Examiners' Report
June 2019

IAL Physics WPH13 01

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June 2019
Publications Code WPH13_01_1906_ER

Introduction

This is the first time the Pearson Edexcel International Level paper WPH13, Practical Skills in Physics I, has been sat by candidates. The paper is worth 50 marks and consists of four questions, enabling candidates of all abilities to apply their knowledge and skills to a variety of styles of question. Each question tests knowledge, understanding and skills candidates developed while completing practical investigations during their Unit 1 and 2 studies.

For this paper, the topics included **materials**, **waves and particle nature of light**. As understanding of the core practicals is assessed by the WPH11 and WPH12 papers, the practical context met in the WPH13 paper may be less familiar. However, it is the skills rather than the details of the practical that we are assessing. The number of marks available for Unit 3 has increased by 10, with an increase in the number of marks available for the demonstration of mathematical skills, which increased the level of challenge for some candidates.

There were many questions that would be familiar for candidates who had studied previous series WPH03 papers, but there are some questions where performances would suggest they were unfamiliar with the practical skills. The long planning question has been replaced with a series of open response questions assessing the same skills. Understanding of keywords (such as **resolution**) and command words (such as **describe how**) proved a challenge to candidates at the lower end of the ability range. At all ability levels, there were some questions where candidates answered in generic terms, rather than being specific to the particular practical described in the question.

Question 1 (a) (i)

This question introduced a common but perhaps unfamiliar piece of practical measuring equipment, a digital caliper. The caliper shown matches the standard resolution of a Vernier caliper, as stated in the specification. However, many responses gave the uncertainty or gave a choice of answers, eg the value and the resolution.

1 During an experiment a student used the measuring instrument shown in the photograph to measure the diameter of a small metal sphere.

(a) (i) State the resolution of the measuring instrument shown in the photograph.

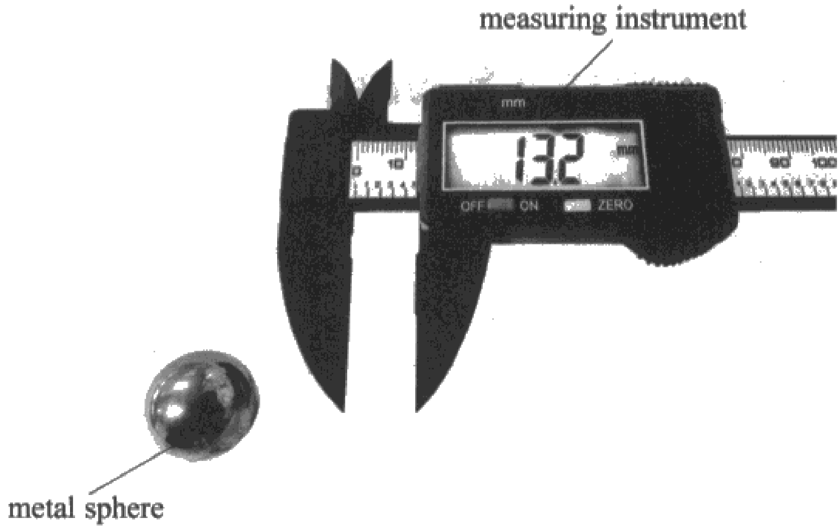
(1)

+ - 0.05 mm to the nearest 0.1 mm

ResultsPlus
Examiner Comments

This response gives 2 answers, so the list rule would apply, but the uncertainty and resolution stated are both correct, so 1 mark was awarded.

1 During an experiment a student used the measuring instrument shown in the photograph to measure the diameter of a small metal sphere.



(a) (i) State the resolution of the measuring instrument shown in the photograph.

(1)

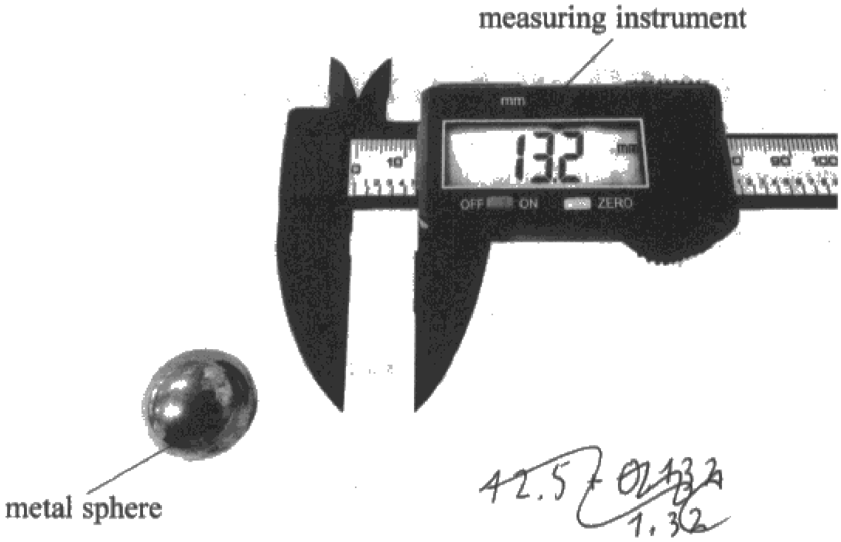
0.01mm

ResultsPlus
Examiner Comments

This example shows a clear powers of 10 error, so scores 0.

There are digital calipers with a resolution of 0.01 mm, but the one shown does not show 2 decimal places.

1 During an experiment a student used the measuring instrument shown in the photograph to measure the diameter of a small metal sphere.



42.5 + ~~0.132~~
1.32

(a) (i) State the resolution of the measuring instrument shown in the photograph.

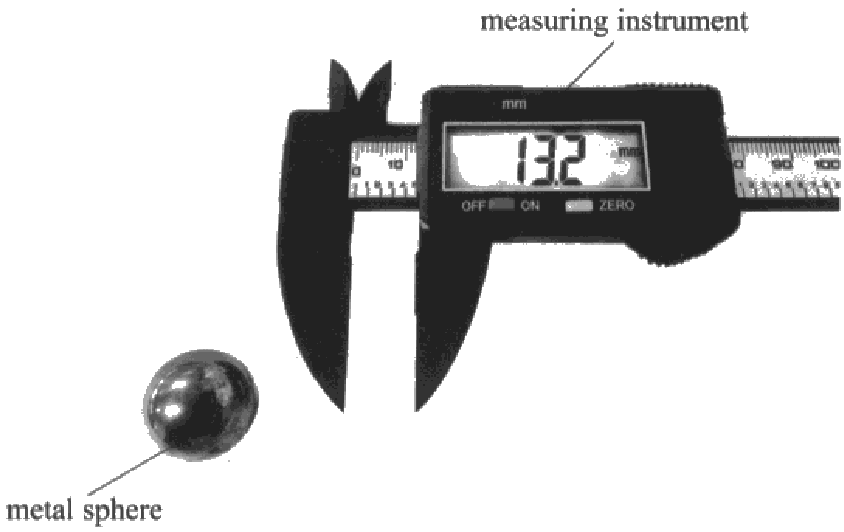
(1)

~~13.25 mm~~ 13.25 mm

ResultsPlus
Examiner Comments

This response gives the maximum value the measurement could be with the uncertainty added, not the resolution, so scores 0.

1 During an experiment a student used the measuring instrument shown in the photograph to measure the diameter of a small metal sphere.



(a) (i) State the resolution of the measuring instrument shown in the photograph.

(1)

± 0.05 mm

ResultsPlus
Examiner Comments

This response gives the uncertainty, not the resolution, so scores 0.

Question 1 (a) (ii)

For this question many candidates answered in generic terms, eg that the caliper had a suitable range to measure the metal sphere. However, this would be true of many measuring devices that are less suitable, eg a ruler.

Most ignored the context of the question, which asked them to justify the use of the digital caliper shown, by suggesting other pieces of equipment that would be suitable, so scored 0 marks.

(ii) Explain why this device is suitable to measure the diameter of the metal sphere.

(2)

As the resolution of the device is very small. The percentage uncertainty while measuring the diameter would be low therefore this device is suitable.

ResultsPlus
Examiner Comments

This response shows the most common answer that scored the first mark.

Many answers missed the word percentage, so did not score the first mark as the uncertainty would be the same no matter what size sphere was being measured.

(ii) Explain why this device is suitable to measure the diameter of the metal sphere.

