Examiners' Report
June 2017

IAL Physics WPH04

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June 2017

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Introduction

The assessment structure of Unit 4, Physics on the Move is the same as that of Units 1, 2 and 5, consisting of Section A with ten multiple choice questions, and Section B with a number of short answer questions followed by some longer, structured questions based on contexts of varying familiarity.

This was a relatively straightforward paper that allowed candidates of all abilities to demonstrate their knowledge and understanding of Physics by applying them to a range of contexts with differing levels of familiarity.

Candidates at the lower end of the range of achievement could complete calculations involving simple substitution and limited rearrangement, including structured series of calculations, but could not always tackle calculations involving several steps or other complications, such as applying trigonometrical functions correctly or remembering to multiply the electronic charge by two for an alpha particle. They also knew some significant points in explanations linked to standard situations, such as electromagnetic induction, but missed important details and did not always set out their ideas in a logical sequence, sometimes just quoting as many key points as they could remember without particular reference to the context.

Steady improvement was demonstrated in all of these areas through the range of increasing achievement and at the higher end all calculations were completed faultlessly, most definitions were given with all the required details and most points were included in ordered explanations of the situations in the questions.

Section A, Multiple choice:

Question	Answer	% correct	Most common incorrect choice
1	**A**	**77**	C (pion)
2	**B**	**66**	A (out of page)
3	**C**	**82**	A (acceleration)
4	**D**	**67**	A **or** B (smaller p.d. **or** decreasing momentum of electron)
5	**D**	**67**	B (energy)
6	**C**	**80**	D (10 V m^{-1})
7	**C**	**68**	B **or** D (ddu, du **or** $\bar{u}\,\bar{s}\,s\,d\,\bar{d}$
8	**B**	**52**	D (work done)
9	**B**	**62**	D (the same, greater, greater)
10	**A**	**71**	B (E_k / 2)

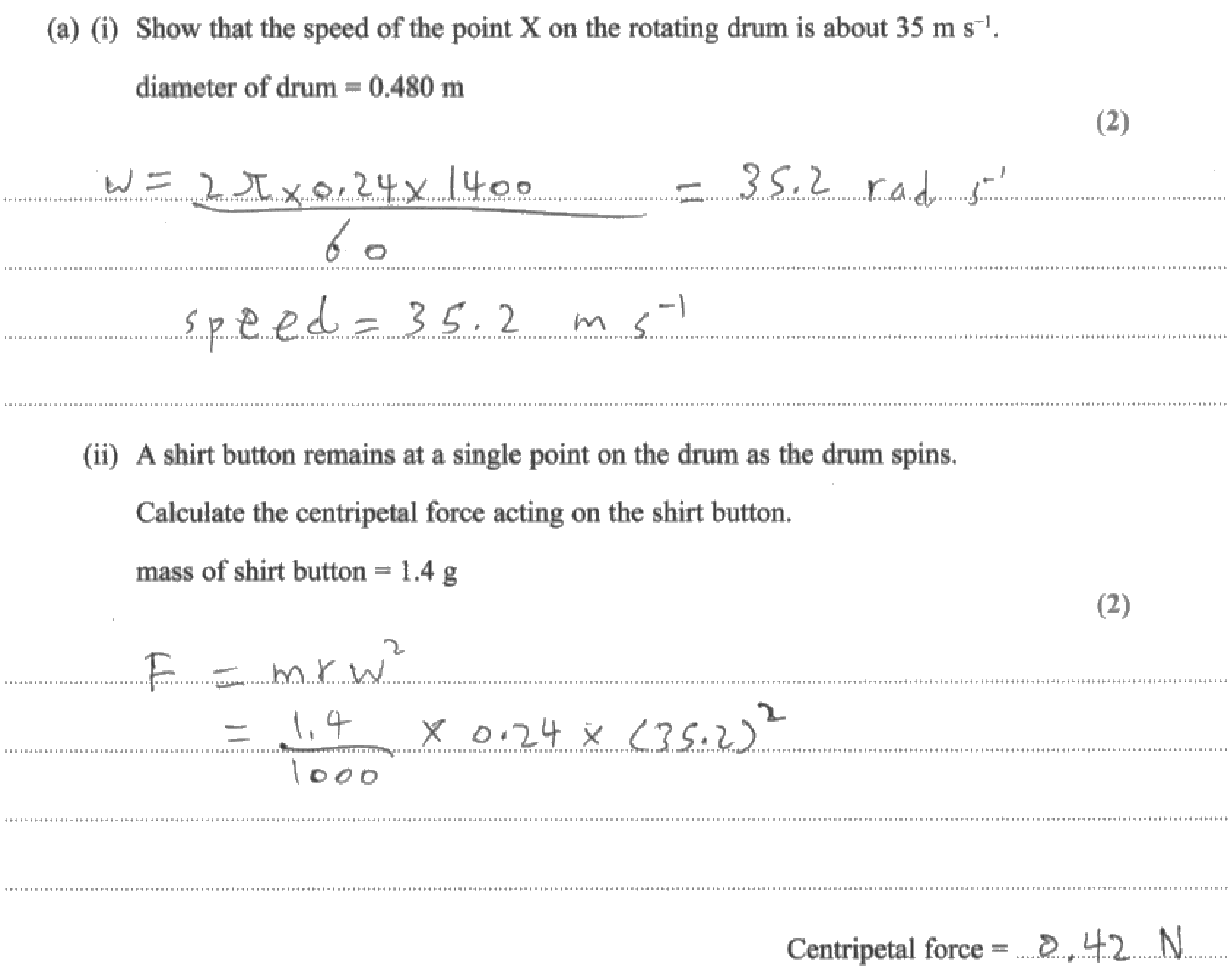
Possible reasons for some incorrect choices:

2. Candidates are possibly treating the direction of the electron as the direction of current.
3. Acceleration is the gradient of a velocity-time graph – perhaps this was chosen because momentum = mass × velocity.
4. These both mean the electron has lower momentum, so candidates may have linked lower momentum with shorter wavelength instead of linking lower momentum to longer wavelength.
5. Candidates are probably thinking of kinetic energy, which they know does not have to be conserved, and not picking up on rest mass.
6. This uses the distance to the halfway point between halfway mentioned in the question – not sticking to the idea of a uniform field.
8. They are not used to thinking of the correct answer, magnetic flux density, as a vector despite needing direction for Fleming's left hand rule, for example, and using the angle in $F = BIl \sin \theta$. Work = force × distance, so possibly it is because they know force is a vector.
10. There are several ways to arrive at the incorrect answer B, but it was very noticeable that the great majority of candidates who wrote out the formula and made the changes got the mark for this question whereas the great majority who made an incorrect choice did not write anything. There are no extra marks for completing questions like this 'in your head', so candidates should always write them out.

For the following questions, 11 to 18, the mark awarded tor each candidate response is shown at the end of the Examiner Comment box.

Question 11 (a)

Few students had significant problems in completing these calculations successfully, with about three quarters getting full marks. Those who did not get all 4 marks made a wide variety of errors. In part (i) errors included: not halving the diameter, not showing full substitution, using 1440/60 for the period of rotation instead of 60/1400 and not quoting the final answer to 3 significant figures. In part (ii) errors included: not converting 1.4 g to kg, using the value of *v* from part (i) as *ω*, missing the power of 2 in their written out substituted formula or in the calculation, not halving the diameter and not including the unit in the final answer.



(a) (i) Show that the speed of the point X on the rotating drum is about 35 m s^{-1}.

diameter of drum = 0.480 m

(2)

$\omega = \frac{2\pi \times 0.24 \times 1400}{60} = 35.2$ rad s^{-1}

speed = 35.2 m s^{-1}

(ii) A shirt button remains at a single point on the drum as the drum spins.

Calculate the centripetal force acting on the shirt button.

mass of shirt button = 1.4 g

(2)

$F = mr\omega^2$

$= \frac{1.4}{1000} \times 0.24 \times (35.2)^2$

Centripetal force = 0.42 N

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Examiner Comments

This candidate seems unsure about the difference between angular velocity and speed in circular motion. In part (i) speed has been calculated correctly but it was initially labelled ω and given in units of radians per second. The value has been used as angular velocity in part (ii).

2,0

(a) (i) Show that the speed of the point X on the rotating drum is about 35 m s^{-1}.

diameter of drum = 0.480 m

(2)

$V = \omega r$

$= \frac{2\pi \times 1400}{60} \times \frac{0.480}{2} = 35.18 \text{ ms}^{-1}$

(ii) A shirt button remains at a single point on the drum as the drum spins.

1000g = 1kg

Calculate the centripetal force acting on the shirt button.

mass of shirt button = 1.4 g

(2)

$F = m r \omega^2$

$= 1.4 \times 10^{-3} \times \frac{0.480}{2} \times \frac{1400 \times 2\pi}{60} = 0.049 \text{ N}$

Centripetal force = 0.049N

Examiner Comments

This candidate has completed part (i) correctly and written an appropriate formula for part (ii) but has substituted just ω and not ω^2.

2,0

(a) (i) Show that the speed of the point X on the rotating drum is about 35 m s^{-1}.

diameter of drum = 0.480 m

(2)

$$\omega = \frac{2\pi}{T} = \frac{2\pi \times 1400}{60} = 146.6 \text{ rad } s^{-1}$$

$$v = \omega r$$

$$= 146.6 \times \frac{0.480}{2} = 35.184 \simeq 35.2 \text{ m}s^{-1}$$

(ii) A shirt button remains at a single point on the drum as the drum spins.

Calculate the centripetal force acting on the shirt button.

mass of shirt button = 1.4 g

(2)

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

$$= \frac{1.4 \times 10^{-3} \times (35.2)^2}{0.24} = 0.205 \simeq 0.21 \text{ N}$$

Centripetal force = 0.21 N

ResultsPlus

Examiner Comments

This candidate has calculated the speed correctly and substituted all values correctly for the force calculation but has not actually squared the value of speed.

2,1

ResultsPlus

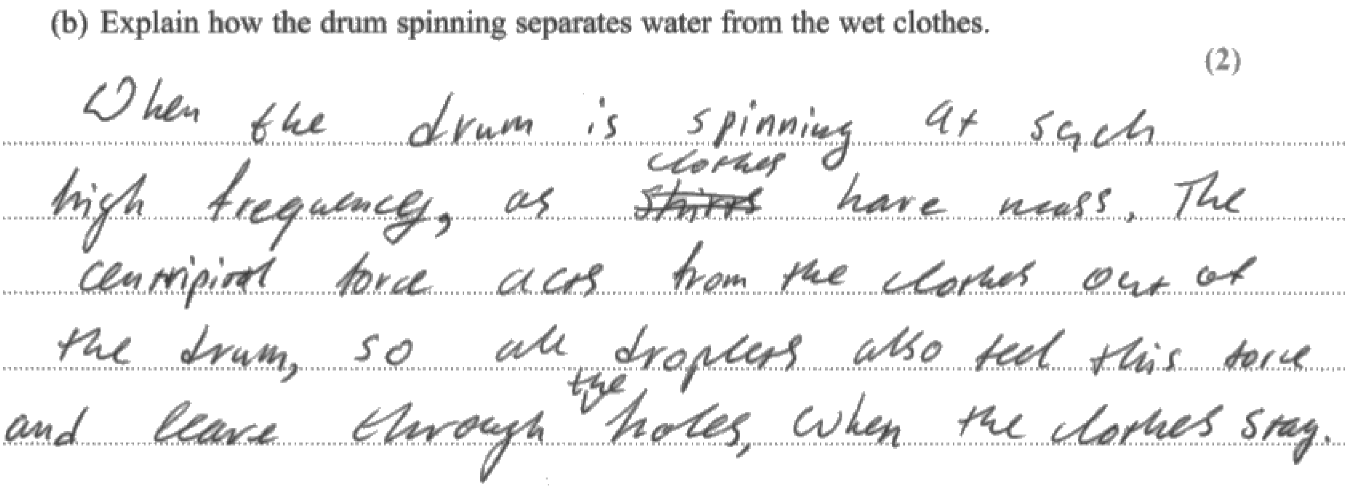
Examiner Tip

When a formula requires a term to be squared, check that you have included the square in the substitution and when you calculate the answer.

