Examiners' Report
June 2016

IAL Physics 4 WPH04 01

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June 2016

Publications Code WPH04_01_1606_ER

Introduction

Although the mean score on this paper was lower than the equivalent paper last summer, it was clear that all of the marking points were accessible to candidates, and that they were regularly scored.

However, there were a number of questions where the awarding of full marks was uncommon due to the fact that considerably more detail was required than the candidates were often providing. It was also clear that for a number of questions, there was an apparent expectation from the candidates that repeating mark schemes from past papers would be sufficient, when it was quite clear that the context of the question was entirely different to that from a previous series they were remembering.

Most of the multiple choice questions were answered well, although question 8 (45% correct) and question 10 (47% correct) were the exceptions. On question 8 the incorrect answers given were spread across all three of the remaining alternatives, whereas on question 10 the overwhelming number of incorrect answers seen were for A. This suggests that the candidates were only taking into account the greater magnitude of charge of the alpha particle, and not considering its greater mass.

Question 11

This question was generally well answered, with three quarters of the candidates scoring 3 or 4 marks. Part (a) was a "show that" question, and most candidates scored both marks here. The only exceptions tended to be from candidates who tried to use the 330km given at the start of the question. Most of these seemed to be trying to establish the linear rather than angular velocity. Unfortunately, the same candidates also failed to cope very well with (b), as they were still attempting to use linear velocity equations such as a = v^2

/r.

More difficulties were encountered in (b), as candidates were required to add the 330km to the 6400km prior to performing a calculation. Many just used the 6400km alone, whilst a number failed to square the angular velocity, even when they had shown it being squared in their symbol equation.

11 The International Space Station (ISS) completes 16 orbits of the Earth every 24 hours.
The ISS is 330 km above the surface of the Earth.

(a) Show that the angular velocity of the ISS around the Earth is about 1×10^{-3} rad s^{-1}. **(2)**

~~$v = \frac{2\pi r}{T} = \frac{2\pi \times 330 \times 16}{24 \times 3600}$~~

$\omega = \frac{2\pi}{T} = \frac{2\pi \times 16}{24 \times 3600} = 1.16 \times 10^{-3}$ rad s^{-1} $= 1.2 \times 10^{-3}$ rads^{-1}

(b) Calculate the acceleration of the ISS in this orbit.

radius of Earth = 6400 km

(2)

$a = r\omega^2$

$a = 6400(1.2 \times 10^{-3})$

Acceleration of the ISS = 9.2×10^{-3} ms^{-2}

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Examiner Comments

(a) This candidate has initially attempted to calculate linear velocity, but has realised their mistake and crossed it out. The new calculation they have shown below is both clear and correct, and their answer is shown to at least one more significant figure than the "show that" value, so scores both marks. On (b) they have given the correct equation, but have then failed to show their angular velocity value being squared in the substitution, so score 0 marks on this section. They have also failed to add the 330km to the 6400km.

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Examiner Tip

For "show that" questions, as the candidates are already given the value they need to calculate, there needs to be evidence that correct substitutions have taken place.
A bald answer of 1.2 x 10^{-3} rads^{-1} would score 0 on part (a) of this question.

11 The International Space Station (ISS) completes 16 orbits of the Earth every 24 hours. The ISS is 330 km above the surface of the Earth.

(a) Show that the angular velocity of the ISS around the Earth is about 1×10^{-3} rad s^{-1}.

(2)

$\omega = \frac{16 \times 2\pi}{24 \times 60 \times 60} \rightarrow \omega = 1.163552835 \times 10^{-3} \rightarrow$

$\rightarrow \omega = 1.16$ rads^{-1} (3s.f.)

$\therefore \omega = 1.16$ rads^{-1} $\simeq 1 \times 10^{-3}$ rads^{-1}

(b) Calculate the acceleration of the ISS in this orbit.

radius of Earth = 6400 km

(2)

$a = r\omega^2 \rightarrow a = (6400+330)(1.163552835 \times 10^{-3})^2 \rightarrow$

$\rightarrow a = 9.11 \times 10^{-3}$ kms^{-2}

Acceleration of the ISS = 9.11×10^{-3} kms^{-2}

ResultsPlus
Examiner Comments

(a) This candidate has scored both marks in (a). They have shown the original answer to 10 significant figures and, even though when rounding have forgotten the power of 10, it is acceptable.

(b) This candidate initially appears to have not taken into account the fact that the values of distance are in km. However, they have added the two values and multiplied it correctly in their equation. The fact that their answer is in kms^{-2} means that it is completely correct, so scores both marks.

11 The International Space Station (ISS) completes 16 orbits of the Earth every 24 hours. The ISS is 330 km above the surface of the Earth.

(a) Show that the angular velocity of the ISS around the Earth is about 1×10^{-3} rad s^{-1}.

(2)

16 orbits in 24 hours $24 \times 60 \times 60 = 86400$ seconds

~~16 orbits 86 seconds~~ $v = \frac{2\pi r}{T}$

$\omega = \frac{2\pi}{T} = \frac{2\pi}{86400} = 7.27 \times 10^{-5}$ rads^{-1} $v = r\omega$ $\omega = \frac{2\pi}{T}$

(b) Calculate the acceleration of the ISS in this orbit.

radius of Earth = 6400 km

(2)

$a = \frac{v^2}{r}$ but $v = r\omega$

$a = r\omega^2$

radius = 330km + 6400km = 6730km = 6730×10^3 meters

$a = 6.73 \times 10^6 \times (7.27 \times 10^{-5})^2 = 0.0356$ ms^{-2}

Acceleration of the ISS = 0.036 ms^{-2}

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Examiner Comments

(a) This candidate has not taken into account the fact that there are 16 orbits of the Earth per day, so has not included a factor of 16 anywhere in their calculation. However, they have scored the "use of" mark as they have divided by the number of seconds in a day. Their answer is obviously incorrect, so they only score MP1 here. For part (b), they have used their value from (a) correctly to get a full error carried forward for 2 marks.

Question 12 (a)

Parts (a) and (b) represented an easy introduction to this question, although (c) was definitely more challenging to most candidates.

All that was expected for (a) was the observation that the meson was composed of one quark and one antiquark. 76% of the candidates managed to make this observation, although some were just a bit too vague with their answer.

12 There are two families of hadrons called mesons and baryons.

(a) State the structure of a meson.

(1)

a meson has 2 quarks one matter and te oter anti matter

ResultsPlus

Examiner Comments

This candidate has the right idea, but the "one matter and the other antimatter" is not sufficient for "quark and antiquark".

12 There are two families of hadrons called mesons and baryons.

(a) State the structure of a meson.

(1)

~~id has~~ it has 1 up quark and 1 down quark

ResultsPlus

Examiner Comments

The candidate is attempting to give a specific example of a meson, but have failed to include an antiquark. However, even if they had listed a particular type of quark and another antiquark, it would still be too specific, and would not suggest that all mesons are made of a quark and antiquark combination.

12 There are two families of hadrons called mesons and baryons.

(a) State the structure of a meson.

(1)

They are made up of two quarks.

ResultsPlus

Examiner Comments

Another answer that is not specific enough.

Question 12 (b)

For part (b), although candidates had been asked to use the information from the table, the conclusion about which quarks were present in each were considered to be proof that the table had been used, so no further working needed to be shown.

Thankfully, very few candidates considered parts (a) and (b) linked, so there were very few answers where a quark and antiquark combination was given in (b).

(b) The table shows the charge on up and down quarks.

Quark	Charge / *e*
up	+2/3
down	−1/3

Use the information in the table to state the quark composition of an antiproton and an antineutron.

(2)

Antiproton $\bar{u}\bar{u}\bar{d}$

Antineutron $\bar{u}\bar{d}\bar{d}$

ResultsPlus
Examiner Comments

An example of the minimum acceptable response for two marks.

(b) The table shows the charge on up and down quarks.

Quark	Charge / *e*
up	+2/3
down	−1/3

Use the information in the table to state the quark composition of an antiproton and an antineutron.

(2)

Antiproton $(\bar{u}\bar{u}\bar{d})$ $(-\frac{2}{3}-\frac{2}{3}+\frac{1}{3})e = -1e$

Antineutron $(\bar{u}\bar{d}\bar{d})$ $(+1/3+1/3-2/3)e = 0\,e$

ResultsPlus
Examiner Comments

Another two mark answer, this time showing the charges for each of the constituent charges, along with the total.

(b) The table shows the charge on up and down quarks.

Quark	Charge / *e*
up	+2/3
down	−1/3

Use the information in the table to state the quark composition of an antiproton and an antineutron.

(2)

Antiproton ddd

Antineutron $u\bar{d}\bar{d}$

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Examiner Comments

This answer scored 0. The antineutron is missing the bar above the up quark. Although at first appearing to be very wrong, the student has at least got the idea that the total charge of the antiproton must be -1, as three down quarks do give that total charge.

Question 12 (c)

On part (c), there were a number of significant hurdles to jump before arriving at a correct answer. It was therefore vital for students to show all of their working, and to show a clear substitution into the relevant equations. As a result, only 22% of the candidates scored all 4 marks on this question.

(c) A proton has kinetic energy of 158 MeV. It annihilates with a stationary antiproton and two photons of equal energy are created.

