Examiners' Report
Principal Examiner Feedback

January 2019

Pearson Edexcel International Advanced Level
In Physics (WPH06) Paper 1
Experimental Physics

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Introduction

The IAL paper WPH06 is called Experimental Physics and 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 candidates in the UK are now assessed on within written examinations. Candidates who do little practical work will find this paper more difficult as many questions rely on candidates being able to apply their knowledge of practical techniques to novel as well as standard experiments. In the forthcoming new specification, it is expected that candidates carry out a range experiments as the skills and techniques learned will be examined in different contexts.

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 January 2019 covered the same skills as in previous series however there were more questions that required longer explanations or were more open-ended than in previous series. This resulted in a mean mark that was slightly lower than in January 2018. Centres should note that these types of questions will appear in the new specification.

Question 1

As in previous series, this question assessed the candidates' ability to calculate and use uncertainties at the level expected of an A2 candidate. This question was set in a more unusual context and concerned determining a value of the packing fraction of a set of four tennis balls packed into a cylinder. The candidates were expected to use uncertainties to judge whether the measured packing fraction was equivalent to the theoretical value of two thirds.

Part (a) (i) asked a definition of the term "systematic error". This was surprisingly poorly answered by the vast majority of candidates. Many tried to use the idea of a zero error but just reworded the stem of the question or described what a zero error is. In addition, most referred to it being an error caused by the instrument without any reference to calibration.

In part (a) (ii) the candidates were asked to explain whether repeat measurements were appropriate when measuring the diameter of the tennis ball. This was well answered by the majority of candidates, often citing the reducing of the effect of random errors or the non-uniformity of the ball as reasons to repeat the measurement. Candidates were often not awarded marks as they were not specific about repeat measurements being required or by referring to eliminating random errors. In addition, there were references to identifying but not removing anomalies, reducing percentage uncertainty and increasing accuracy which were not credited.

The remainder of part (a) involved calculating the percentage uncertainty in the diameter from a set of diameter measurements, followed by calculating the volume of the tennis ball and its uncertainty. It was pleasing that more candidates were using the half range of data to calculate the percentage uncertainty rather than the full range, although candidates were given some credit for using the full range. Centres should note that only the half range will be accepted in the new specification. In addition, only a very small number used the resolution of the vernier calipers, which was not credited. It is expected that the uncertainty should be stated to at least one fewer significant figures than the data, which a large number of candidates did, however answers to three significant figures were accepted on this occasion. The majority of candidates calculated the volume correctly although the most common error was giving more than three significant figures.

Candidates should note that a quantity derived from data should not be presented to more significant figures than the data. There were very few power of ten and unit errors seen, as was not halving the diameter. When calculating the uncertainty, the most common errors were either using three times the half range from (a) (iii) instead of the percentage uncertainty, or just quoting the value of three times the percentage uncertainty. Some candidates tried to halve the percentage uncertainty in the diameter assuming this was the percentage uncertainty in the radius, which is incorrect. It was interesting that candidates who had given the percentage uncertainty to two significant figures in (a)(iii) then went on to use three significant figures in the uncertainty. A good answer is shown below.

(iv) The volume V of the tennis ball is given by the equation

$$V = \frac{4}{3}\pi r^3$$

Calculate V and its uncertainty.

(3)

$V = \frac{4}{3}\pi r^3$

$V = \frac{4}{3} \times \pi \times \left(\frac{6.58}{2}\right)^3$

$V = \frac{4}{3} \times \pi \times (3.29)^3$

$V = \frac{4}{3} \times \pi \times (35.61\ldots)$

$V = 149.16\ldots \text{ cm}^3$

$V = 149 \text{ cm}^3$ (3s.f.)

