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June 2023

GCE Physics 9PH0 03

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June 2023

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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 across the range of marks.

There was a mixed response to the two linkage questions in this paper. Q04 tended to generate better responses than Q07(a). In particular, the responses to Q04 were an improvement to responses seen for linkage questions in previous series. In this question candidates were able to demonstrate an improved ability to link ideas coherently to the context provided in the question.

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 a proportion of 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 years' examination.

There were instances where candidates disadvantaged themselves by not using suitably precise language. This was particularly the case in some of the questions testing indirect practical skills, where candidates had knowledge of the method but could not express it accurately and succinctly.

Some candidates did not seem to understand the language and processes of quantifying uncertainties in practical work. In particular, some candidates struggled to use the terms 'resolution' and 'uncertainty' correctly, and there was general unfamiliarity with the process of combining uncertainties in sums and differences.

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.

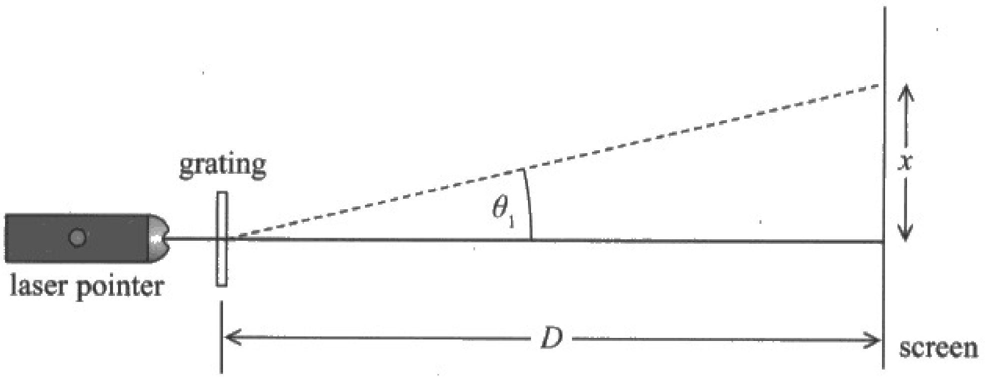
Question 1 (a)

This question was answered reasonably well, with a variety of different approaches seen. The most commonly seen correct responses calculated a value for *d*, *θ*, *l*, or the number of lines per mm. A minority of candidates chose to calculate that the fringe spacing was close to 43.5cm. All of these approaches were valid and could lead to full marks.

The main issue was candidates not realising what *n* and *d* stood for in the diffraction grating equation. It was relatively common for n to be taken as the number of lines per mm, and in quite a few responses *d* was taken as the distance from the slits to the screen. Many candidates struggled with the idea that *d* = 1/(number of lines m^{-1}) when substituting into the equation.

This response scored full marks.

1 A student used a laser pointer to direct monochromatic light normal to the plane of a diffraction grating as shown.



A diffraction pattern was produced on the screen. The distance between the first order maximum and the central maximum of the diffraction pattern was x. The distance between the diffraction grating and the screen was D.

(a) The diffraction grating had 300 lines per mm.
The laser pen was marked with $\lambda = 520\,\text{nm}$.

Determine whether the spacing of the diffraction pattern was consistent with these values.

$x = 43.5\,\text{cm}$
$D = 2.75\,\text{m}$

(4)

$\tan\theta = \dfrac{43.5\times10^{-2}}{2.75}$ $\theta_1 = 8.99°$

$n\lambda = d\sin\theta_2$

$520\times10^{-9} = \dfrac{1}{300000}\sin\theta_2$

$\theta_2 = 8.97°$

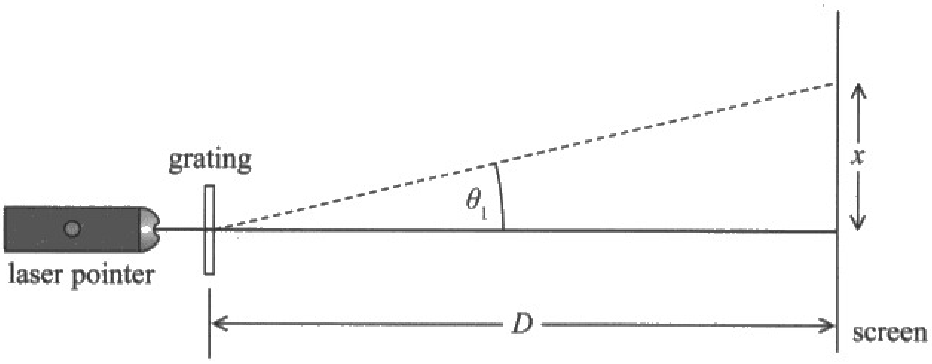
Consistent to 1 dp.

ResultsPlus Examiner Comments

All the elements of the numerical problem are present, and a valid conclusion is drawn.

This response scored 3 marks.

1 A student used a laser pointer to direct monochromatic light normal to the plane of a diffraction grating as shown.



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Determine whether the spacing of the diffraction pattern was consistent with these values.

$x = 43.5\,\text{cm}$
$D = 2.75\,\text{m}$

(4)

$\frac{1}{300 \times 10^3} = 3.33 \times 10^{-6}$

$\tan\theta = \frac{x}{D}$ $\quad \tan\theta = \frac{43.5 \times 10^{-2}}{2.75} \Rightarrow \theta = 8.989$

$n\lambda = d\sin\theta$

$\frac{1(520 \times 10^{-9})}{\sin\theta} = d$

$\frac{1(520 \times 10^{-9})}{\sin(8.99)} = 3.328 \times 10^{-6}$

∴ spacing of diffraction pattern was consistent with these values

ResultsPlus
Examiner Comments

All the elements of the numerical problem are present, and a valid conclusion is drawn. However, no units are given for the calculated quantities.

ResultsPlus
Examiner Tip

Always give units for a final answer in a calculation.

Question 1 (b)

The majority of responses scored at least 2 marks here, usually for knowledge of definitions for accuracy and precision. It was pleasing to see so many responses in which these were clearly defined.

Mark Point 1 was less prevalent and there was some confusion of resolution with uncertainty. The scale on a measuring instrument has a resolution, which is the size of the smallest interval on the scale. A measurement made with the instrument has an uncertainty, which is half of the resolution of the instrument for a single measurement. Another common misconception was that a metre rule has a resolution of 1cm.

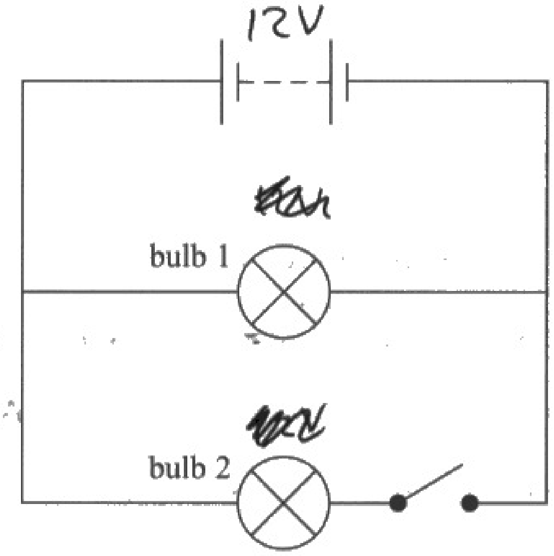
Question 2 (a)

This was very poorly answered with only a few examples scoring all 4 marks. In a large number of responses equations were used to calculate a current of 3.33A. This was then used in $\varepsilon = V + Ir$ to calculate an incorrect terminal potential difference of 10.3V. A number of candidates calculated a value of 13.7 V for the terminal potential difference and were unconcerned that this value was larger than the e.m.f.

Most candidates failed to realise that although the potential difference across the bulb would be a little less than 12 V, the resistance of the bulb would still be its working resistance. This is despite the instruction given in the question that candidates should assume that the resistance of the bulb has its normal working value.

This response scored full marks.

2 A battery has an e.m.f. of 12 V and an internal resistance of 0.50 Ω. The battery is connected into a circuit, as shown.



Each bulb has a normal working power of 40 W when a potential difference (p.d.) of 12 V is applied.

(a) Initially the switch is open.

Calculate the terminal p.d. of the battery when bulb 1 is lit. Assume that the resistance of the bulb has its normal working value.

