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Examiners' Report
June 2018

IAL Physics WPH06 01

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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 A2 Physics students in the UK are assessed on within written examinations. As the questions can be set in a wide variety of familiar and unfamiliar contexts, those students who have carried out a range of experiments using different apparatus and techniques will find the paper more accessible.

This document should be read in conjunction with the question paper and the mark scheme which are available at the Pearson Qualifications website.

The paper for June 2018 was in a similar format as previous years with much the same skills content. Although the performance on this paper was slightly better on average compared to the previous Summer series, suggesting that the paper was more accessible to the majority of students, the range of marks awarded was greater.

Question 1 (a) (i)

As in previous series, Question 1 assessed the students' ability to handle uncertainties at the level expected of an A2 student, i.e. they should handle the uncertainty of a variable that is raised to a power. This question concerned determining a value of the resistivity of a wire given the measurement and uncertainty of the mean diameter along with the length and resistance with their uncertainties. The final part of the question prompted students to choose which metal the wire was most likely to be made from.

The first part of this question focused on the students' ability to justify the use of a micrometer to measure the diameter of the wire when given an estimate of its value. This is a common type of question and the majority of the students scored well.

The first mark was awarded for a statement of the expected resolution of the micrometer. Although on this occasion there were many variations of wording that were accepted for this mark, centres should note that in the new specification only the word resolution will be acceptable. Students who did not score this mark either made no statement or they used the idea of accuracy which was not given credit.

The second mark required a justification involving a calculation of an expected percentage uncertainty along with a comment comparing this value to the measurement. Although most students performed the calculation correctly, the most common error was not comparing the percentage uncertainty with the measurement, for example, saying the percentage uncertainty is suitable rather than small. In some cases, there was no comment at all or no calculation but a comment that compared the resolution with the measurement.

1 A student has a sample of wire made of an unknown metal.

In order to identify the metal, she determines its resistivity.

(a) The student estimates that the diameter of the wire is approximately 0.5 mm.

She measures the diameter of the wire using a micrometer screw gauge.

(i) Explain why the micrometer screw gauge is an appropriate instrument for this measurement.

(2)

Because the micrometer screw guage has an accuracy of 0.01 mm which is well below the value of the ~~apporxo~~ approximated diameter and gives a less percentage error.

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Examiner Comments

In this example the student confuses the idea of resolution with accuracy so does not score the first mark. Since there is no value for the percentage uncertainty given the second mark cannot be awarded despite a reasonable attempt to make a valid comment. Therefore this response scores no marks.

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Examiner Tip

Learn the definitions of accuracy, error, precision, resolution and uncertainty, and be prepared to use them in different contexts.

Question 1 (a) (ii)

Students then had to describe two techniques that would ensure an accurate value for the diameter. Some students referred to taking repeat readings and calculating a mean value. This was not enough for a mark as they had to refer to taking readings along the wire or at different orientations. It appeared that many students thought that repeating and calculating a mean qualified for two techniques. Students often referred to checking for zero error on the micrometer but few mentioned using the ratchet to avoid squashing the wire. References to parallax error were not given any credit here as using a vernier scale does not result in parallax.

(ii) Describe two techniques she should use to make this measurement as accurate as possible.

(2)

- Take several measurements at different parts of the wire and get the mean value
- Repeat each measurement and get average

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Examiner Comments

In this example the student appears to think that this counts as two techniques rather than one so only scores one mark.

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Examiner Tip

Remember that repeating a measurement and calculating a mean value is a technique that reduces the effect of random errors.

(ii) Describe two techniques she should use to make this measurement as accurate as possible.

(2)

- Check for zero error in the micrometer screw gauge
- Measure the diameter at different position / orientation

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Examiner Comments

However in this example the student has not specified that a mean should be calculated so does not score a mark for the second technique. This student has recognised the need to check for zero error hence scores one mark.

ResultsPlus
Examiner Tip

When asked to describe techniques to improve accuracy, think about ways in which both random and systematic errors can be reduced.