Calculate the wavelength of the photons.

mass of stationary proton = 938 MeV/c^2

mass of stationary antiproton = 938 MeV/c^2

(4)

$158\,\text{MeV} + 938\,\text{MeV} + 938\,\text{MeV} = 2034\,\text{MeV}/c^2$

$E = mc^2$

$= 2034 \times 10^{6} \times 1.6 \times 10^{-19}$

$= 3.3 \times 10^{-10}\,\text{J}$

$E = \frac{hc}{\lambda}$

$3.3 \times 10^{-10} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$

$\lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{3.3 \times 10^{-10}}$

$= 6.03 \times 10^{-16}\,\text{m}$

Wavelength of the photons = $6.03 \times 10^{-16}\,\text{m}$

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Examiner Comments

This candidate is one of the few who recognised that the kinetic energy value given could be simply added to the two mass values given, to arrive at 2034MeV. As there were a significant number of students both multiplying and dividing by the speed of light squared, the c squared at the end of their 2034 MeV was ignored in terms of awarding marking point 1. Marking point 2 was awarded here as there is a clear multiplication by the electronic charge value. They have then gone on to use a combination of the wave equation and the photon energy equation to score MP3. Their only mistake is a failure to recognise that there are two photons produced, so they would only have half of the energy created each. Therefore this script scores 3 marks.

(c) A proton has kinetic energy of 158 MeV. It annihilates with a stationary antiproton and two photons of equal energy are created.

Calculate the wavelength of the photons.

mass of stationary proton = 938 MeV/c^2

mass of stationary antiproton = 938 MeV/c^2

(4)

$\Delta E = 158 + 938 + 938 = 2034 \text{ MeV} = 2.034 \times 10^9 \text{ eV}$

$\Rightarrow 2.034 \times 10^9 \text{ eV} = 3.2544 \times 10^{-10} \text{ J}$ in 2 photons $\rightarrow (\div 2)$

$\Rightarrow 1.6272 \times 10^{-10} \text{ J}$ in 1 photon

$E = hf$ $\quad \therefore$ ~~$f = E/h$~~ $\rightarrow f = E/h$

$f = 2.45 \times 10^{23} \text{ Hz}$

~~v~~ $c = f\lambda \quad \therefore \lambda = c/f$

$\lambda = 1.22 \times 10^{-15} \text{ m}$

Wavelength of the photons = 1.22×10^{-15} m

ResultsPlus
Examiner Comments

On such a question, it is unlikely that a candidate will arrive at the correct answer by fluke, and this candidate has the correct answer. However, examiners still need to check the working shown by the candidate to make sure that a correct method has been used, and in this case it has so 4 marks are awarded. However, it is important to note that had the student failed to divide the energy by two, they might have ended up scoring just 2 marks. This is because their combination of equations for marking point 3 has no evidence of what values have been used for h or c.

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Examiner Tip

Show all of the values that have been substituted into equations, including any constants.

(c) A proton has kinetic energy of 158 MeV. It annihilates with a stationary antiproton and two photons of equal energy are created.

Calculate the wavelength of the photons.

mass of stationary proton = 938 MeV/c^2

mass of stationary antiproton = 938 MeV/c^2

(4)

~~E = 938~~

total $E = m_{proton}c^2 + m_{antiproton}c^2 + KE$

$= 938 MeV/c^2 \cdot c^2 + 938 MeV/c^2 \cdot c^2 + 158 MeV$

$= 2034 MeV$

E of one photons $= \frac{2034 MeV}{2} = 1017 MeV$

$p = \sqrt{2mE}$

$= \sqrt{2 \times 1.67 \times 10^{-27} kg \times 1017 \times 10^6 \times 1.6 \times 10^{-19} J}$

$= 7.37 \times 10^{-19} kg m s^{-1}$

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34} Js}{7.37 \times 10^{-19} kg m s^{-1}} = 7.00 \times 10^{-16} m$

Wavelength of the photons = 7.00×10^{-16} m

ResultsPlus
Examiner Comments

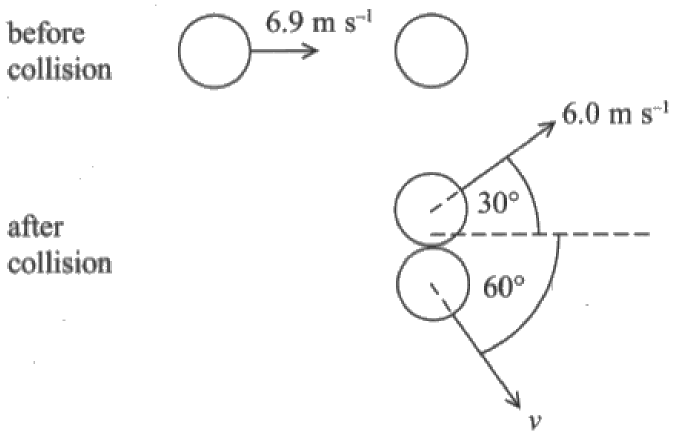
A number of unsuccessful candidates decided that this question was requiring a de Broglie equation calculation to be performed. The only marks accessible to such candidates were marking points 1 and 2. This candidate has scored both of those as they have clearly worked out 2034MeV, halved it and then multiplied by the electronic charge.

Question 13

The main difficulty with this question was that, although most candidates recognised quite clearly that it was concerned with conservation of momentum, no mass values were given in the question (although they had been told that the discs were identical). Quite often this resulted in some candidates losing marks, as they ignored masses in their calculations completely. In spite of this, over a quarter of the students achieved the full 5 marks in total on this question.

13 In the game of air hockey, small identical discs move across a frictionless surface.

One disc moving with a velocity of 6.9 m s^{-1} collides with a stationary disc. After the collision the discs move apart as shown in the diagram.



(a) Calculate the velocity v. In the horizontal direction

(3)

$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$

$m \times 6.9 = m \times 6 \times \cos 30° + m \times V \times \cos 60°$

$6.9 = 6 \times \cos 30° + V \times \cos 60°$

$V = 0.5$ m/s

$v =$ 0.5 m/s.

(b) Explain whether the collision is elastic or inelastic.

(2)

$E_{Kinetic}$ before = ~~$\frac{1}{2} m \times 6.9^2$~~ $\frac{1}{2} m_1 u_1^2 = \frac{1}{2} \times m \times 6.9^2 = 23.8m$ (J)

$E_{Kinetic}$ after $= \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 = \frac{1}{2} \times m \times 6^2 + \frac{1}{2} \times m \times 0.5^2$

$= 18.1$ m (J)

The kinetic energy before is bigger than E_K after, so it is inelastic

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Examiner Comments

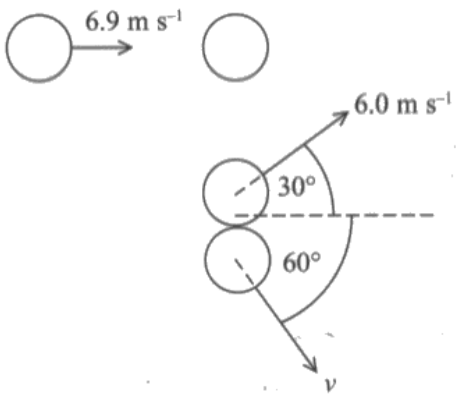
In part (a), this candidate has attempted to perform a conservation of momentum calculation in the horizontal plane of the diagram. They have started with the standard conservation of momentum formula, and have then made it clear that all of the masses are the same by changing all the masses to "m" in the second line. They have then cancelled out m from both sides in the third line. Unfortunately, many candidates started their answer with what is written on the third line, so did not score marking point 1 (no evidence of mass). For this candidate, they have made an arithmetic error, as all of the substitutions (and trigonometry) are correct, so scoring 2 marks.
They have then gone on to calculate a kinetic energy (in terms of m) in part (b), which has been performed correctly for both before and after (using their value from (a)), so score both marks on (b) as their subsequent comment on inelastic is correct for their values.

13 In the game of air hockey, small identical discs move across a frictionless surface.

One disc moving with a velocity of 6.9 m s^{-1} collides with a stationary disc. After the collision the discs move apart as shown in the diagram.

before collision

after collision



(a) Calculate the velocity v.

(3)

initial vertical momentum = 0

final vertical momentum = m(6sin30) ∓ mvsin60

according to conservation of momentum,

~~m~~(6 sin 30) − ~~m~~v sin 60 = 0

$3 = \frac{v\sqrt{3}}{2}$

$v = 2\sqrt{3}$

$= 3{\cdot}46\ ms^{-1}$

v = 3·46 ms^{-1}

(b) Explain whether the collision is elastic or inelastic.

ke = kinetic energy

(2)

initial ke = $\frac{1}{2}m(6{\cdot}9)^2$ ~~=~~ ≈ 24m J ~~23·8m J~~

final ke = $\frac{1}{2}m(6)^2 + \frac{1}{2}m(3{\cdot}46)^2$ ~~= 23·~~ ≈ 24m J

∴ collision is elastic, since ke is conserved

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Examiner Comments

Here is one where they have performed a momentum conservation calculation in the plane that is vertically orientated on the page, for part (a). It gives a slightly different answer for this part, but this candidate has gone on to use it correctly in (b), so scores all 5 marks for the question.

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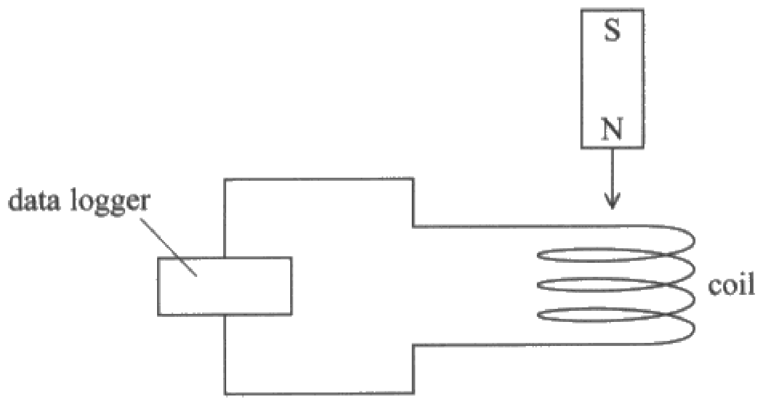
Examiner Tip

Candidates should be more aware of significant figures in their calculations. All of the data given in the question was to two significant figures. Therefore, all that students needed to do in part (b) of this question was to show that the kinetic energy before and after was 24m Joules in order for them to say the collision was elastic. Some students displayed their answers to more significant figures, which was accepted. However, a significant number decided that with values such as 23.80 m Joules before the collision and 23.78m Joules afterwards, that the collision was inelastic.