P. uncertainty in value of volume $= \cancel{0.46 \times 3}$ $\cancel{= 1.3}$

$= 0.455\ldots \times 3$

$= 1.367\ldots \%$

Uncertainty in value of volume $= \frac{1.367\ldots}{100} \times 149.16$

$= 2.040\ldots$

$= \pm 2 \text{ cm}^3$

$V = 149$ $\cancel{\text{cm}^3}$ $\pm$ 2 cm^3

Part (b) introduced the idea of a packing fraction as a ratio of the volume of the balls to the ratio of the tube. In part (i) candidates had to show that this value should be 2/3. Many candidates scored full marks here, the majority of which using an algebraic method. Those who failed to score with this method often forgot to multiply the ball volume by four. A number of candidates used a numerical approach which was also credited, however many lost the final mark by not evaluating the final answer as a decimal. Candidates who rounded the values in the fraction to one significant figure were credited.

The final part of the question, part (b) (ii), required the candidates to determine whether the measured packing fraction was indeed 2/3. This was a less structured question than in previous series and candidates found different, albeit valid, methods which were all credited provided their argument was clear. In previous series this question would have been split into two parts, firstly calculating a final percentage uncertainty then comparing to a final value. Weaker candidates often failed to realise that uncertainties should be used at all and just calculated the packing fraction and compared it to 2/3, hence this part of the question discriminated particularly well. It was expected that the candidates would calculate a percentage uncertainty in the packing fraction then use it to calculate the upper and lower limits for comparison. A number of candidates used the absolute uncertainties to calculate the upper and lower limits, which was also valid, however some candidates who tried this and lost marks did so by using the incorrect combination of maximum and minimum values or by only using the maximum or minimum in one value. A good example of the use of absolute uncertainties is shown below.

(ii) The volume of the tube is $1020 \pm 30\,\text{cm}^3$.

Determine whether the student's measurements confirm that the packing fraction is 2/3

(4)

Mean packing fraction = $\frac{149\times4}{1020} = \frac{596}{1020} = 0.584...$ $\quad \frac{2}{3} = 0.666...$

Maximum ~~pack~~ packing fraction = $\frac{(149+2)\times4}{(1020-30)} = \frac{151\times4}{990} = \frac{604}{990} = 0.6101...$

Minimum packing fraction = $\frac{(149-2)\times4}{(1020+30)} = \frac{147\times4}{1050} = \frac{588}{1050} = 0.56$

Range = 0.56 – 0.61

~~The~~ The value of $\frac{2}{3}$ is greater than the maximum calculated value of 0.6101... for the packing fraction using the ~~student~~ student's measurements. So students measurements do not confirm that packing fraction is 2/3 as 2/3 not within calculated range for packing fraction.

(Total for Question 1 = 15 marks)

Centres should note that the percentage difference method was accepted on this occasion and is only valid when comparing a measured value to an accepted value, in this case for comparing the measured packing fraction to 2/3. This method will not be accepted in the new specification.

Question 2

This question focussed on measuring techniques in the context of investigating how the angle of a ramp affects the horizontal distance a marble travels from the ramp. It was clear that many candidates had not carried out this, or a similar, experiment.

In part (a) candidates were given values of the angle measured by a protractor and the height and length of the ramp using a metre rule. Candidates were then expected to determine which method for determining the angle would be more accurate. In the majority of cases, candidates realised that using the expected percentage uncertainties of these measurements as a comparison was the way to achieve this. The most common error was assuming the protractor had a resolution of 0.1° however candidates that used this value could still gain credit for the calculation. Candidates should note that the recorded measurements indicate the resolution of the instrument used. In addition, some candidates did not evaluate the percentage uncertainty for the ratio of ramp height to length. The final mark could be awarded if the candidates compared their calculated values. Most candidates did realise which method could be more accurate however some did not gain the mark as there was no explicit comparison between the figures. The example below shows all of these common errors however the candidate did score one mark for calculating the percentage uncertainty from the protractor resolution.

(a) The angle α is adjusted so that a marble at the top of the ramp just begins to roll.

