Examiners' Report
Principal Examiner Feedback

October 2019

Pearson Edexcel International Advanced Level
In Physics (WPH06)
Paper 01 Experimental Physics

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Introduction

The IAL paper WPH06 Experimental Physics assesses the skills associated with practical work in Physics. In particular, it addresses the skills of planning, data analysis and evaluation which are equivalent to those that A level Physics students in the UK are now assessed on within written examinations.

Students who do little practical work will find this paper more difficult as many questions rely on applying their knowledge of practical techniques to novel, as well as standard, experiments. In the forthcoming new specification, it is expected that students will carry out a range of core practical experiments as the skills and techniques learned will be examined in this paper.

The paper for October 2019 covered the same skills as in previous series which resulted in a mean mark that was comparable to the October 2018 series. In addition, it appeared that whilst a good number of students were well prepared for this examination, a significant number were not capable of the basic skills expected of an A level student.

Question 1

As in previous series, this question assessed the students' ability to calculate and use uncertainties at the level expected of an A2 student. This question was set in the familiar context of measuring the density of a metal; however, in this paper the object was in the form of a thin sheet which made the question slightly more challenging.

Both parts of question (a) required the students to give one answer only. It was clear that many students did not follow this instruction and wrote a list of answers. If all the answers given are correct then the marks can be awarded, however if there is an incorrect answer in the list then the students may not be awarded marks.

In part (i) the students were asked to state one reason for measuring the thickness of the folded sheet rather than the unfolded sheet. Of those that gave a single reason the main issue was using the term 'uncertainty' rather than 'percentage uncertainty'. Part (ii) required an explanation of one other technique. A number of students appeared to relate this to a practical involving wires or spheres as many would state measuring the thickness at different orientations, which is incorrect. In addition, those that did score marks would do so for stating the technique without including an explanation. Typically, students would describe two techniques which indicates that they were taking note of the number of marks but had not understood the command word.

(a) (i) State one reason for measuring the thickness of the folded sheet rather than an unfolded sheet.

(1)

The thickness of the unfolded sheet would be a small value which would have a higher percentage uncertainty.

(ii) Explain one other technique she should use to ensure that the measurement of the thickness of the folded sheet is accurate.

(2)

Take repeated measurements at different points of the folded sheet and average them also check for zero error.

In this example, the student used a converse argument in part (i) but still scored 1 mark. In part (ii) the student has described two techniques, however neither of these are correct hence scored 1 mark. There is no explanation of either technique, therefore could not score any more marks.

Part (b) involved calculating the mean value of the thickness and the uncertainty from a series of pictures of a micrometer. A surprising number of students could not read a micrometer and typically stated values such as 47 mm, although there were a number of students who stated 0.97 mm or 1.47 mm. In addition, there were some unit errors, such as using cm or not including any at all, and some students recording to too many significant figures, for example 0.470 or 47.0 mm. Despite this, the majority were able to calculate the mean value and those that calculated the mean thickness of a single sheet were given credit. Students are expected to calculate the uncertainty using the half the range of the measurements and this calculation should be shown clearly in their answer.

(i) Record the measurements in the table.

(2)

Total thickness /			
0.47 mm	0.49mm	0.47mm	0.48mm

(ii) Calculate the mean thickness and the corresponding uncertainty.

(2)

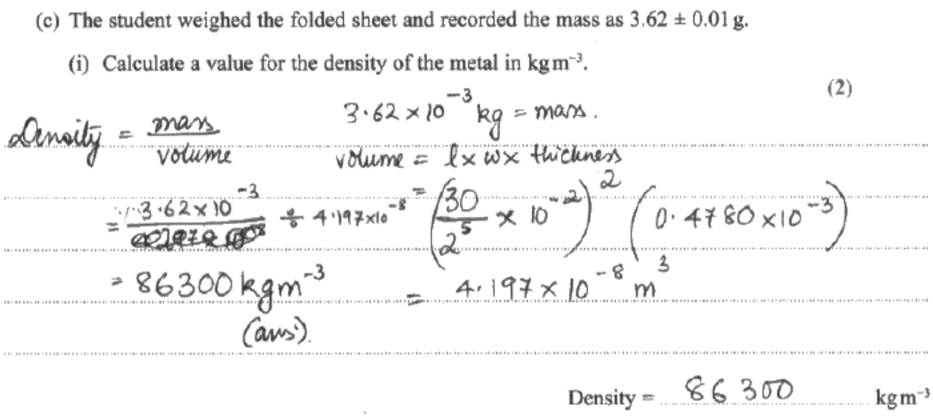
$\frac{0.47 + 0.49 + 0.47 + 0.48}{4}$ = ~~0.4775mm~~ 0.48mm

