Pearson Edexcel

INTERNATIONAL ADVANCED LEVEL

PHYSICS

Exemplars with examiner commentaries
Unit 3 – WPH13

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Introduction

1.1 About this booklet

This booklet has been produced to support teachers delivering the Pearson Edexcel International Advanced Level in Physics specification. The Unit 3 (WPH13) exemplar materials will enable teachers to guide their students in the application of knowledge and skills required to successfully complete this course. The booklet looks at questions 1(d), 1(e), 1(f), 2 (a), 3 (a), 3 (c) (ii), 4 (a) and 4 (b) from the June 2019 examination series, showing real candidate responses to questions and how examiners have applied the mark schemes to demonstrate how student responses should be marked.

1.2 How to use this booklet

Each example covered in this booklet contains:

- Question
- Mark scheme
- Example responses for the selected question
- Example of the marker grading decision based on the mark scheme, accompanied by examiner commentary including the explanation for the decision and guidance on how the answer can be improved to earn more marks.

The examples highlight the achievement of the assessment objectives at lower to higher levels of candidate responses.

Centres should use this content to support their internal assessment of students and incorporate examination skills into the delivery of the specification.

1.3 Further support

A range of materials are available from the Pearson qualifications website to support you in planning and delivering this specification.

Centres may find it beneficial to review this document in conjunction with the Examiner's Report and other assessment and support materials available on the Pearson Qualifications website.

Question 1(d)(i) & 1(d)(ii)

(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)

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

(2)

Mark scheme

1(d)(i)	• Calculation of mean diameter (using 4 or 5 diameters) (1) • Anomaly (18.3 mm) not included giving mean diameter = 19.0 mm (1) <u>Example of Calculation</u> Mean diameter = (19.0 mm + 19.1 mm + 18.9 mm + 19.1 mm) / 4 = 19.0 mm	**2**
1(d)(ii)	• Use of half range (0.1 mm) (1) **Or** value furthest from mean • Percentage uncertainty = 0.5 % (1) Allow full ecf for use of range of values in 1(d)(i) e.g. use of half range of 5 values If the half range of all 5 is used, but was not used in 1(d)(i) – MP2 only If whole range (e.g. 0.2 or 0.8) is used – award only MP2 <u>Example of Calculation</u> Range = 19.1 mm – 18.9 mm = 0.2 mm Percentage uncertainty = (0.1 mm / 19.0 mm) × 100 % = 0.53 %	**2**

Exemplar response A

(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)

$$\frac{19.0 + 19.1 + 19.1 + 18.9}{4} = 19.025$$

$$= 19.0\text{ mm}$$

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)

① $19.1 - 18.9 = 0.2$

$0.2 \div 2 = 0.1$

$\Rightarrow 19.0 \pm 0.1$

② $\frac{0.1}{19.0} \times 100 = 0.5\%$

Percentage uncertainty in the mean diameter = 0.5%

Examiner's comments:

This response 1(d)(i) was given 2 marks and 1d)(ii) was given 2 marks.

1(d)(i)

There is an attempt to calculate the mean diameter using 4 values, so the first marking point was awarded.

A potentially anomalous result was not included in the calculation, the result of which gives the correct answer. As the correct unit was also given, the second marking point could also be awarded.

1(d)(ii)

This answer is clearly set out, with the first step on the left identifying the uncertainty as half the range (0.1 mm), so the first marking point can be awarded.

This is then correctly used to calculate the percentage uncertainty, so the second marking point was also awarded.

Exemplar response B

(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)

$$\frac{19.0+19.1+18.9+19.1}{4} = 19.025$$

Mean diameter of the second metal sphere = 19.0

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

(2)

$19.1 - 18.9 = 0.2$

$$\frac{0.2}{19} \times 100$$

Percentage uncertainty in the mean diameter = 1%

Examiner's comments:

This response 1(d)(i) was given 1 mark and 1(d)(ii) was given 1 mark.

1(d)(i)

There is an attempt to calculate the mean diameter using 4 values, so the marking point mark was awarded.

The potentially anomalous result was not included, giving the correct value as shown in the mark scheme for the second marking point. Unfortunately, the correct unit was not given, so the second marking point could not be awarded.

1(d)(ii)

This response shows a common misunderstanding.