(4)

$\mathcal{E} = I(R+r) \therefore \mathcal{E} = V + Ir \therefore V = \mathcal{E} - Ir$

$P = IV = \frac{V^2}{R} \therefore R_{bulb} = \frac{12^2}{40} = 3.6\,\Omega$

$I = \frac{V}{R_t} = \frac{12}{3.6+0.5} = \frac{120}{41} = 2.93\text{ A}$

$V = 12 - \frac{120}{41} \times 0.5$

$= 10.5366\text{V}$

$= 11\text{V}$

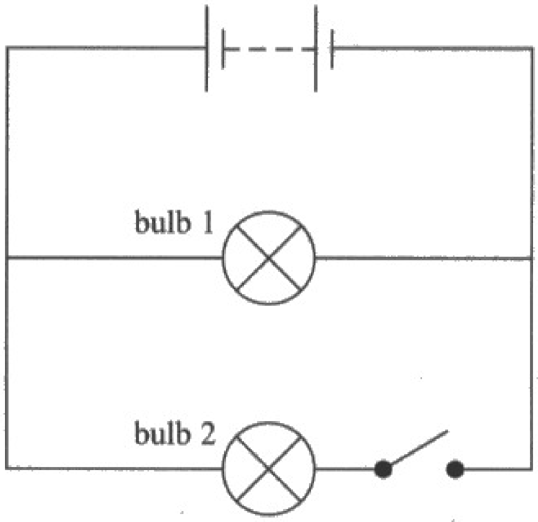
Terminal p.d. of battery = 11 V

ResultsPlus
Examiner Comments

The response closely follows the standard solution given in the mark scheme. Note that the value given in the answer prompt would be sufficient, as data in the question is generally given to 2 significant figures. However, there is no doubt that the calculation has been performed correctly, as the mark scheme answer of 10.5 V is given just above the answer prompt.

This response scored full marks.

2 A battery has an e.m.f. of 12 V and an internal resistance of 0.50 Ω. The battery is connected into a circuit, as shown.



Each bulb has a normal working power of 40 W when a potential difference (p.d.) of 12 V is applied.

(a) Initially the switch is open.

Calculate the terminal p.d. of the battery when bulb 1 is lit. Assume that the resistance of the bulb has its normal working value.

(4)

$P = IV = V^2/R$

[illegible]

$R = \frac{12^2}{40} = 3.6\,\Omega$

$3.6 + 0.5 = 4.1$ $\frac{12}{4.1} \times 3.6 = 10.5\text{V}$

Terminal p.d. of battery = 10.5 V

ResultsPlus
Examiner Comments

This response uses the potential divider idea in formulating an answer. The theory is applied to give the correct value for the terminal potential difference.

Question 2 (b)

This question was very poorly answered. It is clear from the responses seen that candidates struggle with the concepts involved in parallel circuits, with most candidates having a vague recollection of current splitting at a junction from their GCSE knowledge which they then erroneously applied to the situation given in the question.

It was quite common for candidates to state that current is diverted from bulb 1 so that current could pass through bulb 2 when the switch is closed. A small proportion of candidates recognised that the circuit resistance would decrease but did not link this with a larger current in the circuit and hence a small terminal potential difference across the battery.

This response scores full marks.

(b) Explain how the brightness of bulb 1 changes when the switch is closed. No further calculations are necessary.

(3)

When the switch is ~~not~~ closed the current is able to flow through both bulbs but due to Kirchoff's law the p.d across the bulbs are equal. However as the bulbs are in parallel their total resistance decreases and as the internal resistance is constant and $\frac{V}{V_1} = \frac{R}{R_1}$ the ~~R~~ share of p.d. they take up is smaller and as their ~~resist~~ individual resistance is the same and $I = \frac{V}{R}$ the brightness of bulb 1 decreases.

ResultsPlus
Examiner Comments

The response has the essential ideas expressed in the 'either' version of the mark scheme.

This is typical of responses scoring no marks.

(b) Explain how the brightness of bulb 1 changes when the switch is closed. No further calculations are necessary.

(3)

Bulb 1 and Bulb 2 in parallel
∴ both would be recieving equal current
as current is split at junction

The bulb decreses to half its usual brightness
/ Intensity matching bulb 2

ResultsPlus
Examiner Comments

The response assumes that the current in the circuit has stayed constant. However, when a parallel connection is made the circuit resistance deceases and so the circuit current increases. Hence despite the circuit current being shared between the two bulbs, the current in each bulb does not decreases to a half of the initial value. In fact there is a slight decrease in the expected current, as the terminal potential difference of the battery decreases due to a larger current being drawn.

Question 3 (a)

Most candidates realised that the ammeter was incorrectly positioned in the circuit. The easiest way to point this out would be to state that the ammeter should be placed in series with the heater, which many candidates did. However, some candidates made vague statements about where the ammeter should be placed, so it was difficult to give Mark Point 1.

Many candidates realised that the range of the ammeter was too small, and that the milliammeter should be replaced by an ammeter. However, instead of referring to the range a number of candidates referred to the resolution of the instrument. Some candidates thought the meter shown in the circuit was a microammeter.

Question 3 (b)(i)

This was generally well answered. The most common error was to draw a curve rather than a straight line. Although some energy is transferred to the surroundings in this heating process, the effect on the decrease in mass would not produce the curves drawn by such candidates. Many candidates took their lead from the question and labelled the vertical axis with “reading on balance”. Some used mass, or *m* as the label. All these were fine and units were not required. Some candidates completely misunderstood the question and labelled the axes with *I* and *V*.

Question 3 (b)(ii)

This is a straightforward calculation which was generally well done. In some responses there was a power of ten error, as the mass was not converted to a mass in kg, and in other responses units were incorrect or omitted.

Question 3 (b)(iii)

Some candidates used the language of energy stores and pathways taught at GCSE to give a good version of Mark Point 1. The minimum expectation for this mark point was a statement that energy is transferred to the surroundings. Some candidates slipped into using ‘heat’ for ‘energy’ and ‘lost’ rather than ‘transferred’.

Although most candidates stated that the energy was transferred to the surroundings, fewer could give a clear explanation as to what would happen to the calculated value of *L* in comparison to the true value. On seeing reference to a quantity changing in a command sentence candidates should be aware that this usually requires a statement as to how the quantity changes.

Despite the wording of the question, many responses focused on equipment based issues, usually regarding the voltmeter and/or ammeter. As this question is based on a core practical it is expected that candidates would know that energy transferred to the surroundings would be a significant source of error for the experimental set up described in the question.

Question 4

The context for this question was well known to most candidates, and consequently accuracy in the descriptions given was expected. A wide variety of responses were seen, with a full range of marks. The best responses were well laid out and succinct.

Indicative content points were sometimes expressed in terms that were too loose to be creditworthy. For example, some candidates stated that most particles passed through the gold foil, whereas the key evidence is that most particles passed straight through (ie without deflection). Other candidates made vague references to angles without being specific.

Loose or inaccurate descriptions of deflection were used such as bouncing, reflection, and even diffraction. Instead of stating that the charge was at the centre a less detailed description such as “this shows that the atom had a charge” was given by many candidates.

In the six mark linkage question there are 4 marks for indicative content and 2 marks for logical sequencing of ideas. This response scores all 6 marks.

***4** Alpha particle scattering experiments led Rutherford to propose the nuclear model of the atom. Alpha particles were directed towards a thin gold foil.

Describe how evidence from these experiments supports the nuclear model of the atom.

Most particles went straight through gold atoms indicating that the atom is mainly empty space. Few alpha particles were deflected at small angles indicating that there is a concentation of positive charge in the centre of the atom called the nucleus as these alpha particles repelled at small angles when close to it. A very small number of atoms deflected at large angles or straight back from the nucleus which indicated that most of the mass of the atom is concentrated at the nucleus and the nucleus is really small compared to the rest of the atom, this supports our nuclear model of the atom which portrays a small positively charged nucleus in the centre and electron orbitals around it

(Total for Question 4 = 6 marks)

ResultsPlus
Examiner Comments

All six indicative content points are included. The conclusion is linked to the evidence for each of the three degrees of deflection considered and so the marks for logical sequencing of ideas are awarded.

This response scores all 6 marks.

*4 Alpha particle scattering experiments led Rutherford to propose the nuclear model of the atom. Alpha particles were directed towards a thin gold foil.

Describe how evidence from these experiments supports the nuclear model of the atom.

Initially a plum pudding model was used which was a cloud of positive charge with negatively charged electrons inside. In the experiment most alpha particles went straight through the goldfoil. This suggests that the atom is mainly empty space. A few alpha particles were deflected through small angles onto the flourescent screen, this suggests there is a charged nucleus in the atom which deflected the alpha particles. About 1 in 10,000 alpha particles were back scatted at angles > 90°. This suggests that the atom has a very dense charged nucleus that contains most of the mass of the atom. This is because alpha particles were known to be very heavy and charged. So a very heavy charged particle would be needed to cause its direction to change. ~~All there~~ These observations are consistent with ~~an~~ a central nucleus orbitted by electrons. and not the plum pudding model

(Total for Question 4 = 6 marks)

ResultsPlus
Examiner Comments

Although there is extraneous detail relating to the Plum Pudding model (not required by this question), all six indicative content points are included. The conclusion is linked to the evidence for each of the three degrees of deflection considered and so the marks for logical sequencing of ideas are awarded.