(2)

This device is suitable as the ~~resolution~~ precision of this device is much smaller than the diameter of the metal sphere. Thus ~~percentange~~ percentage uncertainty is also much ~~smaller.~~ small.

ResultsPlus
Examiner Comments

This response gives both marking points, though in reverse order, so scored 2.

Question 1 (b)

In this question, candidates were asked to perform a simple percentage calculation, which was completed well by most.

(b) The student measured the diameter. The reading obtained was $20.5 \pm 0.05\,mm$.

Calculate the percentage uncertainty in the measurement of the diameter.

(1)

$\frac{0.05}{20.5} \times 100 = 0.244$

$= 0.2\%$

Percentage uncertainty in the diameter = 0.2%

ResultsPlus
Examiner Comments

A correct calculation, rounded to 1 significant figure, which is acceptable as the uncertainty is also given to 1 sf.

So 1 mark awarded.

(b) The student measured the diameter. The reading obtained was 20.5 ± 0.05 mm.

Calculate the percentage uncertainty in the measurement of the diameter.

(1)

$\cancel{\frac{0.05}{20.5} \times 100}$ $\frac{0.1}{20.5} \times 100$

Percentage uncertainty in the diameter = ~~0.24%~~ 0.49%

ResultsPlus
Examiner Comments

Here a correct calculation was crossed out and replaced with a calculation of the percentage of the resolution, rather than the uncertainty stated.

So 0 marks.

Question 1 (c)

The practical skill tested here is a common one, the idea that the object being measured may not be uniform. However, for this question the candidates were told the mean was calculated, so those that gave just the generic answer “measure in different orientations and calculate the mean” did not score more than 1 mark.

The photo showed the digital caliper could be zeroed, so identifying the need to zero before measuring or check for zero error would be rewarded with a mark. The shape of the sphere means we need to ensure the measurement is taken at the widest point, so identifying this was also rewarded with a mark.

(c) The student took further measurements of the diameter and calculated a mean.

Describe how the student should use this measuring device to make the measurements as accurate as possible.

(2)

By taking repeating results of the experiment and finding an average value. Then plotting a graph.

ResultsPlus
Examiner Comments

As the question clearly stated that the student calculated a mean, the generic answer of "repeat and find an average" was not enough to score a mark.

(c) The student took further measurements of the diameter and calculated a mean.

Describe how the student should use this measuring device to make the measurements as accurate as possible.

(2)

~~I~~ Zero the calliper each time before tauing ~~the~~ ~~a~~ reading, this ~~re~~ reduces any chance of zero error. Take the reading under bright light condition. Take ~~measure~~ mesure ments at different positions of the sphere.

ResultsPlus

Examiner Comments

Here we can see two clear marks:

- zero the caliper each time
- take measurements at different positions.

(c) The student took further measurements of the diameter and calculated a mean.

Describe how the student should use this measuring device to make the measurements as accurate as possible.

(2)

The student should take repeat measurements of the sphere from different orientations and find the mean value of them to obtain the best, most accurate results.

ResultsPlus

Examiner Comments

This was the most commonly seen answer, the idea of taking measurements in different orientations/positions, scoring 1 mark.

However, the "find the mean" statement was not rewarded, as the question states this.

Question 1 (d) (i) - (ii)

This question asked candidates to demonstrate the mathematical skill of calculating a mean. Identifying anomalous results, results that are not in keeping with other results, is a practical skill met in earlier years. As such, candidates that did identify an anomalous result and compensate for this in the mean scored 2 marks for Q01(d)(i).

For Q01(d)(ii), one of the standard methods (**see appendix 10**) of calculating percentage uncertainty for a repeated reading was expected. The results given allow for either of the methods given in **appendix 10** to be used giving the same answer. For those that did not identify an anomaly in part (i), correctly following either method from **appendix 10** was rewarded.

Some candidates used the method for a single measurement, which was not rewarded.

(d) The student measured the diameter of a second metal sphere and recorded the following readings.

19.0 mm   19.1 mm   18.9 mm   18.3 mm   19.1 mm

(i) Calculate the mean diameter of the second metal sphere.

(2)

mean = (19 + 19.1 + 18.9 + 19.1) ÷ 4

= 19.025 mm

= 19.0 mm

Mean diameter of the second metal sphere = 19.0 mm

(ii) Calculate the percentage uncertainty in the mean diameter of the second metal sphere.

(2)

0.2 ÷ 2 = 0.1 mm

uncertainity = $\frac{0.1}{19}$ ×100%

= 0.53%

Percentage uncertainty in the mean diameter = 0.53%

ResultsPlus
Examiner Comments

An example of a full mark response.

Q01(d)(i) shows a correct calculation for 2 marks.

Q01(d)(ii) uses half the range to give a value for uncertainty, which is then used correctly in the calculation for 2 marks.

(d) The student measured the diameter of a second metal sphere and recorded the following readings.

19.0 mm   19.1 mm   18.9 mm   18.3 mm   19.1 mm

(i) Calculate the mean diameter of the second metal sphere.

(2)

$$\text{mean} = \frac{19.0 + 19.1 + 18.9 + 18.3 + 19.1}{5}$$

$$= 18.88\text{ mm}$$

Mean diameter of the second metal sphere = 18.88 mm

(ii) Calculate the percentage uncertainty in the mean diameter of the second metal sphere.

(2)

$$\%\text{ uncertainty} = \frac{0.4}{18.88} \times 100 = 2.12\%$$

$$\text{uncertainty} = \frac{19.1 - 18.3}{2}$$

$$= \pm 0.4\text{ mm}$$

Percentage uncertainty in the mean diameter = 2.12 %

ResultsPlus
Examiner Comments

Q01(d)(i) scored only 1 mark, as all 5 results were included in the mean.

However, Q01(d)(ii) shows a correct calculation, using the difference between the mean and the value furthest from the mean, so scored both marks.

(d) The student measured the diameter of a second metal sphere and recorded the following readings.

19.0 mm   19.1 mm   18.9 mm   18.3 mm   19.1 mm

(i) Calculate the mean diameter of the second metal sphere.

(2)

$$\frac{19.0 + 19.1 + 19.1 + 18.9}{4}$$

Mean diameter of the second metal sphere = 19.025 mm

(ii) Calculate the percentage uncertainty in the mean diameter of the second metal sphere.

(2)

% uncertainty $= \frac{0.01}{19.025} \times 100\%$

Percentage uncertainty in the mean diameter = 0.05%

ResultsPlus
Examiner Comments

Q01(d)(i) scored both marks for a correct calculation, having excluded the anomalous result.

Q01(d)(ii) used an incorrect value for uncertainty (0.01 rather than 0.1) so scored 0.

Question 1 (e) (f)

Q01(e) required candidates to carry out a density calculation, which included demonstrating an understanding of the number of significant figures an answer should give based on the data given in the question. Many missed the reference to the first sphere, or used the value displayed in the photo, rather than the diameter quoted for the first sphere. These candidates were still rewarded for the use of equations. As the mass and diameter were given to 3 significant figures, it was expected that candidates would give the answer to the same number of significant figures.

Q01(f) then asked candidates to determine whether the two spheres were of the same metal. Most understood they needed to compare density, having been led in that direction by part (e).

The command word **determine** indicates some calculation of values is required. As is the case for WPH11 and WPH12, a statement is required for the comparison, not just values.

(e) The student measured the mass of the first metal sphere using a top pan balance.

The mass reading obtained was 35.6 g.

Calculate the density of the first metal sphere.

(4)

Volume of first metal sphere $= \frac{4}{3}\pi r^3$

$= \frac{4}{3}\pi \times \left(\frac{20.5}{2} \times 10^{-3}\right)^3$

$= 4.51 \times 10^{-6}\ m^3$

Density $= \frac{Mass}{volume} = \frac{35.6 \times 10^{-3}\ kg}{4.51 \times 10^{-6}\ m^3} = 7.89 \times 10^3\ kg\ m^{-3}$

Density of the first metal sphere = $7.89 \times 10^3\ kg\ m^{-3}$

(f) The student calculated the density of the second metal sphere to be $7.75 \times 10^3\ kg\ m^{-3}$ with an uncertainty of 2%.

Determine whether the two spheres could be made from the same metal.

(2)

uncertainty of density $= \frac{2}{100} \times 7.75 \times 10^3 = 155\ kg\ m^{-3}$.

Range of density for second sphere = (7595 – 7905) $kg\ m^{-3}$

Density of first ~~M~~ sphere $= 7890\ kg\ m^{-3}$

As the value ~~density~~ of density for first sphere falls within the range of densities for second sphere; both spheres could be made from the same metal.