Question 11 (b)

This part proved more difficult for students, with about one quarter scoring at all and very few getting both marks. Many students thought it was sufficient to state that there was a centripetal force, but that had already been given in part (a). ‘Centripetal force’ is the name we use when the resultant force in a situation is at right angles to the motion of a body so that it follows a circular path; it is not a specific type of force. The candidates were expected to add detail, such as that the centripetal force was provided by the drum or that it was not experienced by the water.

Candidates who considered the forces acting were able to provide the required detail, and diagrams, where seen, helped students to interpret the situation.



(b) Explain how the drum spinning separates water from the wet clothes.

(2)

When the drum is spinning at such high frequency, as ~~shirts~~ clothes have mass, The centripital force acts from the clothes out of the drum, so all droplets also feel this force and leave through the holes, when the clothes stay.

ResultsPlus

Examiner Comments

This candidate answers in terms of a centrifugal force, suggesting that there is an outward force acting on the clothes.

0

A resultant centripetal force in the form of a reaction force from the drum is needed to keep the clothes in circular motion. However, the water does not experience this force as it can go through the holes in the drum, hence is not in circular motion and instead accelerates outwards, away from the clothes.

(Total for Question 11 = 6 marks)

ResultsPlus

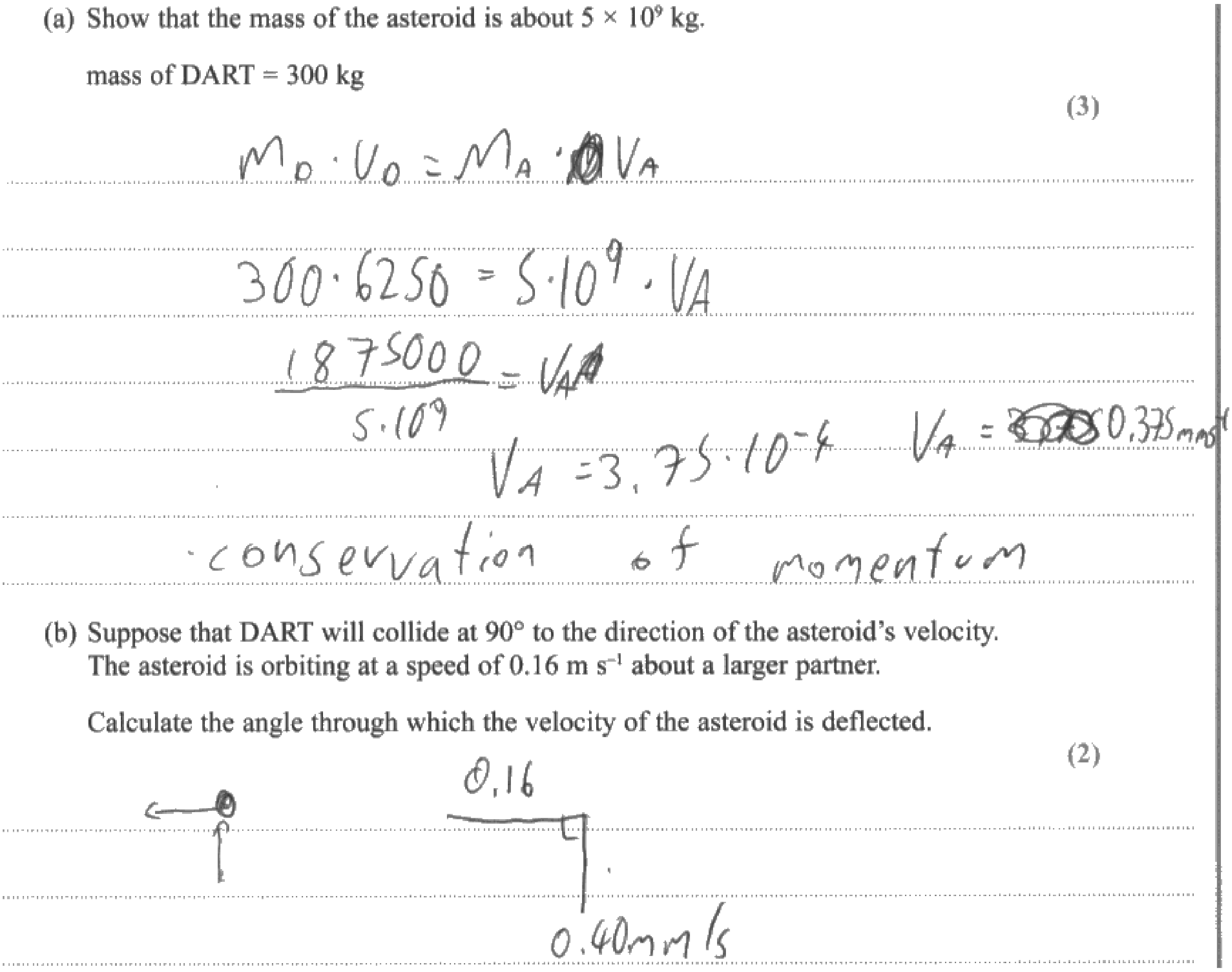
Examiner Comments

This answer correctly describes the action of the centripetal force on the clothes, but again answers in terms of an outward force for the water.

1

Question 12

By applying the principle of conservation of momentum methodically, the majority of candidates were able to calculate the correct mass in part (a). It was not always clear that they all knew that the momentum of DART after the collision was negligible and could be ignored when they omitted it from the calculations, but it was accepted. Part (b) really showed why students should take a moment to draw a vector diagram for a question like this. About a sixth of them used the correct trigonometrical function, tan, and a matching pair of quantities, such as change in velocity and original velocity of the asteroid. The majority used sine and the ratio of the change in velocity of the asteroid to the original velocity of DART.



(a) Show that the mass of the asteroid is about 5 × 10^9 kg.

mass of DART = 300 kg

(3)

$M_D \cdot V_D = M_A \cdot V_A$

$300 \cdot 6250 = 5 \cdot 10^9 \cdot V_A$

$\frac{1875000}{5 \cdot 10^9} = V_A$

$V_A = 3,75 \cdot 10^{-4}$ $V_A = 0,375 \text{mms}^{-1}$

·conservation of momentum

(b) Suppose that DART will collide at 90° to the direction of the asteroid's velocity.
The asteroid is orbiting at a speed of 0.16 m s^{-1} about a larger partner.

Calculate the angle through which the velocity of the asteroid is deflected.

(2)

ResultsPlus

Examiner Comments

In part (i) the question gave data including the change in velocity and asked candidates to use the information to show that the mass matched an approximate value. This candidate used the approximate mass to calculate the change in velocity. The answer they arrived at rounds to 0.40 mm s^{-1} and has an extra significant figure, so it can get credit, but it is not the quantity required by the mark scheme, so the maximum available marks are 2 out of 3.
There is a correct diagram for part (ii), but nothing to go with it.
2, 0

ResultsPlus

Examiner Tip

Remember that, in ‘show that’ questions like this, students are required to state the equations being used, substitute all values and calculate a final answer that rounds to the approximate value in the question, quoting it to 1 significant figure more than given in the question.

Conservation of momentum $P_{before} = P_{after}$

p before $= 6250 \times 300 = 1875000$

p after $= 0.4\times10^{-3} \times (300 + m) = 1875000$

$$m = \frac{1875000}{0.4\times10^{-3}} - 300 = 4.69\times10^{9}\,\text{kg}$$

$= 5\times10^{9}$ kg

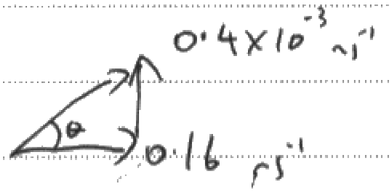
1 s f

(b) Suppose that DART will collide at 90° to the direction of the asteroid's velocity. The asteroid is orbiting at a speed of 0.16 m s^{-1} about a larger partner.

Calculate the angle through which the velocity of the asteroid is deflected.

(2)

$$\theta = \tan^{-1}\left(\frac{0.4\times10^{-3}}{0.16}\right) = 0.14^\circ$$



Angle = 0.14°

ResultsPlus

Examiner Comments

This answer is fully correct. In part (ii) a vector diagram has made it much simpler for the candidate to calculate the angle.

3, 2

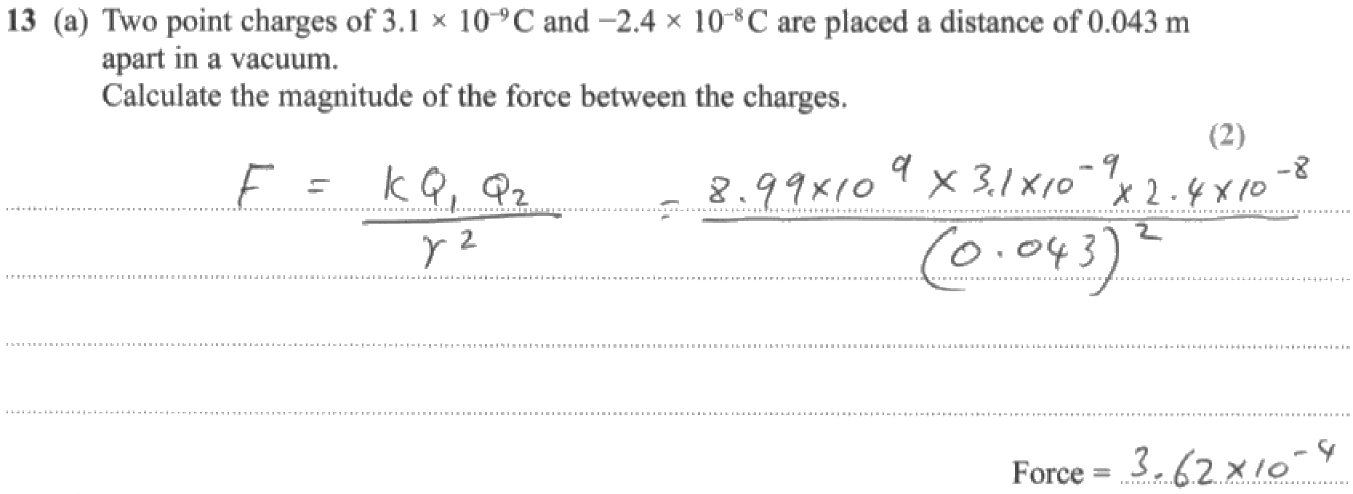
ResultsPlus

Examiner Tip

Use vector diagrams to clarify the situation.

Question 13 (a)

The great majority tackled this straightforward calculation correctly. The errors seen included halving the separation, omitting the power of 2, neglecting to give the unit and, very rarely, using the value of the Boltzmann constant *k* rather than the Coulomb's law constant *k*.



