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Examiners' Report
June 2019

GCE Physics 9PH0 01

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Introduction

The multiple choice section of this paper proved very accessible. Only question 9 proved challenging, with less than a third of candidates managing to get the correct response.

This paper contained two longer questions both worth six marks. Candidates did struggle on both questions. Candidates struggled with Q14(a) because the level of demand was high, although an answer in terms of energy transfer was the easier way to explain the suggestion. Q16(b)(iv) possibly proved challenging as it is a new topic on the specification.

Candidates were well prepared for topics on the specification that have been previously examined, suggesting that centres are making good use of past question papers and mark schemes.

Questions that involved calculations produced significantly better marks than questions requiring discussion or explanation.

There were some very impressive answers to Q17(d) which was not a straight forward 'units' question.

In some questions, the word 'explain' did not illicit the level of detail expected.

Question 11 (a)

This question was about circular motion in a vertical plane. Q11(a) required candidates to 'explain' why the velocity at the top of the circular motion was given by a particular expression. Many candidates did not start with an expression for resultant force, and therefore, didn’t identify the reaction force as zero at the top of the loop.

Mark point 1 was for equating weight with mv^2/r.

Mark point 2 was for adding that the normal reaction force =0 in this case.

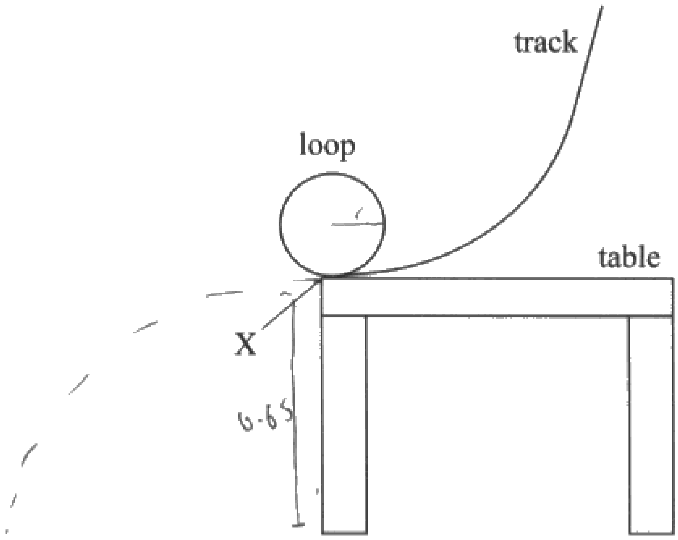
Some candidates tried to simply derive the equation using acceleration equations - this is not an explanation.

Many answers stated that the weight = mv^2/r but didn't explain that the normal reaction of the track on the car would be zero for the minimum speed. These answers usually gained 1 mark rather than 2.

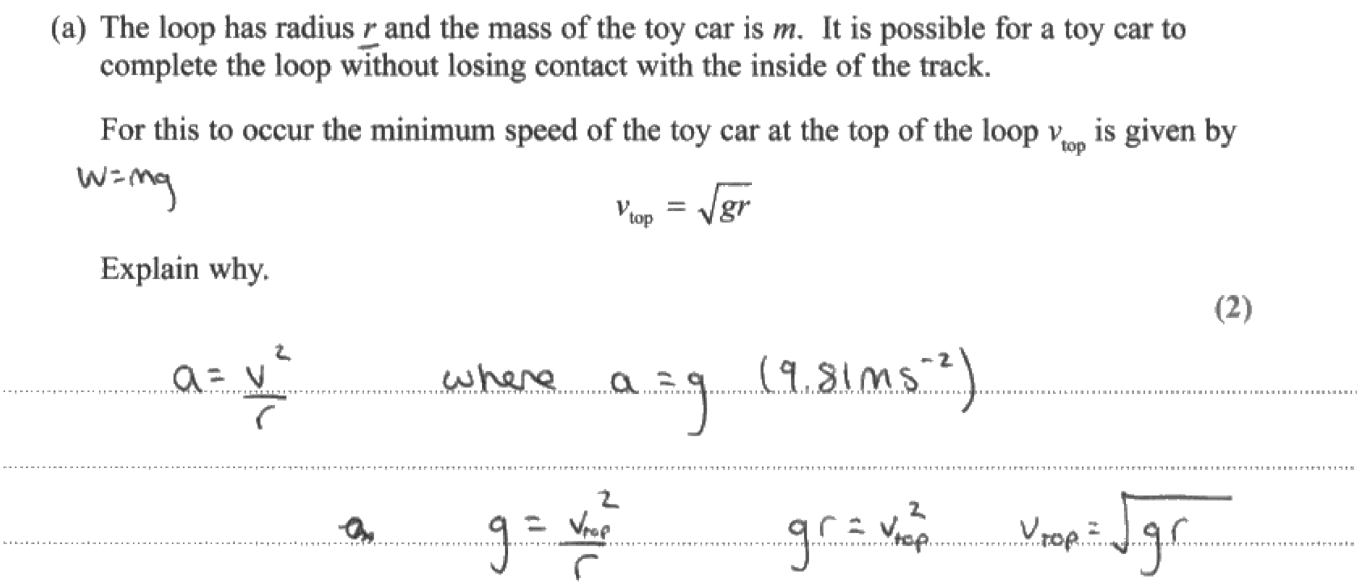
Some answers revealed a muddled understanding that the centripetal force includes weight, a normal reaction and "mv^2/r ".

The question asked for an explanation. An explanation requires a consideration of force.

11 A track for toy cars can be built with a circular loop as shown.



A toy car is placed on the track at various heights. It travels around the loop before leaving the track horizontally at X.



(a) The loop has radius r and the mass of the toy car is m. It is possible for a toy car to complete the loop without losing contact with the inside of the track.

For this to occur the minimum speed of the toy car at the top of the loop v_{top} is given by

W=mg

$$v_{top} = \sqrt{gr}$$

Explain why.

(2)

$a = \frac{v^2}{r}$ where $a = g$ $(9.81ms^{-2})$

~~a~~ $g = \frac{v_{top}^2}{r}$ $gr = v_{top}^2$ $v_{top} = \sqrt{gr}$

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Examiner Comments

Some candidates tried to use equations for acceleration but this doesn't explain the derivation of the equation required, which relies on an understanding of the forces acting at the top of the circle.

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Examiner Tip

Take note of the command word - in this case 'explain'.

Many answers stated that the centripetal force would equal weight or *mg*. There was no explanantion as to why this is the case at the top of the circular motion.

$F = \frac{mv^2}{r}$ $W = \frac{mv^2}{r}$ $gr = v^2$

$v = \sqrt{gr}$

$\Sigma F = W$ $\cancel{m}g = \frac{\cancel{m}v^2}{r}$ $v_{TOP} = \sqrt{gr}$ //

ResultsPlus
Examiner Comments

This example shows the least amount of detail that achieved 1 mark.

This answer recognises that there are two forces acting on the car.

At the top: $F_{cent} = W - N$ At the top point the car feel
Normal=0 $\frac{\cancel{m}v^2}{r} = \cancel{m}g$ weightless as the normal contact force
$v^2 = rg$ will be zero. Now the centripetal force
$v = \sqrt{rg}$ will be equal to the weight.

At the bottom: $N - W = \frac{mv^2}{r}$

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Examiner Comments

This answer tries to explain that there are two forces acting on the particle, the reaction from the track and weight. The answer correctly explains that the reaction from the track is 0 which gains mark point 1.

The second part of the derivation is correct for mark point 2.