Student A measures α with a protractor and records a value of 5°.

Student B measures the distances s and h with a metre rule and records s as 1.000 m and h as 8.7 cm. He calculates α from these measurements.

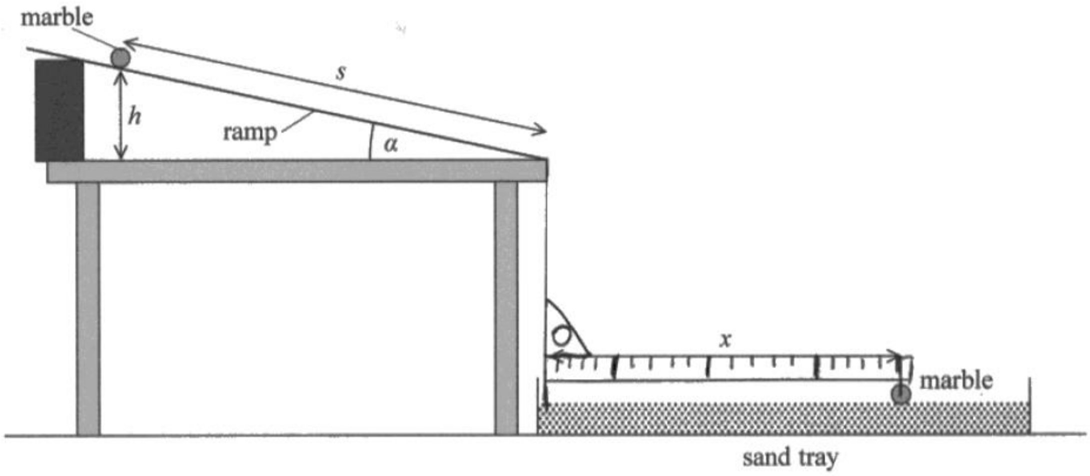
Explain whether student A or student B will obtain a more accurate value for α.

(4)

B is more accurate.
Protractor with presision 0.1°
$\% U = \frac{0.1°}{5°} = 2\%$
B measure long distance, gives more significant figure of angle
$\% U = \frac{1\,mm}{1000\,mm} + \frac{1\,mm}{87\,mm} = 1.1\%$
meter rule precision 1 mm
Repeat, reduce random error.

In part (b) candidates had to explain how to measure the horizontal distance. It was clear from this that candidates had little experience of making measurements of this kind. The first mark was awarded for stating where the distance should be measured from and the second mark was awarded for stating where the distance should be measured to. Of those who scored marks it was often for stating that the distance should be measured to the centre of the marble. In addition, better candidates described measuring to the front and back of the marble and taking a mean value. In general, the first mark was lost as the candidates described measuring from the edge of the sand tray rather than from directly below the edge of the ramp. Marks could be gained from good diagrams and candidates should be encouraged to draw simple diagrams to aid their descriptions. The following candidate gained both marks from a clear diagram.

2 The projectile motion of a marble can be investigated using the apparatus shown.



(b) Describe how x should be measured. You may add to the diagram if you wish.

(2)

Use set square to ensure the meter rule parallel to sand tray.
Use a string perpendicual to the end of ramp

Question 3

This question was based on an experiment involving measuring the resonance of an oscillating string, which is a standard practical in the new specification.

Part (a) involved stating the definition of the term resonance so should have been straightforward to answer. Most candidates seemed to have an understanding of the concept but were often let down by the lack of precision in their use of language. Candidates who lost the first mark did not explain clearly enough that the string was being forced to oscillate, although many candidates did realise the string was oscillating at its natural frequency. Most candidates who scored one mark did so for the idea of a maximum energy transfer however the main error here was using the idea of large or larger rather than a maximum, particularly when describing the amplitude of the oscillation. This is illustrated in the following example where the candidate did not achieve the second mark.

(a) State what is meant by resonance.

