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Examiners' Report
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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 Unit 6 and 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 from carrying out these experiments will be examined in this paper, but the Core Practical experiments themselves are not assessed. 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.

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, command words may be used to 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.

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.

The paper for June 2024 covered the same skills as in previous series and was therefore similar in demand.

Question 1 (a)

This question was set in the context of using an electrolytic capacitor to power a motor. Although this was an unfamiliar context, discharging capacitors is found in Core Practical 11: Capacitor Discharge.

In part (a) candidates had to **state two** safety precautions for connecting and using the circuit. This question was not answered as well as expected. Many candidates concentrated on general precautions for connecting circuits rather than the use of an electrolytic capacitor. At this level, safety precautions should be **specific** to the investigation being described.

This is a good answer where the candidate commented on two safety issues related to using an electrolytic capacitor.

(a) State **two** safety precautions the student should take when connecting and using the circuit.

(2)

The student might get ~~electricu~~ electric shock. Wear insulated gloves.
The capacitor should be fuly discharged after the experiment.
~~Ho~~ Working potential difference should not exceed the fixed pd.

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Examiner Comments

The candidate has made two relevant comments on the final two lines. The idea of fully discharging the capacitor needed an additional comment, which this candidate gave. The final line was given credit for the idea of not exceeding the working p.d. if the capacitor was described sufficiently. The first two lines are too general to be given credit, and the use of insulating gloves would not be accepted for using standard laboratory power supplies.

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Examiner Tip

Avoid general safety comments and focus on safety issues that are specific to the experiment.

Question 1 (b)

In part (b) candidates had to **describe** an **accurate** method to determine a **single value** of the height *h* using a metre rule. This type of question is fairly common and was answered well by most candidates. The first mark was for describing how to ensure the metre rule stayed in a vertical position. Some candidates used the word “perpendicular” but this needs to be relative to something, in this case the floor. Similarly, some candidates used “parallel” or “align” which needs further description. Note that “straight” is not accepted as an alternative for vertical. The final two marks were for techniques to improve the accuracy of the measurements. As this was a **single** value, repeating and calculating the mean was not accepted. Of these marks, reading perpendicularly to the scale was awarded more often. It should be noted that descriptions using the words “parallel” or “horizontal” can become unclear so candidates should avoid using these.

The following is a good answer that covers all points in the mark scheme.

(3)

Ensure ~~ruler~~ metre rule is vertical using set square, and clamp metre rule in place. Read off ruler scale using set square, and read in perpendicular to metre rule scale, to avoid parallax error. Ensure metre rule is close to mass m. Measure distance between mass m and ground by reading positions and subtracting values. Ensure zero on metre rule scale is on ground.

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Examiner Comments

This candidate has thought about where to place the metre rule and how to use it to make accurate measurements. When using a metre rule vertically, it should be held in place with a clamp to keep it in the same position. In addition, the use of a set square ensures it is vertical. This candidate has also used the word "perpendicular" correctly.

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Examiner Tip

Learn the techniques to measure lengths accurately and apply them to different contexts.

The following answer did not quite score full marks.

- Ensure that the meter ruler is perpendicular to the floor by using a set square.
- Place the ruler next to the mass m to avoid parallax errors in the meas-urement.
- ~~read the scales~~ make sure to take the readings perpendicular to the scale to avoid parallax errors

ResultsPlus Examiner Comments

Unfortunately the candidate did not mention how to secure the metre rule but had used the term "perpendicular" correctly by adding "to the floor". In this set up, placing the ruler "next to" the mass was acceptable, but candidates should be careful when using this word as it does not apply in all situations. This candidate did not describe the measurement of *h* but in this case this was already given in the stem of the question. However, it is good practice to include this in method questions.

ResultsPlus Examiner Tip

Using bullet points is a good way to check how many separate points have been made and then compare this to the number of marks available.

Question 1 (c)

Part (c) involved several calculations. Part (c)(i) involved calculating a mean from a set of data. Note that candidates are not expected to identify and remove “anomalous” data. At A2 Level, candidates are expected to give the correct value of the mean to the **same number of decimal places as the data**. Some candidates gave too many decimal places or did not give a unit.

Part (c)(ii) involved a calculation of the percentage uncertainty in the mean value. The candidates **must show** the calculation for the first mark, and this is awarded for calculating the **correct half range or furthest from the mean**. The final mark was for the correct percentage uncertainty given to one or two significant figures. Often candidates gave three significant figures.

The following shows clear calculations of both the mean and percentage uncertainty.

(c) The student repeated the procedure in (b) several times. She recorded the following measurements.

h / m	0.246	0.239	0.243	0.241

(i) Calculate the mean value of h.

(1)

(0.246+0.239+0.243+0.241)÷4= 0.242m

Mean value of h = 0.242m

(ii) Determine the percentage uncertainty in the mean value of h.

(2)

$\frac{(0.246-0.239)\div 2}{0.242} \times 100\% = 1.446\%$

Percentage uncertainty = 1.446%

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Examiner Comments

The mean calculation is shown with the answer given to the same number of decimal places as the measurements, and a unit is given. The percentage uncertainty calculation is in one step which is acceptable as it is clear which values were used for the half range. Unfortunately, too many significant figures were used in the final answer.

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Examiner Tip

Remember that percentage uncertainties should be given to one or two significant figures.

Part (c)(iii) involved calculating the efficiency of the motor. This was answered well, but the most common errors were not using *g* in calculating the gravitational potential energy or not using the factor of ½ for the energy stored in the capacitor. Occasionally power of ten errors caused complications. Some candidates realised that efficiency should be less than 100% so placed the larger value in the denominator. Occasionally, candidates added the gravitational potential energy to the energy stored in the capacitor for the input energy.

The following shows an answer with clear working leading to a correct answer.

(iii) Determine the efficiency of the electric motor.

maximum potential difference across capacitor = 6 V
capacitance of capacitor = 4700 μF
m = 20 g

(3)

$\frac{1}{2} \times 4700 \times 10^{-6} \times 6^2 = 0.0846\ J$

$20 \times 10^{-3} \times 9.81 \times 0.242 = 0.0475\ J$

$\frac{0.0475}{0.0846} \times 100 = 56.1\%$

Efficiency = ...

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Examiner Comments

Although this candidate has not included any formulae, it is clear what is being calculated, particularly as units are included. This candidate has not placed the final answer on the half answer line but it is good practice to do this.