13 (a) Two point charges of 3.1×10^{-9} C and -2.4×10^{-8} C are placed a distance of 0.043 m apart in a vacuum.
Calculate the magnitude of the force between the charges.

(2)

$$F = \frac{kQ_1Q_2}{r^2} = \frac{8.99\times10^{9} \times 3.1\times10^{-9} \times 2.4\times10^{-8}}{(0.043)^2}$$

Force = 3.62×10^{-4}

ResultsPlus

Examiner Comments

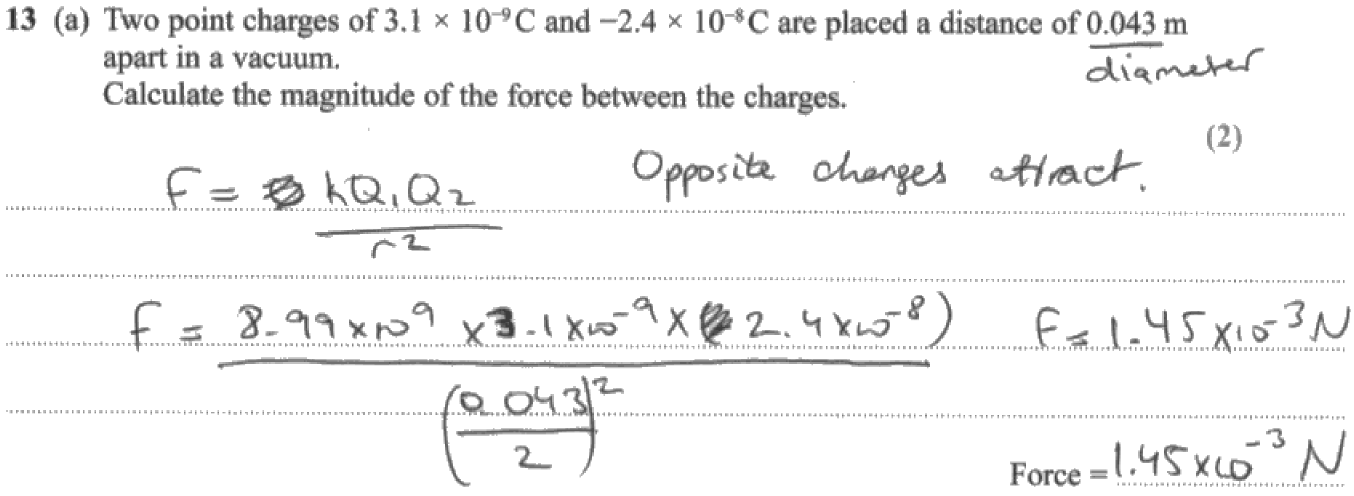
The unit has been omitted from the correctly calculated answer so the final mark cannot be awarded.

1

ResultsPlus

Examiner Tip

Always include the relevant unit with the final answer.



13 (a) Two point charges of 3.1×10^{-9} C and -2.4×10^{-8} C are placed a distance of 0.043 m apart in a vacuum.
diameter
Calculate the magnitude of the force between the charges.

(2)

$$F = \frac{kQ_1Q_2}{r^2}$$

Opposite charges attract.

$$f = \frac{8.99\times10^{9} \times 3.1\times10^{-9} \times (2.4\times10^{-8})}{\left(\frac{0.043}{2}\right)^2}$$

$F = 1.45\times10^{-3}$ N

Force = 1.45×10^{-3} N

ResultsPlus

Examiner Comments

The candidate is thinking of a different situation to that in the question. There is a reference to diameter and the separation has been halved.

1

ResultsPlus

Examiner Tip

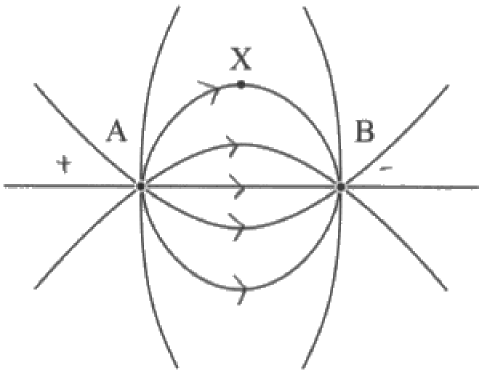
Be sure to answer the question on the paper and not something similar you have done in revision.

Question 13 (b)

(i) A few candidates made general statements about electric fields rather than electric field strength, such as 'a region where a charge experiences a force'. Most made the connection with the magnitude of the force, if not the direction, saying it is the force on a charged object, but a significant proportion did not give sufficient detail, not quoting 'unit positive charge'.

(ii) The majority of candidates got no more than a mark for the direction going from left to right. 'At X' was stated twice, but there was a lot of discussion of the fields due to A and to B in general, ignoring the effect at point X in particular. Many candidates wrote about the field or field lines 'moving' from positive to negative, or about the direction in which a positive charge would move, neither of which was creditworthy. The forces at X perpendicular to the line AB were very rarely considered. This was, again, a question where a simple vector diagram made the situation much clearer for candidates. They just needed to draw the field at X due to each charge separately and then add the resultant.

(b) The diagram represents the electric field around two point charges of equal magnitude. A is a positive charge and B is a negative charge.



(i) State the meaning of electric field strength.

(1)

force experianced by a charge in an electric field.

(ii) By considering the electric field at X due to A and due to B separately, explain the direction of the electric field at X.

(4)

~~erae~~ At X, A exerts an electric field strength towards X

and B ~~tends to~~ exerts an attractive ~~the~~ field strength towards B itself.

Therefore ~~the~~ charge go from A to B as shown in the diagram.

direction of electric field at x is towards B.

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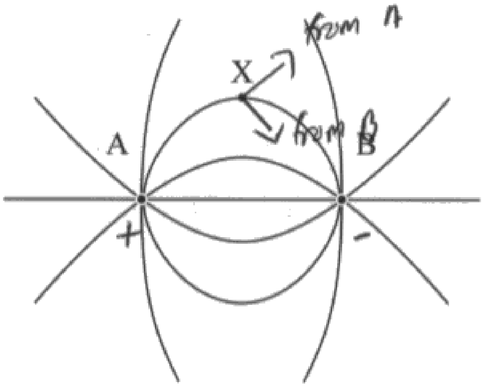
Examiner Comments

(i) This is a general description of an electric field.
(ii) This describes the field at X due to each of A and B but does not deal with the resultant field.
0, 2



(i) State the meaning of electric field strength.

(1)

Electric field strength is the force exerted per unit positive charge

(ii) By considering the electric field at X due to A and due to B separately, explain the direction of the electric field at X.

(4)

The electric field around a point charge is a radial field $\left(E = \frac{kQ}{r^2}\right)$. This strength decreases as r increases. As electric field lines travel from positive to negative, the ~~electrict~~ electric field at X ~~B~~ due to A will be away from A, acting upwards. The electric field from B will be ~~at~~ acting ~~to~~ at X towards B. This will ~~to~~ give a resultant field acting parallel to the direction A B.

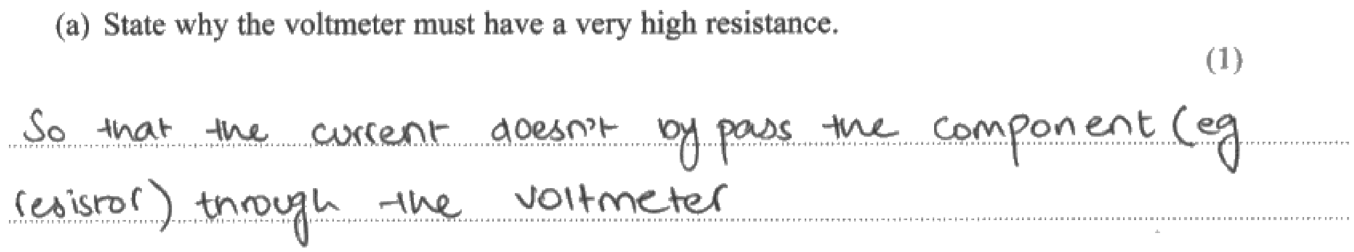
ResultsPlus

Examiner Comments

(i) One of the better answers seen because it includes 'positive'.
(ii) This describes the situation fairly well, getting 3 marks out of 4, but does not account for the components perpendicular to AB.
1, 3

Question 14 (a)

The question tells candidates that charge is stored on a capacitor in the meter so that the charge can be measured. From the rest of the question it was clear that they knew that completing a circuit in series with the capacitor would allow it to discharge. It was also clear that they knew the voltmeter in the coulombmeter was connected across the capacitor. They also very often wrote that a very high resistance would prevent there being a current through the voltmeter. Despite all that, only a very small minority stated that, without a very high resistance, the capacitor would discharge and not give a true value. Most candidates saw 'voltmeter' and 'very high resistance' and wrote an answer to previous questions about voltmeters in circuits. They often wrote things like 'so the current goes through the capacitor and not the voltmeter' despite these being the only components connected to each other. These candidates would probably have been helped by drawing a simple circuit diagram of the situation.



(a) State why the voltmeter must have a very high resistance.

(1)

So that the current doesn't by pass the component (eg resisror) through the voltmeter

ResultsPlus

Examiner Comments

This answer suggests that the student has answered questions about voltmeters in circuits previously and has just repeated the answer without considering the situation in this question.

0

ResultsPlus

Examiner Tip

A question may resemble one you have seen before, but you should look carefully to see if it is really about the same situation before repeating the answer.

So that no current flows and ~~therefore the~~ the amount of charge ~~in~~ on the capacitor does not change.

ResultsPlus

Examiner Comments

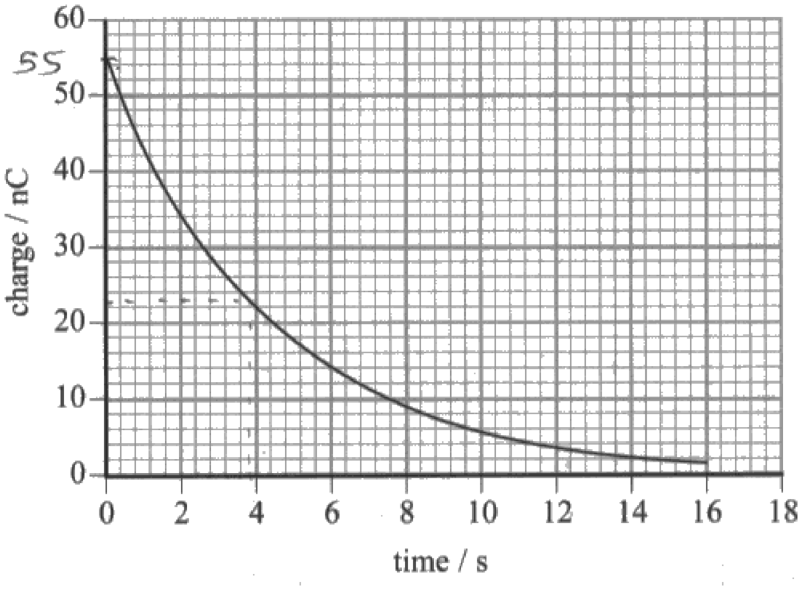
This answer includes the idea of no current, but relates it appropriately to the capacitor.
1

Question 14 (b)

For part (b), a quarter of candidates got the full 5 marks and the majority got at least 3.