Question 14 (a)

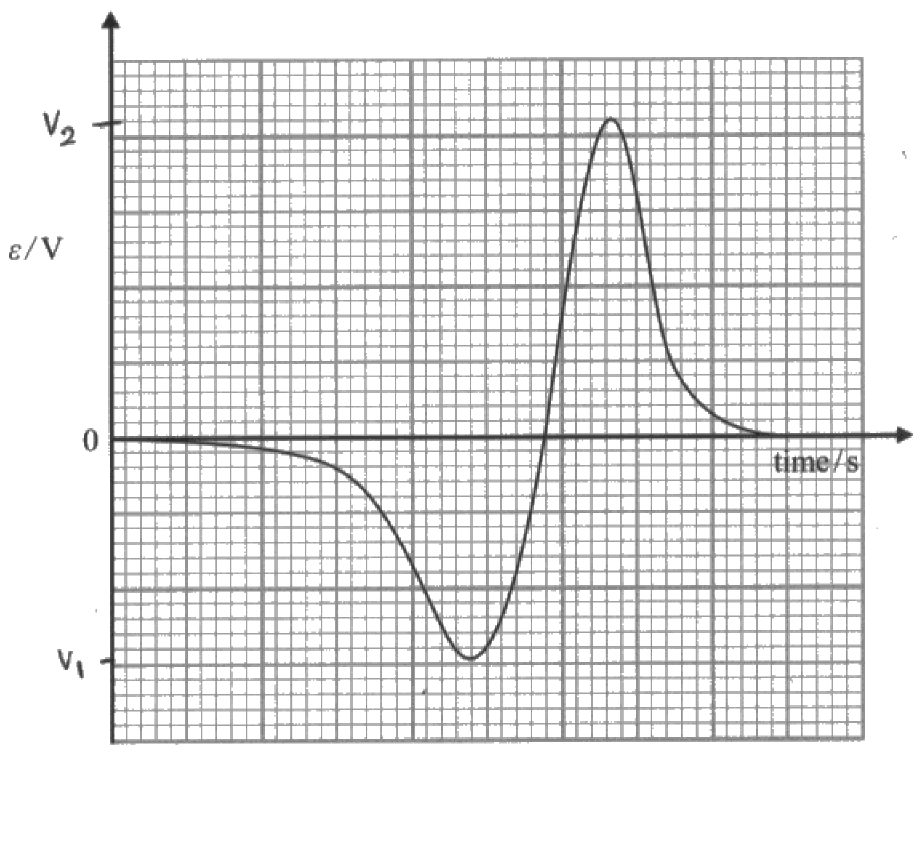
Part (a) was the first of two QWC (quality of written communication) questions on this paper, where the working had to be clear and organised in a logical manner. Although many of the answers were logical and clear to read, it was clear that a number of candidates were thinking of a different question that had come up on a previous examination series. This was evident from the number of candidates who described the magnet becoming stationary in the middle of the coil, and then coming back up afterwards (as if the magnet were attached to a spring). Even those who did not consider this as the situation struggled to explain why the e.m.f. could be zero when at the centre of the coil, with a few explaining that the magnet must be stationary. As a result, very few candidates scored all 5 marks on this question, with almost 30% scoring zero (mainly because their whole answer was a description of the graph rather than an explanation).

14 A student is investigating the laws of electromagnetic induction. She drops a bar magnet through the centre of a coil of wire as shown.



As the bar magnet falls through the coil an e.m.f ε is induced.

The graph shows how ε varies with time t.



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Examiner Comments

One of the rare scripts scoring all 5 marks. The description on lines 2 and 3 is too vague to score marking point 1, but it is then achieved with the equation at the end of line 3. In line 4 the acceleration of the magnet is discussed (ensuring that marking point 2 is awarded). Marking point 3 is scored on lines 5 and 6. Marking point 4 is scored in the last two lines. Marking point 5 is achieved for a long description from lines 6 to 10, with the pivotal part of the description being the change of polarity of e.m.f. from negative to positive. The script is easy to read and follow, so all five marks can be awarded.

*(a) Explain the shape of the graph. $V_2 > V_1$

(5)

As The magnet produces a magnetic field as it moves down te coil cuts te magnetic field terefore since tere is a change in magnetic flux linkage a voltage is induced $e.m.f = \frac{\Delta N\phi}{\Delta t}$. The magnet accelerates downwards $(a = 9.81\,ms^{-2})$ terefore it leaves te coil faster than it enters hence voltage induced as it leaves is greater than when it enters. According to lenzs law te voltage induced opposes te change causing it hence as te magnet enters a North is induced on te top hence ~~current~~ voltage flows in one direction and as it passes te center te boltage induced is in te opposite direction terefore te gradient is initially negative ten positive. Moreover, te area under both te graphs are te same as it represents magnetic flux linkage which remains constant

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Examiner Comments

Another good script that scores marking points 1,2,3 and 4. Lines 4 and 5 have the correct statement for marking point 1, whilst the first line has the correct description of velocity change for marking point 2. Marking point 3 is contained in lines 5 & 6 (all of the relevant points mentioned are labelled on their graph). The last sentence scores marking point 4. Although there is a discussion of the change of polarity of em.f., it is not related to Lenz's Law so does not score marking point 5.

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Examiner Tip

The command word "Explain" implies that more is required than a simple description of the situation. On this question, a number of candidates simply described the change in e.m.f. in terms of relative values on the graph e.g. At first, the e.m.f. is zero, and then it becomes negative, returns to zero, becomes positive, and then falls back to zero.

Question 14 (b)

Part (b) is a very good example of a situation where candidates need to read the question carefully. Although it was possible to score both marks for describing why a data logger would be most suitable in THIS practical, the question would have allowed descriptions for any practical situation where a data logger would be most suitable. This is why alternative suggestions, such as experiments being carried out over a long period of time, were listed in the mark scheme. Even with the possibility that both marks could be scored by talking about the practical used in part (a), only 6% of candidates scored both marks. Most of this was due to poorly-worded answers which were not specific enough, particularly with relation to sampling rate.

(b) A data logger was used in this experiment rather than a voltmeter.

Describe experimental conditions that make a data logger most suitable for collecting data.

(2)

Data logger can take more readings persecond and a graph can be immediatly plotted.

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Examiner Comments

This candidate has clearly got the concept of the rate, as they have said that more readings can be taken per second. This scores 1 mark. Lots of candidates made statements about graph plotting, but these were not credited on this paper.

Question 15 (a)

Parts (a) and (b) scored disappointingly, considering that the technical knowledge required for both was quite limited. This is a classic case of a question where lots of information has been given in the question, but candidates have not always extracted the important detail for each answer part.

In part (a), the fundamental idea to explain was the fact that an object travelling at constant speed can still have a resultant force if it is moving in a circle. Many candidates chose instead to discuss the forces shown on the free body force diagram immediately prior to part (a).

(a) Explain why there must be a resultant force acting on the cyclist.

(2)

Around bend cyclist changes direction, hence velocity changes. Acceleration is taking place. A resultant force is providing the acceleration. Resultant force provided by horizontal component of the reaction force, R.

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Examiner Comments

Here the candidate has scored both marks within the first 12 words of their answer. The remainder of their answer is verging towards what is required for part (b), but gains no credit in this section.

Question 15 (b)

Part (b) was more demanding, as candidates clearly needed to express that it was the horizontal component of the normal reaction that provided the centripetal force. Many candidates simply described "a component" or simply "the normal reaction provides the centripetal force".

(b) Explain why a banked track is an advantage to cyclists.

(2)

~~velocity changes as~~ The centripetal acceleration helps them. Rcos θ is the acceleration not R so easier to maintain.

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Examiner Comments

This candidate scores no marks. Unfortunately, references to RCosθ or RSinθ could not be credited, as θ was not labelled on the diagram that the students had been given. In addition, this candidate has also called this component of force an acceleration.

(b) Explain why a banked track is an advantage to cyclists.

(2)

As the angle θ increases, the Horizontal component of the Normal reaction which acts as the centripetal force increases as well. Thus their acceleration increases and they move with faster speeds.

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Examiner Comments

This answer is a lot clearer, and scores both marks. There was no need to make a comparison between the angle of the banking and the amount of centripetal force contributed by the normal reaction force, but this candidate has included this in addition.

(b) Explain why a banked track is an advantage to cyclists.

(2)

Due to the angle of the banked track a component of the weight of the cyclist (W sin θ) points towards the centre of the cycle. Therefore it is easier for the cyclist to follow the track.

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Examiner Comments

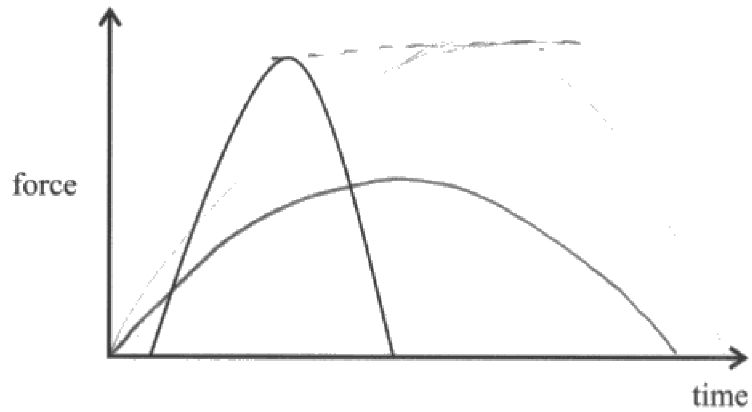
A worrying number of candidates felt that the centripetal force on a banked track was provided by a component of weight. Considering that the weight was clearly shown in the free body force diagram acting vertically downwards, it was unclear why so many students felt that the orientation of this force would change with a banked slope. This one scored no marks.