ResultsPlus
Examiner Tip

Plan your response to an extended open-response question so that you are clear which points you are going to make before you start writing your response.

This response scored 3 marks.

*4 Alpha particle scattering experiments led Rutherford to propose the nuclear model of the atom. Alpha particles were directed towards a thin gold foil.

Describe how evidence from these experiments supports the nuclear model of the atom.

Evidence from these experiments support the nuclear model of an atom as when alpha particles were shot at the gold foil, most of the alpha particles went straight through. Some of the alpha particles were deflected and few bounced back. This supports the idea that the atom ~~of~~ was made a small positive nucleus in the middle surrounded by empty space. The small positive is the reason that the ~~alpha~~ some alpha particles were deflected or bounced back as it is also positive. This proves the nuclear model of the atom was correct rather than the plum pudding model of JJ Thompson.

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Examiner Comments

The main features of the scattering experiments are outlined, but the links between conclusions and evidence aren't clear. IC3 cannot be credited since there is no reference to small angles. IC6 cannot be credited as there is no reference to mass. IC1 and IC5 are clearly stated as evidence from the scattering experiments, and IC2 and IC4 are stated as conclusions. However, it is not clear which conclusion follows from which piece of evidence and so a linkage mark is not awarded.

Question 5 (a)(i)

It was obvious from the responses seen that few candidates were even remotely familiar with this apparatus. However, some candidates were able to state that changes in length due to temperature would be minimised by using a reference wire.

Question 5 (a)(ii)

In contrast to Q05(a)(i), more than half of the responses scored a mark here. References to keeping the wire taut were commonly seen. Phonetic spellings such as ‘taught’ and even ‘torte’ were accepted. Many variations were seen for keeping the wire straight such as “making sure there are no kinks in the wire” which indicated that candidates understood the way in which the apparatus could be used.

Question 5 (b)

It was reasonably common for responses to score 2 marks for this question. Mark Point 1 was the least commonly seen, and Mark Point 2 was the most commonly seen. Mark Point 2 was not awarded for statements such as "extension is more noticeable", as a clear statement that there was a large extension was required.

A reference to percentage uncertainty was required for Mark Point 3 to be awarded, although some responses just discussed uncertainty, which is just dependent upon the measuring instrument.

Quite a few candidates discussed safety aspects and how a long thin wire might have a different breaking point, although loading the wire until it breaks is certainly undesirable.

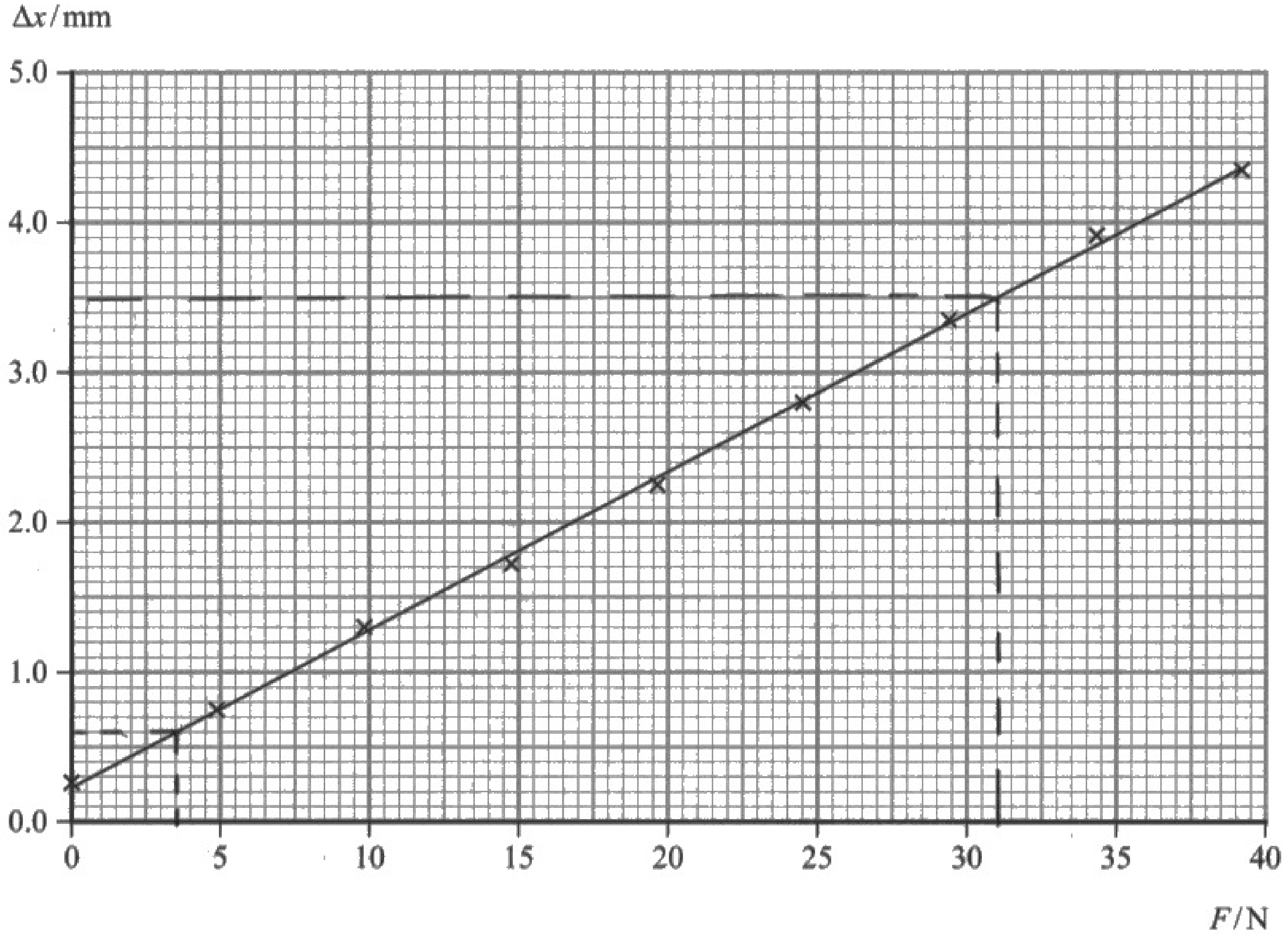
Question 5 (c)

This question was generally well answered, with most candidates demonstrating a good understanding of stress, strain and Young's modulus. A significant minority of candidates were confused about the gradient, and many candidates did not acknowledge the non-zero intercept. A common way not to score Mark Point 5 was to omit units from the final answer.

This response scored all 5 marks.

decrease.

(c) The student varied the load F on the test wire and recorded the corresponding change in length Δx from the vernier scale. The results are shown on the graph.



Determine a value for the Young modulus of brass.

length of wire = 2.75 m
diameter of wire = 5.60×10^{-4} m

(5)

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

$$\Delta x = \frac{x}{AE} \times F$$

$$A = \pi \frac{d^2}{4}$$

$$\Delta x = \frac{x}{\pi r^2 E} \times F$$

$$\text{Gradient} = \frac{x}{\pi r^2 E}$$

$$\frac{(3.5 - 0.6) \times 10^{-3}\,\text{m}}{(31 - 3.5)\,\text{N}} = \frac{2.75\,\text{m}}{\pi (\frac{5.6}{2} \times 10^{-4})^2 \times E}$$

$$1.05 \times 10^{-4} = \frac{2.75\,\text{m}}{\pi (\frac{5.6}{2} \times 10^{-4})^2 \times E}$$

$$E = 1.06 \times 10^{11}\,\text{Pa}$$

Young modulus of brass = 1.06×10^{11} Pa

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Examiner Comments

The gradient is calculated and correctly related to the Young's modulus, *E*, and a correct value for *E* is obtained together with correct units.