(Total for Question 1 = 16 marks)

ResultsPlus

Examiner Comments

This example scored full marks.

Q01(e) shows a correct calculation including the unit, for 4 marks.

Q01(f) shows a calculation of the range of possible densities of the second sphere, with a clear statement that the first sphere's density was within that range, so scored 2 marks.

(e) The student measured the mass of the first metal sphere using a top pan balance.

The mass reading obtained was 35.6 g.

Calculate the density of the first metal sphere.

(4)

mass = 0.0356 kg

radius = $(\frac{19}{2}) \times 10^{-3} = 9.5 \times 10^{-3}$ m

volume of sphere = $\frac{4}{3} \times \pi \times (9.5 \times 10^{-3})^3$

$= 3.59 \times 10^{-6}$

~~Density = $3.59 \times 10^{-6} \div 0.0356$~~ Density = $\frac{0.0356}{3.59 \times 10^{-6}} = 9.92 \times 10^3$

Density of the first metal sphere = ~~9.92×10^3 kgm^{-3}~~ 9.91×10^3 kgm^{-3}

(f) The student calculated the density of the second metal sphere to be 7.75×10^3 kg m^{-3} with an uncertainty of 2%.

Determine whether the two spheres could be made from the same metal.

(2)

Maximum value of metal sphere = ~~(7.75×10^3)~~ + ~~(7.5~~

$= (7.75 \times 10^3) + (7.75 \times 10^3 \times \frac{2}{100})$

$= 7.91 \times 10^3$ kg m^{-3}

The two spheres are not from the same metal as density of the first metal is beyond the second one's

(Total for Question 1 = 16 marks)

ResultsPlus
Examiner Comments

This response demonstated a common error for Q01(e).

The equations are substituted with suitable values, but the wrong diameter was used. This example used the diameter of the **second** sphere. Other examples used the reading from the photograph of the digital caliper. The correct diameter is the one stated in Q01(b).

Q01(f) was correct for this candidate's value from part (e), so both marks were awarded.

(e) The student measured the mass of the first metal sphere using a top pan balance.

The mass reading obtained was 35.6 g.

Calculate the density of the first metal sphere.

(4)

$\cancel{\rho = \frac{m}{V}}$ Density $= \frac{\text{mass}}{\text{volume}} = \frac{0.0356}{4.51 \times 10^{-6}} = 7892.0 \text{ kgm}^{-3}$

$= 7890$ (3sf)

Mass $= 0.0356$ Kg

Volume $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \times \left(\frac{20.5}{2} \times 10^{-3}\right)^3 = 4.51 \times 10^{-6}$

Density of the first metal sphere = 7890 kgm^{-3}

(f) The student calculated the density of the second metal sphere to be $7.75 \times 10^3 \text{ kg m}^{-3}$ with an uncertainty of 2%.

Determine whether the two spheres could be made from the same metal.

(2)

$\frac{7890 - 7.75 \times 10^3}{7.75 \times 10^3} \times 100\% = 1.8\%$

1.8% is less than 2%. (The measurement of the density of second sphere has 2% uncertainty), so yes both could be from same metal.

ResultsPlus
Examiner Comments

Another response that scored full marks.

Though for Q01(f) it was expected that candidates would use the percentage uncertainty to calculate the range of possible density values, this candidate has calculated the percentage difference and compared this to 2%.

There is a percentage calculation and a statement that is consistent with the comparison of the two values, so both marks are scored for equivalent correct work.

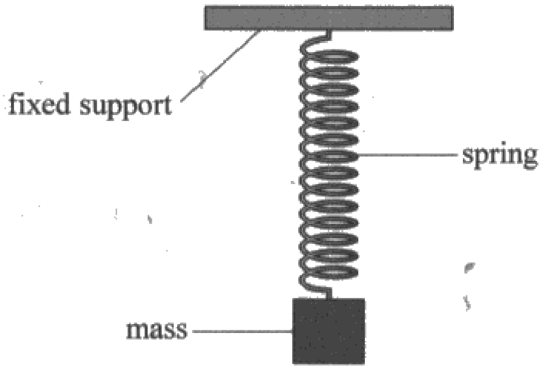
Question 2 (a)

This question tested practical planning skills that were formerly part of the long Question 7 in WPH03.

Here candidates were shown the graph to be plotted and were asked to describe the practical steps the student would be required to take to obtain the data needed. Most candidates scored 2 marks out of 4, as their answers lacked sufficient detail, eg they did not describe how the force values were calculated from the mass hung from the spring. High ability candidates often missed out on the third marking point, describing the measurements and calculations, but missing the detail relating to accuracy.

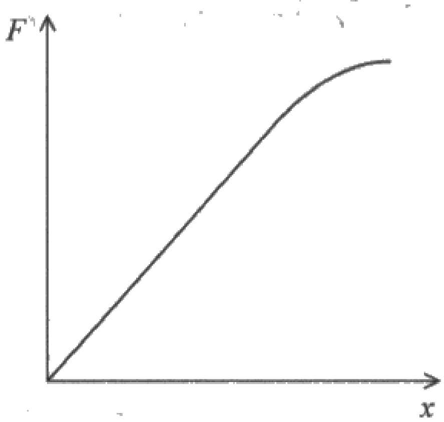
2 A student investigated the extension of a spring to determine its stiffness.

The student suspended the spring from a fixed support and added masses to the lower end of the spring as shown.



The student used a metre rule to make measurements of the spring as the mass was increased.

The student plotted a graph of applied force F against the extension of the spring x.



(a) Describe what the student should do to obtain the data to plot the force-extension graph.

(4)

Measure the original length of spring using metre rule

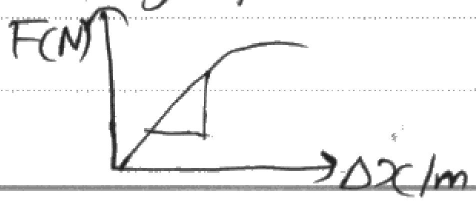
Measure the mass of masses added using a balance to calculate Force

Measure the extension using metre rule when masses are added.

Table values

Force(N)	extension (m)

Plot a graph of F vs Δx



ResultsPlus
Examiner Comments

This response lacks key details for every mark, so scored 0.

- "using a balance to calculate force" - most balances measure mass, so it would need to be clear the balance measured Newtons. As they stated "calculate" this suggested the balance was measuring mass, so this answer needed to include F = mg.

- "measure the extension" - they had already mentioned measuring the original length, so needed to add the idea of subtracting this from the new length.

- "when masses are added" - it is not clear if this is the first masses or that additional masses are being added.

- "using a ruler" - there is no detail of how the ruler is orientated/how it is aligned.

(a) Describe what the student should do to obtain the data to plot the force-extension graph.

(4)

For force, the student must use the formula $f = mg$, where f is the force excerting on the spring, m is the mass of the masses added, this ~~case~~ the mass can be measured using a top pan balance and g is the acceleration due to gravity which is $9.81 m/s^2$. For extension, ~~use~~ the student could use a vertical ruler which is in 90° angle of the support. Measure the length of the spring without masses, then subtract ~~the~~ it from the length of spring with masses.

ResultsPlus
Examiner Comments

This scored 2 marks.

- Calculation of force using F = mg
- Calculation of extension by subtracting new and original lengths.

However, it is clear they have done this for only one mass and there is nothing about the orientation/alignment of the ruler to reduce error.

(a) Describe what the student should do to obtain the data to plot the force-extension graph.

(4)

First, the student should weigh the mass and find out the weight (Force) by multiplying mass with 9.81 ms^{-2} (g) Then the student should find out the original length of spring. It is done by measuring the original length of spring with a metre rule (of resolution 1mm) without the mass. And the final length is measured after adding ~~the masses~~ each different masses. For every different (increasing) mass the ~~en~~ extension is calculated by substracting original ~~final~~ length from final ~~original~~ length.

ResultsPlus
Examiner Comments

This scored 3 marks (the second most common score).

Here they have the calculation of force and extension, along with the idea of additional masses being added.

It only lacks the detail regarding the orientation/position of the ruler to reduce error.

(a) Describe what the student should do to obtain the data to plot the force-extension graph.

