Examiners' Report
Principal Examiner Feedback

October 2021

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

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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 will be examined in this paper but not the Core Practical experiments themselves. 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 October 2021 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 investigating the heating effect of a resistor. Although this is a novel experiment, the techniques for heating and temperature measurement are used in Core Practical 12: Calibrating a Thermistor.

In part (a)(i) students were asked to identify two control variables. It was clear from some answers that students focused on the circuit diagram rather than the description of the investigation by giving answers such as current, voltage and resistance. As the current and resistance change in the experiment, students may not understand what is meant by a "control variable". In many cases, students did identify the water, but were often not precise enough with language. At this level, it is expected that students use the correct terminology for quantities instead of "amount". Very few students mentioned time or the distance between the thermometer and the resistor. The temperature of the surroundings was often mentioned but received no credit. It should be noted here that the question clearly stated **two** control variables. If more than two are listed no credit can be given where there is a choice between a correct and incorrect answer.

Part (a)(ii) involved looking for faults in the **recording** of the data given. Many students recognised that there were variations in the number of significant figures or decimal places. The idea of no repeats being shown was also a popular answer. Many tried to explain that there were not enough readings taken to plot a graph but struggled to formulate the words, e.g., "less readings were taken". As a small range was not an accepted answer this phrase was considered too ambiguous and not given credit. Very few noticed that there were no units on the change in temperature. On occasion, students mentioned that the initial temperature was not recorded but then did not mention the final temperature. Many students tried to answer this mathematically by analysing the data itself, e.g., by trying to find a constant of proportionality. This suggests that students did not read the question carefully enough and relied on learning from past papers. It should be noted that the question was worth three marks, and often students listed fewer than three criticisms.

Finally, part (b) asked students to explain **one** improvement. The first mark is for naming the improvement and the second for explaining how or why it improves the experiment. Most students did not focus on reducing the **uncertainty** in the measurement of $\Delta\theta$ as many gave answers relating to reducing the percentage uncertainty. In addition, many did not focus on **for each value** as often they suggested repeating and calculating a mean, which was in the previous part of the question. Other suggestions included using a digital thermometer or data logger or reducing parallax. Of those that understood the practical issues with heating experiments, several students stated one improvement, or possibly more, without explaining it. This suggests that students do not understand the meaning of explain, which in this question is to give a reason for their choice. Those that did explain the improvement sometimes used terminology imprecisely, e.g., using heat instead of temperature, or referring to preventing rather than reducing energy transfer to the environment.

Question 2

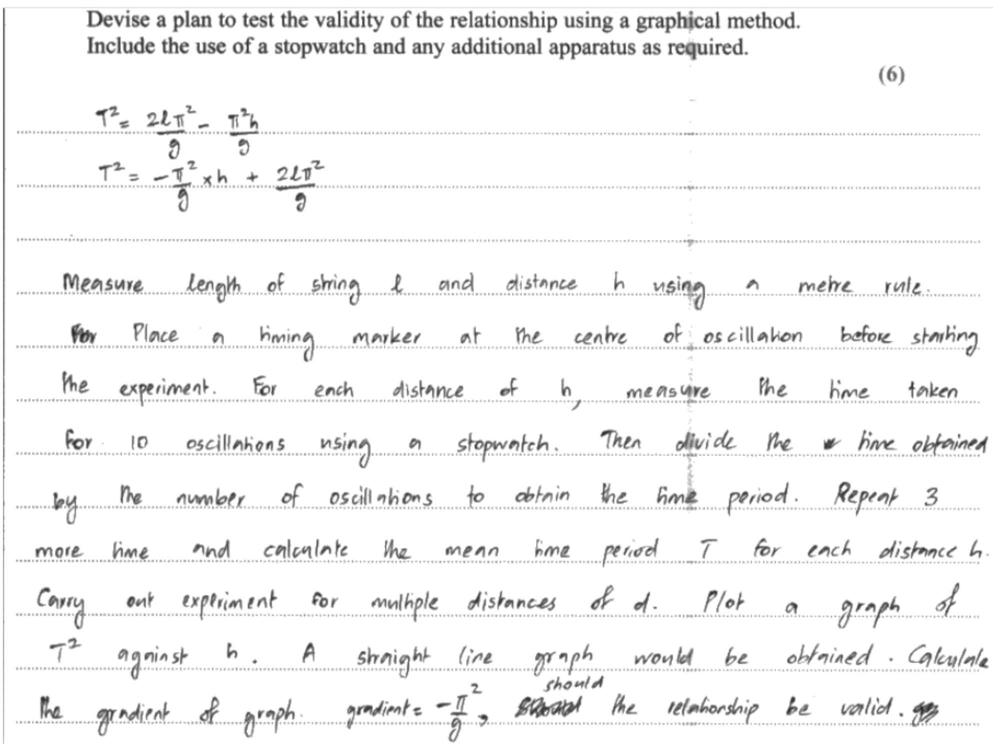
This question assessed planning skills within the context of investigating the time period of an interrupted pendulum. The techniques for measuring the time period of oscillations are used in Core Practical 16:

