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Examiners' Report
June 2017

GCE Physics 9PH0 03

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Introduction

This was the first examination of this paper in the new specification. It consists of 120 marks split between short open, open-response, calculations and extended writing questions. 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 students' experiences of the core practicals.

This 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.

However, the marks for questions 1, 4(c), 6(b), 10(b)(ii), 10(c)(i), and 10(d) which test indirect practical skills, tended to be clustered at the lower end of the scale. Similarly question 5 which is a linkage question, and questions 12 and 13 which are synoptic questions, tended not to be as well answered as other questions on the paper.

As with the previous specification, 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. Occasionally in calculation questions the final mark was not awarded due to a missing unit. The more limited use of the "show that" format in this paper may have increased the level of challenge for some candidates in questions where a calculation was required.

There were many examples of candidates disadvantaging themselves by not actually answering the question, or by not expressing themselves using suitably precise language. This was particularly the case in some of the questions testing indirect practical skills such as 4(c) and 12(b), where candidates sometimes had knowledge of the method, but could not express it accurately and succinctly. Candidates could most improve by ensuring they understand all aspects in sufficient detail and always use appropriate specialist terminology when giving descriptive answers.

Scientific terminology was used imprecisely and incorrectly in a number of responses seen on this paper. In particular, candidates' use of the terms accuracy, error, precision, resolution and uncertainty seemed to be quite fluid with some of these terms being used interchangeably throughout the paper.

The space allowed for responses was usually sufficient. However, candidates need to remember that the space provided does not have to be filled. Candidates should be encouraged to consider the number of marks available for a question, and to use this to inform their response.

Question 1 (a)

This question was meant to provide a straightforward introduction to the paper, focusing on the key terms **error** and **uncertainty**.

When scientists make an experimental measurement, they assume that some "true value" exists, and that their measurements will produce a range of values that this "true value" will fall within.

The terms used in this specification are those described in the publication by the Association for Science Education entitled *The Language of Measurement*. It should be noted that certain terms have a meaning different from those in the previous specification. For further detail, refer to Appendix 10 of the current specification document.

Many candidates seemed to be confused about the differences between an error and an uncertainty, and some clearly thought that they were the same. Weak answers to the question often gave vague descriptions about when the results are wrong due to mistakes made in the process of measurement. Some knew the definitions very well and gave a clear response that scored full marks.

Answer ALL questions in the spaces provided.

1 A physics textbook states that "when carrying out experimental measurements there will always be errors and uncertainties".

(a) Describe what physicists mean by error and by uncertainty.

(2)

Error is where a mistake or a flaw in the practical experiment causes the results produced to disagree with the expected results.
Uncertainty is how accurate a result is based on how precise the equipment used is.

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Examiner Comments

This response did not score either marking point. Error is confused with a mistake, and uncertainty is confused with precision (resolution) of an instrument.

ResultsPlus
Examiner Tip

Learn definitions of key terms given in the specification so that you can write accurate descriptions in the examination.

Answer ALL questions in the spaces provided.

1 A physics textbook states that "when carrying out experimental measurements there will always be errors and uncertainties".

(a) Describe what physicists mean by error and by uncertainty.

(2)

Error is ~~obtaining~~ the difference between the experimental value that is obtained and the true value.

Uncertainty is the range of values that ~~some~~ a value may lie between. For example 10 cm ± 0.5 cm

ResultsPlus

Examiner Comments

This response is worth 2 marks, as both error and uncertainty are defined correctly.

Question 1 (b)

Most candidates usually picked up at least 1 mark here, usually for a statement or description of resolution, although reaction times and parallax error were commonly seen.

Some candidates used the word *precision* in place of *resolution*. On this occasion this was accepted, although in future examination series the term *precision* will be expected to be used for "the closeness of agreement between values obtained by repeated measurement", as defined in Appendix 10 of the specification.

Very few approached the third alternative on the mark scheme, and those that did usually missed it by choosing the wrong factor as not being constant (e.g. the temperature of the room might change during the experiment).

(b) Give two reasons why a measurement may have an uncertainty.

(2)

Human error with reading values from different perspectives, such as parallax error. It's dependant on the level of accuracy, the smaller the value the higher the uncertainty as precision is reduced. The bigger the value the less the uncertainty as the value is more averaged and clearer. It also depends on the type of equipment and the nature of the variable being measured.

ResultsPlus
Examiner Comments

This response is worth 1 mark, as parallax error has been identified as a source of uncertainty in a measurement. Note that "human error" on its own would not be an answer worthy of credit.

(b) Give two reasons why a measurement may have an uncertainty.

(2)

A measurement may have human error involved where reaction speed of a human taking the measurements means the data is higher or lower than the actual value, therefore there is an uncertainty to the data. There could also be a system error in which there is a zero error on a piece of apparatus (eg scale) so that the value measured is higher than the actual value as the machine wasn't set to zero

(Total for Question 1 = 4 marks)

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Examiner Comments

Once again the use of "human error" is insufficient for a mark, although as this is qualified as being a reaction time a mark can be given. The reference to a zero error (referred to as a system rather than a systematic error here) is enough for a second mark to be awarded.

Question 2

This question was chosen as a straightforward experimental determination that should have been familiar to most candidates. The question tests candidates' knowledge of the need for specific measuring instruments to be used, as well as their understanding of simple techniques to improve the accuracy of the density value obtained. The question was marked holistically, so that a precaution given in the answer to part (a) or a reference to an averaging technique in part (b) would be credited.

Most candidates specified both the quantity being measured and the instrument to use. It was expected that candidates would select a micrometer screw gauge to measure *y* and Vernier calipers to measure *x* and *z*.

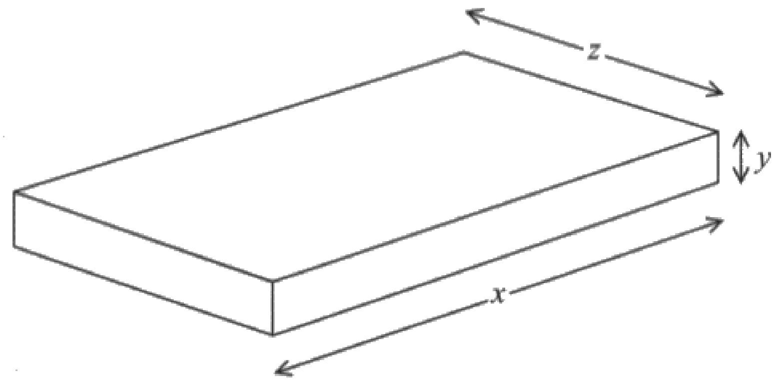
Given that many candidates will have used digital instruments to make such measurements it was accepted that *digital* calipers could be an alternative to using a micrometer to measure *y*. A number of candidates described using a ruler to measure at least one of the lengths, although it was not thought that this was not the most suitable instrument to select.

In the context of the question, using a *scale* to measure the mass was just about acceptable, although *scales* would be a more usual description. Many candidates referred to a *balance*, with some calling it a top pan balance or an electronic balance. All these descriptions were accepted.

Some candidates scored MP4 and MP5 together by describing a length measurement being repeated in several places on the slides and then a mean value being calculated.

2 A student carries out measurements to determine the density of glass. The student has 20 glass microscope slides available.

The approximate dimensions of one slide are shown.



$x \approx 75\,\text{mm}$
$y \approx 1\,\text{mm}$
$z \approx 25\,\text{mm}$

(a) The density is calculated using the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Describe how the student can determine an accurate value for the density of the glass. Your answer should include the measuring instruments required.

(4)

Use of a micrometer screwgauge to measure y and use of vernier calipers to measure x and z. Measure all of the dimensions for all of the glass slides, then put onto a zeroed balance. Divide the mass by 20 to find the mass of 1 slide. Use $\rho = \frac{m}{V}$ where $V = xyz$ (all in metres) to calculate the density of one slide, therefore the density of the glass.

(b) State one precaution that the student should take to ensure the measurements are accurate.

(1)

Ensure the micrometer and vernier calipers are calibrated correctly (set to 0).

ResultsPlus
Examiner Comments

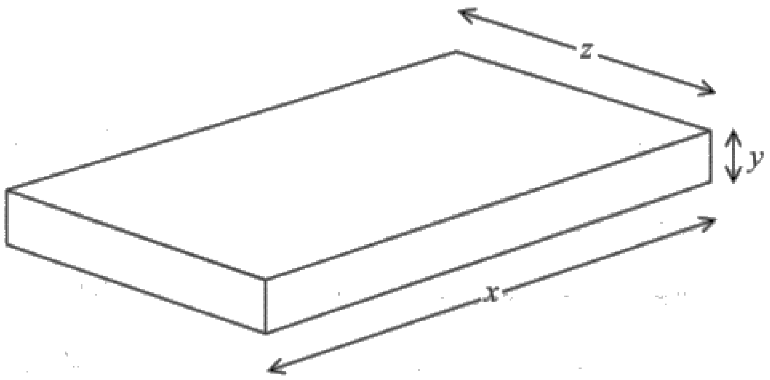
This response makes all the required points and so gains full marks.

ResultsPlus
Examiner Tip

Consider the resolution of all the measuring instruments available to allow the most suitable instrument to be selected.

2 A student carries out measurements to determine the density of glass. The student has 20 glass microscope slides available.

The approximate dimensions of one slide are shown.



$x \approx 75\,\text{mm}$
$y \approx 1\,\text{mm}$
$z \approx 25\,\text{mm}$

(a) The density is calculated using the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Describe how the student can determine an accurate value for the density of the glass. Your answer should include the measuring instruments required.

(4)

We need to use a top-pan balance, a venir calliper and a micrometer. First, check the zero balance of the balance and measure the mass for 20 slides. Take the mean value as the accurate one. Secondly, also check the zero error of calliper, measure the length and the width then take the mean value. Lastly, use the micrometer to measure height (check zero error) for each and take mean value. Hence we can determine an accurate value for the density of glass. We can also calculate uncertainty by % U of mass + % U of volume.

(b) State one precaution that the student should take to ensure the measurements are accurate.

(1)

It is better to check zero error before any measure.

ResultsPlus

Examiner Comments

This response includes an ambiguous statement about determining a mean value, and so MP4 cannot be awarded. All the other marking points are stated and so this response is worth 4 marks.

Question 3

This question uses the command word **deduce**, which requires candidates to draw a conclusion from the information provided. Hence it is vital that for MP3 to be awarded candidates bring the two pieces of evidence together to make a conclusion that refers to wave-particle duality.

This question was well answered, with most candidates giving a description of the conclusions of the two sets of experiments leading to a statement about wave particle duality. Some candidates did not make it explicit which set of experiments they were referring to, and some candidates focused on the detection of charge in the field deflection experiment and ignored the evidence that these provided for the particle nature of electrons.

A small number of candidates, in seeing the use of metal foil, went off at a tangent and described the Rutherford alpha particle experiment results.

3 In the 19th century experiments with magnetic and electric field deflections were used to determine the charge to mass ratio of electrons.
Later experiments showed the diffraction of electrons as they passed through thin metal foils.
Deduce what these experiments tell us about electrons.

(3)

- These experiments show the wave-particle duality of electrons
- The first experiment shows the electrons acting a particle as magnetic fields and electric fields would have no effect on a wave.
- The second experiment shows the wave nature of electrons. This is because only waves will be diffracted when passing through a thin metal foil, but particles wouldn't diffract.

ResultsPlus

Examiner Comments

Although the response refers to the first experiment and the second experiment it is clear from the order in which these experiments are mentioned that correct experiments are being referenced for each effect. Hence 3 marks can be given.

3 In the 19th century experiments with magnetic and electric field deflections were used to determine the charge to mass ratio of electrons.
Later experiments showed the diffraction of electrons as they passed through thin metal foils.
Deduce what these experiments tell us about electrons.

(3)

Most of the electrons passed through the metal foils, suggesting that most of the atom is just empty space. Some of the electrons were deflected less than 90°, suggesting that there was an overall charge, repelling them away. Few deflected greater than 90°, suggesting this charge is centred in a nucleus.

ResultsPlus
Examiner Comments

This response is referring to alpha-particle scattering rather than electron deflection and diffraction experiments, so no credit can be given.

ResultsPlus
Examiner Tip

Read the question carefully to ensure that you are giving an answer to the question being posed.

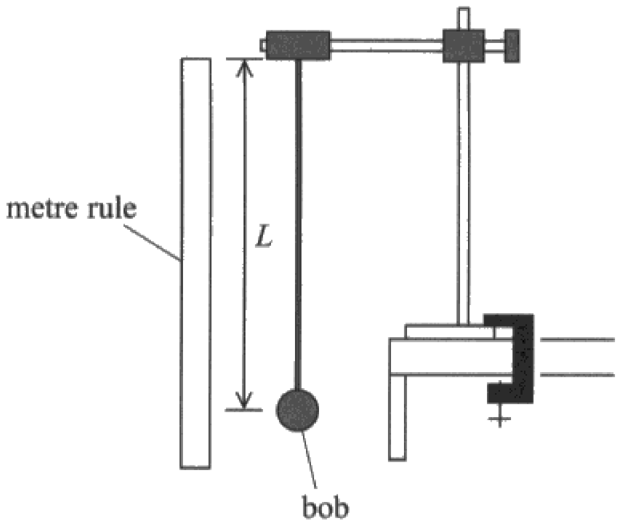
Question 4 (a)

The simple pendulum equation appears in the current specification equation list, although it was not included in the list provided for the previous specification.

