Examiners' Report
June 2024

GCE Physics 9PH0 01

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June 2024

Publications Code 9PH0_01_2406_ER

Introduction

This examination paper, **9PH0_01** tests about half of the Physics A level specification. The topics examined are mechanics, electric circuits, electric and magnetic fields, nuclear and particle physics.

The paper was completed fully by almost all candidates in the allotted time, and most candidates attempted every question.

All candidates should be made aware of the following general points when answering the questions:

- A "show that" question (eg Q16a) should have the answer given to one extra significant figure compared to that given in the question. The numerical substitutions into an equation should be made clear
- A numerical answer (eg Q11b) should have a unit
- A "deduce" question (eg Q18bii) usually requires the comparison of the candidate's answer with a piece of data given in the question plus a conclusion.

The requirements for this paper included a ruler in order to add to the diagram in Q15ai. Many candidates attempted this without a rule and would consequently struggle to gain MP1 and MP2.

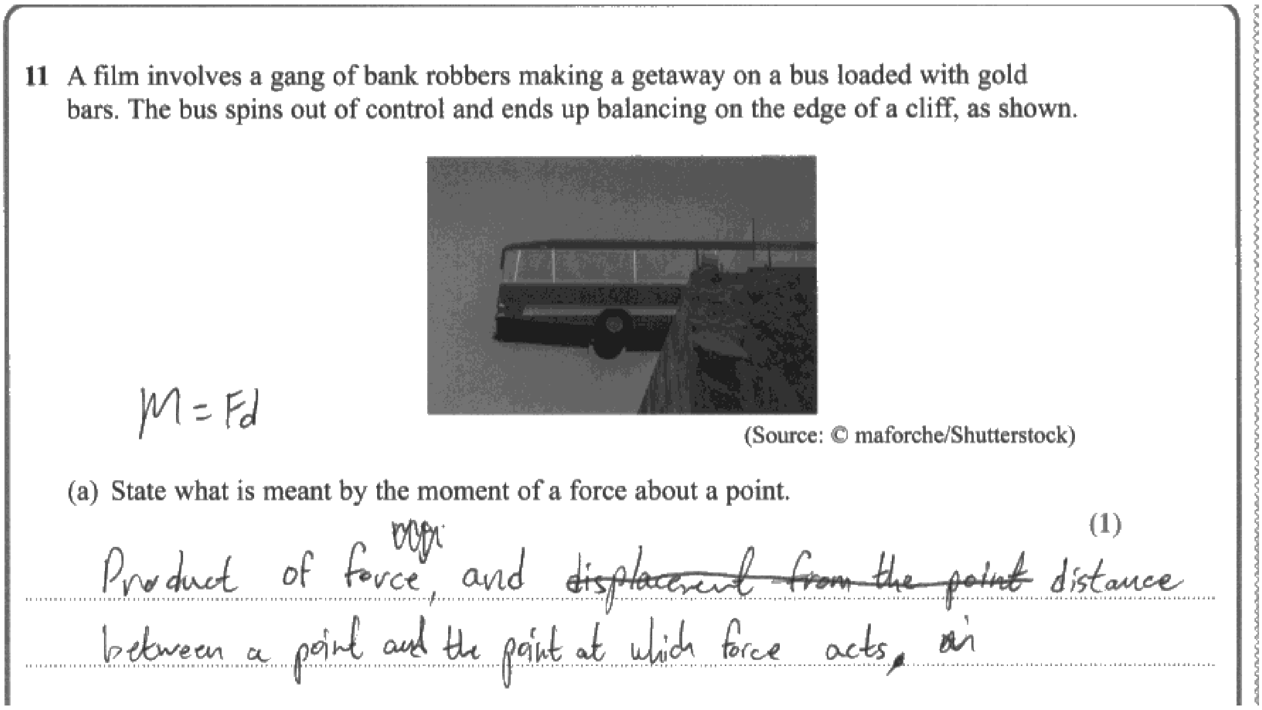
Most questions appeared to elicit the right kinds of response from the candidates. Reading a question carefully can alert candidates to the topic being tested. In Q15 a power supply with a large internal resistance is described. This was to direct candidates to think about the effect of internal resistance on the terminal potential difference. Many candidates did not pick up on this clue.

Certain topics have proved less accessible in past papers. Q18a examined the application of Faraday's and Lenz's laws. It was very pleasing to see a marked improvement in the standard of the answers on this topic.

In general, the numerical questions proved significantly more accessible than the "explanation" questions.

Question 11 (a)

This question asked candidates to explain what is meant by moment of a force. This is the product of force and perpendicular distance from the line of action of the force to the point about which the moment is being calculated. The requirement was simplified for this examination paper to requiring perpendicular as appropriate in the answer.



11 A film involves a gang of bank robbers making a getaway on a bus loaded with gold bars. The bus spins out of control and ends up balancing on the edge of a cliff, as shown.

$M = Fd$

(Source: © maforche/Shutterstock)

(a) State what is meant by the moment of a force about a point.

(1)

Product of force, and ~~displacement from the point~~ distance between a point and the point at which force acts, ai

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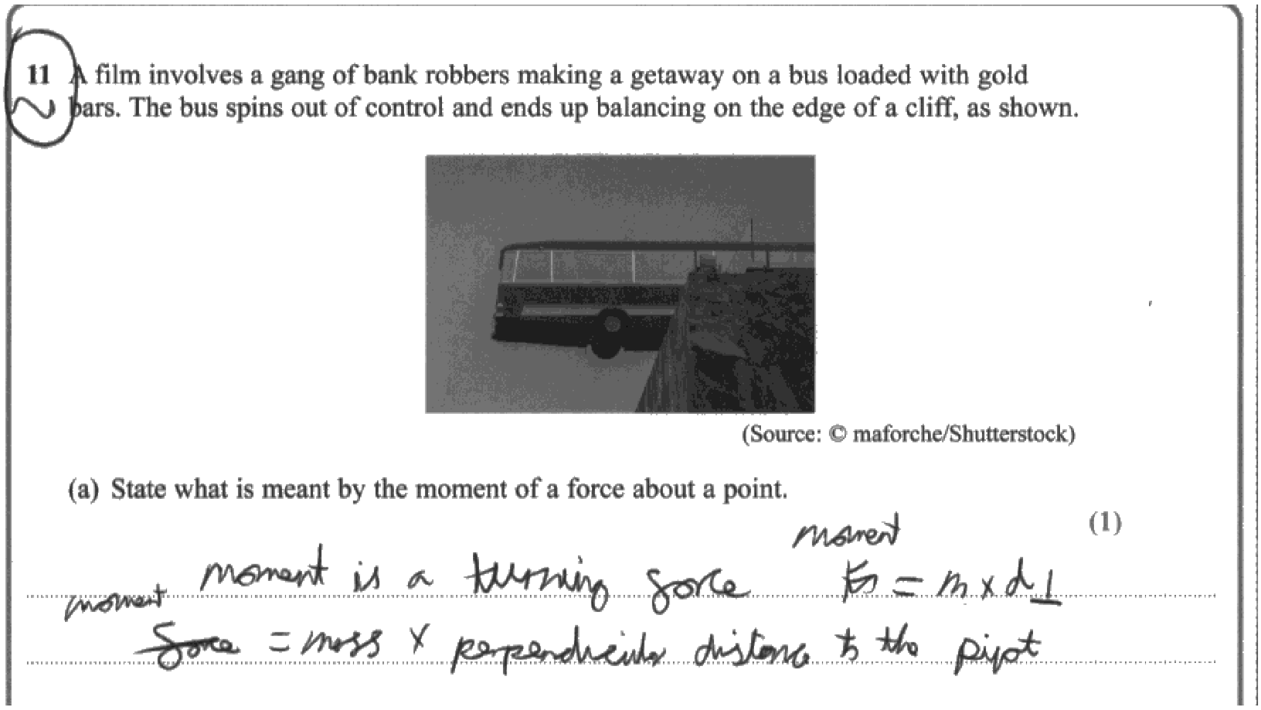
Examiner Comments

This answer does not include "perpendicular" therefore there is no mark.



11 A film involves a gang of bank robbers making a getaway on a bus loaded with gold bars. The bus spins out of control and ends up balancing on the edge of a cliff, as shown.

(Source: © maforche/Shutterstock)

(a) State what is meant by the moment of a force about a point.

(1)

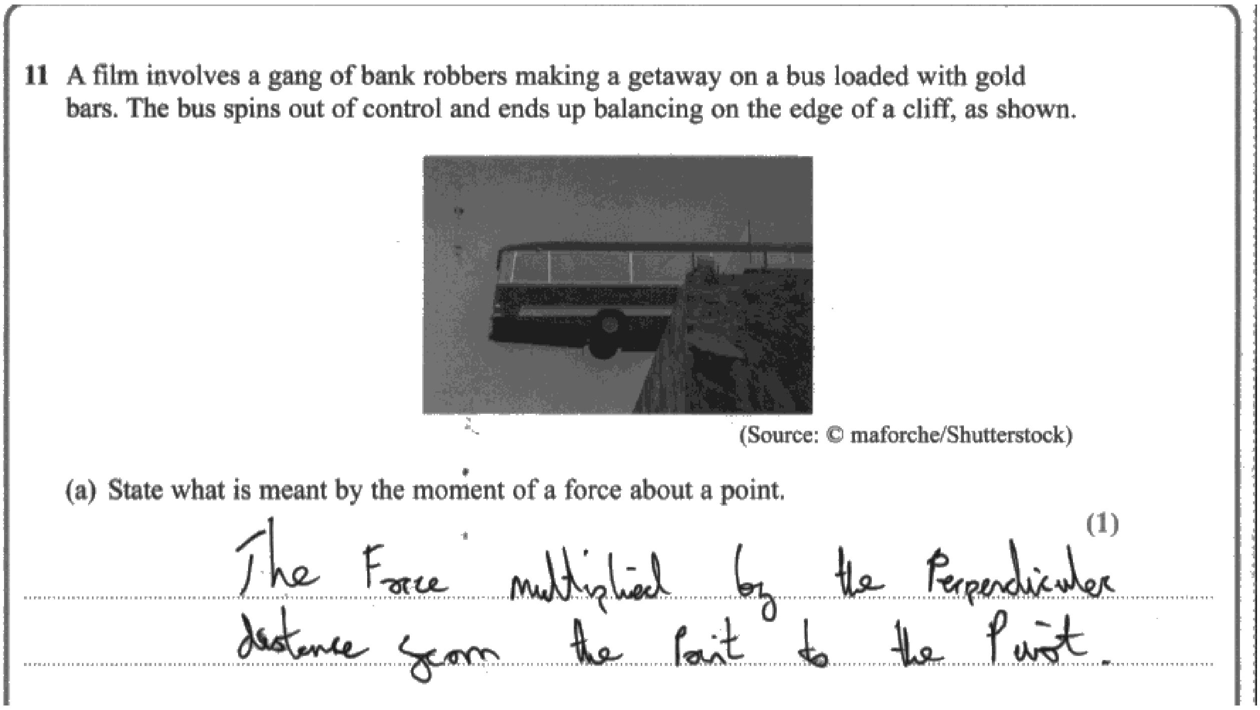
moment is a turning force moment ~~F~~ $= m \times d_{\perp}$

moment ~~force~~ = mass × perpendicular distance to the pivot

ResultsPlus

Examiner Comments

This answer included "perpendicular" but incorrectly substitutes mass for force.



11 A film involves a gang of bank robbers making a getaway on a bus loaded with gold bars. The bus spins out of control and ends up balancing on the edge of a cliff, as shown.

(Source: © maforche/Shutterstock)

(a) State what is meant by the moment of a force about a point.

(1)

The Force multiplied by the Perpendicular distance from the Point to the Pivot.

ResultsPlus
Examiner Comments

This answer includes "perpendicular" so is credited.

ResultsPlus
Examiner Tip

The distance would have been better defined as distance from the line of action of the force to the pivot, however this is a good answer.

Question 11 (b)

The best point to take moments around is the pivot. This means that the reaction force at the pivot will not have a moment.

The centre of gravity of the bus is midway or 5.5 m from either end.

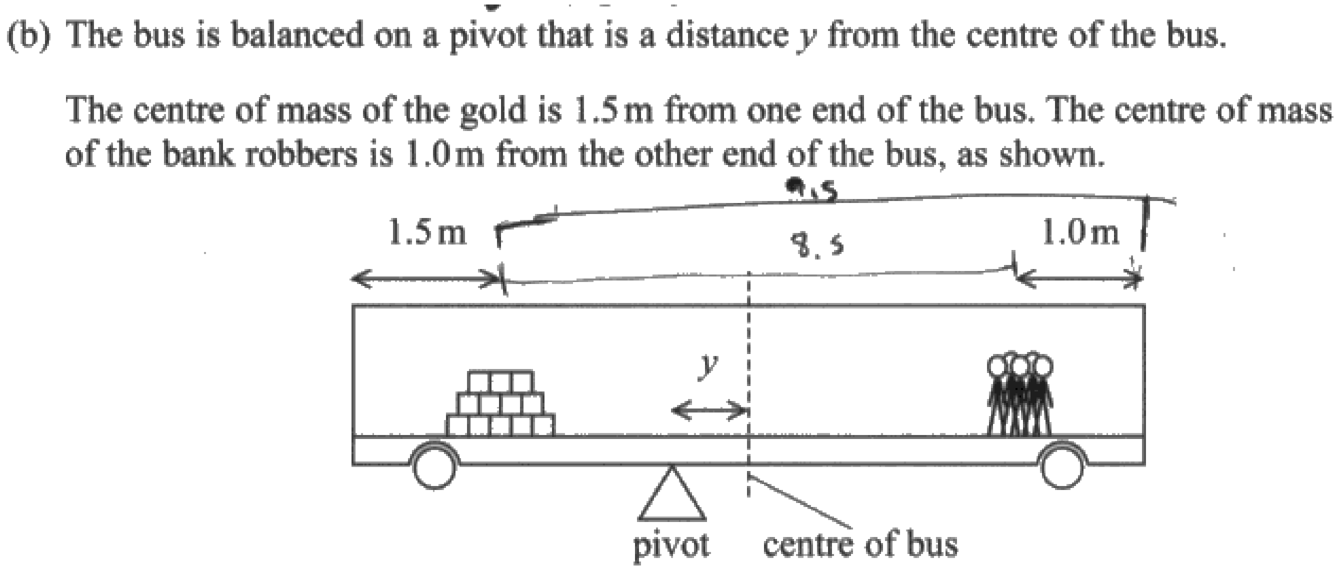
The distance between the pivot and the gold will be 5.5 – 1.5 – y = 4 – y

The distance from the pivot to the robbers 5.5 – 1.0 + y = 4.5 + y

These will be perpendicular distances to the respective weight forces.

So the moment of the gold around the pivot = 31000 x (4 – y)

The most common mistake was to work out these distances incorrectly.



(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.

11 ÷ 2 = 5.5

(5.5 − 1.5) × 31000 = 124000

(5.5 − 1) × 8400 = 39150

124000 − 39150 = 84850

84850 = 32000 × y

2.652 = y

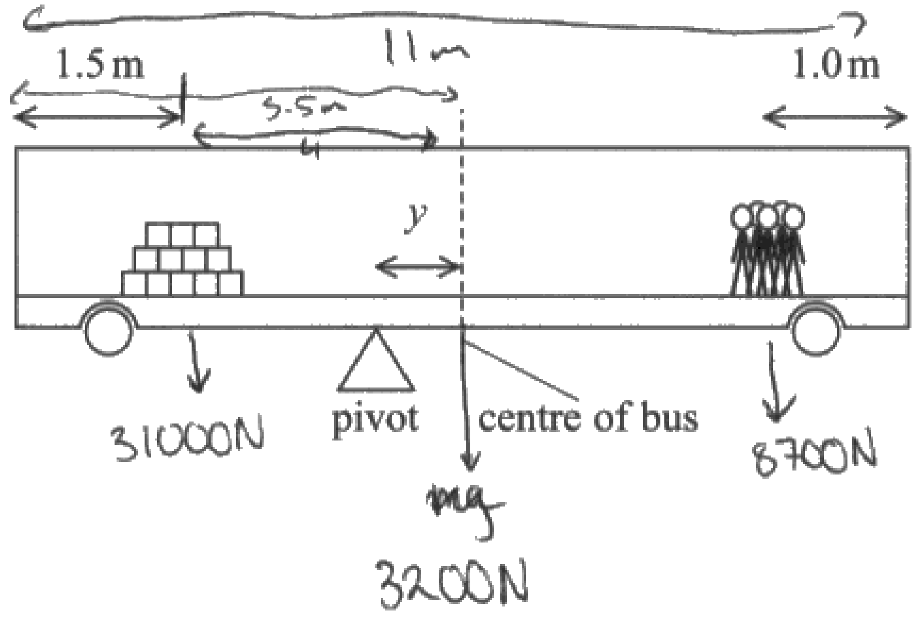
y = 2.7

ResultsPlus
Examiner Comments

This answer forgets the weight of the bus which does have a moment around the pivot.

A clockwise moment is shown equal to an anticlockwise moment so gains MP1 and 2.

It does not have correct expressions for distance to the gold or to the robbers so does not gain MP3.



Ⓟ $32000y + 8700(5.5+y) = 31000(4-y)$

$32000y + 47850 + 8700y = 124000 - 31000y$

$71700y = 76150$

$y = \frac{76150}{71700} = 1.062064156$

$y = 1.1m$

$y =$ 1.1m

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Examiner Comments

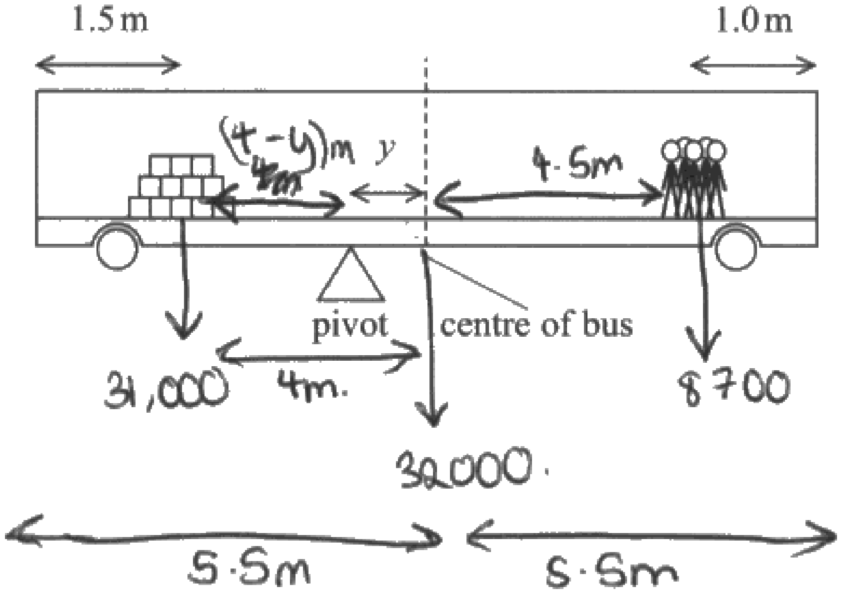
This has the correct moment of weight and the gold around the pivot (distance 4 – y) but has the incorrect distance to the robbers. It loses the last mark.