Question 1 (a) (iii) - (c)

The rest of the question assessed the students' ability to calculate resistivity and combine uncertainties. The first part asked the students to calculate the percentage uncertainty in the diameter and the majority scored this mark. At this stage significant figures were only penalised if the student used more than three, however it is good practice to use at least one fewer significant figure than given in the data for all percentage uncertainties.

The students were then asked to calculate the resistivity using the data provided. In general this was done well although there were some students that did not know how to do this or changed the subject of the formula incorrectly. The main errors seen were either not halving the diameter or not changing the unit correctly. In addition some students used the estimated diameter which was not accepted. It also appeared that some students did not know the formula to calculate the cross-sectional area. The majority of students used the three significant figures quoted in the data but there were some that used fewer and were not given credit for the final answer.

The next part asked the students to combine uncertainties to determine the percentage uncertainty in the resistivity. Of those who used the correct method the most common error was to use three significant figures instead of one or two. In some cases, students thought that the percentage uncertainty in the diameter should also be halved for the radius when they should be the same. Only the absolute uncertainty is halved in this case. There were some students who simply added the percentage uncertainties and did not double the percentage uncertainty for the diameter. In rare cases, students just added the absolute uncertainties or failed to multiply by 100.

Finally the students had to determine the metal the wire was most likely to be made from given a table of values. This caused little difficulty for students who had correctly determined the resistivity with its percentage uncertainty. The students chose to use one of two methods here. The easiest method is to use the percentage uncertainty to calculate a range then comment on which value falls within these limits. The vast majority of students who chose this method scored full marks. The second method is to calculate a percentage difference then compare this to the percentage uncertainty. This method is more prone to errors, in particular using the calculated value rather than the accepted value in the denominator, or making a calculation error. It should be noted here that the calculation as written must be correct therefore students are advised to clear any values left in their calculator. More students using this method did not score full marks. A small number of students chose to calculate a maximum and minimum value from the data. Again this is an acceptable way of doing this however mistakes were often made as students chose the incorrect value to use in the denominator.

(iii) She measures the diameter as 0.275 mm ± 0.003 mm.

Calculate the percentage uncertainty in the measurement of the diameter.

(1)

$\frac{0.003}{0.275} = 0.011 = 1.1\%$

Percentage uncertainty = 1.1%

(b) The student measures the length and resistance of the wire and obtains the following results.

length = 0.800 m ± 0.001 m

resistance = 6.48 Ω ± 0.03 Ω

(i) Calculate the resistivity of the metal.

(2)

$R = \frac{\rho l}{A} \therefore \rho = \frac{RA}{l} = \frac{6.48 \times \pi \times (\frac{1}{2} \times 0.275 \times 10^{-3})^2}{0.8}$

$= 4.81 \times 10^{-7}\ \Omega m$

Resistivity = $4.81 \times 10^{-7}\ \Omega m$

(ii) Calculate the percentage uncertainty in your value of resistivity.

(3)

$\left(\frac{1.1}{2} \times 2\right) + \left(\frac{0.001}{0.800} \times 100\right) + \left(\frac{0.03}{6.48} \times 100\right)$

$= 1.1 + 0.125 + 0.46 = 1.685\%$

$\simeq 1.7\%$

Percentage uncertainty = 1.7%

(c) The table lists the resistivity of some metals used in resistance wires.

Metal	Resistivity / Ω m
constantan	4.9×10^{-7}
copper	1.7×10^{-8}
mild steel	1.5×10^{-7}
nichrome	1.1×10^{-6}

Explain which metal the wire is most likely to be made from.

(3)

$4.81 \times 10^{-7} \times 1.017 = 4.89 \times 10^{-7}$ Ωm => Max value for resistivity

$4.81 \times 10^{-7} \times 0.983 = 4.72 \times 10^{-7}$ Ωm => Min value for resistivity

As can be seen, the wire is most likely made of constatan, as after applying the % error for the calculated value, it only differs by 1.0×10^{-8} Ωm, which is negligible taking into account the uncertainty itself is not precise.