This should have been a straightforward calculation. However, many candidates did not read the stem of the question carefully enough and substituted 1.00 s into the simple pendulum equation rather than 2.00 s.

Occasionally g = 10 N kg^{-1} was used, resulting in just MP1 being awarded, despite an answer very close to the accepted answer. Some candidates seemed to be unaware of the simple pendulum equation and attempted to use equations of motion to obtain a solution.

4 A student set up a "seconds pendulum". This is a simple pendulum for which the time taken to move from the bob's highest position on one side to its highest position on the opposite side is 1.00 s.



(a) Calculate the length L required for the pendulum to be a "seconds pendulum".

(2)

$T = 2\pi\sqrt{\frac{L}{g}}$

$2 = 2\pi\sqrt{\frac{L}{9.81}}$

$\frac{2}{2\pi} = \sqrt{\frac{L}{9.81}}$

$\frac{L}{9.81} = 0.101$

$L = 0.99$

L = 0.99m

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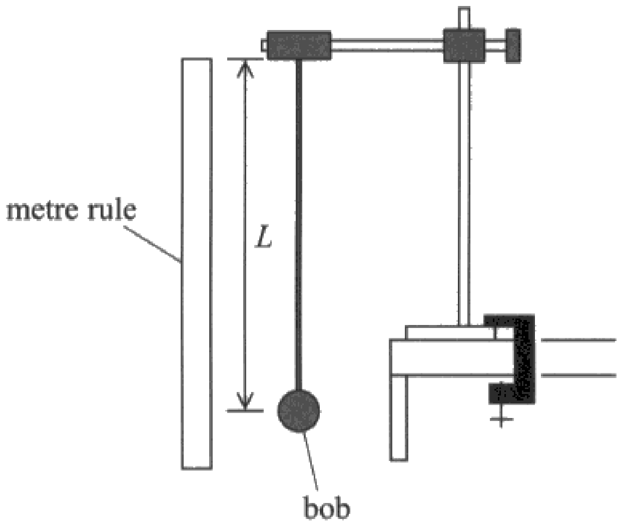
Examiner Comments

This is a correct solution, so 2 marks were awarded.

4 A student set up a "seconds pendulum". This is a simple pendulum for which the time taken to move from the bob's highest position on one side to its highest position on the opposite side is 1.00 s.



(a) Calculate the length L required for the pendulum to be a "seconds pendulum".

(2)

$T = 2\pi\sqrt{\frac{l}{g}} \Rightarrow T^2 = 4\pi \frac{l}{g}$

$\Rightarrow l = \frac{T^2 g}{4\pi} = \frac{(1^2)g}{4\pi} = \frac{g}{4\pi} = \frac{9.81}{4\pi}$

$l = 0.78\text{m}.$

$L =$ 0.78m.

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Examiner Comments

In this response the equation has not been re-arranged correctly before values have been substituted, nor does it show the substitutions into the equation.
0 marks.

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Examiner Tip

Substitute numbers into an equation before re-arranging.

Question 4 (b)

This question tests candidates' knowledge of timing techniques. It is expected that all candidates will have used a stopwatch to make manual measurements of an oscillating system.

Most candidates were awarded MP1, with few choosing to time a single oscillation. Occasionally candidates did not gain this mark as a result of not specifying the number of oscillations that they would time. MP2 was usually awarded as a result of candidates specifying repeats of multiple oscillations and then calculating a mean.

Only a small proportion of candidates made reference to a (fiducial) marker, although many gave extra information such as waiting for the oscillations to settle down before timing, or not displacing the pendulum through too large an angle.

(b) The student set the pendulum into oscillation. She used a stopwatch to check the accuracy of the pendulum's period T.

Describe the procedure the student should have used to obtain an accurate value for T.

(2)

• place a fiducial marker at the centre of oscillations

• start a timer after one oscillation and time for 10 oscillations

• repeat 5 times and find the average and divide by 10

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Examiner Comments

This response includes all the marking points and so is worth 2 marks.

Measure the time periods more (more than 20), and repeat the measurement for many times (more than 5). Then take the mean value of the total time and divide it by the number of measured time periods.

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Examiner Comments

Although there is no indication of a fiducial marker being used, there is enough in this response for 2 marks to be awarded.

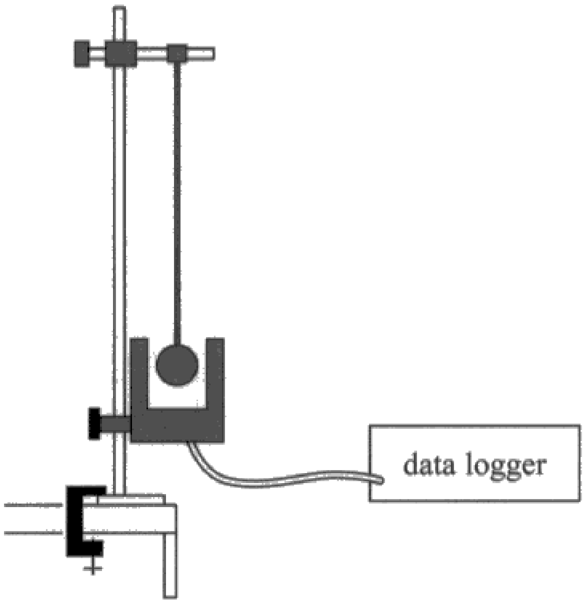
Question 4 (c)

This question required candidates to make a detailed consideration of the merits of using a data logger in place of a manual timing method. The responses seen would tend to indicate that many candidates had learned some advantages of using a data logger without actually using a data logger themselves to collect data. Disadvantages of using a data logger seemed to be confined to the relative cost of data logging equipment compared with that of a stopwatch.

Most candidates scored MP1, with some of these candidates going on to score MP2 also. Some candidates started their answers by stating that the stopwatch and the data logger had the same resolution, and then went on to state that this meant they would also have the same uncertainty. Some candidates used percentage uncertainty in their attempt at MP2, which contradicted MP3. The least commonly awarded marks were MP3 and MP4, which were both very rare to see.

It was clear that for many candidates the data logger would inevitably lead to a better answer, and the only thing preventing data loggers being used to make such measurements was the expense factor.

(c) Another student suggested that the uncertainty in the measurement of the time period of the pendulum could be reduced by using a light gate and a data logger. The data logger would record the time between successive interruptions of the light beam. Both the data logger and the stopwatch have a resolution of 0.01 s.



Comment on the student's suggestion of using a data logger rather than a stopwatch.

(4)

There is human error in starting and stopping a stopwatch at the right time, and a relatively large uncertainty. A light gate and data logger would have a lower uncertainty as there is no delay from human reaction

However, the pendulum bob is not a point mass, and the end of it entering the light gate first would disrupt the beam, meaning the time calculated is only accurate if a sphere and large enough amplitude. If the data logger only measures the time for half the period it's percentage uncertainty will be greater than for 10 periods (as stopwatch can too).

(Total for Question 4 = 8 marks)

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Examiner Comments

Although "human error" on its own would not be enough for MP1, the qualification that this error is associated with starting and stopping the stopwatch is just enough to award MP1. The rest of the response includes all the other marking points, and so this is an example of a response that gains full marks.

Question 5

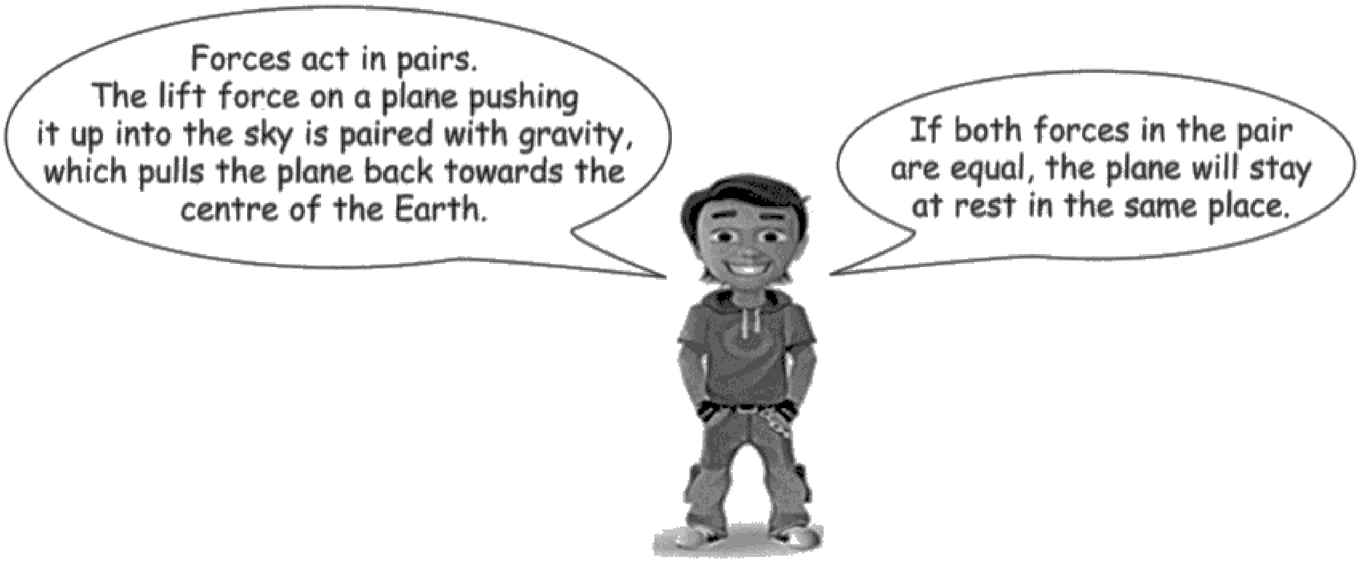
This is an extended writing question which assesses the candidates' ability to show a coherent and logical structured answer with linkage and fully sustained reasoning. There are 6 indicative content (IC) points, for which a maximum of 4 marks can be awarded. There are two further marks available for appropriate linkage of ideas. In this question two linked points from IC 1 – 3 could score 1 linkage mark, as could 2 linked points from IC 4 – 6.

The extracts given relate to the forces acting on a plane. In giving a clear response to the question it is important for candidates to point out that the left hand statements are connected to Newton's 3rd law (N3) and the right hand statement needs to be considered in the context of a particular direction (horizontal or vertical in this case).

Out of the IC points, the most commonly seen were IC1, IC2 and IC3. However, a number of candidates failed to link these to N3. In many of the scripts seen, candidates did not work hard enough to distinguish the vertical motion from the horizontal motion. This restricted their ability to access IC4, IC5, and IC6.

A minority of candidates simply stated what all of Newton's laws were, with very little attempt to relate these to the statements given in the extract.

*5 The following extract comes from a section on forces, on a website written for children.



Criticise this extract.

(6)

– According to Newton's 3rd Law (if object A exerts a force on object B, object B will exert an equal and opposite force on object A), all forces do act in pairs but on different objects.

– However, the lift force and gravity on a plane aren't an example of a Newtonian force pair, since they both act on the same object (the plane) (and are of different types)

– The correct statement should say, that the lift force upwards of the air on the plane is paired with the ~~[illegible]~~ drag equal reaction force downward of the plane on the air. Likewise, the force of gravity downward in the plane to the Earth is paired with the force of gravity of the plane on the Earth upwards.

- The second statement is also ∴ incorrect. The two forces in the Newtonian pair will always be equal in magnitude, and don't mean that the object will stay at rest. An object will stay at rest if there is no resultant force on it (Newton's 1st Law), ∴ only applies to opposing forces.
- Lift and gravity are opposing forces, but when they are equal, the plane isn't at rest, instead, it will either have no vertical acceleration (due to no vertical resultant force – Newton's 2nd Law – F=ma), or will have a constant vertical velocity (Newton's 1st Law).