ResultsPlus
Examiner Tip

Although this candidate got one of the distances incorrect it was sensible to mark the distances on the diagram. Questions on moments are usually helped by a well-annotated diagram.

(b) The bus is balanced on a pivot that is a distance y from the centre of the bus.

The centre of mass of the gold is 1.5 m from one end of the bus. The centre of mass of the bank robbers is 1.0 m from the other end of the bus, as shown.



About the ~~fr~~ pivot.

$(\cancel{31,000\times}\ 31,000 \times (4-y) = 32000y + (4.5+y)8700.$

$124000 - 31,000y = 32,000y + \cancel{39}\,39150 + 8700y$

$124,000 - 31,000y = 40,700y + 39150.$

$84850 = 71700y$

$y = \cancel{1.8}\ 1.183m$

$y =$ 1.183m

ResultsPlus
Examiner Comments

This gains all four marks.

Question 12

Part of this answer required candidates to use the resistivity equation, and this was well-answered. The equation $P = IV$ and then I^2R should be used to calculate the power loss. A significant number of answers used V^2/R. This is incorrect as the V in this equation is potential difference from one end of the length of a cable to the other, which is not given. The transmission voltage is potential difference between one cable and the other.

$$R = \frac{\rho l}{A} \quad \therefore \quad R = \frac{1.7\times10^{-8} \times 720\times10^{3}}{\left(\frac{15}{2}\right)^2 \times \pi}$$

$$= 6.9264\ldots\times10^{-5}$$

$$= 6.93\times10^{-5}\,\Omega$$

$$P = \frac{V^2}{R} \quad \therefore \quad P = \frac{(1100\times10^{3})}{6.93\times10^{-5}}$$

$$= 1.5873\ldots\times10^{10}\,V$$

$$= 1587\,MV$$

$$\therefore \text{efficiency} = \frac{1400}{1587} \times 100 = 88.216\ldots$$

$$= 88.2\%$$

∴ The claim is Not correct.

ResultsPlus

Examiner Comments

This answer was commonly seen. The resistivity equation is used for MP2 and3. The power equation is incorrect.

ResultsPlus
Examiner Tip

The formulas for power $P = IV$, $P=I^2R$ and $P = V^2/R$ tend to be taught as if each quantity is always the same. In this case there are two different powers. Power to be transmitted and power lost by the cables.

$R = \frac{\rho l}{A}$ $\qquad A = \pi r^2 = \pi\left(\frac{d}{2}\right)^2$

$$R = \frac{1.7\times10^{-8} \times 720000}{\pi\left(\frac{0.15}{2}\right)^2} = 0.693\,\Omega$$

$$P = \frac{V^2}{R} = \frac{1100000}{0.693} = 1588121.3\text{ W}$$ = power dissipated across wire

$1400\times10^6 - 1588121.3 \approx 1398\times10^6\text{ W}$

$\frac{1398}{1400}\times100 = 99.89\%$ efficiency

so the claim is correct

ResultsPlus
Examiner Comments

This answer gains MP2 and 3 for the use of resistivity equation. It calculates the power loss incorrectly. It then uses the power loss in the efficiency equation correctly to gain MP5.

Resistance in cable:

$$\frac{1.7\times10^{-8}\times720,000}{\pi\times0.15^2} = 0.17316\ldots\ \Omega$$

~~Power max:~~

~~$\frac{1,100,000^2}{0.17316} = 6.98777\times10^{12}$ W~~ =

Current:

$$I = \frac{P}{V} = \frac{1400\times10^6}{1100\times10^3} = 1272.727\text{ A}$$

Power in UK:

ResultsPlus
Examiner Comments

This calculates the current using *P* = *IV* for MP1. It uses the resistivity equation correctly, although the cross-sectional area is incorrectly calculated from the diameter. It still gains MP2 and 3 for dimensionally correct substitutions. Hence gains 3 marks.

$P = IV$ $\qquad I = \frac{P}{V} = \frac{1400 \times 10^6}{1100 \times 10^3} = 1273\ A$

~~B~~ $R = \frac{\rho L}{A}$ $\qquad \frac{1.7 \times 10^{-8} \times 720 \times 10^3}{\pi \times (7.5 \times 10^{-2})^2} = 0.69\ \Omega$

~~$P = I^2R$~~ $\qquad$ ~~$(1273)^2 \times (0.69)$~~

$P = I^2 R$ $\qquad (1273)^2 \times (0.69) = 1121966.06\ W$

1400 000 000

$\frac{1121966.06}{1400\ 000\ 000}$ ~~x18~~ $\times 100 = 0.08\ \%$

efficient

No the claim for efficiency is incorrect

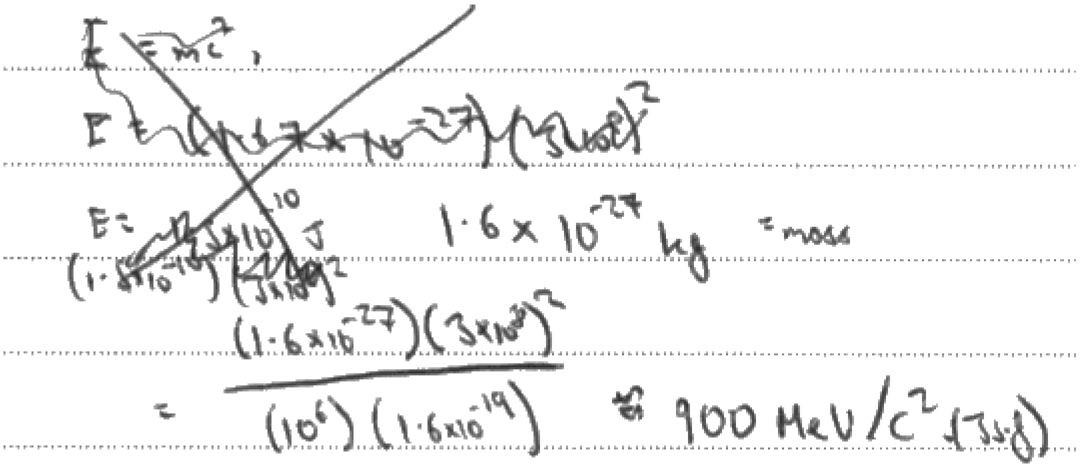
ResultsPlus
Examiner Comments

This answer is a really good attempt. It gains MP1 and 4 for calculating the power loss. It gains MP2 and 3 for using the resistivity equation. It gains MP5 for correctly calculating the % power loss for the transmission system. It should then have calculated the efficiency of the system which is:

100 – 0.08 = 99.92 % and the conclusion would now be that this is close to 100% efficient.

Question 13 (a)

This conversion is now correctly carried out by a significant majority of candidates. One common error was to look up the mass of a proton incorrectly. A few candidates are still getting the conversion inverted.



~~$E = mc^2$,~~

~~$E = (1.67 \times 10^{-27})(3\times10^8)^2$~~

~~$E =$ [illegible] $\times 10^{10}$ J~~ 1.6×10^{-27} kg = mass

~~$(1.6\times10^{-19})(3\times10^8)^2$~~

$$= \frac{(1.6\times10^{-27})(3\times10^8)^2}{(10^6)(1.6\times10^{-19})} = 900 \text{ MeV}/c^2 \text{ (3s.f)}$$

ResultsPlus Examiner Comments

A "show that" question should have the answer written to one extra significant figure to that in the question (900). The answer rounds to 940 MeV/c^2. This answer also shows an incorrect mass of the proton (1.6 x ..) rather than 1.67 x 10^{-27} kg.

It gains MP2 and 3.

ResultsPlus Examiner Tip

In "show that" questions ensure you write the formula and show the numerical substitutions.

mass of proton and anti proton are the same.

$Mp = 1.67 \times 10^{-27}$

$$m = \frac{(MeV) \times 1.6 \times 10^{-19} \times 10^{3}}{3 \times 10^{8}}$$

$$\therefore \frac{1.67 \times 10^{-27} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times 10^{3}} = 3.13 \times 10^{-3}$$

ResultsPlus
Examiner Comments

This answer has MP1 for realising that the antiproton has the same mass as the proton. It has an unusual second line, but the third line shows a conversion with some credit but forgets to square *c*.

It gains MP3 for a conversion from J to eV.

- Proton mass = 1.67×10^{-27} kg

$$\cancel{\sim \frac{(1.67 \times 10^{-27}) \times 10^{6} \times (1.6 \times 10^{-19})}{(3 \times 10^{8})^{2}}}$$

- $E = mc^2$

- $$\frac{(1.67 \times 10^{-27}) \times 10^{6} \times (1.6 \times 10^{-19})}{(3 \times 10^{8})^{2}} =$$

ResultsPlus

Examiner Comments

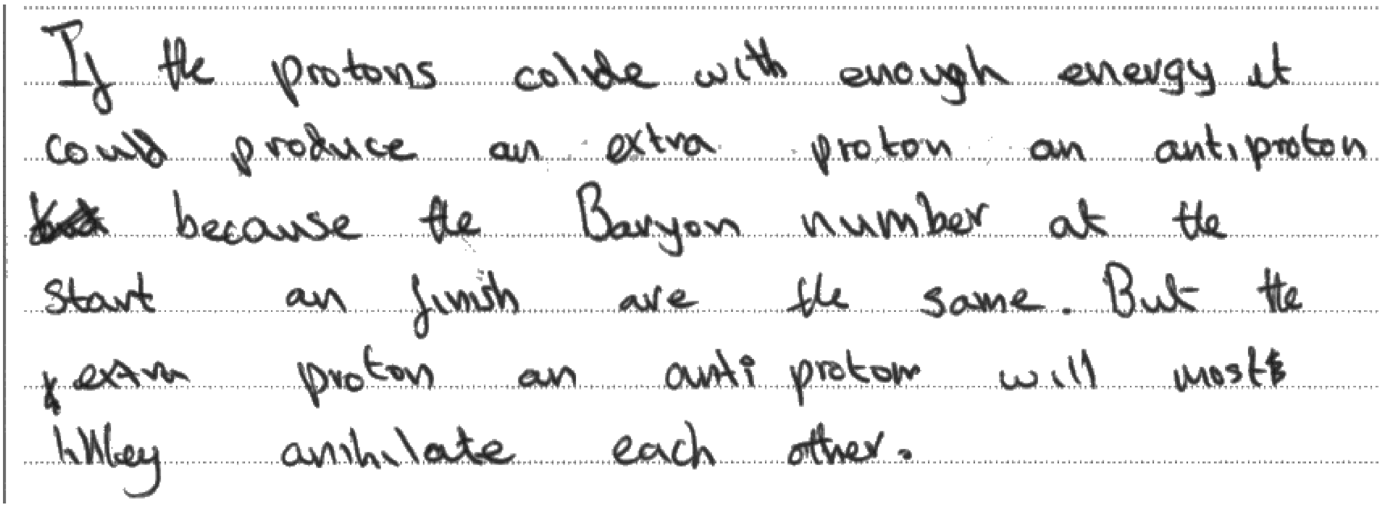
This gains MP1 as the substitution shows that the candidate correctly assumes the mass of an antiproton is the same as that of a proton. The conversion is inverted so scores no further credit.

Question 13 (b)

This question examined how the conservation laws applied to this particular situation.

Most candidates correctly explained that the conservation of charge and baryon number applied.

Fewer candidates went on to explain whether the laws of momentum conservation and mass-energy would apply.



If the protons colide with enough energy it could produce an extra proton an antiproton ~~but~~ because the Baryon number at the start an finish are the same. But the extra proton an anti proton will most likley annihlate each other.

ResultsPlus
Examiner Comments

This gains MP4 for correct consideration of mass-energy conservation. The answer states that the initial protons would need enough energy to create the extra two particles.

To gain the conservation of baryon number more detail was required. It was expected that the answer would spell out the baryon number of each particle.

antiproton in this way.

(4)

Baryon number on ~~right~~ left hand side: 2 (1+1)

Baryon number on right hand side: 2 (1+1+1−1)

Baryon number is conserved on both sides of the equation.

Charge on left hand side: +2 (1+1)

Charge on right hand side: +2 (1+1+1−1)

Charge also conserved on both sides of equation.

∴ ~~Hence~~ Hence it is possible.

ResultsPlus
Examiner Comments

This question nicely explains how charge and baryon number are conserved. It shows the charge and baryon number of each particle involved. It was not sufficient to simply say "the charge on each side is +2".

Charge : +1 +1 -> +1 +1 +1 -1

So charge is conserved.

Baryon number : +1 +1 -> +1 +1 +1 -1

So baryon number is conserved.

Since the colliding two protons move in opposit directions, the total momentum before is 0, so if total momentum after collision is 0, then momentum is conserved. $E = mc^2$. So E_k of colliding protons has to be equal to 1800 $\frac{\text{MeV}}{c^2}$ ~~Energy-Mass is conserved~~. So that energy-mass conserved. It is possible to produce an antiproton this way.

(Total for Question 13 = 8 marks)

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Examiner Comments

This is a good answer. Both MP1 and 2 are gained.

MP3 is quite well explained. The total initial momenta will be 0 as the two protons move in opposite directions so it must be 0 after the collision.

Both MP4 and 5 are present. The *E*k of the protons must be equal to 1800 MeV/c^2 to create the extra particles.

The question has a maximum of 4 marks.

Question 14 (a)

Many candidates collected 2 marks. The mark scheme looked for positive attributes eg Leptons have a non-zero lepton number. In general, negative comments were not awarded a mark eg Leptons do not have a baryon number.

1- They are all Fundermental Particles

2- they are all much smaller than Baryons and mesons

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Examiner Comments

MP3 for fundamental. A common misconception was to suggest leptons are "small" or "have little/no mass".

They are all fundemental particles and have a lepton number of 1.

ResultsPlus
Examiner Comments

This was awarded both marks. Note that leptons can have a lepton number of + or – 1.

(2)

- All leptons are fundamental particles
- All leptons have a neutrino which is a neutral version of that particle.

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Examiner Comments

Neutrinos are leptons. They are not a "version" of a lepton. This gained MP3 only.

(2)

Leptons are fundamental particles, they are not made up of smaller sub-particles.
They all have a lepton number which must be conserved.

ResultsPlus
Examiner Comments

Leptons do not have a lepton number of 0. So the second sentence is incomplete.

Question 14 (b)

The symbols for obscure particles would be given within the question. It was felt that the particles involved in this interaction should be known. The majority of candidates did know the relevant symbols.

$u \longrightarrow \nu_{\nu} + \bar{e} + \nu_e$

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Examiner Comments

The positive muon should have a + sign.

The positron is written e^+

An antineutrino should have a bar above its symbol.

$\mu^+ \longrightarrow e^+ + \nu_e^0 + \nu_\mu^0$

$1 \longrightarrow -1 + 1 + 1.$

ResultsPlus
Examiner Comments

The antineutrino is missing the bar.

$\mu^+ \rightarrow e^+ + \nu_e + \overline{\nu}_\mu$

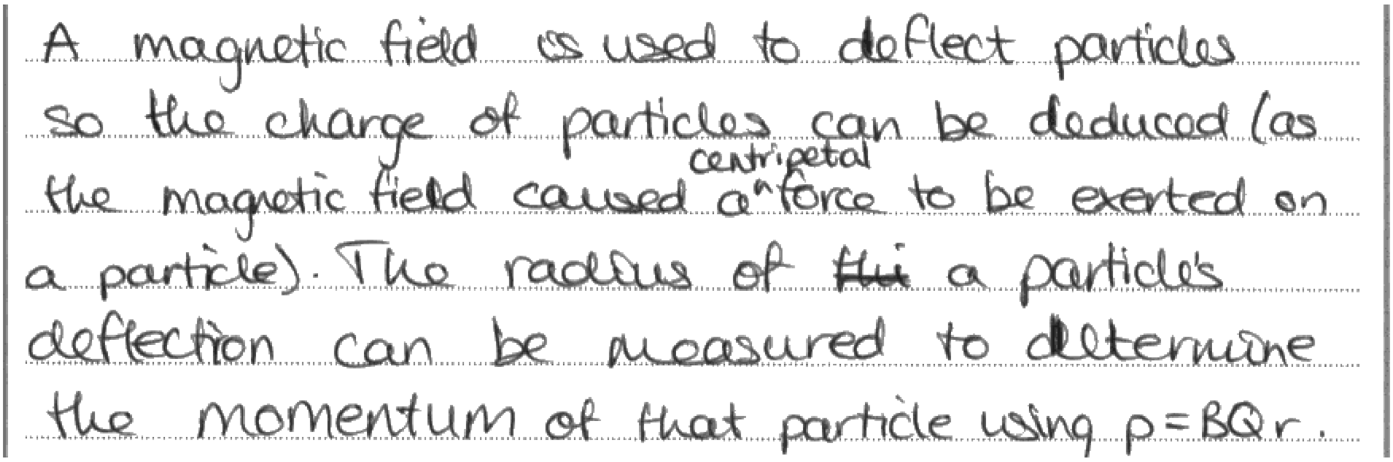
ResultsPlus
Examiner Comments

A good answer

Question 14 (c)

The purpose of the magnetic field is to curve the track. The direction of curvature indicates the sign of the charge of the particle. Note the answer has to spell out direction of curvature. Two particles, created at the same point, with the same sign of charge but different momenta will have paths following different directions but will be curving the same way.

The radius of curvature can be used to calculate the momentum of the particle, using $r = p/Bq$.



A magnetic field is used to deflect particles so the charge of particles can be deduced (as the magnetic field caused a centripetal force to be exerted on a particle). The radius of ~~thi~~ a particle's deflection can be measured to determine the momentum of that particle using $p = BQr$.