%U = $\frac{0.01\,mm}{0.48\,mm}$ = 2.1%

Mean thickness = 0.48 mm ± 0.01mm

In this example, the student has correctly read the micrometer with units to score 2 in part (i). The mean is also correct however it is unclear whether the value of 0.01mm was arrived at using half the range, hence part (ii) scores 1 mark only. It was interesting to note that some students calculated the percentage uncertainty only to use it again to calculate the absolute uncertainty when only a simple calculation of the half range would have sufficed.

Part (c)(i) concerned using the values to calculate the density of the metal. Although this is a straightforward calculation, some students also did not know how to calculate the volume as there were occasions where only two values were used, or they calculated the volume of a cylinder or sphere. Although there was an error carried forward from (b)(ii), there were a number of students who made a power of ten error in (b)(ii) who then did not gain the correct value using their data. It appeared that these students had arrived at an answer and then tried to make it look similar to the value given in part (c)(ii). Many students either forgot to divide the thickness by 32 or 2^5. In some cases, the thickness was divided by 5 or 25, or the thickness was divided by 32 or 5 twice, as shown by the following example. In this case the student was awarded the "use of" mark, hence scored 1.


(c) The student weighed the folded sheet and recorded the mass as 3.62 ± 0.01 g.

(i) Calculate a value for the density of the metal in $kg\,m^{-3}$.

(2)

Density $= \frac{mass}{volume}$ $\qquad 3.62 \times 10^{-3}$ kg = mass.

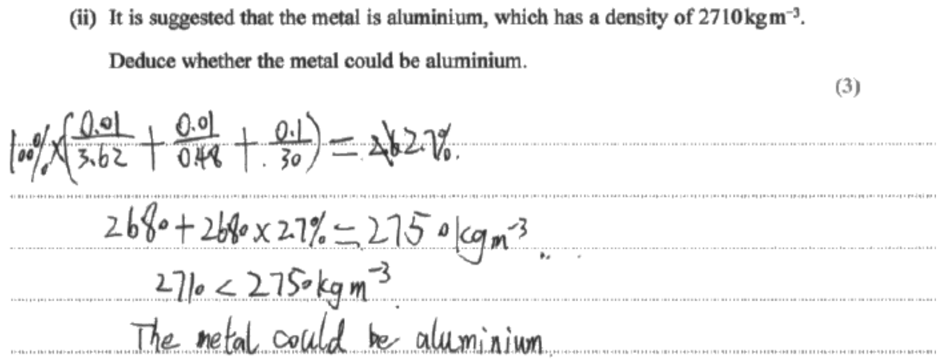
volume = l × w × thickness

$= \frac{3.62 \times 10^{-3}}{4.197 \times 10^{-8}}$ $\qquad = \left(\frac{30}{2^5} \times 10^{-2}\right)^2 \left(0.4780 \times 10^{-3}\right)$

$= 86300\ kgm^{-3}$ (ans) $\qquad = 4.197 \times 10^{-8}\ m^3$

Density = 86 300 $kg\,m^{-3}$

The final part of the question, part (c)(ii), required the students to determine whether the metal could be aluminium by comparing their density with a quoted value. This was slightly less structured than in previous series as the students had not been prompted to calculate the percentage uncertainty in the density, however many students attempted this. There were some errors in calculating the percentage uncertainty, in particular some did not use twice the percentage uncertainty in the length, as shown in the example below, or did not include the uncertainty in the mass.