(Total for Question 5 = 6 marks)

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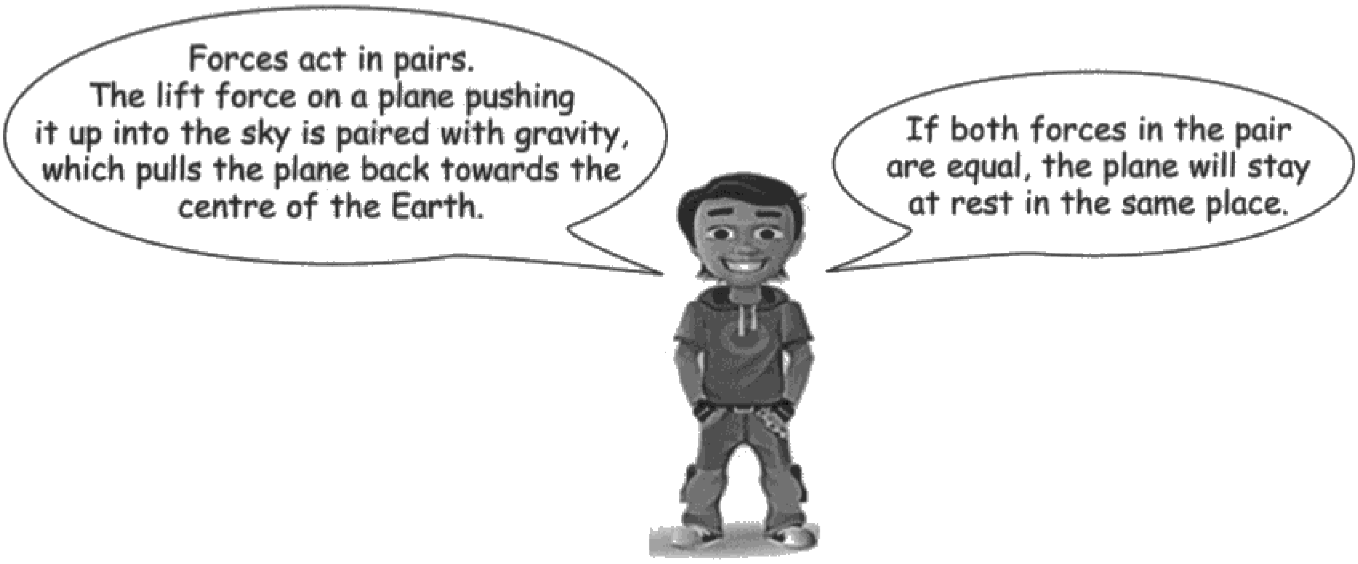
Examiner Comments

This is an excellent response to the question. All 6 indicative content points are stated and there is good linkage of ideas, giving this response 6 marks.

***5** The following extract comes from a section on forces, on a website written for children.



Criticise this extract.

(6)

According to Newtons first law, if the forces are balanced, the net force is zero and the plane will remain at constant velocity. Newtons third law states that forces do come in pairs, however they do not act on the same object so the lift and gravity are not a pair. Third law also states that the forces are always opposite and equal in magnitude, so there is no question if the forces are equal. The acceleration of the plane is not determined by third law pairs but by external forces. The pairs in the situation act between the plane and the air and the plane and the Earth.

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Examiner Comments

In places this response is in danger of losing sight of the context of the question. However, the first 3 indicative points are just about stated (giving 2 marks), and there is some logical linkage between these points (giving 1 mark) and so 3 marks are justified.

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Examiner Tip

Always relate answers to the context given in the question.

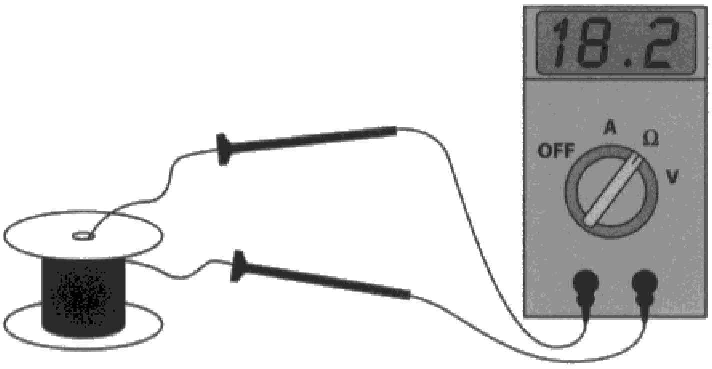
Question 6 (a)

This question assesses candidates' ability to calculate and combine uncertainties. In this case it was acceptable for candidates to calculate the percentage uncertainty in the resistance reading by taking the full range or just half the range. However, in future examination series the half range value is expected to be used in calculating the percentage uncertainty. This is clarified in an updated section in Appendix 10 of the specification.

This question was answered well in general. All of the marking points were commonly seen although MP4 was the least commonly awarded. A small number of candidates halved the diameter reading before applying the same ± value to the radius as there was for the diameter. As this is incorrect such candidates were not awarded MP3.

6 A student carried out an experiment to determine the resistivity of nichrome wire.

He used an ohmmeter to measure the resistance of a length of nichrome wire as shown.



The diameter of the wire was measured as 0.27 mm ± 0.01 mm.
The length of the wire was measured as 1.25 m ± 0.05 m.

(a) Determine which of the three measurements introduces the greatest uncertainty into the value for the resistivity.
Your answer should include calculations.

(4)

Uncertainty in diameter: $\frac{0.01}{0.27} \times 100 = 3.7\%$

Uncertainty in length: $\frac{0.05}{1.25} \times 100 = 4\%$

$\rho = \frac{RA}{l}$ where $A = \frac{\pi d^2}{4}$

Uncertainty in $A = 3.7 \times 2 = 7.4\%$

Uncertainty in resistance: $\frac{0.1}{18.2} \times 100 = 0.55$

The measurement of diameter introduces the greatest uncertainty into the value for resistivity as it is at 7.4%

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Examiner Comments

This response scores all 4 marks.

Question 6 (b)

Many candidates could describe the correct technique of measuring the diameter in multiple places/orientations then calculating a mean. However, a smaller number of candidates stated that they would do this to remove the effect of random error.

Some candidates missed the point of the question and stated that they would use a micrometer or a digital caliper. As the resolution had already been shown as 0.01 mm it is not clear what such candidates thought the original measurements had been made with.

A number of candidates also decided to change the experiment by stating that the student could use a thicker wire to reduce the percentage uncertainty of the diameter reading. Although it is true that using thicker wire would reduce the percentage uncertainty, this would not be a solution for this particular experiment.

*(b) Explain how the student could reduce the uncertainty in the measurement of the diameter.

(2)

To reduce the uncertainty in the measurement of the diameter, the student could use the micrometer to measure the diameter in three places and then calculate a mean average for the diameter. This will reduce the effect of random error.

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Examiner Comments

This response score both marks.

(b) Explain how the student could reduce the uncertainty in the measurement of the diameter.

(2)

Could measure diameter of several wires together in a coil and divide by number of turns/coils. This measures a larger value so lower percentage uncertainty as instrument is already very precise.

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Examiner Comments

Although measuring a number of wires side by side would appear to reduce the percentage uncertainty by making the total measurement larger, in practice this is not a feasible technique. The response does include a reason, but as the method would not work, the reason is invalid and so this response did not score any marks.

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Examiner Tip

Take care with explain questions. In such questions there will be credit for a valid reason or justification.

Question 6 (c)

There were some good answers seen to this question, although MP4 was less commonly awarded than the other 3 marking points.

A few candidates used diameter instead of radius for the area calculation. In addition, power of 10 errors for the diameter were common. However, the measurement that most candidates tripped up with was the need to use a maximum length (as it is the denominator in the resistivity formula). Many candidates used the minimum value of the length.

A good proportion of the candidates did the calculation with all of the original values and then subtracted their total percentage uncertainty from (a), which was a valid method.

(c) Calculate the minimum value of resistivity possible from the student's data.

(4)

$d = 0.26\,mm$, $l = 1.20\,m$

$R = \frac{\rho l}{A}$, $\rho = \frac{RA}{l} = \frac{18.2 \times (0.26 \times 10^{-3})^2 \pi}{1.20} = 3.22 \times 10^{-6}\,\Omega m$

Minimum resistivity = $3.22 \times 10^{-6}\,\Omega m$

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Examiner Comments

In this response the diameter has been used in place of the radius, and so the area value is incorrect. MP2 can be awarded for use of the resistivity equation, but the values selected would not lead to a minimum value of the resistivity and so no further credit can be given.

Question 7 (a)

This question involves a more standard data logger application than that in Q4, although many candidates struggled to do more than state that the time interval being measured was very short.

A good number of candidates realised that the time interval that had to be measured was short and that the data logger was appropriate. However, few candidates had the idea of a high sampling rate being necessary for measuring such short times. It was common to see references to simultaneous measurements between voltage and time. Although true this was not a relevant feature for this application.

There was no expectation for candidates to make a comparison with humans performing the experiment with a stopwatch, but many candidates seemed to feel the need to do this. As a result, these candidates often struggled to achieve MP2 as they wrote about the uncertainty in the stopwatch being greater than that of the data logger.

(a) Explain why a data logger is appropriate for this demonstration.

(2)

It can record multiple values over a period of time and store them. It is precise and has a good resolution. There is no human error.

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Examiner Comments

This response just repeats standard things about data loggers, and does not relate the data logger use to this particular context. No marks were awarded.

(a) Explain why a data logger is appropriate for this demonstration.

(2)

Human methods of recording data would be wildly inaccurate considering there is less than 400 microseconds to react accordingly.

ResultsPlus

Examiner Comments

This response concentrates on why timing with a stopwatch would be wrong, rather than why timing with a data logger is correct. Nonetheless there is enough for MP1 to be awarded.

Question 7 (b) (i)

On the whole this was a well answered question, with many candidates taking correct readings from the graph and using an appropriate equation to calculate the speed of the pulse.

The factor of 2 (required because the pulse travels along the rod and then back) often seemed to "arrive" at some point in the calculation. For a few candidates this happened after they had worked out a speed of 2950 m s^{-1}, which they then doubled to 5900 m s^{-1}. Such candidates could score a maximum of 2 marks.

A number of candidates thought that a standing wave method could be used to solve this problem. These candidates used the contact time to calculate a frequency and then used $v = f\lambda$ to calculate the wave speed. Candidates attempting this method obtained the correct numerical answer, but without any clear indication of why such a solution is appropriate.

(b) (i) Use the graph to show that the speed of the pulse in the rod is about 6000 m s^{-1}.

length of steel rod = 1.18 m

(3)

1400 − 1000 = 400 us   1.18 m   2.36 m

m/s = v $1.18 / 200\times10^{-6}$ = 5900 m s^{-1}

ResultsPlus

Examiner Comments

In this response the candidate does not seem to be sure if they should double the distance or halve the time. However, their calculation leads to the correct answer and appears not to be fiddled.

(b) (i) Use the graph to show that the speed of the pulse in the rod is about 6000 m s^{-1}.

length of steel rod = 1.18 m

(3)

$t = 1400 - 1000 = 400\,\mu s = 400 \times 10^{-6}\,s = 4 \times 10^{-4}\,s$

$l = 1.18\,m$ ~~$v = 2\left(\frac{1.18}{4 \times 10^{-4}}\right) =$~~ $x = 2l = 1.18 \times 2 = 2.36\,m$

$v = \frac{2.36\,m}{4 \times 10^{-4}\,s} = 5900\,ms^{-1} \approx 6000\,ms^{-1}$

ResultsPlus

Examiner Comments

This response is clearer about how the speed is calculated. The final value quoted is 6000 m s^{-1}, although immediately prior to this a 2 significant figure value has been given and so this scores all 3 marks.

ResultsPlus

Examiner Tip

In a “show that” question be sure to make your working clear and quote your answer to at least 1 more significant figure than the value given in the question.

Question 7 (b) (ii)

The Young Modulus is a quantity that A level candidates should be familiar with, and so it is to be expected that the SI units of Pa (or N m^{-2}) would be well known.

This question was well answered by most candidates, but many omitted or gave incorrect units. Some candidates re-arranged the given equation incorrectly before substituting values into it. The mark for "use of" a formula can only be awarded if the candidate substitutes dimensionally correct quantities into a correct equation.

As this question relied upon the answer to part (i), candidates should be aware that if their answer to part (i) is nowhere near the "show that" value, they should use the "show that" value for any further calculations.

length of steel rod = 1.18 m

(3)

$V = \frac{S}{t} = \frac{1.18 \times 2}{400 \times 10^{-6}} = 5900\ ms^{-1}$

$t = (1400\ \mu s - 1000\ \mu s) = 500\ \mu s = 500 \times 10^{-6}$

(ii) The speed of sound v in the rod depends on the Young modulus E and the density ρ of the material of the rod as given by the equation

$$v = \sqrt{\frac{E}{\rho}}$$

Calculate the Young modulus of steel.

$\rho_{steel} = 7850\ kg\ m^{-3}$

(2)

$V^2 = \frac{E}{\rho} \rightarrow E = V^2 \times \rho$

$E = (5900^2) \times 7850 = 2.732 \times 10^{11}$

2.73×10^{11}

Units

$kg m^{-3} \times m s^{-1} \rightarrow kg\ m^{-2} s^{-1}$

Young modulus of steel = $2.73 \times 10^{11}\ kg\ m^{-2} s^{-1}$

(Total for Question 7 = 7 marks)

ResultsPlus
Examiner Comments

In this response the unit for the Young Modulus has been incorrectly stated. The candidate has tried to work out the units from the equation given in the question, but has ended up with a wrong unit. For this reason MP2 cannot be awarded and the response scores just 1 mark.

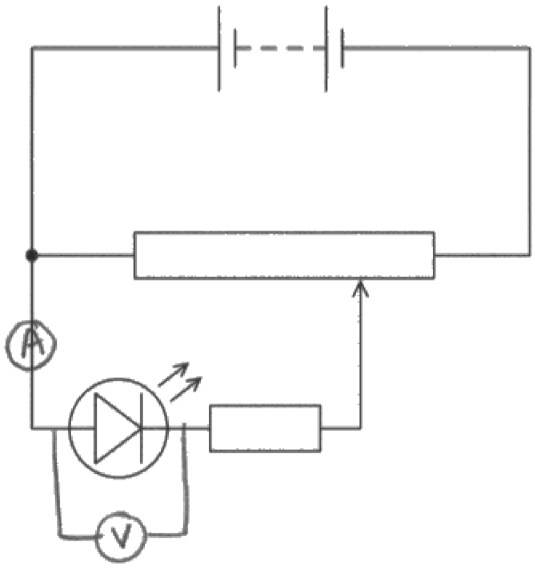
ResultsPlus
Examiner Tip

Note that if the candidate had worked out the units correctly as kg m^{-1} s^{-2}, then full credit would have been given (although the SI unit for the Young Modulus is Pa or N m^{-2}).