Question 15 (c)

Candidates fared somewhat better on part (c) with over half of them achieving at least 2 marks. The majority of those achieving 2 marks did so with the graph being completely correct. Unfortunately, although a lot of these candidates went on to explain using the equation $F=\Delta p/\Delta t$ why an increase in time decreased the force, many failed to state that the change of momentum would still be the same in this equation. The vast majority of the mistakes with the graph were to assume that the force was lower but the time was the same. This made it highly unlikely that marking point 3 would be scored, as the two graphs would obviously have different areas beneath them.

(c) An inflatable airbag helmet for cyclists has been designed to prevent head injuries. It is worn like a scarf around the neck. In-built sensors detect when the cyclist is involved in a crash and inflate the airbag over the cyclist's head in 0.1 s.

The graph shows how the force on a cyclist's head during a collision varies with time when an airbag is not used.



Add to the axes, the graph that shows how the force on a cyclist's head during a collision varies with time when the airbag is used.

Justify the shape of your graph.

(3)

When the collision occurs, with airbag ~~the~~ less ~~same~~ force is applied ~~so the graph has same height~~, ~~but~~ but, when air bag is used the Impulse is same ~~less~~. ~~F = F/t (t)~~, ~~I = F×t~~ I = F×t, So for both graphs the area under graph is equal. So

ResultsPlus

Examiner Comments

This candidate has produced a clear 3 mark answer. It is important to note that seeing as there were no values marked on the axes of the given graph, it did not matter where the candidate's graph started on the time axis, as long as it was clear that it spanned a greater time than the one drawn originally.

Question 16 (a)

Most candidates on part (a) simply stated that photons have no charge, but did not refer to the lack of ionisation, which is the process which ultimately leads to tracks appearing or not appearing.

(a) State why the photon leaves no track.

(1)

the photon is neutral, so it doesn't ionise particles, so no track

ResultsPlus
Examiner Comments

This candidate starts with the typical response about either no charge or that it is neutral, but then follow it with a correct comment about ionisation to score the mark.

Question 16 (b)

On part (b), a significant number of candidates did not read the question carefully, and answered "Track A" with no justification.

(b) The magnetic field acts into the page.

State with justification whether track A or track B is the track of the electron.

(1)

As FLHR, ~~and~~ the charge of A is negative.
Track A is electron

ResultsPlus
Examiner Comments

FLHR was accepted as an alternative to mentioning Fleming's Left Hand Rule in words. This candidate scores the mark.

(b) The magnetic field acts into the page.

State with justification whether track A or track B is the track of the electron.

(1)

A is track of electron.
the direction of motion is opposite to that of current.

ResultsPlus
Examiner Comments

This candidate has identified the correct track, but has not stated that it is Fleming's Left Hand Rule that has enabled them to come to this decision, so no mark.

Question 16 (c)

Part (c) was the other question on the paper testing quality of written communication. Although most candidates referred to certain aspects of the scenario, linkage was not always clear or correct. Many referred to the direction of motion as being due to conservation of momentum rather than of charge. Many referred to the radius of curvature as being due to the particles having the same velocity.

References to marking point 4 were often simply in terms of the particles "losing energy" rather than kinetic energy. In addition, the reduction of radius was not always linked to an equation.

Many students tended to focus more on the idea that the electron and positron appeared from the photograph to have a slightly different radius of curvature.

Unfortunately, for these students a lot of the discussion about how radius was affected in the equation r=mv/Bq was not from the point of view of ionisation decreasing the speed, but from ideas that the initial velocities of the particles were different. Some candidates were also confused that the slight difference in radius was due to one of them having a greater mass, and it was clear that some of them had perhaps misread positron or photon for "proton".

*(c) Explain the shape of the electron-positron tracks.

(5)

The electron-positron has positive charge. By Fleming left hand rule, B is electron-positron tracks. ~~the~~

The magnetic field will give it a ~~force~~ magnetic force. This force is centripetal force, the force is alway perpendicular to the direction of motion. Thus cause the electron-position moves in circular path.

The velocity of electron-position is reduce when it moves. Duo to $r=\frac{mv}{BQ}$, the radius became smaller, B, Q, m are constant.

ResultsPlus

Examiner Comments

In lines 3 to 6 there is a clear link between circular motion and contains the correct description of the orientation of the magnetic force in relation to the direction of motion, so scores marking point 3 here. The last two lines score both marking points 4 and 5, although for marking point 5 there had to be a link to the equation. So this script scored 3 marks in total.

*(c) Explain the shape of the electron-positron tracks.

(5)

- They both curve in oppos~~i~~ite sides because they have the opposite charge type.
- They both loose energy as they ionise liquid hydrogen, so their velocity decreases, therefore their momentum decreases. Decreasing momentum causes the particles to spiral inwards according to $r = \frac{p}{Bq}$, when B and q are constant, the radius is directly propotional to momentum. So radius decreases.
- Since the mass of the ~~proton~~ positron is higher, it's velocity is low, so its momentum is less, ~~which is~~ therefore the radius is smaller. When the particles loose all energy, they come to rest, and then show no track.

ResultsPlus
Examiner Comments

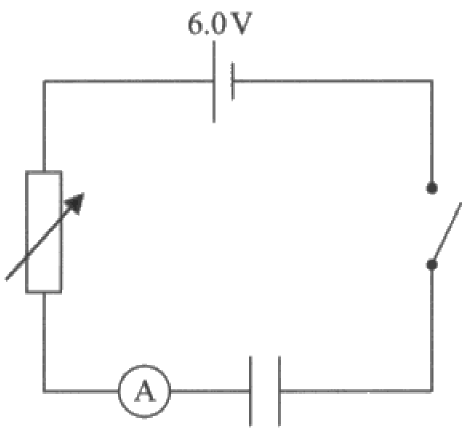
Although not very well worded, marking point 1 is achieved here in the first two lines of the answer.

The comment about losing energy in line 3 is not enough for marking point 4, but this is eventually achieved in line 4 with "velocity decreases". They could also have achieved the same mark with "momentum decreases" on the same line. On lines 5,6 and 7 they gain marking point 5, which gives a total score of 3 marks for this answer. The remainder of their answer is incorrect as they assume that the positron has a higher mass, so there is nothing of further credit.

Question 17 (a)

Almost two thirds of the candidates scored no marks on part (a). This was partly due to a lack of clarity in descriptions, but also a lack of acknowledgement that the answer related very closely to talking about potential differences rather than currents.

17 A student is investigating capacitance. She sets up the circuit shown.



(a) When the switch is closed there is a maximum current, which decreases to zero over a period of time as the capacitor charges. Explain why.

(3)

• ~~There is curr~~ The current is provided inatially by the battery, which pass through the resistor and capacitor, the capacitor charges as one plate becomes positive and the other negatively charged until the pd accross the capcitor is equal to pd of the battery. So $V_{cell} = V_{resistor} + V_{capacitor}$ so capcitor charges and so current decreases to zero and so current accross resistor equals zero. Since the capacitor charges exponentially, so current decreases over a period of time (not instantaneously).

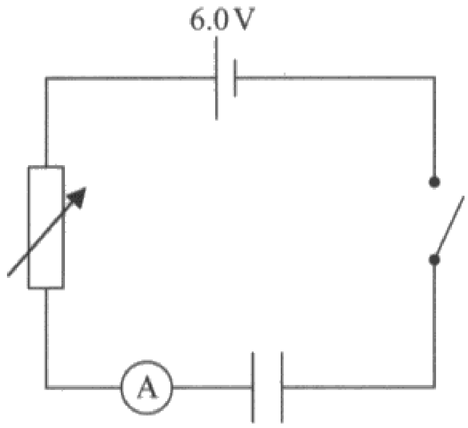
ResultsPlus
Examiner Comments

This candidate scored marking point 3 only with their comment at the start of line 4.

ResultsPlus
Examiner Tip

Note that this candidate was very much in danger of going beyond the scanned area of the question. If you are likely to continue writing beyond the space given, it is important to make a note of this within the area the examiner will see e.g. "Continued at the bottom of page 19".

17 A student is investigating capacitance. She sets up the circuit shown.



(a) When the switch is closed there is a maximum current, which decreases to zero over a period of time as the capacitor charges. Explain why.

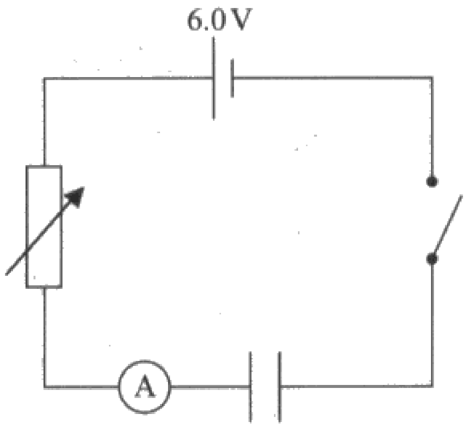
(3)

when the switch is closed, the Voltage across the resistor will be equal to the supply voltage (6V), so rate of flow of charge is a maximum, current is maximum. as the capacitor charges voltage builds up across the capacitor and voltage across the resistor decreases and will finally become zero volts when voltage across capacitor is equal to supply voltage (6V). so charge stops flowing and current will be zero.

