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June 2024

GCE Physics 9PH0 03

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June 2024

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Introduction

This paper comprises short, open-response, calculation and extended writing questions worth a total of 120 marks. The questions draw on a range of the topics in the specification and include synoptic questions drawing on two or more different topics. The paper also includes questions that assess conceptual and theoretical understanding of experimental methods (indirect practical skills), some of which draw on candidates' experiences of the core practicals.

The paper gave candidates the opportunity to demonstrate their understanding of a wide range of topics from the specification, with all of the questions eliciting responses that scored across the range of marks.

There was a mixed response to the two linkage questions in this paper. Q03 tended to generate better responses than Q08(a). In general the responses to both questions were commensurate with the responses to linkage questions seen in previous series.

There is still evidence that candidates are not paying sufficient attention to the command words used in the question. In a number of cases, questions requiring an explanation were answered with a description and vice versa by some candidates.

In general, calculation and 'show that' questions gave candidates an opportunity to demonstrate their problem solving skills to good effect. Some very good responses were seen for such questions, with well-crafted solutions which were accurate and clearly set out. In some calculation questions the final mark was not awarded due to a missing unit. This seemed to be more prevalent in this year's examination.

There were instances where candidates disadvantaged themselves by not using suitably precise language.

Candidates' knowledge of the processes of quantifying uncertainties in practical work was generally sound, with good success displayed by many candidates in combining uncertainties.

The space allowed for responses was usually sufficient. However, sometimes candidates started their response by repeating the question, so they struggled to get all of the relevant points in the space provided.

Candidates should be encouraged to consider the number of marks available for a question, and to use this to determine the length of response required. If candidates either need more space or want to replace an answer with a different one, they should indicate clearly where the response they wish to be marked by examiners can be found.

Candidates should be encouraged to work with mark schemes in preparation for their exam. However, it is important that they understand that mark schemes do not provide model answers to questions. Mark schemes are written for examiners and so sometimes refer to what examiners expect to see rather than giving a complete answer.

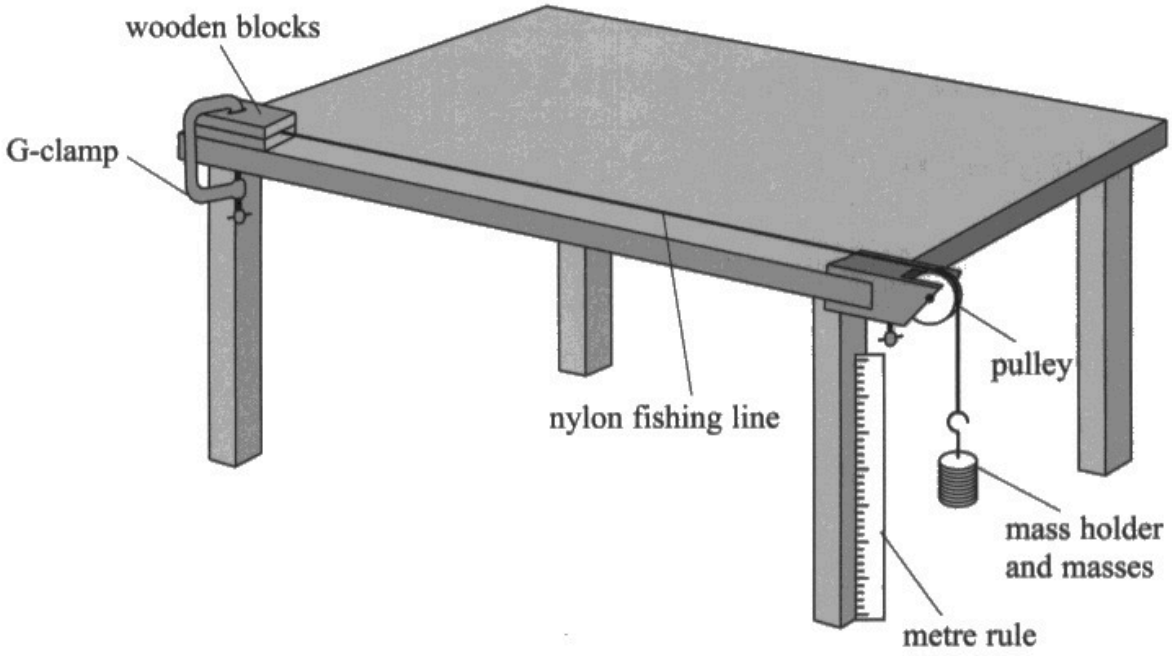
Question 1 (a)-(b)

The vast majority of responses to part (a) included a reference to an inconsistent number of significant figures (decimal places) for the data recorded in the table. Many candidates thought that the inconsistent changes in the value of added mass were a problem, although such statements did not gain credit. Some responses included reference to the experimental method, although the question specifically refers to the recording of the results.

The command word in part (b) is 'describe', but a number of responses included explanations as well as descriptions. Many responses referred to checking that the metre rule was vertical, although the method of doing this was often omitted. Some stated that verticality could be checked with a set square, but very few had any idea how to do this. In some cases annotations were added to the diagram on the previous page, which was a clear way of communicating detail. It would be helpful if candidates were to refer to the fact that they have added to their diagram in their description.

Many candidates stated that repeat readings should be taken, and usually they went on to say that an average or mean should be calculated. This was enough for MP5, although it was surprising that so few responses referred to collecting loading and unloading values of the extension.

1 A student stretched a length of nylon fishing line using the apparatus shown below.



(a) The nylon fishing line was stretched by adding masses to the mass holder. The positions of the bottom of the mass holder were measured as masses were added. For each mass, the extension of the nylon fishing line was calculated. The student recorded the results, as shown in the table.

Mass / kg	Extension / cm
0.05	0.4
0.1	0.8
0.25	2.1
0.5	3.9
0.75	6.0
1.0	7.2

Criticise the recording of these results.

(2)

range is too small, no evidence of repeats, the results ~~dddddd~~ are in different decimal places / significant figures.

(b) Describe how the extension of the nylon fishing line could have been determined as accurately as possible.

(3)

use a fiducal marker ~~to~~ to point where the mass correlates on the ruler. ~~Record the~~ Be at eye level when reading of the meter rule, and repeate the same ~~experiment~~ experiment with the same number of mass at least 3 times.

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Examiner Comments

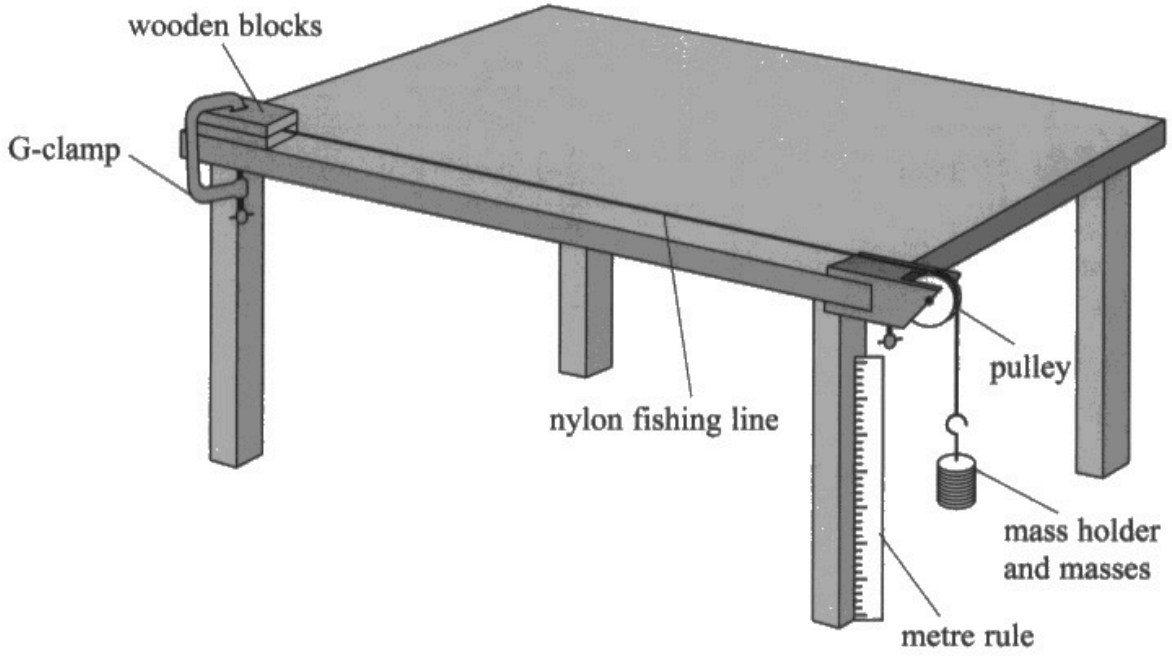
The reference to decimal places / significant figures scores MP2 in (a). No extra credit is gained for the range, nor for the lack of repeats.

In (b) the reference to a fiducial marker is just enough for MP3 (alternative under additional guidance). The reference to eye level gets MP1, but the reference to repeats is not sufficient for MP5, as there is no mention of calculating a mean.

ResultsPlus
Examiner Tip

If repeat readings are taken, then we always need to calculate a mean from the repeat values.

1 A student stretched a length of nylon fishing line using the apparatus shown below.



(a) The nylon fishing line was stretched by adding masses to the mass holder. The positions of the bottom of the mass holder were measured as masses were added. For each mass, the extension of the nylon fishing line was calculated. The student recorded the results, as shown in the table.

Mass / kg	Extension / cm
0.05	0.4
0.1	0.8
0.25	2.1
0.5	3.9
0.75	6.0
1.0	7.2

Criticise the recording of these results.

(2)

- the mass was not recorded to a consistent number of decimal places
- the raw data (the original position and final position of the mass) is not shown in the table.

(b) Describe how the extension of the nylon fishing line could have been determined as accurately as possible.

(3)

- Use a set-square to ensure the metre rule is vertical, and hold ruler close to the fishing line
- take measurements at eye level to reduce error of parallax
- take repeat measurements of the extension, discount any anomalies, and find an average extension (to reduce random error)
- add a pointer to the bottom of the mass holder

ResultsPlus
Examiner Comments

In (a) both marks are scored as per the MS.

In (b) MP1, MP2, and MP5 are met. Note that the reference to using a set square to ensure that the metre rule is vertical is not detailed enough for MP4.

Question 1 (c)(i)

There are a number of ways of defining the yield point, and most responses gave an acceptable answer. Some candidates mixed this up with the limit of proportionality, and stated that it is the point at which Hooke's law is no longer obeyed. Another common wrong answer was to state that it is the point at which the line gives a large extension for a small force. This is not acceptable, as it could just be describing a material with a low stiffness.

(c) The strain for the nylon fishing line at its yield point is 0.04

(i) State what is meant by yield point.

(1)

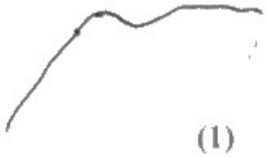
The point at which the line will continue to extend with no ~~addde~~ additional force.

ResultsPlus
Examiner Comments

This meets the **Or** version of the MP.

(c) The strain for the nylon fishing line at its yield point is 0.04

(i) State what is meant by yield point.



(1)

point beyond which extension stops being linear, following Hooke's law.

ResultsPlus
Examiner Comments

Yield point was often confused with limit of proportionality, as in this response here. No marks.

Question 1 (c)(ii)

This question was well answered, but only a very small proportion of responses gaining less than full marks.

(ii) The original length of the nylon fishing line was 2.00 m.

Determine whether the fishing line was stretched beyond its yield point.

(2)

$\varepsilon = \frac{\Delta x}{x} \Rightarrow \Delta x = 0.04 \times 2 =$ 0.08m

$\therefore 0.072\text{m} < 0.08\text{m}$

∴ It was not stretched beyond its yield point

ResultsPlus Examiner Comments

This is one way of gaining both marks.

(ii) The original length of the nylon fishing line was 2.00 m.

Determine whether the fishing line was stretched beyond its yield point.

(2)

$\text{strain} = \frac{\Delta x}{x} = \frac{0.8 \times 10^{-2}}{2.00} = 4 \times 10^{-3}$

ResultsPlus Examiner Comments

This response includes a correct calculation so MP1 is scored, but no conclusion, so no further marks.