Question 8 (a)

A surprisingly large proportion of candidates placed either the ammeter or the voltmeter in the wrong position in the circuit.

8 A student wanted to plot a graph of current against potential difference for a light emitting diode (LED). He used the circuit shown.



ResultsPlus
Examiner Comments

This shows the ammeter and voltmeter in correct positions in the circuit.

ResultsPlus
Examiner Tip

Ammeters are connected in series with the component through which they are measuring the current. Voltmeters are connected in parallel with the component across which they are measuring the p.d.

Question 8 (b) (i)

This question used the command word criticise, which requires candidates to "look at the merits and/or faults of the information presented and back judgements made".

Some candidates were not able to state clearly what is meant by an ohmic conductor. This may have led such candidates to state that the LED was not an ohmic conductor, but that it did conform to Ohm's Law.

Better answers often started off well but then candidates contradicted themselves by stating that after 2 V the graph was linear suggesting that it could be ohmic for higher values of potential difference.

(i) The student wrote the following conclusion.

"The graph shows that in general the LED is not an ohmic conductor. However, for potential differences greater than +2 V, Ohm's law is obeyed since the graph is linear in this region."

Criticise the student's conclusion.

(2)

The end of the graph only goes to +2.5V and so only for the reigon between +2V and +2.5V do we see Ohm's Law being obeyed, we do not know if this relationship continues as we cannot extrapolate the data. So you cannot conclude 'for p.d. greater than +2V'

ResultsPlus

Examiner Comments

In this response there is no statement of Ohm's law or expectation of what the behaviour of an ohmic conductor should be. In addition there is a suggestion that Ohm's law may be obeyed within a certain range of p.d.s. No marks are awarded.

ResultsPlus

Examiner Tip

Read through your answers to ensure that what you have written makes sense.

(i) The student wrote the following conclusion.

"The graph shows that in general the LED is not an ohmic conductor. However, for potential differences greater than +2 V, Ohm's law is obeyed since the graph is linear in this region."

Criticise the student's conclusion.

(2)

Ohm's law ~~states~~ that potential difference is directly proportional to the current, therefore for ohm's law to be obeyed the graph should be a straight line from the start with the line crossing the origin, hence ohm's law is not obeyed. The LED is never an ohmic conductor the phrase "in general" should not be in that sentence.

ResultsPlus

Examiner Comments

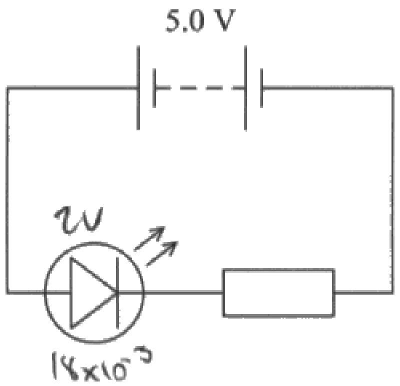
This response scores both marks.

Question 8 (b) (ii)

This question was answered well with a good proportion of candidates gaining all 4 marks.

Those candidates who performed poorly on this question often did so because they had worked out the resistance of the whole circuit and had not considered that the LED had any resistance.

(ii) The student used the LED with a 5.0 V power supply as shown in the circuit.



To be lit to normal brightness the current through the LED must be 18 mA.

Calculate the resistance of the resistor needed in the circuit.

(4)

$5 - 2 = 3 \quad R = \frac{V}{I} = \frac{3}{18\times10^{-3}} = 166.67\,\Omega$

$= 167\,\Omega$

Resistance = $167\,\Omega$

ResultsPlus

Examiner Comments

This concise response scores all 4 marks.

Question 9 (a)

One question in this paper is used to assess candidates' ability to draw and interpret graphs. This may include using a logarithmic plot to test a power law variation as in this example.

Most candidates picked up both marks, being well drilled in this style of question. However, a small number were not able to simplify the equation using logs.

The majority of those who obtained a correct log equation but missed out on MP2 did so by not making a clear link between their equation and the equation of a straight line ($y = m\,x + c$).

Explain why a graph of log L against log M would give a straight line.

(2)

$\log L = \log L_{sun} + p \log M.$

$(\log L) = (p \log M) + (\log L_{sun})$

$(y) = (m\,x) + (c)$

The equation can be expressed in the form $y = mx + c$, where $\log L$ is on the y-axis, $\log M$ is on the x axis and p is the gradient.

ResultsPlus

Examiner Comments

This response clearly shows the links between the log equation and the general equation of a straight line and is worth both marks.

Explain why a graph of log L against log M would give a straight line.

(2)

~~$\log L = \log M +$~~ ~~$\frac{L}{L_{sun}} = M^{P}$~~

~~$\ln\left(\frac{L}{L_{sun}}\right) = P \log M$~~

$\log L = P \log M + \log (L_{sun})$

ResultsPlus

Examiner Comments

This response applies logs correctly but omits the reference to the general equation of a straight line, so only MP1 is awarded.

Question 9 (b) (i)

In plotting a graph, candidates should choose scales that spread the plotted points over more than half of the available graph paper. Difficult scales (i.e. scales increasing in "3"s, "7"s etc.) must not be used, and axes should be clearly labelled; where appropriate, units should be included. Points should be plotted clearly (preferably using crosses) and a line of best fit drawn to show the trend.

Most candidates completed the table giving their data to 3 or 4 significant figures, and so MP1 was frequently awarded. Similarly MP3, 4 and 5 were quite commonly seen, although a number of candidates did not plot the point for which log (M) was negative. For those who plotted the points correctly, the mark for the best fit line was rarely missed.

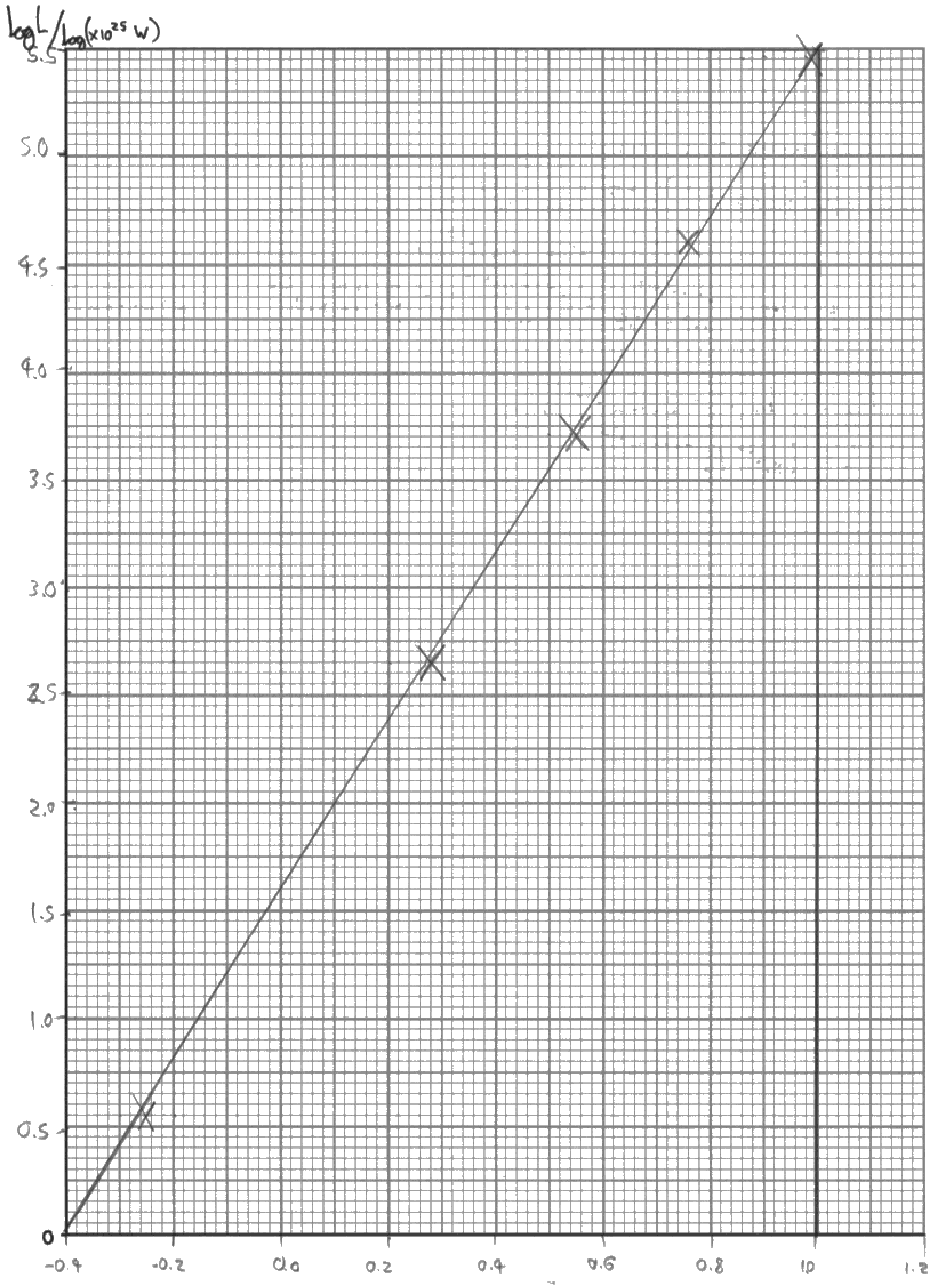
MP2 was the least commonly awarded mark, as most candidates were unable to show the label for the *y*-axis correctly. In addition, some had the axes the wrong way round.

(b) The table shows data for a range of main sequence stars.

$L/10^{25}$ W	M	Log(L) / log (10^{25} w)	log M /
3.63	0.557	0.560	−0.25
469	1.88	2.671	0.27
5920	3.52	3.772	0.55
40 800	5.85	4.611	0.76
294 000	9.72	5.468	0.99

(i) Plot a graph of log L against log M. You may use the columns provided to show any processed data.

(5)


log L / log(x10^25 W)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2

ResultsPlus

Examiner Comments

The response above has an incorrect number of significant figures in the log M column of the table and the labelling on the y-axis is not correct. Otherwise the scaling and plotting is correct with a good line of best fit drawn, and so the response scores 3 marks.

(b) The table shows data for a range of main sequence stars.

$L/10^{25}$ W	M	log (L/10²⁵ W)	log M
3.63	0.557	0.560	−0.254
469	1.88	2.67	0.274
5920	3.52	3.77	0.547
40 800	5.85	4.61	0.767
294 000	9.72	5.47	0.988

(i) Plot a graph of log L against log M. You may use the columns provided to show any processed data.

(5)

log (L /10²⁵ W)

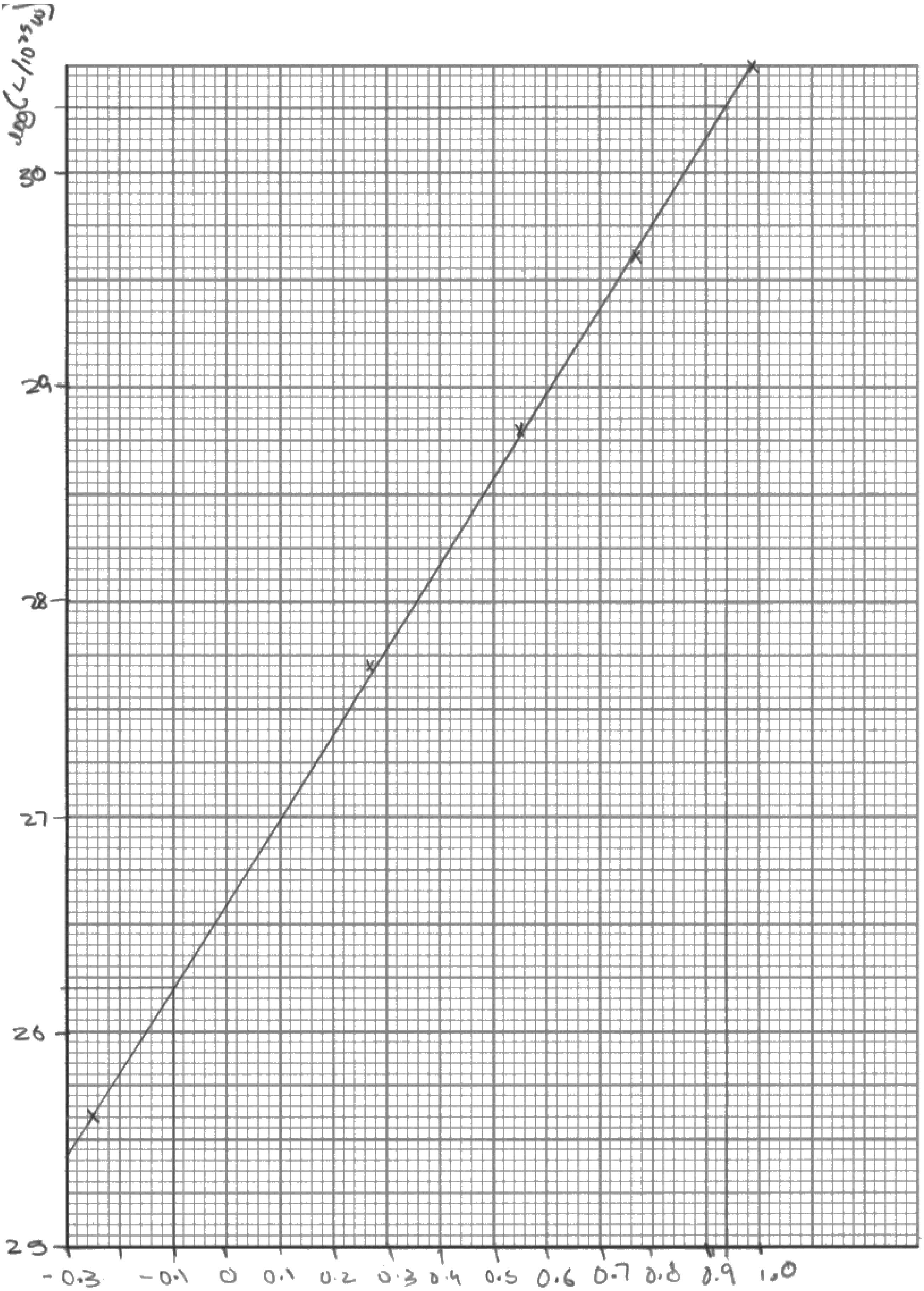
25.6

27.7

28.8

29.6

30.5


log(L/10^25 W)
30
29
28
27
26
25
-0.3
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

ResultsPlus

Examiner Comments

The response above scores all 5 marks.