Note that the centripetal force = W - N is actually incorrect - it should be W +N, however, this answer was given full credit as it correctly identified the mark scheme points.

This is an excellent explanation for full credit.

At minimum speed, $R=0$ between car and loop. At the top

$F_c = W + R$ ∴ when $R=0$, $F_c = W$

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

$$v_{top} = \sqrt{gr}$$ /1

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Examiner Comments

This answer gives a full and correct explanation.

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Examiner Tip

Circular motion often involves two forces. The resultant force gives the centripetal force. In this case it is the weight plus the normal reaction from the track. To derive an expression for the minimum speed the normal reaction can be taken as 0.

Question 11 (b)

This question requires a consideration of energy transfer.

Gravitational potential energy is transferred to kinetic energy and any attempt to do this was given mark point 1.

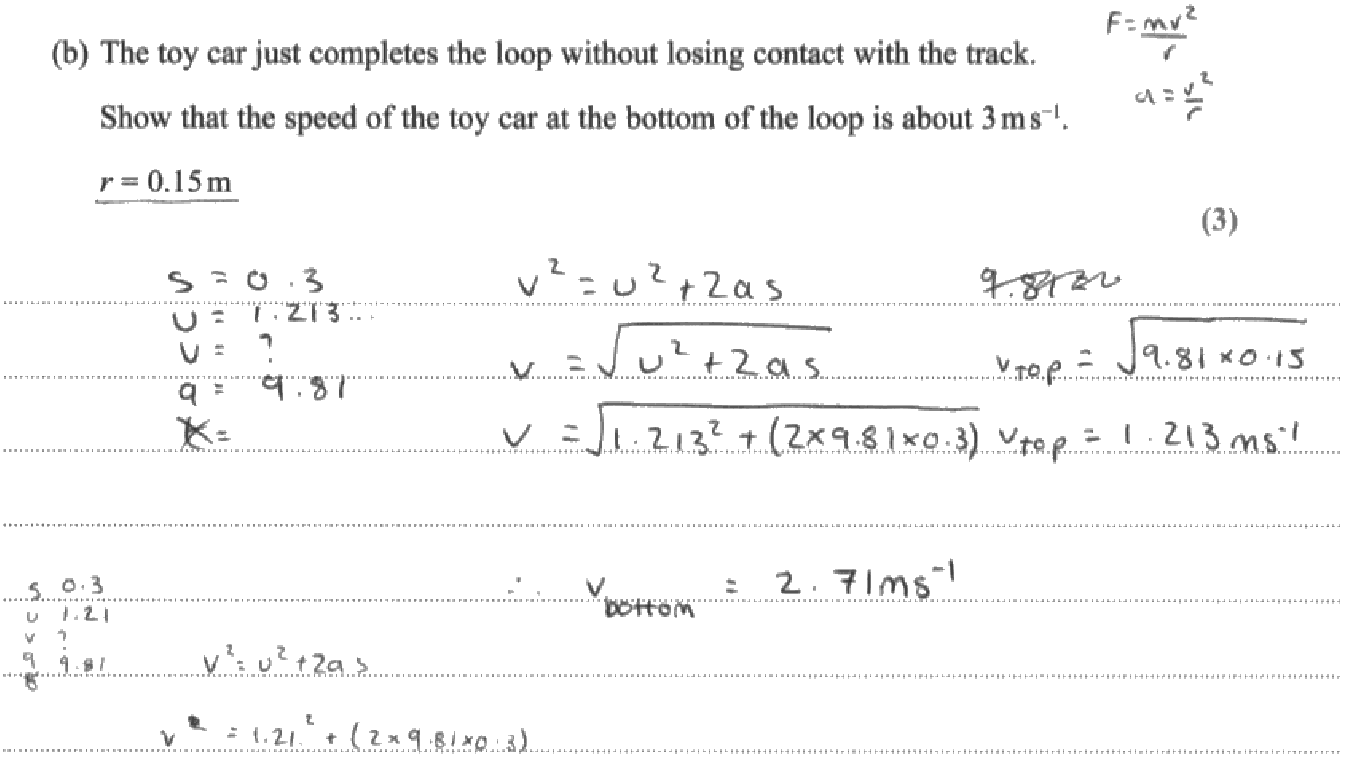
The car already has some kinetic energy at the top of the track, so the gravitational potential energy has to be added to initial kinetic energy (which was given by the equation in Q11(a)) for mark point 2.

A correct answer gained mark point 3.

This question was well-answered by most students. SUVAT equations should not be used in this context because this motion is not linear.

Equations of motion can only be used for linear motion.

The velocity of the car will be changing direction as it completes the loop.



(b) The toy car just completes the loop without losing contact with the track.

Show that the speed of the toy car at the bottom of the loop is about 3 m s^{-1}.

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

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

$r = 0.15$ m

(3)

$s = 0.3$

$u = 1.213...$

$v = ?$

$a = 9.81$

~~K~~=

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

$v = \sqrt{u^2 + 2as}$

$v = \sqrt{1.213^2 + (2 \times 9.81 \times 0.3)}$

~~9.81~~

$v_{top} = \sqrt{9.81 \times 0.15}$

$v_{top} = 1.213\ ms^{-1}$

$\therefore\ v_{bottom} = 2.71 ms^{-1}$

s 0.3

u 1.21

v ?

a 9.81

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

$v^2 = 1.21^2 + (2 \times 9.81 \times 0.3)$

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Examiner Comments

These answers gained 0 marks because the physics is incorrect.

This answer correctly identifies a transfer of gravitational potential energy (GPE) to kinetic energy.

$F = \frac{mv^2}{r}$ $\cancel{m}g\Delta h = \frac{1}{2}\cancel{m}v^2$

$\sqrt{gr} = \frac{1}{2}mv^2 \Rightarrow gr = \frac{1}{2}v^2$

$9.81 \times 0.15\,m = 1.4715\,J$

$1.4715 \times 2 = 2.9\cancel{3}43\ ms^{-1}$

$2.94_{ms^{-1}} \infty 3\,ms^{-1}$

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Examiner Comments

The answer omits to add the GPE to the initial kinetic energy but gains 1 mark.

Some answers suggested that candidates muddled the top and bottom of the circular path.

At the bottom, $F_c = R - W$

$\cancel{\frac{mv^2}{r} = mg}$

$v\ \cancel{top} = \cancel{\sqrt{gr}}$ F_c top $= mg$

$v = \sqrt{gr}$

$v = 1.21305\ ms^{-1}$ in the ring at the top

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Examiner Comments

This answer calculates the velocity at the top of the loop.

It doesn't consider energy transfer so does not get any marks.

This answer lays the working out well and gives a full explanation.

As mechanical energy is conserved;

$$KE_{at\ bottom} + GPE_{at\ bottom} = KE_{at\ top} + GPE_{at\ top}$$

$$KE_{at\ bottom} = KE_{at\ top} + \Delta GPE$$

$$\frac{1}{2} \cancel{m} v^2_{bottom} = \frac{1}{2} \cancel{m} v^2_{at\ top} + \cancel{m} g \Delta h$$

$$\frac{1}{2} v^2_{bottom} = \frac{1}{2} \times (\sqrt{9.81 \times 0.15})^2 + 9.81 \times 2(0.15)$$

$$v^2_{bottom} = 2 \times (\frac{1}{2} \times (\sqrt{9.81 \times 0.15})^2 + 9.81 \times 0.3)$$

$$v^2_{bottom} = 7.3575$$

$$v_{bottom} = 2.7 ms^{-1}\ (2sf)$$

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Examiner Comments

The mass of the car cancels, as it is a common term throughout the expression.