In part (b) (i), quite a few carried out the correct procedure but misread the graph, for example drawing a line across at 22 nC rather than 20.2 nC when they were determining the time constant, so missing out on the final mark. The unit was sometimes quoted as s Ω^{-1}, but only F was accepted as it is the correct SI unit for capacitance.

For part (b)(ii), the formula sheet quotes $W = ½ QV$, but in this question candidates did not know V. Candidates are required to be able to derive the relationship $W = ½ Q^2 / C$ and those who remembered this were slightly more successful than those who determined V in order to complete the calculation. Candidates occasionally forgot ½ or the power of 2. While some answers to part (i) ought to have seemed unreasonable, candidates may not be that familiar with typical capacitances. When they got answers involving thousands of volts or millions of joules they should have had second thoughts.



5 — 2
1 — n

(i) Use the graph to determine the capacitance of the capacitor in the coulombmeter.

(3)

~~$\frac{37}{100} \times 55 =$ [illegible] 20·35~~

① $\frac{37}{100} \times 55 = 20{\cdot}35\,nC$

② ∴ when $T = 3{\cdot}8s$

③ ∴ ~~[illegible]~~ $T = RC$; $C = \frac{T}{R}$

Hence $\frac{3{\cdot}8}{4{\cdot}6 \times 10^{6}} = \underline{\underline{8{\cdot}26 \times 10^{-7}\,F}}$

Capacitance = $8{\cdot}26 \times 10^{-7}\,F$

(ii) Calculate the energy initially stored by the capacitor.

(2)

$\mathcal{E} = \frac{1}{2} QV$

$= \frac{1}{2}$

$\mathcal{E} = \frac{1}{2} CV^2$

$= \frac{1}{2} \times 8{\cdot}26 \times 10^{-7} \times \left(\frac{55 \times 10^{-9}}{8{\cdot}26 \times 10^{-7}}\right)^2$

$= \underline{\underline{1{\cdot}83 \times 10^{-9}\,J}}$

$Q = CV$

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

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

Energy = $1{\cdot}83 \times 10^{-9}\,J$

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Examiner Comments

The candidate has correctly determined the initial charge divided by e, but has incorrectly read the time off the graph, using a charge value of 23.5 nC rather than 20.35 nC. This is caused by only looking at the scale value below the required value on the graph and not the one above as well to check the scale, i.e. by looking at 20 nC and counting up one and a half divisions as if the next scale value is 21 nC rather than 30 nC.

2, 2

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Examiner Tip

When reading from a graph, students should always check the quantity labels above and below the point they are measuring to be sure they apply the correct scale.

(i) Use the graph to determine the capacitance of the capacitor in the coulombmeter.

(3)

$55 \times 37\% = 20.35\ C$

$Q = Q_0 e^{-t/RC}$

$0.37 = e^{-44/4.6\times10^6 C}$

$\cancel{C} = \ln 0.37 = -44/4.6\times10^6 C$

$C = \dfrac{-44}{4.6\times10^6 \ln 0.37} = 9.62\times10^{-7}\ C/V$

Capacitance = $9.62\times10^{-7}\ C/V$

(ii) Calculate the energy initially stored by the capacitor.

(2)

$E = \frac{1}{2} C V$

$= \frac{1}{2} \frac{Q^2}{C}$

$= \frac{1}{2} \times (55\times10^{-9})^2 \div (9.62\times10^{-7})$

$= 1.57\times10^{-9}\ J$

Energy = $1.57\times10^{-9}\ J$

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Examiner Comments

The calculations are all correct, but a unit of C/V has been used instead of F.

2, 2

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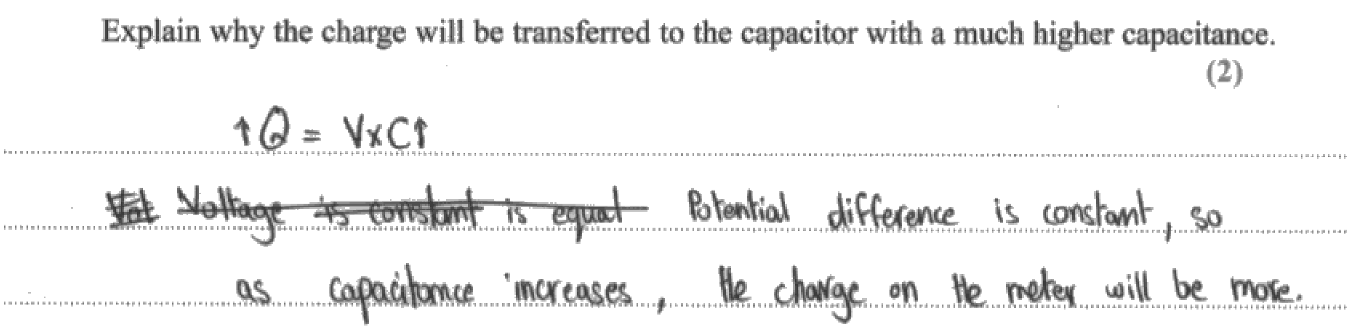
Examiner Tip

Where a quantity has a specific derived SI unit it must be used.

Question 14 (c)

About a quarter of candidates invoked the proportionality of capacitance and charge with sufficient clarity, but few made the connection with equalised potential differences, the most common statement of that nature being that 'voltage is constant', which is not the correct interpretation. Those who wrote the capacitance equation to support their explanation wrote better answers.



Explain why the charge will be transferred to the capacitor with a much higher capacitance.

(2)

$\uparrow Q = V \times C \uparrow$

~~Vat~~ ~~Voltage is constant is equal~~ Potential difference is constant, so as capacitance increases, the charge on the meter will be more.

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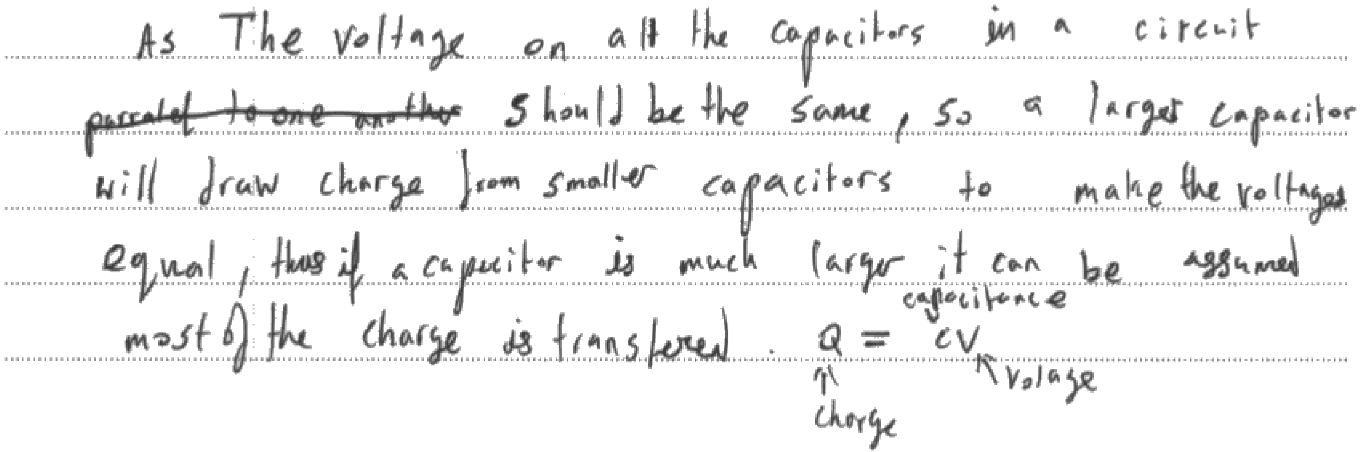
Examiner Comments

This gets the connection between charge and capacitance, but only says potential difference is constant for the rest. The required idea is that potential difference must become the same, not stay the same.

1



As The voltage on all the capacitors in a circuit ~~parralel to one another~~ should be the same, so a larger capacitor will draw charge from smaller capacitors to make the voltages equal, thus if a capacitor is much larger it can be assumed most of the charge is transfered. $\underset{\uparrow\ \text{charge}}{Q} = \overset{\text{capacitance}}{C}\underset{\nwarrow\ \text{volage}}{V}$

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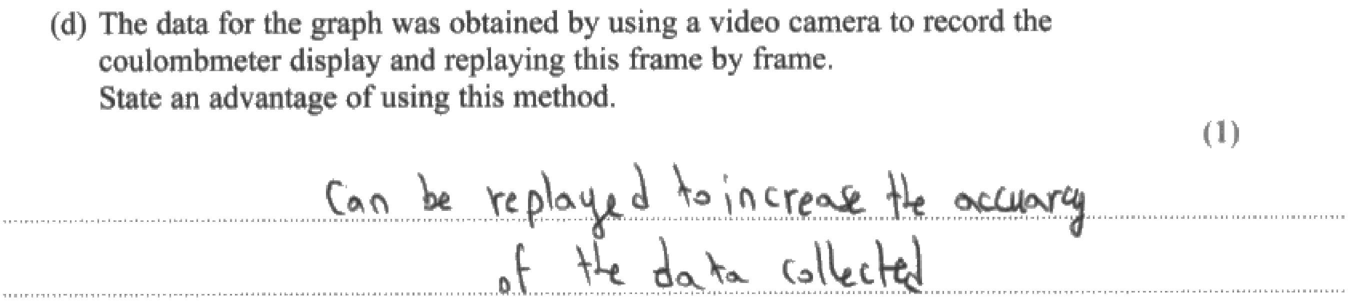
Examiner Comments

An example of a good answer.

2

Question 14 (d)

The question stated that the video was replayed frame by frame, but a majority of candidates effectively restated it as their answer, repeating an acceptable answer to previous questions about video recording. Many others just referred to 'human error'.



(d) The data for the graph was obtained by using a video camera to record the coulombmeter display and replaying this frame by frame.
State an advantage of using this method.

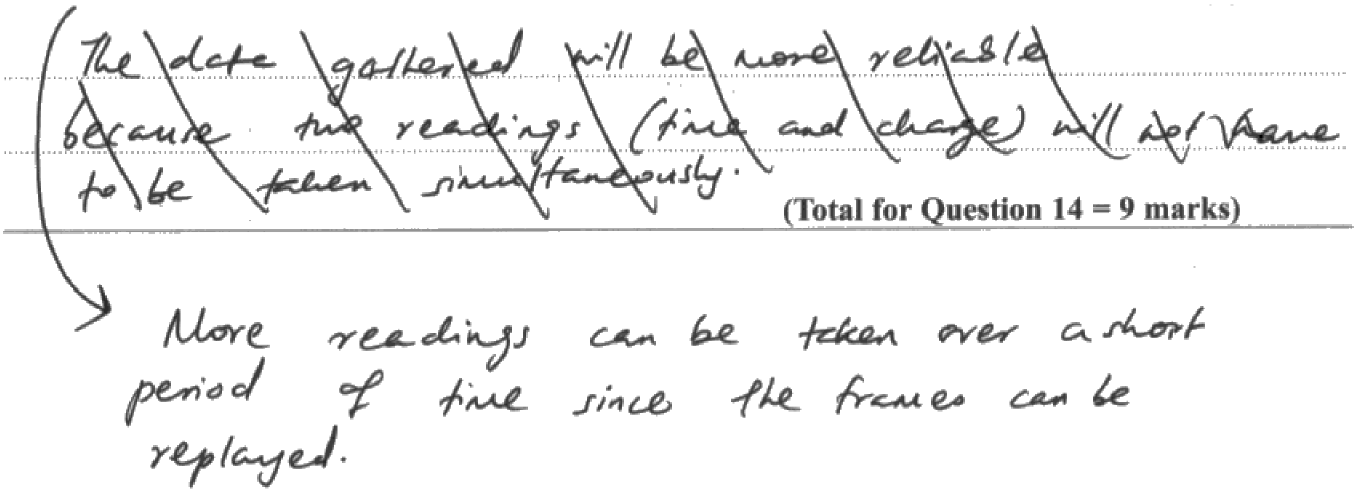
(1)

Can be replayed to increase the accuracy of the data collected

Examiner Comments

This answer does little more than repeat the information in the question. It could have been relevant if the question had not mentioned replaying, suggesting that this is another example of giving the answer to a previous question seen in revision.