(ii) The original length of the nylon fishing line was 2.00 m.

Determine whether the fishing line was stretched beyond its yield point.

(2)

$E = \frac{F}{A} \times \frac{x}{\Delta x} = 2$

$\text{strain} = \frac{\Delta x}{x} = \frac{0.072}{2}$

$= 0.036$

∴ not yet

(Total for Question 1 = 8 marks)

ResultsPlus
Examiner Comments

This is another way of gaining both marks.

Question 2 (a)(i)-(ii)

This was a challenging question based on combining uncertainties. The best responses were set out clearly so that all the steps could be seen. Such solutions usually went on to score full marks. Most candidates used the half-resolution value when calculating the percentage uncertainty, and the rules for combining uncertainties in products and quotients were well understood and applied.

2 A student made measurements to determine if some gold coins were made from pure gold. The coins that were available to the student are shown below.

(Source: © Bjoern Wylezich/Shutterstock)

(a) The student used digital calipers to measure the thickness t and the diameter d of one of the coins.

(i) Calculate the volume V of the coin, and the percentage uncertainty in V.

$t = 1.54\,\text{mm} = 1.54\times10^{-3}\,\text{m}$
$d = 22.16\,\text{mm} = 22.16\times10^{-3}\,\text{m}$

(7)

$V = \pi r^2 \times t = \pi \times \left(\frac{22.16\times10^{-3}}{2}\right)^2 \times 1.54\times10^{-3}$

$= 5.94\times10^{-7}\,\text{m}^3$

absolute unc in t, $= 1.54 \pm 0.005\,\text{mm}$

% unc in $t = \frac{0.005}{1.54} \times 100 = \pm 0.324\%$

absolute unc in $d = 8 \pm 0.005\,\text{mm}$

% unc in $d = \frac{0.005}{22.16} \times 100 = \pm 0.0226\%$

$\therefore$ % uncertainty $= 2\times 0.0226 + 0.324$

$= \pm 0.37\%$

$V = 5.94\times10^{-7}\,\text{m}^3$

Percentage uncertainty in $V = \pm 0.37\%$

(ii) The student measured the mass of the coin using an electronic balance. The balance had a resolution of 0.1 g.

Assess whether the coin could be made from pure gold.

density of pure gold = $1.93 \times 10^4 \text{ kg m}^{-3}$
mass of coin = 11.2 g

(4)

$\rho = \frac{m}{V} = \frac{11.2 \times 10^{-3}}{5.94 \times 10^{-7}} = 1.886 \times 10^4 \text{ kgm}^{-3}$

absolute uncertainty of mass = $\frac{0.1}{2} = \pm 0.05\text{g}$

∴ % uncertainty of mass = $\frac{0.05}{11.2} \times 100 = \pm 0.446\%$
$= 0$

∴ total % uncertainty in density = $0.446 + 0.37$
$= \pm 0.82\%$

max ρ = $1.886 \times 10^4 \times 1.0082 = 1.90 \times 10^4$ (3s.f)

the max ρ is less than 1.93×10^{-4}, ∴ this coin is probably not pure gold.

ResultsPlus
Examiner Comments

This response shows correct answers for both (i) and (ii) and scores full marks for each item.

Question 2 (b)

There were good responses seen to this question. MP1 is about stacking coins and MP3 is about repeating and averaging. Some responses were worded so ambiguously that it was difficult to identify which method was being described.

Random errors cannot be eliminated, but the effect of random errors on the measured value can be reduced. Zero/parallax errors are examples of systematic errors, and so these can be removed/eliminated.

For MP2, many referred to uncertainty instead of percentage uncertainty. This was not sufficient for the mark to be awarded, as uncertainty stays the same, but percentage uncertainty is reduced.

Many forgot that the calipers used had a resolution of 0.01 mm. Replacing the calipers with a micrometer screw gauge would not have led to an improved measurement.

(b) The student's experimental method could have been improved.

Explain two changes the student could have made to the experimental method.

(4)

The student could have used measuring instruments with a higher resolution, say a micrometer screw gauge to measure the coins. This will reduce the percentage uncertainty in the value for V of the coin. They could have also used a higher resolution mass balance to reduce % uncertainty. Furthermore, the student should have repeated their measurements for the values of t and d, measuring at different locations and orientations and then calculating a average/mean as this will reduce the effect of random errors in the calculation for V.

(Total for Question 2 = 15 marks)

ResultsPlus
Examiner Comments

This response scored all 4 marks.

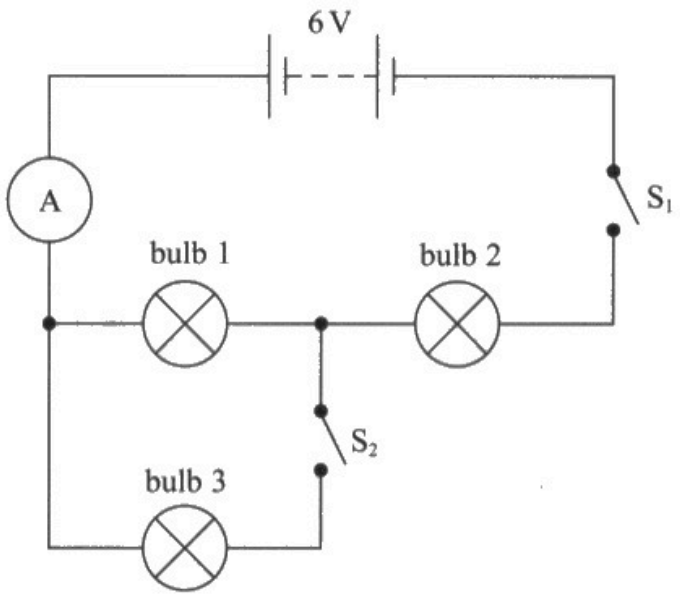
The reference to use a micrometer screw gauge does not gain any credit, as the digital caliper is already reading to the nearest 0.01 mm. However, the reference to replacing the balance does gain MP1, using the alternative version of MP1 from the additional guidance. The response goes on to state that the percentage uncertainty is reduced, so MP2 is also awarded. The rest of the response gains MP3 and MP4.

Question 3

This question challenged candidates' understanding of series and parallel circuits. Although some good responses were seen, it is clear that many candidates are confused about the general circuit principles involved.

IC1 was credited in most responses, although this part of the response often took up about half the available space. Nonetheless, a reasonable number of responses just stated that the brightness of the two bulbs would be the same without any kind of justification. Many candidates believed that the split in potential difference across the two bulbs remains the same when S2 is closed, and a reasonable number went on to state that less current would flow through bulb 1 because current was also flowing through bulb 3. In some responses bulbs 1, 2 and 3 were muddled up, which made answers that looked correct completely wrong.

*3 A student connects three identical 3 V bulbs to a 6 V battery of negligible internal resistance. The circuit includes two switches, S_1 and S_2, as shown.



The student closes S_1 and records the brightness of each bulb.

With S_1 still closed, the student closes S_2.

Explain how the brightness of bulb 1 compares with the brightness of bulb 2 before and after S_2 is closed.

Initially both bulb 1 and 2 have the same brightness as they have the same resistance so the potential difference across each is equal. when S_2 closes the parallel set up of bulb 1 and 3 means that the overall resistance of the combination is less than a single bulb. So bulb 2 has a higher resistance compared with bulb 1 and 3 combined, so a larger potential difference will be across bulb 2 (higher proportion) so bulb 2 will become brighter. therefore the potential difference across bulb 1 will be smaller and it will have to share current with bulb 3 as they are in parallel, so bulb 1 will be less bright (dimmer). So after S_2 is closed bulb 2 will be brighter than bulb 1.

ResultsPlus
Examiner Comments

This response scores 6 marks.

There are 4 marks for the indicative content:

IC1 is seen in lines 1 – 3 of the response.

IC2 is seen in lines 9 – 10 of the response.

IC3 is seen in lines 3 – 5 of the response.

IC4 is seen in lines 5 – 7 of the response.

IC5 is seen in lines 10 – 11 of the response.

IC6 is seen in lines 11 – 12 of the response.

The ideas are logically sequenced, and so there are 2 marks for the linkage.

Question 4 (a)

Many responses scored full marks. An incorrect formula for V was usually the reason why only 3 marks were scored overall.

4 Helium is available in small metal canisters. The helium can be used to fill party balloons.

(a) A full canister contains helium gas at a temperature of 18.5°C and a pressure of 1.65×10^7 Pa. The canister is approximately spherical, with a radius of 4.36×10^{-2} m.

Calculate the mass of helium gas in the full canister.

mass of 6.02×10^{23} atoms of helium = 4.00×10^{-3} kg

(5)

$V = \frac{4}{3}\pi r^3$ $V = \frac{4}{3}\pi \times (4.36 \times 10^{-2})^3$

$= 3.47 \times 10^{-4}\ m^3$

$PV = NkT$

$1.65 \times 10^7 \times 3.47 \times 10^{-4} = 5728 = NkT$

$k = 1.38 \times 10^{-23}$

$5728 = N \times 1.38 \times 10^{-23} \times 18.5$

$N = 2.24 \times 10^{25}$

$\frac{2.24 \times 10^{25}}{6.02 \times 10^{23}} = 37.3$

$37.3 \times (4 \times 10^{-3}) = 0.15\ kg$

Mass of helium = 0.15kg

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Examiner Comments

This response uses the correct expression for the volume of a sphere, so MP1 is given. However, the temperature is not converted to kelvin. This means that the final answer is incorrect. However, MP2 can still be awarded, as all the other substitutions into the gas law equation are correct. The calculation of the mass of helium uses the correct method, so MP4 is scored. The total for this response is 3 marks.

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Examiner Tip

Before substituting convert Celsius temperatures to kelvin, unless a temperature difference is being calculated.

4 Helium is available in small metal canisters. The helium can be used to fill party balloons.

(a) A full canister contains helium gas at a temperature of 18.5°C and a pressure of 1.65×10^7 Pa. The canister is approximately spherical, with a radius of 4.36×10^{-2} m.

Calculate the mass of helium gas in the full canister.

mass of 6.02×10^{23} atoms of helium = 4.00×10^{-3} kg

(5)

$V = \frac{NkT}{p}$ $\frac{6.02 \times 10^{23} \times 1.38 \times 10^{-23} \times (18.5 + 273)}{1.65 \times 10^7}$

Vol He = 1.47×10^{-4} kg m^{-3}

Vol canister

$4/3 \pi r^3$

$= 4/3 \pi \, 4.36 \times 10^{-2\,3}$

$= 3.47 \times 10^{-4}$ kg m^{-3}

$\frac{3.47 \times 10^{-4}}{1.47 \times 10^{-4}} = 2.36$

mol He = $4 \times 10^{-3} \times 2.36$

$= 9.44 \times 10^{-3}$

Mass of helium = 9.44×10^{-3}

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Examiner Comments

This response scores 4 marks.

The method is correct and the final answer has the correct value. However, the units are omitted, and so MP5 is not given.

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Examiner Tip

Always include the units to final values in a calculation question.

4 Helium is available in small metal canisters. The helium can be used to fill party balloons.

(a) A full canister contains helium gas at a temperature of 18.5°C and a pressure of 1.65×10^7 Pa. The canister is approximately spherical, with a radius of 4.36×10^{-2} m.

Calculate the mass of helium gas in the full canister.

mass of 6.02×10^{23} atoms of helium = 4.00×10^{-3} kg

(5)

$PV = NkT$ $\quad 18.5 + 273 = 291.5\,K$

$N = \frac{PV}{kT} = \frac{1.65 \times 10^7 \times 3.47 \times 10^{-4}}{1.38 \times 10^{-23} \times 291.5\,K} = 1.42 \times 10^{24}$

Vol of sphere $= \frac{4}{3}\pi r^3$

$= \frac{4}{3} \times \pi \times (4.36 \times 10^{-2})^3$

$= 3.47 \times 10^{-4}\,m^3$

mol of He $= \frac{1.42 \times 10^{24}}{6.02 \times 10^{23}}$

$= 2.36$ mol

Mass of He $= 2.36 \times 4.00 \times 10^{-3}$ kg

$= 9.46 \times 10^{-3}$ kg

$n = \frac{m}{M_r}$

$m = n M_r$

Mass of helium = 9.46×10^{-3} kg

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Examiner Comments

This is a correct solution, scoring all 5 marks.