ResultsPlus

Examiner Tip

Remember to indicate the units of quantities when labelling axes.

Question 9 (b) (ii)

Most candidates knew to use a large triangle when calculating the gradient of the line, although many did not obtain a value for m within the expected range. This is disappointing, as the data was selected to give an unambiguous mean line which should have resulted in all candidates calculating a value for m within the range.

Most candidates read the value of the *y*-intercept off the graph and found the inverse log to obtain a value for L_{Sun}. Having done so, many candidates did not then go on to write a relationship and be awarded MP4.

(ii) Determine values for p and L_{Sun} and hence state the mathematical relationship between L and M.

(4)

$\log L_{sun} = 26.6$ $\quad L_{sun} = 10^{26.6} = 3.98 \times 10^{26}$

gradient $= p = \dfrac{30.25 - 25.75}{0.92 - (-0.22)} = 3.95$

$L = 3.98 \times 10^{26} M^{3.95}$

ResultsPlus

Examiner Comments

This response scores all 4 marks.

Question 10 (a)

Although not a core practical, the experiment described in this question uses many of the skills and techniques developed in carrying out core practical 15. It was disappointing to see that so many candidates were unfamiliar with basic counting techniques, and appeared to know so little of the use of a GM-tube to measure radioactive counts.

This should have been a straightforward process to describe, but a great deal of confusion was demonstrated on account of hurried half descriptions of how to proceed. Many candidates suggested subtracting count rates from counts and vice versa. Too many candidates seemed to think that the count and the count rate were interchangeable, so MP2 was often not awarded.

(a) Describe how to determine the corrected count rate from the source.

(2)

Remove Source from the room and leave ~~ROM~~ GM tube for 10 minutes to Calculate background Count. Then divide by 5 to get average for two mins.

ResultsPlus

Examiner Comments

This response is good enough for MP1, but there is no detail given about finding the count rate and so MP2 is not awarded.

(a) Describe how to determine the corrected count rate from the source.

(2)

~~Remove~~ Before placing the source in the holder measure the count without a source - this is the background radiation. Note down this value and deduct it from ~~an~~ the values of count rate collected /measured.

ResultsPlus

Examiner Comments

This response omits any time for the background count, and then refers to subtracting a count from a count rate. No marks awarded.

ResultsPlus

Examiner Tip

When outlining a process, you need to be clear what is happening at each stage.

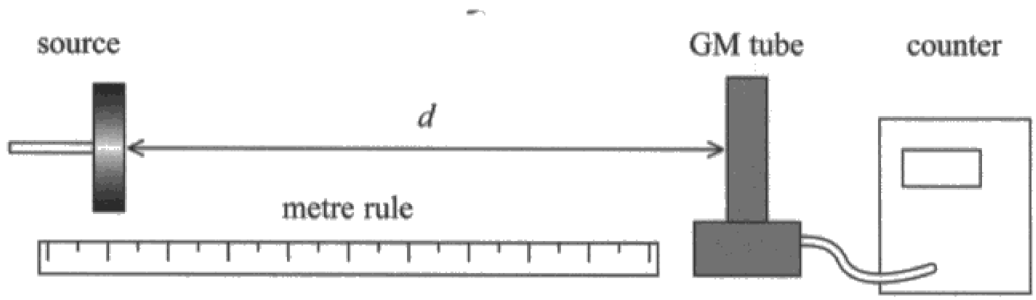
Question 10 (b) (i)

The mark scheme allowed for two different approaches. The second approach was rarely seen, although it did allow 2 marks to be scored in a small number of cases.

The majority of candidates gained MP1 from the first approach by stating that there would be an increased area of tube exposed to the *γ*-rays with the tube turned on its side.

Some candidates did consider how this would affect the count rate, but most simply said that there would be "more radiation detected" or that the "count rate is more accurate". The advantage to be gained by increasing the area exposed to the *γ*-radiation (an increased count rate) was much less frequently seen.

(b) His teacher turned the GM tube through 90° so that the side of the tube faced the source as shown below.



(i) Explain why this arrangement could lead to more accurate data.

(2)

this way there is more area for the gamma rays to hit meaning a greater proportion of the emitted rays will be detected

ResultsPlus

Examiner Comments

This response identifies the larger area and so is awarded MP1. The reference to a greater proportion of *γ*-rays being detected is close, but not close enough for MP2 to be awarded. To meet MP2 it is necessary to refer to an increased count rate.

Question 10 (b) (ii)

A number of candidates discussed measuring background radiation here, although this had been considered in part (a). However, many candidates were awarded MP1 by stating that the count should be taken for a much longer time. Few went on to give a clear reason why this would lead to data with an improved accuracy.

At this point in Q10, a number of candidates decided to change the experiment by putting the source and detector closer together so that more counts would be recorded in 2 minutes.

(ii) Explain another modification to the experimental method which would improve the accuracy of the data.

(2)

Increase the time for recording the count as radioactive decay is random so to avoid this an average must be taken. The larger the time interval the less the randomness should affect the data.

ResultsPlus

Examiner Comments

This response says enough for both marks to be awarded.

Question 10 (c) (i)

Although many candidates drew a good line of best fit through the plotted points, quite a number of students drew a straight line through the origin. Of those who did not force the data through the origin, many joined first and last points. This only left points above the line, and so was not the line of best fit.

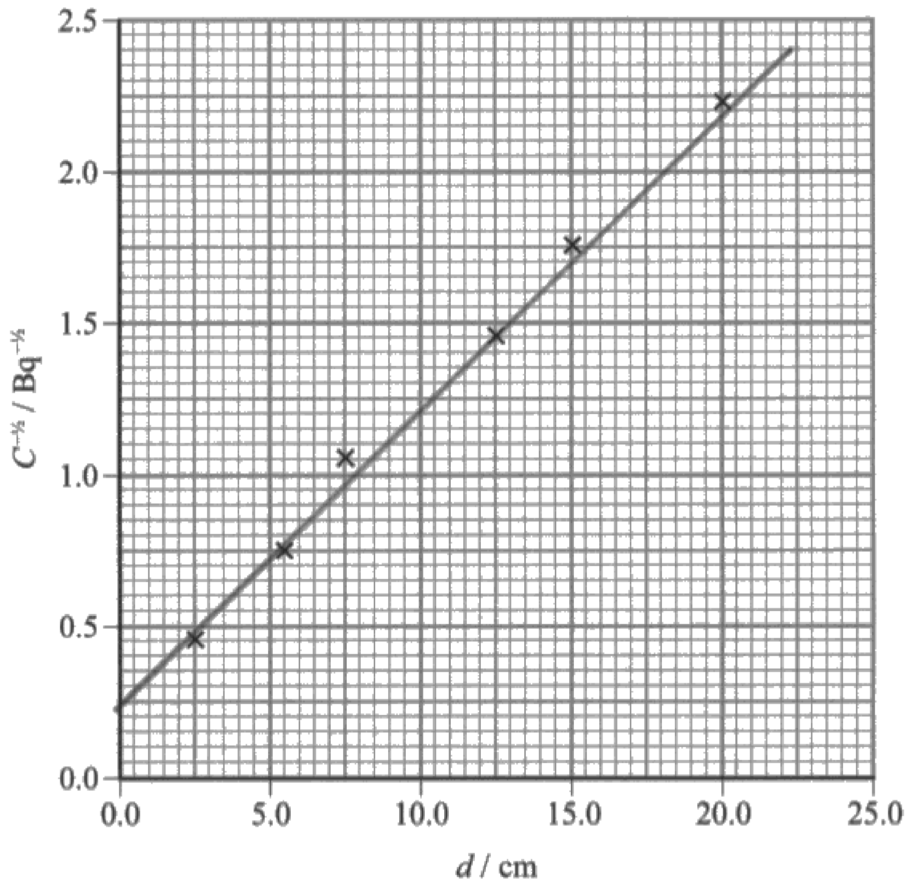
to the detector

(c) The variation in the intensity of gamma radiation with distance from a point source should obey an inverse square law. If this is the case, then the count rate C should vary with d according to the equation

$$C = \frac{K}{4\pi d^2}$$

where K is a constant.

The student plotted $\frac{1}{\sqrt{C}}$ against d and obtained the following graph.



(i) Draw a line of best fit on the graph.

(1)

ResultsPlus

Examiner Comments

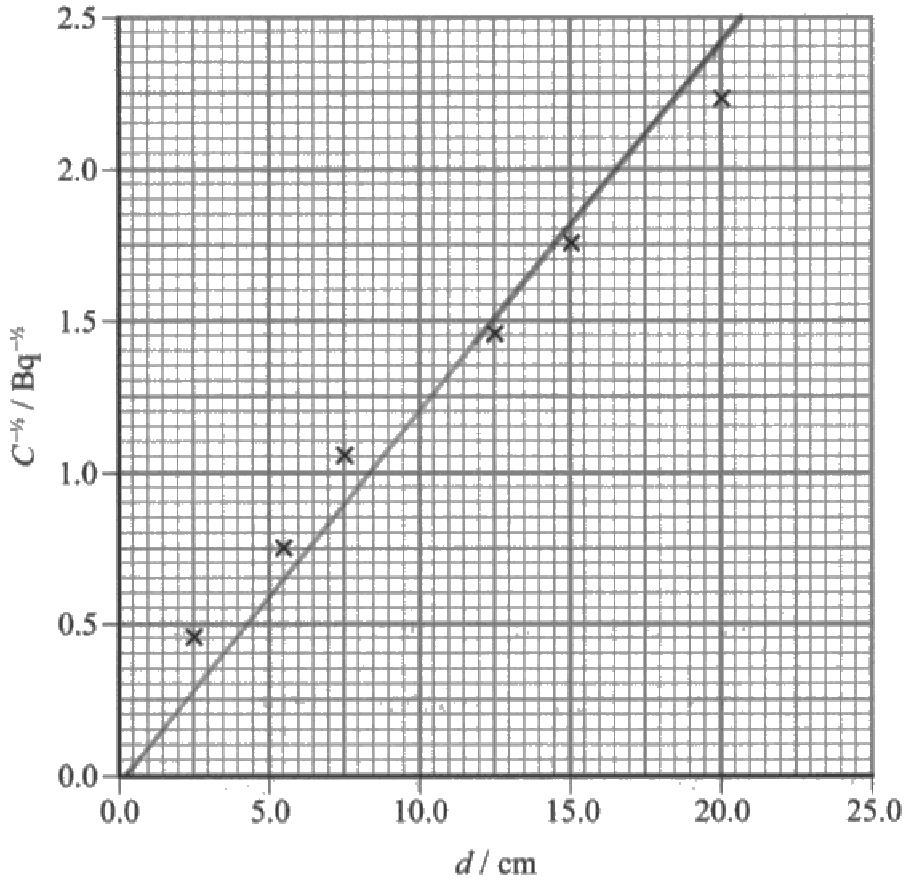
This graph was not awarded the mark, as the line drawn has all off line points above the line.

(c) The variation in the intensity of gamma radiation with distance from a point source should obey an inverse square law. If this is the case, then the count rate C should vary with d according to the equation

$$C = \frac{K}{4\pi d^2}$$

where K is a constant.

The student plotted $\frac{1}{\sqrt{C}}$ against d and obtained the following graph.



(i) Draw a line of best fit on the graph.

(1)

ResultsPlus
Examiner Comments

This line was not awarded the mark as the candidate has forced it through the origin.