(4)

The student should ensure that the ~~mete~~ rule is in the vertical plane using a set square. Then he should measure the initial length of the spring using the meter rule. Mete rule is suitable because it has a precision of 1 mm and as the readings obtained are large, percentage uncertainity is small. Then add the mass and measure the new length using the meter rule. The extension is equal to the difference between the two lengths. The force could be found by multiplying the mass with 9.81, F=mg. Then repeat the procedure ~~by~~ adding masses and calculate the corresponding forces and extensions. Then plot the graph.

ResultsPlus
Examiner Comments

This is an example of the rare full mark answer.

It includes the often missing idea of using the set square in the first lines.

Question 2 (b)

This question was generally answered well, with most scoring both marks. The graph the candidates had seen in the paper included a curved section, with data plotted for forces beyond the limit of proportionality. As such, this detail was required for the explanation.

(b) Explain how you would use the graph to determine the stiffness of the spring.

(2)

area under graph will be the stiffness

or Draw the graph and

~~Drazy~~ identify the gradient, the gradient will be the stiffness,

stiffness $= \frac{\text{Force}}{\text{extension}} =$ gradient

ResultsPlus
Examiner Comments

A common incorrect answer. As candidates are asked to use the graph, many went with the idea of area rather than gradient.

(b) Explain how you would use the graph to determine the stiffness of the spring.

(2)

$F = kx \Rightarrow k = \frac{F}{x} = $ gradient.

· Find the gradient of the graph.

ResultsPlus
Examiner Comments

A typical 1 mark answer.

The use of gradient is clearly identified, so they have answered the **how** part of the question. However, as the graph given included the curve beyond the limit of proportionality, we required answers that explained that this needed to be determined for the linear section of the graph.

(b) Explain how you would use the graph to determine the stiffness of the spring.

(2)

~~F = kΔx F/Δ~~

Calculate the gradient of the ~~Force - extension graph~~ ~~to~~ linear region of the Force-extension graph. Make sure to use ~~f~~ a larger triangle.

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Examiner Comments

This example shows a common 2 mark answer.

Though many answers went beyond the given writing area, it was possible for an explanation to score both marks in a single line, which this example did.

"Calculate the gradient of the linear region".

Question 3 (a)

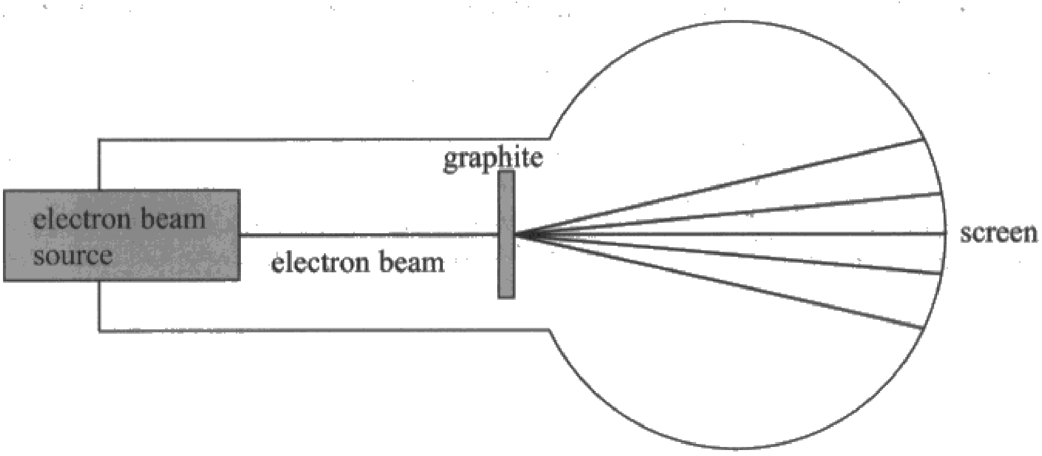
The understanding of how diffraction experiments provide evidence for the wave nature of electrons is specification point 53. However, it was clear many candidates were not familiar with the graphite diffraction tube experiment.

Determining the radius of a circular object is a common practical skill and one already introduced earlier in the paper, so those two marking points should have been straightforward. However most failed to score, with many candidates attempting to calculate the diameter using the equation $nl = d \sin \theta$, mistaking d for the diameter.

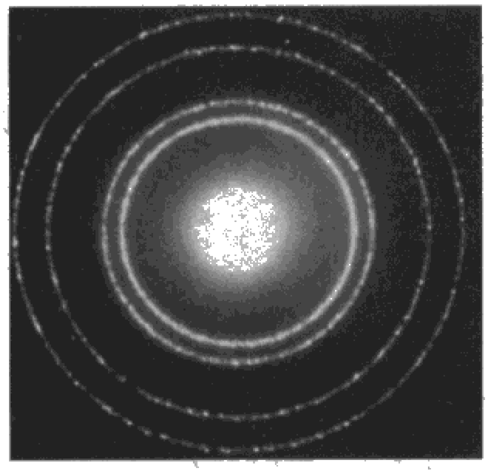
Here we expected to see similar answers to Q01(c) with additional steps of calculating the mean and halving the diameter.

Some identification of the difficulty of measuring diameter on a curved screen or that the ring of light itself had a width makes the final marking point we expected.

3 A student used an electron beam tube to accelerate electrons towards a thin slice of graphite as shown. The electrons passing through the graphite produced a diffraction pattern on the screen. This is similar to the effect seen when light passes through a diffraction grating.



The diffraction pattern seen on the curved screen is shown below.



(a) Describe how the student can accurately determine the radius of the first bright ring of the diffraction pattern.

(4)

As the screen is curved the student would use a measuring tape. The student would measure the diameter of the first bright ring and take readings at different ~~angles or~~ orientations. An average would be calculated from all the values and the value would be divided by 2 to find the radius. This should be repeated for ~~reliabl~~ reliability.

ResultsPlus
Examiner Comments

This is an example of a full mark response.

In addition to the standard "multiple orientations and mean" and the extra detail of needing to halve the diameter, it clearly identifies the issue of the curved screen and gives suitable measuring equipment to compensate.

(a) Describe how the student can accurately determine the radius of the first bright ring of the diffraction pattern.

(4)

~~Using a~~ Check a vernier calliper for zero error. Place the jaws of the vernier calliper lightly against the curve screen and make sure the jaws touch the circumference. Record the reading off the vernier calliper and ~~halve it to~~ several times and calculate ~~and~~ an average. Halve it to find radius

ResultsPlus
Examiner Comments

This example came close to full marks. Unfortunately, though readings are to be recorded several times and an average calculated, it is missing the key detail of repeating the measurements in different orientations/positions.

(a) Describe how the student can accurately determine the radius of the first bright ring of the diffraction pattern.

(4)

The student could place a metre rule on the screen passing right down the centre of the first bright ring and measure the dimeter. He could then divide the diameter by 2 to get the radius. The student should take measurement from different orientations and average them to get the mean radius.

ResultsPlus
Examiner Comments

This was the most common answer, with repeats in different orientations, calculation of a mean and halving the diameter, so being rewarded with 2 marks.

As the screen is curved a metre rule is not suitable equipment. If additional equipment, such as a pair of setsquares had been added, then the first marking point may have been awarded. There is no identification that the screen is curved or that the ring itself has a width, hence the need to measure to the brightest part of the ring.

(a) Describe how the student can accurately determine the radius of the first bright ring of the diffraction pattern.

(4)

By tracing the diffraction pattern onto a piece of paper and measuring the radius using a ruler.

ResultsPlus
Examiner Comments

This example scored the first mark only, for a suitable method of using a ruler to measure the diameter on a curved screen.

However, it lacked any explanation of how radius is determined from diameter or how an accurate value could be achieved.

Question 3 (b)

The understanding of how diffraction experiments provide evidence for the wave nature of electrons is specification point 53. However, many answers failed to mention **electrons** at all.

Most simply stated that there was diffraction, however this fact was given in the question. The question asked candidates to consider how the result of the practical, the diffraction pattern, gave evidence to suggest the **electrons** have a wave nature.

Candidates were given the hint that the pattern is similar to that caused by light passing through a diffraction grating, so the linking of electrons and superposition/interference was expected. Many answers only referred to light/waves interfering or superposing, so could not be awarded the first marking point, and most scored zero due to lack of clarity and detail.

(b) Explain how the diffraction pattern provides evidence for the wave nature of electrons.

(2)

The Dark and bright pattern shows that interference has occured (constructive and destructive) which is characteristic of a wave. The electrons spread out (diffract) and produce this pattern.