The specification for Unit 3 states that candidates should be able to "determine the percentage uncertainty in measurements from multiple readings using the half range", which in this case would be 0.1 mm (as the 18.3 value was not included). In Appendix 10, the alternative method "using the reading furthest from the mean" is described – which for these values also gives an uncertainty of 0.1 mm.

Here the full range, (0.2 mm), was used, so only the second marking point could be awarded.

Note – calculations of percentage uncertainty using the method for a single value (half the resolution) were not awarded any marks as this is not the correct method stated in the specification.

Question 1(e) & 1(f)

(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)

(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)

Mark scheme

1(e)	• Use of $V = \frac{4}{3}\pi r^3$ (1) • Use of $\rho = \frac{m}{V}$ (1) • Density = $7.89 \times 10^3\,\text{kg m}^{-3}$ ($7.89\,\text{g cm}^{-3}$) (1) • Value given to 3 s.f. (1) <u>Example of Calculation</u> $V = \frac{4}{3}\pi(10.25 \times 10^{-3}\,\text{m})^3 = 4.51 \times 10^{-6}\,\text{m}^3$ $\rho = \frac{35.6 \times 10^{-3}\,\text{kg}}{4.51 \times 10^{-6}\,\text{m}^3} = 7.89 \times 10^3\,\text{kg m}^{-3}$	**4**
1(f)	• Uses percentage uncertainty to calculate the range of density values (1) • Comparative statement consistent with their value for density from (e) (1) <u>Example of Calculation</u> $7.75 \times 10^3\,\text{kg m}^{-3} \times 1.02 = 7.91 \times 10^3\,\text{kg m}^{-3}$ $7.75 \times 10^3\,\text{kg m}^{-3} \times 0.98 = 7.60 \times 10^3\,\text{kg m}^{-3}$	**2**

Exemplar response A

(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 metal sphere $= \frac{4}{3}\pi(r)^3 = \frac{4}{3}\pi(10.25)^3$

$= 4510.9\,mm^3$

Volume $= 4510.9 \times 10^{-9} = 4.51 \times 10^{-6}\,m^3$

Density = Mass ÷ Volume

$= 0.0356\,kg \div (4.51 \times 10^{-6})\,m^3$ ~~0.356 kg~~

~~= 7896.1 kgm⁻³~~ $= 7893.6$

~~≈ 7880 kgm⁻³~~ ≈ 7890

Density of the first metal sphere = ~~7880~~ ~~787~~ 7890 kgm^{-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)

Density of second metal sphere is $7.75 \times 10^3\,kgm^{-3}$ which have a % uncertainty of 2%, so range of density of the second sphere is $(7595 - 7905)\,kgm^{-3}$. Since density of ~~A~~ first sphere ~~can~~ falls in the range of density of second sphere, they are made from same metal.

(Total for Question 1 = 16 marks)

Examiner's comments:

This response 1(e) was given 4 marks and 1(f) was given 2 marks.

1(e)

The correct diameter given to candidates in part 1(b) was used in the correct equation for the volume of a sphere, so the first marking point was awarded. This volume was used with the mass given in the density equation for the second marking point.

The correct final value was calculated, gaining the third marking point, which was then rounded to the same number of significant figures as the measurements used in the calculation.

Note - this final mark is independent, so an incorrect value rounded to 3 significant figures would have been awarded the fourth marking point.

1(f)

The full range of uncertainty in the second metal sphere's density was calculated, earning the first marking point. There is a clear comparison between this range of values and the value calculated in part 1(e), which achieves the second marking point.

Exemplar response B

(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 $= \frac{4}{3}\pi r^3$

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

$= 4511 \text{ mm}^3$

~~$4511 \times 10^{-2} \times 10^{-2} \times 10^{-2}$~~ $4511 \times 10^{-3} \times 10^{-3} \times 10^{-3}$

~~$= 4.5 \times 10^{-6} \text{ m}^3$~~ ~~$= 4.5 \times 10^{-3} \text{ cm}^3$~~ $= 4.5 \times 10^{-6} \text{ m}^3$

~~Density = mass / volume~~ ~~$= \frac{35.6}{4.5 \times 10^{-6}}$~~ $= \frac{35.6}{1000} = 0.0356 \text{ kg}$

Density $= \frac{\text{mass}}{\text{volume}} = \frac{0.0356}{4.5 \times 10^{-6}} = 7911 = 7.9 \times 10^3 \text{ kg m}^{-3}$

Density of the first metal sphere = $7.9 \times 10^3 \text{ kg m}^{-3}$

(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)

~~Both the spheres could be~~

Even though there is a slight difference in density, second sphere has an uncertainty of 2%. So it could be ~~sayed~~ said they are made from same metal.