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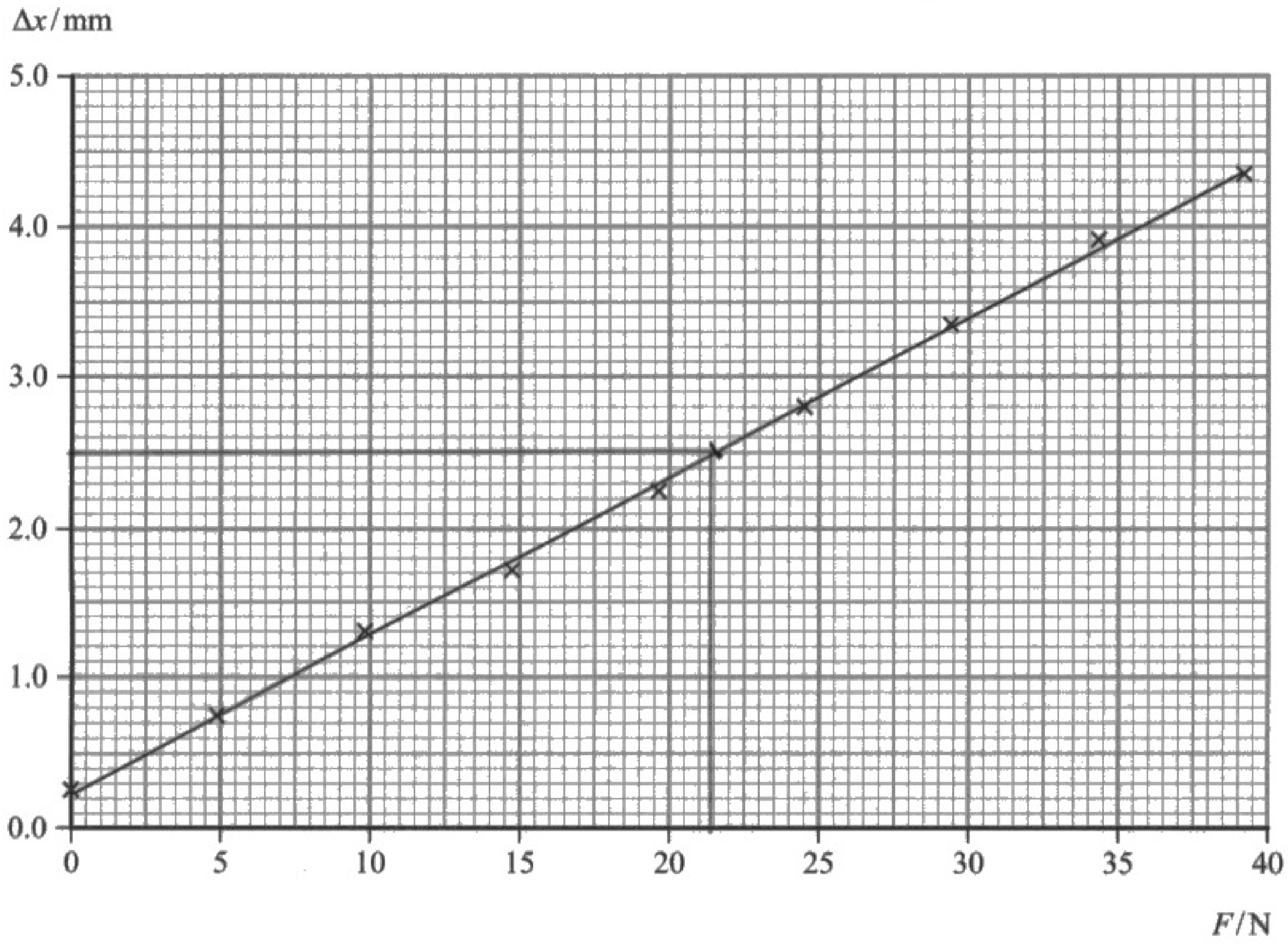
Examiner Tip

Always include units in a final numerical answer.

This response scored 3 marks.

(c) The student varied the load F on the test wire and recorded the corresponding change in length Δx from the vernier scale. The results are shown on the graph.



Determine a value for the Young modulus of brass.

length of wire = 2.75 m
diameter of wire = 5.60×10^{-4} m

(5)

$E = \frac{\text{stress}}{\text{strain}}$

stress = $\frac{F}{A}$ strain = $\frac{\Delta x}{x}$

$A = \pi(\frac{d}{2})^2$ $x = 2.75$ m

$F = 21.5$ N Δx 2.5 mm $= 2.5 \times 10^{-3}$ m

$A = \pi(\frac{5.6 \times 10^{-4}}{2})^2 = 2.463 \times 10^{-7}$ m^2

stress = $\frac{21.5}{2.463 \times 10^{-7}}$ strain = $\frac{2.5 \times 10^{-3}}{2.75}$

$= 87291614.2$ $= 9.091 \times 10^{-4}$

$E = \frac{87291614.2}{9.091 \times 10^{-4}} = 9.6 \times 10^{10}$

Young modulus of brass = 9.6×10^{10} N m^{-2}

ResultsPlus
Examiner Comments

In this response the intercept on the extension axis has been ignored and hence the value calculated for the Young's modulus is inaccurate. The response scores Mark Point 1, Mark Point 3 and Mark Point 4.

Question 6 (a)

This question was generally well answered, although many responses included extraneous detail. This was often because candidates thought that they had to give the reasoning behind their method. This may be because a similar question in a previous series had required candidates to explain the method, whereas this question just asked candidates to describe the method.

All 4 mark points were seen quite commonly, although Mark Point 2 was probably the least commonly awarded.

Question 6 (b)

This question was well answered, with about half of the entry scoring full marks. Of those who did not score full marks, some candidates omitted units, or forgot to convert centimetres to metres. Some candidates didn't realise that sin ωt is 1 at maximum velocity .

A minority of candidates didn’t realise that they needed to use the graph to determine the period. Some incorporated the amplitude value with the time to go from zero displacement to the maximum for the calculation. Some candidates attempted to calculate speed using distance divided by time, or tried to use $v = f l$.

Question 6 (c)(i)

Many candidates had memorised the description of resonance, and these candidates usually scored at least 3 marks. Many just described the shape of the curve and didn't apply any Physics terms or refer to the peak at 2 Hz. Some candidates confused natural frequency with resonant frequency and thus did not score Mark Point 2. Some candidates were unable to explain that the energy transfer was coming from the frequency generator to the trolley and hence were not specific enough to score Mark Point 3.

This response scored full marks.

(i) Explain the shape of the graph.

(4)

As driving frequency from vibrator increases the amplitude of vibrations continues to increase. Until 2Hz where it reaches the maximum amplitude of 5cm, this is due to resonance when driving frequency is equal to the natural frequency of the trolley so causes a significant increase in amplitude and maximum energy transfer. After since no longer at natural frequency the amplitude decreases. Initially amplitude at 0.6cm since this is the amount it has been displaced before let to

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Examiner Comments

All the essential detail included in the mark scheme answer is included in this response.

Question 6 (c)(ii)

This should have been a straightforward question, but many candidates made it more difficult than it should have been. A common way not to score marks was to re-arrange the equation for the period of a mass spring system before substituting data into the expression. Basic algebraic errors produced an incorrect expression which gave the wrong answer.

A 'use of' mark is given for substitutions into a correct physical equation and so, if the expression is rearranged incorrectly the 'use of' mark cannot be awarded.

Some candidates tried to base their solution on Hooke's law, although there was no credit for this unless the resultant force (kx) was equated to $m\omega^2 x$ and then $\omega = 2\pi f$ used.

Perhaps because k is referred to as the spring constant, some candidates thought that no units were necessary. Most candidates did include a unit, with N m^{-1} being most commonly seen. However, a significant minority of responses gave kg s^{-2} as the unit. This was accepted, although it is a somewhat unusual unit in which to measure k.

This response scored both marks.

(ii) Determine the effective spring constant k of the oscillating trolley system.

mass of trolley = 0.87 kg

(2)

$T = 2\pi\sqrt{\frac{m}{k}}$ $\qquad \frac{1}{f} = T = 0.5\,s$

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

$\frac{0.5^2}{4\pi^2 \times m} = \frac{1}{k} \rightarrow \frac{1}{k} = ans \rightarrow \frac{1}{ans} = k$

$k = 137.4$

$k =$ 137.4 N m^{-1}

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Examiner Comments

Values are substituted into a physically correct equation, to obtain a correct value for k including units.

This response scored just 1 mark.

(ii) Determine the effective spring constant k of the oscillating trolley system.

mass of trolley = 0.87 kg

(2)

max freq.