Question 4 (b)

Responses to this question indicated that the concept of upthrust seems unclear to many candidates. Few stated that the upthrust depends on the weight of the fluid displaced.

A surprising number seemed to think that helium has an upthrust even when under pressure inside the cylinder. Many candidates thought that helium is replaced by air in the cylinder and that the upthrust would change if there was air inside the cylinder.

Despite the misconceptions relating to upthrust, MP3 and MP4 were frequently awarded.

(b) Student X and Student Y discuss the weight of the canister and its contents after a number of balloons have been filled.

Student X suggests that the weight will have increased, because the upthrust exerted on the canister by the helium will be reduced.

Student Y suggests that the weight will have decreased, because helium has been released from the canister.

Assess which student's suggestion is correct.

(4)

$U = \rho_f V_s$

Student X: The upthrust = weight of the displaced fluid. ∴ In this case, the upthrust is the weight of the outside air displaced by the canister. Since the canister have a fixed volume, the upthrust does not change. ∴ The upthrust is dependent on the air outside.

Student Y: When helium has been let out, the no. of molecules inside the ~~atmosphere~~ canister decreases. ~~Thus~~ ∴ The mass decrease. Since $W = mg$, the weight decreases.

∴ Student Y is correct.

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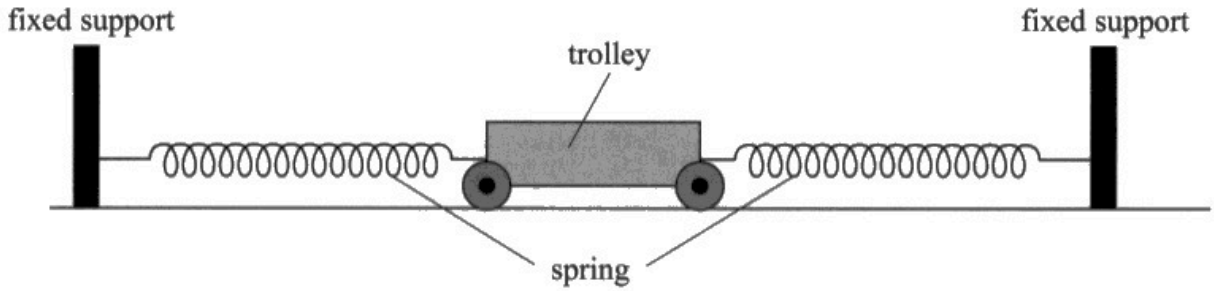
Examiner Comments

All the points in the MS are included in this response and so all 4 marks are awarded.

Question 5 (a)

All of MP1−MP5 were commonly credited, although MP6 was rarely credited. Quite a few candidates suggested that the marker should go on the trolley.

5 A student used springs to attach a trolley between two fixed supports, as shown.



When displaced horizontally, the trolley oscillated with simple harmonic motion.

To determine the time period T of oscillation of the trolley, the student displaced the trolley from its equilibrium position and released it. As she released the trolley, she started a stopwatch. She stopped the stopwatch when the trolley had returned to its starting point.

(a) Explain how the procedure used by the student to determine T could have been improved.

(6)

The student could have used a fiducial marker at the equilibrium point, as this is where the trolley's at its fastest, so it would be the easiest place to take a reference point. Also, the student could have used a countdown method, so they would know when to count the oscillations. The student could have increased the time period T (e.g 20 oscillations), as this means a greater time would have been measured, so the percentage uncertainty would have been reduced. The student could have used a data logger rather than a stopwatch to eliminate human reaction time, so the result would be more precise.

and divide by 20 to calculate the mean time period

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Examiner Comments

This response scores all 6 marks.

Note that there are two possible versions of MP6 included in this response. The reference to the trolley travelling fastest at the equilibrium point is not quite enough, as there is no mention of reaction time at this point. However, the reference to a datalogger does meet this MP, as reaction time is referenced here.

Question 5 (b)

Those candidates who substituted total mass = (M + m) into the mass on a spring equation usually went on to score full marks.

(b) The mass of the trolley was M. The student added a small mass m to the trolley and determined the new value of T. She repeated the procedure for a range of values of m.

She plotted a graph of T^2 against m.

Explain how she could use her graph to determine a value for M.

(4)

$T = 2\pi\sqrt{\frac{m+M}{k}}$

$T^2 = 4\pi^2 \times \frac{m+M}{k}$

$T^2 = \frac{4\pi^2}{k}m + \frac{M4\pi^2}{k}$

$y = mx + c$

y intercept of the graph is $\frac{M4\pi^2}{k}$

$M = \frac{y\text{ value of intercept} \times k}{4\pi^2}$

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This response scores 3 marks only.

The substitution into the mass on a spring expression and expansion is carried out correctly for MP1 and MP2.

Although the value of yje intercept is identified, there is no mention of the gradient and so MP4 is awarded, but not MP3.

(b) The mass of the trolley was M. The student added a small mass m to the trolley and determined the new value of T. She repeated the procedure for a range of values of m.

She plotted a graph of T^2 against m.

Explain how she could use her graph to determine a value for M.

(4)

$$T = 2\pi\sqrt{\frac{m}{k} + M}$$

$$T^2 = 4\pi^2 \times \frac{m + M}{k}$$

$$T^2 = \frac{4\pi^2 m}{k} + \frac{4\pi^2 M}{k}$$

This resembles the equation $y = mx + c$ where $\frac{4\pi^2}{k}$ is the gradient and $\frac{4\pi^2 M}{k}$ is the y intercept

(Total for Question 5 = 10 marks)

and $m = \frac{4\pi^2 m}{k}$

so $\frac{4\pi^2}{k}$ is the gradient. Use your value of the gradient to calculate k then find value of y intercept from graph. Use this value and your value for k to calculate M

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Examiner Comments

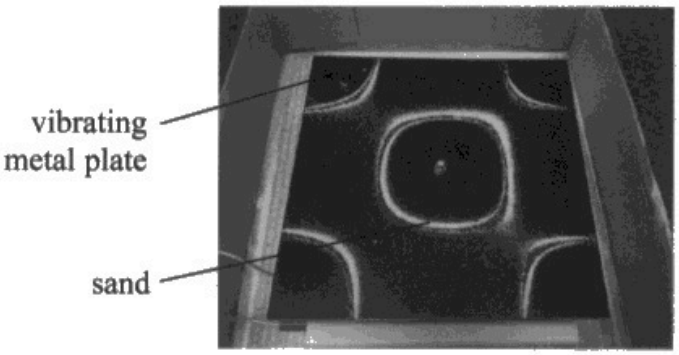
All 4 marks are scored here.

Question 6 (a)

Most candidates identified that the pattern consisted of nodes and antinodes then spent time describing how these were formed which was not required by the question. Candidates who then failed to score any more marks generally had incorrectly assumed the sand showed the positions of maximum displacement rather than being moved away from the antinodes.

6 Rosslyn Chapel is a 15th century chapel in Scotland. Inside the chapel, small sandstone cubes protrude from a number of arches. It has been suggested that carvings on these cubes bear a resemblance to standing wave patterns that can be produced on a vibrating metal plate.

A metal plate is made to vibrate and sand is scattered evenly across its surface. At a certain frequency the sand moves to produce the standing wave pattern shown below.



(Source: https://skullsinthestars.com/2013/05/02/physics-demonstrations-chladni-patterns/#jp-carousel-7353)

(a) Explain why the sand moves to different positions when a standing wave is formed on the plate.

(3)

< At nodes there is no displacement so when there is sand there it doesn't move and is stationary

- At antinodes there and any where that isn't a node there is displacement so the sand moves until it reaches a node & where it doesn't experience displacement

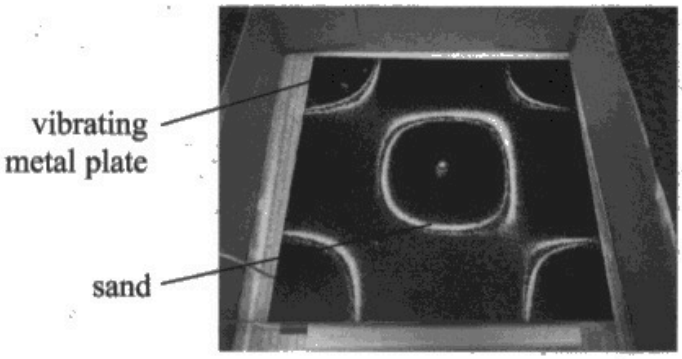
ResultsPlus
Examiner Comments

This response concentrates on why the sand moves due to the standing wave that is set up on the plate. It is clear regarding nodes and antinodes and sand settling at the nodes.

The response scores all 3 marks.

6 Rosslyn Chapel is a 15th century chapel in Scotland. Inside the chapel, small sandstone cubes protrude from a number of arches. It has been suggested that carvings on these cubes bear a resemblance to standing wave patterns that can be produced on a vibrating metal plate.

A metal plate is made to vibrate and sand is scattered evenly across its surface. At a certain frequency the sand moves to produce the standing wave pattern shown below.



(Source: https://skullsinthestars.com/2013/05/02/physics-demonstrations-chladni-patterns/#jp-carousel-7353)

(a) Explain why the sand moves to different positions when a standing wave is formed on the plate.

(3)

Standing wave is the Formed on the plate when coherent waves superpose. This occurs when produced sound waves interact with reflected sound waves. When the waves are in phase, constructive interference occurs and maximum amplitude wave is created, antinode. When waves are in antiphase, deconstructive interference occurs, no amplitude created this is a node. Sand is displaced by the by the amplitude of the the standing waves from the antinodes, to the nodes.

ResultsPlus
Examiner Comments

This response also scores 3 marks. It includes more detail than is necessary. The question is about where the sand settles and why, not about the production of a standing wave. Although the extraneous detail doesn't affect the total mark it wastes time.

ResultsPlus
Examiner Tip

Answer the question, not what you think the question might be.

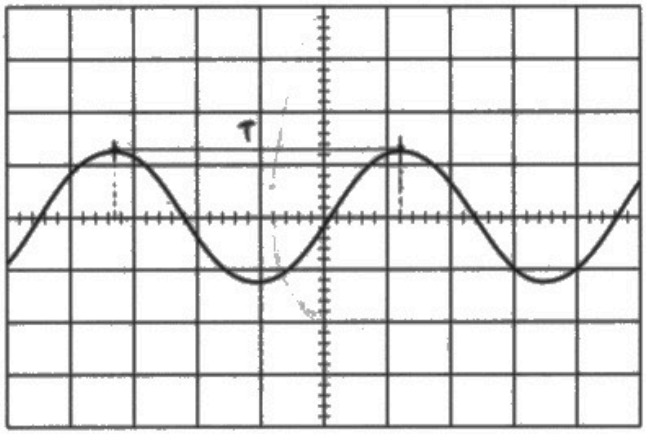
Question 6 (b)

Candidates who correctly read the trace on the oscilloscope trace generally went on to score full marks. Candidates who incorrectly read the trace generally correctly converted their misread divisions to a time, then a frequency, and determined a speed, scoring 3 marks.

Candidates should be encouraged to show their working, as it was not always easy to see the steps taken to get to MP2.

(b) The plate is set into movement by a vibration generator. The wavelength of the waves produced in the plate was estimated to be 0.32 m.

The signal applied to the vibration generator is shown on the oscilloscope trace below. The time base of the oscilloscope was set to 0.50 ms div^{-1}.



The waves produced in the plate travel at a speed much less than the speed of sound in air.

Evaluate whether the data supports a value for the speed of waves in the plate that is much less than the speed of sound in air.

speed of sound in air = 340 m s^{-1}

(5)

$\lambda = 0.32\,m \rightarrow T = 4.5$ divisions $= 4.5 \times (0.5 \times 10^{-3}) = 2.25 \times 10^{-3}$ s.

$f = \frac{1}{T} = \frac{1}{2.25 \times 10^{-3}} = 444.44$ Hz.

$v = \lambda f =$

$= 0.32 \times 444.44 = 142.22$ m/s.

142.22 m/s < 340 m/s.