(Total for Question 1 = 16 marks)

Examiner's comments:

This response 1(e) was given 3 marks and 1(f) was given 0 marks.

1(e)

The correct diameter given to candidates in 1(b) was used in the equation for the volume of a sphere, with diameter shown as being divided by 2, so the first marking point was awarded.

This volume was used with the mass given in the density equation for the second marking point. A correct final value was calculated having rounded the volume value before the density calculation, gaining the third marking point. However, the final density value was rounded to 2 significant figures. Mass and diameter were both given to 3 significant figures.

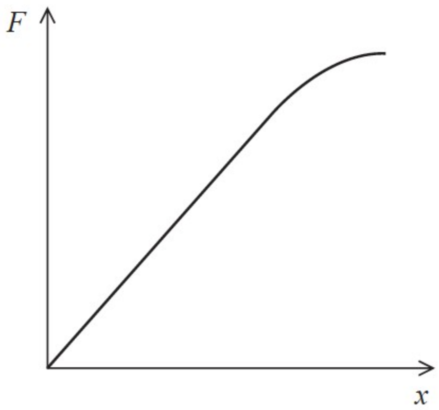
1(f)

A common error was made here. The question includes the command word "**determine**", which is defined in the specification to mean "**the answer must have an element which is quantitative from the stimulus provided or must show how the answer can be reached quantitatively.**" No attempt was made to perform a calculation, so the first marking point was not achieved. The comparison made "there is a slight difference" has no *quantitative element* so the second marking point was not awarded.

Question 2(a)

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)

Mark scheme

2(a)	• Reference to Force = *mg* **Or** reference to use of a Newtonmeter to measure weight (1) • Measure initial length of spring and length with load, and subtract to give extension **Or** align zero on ruler to bottom end of spring and read opposite bottom when loaded to measure extension **Or** read scale opposite bottom of spring initially and again with load, and subtract to get extension (1) • Use of a set square to ensure the ruler is vertical **Or** use of a set square to reduce parallax error when measuring length/extension **Or** use of a pointer attached to the lower end of spring to reduce parallax error when measuring length/extension **Or** ensure ruler and spring are at eye-level to reduce parallax (1) • Uses a range of masses/forces to obtain multiple pairs of values (1)	**4**

Exemplar response A

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

(4)

Measure the mass of the load using an electronic balance and repeat for same mass. Multiply with gravitational accelaration to get F. Use a meter-rule ~~$~~and set square to place the meter rule parallel to the spring and measure the initial ~~mass~~ length. Hang ~~m~~ loads of varying masses and measure the final length of the spring for each mass. Substract initial length to find extension for each of value of F. ~~Plot the graph~~, Repeat measurements of each mass and its corresponding extension.

Examiner's comments:

This response was given 4 marks.

The first marking point is clear in the first 3 lines of this response.

There is a clear reference to the calculation of extension by subtracting the initial length from the final length in the 7th and 8th lines, so achieving the second marking point.

Although the response does not refer to parallax, it does make a credit worthy attempt at the third marking point, using the set square and ensuring the ruler is parallel to the spring.

Note – this mark was awarded rarely, as many candidates did not include ideas of accuracy when giving an account of what should be done to obtain the data.

The final marking point is awarded for responses that explain how the multiple pairs of force/mass and extension needed to plot a graph are achieved. Here, "hang loads of varying masses" is enough for the final marking point.

Exemplar response B

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

(4)

The student should first measure the original length of the spring without any force applied to it; then record it. Then the student can add a mass to the lower end of the spring and record the new length of the Spring. To get extension; (new length – Old length of the spring) Then this is recorded on a table for each mass that the student used (wide range). This will allow the student to plot a graph of force against extension.

Examiner's comments:

This response was given 2 marks.

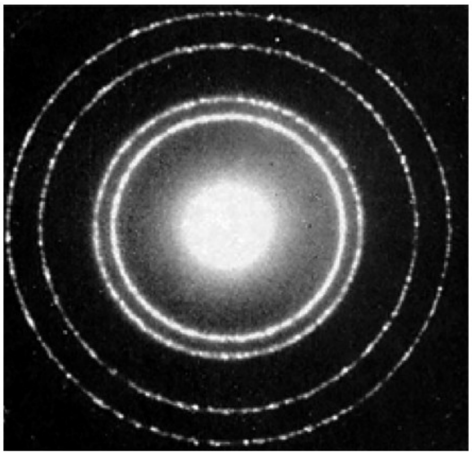
This is a more typical response. The description of how to ensure accurate lengths are measured is missing, so the third marking point was not awarded.