$T = \frac{1}{f} \overset{?}{=} \frac{1}{2}$

$= 0.5$

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

$T = 2\pi\sqrt{\frac{0.87}{k}}$

$\left(\frac{T}{2\pi}\right)^2 \times k = 0.87$

$\therefore \frac{0.87}{\left(\frac{T}{2\pi}\right)^2} = k$

$k =$ 137.38

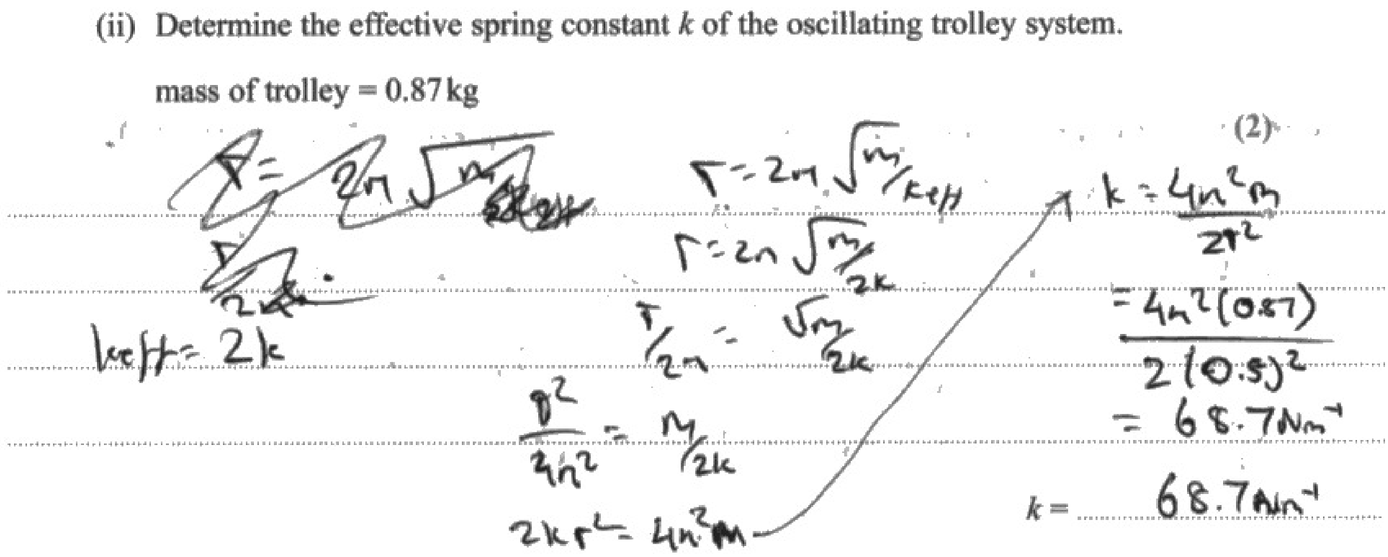
(Total for Question 6 = 15 marks)

$\frac{0.87}{\left(\frac{0.5}{2\pi}\right)^2} = k \qquad \therefore k = 137.38$

ResultsPlus
Examiner Comments

Values are substituted into a physically correct equation to obtain a correct value for *k*, but units are omitted.

This response scored zero.



(ii) Determine the effective spring constant *k* of the oscillating trolley system.

mass of trolley = 0.87 kg

(2)

$k_{eff} = 2k$

$T = 2\pi\sqrt{m/k_{eff}}$

$T = 2\pi\sqrt{m/2k}$

$T/2\pi = \sqrt{m/2k}$

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

$2kT^2 = 4\pi^2 m$

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

$= \frac{4\pi^2(0.87)}{2(0.5)^2}$

$= 68.7\ Nm^{-1}$

k = 68.7 Nm⁻¹

ResultsPlus
Examiner Comments

The correct equation has been re-arranged incorrectly. Hence the final answer is incorrect and a 'use of' mark cannot be given.

ResultsPlus
Examiner Tip

Substitute numerical values before rearranging an equation.

This response scored zero.

(ii) Determine the effective spring constant k of the oscillating trolley system.

mass of trolley = 0.87 kg

(2)

$F = -k \Delta x$ $\quad$ $kgms^{-2} = k\,m$

$ma = 0.05\,k$ $\quad$ $k = kgs^{-2}$

$0.87 \times 96 \cos(40\pi t) = 0.5k$

$0.87 \times 96 \cos(40\pi \times \frac{1}{2}) = 0.5k$

$k = \dfrac{0.87 \times 96 \cos 20\pi}{0.5}$

$k = 167.04$

$k =$ 167 kgs^{-2}

(Total for Question 6 = 15 marks)

ResultsPlus Examiner Comments

This response is typical of a number of responses seen. The solution is based on equating the restoring force (obtained from Hooke's law) to ma. A correct application of this would substitute $a = \omega^2 x$ with ω calculated from $\omega = 2\pi f$ or $\omega = 2\pi / T$.

Question 7 (a)

Most candidates found this linkage question more difficult than Q04, and very few candidates were able to score full marks. The best answers were well laid out and showed a logical sequence from current to energy transfer to quantum levels inside the neon.

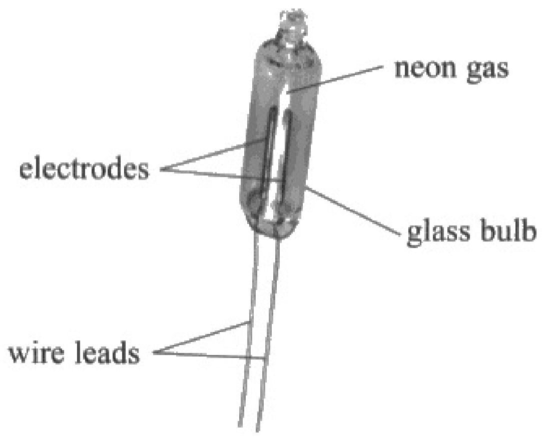
It was very rare to find a response that appreciated the full process occurring here. Few candidates were able to visualise the electrons moving through the gas and how these electrons might transfer energy to the electrons in the atoms. Some candidates were very vague about the location of the electrons that get excited. A significant minority of candidates did not distinguish whether they were talking about electrons in the metal or the neon.

Very few candidates were specific enough to gain credit for the initial three indicative content points, but most candidates gained more credit from the final three indicative content points.

Incorrect responses often referred to thermionic emission, the photoelectric effect, resistance and lattice vibrations, electric fields and capacitors, and even magnetic fields.

In the six mark linkage question there are 4 marks for indicative content and 2 marks for logical sequencing of ideas. This response scores all 6 marks.

7 The neon lamp shown is a glass bulb filled with neon gas at low pressure.



(Source: https://media.digikey.com/Photos/Visual%20Communications%20Company%20VCC/A1A.JPG)

*(a) When in use, the neon gas between the electrodes emits electromagnetic radiation.

Explain why this happens when there is an electric current between the electrodes.

(6)

The electric current allows electrons to travel across the electrodes. As the electron travels across this gap, they may collide with a neon gas atom. When this occurs energy is transferred to the neon gas. The electrons in the neon gas are only able to exist on certain energy levels. In order for the electron to increase in energy levels, it can only absorb a discrete amount of energy which is equivalent to the energy between the energy levels. Once the electron has increased in energy levels, it falls back down to a lower energy level and emits a photon of a discrete amount of energy equivalent to the energy required to jump up an energy level. This photon then has a discrete wavelength of light and therefore a discrete frequency of light which can be classed as electromagnetic radiation.

$E = hf$

ResultsPlus
Examiner Comments

All six indicative content points are included. The two elements of the explanation (how energy is transferred to the neon atoms and how neon atoms emit electromagnetic radiation) are clearly described.

ResultsPlus
Examiner Tip

Plan your response to an extended open-response question so that you are clear which points you are going to make before you start writing your response.

Question 7 (b)

This question was very well answered, with most candidates scoring full marks. A minority of candidates forgot to square the velocity in the kinetic energy equation so did not score full marks.

A significant minority of candidates who did obtain the correct numerical answer went on to conclude a metal other than caesium.

Question 8 (a)

This was a well answered high mark calculation with most candidates scoring at least three marks for calculating the capacitance of the capacitor. Most candidates were comfortable with rearranging the equation to correctly determine *C*, with many using time constant = *RC* as an easier and more reliable route. Not all candidates were able to use the given tolerance to create a range (or in this case an upper bound) so that a conclusion could be made.

This response scored full marks.

(a) The capacitor was marked 220 μF ± 20%.

Deduce whether the student's data give a value of capacitance within the stated range.

$R = 82\,\text{k}\Omega$

(5)

$V_0 = 6\,V \quad V = 0.8\,V \quad t = 45\,s$

$V = V_0 e^{-t/RC}$

~~lnV~~ $\ln V_0 - \ln V = \frac{t}{RC}$

$C = \frac{t}{R(\ln V_0 - \ln V)}$

$= \frac{45}{82 \times 10^3 (\ln 6 - \ln 0.8)}$

$= 272\,\mu F$

$220 \times 0.2 = 44$

$220 + 44 = 264$

$272 > 264$, so not within the range

ResultsPlus
Examiner Comments

The solution used in this response follows the first alternative given in the mark scheme (use of the exponential equation).

This response scored full marks.

(a) The capacitor was marked 220 μF ± 20%.

Deduce whether the student's data give a value of capacitance within the stated range.