ResultsPlus
Examiner Comments

Though this response leaves us with some work to put the ideas together, it does link the pattern to interference and the electrons to the pattern, so the first mark is awarded.

It also states interference is a wave characteristic, so scores the second mark too.

(b) Explain how the diffraction pattern provides evidence for the wave nature of electrons.

(2)

→ because electrons difract and ~~supe~~ superposition takes place as constructive and distructive interfence occurs and fringes can be seen on the screen.

ResultsPlus
Examiner Comments

This response links the electrons to superposition and interference, but does not state that those properties are evidence of wave nature, so scores only the first mark.

(b) Explain how the diffraction pattern provides evidence for the wave nature of electrons.

(2)

The diffraction pattern suggests ~~[illegible]~~ the electrons interfere which each other like waves because we can ~~[illegible]~~ see that they ~~[illegible]~~ interfere constructively producing bright rings ~~[illegible]~~ or destructively producing dark areas ~~[illegible]~~ just like waves

ResultsPlus
Examiner Comments

This is a much clearer 2 mark answer, stating electrons interfere constructively and destructively just like waves.

Question 3 (c) (i)

This question would have been quite familiar to the candidates, having appeared in many of the previous specification WPH03 papers. Many responses included a list of answers, more than required by the mark indicated. In future series, we may need to apply a list rule, as the general list of criticisms many candidates produce are not always relevant or correct. If candidates write a general list of possible answers rather than responding to the question, then they may score fewer marks through including incorrect or contradictory information.

Most scored full marks.

(i) Criticise these results.

(2)

range are too small

only 5 results

there has no ~~repitition~~ repitation shown.

ResultsPlus
Examiner Comments

This example shows a typical answer, giving a list of 3 criticisms for a 2 mark answer.

The "range are too small" is too vague to score, but is not incorrect. The other two criticisms offered clearly match the mark scheme.

(i) Criticise these results.

(2)

Inconcistent significant figures for wavelength column. No evidence of repeats or no repeats shown. Small range of readings – only 5 sets of readings.

ResultsPlus
Examiner Comments

This example shows a typical answer, giving a list of 4 criticisms for a 2 mark answer.

All 4 are on the mark scheme, so even if we did apply a list rule, this response would still score 2 marks.

(i) Criticise these results.

(2)

- ~~For~~ Too few readings are taken.
- No evidence for repeatation.
- Small range.

ResultsPlus
Examiner Comments

This example shows a typical answer, giving a list of 3 criticisms for a 2 mark answer.

The "too few readings are taken" was accepted as an alternative wording for "only 5 sets of results". "No evidence for repetition" clearly matches the mark scheme.

Question 3 (c) (ii) - (iii)

These two part questions would also have been quite familiar to the candidates, having appeared in many of the previous specification WPH03 papers, testing mathematical skills C.3.2 and C.3.4.

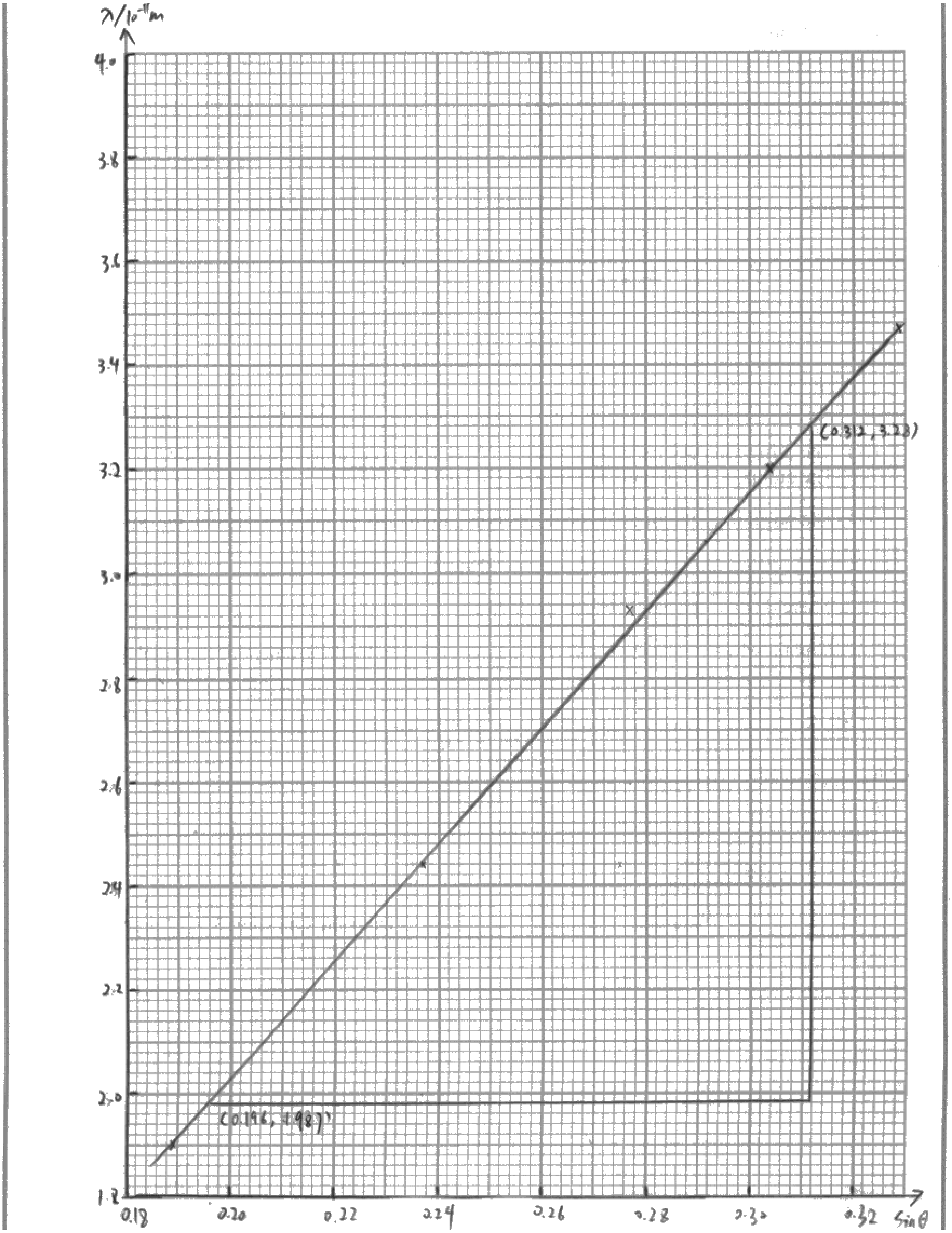
Q03(c)(ii) has one more mark than in previous series, as candidates were asked to calculate sin θ, from data that was given to 3 significant figures. As such their calculated values should also have been rounded to 3 significant figures. However, it was very common to see calculated data rounded to only 2 significant figures.

The marks for the graph were awarded using the same criteria as in previous specification WPH03 papers. However, there remain the same issues highlighted in previous reports: unsuitable choices of scales, inaccurate plotting and unbalanced lines of best fit. In this case, scales including the origin were not useful as they prevented the plots being "spread over half of each axis".

Q03(c)(iii) asked candidates to calculate the gradient. This basic mathematical skill proved to be a considerable challenge to most. It was common to see answers that were in the correct range, but lacked the powers of 10 from the y-axis, so could not be awarded the second marking point. Many candidates forgot to include the unit.

$\lambda / 10^{-11}$ m	$\theta / °$	$\sin\theta$
3.47	19.2	0.329
3.2	17.7	0.304
2.93	16.1	0.277
2.44	13.7	0.237
1.9	10.9	0.189

(ii) Use the results in the table to plot a graph of λ on the y-axis against $\sin\theta$ on the x-axis on the grid provided. Use the right-hand column of the table for your processed data.
(6)



λ/10⁻¹¹m
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
0.18
0.20
0.22
0.24
0.26
0.28
0.30
0.32
sinθ
(0.312, 3.28)
(0.196, 1.98)

(iii) Determine the gradient of the graph.

(3)

∵ the gradient of $\lambda - \sin\theta$ graph means $\frac{d}{n}$.

∴ $m = \frac{y_2 - y_1}{x_2 - x_1}$

$= \frac{(3.28 - \cancel{\ } 1.987) \times 10^{-11}}{\cancel{\ } 0.312 - 0.196}$

$= \cancel{\ } 1.12 \times 10^{-10}$ m.