The first marking point cannot be awarded, as there is no description of how the candidate obtained force data for the graph.

However, there is a good description of how extension data can be obtained, so marking point 2 can be awarded, and there is an implication that a wide range of masses are used, so the final marking point is also achieved.

Question 3(a)

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)

Mark scheme

3(a)	• Use of Vernier calipers **Or** use of dividers/calipers to transfer the measurement to a ruler **Or** use of paper (tape) and marking points to be measured with a ruler **Or** use a flexible measuring tape (1) • Measure diameter of (first) ring and divide by 2 (1) • Measure in multiple orientations and calculate the mean (1) • Measure to the middle/brightest part of the ring **Or** refers to surface of the screen being curved (so diameter cannot be measured directly) (1)	**4**

Exemplar response A

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

(4)

Use a vernier calliper to lower percentage uncertainty in the reading.
Measure the diameter across the ring at several positions and calculate a mean. $r = \frac{\text{diameter}}{2}$. increase distance between source and graphite to get larger circles so lower percentage uncertainty.

Examiner's comments:

This response was given 3 marks.

The first line gives a clear reference to a measuring instrument, or method, that would allow for measurements of diameter/radius on a curved screen. However, as the response does not reference the curve of the screen, only marking point 1 can be awarded.

The response does include the commonly seen marking point 2 and marking point 3, measuring the diameter at different position, calculating the mean diameter and dividing this by 2 to give the radius.

Note - unlike 1(e), where the idea of the mean was given in the question instruction, here it is a required part of marking point 3. In some examples the candidates measured the diameter in different orientations and divided by 2 to give the radius before calculating the mean radius. This was an acceptable alternative.

As in this case, most candidates' descriptions were missing the additional detail which marking point 4 rewards.

- Despite the diagram of the apparatus showing a clearly curved surface, very few candidates referred to this issue when describing their measurements. Most referred to using a ruler, apparatus suitable to measure on a flat surface.
- The photograph shows the rings have a significant thickness, but few identified where on a ring to make measurements to.

Exemplar response B

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

(4)

- The student can use a ruler with small division and measure the diameter of the ring.
- The student can find repeat readings for the diameter by measuring from different sides of the ring. The student can repeat alteast three times to get a mean. The student can ~~et~~ calculate the radius by using the equation, radius = $\frac{\text{diameter}}{2}$

Examiner's comments:

This response was given 2 marks.

This more typical example only attempts to describe the basic measurement technique, so marking point 2 and marking point 3 can be awarded.

The choice of measuring instrument, a ruler, is unsuitable unless used with some other form of equipment that allows for the measurement to be taken from the curved surface. For example, some candidates described drawing the ring on tracing paper before taking measurements with a ruler.

Note – some candidates described taking a photograph of the screen and then measuring the diameter with a ruler. This was only rewarded with the first marking point if there was a clear description of how this measurement from the photograph could be scaled back to the actual measurement.

Question 3(c)(ii)

(c) The student determined the radius of the first bright ring of the diffraction pattern for a range of electron energies. The student then calculated the de Broglie wavelength λ of the electrons and the angle of diffraction θ. The results are shown in the table.

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

(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.