0



~~The data gathered will be more reliable because the readings (time and charge) will not have to be taken simultaneously.~~

(Total for Question 14 = 9 marks)

More readings can be taken over a short period of time since the frames can be replayed.

Examiner Comments

This is a sensible answer and the crossed out part has the idea of an acceptable alternative.

1

Question 15 (a)

The majority of students interpreted this question correctly and explained it correctly, although they frequently missed a detail so that only a third got the full 3 marks. It is a standard situation and should have been learned thoroughly - an example of an occasion where previous mark schemes are fairly directly applicable. Some just said there was a varying magnetic field and did not relate it to the coil and some said the magnet was cutting the magnetic field lines of the coil. There was not always a clear statement that an e.m.f. was induced, some just saying that a current was induced and some that an e.m.f. was produced. A statement about a full circuit allowing a current was not always included.

(a) Explain how shaking the torch produces an electric current.

(3)

When the torch ~~mag~~ is shaken, the magnet moves up and down through the coil of the wire. This causes the coil to repeatedly cut the field lines of the ~~magnet~~ magnet as it moves up and down. The repeated cutting of the magnetic field lines will cause electricity to be induced, thereby producing an electric current.

ResultsPlus

Examiner Comments

This answer misses two important details. It says 'electricity' instead of e.m.f. and does not mention a complete circuit.

1

(3)

Shaking torch caules the motion of ~~coil~~ magnet. so the coil will cuts the magnetic flux lines which cause a change in magnetic flux linkage. due to the faraday's law, the magnitude of rate of change of flux linkage is proportional to that of induced emf, so there's a emf induced in the coil, due to the closed coil produces closed circuit there's current flows in the coil

ResultsPlus

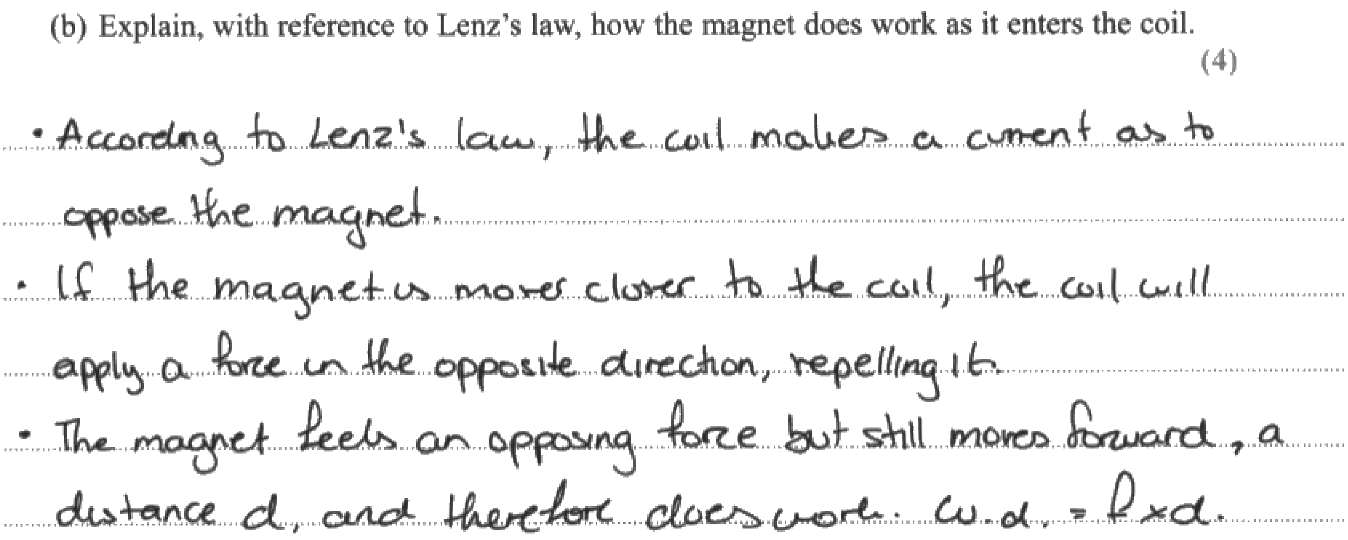
Examiner Comments

This is a good answer scoring full marks.

3

Question 15 (b)

The majority of students made an acceptable statement of Lenz's law, although, despite the question saying 'with reference to Lenz's law', some did not make any statement. Few made statements specific enough to the situation to gain much more credit, for example by saying that the induced current produced a field opposing the motion of the magnet. Those who identified a force acting on the magnet only said that work was done against the force without relating it to motion as they could have done by quoting work = force × distance.



(b) Explain, with reference to Lenz's law, how the magnet does work as it enters the coil.

(4)

- According to Lenz's law, the coil makes a current as to oppose the magnet.
- If the magnet is moves closer to the coil, the coil will apply a force in the opposite direction, repelling it.
- The magnet feels an opposing force but still moves forward, a distance d, and therefore does work. w.d. = $F \times d$.

ResultsPlus

Examiner Comments

This candidate has a general understanding, but only gets the last two marking points. The statement of Lenz's law is incomplete and there is no detail on how the opposing force arises. The statement regarding work shows the value of quoting the relevant formula.

2

According to Lenz's Law, the direction of induced current is such as to oppose the change causing the current. As current is induced in coil, a magnetic field is produced around the coil which is in opposite direction to magnetic field by magnet. As a result, since ~~it~~ field by coil repels the magnet, the magnet feels an opposite force ~~to it~~ while moving. As Work = Force × distance, work is done by magnet against magnetic field of coil, as it enters it.

ResultsPlus

Examiner Comments

This is a good answer with all the required detail.

4

Question 15 (c)

It is probable that the great majority of candidates knew the full answer to this part, but they did not all explain in sufficient detail to gain a second mark. They did not all make a clear statement that an alternating current was produced or else they wrote that the diode rectified it to direct current but did not state why this was important for the battery.

(c) The circuit in the torch contains a diode between the coil and the battery.

Explain why the diode is needed if the battery is to charge.

(2)

The current produced due to induction will be alternating current but direct current is required to charge the battery.

ResultsPlus

Examiner Comments

This mentions that the current produced would be alternating current, but does not explicitly link the production of direct current to the diode.

1

(c) The circuit in the torch contains a diode between the coil and the battery.

Explain why the diode is needed if the battery is to charge.

(2)

So that the current won't go in the opposite direction and ~~ch~~ discharge the battery. The diode only allows the charges to flow into the battery.

ResultsPlus

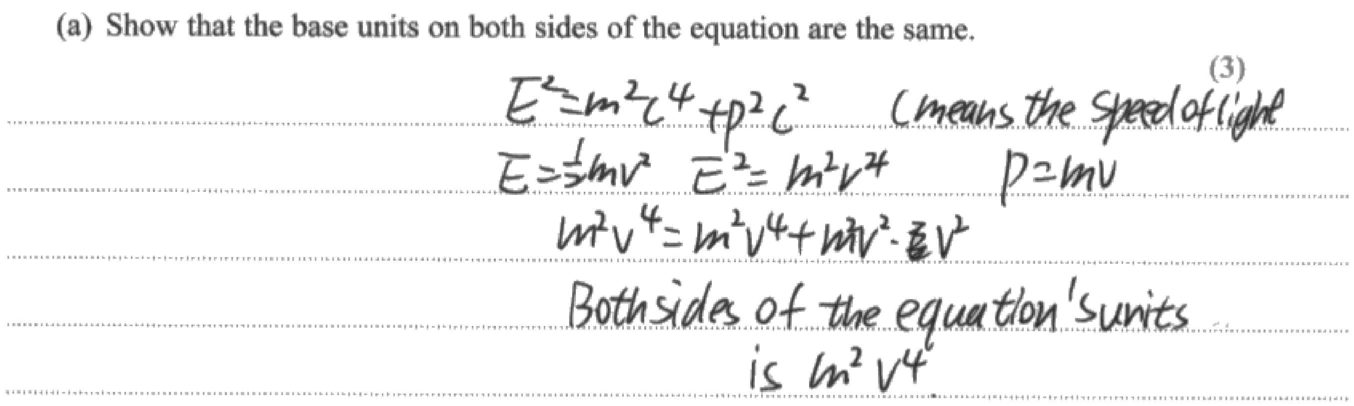
Examiner Comments

This does not mention that an alternating current would be produced, but it has the idea of the action of the diode. Some answers show that students do not fully realise that, when there is a current, net charge flows in the same direction throughout the circuit, so charge would always flow into the battery and out of the battery at the same rate.

1

Question 16 (a)

This was done relatively well with the majority gaining 2 marks showing that they understood what was required and half completing the algebraic manipulation successfully to gain all 3 marks.



(a) Show that the base units on both sides of the equation are the same.

(3)

$E^2=m^2c^4+p^2c^2$ c means the speed of light

$E=\frac{1}{2}mv^2$ $E^2=m^2v^4$ $p=mv$

$m^2v^4=m^2v^4+m^2v^2\cdot$ [illegible] v^2

Both sides of the equation's units is m^2v^4

ResultsPlus

Examiner Comments

Some candidates, like this one, attempted this question in terms of quantities rather than units. Even so, speed is not a base quantity, so this would not be correct even if it had been asked in those terms.

0

ResultsPlus

Examiner Tip

Be sure that you know the difference between base quantities and base units.

(3)

$E = \frac{1}{2}mv^2$ $\quad (J)^2 = (kg)^2(ms^{-1})^2 + (kgms^{-1})^2(ms^{-1})^2 \quad p = mv$

$(kg\,m^2s^{-2})^2 = kg^2m^4s^{-4} + kg^2m^4s^{-4}$

$\boxed{kg^2m^4s^{-4} = kg^2m^4s^{-4} + kg^2m^4s^{-4}}$ ✓

$kg^2m^4s^{-4} = 2\,kg^2m^4s^{-4}$

numbers ~~often~~ are not units.

ResultsPlus

Examiner Comments

Candidates derived the units of energy in different ways, this one using kinetic energy but others using work = force × distance. This answer has been shown fully in the required detail.

3

Question 16 (b)

Although part (b) seemed simpler than part (a), only a similar proportion got full marks. Some did not start successfully because they did not make the connection between zero velocity and zero momentum. Some did not make the final step to the most globally famous equation in physics and left it as $E^2 = m^2c^4$.

(b) Simplify the equation for particles with zero velocity.

(2)

rest mass → zero velocity. $v=0$

$$E^2 = m^2c^4 + \underbrace{(mv)^2c^2}_{(0^2)\times c^2} \rightarrow \boxed{E^2 = m^2c^4}$$

ResultsPlus

Examiner Comments

This candidate did not take square roots to complete the simplification.