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Examiner Comments

In this example the student makes the mistake of halving the percentage uncertainty in the diameter to obtain the percentage uncertainty in the radius, hence only scores the first mark in part (b)(iii). This student makes a promising start in part (c) by correctly calculating the range from the percentage uncertainty, however then fails to use it specifically in the rest of the answer hence does not score the second mark. However the student correctly identifies the metal based on a calculation therefore scores two for this part. Overall this student scores six marks as both (a)(iii) and (b)(i) scores full marks.

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Examiner Tip

The percentage uncertainty is the same for both a diameter and radius.

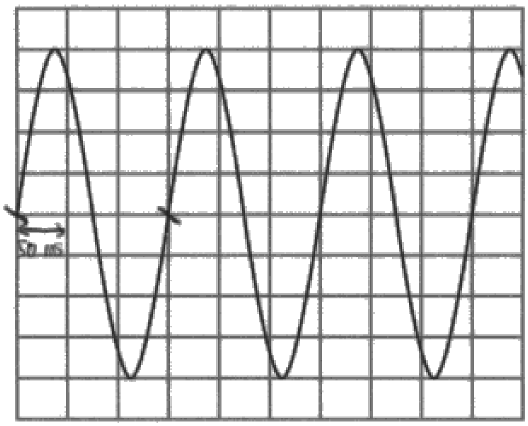
Question 2 (a)

This question focussed on planning an experiment to test the electrical characteristics of a coil of wire however it was set within a more unusual context of using alternating current.

In this part of the question students were shown the output of the signal generator on an oscilloscope screen. Most students coped well with determining the frequency of the signal however since this was a 'show that' question those only scoring one did not use enough significant figures. It is usual for this type of question to use at least one more than is given in the question. There were few students who did not correctly convert from milliseconds to seconds which had to be shown in the calculation.

2 (a) A student connects a variable frequency signal generator to an oscilloscope.

The oscilloscope displays how the output from the signal generator varies with time as shown.



On the horizontal scale of the oscilloscope screen, one division represents 50 ms.

Show that the frequency of the signal is about 6.7 Hz.

(2)

$f = \frac{1}{T}$ $T = 3(50\,ms) \rightarrow 3(50 \times 10^{-3}\,s) = 0.15\,s$

$f = \frac{1}{0.15} = 6.67$ $T = 150\,ms$ [crossed out] =

$6.67 \approx$ **6.7 Hz** $T = 150 \times 10^{-6}$

ResultsPlus
Examiner Comments

This is an excellent example of how this type of question should be answered to score full marks. The student has clearly converted from milliseconds to seconds and given a correct answer to one more significant figure than the 'show that' value.

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Examiner Tip

Always show a full calculation with measurements converted into SI units.

Question 2 (b)

The students then had to plan the experiment. Although this was a longer written exercise the majority of students followed the structure given. As usual, this type of question resulted in a wide range of marks. The majority realised they had to use a voltmeter and ammeter to measure potential difference and current however there were some that included other pieces of equipment. Those that had no bearing on the experiment, such as a metre rule, were ignored. However, the inclusion of a stopwatch to measure time was penalised as this indicated a lack of understanding of the experiment, perhaps confusing it with mechanical oscillations. Very few students realised that the first part of the question was leading them into the experiment as it was rare to see the time period of the signal quoted as a measurement. Some did realise that the frequency was required but this cannot be measured from the oscilloscope directly, although those that had stated that the frequency could be obtained from the signal generator or a frequency meter were credited.

The final aspect of the plan was to describe how the measurements would be used. It was here that students often scored fewer marks as they did not describe each stage of the process. Most realised that the impedance Z had to be calculated but this had to be stated explicitly rather than just quoting the formula given in the question. Few students stated that the values of Z and f had to be squared in order to plot the relevant graph. Most students did sketch the correct graph but some did not include a positive y intercept.

Write a plan for an investigation to verify the relationship $Z^2 = 4\pi^2 L^2 f^2 + K^2$ using a graphical method.

