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Examiners' Report
June 2022

IAL Physics WPH16 01

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Introduction

The IAL paper WPH16 Practical Skills in Physics II assesses the skills associated with practical work in Physics and builds on the skills learned in the IAL paper WPH13. This paper assesses the skills of planning, data analysis and evaluation which are equivalent to those that A level Physics candidates in the UK are assessed on within written examinations. This document should be read in conjunction with the question paper and the mark scheme which are available at the Pearson Qualifications website, along with Appendix 10 in the specification.

In this specification, it is expected that candidates will carry out a range of Core Practical experiments. The skills and techniques learned will be examined in this paper but not the Core Practical experiments themselves. Candidates who do little practical work will find this paper more difficult as many questions rely on applying the learning to novel as well as other standard experiments.

It should be noted that, whilst much of the specification is equivalent to the previous specification, there are some notable differences. Candidates are expected to know and use terminology appropriately, and use standard techniques associated with analysing uncertainties. These can be found in Appendix 10 of the specification. In addition, new command words may be used which challenge the candidates to form conclusions. These are given in Appendix 9 of the specification, and centres should make sure that candidates understand what the command words mean.

The paper for June 2022 covered the same skills as in previous series and was therefore comparable overall in terms of demand.

Question 1 (a)(i)

Part (a) focused on the resolution of the thermometer used in the investigation. In part (i) candidates had to state the resolution of the centigrade scale. A surprising number did not manage this and often gave either the reading shown or the range of temperatures. This indicates that candidates either misunderstood the term "resolution" or did not know how to apply it to an analogue scale. Centres should note that the term "precision" is not equivalent to "resolution" in this specification.

Question 1 (a)(ii)

Part (ii) also proved challenging for most candidates which shows a misunderstanding in the techniques for using analogue instruments. As this was part of the same question, answers relating to the resolution were expected. The more successful candidates realised that the resolution of the thermometer was relatively large which would lead to a large uncertainty in the temperature value if the temperature was taken at fixed time intervals.

(ii) The student heated the liquid. He started a stopwatch and recorded the temperature of the liquid. He recorded the time at fixed intervals of temperature, as the temperature increased.

Explain why this method was better than starting a stopwatch and recording the temperature at fixed intervals of time.

(2)

Recording temperature at fixed intervals of time may result in temperatures which are not multiples of 5 in degrees celsius. The temperature may fall between an interval. This increases uncertainty and percentage uncertainty of temperature.

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Examiner Comments

This response shows a clear understanding of the problem in using this thermometer and scored both marks. Although the candidate does not use the term "resolution", it is clear that this is what they mean as the value of the resolution is stated, and they use the term "interval".

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Examiner Tip

Think about how to use an analogue instrument more effectively when measuring a quantity that is constantly varying.

Question 1 (b)(i)

Part (b) focused on using the same procedure to compare the specific heat capacities of different liquids. For part (i) candidates had to state a control variable. A large number of candidates quoted volume rather than mass, which is incorrect and implies that candidates were using their knowledge from similar questions.

Question 1 (b)(ii)

In part (ii) candidates were asked to sketch a line of the graph for a liquid with greater specific heat capacity. Despite being told that the investigation started at the same initial temperature, a number of candidates did not start the graph at the same point. Many candidates drew the line below the original, but it was straight rather than curved.

Question 1 (c)

In part (c) candidates had to give two reasons why a data logger would improve the investigation. As is usual for this type of question, candidates gave general answers that were not related to the context of the experiment, including reducing reaction time and automatically drawing graphs.

There are two main problems with this experiment. The temperature would be varying, therefore taking readings from both the thermometer and stop clock at the same time may be difficult. In addition, the temperature may be varying quickly, therefore being able to take more readings in a short time would lead to a more accurate graph. A data logger would overcome both of these problems.

(c) Another student performed the investigation using a temperature probe connected to a data logger.

Give two reasons why this would improve the investigation.

(2)

→ Temperature and time both readings can be taken simultaneously
→ Eliminates human reaction error.
→ More readings can be taken in a short interval.

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Examiner Comments

This response scores both marks, however the candidate has written three reasons instead of two. In this case, the extra reason was ignored. Candidates will often refer to "reaction time" without relating it to the context, which in this case would be an extension of the idea of simultaneous readings.