Question 11 (c)

This question was a 'projectile style' question and was completed correctly by the vast majority of candidates.

Use of the correct SUVAT equation in the vertical plane gained mark point 1. If candidates used an incorrect initial velocity this mark was not penalised.

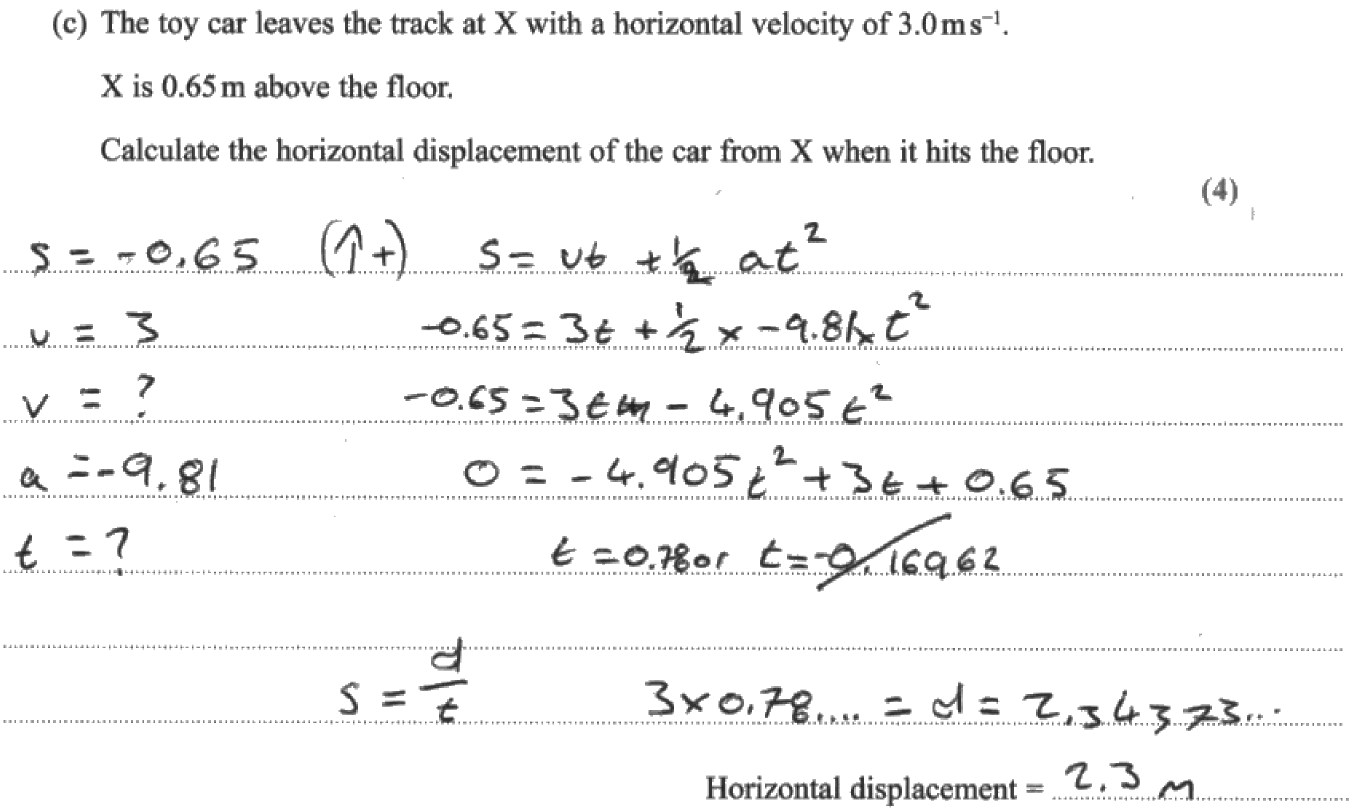
The second mark was for correct substitution of u = 0.

Mark point 3 was for using distance = speed x time (in the horizontal direction).

Mark point 4 for the correct answer.

A small number of candidates made the error of substituting $u_v = 3\ ms^{-1}$ in the equation for vertical motion.

The initial velocity of the car in the vertical direction is zero.



(c) The toy car leaves the track at X with a horizontal velocity of $3.0\,m\,s^{-1}$.

X is 0.65 m above the floor.

Calculate the horizontal displacement of the car from X when it hits the floor.

(4)

$s = -0.65$ $(\uparrow +)$ $s = ut + \frac{1}{2} at^2$

$u = 3$ $-0.65 = 3t + \frac{1}{2} \times -9.81 \times t^2$

$v = ?$ $-0.65 = 3t - 4.905t^2$

$a = -9.81$ $0 = -4.905t^2 + 3t + 0.65$

$t = ?$ $t = 0.78$ or $t = \cancel{-0.}16962$

$s = \frac{d}{t}$ $3 \times 0.78\ldots = d = 2.34373\ldots$

Horizontal displacement = 2.3 m

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Examiner Comments

This candidate uses the correct equations but substitutes the initial vertical velocity as 3.

The value of horizontal velocity is 3.

There are two correct equations being used for 2 marks.

This answer leaves values in fractional (rather than decimal) form. An unusual but correct format.

$\updownarrow$ $u=0$ $a=g$ $t=?$ $s=0.65$

$s=ut+\frac{1}{2}at^2$

$0.65=0+\frac{g}{2}t^2$ $t=\sqrt{\frac{130}{981}}$

$\rightarrow$: $s=\frac{d}{t}$ $3=\frac{d}{\sqrt{\frac{130}{981}}}$ $d=1.1\text{m}$

Horizontal displacement = 1.1m

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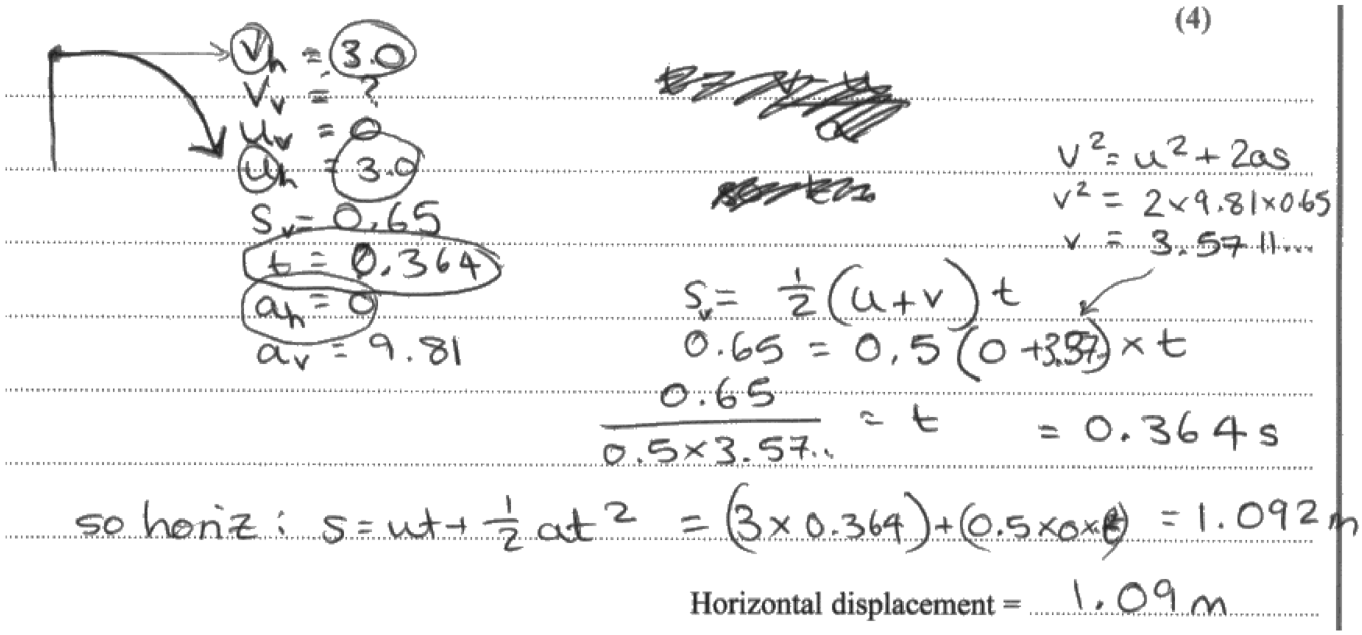
Examiner Comments

This answer follows the mark scheme for full credit.