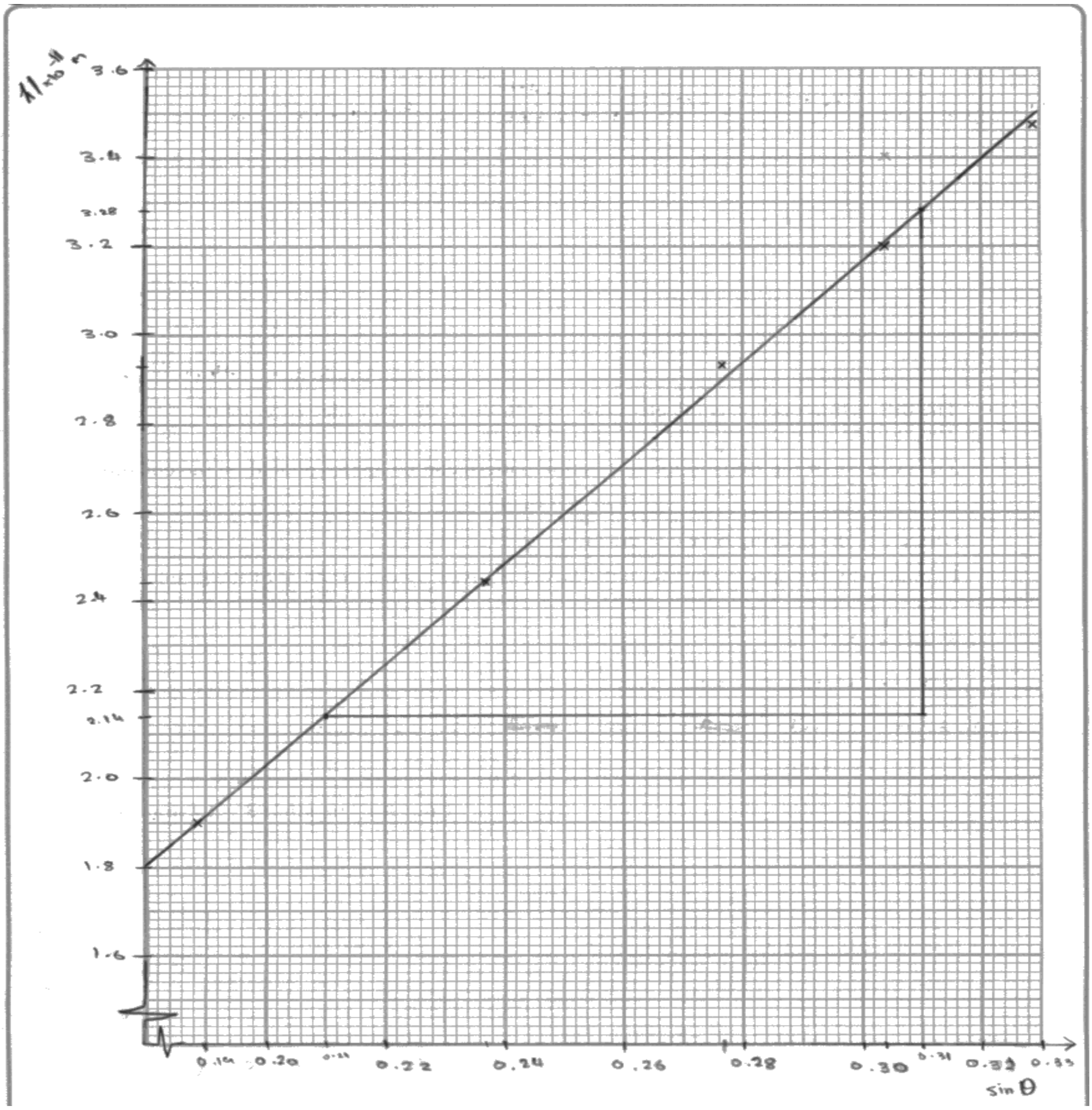
(6)

Mark scheme

3(c)(ii)	• Correct $\sin\theta$ values to 3 s.f. • Labels axes with quantities **and** unit for λ and with no unit for $\sin\theta$ (Accept $\sin(\theta/°)$ but not $\sin\theta/°$) • Sensible scales • Plotting values • Line of best fit	(1) (1) (1) (2) (1)	**6**

Exemplar response A

$\lambda / 10^{-11}$ 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



Examiner's comments

This response was awarded 6 marks.

The first marking point can be awarded for the correctly rounded values in the table.
As sin θ is given to 3 significant figures, so should sin θ.

The graph has correctly labelled axis, achieving marking point 2.

The scales are suitable, in that the plotted area covers over half of each axis. The scales also increase in suitable increments, 0.02 on the x-axis and 0.2 on the y-axis.

Note – generally increments are expected with powers of 10 of 1, 2 or 5 on the 2 cm axis lines. In this example, both axes increase in increments that are powers of 10 of 2 (0.2 and 0.02) every 2 cm.

The plots are small with a clear ×. The plots are to within 1 mm of the values in the table, so both marks for marking point 4 can be awarded.

The line of best fit is balanced. There is some variation in pressure, suggesting the line was not drawn in one movement, but the final line is clear and straight so the final marking point can be awarded.