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Examiner Tip

Think about the problems with taking readings in a particular experiment, and how a data logger would overcome these.

Question 2 (a-b)

This question assessed planning skills within the context of investigating the energy transfer between two coupled pendulums. Although this is an unusual context, this experiment uses the techniques found in Core Practical 16: Oscillations.

Part (a) was the familiar planning question using another new command word, "Devise". Candidates should be aiming to write a method for the investigation described in the question that could be followed by a competent physicist. Although marks were not awarded for linking ideas, candidates often suffered as their use of language was imprecise or their descriptions became muddled making their intentions unclear. The best answers were well structured and concise, leading to a method that could be followed easily.

The mark scheme for this type of question can vary owing to the context of the experiment however they all follow a similar structure. The first four marks were dedicated to collecting the relevant measurements, in particular identifying appropriate instruments and the number of measurements needed, and how to analyse the data. The majority of candidates should be able to achieve two or three of these marks, but many did not. Most stated that a metre rule should be used to measure the distance, however there was either little or no indication of how many sets of data should be obtained. Although some candidates did state that a log graph should be drawn, the most common error was not including the concept of **checking** that it is a straight line or has a constant gradient. It appeared that many candidates assumed that the prediction was valid therefore the graph “will be” a straight line rather than “should be” a straight line. Occasionally, candidates referred to the formula for a simple pendulum rather than the power law that was given in the question.

The final two marks were for appropriate measuring techniques. Here candidates could state any two out of three to be awarded both marks. Many candidates were able to state that the metre rule should be vertical, but some stated the metre rule should be “perpendicular” but without a reference point, eg perpendicular to the bench. The techniques for timing the “oscillations” or cycles of energy transfer proved more challenging. It seemed that many candidates misunderstood what the value of the time period referred to and gave a list of techniques associated with determining the time period of a simple pendulum. This often led to candidates not being awarded the mark for timing multiple cycles. Candidates often cited “repeat and calculate a mean” which was accepted provided it was clear they were referring to timing without changing the value of the distance. This is often added as an afterthought at the end making it unclear what was being repeated.

Devise a plan to test the validity of this relationship using a graphical method.

(6)

For each length L:

- Measure the length L using a metre rule
- Use a set square placed on the metal ~~rod~~ rod to ensure that the ruler is vertical ~~ruler is vertical~~ and look at the scale perpendicularly to avoid parallax.
- Place a marker at the equilibrium position of each pendulum to ~~ensure~~ know accurately the start and end of the oscillation
- Displace one of the pendulums by a reasonably large angle and start the stopwatch when you let it
- Observe the other pendulum and stop the stopwatch when it stopped oscillating for the 5th time after oscillating and then divide the time by 5. Repeat the whole procedure and calculate the mean for the time P.

Perform ~~the~~ the whole procedure written above for at least 10 different values of L. Plot a graph of ln (P) against ln (L) and it should be a straight line with gradient b and constant ln (a) (y-intercept)

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Examiner Comments

This is a clear method which scores 5 marks. The candidate has thought carefully about the two variables and the techniques associated with their measurement. Note that the use of bullet points, or numbered lines, is fine to use and can often lead to a logically sequenced method.

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Examiner Tip

When devising a plan, consider how to measure each variable in turn, then describe how to use the data to plot a suitable graph.

In part (b) candidates had to suggest why using a video camera would improve the value of the time period. Again, this prompted general remarks about reducing reaction time without relating it to the experiment. This was accepted if there was a clear indication of how this would be achieved, eg by viewing the recording in slow motion.

(b) A student recorded the motion of the pendulums using a video camera.

Suggest how this may improve the measurement of P.

(2)

The experiment happens very quickly and the video camera allows pausing, rewinding allowing us to trace the exact time. This eliminates human reaction time (*) and therefore it reduces the percentage uncertainty of the values of P.

(Total for Question 2 = 8 marks)

(*) And the high framerate means that the resolution of the video camera is better than the resolution of the stopwatch.

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Examiner Comments

This response scores both marks. This candidate has thought carefully about a potential problem with this experiment, as changes in the motion could happen quickly. As is often with these questions, the candidate mentions reaction time, but there is just enough in the answer to indicate how using the video recording could help to eliminate it.

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Examiner Tip

Practise recording motion using a camera phone and compare it to timing with a stop clock.