1

$\Rightarrow p=0$

$E^2 = m^2c^4$

$E^2 = (mc^2)^2$

$E = mc^2$

ResultsPlus

Examiner Comments

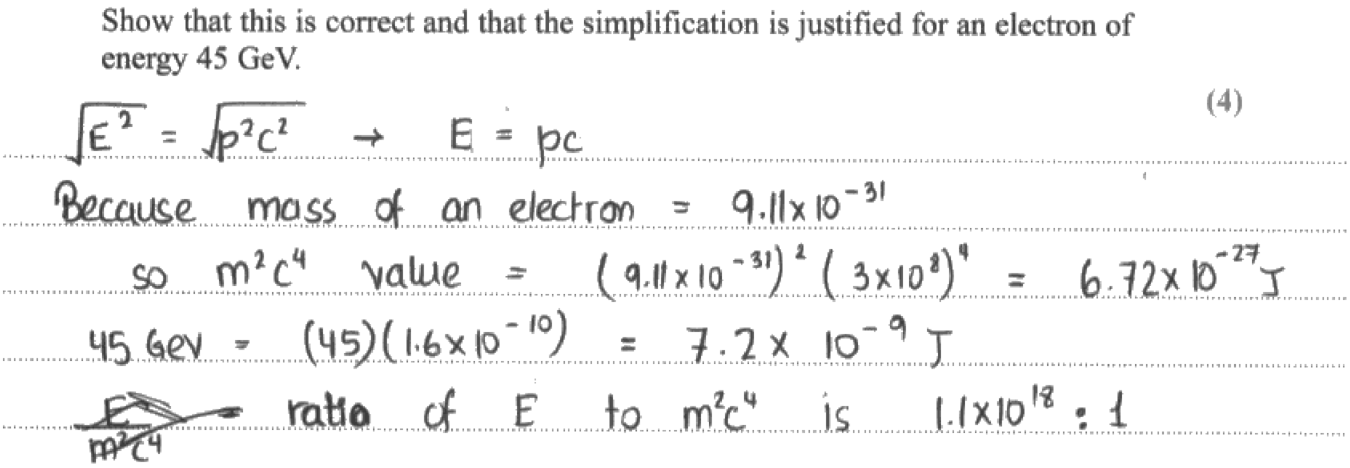
An example of a fully correct answer

2

Question 16 (c)

The great majority scored at least one mark, usually for attempting to use the GeV conversion factor, but only a third gained a second mark, most often for using $E^2 = m^2c^4$ or $E = mc^2$. About a third of those with two marks got the third mark for a comparison. Many who completed calculations correctly did not get the comparison mark because they were comparing an energy value with a value for energy squared. Candidates often did not attempt to show that the equation simplifies to $E = pc$ at the start, suggesting that they missed the significance of the statement in the question.

A number attempted to show the simplification was justified by deriving a relativistic speed for a 45 GeV electron, but this proof was not valid.



Show that this is correct and that the simplification is justified for an electron of energy 45 GeV.

(4)

$\sqrt{E^2} = \sqrt{p^2c^2}$ → $E = pc$

Because mass of an electron = 9.11×10^{-31}

so m^2c^4 value = $(9.11 \times 10^{-31})^2 (3 \times 10^8)^4 = 6.72 \times 10^{-27}$ J

45 GeV = $(45)(1.6 \times 10^{-10}) = 7.2 \times 10^{-9}$ J

~~$\frac{E}{m^2c^4}$~~ ratio of E to m^2c^4 is $1.1 \times 10^{18} : 1$

ResultsPlus

Examiner Comments

The simplification has been justified and suitable calculations carried out for E and mc^2, but a value of energy has been compared with a value of energy^2 at the end.

3

(4)

$E = mc^2$ ~~$E^2 = m^2c^4 + p^2c^2$~~ ~~$E = m^2c^4$~~

$= 9.1 \times 10^{-31} \times 9 \times 10^{16} = 8.19 \times 10^{-14}$ J ~~$= (9.11 \times 10^{-31})^2 \times (3 \times 10^8)^4$~~

E_{total} ~~E~~ $= 45 \times 10^9 \times 1.6 \times 10^{-19}$ ~~8.19×10^{-14} J 6.71×10^{-27}~~

$= 7.2 \times 10^{-9}$ J ~~Because~~ ~~7.2×10^{-9} is larger~~

Since 7.2×10^{-9} is larger than 8.19×10^{-14}, so much ~~than 8.19×10^{-14} so much~~, then m^2c^4 is negligible,

~~then~~ so $E^2 = p^2c^2$

$\therefore E = PC$

ResultsPlus

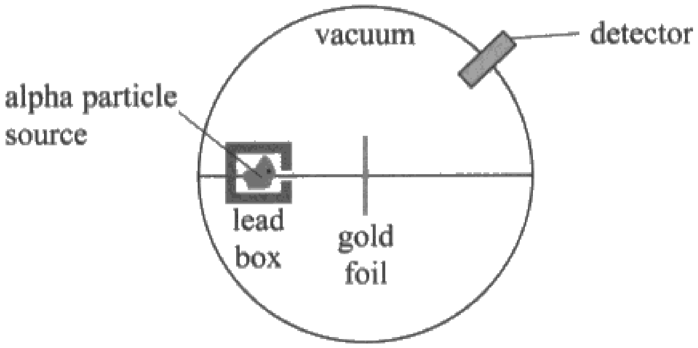
Examiner Comments

This is a fully correct example, comparing energy with energy and justifying the simplification.

4

Question 17 (a)

Three quarters of the candidates got one mark here, but only just over a quarter got both marks. The single mark was usually for writing in some way about the alpha particles following a single path; the part played by lead was much less frequently discussed. Candidates should note that the question asked them to 'explain', so there will be at least two linked points. In this case they were the outcome – the alpha particle beam – and how it was achieved – by lead absorbing other particles. Another way to consider this question would be to note the lead box and the single small hole and to describe the part played by each.



(a) Explain why the alpha source was placed in a lead box with a single small hole.

(2)

To make the alpha particles going in the same direction(towards foil) as a beam of particles and prevent them from spreading in all directions what would affect the readings of the detector => test is not fair

ResultsPlus

Examiner Comments

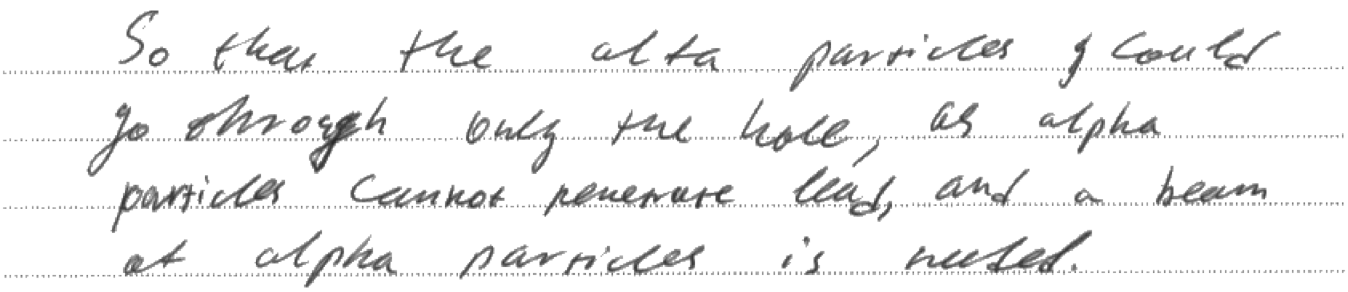
This answer deals with the desired outcome, but not the part played by lead.

1

ResultsPlus

Examiner Tip

There should be at least two distinct parts to an explanation - here they deal with the absorbing properties of lead and the resultant beam of alpha particles.


So that the alta particles could go through only the hole, as alpha particles cannot penenrate lead, and a beam of alpha particles is needed.

ResultsPlus

Examiner Comments

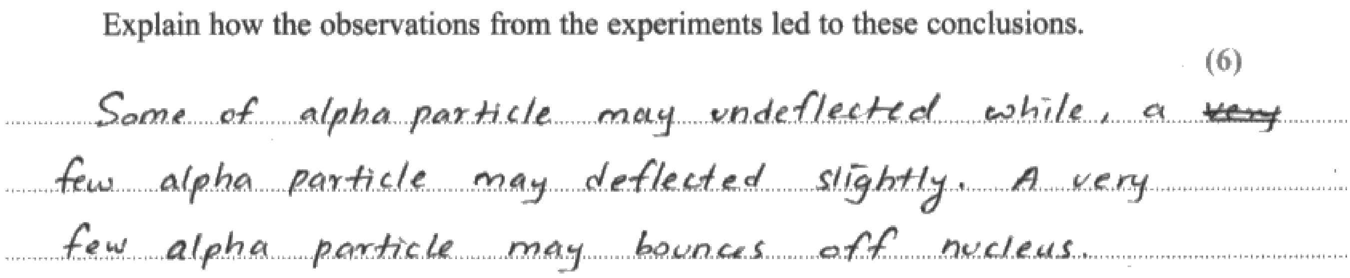
This is an example of a fully correct response.

2

Question 17 (b)

Candidates rarely got more than 3 marks here, a more typical mark being 2. Candidates generally made a single statement of an observation linked to each conclusion, the most common being 'most alpha particles went straight through' for conclusion 1. Candidates again did not follow the instruction to 'explain' by making an additional statement linking the observation to the conclusion.

Those who did not get the three marks usually did not describe the relative numbers of alpha particles linked to each observation in the required way, for example they just referred to some. Something corresponding to 'most – few – very few' was required. The well known fraction 1 in 8000 was occasionally seen for conclusion 3.


Explain how the observations from the experiments led to these conclusions.

(6)

Some of alpha particle may undeflected while, a ~~very~~ few alpha particle may deflected slightly. A very few alpha particle may bounces off nucleus.

ResultsPlus

Examiner Comments

While others wrote more, this is a fairly typical example of the parts of the responses not repeating the question. In this case the first mark was not awarded because 'some' does not convey the sense of 'most'. The last sentence got the relative quantity correct with 'very few', but 'bounce' was not accepted. Only the mark for 'few ... deflected slightly' was awarded.

1

- Most of the alpha particle ~~when~~ went straight through the gold foil. meaning that atoms are mainly empty space.

- Some alpha particle got deflected at a small angle. this is because positive charges repel. Therefor charge is concentrated at the center

- Very few alpha particle came straight back. This is because mass of atom concentrated at nuclei and alpha particle hits the nucleus.

ResultsPlus

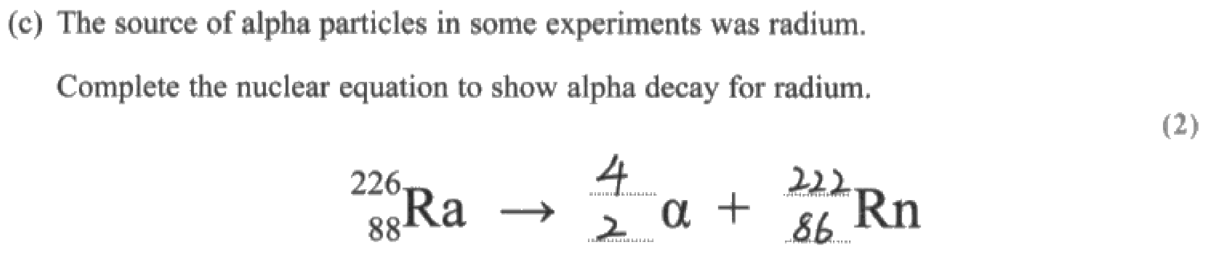
Examiner Comments

This gained one mark for the first bullet point and one mark for the third. 'Some' was not accepted for observation 2. There is some attempt to give an explanation. The second bullet point, however, just deals with the presence of charge and not its concentration and the third does not discuss the large relative mass required for this effect.