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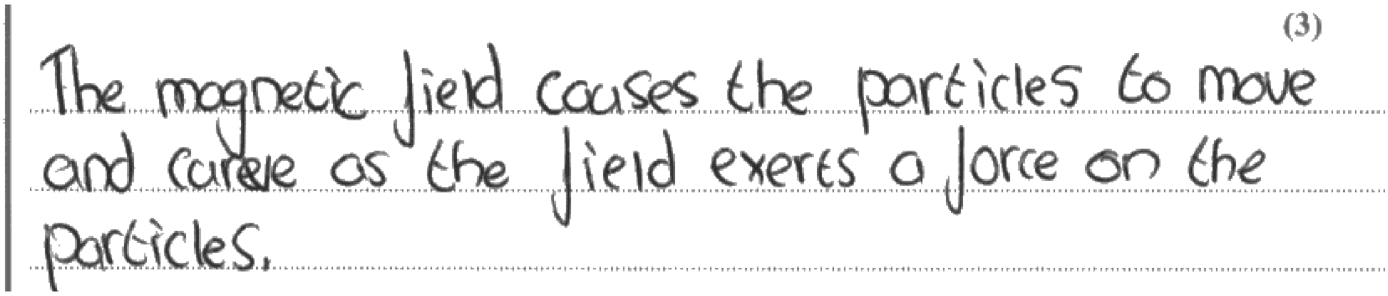
Examiner Comments

This answer gains MP1 and 3. It is not sufficient to say the deflection will give the charge for MP2.

ResultsPlus
Examiner Tip

When moving particles of the opposite charge are in a magnetic field they will **curve** in opposite directions. It would also be correct to say one particle will curve in a clockwise direction and one with the opposite charge in an anticlockwise direction.

It is not sufficient to say curve in different directions as particles with the same charge, but different momenta will move in different directions.


(3)

The magnetic field causes the particles to move and curve as the field exerts a force on the particles.

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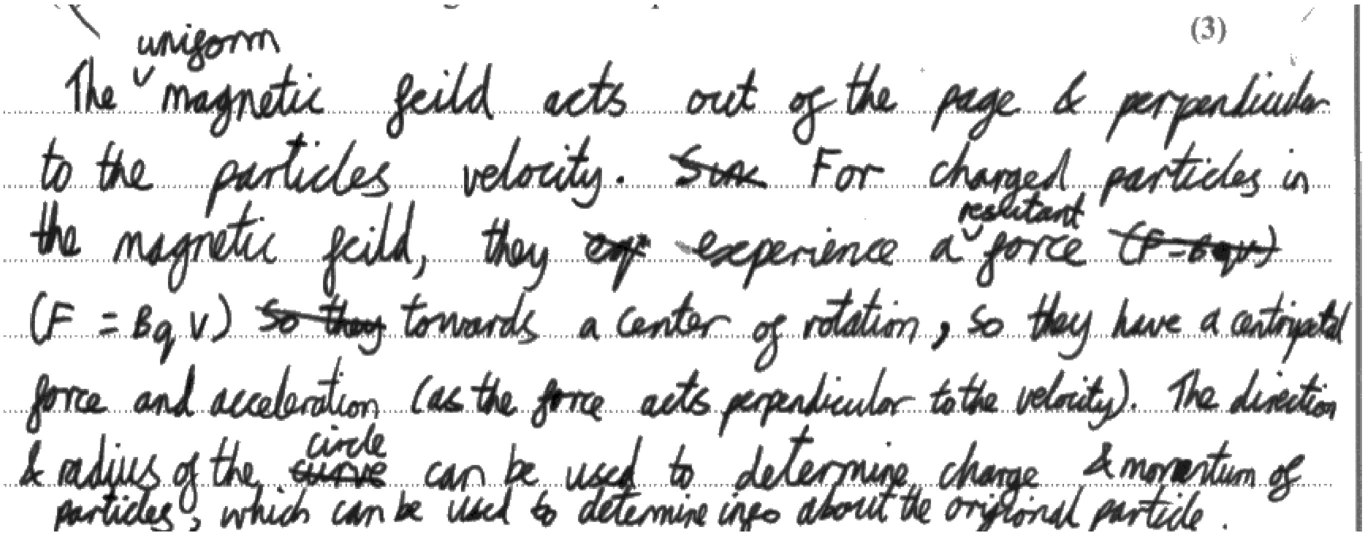
Examiner Comments

The magnetic field is not there to make the particles "move". It is there to curve their paths. This answer was given MP1.


(3)

The uniform magnetic feild acts out of the page & perpendicular to the particles velocity. ~~Sta~~ For charged particles in the magnetic feild, they ~~exp~~ experience a resultant force ~~(F=Bqv)~~ (F = Bq v) ~~so they~~ towards a center of rotation, so they have a centripetal force and acceleration (as the force acts perpendicular to the velocity). The direction & radius of the circle ~~curve~~ can be used to determine charge & momentum of particles, which can be used to determine info about the origional particle.

ResultsPlus
Examiner Comments

The phrase "direction of the circle" is a sufficient description for the direction of curvature for MP2. The answer was given the benefit of doubt as it should have more correctly said the "sign of the charge".

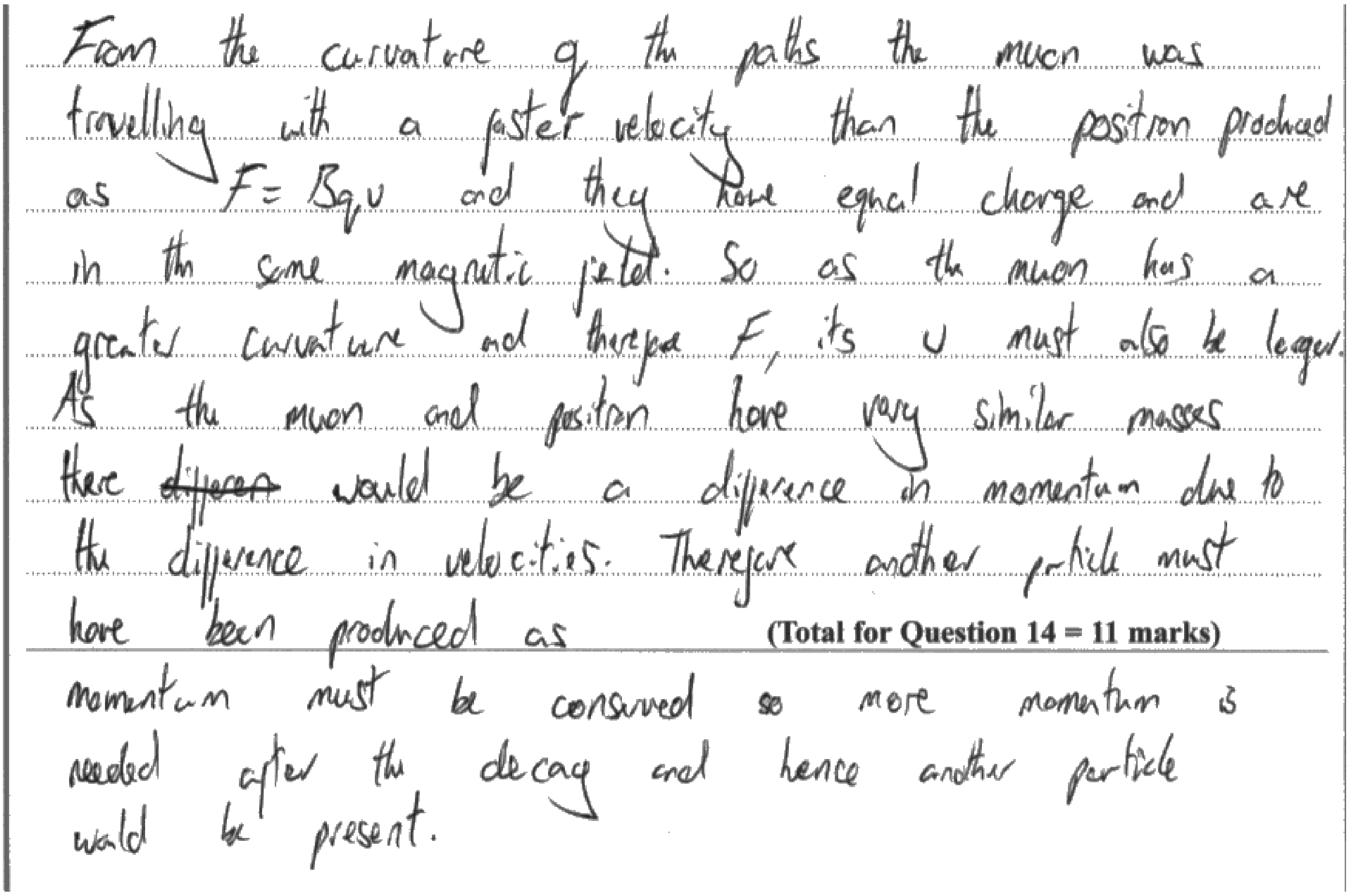
Question 14 (d)

The direction of the path of the muon is different to the direction of the path of the positron at the point of decay. This indicates that the momenta of the two particles is different at that point. This gives MP1 and 2.

This idea can easily be mis-communicated. Answers such as "the direction of the particles is changing". This answer confuses the idea that the particles will be slowing down inside the detector, so their momenta are continuously changing with the abrupt change at the point of decay.

It was also acceptable to point out the different radii of curvature at the point of decay and this indicates different values of momenta for MP1 and 2.

Again, a poorly expressed answer such as "the radius of the track changes" is not clear whether this is describing one of the particles as they slow down.



From the curvature of the paths the muon was travelling with a faster velocity than the positron produced as $F = Bqv$ and they have equal charge and are in the same magnetic field. So as the muon has a greater curvature and therefore F, its v must also be larger. As the muon and positron have very similar masses there ~~difference~~ would be a difference in momentum due to the difference in velocities. Therefore another particle must have been produced as

(Total for Question 14 = 11 marks)

momentum must be conserved so more momentum is needed after the decay and hence another particle would be present.

Examiner Comments

This gains all four marks but does have an incorrect statement. The four-mark points are all present in the answer. However, the statement that the mass of a muon is similar to that of a positron is incorrect. This doesn't detract from the key points of the argument which are well made for full credit.

(4)

Because for conservation laws, the momentum of the decay particle should be conserve, so at the point where the positron is decayed, the must be another particle decayed but goes to an opposite direction.

Examiner Comments

This answer gains MP3 and 4. It does suggest that momentum is only conserved if other particle(s) are present at the decay.

the track changes direction so conservation of momentaum has not been conserved in the decay . the radius of curvature increases , and since they have the same charge , force is constant , $F = mv^2/r$ so again mass or velocity has changed so momentum before ≠ momentum after inf this it the only particle produced

(Total for Question 14 = 11 marks)

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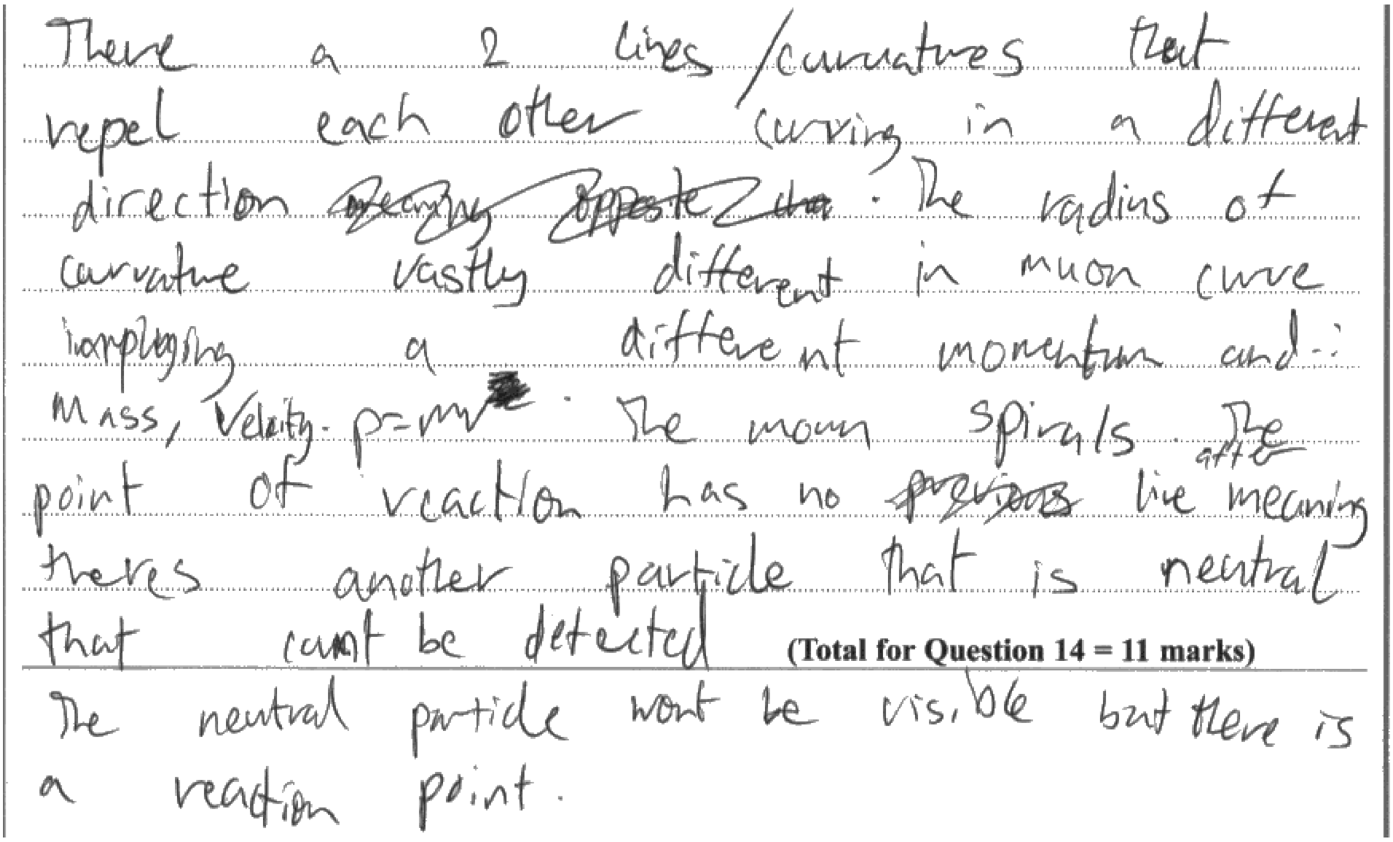
Examiner Comments

This answer was given MP1 and 2. The track changes direction and there is enough context to suggest "at the point of decay" gains MP1. There is enough description to suggest that the momenta are different before and after decay. But there is no reference to momentum needing to be conserved etc.



There a 2 lines /curvatures that repel each other curving in a different direction ~~[illegible] opposite the~~. The radius of curvature vastly different in muon curve implying a different momentum and ∴ Mass, Velocity. $p=mv$. The moun spirals. ~~The~~ after point of reaction has no ~~previous~~ line meaning theres another particle that is neutral that cant be detected

(Total for Question 14 = 11 marks)

The neutral particle wont be visible but there is a reaction point.

ResultsPlus
Examiner Comments

This answer reveals a number of mistakes. The two curves are in the same direction because the two particles (the positron and the muon) have the same charge – positive. The radii of curvature are different and the momenta of the two particles is different. This collects MP1 and 2. There is no further credit as this answer does not continue to discuss conservation of momentum.

([illegible])

The path starts from nothing meaning that the decayed particle was positive (muon). At a point, the path changes direction meaning that the particles collided. The path then dissapears meaning that they collided again or another particle was created. This shows that other particles were produced in this decay.

(Total for Question 14 = 11 marks)

ResultsPlus
Examiner Comments

This answer has misinterpreted the diagram. The candidate thinks that the two particles (the muon and the positron) are moving along the curved paths and collide at the point where the muon decays. No mention of conservation of momentum.

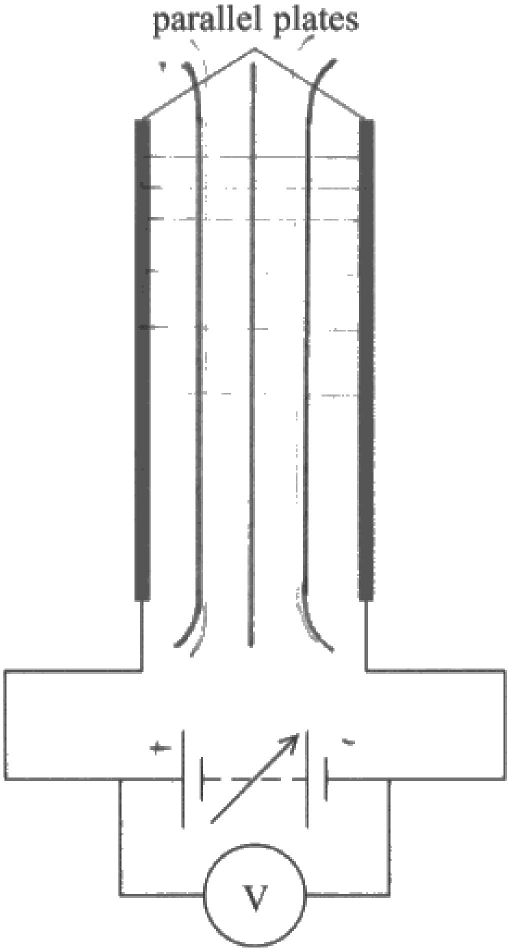
Question 15 (a)(i)

This question examined the ability to draw lines to represent a uniform electric field.

The lines should be drawn with a ruler. The requirements on the front of the examination paper stated ruler but a significant number of candidates did not appear to use one.