ResultsPlus
Examiner Comments

A model 3 mark answer.

17 A student is investigating capacitance. She sets up the circuit shown.



(a) When the switch is closed there is a maximum current, which decreases to zero over a period of time as the capacitor charges. Explain why.

(3)

Initially, there is no charge on either of the plates of the capacitor, so charge flows quickly onto these plates. As more and more charge builds on these plates, it becomes increasingly more difficult for additional charge to flow onto the plates due to electrostatic repulsion between like charges. Eventually, when the p.d. across the capacitor equals the p.d. of the power supply, no more charge flows onto the plates, so current is zero.

ResultsPlus
Examiner Comments

This one scores marking points 2 and 3. The second alternative of marking point 2 is seen on lines 2 to 4, whilst lines 4 and 5 score marking point 3.

ResultsPlus
Examiner Tip

When answering questions where equations might be used to help with the explanation, ensure that all terms used in equations are named, rather than simply giving symbols. On this question, the letter V with a subscripted letter was often seen. However, a lot of these are not standard symbols, so it cannot be expected that an examiner will accept them.

Often candidates quoted $V_B = V_C + V_R$

, without a description of what the symbols stood for.

Question 17 (b)

The vast majority of candidates scored either 3 or 5 marks on (b). This is because many candidates felt that it was not necessary to work out the area of both the rectangle and triangle from the graph in part (b)(i). The area calculation for just a rectangle resulted in just 1 mark being available in this part, although many of these candidates achieved a full error carried forward in (b)(ii).

Those who did not score 3 or 5 on (b) tended to suffer from other issues such as unit errors on capacitance, or a failure to recognise that in the equation W = ½ CV^2, that the C did not stand for charge. The only other issues with (i) were for those who either failed to convert powers of 10 correctly, or managed to multiply by 6 Volts instead of dividing.

(i) Determine the capacitance of the capacitor.

(3)

$C = \frac{Q}{V}$

$= \frac{2.4 \times 10^{-3} \times 100}{6}$

$= 0.04$ F

Capacitance = 0.04 F

(ii) Hence determine the energy stored by the capacitor when it is fully charged.

(2)

$W = \frac{1}{2}CV^2$

$= 0.02 \times 36$

$= 0.72$ J

Energy stored = 0.72 J

ResultsPlus
Examiner Comments

A typical answer to part (i) where no consideration has been taken of the small triangle at the end of the graph, so only marking point 2 is scored here. Although we do not see their capacitance value (0.04) directly in part (ii), they have replaced ½ C with 0.02, which is clear enough to get 2 marks error carried forward in this part.

(i) Determine the capacitance of the capacitor.

(3)

~~V/I~~ $Q = It$

$Q =$ ~~2.5×10^{-3}~~ $2.4 \times 10^{-3} \times$

$\frac{1}{2} \times 10 \times 2.4 \times 10^{-3}$ + $2.4 \times 10^{-3} \times 100 = 0.24 + 0.012$

$Q = 0.252$

~~Q~~ $0.252 = 6C$

$0.042\ F$

Capacitance = 0.042F

(ii) Hence determine the energy stored by the capacitor when it is fully charged.

(2)

$\frac{1}{2} \times C \times V^2$

$\frac{1}{2} \times 0.042 \times 36 = 0.76\ J$

Energy stored = 0.76 J

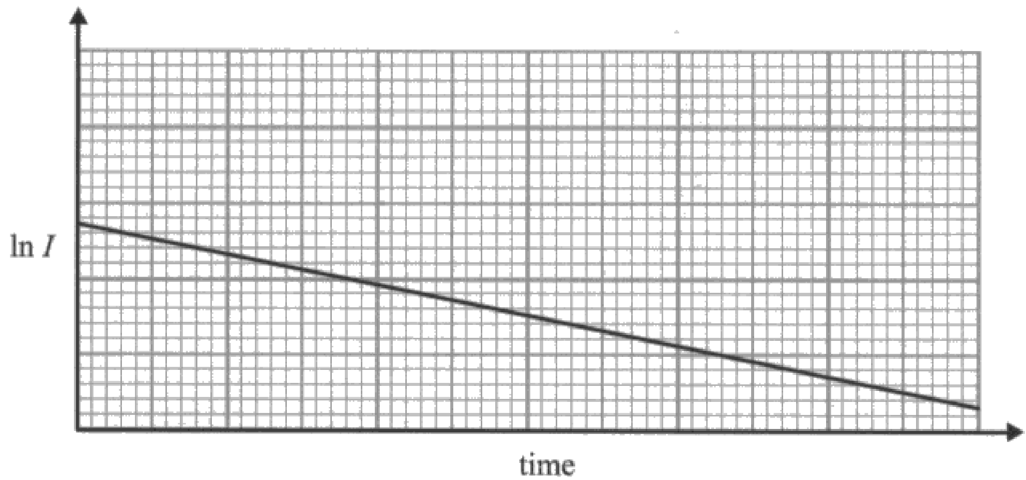
ResultsPlus
Examiner Comments

Unfortunately, this is a rarely seen example of a fully-correct calculation scoring 3,2.

Question 17 (c) (i)

The most commonly missed marking point in (c)(i) was the explicit statement to "determine" the gradient. Words such as "find" and "calculate" were accepted, but many candidates simply gave the equation and said "gradient = …"

(c) Capacitance can also be determined by measuring the current I at regular time intervals, as a capacitor discharges through a resistor, and plotting a graph of $\ln I$ against time.



(i) Explain how capacitance can be determined using this graph.

(3)

$I = I_0 e^{-\frac{t}{RC}}$ $\quad \therefore C = -\frac{1}{R\,\text{gradient}}$

$\ln I = \ln I_0 - \frac{t}{RC}$

$\ln I = -\frac{1}{RC}t + \ln I_0$

⇓ ⇓ ⇓ ⇓

y k x c

$\text{gradient} = -\frac{1}{RC}$

ResultsPlus
Examiner Comments

This is a typical 2 mark response, scoring marking points 1 and 3. A number of candidates with the correct equation still neglected to include the minus sign in their gradient, which prevented the awarding of marking point 3 in a number of cases. There is no mention of finding/calculating/measuring the gradient, so no marking point 2.

Question 17 (c) (ii)

A number of candidates picked up significant scores on (c)(ii) although it was clear from the following discussions that quite a few of these candidates did not know the significance of working out the time constant.

For some, the time constant calculation came in the middle of lots of separate calculations, and a significant number decided to use the values for current and e.m.f. given earlier in the question. However, the values given in (c)(ii) were not related to those given/calculated earlier on in the question, so these calculations could not be credited here. Most of the incorrect discussions were linked to the current value being too small to measure with an ammeter.

(ii) A capacitor was discharged through a 390 Ω resistor. The capacitance of the capacitor was calculated as 2200 μF.

Explain why the data for the graph for this circuit would be difficult to obtain using an ammeter. Your answer should include a calculation.

(3)

$t = RC$

$= 390 \times 2200 \times 10^{-6}$

$= 0.858 s$

$t_{1/2} = RC \ln 2$

$= 0.595$

x Therefore with the current in a discharge having a half life of 0.595 shows that the rate of discharge is very high in a very small period of time and will not be able to measure using an ameter.

x The best form of measuring this would be via a data logger for digital multimeter.

(Total for Question 17 = 14 marks)

ResultsPlus

Examiner Comments

A good answer with a clear link to a high discharge rate for the capacitor, so scoring all 3 marks. The unit of seconds was required for marking point 2, otherwise a comparison of the speed of discharge was not relevant.

(ii) A capacitor was discharged through a 390 Ω resistor. The capacitance of the capacitor was calculated as 2200 μF.

Explain why the data for the graph for this circuit would be difficult to obtain using an ammeter. Your answer should include a calculation.

(3)

$\tau = RC$

$= 390 \times 2200 \times 10^{-6}$ $I_0 = 2.4$ mA

$= 0.858$ s $0.37\ I_0 = 0.888$ mA

The change is too insignificant, it can't only $I = 0.000888$ A
be noticed if the ammeter ~~were~~ was precise to
5 s.f. An ammeter is only precise to 2 s.f.

ResultsPlus
Examiner Comments

An example of a candidate who is not entirely sure what the key factor is in their answer. They have worked out the time constant, but also calculated a current from data that is not relevant to this part of the question. Their explanation is all in terms of current rather than time. This scores 2 marks.

(ii) A capacitor was discharged through a 390 Ω resistor. The capacitance of the capacitor was calculated as 2200 μF.

Explain why the data for the graph for this circuit would be difficult to obtain using an ammeter. Your answer should include a calculation.

(3)

Ammeter have resistance.
D.C. supply have interval resistance.

$C = \frac{Q}{V}$ $\tau = RC = 2200 \times 10^{-3} \times 390 = 858$ s.
Time is too short, therefore uncertainty ~~and~~ is great.

ResultsPlus
Examiner Comments

This candidate has the wrong power of 10 conversion for micro, so ends up with a time of 858 seconds. This scores marking point 1 only. The description relating to "time is too short" is not relevant for a capacitor that they are proposing will take 14 minutes to discharge to 37% of it's original charge.

Question 18 (a)

Overall, this question was answered quite well, with the majority of candidates scoring full marks on (a), (b) and (c)(i).

Part (a) could be worded in a number of acceptable ways.

18 In a large-angle alpha particle scattering experiment, alpha particles were directed at thin gold foil and their paths observed. Most of the alpha particles passed straight through the foil or were deflected through a small angle. A very small number were deflected through an angle greater than 90°.