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Examiner Tip

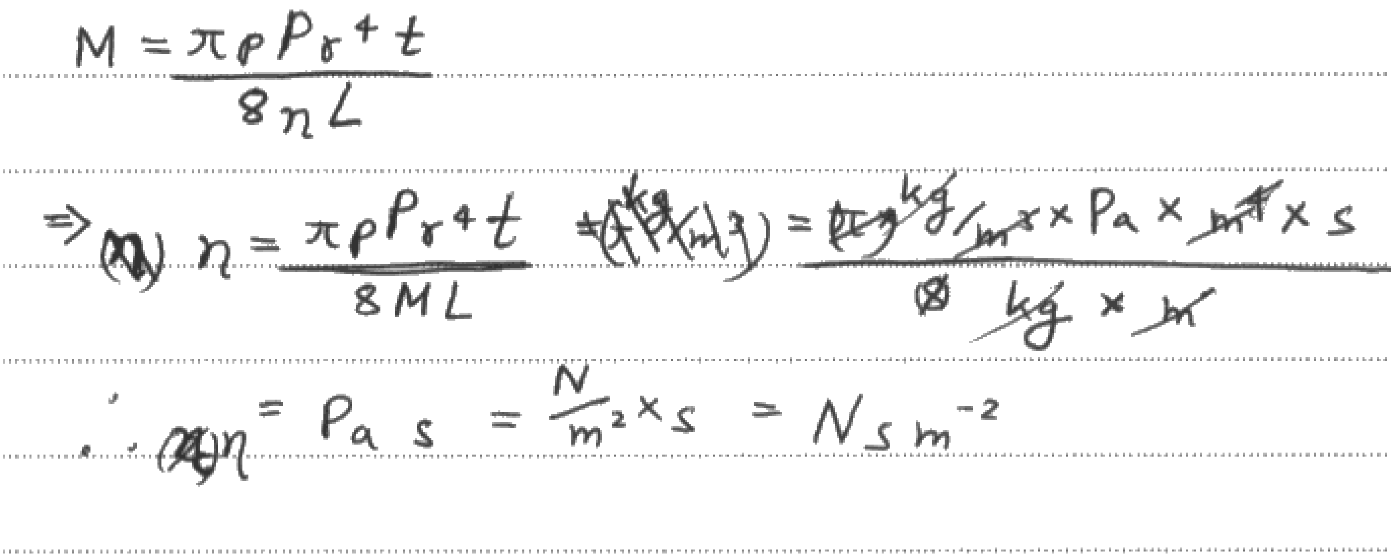
Include all working for calculations, preferably with the formula being used.

Question 2 (a)

This question assessed planning skills within the context of investigating the flow of water through a pipe. As this is a non-standard practical, the formula was given in the way it was expected to be used.

In part (a) candidates had to use the formula to **show that** the unit for viscosity is N s m^{-2}. This was performed well by most candidates, and those candidates that used Pa for the unit of pressure found this more straightforward. The first mark was for substituting the units for all the variables. Occasionally, candidates omitted one or did not use the correct power for a unit. The final mark was for rearranging the formula, although most candidates started from this point, and used some form of processing to arrive at the final answer. As this was a "Show that" question, an additional step was expected. However, candidates often rearranged the formula, substituted the units but did no further processing.

This is an example of a candidate using the units of Pa for pressure to successfully arrive at the correct unit.



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Examiner Comments

As with most candidates, this one started by rearranging the formula then substituted in the units. It is clear by the crossing out that the candidate was left with a unit of Pa s and then equated Pa to N m^{-2}.

$$8\eta L = \frac{\pi \rho P r^4 t}{M}$$

$$\eta = \frac{\pi \rho P r^4 t}{M} \div 8L$$

$$= \frac{\pi \rho P r^4 t}{8ML}$$

$$= \frac{kg\,m^{-3} \times N\,m^{-2} \times m^{4} \times s}{kg \times m}$$

$$= N\,s\,m^{-2} \text{ (showed)}$$

ResultsPlus Examiner Comments

This candidate used pressure expressed in Newtons and metres. This candidate did just enough cancellation to be awarded full marks.

$$\eta = \frac{\pi \rho P r^4 t}{8ML}$$

$$\text{unit } \eta = \frac{kg m^{-3} \cdot N m^{-2} \cdot m^4 \cdot s}{kg \cdot m}$$

$$= N s m^{-2}.$$

ResultsPlus Examiner Comments

This candidate rearranged the formula and substituted the units but did no further manipulation to arrive at the final answer.

ResultsPlus Examiner Tip

In "Show that" questions using algebraic manipulation, ensure that several steps are shown to arrive at the final answer.

Question 2 (b)

Part (b) was the familiar planning question. Candidates should be aiming to write a method for the investigation described in the question that could be followed by a competent physicist. Despite this being an unusual context, many candidates answered this question well as the mark scheme for this type of question follows a similar structure in each series. Although marks were not awarded for linking ideas, candidates using vague language or not describing a method logically can lead to marks not being awarded. The best answers were structured and concise, leading to a method that could be followed easily.

The first two marks were for describing how to determine the internal diameter of the pipe as the length of the pipe had already been measured. The most common errors were using a micrometer or not stating “internal”. In addition, some candidates did not calculate a mean from several readings. The third mark was achievable in several ways. Many candidates stated keeping the metre rule horizontal but not the pipe, or placed the stopwatch close to the tap. Some candidates referred to keeping the flow rate constant, which was given in the question, or referred to pressure instead of pressure difference.

The final three marks were for obtaining sufficient and valid data to determine a value for viscosity, and these marks were scored most often. Of these, candidates most often scored the marks for measuring the mass of water at a particular time, and for stating the graph to plot, however it should be noted that if a gradient is stated it should be correct for that graph. For the fifth mark, some candidates were too vague in their descriptions as it was unclear whether they were repeating to calculate a mean or measuring at five different values to plot a graph. Occasionally candidates tried to vary the length or pressure difference, both were impractical for the set up being used but could still score the majority of the marks.

The following answer addressed all points on the mark scheme to score full marks.

(b) The student used a metre rule to measure *L* and a stopwatch to measure *t*.
He adjusted the water tap to give a constant flow of water.

Describe a method to determine an accurate value for *η*. $* \eta = \frac{\pi \rho P r^4}{8 \cdot L \cdot \text{gradient}}$

Your method should use a suitable graph. Also record readings on digital pressure gauges and calculate their difference. **(6)**

To measure L, using the metre rule place a set square on each of the pressure gauges to ensure rule is parallel to the pipe and avoid parallax error. Repeat and take an average to reduce the effect of random errors. Keep the length between the pressure gauges constant. Once water starts leaving the pipe and reaches the balance start the stopwatch and record the mass of water recorded on the balance at given time intervals. Place stopwatch close to reading on balance to reduce the effect of reaction time. Take at least 6 set of values. Repeat this process and take an average to reduce the effect of random errors. To measure the internal radius of the pipe use a digital vernier calliper. Repeat at different directions and take an average. Plot a graph of M against t.

$M = \frac{\pi \rho P r^4}{8 \eta L} \cdot t + 0$. Graph should be a straight line through the origin.

$y = m x + c$. Gradient is equal to $\frac{\pi \rho P r^4}{8 \eta}$, so to find η

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Examiner Comments

This is a very clear method which is easy to follow. This candidate described taking six sets of values. Although the candidate has not specified these are at different values of time, reading back to the lines above this can be inferred from the use of time intervals. In addition, the following sentence is repeating the "process" before calculating a mean, therefore the candidate has done enough to convince the examiner they are not repeating six times to calculate the mean.