Examiners try to recognise alternative, but correct, arguments as shown by this response.



(4)

$V_h = 3.0$
$V_v = ?$
$U_v = 0$
$U_h = 3.0$
$S_v = 0.65$
$t = 0.364$
$a_h = 0$
$a_v = 9.81$

$v^2 = u^2 + 2as$
$v^2 = 2 \times 9.81 \times 0.65$
$v = 3.5711...$

$S_v = \frac{1}{2}(u+v)t$
$0.65 = 0.5(0 + 3.57) \times t$
$\frac{0.65}{0.5 \times 3.57..} = t$ $= 0.364\,s$

so horiz: $s = ut + \frac{1}{2}at^2 = (3 \times 0.364) + (0.5 \times 0 \times t) = 1.092\,m$

Horizontal displacement = 1.09 m

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Examiner Comments

This answer takes an extra step by using different equations of motion but is correct for full credit.

Question 12 (a)

This question required an explanation of the action of a transformer. There were 4 marks allocated.

The first mark was given for associating a changing or alternating current with a changing magnetic field in the primary coil.

The second mark was given for stating that the magnetic flux was linked to the secondary by the iron core.

The third mark was for stating that the induced emf in the secondary coil was created by the changing magnetic flux.

The final mark was for noting more turns on the secondary coil.

Reference to the function of the iron core was commonly missed or poorly explained.

Many answers scored mark 4 for more turns on the secondary coil as a minimum.

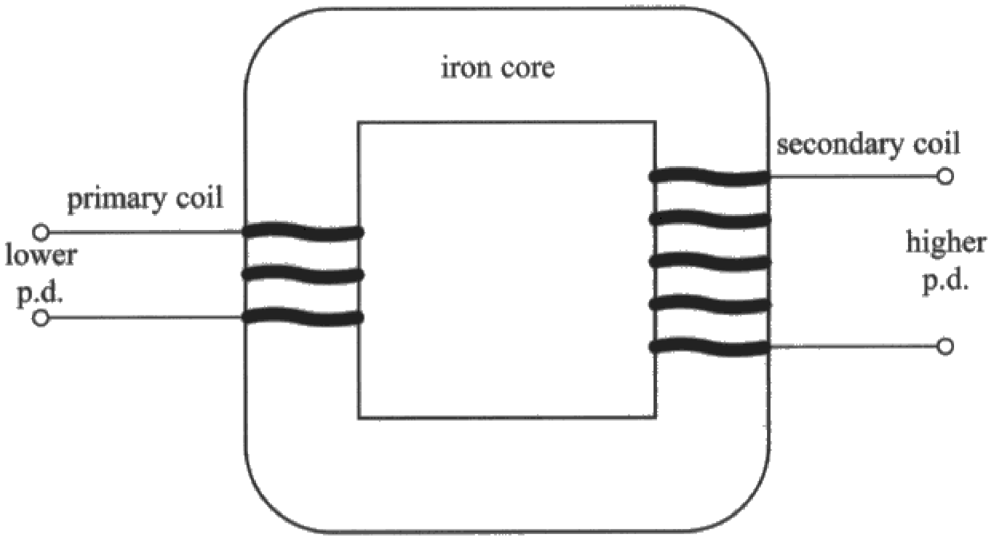
12 Electrical transmission systems are used to transmit electrical power from place to place. Transformers are used to change potential differences (p.d.) and power transmission cables are used to transmit power.

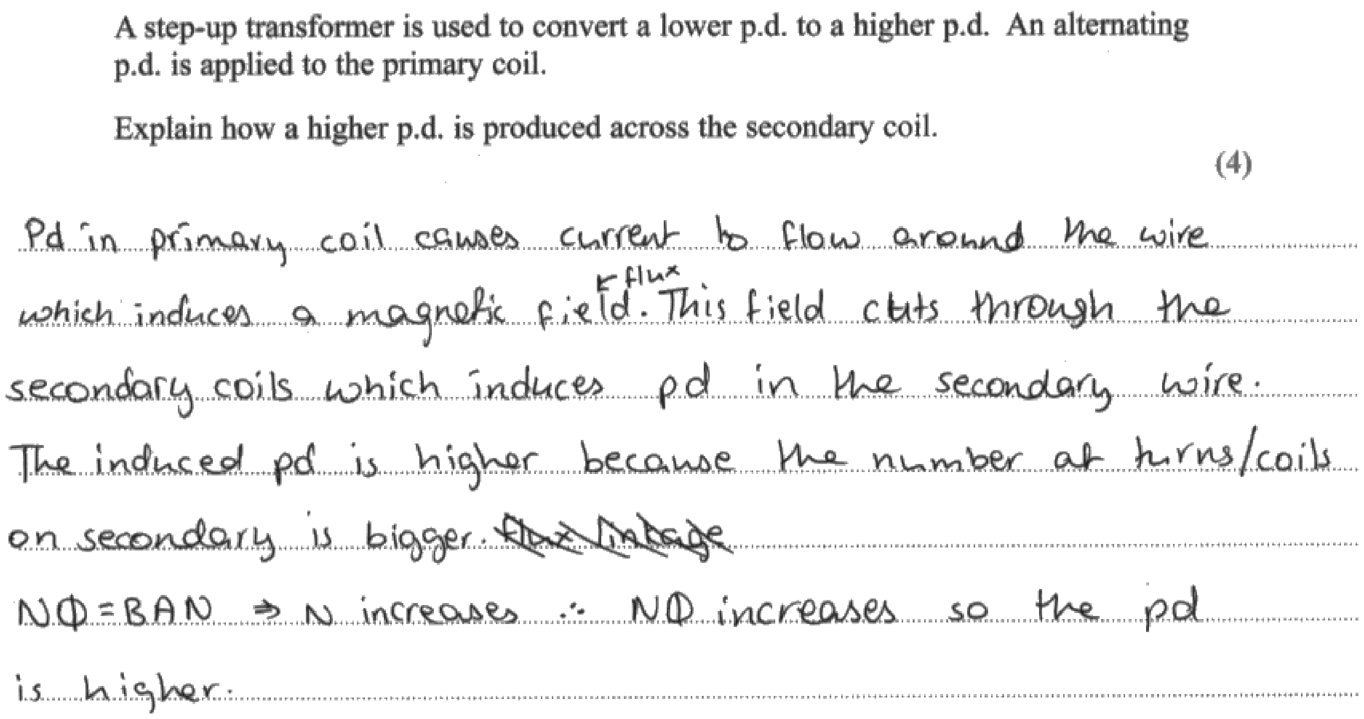
(a) The diagram shows a step-up transformer.