$R = 82\,\text{k}\Omega$

(5)

~~$V = V_0 e^{-\frac{t}{RC}}$~~ Time constant = RC

~~$\ln V - \ln V_0 = -\frac{t}{RC}$~~ Corresponding voltage = $\frac{V_0}{e} = \frac{6}{e}$

$= 2.21$

$\therefore RC = 22.5$

$C = \frac{22.5}{82 \times 10^3} = 274\,\mu\text{F}$

$220 \times 1.2 = 264 < 274$

∴ the student's data doesn't give a value of capacitance

ResultsPlus Examiner Comments

The solution used in this response follows the second alternative given in the mark scheme (use of the time constant).

Question 8 (b)

This question was poorly answered in general. The question demonstrated poor articulation by some candidates, who clearly had the idea that two values could not be taken at the same time but referred to reaction time instead of the idea of taking readings simultaneously.

A significant minority of candidates recognised that a data logger has a high sample rate and so Mark Point 1 was probably scored more frequently than Mark Point 2. It was quite unusual to actually see responses that drew a conclusion as to whether the suggestion to use a data logger was correct or not.

Question 9 (a)(i)

The majority of candidates were able to score the mark here. However, a significant minority of candidates labelled both plates as positive. Others tried to label the diagram with field lines instead of indicating the polarity of the power supply.

Question 9 (a)(ii)

It was pleasing to see many fully correct responses to this question. Only a minority of candidates failed to correctly calculate the oil drop volume. The most common error usually occurred when candidates used the radial field equations. Disappointingly, a small number of candidates missed out on Mark Point 6 having calculated a correct value of 4.24, by stating that this is close enough to a whole number multiple of the charge on an electron without any further discussion.

This response scored full marks.

(ii) The oil drop was at rest when $V = 4870\,\text{V}$.

The student expected the charge on the oil drop to be a whole number multiple of the charge on an electron.

Deduce whether this is confirmed by the experimental data.

distance between top plate and bottom plate = 1.55 cm
density of oil = $920\,\text{kg}\,\text{m}^{-3}$
radius of the oil drop = $1.78 \times 10^{-6}\,\text{m}$

(6)

$W = F_{el}$ $\quad \rho = m/V \quad E = F/Q = V/d \quad F = VQ/d$

$mg = \rho V g = Vq/d$

$920 \times 4/3\pi (1.78\times10^{-6})^3 \times 9.81 = \dfrac{4870\,q}{1.55\times10^{-2}}$

$q = 6.786\times10^{-19}\,\text{C}$

in eV, $q = \dfrac{6.79\times10^{-19}}{1.6\times10^{-19}} = 4.24$

4.24 is not a whole number multiple of electron charge

∴ NO → not confirmed by data

ResultsPlus Examiner Comments

All the steps in the calculation are correct and set out clearly. A valid conclusion is given.

This response scored full marks.

(ii) The oil drop was at rest when $V = 4870\,\text{V}$.

The student expected the charge on the oil drop to be a whole number multiple of the charge on an electron.

Deduce whether this is confirmed by the experimental data.

distance between top plate and bottom plate = 1.55 cm

density of oil = $920\,\text{kg}\,\text{m}^{-3}$

radius of the oil drop = $1.78 \times 10^{-6}\,\text{m}$

(6)

$\frac{F}{Q} = E = \frac{V}{d}$

$F = EQ$

$= W = mg$

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

$E = V/d = \frac{4870}{0.0155} = 314193\,\text{NC}^{-1}$

$F = EQ = mg$

$Q = \frac{mg}{E} = \frac{\frac{4}{3}\pi r^3 \times \rho \times g}{E} = \frac{\frac{4}{3}\pi(1.78\times10^{-6})^3(920)\times 9.81}{314193}$

$= 6.786 \times 10^{-19}\,\text{C}$

$\frac{6.786\times10^{-19}}{1.6\times10^{-19}} = 4.2412$

4.2412 is not an integer. So this is not confirmed by the practical

Although all the steps are correct, the clarity of the solution could be improved by adding a little more annotation. Nonetheless a correct value for *N* is obtained and a valid conclusion is made.

ResultsPlus
Examiner Tip

Set your work out clearly including all essential details when problem solving.

Question 9 (b)(i)

Many candidates scored Mark Point 1 for the idea that the object is not at terminal velocity initially, and it takes time to reach that velocity. Those that had acknowledged the command of 'explain' often missed out on Mark Point 2 by being too general in their explanation. Only a minority of candidates went on to state how not waiting a short while would affect the value obtained for the terminal velocity.

Question 9 (b)(ii)

In general this question was answered very well. Only those candidates who misread the direction of the scale tended to drop marks. However, these candidates could still score Mark Point 2 for use of the equation for speed. For some reason a significant minority of candidates tried to use '*suvat*' equations to calculate terminal velocity.

Question 9 (c)

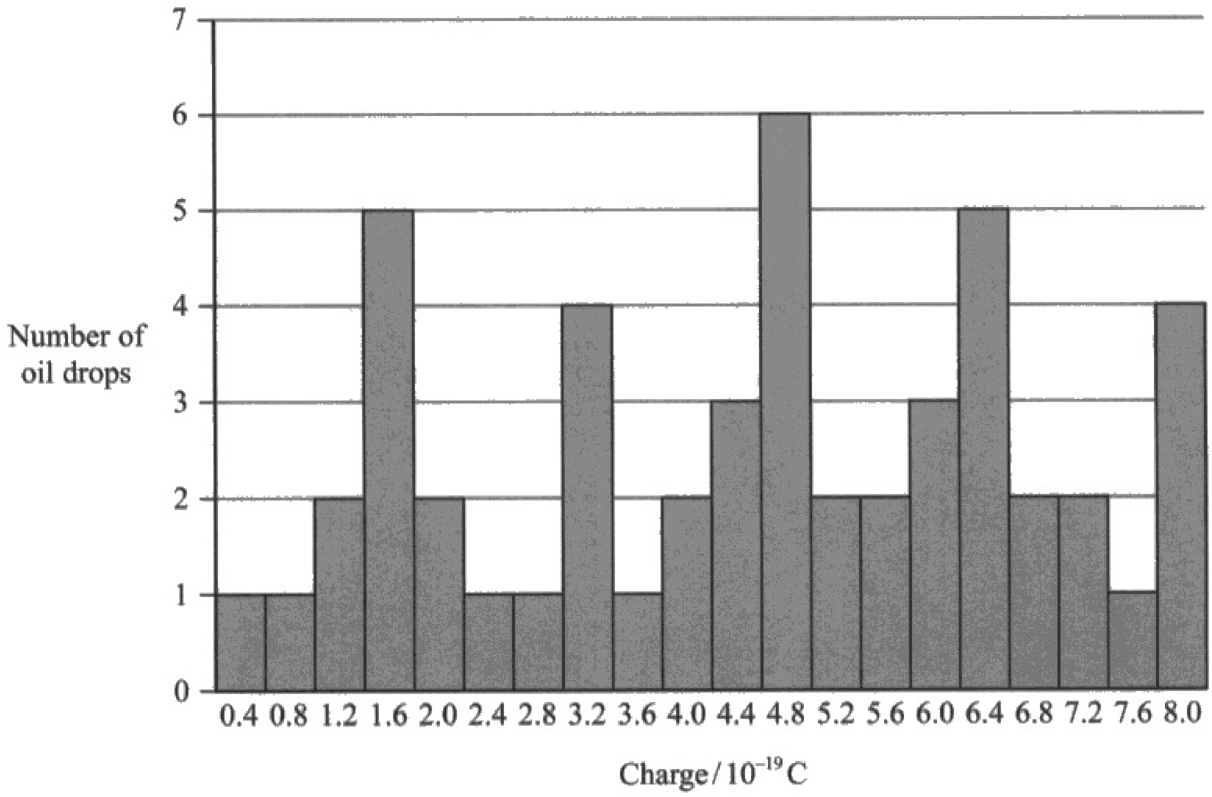
Responses to this question were often quite muddled. Many candidates mistook “whole number multiples of e” for actual integer values and counted totals for the wrong bars on the graph. Most candidates who did understand the bar chart managed to hit both Mark Point 1 and Mark Point 2 in one go with a discussion of 24 out of 50 drops having an integer charge.

A significant minority of candidates did not understand that 1.6 is an integer charge and tried to answer the question using the numbers 2, 4, 6 and 8, scoring no marks. Very few candidates were able to articulate that the evidence was inconclusive for Mark Point 3.

This response scored all 3 marks.

(c) The student repeated the measurements on fifty oil drops. For each drop the student calculated the charge on the oil drop.

His results are shown in the bar chart.



The student predicted that the charge on each oil drop would be a whole number multiple of the charge on an electron.

Comment on the extent to which the bar chart supports the student's prediction.

