Examiners' Report
Principal Examiner Feedback

January 2023

Pearson Edexcel International Advanced Level
In Physics (WPH16) Paper 1
Practical Skills in Physics II

General

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 students 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 students will carry out a range of Core Practical experiments. The skills and techniques learned from carrying out these experiments will be examined in this paper, but the Core Practical experiments themselves are not assessed. Students 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. Students 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 to challenge the students to form conclusions. These are given in Appendix 9 of the specification, and centres should make sure that students understand what the command words mean.

The paper for January 2023 covered the same skills as in previous series and was therefore comparable overall in terms of demand.

Question 1

This question was set in the context of estimating the temperature of a Bunsen Burner flame. The use of heating equipment is found in Core Practical 12: Thermistor.

In part (a) students had to describe a safety issue and how it should be dealt with. Although this question was aimed at the lower end of the grade scale, very few students scored both marks and many descriptions were too vague. Some students noted that the flame would be hot without referring to the screw. Some students thought that holding the screw in the flame with gloves would be appropriate. A good example is shown below.

There is a risk of burns to skin of student, so wear gloves, to prevent burns, and also hold the steel screw with long tongs instead of holding them with hand.

In part (b) students had to criticise the recording of the data. This was much more familiar to students although some referred to the range or the uneven intervals in the values of mass. Although there was no indication of the use of a graph, the idea that there were insufficient sets of data was accepted. A good example is shown below.

The significant figures are changing.
Temperature increase should have unit.
The ~~number~~ amount of data are small, they should do more times.

Part (b)(ii) proved to be problematic for many students. The question clearly stated **one** variable, but some students gave too many answers. In this case, if a wrong answer was given then the mark was not awarded. Typically, students would identify the mass or volume of water, which was the independent variable in the table. Some students also referred to time without clarifying which time they were describing. The following student also explained why this variable should be controlled, which was not necessary but shows a good understanding of the experiment.

(1)

Time taken to heat steel screw, more time take more heat energy is given to steel screw

Finally, in part (b)(iii) the students had to use data from the table to show that the temperature of the Bunsen burner flame was about 1500 °C. Most students managed this well. Those that did not score full marks either used a mean mass and mean temperature difference, or used too many significant figures. Some students incorrectly converted the temperature difference to Kelvin, and some tried reverse working which could only score a maximum of two marks. There were some students who tried to use an initial temperature and got confused, although those that managed this successfully could still score full marks. The following example shows clear working and an appropriate use of significant figures.

Energy dissipated in cooling = energy gained by water in heating

$m_s c_s \Delta\theta = m_w c_w \Delta\theta$

$\frac{4.11}{1000} \times 420 \times \Delta\theta = \frac{16.6}{1000} \times 4180 \times 37.5$

$1.7262 \times \Delta\theta = 2602.05$

$\Delta\theta = \frac{2602.05}{1.7262} \doteq 1507 \approx 1500\ °C$

Question 2

This question assessed planning skills within the context of investigating circular motion. The techniques used in this practical are similar to Core Practical 16: Oscillations.

In part (a) students had to show that the relationship between period of rotation and the mass could be written as $T^2 = 4\pi^2 \frac{mx}{Mg}$ given the formula $Mg = mr\omega^2$. There were a several ways this could be answered. The vast majority of student scored both marks, and well-structured answers were seen, such as the one below. Those that scored no marks often tried to use the formula for simple harmonic motion on a spring or pendulum.

$\cancel{\omega^2 = Mx}$ $\omega^2 = \dfrac{Mg}{mx}$

but $\omega = \dfrac{2\pi}{T}$

$\left(\dfrac{2\pi}{T}\right)^2 = \dfrac{Mg}{mx}$

$\dfrac{4\pi^2}{T^2} = \dfrac{Mg}{mx}$

$\dfrac{T^2}{4\pi^2} = \dfrac{mx}{Mg}$

$T^2 = 4\pi^2\left(\dfrac{Mx}{Mg}\right)$

$T^2 = 4\pi^2\dfrac{mx}{Mg}$

Part (a)(ii) was the familiar planning question. Students 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, students often used vague language, or their descriptions did not follow logically. The best answers were structured and concise, leading to a method that could be followed easily. Unusually, this question was not answered well overall, suggesting that students had not realised the techniques used would be the same as those for measuring the time period of an oscillation. Many students used “oscillation” instead of “rotation” which was accepted.