$V_s > V_p$

$I_s < I_p$

$N\Phi_s < N\Phi_p$





A step-up transformer is used to convert a lower p.d. to a higher p.d. An alternating p.d. is applied to the primary coil.

Explain how a higher p.d. is produced across the secondary coil.

(4)

Pd in primary coil causes current to flow around the wire which induces a magnetic field flux. This field cuts through the secondary coils which induces pd in the secondary wire. The induced pd is higher because the number of turns/coils on secondary is bigger. ~~flux linkage~~

$N\Phi = BAN \Rightarrow N$ increases $\therefore N\Phi$ increases so the pd is higher.

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Examiner Comments

This answer gains mark point 4.

There is no mention of **alternating** current or **changing** magnetic field for mark point 1. Note the word 'induces' on the second line is incorrect.

As there is no mention of changing field, mark point 3 cannot be awarded.

Although candidates referred to the iron core, its function was usually omitted.

So the alternating current in the primary coil produces a constanly changing rate of change ~~flux state~~ of flux within the iron core. The greater coils of the secondary coil, because it's a step-up, means that this changing flux interacts with a larger area of wire, so a greater p.d is induced to the secondary coil.

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Examiner Comments

This gains mark point 1 and 4.

The answer does not clearly indicate the function of the iron core.

It also refers to an induced pd (induced emf is required) for the award of mark point 3.

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Examiner Tip

This answer might have benefitted if the candidate recalled there were 4 marks and therefore, 4 points to be made.

To gain mark point 1 candidates had to explain that the magnetic field in the primary coil is produced by a current (not a p.d.).

As there is alternating pd the flux linkage will change which induces an emf in the primary coil, which is passed to the secondary coil through the iron core. As there are more turns it the secondary coil than the primary coil there will be a greater ~~chan~~ change in flux linkage as $N\phi = NBA$ as Faraday's law states a ~~induge~~ induced emf is equal to the rate of change of flux linkage when flux linkage increase so will emf which will cause a greater pd in secondary coil than the primary coil.

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Examiner Comments

This answer gained mark points 2, 3 and 4.

Mark point 1 was not given as the answer refers to an alternating pd rather than an alternating current.

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Examiner Tip

Magnetic fields around coils and wires are produced by a current.

Question 12 (b)

This question required candidates to solve a numerical problem using skills and knowledge from different areas of the specification.

This question required candidates to look up a value on a log scale for mark point 1.

Mark point 2 was for calculating current using P = VI. This was often missed because candidates incorrectly used V=IR.

Mark point 3 was for using the resistivity equation.

Mark point 4 was for calculating power loss in the cables using I^2R.

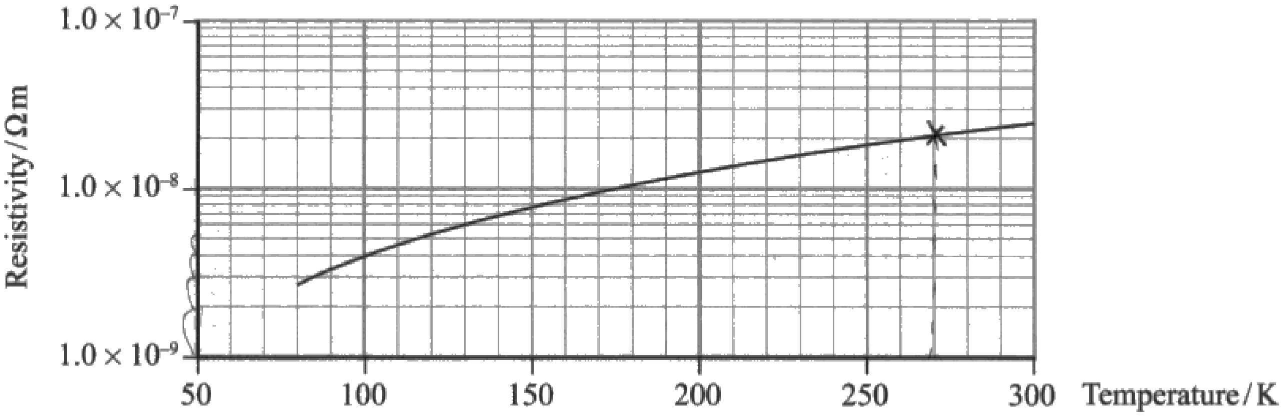
Mark point 5 was for comparing with the power loss for the superconductor and making a suitable comment. This mark could only be gained from previous correct physics.

Many candidates appeared to be unfamiliar with log scales and were unable to read off the value of resistivity from the graph. Good use of the resistivity equation was recognised in many responses, but some candidates confused transmission potential difference for potential difference drop along the length of cable.

(b) Efficient electrical transmission systems are being developed using superconductors. Superconductors have zero resistance at low temperatures, and therefore no power is wasted by transfer to thermal energy unlike copper cable systems.

In one project a 1.05 km length of copper cable at a temperature of 270 K has been replaced by a superconductor. The superconductor has a cooling system which requires power.

The graph shows the variation of resistivity with temperature for copper.



This answers gains all the marks.

Deduce whether the power requirement of the superconductor cooling system is less than the power losses in the copper cable.

transmission power = 40 MW

transmission potential difference = 110 kV

cross-sectional area of copper cable = 145 mm^2

power requirement of cooling system for the superconductor = 7 kW

(5)

$P = VI$ $\quad P = I^2 R$ $\quad 40\times10^6 = 110\times10^3 I$

$I = 363.64\,A$

$P_{loss} = I^2 R$ $\quad R = \frac{\rho L}{A}$

$R = \frac{\overset{2}{\cancel{1.7}}\times10^{-8}\times1.05\times10^{3}}{145\times10^{-6}}$ ~~$= 7.97\times10^{-5}\,\Omega$~~

~~$P = (363.64)^2\times7.97\times10^{-5}$~~ $\quad 0.145\,\Omega$

~~$P_{loss} = 10.53W$~~ $\quad P = (363.64)^2 \times 0.145 = 19{,}173.94\,W$

$= 19.17\,kW$

19.17 kW > 7 kW. Power requirement for cooling system is less then power lost in copper cable.

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Examiner Comments

This answer follows all the mark scheme points for full credit.

This answer was often seen and was credited with 2 marks.

At 270K resistivity of copper = ~~1.7×10^{-8}~~ $2\times10^{-8}\ \Omega\text{m}$

$\frac{145}{1000^2} = 1.45\times10^{-4}\ \text{m}^2$

$R = \frac{\rho l}{A}$ $R = \frac{2\times10^{-8}\times1050}{1.45\times10^{-4}} = 0.145\ \Omega$

ans ~~$\frac{110000}{0.145} = 7.59\times10^{5}\ \text{A}$ $P = 7.59\times10^{5}\times110000 = 8.34\times10^{10}\ \text{W}$~~

$P = \frac{V^2}{R} = \frac{110000^2}{0.145} = 8.345\times10^{10}\ \text{W}$

$8.345\times10^{10} - 40\times10^{9} = 4.345\times10^{10}\ \text{W}$ $4.345\times10^{10} > 7\times10^{3}$

The power requirement of the superconductor cooling system is less than the power loss in the copper ~~wo~~ cable

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Examiner Comments

This gains mark point 1 and 3.

This answer gains the second mark point for use of *P*= *IV*.

