Pearson

Edexcel

Examiners' Report
June 2023

International Advanced Level Physics WPH13 01

ResultsPlus

Introduction

The Pearson Edexcel International AS-level paper WPH13, Practical Skills in Physics I, is worth 50 marks and consists of four questions, which enables candidates of all abilities to apply their knowledge and skills to a variety of styles of question.

A candidate's understanding of the 8 core practical tasks will be assessed by the WPH11 and WPH12 papers. As such, the practical contexts met in the WPH13 paper may be less familiar but are similar to practical investigations candidates may complete during their AS Physics studies.

The scenarios outlined will be related to content taught during the study of WPH11 and WPH12. However, the focus of WPH13 is the assessment of the practical skills the candidates have developed, during the completion of the required core practical tasks and other experiments, as applied to the physics context described in the question.

There will always be questions that are familiar to candidates who have revised using the earlier series of WPH03 and WPH13 papers, but some performances would suggest some candidates were unfamiliar with the practical skills outlined in the specification for Unit 3. A particular issue commonly seen related to the uncertainty in measured data and the calculation of percentage uncertainty.

At all ability levels, there were some questions which candidates answered with generic and pre-learned responses, rather than being specific to the particular scenario as described in the question. Additionally, understanding the meaning of the standard command words (such as evaluate and determine) proved a challenge to candidates at the lower end of the ability range.

Question 1 (a)(iii)

Many candidates interpreted this as a slightly different question. They answered "how she could reduce the uncertainty in t?" and gave the standard response of "repeat the measurement in different places and calculate the mean".

However, the question asked candidates to explain how the error (defined in the specification as "the difference between the measurement value and the true value") in the single measurement shown (1.72 mm) can be reduced.

The specification also states that errors can be "due to both systematic and random effects".

If the micrometer ratchet is not used while closing the micrometer screw gauge, the rotating action of the micrometer allows considerable force to be applied by the spindle.

It is possible to permanently damage the micrometer (bending the frame), causing a systematic error (a zero error), which can be checked for (and either the micrometer can be recalibrated or the error can be compensated for in the final value).

Or, compression could occur within the object being measured, affecting the thickness (a random effect).

An explanation of how either sources of error can be reduced was rewarded.

(iii) Explain how she should reduce a source of error in this measurement of *t*.

(2)

Check zero error for the micrometer and reset it, ~~[illegible]~~ to prevent systematic error.
look perpendicular to the readings to prevent parallex error. Repeat & calculate the mean.

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Examiner Comments

This candidate's answers shows a complete explanation of the first approach – checking for zero error to prevent systematic error.

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Examiner Tip

Note – this candidate gives two answers, when the question only asks for "a source of error". Fortunately, the second answer is not wrong – just irrelevant – as the arrangement of the scales of a micrometer screw gauge will not cause a parallax error. Beware of giving a list of answers – as "right + wrong = wrong".

(iii) Explain how she should reduce a source of error in this measurement of t.

(2)

She should tighten the ratchet knob enough so that the ruler doesn't deform & the reading will be more accurate

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Examiner Comments

This candidate's answer uses the second approach.

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Examiner Tip

You may not know the correct names for the parts of every measuring device (eg ratchet). If in doubt, describe it clearly so examiners can understand which part you mean.

Question 1 (a)(i–ii)

The context of this question is a measurement of thickness, made using a micrometer screw gauge.

Candidates are likely to have taken similar measurements for the diameter of a small metal ball while completing core practical 2, or a wire while completing core practicals 3 and 7.

Q01(a)(i) shows a diagram of a micrometer screw gauge reading, showing the sleeve and thimble scales.

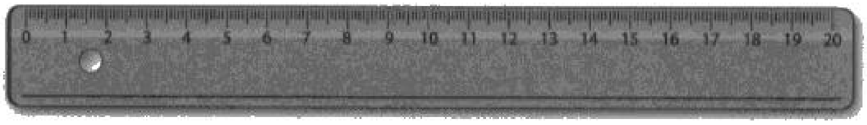
Candidates should know that the sleeve of the micrometer is marked in whole and half-millimetres, with the thimble, marked in 50 parts, rotating twice per mm.

This means the sleeve is showing a measurement of 1.50 mm and the thimble is showing a further measurement of 0.22 mm, giving a total measurement of 1.72 mm.

Q01(a)(ii) requires candidates to recall that the resolution of a micrometer screw gauge is 0.01 mm and that to calculate the percentage uncertainty of a single measurement they should use half the device resolution in their calculation.

This is stated in the specification for unit 3 and is described in Appendix 10: Uncertainties and Practical Work.

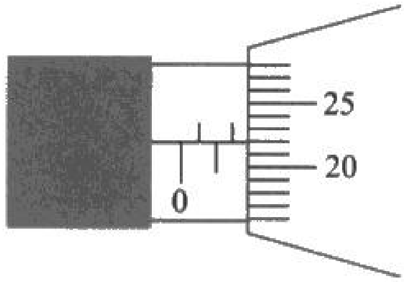
1 A student made measurements of the ruler shown.



(Source: © Dragance137/Shutterstock)

(a) She used a micrometer screw gauge to measure the thickness t at the centre of the ruler.

The diagram below shows the reading on the micrometer.



(i) State the value of t shown on the micrometer.

(1)

$t =$ 22.3 mm

(ii) Determine the percentage uncertainty in this value of t.

(2)

$U = \frac{1}{2} \times \text{resolution}$ | $U\% = \frac{U}{V} \times 100$

$U = \frac{1}{2} \times 0.1\text{mm}$ | $U\% = \frac{0.05}{22.3} \times 100$

$U = 0.05$ | $\boxed{U\% = 0.22\%}$

Percentage uncertainty in $t =$ 0.22%

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Examiner Comments

Q01(a)(i) This candidate seems to recall the need to combine the values from both micrometer scales.

However, the candidate has reversed them. 22 mm from the rotating thimble scale and 0.3 mm as an incorrect interpretation of the sleeve scale.

Q01(a)(ii) The mark scheme allows for error carried forward from (a)(i), which we allowed for both the value and the uncertainty. As the value in (a)(i) is written to a resolution of 0.1 mm, we accepted the use of 0.05 mm to be the half-resolution. So both marks were awarded.

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Examiner Tip

Use online simulations of a micrometer to practice interpreting the scale.

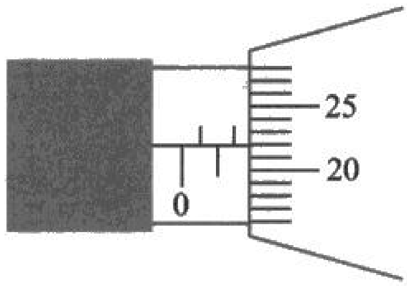
There are several available – eg http://www.stefanelli.eng.br/en/simulator-virtual-micrometer-hundredths-millimeter/

1 A student made measurements of the ruler shown.

(Source: © Dragance137/Shutterstock)

(a) She used a micrometer screw gauge to measure the thickness t at the centre of the ruler.

The diagram below shows the reading on the micrometer.



(i) State the value of t shown on the micrometer.

(1)

t = 1.72

(ii) Determine the percentage uncertainty in this value of t.

(2)

$\frac{0.005}{1.72} \times 100 = 0.29\%$

Percentage uncertainty in t = 0.29%

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Examiner Comments

This example shows the ideal candidate response.

Q01(a)(i) The candidate does not provide a unit with the answer.