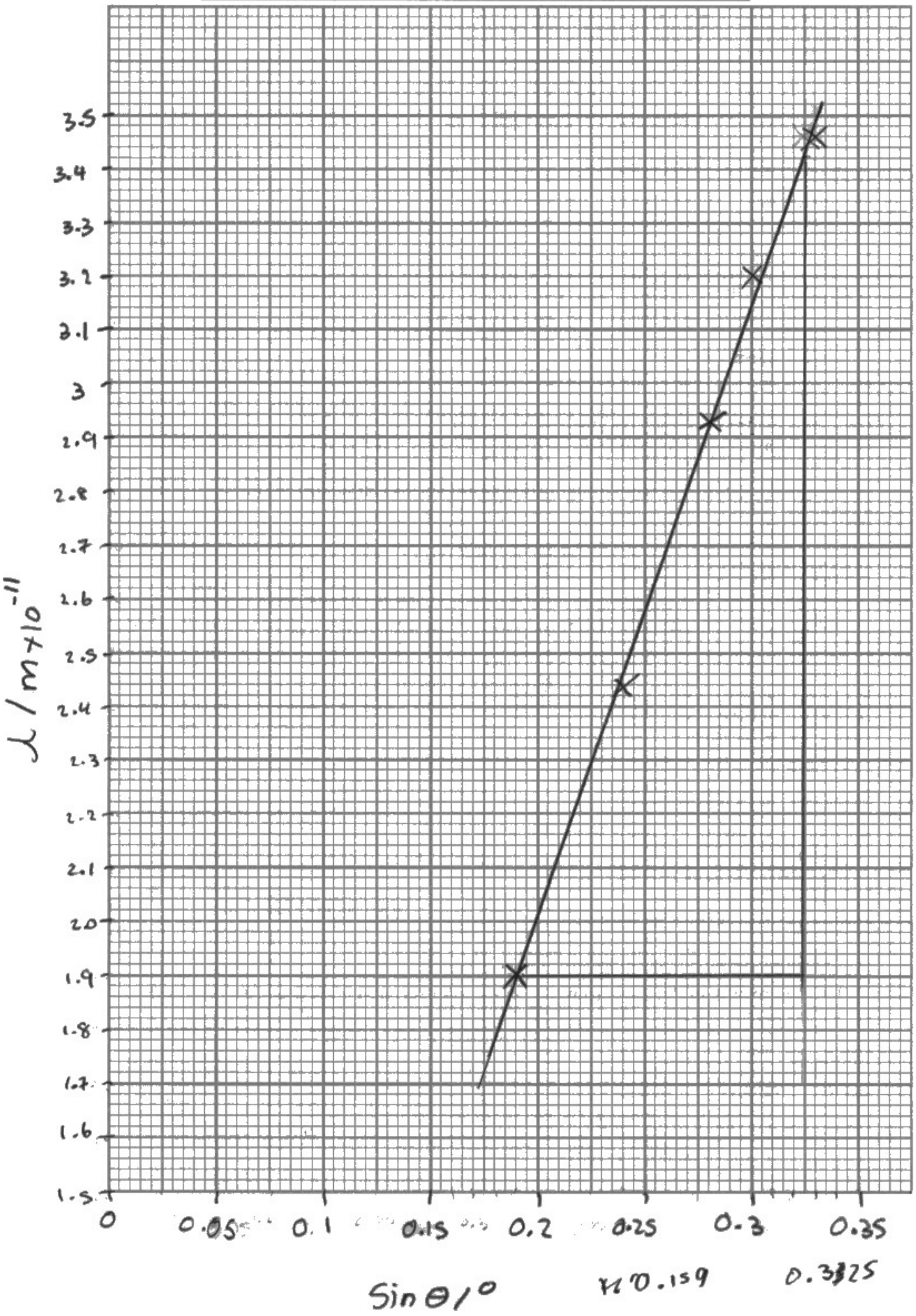
Note – it is not expected that a line of best fit will pass through the origin.

Practical results often include systematic errors, so graphs of results expected to be proportional may give lines that miss the origin. In this case, the data given leads to a line with a y-axis intercept that has small negative value.

So, lines forced through the origin would not achieve the final marking point in many cases.