(2)

The phenomena of the great increase in the amplitude of an oscillating system because the driving frequency is close to the natural frequency of the system

Part (b) was a more unusual question as the candidates had to relate the predicted formula to the graph drawn to assess whether the prediction was valid. This longer explanation question produced a good spread of marks and was particularly discriminating. In the main, candidates were successful in realising that there was a y intercept which was not in the predicted formula. Candidates who scored this mark often went on to score the final mark. In a few cases candidates were credited for recognising that this may indicate a systematic error in the experiment. The first two marks seemed less straightforward to achieve as many candidates did not express clearly enough that the straight line was a consequence of the formula $f^2 = k^2m$ being in the form of $y = mx$ or that f^2 is directly proportional to m. In some cases, the formula was incorrectly expanded to $f^2 = km$ which did not gain the mark. In addition, some candidates used the data points to find values of k which did not gain any credit. The example below is unusual in that the candidate did not state that the graph is a straight line, hence only scored three marks.

Discuss whether the graph supports the student's prediction.

(4)

In the student's prediction, $f^2 = k^2m$, meaning that f^2 is directly proportional to m., The gradient is k^2.

The graph should have passed through the origin.

However, the graph above doesn't pass through the origin

It's in the form of $y = mx + n$, suggesting that there should be another constant in the equation.

So the graph doesn't support his prediction.

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 candidates were presented with the context of measuring the electrical characteristics of a diode.

Part (a) involved explaining why the lamp did not light despite all the components working correctly. This question was poorly answered and exposed the candidates' lack of knowledge about simple electrical circuits in a practical context. Many candidates assumed that the diode was in reverse bias which suggests that they either did not read the question sufficiently or could not interpret the circuit diagram correctly. Of those that scored a mark it was for stating that the voltmeter had a high resistance. The explanations that followed were often too vague or candidates became confused by describing both current and potential differences in the circuit. Only a few exceptional candidates scored more than one mark in the first part, such as in the example below.

(a) Although the components were not faulty, when the slider was moved from A to B and the voltmeter reading changed from 0 V to 3 V, the lamp did not light.

(i) Explain this observation.

(3)

The ~~va~~ voltmeter is connected in series with the lamp.

The voltmeter has a very high resistance. It's like a break in circuit. ~~The~~ Very little current can pass by it and the lamp.

~~So +~~ It's not enough for the ~~lantern~~ lamp to light up.

Candidates were much more successful in the second part in describing how to alter the circuit to allow the lamp to light. Again, candidates were often let down by a lack of precision in the language although some candidates did support their answer with a diagram which could gain credit.

Part (b) is another standard question used in previous papers where they have to explain why the graph should produce a straight line. Here candidates 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, however there were occasions where the comparison to the equation of a straight line was written such that the order of the terms did not correspond with the expanded equation. An example of this is given below.

Explain why plotting a graph of $\ln I$ against V will produce a straight line.

(2)