(ii) It is suggested that the metal is aluminium, which has a density of 2710 kg m^{-3}.

Deduce whether the metal could be aluminium.

(3)

$100\% \times \left(\frac{0.01}{3.62} + \frac{0.01}{0.48} + \frac{0.1}{30}\right) = \pm 2.7\%$

$2680 + 2680 \times 2.7\% \approx 2750$ kg m^{-3}

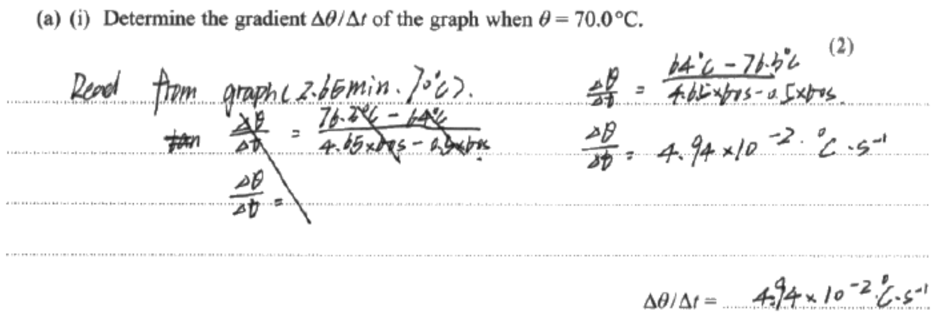
$2710 < 2750$ kg m^{-3}

The metal could be aluminium

It is expected that the students then use this to calculate the upper and lower limits for comparison. Here the student had used the percentage uncertainty correctly and drawn the correct conclusion and scored 2 marks. Many students calculated a percentage difference which was acceptable, however they must use the quoted value in the denominator. It was pleasing that more students wrote a conclusion that included a comparison of values, either comparing the quoted value to the limits of the measured value of comparing the percentage difference with the percentage uncertainty.

Question 2

This question focussed on analysing the graph produced from measuring the temperature of water as it cooled. Part (a)(i) asked for a determination of the gradient at a point on the graph and it was clear that some students did not know how to do this as there was no attempt at drawing a tangent. Those that did draw the tangent often produced a reasonable line and were generally successful in calculating the gradient, but some stated this as positive rather than negative. In addition, units were not necessary unless the gradient was processed to give an answer using seconds rather than minutes, as shown in the example below. Here the candidate had drawn a good tangent but unfortunately missed out the minus sign therefore scored 1 mark.



(a) (i) Determine the gradient $\Delta\theta/\Delta t$ of the graph when $\theta = 70.0$ °C.

(2)

Read from graph (2.66 min, 70 °C).

$\frac{\Delta\theta}{\Delta t} = \frac{64 °C - 76.5 °C}{4.65 \times 60 s - 0.5 \times 60 s}$

$\frac{\Delta\theta}{\Delta t} = 4.94 \times 10^{-2}$ °C s^{-1}

$\Delta\theta/\Delta t = 4.94 \times 10^{-2}$ °C s^{-1}

The students then had to use this value to calculate the rate at which thermal energy was transferred to the surroundings. In general, this was completed successfully although there were occasions where students used too many significant figures or incorrect units, in particular using minutes then giving the unit as Watts. In this example, the student used the value of the gradient from above to calculate the rate of energy transfer in Watts, hence scoring 2 marks.

(ii) Hence calculate the rate at which the water is transferring thermal energy to the surroundings when $\theta = 70.0\,°C$.

density of water = $1.0\,g\,cm^{-3}$

specific heat capacity of water = $4.2\,J\,g^{-1}K^{-1}$

(2)

$\Delta E = mc\Delta\theta$ $\qquad m = \rho V$

$P = m \cdot c \cdot \frac{\Delta\theta}{t}$ $\qquad m = 1g \cdot cm^{-3} \times 100cm^3$

$P = 100g \times 4.2 J g^{-1} \cdot K^{-1} \times 4.94 \times 10^{-2}$ $\qquad m = 100g$

$P = 20.7W$

Rate = 20.7W

In part (b) the students had to consider how to repeat this experiment for an insulated beaker in order to make a valid comparison. In part (i) the students had to state one control variable and a significant number again produced a list. Although many chose the volume or mass of the water, those that stated temperature had to specify which, i.e. of the surroundings or initial temperature of the water. There were some that stated time however this could not be accepted as the time was the independent variable. In this example the student had produced a list however the inclusion of time unfortunately meant that the student did not score the mark.