$R = \frac{\rho L}{A}$

$P = VI$

$I = \frac{40\times10^{6}}{110000}$

$= 363\ \text{m s}^{-1}$

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Examiner Comments

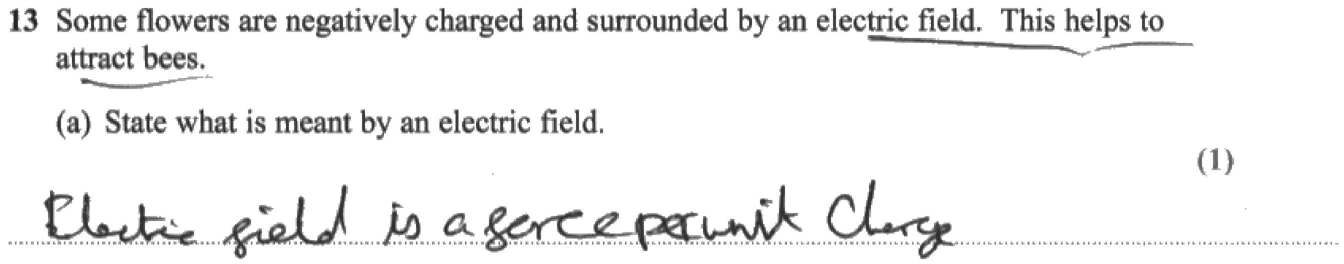
This answer gains mark point 2 only.

Question 13 (a)

An electric field is a region in space in which a charged particle experiences a force.

A few candidates defined electric field strength rather than explaining what is meant by an electric field.

Some candidates defined electric field strength. This does not answer this question.



13 Some flowers are negatively charged and surrounded by an electric field. This helps to attract bees.

(a) State what is meant by an electric field.

(1)

Electric field is a force per unit Charge

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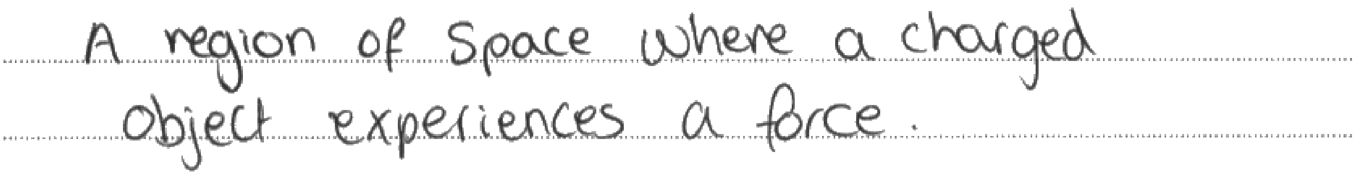
Examiner Comments

'What is meant by an electric field' and 'what is electric field strength' are two different questions.

This response answers this question.



A region of Space where a charged object experiences a force.

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Examiner Comments

Most candidates answered this correctly with an answer that followed the mark scheme.

Question 13 (b) (i)

This question tested specification point 112. Electric field strength is given by the gradient of electric potential.

Mark point 1 was given for any attempt to determine a difference between two potentials.

Mark point 2 was for attempting to find the gradient by using a difference in distance.

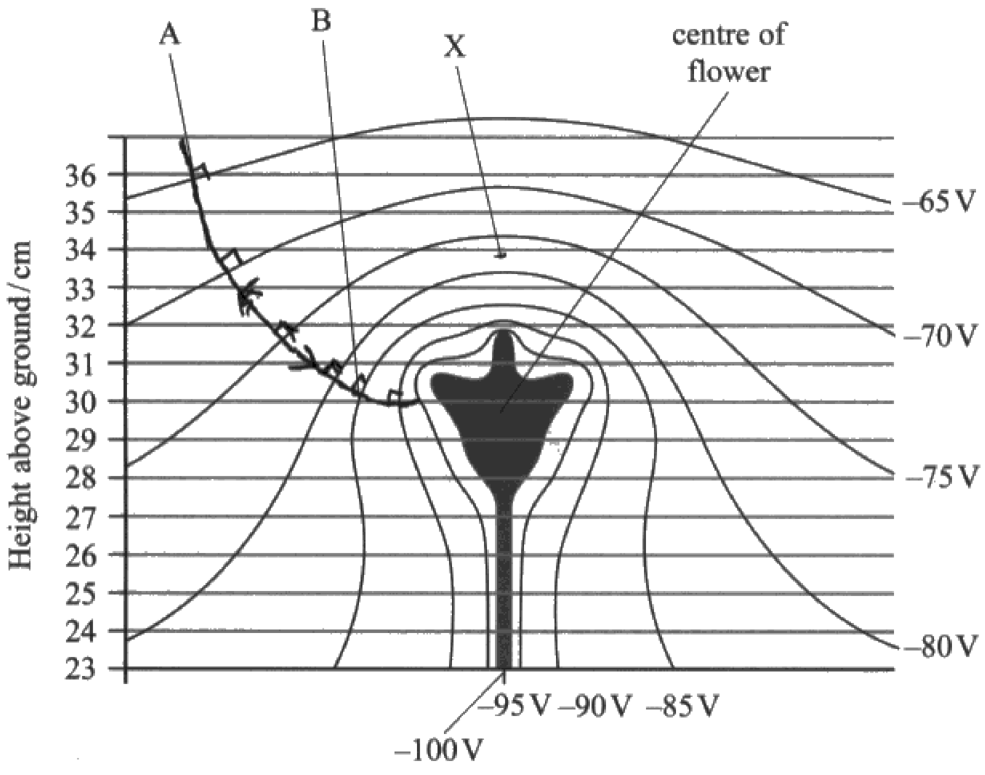
Mark point 3 was for a value falling within a range.

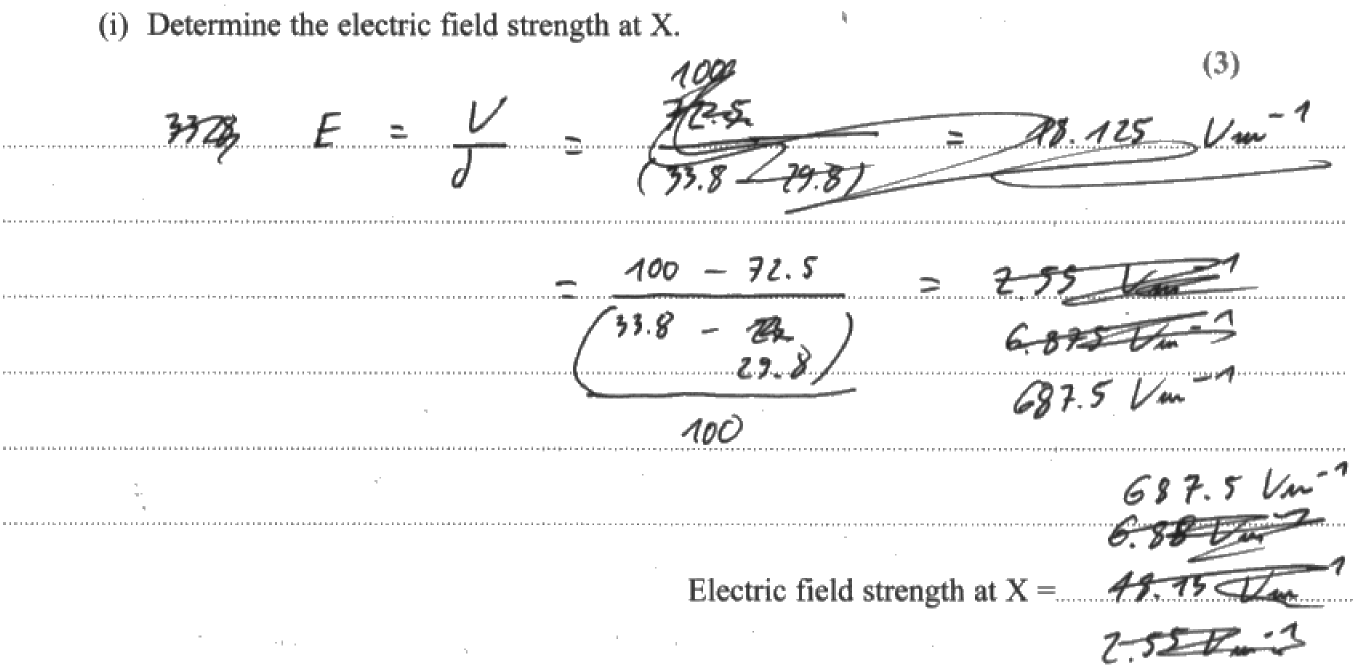
Many candidates tried to use *E=V/d* but didn't understand that this equation can be potential difference/distance between the two potentials.