Although for this exam the unit is in brackets in the mark scheme, this is not always the case. In other exams and on other questions in this exam, a lack of unit would mean the mark would not be awarded.

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Examiner Tip

Always provide an appropriate unit with a numerical answer.

Question 1 (b)

The concept of the centre of gravity and how this can be used alongside the principle of moments is taught to candidates in unit 1.

The key to this question is that the ruler (or pivot) need to be moved, so that the weight of the ruler causes a moment that can then be balanced by the moment of the weight of the 20 g mass.

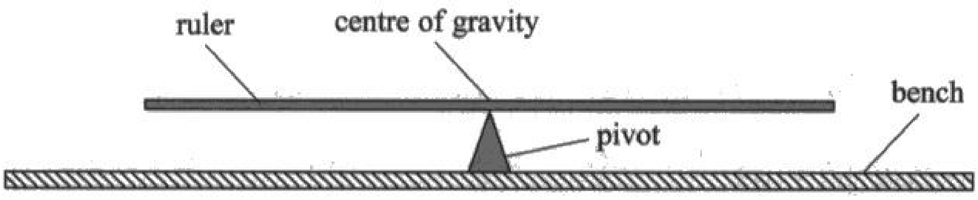
Many candidates missed this key detail, so when they described adding the 20 g mass and moving it until the ruler balanced again, they were describing a state where the 20 g mass was also above the pivot. Neither weight would have a moment. These candidates could score 1 mark at most (the third mark).

Those candidates who did realise the ruler (or pivot) needed to be moved, generally scored the first and third marks.

Clear descriptions of how to measure the two distances to the pivot were rare. Some candidates only described the distance of the 20 g mass. A few described complicated methods, defining all measurements as from 0 on the ruler, so the second mark was awarded less often.

The fourth mark was rarely awarded. Most students had not picked up the requirement for an "accurate value", and most that had gave a very basic "repeat and mean" style answer. However, we rarely repeat the measurement the exact same way (eg when measuring the diameter of a wire, we would repeat in different places or for the stiffness of a spring we would apply different forces)

(b) The student balanced the ruler on a pivot as shown, and recorded the position of the centre of gravity of the ruler.



The student has a 20 g mass.

Describe how the student should determine an accurate value for the mass of the ruler using the 20 g mass and the apparatus shown.

(4)

By using Moments. • the Student can adjust the position of the ruler and add the 20g mass to balance the rotational forces (make it in equilibrium)

• Then by measuring the distance from the pivot she placed the mass, (and the centre of gravity) use the formula Moment = mx (mass x length) and equate the clockwise rotational force's and anticlockwise rotational forces.

• We then have a ~~unknown~~ unknown in the ~~distance from~~ mass of the centre of gravity ~~to the pivot~~. So by taking multiple measurement (7 measurements) of different distances, we can solve for the mass of the ruler.

(Total for Question 1 = 9 marks)

•Change the distance of the mass from the pivot and calculate a ~~max~~ mean mass.

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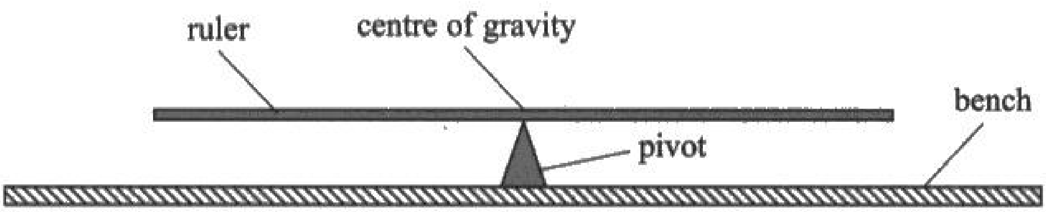
Examiner Comments

This is an example of a full-mark answer.

(b) The student balanced the ruler on a pivot as shown, and recorded the position of the centre of gravity of the ruler.



The student has a 20 g mass.

Describe how the student should determine an accurate value for the mass of the ruler using the 20 g mass and the apparatus shown.

(4)

Put the mass on one side of the ruler and change the position of ruler on the pivot ~~or~~ until it is balanced. Measure the distance ~~of~~ between the mass and the privot and the distance between centre of gravity for ruler and the pivot.

~~0.2~~ $0.02 \times d_{mass} = M_{ruler} \times d_{ruler}$

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Examiner Comments

This candidate scored 3 marks.

Note that, since the principle of moments would require the use of gravitational field strength *g* on both sides of the equation, we accepted examples where the *g* had already been cancelled for the third mark. But that might not be true for other exams where there may be separate marks for each step.

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Examiner Tip

Always show the steps in your algebra, even for a describe question.

Question 2 (a)(i)

The context of this question was clearly unusual for many candidates.

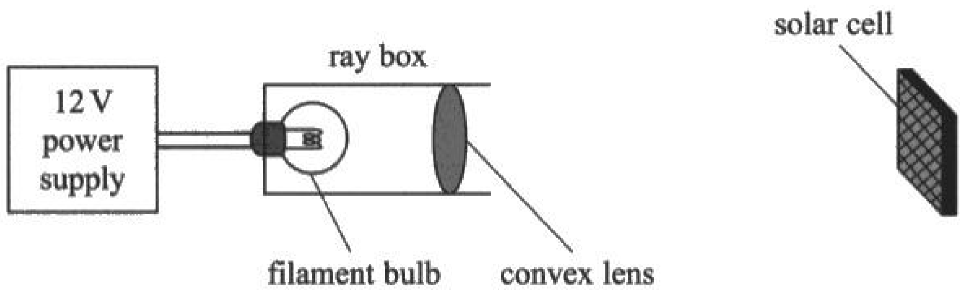
It is possible that few had experience using this type of cylindrical convex lens in a ray box, to ensure the rays are parallel.

However, most candidates would be aware that a convex lens would converge the rays of light, concentrating the light and reducing the spread of light from the filament bulb.

So, we allowed for this lack of experience by giving several alternatives for the two marks.

2 A student investigated the properties of a solar cell.

He illuminated the solar cell using the apparatus shown.



(a) (i) Explain the purpose of the convex lens.

(2)

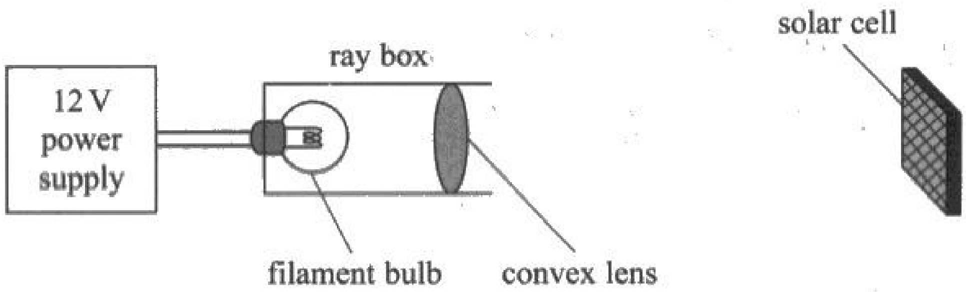
Concentrates the light ~~fom~~ from the bulb onto the solar cell to ensure that all rays reach the cell and aren't ~~diverted~~ ~~diverged~~ ~~els~~ spreaded elsewhere

ResultsPlus
Examiner Comments

This candidate clearly understands that the convex lens will converge the light, which will make it more concentrated (first mark), as otherwise it would spread out (second mark).