Question 3 (a)

In part (a) candidates had to explain why a graph of log Z against log f should produce a straight line. This type of question should be very familiar however there may be a slightly different emphasis that candidates should be aware of. The first mark was for performing a correct log expansion of the given formula. There are only two forms this can take, either a power law such as this, or an exponential function. However a large number of candidates did not complete this successfully. For the second mark, candidates had to compare their log expansion with y = mx + c which is standard for this type of question. The most common error here was not writing this in the same order as the log expansion. Candidates then had to state that the gradient is constant. The vast majority of candidates were not awarded the mark as most only stated the gradient was n. This would be correct if the question had asked how the log graph would lead to a value for n but the emphasis here was why it would lead to a straight line. Candidates should also state "the gradient is" rather than refer to "m" as this shows an understanding of the equation of a straight line.

3 Atoms of an element emit characteristic spectral lines when they are bombarded with a beam of high energy electrons. The spectral lines can be used to identify the element.

(a) The relationship between the atomic number Z and the frequency f of the most intense spectral line is given by

$$Z = kf^n$$

where k and n are constants.

Explain why a graph of log Z against log f would give a straight line.

(2)

From the given equation, we have log Z = log K + n log f.

By comparing y = mx + c with log Z = n log f + log K, the graph of log Z against log f should be a straight line with a constant gradient n with the intercept on the log Z axis as log K, which is also a constant.

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Examiner Comments

This response scores both marks and is a good example of an explanation. Initially, it looks like the order of the expanded formula on the first line does not match with $y=mx+c$, however the candidate then carries on to make the correct comparison. There is a clear statement relating to a constant gradient to enable the second mark to be scored.

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Examiner Tip

Refer explicitly to the gradient not *m*, and in the case of a straight line the need for the gradient to be constant.

Question 3 (b-c)

Part (b)(i) assessed the candidates’ ability to process data and plot the correct graph. This type of question appears in every paper with a common mark scheme, therefore there is plenty of opportunity to practise this skill and consult Examiner’s Reports to correct common errors. A strong candidate should be able to access most of the marks and most candidates should be able to score some marks.

The first two marks were for processing the data correctly and was awarded most often. The number of decimal places given should be sufficient to plot a graph on standard graph paper. For logarithms candidates should give a minimum of two decimal places although three is accepted. Some candidates converted the frequency into Hz despite the instruction not to do so. The most common errors here were truncating rather than rounding and using an inconsistent number of decimal places in processed data.

(b) The table shows the frequency of the most intense spectral line for a range of elements.

Element	Z	f / 10^{15} Hz	log z	log (f/10^{15} Hz)
Li	3	0.16	0.48	−0.80
C	6	0.69	0.78	−0.16
Si	14	4.19	1.15	0.62
Mn	25	13.82	1.40	1.14
Sr	38	33.98	1.58	1.53
Hg	80	154.64	1.90	2.19

(i) Plot a graph of log Z against log f on the grid opposite. Use the additional columns for your processed data.

You should **not** convert the values of f from 10^{15} Hz to Hz.

(6)

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Examiner Comments

This is an excellent example of a graph that scores full marks. In the table, all the values are correct and given consistently to 2 decimal places. The headings in the table look promising, but these are not given credit here.