In part (a) students had to calculate the time period of the pendulum. It is important that students show their working as marks were awarded for the method. Most students could apply the formula for the time period of a pendulum, but many only calculated the period for one relevant length, often 0.75 m. Most students that realised that a sum of two half periods for different lengths was needed went on to score full marks. Unit errors and significant figure errors were rare. Occasionally, students added the whole time periods or used a further factor of two. A minority of students tried to use the formula stated in part (b), which was not given any credit.

Part (b) was the familiar planning question using another new command word, Devise. Students should be aiming to write a method for the investigation described in the question that could be followed by a competent physicist. There was a noticeable improvement in the responses to this type of question, presumably as pendulums should be familiar to the students, but overall, there was a wide range of marks awarded. Although marks were not awarded for linking ideas, students 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 the question can vary owing to the context of the experiment. The first four marks were dedicated to how to collect the relevant measurements. The first marking point is for stating what instrument to use to measure one of the variables. Students were successful in recognising that a metre rule should be used but were often vague about which length should be measured. A maximum of three marks were available for describing the appropriate techniques for measuring time period. Most students showed a good knowledge of measuring techniques and often scored well, with the use of multiple oscillations and repetitions most often stated. Occasionally, students appeared to state “repeat and calculate a mean” as an afterthought, without linking it directly to the measurement of the time period so did not gain any credit. The use of a timing marker was seen quite often but some students did not state where to put it or appeared to attach it to the pendulum itself. Starting to time after several oscillations was stated less often, but those that stated that the stopwatch should be started on the first oscillation were not penalised. Only a few students stated that a small angle should be used.

The final two marks are for understanding how to use a graphical method. Although some students stated that *h* should be varied, they did not specify how many values of *h* should be used. It is expected that a minimum of 5 sets of readings should be taken for a graph. Occasionally, students expressed this in a table, or stated the values of *h* that should be used. The final mark is for stating which graph to plot and describe how to use the graph to check the validity of the formula. Although most students stated a valid graph, they were often let down by the concept of **checking** that it is a straight line. It appeared that many assumed that the formula stated was valid therefore the graph "will be" a straight line rather than "should be" a straight line. There were other ways of expressing this, including the use of the relevant gradient. Some students wasted both time and space in trying to do a log expansion, or by comparing to $y = mx + c$, both of which were unnecessary. The example below shows a response that scored five marks. The plan is clear and methodical, but unfortunately the student did not specify the number of sets of readings that would be needed.


Devise a plan to test the validity of the relationship using a graphical method. Include the use of a stopwatch and any additional apparatus as required.