2 A student investigated the properties of a solar cell.

He illuminated the solar cell using the apparatus shown.



(a) (i) Explain the purpose of the convex lens.

(2)

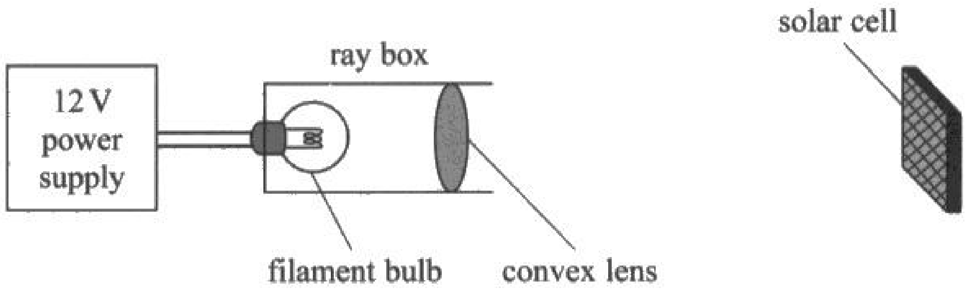
To concentrate the light from the ~~bub~~ bulb onto ~~a single point~~ ~~on~~ the solar cell ~~to m~~ and ~~keep~~ make experiment ~~results~~ more accurate.

ResultsPlus
Examiner Comments

This response was awarded the first mark, for the idea of concentrating the light.

2 A student investigated the properties of a solar cell.

He illuminated the solar cell using the apparatus shown.



(a) (i) Explain the purpose of the convex lens.

(2)

It makes sure the light from the filament bulb is directly on the solar cell instead of spreading out and reducing its lights intensity

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Examiner Comments

This response has two correct ideas, light spreading out, the lens stopping light intensity reducing. Unfortunately, both of these ideas were the second mark.

The idea of the light being "directly" on the solar cell was not enough, more detail was needed for the first mark.

Question 2 (a)(ii)

Candidates were asked how to keep the light intensity on the solar cell constant. This question was generally answered well by those who focused their response on the solar cell.

Many candidates described methods of keeping the bulb's intensity the same. Such answers were not given credit, as this factor was covered by the question information.

(ii) The power supply provided a constant 12 V potential difference across the filament bulb.

Describe **two** more ways to keep the light intensity incident on the solar cell constant.

(2)

Keep the distance from the filament bulb to the solar cell constant. It should be ~~kegt~~ kept at the same angle at all times. Take background light into account. Carry out the investigation in a dark room.

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Examiner Comments

This candidate has described all three options in the mark scheme.

As the candidate was only asked for two more ways, we credited the first two.

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Examiner Tip

Be wary of providing an answer with more options than are required. Irrelevant extra information may be ignored, but we cannot ignore incorrect physics.

Question 2 (b)(i)

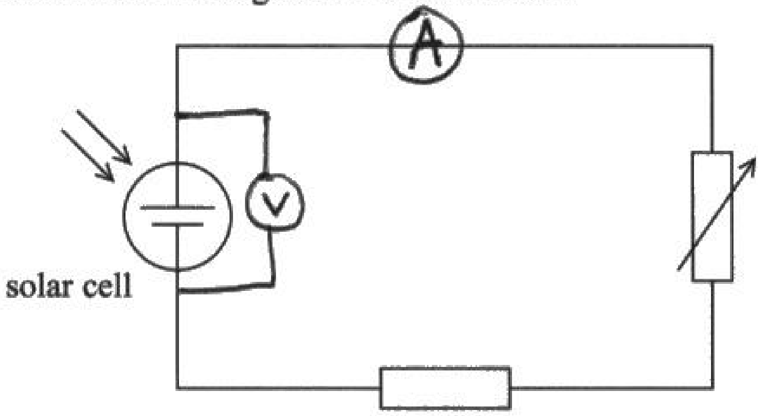
The question asked candidates to add an ammeter and voltmeter, so that potential difference across the solar cell and current through the solar cell can be measured.

Most candidates scored both marks, but it was common to see the voltmeter connected across one of the other components, so not measuring the potential difference across the solar cell.

(b) The student investigated how the potential difference across the solar cell varied with the current through the solar cell.

The light intensity incident on the solar cell was kept constant during the investigation.

The circuit diagram for the investigation is shown below.



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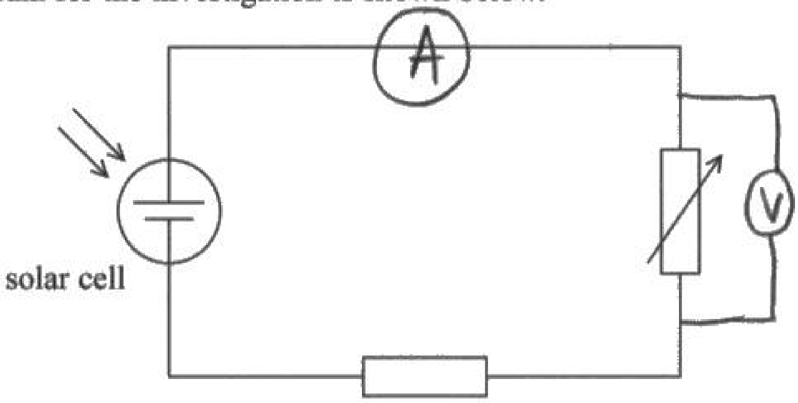
Examiner Comments

This example shows both meters connected correctly.

(b) The student investigated how the potential difference across the solar cell varied with the current through the solar cell.

The light intensity incident on the solar cell was kept constant during the investigation.

The circuit diagram for the investigation is shown below.



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Examiner Comments

Although the ammeter can be connected anywhere in the series circuit, the voltmeter is across the variable resistor. This means the voltmeter is also across the ammeter, solar cell and fixed resistor.

We can assume the ammeter has zero resistance, so no potential difference across it. But the fixed resistor would have a potential difference across it, so the voltmeter as shown would not be measuring the potential difference across the solar cell.

Question 2 (b)(ii)

Most candidates found this question very difficult.

It was common to see an answer of "to reduce current" or "to prevent overheating" without context.

Candidates are most likely to have used a protective resistor when investigating diodes or LEDs while studying unit 2.

If the variable resistor was reduced to zero resistance the resistor would prevent a short circuit. By **limiting** the current, the resistor can protect other components.

(ii) Suggest a reason for using a fixed resistor in the circuit.

(1)

To prevent over heating of the cell and to limit the the amount of current in circuit.

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Examiner Comments

This candidate suggests the reason was to limit the current.

(ii) Suggest a reason for using a fixed resistor in the circuit.

(1)

To set a minimum resistance as to not short-circuit the circuit when the variable resistor is set near zero.

ResultsPlus
Examiner Comments

This candidate suggests the reason was to avoid a short-circuit occurring.

Question 2 (c)

Although the question asks candidates to describe two advantages of using the solar cells, many gave reasons why the solar cell could power the pump. It was common to see answers such as "the pump does not required much energy" or "the plants only need water in the day time".

For this question, we needed answers to give advantages over other sources of electrical power for the pump.

The alternative sources of electrical power were not given in the question. So, the answers needed to focus on the advantages of solar cells, **not** the disadvantages of other methods.

As with previous questions, it was also common to see a list of more than two answers.

(c) Solar cells are used as a source of electrical power.

Describe **two** advantages of using solar cells to power a small water pump in a garden.