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Examiner Tip

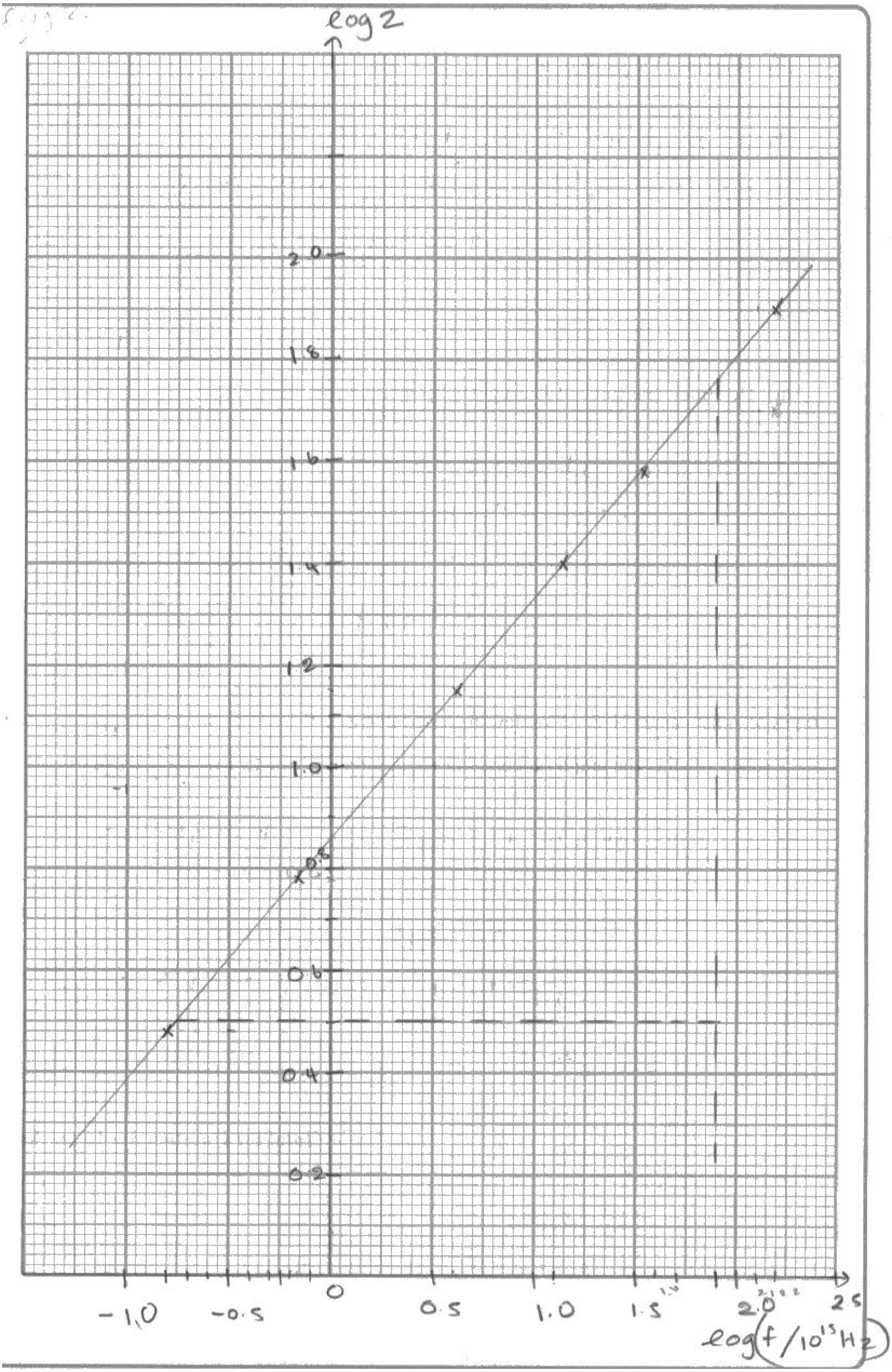
Ensure calculators show values to at least 5 decimal places in order to avoid issues with rounding.

The third mark was for placing the axes the correct way around and labelling with the correct quantity. There were unusually high number of candidates that placed the axes the wrong way around, ie plotted log *f* against log *Z*. Candidates should note that the question is always written in the form “plot *y* against *x*”. This also often led to mistakes in parts (ii) and (iii). The most common mistake is not using the correct format for labelling a log axis, either by missing out the brackets or units or both. The correct form is log (quantity/unit), eg log (f / 10^{15} Hz).

The fourth mark was for choosing an appropriate scale. At this level, candidates 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**. Candidates 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, and a landscape graph can be used if it produces a more appropriate fit. In this case it was unnecessary. Candidates at this level should also realise that scales do not have to start from zero and scales based on 3, 4 (including 0.25) or 7 are not accepted. There were an unusually high number that used 0.25 on the *y* axis or 0.4 on the *x* axis, and other types of awkward scales. On this paper candidates are not awarded the plotting mark if an awkward scale is used. Candidates should also be encouraged to label every major axis line, ie every 10 squares, with appropriate numbers, so that examiners can easily see the scale used. Occasionally, candidates mislabelled their axes so that the scale appeared to change.

The fifth mark is for accurate plotting. Candidates should be encouraged to use neat crosses (´ or +) rather than dots when plotting points. Candidates were not awarded this mark if they used large dots that extended over half a square or used an awkward scale. Mis-plots were often seen, and candidates should be encouraged to check a plot if it lies far from the best fit line.