The mark scheme for this type of the question can vary owing to the context of the experiment however they all follow a similar structure. The first three marks were for describing how to obtain an accurate time period. Most students should be able to achieve at least one of these marks, but many did not. As is usual, students recite “repeat and take a mean” without any thought as to how this should be done in the context of the investigation, therefore were not credited if it was unclear. Those that stated that a timing marker should be used at the equilibrium position were not credited. The mark for timing multiple rotations was awarded most often.

The fourth and fifth marks were for describing how to obtain sufficient and valid data to plot a graph. Often, the control variable was missing from answers. The final mark was for stating which graph to plot to test the validity of the relationship. Again, some students just missed this mark by not including the idea of **checking** the line is straight, for example, by saying the line will be straight. In addition, some students gave the wrong gradient, and some confused *m* with *M*.

The following example illustrates a logical answer that was worth 4 marks.

Get a range of different mass M. Put a sand bed ~~under~~ below the masses to avoid hurting yourself. Place a time marker so that you start and stop the stopwatch for a complete oscillation of the rubber bung. Let the rubber bung oscillate a few times for it to gain constant(ω). Repeat for each mass M and calculate the averate. Plot a graph of T^2 against $\frac{1}{M}$, if the graph is a straight line then the relationship between them is valid.

In part (b) students had to comment on the suggestion that using a video recording would improve the determination of *T*. The performance on this question was higher than usual owing to the command word. As is usual for this type of question, students made general remarks about reaction time without relating it to the investigation. Most students who scored a mark described how to use the video recording, for example by slowing it down. It was more unusual to see students describing that it would be difficult to judge when a complete rotation accurately. The following example just managed to do this.

A video recording would ~~allow~~ enable the student to determine the exact time when one oscillation had completed, which would, hence, improve the accuracy in determining T.

Question 3

This question involved plotting and analysing the graph for the amplitude of a damped torsional pendulum. This relationship is of the form of an exponential decay which appears in experiements such as in Core Practical 11: Capacitor Decay. A question involving a graph appears in each series 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 good student should be able to access most of the marks and most students should score some marks.

In part (a) students had to explain how a graph of ln θ against n can be used to determine the value of the constant λ. This type of question should be very familiar however there may a slightly different emphasis that students 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 or an exponential function. However, some students did not complete this successfully. For the second mark students 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. It should be noted that where two forms of the expansion are given, it is the final one that is used as the comparison. In some cases, students wrote $y = mx - c$ or missed out the operators, both of which were not credited. Students then had to identify the gradient correctly as $-\lambda$. Some students missed the – sign, and some referred to "m" rather than state "the gradient is". The following example shows an answer scoring full marks.

$\theta = \theta_0 e^{-\lambda n}$.

$\ln\theta = \ln\theta_0 - \lambda n$.

$\ln\theta = -\lambda n + \ln\theta_0$.

$y = mx + c$.

~~$m = -\lambda$~~

~~Since $-\lambda$ is the gradient of the line,~~

$-\lambda$ is the gradient, $\ln\theta$ is on the y axis & n is on the x-axis

Part (b)(i) assessed the students' ability to process data and plot the graph of ln θ against n. The first mark was for processing the data correctly and was awarded most often. As the relationship was an exponential only the use of natural logs was accepted. Occasionally, students gave the values for ln n. The number of decimal places given should be sufficient to plot a graph accurately on standard graph paper. For logarithms students should give a minimum of two decimal places although three is accepted. The most common errors here were truncating rather than rounding and using an inconsistent number of decimal places in processed data.