(2)

It can reduce ~~some~~ some energy that used, such as coal, gas. Solar cells is renewable energy, use this can reduce the damage chemical ~~em~~ ~~[illegible]~~. gas, ~~set~~ ~~se~~ such as CO_2, CO.

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Examiner Comments

This candidate gives three "advantages":

- reduced sound energy
- solar is renewable energy
- reduced damaging chemical gas such as CO_2.

The first option is irrelevant, rather than incorrect, so was ignored. However, the other two advantages match the first and second mark points.

ResultsPlus
Examiner Tip

Avoid giving lists with extra responses. Irrelevant answers can be ignored, but incorrect physics cannot be rewarded.

(c) Solar cells are used as a source of electrical power.

Describe **two** advantages of using solar cells to power a small water pump in a garden.

(2)

Renewable sources of energy, so more ethical and doesn't case global warming, cells won't need to be charged and plants will be watered regularly.

(Total for Question 2 = 9 marks)

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Examiner Comments

Another candidate who describes more than two advantages:

- renewable source of energy (so more ethical)
- doesn't cause global warming
- cells won't need to be charged
- plants will be watered regularly

The first two match the first and second mark points.

The remaining two advantages are irrelevant, rather than incorrect. If the two extra advantages had been incorrect (wrong application physics) they would not be ignored. This could mean the first and second marks were contradicted, so not awarded.

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Examiner Tip

This response gives four advantages for a question that asked for two. The more answers a candidate adds, the more likely the answer will become a contradiction.

Question 3 (a)(i)

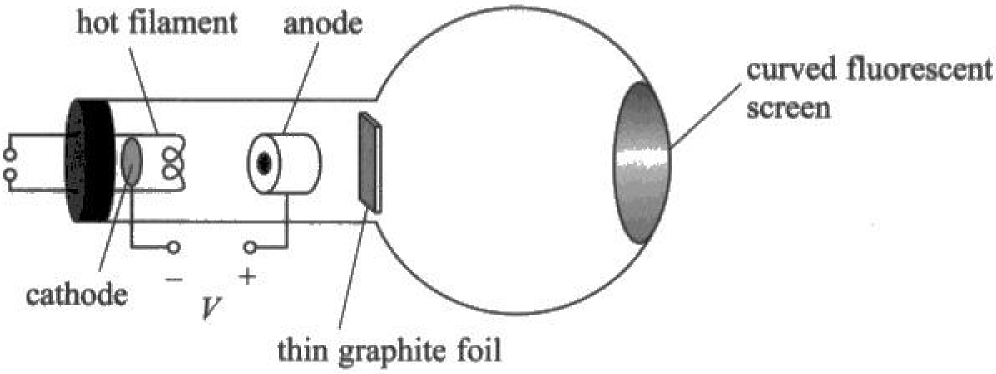
This question was answered poorly as many answers focused on the ruler. Candidates needed to give two reasons why the vernier caliper was **more** appropriate.

So, answers giving reasons why the ruler is less appropriate, with no comparison with the vernier caliper did not answer the question asked.

It was clear that many candidates experience of using a vernier caliper was for physical objects that fit within the jaws, rather than making measurements by aligning the tips. However, we ensured there were still two mark points available for such candidates.

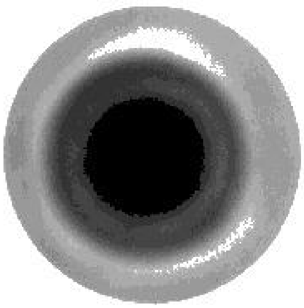
It was common to see "the ruler couldn't bend" with no further context, but even if a flexible ruler was used it would not be measuring the diameter of the rings. A non-flexible ruler would not be near the rings, so there would be a parallax error with the ruler that would not occur with the vernier calipers.

3 A student investigated the diffraction of electrons using an electron beam tube as shown.



The potential difference, V, accelerates electrons from the hot filament towards the thin graphite foil.

The electrons diffract as they pass through the foil, producing a ring pattern on the curved fluorescent screen as shown below.



(Source: © ANDREW LAMBERT PHOTOGRAPHY/SCIENCE PHOTO LIBRARY)

(a) The student used vernier calipers to measure the diameters of the rings on the curved screen.

(i) Give **two** reasons why vernier calipers are more appropriate for these measurements than a transparent ruler.

(2)

Because they have a better resolution (0.01cm instead of 0.1 cm of a ruler) and you avoid parallax errors from the ruler using a vernier calipers

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Examiner Comments

Although "better resolution" alone would not normally be clear enough, this candidate has clarified by stating resolution values.

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Examiner Tip

There is a language contradiction when describing resolution – higher and smaller resolution both have the same meaning, eg a higher resolution screen has smaller pixels and can resolve smaller details.

Question 3 (a)(ii)

This is a standard question, and unlike Q01(a)(iii) it does not refer to a single measurement.

As such, the standard response was expected – repeat the diameter measurement in different orientations on the same ring and calculate the mean diameter.

Most students scored at least 1 mark, with many forgetting to clearly state the need to calculate the mean diameter.

There were some examples where candidates had assumed the question referred to a single measurement, so we accepted "check for zero error" as sufficient for a single mark to be awarded.

(ii) Describe how the student should measure the diameter of a ring as accurately as possible.

(2)

The student needs to Check for zero error before each measurement and measure the diameter of the ring from different positions at least 5 times and Calculate their mean to reduce % uncertainty.

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Examiner Comments

The “compensatory” mark for "check for zero error" can be seen in the first line, but that is not required as we can award the two marks for the rest of the answer.

Question 3 (b)(iii)

It is very common during practical work to use a graphical method to determine a constant, rather than calculating the constant from a small set of data and determining the mean.

So, candidates will be very familiar with this technique. But few could explain why using a graphical method would be **better**.

Almost half of candidates scored zero marks.

Many only scored a mark for the basic idea that having more data would likely lead to a more accurate value of a.

Many responses lacked detail – eg "it is easier to spot anomalies" would be true if the plots were compared to the line of best fit. "You can determine systematic error" is true if you extend the line to the axes.

(iii) A different student repeated the investigation using six values of V. She plotted a graph of V against $\frac{1}{\lambda^2}$ and determined the constant a from the gradient.

Give **two** reasons why this is a better method to determine a value for a.

(2)

• The line of best fit ~~to~~ is a better average of all the data points so the gradient will give a more accurate α value • Anomalies can be more easily identified to be removed to make the line and gradient more accurate
• So percentage uncertainty of α decreases.

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Examiner Comments

This candidate has understood that the act of drawing a line of best fit and calculating the gradient is an averaging method – so the second marking point can be awarded.

Although the candidate makes a generic statement that "anomalies can be more easily identified", it is made in context of the line of best fit, so is sufficient for the third marking point to be awarded.

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Examiner Tip

Here the candidate has given three advantages, where only two were asked for.

Fortunately, in this case the third advantage is not incorrect, so it can be ignored.

Question 3 (b)(i–ii)

This question was answered well, with over a third of candidates scoring full marks for both parts.

The most common error in Q03(b)(i) was failing to include the powers of ten shown in the table, so giving an answer of 1.22 m^2 V, rather than 1.22×10^{-18} m^2 V.

A less common error was to discard a value, assuming it was an anomaly. Since 1.23 and 1.11 are 0.12 apart, and 1.32 and 1.23 are 0.11 apart, none of the values are clear anomalies. As such, all should be included in the mean calculation.