(6)

$T^2 = \frac{2l\pi^2}{g} - \frac{\pi^2 h}{g}$

$T^2 = -\frac{\pi^2}{g} \times h + \frac{2l\pi^2}{g}$

Measure length of string l and distance h using a metre rule. ~~For~~ Place a timing marker at the centre of oscillation before starting the experiment. For each distance of h, measure the time taken for 10 oscillations using a stopwatch. Then divide the time obtained by the number of oscillations to obtain the time period. Repeat 3 more time and calculate the mean time period T for each distance h. Carry out expriment for multiple distances of d. Plot a graph of T^2 against h. A straight line graph would be obtained. Calculate the gradient of graph. gradient $= -\frac{\pi^2}{g}$, should the relationship be valid.

In part (c) students had to discuss whether a light gate and data logger would improve the experiment. As with questions of this type, students tend to focus on the benefits of this arrangement and not the difficulties. The command word Discuss requires students to explore all aspects of a situation. Most students stated that reaction time would be eliminated, but some students still insisted on using the phrase “human error” which is not accepted at this level. Occasionally the idea of the light gate providing a fixed reference point or reducing parallax was seen. A few students stated it would be difficult to use light gates with no further detail. Many students focused on the use of a data logger and gave standard answers regarding sampling rates and taking simultaneous measurements. This suggests that students find it difficult to apply their knowledge to the context. Centres should encourage students to think about the experiment they have planned and then discuss whether the improvement suggested would be better or worse than their plan and why.

Question 3

This question involved an investigation of the resonance of air inside a bottle. Although this is a more novel experiment the use of an oscilloscope to measure time is covered in Core Practical 6: Measuring the Speed of Sound.

Part (a) asked the students to describe how to use the oscilloscope to identify the resonant frequency **and** determine its value. Students are expected to know how to use an oscilloscope to measure time and potential difference and, although there were some very good answers, the majority were not. For the first mark, students had to describe how to use the oscilloscope trace to identify when resonance occurred. Although there were references to maximum amplitude, some students referred to large, larger or increasing amplitude all of which were not credited. Occasionally, students repeated that a loud noise would be heard which was given in the question. It is not clear whether some students did not realise there were two parts to the question as some simply defined resonance. The next two marks were for describing how to use the oscilloscope trace to determine the time period. These were rarely awarded. Either students simply left this out or stated “measure the time period of the wave” without describing how. The final mark for converting time period into frequency was awarded most often, although some students tried to use the wave equation.

Part (b)(i) assessed the students’ ability to process data and plot the correct graph. This is a question that 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 good student should be able to access most of the marks and most students should score some marks.

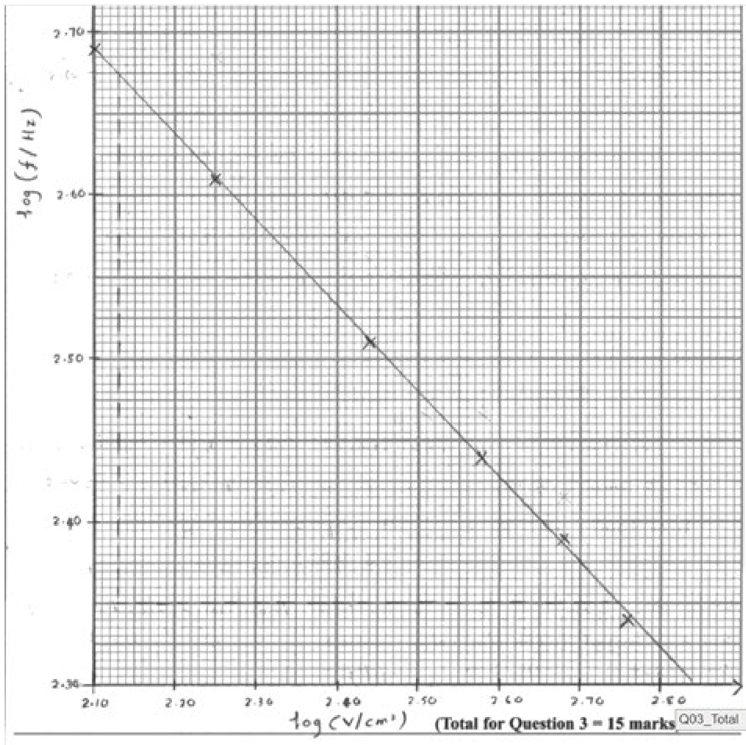
The first two marks are for processing the data correctly. These were awarded most often although there were some occasional errors in rounding as students simply truncated their answer. The number of significant figures given should be sufficient to plot a graph on standard graph paper. For logarithms students should give a minimum of two decimal places although three is accepted. There were very few instances of logs being used to an unusual base in this series, or numbers that appeared to be made up. It should be noted that values do not need to be converted into SI units before calculating a log. This often results in negative numbers making the graph and gradient calculation more difficult.