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Examiner Tip

When planning an investigation, it is useful to start with the formula and identify the variables that will be used to plot the graph.

The following example is short but contains enough information to gain four marks.

Use meter rule to measure L, Use stop watch to measure t. Use micrometer to measure r. ~~Ha~~ Measure from different orientations and find the mean value. Take the readings of digital pressure gauge at two ends of the tube, subtract them to get pressure difference P. The density of water is known. The flow of water is constant.

Vary the time t to get at least 6 sets of data of M. Plot a graph of M against t, ~~The~~ ~~gra~~ $M = \frac{\pi \rho P r^4}{8\eta L} \times t$, compared to $y = mx$. the gradient of graph is $\frac{\pi \rho P r^4}{8\eta L}$.

$\eta = \frac{\pi \rho P r^4}{8 \times L \times \text{gradient}}$.

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Examiner Comments

This candidate scored the three most common marking points in the final four lines. It is clear that the plan includes taking values of *M* at six different values of *t*. The way the sentence is worded means it gains both marks. The graph is valid and the gradient is correct. The fourth mark was for the technique to measure the diameter, but unfortunately this candidate stated a micrometer instead of vernier calipers.

ResultsPlus
Examiner Tip

Use the names of quantities rather than the symbols when writing a method.

Question 2 (c)

In part (c) the candidates were told that the balance could be connected to a data logger. Candidates were asked to **give two reasons** why a data logger would improve the investigation. As is usual for this type of question, candidates gave a range of answers when only two were required and some did not relate this to the context of the investigation. Answers that were similar to questions on previous series, such as being able to use a data logger remotely or for a long time, or storing a large amount of data were seen. Other answers that could not be credited were related to reaction time without further explanation, or automatically drawing a graph. Although these are not contradictions, they are irrelevant to this context. Most candidates gave the idea of simultaneous measurements, however the most common error was not using the idea of time in describing sampling rate.

(2)

- Data logger can take readings ~~of~~ continuously.
- Data logger can take two ~~readin~~ data readings simultaneously.

ResultsPlus Examiner Comments

This candidate used two bullet points to match with the number of marks being awarded. Unfortunately "continuously" implies being able to use a data logger for a long time rather than having a high sampling rate.

The following example scores both marks.

can measure simultaneously (mass and time) ∴ No reaction error ∴ No random error. can be used remotely. High sampling rate. Large amounts of data can be collected in a certain time period.

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Examiner Comments

This candidate has ignored the "two" in the question but has not contradicted the correct answers. There are several ways of expressing the idea of a high sampling rate, and this is an example of this.

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Examiner Tip

It is useful to think about when, where and how long an experiment will take when deciding why a data logger may be an improvement.

Question 3 (a)

This question involved plotting and analysing the graph for an investigation involving the rotational oscillations of a mass on a spring. This involved the techniques used to determine time period which candidates encounter in Core Practical 16: Oscillations. A question involving a graph appears in each series therefore there are plenty of opportunities to practise this skill and consult Examiners' Reports to correct common errors.

Part (a) was a familiar question in which candidates had to **describe** how to determine the time period of the oscillation. In general, candidates scored well on this question. As this was a rotational oscillation, candidates had to be clear where a timing marker should be placed although it is good practice to state this for any oscillation. Candidates should also check the number of marks being awarded as some responses went beyond the lines given.

The following example is a good answer that addresses all the points in the mark scheme.

(3)

- Place a timing marker at the centre of each oscillation.
- Wait for a while for oscillations to settle before measuring.
- Measure multiple oscillations and divide by the number of oscillations to calculate the mean.

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Examiner Comments

This candidate has included "to calculate the mean", but this is related to the technique of timing multiple oscillations rather than repeating the measurement.

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Examiner Tip

Keep the techniques of timing multiple oscillations and repeating the measurement to calculate a mean separate to avoid confusion.

The following example did not include the use of a timing marker.

(3)

Start timing after a few oscillations.

Time numbers of oscillations, and divide by the number of oscillations to get T.

Obtain at least 5 sets of data,

and calculate a mean value of T.

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Examiner Comments

This candidate did not include a timing marker so could not gain full marks. Although this has three separate points, it could only score two marks. For this context, credit was given for repeating to calculate a mean or starting timing after a few oscillations.

ResultsPlus
Examiner Tip

Think about the most important techniques needed for the experiment being described.

Question 3 (b)(i)

In part (b)(i) candidates had to **explain** how a graph of log *T* against log *M* could be used to determine the value of *b* given the relationship. This type of question should be very familiar however there may 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 or an exponential function. However, some candidates did not complete this successfully. For the second mark candidates must compare their log expansion with $y = mx + c$, which is standard for this type of question. The comparison must be **explicit**, ie the order of the log expansion must match the order of terms of the equation of a straight line. It should be noted that where two forms of the expansion are given, it is usually the final one that is used as the comparison. In some cases, candidates missed out the + and = which were not credited. Candidates then had to identify the gradient correctly as *b*. Some candidates referred to "*m*" or relied on a loop or arrow rather than state "the gradient is". As this is an "explain" question, this had to be explicit.

The following two examples show common errors candidates make with this question.

$\log T = \log a + b \log M$

$\log T = b \log M + \log a$

$y = m x + c$

ResultsPlus Examiner Comments

There is a correct comparison to $y = mx + c$ and the candidate has linked the constant *b* to *m*, but has not stated explicitly what *m* represents on a graph.

ResultsPlus Examiner Tip

Use the phrases "gradient" and "*y* intercept" when stating what *m* and *c* represent.

(2)

$\log T = \log a + b \log M$

Which is in the form of $y = mx + c$ where $\log a$ is constant and the gradient is b.

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Examiner Comments

This candidate does state that the gradient is *b* but the order of the logarithmic expansion does not match with $y = mx + c$.

ResultsPlus
Examiner Tip

Rearrange the formula to ensure that it matches the form of $y = mx + c$.

Question 3 (b)(ii)-(iv)

Part (b)(ii) assessed the candidates' ability to process data and plot the graph of log *T* against log *M*, and there was a marked improvement in graph drawing this series. The mark scheme follows the same format for each series. The first two marks were for processing the data correctly. It is expected that candidates use base 10, however as the logarithms for both variables are required other bases were not penalised. On rare occasions, candidates gave one set of values to base 10 and used natural logs for the other set of values. To gain these marks, the values must be **correct** and given to a **consistent** number of decimal places sufficient to plot a graph accurately on standard graph paper. For logarithms, candidates should give **three** decimal places although **two** can be accepted if it is valid for the graph. The most common errors here were truncating rather than rounding, using an inconsistent number of decimal places in processed data, or using too many decimal places.