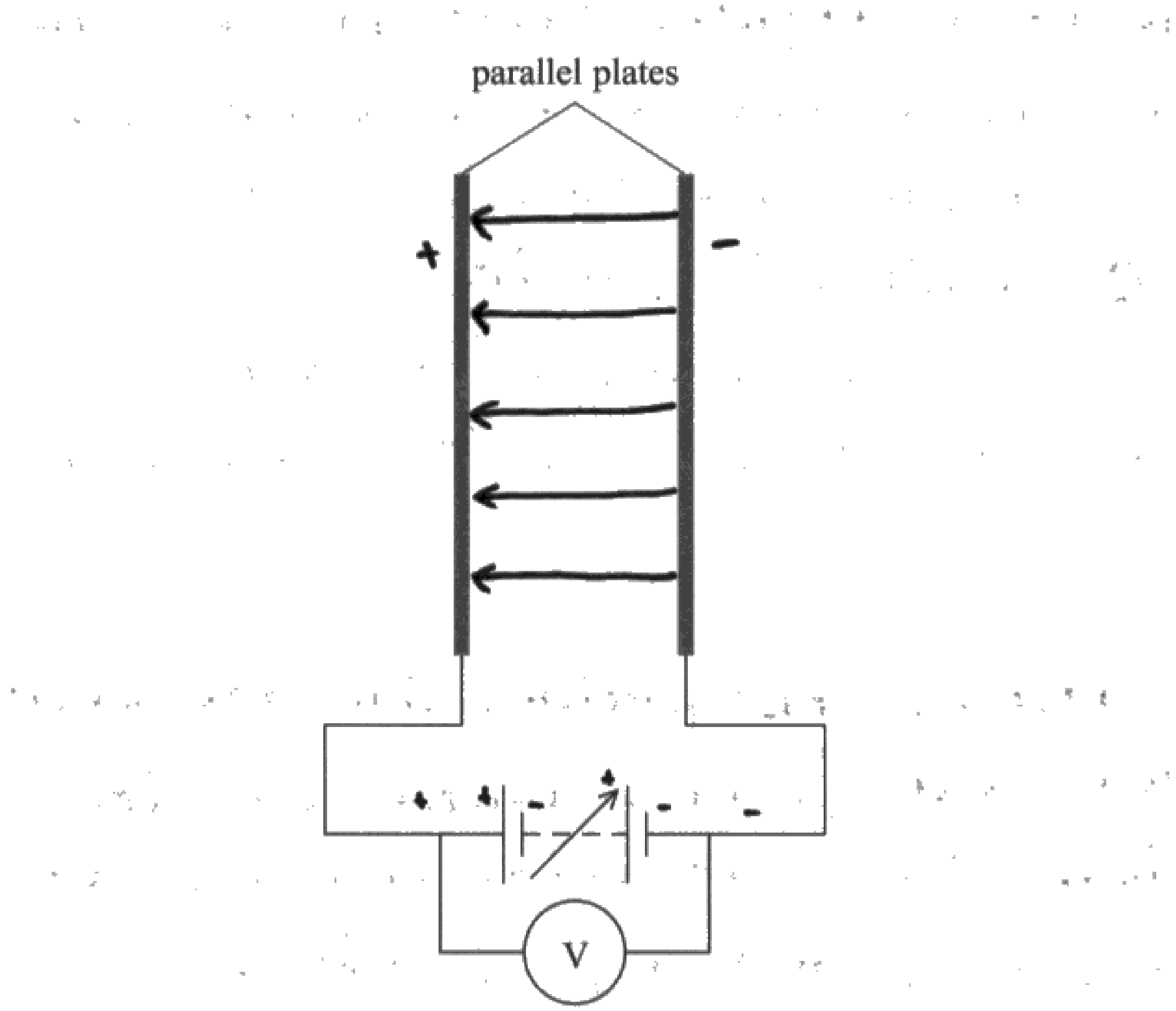
The lines should be straight, parallel and equally spaced.

An arrow representing the direction of the force on a positive charge ie left to right was required for MP3.



ResultsPlus
Examiner Comments

The lines in this diagram are equipotential lines.

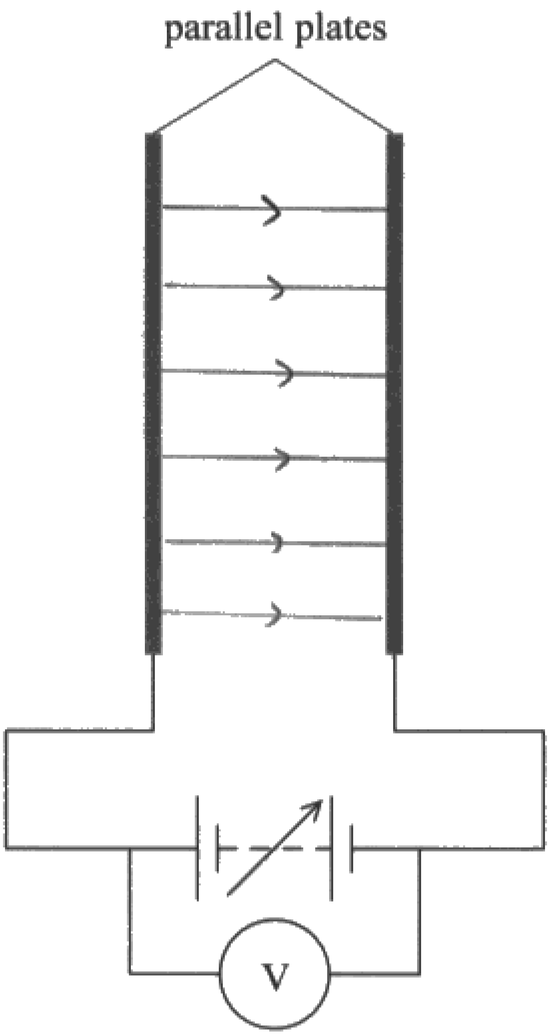


ResultsPlus
Examiner Comments

The lines in this diagram have not been drawn with a ruler.

They are reasonably parallel (MP1) but they are not equally spaced.

The arrow is in the wrong direction.

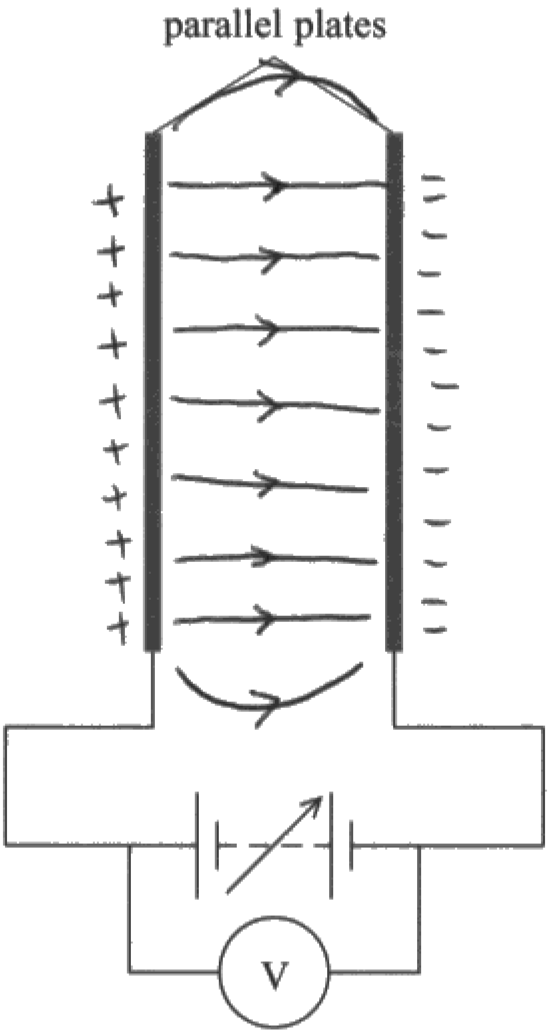


ResultsPlus
Examiner Comments

These lines are drawn with a ruler and are parallel (MP1).

Most of the gaps between lines are equal (MP2) although a harsher view would be that the bottom gap is smaller than the others.

The arrow is correct (MP3)



ResultsPlus
Examiner Comments

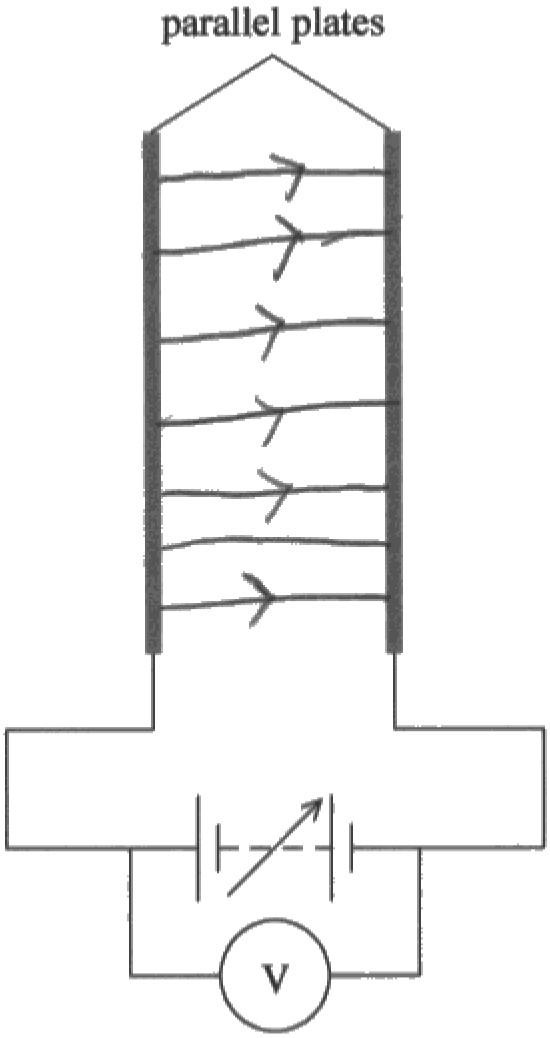
These lines were not drawn with a ruler, and they are not parallel.

They are not equally spaced, and they have little gaps at either end.

The arrow was correct (MP3).

ResultsPlus
Examiner Tip

Ensure you have a ruler to complete electric field diagrams.



ResultsPlus
Examiner Comments

These lines were not drawn with a ruler and are not parallel.

They are not equally spaced.

The arrow is correct (MP3).

Question 15 (a)(ii)

The clue to this question was in the information given at the start of the question. It states that the power supply had a large internal resistance.

When a question refers to power supplies with (large) internal resistance it is likely that there will be a discussion about emf, terminal potential difference, "lost volts" etc.

In this case there is no current in this "circuit" as there is a gap between two plates.

In which case there will be no potential difference across the internal resistance of the power supply so the terminal potential difference will equal the emf.

The Voltmeter gives us the actual voltage of the Power Supply ε being the e.m.f $\varepsilon = V + Ir$

ResultsPlus
Examiner Comments

This answer comes close to gaining credit but needed to use the correct terminology.

The "actual voltage of the power supply" is technically called the terminal potential difference. The use of the correct terms would gain credit.

power supply has large internal resistance so minimum/negligible current through power supply so no heating effect so reduced or minimum lost volts hence voltmeter and EMF ideal readings.

agree

ResultsPlus
Examiner Comments

This gains MP1 for recognising there is no current.

It gains MP2 for recognising there is "minimal" lost volts.

(2)

Because it is reading the lost volts and the terminal voltage ~~R~~ because it is over the battery and ε = lost volts + terminal p.d.

ResultsPlus
Examiner Comments

This answer suggests a partial knowledge of the appropriate technical terms and how they apply. It does not appreciate that the voltmeter measures the terminal potential difference. This will equal E if the "lost volts" are 0.

- $V = \mathcal{E} - Ir$
- As internal resistance is so high, current will be very low, this means $Ir \approx$ close to 0, ∴ the voltmeter would show the $\mathcal{E}$.

ResultsPlus
Examiner Comments

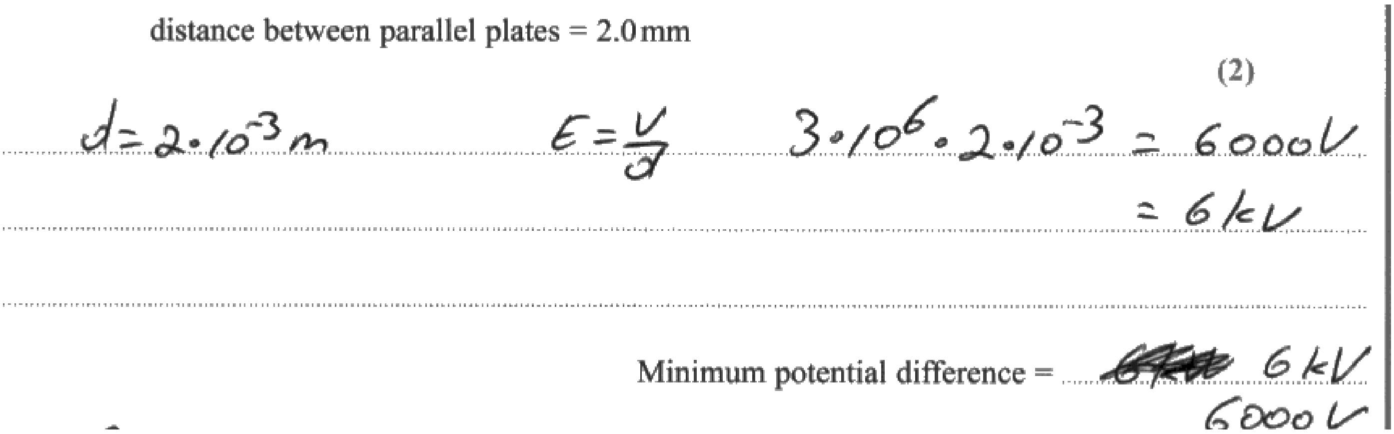
This answer illustrates a nice way to answer this question using the formula.

The equation is rearranged to recognise that the relevant symbol V is the voltmeter reading.

By referring to the equation the answer conveys the full argument for full credit.

Question 15 (b)(i)

A straightforward use of the equation *E* = *V*/*d* which the vast majority of candidates completed successfully.



distance between parallel plates = 2.0 mm

(2)

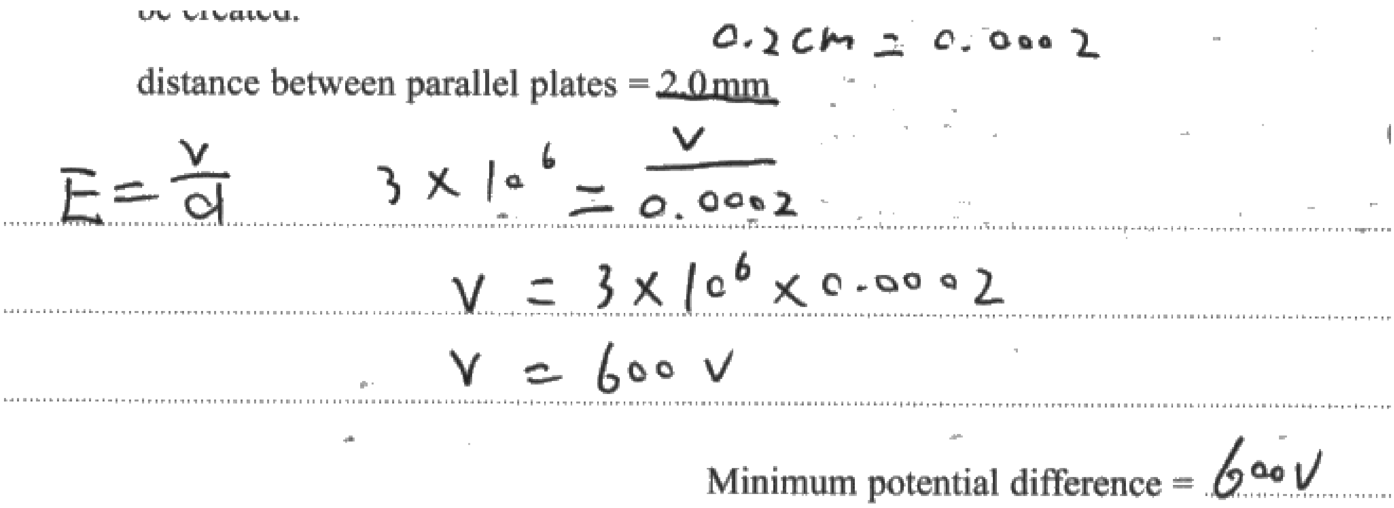
$d = 2 \cdot 10^{-3}$ m $E = \frac{V}{d}$ $3 \cdot 10^6 \cdot 2 \cdot 10^{-3} = 6000$V

$= 6$kV

Minimum potential difference = ~~[illegible]~~ 6kV
6000V

ResultsPlus
Examiner Comments

A few candidates gave their answer in kV which is fine but ensure the unit is included.



0.2cm = 0.0002

distance between parallel plates = 2.0mm

$E = \frac{V}{d}$ $3 \times 10^6 = \frac{V}{0.0002}$

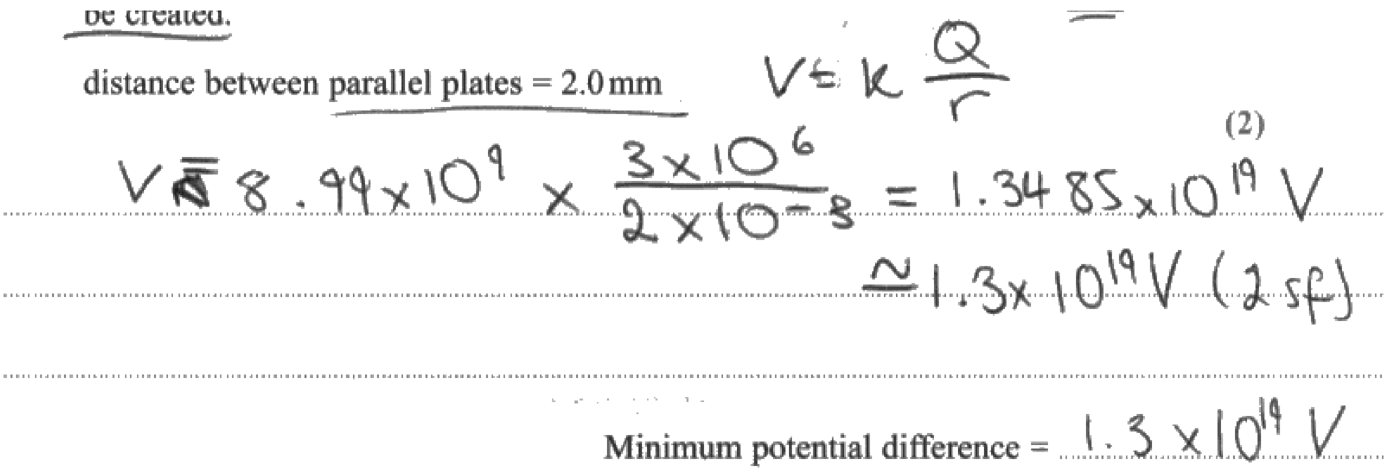
$V = 3 \times 10^6 \times 0.0002$

$V = 600$ V

Minimum potential difference = 600V

ResultsPlus
Examiner Comments

A few candidates did not convert mm correctly into m. This lost MP2.



be created.

distance between parallel plates = 2.0 mm

$V = k\frac{Q}{r}$

(2)

$V = 8.99\times10^{9} \times \frac{3\times10^{6}}{2\times10^{-3}} = 1.3485\times10^{19}$ V

$\simeq 1.3\times10^{19}$ V (2 sf)

Minimum potential difference = 1.3×10^{19} V

ResultsPlus
Examiner Comments

A few candidates tried to use the equations for radial electric fields.