The final mark is for the best-fit line. Often candidates will join the first and last points instead of judging the scatter of the data points. However, this mark was awarded often as the data used did not produce a significant scatter.


log z
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-1.0
-0.5
0
0.5
1.0
1.5
2.0
2.5
log(f/10^15 Hz)

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Examiner Comments

This graph shows what can be achieved by an A level candidate. It is clearly labelled, both with the correct axes titles from the table and the scale values on each major grid line. The scales are sensible, *x* is in 0.5 and *y* is in 0.2, and allow the points to be plotted over half the page. Both the plots and best fit line are neat and accurate. The candidate has also drawn a large triangle using sensible points from either end of the graph which is used in part (ii).

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Examiner Tip

Practise drawing graphs on a regular basis.

In part (b)(ii) candidates were asked to determine a value for *n*. As this question is in the same part as the graph, the graph should be used, ie by calculating a gradient. There were several errors seen in this part. Many candidates used the first and last points, or other data points from the table. This is only acceptable if the data points lie **exactly** on the best fit line. Candidates should be encouraged to find places where the best-fit line crosses an intersection of the grid lines near the top and bottom of the best-fit line and marking these on the graph. Those candidates that used awkward scales were often only successful when sensible values were used. Occasionally, candidates used the 10^{15} factor, which is incorrect, and some rounded their final value to 0.5. There were some candidates who calculated the gradient in part (iii), but these candidates were given credit.

(ii) Determine the value of n.

(3)

$$n = \frac{y_2 - y_1}{x_2 - x_1} = \frac{1.76 - 0.5}{[1.9 - (-0.75)] \times 10^{15}}$$

$$= 4.7547 \times 10^{-16}$$

$n =$ 4.75×10^{-16}

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Examiner Comments

This response scores 2 marks. The large triangle drawn on the graph was used to extract the data correctly to score the first mark. Unfortunately this candidate mistakenly used the factor x10^{15} in the denominator, therefore the final answer was not in range, so the second mark was not scored. However, the final value is based on a gradient calculation and given to 3 significant figures so the final mark could be scored.

ResultsPlus
Examiner Tip

Draw a large triangle using sensible points of intersection near each end of the best fit line to aid a gradient calculation.

In part (b)(iii) candidates had to use the graph to determine a value for *k*. A number of candidates did not use the graph, although correct numerical answers were accepted. The most common error here was not reading the intercept of the graph correctly. This was more prevalent amongst those candidates that had inverted the axes or converted the values of *f*. It was not uncommon to see candidates use the value where the line crossed the *x* axis or where the line reached the end of the grid. In addition, some used the incorrect antilog. Candidates could also use the straight-line formula and the value of their gradient, but sometimes candidates took values from the line then calculated the log of these values.

(iii) Determine the value of *k* using your graph.

(3)

$\log k = c$

$\log k = 0.86$

$k = 10^{0.86}$

$= 7.2444$

$k = 7.24$

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Examiner Comments

This response scores 3 marks. The candidate correctly reads the *y* intercept from the graph and shows a full calculation to obtain the value of *k* in the range stated to 3 significant figures.

ResultsPlus
Examiner Tip

To find the value of a constant from a *y* intercept, draw the *y* axis at *x* = 0 instead of at the side of the page.

In part (c) candidates had to explain whether the graph supported the formula given. It appears that many candidates remembered answers based on similar questions and used data from the table to calculate a constant. The question was based on **the graph**, so candidates should be using **features of the graph** to answer this. Where candidates did this, they often just stated their value of *n* was close to 0.5 without making clear what the value of *n* referred to or stating what their value of *n* was.

(c) A scientist named Henry Moseley suggested that $Z \propto f^{0.5}$

Explain whether the graph supports this suggestion. log z   gradient
0.5 log f
(2)

The graph of log z against log f is a
Straight line.
log z ∝ 0.5 log f
This suggestion is valid as n = 0.5.

ResultsPlus
Examiner Comments

Unfortunately this candidate had not done quite enough to score any marks. It looks like there is an attempt to show that the gradient should be 0.5, but this was not explicit enough to score the mark. Also there is a statement that *n* = 0.5, however there is no explicit comparison and they seem to have forgotten that their value had a factor of 10^{-16} so the conclusion is incorrect on this basis.