Gradient = 1.12×10^{-10} ~~m~~ m

ResultsPlus

Examiner Comments

Q03(c)(ii) - 6 marks

The sin θ values are correctly calculated to 3 significant figures, the axes are labelled correctly and the plots are accurate to within 1mm, so 4 marks can be awarded.

The scale does not start at the origin, meaning the plots cover the full range of each axis and the divisions are sensible (going up in 2s on the 2cm lines).

The line is also well balanced, with 4 plots on or slightly below the line, with one above a little further away.

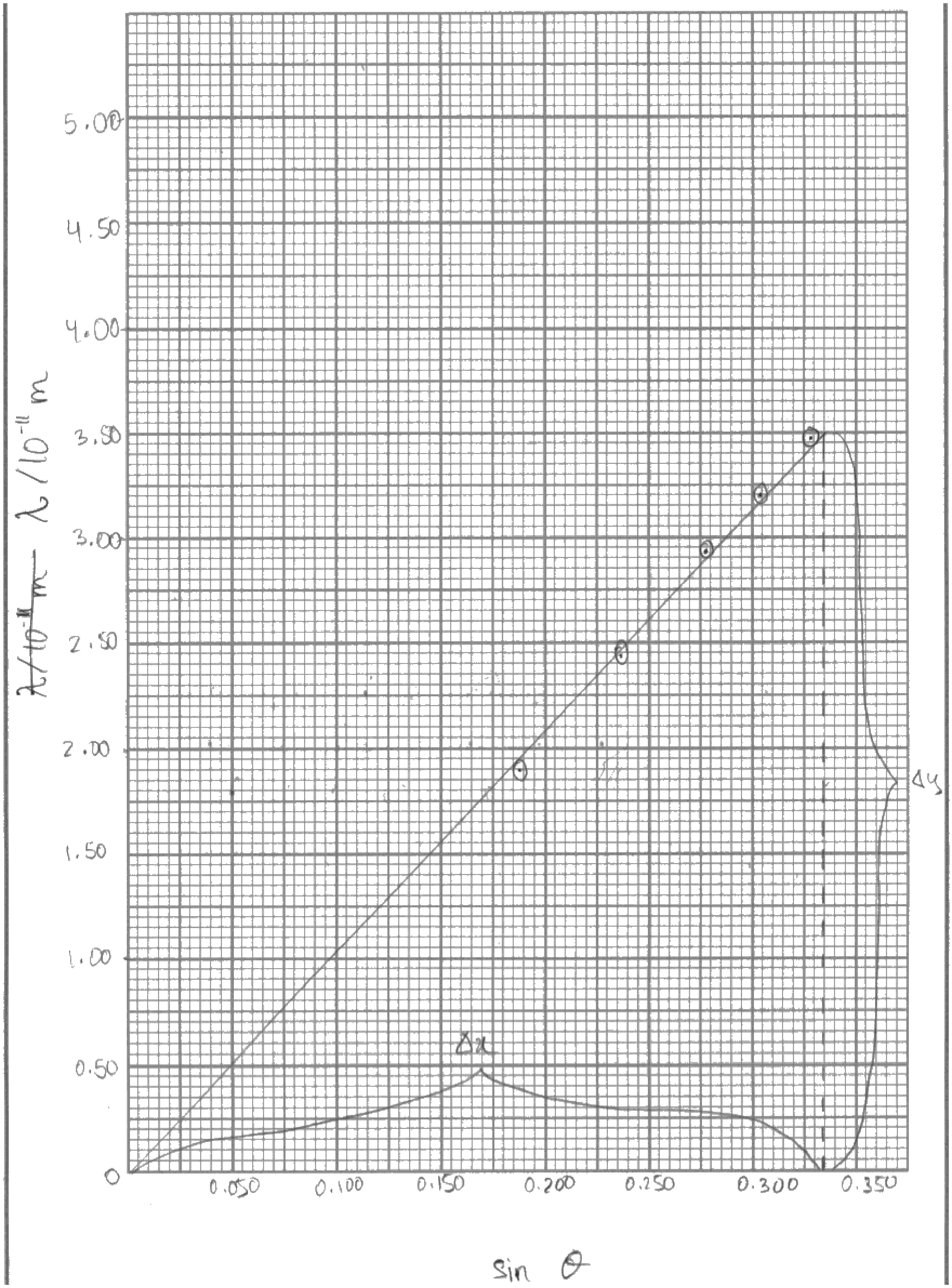
Q03(c)(iii) - 3 marks

The gradient calculation is performed correctly with a large triangle clearly drawn. The value is given to 3 significant figures which is within the acceptable range with the correct unit given.

$\lambda / 10^{-11}$ m	$\theta / °$	$\sin\theta$
3.47	19.2	0.329
3.2	17.7	0.304
2.93	16.1	0.277
2.44	13.7	0.237
1.9	10.9	0.189

(ii) Use the results in the table to plot a graph of λ on the y-axis against $\sin\theta$ on the x-axis on the grid provided. Use the right-hand column of the table for your processed data.

(6)



5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0
λ / 10⁻¹¹ m
0.050
0.100
0.150
0.200
0.250
0.300
0.350
sin θ
Δx
Δy

(iii) Determine the gradient of the graph.

(3)

gradient $= \frac{\Delta y}{\Delta x} = \frac{3.5 - 0}{0.335 - 0} = 10.4 \times 10^{-11}$ m

Gradient = 10.4×10^{-11} m

ResultsPlus
Examiner Comments

Q03(c)(ii) - 4 marks

The sin θ values are correctly calculated to 3 significant figures, the axes are labelled correctly and the plots are accurate to within 1mm, so 4 marks can be awarded.

For the scale, although the divisions are sensible (going up in 5s on the 2cm lines) the plots cover less than half the available space on each axis.

The line is also unbalanced, with all three plots on the right being above the line.

Q03(c)(iii) - 2 marks

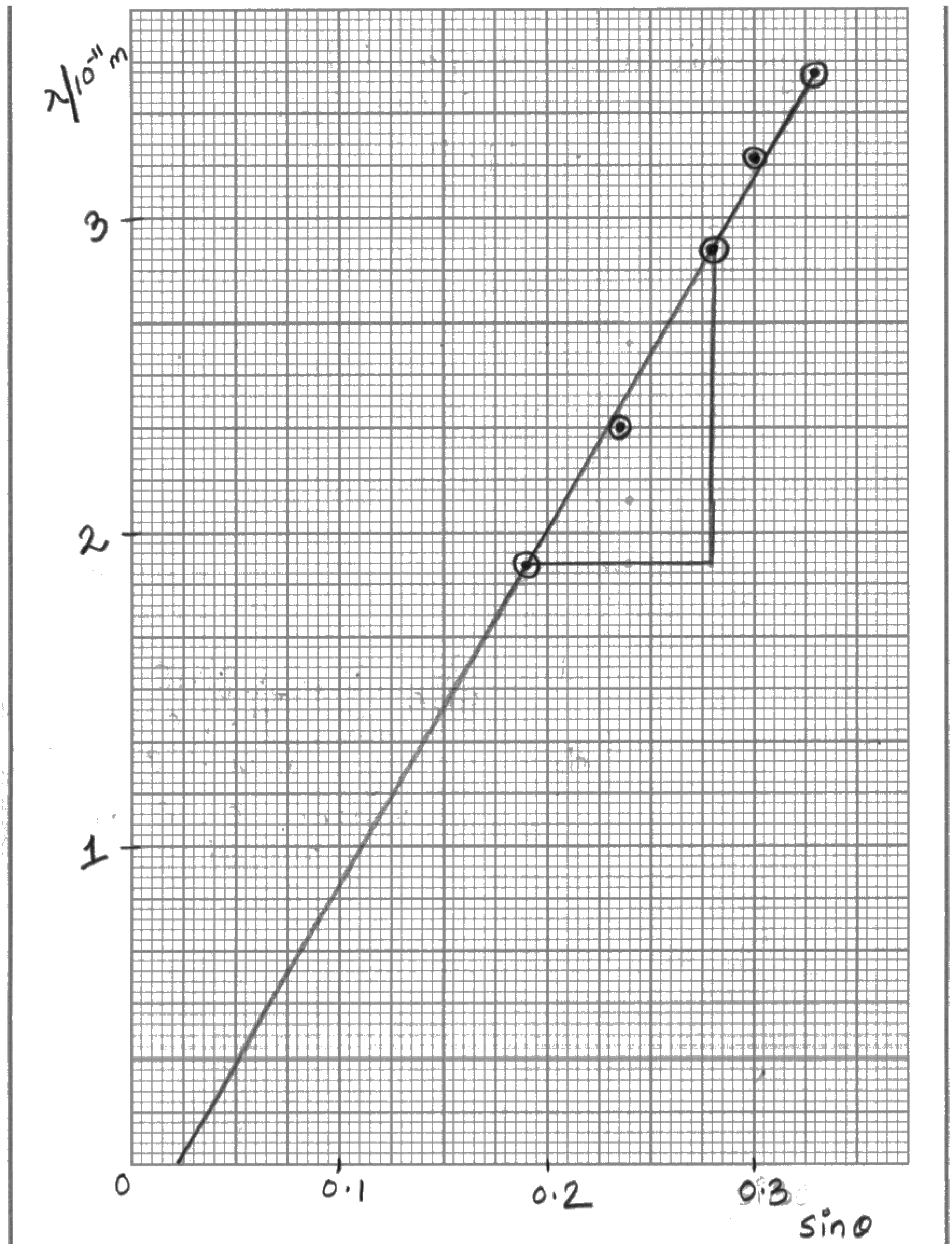
The gradient calculation is performed correctly and the value is given to 3 significant figures with the correct unit.