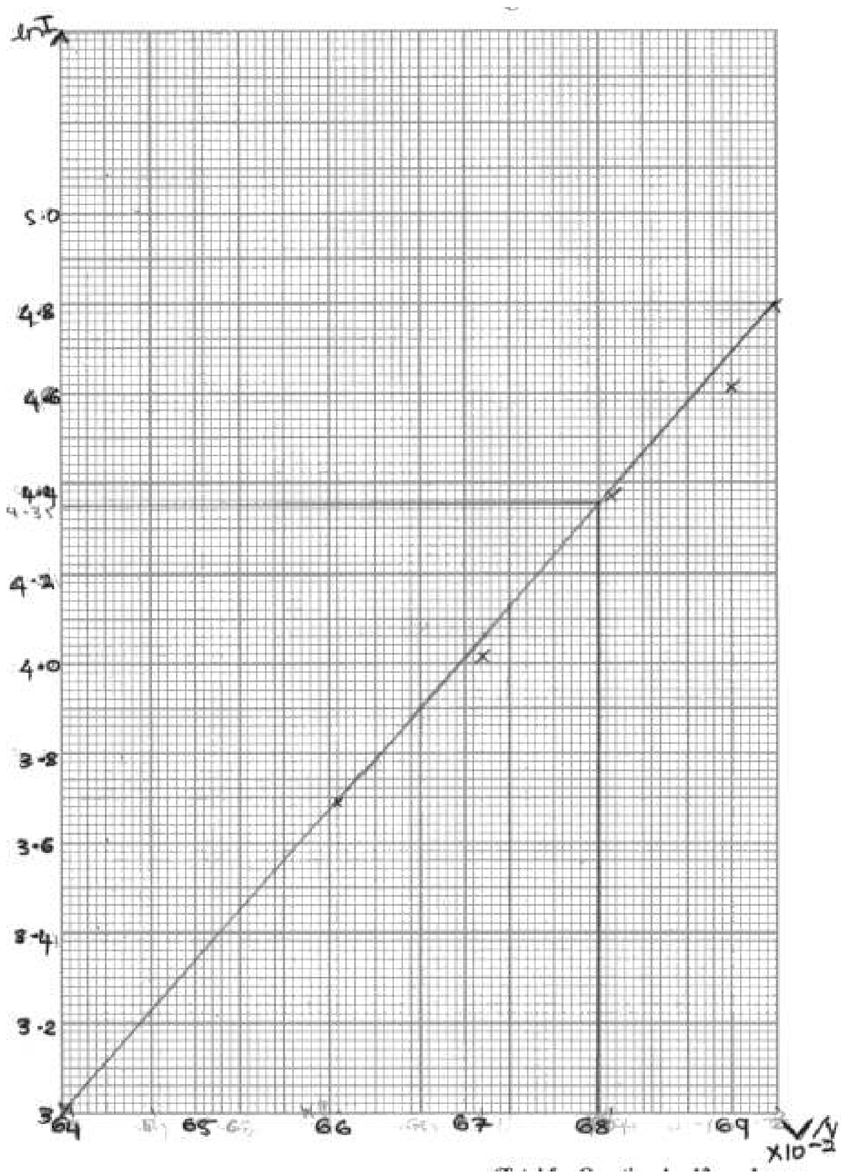
lnI = lna + bV is in the form of y = mx + n.
the gradient = b , Interception = lna.
b is constant so it's a straight line.

The second mark also required the gradient to be specified. In a departure from previous series the second mark was dependent on the expansion being correct. As the question stated that *b* 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, candidates should be responding with sentences rather than just using mathematical symbols.

Finally, part (c) assessed the candidates' ability to process data and plot the correct graph. A good candidate should be able to access the majority of the marks here and many good graphs were seen. The majority of candidates processed the data to three significant figures although there were some occasional errors in rounding. There were fewer candidates that plotted seemingly random numbers compared to previous series. The most common error in the graph was not labelling the *y*-axis in the correct form, i.e. ln(*I* / mA). Some candidates chose to convert the current into Amps, which was unnecessary and produced negative values which candidates often find harder to plot. At this level the 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 that started the *y*-axis from zero did not gain this mark. Scales based on 3, 4 or 7 are not accepted and often lead to plotting errors. A number of candidates presented *y* scales in 0.25 in order to fill the grid which is not accepted. Candidates should realise that although the graph paper given in the question paper is a standard size the graph may not necessarily fill the grid.