ResultsPlus
Examiner Tip

Use features of the graph, such as the gradient or the presence of a *y* intercept, when the question asks whether a graph supports a relationship.

Question 4 (a)(i)

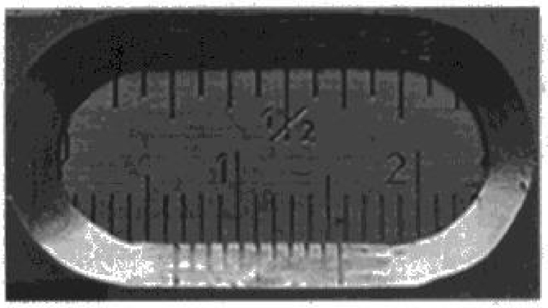
This question involved determining a value for the density of a metal in the form of a hexagonal nut. The measurements involved the use of calipers and candidates should learn the techniques for using instruments such as this. In addition, the analysis of uncertainties is common to all past papers therefore candidates should be encouraged to analyse uncertainties on a regular basis, either whilst making measurements or using past papers. Candidates should read Appendix 10 of the specification and include all working as marks are awarded for the method.

In part (a)(i) candidates were shown two measurements of the diameter using a set of Vernier calipers and a set of digital calipers. They were then asked why the digital calipers would be a better choice of instrument. This is a question used in a number of past papers, but the difference was the use of actual measurements rather than estimates. It was also worth 4 marks rather than the usual 2 marks, so candidates should have realised that more detail was needed, including calculations which was stated in the question.

4 A student measured a metal nut of the type shown below.

(a) The student measured the diameter d of the hole in the centre of the metal nut.

(i) She made one measurement in cm using Vernier calipers and one measurement in mm using digital calipers. The photographs show the measurements. 0.658 cm



Explain why the digital calipers would be a better choice of instrument for this measurement.

You should include calculations in your answer.

(4)

% uncertainty for digital caliper = $\frac{0.005\text{ mm}}{6.58\text{ mm}} \times 100\% = 0.076\%$

% uncertainty for vernier caliper = $\frac{0.005\text{ cm}}{0.66\text{ cm}} \times 100\% = 0.76\%$

% uncertainty for digital caliper is smaller than that of vernier caliper.

Digital caliper also give reading to more significant figures hence digital caliper is more precise.

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Examiner Comments

This scores 4 marks. Both percentage uncertainty calculations are correct to score the second and third mark with the correct comparison for the fourth mark. Although the candidate does not state the term "resolution" the use of "more significant figures" is acceptable here. The candidate also states "more precise" but this is not "precision" so is treated as a null statement.

ResultsPlus
Examiner Tip

Practise reading Vernier scales and use half the resolution for the uncertainty when given single measurements.

Question 4 (a)(ii)

Part (a)(ii) was another familiar question in which candidates had to **explain** another technique for using digital calipers. As is usual in this type of question, many candidates only described the techniques but did not link them to a particular type of error or gave two techniques instead of the one the question asked for. It is also expected that candidates give enough detail in relation to the context of the experiment for each technique. Therefore, for a repeated measurement it is expected that the candidates describe where or how to take the repeated measurement. Often, candidates omitted “at different orientations” or words to that effect. For the concept of the zero error associated with a piece of apparatus, it is expected that candidates state that it must be corrected for and not just checked. The second mark was for linking the technique to its particular type of error. Candidates who attempted this did it well, although it should be noted that a random error can only be reduced not eliminated.

(ii) The student determined a more accurate value for *d*.

Explain one technique she could have used.

(2)

~~Check for zero error to elimitate systematic error~~ Measure the values at different positions for a few times and calculate the mean to reduce the effect of random errors.

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Examiner Comments

This response scored both marks. Although the candidate does not state "repeat", "for a few times" is acceptable. The correct explanation is given for this technique. Of interest is the crossed out work, which would not have been marked as there was an alternative answer. This would not have scored the first mark as there is no idea of "correcting for" but would have scored the second mark.

ResultsPlus
Examiner Tip

Check whether the question is "describe" or "explain". For an "explain" question a reason is also needed.