However, the value is outside the range accepted.

λ / 10^{-11} m	θ / °	$\sin\theta$	
3.47	19.2	~~0.33~~ ~~0.329~~	0.33
3.2	17.7	~~0.304~~	0.30
2.93	16.1	~~0.28~~ ~~0.277~~	0.28
2.44	13.7	~~0.237~~	0.24
1.9	10.9	~~0.189~~	0.19

(ii) Use the results in the table to plot a graph of λ on the y-axis against $\sin\theta$ on the x-axis on the grid provided. Use the right-hand column of the table for your processed data.

(6)


λ/10⁻¹¹ m
3
2
1
0
0.1
0.2
0.3
sin θ

(iii) Determine the gradient of the graph.

(3)

$$\text{gradient} = \frac{2.93 - 1.9}{0.28 - 0.19}$$

$$= 11.4$$

Gradient = 11.4

ResultsPlus
Examiner Comments

Q03(c)(ii) - 2 marks

The sin θ values are correctly calculated but are rounded to 2 significant figures (if the crossed out values had not been replaced, the first mark point could have been awarded).

The axes are labelled correctly and the line of best fit is well balanced (3 points on the line, 1 above and 1 below) - so 2 marks can be awarded.

Points need to be plotted to within 1 mm of the value in the table. As this graph paper has small squares that are 2 mm by 2 mm, plotted points that fill a small square, so are themselves larger than 1 mm, cannot fulfil this criteria - so no marks for plotting could be awarded.

For the scale, though the divisions are sensible (going up in 1s on the 2cm lines), the plots cover less than half the available space on each axis.

Q03(c)(iii) - 0 marks

The gradient calculation is performed correctly, but used values from a triangle that included less than half the line.

The value given has been calculated with a powers of 10 error, as the 10^{-11} factor from the y-axis has not been included.

The answer has been rounded to 3 significant figures, but no unit has been given.

The value is outside the range accepted.

Question 3 (c) (iv)

Linking the equation given to the equation nl = d sin q and that of a linear graph y = mx + c was a standard question on the previous specification WPH03 papers. As such candidates were expected to be able to demonstrate this link to be awarded the first marking point and most did so, with the best answers showing the link clearly (eg by circling equivalent parts of the equations).

However, very few added the additional detail that n = 1 and that d was a constant.

(iv) The diffraction occurs as the electrons pass through the thin slice of graphite. The atoms in the graphite are arranged in layers.

The position of the rings in the diffraction pattern can be approximated by the equation

$$n\lambda = d \sin\theta$$

where d is the spacing between the layers.

Explain why the spacing between the layers is given by the gradient of the graph.

(2)

$\lambda = \frac{d}{n} \sin\theta \rightarrow y = mx$

~~and~~ n = 1 so d is m in y = mx and d is constant.

ResultsPlus
Examiner Comments

In the first line there is a comparison between a rearranged version of the equation and y = mx. This was commonly seen.

This response also includes the additional detail, that d is therefore constant and that n = 1. As such this scored both marks.

(iv) The diffraction occurs as the electrons pass through the thin slice of graphite. The atoms in the graphite are arranged in layers.

The position of the rings in the diffraction pattern can be approximated by the equation

$$n\lambda = \text{d} \sin\theta$$

where d is the spacing between the layers.

Explain why the spacing between the layers is given by the gradient of the graph.

(2)

$n\lambda = d\sin\theta$ $n=1$

$\lambda = \frac{d\sin\theta}{n} = d\sin\theta$

$\lambda = d \sin\theta$ d is the gradient and it is constant and $c=0$

$y = m\ x\ + c$ so there is no y-intercept. Graph is λ vs $\sin\theta$

ResultsPlus
Examiner Comments

This response is much clearer in the comparison between the equation given and y = mx + c.

As n = 1 was identified earlier in the answer, the comparison did not include n.

This response also includes the additional detail, that d is therefore constant so scored both marks.

(iv) The diffraction occurs as the electrons pass through the thin slice of graphite. The atoms in the graphite are arranged in layers.

The position of the rings in the diffraction pattern can be approximated by the equation

$$n\lambda = \text{d} \sin\theta$$

where d is the spacing between the layers.

Explain why the spacing between the layers is given by the gradient of the graph.

(2)

~~A λ~~ $n\lambda = d \sin\theta$

$\lambda = d \times \dfrac{\sin\theta}{n}$

$y = m \;\; x \;\; + c$

here $c = 0$ and as λ is directly proportional to $\dfrac{\sin\theta}{n}$ the gradient ~~is given~~ gives the d

(Total for Question 3 = 19 marks)

ResultsPlus
Examiner Comments

This response is more typical of the answers seen.

It was less clear in the comparison between the equation given and y = mx +c, but given the layout of the rearranged equation and the identification that c = 0, it was enough to earn the first marking point.

However, n is still shown in the equation, with no statement that n=1. Nor is d identified as being a constant (as the gradient is constant).

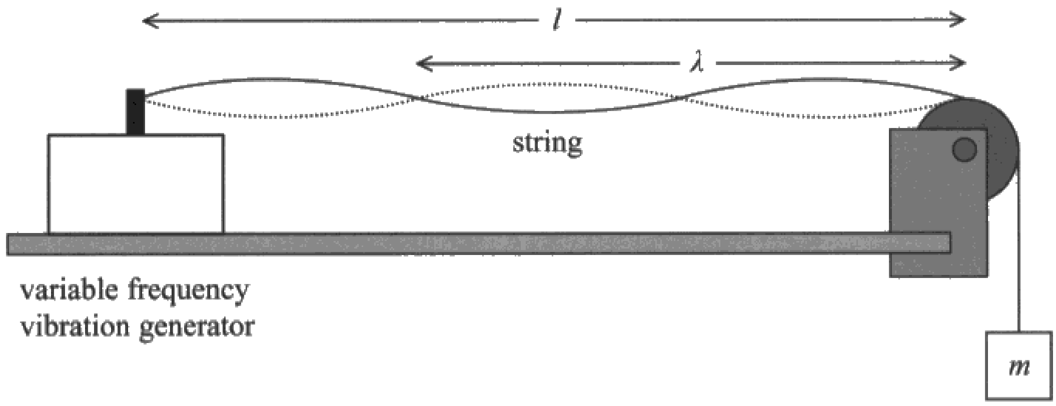
Question 4 (a)

This calculation would be familiar to candidates who had performed the standing waves on a string practical. However, this was an opportunity to demonstrate basic mathematical skills.It was generally performed well, with most calculating the correct value.

Just under half of those that did correctly calculate the value were not awarded full marks due to the lack of a unit. The question stem introduced μ as the mass per unit length, so a unit of kg m^{-1} was expected.

A quarter of responses scored only 1 mark, as they did not correctly convert the length given to the wavelength, despite the diagram clearly showing wavelength was 2/3 of the length of the string. The most common error was calculating λ = length × 3/2 or λ = length ÷ 2/3.

4 A student carried out an experiment to determine the mass per unit length μ of a string, using a standing wave. The standing wave produced is shown in the diagram.



The student recorded the following data.