However, since Q03(b)(ii) includes error carried forward from (b)(i), most candidates managed to calculate the percentage uncertainty, using the method described in appendix 10 of the specification.

(b) The student used the diameter of the rings to determine the wavelength λ of the electrons.

He repeated this for two more values of V.

The student also determined the value of a constant a using the formula

$$a = V\lambda^2$$

The results are shown in the table below.

V / kV	λ / 10^{-12} m	a / 10^{-18} m^2 V
200	2.67	1.23
250	2.44	1.11
300	2.14	1.32

(i) Determine the mean value of a in m^2 V.

(2)

$\bar{a} = \frac{1.23 + 1.11 + 1.32}{3} \times 10^{-18} = 1.22 \times 10^{-18}$ m^{2}V

Mean value of a = 1.22×10^{-18} m^2 V

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

(2)

$R = 1.32 - 1.11 = 0.21 \times 10^{-18}$ m^{2}V.

$\%u = \frac{\frac{1}{2}R}{\bar{a}} = \frac{\frac{1}{2} \times 0.21 \times 10^{-18}}{1.22 \times 10^{-18}} = \cancel{8.6\%}$ 8.6%

Percentage uncertainty in the mean value of a = 8.6%

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Examiner Comments

This candidate gives a correct calculation to determine the mean value of *a*. Although the powers of 10 were not included in the calculation, they were correctly added to the answer.

The candidate correctly uses the "half range of values" method to calculate the uncertainty in the repeated *a* values, correctly using this to determine the percentage uncertainty in the mean value of *a*.

(b) The student used the diameter of the rings to determine the wavelength λ of the electrons.

He repeated this for two more values of V.

The student also determined the value of a constant a using the formula

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V / kV	λ / 10^{-12} m	a / 10^{-18} m^2 V
200	2.67	1.23
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300	2.14	1.32

(i) Determine the mean value of a in m^2 V.

(2)

$\frac{1.23 + 1.11 + 1.32}{3} = 1.22\ \text{m}^2\text{V}$

Mean value of a = 1.22 m^2 V

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

(2)

Percentage uncertainty = $\frac{\text{uncertainty}}{\text{measured value}} \times 100\%$

Uncertainty = $\frac{\text{range}}{2} = \frac{1.32 - 1.11}{2} = 0.105$ $= \frac{0.105}{1.22} \times 100 = 8.6\%$

Percentage uncertainty in the mean value of a = 8.6%

ResultsPlus
Examiner Comments

This candidate gives a correct calculation to determine the mean value of *a*. However, the powers of 10 were not included in the calculation, nor were they added to the answer. So, only one mark was awarded for (b)(i).

The candidate correctly uses the "half range of values" method to calculate the uncertainty in the repeated *a* values, correctly using this and the mean stated in (b)(i) to determine the percentage uncertainty in the mean value of *a*.

Question 3 (c)(i–ii)

Both parts of Q03(c) cover skills have appeared regularly in WPH13 papers.

Most students scored at least 2 marks, with 85% of students split evenly across 2, 3 or 4 marks.

Q03(c)(i) was a more complex calculation using given data, in this case in the question and in the list of data at the end of the paper. Most candidates completed this calculation successfully.

Q03(c)(ii) required candidates to compare a 6% uncertainty in their calculated value of *h* with 6.63×10^{-34} J s.

Some candidates determined the percentage difference between the two values of *h*. If this approach was used, we expected candidates to follow convention and calculate the percentage difference from the standard value (6.63×10^{-34} J s).

In either case, many candidates did not give a conclusion based on a comparison.

Some candidates applied the 6% percentage uncertainty to the standard value, rather than the calculated value. We allowed 1 mark only for the process, as the comparison would not be correct.

(c) The value of a can also be calculated using the formula

$$a = \frac{h^2}{2em_e}$$

where
h is the Planck constant
e is the electron charge
m_e is the electron mass.

(i) Calculate the value of h, in J s, when a is $1.46 \times 10^{-18}\,\text{m}^2\,\text{V}$.

(2)

$1.46 \times 10^{-18} = \dfrac{h^2}{2 \times -1.6\times10^{-19} \times 9.11\times10^{-31}}$

$h^2 = -4.256192 \times 10^{-67}$

$h = 6.5239 \times 10^{-34}$

$h =$ 6.5239×10^{-34}. J s

(ii) The percentage uncertainty in the calculated value of h is 6%.

Comment on the accuracy of your calculated value of h.

(2)

$6.5239\times10^{-34} \times 0.06 = 3.9144\times10^{-35}$

$3.9144\times10^{-35} + 6.5239\times10^{-34} = 6.9153\times10^{-34}$.

ResultsPlus
Examiner Comments

The calculation is correct in (c)(i) and the upper boundary of range of uncertainty is calculated in (c)(ii).

However, there is no comparison made and there is no comment on the accuracy.

ResultsPlus
Examiner Tip

When asked to comment on accuracy, or to determine whether a value is accurate, remember to write a statement that includes a comparison of values.

(c) The value of a can also be calculated using the formula

$$a = \frac{h^2}{2em_e}$$

where
h is the Planck constant
e is the electron charge
m_e is the electron mass.

(i) Calculate the value of h, in J s, when a is $1.46 \times 10^{-18}\,\text{m}^2\,\text{V}$.

(2)

$h^2 = 2em_e \cdot a$ ~~= 2 × 1.46~~ $2 \times 1.46 \times 10^{-18} \times 1.6 \times 10^{-19} \times 9.11 \times 10^{-31}$

$h^2 = 4.256192 \times 10^{-67}$ $h = \sqrt{4.256192 \times 10^{-67}} = 6.52 \times 10^{-34}$

$h =$ 6.52×10^{-34} J s

(ii) The percentage uncertainty in the calculated value of h is 6%.

Comment on the accuracy of your calculated value of h.

(2)

$h = 6.63 \times 10^{-34}$ $6.52 \times 10^{-34} \times (1 + 6\%) = 6.91 \times 10^{-34}$

The real value of h is within the uncertainty, so the h calculated in (c)(i) is fairly accurate

ResultsPlus
Examiner Comments

The calculation is correct in (c)(i) and the upper boundary of range of uncertainty is calculated in (c)(ii).

This time there is a comparison made and there is a correct comment on the accuracy.

Question 4 (a)

Candidates will have completed core practical 3, where a mass was used to stretch an elastic material, usually a wire.

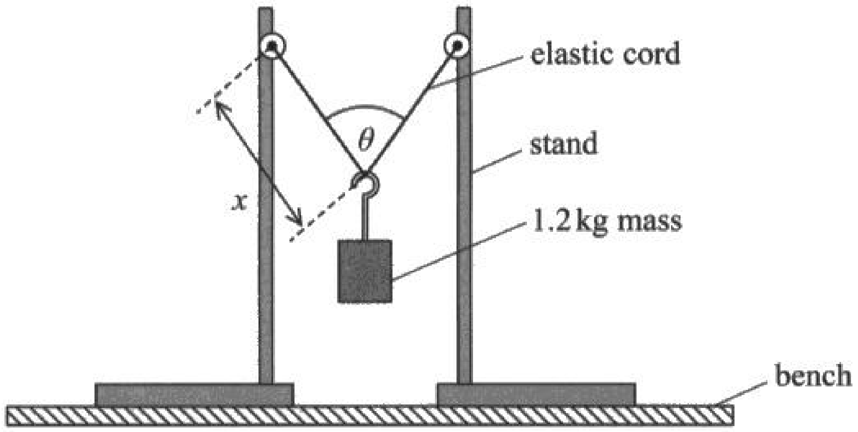
Although the context of this questions is not the same as the core practical, two of the health and safety issues are likely to be the same, the material snapping under tension and the mass falling.