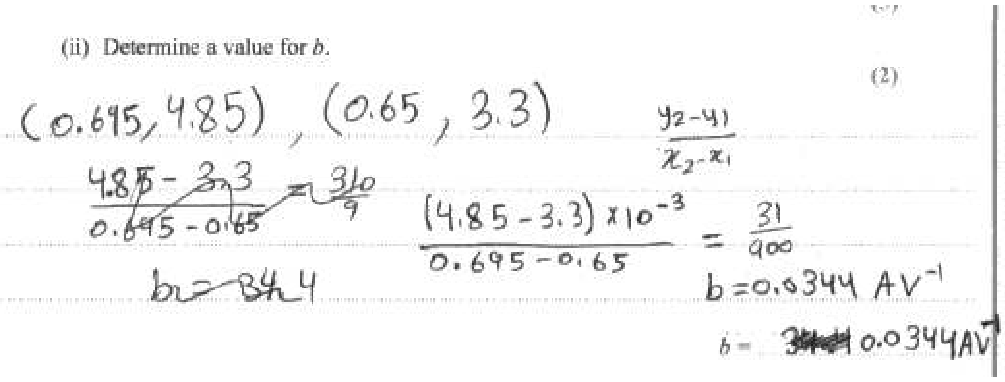
Most candidates were able to plot the graph accurately using neat crosses (× or +). If a dot extends over half a small square then this is not considered to be accurate plotting so candidates should be encouraged to use crosses. The most common error was misplotting the data point at 4.09, often placing it at 4.01 rather than nearer to 4.1. Best fit lines were generally good since there was little scatter in the points, however it is expected that there should be an even number of points either side of the best fit line. In addition, some lines 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 hence could not gain this mark.

An example of a graph that initially looks like it will gain marks is shown below.



Unfortunately this candidate did not gain any marks from the graph. The *y* axis is not labelled correctly as ln(*I* / mA) so did not achieve the axis mark. At first glance it appears that the scales are such that the plots fill over half the grid but the candidate has used an awkward scale based on 3 in the *x* axis in order to ensure the entire grid was used so did not achieve the scale mark. The plot at 4.09 is clearly incorrect as it is nearer 4.0 than 4.1. The best fit line mark could not be awarded as there are three plots below the line. It appears that the candidate has fallen into the trap of simply joining up the first and last points without evaluating the scatter of the points.

In the final part the candidates had to use their graph to determine a value of *b*. Since this is a linear graph it is expected that the gradient of the graph should be used as it is this skill that is being assessed. It should be noted that candidates are awarded marks for their ability to use the graph they have drawn. It is expected that candidates at this level should use a large triangle automatically and to show clear working as marks are awarded for the method used. There were some cases where the candidate had misread from the graph, forgotten that the line did not start from 0,0 or used data points from the table which did not lie on the best fit line. Candidates who label the triangle on the graph are often more successful in the calculation. In addition, some candidates became confused by the use of mA and tried to use a factor of 10^{-3} which resulted in an incorrect answer as in the example below. The final answer should have been given to three significant figures, which most managed, however only the better candidates gave a correct unit.


(ii) Determine a value for b. (2)

$(0.695, 4.85)$, $(0.65, 3.3)$ $\quad \dfrac{y_2-y_1}{x_2-x_1}$

$\cancel{\dfrac{4.85-3.3}{0.695-0.65} = \dfrac{310}{9}}$ $\quad \dfrac{(4.85-3.3)\times10^{-3}}{0.695-0.65} = \dfrac{31}{900}$

$\cancel{b = 34.4}$ $\quad b = 0.0344\ AV^{-1}$

$b =$ 0.0344AV^{-1}

In this example the candidate had used sensible points from the graph which were clearly labelled so gained the first mark, but had used the factor of 10^{-3} leading to an incorrect answer. This candidate had attempted to use a unit but, like many, had included the unit of A which suggests that candidates do not understand that logarithmic values are dimensionless.

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 and suggested practical activities are given in the specification. In particular they should make measurements on simple objects using vernier scales, 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.

- Use the number of marks given in a question as an indication of the number of answers required.
- 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 not the value left in a calculator.
- 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.
- Measurements are recorded to the resolution of the instrument used.
- Draw simple diagrams to aid descriptions of measurements or apparatus.
- 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 and 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.

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