Therefore yes, the data supports that a value for speed of waves in the plate is much less than the speed of sound in the air.

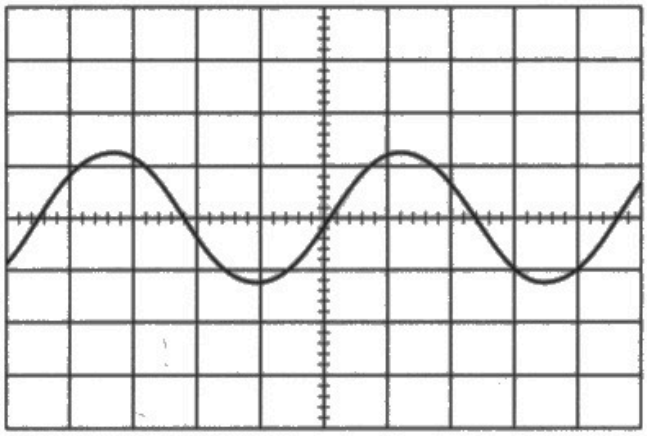
ResultsPlus
Examiner Comments

This response scores all 5 marks.

(b) The plate is set into movement by a vibration generator. The wavelength of the waves produced in the plate was estimated to be 0.32 m. λ

The signal applied to the vibration generator is shown on the oscilloscope trace below. The time base of the oscilloscope was set to 0.50 ms div^{-1}.

0.5×10^{-3}
t



The waves produced in the plate travel at a speed much less than the speed of sound in air.

Evaluate whether the data supports a value for the speed of waves in the plate that is much less than the speed of sound in air.

speed of sound in air = 340 m s^{-1}

(5)

$f = \frac{1}{T}$

$f = 2000$

$v = f\lambda$

$= 640 \text{ ms}^{-1}$ in plate

v

$\therefore$ speed of wave is much higher than speed of sound

ResultsPlus
Examiner Comments

It is possible that there is some valid physics being applied in this question. However, the final answer is incorrect, no substitutions are shown and so no process marks can be given. The response scores no marks.

ResultsPlus
Examiner Tip

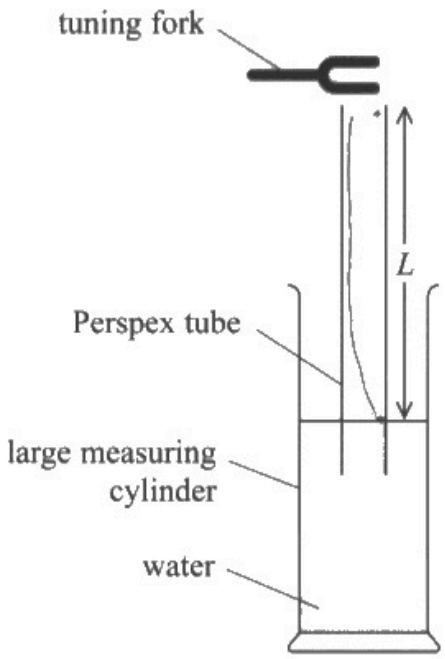
Always show your working and make it clear how you are using the relevant equations by showing your substitutions.

Question 6 (c)

This question was not well answered. Most candidates realised that the length of the air column was related to the wavelength and hence suggested plotting L against $1/f$ or f against $1/L$. The weakest responses just suggested a plot of L against f .

However, the most common error was to identify L as half a wavelength rather than a quarter of a wavelength.

(c) The speed of sound in air can be determined by creating a standing wave in a column of air. The diagram shows a tuning fork just above the open end of a tube.



The tuning fork produces a sound wave of known frequency *f*. Several tuning forks are available, each with a different frequency.

A student adjusted the length *L* of the air column. A loud sound was heard when a standing wave was produced. A node was formed at the water surface, and an antinode was formed at the open end of the tube.

The student used values of *L* and *f* to determine a value for the speed of sound.

Describe a graphical method that the student could have used to determine a value for the speed of sound.

(3)

$v = f\lambda \rightarrow \lambda = \frac{v}{f}$, $L = \frac{\lambda}{4}$

$L = \left(\frac{v}{4}\right) \times \frac{1}{f}$. Therefore, plot L against $\frac{1}{f}$ (which is a straight line). The gradient of this graph $= \frac{v}{4}$ so the speed of sound = 4 x gradient.

ResultsPlus
Examiner Comments

This is a correct solution. It is clearly set out and scores all 3 marks.

Question 7 (a)

Balancing this reaction is a very straightforward exercise, and the vast majority of candidates scored both marks. The small minority of candidates who could not recall the nucleon number or the proton number of the alpha particle usually scored zero, as they were likely to get both the top line and the bottom line wrong.

7 Radon is a radioactive gas. One isotope of radon, $^{220}_{86}Rn$, decays to polonium, Po, by emitting an alpha particle.

(a) Complete the nuclear equation for the decay of radon.

(2)

$$^{220}_{86}Rn \rightarrow \underset{84}{216}Po + \underset{2}{4}\alpha$$

ResultsPlus Examiner Comments

An example of one of the many correct responses.

7 Radon is a radioactive gas. One isotope of radon, $^{220}_{86}Rn$, decays to polonium, Po, by emitting an alpha particle.

(a) Complete the nuclear equation for the decay of radon.

(2)

$$^{220}_{86}Rn \rightarrow \underset{84}{116}Po + \underset{2}{4}\alpha$$

ResultsPlus Examiner Comments

Just 1 mark here for a correct bottom line. Although *A* and *Z* for the alpha are correct, the arithmetic for the top line is incorrect.

ResultsPlus Examiner Tip

Take time to check the arithmetic carefully when balancing equations.

7 Radon is a radioactive gas. One isotope of radon, $^{220}_{86}Rn$, decays to polonium, Po, by emitting an alpha particle.

(a) Complete the nuclear equation for the decay of radon.

(2)

$$^{220}_{86}Rn \rightarrow \ ^{219}_{85}Po + \ ^{2}_{2}\alpha$$

ResultsPlus
Examiner Comments

In this response the configuration of the alpha is not recalled correctly, and so no marks are scored.

ResultsPlus
Examiner Tip

Learn *A* and *Z* for alpha, beta particles.

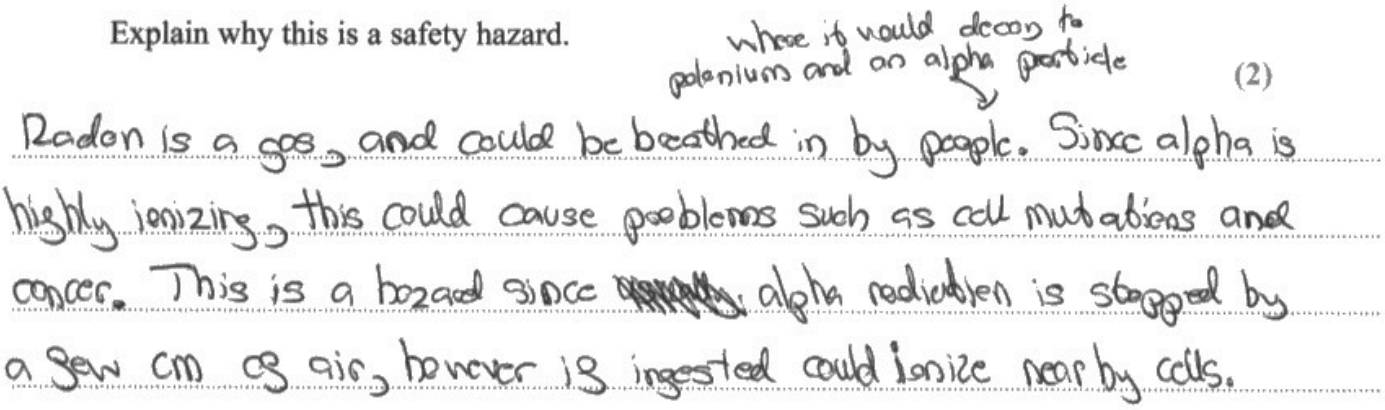
Question 7 (b)

Most responses were credited with MP2 for stating that alpha radiation is very ionising. It was less frequent for candidates to realise that, as a gas, radon can be breathed in where the alpha radiation can cause serious damage to living cells. Many responses simply referred to damage or cancers in a general way.

(b) Radon is produced in the ground and escapes into the atmosphere.

Explain why this is a safety hazard.

(2)



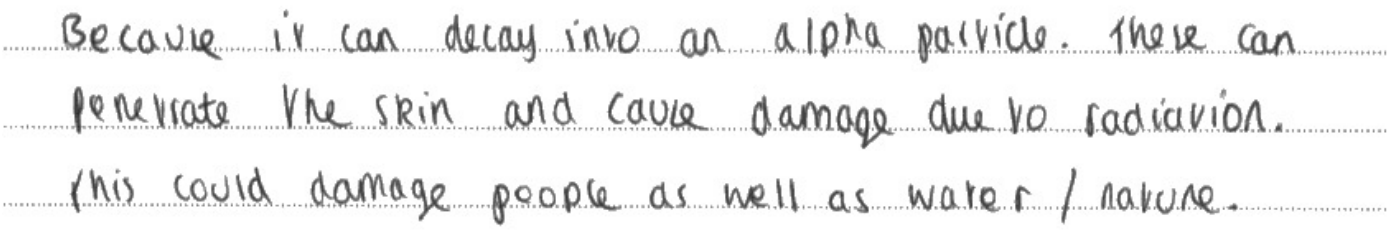
ResultsPlus
Examiner Comments

This is a very detailed response that scores both marks in the first two lines.

(b) Radon is produced in the ground and escapes into the atmosphere.

Explain why this is a safety hazard.

(2)



ResultsPlus
Examiner Comments

In this response the statement that alpha radiation can penetrate the skin is seen. This was a common misconception. In addition, there is no statement that alpha radiation is very ionising, so this response scores no marks.

(b) Radon is produced in the ground and escapes into the atmosphere.

Explain why this is a safety hazard.

(2)

It releases ionising radiation, which can ionise human body cells, alpha radiation is highly ionising

ResultsPlus
Examiner Comments

This response scores 1 mark for stating that alpha radiation is highly ionising. Note that the initial statement, "it releases ionising radiation", is not sufficient for this mark.

Question 7 (c)(i)

The idea of electrons being released by the ionisation process was very rare to see.

Most candidates ignored the high ionising power of alpha radiation. They simply stated that the current was caused by the alpha particles being positively charged and therefore attracted to the electrode.

Some candidates ignored the statement given in the stem of the question, that radon is an alpha emitter, and suggested that electrons were emitted in the decay of radon.

(i) Explain why a current is produced in the decay chamber.

(2)

Radon gas decaying produces alpha particles which are highly ionising & knock electrons out of gas particles in the decay chamber. These electrons are charge carriers and ~~flow~~ complete the circuit, allowing charge to flow. Therefore a current is produced.

ResultsPlus
Examiner Comments

This response is a rare example of 2 marks.

Question 7 (c)(ii)

This was well answered with the majority of candidates calculating the percentage of activity that remains and others calculating the time taken for the activity to fall to 1%.

Some candidates recognised that 450 s is just over 8 half lives, and went on to use the constant ratio rule to determine the activity after 8 half lives. Although this did not give an 'exact' answer, it was acceptable in this case and full marks could be scored using this method.

(ii) A teacher is demonstrating the operation of the decay chamber to her class. She squeezes the bottle to introduce radon into the chamber.

She claims that within 450 s the activity of the radon in the chamber will be less than 1% of its initial value.

Assess whether her claim is correct.

half-life of radon = 55.6 s

(3)

$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = 0.0125\ s^{-1}$

$A = A_0 e^{-\lambda t}$, $\ln A = \ln A_0 - \lambda t$, $t = \frac{1}{\lambda}\ln\left(\frac{A}{A_0}\right)$

$t = \frac{-1}{0.0125}\ln(0.01) = 370\ s$

$370\ s < 450\ s$ so the teacher is correct that with 450 s the activity will be less than 1% of initial

ResultsPlus Examiner Comments

This response scores full marks. Note that the exponential equation is expanded by taking logs before substituting values. This is done correctly in this response, but substitution of values into an incorrect log equation would not get MP2.