(a) State what can be deduced about the atom given that most alpha particles passed straight through the foil.

(1)

The atom is mostly empty space and that the mass is concentrated in the nucleus

ResultsPlus
Examiner Comments

One example of a correct answer, followed by some extra, unnecessary information.

18 In a large-angle alpha particle scattering experiment, alpha particles were directed at thin gold foil and their paths observed. Most of the alpha particles passed straight through the foil or were deflected through a small angle. A very small number were deflected through an angle greater than 90°.

(a) State what can be deduced about the atom given that most alpha particles passed straight through the foil.

(1)

The atom has a lot of empty space in it.

ResultsPlus
Examiner Comments

This answer was too vague to score the mark.

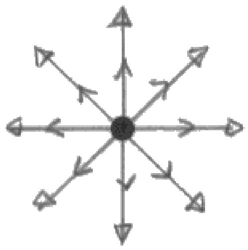
Question 18 (b)

Part (b) was generally done well, with a significant majority knowing that the arrows had to be pointing outwards. Once again, however, there was a suggestion that some candidates had not read the question at all. A number decided to assume that as the diagram depicted a gold nucleus, they were supposed to draw the paths of various alpha particles as they passed the nucleus.

(b) The point below represents a gold nucleus.

Add lines to show the electric field due to the gold nucleus.

(2)



ResultsPlus

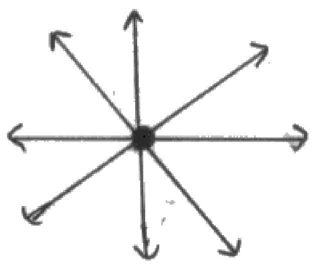
Examiner Comments

This is an acceptable diagram to score 2 marks. There are double arrow heads on the lines, but these are allowed as long as they all point outwards. They are also equally spaced, equal in length, and apparently drawn with a ruler and pencil, which is the ideal combination.

(b) The point below represents a gold nucleus.

Add lines to show the electric field due to the gold nucleus.

(2)



ResultsPlus

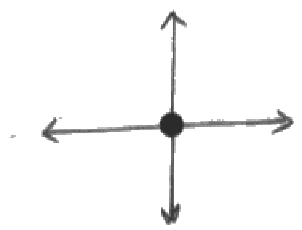
Examiner Comments

This candidate has not spaced the lines very well, with some closer than others, so marking point 1 is not awarded. However, they are pointing outwards so scores marking point 2.

(b) The point below represents a gold nucleus.

Add lines to show the electric field due to the gold nucleus.

(2)



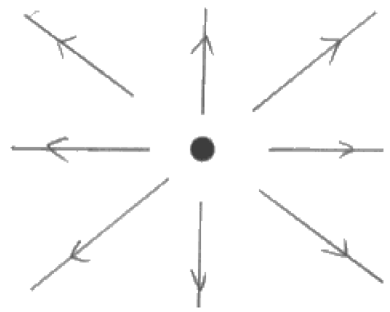
ResultsPlus
Examiner Comments

This candidate has probably just achieved the minimum acceptable response for 2 marks. The lines are not all equal in length and are not perfectly at right angles to each other, but are just about acceptable for equal spacing. To show a radial field, 4 lines is the minimum acceptable on this unit.

(b) The point below represents a gold nucleus.

Add lines to show the electric field due to the gold nucleus.

(2)



ResultsPlus
Examiner Comments

This one scores marking point 2 only, as they have not drawn their lines all the way up to the dot in the middle.

Question 18 (c) (i)

Although a lot of correct answers were seen, the common mistakes in (c)(i) were to ignore the electronic charges, to assume that the alpha particle had a charge of 4e, using one charge instead of two, to fail to square the separation value, to halve the separation value as if it were a diameter and to use the wrong value for the constant in the equation.

It is worth reminding candidates that "Use of…" in a mark scheme can only be awarded if ALL of the values to be used in the equation are inserted.

(c) An alpha particle that is moving directly towards a gold nucleus is deflected back along its original path. The minimum separation between the alpha particle and the gold nucleus is 3.8×10^{-14} m.

atomic number of gold = 79

(i) Calculate the electrostatic force on the alpha particle when it is at the minimum separation from the gold nucleus.

(2)

$$F = \frac{k q_1 q_2}{r^2}$$

$$= \frac{8.99 \times 10^9 \times 2 \times 1.6 \times 10^{-19} \times 79 \times 1.6 \times 10^{-19}}{(3.8 \times 10^{-14})^2}$$

$= 25.2$ N

Force on alpha particle = 25.2 N

ResultsPlus
Examiner Comments

This candidate has the correct answer, but a quick check of their working shows that they have also inserted all of the values correctly into the equation and thus scores both marks. Apart from the correct k constant, it is also acceptable to use $1/4\pi\varepsilon_0$, with the correct value of ε_0.

(c) An alpha particle that is moving directly towards a gold nucleus is deflected back along its original path. The minimum separation between the alpha particle and the gold nucleus is 3.8×10^{-14} m.

atomic number of gold = 79

(i) Calculate the electrostatic force on the alpha particle when it is at the minimum separation from the gold nucleus.

(2)

$F = k\frac{Q_1 Q_2}{r^2}$

$= 1.38\times10^{-23} \times \frac{(2\times79)\times(1.6\times10^{-19})^2}{(3.8\times10^{-14})^2}$

$= 3.866\times10^{-32} \approx 3.9\times10^{-32}$ N

Force on alpha particle = 3.9×10^{-32} N

ResultsPlus

Examiner Comments

This candidate has used the Boltzmann constant as k, so scores no marks.

(c) An alpha particle that is moving directly towards a gold nucleus is deflected back along its original path. The minimum separation between the alpha particle and the gold nucleus is 3.8×10^{-14} m.

atomic number of gold = 79

(i) Calculate the electrostatic force on the alpha particle when it is at the minimum separation from the gold nucleus.

(2)

$F = \frac{kqQ}{r^2} = \frac{8.99\times10^{9} \times (79\times1.6\times10^{-19}) \times (2\times1.6\times10^{-19})}{3.8\times10^{-14}\text{ m}}$

9.56×10^{-13} N

Force on alpha particle = 9.56×10^{-13}

ResultsPlus

Examiner Comments

Another very common mistake where the candidate has written the correct equation in symbol form, then forgotten to square the value of r, resulting in scoring no marks.

Question 18 (c) (ii)

On (c)(ii) a lot of candidates picked up marking point 1, but a significant number failed to get any further as they failed to recognise the fact that the mass would be 4u. Large numbers of candidates used 2u instead or used the mass of an electron, perhaps indicating a confusion between alpha and beta particles.

(ii) The initial kinetic energy of the alpha particle is 6.0 MeV.

Calculate the change in momentum of the alpha particle, in N s, as it travels to its minimum separation from the gold nucleus.

(3)

$KE = \frac{1}{2}mv^2 = 6\ MeV = 6 \times 10^6\ eV = 9.6 \times 10^{-13}\ J$

$\Rightarrow 9.6 \times 10^{-13} = \frac{1}{2} \times mv^2$

$v = 1.45 \times 10^9 \quad \therefore \Delta mv = 1.3 \times 10^{-21}\ Ns$

Change in momentum = 1.3×10^{-21} N s

ResultsPlus

Examiner Comments

This candidate has a clear piece of working out to demonstrate marking point 1 in the first line. However, they then perform a kinetic energy calculation followed by a momentum calculation, where none of the values used in the equation are shown. It is clear that this method is wrong as the velocity they calculate is faster than the speed of light, so it only scores 1 mark in total.

(ii) The initial kinetic energy of the alpha particle is 6.0 MeV.

Calculate the change in momentum of the alpha particle, in N s, as it travels to its minimum separation from the gold nucleus.

(3)

$p = \sqrt{2mE_k}$

$= \sqrt{2 \times 4u \times 6\times10^{6} \times 1.6\times10^{-19}}$

$= 1.13\times10^{-19}$ N s.

Change in momentum = 1.13×10^{-19} N s

ResultsPlus
Examiner Comments

This candidate has the correct answer, and their working all looks good, so scores all 3 marks. This is an occasion where we are willing to accept "u" or "1.66 x 10^{-27}

kg" as an alternative to the exact value required for 1 proton/neutron.

Unlike "k", there is no ambiguity in the value that the candidate is intending to use here.

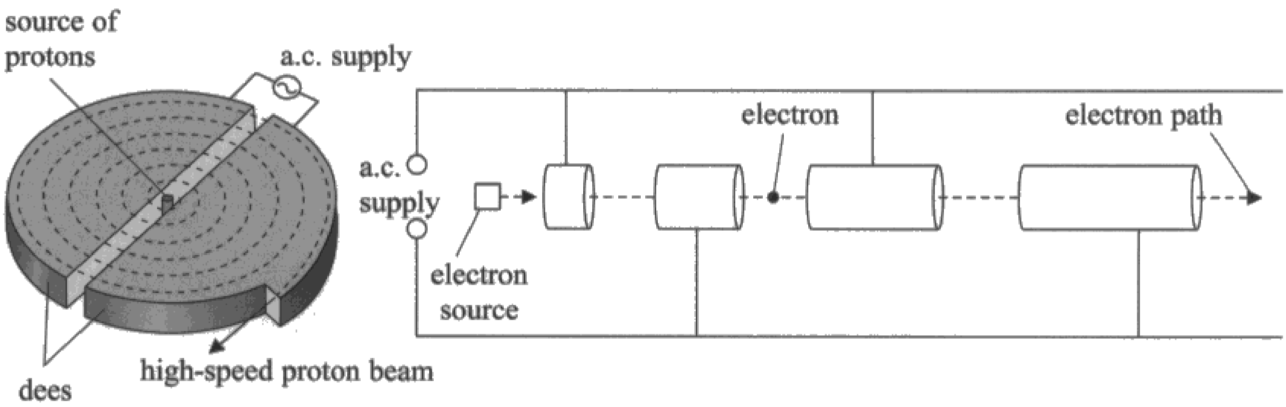
Question 19 (a)

Part (b)(i) was the only section in this question that scored very well, with the remaining sections generally being low-scoring.