2

Question 17 (c)

80% got full marks for this part. Some of those who did not reversed A and Z for the alpha particle and some used the corresponding quantities for a beta particle.



(c) The source of alpha particles in some experiments was radium.

Complete the nuclear equation to show alpha decay for radium.

(2)

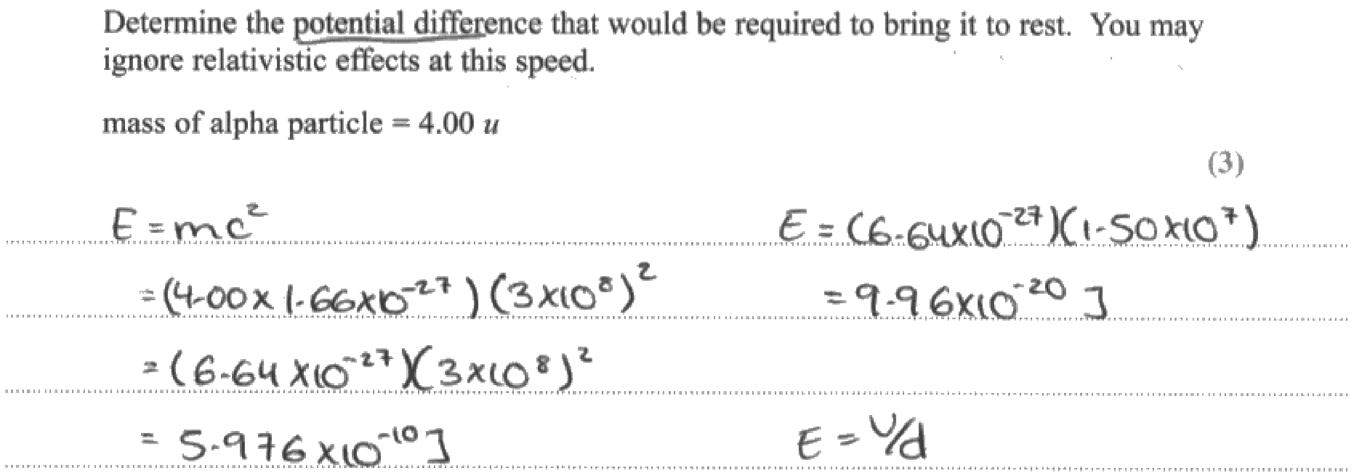
$$^{226}_{88}\text{Ra} \rightarrow {}^{4}_{2}\alpha + {}^{222}_{86}\text{Rn}$$

ResultsPlus
Examiner Comments

A correct response
2

Question 17 (d)

The majority scored at least 2 marks here for calculating kinetic energy and dividing by charge, but they frequently did not remember that the charge of an alpha particle is 2*e* and not just *e*. A first proportion used the mass of a proton and not *u*. They are very similar, but not the same thing.



Determine the potential difference that would be required to bring it to rest. You may ignore relativistic effects at this speed.

mass of alpha particle = 4.00 *u*

(3)

$E = mc^2$

$= (4.00 \times 1.66 \times 10^{-27})(3 \times 10^8)^2$

$= (6.64 \times 10^{-27})(3 \times 10^8)^2$

$= 5.976 \times 10^{-10}\ \text{J}$

$E = (6.64 \times 10^{-27})(1.50 \times 10^7)$

$= 9.96 \times 10^{-20}\ \text{J}$

$E = V/d$

ResultsPlus
Examiner Comments

This candidate has made two attempts to calculate energy, but one is rest mass energy and one is actually momentum.
0

$E = eV = \frac{1}{2}mv^2$

$V = \frac{\frac{1}{2}mv^2}{e} = \frac{\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times (1.5 \times 10^7)^2}{1.6 \times 10^{-19}} = 4.67 \times 10^6 \text{ V}$

Potential difference = 4.67×10^6 V

ResultsPlus

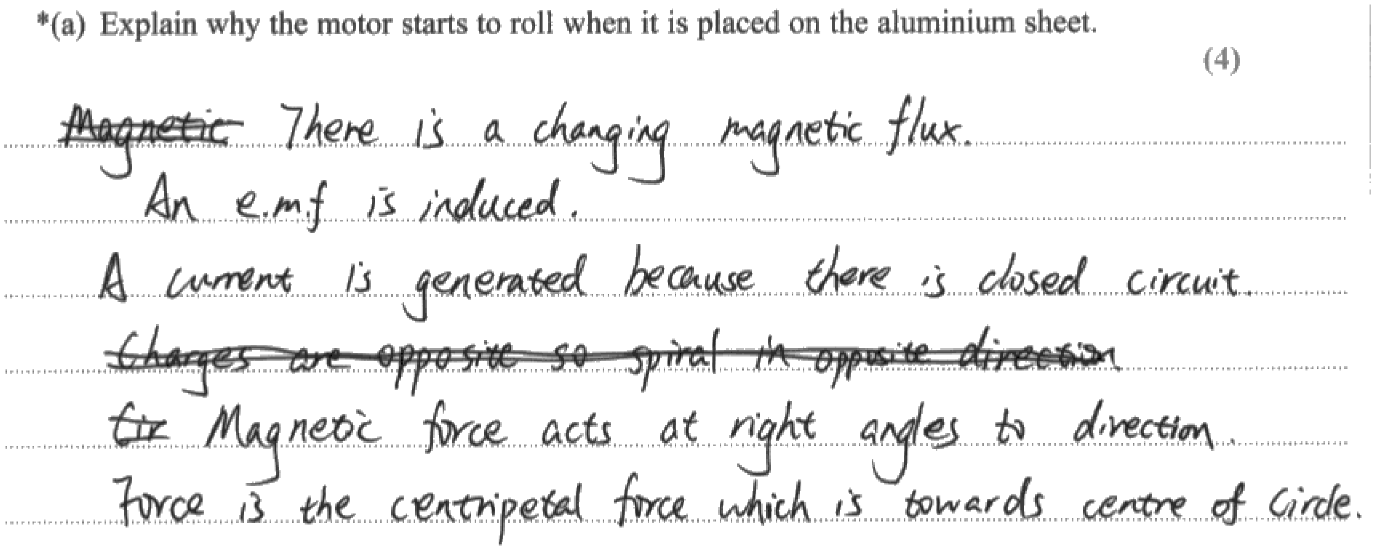
Examiner Comments

The candidate has applied the correct techniques, but has only included the charge of one proton.

2

Question 18 (a)

Many candidates did not realise that this was about the motor effect, despite the use of the word motor four times in the four sentences before the answer lines. Many thought they were expected to write another explanation related to electromagnetic induction after completing the previous long question on the topic, question 15. Virtually all of them did use the motor effect formula in part (b) (iii). Very few candidates got more than 1 mark, the score of just over a quarter. The mark awarded most commonly was for mentioning a current in the aluminium, although not if they thought it was an electromagnetically induced current, as many did. Candidates who picked up on 'motor' and used $F = BIl$ as the basis of their answer were more successful.



*(a) Explain why the motor starts to roll when it is placed on the aluminium sheet.

(4)

~~Magnetic~~ There is a changing magnetic flux.

An e.m.f is induced.

A current is generated because there is closed circuit.

~~Charges are opposite so spiral in opposite direction~~

~~Etc~~ Magnetic force acts at right angles to direction.

Force is the centripetal force which is towards centre of Circle.

ResultsPlus

Examiner Comments

This is a fairly typical example of many of the responses seen. The first three lines could be from question 15. This might have been eligible for a mark if we were told a bit more about the direction in the fourth sentence. This candidate is not alone in referring to centripetal force in this question.

0

Aluminium sheet is a conductor, so current starts to flow as the circuit is completed. The direction of current is at right angle to the magnetic field, so according to Fleming's left hand rule, a force is acting on the aluminium sheet. There is ~~an~~ a reaction force acting back on the motor due to Newton's third law, so it starts to roll as unbalanced force created a torque. (Newton's first law)

ResultsPlus

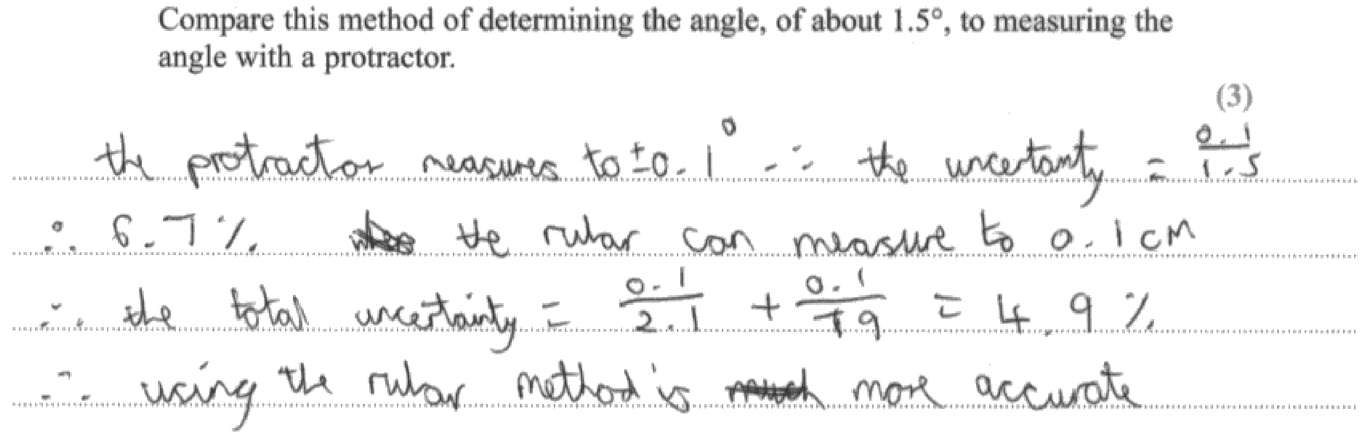
Examiner Comments

This is an unusually good answer and only misses out on the final mark by not fully answering the part of the question that says 'starts to roll' by referring to acceleration.

3

Question 18 (b)(i)

Candidates who did not refer to specific numerical uncertainties were not able to score on this question. About half did not gain any marks, often because they just discussed uncertainty in general terms. Many calculated the angle using the given lengths and compared it to the approximate value stated, but the 'true value' was not given so that did not help with the comparison in their answers.



Compare this method of determining the angle, of about 1.5°, to measuring the angle with a protractor.