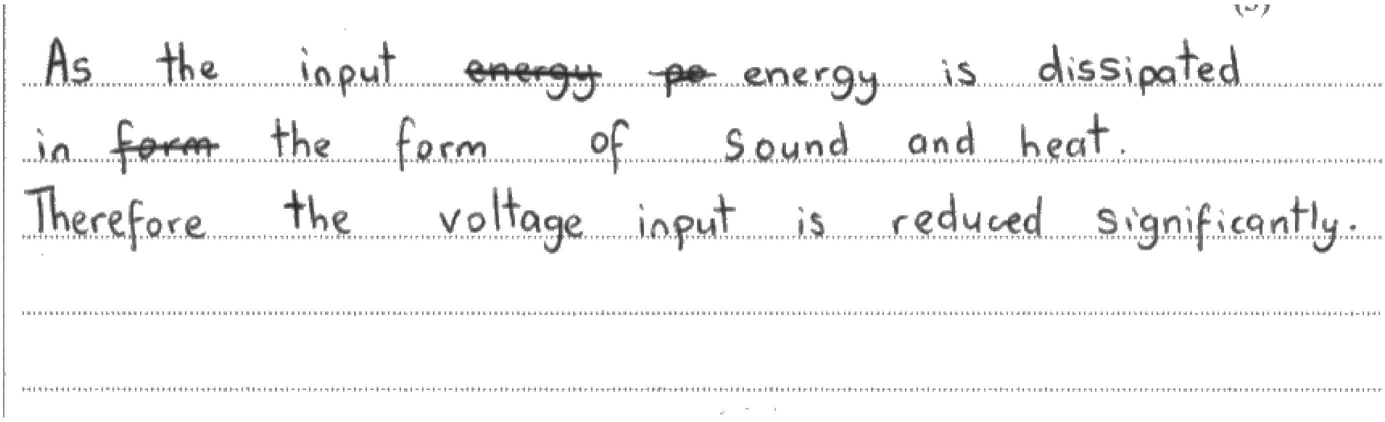
Question 15 (b)(ii)

This question examined the consequences of the power supply having a large internal resistance. An efficient way to answer this question was to refer to $V = E - Ir$.

The first mark was to point out that a current flows in the circuit when there is a spark.

The current will produce a potential difference across the internal resistance (sometimes called lost volts). The Ir in the equation above.

The terminal potential difference (V in the equation above) will decrease or be less than the emf of the power supply.



As the input ~~energy~~ ~~po~~ energy is dissipated in ~~form~~ the form of sound and heat. Therefore the voltage input is reduced significantly.

ResultsPlus
Examiner Comments

A significant number of candidates tried, unsuccessfully, to answer the question in terms of energy.

(3)

- The circuit is closed when sparks form current can flow
- air has very high resistance so when sparks occur ↑ Resistance ↑ p.d across air.
- when resulting in the voltmeter reading low p.d. and the significant internal resistance takes up alot of the p.d as well as $R \propto V$

(Total for Question 15 = 10 marks)

ResultsPlus
Examiner Comments

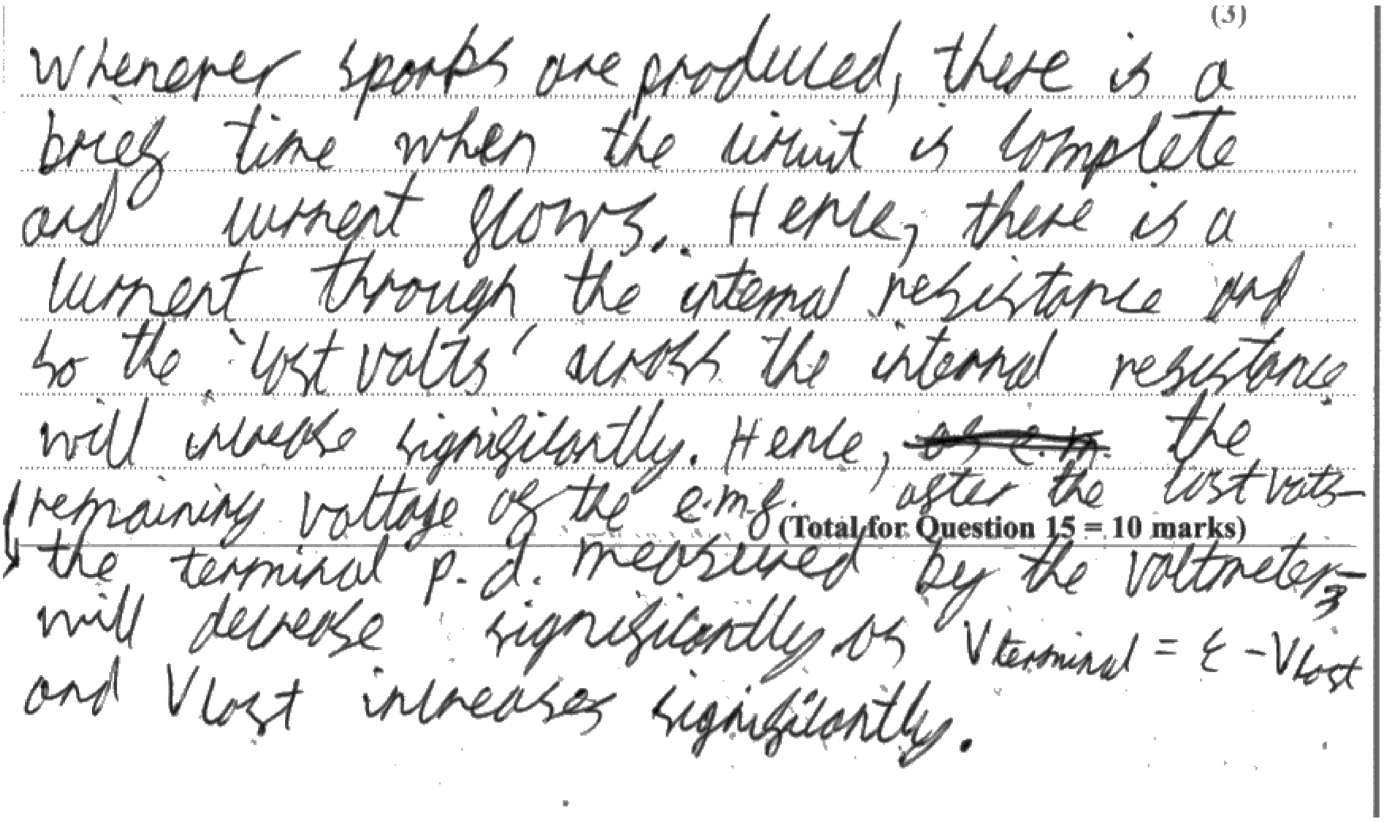
Many candidates conveyed the idea of a current flowing for MP1.

(3)

When sparks are produced electrons are jumping from one plate to the other. This causes a current to form on both sides. V = IR so as I increases on the second plate the potential difference between the two sides of the circuit decreases.

ResultsPlus
Examiner Comments

A flow of charge or electrons could also gain MP1.



(3)

Whenever sparks are produced, there is a brief time when the circuit is complete and current flows. Hence, there is a current through the internal resistance and so the 'lost volts' across the internal resistance will increase significantly. Hence, ~~of e.m.~~ the remaining voltage of the e.m.f. after the lost volts – the terminal p.d. measured by the voltmeter – will decrease significantly as $V_{terminal} = \varepsilon - V_{lost}$ and V_{lost} increases significantly.

3

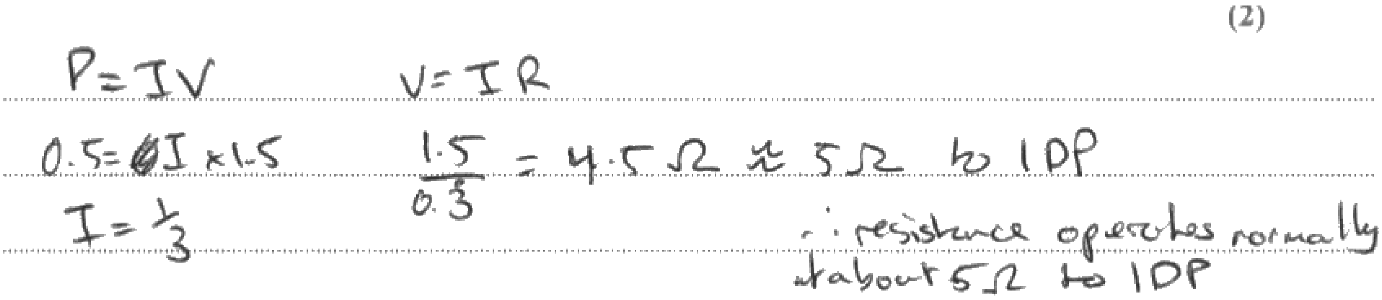
(Total for Question 15 = 10 marks)

ResultsPlus
Examiner Comments

This is a very good answer which conveys all three-mark points succinctly.

Question 16 (a)

This "show that" question was completed successfully by almost all the candidates. In a "show that" question you must present the answer to one further significant figure than the value given in the question. You must also show your substitutions into an equation.



(2)

$P = IV$ $V = IR$

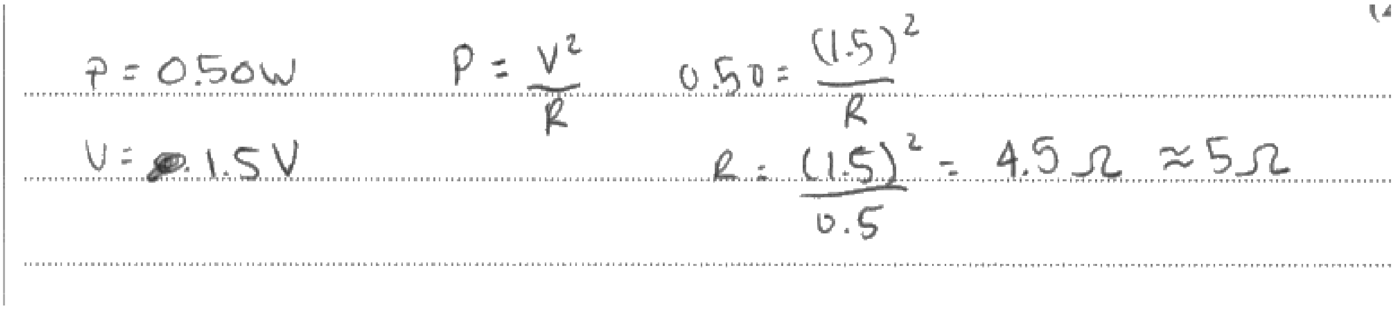
$0.5 = I \times 1.5$ $\frac{1.5}{0.3} = 4.5\,\Omega \approx 5\,\Omega$ to 1DP

$I = \frac{1}{3}$

∴ resistance operates normally at about $5\,\Omega$ to 1DP

ResultsPlus
Examiner Comments

This method of calculating the current then using *V* = *IR* is fine.



$P = 0.50\text{W}$ $P = \frac{V^2}{R}$ $0.50 = \frac{(1.5)^2}{R}$

$V = 1.5\text{V}$ $R = \frac{(1.5)^2}{0.5} = 4.5\,\Omega \approx 5\,\Omega$

ResultsPlus
Examiner Comments

Most candidates used $P = V^2/R$ and showed their substituted values for full credit.

Question 16 (b)

This is the indicative content question. It examined a potential dividing circuit called a potentiometer. A potentiometer is usually a length of wire (a resistance) along which a slider makes contact and can be moved from one end to the other. A bulb is connected to the output (the slider) of the potentiometer.

When both terminals of the bulb are connected at end A there will be zero potential difference across the bulb, and it will be unlit or off. IC1.

When one terminal of the bulb is at A and the other end is at B there will be 1.5 V across the bulb, and it will be on and lit normally. IC2 and 3.

As the slider is moved from A to B the brightness of the bulb will increase because the potential difference across the bulb increases. IC4 and 5.

The bulb is in parallel with the section of the potentiometer between end A and the slider. The resistance of this section of the potentiometer is high compared with the bulb. When two unequal resistors are connected in parallel the overall resistance tends towards the resistor with the lowest value, in this case the bulb. The other part of the potentiometer between the slider and end B can be thought of as in series with the bulb. This section has a high resistance compared to the bulb and so will have a high potential difference across it compared to the bulb.

This means that for much of the movement of the slider from A to B the bulb would be off and only come on as the slider moves close to A.

IC6 was given for any sensible explanation that referred to part of the circuit's resistance and how it would change as the slider moves.

The filament bulb is connected to the potentiometer slider. Moving from A to B will see an increase in resistance in the potentiometer. This changes the ratio at which ~~voltage~~ ~~current~~ current is shared across them. As moving from A to B will see an increase resistance across it, the brightness of the filament bulb decreases. This is due to more current being shared to the potentiometer as the slider moves from A to B.

ResultsPlus
Examiner Comments

This candidate needed to be more specific. The resistance of the potentiometer is constant. The section between end A and the slider will increase as the slider moves to B. "The current is shared between them" is not clear. The brightness of the bulb will increase as the slider moves to B.

The potentiometer creates a parallel circuit with a variable resistor on the other branch essentially. As the slider moves more towards B, less of the resistor is in series, meaning the outside part gets a lower ratio of the total p.d, since its resistance decreased and V=Ir. This means the part inside the parallel branch has a higher resistance and so a ~~greater~~ lower ratio of current than the light bulb. However both branches ~~are~~ in parallel have the same total voltage, which has now increased since the resistance outside has decreased, this means the light bulb has become brighter as the slider moved towards B; and so will become dimmer if moved towards A.

ResultsPlus
Examiner Comments

This a good attempt at IC6. The candidate describes the nature of the circuit and how it will change as the slider moves.

The answer gains IC4,5 and 6.

However, the answer doesn't explicitly state what happens at A and B.

(6)

~~As the~~ ~~The p~~ When the potentiometer Slide starts at A, the brightness of the filament lamp will be very dim. As the ~~s~~ Slider is moved towards B the brightness increases proportionalall with luminosisty against potential difference. When the Slider reaches B, the ~~potent~~ brightness of lamp will be at its brightest, due to a maximum Supply of potential difference (terminal p.d.) This may not be equal to the emf due to internal resistance & lost volts.

ResultsPlus
Examiner Comments

Many candidates used phrases like "at A the bulb will be dim". This is incorrect the bulb will be off. This answer does get IC2,3 and 4.

ResultsPlus
Examiner Tip

There is difference between a potential divider (or potentiometer) circuit which just shows an output arrow between A and B and this one which has a connection to a bulb.

When the arrow (or output) only is shown the explanation is straightforward. The potential increases linearly from A to B as the length of wire between A and the slider increases.

When a bulb is added the circuit is more complex. It should now be thought of as two series resistors either side of the slider (the potentiometer) with the bulb in parallel with the resistor to the left of the slider. The potential will no longer increase linearly.

~~as the point when slider is at A, the resistance of the~~ ~~the bulb is~~ the brightness increases Because as the slider moves from A to B, the resistance across the portentiometer increases ~~so the resistance~~ So the resistance across the filament bulb is smaller ~~so~~ $I = \frac{V}{R}$ so as resistances decreases the current through the filament bulb increases which increases the brightness.

ResultsPlus
Examiner Comments

This type of answer was commonly seen. IC4 and 5 given.

(6)

At point A, the potential difference of the ~~circuit~~ lamp is 0 therefore the bulb will have no (minimum) brightness. This is because resistance of potentiometer at that point is 0 ~~as~~ so no work is done (~~p.d. not~~ potential difference not shared). As the slider moves from A to B, the length of the wire increases therefore R resistance also increases as $R = \frac{\rho L}{A}$. This means lamp requires a higher share of p.d. therefore p.d. across it increases. As a result, brightness of the lamp increases as it is moved along. At point B, the potential difference of the lamp is equal to that of the power supply (1.5V). Resistance of potentiometer at the maximum therefore p.d. shared at a maximum so the brightness of the ~~lamp~~ bulb is at ~~the~~ its maximum at point B. The resistance of lamp (5Ω) very low compared to resistance of potentiometer so it barely effect the share of p.d. provided to the bulb.

ResultsPlus
Examiner Comments

This answer gains IC1 for the potential difference across the bulb is 0 when the slider is at A. It then gains IC4 and 5 as the slider moves to B the bulb gets brighter etc. It also gains IC2 and 3 for describing the bulb having maximum brightness at B because it will be at 1.5 V.

It didn't get IC6 because it doesn't describe any specific aspect of the circuit's resistance and how it will change.

As the slider moves from A to B the brightness of the bulb increases because as the slider moves from A to B the resistance in the parallel section with the bulb increases (resistance is proportional to length) which gives the parallel section a larger share of the resistance in the circuit and hence a larger share of the P.D. in the circuit and since the P.D in parallel branches must be the same this increases the P.D. across the bulb which makes it appear brighter. When the slider is at A the bulb will be off because the branch parallel to the bulb has no resistance (so P.D. across bulb will be 0V) and at B it will be at its brightest with the P.D. across being its maximum of 1.5V (emf of the cell).

ResultsPlus
Examiner Comments

This gains all six IC points.