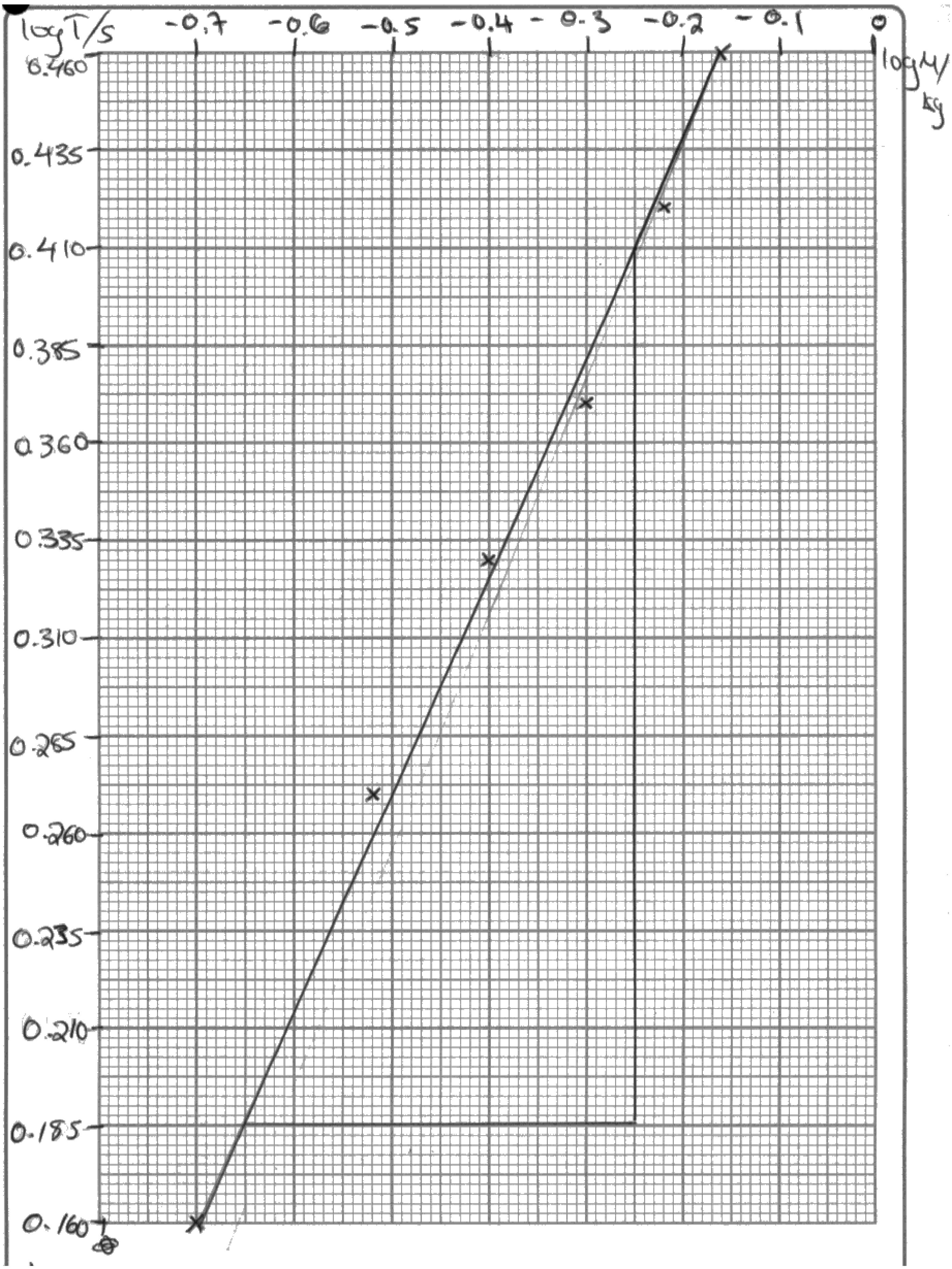
The third mark was for placing the axes the correct way around and labelling with the correct quantity. Some candidates reversed the axes, ie, they plotted log *M* against log *T*. Candidates should note that the question is always written in the form "plot *y* against *x*". The most common error is 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 (*T* / s). Some candidates converted their *M* values, presumably to avoid negative numbers, however some then did not use the correct unit in the axis label. As the graph involved negative numbers, candidates often inverted this axis which was not accepted. In addition, candidates placed their axes on the left of the grid which was accepted but often led to mistakes later in the question.

The fourth mark was for choosing an appropriate scale. 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 **all** the plotted points occupy **over half the grid in both directions**. Candidates should note that, although the graph paper given in the question paper is a standard size, the graph does not have to fill the grid and using the grid in landscape is 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 awkward and not accepted. Candidates should also label every major axis line, ie every 10 small squares, with appropriate numbers, so that examiners can easily see the scale used. A minority of candidates tried to use the values of logarithms as their scales.

The fifth mark is for accurate plotting. Candidates should use **neat crosses** (x or +) rather than dots when plotting points. Candidates were not awarded this mark if they used large dots that extended over a small square or used an awkward scale. Mis-plots were less common than usual but candidates should check a plot if it lies far from the best fit line.

The final mark is for drawing a reasonable best-fit line and was awarded most often. When drawing a best-fit line, candidates will often join the first and last points instead of judging the scatter of the data points. Candidates should ensure there are plots on both sides of the line and that the line cannot be rotated. Other errors include the line being too thick, ie over half a small square, discontinuous, or containing a clear bend. Candidates should use a single piece, 30 cm ruler for this examination.

The following is an example of what appears to be a good graph but which scored very few marks.


log T/s
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
log M/kg
0.460
0.435
0.410
0.385
0.360
0.335
0.310
0.265
0.260
0.235
0.210
0.185
0.160

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Examiner Comments

This candidate was inconsistent with the decimal places for one of the log values, typically leaving off a zero. Although the axes are the correct way around, ignoring the *y* axis on the left of the page, the axis labels are not in the correct format, ie the brackets are missing. This candidate has labelled each major axis line, but the value of each small square is 0.0025 which is awkward so does not score the scale or plot marks. The best-fit line is reasonable so this graph only scored two marks in total, one for the log *T* values and one for the best-fit line. Note that this candidate drew a large triangle using sensible values which was successfully used in the gradient calculation.