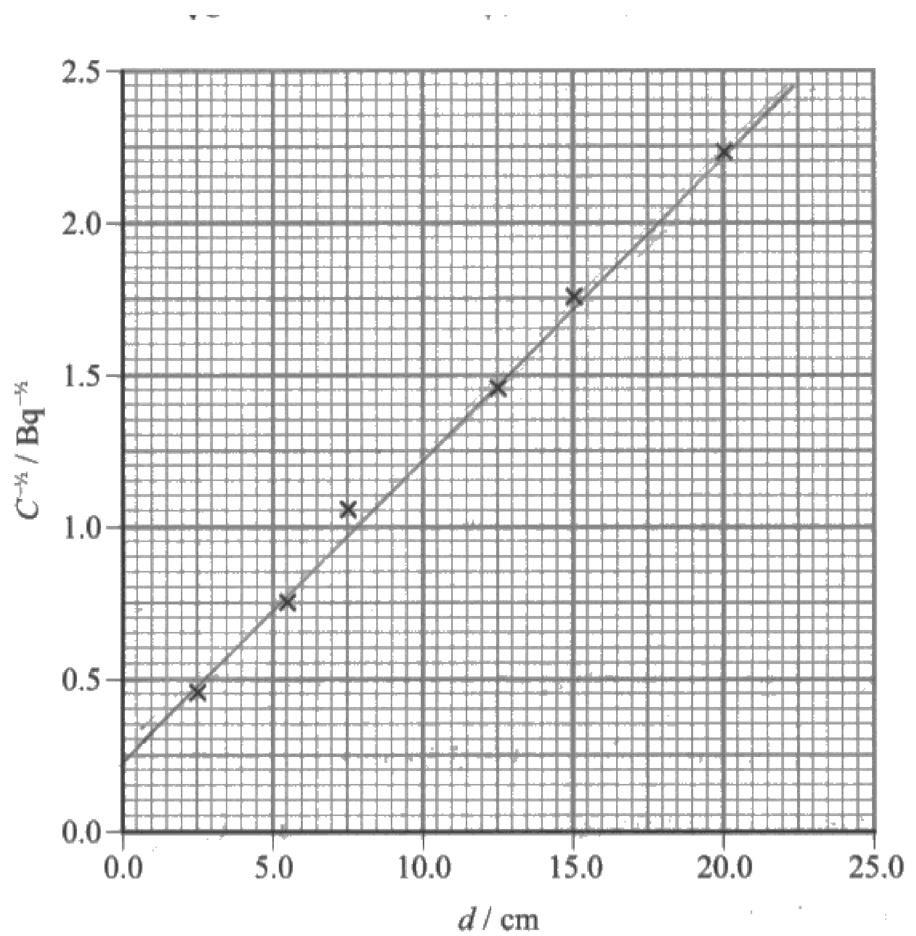
ResultsPlus
Examiner Tip

Not all straight line graphs go through the origin. When drawing a mean line aim to have points equally scattered on either side of the line.

Question 10 (c) (ii)

This question asks candidates to discuss the extent to which the data supports the conclusion given. In this context *discuss* requires the candidate to investigate the situation by mathematical reasoning.

The first three marking points were commonly seen, with MP2 and MP3 the most commonly awarded. It was rare to see reference to systematic error for MP4 to be awarded.



(ii) The student concluded that the graph was consistent with the gamma radiation intensity obeying an inverse square law.

Discuss the extent to which the data obtained supports the student's conclusion.

(4)

$C = \frac{K}{4\pi d^2}$ K and 4π are constant so

$C = \frac{A}{d^2}$ $\therefore$ $C \propto \frac{1}{d^2}$ so $d^2 \propto \frac{1}{C}$

$d \propto \frac{1}{\sqrt{C}}$, this is a linear graph

so it supports ~~that d is~~ than' that C is

proportional to $\frac{1}{d^2}$, but the graph does not

pass through the origin which means

they can't be directly proportion ~~or~~ and ~~C is~~ '$C \propto \frac{1}{d^2}$' is incorrect. But the graph not passing through origin may be due to systematic error or random error (as decay is random and spontaneous) so we can assume student's conclusion is correct and graph is inverse square law

ResultsPlus
Examiner Comments

This response includes all the detail necessary for the first 3 marking points. The statement about systematic error was considered to be enough to award MP4, even though the candidate hedges their bets a little by also making reference to the random nature of radioactivity.

Question 10 (d)

Some candidates struggled to apply what they knew about the penetrating power of *α*-particles and *ß*-particles. It was common to see answers expressing the belief that *α*-particles would be able to penetrate the air and so would arrive at the GM-tube, and that *ß*-particles would not be able to travel more than about 20 cm in air and so would not arrive at the GM-tube. In reality, candidates only needed to consider the likelihood of these radiations penetrating the sides of the GM-tube to give an answer to the question.

(d) It is suggested that the investigation into the way in which gamma radiation spreads out from a source, using the apparatus as shown in (b), could be carried out successfully using a radium-226 source.

Radium-226 emits α, β and γ radiation.

Justify this suggestion.

(2)

~~A~~ α ~~am.~~ radiation would be absorbed by the air between the source and the detector and β radiation would be absorbed by the wall of the GM-tube, so only γ radiation would cause ionisation in the tube (as it penetrates the wall) so the count rate is solely due to γ radiation.

(Total for Question 10 = 13 marks)

ResultsPlus

Examiner Comments

This response says enough for both marks to be awarded.

Question 11 (a)

In this question, candidates were asked to criticise the student's table. This required them to inspect the data set, and look at the merits and/or faults of the information presented.

Most candidates could spot that data in the table was given to an inconsistent number of decimal places. References to an inconsistent number of significant figures were accepted for MP1. However, very few candidates realised that a good deal of raw data was missing from the table, since extension of the spring cannot be measured directly.

(a) Criticise the student's table.

(2)

The values of extension ~~are not~~ and stretching force are not consistent in their levels of precision, with rounding to zero decimal places, one and two decimal places. Also, the raw data of the length of the ~~coins~~ mass' positions should be recorded for every mass added, then deducted to find the extension.

ResultsPlus
Examiner Comments

This response says enough to meet both marking points.

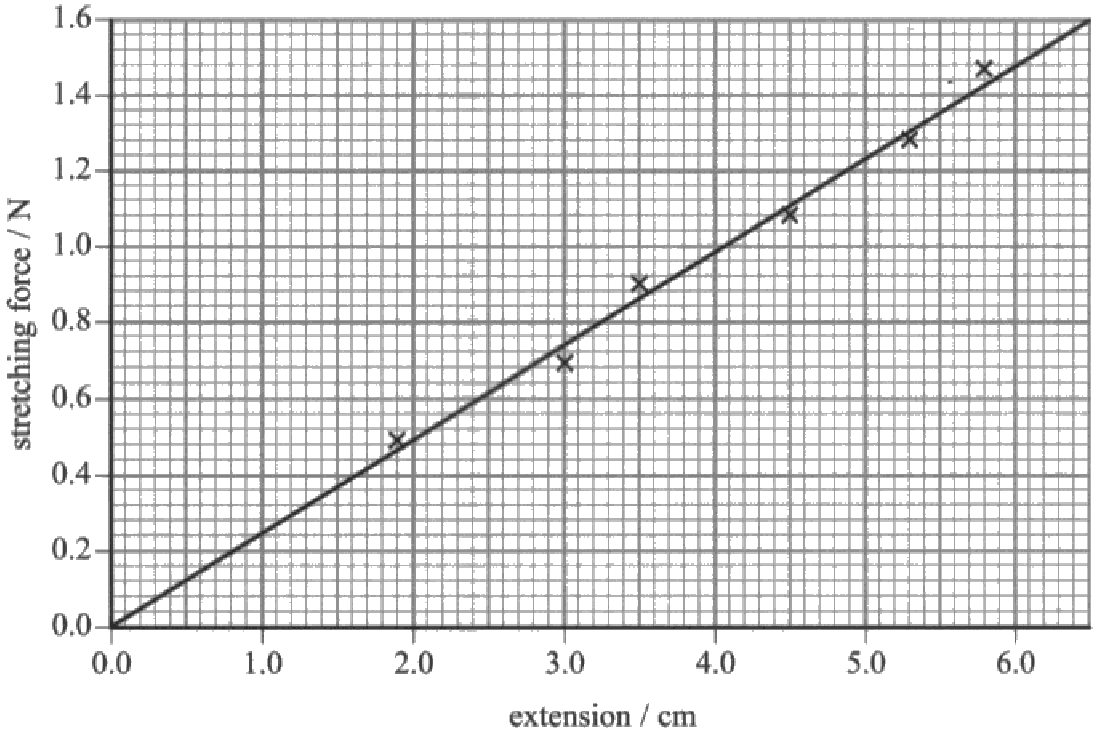
ResultsPlus
Examiner Tip

When recording experimental data always include all of the raw data in your results table.

Question 11 (b)

This question was answered well, and good application of unit conversions was seen from some, but not all, candidates.

(b) The student used her data to plot a graph as shown.



Determine a value for the force constant k of the spring.

(2)

$\Delta F = K \Delta x$

$K = \frac{\Delta F}{\Delta x}$

$= \frac{1.46}{5.8\text{cm}\ (0.58\text{m})}$

$= 2.517$

$= 2.52\ \text{Nm}^{-1}$

$k =$ $2.52\ \text{Nm}^{-1}$

ResultsPlus
Examiner Comments

This response is worth just 1 mark, as there is a unit conversion issue and the final answer is out by a power of 10.

ResultsPlus
Examiner Tip

Take care with units – the units of your final answer should match the units of the data used to calculate your answer.

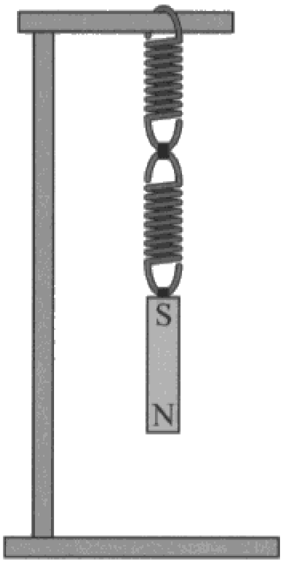
Question 11 (c)

This question is a more open-ended calculation which requires candidates to apply more sophisticated problem-solving skills than simply substituting values into an equation.

Many candidates either calculated an incorrect spring constant for the spring combination or simply used the value given in the question. Those candidates who calculated the spring constant of the combination correctly usually went on to score all 4 marks.

A small number of candidates seemed to be unaware of the mass on a spring time period equation.

(c) Two identical springs are joined in series and a bar magnet is hung from one end as shown.



The bar magnet is displaced a small distance vertically from its equilibrium position and released.

Calculate the frequency at which the system oscillates.

mass of magnet = 120 g
spring constant of each spring = 22 N m^{-1}

(4)

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

2 springs ∴ $K_{TOT} = ½ k$

$T = 2\pi\sqrt{\frac{120\times10^{-3}}{11}} = 0.656$ sec.

$F = 1/T = 1.52$ Hz

Frequency = 1.52 Hz

ResultsPlus

Examiner Comments

In this response the spring constant for the spring combination has been correctly calculated and the calculation for the frequency of oscillation is correct, so this is worth 4 marks.

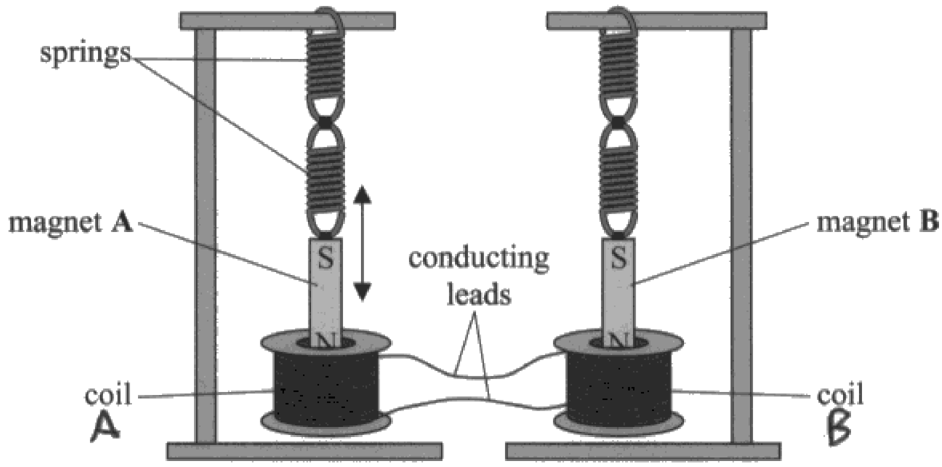
Question 11 (d)

This question is another extended writing question assessing the candidates' ability to show a coherent and logical structured answer with linkage and fully sustained reasoning. There are 6 indicative content (IC) points, for which a maximum of 4 marks can be awarded. There are two further marks available for appropriate linkage of ideas. In this question three linked points from IC 1 – 4 could score 1 linkage mark, as could 2 linked points from IC 5 – 6.

This was quite a novel context, and it was heartening to see some very good responses to this question. IC1, 2 and 3 were commonly seen, but poor expression meant that many candidates struggled to express IC4 with sufficient clarity. Weaker responses introduced confusion as to what is induced, with many responses only referring to a current being induced.