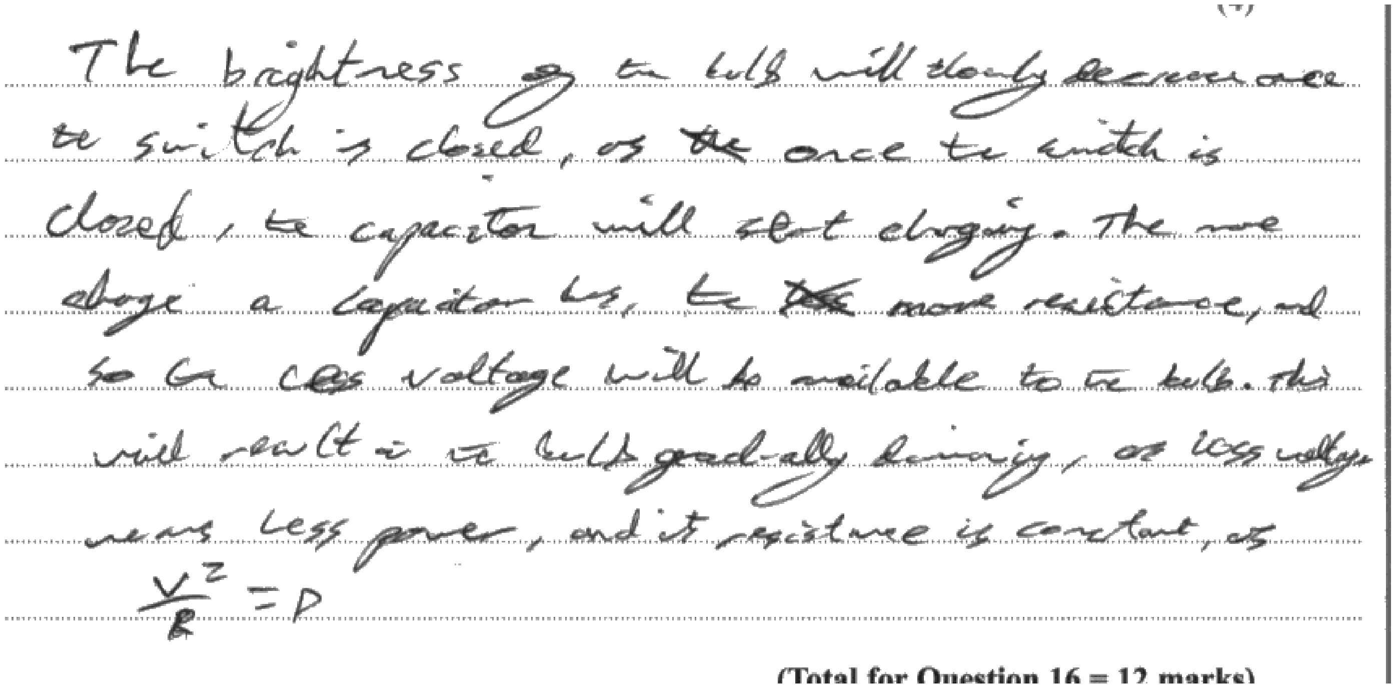
Question 16 (c)

This question is about charging a capacitor connected in series with a bulb. When the switch is closed there will be 0 V across the uncharged capacitor and therefore 1.5 V across the bulb as they are in series.

The bulb will be initially at normal brightness.

As the capacitor charges the potential difference across it increases. Therefore, the potential difference across the bulb decreases as does its brightness.

This will be an exponential decrease, or candidates could calculate the time constant for MP4.



(4)

The brightness of the bulb will slowly decrease once the switch is closed, as ~~the~~ once the switch is closed, the capacitor will start charging. The more charge a capacitor has, the ~~the~~ more resistance, and so the less voltage will be available to the bulb. this will result in the bulb gradually dimming, as less voltage means less power, and it resistance is constant, as

$\frac{V^2}{R} = P$

(Total for Question 16 = 12 marks)

ResultsPlus
Examiner Comments

This gained MP3 as the answer states that the capacitor is charging, and the brightness of the bulb will decrease.

(4)

The Capacitor will Start to charge and Store charge. the voltage ope the Capacitor will exponentially increase to the max and the current around the circuit will exponentially decay until pd of Capacitor = pd of Source ie 1.5V. V of source = 1.5V = Pd of Capacitor + pd of bulb ∴ as Capacitor charges pd of Bulb decrease from 1.5V exponentially to 0V and current through exponentially decreases as well as in series. P = IV as

(Total for Question 16 = 12 marks)

current and voltage of bulb both exponentially ~~decrease to~~ decreases 0 the power ∴ brightness will also decrease exponentially to 0 ∴ When switch closed Capacitor charges ∴ bulb will get exponentially dimmer and less bright.

ResultsPlus
Examiner Comments

This answer is a good explanation of the circuit once the switch is closed. However, it doesn't answer the question clearly, which was about the brightness of the bulb.

However, it gained MP1,3 and 4.

(4)

- When the switch is closed, the capacitor will begin to charge
- ~~This to~~ The capacitor has a 2 plates with an insulator dielectric between them, so no electrons can flow through it
- The capacitor will charge at an exponentially decreasing rate until it reaches 1.5V.
- As the capacitor charges, the current across the circuit exponentially ~~de~~ decreases
- So the bulb's brightness will exponentially decrease ~~over~~ once the switch is closed, until the capacitor is fully charged, when it will be dark as no V across it. As the capacitance is 1.2F, It will take 5×1.2×5 = 30 seconds for the capacitor to charge fully, so the bulb will be off after 30 seconds

(Total for Question 16 = 12 marks)

ResultsPlus
Examiner Comments

This answer concentrates on the capacitor rather than the brightness of the bulb.

This answer still gains MP3 and 4.

(4)

Initially the bulb will be at 1·5V and the brightest as Rcapacitor=0, Capacitor charges exponentially and builds up charge on one side of the plate. This causes the resistance of capacitor to increase and when charge reaches its maximum R is so high that potential difference in capacitor = 1·5V so 0V in bulb ~~so~~ ~~brig~~ so it doesn't light up

(Total for Question 16 = 12 marks)

ResultsPlus
Examiner Comments

This answer does concentrate on the brightness of the bulb. It gained MP1,2 and 3.

Question 17 (a)

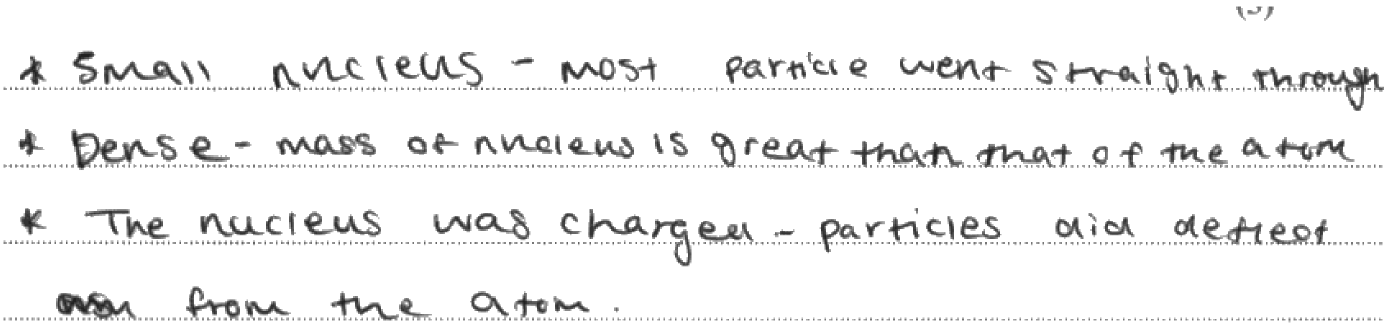
This question asked for the model of the atom that Rutherford proposed not the results of the scattering experiment.

There are three marks:

The atom is mainly empty space.

There is a dense centre (the nucleus) which is charged.

This centre (nucleus) is very small compared to the atom.



* Small nucleus - most particle went straight through

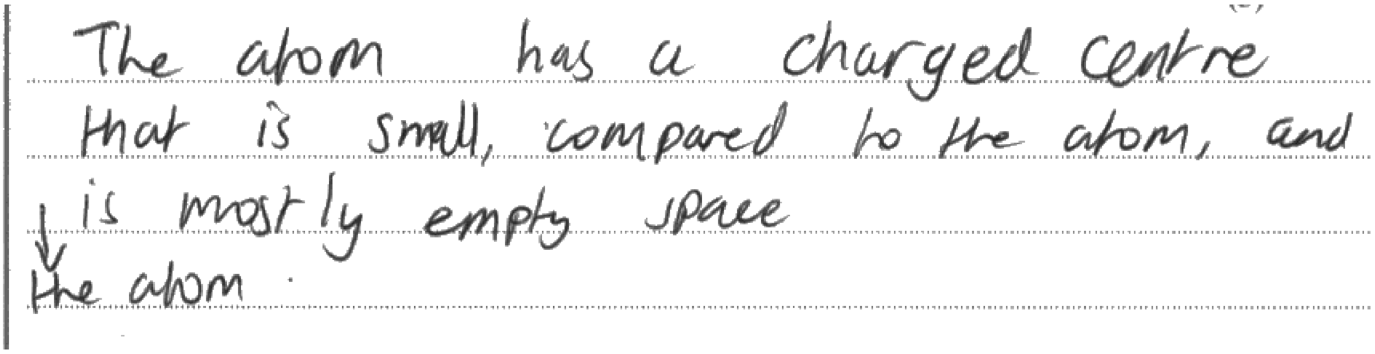
* Dense - mass of nucleus is great than that of the atom

* The nucleus was charged - particles did deflect from the atom.

ResultsPlus
Examiner Comments

This answer gained MP2 for dense, charged nucleus.

To gain Mp3 it needs to say small compared to the size of an atom.



The atom has a charged centre that is small, compared to the atom, and is mostly empty space the atom.

ResultsPlus
Examiner Comments

This answer gains MP1.

It has a small concentrated, positively charged nucleus.
It is mostly made up of empty space.

ResultsPlus
Examiner Comments

This gains MP1 and 2

Most α particles passed straight through the foil, showing that the atom is mostly empty space. Some α particles were deflected by a small amount, showing that the atom's mass was concentrated in a small, massive charged nucleus. ~~A~~ very few α particles were deflected by more than 90°, showing the small dense nucleus has a positive charge.

ResultsPlus
Examiner Comments

This answer tells us about the experimental results so wastes time.

It gains MP1 and 2.

(3)

- atom is mostly empty ~~sap~~ space
- almost all mass of the atom is concentrated in the nucleus
- very small charged nucleus

ResultsPlus
Examiner Comments

This gains MP1 and 2.

It is not sufficient to say the nucleus is very small. An atom is very small.

The atom consists mostly of empty space.
Nucleus is very small (about 1/1000 times the size of atom).

Nucleus is very dense and is positively charged.

ResultsPlus
Examiner Comments

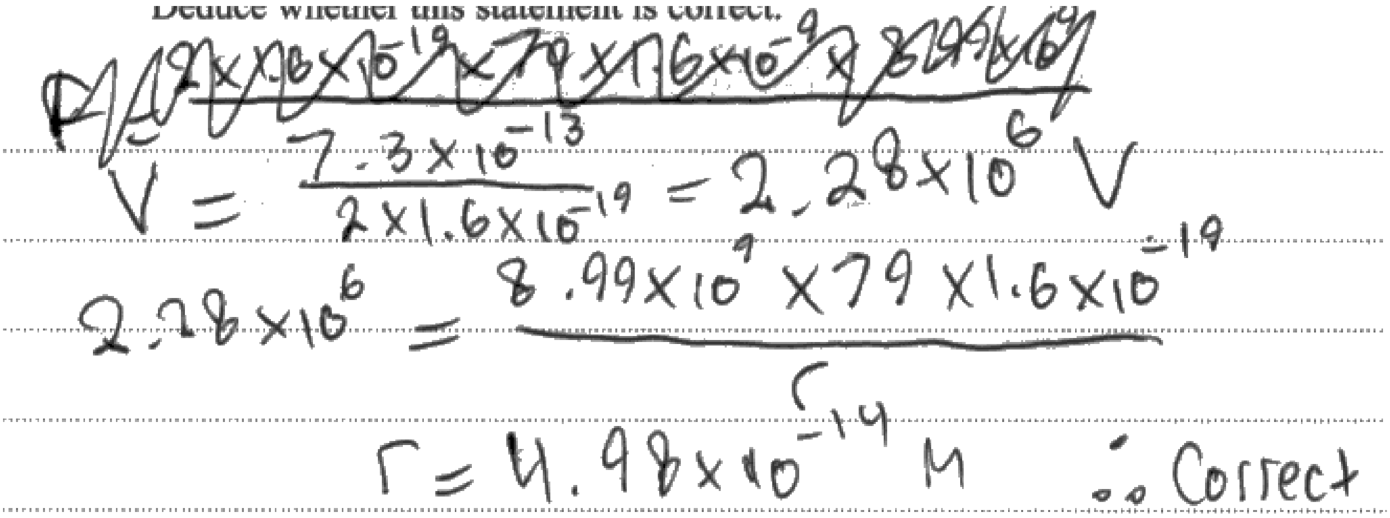
This gains all three marks. Note that the ratio 1/1000 times smaller is actually incorrect. It is 1/10000. However, the answer conveys the comparison of the nucleus being much smaller than an atom for MP3.

Question 17 (b)(i)

This question examines the use of the electrical potential equation.

It asked you to check whether the closest distance of approach of an alpha particle to a nucleus of gold was a particular distance.

The charge on an alpha particle is 2*e* and the charge on the gold nucleus is 79*e*.



Deduce whether this statement is correct.

[illegible]

$V = \frac{7.3 \times 10^{-13}}{2 \times 1.6 \times 10^{-19}} = 2.28 \times 10^{6}$ V

$2.28 \times 10^{6} = \frac{8.99 \times 10^{9} \times 79 \times 1.6 \times 10^{-19}}{r}$

$r = 4.98 \times 10^{-14}$ M $\therefore$ Correct

ResultsPlus
Examiner Comments

This answer illustrates a correct method.

The candidate calculates the potential at the point where the alpha particle would be brought to rest.

The candidate then calculates the distance from the gold nucleus for this potential. This then gives the value of distance given in the question.

Many candidates combined the two equations into one: $V = kQ_1Q_2 / r$ which was equally correct.

ResultsPlus
Examiner Tip

Some candidates made a simple arithmetic error with their calculator so that the answer was incorrect.

To gain mark point 1 the substitutions need to all be shown ie including 8.99 x 10^9 or the value of e_0.

$E_k = qV$ [illegible]

$$V = \frac{E_K}{q} = \frac{7.3 \times 10^{-13}}{(2 \times 1.6 \times 10^{-19})} = 2281250\,\text{ms}^{-1}$$

ResultsPlus
Examiner Comments

This answer looks as if it should gain MP2 (correct charge on the alpha particle) and MP3, the use of $W = qV$.

However, this candidate thinks V is a velocity so loses MP3 but still gains MP2.

$E = \frac{1}{2}mv^2$ $\qquad$ $E = \frac{Q.Q_2}{4\pi\varepsilon_0 r}$

~~[illegible]~~

~~[illegible]~~

~~[illegible]~~

$\therefore \frac{1}{2}mv^2 = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$

$\frac{1}{2}(4\times1.6\times10^{-19})\times v^2 = \frac{(2\times1.6\times10^{-19})\times(79\times1.6\times10^{-19})}{5.0\times10^{-14}}\times8.99\times10^9$

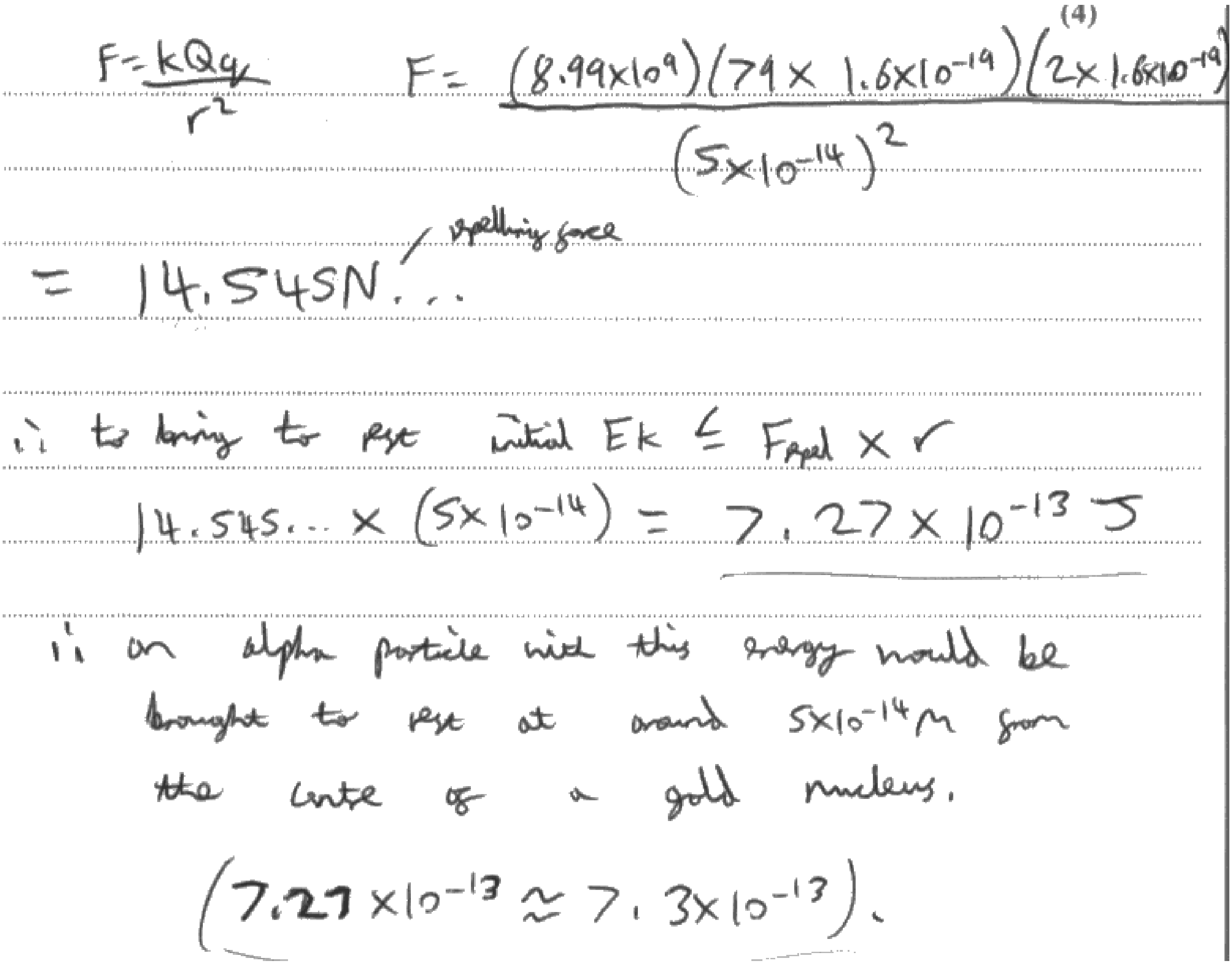
$\therefore v^2 = 2.27\times10^6 \quad \therefore v = 1507.5\,\text{ms}^{-1}$ (1dp) $\neq 0\,\text{ms}^{-1}$ ∴ <u>No, not correct</u>

ResultsPlus
Examiner Comments

A number of candidates used the equation for kinetic energy rather than substituting the value given in the question.

This will, if used correctly, predict the velocity of the alpha particle when it was outside the gold atom. However there is no value of this given in the question.

There is also an error in the mass substituted in this answer.