The third mark is for placing the axes the correct way around and labelling with the correct quantity. 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* / Hz). Occasionally, ln values were calculated, which is acceptable, but the label must be given as ln or $\log_e$ not log.

The fourth mark is 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 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. Students 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. Students should also be encouraged to label every major axis line, i.e., every 10 squares, with appropriate numbers. Occasionally students used an even scale, such as 0.1, but labelled the axes with numbers such as 2.04, 2.14 etc. which is unconventional but was not penalised.

The fifth mark is for accurate plotting. Although there was improvement with this skill compared to other series, students that were not awarded this mark either used large blobs extending over half a square or used an awkward scale. Students should be encouraged to use neat crosses (× or +) rather than dots when plotting points. Mis-plots were rarely seen but students should check a plot if it lies far from the best fit line.

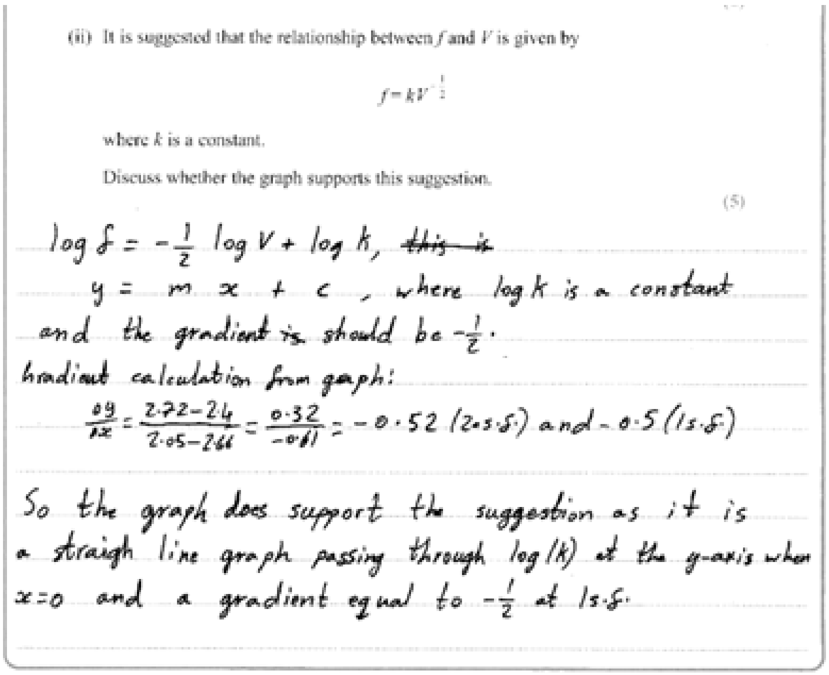
The final mark is for the best-fit line. It appears that many students simply join the first and last points without judging the scatter of the points. There should be a spread of data points above and below the best-fit line. Occasionally lines looked disjointed or did not extend across all data points, perhaps a result of using a ruler that is too small. It is recommended that students use a 30 cm ruler in this examination. Lines that were too thick also did not gain this mark. The following graph is an example of a graph that scored full marks.