(3)

The bar chart Somewhat supports prediction as not all charges on each oil drop is a whole number of oil drops, 26 of the drops are not. However, the most common charges on the oil drops have been whole multiples of charges which accounts for 24 of the oil drops.

(Total for Question 9 = 15 marks)

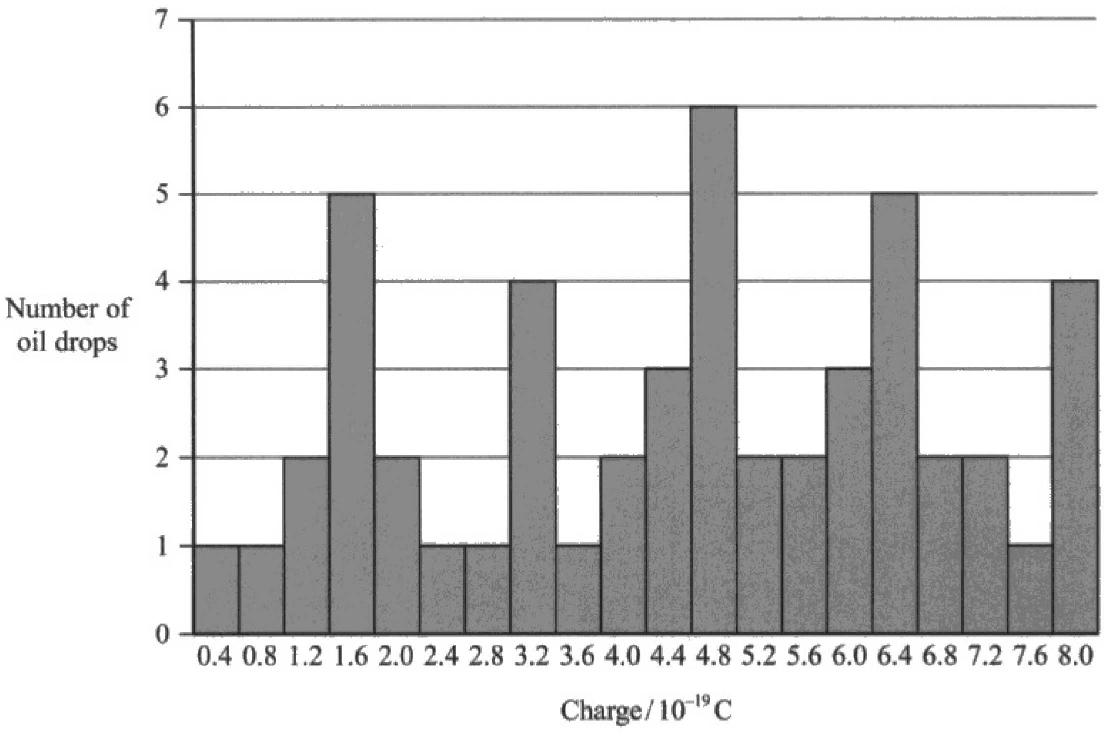
ResultsPlus
Examiner Comments

The bar chart has been interpreted correctly, and the numbers of charges with integer and non-integer charge correctly totalled. The phrase "somewhat supports the student's prediction" was just enough for Mark Point 3.

This response scored 2 marks.

(c) The student repeated the measurements on fifty oil drops. For each drop the student calculated the charge on the oil drop.

His results are shown in the bar chart.



The student predicted that the charge on each oil drop would be a whole number multiple of the charge on an electron.

Comment on the extent to which the bar chart supports the student's prediction.

(3)

Each peak on the graph corresponsds to a whole number of charges of an electron (1.6, 3.2, 4.8, 6.4, 8.0 ~~x~~ 10^{-19} C correspond to 1, 2, 3, 4, 5 electrons). This supports the student's prediction. Other results may be caused by a ~~xx~~ random error due to the environment.

ResultsPlus
Examiner Comments

There is enough in the first sentence of this response for Mark Point 1 to be awarded. The reference to "random error due to the environment" was accepted as being enough to award the second alternative for Mark Point 3.

Question 10 (a)(i)

Most candidates scored full marks here. The most common error was failing to square π.

Despite the similarity in form of the expression for the period of a simple pendulum to the expression for the period of a mass on a spring, there were fewer problems in rearranging than were evident in Q06(c)(ii).

Once again, it is worth candidates noting that a ‘use of’ mark is only given for substitutions into a correct physical equation.

Question 10 (a)(ii)

Many candidates scored Mark Point 1 for identifying that the reduction in amplitude was due to damping or resistive forces acting on the pendulum. Many candidates went on to link the energy being transferred to the surroundings with a decrease in amplitude. Only the best referred to work being done against resistive forces. Candidates should be encouraged to refer to the object that the forces act on when such a phenomenon occurs. Some candidates referred to work done by gravitational forces, which is incorrect.

Question 10 (b)(i)

Most candidates scored full marks here. Taking logs and re-arranging the equation proved to be a straightforward task for the vast majority. Familiarity as to how to compare this to the equation of a straight line varied from those candidates just stating that this means the line will be straight to those who demonstrated in multiple ways how it compared to the equation of a line. However, most candidates explicitly linked their equation to $y = mx + c$, the equation of a straight line.

Question 10 (b)(ii)-(iii)

Involving some kind of log plot is a regular feature of this paper. It is disappointing therefore that many candidates were unable to write units onto a graph axis correctly in Q10(b)(ii).

Correct responses for ln (A/cm) were usually quoted to 2 decimal places. However, a significant minority of candidates quoted their values to just 1 decimal place. This was inappropriate, and led to considerable scatter when the points were plotted.

The axes label mark was not usually scored. Scales were generally good but many candidates were tempted to employ a scale of 2.5 on the time axis due to the data presented. Acceptable scales should increase in intervals of 1, 2, 5, 10 etc. Candidates should balance filling a good proportion of the available grid with an easy to read scale.

Plotting was generally good and the line of best fit mark was usually awarded.

In Q10(b)(iii) the analysis of the graph required quite tricky analysis. Some candidates did not look ahead when considering the scale when plotting the graph to realise that an intercept would be required. This usually prevented them from obtaining a correct value for A_0. Only the best responses had a correct use of the equation with the gradient to extrapolate a value for A_0.

For those candidates who used a scale that allowed the correct intercept value to be read off, an incorrect reading was seen quite regularly, with 3.08 (or similar) often recorded as 3.8. The inverse log processing mark was usually given and most responses showed the correct unit. Mark Point 3 and Mark Point 4 were scored quite regularly.

The significance of units and significant figures was also missed by some candidates, a requirement of Mark Point 2 and Mark Point 4 being awarded.

Question 11 (a)

Many responses started well with a statement of the resolution of the metre rule. However, quite a few candidates stated that "a half metre rule has a resolution of 1cm, whereas a 30cm ruler has a resolution of 1mm".

Most candidates did not make the distinction between measuring the diameter and measuring the thickness, although the question clearly states that each washer has an external diameter of about 4.5 cm. and an internal diameter of about 2.5 cm, whereas the thickness of each washer is about 4 mm (0.4 cm). It is appreciated that it is easier to comment on the suitability of a particular instrument when the things to be measured are physical objects in front of the candidate. However, candidates should be using all the information that they are given in the question, as it is given to them for a reason.

The most common mark awarded was for suggesting a more appropriate measuring instrument. Candidates often suggested both a micrometer and a digital/vernier calliper. Few considered the reason for their choice of improved measuring instrument, and not many responses saw a statement of the smaller resolution. When resolutions were stated, most were correct.

Some responses were very general when discussing the decreased % uncertainty and did not specifically refer to t for which this is most significant.

Question 11 (b)

It was encouraging that some candidates had actually carried out a similar determination practically and were able to suggest stacking the discs so that the distance being measured is greater. However, even those candidates who suggested stacking the discs often stated that this would lead to a decrease in percentage uncertainty, but they were rarely able to explain why in terms of the increased measurement.

Most candidates went for repeat at different places and calculate a mean. These candidates sometimes went on to state that this decreased the percentage uncertainty, but this is not correct for this method and so Mark Point 3 was not awarded in such cases.

Question 11 (c)(i)-(ii)

In general, Q11(c)(i) was poorly answered.

Most candidates seemed to be unaware that:

- when measurements are added or subtracted in a calculation the uncertainty for each measurement is added to calculate the total uncertainty.
- when multiplying or dividing measurements, the total percentage uncertainty is calculated by adding together the percentage uncertainties for each measurement.

These rules are explicitly stated in Appendix 10 of the specification, and so it is expected that candidates would have engaged with these in preparation for this paper.

Those candidates who knew these rules could often apply them accurately to obtain the required result. Common errors made by these candidates included failing to follow the formula as given.