Exemplar response B

$\lambda / 10^{-11}$ m	$\theta / °$	$\sin\theta$
3.47	19.2	0.33
3.2	17.7	0.30
2.93	16.1	0.28
2.44	13.7	0.24
1.9	10.9	0.19



Examiner's comments:

This response was given 3 marks.

In this response the values were calculated correctly, but rounded incorrectly to 2 significant figures, so the first marking point cannot be awarded.

The y-axis label would have been given the *benefit of doubt* for the reversal had that been the only error; however, the x-axis label is incorrect as the sine function does not give values that have a unit. This means marking point 2 is not achieved.

Note – the correct axis label incorporating the unit of angle would be $\sin(\theta/°)$.
This is similar for other functions that are unitless, such as the Ln function seen in later units.

The axes have scales that increase in suitable increments (0.2 and 0.05 every 2 cm); however, the plotted area covers less than half of the x-axis, so the third marking point is not awarded.

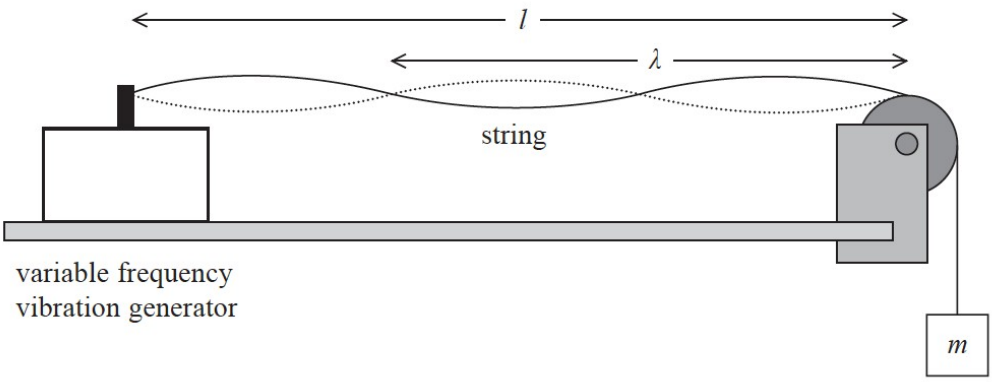
The plots have crosses that are 4 mm in size; however, as they are drawn with narrow lines with a clear crossing point their accuracy can be checked. In this example all points appear within 1 mm of the plots expected for the data in the table, so both plotting marking points can be awarded.

Note – use of a blunt pencil or thick ink pen can result in plots where the mark itself covers more than 1 mm (half a square). These cannot be checked for accuracy. If an unsuitable scale was chosen, particularly those with increments of 3 or 7 (as stated in the mark scheme), it is unlikely the accuracy of plots can be checked.

The line is balanced and follows the trend for these plots, so the final marking point is given.

Question 4(a)

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)

Mark scheme

Question Number	Answer		Mark
4(a)	• Use of $\sqrt{\frac{mg}{\mu}} = f\lambda$	(1)	
	• Use of $l = 1.5 \times \lambda$	(1)	
	• $\mu = 3.2 \times 10^{-4}$ kg m^{-1}	(1)	3
	<u>Example of calculation</u> $1.5 \times \lambda = 1.25$ m $\lambda = 0.833$ m $\mu = (0.25 \text{ kg} \times 9.81 \text{ m s}^{-2}) / (105^2 \text{ Hz}^2 \times 0.833^2 \text{ m}^2)$ $\mu = 3.21 \times 10^{-4}$ kg m^{-1}		

Exemplar response A

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

(3)

$N \qquad \frac{mg}{N} = (f\lambda)^2$

$\lambda = \frac{2}{3} \times 1.25 \qquad \frac{mg}{(f\lambda)^2} = N \qquad \frac{0.25 \times 9.81}{(165 \times 5/6)^2}$

$\mu =$ 3.2×10^{-4} kg

Examiner's comments:

This response was given 3 marks.

The diagram for this question clearly indicates the wavelength and the length, with wavelength covering 2 antinode loops, but the length covering 3 antinode loops. This response has identified this relationship, so achieving the second marking point.

The response correctly included this wavelength in the calculation, so marking point 1 can be awarded.

The calculated value is correct and includes the correct unit for mass per unit length, so the final marking point is given.