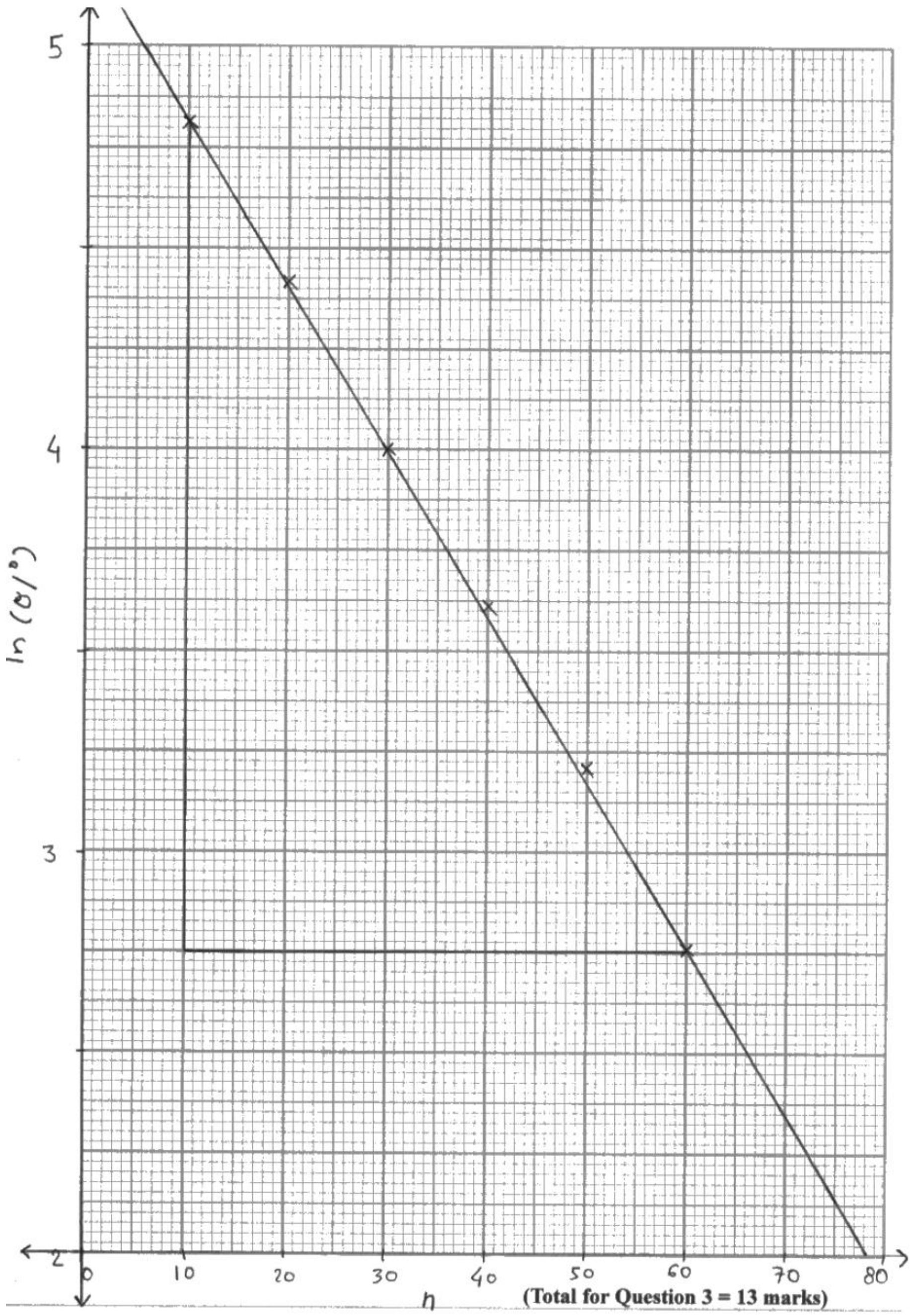
The second mark was for placing the axes the correct way around and labelling with the correct quantity. Some students inverted the axes, i.e., they plotted n against ln θ. Students should note that the question is always written in the form "plot y against x". This also often lead to mistakes in later parts. 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), e.g. ln (θ / °).

The third mark was for choosing an appropriate scale. At this level, the students should be able to choose the most suitable scale in **values of 1, 2, 5 and their multiples of 10** such that **all** the plotted points occupy **over half the grid in both directions**. Students should realise that although the graph paper given in the question paper is a standard size the graph does not have to fill the grid, and a landscape graph can be used if it produces a more appropriate fit. In most cases this is unnecessary. Students at this level should also realise that scales do not have to start from zero. The most common error was using a y-scale starting from 0 and going up in 0.5. Scales based on 3, 4 (including 0.25) or 7 are awkward and not accepted. Students should also be encouraged to label every major axis line, i.e. every 10 small squares, with appropriate numbers, so that examiners can easily see the scale used.

The fourth mark is for accurate plotting. Students should be encouraged to use neat crosses (× or +) rather than dots when plotting points. Students were not awarded this mark if they used large dots that extended over half a square or used an awkward scale. Mis-plots were unusual, but students 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. This mark was awarded often as the data used did not produce a significant scatter. Often students will join the first and last points instead of judging the scatter of the data points which can lead to errors. Where students were not awarded this mark it was either because the line was too thick, i.e. over half a small square, or was not continuous. Students should be encouraged to use a 30 cm rule for this examination.

The following an example of a graph that may look good but only scored two marks, the processing mark and the axis labels. This is an awkward scale, so is not awarded the scale or plotting mark. This student had joined the first and last points so that three plots were clearly above the line, so did not score the best fit line mark.