Your plan should include:

(i) any additional components required, **(1)**

(ii) the measurements to be taken, **(2)**

(iii) how the measurements will be used, **(3)**

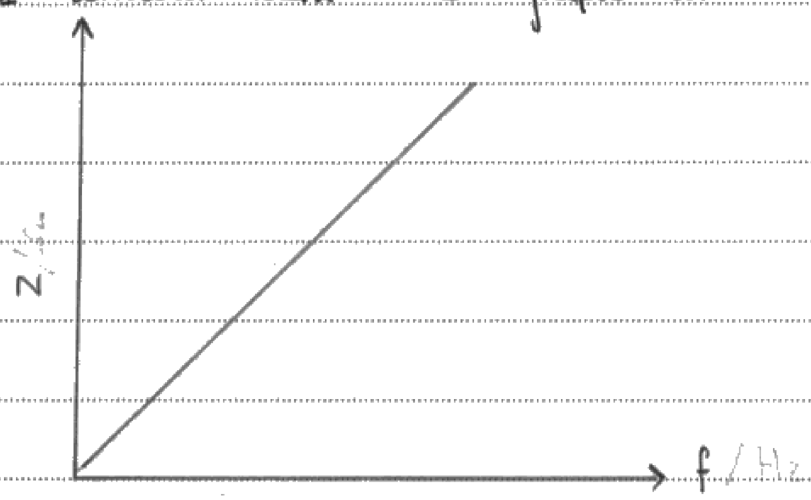
(iv) a sketch of the expected graph. **(1)**

i) Voltmeter and ammeter ~~to~~

ii) ~~Z (impendance) or~~ Voltmeter and ammeter are needed to find the potential difference and alternating current with respect to the frequency found through the variable frequency signal generator

iii) The voltmeter and ammeter are used to find Z (impendence) through the formula $Z = \frac{V}{I}$. Z will then be plotted on the y-axis of the graph. The frequency that has been measured by the ~~var~~ signal generator will be plotted on the x-axis. The results do not to be squared as without them the graph will be a straight line.

iv)



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Examiner Comments

This is an example of a fairly typical answer in which the student chose to follow the outline given. Unusually, this student had specified that the frequency should be measured from the signal generator hence scores both marks for part (ii). In part (iii) the calculation of impedance was specified however the student then states that they do not need to be squared, hence scoring only one mark here. The graph is clearly incorrect as it is not Z^2 against f^2 however this was more unusual to see. Overall this student scores four marks.

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Examiner Tip

When asked how the measurements will be used, ensure that any calculations are described explicitly.