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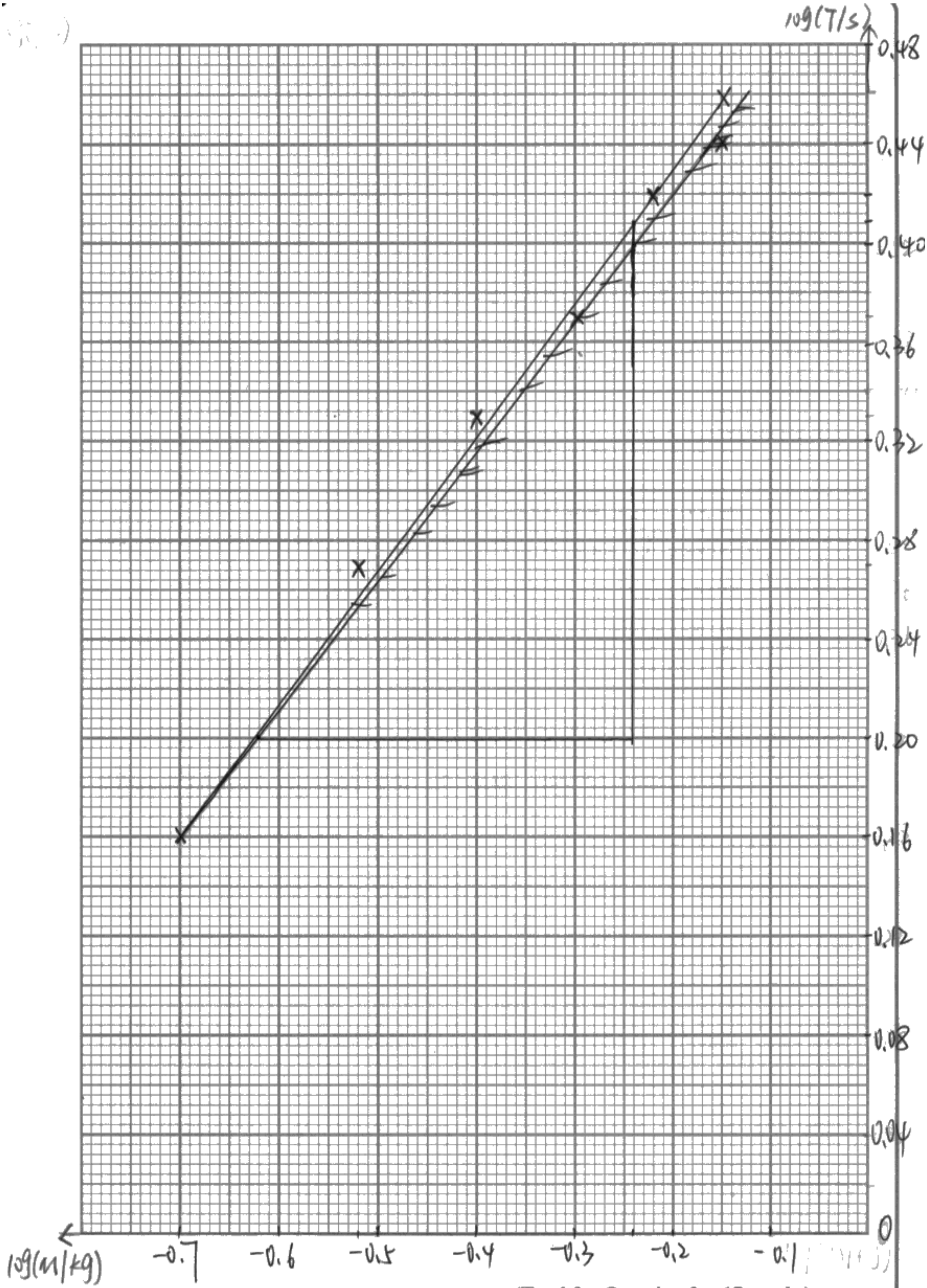
Examiner Tip

Use the correct format for labelling axes, ie log (quantity / unit).

This is another example of an awkward scale.



(Total for Question 3 = 17 marks)

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Examiner Comments

Unlike the previous example, this candidate gave both sets of log values to consistent decimal places and has labelled the axes using the correct format. This candidate has used a *y* scale based on 4, ie each small square is worth 0.004, which is awkward. Clearly, this candidate realised that the plot at the top had been mis-plotted, so it was replotted and the best-fit line redrawn. This ensured that there were plots on either side of the line as the original line would have been too low. This graph scored all the marks except the scale and plotting marks.

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Examiner Tip

Use scales where the smallest square is a value of 1, 2 and 5 and their multiples of 10 only.

In part (b)(iii) candidates were asked to **determine the gradient** of the graph. There were several common errors seen. The first mark is for using a **large triangle** taking up at least half of the plotted line to calculate the gradient of the graph. Unusually, some candidates inverted their gradient. 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 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 **mark these as a triangle on the graph**. Those candidates 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 candidates used too many or too few significant figures.

The following example scored full marks.

(ii) The student varied *M* and determined the corresponding values of *T*.
She recorded the following data.

M / kg	*T* / s	log(T/s)	log(M/kg)
0.200	1.46	0.16	−0.699
0.300	1.86	0.27	−0.523
0.400	2.14	0.33	−0.398
0.500	2.36	0.37	−0.301
0.600	2.63	0.42	−0.222
0.700	2.88	0.46	~~0.~~ −0.155

Plot a graph of log *T* against log *M* on the grid opposite.

Use the additional columns for your processed data.

(6)

(iii) Determine the gradient of the graph.

(3)

gradient $= \frac{0.41 - 0.2}{-0.24 - (-0.62)}$ = ~~0.53~~ 0.55

Gradient = ~~0.53~~ 0.55

(iv) Determine the value of *a*.

(3)

log T = b log M + log a.