On part (a), the most commonly scored marking points were 1 and 3, with the others being much more rarely seen.

There is a possibility that the scores might have been higher if candidates had been asked to simply list the similarities and differences, without being restricted to "two" of each. This is because many of the similarities and differences being quoted were just too obvious from the diagrams given, or from simple understanding. For example, a number of candidates in the section on similarities stated "an a.c. supply is used" , which is clearly shown on the diagrams. For the differences, the most commonly seen answers that were not accepted were "particles in a linac travel in straight lines, whilst in a cyclotron they travel in circles" and "cyclotron uses protons whereas linac uses electrons".

19 The diagrams show two particle accelerators, the cyclotron and the linac.



(a) Describe two similarities and two differences in how the accelerators operate.

(4)

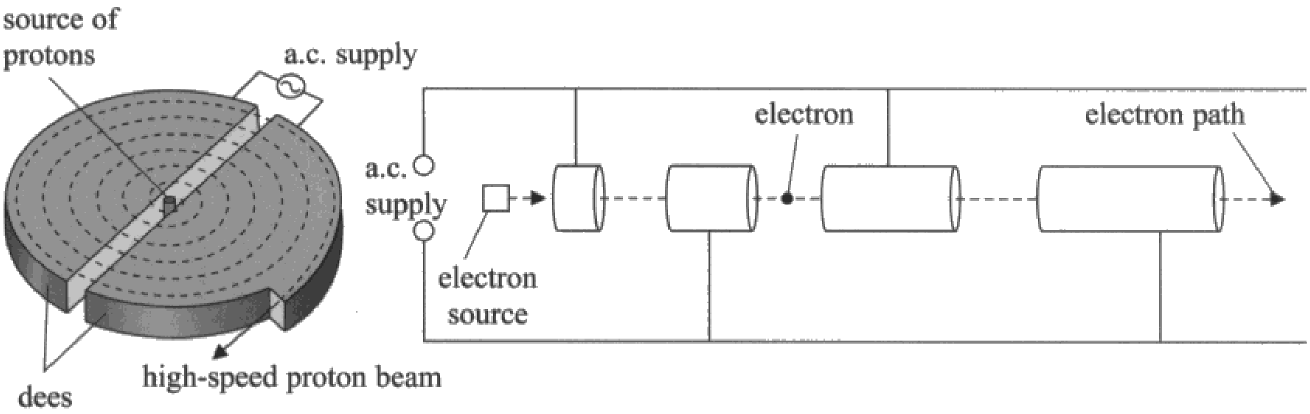
Two similarities ~~elec~~ particle accelerates because of the electric field in the gaps between the Dees or the tubes. They both use a.c ~~curren~~ supplies.

Two differences the cyclotron has electric and magnetic fields and linac only has the electric field.
Particles at cyclotron ~~are forced~~ are forced in a semicircular path and magnetic field strength is changed while in the linac particles follow a straight path

ResultsPlus
Examiner Comments

A typical 2 mark response scoring marking points 1 and 3 only. They have not stated clearly enough that the acceleration ONLY takes place in the gaps for marking point 2.

19 The diagrams show two particle accelerators, the cyclotron and the linac.



(a) Describe two similarities and two differences in how the accelerators operate.

(4)

Two similarities ~~Accelerate particles with the ... ... from AC electric field and a magnetic field (Both).~~
ⓒ Both use an electric field (alternating).
⊗ Both accelerate particles upto the speed of light.

Two differences ⊗ Particles travel in a straight line in the linac.
~~Ⓧ Collisions can be done to ...~~
⊗ Particles follow a circular path in the cyclotron.
ⓒ ~~Both use~~ Cyclotron uses a B field.

ResultsPlus
Examiner Comments

Unfortunately, this candidate has not made it clear that the electric field is the cause of the acceleration, so does not score marking point 1. In the section on differences, they state that the cyclotron uses a B field (which would be accepted for "magnetic field") but fail to then go on to say that a linac does not use a B field. Unfortunately, this leads to a score of 0 on this answer.

ResultsPlus
Examiner Tip

When a question asks for the difference between two things, there needs to be an aspect of comparison.

Statements such as "cyclotrons use magnetic fields to make the protons travel in circular paths, but in a linac the particles travel in straight lines" is comparing the shape of the path, but there is no clear indication that linacs do not have a magnetic field.

Question 19 (b) (i)

Part (b)(i) was another "show that" question, so a value of at least one more significant figure than the given value was required. There also needed to be a clear substitution of figures into the formula for marking point 1 to be awarded. Almost 85% of the candidates scored both marks here.

(b) (i) Electrons in an electron beam are moving at a speed of 8.2×10^6 m s^{-1}.

Show that the de Broglie wavelength associated with these electrons is about 9×10^{-11} m.

(2)

$$\lambda = \frac{6.63\times10^{-34}}{(9.11\times10^{-31})(8.2\times10^{6})} = 8.9\times10^{-11}\ \text{m}$$

$$\lambda = \frac{h}{mv} = \frac{h}{p} \qquad h = \text{planck constant}$$

ResultsPlus

Examiner Comments

A good, clear calculation leading to an answer that has one more significant value than the "show that" value, so scores both marks.

(b) (i) Electrons in an electron beam are moving at a speed of 8.2×10^6 m s^{-1}.

Show that the de Broglie wavelength associated with these electrons is about 9×10^{-11} m.

(2)

$$\lambda = \frac{6.63\times10^{-34}}{(8.2\times10^{6}\times9.11\times10^{-31})} = 8.875\times10^{-11}$$

ResultsPlus

Examiner Comments

Another clear answer for 2 marks. Units are missing on the answer, but they are given in the question so this is not penalised on a "show that " question.

(b) (i) Electrons in an electron beam are moving at a speed of $8.2 \times 10^6 \text{ m s}^{-1}$.

Show that the de Broglie wavelength associated with these electrons is about 9×10^{-11} m.

(2)

$\lambda = \frac{h}{p}$ $p = m \times v = 9.11 \times 10^{-31} \times 8.2 \times 10^{6}$

$= ~~7.4~~ \; 7.5 \times 10^{-24}$

$= \frac{6.63 \times 10^{-34}}{7.5 \times 10^{-24}} = ~~8.8~~ \; 9 \times 10^{-11}$ m

ResultsPlus
Examiner Comments

This candidate has performed an interim step in their calculation, working out the momentum first before putting this into the de Broglie equation. However, the answer they have given is only to 1 significant figure, so this answer only gains 1 mark.

Question 19 (b) (ii)

For (b)(ii), there needed to be a comparative statement between the wavelength of the electron and the diameter of the proton, but most candidates seemed to focus much more on the observation that significant diffraction takes place when the gap size is equal to the wavelength. This does not answer the question. A reasonable number of candidates also confused their negative powers of 10 and thought that the wavelength was much smaller than the diameter of the proton.

(ii) In the 1950s physicist Robert Hofstadter used electron diffraction to estimate the diameter of the proton. He obtained a value of 5.6×10^{-25} m.

State why electrons moving at 8.2×10^{6} m s^{-1} would not be suitable for this.

(1)

Wavelength of electrons much greater than diameter of proton, ~~so diffraction exists.~~ They need to be similar

ResultsPlus
Examiner Comments

This is an ideal answer for 1 mark, followed by the idea that they have to be similar sizes (not relevant to the answer expected, but also not contradictory).

(ii) In the 1950s physicist Robert Hofstadter used electron diffraction to estimate the diameter of the proton. He obtained a value of 5.6×10^{-25} m.

State why electrons moving at 8.2×10^{6} m s^{-1} would not be suitable for this.

(1)

Their de-Broglie wavelength is much higher

ResultsPlus
Examiner Comments

No comparison with the proton or its diameter, so no mark.

(ii) In the 1950s physicist Robert Hofstadter used electron diffraction to estimate the diameter of the proton. He obtained a value of 5.6×10^{-25} m.

State why electrons moving at 8.2×10^{6} m s^{-1} would not be suitable for this.

(1)

because their wavelengnt = 9 x 10^{-11} much smaller than 5.6 x 10^{-25} so no diffraction

ResultsPlus

Examiner Comments

An example of a candidate who has mixed up the powers of 10 and feels that the wavelength is smaller than the proton. Just referring to the numerical values in the answer was acceptable on this question e.g. "9 x 10^{-11} m is much greater than 5.6 x 10^{-25} m" would score the mark.

Question 19 (c)

Parts (c)(i) and (c)(ii) were marked together, so there are no statistics for these two parts separately. However, the general feeling was that (c)(i) was answered better than (c)(ii). Within both parts there is a need both to read the question carefully, but also to make sure that the basic points of the answer are listed before moving on to the higher level of understanding.

In both (i) and (ii) there was a lot of discussion of mass changes as the speed of light is approached, although neither of the questions were requesting this information.

