said that ideal gases obey all the gas laws.

Question 4 (a) (ii)

(ii) The average kinetic energy of the particles (atoms) in an ideal gas at absolute (kelvin) temperature T is given by the equation

average kinetic energy = $\frac{3}{2}kT$

where k is the Boltzmann constant.

Use this equation and the equation $pV = \frac{1}{3}Nm\overline{c^2}$ to show that the pressure p of a fixed mass of an ideal gas at constant volume is directly proportional to its absolute (kelvin) temperature T.

Explain your reasoning.

[3]

Some candidates initially used the incorrect symbol *v* instead of *c*, and then had to fudge the algebra to correct themselves to give the relationship pV = NkT. Many did not state that N and V were constant.

Question 4 (b)

(b) Argon is a gas at room temperature. You may assume that it behaves as an ideal gas at this temperature.

The molar mass of argon is 0.0399 kg mol^{-1}.

Calculate the root mean square speed of argon atoms when the gas is at a temperature of 293 K.

root mean square speed = ... m s^{-1} **[3]**

Most candidates were able to correctly rearrange the equation for $\overline{c^2}$ or $\sqrt{\overline{c^2}}$, but then used incompatible values for the constant and mass. Either candidates should use the Boltzmann constant, k (1.38 × 10^{-23}) with the molecular mass (0.0399 ÷ 6.02 × 10^{23}) or the molar gas constant, R (8.31) with the molar mass (0.0399). Another common error was to forget to square root the value for $\overline{c^2}$.

Question 4 (c) (i)

(c) A student performs an experiment to investigate if the pressure of a constant volume of air is directly proportional to its absolute (kelvin) temperature.

Fig. 4.1 shows the apparatus used.

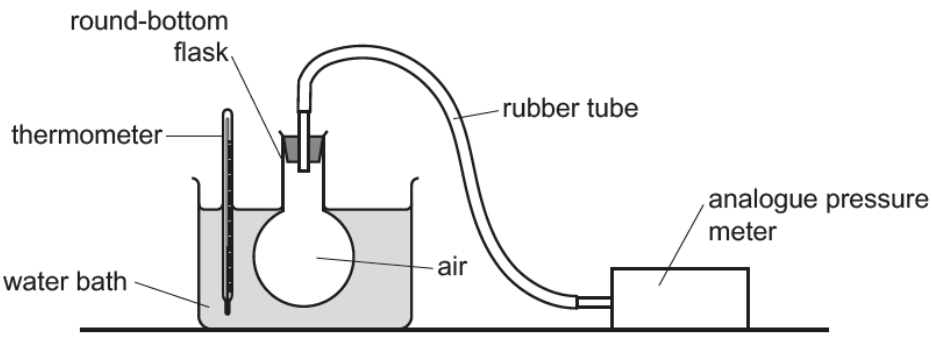

Fig. 4.1

(i) Fifteen apparently identical thermometers are available.

Describe how the student can determine the uncertainty in the reading of the temperature by using all the available thermometers.

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.... **[2]**

Most candidate were able to achieve both the marks in this question, by using all the thermometers to measure temperature, and then finding uncertainty either by halving the difference between the maximum and minimum values, or by subtracting the mean temperature from the maximum value.

Question 4 (c) (ii) (1)

(ii) Fig. 4.2 shows the graph of the data collected, including the uncertainty in the pressure readings.