b = ~~0.53~~ 0.55

0.16 = ~~0.53~~ 0.55 × (−0.699) + log a

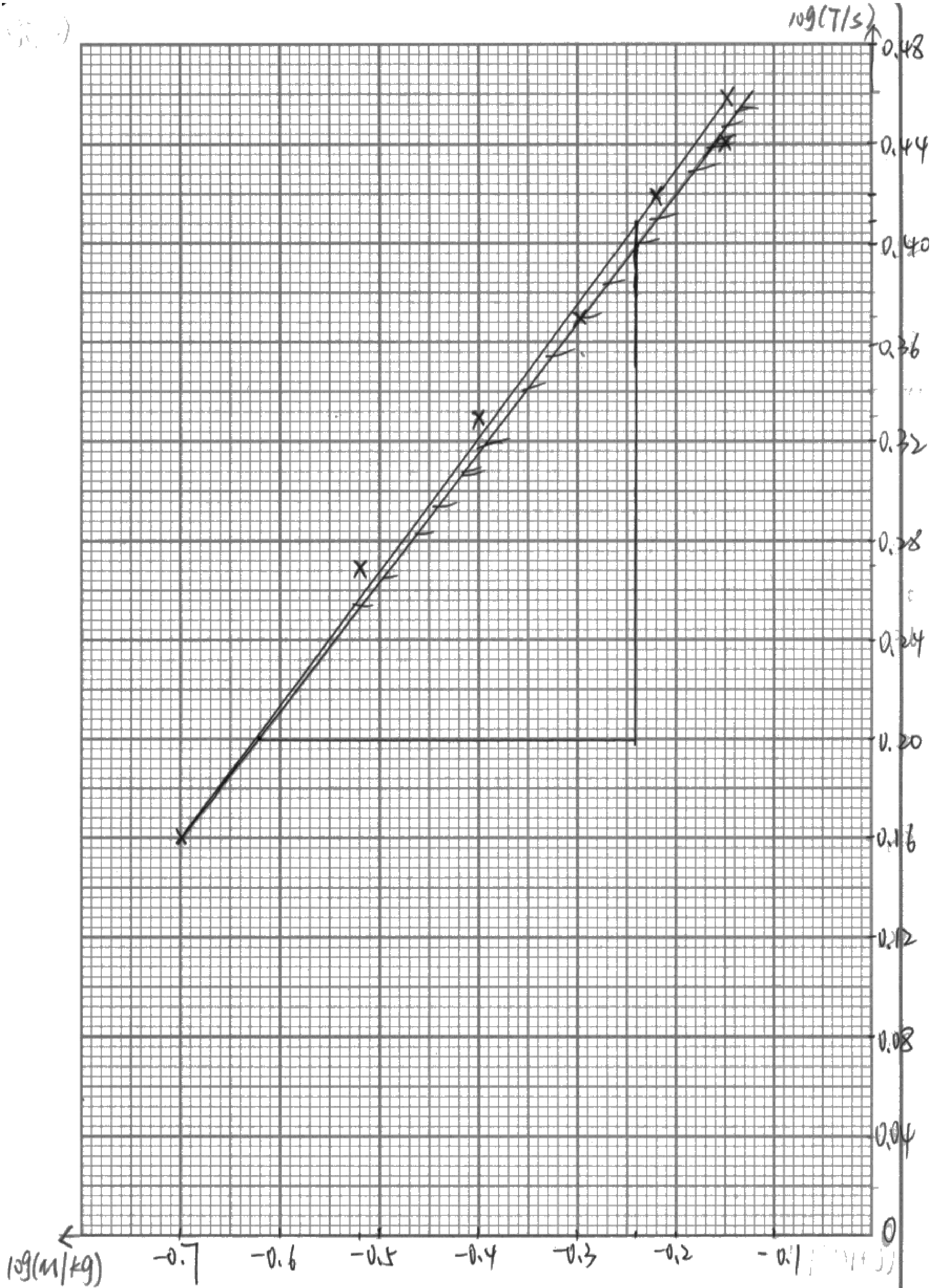
~~log a = 0.5305~~

~~a = 3.39~~

log a = 0.54

a = 3.5

a = ~~3.39~~ 3.5



(Total for Question 3 = 17 marks)

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Examiner Comments

This candidate had drawn a large triangle on their graph using sensible points. This often reduces the chances of making a mistake when extracting the data. Note that the candidate also included the minus signs in the calculation, which also helps to avoid arithmetic errors. This candidate chose not to use the first and last points in the data table even though they were on the best-fit line.

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Examiner Tip

Draw a large triangle on the graph which covers at least half the drawn line. Use sensible data points where the best-fit line crosses an intersection on the grid. Use the *y*-intercept if possible.

The following example only scored the mark for using a large triangle.

(iii) Determine the gradient of the graph.

(3)

$m = \frac{0.465 - 0.17}{-0.16 + 0.68}$; $m = 0.5674\ \text{s kg}^{-1}$

$m = \frac{0.295}{0.52}$

Gradient = $0.5673\ \text{s kg}^{-1}$

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Examiner Comments

Although this candidate drew a large triangle on the graph, a small error in extracting the data led to an answer outside the range. In addition, this candidate put a unit on the gradient when log values are dimensionless.

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Examiner Tip

Gradients on log-log graphs do not have units.

In part (b)(iv) candidates had to **determine** a value for the constant *a*. Most candidates scored at least one mark. Many read the value of log *a* correctly from the graph, or correctly calculated the value using the calculated gradient and a set of data points lying on the best-fit line. It was here that those candidates who placed their *y* axis on the left of the page made a mistake in determining the *y* intercept as they extrapolated the line to the axis drawn. In addition, some candidates tried to estimate a *y*–intercept by extending the axis beyond the grid lines, or stated that this was the value of *a*. Many candidates scored the second mark by converting the log value, but some candidates used the incorrect antilog function. Some candidates used the original formula, which was accepted provided the values used were taken from a point lying on the best-fit line. The final mark was for the correct value given to two or three significant figures.

The following example scored full marks.

(iv) Determine the value of a.

(3)

$\log T = \log a + b \log M$

$0.41 = \log a + 0.5625$ ~~log of~~ (-0.25)

$\frac{881}{1600} = \log_{10} a$

$10^{\frac{881}{1600}} = a$

$a =$ 3.55

ResultsPlus
Examiner Comments

Although this candidate extrapolated the best-fit line to the *y* axis, they chose to use a data point from their calculated gradient. As this data point was on the best-fit line, this was accepted. The candidate also used the negative numbers correctly in the formula. Note that this candidate left an intermediate answer as a fraction, which is fine as the final answer is given as a decimal. Units were not expected for this calculation, but those candidates that used dimensionally correct units could still score the final mark.

ResultsPlus
Examiner Tip

It is usually best to use the *y*-intercept for these calculations, particularly when there are negative numbers.

Question 4 (a)(i)

This question involved making measurements on a plastic protractor. In addition, the analysis of uncertainties is common to all past papers therefore candidates should 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 had to **explain** a technique to determine the thickness of the protractor using a micrometer screw gauge. The first mark was for stating the technique and the second was for explaining the technique in terms of errors. A few candidates described another method, eg stacking several together, which is not a technique for using a micrometer. As this is A2 Level, more detail is required for this question compared to AS Level, such as checking **and** correcting for zero error. Candidates also need to think about the object being measured. Many candidates used the word “orientations” which should only be used for a diameter of an object with a uniform cross-sectional area, such as a wire or sphere. Although phonetic spellings are accepted, candidates must be careful not to use a different word, such as “systemic” for “systematic”.

The following example scored both marks using the calibration technique.

Explain **one** technique she should use when measuring *t*.

* Check & correct zero error
* to ~~remove~~ reduce systematic error

ResultsPlus Examiner Comments

This candidate remembered to "correct" for zero error, which is expected at this level. Reducing systematic error is acceptable.

ResultsPlus Examiner Tip

Learn the techniques for measuring dimensions using vernier calipers and micrometer screw gauges and explain them using errors.

Another example that scored full marks, this time using the repeating technique.

(2)

measure 't' from different positions ~~ang~~ and get an average value for 't' to reduce random errors.

ResultsPlus
Examiner Comments

This candidate clearly thought about the object being measured as they referred to "places" not "orientations". The use of "get" is acceptable in this context, but it is good practice to use "calculate" or "determine".

ResultsPlus
Examiner Tip

Think about the object being measured before using the word "orientations".

This is an example that did not score any marks.

Take measurements at different positions and orientations, and calculate the mean to avoid random error.