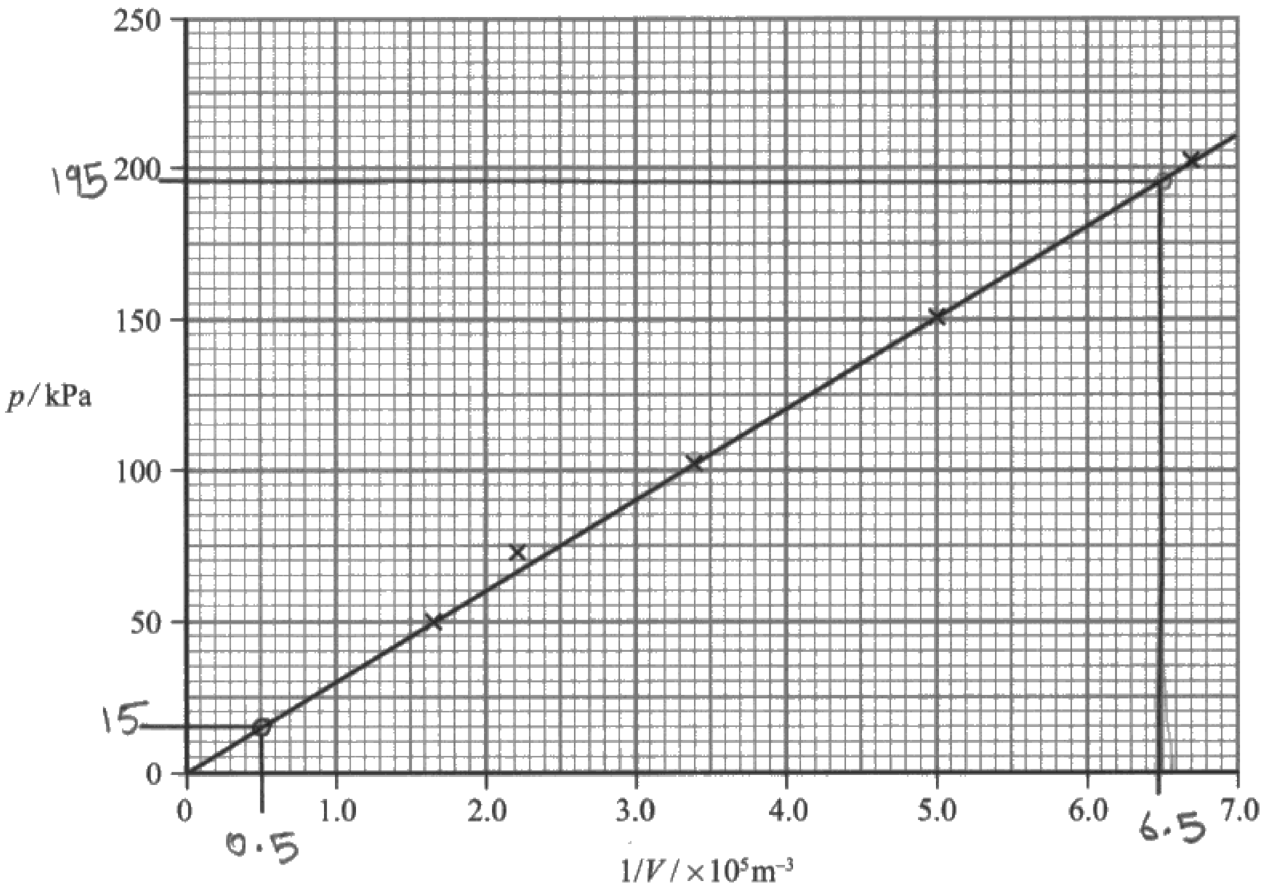
Question 3

This question involved analysing a Boyle's Law graph obtained from measurements of the pressure and volume of a sample of air trapped in a syringe. In the first part they had to calculate the gradient of the graph which most coped well with. The most common errors here included using only one significant figure where two or three should be used, or not converting the units. Occasionally students misread from the graph or used a triangle that was too small. It was surprising how many chose not to use the origin or places where the best fit line lay on simple values.

In the second part the students should have used the value of the gradient to calculate the number of molecules in the syringe. Some students chose to use a set of values from the graph which was accepted however this lead to some not using the correct value for the volume. There were instances where the temperature had not been converted to Kelvin but using the incorrect formula or value for the Boltzmann constant was rare.

3 A student investigates how the volume V of air in a syringe varies with pressure p.

She plots a graph of p against $1/V$ as shown.



(a) Determine the gradient of the graph.

(2)

$m = \dfrac{(195-15)\times10^3}{10^5\times(6.5-0.5)} = \dfrac{30\ \text{kPa}}{1\times10^5\ m^{-3}} = \dfrac{30\times1000}{10^5}\ Pa\,m^3$

$= 0.3\ Pa\,m^3$

~~$p = (m) \cdot \frac{1}{V}$~~

Gradient = $0.3\ (Pa\,m^3)$

(b) The investigation is carried out at a temperature of 25 °C.

Calculate the number of molecules of air in the syringe.

(2)

$pV = NkT$ $\quad\quad p = m \cdot \frac{1}{V}$

$m = NkT$ $\quad\quad \therefore pV = m$

$0.3 = N \times 1.38 \times 10^{-23} \times (298)$ $\quad\quad k = 1.38 \times 10^{-23}$

$\therefore N = 7.30 \times 10^{19}$ ~~moles~~

$\therefore$ no. of molecules $= 7.30 \times 10^{19}$

Number of molecules of air = 7.30×10^{19}

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Examiner Comments

In part (a) this student makes the mistake of giving the final answer for the gradient to one significant figure. However a large triangle is evident hence this part scores one mark. The calculation in part (b) is a perfect example of how to use the gradient. Overall this student scores three marks.