(Total for Question 3 = 13 marks)

In part (b)(ii) students were asked to determine a value for λ from the graph. There were several common errors seen. Many students 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. Students 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 **to mark these as a triangle on the graph**. Those that used awkward scales were often only successful when sensible values were used. The final mark could be awarded from an incorrect gradient, but often students used too many or too few significant figures. The following example shows a student using the first and last points in the calculation, but these were lying on the best fit line and corresponded to a triangle drawn on the graph. Unfortunately, only one significant figure was used on the answer line so only two marks could be awarded.

Gradient = rise/run = $\cancel{\frac{2.77 - 4.82}{60 - 10} = -0.041}$

$= \frac{2.75 - 4.8}{60 - 10} = -0.041$

$-\lambda = -0.041$

$\lambda =$ 0.04

In part (b)(iii) students had to deduce whether the initial displacement angle was greater than 180°. Those that realised that this required extrapolating from the graph or using their value of the gradient and a data point from the graph often scored full marks. The most common error here was using data from the table that did not lie on the best fit line, or trying to estimate a *y*-intercept by extending the axis beyond the grid lines. This example followed on from the graph given above and scored two marks as the *y*-intercept was not on the grid.

The y-intercept value = 5.225.

$\ln(\theta_0) = 5.225$

$\theta_0 = e^{5.225} = 185.86°$

~~There~~ Hence, the claim is correct.

Question 4

This question involved determining a value for the density of a metal in the shape of a ring. This involved the the techniques used measure diameter which students encounter in several AS core practicals. In addition, the analysis of uncertainties is common to all past papers therefore students should be encouraged to analyse uncertainties on a regular basis, either whilst making measurements or using past papers. Students should read Appendix 10 of the specification and **include all working** as marks are awarded for the method.

Part (a)(i) was familiar question in which students had to **explain one technique** when using a set of digital calipers for measuring the diameter of the hole at the centre of the metal ring. As is usual in this type of question, many students only described the technique 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 students give enough detail in relation to the context of the experiment for each technique. Therefore, for a repeated measurement it is expected that the student describes where or how to take the repeated measurement. Often, students 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 students state that it must be corrected for not just checked. The second mark was for linking the technique to its type of error. Students who attempted this did it well, although it should be noted that a random error can only be reduced not eliminated or avoided. Phonetic spellings for “systematic” are accepted but the word “systemic” has a different meaning and is not accepted. The following is a good example that scores both marks.

Measure at different orientations and calculate
the mean to reduce the random error.

Part (a)(ii) 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**. Many students gave too many decimal places. The second two marks were for the uncertainty calculation. The students **must show** the uncertainty calculation for the second mark, and this is awarded for calculating the **half range or furthest from the mean**. Some students calculated the percentage uncertainty. The final mark was for the correct uncertainty given to the same number of decimal places as the mean. The following student clearly shows their working, including the answers rounded to the correct number of decimal places.

$$\text{mean value} = \frac{8.53 + 8.56 + 8.55 + 8.53}{4} = 8.5425 \text{ mm} \approx 8.54 \text{ mm}$$

$$\text{uncertainty} = \frac{8.56 - 8.53}{2} = 0.015 \text{ mm}$$

Mean value of d = 8.54 mm ± 0.02 mm

In part (b)(i) students were given measurement of the diameter of the hole for a different metal ring along with its uncertainty. They were asked to show that the uncertainty in the diameter squared is about 1 mm^2. As in all calculations, an answer that looks correct but is arrived at using the wrong method is not credited. There were two methods that could be used, either using the percentage uncertainty or calculating the half range of the maximum and minimum values, and both proved straightforward. The most common errors were either multiplying the uncertainty in the diameter by two or giving too many significant figures. The following example shows clear working leading to a correct answer.

$$\frac{0.06}{10.7} \times 100\% \times 2 = 1.12\%$$

$$10.70^2 \times 1.12\% = 1.3 \text{mm}^2$$

In part (b)(ii) they were asked to **show that** the percentage uncertainty in the shaded area was about 0.4%. Students used two methods of solving this, either by combining absolute uncertainties, or by using the maximum and minimum method. Those that started by calculating the percentage uncertainties in the two values often scored no marks as this is an invalid method despite arriving at a very similar answer. As is often the case with the maximum and minimum method, students did not use the correct combination in their calculation. Those that were successful in this often scored well despite the additional work. Those that chose to combine the absolute uncertainties often got confused with use of the factor of $\frac{\pi}{4}$, most commonly using it to find the value of the shaded area but not multiplying the uncertainty by $\frac{\pi}{4}$. Sometimes the $\frac{\pi}{4}$ factor was missing from both numerator and denominator in the percentage uncertainty calculation. Although this is a common factor which cancels out, this is a "show that" question so all working should be shown. A good example of this is shown below.