A common mistake with IC5 was to talk about the magnet oscillating at its natural frequency, without making it clear that this was the same frequency with which the other magnet was oscillating. However, resonance was mentioned relatively frequently.

*(d) Identical bar magnets are suspended from identical springs, with the North pole of each magnet inside a coil of wire as shown. The two coils are connected together with conducting leads.



Magnet A is displaced so that it oscillates vertically. The North pole of magnet A moves into and out of the coil of wire with simple harmonic motion. As this motion continues, magnet B starts to oscillate. The amplitude of oscillation of magnet B increases over time.

Explain why magnet B starts to oscillate with an increasing amplitude.

(6)

Magnet A's oscillation means that there is a changing flux linkage inside coil A (see diagram). This changing flux linkage induces an emf in coil A due to Faraday's Law. As there is a full circuit, the emf drives a current around coil A which is attached to coil B. The ~~current~~ induced current sets up a magnetic field ~~in a direction~~ in coil A and B in a direction as such to oppose the change which created it (Lenz's law). The magnetic field of the current will repel the north pole of magnet A as it approaches and attract the south pole of the magnet passes through the coil. This current also is present in coil B so the north pole of Magnet B is initially repelled. ~~B~~ Both springs are the same so have the same natural frequency, the induced current in coil B forces Magnet B to oscillate at its natural frequency. Therefore maximum energy transfer occurs and the amplitude of oscillation is increased. The size of the induced emf is determined by the rate of change of flux linkage. Magnet B resonates at its natural frequency hence a large amplitude of oscillation

(Total for Question 11 = 14 marks)

ResultsPlus
Examiner Comments

This is a textbook answer to the question, with all of the indicative content points seen with good linkage included. This response is therefore worth 6 marks.

ResultsPlus
Examiner Tip

Plan your answer to a question like this before you start to write. Planning your response will help you to write your answer out logically and with a minimum of repetition.

Question 12 (a)

This is a standard calculation, for which most candidates should have scored at least 2 marks. However, MP1 was often not awarded because candidates substituted 650.0 nm instead of 650.2 nm in the denominator of the Doppler equation. Such candidates usually went on to score a mark for the magnitude of the velocity, although most candidates either thought that the star was moving away from the Earth or made no comment relating to the direction of movement.

12 Barnard's star is a red dwarf star in the vicinity of the Sun. The wavelength of a line in the spectrum of light emitted from Barnard's star is measured to be 656.0 nm. The same light produced by a source in a laboratory has a wavelength of 656.2 nm.

(a) Calculate the velocity of Barnard's star relative to the Earth.

(3)

$z = \frac{656.2 - 656}{656}$

$= 3.05 \times 10^{-4}$

$\therefore V = cz$

$= 3.05 \times 10^{-4} \times 3 \times 10^{8}$

$= 91400\ m/s = 91.4\ km/s$

Velocity = 91.4 km/s

ResultsPlus

Examiner Comments

This is worth just 1 mark, as 650 nm has been substituted in the denominator rather than 650.2 nm, and there is no indication of the direction of the star.

ResultsPlus

Examiner Tip

Always check that you have substituted similar quantities into the correct places in an equation such as the Doppler equation, which contains two different wavelengths (or frequencies) and two different velocities.

Question 12 (b)

As this experiment is core practical 8, candidates should have been able to describe how the diffraction grating is used without difficulty. However, it was disappointing to see that many candidates were unfamiliar with even the most basic details of the experiment.

The command word comment requires the synthesis of a number of variables from data/information to form a judgement. In this question, many candidates thought that a simple statement would suffice for a comment that is identified as being worth 4 marks.

In part (i), few candidates described or drew the set up correctly (the laser light needs to be perpendicular to the plane of the diffraction grating for an accurate value of the wavelength to be determined).

Although many candidates may have referred to the distances required, few specified that they should be measured.

There was confusion with other interference experiments in calling the orders fringes, and many referred to measuring angles rather than the distance between orders.

In part (ii), only a small proportion of candidates realised that the question was about whether or not the grating would separate the two wavelengths from Barnard's star sufficiently well to make an accurate measurement of their difference. Those who did usually scored full marks for this part.

A large proportion of candidates did not attempt to use the grating equation, and these candidates wrote about comparing λ with the line spacing of the grating instead. In the better responses, candidates did attempt to use the grating equation, but most of them only attempted to calculate the angle of a constructive order for just one of the wavelengths.

A significant number of candidates did not seem to know what quantities each of the terms in the equation $n\lambda = d \sin \theta$ represented. Some candidates thought that n was the number of lines per metre of the grating.

(b) A diffraction grating can be used to analyse the radiation emitted by a variety of sources.

(i) A diffraction grating of known grating spacing is used in a school laboratory to analyse the light emitted by a laser.

Describe how the diffraction grating is used and the measurements that should be taken.

(3)

The diffraction grating should be placed just in front of the laser and there should be a wall or clear surface a distance d away from the diffraction grating*. A series of lines will appear on the surface and you should identify the 0 order point and then measure the distance either side of the

O point to get the first order maximum, (get the 2 distances, add them and divide by 2). Do this for increasing orders ~~then change the distance~~ and then repeat at least 5 times.

* Ensure you measure the distance d as well.

(ii) A diffraction grating with grating spacing of 2.2×10^{-6} m is used to determine the difference in wavelength for the spectral line emitted by Barnard's star.

Comment on the suitability of using a diffraction grating with this spacing. You should include appropriate calculations.

(4)

$n\lambda = d\sin\theta$ $d = 2.2\times10^{-6}$

use $n=1$ as first order maximum

$656.0\times10^{-9} = 2.2\times10^{-6}\sin\theta \rightarrow \sin\theta = 0.298$

$\theta = 17.348°$

$656.2\times10^{-9} = 2.2\times10^{-6}\sin\theta \rightarrow \sin\theta = 0.298$

$\theta = 17.354°$

∴ the difference is θ between the 2 wavelengths is 0.006° which is extremely small and far too difficult to measure accurately ∴ the grating is not suitable.

ResultsPlus
Examiner Comments

The response in part (i) indicates the two distances that need to be measured (although the use of "d" for the distance from the grating to the wall is a poor choice of symbol). There is no indication that the plane of the grating needs to be perpendicular to the light from the laser, although this could have easily been shown with a labelled diagram. This gives this part of the question 2 marks.

In part (ii), all the required elements are included and the response is worth all 4 marks.

ResultsPlus
Examiner Tip

A well-drawn, correctly labelled/annotated diagram can often help to score marks in a question.

Question 12 (c) (i)

This was answered well by the vast majority of candidates. Occasionally the use of the wrong 'k' from the data list or the omission of the "3" (or the "2") from the "3/2" factor resulted in marks not being awarded.

(c) Visible light from the star originates from the photosphere. In the photosphere of Barnard's star, hydrogen and helium atoms are at a temperature of 3100 K.

(i) Calculate the mean kinetic energy of an atom in the photosphere at a temperature of 3100 K. =J

(2)

$KE = \frac{1}{2}mv^2 = \frac{3}{2}kT = \frac{3}{2} \times 3100 \times 8.99 \times 10^9 = 4.18 \times 10^{13}$ J

Mean kinetic energy = 4.18×10^{13} J

ResultsPlus

Examiner Comments

This response uses the wrong value for the constant k, so no marks are awarded.

ResultsPlus

Examiner Tip

Check any equations and data that you use from the list supplied in the exam paper very carefully before you use them.

Question 12 (c) (ii)

Quite a lot of candidates knew exactly what to write, and wrote a competent answer in terms of energy levels. However, some candidates omitted any reference to electrons, referring just to the atom becoming excited etc.

Most commonly, if only one mark was awarded, it was due to the lack of the word photon in MP2.

(ii) Describe how these atoms emit visible light.

(2)

- Atoms receive energy from photon ⇒ Electrons moves to the next energy level ⇒ less stable

- After random time, electrons move back to a lower energy level which is more stable ⇒ Energy is released is electromagnetic radiation

- If amount of energy released is appropriate ⇒ Release visible light

ResultsPlus

Examiner Comments

This response is close to meeting both marking points but actually was only awarded 1 mark for the first part of the answer. MP2 was not given, as it was not clear that the electromagnetic radiation was emitted as a photon.

ResultsPlus

Examiner Tip

Be specific and use technical terms wherever possible.

Question 13 (a)

This was generally well answered. Some textbook descriptions were seen, although some candidates answered in terms of mass and atomic number, which tends to mask the similarity and difference seen between isotopes.

(a) State what is meant by isotopes.

(1)

Isotopes are atoms of an element with a different number of neutrons, and therefore a different mass to a ~~*~~ normal atom of that element.

ResultsPlus

Examiner Comments

This response uses the term "normal atom" which is an undefined term. If the candidate had clarified that "normal atoms" of a given element all contain the same number of protons, then the mark could have been awarded.

13 Mass spectrometry is a technique used to separate ions based on their charge to mass ratio.

The atoms in a sample are ionised and then accelerated and formed into a fine beam. This beam is passed into a region of uniform magnetic field and the ions are deflected by different amounts according to their mass.

(a) State what is meant by isotopes.

(1)

Isotopes are atoms of the same element that have the same number of protons but different number of neutrons.

ResultsPlus

Examiner Comments

A textbook answer, worth 1 mark.

Question 13 (b)

This was answered well by most candidates, with working out clearly shown. However, a significant number of candidates forgot that on “show that” questions you need to clearly see the working that went behind the answer. Such candidates wrote out the whole expression algebraically, then wrote the answer without showing any substitutions.

Although told in the question that it is a singly-charged ion, a significant number of candidates used 35*e*.

(b) In a mass spectrometer, chlorine-35 ions are accelerated through a potential difference of 8.50 kV to produce an ion beam. → $+1.6\times10^{-19}$

Show that the speed of singly ionised chlorine-35 atoms is about 2.2×10^5 m s^{-1}.

mass of an ion of chlorine-35 = 34.97 u

(4)

$qV = \frac{1}{2}mv^2$

$1.6\times10^{-19} \times 8.5\times10^3 = \frac{1}{2} \times (34.97\times1.66\times10^{-27}) \times v^2$

$1.36\times10^{-15} = \frac{1}{2}\times5.80502\times10^{-26}\times v^2$

$v^2 = 4.69\times10^{10}$ m^{2}s^{-2}

$v = 2.16\times10^5$ ms^{-1}

ResultsPlus

Examiner Comments

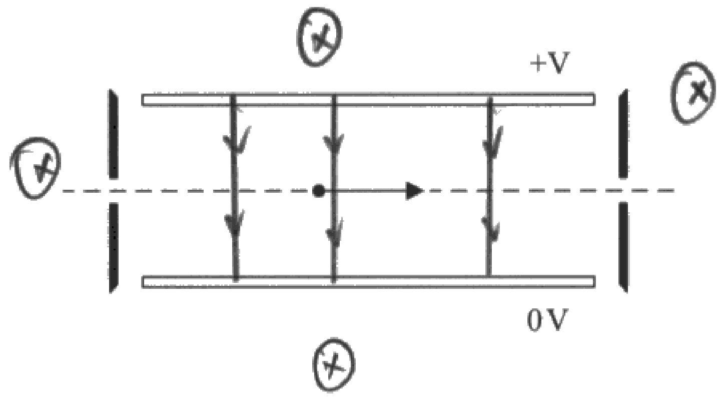
A textbook answer, worth all 4 marks.

Question 13 (c) (i)

The majority of candidates were able to indicate the direction of the electric field correctly, although many of these candidates drew the magnetic field in the opposite direction to the electric field. Maybe they were thinking about the direction of the electric and magnetic forces.

Many diagrams consisted of arrows or markings with no labelling. Candidates should be encouraged to label their diagrams to avoid ambiguities.

(c) In most mass spectrometers the ions are passed through a velocity selector, after being accelerated, to produce a beam of ions of a particular velocity.
The velocity selector consists of a pair of parallel plates, across which a potential difference (p.d.) is applied to create an electric field.



In one mass spectrometer the plates are 2.5 cm apart and a p.d. of 135 V is applied.

A magnetic field is also applied to produce a force on the ions in the opposite direction to the force from the electric field. For one particular speed the ions travel in a straight line and emerge from the selector.

(i) Add to the diagram to indicate the directions of the electric field and the magnetic field.
(2)

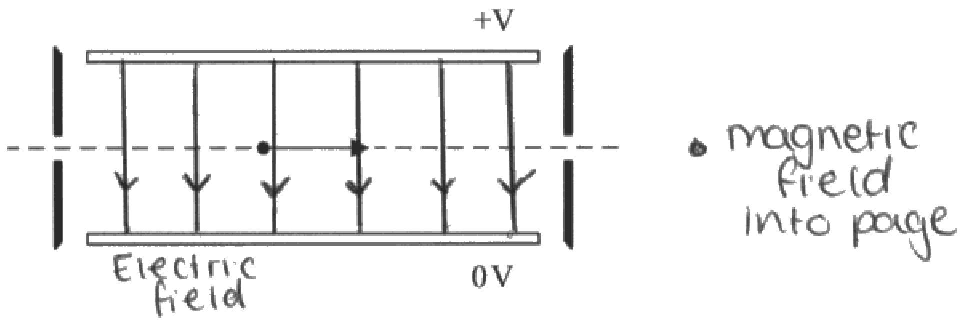
ResultsPlus
Examiner Comments

This response scored zero. There is no labelling and so the examiners can only guess at the directions of the two fields.