(3)

the protractor measures to ±0.1° ∴ the uncertainty = $\frac{0.1}{1.5}$

∴ 6.7% ~~whe~~ the ruler can measure to 0.1 cm

∴ the total uncertainty = $\frac{0.1}{2.1} + \frac{0.1}{79}$ = 4.9%

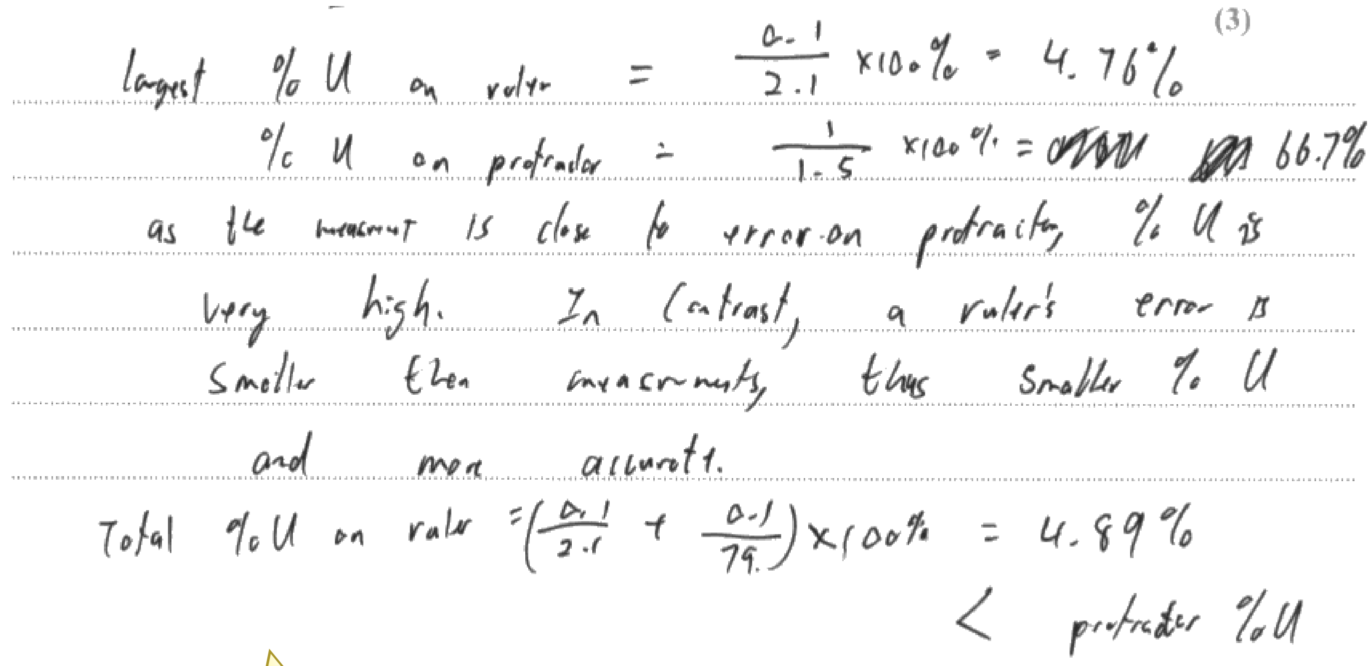
∴ using the ruler method is ~~much~~ more accurate

ResultsPlus

Examiner Comments

This is a fairly good answer, but misses the second mark because the absolute uncertainty of the protractor measurement is given as 0.1° rather than a scale division, 1°.

2



(3)

largest % U on ruler = $\frac{0.1}{2.1}$ ×100% = 4.76%

% U on protractor = $\frac{1}{1.5}$ ×100% = ~~[illegible]~~ 66.7%

as the measurement is close to error on protractor, % U is very high. In contrast, a ruler's error is smaller than measurements, thus smaller % U and more accurate.

Total % U on ruler = $\left(\frac{0.1}{2.1} + \frac{0.1}{79.}\right)$×100% = 4.89%

< protractor % U

ResultsPlus

Examiner Comments

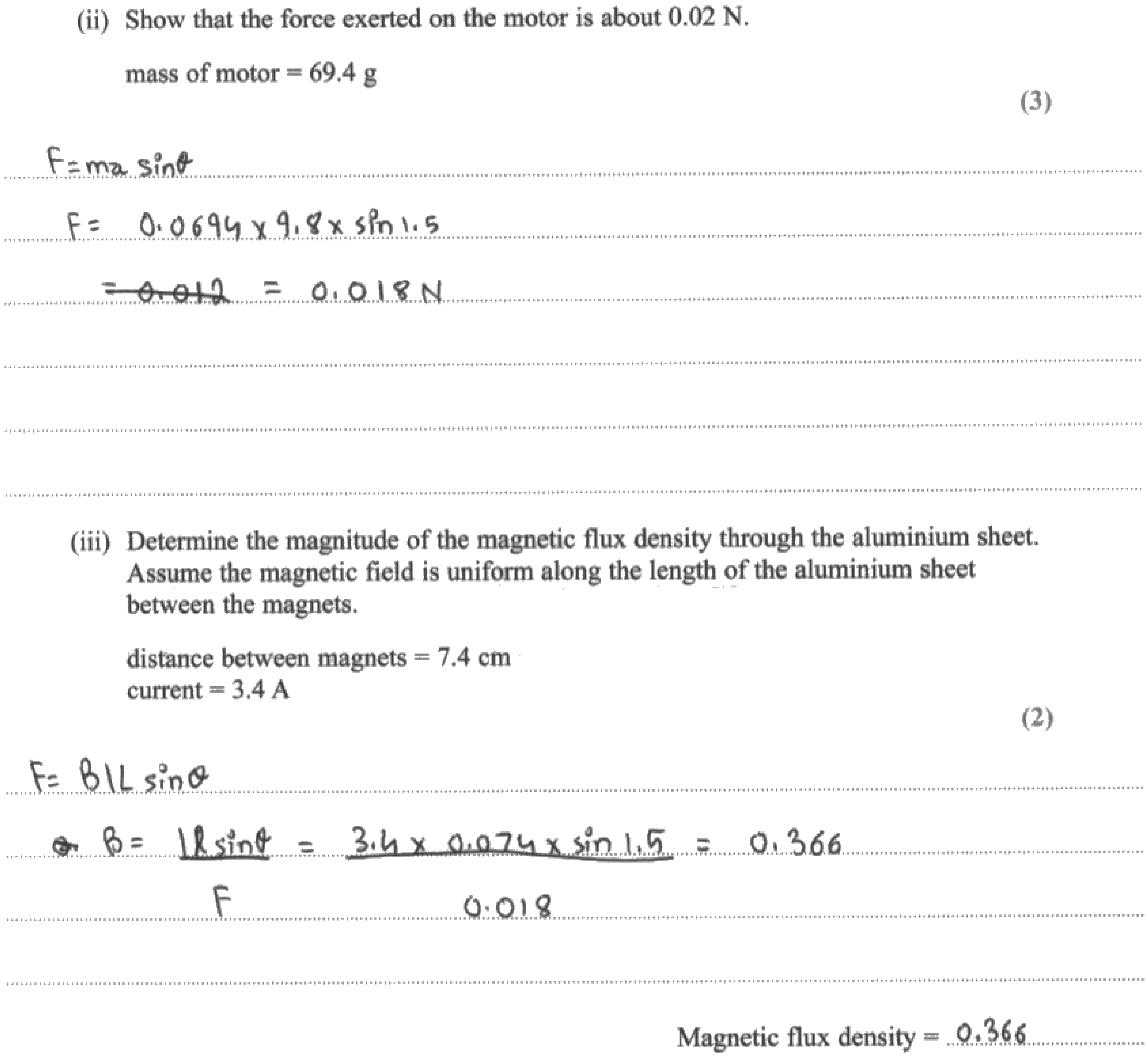
This is an example of a response scoring full marks by correctly estimating the percentage uncertainty for each method.

3

Question 18 (b)(ii–iii)

A good majority completed part (b)(ii) successfully. Occasionally the wrong trigonometrical function was used – another example of a situation where a diagram would help. A significant minority truncated the calculated answer 0.178 N, writing 0.17, and this was not accepted.

In part (b)(iii), nearly all students quoted either $F = BIl \sin \theta$ or $F = BIl$. The majority who wrote $F = BIl \sin \theta$ then incorrectly used 1.5° as θ, possibly assuming that the field was vertical rather than perpendicular to the aluminium sheet as it actually was so that $\sin \theta = 1$.



(ii) Show that the force exerted on the motor is about 0.02 N.

mass of motor = 69.4 g

(3)

$F = ma \sin\theta$

$F = 0.0694 \times 9.8 \times \sin 1.5$

~~$= 0.012$~~ $= 0.018\,N$

(iii) Determine the magnitude of the magnetic flux density through the aluminium sheet. Assume the magnetic field is uniform along the length of the aluminium sheet between the magnets.

distance between magnets = 7.4 cm
current = 3.4 A

(2)

$F = BIL \sin\theta$

~~a~~ $B = \dfrac{IL\sin\theta}{F} = \dfrac{3.4 \times 0.074 \times \sin 1.5}{0.018} = 0.366$

Magnetic flux density = 0.366

ResultsPlus
Examiner Comments

Part (ii) is completed successfully, but part (iii) is wrong in more than one way. Sin 1.5° has been included and the rearrangement of the formula is upside down. Substitution into an incorrectly rearranged formula does not get a method mark for 'use of' the formula, but this is already incorrect because of the inclusion of the sine of the wrong angle - sin 90° would be accepted.
3, 0

(ii) Show that the force exerted on the motor is about 0.02 N.

mass of motor = 69.4 g

(3)

$F = mg\sin\theta \quad = \frac{69.4}{1000} \times 9.81 \times \sin(15^\circ)$

$= 0.018\text{ N} \approx 0.02\text{ N}$

(iii) Determine the magnitude of the magnetic flux density through the aluminium sheet. Assume the magnetic field is uniform along the length of the aluminium sheet between the magnets.

distance between magnets = 7.4 cm
current = 3.4 A

(2)

$F = BIL$

$0.02 = B \times \overset{3.4}{\cancel{\frac{3.4}{100}}} \times \frac{7.4}{100}$

B= 0.0~~8~~79 NA^{-1} m^{-1}

Magnetic flux density = 0.079 A^{-1}m^{-1} N

ResultsPlus
Examiner Comments

The calculations have all been carried out correctly to give the correct numerical answers, but magnetic flux density has been given units based on *F/Il* rather than T or Wb m^{-2}.
3, 1

Paper Summary

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

- Check that quantitative answers represent sensible values and to go back over calculations when they do not;
- Learn standard definitions in detail with the correct technical terms and do not omit key words, such as ‘unit’ and ‘positive’ for electric field strength;
- Learn standard descriptions of physical processes, such as electromagnetic induction, and be able apply them with sufficient detail to specific situations, identifying the parts of the general explanation required to answer the particular question;
- Be sure to know the standard SI prefixes and be able to apply the correct power of ten – this is frequently required with eV;
- Be sure you know the command words and understand the level of required response for each of them, e.g. explain would mean you must say why something happens and not just describe what happens. There will always be at least two linked marking points for a question asking you to ‘explain’;
- Explanations can often be supported by reference to formulae on the data, formulae and relationships sheet;
- While past paper mark schemes can be useful revision aids, questions will not be identical so quoting them directly is unlikely to answer a particular question. Be sure to answer the question on the paper and not a question from a previous paper with a similar situation;
- Physical quantities have a magnitude and a unit and both must be given in answers to numerical questions;
- When working with components it can help to sketch the relevant triangles rather than trying to apply them from memory;
- When working with vectors, it can be helpful to sketch a vector diagram;
- When describing the effects of forces, a force diagram can help to understand the situation;
- Do not use the mass of a proton when you are instructed to use u, the unified atomic mass unit 9;
- When substituting in an equation with a power term, e.g. x^2, do not suddenly miss off the power.

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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