This response initially looks to use *E* = *V/d* which was often used incorrectly.

On further reading, this candidate has correctly used *ΔV/Δd.*

(b) The diagram shows lines of equipotential surrounding a flower.





(i) Determine the electric field strength at X.

(3)

~~3328~~ $E = \frac{V}{d} = \frac{\cancel{72.5}\ 100}{(33.8 - 29.8)} = \cancel{98.125}\ Vm^{-1}$

$= \frac{100 - 72.5}{(33.8 - 29.8)}$ = ~~2.55 Vm⁻¹~~ ~~6.875 Vm⁻¹~~ 687.5 Vm⁻¹

100

Electric field strength at X = 687.5 Vm⁻¹ ~~6.88 Vm⁻¹~~ ~~49.15 Vm⁻¹~~ ~~2.55 Vm⁻¹~~

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Examiner Comments

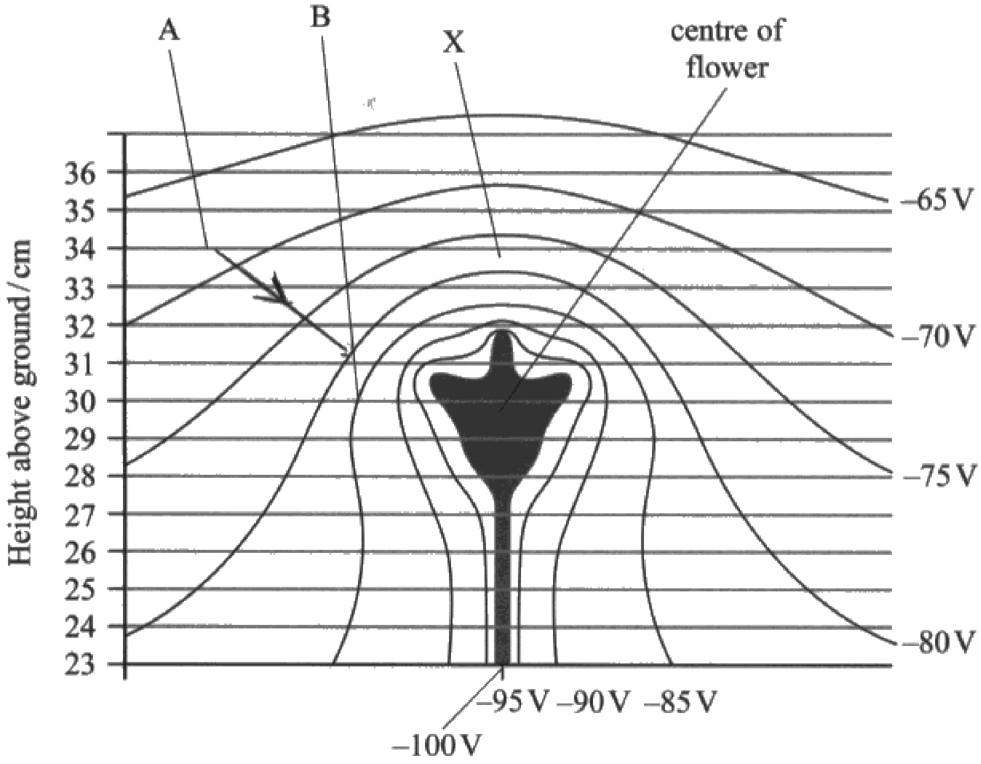
This answer contains a difference in potential for mark point 1.

It goes on to attempt to find a gradient using a difference in distance for mark point 2.

The answer falls out of range so does not collect mark point 3.

This response incorrectly uses $E = V/d$.

(b) The diagram shows lines of equipotential surrounding a flower.



(i) Determine the electric field strength at X.

(3)

~~$E = \frac{Q}{4\pi\varepsilon_0 r^2}$~~ $E = \frac{V}{d}$ ~~$d=$~~ $d \approx 33.8\text{cm} \Rightarrow 33.8\times10^{-2}\text{m}$

$V \approx 77.5\text{V}$

$\frac{77.5}{33.8\times10^{-2}} = 229.3\ \text{Vm}^{-1}$

Electric field strength at X = $229.3\ \text{Vm}^{-1}$

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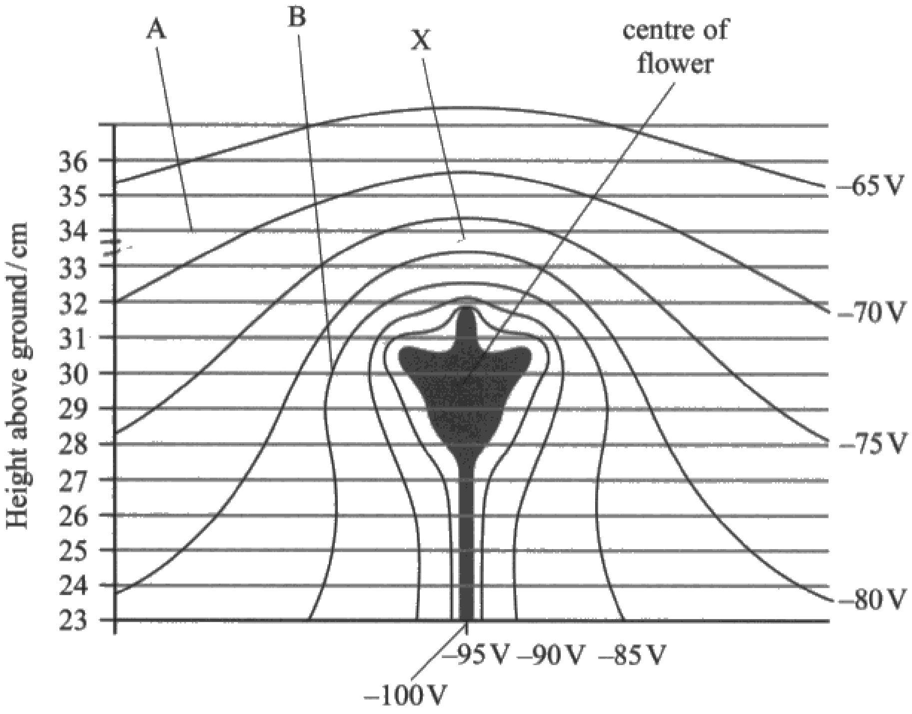
Examiner Comments

This was a common answer.

There is no attempt to calculate potential difference so 0 marks.

Some candidates made assumptions about the charge on the flower without the data being given within the question.