From the diagram we can see the arrangement of the stands is likely to be unstable, unless the stand bases were heavier than standard.

So, these were the three health and safety issues that were expected.

This question was answered well by candidates. Almost 75% scored full marks and only 10% failed to score a mark.

4 A student investigated the extension of an elastic cord. She hung a 1.2 kg mass from the elastic cord as shown.



(a) Identify a health and safety issue and how it may be dealt with.

(2)

If the mass is too heavy it would break the Elastic cord and fall on the bench. The elastic cord could damage your eyes and cause injury. Wear safety goggles to avoid that.

ResultsPlus
Examiner Comments

This examples identifies the elastic cord snapping, which can be dealt with by wearing safety goggles.

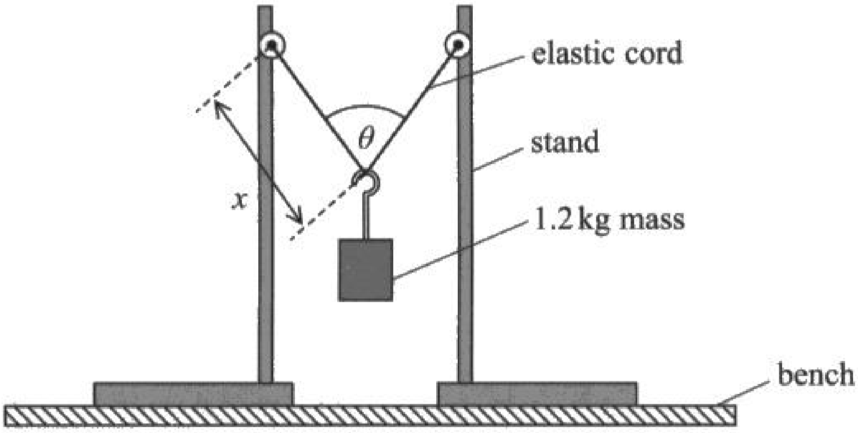
The falling mass was also identified for the first mark, but the cord snapping answer scored both marks.

ResultsPlus
Examiner Tip

The question only asks for a single health and safety issue.

If the extra health and safety issue (falling mass) had been incorrect, there could be a contradiction for the first mark – which then would not be awarded.

4 A student investigated the extension of an elastic cord. She hung a 1.2 kg mass from the elastic cord as shown.



(a) Identify a health and safety issue and how it may be dealt with.

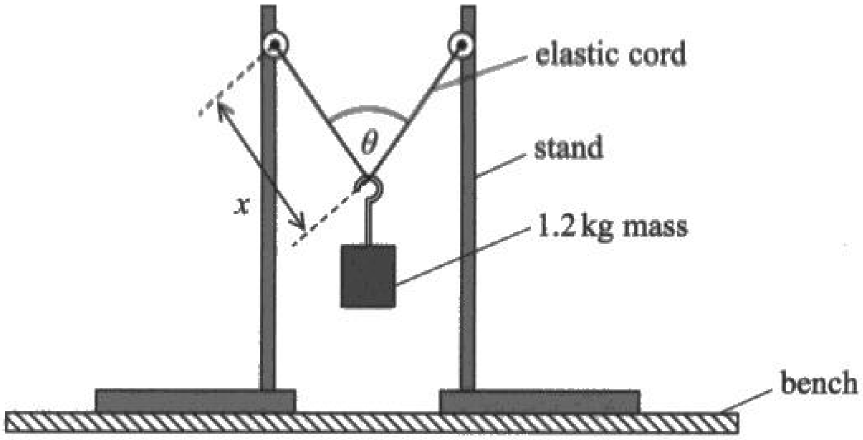
(2)

Injuries caused due to falling masses ~~by~~ can be reduced by ~~using~~ placing a padded cushion underneath the mass on top of the bench.

ResultsPlus
Examiner Comments

This candidate identifies the issue caused by the falling mass and solves this using a padded cushion.

4 A student investigated the extension of an elastic cord. She hung a 1.2 kg mass from the elastic cord as shown.



(a) Identify a health and safety issue and how it may be dealt with.

(2)

The student should use a clamp to fix the stand, preventing it falling over.

ResultsPlus
Examiner Comments

This candidate identified the third option – the stands falling over, which is solved using a clamp to fix them.

Question 4 (b)(i–ii)

Although the question was split into two parts, the answers were marked holistically, so if an answer to Q04(b)(ii) was seen within the answer to Q04(b)(i), it was rewarded.

However, most students gave very generic answers, rather than linking them specifically to this context. This limited the marks awarded – with most scoring only 1 or 2 marks.

For example, it was common to see parallax error solved using a set-square. This would be applicable if the practical context prevented the ruler or protractor from being close to the object being measured (the string). But, in this context that is not the case. It would be easy to hold the ruler or protractor onto the string.

Another common error seen was zero error. But, unless the end of the ruler or edge of the protractor was broken, there is unlikely to be a zero error. Where candidates made it clear that they meant the zero of the ruler or protractor was not correctly aligned, then we awarded the third marking point.

But a generic "zero error" or "parallax error" with no context, was not worthy of credit.

(b) The student varied the distance between the two stands to vary the angle θ.

She measured θ using a protractor. For each value of θ she measured the corresponding length x with a metre rule.

(i) Identify **two** sources of uncertainty with this method.

(2)

There can be a parallax error when measuring the length x using the metre rule. The protractor might not be aligned properly resulting in an innacurate measurement for θ.

(ii) Suggest a modification to reduce the effect of **one** of these sources of uncertainty.

(1)

The ~~metre rule should~~ metre rule should be at eye level when measuring length x to reduce the effect of the parallax error.

ResultsPlus
Examiner Comments

For part (i), the candidate has identified parallax error in the measurement of the length and the protractor not being aligned correctly, so scoring the first and third marks.

In part (ii), the candidate has correctly linked a modification to one of the identified sources of uncertainty.

Question 4 (c)(i)

Questions where candidates re-arrange a given equation and compare to $y = mx + c$ are common on WPH13.

Yet, with 1 mark being awarded to 25% of candidates, and the remaining candidates split fairly evenly between 0 and 2 marks, it is clear this question proved more difficult than expected.

Candidates should be well practiced in using the gradient or the y-intercept of a graph to determine a constant (in this case g), as this skill is listed as a requirement in the specifcation for unit 3.

In this case, the candidates were told which parts of the equation would be plotted on the y and x axes, so the re-arrangement required was minimal (separating Δx from the fraction to give $1/\Delta x$).

By comparing this to $y = mx + c$ or re-arranging further to match the gradient calculation of the graph described in the question, candidates would be able to identify the link between k and the gradient.

(c) The student determined the extension Δx of the elastic cord for each value of θ.

The relationship between θ and Δx is given by

$$\cos\left(\frac{\theta}{2}\right) = \frac{mg}{k\Delta x}$$

where
m is the mass hung from the elastic cord
k is the stiffness of the elastic material.

(i) Explain why a graph of $\cos\left(\frac{\theta}{2}\right)$ against $\frac{1}{\Delta x}$ can be used to determine a value for g.