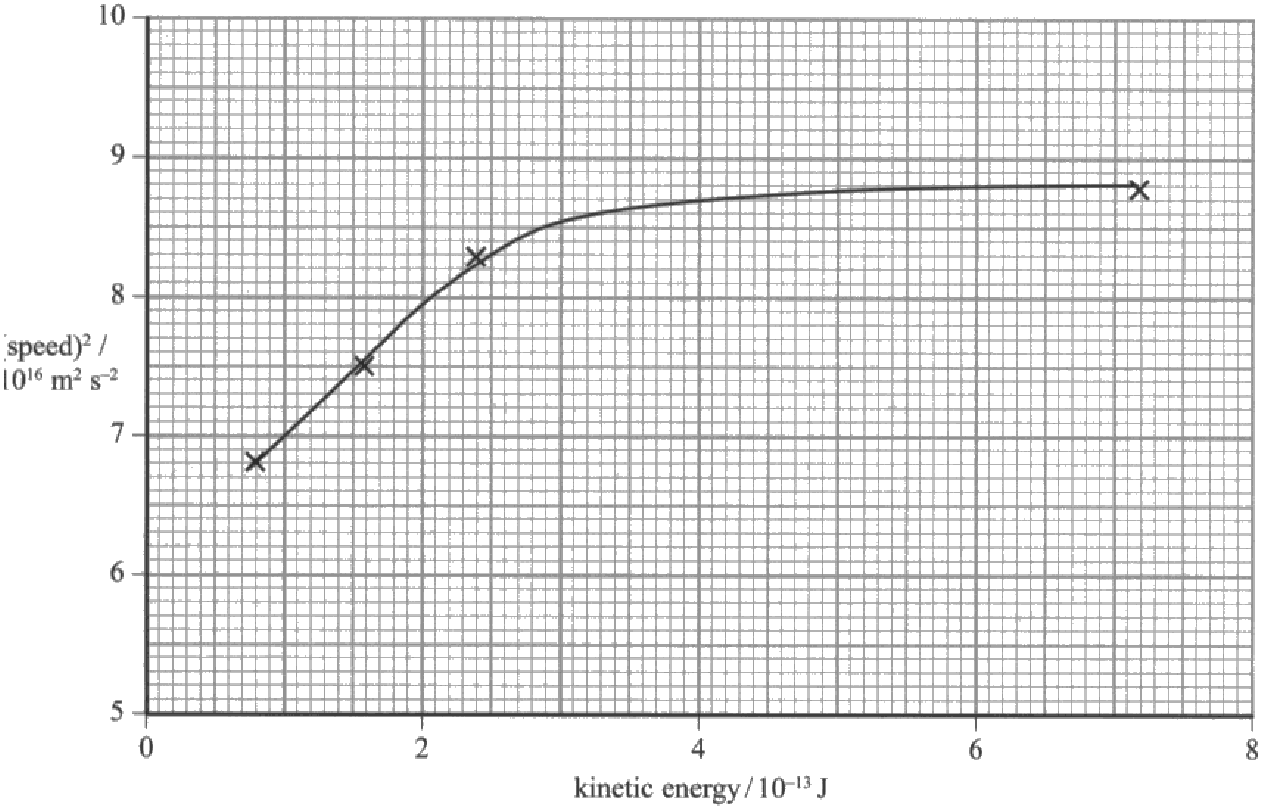
In (c)(i), surprisingly few candidates stated quite clearly that the value quoted was the speed of light squared. However, a lot of them then went on to discuss how particles could not travel faster than the speed of light, so they had obviously realised (without saying) that this was the speed of light squared.

Considering that the graph shown is for electrons, it only shows us that electrons cannot travel at the speed of light, so there did need to be some mention of electrons or particles for marking point 2.

(c)(ii) asked specifically for candidates to explain how the graph shows that the equation does not apply. Unfortunately, descriptions such as “the graph levels off” were not acceptable here, as this information had been given already in the question for part (i). Many candidates also focussed too heavily on talking about what would have happened if the relationship had applied, without then telling the examiner what really happens.

(c) Developments in particle accelerator technology in the 1960s enabled experiments with high-energy electrons to be carried out. At these energies, relativistic effects occur.

The graph below, of $(\text{speed})^2$ against kinetic energy, shows data from one of these experiments.



(i) Explain why the graph levels out at a value close to 9×10^{16} m^2 s^{-2}.

(2)

No particle can travel at the speed of light. So the electron gains mass as the kinetic energy increases.

(ii) The non-relativistic equation for kinetic energy, $E_k = \frac{1}{2}mv^2$, does **not** apply for high-energy electrons. Explain how the graph shows this.

(2)

Graph isn't linear as the y-axis reaches close to 9×10^{16}. The mass isn't a constant factor anymore. The graph shows an asymptote.

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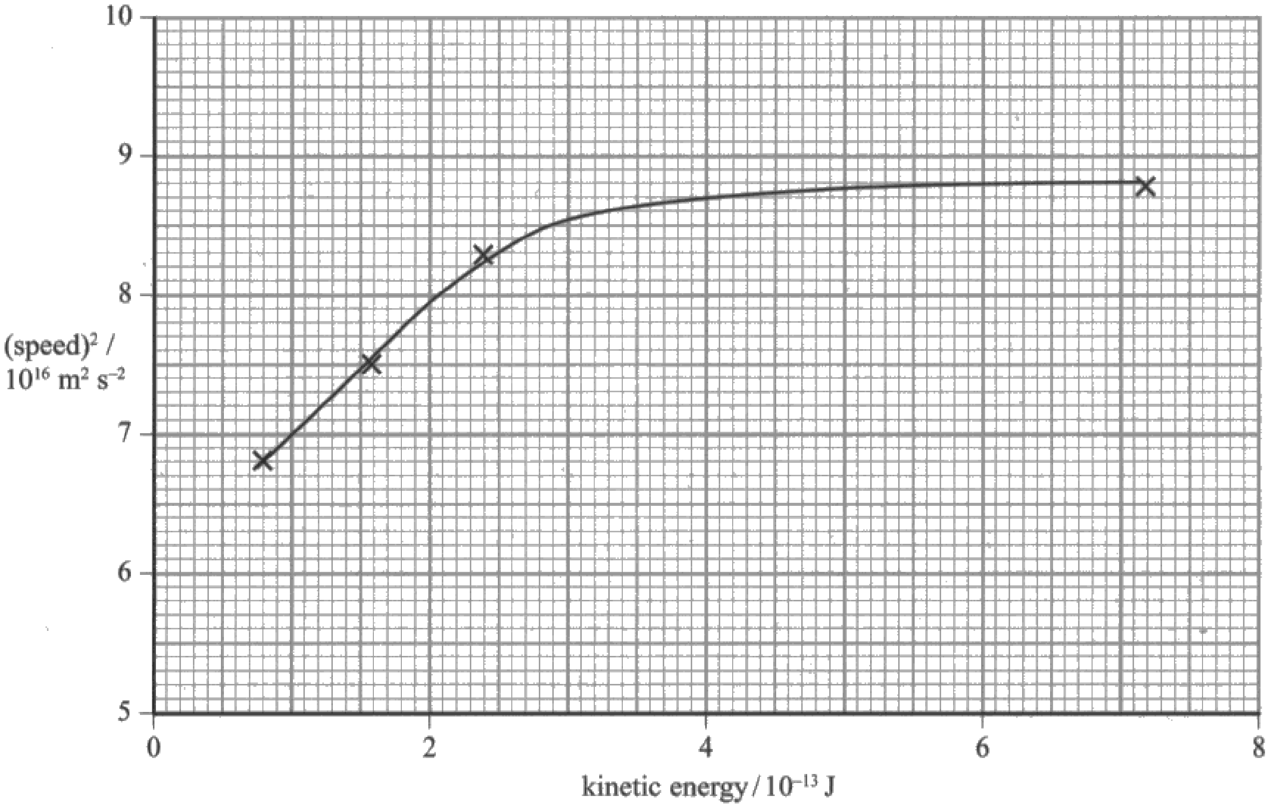
Examiner Comments

This candidate scores 1 mark in each section. In (c)(i) they score the second marking point for their comment about particles not being able to travel at the speed of light. However, there is no reference to the fact that the given value is the speed of light squared. In (c)(ii) they have described the graph as non-linear so score marking point 2.

(c) Developments in particle accelerator technology in the 1960s enabled experiments with high-energy electrons to be carried out. At these energies, relativistic effects occur.

The graph below, of $(\text{speed})^2$ against kinetic energy, shows data from one of these experiments.



(i) Explain why the graph levels out at a value close to $9 \times 10^{16}\ m^2\ s^{-2}$.

(2)

when te ~~graph~~ speed ~~mates~~ of te electron is close to te speed of light and te particle moves with a relativistic speed terefore it's mass increases and kinetic energy remains constant.

$E_K = \frac{mv^2}{2}$ $v^2 = \frac{2E_K}{m}$

(ii) The non-relativistic equation for kinetic energy, $E_k = \frac{1}{2} mv^2$, does **not** apply for high-energy electrons. Explain how the graph shows this.

(2)

te graph shows this as initially $v^2 \propto E_K$ as te electrons are moving at non relatinistic speeds however as it moves closer to te speed of light the particles mass increases hence kinetic energy remains constant and te graph levels out.

ResultsPlus
Examiner Comments

This scores 0,0. Although the candidate is clearly making a discussion in terms of the speed of light in (c)(i), they have not related it to the value given, and only talk about the electron speed being close to the speed of light. The answer to (c)(ii) is more promising as they are clearly talking about the relationship between velocity squared and kinetic energy. However, they do not tell us that the relationship does not show proportionality. The comment that "the graph levels out" is taken directly from the question in (c)(i) so gains no credit.

Paper Summary

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

- Check clearly that your answers are an attempt to answer this question on this paper, and not a question from a previous paper where you have remembered the mark scheme.
- Read the question thoroughly to establish whether more than one thing is being requested e.g. "State and justify…"
- Show all of your substitutions in calculations.
- Try to write full words when describing or explaining things in answers. Symbols that might be familiar to you might not be conventional symbols used worldwide, although the worded descriptions usually will be understood.

Grade Boundaries

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