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Examiner Tip

When calculating a gradient, use sensible values from the best fit line and show a full calculation. Don't forget to check the units given in the axes labels.

Question 4 (a) (i)

The final data-handling question assessed the students' ability to analyse a non-linear relationship. In this series, the data was obtained from an experiment where measurements of the light intensity of light from a desk lamp passing through a set of polaroid filters was recorded as the filters are rotated relative to each other. Although this is not a standard experiment the majority of students scored well in certain areas.

This part of the question asked the students to state why the distance between the lamp and light meter should be kept constant. Although only a simple statement that varying the distance would vary the light intensity was required, those students who failed to score often gave a vague description or simply referred to a fair test. Some students went further and described how the light intensity would vary with distance. Some students stated that keeping the distance constant would keep the light intensity constant although for this they had to refer to a specific place, i.e. at the light meter or filters.

Question 4 (a) (ii)

In this part of the question the students had to identify the main source of uncertainty in the experiment. Students should realise that the main source of uncertainty may affect all measurements therefore those that stated the measurement of angle were not given credit. Most students specified background light but expressed this in a variety of ways which was acceptable.

Question 4 (b) (i)

This part of the question posed little difficulty for the majority of students since the formula was in the form of a power law despite the use of the cos function. In general, even weaker students were able to manipulate the formula into a straight-line form but a surprising number were still not explicit enough in comparing this to the equation of a straight line $y = mx + c$. Often they did not ensure that the order of the expanded formula matched the order of these terms in the equation of a straight line, however very few students did not include the + and = in the equation. The better students were able to express this well and often went further by explicitly defining the variables as well as the gradient. Students that scored one mark often did so by stating that the gradient was equal to *n* however some went further and stated that this was constant.

(b) The relationship between the measured light intensity I and the angle θ between the filters is given by

$$I = k(\cos\theta)^n$$

where k and n are constants.

(i) Explain why a graph of log I against log $(\cos\theta)$ should produce a straight line.

(2)

log I = log k + n log (cos θ).

This is in the form of y = mx + c. Where the gradient is n, which is a constant. The y, intercept is logk.

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Examiner Comments

This is a typical example of a student who does not score the first mark as the order of the expanded formula does not match the equation of the straight line. To score this mark the student could have stated $y = c + mx$ or defined each variable including y and x. The gradient is identified correctly hence scores one mark.

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Examiner Tip

Ensure that the order of the equation of a straight line and the expanded equation match.

Question 4 (b) (ii) - (iv)

Part (b)(ii) of this question involved processing the data and plotting the graph. The vast majority of students were able to calculate the logarithms but there were a number that only gave values to two significant numbers where three was expected, particularly for the cosθ values. Occasionally there were rounding errors in the processed data. Some students realised that the cosθ values would result in a negative value for the log so they appeared to multiply the values up by powers of 10 first however this was not evident in the table headings.

As is usual few scored well on the axis labelling, mostly omitting the brackets on the *y* axis label. Some students tried to include the degrees symbol on the *x* axis label but did so unsuccessfully. In general students chose sensible scales that allowed the plots to cover over half the scales. The most common reason for losing this mark is using a zero origin where it is not needed. Those students that used natural logs often missed this mark as this did not fit the page sufficiently however if the graph paper was used in landscape then this resulted in a large enough graph.

The negative values appeared to cause more problems when plotting this graph as some tried to plot negative points on a positive scale or used a negative axis in reverse. Provided the scale was sensible the plotting was accurate although the most mistakes occurred with the value at log *I* = 2.02. In addition, more students used neat crosses (+ or ×) rather than 'blobs' which, if larger than half a small square can lose the mark.

Finally, the best fit lines were reasonable as there was little scatter in the points, although there were instances where the lines were too high or too low resulting in too many plots above or below the line. In addition, the students should have realised that the best fit line had to extend to the *y* axis in order to determine a value for one of the constants.