ResultsPlus Examiner Comments

This candidate has put both positions and orientations in the answer. In this case, orientations is incorrect so could not score the mark. In addition, they have used "avoid" for random error which is not credited.

ResultsPlus Examiner Tip

Random errors can only be reduced not eliminated.

Question 4 (a)(ii)

In part (a)(ii) candidates had to **explain** why a micrometer screw gauge is a suitable instrument to measure a thickness of 1.41 mm. The question encouraged the candidate to include a calculation which was intended to give them a clue as to what was expected, however some candidates only included the calculation with no explanation.

The first mark was for stating the resolution of a standard micrometer screw gauge, ie 0.01 mm. Some candidates used 0.1 mm or 0.001 mm despite the thickness being given to two decimal places. Some candidates did not include a unit. As this is an **explain** question this could not be inferred from a calculation. Other terms are accepted for resolution however **precision** and **accuracy** are not accepted. In addition, some candidates confused resolution with uncertainty. It is expected that the uncertainty in a **single** measurement is **half** the resolution. This was also a common error in the calculation of the percentage uncertainty in the second mark. Most candidates did calculate this correctly, however they then did not make a suitable statement. Some candidates compared this to an arbitrary percentage, eg 5% or 1%. Some candidates compared this to the percentage uncertainty for vernier calipers, which was acceptable if done correctly.

The following examples show common errors candidates made with this question.

(2)

uncertainty = $\frac{0.01 \text{ mm}}{2}$ = 0.005 mm

percentage uncertainty = $\frac{0.005}{1.41}$ = 0.35%

So it is an appropriate instrument.

ResultsPlus Examiner Comments

This candidate did not use the term "resolution" but used "uncertainty" instead. The calculation is correct, but there is no comment about the percentage uncertainty being small. This candidate has just repeated the question.

ResultsPlus Examiner Tip

Comment on the percentage uncertainty as this is why the instrument is appropriate.

$$\% u = \frac{0.005}{1.41} \times 100$$

$$= 0.35\%$$

~~~~ % uncertainty is very low so value of x will be accurate.

ResultsPlus
Examiner Comments

This candidate has performed a correct calculation and included a comment. However, there is no explicit statement about the resolution or uncertainty.

ResultsPlus
Examiner Tip

Ensure that the resolution of the instrument or the uncertainty of the measurement is stated.
~~~~

resolution of micrometer screw gauge = 0.01 so uncertainty in micrometer = ±0.005.

$\frac{0.005}{1.41} \times 100 = 0.35\%$. Using micrometer results in a very small percentage uncertainty in the measurement which is why it is appropriate.

(for example vernier calipers give %U of ≈ 3.5% which is much more)

ResultsPlus
Examiner Comments

Unfortunately, this candidate omitted the units for the resolution so did not score the first mark. The rest of the answer is fine for the second mark.

ResultsPlus
Examiner Tip

Ensure units are included when discussing a resolution or uncertainty.

Question 4 (b)

In part (b)(i) candidates were asked to **show that** the volume of the protractor was about 6.2 m^3. For a **"show that"** question, all working must be shown and candidates should give their final answer to at least one more significant figure than the value. It should be noted that a sensible number of significant figures is expected in a practical paper, so the mark may not be awarded if there are too many. Candidates were expected to be able to use the area of a semicircle and rectangle for this question, but there were a number of candidates that did not do this. Those candidates that could, often scored both marks in this part as they gave their final answer to three significant figures.

In part (b)(ii) candidates were asked to **show that** the uncertainty in the volume was about 0.2 cm^3. Candidates used two methods of solving this, either by combining percentage uncertainties, or by using the maximum and minimum method. Candidates that used the maximum and minimum method were often more successful, but occasionally did not score full marks as a half range was not calculated or the values were rounded too early. Those candidates that combined percentage uncertainties often did not score the final two marks as they did not take account of the addition of the two areas or volumes. Occasionally, candidates added the absolute uncertainties, which gave a similar number but was not credited as the method is invalid. Again, the number of significant figures is important in a practical paper, particularly for uncertainties, and only two or three significant figures was expected.

The following examples scored full marks.

This candidate used the percentage uncertainty method in part (ii).

The student recorded the following measurements.

$D = 10.10\,\text{cm} \pm 0.05\,\text{cm}$
$x = 4.5\,\text{mm} \pm 0.1\,\text{mm}$
$t = 1.40\,\text{mm} \pm 0.02\,\text{mm}$

$V = \pi\left(\frac{d}{2}\right)^2 \times \frac{1}{2} \times t + t x D$
$= \frac{1}{8}\pi d^2 t + t x D$

(i) Show that V is about $6.2\,\text{cm}^3$.

(2)

$V = \left(\pi\left(\frac{10.1}{2}\right)^2 \times \frac{1}{2} \times 1.4\times10^{-1}\right) + (4.5\times10^{-1} \times 1.4\times10^{-1} \times 10.1)$

$= 6.24\,\text{cm}^3$ (shown)

(ii) Show that the uncertainty in V is about $0.2\,\text{cm}^3$.

(4)

% U in d^2t $= \frac{0.05\times2}{10.1}\times100\% + \frac{0.02}{1.4}\times100\% = 2.4\%$

U in d^2t $= \frac{2.4}{100} \times (10.1)^2 \times 1.4\times10^{-1} \times \frac{\pi}{8} = 0.13\,\text{cm}^3$

% U in txD $= \frac{0.05}{10.1}\times100\% + \frac{0.02}{1.4}\times100\% + \frac{0.1}{4.5}\times100\%$

$= 4.15\%$

U in txD $= \frac{4.15}{100} \times 1.4\times10^{-1} \times 4.5\times10^{-1} \times 10.1$