Question 4 (a)(iii)

Part (a)(iii) involved calculating a mean and uncertainty from a set of data. The first mark was for the correct value of the mean given to the same number of decimal places as the measurements. Most candidates gained this mark, but a small number gave too many decimal places. The second two marks were for the uncertainty calculation. The candidates **must show** the uncertainty calculation for the second mark, and this is awarded for calculating the **half range or furthest from the mean**. A small number of candidates used the first and last values given in the table instead of the highest and lowest values. Some candidates also calculated the percentage uncertainty. The final mark was for the correct uncertainty given to the same number of decimal places as the measurements. It was rare to see candidates give too many figures.

(iii) The student recorded the following measurements.

d / mm	6.57	6.58	6.54	6.52

Determine the mean value of *d* and its uncertainty in mm.

(3)

$$\frac{6.57+6.58+6.54+6.52}{4} = 6.55$$

$$\frac{6.58-6.52}{2} = 0.03$$

Mean value of *d* = 6.55 mm ± 0.03 mm

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Examiner Comments

A perfect answer with calculations included, scores 3 marks.

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Examiner Tip

Include working in all calculations.

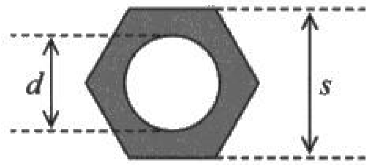
Question 4 (b)

In part (b) candidates were given a formula for the area of the hexagonal nut with data for the measurements. They were asked to **show that** the uncertainty in the area *A* was about 0.01 cm^2. This required the candidates to show a full calculation as the first three marks were awarded for the method. The final mark was for the **correct** final answer given to one more figure than 0.01 cm^2. It should be noted that the final value varied slightly owing to rounding. Candidates used two methods of solving this, either by combining percentage and absolute uncertainties, or by using the maximum and minimum method.

Combining uncertainties proved to be less successful. Candidates often calculated the percentage uncertainty in s^2 and d^2 correctly, but then added them together, hence only the first mark was scored. Some candidates then calculated the absolute uncertainty in either s^2 or d^2. Those candidates that did this often then added these together to gain the second and third mark, but either did not use the scaling factors in the formula or did not successfully convert from mm^2 to cm^2 to gain the final mark. Those candidates that did, often gained the final mark by giving the additional digit. The best candidates performed this in one calculation.

Using the maximum and minimum method was more successful. The main issue was using either both maximum values to calculate the maximum, or both minimum values to calculate the minimum. The best candidates calculated both maximum and minimum values then averaged them for the final answer, although just one value was accepted.

(b) The student was given a different size metal nut. She measured the distances shown.



She calculated the shaded area A of the metal using the formula

$$A = \frac{\sqrt{3}}{2}s^2 - \frac{\pi}{4}d^2$$

$s = 16.83\,\text{mm} \pm 0.02\,\text{mm}$
$d = 8.55\,\text{mm} \pm 0.04\,\text{mm}$
$A = 1.88\,\text{cm}^2$

Show that the uncertainty in A is about $0.01\,\text{cm}^2$.

(4)

$\%U$ of $s^2 = \left(\frac{0.02}{16.83} \times 100\right) \times 2 = 0.238$

U of $\frac{\sqrt{3}}{2}s^2 = \frac{\sqrt{3}}{2} \cdot \left(\frac{16.83}{10}\right)^2 \times \frac{0.238}{100} = 5.84 \times 10^{-3}\,\text{cm}^2$

$\%U$ of $d^2 = \left(\frac{0.04}{8.55}\right) \times 100 \times 2 = 0.936\%$

U of $\frac{\pi}{4}d^2 = \frac{\pi}{4} \cdot \left(\frac{8.55}{10}\right)^2 \times \frac{0.936}{100} = 5.37 \times 10^{-3}\,\text{cm}^2$

U of $A = 5.37 \times 10^{-3} + 5.84 \times 10^{-3} = \boxed{0.0112\,\text{cm}^2 \approx 0.01\,\text{cm}^2}$

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Examiner Comments

This response scores 4 marks. The candidate has used the combining uncertainties method. The working is clear leading to a slight variation in the final answer owing to the level of rounding. The candidate has stated what is being calculated, which helps to structure the working. It appears that the candidate has considered each aspect of the formula in turn.

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Examiner Tip

Practise using the rules for combining uncertainties.