(2)

$\cos\left(\frac{\theta}{2}\right) = \frac{mg}{k} \cdot \frac{1}{\Delta x}$

$y = m \quad x$

Gradient $= \frac{mg}{k}$

$g = \frac{\text{Gradient} \times k}{m}$

ResultsPlus
Examiner Comments

In this candidate's response, we can clearly see the re-arranged equation is compared to $y = mx$.

The gradient is then clearly linked to mg/k and re-arranged to show how g is determined.

ResultsPlus
Examiner Tip

If comparing to y = mx + c, ensure the comparison is clear, eg line up the components, use arrows or loops to ensure there is no confusion.

Question 4 (c)(ii–iv)

The skills assessed by this part of the WPH13 exam paper remain fairly consistent each exam series.

There is a table of data that requires further processing.

There is a graph to be plotted, assessed using the standard rules:

- axes that are correctly labelled, including the standard SI convention for the units (eg / m^{-1}). The label for Δ*x* in the table shows this convention, as do all the other data tables in this exam paper.
  Note, we do not accept units in brackets alone.
- scales chosen that increase in sensible increments (a powers of 10 of 1, 2 or 5) on the thicker 2 cm lines, that allow for maximum use of the space (over half of each axis to be used for plots).
  In this case the sensible scale would be 0.05 every 2 cm on the *y*-axis and 0.1 every 2 cm on the *x*-axis.
- Plots marked with a small, clear symbol (eg ×), so that the plots can be checked for accuracy to within ±1 mm
- A line of best fit that is reasonably balanced with a similar number/distance of plots above and below the line.

The gradient of the graph is to be determined – using a data range covering over half the line of best drawn.

A constant is to be determined using the gradient calculated.

The total mark for the three sections is 11 and this section of the exam proved to be an excellent discriminator, with just under 10% of candidates scoring each mark and 3% of candidates scored full marks.

The quality of candidates' graphs was higher than in previous exams, though there were many examples of graphs where the candidate insisted on including the (0,0) origin so the plots covered only a few cm of the graph paper.

Less common than in previous exams was the use of large circular plots covering whole 2 mm squares, similar to those produced by default when using spreadsheet software. Hopefully, this is evidence that candidates are practicing plotting graphs more consistently as part of their lessons.

The line of best fit remains an issue: it was common to see lines that simply joined the first and last plots.

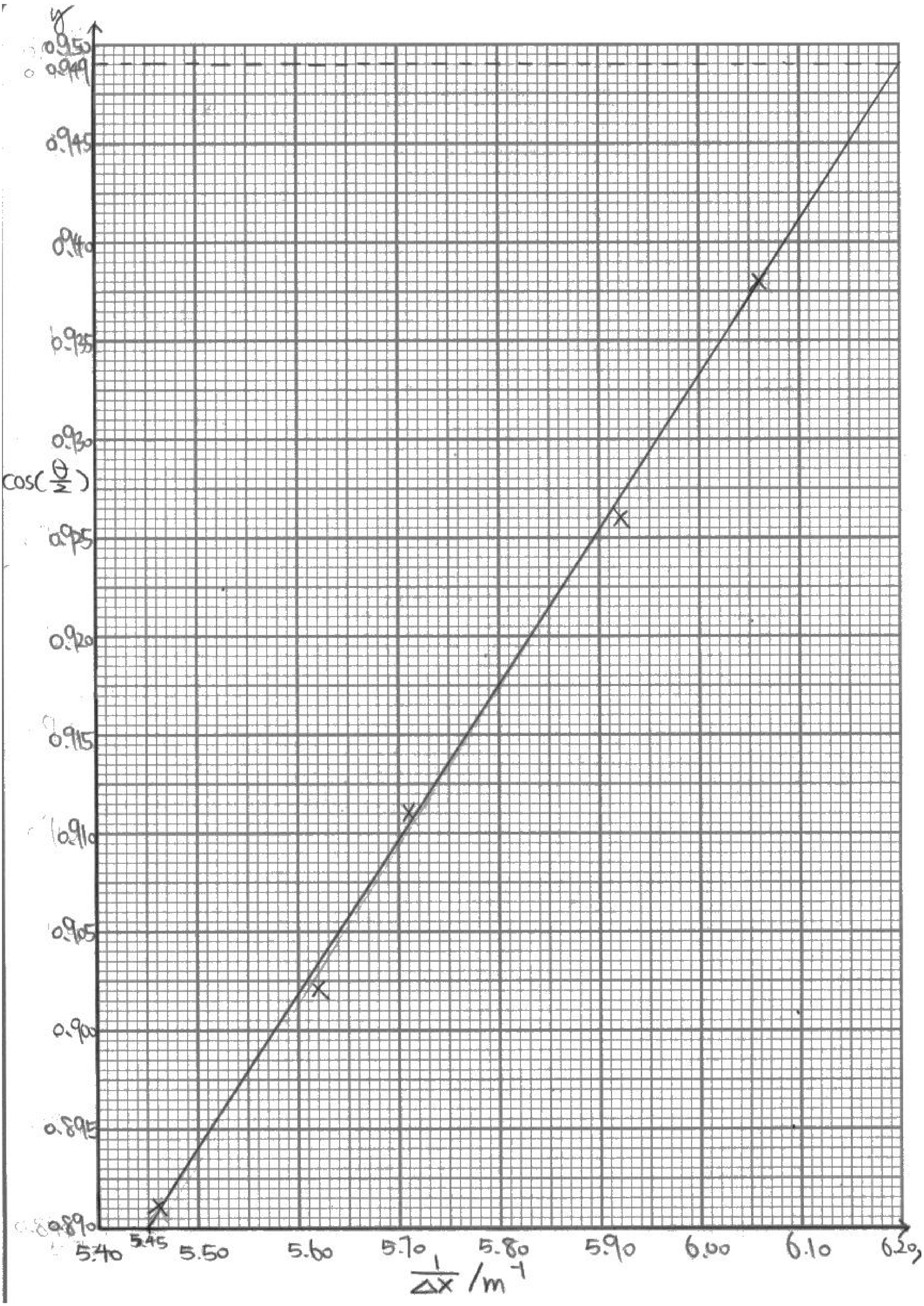
(ii) The student recorded the following data.

$\cos\left(\frac{\theta}{2}\right)$	Δx / m	$\frac{1}{\Delta x}$ / m^{-1}
0.938	0.165	6.06
0.926	0.169	5.92
0.911	0.175	5.71
0.902	0.178	5.62
0.891	0.183	5.46

Plot a graph of $\cos\left(\frac{\theta}{2}\right)$ on the y-axis against $\frac{1}{\Delta x}$ on the x-axis on the grid opposite.

Use the additional column of the table for your processed data.

(6)


y
0.950
0.949
0.945
0.940
0.935
0.930
$\cos(\frac{\theta}{2})$
0.925
0.920
0.915
0.910
0.905
0.900
0.895
0.890
5.40
5.45
5.50
5.60
5.70
5.80
5.90
6.00
6.10
6.20
$\frac{1}{\Delta x}$ / m^{-1}

(iii) Determine the gradient of the graph. **(3)**

$$\cancel{\frac{dy}{dx} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.938 - 0.891}{6.06 - 5.46} = 0.078}$$

$$\cancel{\frac{dy}{dx} = \frac{0.949 - 0}{5.45 - 0} =}$$

$$\frac{dy}{dx} = \frac{0.949 - 0.890}{6.20 - 5.45} = 0.079$$

Gradient = ~~0.078~~ 0.079

(iv) Determine a value for g from the gradient of the graph.