In part (c)(ii), students had to discuss whether the graph supported the suggested relationship. This is a new command word where students are expected to use a line of reasoning to lead to a conclusion. Students should have realised that the suggested relationship was not in a logarithmic form, therefore the first mark was for expanding the relationship using logarithms. The majority of those that attempted this were successful. Then, students should have compared this to $y = mx + c$ to extract the main features of the graph. The main error here was not putting this in the same order as the expanded relationship. In addition, students should be encouraged to state explicitly "the gradient is" and "the *y* intercept is" rather than relying on arrows or loops, or stating what *m* and *c* are equal to.

Next, students should have realised that the gradient had a definite value with which to compare to, therefore the next two marks were for a correct gradient calculation. It was pleasing to see that the vast majority used a large triangle. However, too many students are relying on using the data from the table which 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 marking these on the graph, as in the example above. Those that used awkward scales were often only successful when sensible values were used.

The final mark was for the conclusion. Although there were significant improvements in how the students did this, there were a number that did not make a specific link between the **expected** gradient and the **calculated** gradient, often because the students only gave mathematical statements with little in the way of discussion. The example below shows an answer that gained full marks. The line of reasoning is very clear in this answer as is the conclusion.



(ii) It is suggested that the relationship between f and V is given by

$$f = kV^{-\frac{1}{2}}$$

where k is a constant.

Discuss whether the graph supports this suggestion.

(5)

$\log f = -\frac{1}{2}\log V + \log k$, ~~this is~~

$y = m x + c$, where $\log k$ is a constant

and the gradient ~~is~~ should be $-\frac{1}{2}$.

Gradient calculation from graph:

$\frac{\Delta y}{\Delta x} = \frac{2.72-2.4}{2.05-2.66} = \frac{0.32}{-0.61} = -0.52$ (2 s.f.) and -0.5 (1 s.f.)

So the graph does support the suggestion as it is a straigh line graph passing through $\log(k)$ at the y-axis when $x=0$ and a gradient equal to $-\frac{1}{2}$ at 1 s.f.

Question 4

This question involved determining the shear modulus of metal using a deflection method. The techniques for measuring distance and diameter, and the use of a micometer screw gauge are found in many Core Practicals. In addition, the analysis of uncertainties is common to all past papers. Students should be encouraged to read Appendix 10 of the specification and include all working as marks are awarded for the method.

Part (a) focused on the measurement of the height of the steel rod above the bench. Part (i) involved describing two techniques to measure the height. For this type of question students should concentrate on describing **what they should do** when taking a single measurement. Although many stated that they would check that the metre rule was vertical, the mark was often missed by not stating how. In addition, students simply stated "use a set square" without describing how it would be used. A surprising number did not realise that the steel rod should be close to the metre rule. Although many stated that they would reduce parallax error, sometimes this was poorly worded, e.g., by using parallel instead of perpendicular. Students should be encouraged give a reference point when using these words, eg "perpendicular **to** the bench".

In part (a)(ii) the students had to explain why the uncertainty in the **difference** between the heights was recorded as 1 mm. The most common error was a simple statement such as "the resolution is 1 mm", indicating that the students had not realised that there were two measurements involved. The first mark was for stating what the uncertainty in a single measurement is in this context. Many simply stated that the uncertainty would be 0.5 mm without relating it to the resolution of the metre rule. In addition, many students used the word "precision" to mean resolution, which is not acceptable in this specification. Precision has a different meaning which is given in Appendix 10. The second mark was for explaining how to calculate the uncertainty when two variables are subtracted. The main reason for not achieving this mark was in stating that the uncertainty would be doubled. Although this is mathematically correct, the student had to be clear that the uncertainties should be **added**. Students who gave a correct mathematical expression were given credit.