In part (b)(iii) the majority scored at least one mark for determining the gradient correctly. Surprisingly few scored two marks, usually not scoring the final mark as too many significant figures were used or giving the gradient as positive or negative so it did not match the graph drawn. Again, it was surprising that students were not choosing sensible values to extract from the line. Occasionally students used values from the table which is acceptable provided they lie on the best fit line. Very few students did not realise that they had to calculate the gradient to determine *n.*

Finally, in part (b)(iv) provided the *y* axis was correctly drawn at *x* = 0 students tended to read it off correctly for the first mark. Almost all who got this far completed the calculation to score both marks. The exception tended to be where they plotted in log, and then tried to do inverse ln to get final value. Those that had not extended their best fit line to the *y* axis could still get these marks by using their value for *n* and a data point from the best fit line to substitute back into the formula. Students who plotted negative values on a positive scale tended not to score in this part.

(ii) The student records the following data.

θ/°	I/lux	$\cos\theta$	log(I/lux)	log(cosθ)
30	398	0.866	2.60	-0.0625
40	330	0.766	2.52	-0.116
50	256	0.643	2.41	-0.192
60	172	0.500	2.24	-0.301
70	105	0.342	2.02	-0.466
80	40	0.174	1.60	-0.759

Plot a graph of log I against log ($\cos\theta$) on the grid opposite. Use the additional columns to record your processed data.

(6)

(iii) Determine the value of n.

(2)

$m = \frac{2.52 - 1.69}{0.1125 - 0.675}$

$n =$ -1.48

(iv) Determine the value of k.

(2)