(i) State one control variable in these experiments.

(1)

1. The room temperature should be constant.

2. The initial temperature of water should be the same.

3. The time should be the same 4. The mass of water should be the

Part (ii) involved discussing how the results of the two experiments should be compared. It was expected that the students should realise that the gradients of the two graphs at the same temperature should be compared since this was the focus of part (a)(i). Although some realised this, many did not specify at the same temperature. Those that described comparing times or temperature intervals again were not specific enough to gain both marks, unlike the following example which was judged just enough to gain both marks.

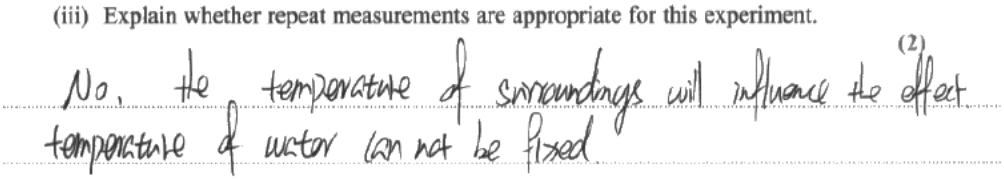
(ii) Describe how the results of the two experiments should be compared.

(2)

The ~~tone~~ time using when a ~~cons~~ same temperature decreases

The value of temperature decrease in a same time interval

Finally, part (iii) required the students to explain whether repeat measurements would be appropriate for this experiment. It seemed that almost all of the students did not consider the context of the experiment and stated the standard answer for why repeats are appropriate. In a heating experiment, the temperature of the surroundings cannot be easily controlled hence repeats are not appropriate and more readings should be taken. Below is a rare example of a student gaining both marks despite some poor wording.


(iii) Explain whether repeat measurements are appropriate for this experiment.

(2)

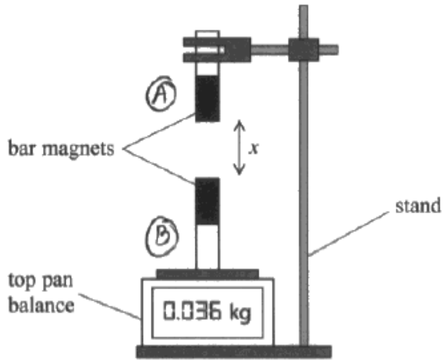
No, the temperature of surroundings will influence the effect temperature of water can not be fixed.

Question 3

This question involved planning an experiment to verify the relationship between the force between two magnets and the distance between them. Although this was a novel experiment, the method is similar to a standard experiment involving the force on a current carrying wire. As this was a more unusual experiment, the question was more scaffolded than in previous series, however students often were not given credit as their descriptions were not explicit enough. In addition, marks were awarded for correct answers seen in either part.

Part (a) involved describing how the measurements should be made. The majority of students were able to describe how the distance should be measured but fewer suggested that a series of measurements should be taken. There was some confusion with some students who stated that the top pan balance would directly measure the force rather than the mass. Only a few students realised that the balance should read zero with only the bottom magnet present, or that the reading with only one the bottom balance present should be subtracted from subsequent readings. In this example, the student scored all 3 marks. The labelling of the diagram made it clear how the measurements would be made.

3 The force F between two bar magnets placed a distance x apart can be measured using the apparatus shown.



A student predicts that F varies with x according to the relationship

$$F = ax^b$$

where a and b are constants.

(a) Describe how the apparatus could be used to investigate this relationship.
Your description should include any additional apparatus that may be required.