$= 0.03\,\text{cm}^3$

U in V $= 0.03 + 0.13$

$= 0.16\,\text{cm}^3$

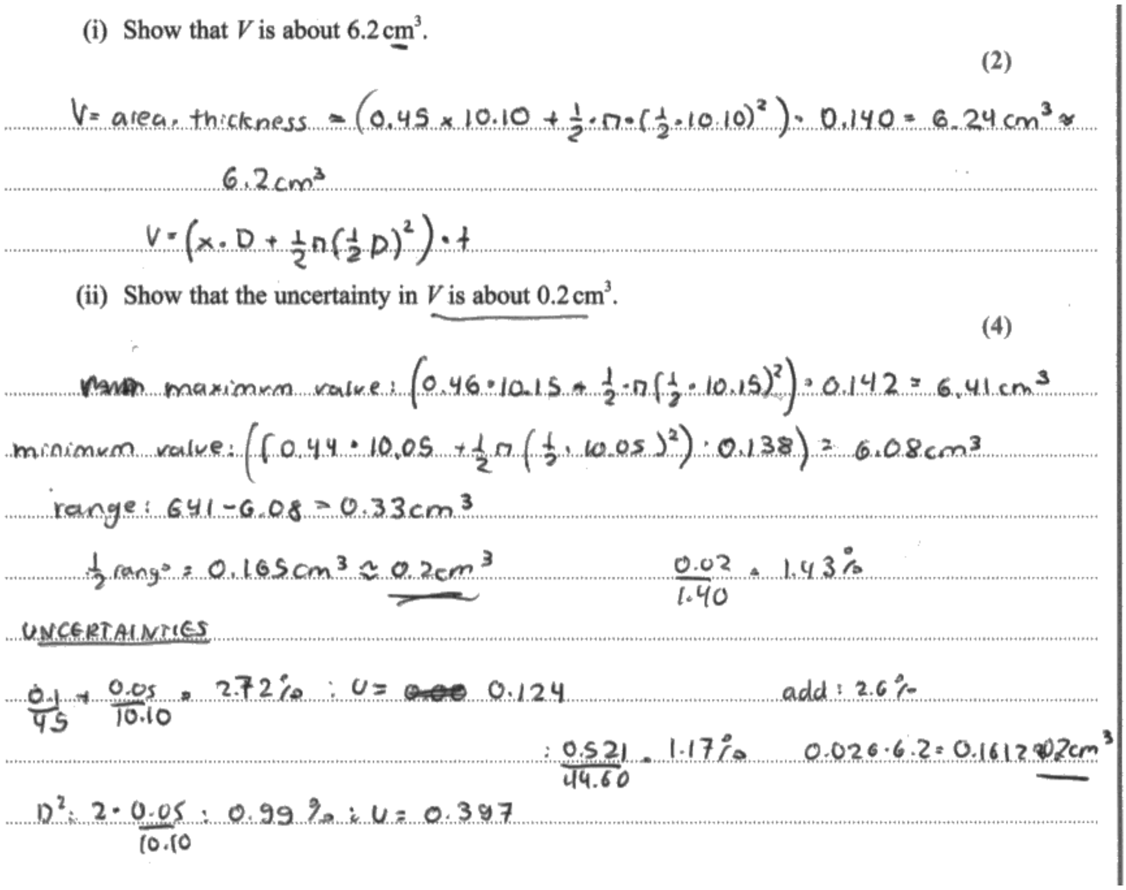
ResultsPlus
Examiner Comments

In part (i), the candidate calculated the volume of the semicircular part and rectangular part separately and have included a formula. This clearly helped this candidate structure their answer to part (ii). Part (ii) is very easy to follow as they have labelled each calculation.

ResultsPlus
Examiner Tip

In "Show that" questions, label each step of a calculation as this helps to structure your answer.

This candidate used the maximum-minimum method in part (ii).



(i) Show that V is about 6.2 cm³.

(2)

V = area × thickness = $(0.45 \times 10.10 + \frac{1}{2} \cdot \pi \cdot (\frac{1}{2} \cdot 10.10)^2) \cdot 0.140 = 6.24\ cm^3 \approx$

$6.2\ cm^3$

$V = (x \cdot D + \frac{1}{2}\pi(\frac{1}{2}D)^2) \cdot t$

(ii) Show that the uncertainty in V is about 0.2 cm³.

(4)

maximum value: $(0.46 \cdot 10.15 + \frac{1}{2} \cdot \pi (\frac{1}{2} \cdot 10.15)^2) \cdot 0.142 = 6.41\ cm^3$

minimum value: $((0.44 \cdot 10.05 + \frac{1}{2}\pi(\frac{1}{2} \cdot 10.05)^2) \cdot 0.138) = 6.08\ cm^3$

range: $6.41 - 6.08 = 0.33\ cm^3$

$\frac{1}{2}$ range = $0.165\ cm^3 \approx 0.2\ cm^3$ $\frac{0.02}{1.40} = 1.43\%$

UNCERTAINTIES

$\frac{0.1}{45} + \frac{0.05}{10.10} = 2.72\%$ ∴ $U = 0.124$ add: 2.6%

∴ $\frac{0.521}{44.60} = 1.17\%$ $0.026 \cdot 6.2 = 0.1612 \approx 0.2\ cm^3$

D^2: $2 \cdot \frac{0.05}{10.10} = 0.99\%$ ∴ $U = 0.397$

ResultsPlus
Examiner Comments

Unlike the previous candidate, this candidate calculated the total area. The inclusion of the formula in part (i) is useful to structure the calculation. In part (ii) the candidate used the maximum-minimum method and has shown clear, labelled calculations. Both maximum and minimum values have sufficient significant figures and a half-range is calculated. The uncertainties below do not add to the answer and were ignored.

ResultsPlus
Examiner Tip

When using the maximum-minimum method, ensure that there are sufficient significant figures in the intermediate calculations to be able to arrive at the "show that" value. Always calculate a half-range for this method.

Question 4 (c)

In part (c) candidates were given the density of Perspex and had to **explain whether** the protractor could be made from Perspex. This is a standard type of question used in every series and was performed well by the majority of candidates, but there were a few that did not attempt this or just made a vague statement with no calculation. It is expected that candidates use the percentage uncertainty to calculate limits, but the most common error here was calculating the limits of the stated density rather than the calculated density. 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 relevant values.

The following examples show common errors that candidates made with this question.

Your answer should include a calculation.

~~1.04 x f1.0~~ $1.04(1+0.03) = 1.071\ g\ cm^{-3}$

which is less than $1.18\ g\ cm^{-3}$

ResultsPlus
Examiner Comments

This candidate calculated the upper limit correctly and compared it to the quoted value but did not include a statement that answered the question.

ResultsPlus
Examiner Tip

Ensure that a conclusion includes a comparison and a statement.

Your answer should include a calculation.

(2)

u of plastic = 1·04 × 3% = 0·03

upper limit of plastic = 1·04 + 0·03

= ~~1·07 g cm^{-3}~~ 1·07 g cm^{-3}

∴ No protactor could not be made of perspex.

ResultsPlus
Examiner Comments

Unlike the last example, this candidate did not compare the upper limit to the quoted value. The statement is well presented but could not score the final mark.

ResultsPlus
Examiner Tip

Ensure that the statement answers the question.

Paper Summary

Based on their performance on this paper, candidates should:

- Be able to describe how to measure dimensions, time, current, potential difference, time period, radioactivity, pressure and temperature using the most appropriate apparatus and techniques.
- Refer to random or systematic errors when explaining techniques.
- Practice the process of planning an experiment to obtain sufficient and valid data.
- Show working in all calculations and include a unit.
- Check the number of decimal places or significant figures needed for different calculations.
- Choose graph scales that are sensible, ie the value of a small square is 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, eg 0.25, 3, 4 or 7.
- Plot data using neat crosses (x or +) and check any points that lie far from the best-fit line.
- Use a one piece, 30 cm ruler to draw a straight best-fit line. Ensure there are data points on both sides of the line and that the line cannot be rotated.
- Draw a large triangle that covers at least half of the best-fit line 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 Level.