ResultsPlus Examiner Tip

"Use of" marks are given for relevant values substituted into a correct physical equation.

(ii) A teacher is demonstrating the operation of the decay chamber to her class. She squeezes the bottle to introduce radon into the chamber.

She claims that within 450 s the activity of the radon in the chamber will be less than 1% of its initial value.

Assess whether her claim is correct.

half-life of radon = 55.6 s

(3)

R = inital activity of Radon. $\frac{450}{55.6} = 8.09$

$\left(\frac{1}{2}\right)^8 = 3.9 \times 10^{-3}$

$3.9 \times 10^{-3} \times 100$

$= 0.39\%$

0.39% < 1% therefore her claim is likely to be correct.

As it would have decayed 8 times.

ResultsPlus
Examiner Comments

This response was given all 3 marks. Note that strictly the method should use $(1/2)^{8.09}$, but in this situation it was felt that approximating 8.09 to 8 was acceptable.

(ii) A teacher is demonstrating the operation of the decay chamber to her class. She squeezes the bottle to introduce radon into the chamber.

She claims that within 450 s the activity of the radon in the chamber will be less than 1% of its initial value.

Assess whether her claim is correct.

half-life of radon = 55.6 s

(3)

electrode produces an electric field

$A = A_0 \quad \lambda = \ln 2 / 55.6 = 0.01247$

$\Rightarrow A = A_0 e^{-\lambda t} \Rightarrow A/A_0 = e^{-\lambda t}$

$\Rightarrow \frac{A}{A_0} = e^{-(0.01247)(450)} = 3.6556 \times 10^{-3}$

$\Rightarrow \frac{A}{A_0} \times 100\% = (3.6556 \times 10^{-3}) \times 100\% = 0.3656\%$

after 450s the activity of the radon is ~~a~~ 0.36% of its initial value, so her claim is correct.

(Total for Question 7 = 9 marks)

ResultsPlus
Examiner Comments

This response follows the example of calculation given in the MS, and scores full marks.

Question 8 (a)

It was expected that the context outlined in the question would be familiar to most candidates, although it was clear that some candidates were approaching the situation for the first time.

It should have been clear from the stem that the modelling clay is propelled forwards when the 'spring gun' is fired. However, a small minority of candidates seemed to think that the spring gun made contact with the wooden bob.

Many candidates began their response by assuming that the clay was already moving and so had kinetic energy to begin with, so IC1 was often omitted.

Some candidates tried to discuss momentum conservation in the context of the 'spring gun', which was generally unhelpful

IC3, IC4 and IC5 were often credited, but many candidates thought that kinetic energy must be conserved for momentum to be conserved and so IC5 was often not credited, as the collision was incorrectly referred to as being elastic.

Most candidates stated that after the collision kinetic energy is transferred to GPE, but they usually failed to make it clear that at the maximum height all of the kinetic energy had been transferred to GPE.

8 A student investigated the behaviour of a pendulum. The student used a 'spring gun' to fire a small sphere of modelling clay at the wooden pendulum bob, as shown in Figure 1. The clay stuck to the pendulum bob, which swung to one side, as shown in Figure 2.

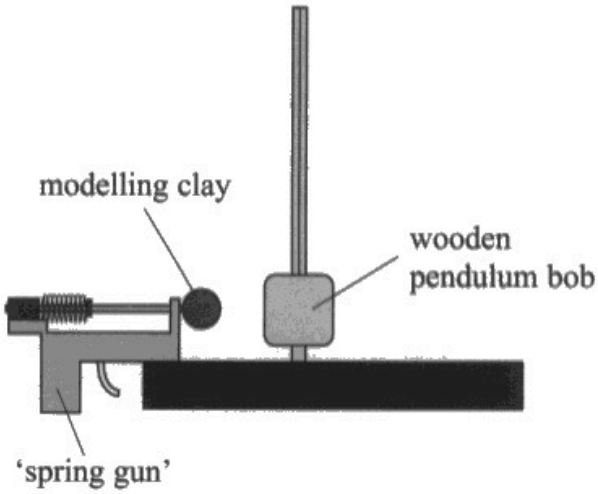


Figure 1

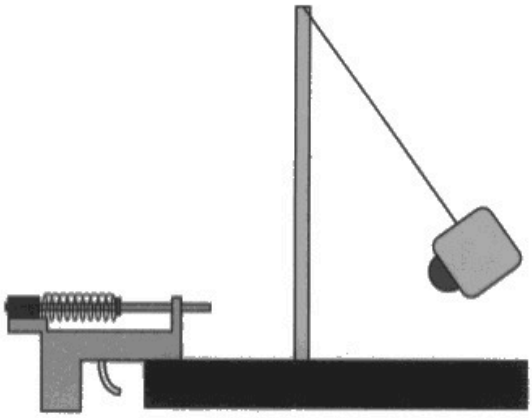


Figure 2

*(a) Describe how the principle of energy conservation and the principle of momentum conservation apply to this situation.

Consider the situation from the instant the spring gun is released to the instant the bob reaches its maximum height.

(6)

- When the spring gun is released, elastic potential energy, $E_{el} = \frac{1}{2}kx^2$, is converted to the kinetic energy of the clay, $E_k = \frac{1}{2}mu^2$.
- This then collides with the pendulum bob. The momentum of the clay directly before the collision, $p_i = mu$, must equal the momentum of the bob + clay after the collision, $p_f = (M+m)v$.
- The kinetic energy of the clay was not all transferred to the kinetic energy of the bob + clay system, since the collision was inelastic, so kinetic energy was not conserved. Total energy is conserved, since the kinetic energy lost was used to deform the clay, and also released as heat + sound energy.
- Then as the pendulum rises, its kinetic energy, $\frac{1}{2}(m+M)v^2$ is all converted to gravitational potential energy, $(m+M)gh$.

ResultsPlus
Examiner Comments

All 6 IC points are seen in this response and the sequencing is logical. Hence this response scores all 6 marks. Note that the language used is that of an energy conversion model, rather than an energy store or energy transfer model. This was not seen as a problem in this question – responses were seen in which each of these models was used. In each case credit was given.

Question 8 (b)(i)-(ii)

In part (i) most candidates scored all 3 marks by substituting the correct values into the simple pendulum equation and identifying that the time taken was equal to a quarter of a time period.

It was relatively common to award full marks for part (ii), although some candidates substituted $T/4$ instead of T into the mass on a spring equation. Some tried to use the simple pendulum equation again.

(b) When the modelling clay hits the pendulum bob, the pendulum swings to one side.

(i) Show that the time taken for the pendulum bob to move from its lowest position to its highest position is about 0.6 s.

effective length of pendulum = 1.25 m

(3)

~~period = 0.6 × 4 = 2.4 s~~

$T = 2\pi\sqrt{\frac{1.25}{9.81}} = 2.24\text{ s}$

lowest to highest position = $\frac{1}{4}$ of a period

$= \frac{2.24}{4} = 0.56\text{ s} \approx 0.6\text{ s}$

(ii) The pendulum bob was then attached to a spring of stiffness 0.12 N m^{-1}. When the bob was displaced vertically and released, it oscillated with a time period equal to that of the pendulum.

Calculate the mass of the pendulum bob.

(2)

$2.24 = 2\pi\sqrt{\frac{m}{0.12}}$

$m = 0.015\text{ kg}$

Mass of pendulum bob = 0.015 kg

ResultsPlus
Examiner Comments

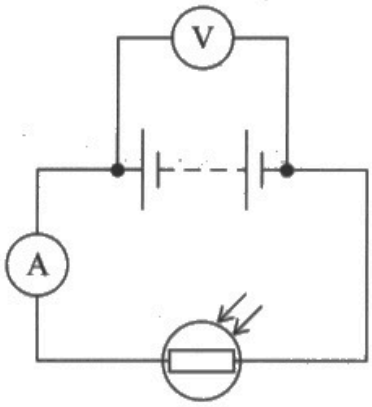
Each part is set out clearly, and the final answer is correct for (i) and (ii), so full marks for this response.

Question 9 (a)(i)

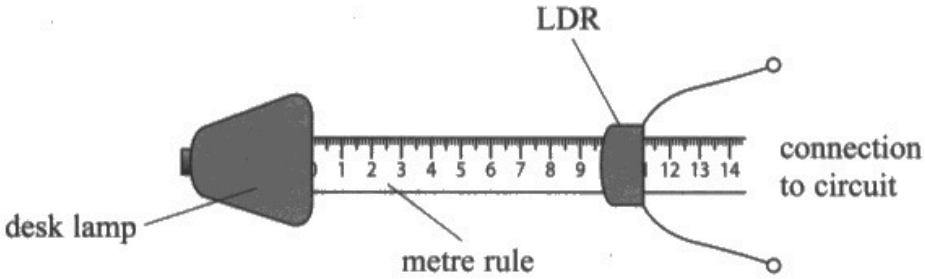
Most candidates recognised that the intensity followed the inverse square law, and many then went on to say that the light intensity would not increase uniformly. Most also realised that a larger range was also needed. MP3 was awarded least often, as many candidates struggled to express this clearly.

Candidates who did not score marks on this question often focused on errors with the experimental technique (eg no repeat measurements, not measuring the current, or not measuring the distance correctly) rather than the specific points mentioned in the student's method.

9 A student carried out an experiment with a light dependent resistor (LDR). He connected the LDR in series with an ammeter and a power supply, as shown in the circuit diagram.



The student placed the LDR a known distance from a desk lamp, as shown.



The student noted the reading on the ammeter as he brought the LDR closer to the lamp.

(a) The student planned to vary the intensity of light incident upon the LDR by adjusting the distance x between the LDR and the lamp.

$I \propto \frac{1}{d^2}$

He thought that the intensity of light on the LDR would increase uniformly if he decreased x by equal intervals. He therefore planned to take ammeter readings as he decreased x from 20.0 cm to 10.0 cm in equal intervals.

(i) Criticise the student's plan for data collection.

(3)

- Intensity is inversely proportional to distance squared.
- So intensity of light would NOT increase uniformly
- distance intervals too small leading to high percentage uncertainty each reading.
- ~~LDR~~ No evidence of taking repeat readings
- Too small range of distances

ResultsPlus
Examiner Comments

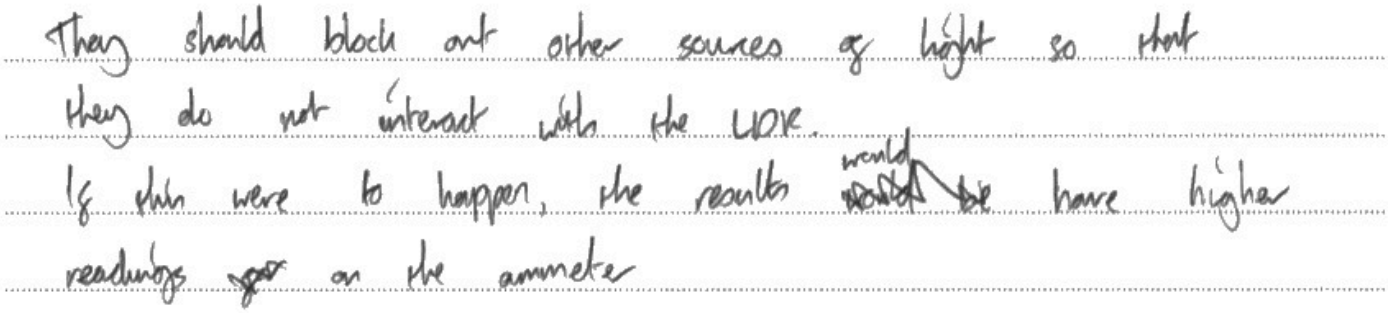
This response scores all 3 marks. The first line almost gives an incorrect statement (many responses were seen in which it was stated that intensity is proportional to distance squared), but the important word, "inversely", is added to the statement giving MP1. MP2 is then seen, and MP4 is given for "too small a range of distances" which is equivalent to stating that a greater range of distances should be used.

Question 9 (a)(ii)

A number of candidates scored both marks, usually by referring to taking measurements at eye level to reduce parallax error. Candidates who referred to taking multiple measurements and calculating a mean tended to score 1 mark, as they often stated that this removes/eliminates random error rather than reducing the effect of random error. Candidates who referred to factors affecting light intensity usually scored just 1 mark as they did not link this idea to how it would affect the ammeter reading.