(3)

Meter rule (of precision 1mm) needed along with set-square to ensure ruler is perpendicular to the ground. This apparatus (meter rule) is used to measure distance (x) between the bar magnets. Bar magnet (A) (as labelled in my diagram), at first is not present. Mass of (B) is noted on the top pan balance and subtracted from subsequent readings. Bar magnet (A) is moved closer to (B) at intervals of 2cm, (eg:- 4cm away, 6cm, 8 cm away...) measured by the meter rule and changes in mass on the balance, noted. In order to find F, this mass is multiplied by 9.81 N/kg. because F = mg. Repeat readings using different intervals (eg:- every 5cm ~~showing~~ closer, showing a change in top pan balance's mass).

Part (b) assessed the students' ability to describe how the data would be used to verify the relationship which was given in the form of a power law. The majority of students who realised that the mass had to be converted to force by multiplying by g wrote this in part (a), as in the example above, however they were still given credit in part (b). Students should realise that verifying a power law relationship requires a log-log graph to be drawn, although students were credited for ln-ln graphs. Many stated this but then went on to compare to $y = mx + c$ which was unnecessary since this is an explanation. However, they should have stated explicitly what the graph would look like if the relationship was valid rather than simply stating it is a straight line, hence this mark was only achieved by a small number of students. In the example below, the student had already described converted mass into force in part (a) so had already scored 1 mark. The final 2 marks were awarded in the final two lines, hence scored all 3 marks for part (b).

(b) Describe how the data collected in (a) should be used to verify this relationship.

(3)

$F = ax^b$

$\log F = \log ax^b \quad \log F = b\log x + \log a$

Use many sets ~~of~~ of values to calculate $\log F$ and $\log x$

$\log F = b\log x + \log a$

$y = kx + b$ plot a graph $\log F$ against $\log x$

the graph should be a straight line

Question 4

This is the data handling question that requires students to process data and plot a graph to determine a constant. In this question students were presented with data from measurements of the amplitude of the oscillations of a damped spring.

Part (a) involved a simple definition of damping which only half of the students did successfully. Those that gained a mark did so by stating that the amplitude decreases. Students were less successful in describing the reason for this in terms of energy dissipation and there were a number of students who appeared to describe simple harmonic motion or resonance.

Part (b) is another standard question used in previous papers where they have to explain why the graph should produce a straight line. Here, students were more successful in understanding what they had to do. In the majority of cases the logarithmic expansion was done correctly, hence gaining the first mark. For the second mark, the expanded formula must be compared explicitly to the equation of a straight line, $y = mx + c$. In some instances, the equation of the straight line was not written out in full, i.e. without the + or =, hence these students could not gain this mark. There were occasions where the order of the terms did not correspond with the expanded formula, however students could still gain credit if all of the symbols were defined. In this example, the order does not match, and the symbols are not defined, hence only the first mark was awarded.

(b) It is suggested that the relationship between the amplitude A and the number n of the oscillations is

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

where A_0 is the initial amplitude of the oscillation and λ is the decay constant.

Explain why a graph of $\ln A$ against n can be used to determine a value for λ.

(2)