Length of string l	1.25 m
Frequency f	105 Hz
Mass m	0.25 kg

(a) Calculate μ given the equation below.

$$\sqrt{\frac{mg}{\mu}} = f\lambda$$

(3)

$\frac{\sqrt{mg}}{\sqrt{\mu}} = f\lambda$ $\lambda = \frac{\cancel{1.25}}{\cancel{2.5}} \cancel{\times 2}$

$\lambda = \frac{1.25}{\frac{2}{3}}$

$\frac{\sqrt{0.25 \times 9.81}}{\sqrt{\mu}} = 105 \times 1.875$

$\lambda = 1.875$

$\sqrt{\mu} = \frac{\sqrt{0.25 \times 9.81}}{105 \times 1.875}$

$\mu = 0.00795^2 = 6.32 \times 10^{-5}$

$\mu =$ 6.32×10^{-5}

ResultsPlus
Examiner Comments

Here the wavelength was calculated incorrectly using λ = length ÷ 2/3.

This meant the only mark that could be awarded was the use of the equation.

(a) Calculate μ given the equation below.

$$\sqrt{\frac{mg}{\mu}} = f\lambda$$

(3)

$\lambda = \frac{2}{3} l$

$\lambda = \frac{2}{3} \times 1.25$

$= 0.83\,m$

$\mu = \frac{mg}{\sqrt{f\lambda}}$

$= \frac{0.25 \times 9.81}{\sqrt{105 \times 0.83}}$

$\mu =$ 0.26

ResultsPlus
Examiner Comments

In this example, the wavelength was correctly calculated using λ = length × 2/3.

However, the equation was incorrectly rearranged, so only one mark could be awarded.

(a) Calculate μ given the equation below.

$$\sqrt{\frac{mg}{\mu}} = f\lambda$$

(3)

$$\left(\sqrt{\frac{mg}{\mu}}\right)^2 = (f\lambda)^2$$

$$\frac{mg}{\mu} = f^2\lambda^2$$

$$\frac{mg}{f^2\lambda^2} = \mu$$

$$\frac{0.025 \times 9.81}{(105)^2 \times \left(\frac{2}{3} \times 1.25\right)^2} = \mu$$

$$\frac{2.4525}{11025 \times 0.694}$$

$$= \frac{2.4525}{7656.25}$$

$$= 3.2 \times 10^{-4}$$

$\mu =$ 3.2×10^{-4}

ResultsPlus
Examiner Comments

This answer shows a correct calculation, including the final value.

However, as no unit was given the final mark could not be awarded.

(a) Calculate μ given the equation below.

$$\sqrt{\frac{mg}{\mu}} = f\lambda$$

(3)

$L = \frac{3}{2}\lambda$

~~$1.25 = \frac{3}{2}\lambda$~~

$1.25 = \frac{3}{2}\lambda$

$\lambda = 0.83$

$\therefore \sqrt{\frac{mg}{\mu}} = f\lambda$

$\Rightarrow \frac{mg}{\mu} = f^2\lambda^2$

$= \frac{0.25 \times 9.81}{\mu} = 105^2 \times 0.83^2$

$\cancel{\mu = \frac{0.25 \times 9.81}{105^2 \times 0.83}}$ $\mu = \frac{0.25 \times 9.81}{105^2 \times 0.83^2}$

$\mu =$ 3.2×10^{-4} $kg\,m^{-1}$

ResultsPlus
Examiner Comments

This example shows a correct calculation, this time with the correct unit. So full marks could be awarded.

Question 4 (b)

This question tested practical planning skills that formerly were part of the long Question 7 in WPH03.

For Q04(b)(i) it was common to see a list of answers. However, as we had identified the student's measurements earlier in the question, responses that identified uncertainty in measurements other than length, frequency or mass were not considered. It was common to see answers suggesting issues in measuring the position of nodes or the wavelength.

As candidates were specifically asked for 2 significant sources of uncertainty, a list rule was applied so additional incorrect responses were considered when determining the final mark.

It was common to see answers for Q04(b)(i) written as part of the answer to part (ii), so the two parts were read and marked as one. However, repeating the same idea did not result in two marks, eg mentioning parallax error in length scored 1 mark for part (i), but for part (ii) we needed the extra detail explaining how this could be reduced.

Many responses scored zero marks as many answers gave generic statements regarding uncertainties, rather than being specific to the context of this question.

(b) (i) Identify two significant sources of uncertainty in the student's measurements.

(2)

Parallax error in reading off the length of the string from the metre rule, and zero error on the top pan balance when measuring the mass added.

(ii) For each of these sources of uncertainty, describe an experimental technique the student could have used to obtain an accurate measurement.

(4)

To reduce parallax error, the student should turn off the vibration generator so that the string is not oscillating, and use a metre rule to measure the length of the string from the vibration generator to the pulley at eye level.

In order to obtain an accurate measurement of mass, the student should check the top pan balance for zero error before placing the mass, and then correct their reading of mass.

ResultsPlus
Examiner Comments

Q04(b)(i) - 2 marks

Two clear sources of uncertainty given for the measurements listed in the question.

Q04(b)(ii) - 3 marks

The description of the technique to compensate for parallax was well written and scored 2 marks.

The idea of checking the balance for zero error was enough for one mark, but "correct their reading" was not sufficient for the additional detail.

(b) (i) Identify two significant sources of uncertainty in the student's measurements.

(2)

~~mass~~ parallax error when ~~measu~~ measuring length of string.

systematic error in balance when measuring mass (kg).

~~random error when code~~ systematic error in vibration generator.

zero error in balance when measuring mass m (kg).

(ii) For each of these sources of uncertainty, describe an experimental technique the student could have used to obtain an accurate measurement.

(4)

When measuring length of string make sure your eye is right over the scale and the strang is straight to avoid parallax error.

Fix zero position in balance and repeat and take average to avoid random errors in balance. repeat and take mean for all values, repeat and take ~~average~~ for all values,

ResultsPlus
Examiner Comments

Q04(b)(i) - 2 marks

Two clear sources of uncertainty given for the measurements of length and mass.

There was a list of 4 answers given, but the others simply lacked detail, rather being incorrect, so the two marks could be awarded.

Q04(b)(ii) - 3 marks

The description of the technique to compensate for parallax was well written and scored 2 marks.

The idea of correcting the balance for zero error ("fix zero position") was enough for one mark, but repeating and averaging the balance reading is not a correct technique as zero error is not a random error.

(b) (i) Identify two significant sources of uncertainty in the student's measurements.

(2)

There could be ~~systematic~~ parallax errors and zero error when measuring the length.

Also there could be a ~~systematic~~ random error when measuring the mass from electric balance.

(ii) For each of these sources of uncertainty, describe an experimental technique the student could have used to obtain an accurate measurement.

(4)

To measure the length of the string the student could use a meter rule with a fiducial marker, and he should measure the length by keeping the eyes in line with the marker. ~~Then~~

Also the student could measure the mass for several times and calculate the mean mass and he should not include anamalous data in it.

ResultsPlus
Examiner Comments

This response is more typical, with 2 marks being the most common mark awarded.

Q04(b)(i) - 1 mark

Only parallax error in length was rewarded.

Zero error would be more significant on the balance, which would be a systematic error rather than random.

It is unlikely the metre ruler did not start at zero.

Q04(b)(ii) - 1 mark

The description of the technique to compensate for parallax was well written but lacked the idea of measuring this while the string is stationary and straight.

Repeating mass measurement and averaging would help if the error in mass was random, but as only a single mass was being measured this is unlikely.

Paper Summary

This paper provided candidates with a range of practical contexts from which their knowledge, understanding and skills developed within this unit could be tested.

A sound knowledge of the subject was evident for many, but the responses seen did not reflect this as the language lacked precision and its ambiguity prevented some marks from being awarded.

Based on their performance on this paper, candidates are offered the following advice:

- Ensure answers are specific to the context of the question, rather than generic statements supplied as a list of answers.

- When plotting graphs your **plots** must use at least 50% of the graph paper in either direction so make sure your scale is large enough. Lines of best fit should be continuous and **thin**.

- Avoid unusual scale divisions (power-of-10 multiples of 1, 2 and 5 per 2 cm are the standard) and start scales at a suitable value; it is not always necessary or useful to start a scale at 0 if this makes the plotted region small.

- When using a graph to determine a gradient, the points taken for the gradient must actually sit on your line of best fit. If a plotted point does not sit on the line of best fit then it should not be one of the points you use for the gradient.

- Review **appendix 10** of the specification, particularly the keywords listed in the **glossary** and the methods for **calculating uncertainty**.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

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