(ii) Explain one precaution that the student should take to ensure that results are accurate.

(2)



ResultsPlus Examiner Comments

This response scores both marks. "Block out other sources of light" is equivalent to "subdued lighting", and the response goes on to state that if this wasn't the case the ammeter reading would be higher.

Question 9 (b)

Few students related the increase in *n* to the incident photons. Those candidates who did refer to photons, often repeated standard statements appropriate to a consideration of the photo-electric effect. Having established that the number density of free electrons increases, many responses went on to state that the resistance decreases. However, a change in resistance does not logically follow on from an increase in the number density of free electrons. Better responses connected $I = nAvq$ to the increase in current.

(b) Explain why the ammeter reading increased as the LDR was brought closer to the lamp. Your answer should include reference to the charge carriers in the LDR.

(3)

As intensity increases due to the photoelectric effect now more electrons are released as more photons interact with electrons when more electrons are released as electrons can carry a charge the number of charge carriers increases so using the formula $I = nqvA$ as q, v and A are constants as n increases I will also increase.

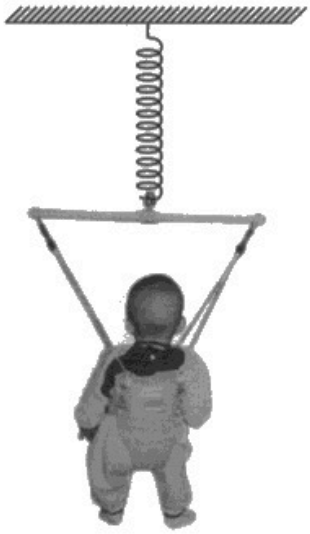
ResultsPlus
Examiner Comments

This response refers to the photoelectric effect rather than stating that electrons are promoted to the conduction band. This was seen in a number of responses. However, the idea that photons release electrons as charge carriers is enough for MP1. The response states that n increases and refers to $I = nAvq$, as so MP2 and MP3 can be given, hence this response scores full marks.

Question 10 (a)

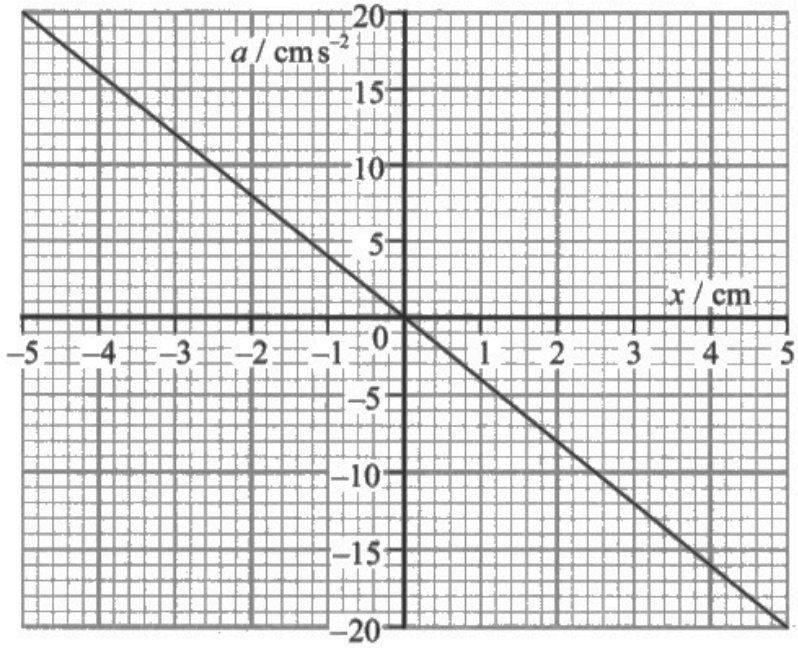
Most students were able to use the graph to establish the value of ω. The equation given in the data booklet for velocity is $v = -A\omega \sin \omega t$. Candidates need to realise that to find the maximum velocity, they must put $\sin \omega t = 1$. Most did so, but a minority tried to substitute values for ω and t into $\sin \omega t$. A small number of candidates tried to use the equations of motion.

10 A 'jumperoo' is a harness, suspended by a vertical spring, into which a baby can be placed, as shown.



The jumperoo is adjusted so that the baby's feet are a few centimetres above the floor. If the baby is then displaced downwards and released, he oscillates vertically.

(a) The graph shows how the acceleration a of the baby depends upon the displacement x of the baby from its equilibrium position.



For safety reasons, it is suggested that the maximum velocity of the baby should not exceed $0.5\,m\,s^{-1}$.

Assess whether it is safe for the baby to oscillate in the jumperoo with an amplitude of 22 cm.

(3)

~~At 22cm, a = 88cms^{-1}~~

$x = A\cos\omega t \qquad a = -\omega^2 x$

$20 = -(\omega)^2(-5)$

$\omega = 2\,cms^{-1}$

$v = -(22)(2)\sin 2$

$= 1.54\,ms^{-1}$ ∴ No, it is not safe.

ResultsPlus
Examiner Comments

This response scores 1 mark, for use of the shm acceleration equation. MP2 is not given, as for the maximum velocity $\sin\omega t = 1$. The final answer is incorrect and so MP3 is not given.

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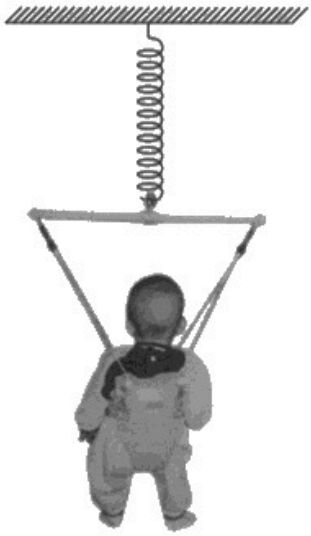

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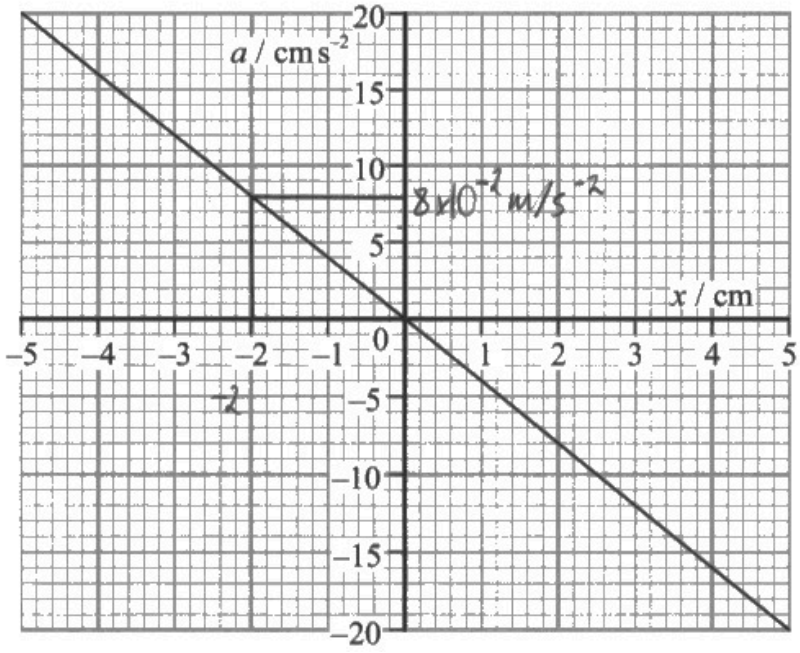


For safety reasons, it is suggested that the maximum velocity of the baby should not exceed $0.5\,m\,s^{-1}$.

Assess whether it is safe for the baby to oscillate in the jumperoo with an amplitude of 22 cm.

(3)

$a = -\omega^2 x$ $v = \omega r$ $T = \frac{2\pi}{\omega}$

$\omega^2 = \frac{8}{-2} = 4$ $\omega = 2$ $v = 2 \times 0.22 = 0.44\,ms^{-1}$

$0.44 < 0.5$ it is safe

ResultsPlus
Examiner Comments

This response scores all 3 marks.

Question 10 (b)

The quantitative connection between period and frequency for a mass on a spring was made by most, although fewer were able to quote the importance of the natural frequency to the problem.

(b) The amplitude of the oscillations quickly decreases, so the baby has to push down on the floor to maintain the oscillations.

When the baby pushes at a particular frequency, the amplitude of oscillation increases to a maximum.

A baby of greater mass is placed in the jumperoo.

This baby pushes on the floor at a frequency that produces a maximum amplitude of oscillation.

Explain how this frequency compares with the frequency of pushing of the original baby.

A calculation is not necessary.

(3)

- both babys oscillate at a natural frequency
- heavier baby has lower natural frequency
- as driving frequency approaches natural frequency, amplitude increases to maximum and is at resonant frequency when driving = natural
- $T = 2\pi\sqrt{\frac{m}{k}}$ so as m increases, T increases
- $T = \frac{1}{f}$ $f = \frac{1}{T}$ so as T increases, f decreases
- so heavier baby has lower frequency of pushing than original

(Total for Question 10 = 6 marks)

ResultsPlus
Examiner Comments

This response is detailed, and includes all of the MP, so it scores all 3 marks.

Question 11 (a)

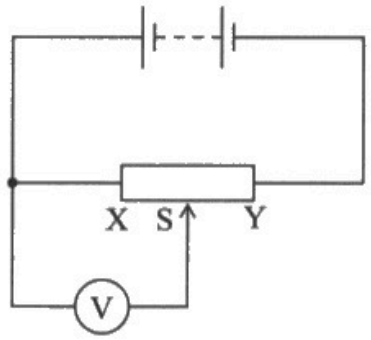
This question revealed that many candidates are unsure about the operation of a potential divider in a circuit.

MP3 was scored by most candidates, who stated that the reading on the voltmeter increased as the slider moved from X to Y. However, some candidates were under the impression that the voltmeter reading would decrease as the slider was moved from X to Y.

Many candidates stated that the resistance increased as the slider moved towards Y but didn't state that the resistance was proportional to the length, so they didn't score MP2.

Candidates often stated that the pd would be a minimum at X rather than 0 V so they didn't score MP1.

11 A student connected a voltmeter to a potential divider, as shown in the circuit diagram.



(a) The potential divider was adjusted by moving sliding contact S from position X to position Y.

Explain how the voltmeter reading V depends upon the position of S.

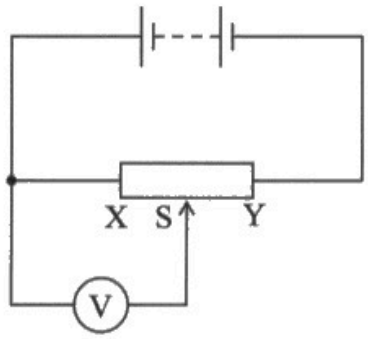
(3)

As the slider moves from X to Y the resistance of the potential divider increases directly proportionally to length. Therefore as $V = IR$, the potential difference at X is zero and is at its largest at point Y. ~~Therefore~~ Therefore the reading on the voltmeter ~~increasing~~ increases as the contact is moved from position X to position Y.

ResultsPlus
Examiner Comments

Although this response is quite minimalist in terms of its explanation of the action of a potential divider, there is enough detail for all 3 MP to be given. Hence this response scores all 3 marks.

11 A student connected a voltmeter to a potential divider, as shown in the circuit diagram.



(a) The potential divider was adjusted by moving sliding contact S from position X to position Y.

Explain how the voltmeter reading V depends upon the position of S.

(3)

- The resistance of the potential divider is determined by the position of S.
- The ratio of resistance is proportional to the ratio of the p.d. shared $\Rightarrow \frac{R_1}{R_2} = \frac{V_1}{V_2}$
- therefore as S moves from X where there is no resistance so $V = 0V$, to Y where resistance is max. so V is max. a reading

ResultsPlus
Examiner Comments

This response uses the idea of the terminal potential difference from the supply being shared in the ratio of the resistance. Although the sequencing of ideas could be a little clearer, there is enough here for all 3 marks.