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

$\ln A = \ln A_0 - \lambda n \quad \ldots (i)$

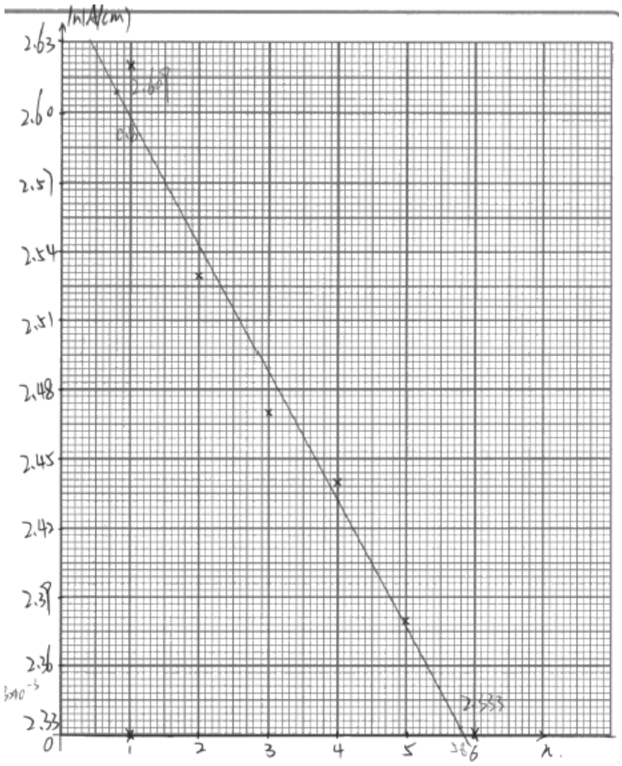
Comparing (i) to $y = mx + c$ where gradient $= -\lambda$ which is a constant and produces a straight line graph with a negative slope and positive y intercept $= \ln A_0$.

The second mark also required the gradient to be specified as well as being negative. As the question stated that λ is a constant, it was not necessary to state that the gradient was constant although it is good practice to state this. As this question asked for an explanation, students should be responding with sentences rather than just using mathematical symbols although this was accepted for this specification.

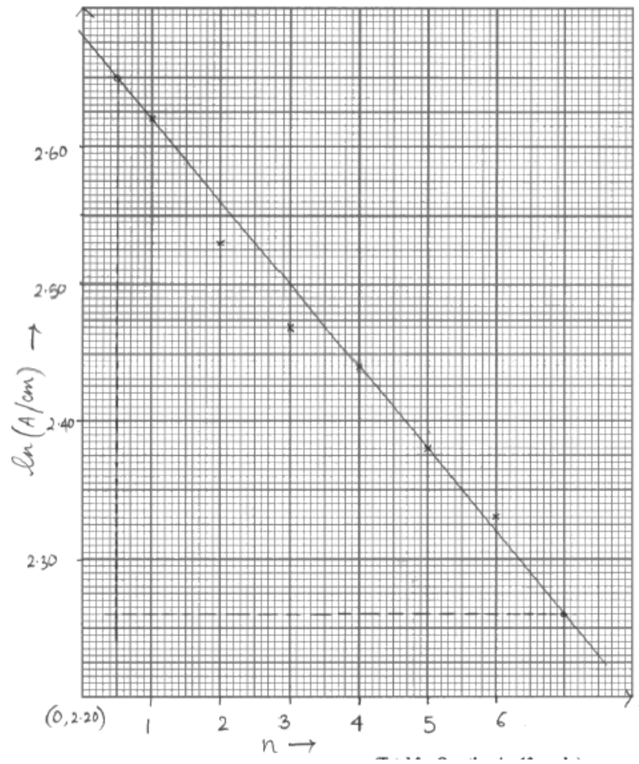
Part (c) assessed the students' ability to process data and plot the correct graph. A good student should be able to access the majority of the marks here and many good graphs were seen. The majority of students processed the data to three significant figures although there were some occasional errors in rounding, presumably as a result of rounding to four significant figures then rounding that value to three significant figures. There were fewer students that plotted seemingly random numbers compared to previous series however there were some cases where students had plotted the ln values against the values for A.

The most common error in the graph was not labelling the y-axis in the correct form, i.e. $\ln A$ or $\ln A$ / cm rather than $\ln(A$ / cm). Some students chose to convert the amplitude into metres, which was unnecessary and produced negative values which students often find harder to plot. At this level the students should be able to choose the most suitable scale in values of 1, 2, 5 and their multiples of 10 such that the plotted points occupy over half the grid in both directions. Students should realise that although the graph paper given in the question paper is a standard size the graph does not have to fill the grid. Students at this level should also realise that scales do not have to start from zero and scales based on 3, 4 or 7 are not accepted.