(4)

$F = \frac{kQq}{r^2}$ $F = \frac{(8.99\times10^{9})(79\times 1.6\times10^{-19})(2\times1.6\times10^{-19})}{(5\times10^{-14})^2}$

$= 14.545N...$ / repelling force

∴ to bring to rest initial $E_k \leq F_{repel} \times r$

$14.545... \times (5\times10^{-14}) = 7.27\times10^{-13}$ J

∴ an alpha particle with this energy would be brought to rest at around 5×10^{-14} m from the centre of a gold nucleus.

$(7.27\times10^{-13} \simeq 7.3\times10^{-13})$.

ResultsPlus
Examiner Comments

The force between two point charges varies with distance so applying the equation work = force x distance is incorrect physics.

This answer still gains MP2 for correct charge on either gold or the alpha particle.

Question 17 (b)(ii)

The most straightforward way to do this question was to use the equation $E_k = p^2 / 2m$

The mass of an alpha particle can be approximated to 4 x amu or 4 x mass of a proton.

It was not uncommon to see the omission of the unit to this answer.

(3)

$\sqrt{\frac{7.3\times10^{-13}\times2}{1.67\times10^{-27}}} = v = 2.96\times10^{7}\,ms^{-1}$

$\times 1.67\times10^{-27}$

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

$= 4.9$[illegible]$\times 10^{-20}\,kgms^{-1}$

$p = mv$

$\sqrt{\frac{KE\times2}{m}} \times m = p$

Initial momentum = $4.9\times10^{-20}\,kgms^{-1}$

ResultsPlus Examiner Comments

This error occurs because the mass is 4 x 1.67 x 10^{-27} kg.

(3)

$E_k = \frac{p^2}{2m}$

$2m \times E_k = p^2$ $\qquad p = \sqrt{2E_k m}$

$p = \sqrt{2 \times 7.3\times10^{-13} \times 4 \times \cancel{1.66\times10^{-27}}\ 1.67\times10^{-27}}$

$= 9.88\times10^{-20}$

Initial momentum = 9.88×10^{-20}

ResultsPlus Examiner Comments

Omission of the unit.

(3)

$$\frac{p^2}{2m} = 7.3\times10^{-13}$$

$$p^2 = (7.3\times10^{-13})(8\times1.67\times10^{-27})$$

$(mv)^2$ = ~~6.983×10^{-20}~~ 9.8756×10^{-20}

Initial momentum = 9.9×10^{-20} kg ms^{-1}

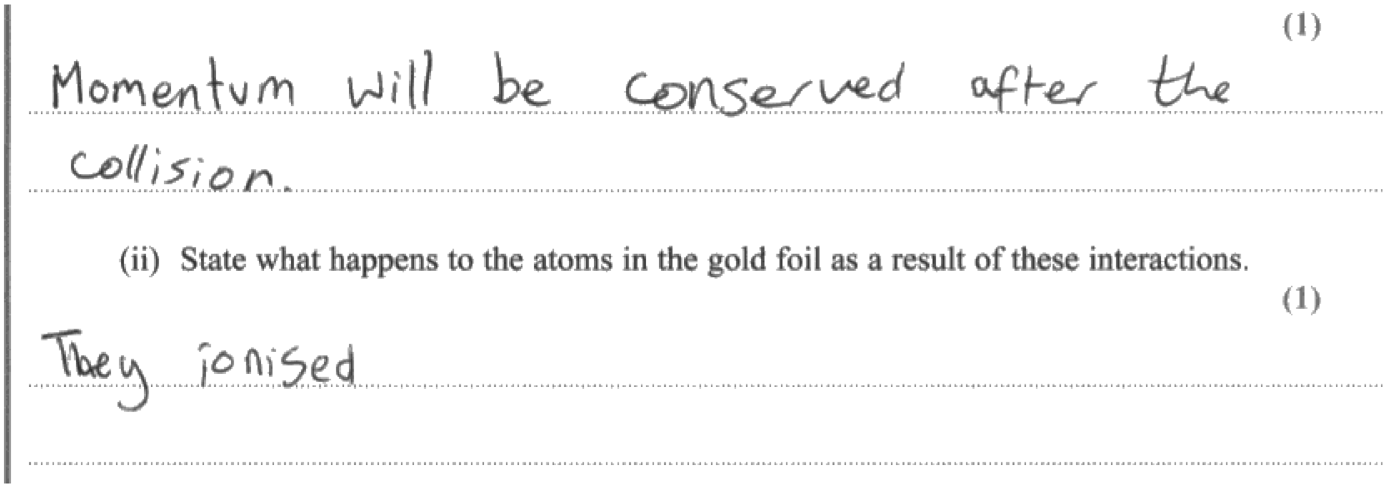
ResultsPlus
Examiner Comments

A fully correct method and answer with unit.

Question 17 (c)(i-ii)

In c(i) the candidates had to recall that an elastic collision means that the total kinetic energy is conserved.

In c(ii) the candidates had to offer a sensible possibility.



(1)

Momentum will be conserved after the collision.

(ii) State what happens to the atoms in the gold foil as a result of these interactions.

(1)

They ionised

ResultsPlus
Examiner Comments

(i) No mention of kinetic energy conservation.

(ii) A common error.

$m_1u_1 = m_1v_1 + m_2v_2$ $\quad - m_2v_1$

(i) An elastic interaction occurs and the alpha particle recoils. $(p_2 = m_1u_1 - m_1v_1)$

State what is meant by an elastic interaction.

(1)

Elastic interaction is a ~~et~~ collision where both kinetic energy and momentum are conserved.

(ii) State what happens to the atoms in the gold foil as a result of these interactions.

(1)

gold foil atoms will ~~the~~ ~~move off~~ gain kinetic energy and move off with the change of momentum of the alpha particles.

ResultsPlus
Examiner Comments

(i) Correct

(ii) Idea that the gold atoms or nuclei would move.

State what is meant by an elastic interaction.

(1)

kinetic energy is conserved

(ii) State what happens to the atoms in the gold foil as a result of these interactions.

(1)

They experience an electrostatic force of repulsion
they move in opposite direction to alpha particle

ResultsPlus
Examiner Comments

(i) Correct

(ii) Idea that they would move gains MP1.

Question 18 (a)

This question examined the use of Faraday's and Lenz's laws.

MP1 and 2 are about applying Faraday's laws to this situation.

MP3 (and 4) was about applying Lenz's law to this situation which proved more challenging.

Lenz's law tends to be learnt rather than understood. A lot of answers didn't make sense, many candidates saying things like "direction of emf opposed the direction of motion".

As the coil rotates, the motor effect is induced as the coil interacts with the magnetic field. The copper rings make sure the coil kn changes direction every half turn. The current produced is supplied back to the power transmission system through the carbon blocks.

ResultsPlus
Examiner Comments

This candidate has misinterpreted the diagram. It is not about a motor effect – it is about the dynamo effect.

with the rings as they rotate.

(a) Describe how this arrangement can be used as a regenerative brake.

$$\varepsilon = -\frac{d(N\phi)}{dt}$$

(4)

AS the coil rotates with the wheels ~~on~~ the train and the coil rotates within the magnetic field there is a chage in magnetic flux linkage which leads to an induced e.m.f (Faraday's law). Due to Lenz's law there will also be a force that acts in the opposite direction to the induced e.m.f. , so this force slows down and eventually stops the coils rotating which will also slow the wheels of the train down (they're connected) therefore acting as a regenerative brake.

ResultsPlus
Examiner Comments

This gains MP1 and 2 for a good application of Faraday's law.

A force cannot act in the opposite direction to a potential difference. They are two different quantities.

(4)

- The rotation of the coil, causes a change in magnetic flux linkage
- this change, due to Faradays and Lenz's laws $\mathcal{E} = -\frac{d(N\phi)}{dt}$, causes an induction of EMF in the coil ~~to~~ and its motion is so to oppose the change in magnetic flux linkage
- this induced emf, ~~induces~~ has a current and this current causes a force on the coil, which opposes its rotation
- this force will slow down the rotation of the coil, which ~~the~~ will slow down the wheels

ResultsPlus
Examiner Comments

This is a good answer. It gains MP1 and 2 for applying Faraday's law.

It gains MP3 for correctly quoting Lenz's law to this situation: "its motion is such to oppose the change in flux linkage".

This explains why the coil (and wheels) will slow down.

- As the coil rotates, there is a change in flux linkage.
- The rate of change of flux linkage induces an EMF in the coil.
- ~~The EMF~~ This EMF allows for current to be ~~[illegible]~~ induced in the coil which will create a force acting perpendicular to the field.
- By Lenz's law, the EMF induced will oppose the change that is producing it as to conserve energy.
- Therefore this opposes the rotation of the coil which slows the vehicle.

ResultsPlus
Examiner Comments

MP1 and 2 given for applying Faraday's law.

MP3 given for a good attempt to apply Lenz's law to this situation.

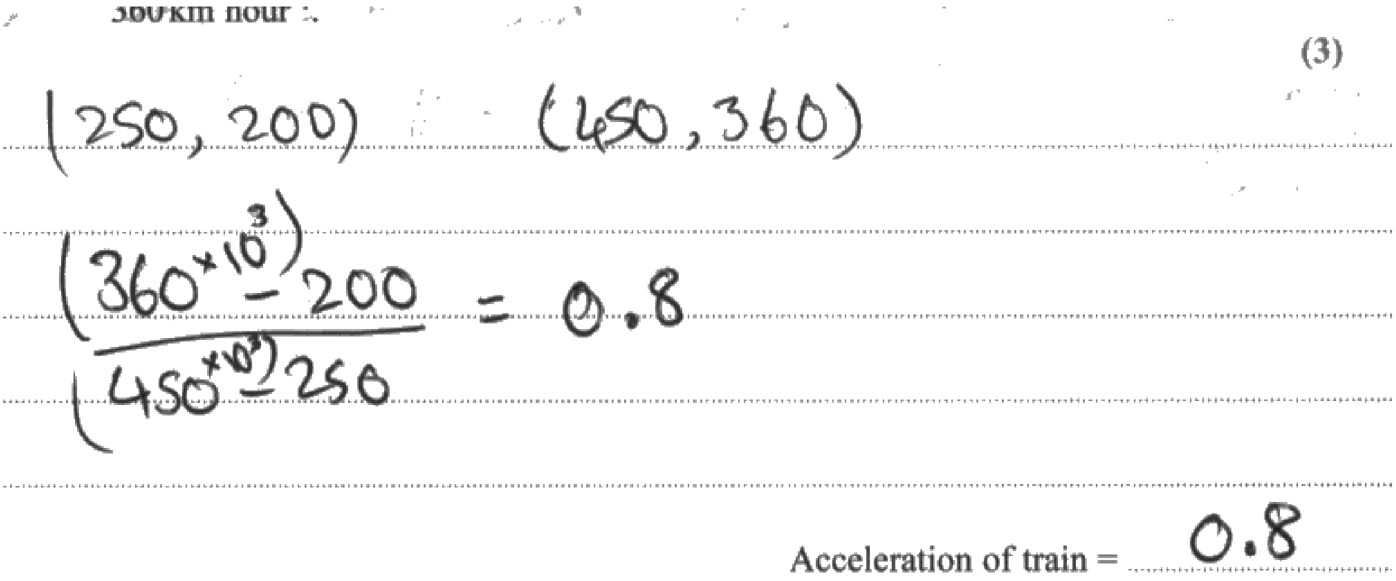
"The emf induced will oppose the change that created it....to conserve energy"....is a very decent attempt to articulate Lenz's law to this situation.

It would have been improved by "The direction of the induced current...."and would then have flowed naturally from the previous sentence.

Question 18 (b)(i)

This question was primarily aimed at interpreting a velocity time graph to determine acceleration.

Most candidates determined the gradient, but some forgot to convert either the units of velocity to m s^{-1} or time to hours.



360km hour

(3)

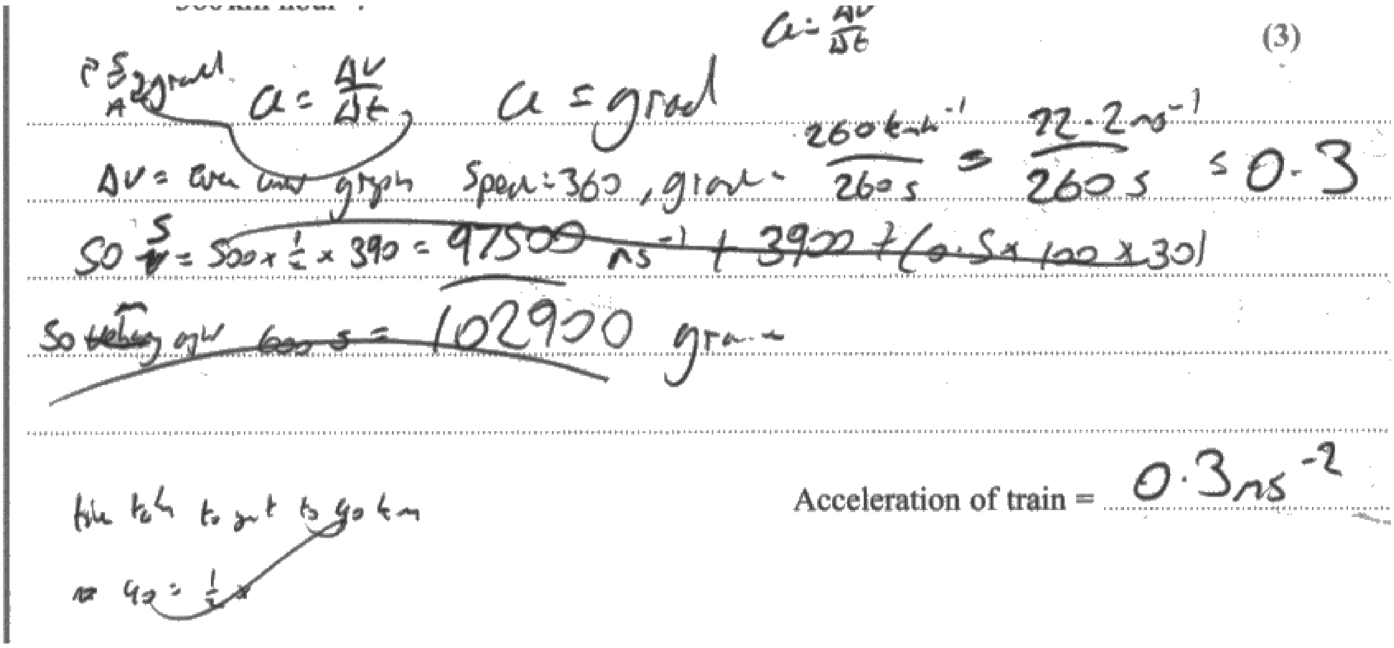
(250, 200)   (450, 360)

$$\frac{(360\times10^{3}) - 200}{(450\times10^{3}) - 250} = 0.8$$

Acceleration of train = 0.8

ResultsPlus
Examiner Comments

This correctly determines the gradient but does not convert either unit.



$a = \frac{\Delta v}{\Delta t}$

(3)

s = grad $a = \frac{\Delta v}{\Delta t}$, a = grad

Δv = area under graph Speed = 360, grad = $\frac{260\,\text{kmh}^{-1}}{260\,\text{s}} = \frac{72.2\,\text{ms}^{-1}}{260\,\text{s}} = 0.3$

~~So s = 500 × ½ × 390 = 97500 ms⁻¹ + 3900 + (0.5 × 100 × 30)~~

~~So taking over 600 s = 102900~~ gra

Acceleration of train = $0.3\,\text{ms}^{-2}$

~~the time to get to 90 km~~

~~40 = ½~~

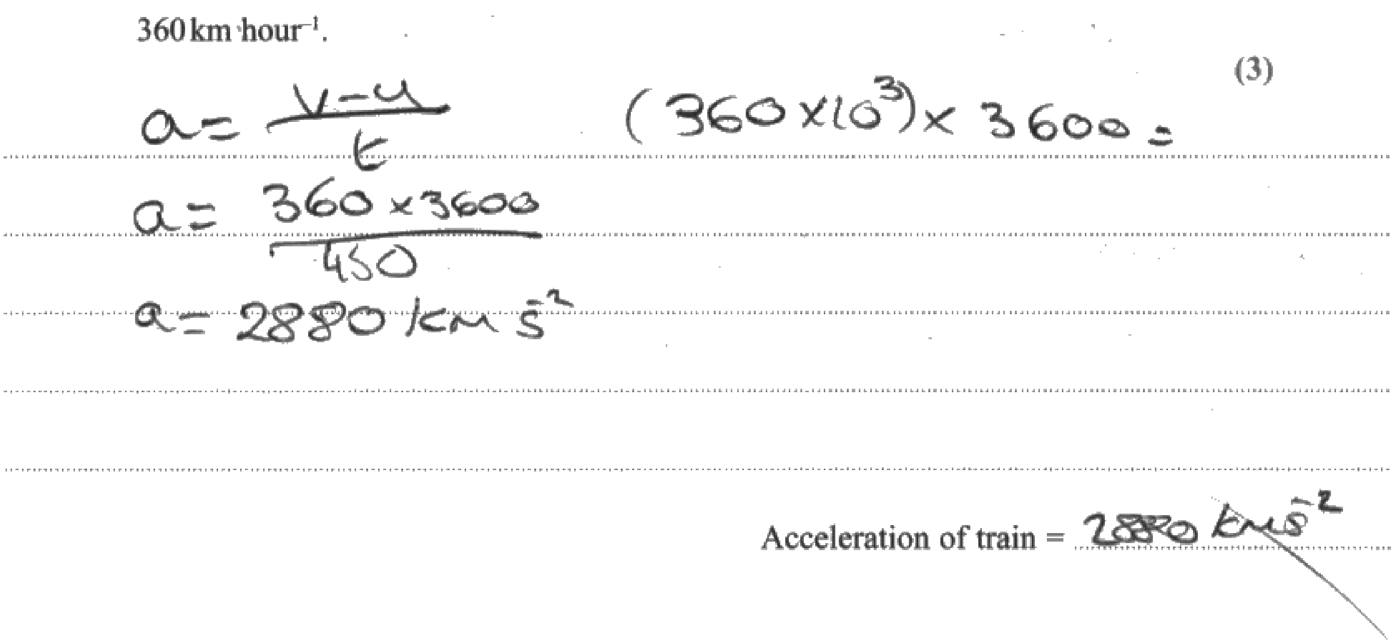
ResultsPlus
Examiner Comments

A few candidates drew a tangent that determined the instantaneous acceleration at a particular time. This answer could still gain the conversion of units MP2.