Question 11 (b)

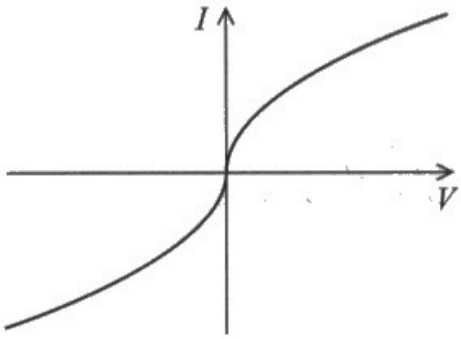
Many responses were descriptions rather than explanations of the shape of the graph.

The logical sequence of increasing V leading to increasing I, leading to higher temperature and therefore higher resistance, was missing from most answers.

Nonetheless, many candidates linked the increase in temperature of the filament lamp to the increase in current. Amongst lots of other statements, they then often linked the change in shape to the increase in resistance.

(b) A filament bulb and ammeter were connected to the potential divider. The potential divider was used to vary V across the filament bulb. The ammeter gave the corresponding current I in the filament.

I varied with V, as shown in the graph below.



Explain the shape of the graph.

(2)

It shows that as voltage increases, so does current. However, the rate at which they both increase changes and is not constant.

ResultsPlus Examiner Comments

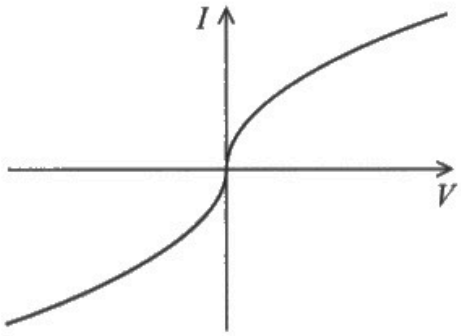
This response describes rather than explains the shape of the graph. The response scores zero, in common with many similar responses in which the shape of graph was described.

ResultsPlus Examiner Tip

Pay attention to the command word – "explain" requires reasoning, unlike "describe".

(b) A filament bulb and ammeter were connected to the potential divider. The potential divider was used to vary V across the filament bulb. The ammeter gave the corresponding current I in the filament.

I varied with V, as shown in the graph below.



$R = \frac{V}{I}$

Explain the shape of the graph.

(2)

The shape of the graph is an S-shape this is because at extremely low voltages ohms law is obeyed but as voltage increases ohms law isn't obeyed as voltage isn't directly proportional to current. As current increases, the filament in bulb heats up causing increased amplitude in oscillations of the ions in lattice and increased collisions with electrons so resistance increases causing the gradient to be less steep as gradient = $\frac{1}{R}$. (as current & voltage increases)

ResultsPlus
Examiner Comments

The first 3 lines of this response do not gain any credit. However, MP1 is seen in line 4, and MP2 is seen in line 6, hence this response scores full marks.

Question 11 (c)(i)

Carrying out the log expansion was managed by the majority of candidates. Making the explicit connection between the terms in the equation they produced and the general form was less frequently seen.

(c) The temperature T of the filament varies with the potential difference V across the filament according to the expression

$$T = aV^b$$

where a and b are constants.

(i) Explain why a graph of log T against log V would give a straight line. (2)

$\log T = \log a + \log V^b$

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

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

$y = mx + c$

$y = \log T$

$b = m$

$\log V = x$

$\log a = c$

ResultsPlus
Examiner Comments

The log expansion is done correctly, and the equation is compared with the equation of a straight line, $y = mx + c$.

The specific links between the two equations are given, with b = m being deemed sufficient for identifying b as the gradient, hence this response scores both marks.

Question 11 (c)(ii)-(iii)

In part (i) most candidates completed the table correctly. The majority used $\log_{10}$, but a small number used natural logs. Either was equally acceptable.

Axes were incorrectly labelled in almost half of the responses seen.

In many responses labelling such as log *V* / V and log *T* / K was used. In such cases it is unclear whether the log of the quantity is being divided by the units of the quantity or if the log is being taken of the log of the quantity divided by its units. This matters, because the $\log_{10}$ of a quantity is a power of 10 and therefore has no units.

The correct labelling is log (*V*/V) and log (*T*/K).

Too many candidates chose scales which were too small and meant that the plotted points didn't occupy at least 50% of the grid.

Awkward scales which are difficult to use when plotting/reading points were also chosen by some. The inability to use the chosen scale was also demonstrated frequently.

In drawing a line of best fit a number of responses were seen in which the drawn line was forced to go through a false origin. Candidates should aim for a balanced spread of off-line points on either side of the drawn line. If a point is identified as an outlier and therefore not used to estimate the line of best fit, then this should be clearly indicated.

The majority of lines were drawn well, although occasionally the line of best fit was too thick to award this mark. A small number had double lines, or lines with a discontinuity. Some even drew lines that were not straight.

In part (iii) most earned MP1, but a small proportion of responses did not gain this mark due to too small a triangle being used. Candidates should make sure that the points chosen for the gradient calculation make use of at least half of the drawn line. Using numbers from the table is only acceptable if the points selected lie on the line of best fit.

Awkward and inappropriate scales often resulted in misreading coordinates and a value for the gradient which is out of range.

(ii) Data for T and V is shown in the table below.

T/K	V/V	log(T/K)	log(V/V)
1480	5.03	3.170	0.702
1680	6.89	3.225	0.838
1850	8.95	3.267	0.952
2010	11.11	3.303	1.046
2140	12.94	3.330	1.112
2280	15.06	3.358	1.178

Plot a graph of log T against log V on the grid opposite. Use the extra columns provided to show any processed data.

(5)

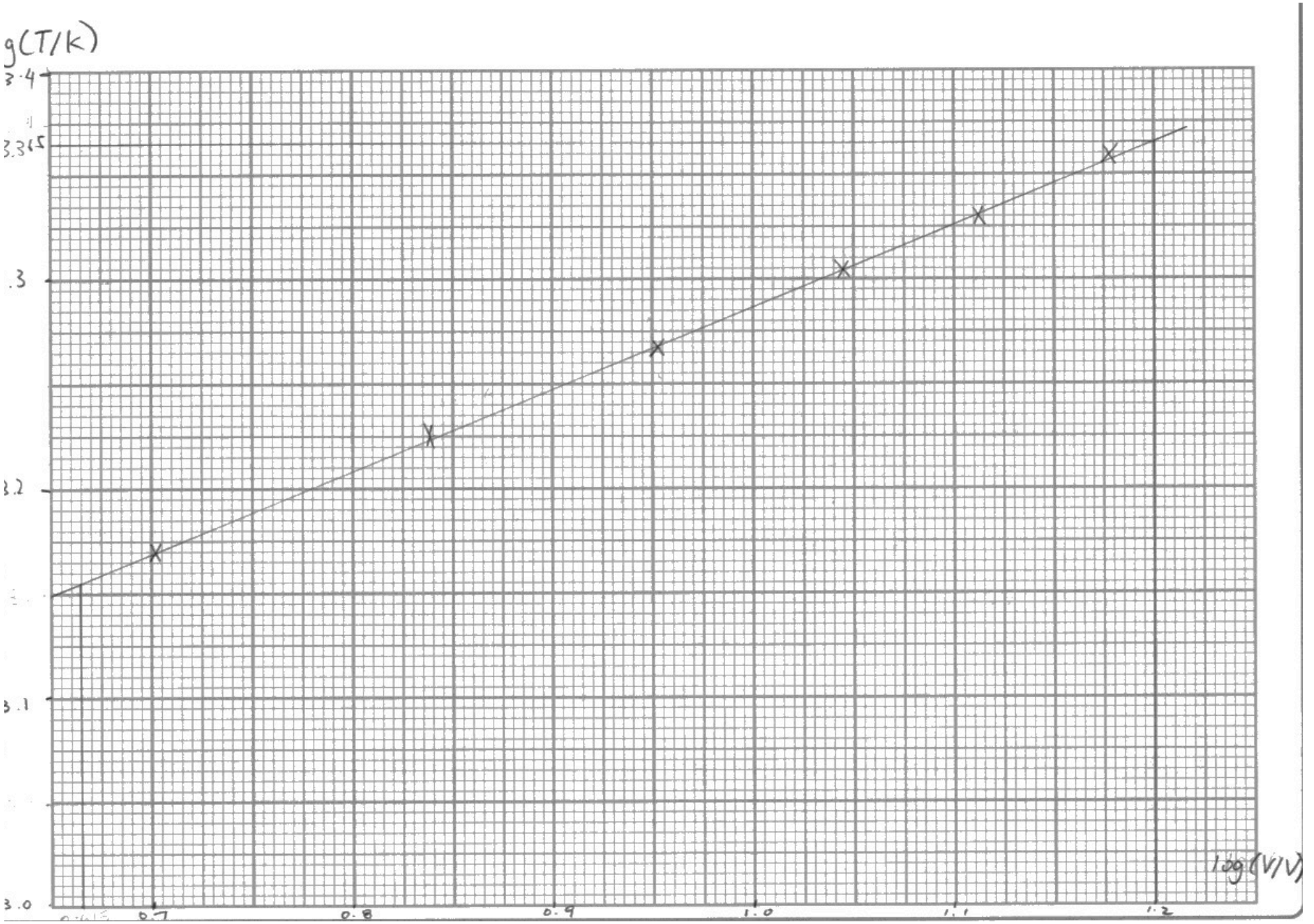
(iii) Determine a value for b using your graph.

(2)

$m = \frac{3.365 - 3.155}{1.2 - 0.665} = \frac{42}{107} = 0.3925233...$

$= 0.393$ (3sf)

$b =$ 0.393 (3sf)


log(T/K)
3·4
3.315
.3
3.2
3.1
3.0
0·7
0·8
0·9
1·0
1·1
1·2
log(V/V)

ResultsPlus
Examiner Comments

This response scores full marks for both parts.

The log values in the table are correct to 3 decimal places. The labels on the graph axes are correct, the grid has been rotated to fit the data, and the scales chosen are easy to read. Points are plotted correctly, and the spread of points covers just over half of the space on the grid. The line of best fit is acceptable.

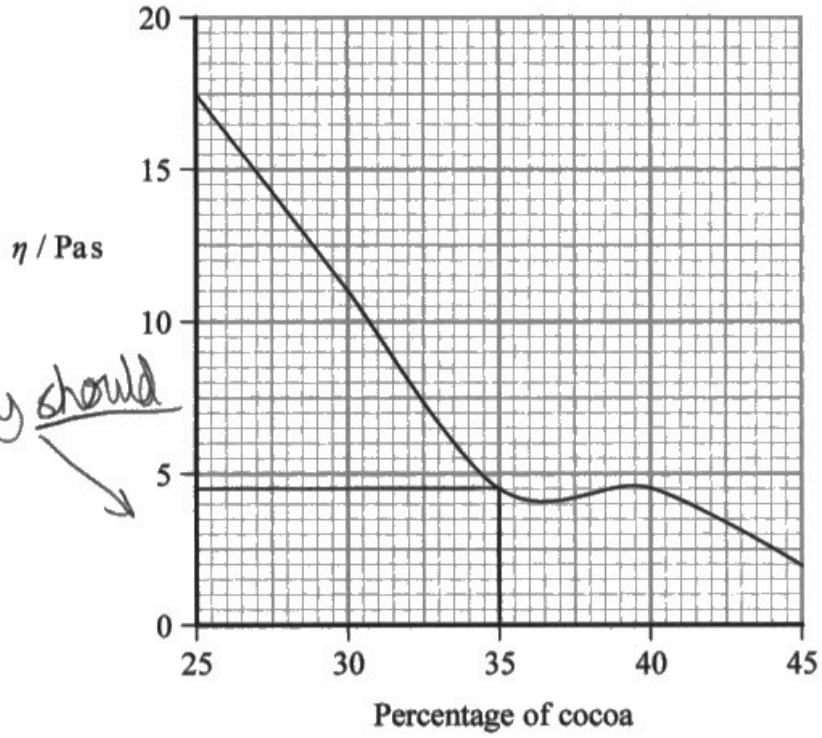
A large triangle is used for the gradient calculation, and the calculated value is within range and given to 3 significant figures.

Question 12 (a)(i)

Many good responses were seen. A small number of students misread the graph. Some candidates did not make a clear conclusion.