Part (b) focused on measuring the diameter of the steel rod. In part (i) students had to explain the choice of the **most** appropriate instrument to measure a diameter of approximately 2 mm. The first mark was for stating the instrument which was achieved by most students. A significant number stated that a Vernier caliper should be used, suggesting that students has not considered the word “most” in the question. The second mark was for the reason for using a micrometer screw gauge, therefore a reference to an expected percentage uncertainty was expected. Sometimes, students calculated the percentage uncertainty, but then did not state the significance of it. Often, students did not state a reason at all, suggesting that they do not understand the command word “explain”.

In part (b)(ii) students had to explain one technique. Whilst many students described a suitable technique for the first mark, a good portion of these did not explain why it is used. Sometimes two techniques were described. It should be noted that repeating a measurement must be related to the context, in this case at different orientations along a wire. The explanation must relate to the concept of reducing errors. It should be noted that random errors can only be reduced but not eliminated.

The rest of the question focused on the analysis of the measurements. In part (b)(iii) the students had to calculate the mean diameter with its uncertainty. This is a relatively simple calculation, and the majority of students performed this well. However, some students used too many decimal places in the mean value, and some did not show how they arrived at the value of the uncertainty. Occasionally, students calculated a percentage uncertainty, which was not asked for in the question.

In part (c) students had to calculate the shear modulus using the stated formula and data. Students must show all their working and the vast majority did. Although the formula was quite complex, most students arrived at the correct answer with the correct number of significant figures. The units were given in the question, but a small number of students did not convert the units given.

Finally, in part (d) the student had deduce whether the data used in part (c) would allow the student to determine the type of steel the rod was made from. This type of question is used in each series, and it is expected that uncertainties are used to form a conclusion. A number of students simply made a statement that their value was close to one of the values without any consideration of the uncertainties given in the data. Where students realised that had to use uncertainties, they generally scored well. The first two marks were for calculating the percentage uncertainty in the shear modulus. On occasion, students added the percentage uncertainties in each variable without taking note of those raised to a power. The second two marks were for using the calculated percentage uncertainty and forming the conclusion. The most successful method is to calculate an upper and lower limit as more mistakes can occur with the percentage difference method, namely the denominator not being the quoted value. In addition, some candidates only calculated the percentage difference for the value nearest to their calculated value. This may be acceptable if this value could be ruled out, but usually both would be needed. The maximum and minimum method was rarely seen, but again this can cause issues, e.g., by using the maximum value in the denominator when calculating the maximum. As in previous series, the main error with the conclusion was not explicitly making a comparison between values. The response below shows an excellent example scoring full marks.

(d) The table shows values of G for different types of steel.

Type of steel	Structural steel	Carbon steel
$\mathbf{G / 10^9\,N\,m^{-2}}$	79.3	77.0

Deduce whether the data provided in part (c) would allow the student to determine the type of steel the rod was made from.

(4)

% u in G = $\left(\frac{0.1}{58.9} + \frac{2 \times 0.1}{10.3} + \frac{1}{26} + \frac{4 \times 0.02}{2.35}\right) \times 100 = 9.4\%$

upper limit of G = $79 \times 10^9 + (0.094 \times 79 \times 10^9) = 86 \times 10^9\ Nm^{-2}$

lower limit of G = $79 \times 10^9 - (0.094 \times 79 \times 10^9) = 72 \times 10^9\ Nm^{-2}$

The data does not allow for type of steel to be determined because G values of both structural steel and carbon steel lie within the range of G of the steel rod ($72 \times 10^9\ Nm^{-2}$ to $86 \times 10^9\ Nm^{-2}$). So the rod could be made from either of the steels

(Total for Question 4 = 16 marks)

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. 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.
- Be consistent with the use of significant figures. Quantities derived from measurements should not contain more significant figures than the data and percentage uncertainties should be given to at least one fewer significant figure than the derived quantity.
- Choose graph scales that are sensible, i.e., 1, 2 or 5 and their powers of ten only so that at least half the page is used. It is not necessary to use the entire grid if this results in an awkward scale, i.e., in 3, 4 or 7. Grids can be used in landscape if that gives a more sensible scale.
- 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.

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