ResultsPlus
Examiner Tip

Watch out for different units on each axis of a graph. This has velocity in km h^{-1} but time in s.

One of these needs changing either to present the answer to (k)m s^{-2} or to (k)m h^{-2}



360 km hour^{-1}.

(3)

$a = \frac{v-u}{t}$ $(360 \times 10^3) \times 3600 =$

$a = \frac{360 \times 3600}{450}$

$a = 2880 \text{ km s}^{-2}$

Acceleration of train = 2880 km s^{-2}

ResultsPlus
Examiner Comments

This answer is unusual. The candidate determines the gradient for MP1.

The units are incorrectly converted so loses MP2.

Because the units were incorrectly converted the units for the answer are incorrect.

360 km hour^{-1}.

(3)

$t = 455s = \frac{91}{720}$ hrs

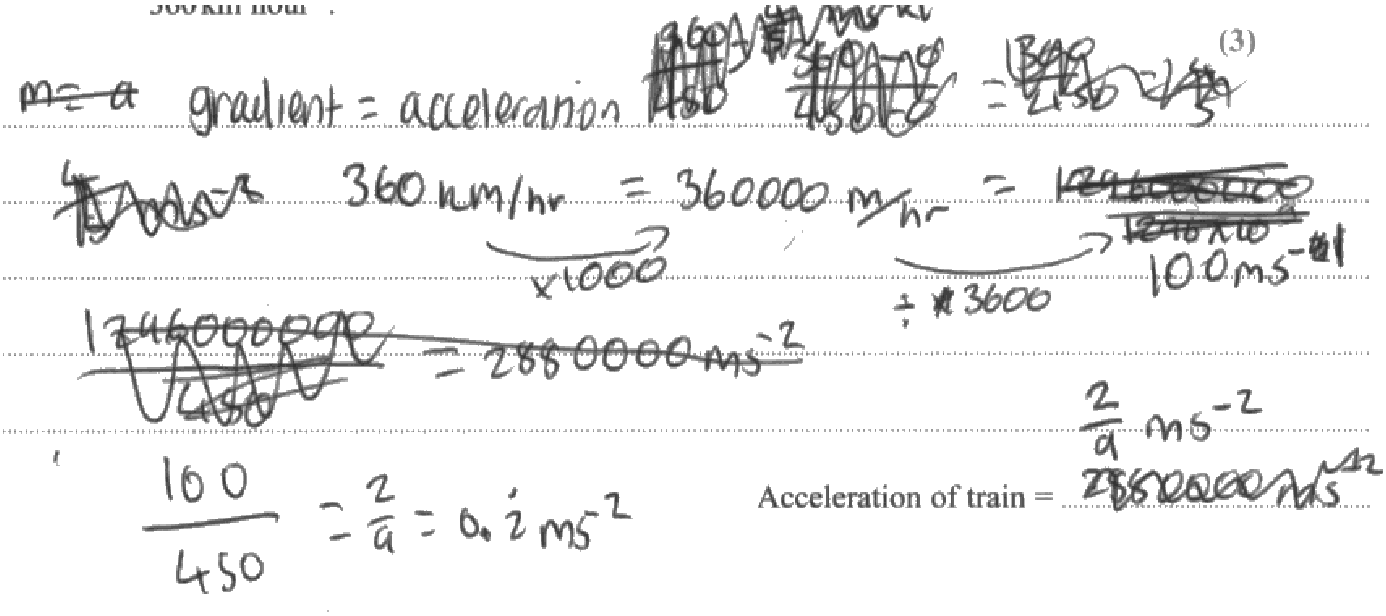
gradient $= \frac{360}{\frac{91}{720}} = 2848.35\ldots$ km hour^{-2}

Acceleration of train = 2850 km hour^{-1}

ResultsPlus
Examiner Comments

This answer correctly converts the time to hours and determines the gradient.

The units for acceleration are correctly stated within the answer space so even though they are incorrect on the answer line it still gains MP3.



(3)

~~m = a~~ gradient = acceleration ~~360/450~~ ~~[illegible]~~ ~~= [illegible]~~

~~[illegible]~~ 360 km/hr = 360000 m/hr = ~~1296000000~~ ~~1296×10~~ 100 ms^{-1}

$\times 1000$ $\div 3600$

~~$\frac{1296000000}{450} = 2880000 \text{ ms}^{-2}$~~

$\frac{2}{9}$ ms^{-2}

Acceleration of train = ~~2880000 ms^{-2}~~

$\frac{100}{450} = \frac{2}{9} = 0.\dot{2} \text{ ms}^{-2}$

ResultsPlus Examiner Comments

A fully correct answer for all 3 marks.

Note that the candidate uses a fraction on the answer line. This would normally lose the MP3 mark. In physics answers should be calculated to 2 or 3 significant figures depending on the data given in the question.

This did not lose MP3 because the value is given within the answer 0.2 recurring.

Question 18 (b)(ii)

This is a "deduce.." question. The candidates have to use the data in the graph to decide whether this train meets a specification.

There are many different approaches.

The most common was to determine the area under the graph up to a velocity of 360 km h^{-1} which is the actual distance moved by the train. This is about 22.5 km and is less than 40km, so the specification is met. Note that it is important to compare the figures when drawing a conclusion.

Another method was to use an equation of motion to determine either the distance, time or acceleration and compare.

$s = \overset{\nearrow 0}{\cancel{ut}} + \frac{1}{2}at^2$

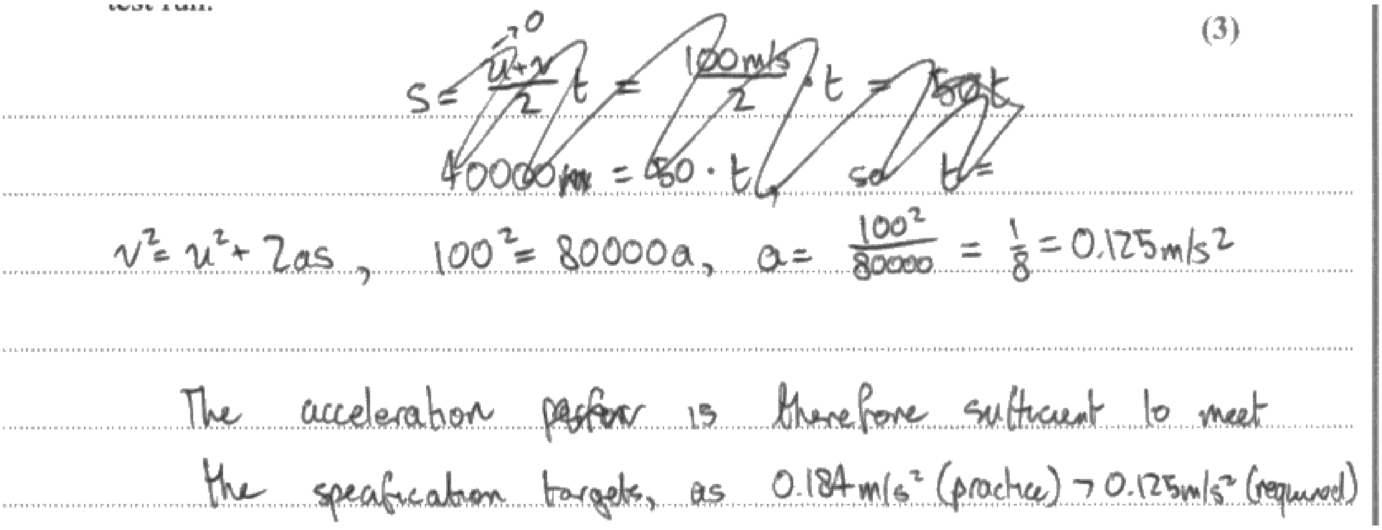
$= \frac{1}{2} \times 0.22 \times 450^2 = 22.498$ km

So takes 22.5km to accelerate

∴ meets specification

ResultsPlus
Examiner Comments

This answer uses the equation of motion s = 1/2 at^2 to correctly calculate the distance moved by the train. The candidate does not compare the answer to 40 km so loses MP3.



(3)

~~$s=\frac{\cancel{u}^{0}+v}{2}t=\frac{100m/s}{2}t=50t$~~

~~$40000m = 50 \cdot t$, so $t=$~~

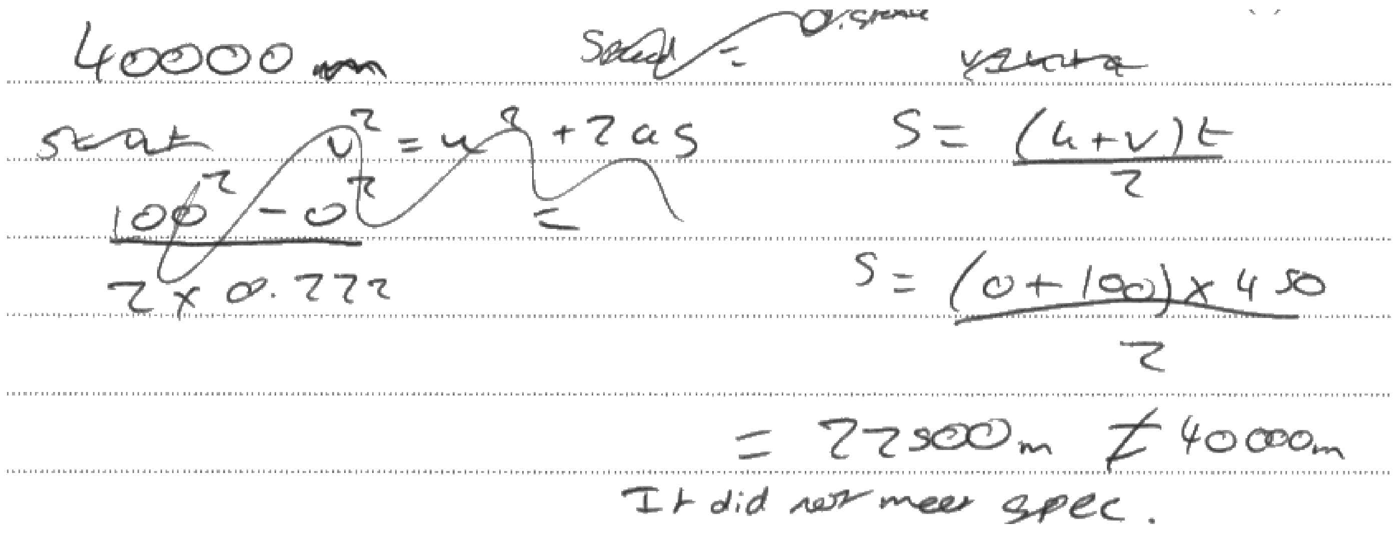
$v^2=u^2+2as$, $100^2=80000a$, $a=\frac{100^2}{80000}=\frac{1}{8}=0.125m/s^2$

The acceleration ~~perfor~~ is therefore sufficient to meet the specification targets, as 0.184 m/s² (practice) > 0.125 m/s² (required)

ResultsPlus
Examiner Comments

This candidate uses an equation of motion to correctly calculate the acceleration required to cover 40 km.

Their answer to the previous question bi was an acceleration of 0.184 which is larger than that required so the candidate correctly states that it will meet the specification for full credit.



40000 ~~m~~m ~~Speed = distance~~ ~~velocity~~

~~start~~ ~~$v^2=u^2+2as$~~

~~$\frac{100^2-0^2}{2\times 0.222}$ =~~

$s=\frac{(u+v)t}{2}$

$s=\frac{(0+100)\times 450}{2}$

$= 22500m \neq 40000m$

It did not meet spec.

ResultsPlus
Examiner Comments

This candidate uses an equation of motion to calculate the distance moved by the train for 2 marks. However, they draw the wrong conclusion.

(3)

$S = \frac{d}{t}$ ~~$340 = \frac{d}{430}$~~ ~~$340 \times 430 = d$~~

~~$d = 146200 \div 1000$~~

~~$d = 146.2$ km~~

$360 = \frac{d}{450}$

$360 \times 450 = 162000 \div 1000 = 162$ km

needed 162km not 40km

did not meet specification as it reached speed at 162km.

ResultsPlus
Examiner Comments

This candidate incorrectly calculates a distance using speed = distance/time. The train is accelerating so this equation doesn't apply.

However, they draw the correct conclusion for their value with a comparison so gain MP3.

(3)

$s = ?$

$u = 0$

$v = 100$

$a = 0.22$

t

$v^2 - u^2 = 2as$

$100^2 = 2(0.22)s$

$s = \frac{100^2}{2(0.22)}$

$S = 2.275 \times 10^4$ m

$= 22.8$ km

22.8km < 40 km ∴ yes the train does meet this.

ResultsPlus
Examiner Comments

This candidate uses an equation of motion to predict the distance covered. They add a comparison and draw the appropriate conclusion for full credit.

Question 18 (c)(i-ii)

This question examined candidates' understanding of circular motion.

(i) They are asked why there is a safe limit to the speed of a train on a curved track.

On a curved track there must be a centripetal force if the train is to continue on the track.

This force is provided by the reaction from the track on the wheels of the train.

As $F = mv^2/r$ as v increases the centripetal force required increases but the reaction force will have a limit and at this point the train will leave the track.

In (ii) the candidates have to recognise that as $F = mv^2/r$ the relationship between maximum safe speed and radius of curvature is v^2 proportional to r. This assumes that the limiting value of force between the track and wheels is constant.

(4)

When going around a curve there is a centripetal force acting on the train, there is also a frictional force acting on the train which stops it from derailing. If the train goes too fast around the curve the centripetal force will be much larger than the frictional force so the frictinal force can't counter act it and the train will derail

(ii) When the train travels at 200 km hour^{-1}, the minimum safe radius of curvature of the track is 1800 m.

Calculate the minimum safe radius of curvature for a speed of 360 km hour^{-1}.

(2)

$v = wr$

$200 = w\,1.8$

$w = 111.\dot{1}$

$v = wr$

$360 = 111.\dot{1}\,r$

$r = 3.24\,km$

Minimum safe radius of curvature = 3240 m

ResultsPlus
Examiner Comments

(i) This answer suggests there are two forces. A "centripetal force" and "friction".

This type of answer gained MP1 only.

(ii) The candidate has assumed a proportional relationship between *v* and *r*.

When a train travels on a curved track, a resultant force is required to turn this train (centripetal force). This is provided by friction, which has a maximum value. The required centripetal force is $F = \frac{mv^2}{r}$, so the ~~centripetal~~ speed ~~velocity~~ (speed) of the train as it travels around a curved track must be limited.

(ii) When the train travels at 200 km hour^{-1}, the minimum safe radius of curvature of the track is 1800 m.

Calculate the minimum safe radius of curvature for a speed of 360 km hour^{-1}.

(2)

$200 \text{ km/hr} = \frac{200000\text{m}}{3600\text{s}} = 55.56 \text{ m/s}$ $\downarrow$ 100 m/s

$F = \frac{mv^2}{r}$ $\frac{F_2}{F_1} = \frac{\frac{mv_2^2}{r_2}}{\frac{mv_1^2}{r_1}} = \frac{r_1 v_2^2}{r_2 v_1^2}$ $F_1 = F_2$

$\Rightarrow r_1 v_2^2 = r_2 v_2^2, \; r_2 = r_1 \frac{v_2^2}{v_1^2}$

$\frac{v^2}{r} = c = \frac{200^2}{1800} = 22.2..$

$r = \frac{c}{v^2} =$

Minimum safe radius of curvature = 5830 m

(Total for Question 18 = 16 marks)

ResultsPlus
Examiner Comments

(i) A good answer. The candidate makes it clear that the "friction" is the centripetal force. Friction was allowed as an alternative to reaction force.

(ii) v^2 proportional to r is used correctly.

(4)

- $F = \frac{mv^2}{r}$ There is a maximum safe speed because when travelling on a curved track there is a centripetal force.
- When the train is too fast on a track with a radius, the force overcomes the resistive frictional force between the train and the track.
- If this happens, the train could derail and crash.

(ii) When the train travels at 200 km hour^{-1}, the minimum safe radius of curvature of the track is 1800 m.

Calculate the minimum safe radius of curvature for a speed of 360 km hour^{-1}.

(2)

$F = \frac{mv^2}{r}$ $F = \frac{x(55.\dot{5}\,ms^{-1})^2}{1800}$ $\frac{m \times (100)^2}{r} = 1.7146m$

$r = 5832$

$F = 1.7146\,m$

Minimum safe radius of curvature = 5832 m

ResultsPlus
Examiner Comments

(i) This answer gains MP1 and 3. The equation and centripetal force are stated. The candidate then describes a resistive frictional force, and it could be interpreted that there are two forces rather than the frictional force is the centripetal force.

(ii) The relationship between v^2 and *r* is correctly applied.

$f = ma \quad , f = \frac{mv^2}{r}$

$\cancel{m}a \quad = \frac{\cancel{m}v^2}{r}$

- max speed = 0 acceleration
- is a train passes a certain speed its centripetal force going around the curved track would be greater than the threshold force. This would cause the train to derail off of the track

ResultsPlus
Examiner Comments

(i) This answer gains MP1 for centripetal force.

(4)

[illegible] Train is in circular motion on curved path ~~is centripetal~~ $F = \frac{mv^2}{r}$ r is radius of curved path and F will be max centripetal force if v is too large and F is greater then with max centripetal force the train will tip because centripetal force isn't great enough to keep the train in circular motion along the original track, it tries to follow circular motion with a larger radius

(ii) When the train travels at 200 km hour^{-1}, the minimum safe radius of curvature of the track is 1800 m.

Calculate the minimum safe radius of curvature for a speed of 360 km hour^{-1}.

(2)

$a = \frac{v^2}{r}$ $\frac{v^2}{r} = \frac{v^2}{r}$ $\frac{200^2}{1800} = \frac{360^2}{r}$

$r = 360^2 \div \frac{200^2}{1800} = 5832\text{ m}$

$\to$ 5800m

Minimum safe radius of curvature = 5800m

ResultsPlus
Examiner Comments

(i) This has the equation and mentions centripetal force. It doesn't explain what causes the centripetal force so gains 2 marks.

(ii) fully correct.

Paper Summary

Based on their performance on this paper, candidates should:

- show numerical substitutions in an equation, including any constants
- "deduce" questions require the comparison of a candidate's numerical answer with a piece of data given in the question
- reading the question should reveal the topic that is being subsequently examined
- check that you have all the items that the "requirements section" on the front cover states: eg ruler
- if a diagram is supplied with a question, it can be useful to annotate the diagram to add to any explanations
- if an "explain" question has four marks it is likely that there are four relevant separate points that can be made in the answer.

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