log k = y-intercept

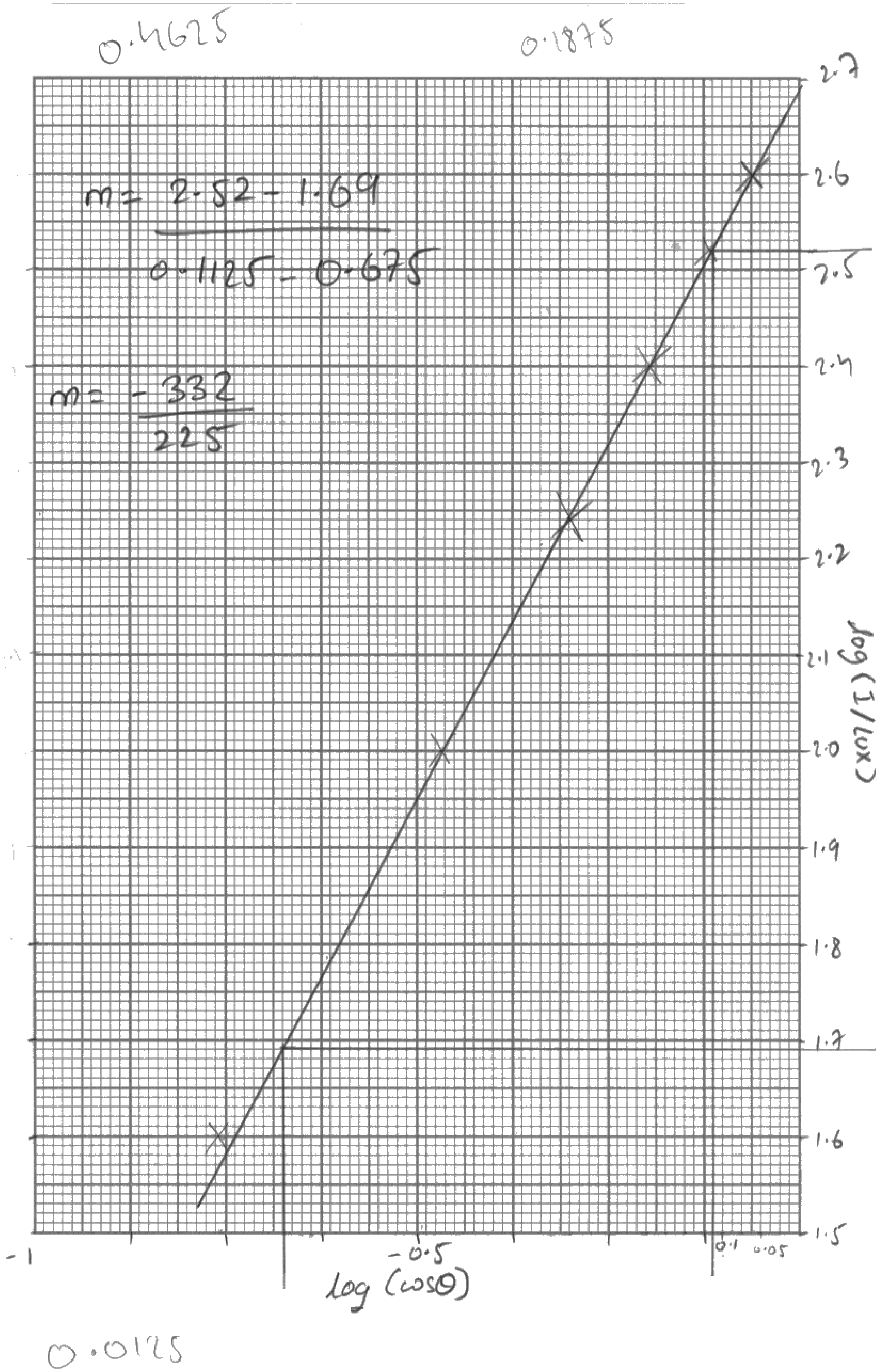
log k = 2.685

$\log_{10} k = 2.685$

$k = 10^{2.685}$

$k =$ 484

$\log_3 9$ $3^2 = 9$


0·4625
0·1875
m = 2·52 − 1·69 / 0·1125 − 0·675
m = −332 / 225
2·7
2·6
2·5
2·4
2·3
2·2
2·1
2·0
1·9
1·8
1·7
1·6
1·5
log (I/lux)
−1
−0·5
0·1
0·05
log (cosθ)
0·0125

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In this example, the student correctly calculates both sets of log values using three significant figures. The axes on the graph are labelled correctly however the scale of the *x* axis is not given to 1, 2 or 5 therefore this does not score the scale mark. In addition, there is a clear misplot on the graph and the best fit line is too low as there are more plots above the line than below, hence the graph scores three marks. In part (b)(iii) the gradient calculation is correct however the student has got confused with the use of the negative numbers and given a negative value when the gradient is shown as positive, hence scoring only one mark. The intercept is used correctly in the final part scoring both marks. Overall this student scores five marks.

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Examiner Tip

Use scales that are sensible, i.e. in 1, 2 or 5 and their powers of 10.

Paper Summary

This paper requires students to apply standard experimental techniques and skills to both familiar and unfamiliar contexts. Students that routinely carry out and plan practical activities for themselves using a wide variety of techniques will find this paper more accessible. In particular they should make measurements on simple objects using vernier scales, and complete experiments involving electrical circuits, heating, timing and mechanical oscillations. These can be simple experiments that do not require expensive, specialist equipment and suggested practical activities are given in the specification.

Based on their performance on this paper, students are offered the following advice:

- Use the number of marks given in a question as an indication of the number of answers required.

- If a question asks for an explanation or is a planning question, use sentences in a reasoned order. In particular describe explicitly each stage of a process including how data will be processed before a graph can be plotted.

- Where a calculation is used in an explanation, complete the answer with a written conclusion based on the results of the calculation.

- If a rounded answer is written down in a subsequent calculation ensure that this is the number used in the calculation.

- Show full 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. Use the number of significant figures shown in the data and uncertainties should be given to at least one fewer.

- Choose graph scales that are sensible, i.e. 1, 2 or 5 and their powers of ten only so that the plots cover at least half the page. It is not necessary to use the entire grid and grids can be used in landscape if that gives a more sensible scale.

- Learn standard measuring techniques and the reason they are used in terms of reducing the effect of both random and systematic errors.

- Learn the definitions of the terms used in practical work. These are given in Appendix 10 of the new IAL specification.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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