$m = 1.20\,\text{kg}$
$k = 145\,\text{N m}^{-1}$

(2)

$$0.078 = \frac{mg}{k}$$

$$g = \frac{\cancel{0.078}\ 0.079 \times 145}{1.20}$$

$$g = \cancel{9.47}\ \text{N/kg}$$

9.51

g = ~~9.47~~ 9.51 N/kg

ResultsPlus
Examiner Comments

This example is included to demonstrate the ideal.

For the graph (c)(ii) we can see

- Correctly calculated and rounded additional data in the table (with the correct unit, though that is credited when labelled on the axes)
- Correctly labelled axes, with the unit given using the / convention.
- Scales that increase in sensible increments, and the plots cover of half of the space of each axis.
- Plots that are all accurate with ± 1 mm (half a small square).
- A line that is not perfect, the 2 plots below the line are further than the 2 plots above the line, but it demonstrates some attempt at balance.

For the gradient (c)(iii) we can see

- The data range used the full length of the line.
- The value is within the accepted range.
- The final value is rounded to 2 significant figures (which matches Δy and Δx).

For the calculation of g (c)(iv) we can see

- The use of the candidate's gradient value with a correct substitution of the gradient equation.
- A correct value of g and the correct unit for the data provided in the question.

(ii) The student recorded the following data.

$\cos\left(\frac{\theta}{2}\right)$	Δx / m	$\frac{1}{\Delta x}$
0.938	0.165	6.060 → 6.06
0.926	0.169	5.917 → 5.92
0.911	0.175	5.714 → 5.71
0.902	0.178	5.617 → 5.62
0.891	0.183	5.464 → 5.46

Plot a graph of $\cos\left(\frac{\theta}{2}\right)$ on the y-axis against $\frac{1}{\Delta x}$ on the x-axis on the grid opposite.

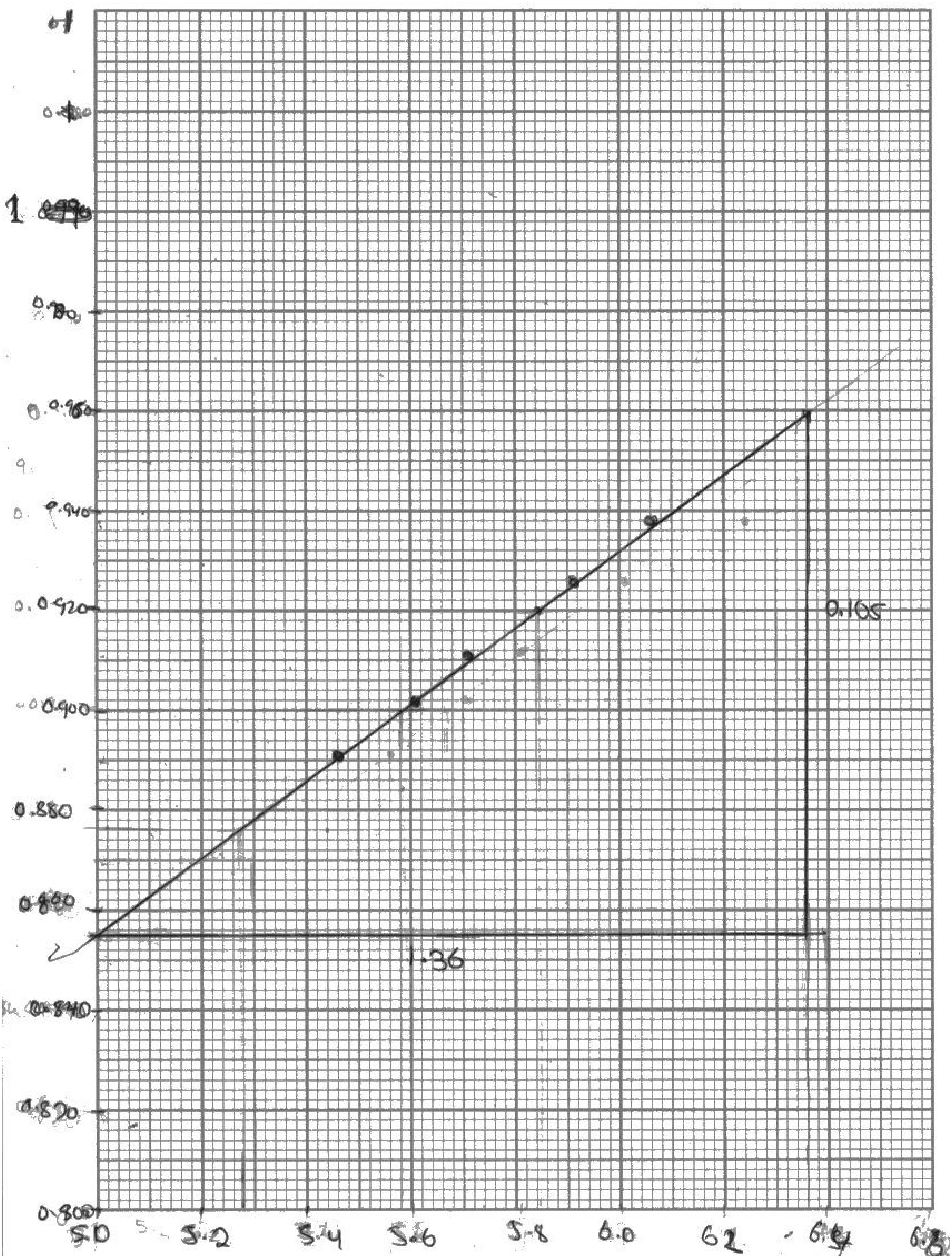
Use the additional column of the table for your processed data.

(6)

9.60 - 8.55

-5.0

9.41 — 9.55 0.06



ResultsPlus
Examiner Comments

This example is included to demonstrate a graph that scored zero marks – so the only mark for (c)(ii) was the calculated and rounded data in the final column of the table.

For the graph we can see:

- There are no labels on the axes
- Although the scale increments are sensible (0.02 and 0.2 every 2 cm), the size of the increment means the plots cover less than half of the *y*-axis.
- Every plot is the size of a 2 mm square, so we cannot check the plot accuracy to within ±1 mm.
- The line joins the second and last plots, leaving every other plot above the line, so the line is not balanced.

ResultsPlus
Examiner Tip

The graph will take longer to draw than the usual target of 1 mark every minute.

The unit 1 and 2 papers allow for 1 mark per minute, and then 10 extra minutes

The unit 3 papers allow for 1 mark per minute, plus an extra 30 minutes (20 more).

It is advisable to keep to the target pace on the earlier questions to allow you the 20 minutes to spend on the graph.

Paper Summary

Based on their performance on this paper, candidates should:

- Study the taxonomy list given in appendix 9 of the specification, so they understand the definitions of the various command words used in questions. This will ensure they answer the quesiton in the correct way.
- Review the use and estimation of uncertainties as outlined in appendix 10 of the specification, particularly when to use the "half range" or "half resolution" methods to calculate the uncertainty in a value.
- Aim for the target pace of 1 minute per mark on other questions, to allow the extra time allocated to be used to complete the graph and gradient questions.
- Ensure answers are linked to the context in the question, rather than generic answers with no detail linking the answer to the specific context of the question.
- Avoid providing lists of answers, particularly where a specific number of responses has been identified in the question, as there is an increased chance the answer will become a contradiction.