(4)

$$\% U_{s^2} = \left(\frac{2}{881} \times 100\right) \times 2$$

$$\boxed{\% U_{s^2} = 0.45\%}$$

$$U_A = U_{s^2} + U_{d^2}$$

$$= 2 + 1$$

$$\boxed{U_A = \pm 3\,\text{mm}^2}$$

$$\% U_A = \frac{U_A}{\text{mean}} \times 100$$

$$\% U_A = \frac{3}{881 - (10.7)^2} \times 100$$

$$\boxed{\% U_A = 0.39\%}$$

In part (c) students were asked why measuring the mass of 10 rings is better than measuring the mass of one ring. Most students who scored a mark stated that the percentage uncertainty would be reduced. Fewer students stated that the uncertainty would be the same for both measurements. It should be noted that the use of "precision" is not accepted as an alternative to "resolution". Some students contradicted themselves by not using "percentage". The following shows a clear explanation worthy of full marks.

(c) Because in terms of measuring ~~ø~~ 10 metal rings, the random error decreases, and in the same resolution of ~~ruler~~ measuring object, the u% will ~~detr~~ decrease.

$$u\% = \frac{\frac{\text{resolution}}{2}}{\text{Value}} \times 100\%$$

In part (d) the students were given measurements of mass and thickness along with their uncertainties, alongside the value of area with a percentage uncertainty. If values are given, then students are expected to use them. Part (i) was a density calculation made slightly more challenging as the values of thickness and area were given in mm and mm^2 respectively. Most students were able to substitute the values correctly to gain the first mark, although some did not convert the units correctly. Many students managed to calculate the correct answer although there were some that gave too many or too few significant figures. Occasionally, students went on to divide by 10, presumably as they had used the values for 10 metal rings. Below is a good example if this calculation.

$$\rho = \frac{m}{V} = \frac{m_{10}}{x_{10} A} \qquad 602\,mm^2 = 6.02\,cm^2$$

$$\rho = \frac{63}{6.02 \times 1.403} = \cancel{7.46\,cm} \qquad 14.03\,mm = 1.403\,cm$$

$$7.46\,g\,cm^{-3}$$

$\rho =$ 7.46 g cm^{-3}

Finally, in part (ii) students were given a range of values for the density of stainless steel and had to deduce whether the rings could be made from stainless steel. This is a standard type of question used in every series but there were a significant number that did not attempt this. Students can use different methods, but they **must show their working** as marks are awarded for the method, and the final value may differ slightly owing to different levels of rounding.

The first method was calculating the limits for both values using a calculated percentage uncertainty. Here the main error was not calculating the percentage uncertainty correctly. A smaller number 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. Some used the maximum and minimum method, but again this could lead to errors as the incorrect combinations were used. In addition, some added the percentage uncertainty as a number rather than as a percentage.

For all methods, the final mark was for a correct conclusion. As in previous series, the main error with the conclusion was not explicitly making a comparison between values. Some students also claimed that both limits were in the range, or the rings were not made of steel as one of the limits fell out of the range. The example below does have a clear comparison of limits to the published values and a correct conclusion.

$$\left(\frac{0.04}{14.03} \times 100\right) + \left(\frac{0.5 \times 100}{63}\right) = 1.08\%$$

$$1.08\% + 0.4\% = 1.48\%$$

Upper: $7.46 \times \left(1 + \frac{1.48}{100}\right) = 7.57$

Lower: $7.46 \times \left(1 - \frac{1.48}{100}\right) = 7.35$

range = $7.35 - 7.57$

∴ the range of the density of stainless steel (7.48) is in range, so the rings could be made from it.

Summary

Students will be more successful if they routinely carry out and plan practical activities for themselves using a wide variety of techniques. These can be simple experiments that do not require expensive, specialist equipment. 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.

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

- 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, i.e. 1, 2 or 5 and their powers of ten only so that at least half the page is used. It is not necessary to use the entire grid if this results in an awkward scale, i,e. in 3, 4 or 7. Grids can be used in landscape if that gives a more sensible scale.
- Plot data using neat crosses (× or +), and to 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.