Most students were able to plot the graph accurately using neat crosses (× or +). If a dot extends over half a small square, then this is not considered to be accurate plotting so students should be encouraged to use crosses. It was expected that students would realise that the first plot was an anomaly and base the best fit line around the subsequent plots, however many did not so any good best fit line was accepted. If a point is not used to judge the best fit line then this must be indicated on the graph, usually by circling the plot or labelling this as an anomaly. Students that joined the first and last points could not gain this mark as there would have been too many points below the line. In addition, lines that looked disjointed or did not extend across all data points, perhaps a result of using a ruler that is too small or were too thick could not gain this mark.



In this example, the ln values had been processed correctly to three significant figures and the axes are labelled in the correct format scoring the first two marks. Unfortunately, the *y* axis scale is in 3s therefore does not score the scale or the plotting marks, however this was judged to be a reasonable best fit line as there is an even spread of data. Overall this graph scored 3 marks. The following graph did not score the best fit line mark as there are two points too far below the line, however all other marks were scored hence this was worth 4 marks.



In part (c)(ii) the students had to use their graph to determine a value of λ. It is expected that the gradient of the graph should be calculated, which the majority did well particularly those that labelled this on the graph, as in the example above. The triangle used should cover at least half of the plotted points and most did so. The main reasons for students not gaining full marks was including a minus sign, using too few or too many significant figures, or including a unit usually cm. The example below shows the calculation following on from the above graph. The triangle shown on the graph is large and sensible values were used making the data extraction straightforward. The calculation is correct, however only one significant figure is used and there is an inclusion of a unit, hence this scores only 1 mark. It is interesting to note that the unit is based on time presumably because the student had misunderstood the context of the experiment.

(ii) Use your graph to determine a value for λ. **(2)**

$\lambda = -\text{gradient} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{2.65 - 2.26}{0.5 - 7}$

$= -0.06\ s^{-1}$

value of $\lambda = 0.06\ s^{-1}$

$\lambda =$ $0.06\ s^{-1}$

Finally, the students had to explain how using a datalogger would lead to a more accurate measurements of *A*. Again, students did not relate this to the context of the experiment and how the datalogger would be used, and instead just stated some properties of dataloggers. Very few students scored marks in this part however the following answer was just enough to score 1 mark as it relates the difficulty of judging the maximum displacement owing to parallax error.

(d) The student modified the experiment by using a data logger attached to a position sensor.

Explain how this may lead to a more accurate value for *A*.

(2)

It is diffrcult to rerord A and ensure max displacemene position. If you confirm mass to a maximum displacement position, you record A, you will have a reaction time and parallax error. it can be avoid or reduced by data logger and position sensor ✓

Summary

Students will be more successful if they routinely carry out and plan practical activities for themselves using a wide variety of techniques. These can be simple experiments that do not require expensive, specialist equipment and suggested practical activities are given in the specification. In particular they should make measurements on simple objects using vernier calipers and micrometers, and complete experiments involving electrical circuits, heating, timing and mechanical oscillations.

In addition, the following advice should help to improve the performance on this paper.

- If a question asks for a certain number of answers, only give that many answers.
- Learn what is expected from different command words, in particular the difference between ‘describe’ and ‘explain’.
- Be able to describe different measuring techniques and explain the reason for using them.
- Show working in all calculations as many questions rely on answers from another part in the question, or marks are awarded for the method used.
- Be consistent with the use of significant figures, in particular that quantities derived from measurements should not contain more significant figures than the data and uncertainties should be given to at least one fewer significant figure than the derived quantity.
- Choose graph scales that are sensible, i.e. 1, 2 or 5, and their powers of ten only so that at least half the page is used. It is not necessary to use the entire grid if this results in an awkward scale, i.e. in 3, 4 or 7. Grids can be used in landscape if that gives a more sensible scale.
- Use a sharp pencil to plot data using neat crosses (× or +), and to draw best fit lines. Avoid simply joining the first and last data points.
- Draw a large triangle on graphs using sensible points. Labelling the triangle often avoids mistakes in data extraction.
- Learn the definitions of the terms used in practical work. These are given in Appendix 10 of the new IAL specification. In addition, understand what is meant by dependent, independent and control variables.

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