Question 4 (c)

In part (c)(i) the candidates had to calculate a value of the density **using the data given**. This was a relatively straightforward calculation seen in a variety of past papers. The data was given in a variety of units and some candidates either did not convert them at all or did it incorrectly. Those that did so only scored the first mark. The second mark was for the correct answer given to three significant figures only. Only a few candidates used a different number of significant figures.

(c) The student measured the mass m and the thickness x of the metal nut.

$m = 10.3\,\text{g} \pm 0.1\,\text{g}$
$x = 7.92\,\text{mm} \pm 0.03\,\text{mm}$
$A = 1.88\,\text{cm}^2 \pm 0.01\,\text{cm}^2$

1cm = 10mm.
- 7.92

(i) Determine the density ρ of the metal from which the nut is made.

(2)

$D = m/V$

$$= \frac{10.3}{1.88 \times \frac{7.92}{10}} = 6.92\,\text{gcm}^{-3}$$

$\rho =$ 6.92gcm^{-3}.

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Examiner Comments

A perfect answer to score both marks.

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Examiner Tip

Check the units needed later in the question and convert values before substituting into a formula.

In part (c)(ii) the candidates were given the range of values for the density of steel then asked to deduce whether the metal nut could be made from steel using their calculated value of density. This is a standard question used in every series but there were a significant number of candidates that did not attempt this. Those that did often scored well using one of the three different methods. Candidates must show their calculations as marks are awarded for the method and the final value may differ slightly owing to different levels of rounding.

The first method was combining uncertainties and calculating the limits. It was pleasing to see most candidates combine the uncertainties correctly. The main error was using absolute rather than percentage uncertainties. In addition, it appeared that some candidates used the values from part (b) instead of the data given. Some candidates chose to use a maximum or minimum method. They were largely successful with this, but again the main error was either using all maximum values or all minimum values instead of a combination. A smaller number of candidates used the percentage difference method. This is an approximate method and should only be used when an uncertainty on the measurements is not available. However, this is accepted but can produce more errors, most notably using the calculated value or a mean of the quoted values in the denominator rather than just one of the quoted values. Although most candidates calculated the percentage difference for the quoted value closest to their calculated value, some used the quoted value furthest from the calculated value. For all three methods, the final mark is for a correct conclusion. As in previous series, the main error with the conclusion was not explicitly making a comparison between values.

(ii) The density of steel ranges from 7.85 g cm^{-3} to 8.03 g cm^{-3}.

Deduce whether the metal nut could be made from steel.

(3)

% U in Density = % U in mass + % U in volume .

$= \left(\frac{0.1}{10.3} \times 100\right) + \left(\frac{0.03}{7.92} \times 100\right) + \left(\frac{0.01}{1.88} \times 100\right)$

= 0.971% + 0.3787% + 0.532%

= 1.8817%

(Total for Question 4 = 18 marks)

TOTAL FOR PAPER = 50 MARKS

∴ upper limit = (1.882% × 6.92) + 6.92

= 7.05 g cm^{-3} .

7.05 < 7.85

∴ no it cannot be made of steel .

ResultsPlus Examiner Comments

A perfect answer to score 3 marks. This candidate has used the combining uncertainties and calculating a limit method. The working is very clear and easy to follow. Note that the answer does continue into the blank space below which is fine. The limit is correct and there is an explicit comparison to the relevant quoted value. The comment is valid based on the comparison.

ResultsPlus Examiner Tip

Practise calculating limits using uncertainties and ensure conclusions contain clear numerical comparisons.

Paper Summary

Candidates 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. In particular, they should make measurements on simple objects using Vernier calipers and micrometer screw gauges and complete all the Core Practical experiments given in the specification.

Based on their performance on this paper, candidates should:

- learn what is expected from different command words, in particular the difference between "describe" and "explain".
- use the number of marks available to judge the number of separate points required in the answer.
- be able to describe different measuring techniques in different contexts and explain the reason for using them.
- show working in all calculations.
- choose graph scales that are sensible, ie 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, ie in 3, 4 or 7. Grids can be used in landscape if that gives a more sensible scale.
- plot data using neat crosses (´ or +) and draw best fit lines. Avoid simply joining the first and last data points without judging the spread of data.
- 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 and standard techniques for analysing uncertainties. These are given in Appendix 10 of the IAL specification.
- revise the content of WPH13 as this paper builds on the knowledge from AS.