Q11(c)(ii) was normally well answered, with a large number of candidates scoring full marks. Some candidates did not calculate a mean thickness, but most candidates were able to determine a value for the density.

Only a small proportion of candidates thought to calculate the percentage uncertainty in t and combine with the percentage uncertainty in A that they had calculated previously to obtain a value for the range in which the density might lie.

Candidates who didn't obtain a range of values usually made a conclusion based on the closeness of the calculated density to those for iron and steel given in the question.

The best responses obtained a range in which the density might lie and made a correct conclusion from this. Having got this far, a minority of these candidates made simple errors such as not giving units for their final answer or choosing the metal that was outside of the range.

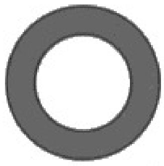
This response scored full marks for both parts.

(c) The student obtained the following mean values.

$d_1 = 4.52\,\text{cm} \pm 0.02\,\text{cm}$

$d_2 = 2.53\,\text{cm} \pm 0.02\,\text{cm}$

She calculated the area A of a washer indicated by the shaded section below.



She used the formula $A = \frac{\pi}{4}(d_1 + d_2)(d_1 - d_2)$ $d_1^2 - 2d_1d_2 + d_2^2$

(i) Show that the percentage uncertainty in her value for the area of a washer is about 3%.

(4)

$d_1 + d_2 = \pm 0.04$ $d_1 - d_2 = \pm 0.04$

$\left(\frac{0.04}{4.52+2.53} + \frac{0.04}{4.52-2.53}\right) \times 100 = 2.58\%$

(ii) The student obtained the following values of t for each of the five washers.

t/mm	4.3	4.2	4.1	3.9	4.0

The table shows the density of iron and steel.

Metal	Iron	Steel
Density/g cm^{-3}	6.9	7.9

Deduce whether the washers are made from iron or steel.

mean mass of a washer = 32.0 g

The uncertainty in the mass is negligible.

(6)

t/cm mean = $\frac{0.43 + 0.42 + 0.41 + 0.39 + 0.4}{5}$

= 0.41 cm

% uncertainty in t

= $\frac{0.41 - 0.39}{0.41} \times 100 = 4.88\%$

density = $\frac{mas}{vol}$

volume = $\frac{\pi}{4}(4.52 + 2.53)(4.52 - 2.53) \times 0.41 = 4.52 \pm 7.88\%$

density = $\frac{32}{4.52}$ = 7.08 ± 7.88% gcm^{-3}

7.08 + (7.08 × 0.0788) = 7.637

7.08 − (7.08 × 0.0788) = 6.52

as iron lies within uncertainty range but steel does not, the washers are made from iron.

ResultsPlus
Examiner Comments

In Q11(c)(i) the uncertainties are added for each bracket, and then the fractional uncertainties added to obtain the percentage uncertainty in the product of the two brackets.

In Q11(c)(ii) the uncertainties are used to calculate a range for the calculated value of the density. Iron is then correctly selected as having a density that is within this range, whereas the density of steel is not within this range.

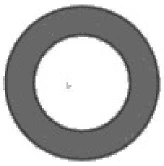
This response scored full marks for Q11(c)(i), and 5 marks for Q11(c)(ii).

(c) The student obtained the following mean values.

$d_1 = 4.52\,\text{cm} \pm 0.02\,\text{cm}$

$d_2 = 2.53\,\text{cm} \pm 0.02\,\text{cm}$

She calculated the area A of a washer indicated by the shaded section below.



She used the formula $A = \frac{\pi}{4}(d_1 + d_2)(d_1 - d_2)$

(i) Show that the percentage uncertainty in her value for the area of a washer is about 3%.

(4)

~~absolute~~ absolute uncertain in $d_1 + d_2$ and $d_1 - d_2$:

$0.02 + 0.02 = \pm 0.04$ cm

$d_1 + d_2 = 7.05 \pm 0.04$ cm, $\%: \frac{0.04}{7.05} \times 100 = 0.57\%$

$d_1 - d_2: 1.99 \pm 0.04$ cm, $\% = \frac{0.04}{1.99} \times 100 = 2.01\%$

% uncertainty in area:

$0.57 + 2.01 = 2.58\% \approx 3\%$

(ii) The student obtained the following values of t for each of the five washers.

t/mm	4.3	4.2	4.1	3.9	4.0

The table shows the density of iron and steel.

Metal	Iron	Steel
Density/g cm^{-3}	6.9	7.9

Deduce whether the washers are made from iron or steel.

mean mass of a washer = 32.0 g

The uncertainty in the mass is negligible.

(6)

$\rho = \frac{m}{V}$, mean t: $\frac{4.3+4.2+4.1+3.9+4}{5} = 4.1$mm

% uncertainty in t: $\frac{(4.3-3.9)\div 2}{4.1} \times 100 = 4.88\%$

V = A × t : ~~$\frac{\pi}{4}$ (7.05) (1.99)~~

$= \frac{\pi}{4}(0.0705)(0.0199) \times 4.1 \times 10^{-3} = 4.52 \times 10^{-6}\ m^3$

% uncertaint in V: 4.88 + 2.58 = 7.46%

% uncertainty of mass: $\frac{0.05}{32} \times 100 = 0.16\%$

$\rho = \frac{32\ g}{4.52\ cm^3} = 7.08$ ~~kg~~ g cm^{-3}, so it made from steel

% uncertainty in ρ: 0.16 + 7.46 = 7.62%

ResultsPlus
Examiner Comments

In Q11(c)(i) all the uncertainties are combined correctly.

In Q11(c)(ii) the first five marking points are all awarded. Although the percentage uncertainty in the density is calculated, this is not used to calculate a range and so a valid conclusion is not made. For this reason Mark Point 6 is not awarded.

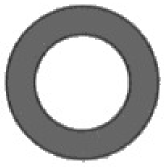
This response scored full marks for Q11(c)(i), but only 3 marks for Q11(c)(ii).

(c) The student obtained the following mean values.

$d_1 = 4.52\,\text{cm} \pm 0.02\,\text{cm}$

$d_2 = 2.53\,\text{cm} \pm 0.02\,\text{cm}$

She calculated the area A of a washer indicated by the shaded section below.



She used the formula $A = \frac{\pi}{4}(d_1 + d_2)(d_1 - d_2)$

(i) Show that the percentage uncertainty in her value for the area of a washer is about 3%.

(4)

$A = \frac{\pi}{4}(d_1 + d_2)(d_1 - d_2)$

$= \frac{\pi}{4}(4.52 + 2.53)(4.52 - 2.53)$

$= \frac{\pi}{4}(7.05)(1.99)$

$= 11.019\ \text{cm}^2$

Abs unc of

$d_1 + d_2 = 0.02 + 0.02$

$d_1 - d_2 = 0.02 + 0.02$

% unc of $d_1 + d_2 = \frac{0.04 \times 100}{7.05}$

$= \pm 0.567\%$

$d_1 - d_2 = \frac{0.04 \times 100}{1.99}$

$= \pm 2.01\%$

% unc of $A = 0.567 + 2.010 = \pm 2.577\% \approx \pm 3\%$

(ii) The student obtained the following values of t for each of the five washers.

t / mm	4.3	4.2	4.1	3.9	4.0

The table shows the density of iron and steel.

Metal	Iron	Steel
Density / g cm^{-3}	6.9	7.9

Deduce whether the washers are made from iron or steel.

mean mass of a washer = 32.0 g

The uncertainty in the mass is negligible.

(6)

4.3 + 4.2 + 4.1 + 3.9 + 4.0 = 20.5

$\frac{20.5}{5} = 4.1$

mean of t = 4.1 mm

= 0.41 cm

$11.019 \times 10^{-4} = 1.1019 \times 10^{-3}$ m^2

$1.1019 \times 4.1 \times 10^{-3} = 4.518 \times 10^{-6}$ m^3

$\rho = \frac{m}{V} = \frac{0.032}{4.518 \times 10^{-6}} =$

$11.019 \times 10^{-4} \times 0.41 = V = 4.518 \times 10^{-4}$ cm^3

$\rho = \frac{m}{V} = \frac{32}{4.518 \times 10^{-4}} = 70831$

∴ Metal used may iron

ResultsPlus
Examiner Comments

In Q11(c)(i) the uncertainties are added correctly to calculate the percentage uncertainty in the area. The calculated value is given to 4 significant figures, which is fine. At least 2 significant figures are required here, as the 'show that' value is given to 1 significant figure.

In Q11(c)(ii) a correct value for the density is obtained, but there is no attempt to use the uncertainties to calculate a range for this calculated value.

ResultsPlus
Examiner Tip

In a 'show that' question you must give your final answer to at least one more significant figure than the value quoted in the question.

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:

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