ResultsPlus
Examiner Tip

A correctly labelled/annotated diagram helps to score marks in a question.

(c) In most mass spectrometers the ions are passed through a velocity selector, after being accelerated, to produce a beam of ions of a particular velocity.
The velocity selector consists of a pair of parallel plates, across which a potential difference (p.d.) is applied to create an electric field.



In one mass spectrometer the plates are 2.5 cm apart and a p.d. of 135 V is applied.

A magnetic field is also applied to produce a force on the ions in the opposite direction to the force from the electric field. For one particular speed the ions travel in a straight line and emerge from the selector.

(i) Add to the diagram to indicate the directions of the electric field and the magnetic field.
(2)

ResultsPlus
Examiner Comments
This response is clear – both marks can be awarded.

Question 13 (c) (ii)

There are a number of valid ways to answer this question. Although in the mark scheme it suggests comparing the two forces, many candidates used the magnetic force on a charged particle expression ($F = BQv$) to show that the speed needed is around 2.2×10^5 m s^{-1}. Some candidates use the expression with the value of speed inserted to work out what the magnetic flux density should be, and show that this is therefore suitable.

(ii) The magnetic flux density applied to the velocity selector is 24.5 mT.

Deduce whether this magnetic flux density is suitable to produce a beam of chlorine-35 ions of speed 2.2×10^5 m s^{-1}.

(4)

For electric field. $E = \frac{F}{Q} = \frac{V}{d}$. $F = \frac{V}{d} Q$

$= \frac{135}{2.5 \times 10^{-2}} \times 1.6 \times 10^{-19} = 8.64 \times 10^{-16}$ N

For magnetic field. $F = Bqv$ $q = e$ $F = BeV$

$= 24.5 \times 10^{-3} \times 1.6 \times 10^{-19} \times 2.2 \times 10^{5}$

$= 8.63 \times 10^{-16}$ N

The results are almost the same the magnetic flux is suitable

ResultsPlus
Examiner Comments

One way to score full marks.

(ii) The magnetic flux density applied to the velocity selector is 24.5 mT.

Deduce whether this magnetic flux density is suitable to produce a beam of chlorine-35 ions of speed 2.2×10^5 m s^{-1}.

(4)

~~[illegible]~~ $F = Bq\,v$

$\frac{Vq}{d} = Bq\,v$

$\frac{V}{d} = Bqv$

~~2.2×10^5 m/s~~

The magnetic flux density of ~~20~~ 24.5mT is able to produce a beam of chlorine-35 ions of speed 2.2×10^5 m/s

$V = 2.204\ldots \times 10^5$ m/s

$V \approx 2.2 \times 10^5$ m/s

ResultsPlus

Examiner Comments

Another way to score full marks.

Question 13 (d) (i)

Quite often, candidates just stated that force is perpendicular to “the ion” or to “the motion”, so they did not say enough for MP1 to be awarded. Similarly MP2 was rarely awarded, as many candidates seemed to think that a bald reference to “centripetal force” would be enough.

(d) After passing through the velocity selector the ion beam enters a region of uniform magnetic flux density 0.35 T with the ions travelling at right angles to the field direction.

(i) Explain why the ions travel in a circular path.

(2)

There is a constant resultant force acting on the ions causing it to accelerate to the side. As the magnetic field is curved, this is centripetal acceleration resulting in circular motion.

ResultsPlus

Examiner Comments

This response includes a number of key words, but it is too vague to allow any marks to be awarded.

ResultsPlus

Examiner Tip

When explaining a phenomenon be sure to express your ideas clearly and unambiguously.

(2)

Magnetic force always acts towards the centre of orbit, it is therefore the centripetal force. It always acts a right angle to the direction of motion (and direction of magnetic field). So the ions always accelerate towards a centre, hence ~~greater~~ operate under circular motion.

ResultsPlus

Examiner Comments

This is a good answer to the question worthy of both marks.

Question 13 (d) (ii)

This question was answered well by the vast majority of candidates.

The equation is given on the paper as *p*/*BQ* and some candidates omitted the velocity and just calculated the mass for the numerator.

Some candidates chose to derive this equation themselves and used separate equations, equating mv^2/r with Bqv. However those who chose this method often omitted terms or made arithmetic errors.

(ii) Calculate the radius of the circular path.

(2)

$$r = \frac{mv}{BQ} = \frac{34.97 \times (1.67 \times 10^{-27}\ kg) \times (2.2 \times 10^{5}\ ms^{-1})}{0.35T \times (1.60 \times 10^{-19}\ C)}$$

$= 0.229m$

$= 22.9$ cm.

Radius = 22.9 cm.

ResultsPlus

Examiner Comments

This response uses the equation given in the formula list and a correct final answer is obtained gaining it full marks.

(ii) Calculate the radius of the circular path.

(2)

$F = \frac{mv^2}{r} = Bqv$

$\frac{mv^2}{r} = Bqv$

$\frac{mv}{r} = Bq$

$\frac{mv}{Bq} = r = \frac{34.97 \times 1.66 \times 10^{-27} \times 2.2 \times 10^{5}}{0.35 \times (35 \times 1.6 \times 10^{-19})} = 6.52 \times 10^{-3}$ m

Radius = 6.52×10^{-3} m

ResultsPlus

Examiner Comments

In this response an attempt is made to derive the equation for the radius of the path from first principles. Unfortunately the derivation contains errors and no marks can be awarded.

ResultsPlus

Examiner Tip

Know which of the standard equations given in the specification are listed on the formula sheet at the end of the exam paper.

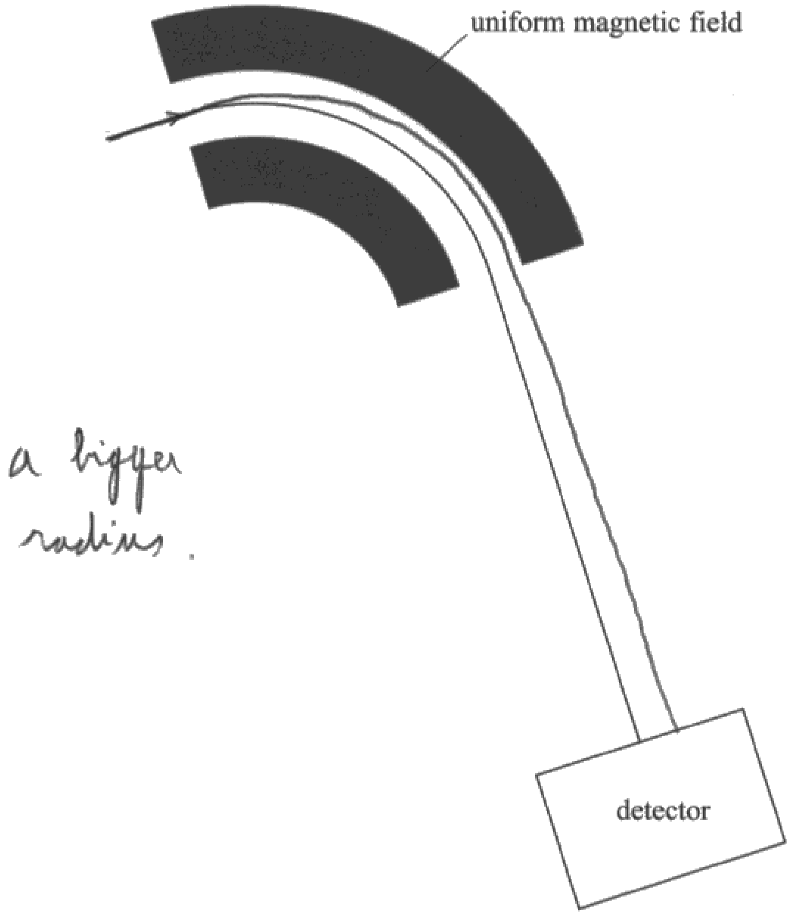
Question 13 (d) (iii)

The paths drawn by most candidates were generally correct, with the best responses showing a continually increasing radius. Disappointingly, some of the diagrams seen were drawn with very little care

Explanations were not as strong as identifying the path. Most candidates identified that the difference was because the mass had increased, but few stated that the charge would be the same, so it was common to award 1 mark here.

Some candidates thought that that the charge has increased to 37*e* and gave that as the reason for the change in curvature.

(iii) The diagram shows the path of the chlorine-35 ions in the field. Chlorine-37 ions enter the magnetic field with the same velocity.



1. Add another line to the diagram to show the path of these chlorine-37 ions.

(1)

2. Explain any differences in the paths.

(2)

Since $r = \frac{mv}{B \cdot q}$, velocity, the magnetic field and the charge of the ions are the same. The mass of these two ions charge, so a bigger mass will travel in a circular path with a bigger radius, so chlorine-37 will have a bigger radius

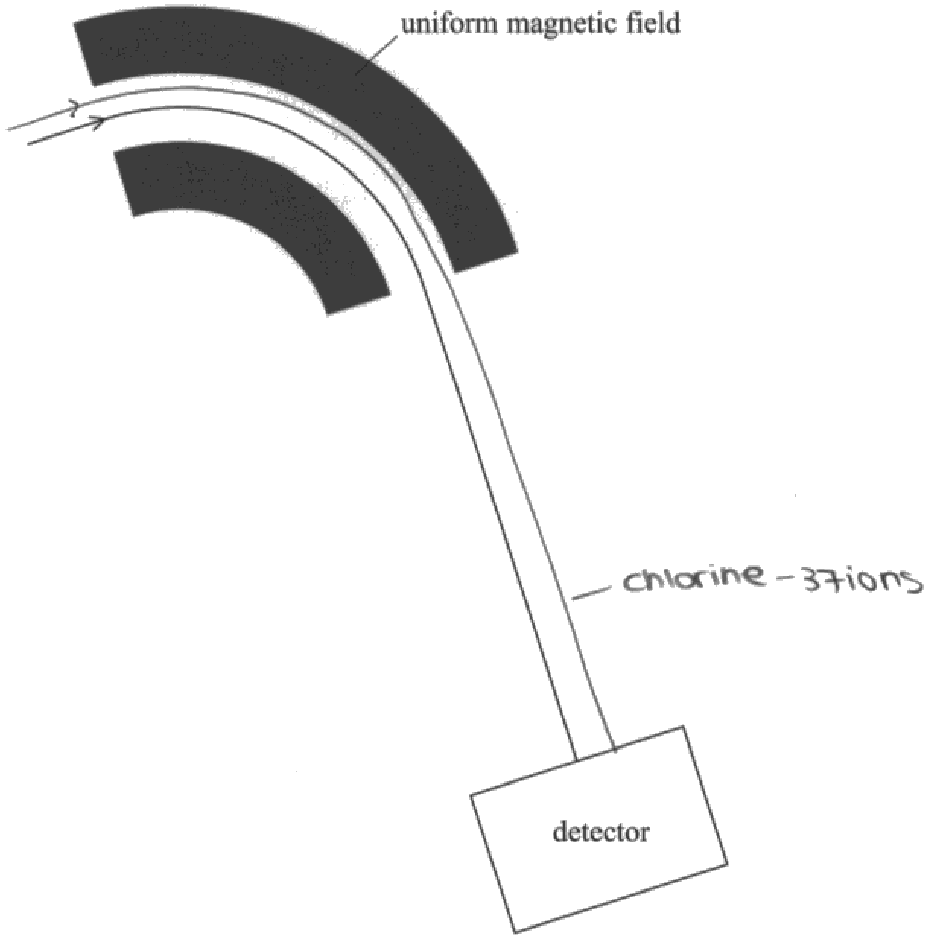
(Total for Question 13 = 18 marks)

ResultsPlus

Examiner Comments

This response includes a correct path for the more massive ion and a correct explanation as to why the radius of curvature is greater, giving 3 marks in total.

(iii) The diagram shows the path of the chlorine-35 ions in the field. Chlorine-37 ions enter the magnetic field with the same velocity.



$\uparrow r = \frac{\uparrow mv}{BQ}$

1. Add another line to the diagram to show the path of these chlorine-37 ions.

(1)

2. Explain any differences in the paths.

(2)

Chlorine37 ions are heavier than chlorine-35ions because less electrons are lost so from the equation $\uparrow r = \frac{\uparrow mv}{Bq}$, a greater mass means greater momentum so greater radius.

ResultsPlus
Examiner Comments

In this response the path of the more massive ion is drawn with the same curvature as the original ion – just displaced slightly, so the first marking point is not met. Nonetheless a mark is awarded for the statement that the greater mass leads to a greater radius of curvature.

ResultsPlus
Examiner Tip

Take care to draw diagrams as carefully as possible.

Paper Summary

Based on their performance on this paper, candidates are offered the following advice in order to improve their performance:

- Ensure that 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 their workings in calculations;
- For descriptive questions:
  - Make a note of the marks and include that number of different physics points;
  - Try to base the answer around a specific equation or principle.

Grade Boundaries

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

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

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