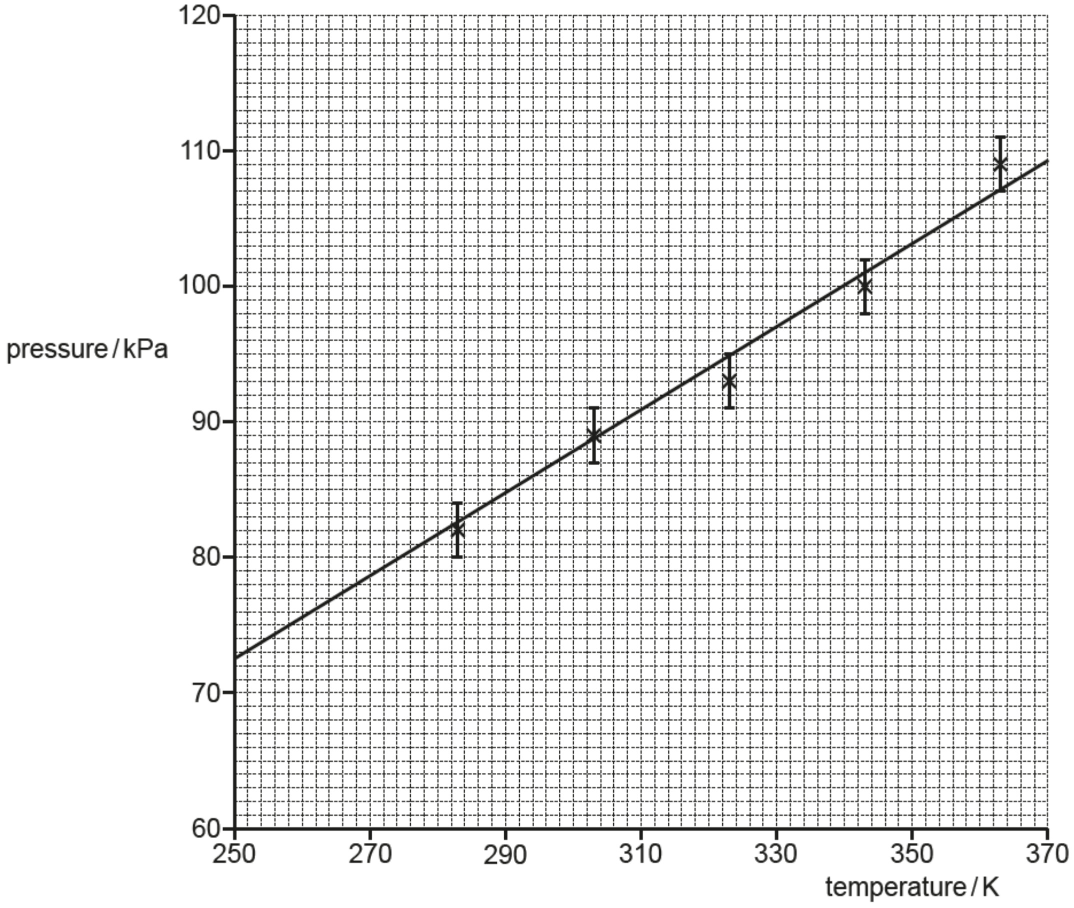

Fig. 4.2

1 The best-fit straight line is shown.

On Fig. 4.2, add a worst-fit straight line that gives the **maximum** gradient. **[1]**

Many candidates drew an acceptable line here. A common error was to draw a steeper line from the extremes of the first and last error bars, which then completely missed the error bar from the fourth plot.

Question 4 (c) (ii) (2)

2 The gradient of the best-fit straight line suggests that the pressure of the gas will fall to zero at a temperature of about 10 K.

Determine the gradient of your worst-fit straight line.
Use your gradient value to calculate the temperature at which the pressure falls to zero, assuming the change in pressure per unit kelvin is constant.
Show all your working.

temperature at which pressure falls to zero = ... K **[5]**

Most candidates were able to calculate a gradient of the line using points which were far enough apart; in fact, many of them used the entire width of the grid. There were some who were confused about the two lines and mis-read the coordinates. Once obtaining the gradient many candidates did then use one set of coordinates to find the equation of the line in terms of $p = mT + c$. A common error here was to use read off the y-intercept from the grid as if the left-hand edge was $x = 0$, rather than $x = 250$ K. Others found the difference in temperature relating to a pressure drop to zero. Alternative methods such as finding dT/dp (instead of dp/dT) and then finding an equation of the form $T = mp + c$ was also acceptable.

Question 4 (d)

(d) The student notices that the top of the round-bottom flask is above the level of the liquid in the water bath and suggests that this will produce a systematic error in the data which could account for the incorrect value for the temperature at which the gas pressure falls to zero.

The temperature of the laboratory at the time of the experiment was 25 °C.

Explain what is meant by a *systematic error*. Explain how the low level of liquid in the water bath could lead to a systematic error and assess if the error is likely to be significant.

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.... **[4]**

There were a number of comments available in this question which would get credit and many candidates were able to get 2 or 3 marks. Most stated that a systematic error gave a consistently incorrect measurement, and that as most of the temperatures were higher than room temperature, the measured temperature would be higher than the actual temperature of the air in the flask. Candidates did need to be quite specific here to make sure that it was clear which temperature they were referring too, as muddled responses would not have gained credit. Many candidates also gave a reason for the significance of the error. This is quite a complex systematic error as it will have different effects at different temperatures and is likely to cause a rotation of the line of best fit, rather than a translation.

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