Exemplar response B

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

(3)

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

$$m \cdot \frac{m}{s} = \frac{m^2 s^{-1}}{s^{-1} \cdot m}$$

$$\mu = \frac{mg}{(f\lambda)^2} = \frac{0.25\,(9.81)}{(105 \cdot 1.25)^2} = 1.42 \times 10^{-4}$$

$\mu =$ $1.42 \times 10^{-4}\ \text{kg}\,\text{m}^{-1}$

Examiner's comments:

This response was given 1 mark.

This response demonstrates a common misconception. The table is clearly labelled "length of string", but the value of length has been substituted as the wavelength.

As this is a *dimensionally correct* (e.g. is in metres) value, it can be accepted for the first marking point only as an example of the "use of" the equation.

Note – an incorrect conversion between length and wavelength will also give a *dimensionally correct* value, so can score the first marking point if substituted correctly.

Question 4(b)

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

(2)

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

(4)

Mark scheme

4(b)(i)	Mark 4(b)(i) and (b)(ii) holistically **Max 2 from** *Frequency* • Uncertainty in identifying when nodes form • Uncertainty in identifying maximum amplitude *Length* • Parallax error when measuring length • Uncertainty in measuring length to top of pulley **Or** uncertainty in measuring length as string is not straight *Mass* • Zero error on mass balance	 (1) (1) (1) (1) (1)	**2**
4(b)(ii)	**Max 4 (from only 2 pairs)** **For each source from (b)(i)** Description of experimental technique Additional detail *Examples* *Frequency* • Repeat and calculate the mean frequency • Vary frequency from above and below resonance to find two values for the frequency when the standing wave forms *Length* • Use a set square to reduce parallax error in length **Or** hold ruler in contact with the wire to reduce parallax error in length **Or** ensure ruler and string are at eye-level • Switch off vibrator **Or** ensure string is straight *Mass* • Zero balance before each measurement • To remove systematic error **Or** idea that this error is not reduced by repeating	 (1) (1) (1) (1) (1) (1) (1) (1)	**4**

Exemplar response A

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

(2)

~~Parall~~ Frequency for which a standing wave of maximum amplitude is produced. Hard to judge ~~when~~ for which frequency maximum amplitude occurs.

Parallax error in measuring the length of the string.

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

(4)

Alter the frequency around the expected value of frequency and record the optimal frequency. ~~Ta~~ Take repeat reading of frequency for each mass and excluding the anamolous results, find a average frequency which reduces random error.

Take reading from eye level. Take readings from different positions of the meter rule and average them. Straighten the string before taking readings.

Examiner's comments:

This response (b)(i) was given 2 marks and (b)(ii) was given 4 marks.

4(b)(i)

This question asked students to identify sources of uncertainty in the candidate's measurements. These were given in part (a) so answers were only acceptable if they were linked to the three measurements stated; the length of string, frequency and the mass hanging on the string. References to mass of string, wavelength, etc. are not acceptable alternatives.

Note - the question also asks for two sources. Additional incorrect or contradictory examples could negate marks. In this response, there are two clear sources of uncertainty, each linked to one of the three measurements listed – so 2 marking points can be awarded.

4(b)(ii)

Here the marks are awarded in pairs, 2 marking points for each example from (b)(i) where a basic technique is awarded marking point 1, but additional detail achieves a second marking point. Repeating and calculating the mean frequency scored 1 marking point, but the additional detail of altering frequency "around" the expected value suggests the idea of measuring from above and below, so the second marking point for frequency can be awarded. For the length measurement, the idea of taking readings at eye level earned the basic technique marking point. The additional detail of ensuring the string is straight gains the second marking point for length.

Note – it is possible for marking points for part (b)(i) to be awarded for text written in part (b)(ii) so both parts should be read before marking points are awarded.

Exemplar response B

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

(2)

→ Parallax error while measuring length

→ zero error on balance while measuring mass

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

(4)

→ Read value of metre rule perpendicular to eye level

→ use digital balance to eliminate zero error

Examiner's comments:

This response (b) (i) was given 2 marks and (b) (ii) was given 1 mark.

4(b)(i)

In this response, there are two clear sources of uncertainty, each linked to one of the three measurements listed. In this case, parallax when measuring length and zero error on the mass balance – so 2 marking points can be awarded.

Note – zero error in length measurements is not acceptable as it is unlikely a metre rule did not start at 0.

4(b) (ii)

There is a basic technique to reduce uncertainty in the length measurement – so 1 marking point can be awarded here.

However, the use of a digital balance would not eliminate zero error. This would still need to be set to zero before use.

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