In some responses there was no evidence of a mean time being determined. In such cases candidates seemed to have decided to ignore 9.9 s as an anomalous value and just used 9.6 s. It should be noted that in a data set which only contains 3 values, it is practically impossible to decide if any of the points are anomalous.

The graph is taken from a commercial website. It shows how, at the temperature of the experiment, η depends on the percentage of cocoa in the chocolate.



Viscosity should =4.5

The chocolate wrapper indicated that the chocolate had a 35% cocoa content.

Assess whether the student's timing data supports this percentage cocoa content.

$r = 4.25 \times 10^{-3}$ m
$\rho_B = 7750\,\text{kg m}^{-3}$
$\rho_C = 1330\,\text{kg m}^{-3}$

Mean $t = \frac{9.6_8 + 9.9_8 + 9.6_8}{3} = 9.7_8$

(5)

$\eta = \frac{2r^2 g(\rho_B - \rho_C)}{9v} = \frac{2(4.25\times10^{-3})^2 \times 9.81(7750-1330)}{9\times(0.02319...)}$

$= 10.89829...$ Pas

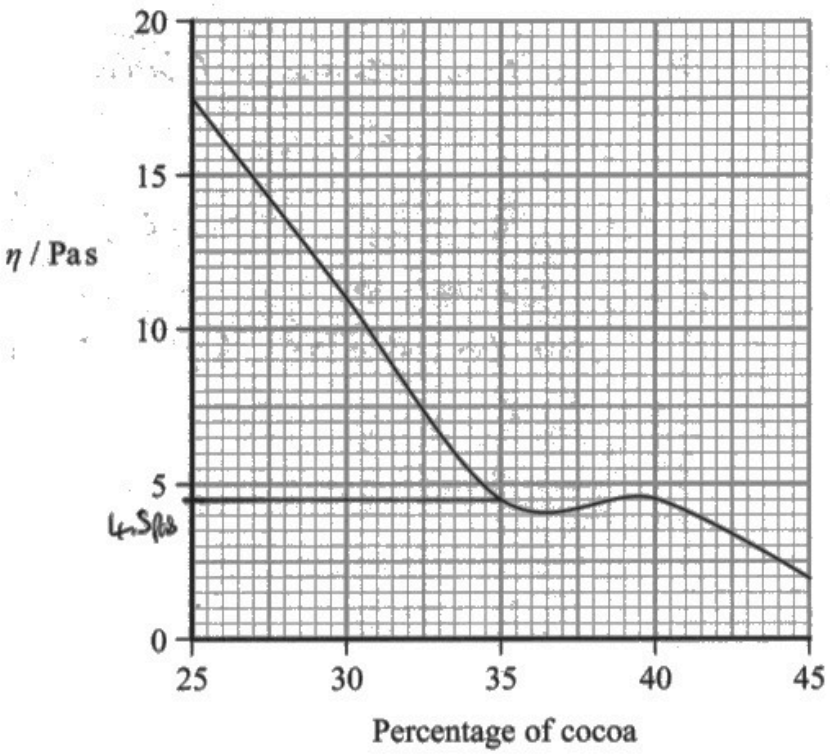
$10.89829\,\text{Pas} \neq 4.5\,\text{Pas}$

= The student's timing data does not support the indicated cocoa percentage.

ResultsPlus
Examiner Comments

This response scores full marks. The response includes all the required stages leading to a correct final value. The conclusion is clear.

The graph is taken from a commercial website. It shows how, at the temperature of the experiment, η depends on the percentage of cocoa in the chocolate.



The chocolate wrapper indicated that the chocolate had a 35% cocoa content.

Assess whether the student's timing data supports this percentage cocoa content.

$r = 4.25 \times 10^{-3}$ m
$\rho_B = 7750\,kg\,m^{-3}$
$\rho_C = 1330\,kg\,m^{-3}$

(5)

4.5 Pas $\quad v = \dfrac{2 \cdot (4.25 \times 10^{-3})^2 \cdot 9.81 (7750 - 1330)}{9 \cdot 4.5}$

$v = 0.0562\ ms^{-1}$ $\quad 22.5\,cm = 0.225\,m$

$v = \dfrac{d}{t}$ $\quad \dfrac{d}{v} = t$ $\quad \dfrac{0.225}{0.0562} = 4.005$

~~4 ≠ 9.6~~

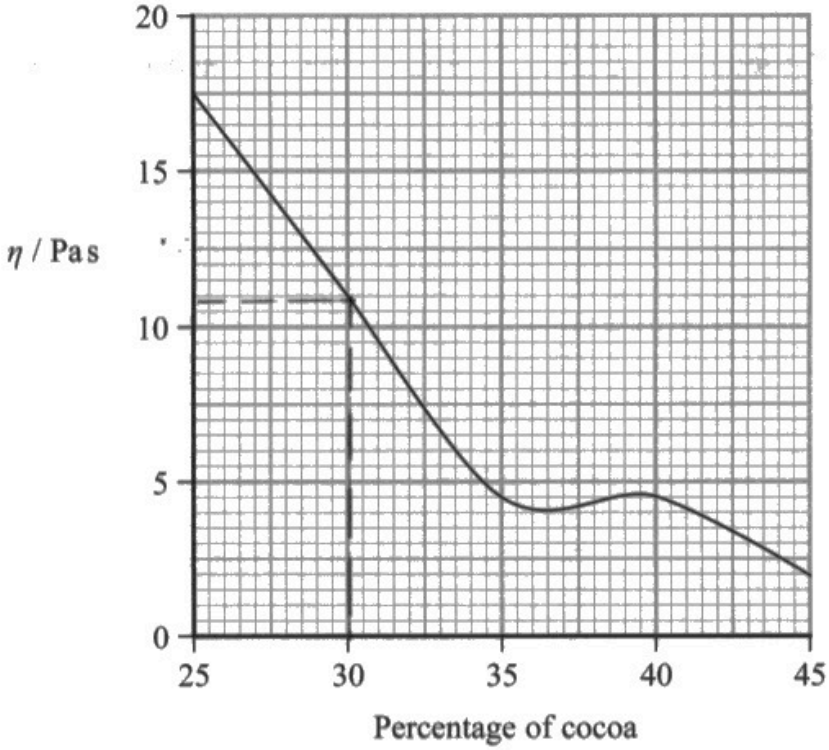
$\dfrac{9.6 + 9.9 + 9.6}{3} = 9.7$

$4 \neq 9.7$ ∴ no the students data does not support this percentage cocoa content.

ResultsPlus
Examiner Comments

This response follows an alternative route, but calculates a correct value of time and gives a conclusion by comparing this time with the mean of the times given in the question. The response scores all 5 marks.

The graph is taken from a commercial website. It shows how, at the temperature of the experiment, η depends on the percentage of cocoa in the chocolate.



The chocolate wrapper indicated that the chocolate had a 35% cocoa content.

Assess whether the student's timing data supports this percentage cocoa content.

$r = 4.25 \times 10^{-3}\,\text{m}$
$\rho_B = 7750\,\text{kg m}^{-3}$
$\rho_C = 1330\,\text{kg m}^{-3}$

(5)

$V = \dfrac{2\times(4.25\times10^{-3})^2\times9.81\,(7750-1330)}{9\eta}$

$s = \dfrac{d}{t}$ $\quad s = \dfrac{22.5\times10^{-2}}{9.7}$ $\quad t = \dfrac{9.6+9.9+9.6}{3} - 9.7$

$= 0.023196$

$0.023196 = \dfrac{2.2751597}{9\eta}$

$\eta = 10.898$

$= 10.90 \Rightarrow 30\%$ cocoa $<$ 35% cocoa

$\therefore$ doesn't support

ResultsPlus
Examiner Comments

Another response scoring full marks. This time the route to the conclusion is slightly different again.

Question 12 (a)(ii)

A reasonable number of candidates fixated on the impact of the rod rather than anything else. This led to the idea of the flow not being laminar or turbulent but they then failed to link this to the impact turbulent flow would have on the velocity. A lot of candidates who mentioned the temperature merely stated that the temperature might have been different from the temperature of the commercial data.

(ii) Explain one reason why the student's data may have led to an inaccurate conclusion about the cocoa content.

(2)

reaction time error when measuring the time so the actual time is smaller to travel 22.5 cm. Therefore, the terminal velocity is greater than the one calculated.

ResultsPlus
Examiner Comments

Reaction time error is stated for the first MP of the first alternative in the MS. This is then expanded to conclude that the actual terminal velocity would be greater than the calculated value for the second MP in the first alternative in the MS.

(ii) Explain one reason why the student's data may have led to an inaccurate conclusion about the cocoa content.

(2)

~~22~~ There could be extra drag forces acting on the ball due to the rod attached to it meaning it will have a smaller value of terminal velocity.

ResultsPlus
Examiner Comments

Extra drag forces leading to a smaller terminal velocity scores both marks via the second alternative in the MS.

(ii) Explain one reason why the student's data may have led to an inaccurate conclusion about the cocoa content.

(2)

~~The ball may not have reached terminal~~ velocity, ~~T_2 may have been an anomaly~~, leading to a smaller ~~s~~ Stokes ~~The ball~~ may have ~~not~~ reached terminal velocity ~~Chocolate may have hot~~ Temperature of the chocolate may have been lower at the centre of the cylinder, leading to a higher viscosity / temperature not the same throughout as the student is not stirring as it would disrupt the laminar flow which would prevent Stokes law from applying

ResultsPlus
Examiner Comments

This response gives the idea of the temperature not being constant, and hence the viscosity varying, so gains both marks from the first version in the MS.

Question 12 (b)

This was answered well by most candidates. Common errors were not using correct masses, not calculating a temperature difference, adding 273 to a temperature change, and not making a numerical comparison as part of their conclusion.

(b) One type of chocolate melts at a temperature of 32°C.

The energy released when 65 g of this chocolate is digested is 345 kcal.

It is suggested that the energy used to melt a piece of this chocolate is at least 15% of the energy released when the chocolate is digested.

Assess the accuracy of this suggestion.

initial temperature of chocolate = 15°C
specific heat capacity of chocolate = 3.9×10^3 J kg^{-1} K^{-1}
specific latent heat of chocolate = 1.50×10^5 J kg^{-1}
1 kcal = 4200 J

(6)

$345 \times 4200 = 1449000$ $1449000 \times 0.15 = 217350$J

$E = mc\Delta C$ $E = L4m$ 0.065

$\rightarrow 1.5 \times 10^5 \times 65 = 9750$

b

$0.065 \times 3.9 \times 10^3 \times (32-15) = 4309.5$J

$4309.5 + 9750 = 14,059.5$J

$217350 > 14,059.5$ therefore may less than 15% of the energy released by digestion.

∴ claim is inaccurate / not correct.

ResultsPlus
Examiner Comments

All the steps in the calculation are shown in a logical order, and there is a detailed conclusion that includes a comparison, hence this response scores full marks.

(b) One type of chocolate melts at a temperature of 32°C.

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specific heat capacity of chocolate = 3.9×10^3 J kg^{-1} K^{-1}
specific latent heat of chocolate = 1.50×10^5 J kg^{-1}
1 kcal = 4200 J

(6)

Energy used to melt chocolate:

$E_{total} = mc\Delta\theta + L_f m$

$= (0.065)(3.9 \times 10^3)(32 - 15) + (1.5 \times 10^5)(0.065)$

$= 14059.5$ J

Energy released by the chocolate:

345 kcal $= 345 \times 4200$

$= 1449000$ J

$\frac{14059.5}{1449000} \times 100 = 0.9702848...$

$= 0.97\%$

$0.97\% < 15\%$ so the suggestion is extremely inaccurate

ResultsPlus
Examiner Comments

Another correct calculation with a detailed conclusion scoring full marks.

Paper Summary

Based on their performance on this paper, candidates should:

- Ensure they have a thorough knowledge of the physics' content of the whole specification.
- Be ready to apply their knowledge of core practicals and general techniques to questions testing their indirect practical skills.
- Read each question carefully, and answer what is asked.
- Show all workings in calculations.
- Make a note of the marks available and include that number of different physics points in their response.
- Try to base the answer around a specific equation or principle. Formulate a response that is consistent with the command word used in the question.

Grade boundaries

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

https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html

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