(b) The diagram shows lines of equipotential surrounding a flower.



(i) Determine the electric field strength at X.

(3)

$E = \frac{Q}{4\pi\varepsilon_0 r^2}$

r = 33.8cm = 0.338m

$E = \frac{-1.6 \times 10^{-19}}{4\pi\varepsilon_0 \times 0.338^2}$

$E = 1.259312306 \times 10^{-8}$ NC^{-1}

Electric field strength at X = 1.26 NC^{-1}

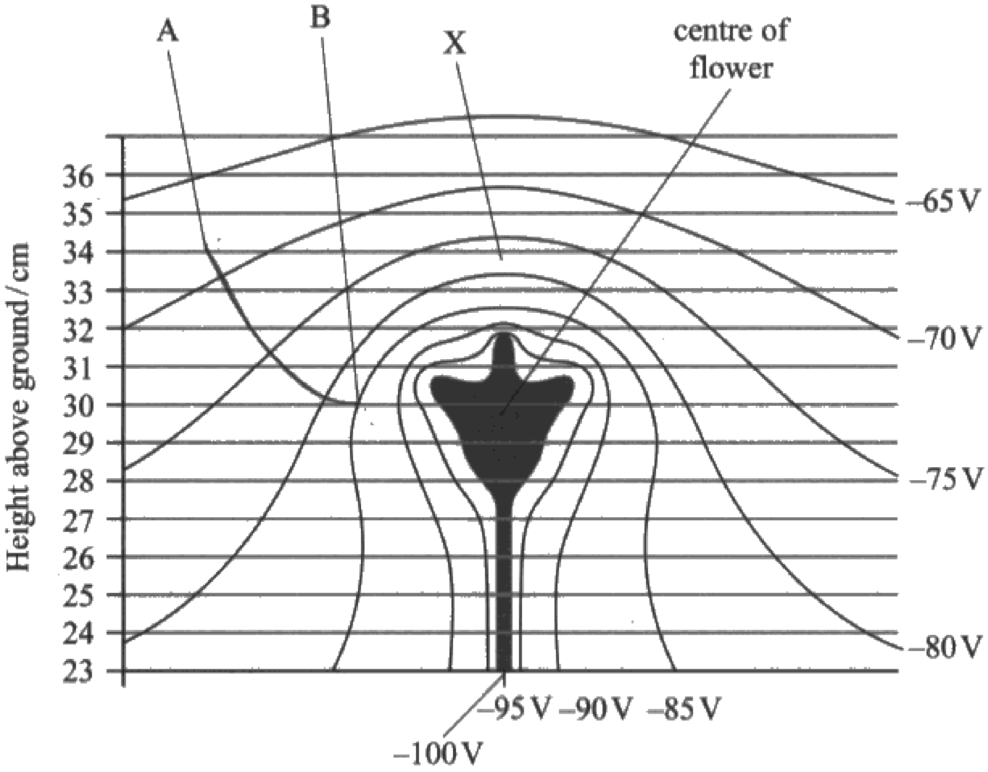
ResultsPlus
Examiner Comments

This answer assumes the field is radial.

It also assumes that the charge on the flower is the charge on an electron, which was not given by the question.

This answer gains full credit.

(b) The diagram shows lines of equipotential surrounding a flower.



(i) Determine the electric field strength at X.

(3)

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

$E = \frac{5}{0.01} = 500\ NC^{-1}$

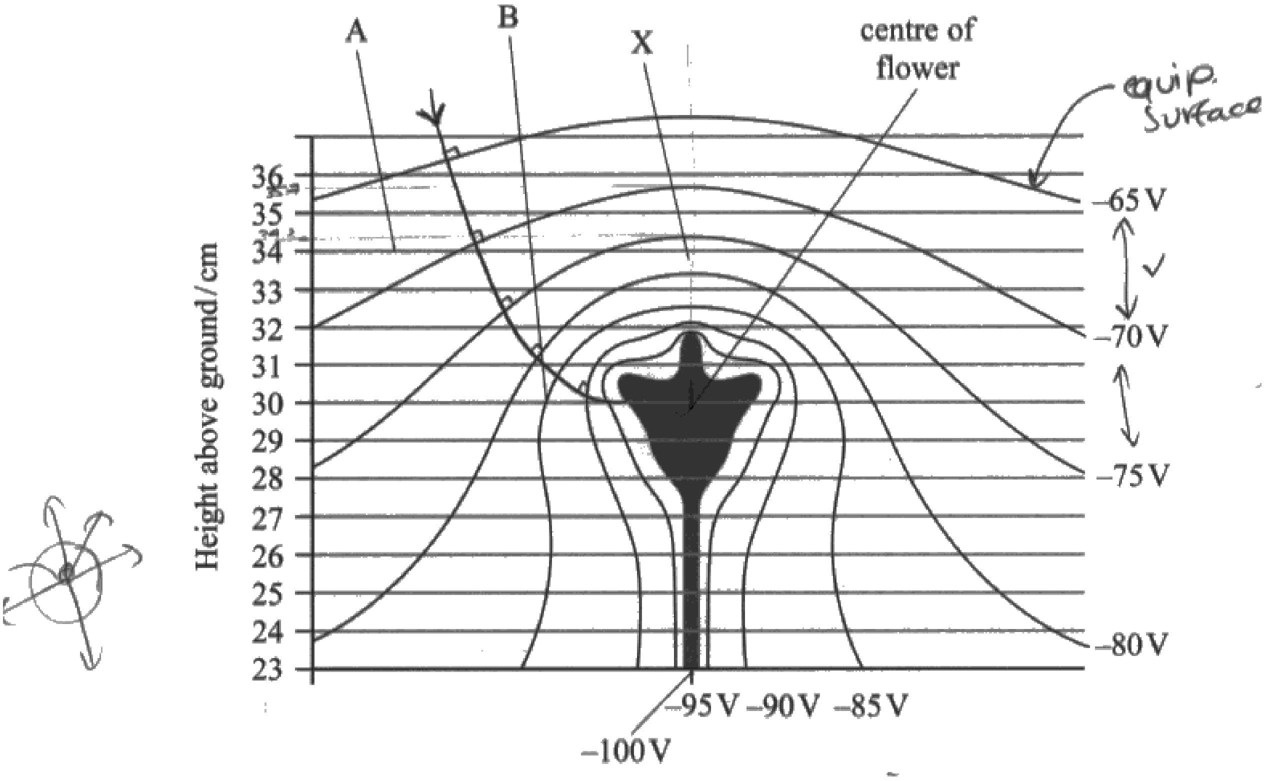
Electric field strength at X = 500 N/C

ResultsPlus
Examiner Comments

This answer gains full credit and follows the mark scheme.

This answer achieves the first two marks for attempting to use *E = ΔV/Δd.*

(b) The diagram shows lines of equipotential surrounding a flower.



(i) Determine the electric field strength at X.

(3)

$\varepsilon = F/Q \quad \varepsilon = k\frac{Q}{r^2}$

$\varepsilon = V/d$

where $V = 5V$ and $d = 35.7 - 34.3$

$= 1.4\text{cm}$ $\quad \therefore \varepsilon = \frac{5}{0.014}$

$= 0.014\text{m}$ $\quad = 360\ \text{Vm}^{-1}$

Electric field strength at X = 360Vm^{-1}

ResultsPlus
Examiner Comments

This answer has a difference in potential for mark point 1.

It attempts to find a gradient using a difference in distance for mark point 2.

The answer is out of range for mark point 3. This is because the distance has been scaled off the diagram incorrectly.

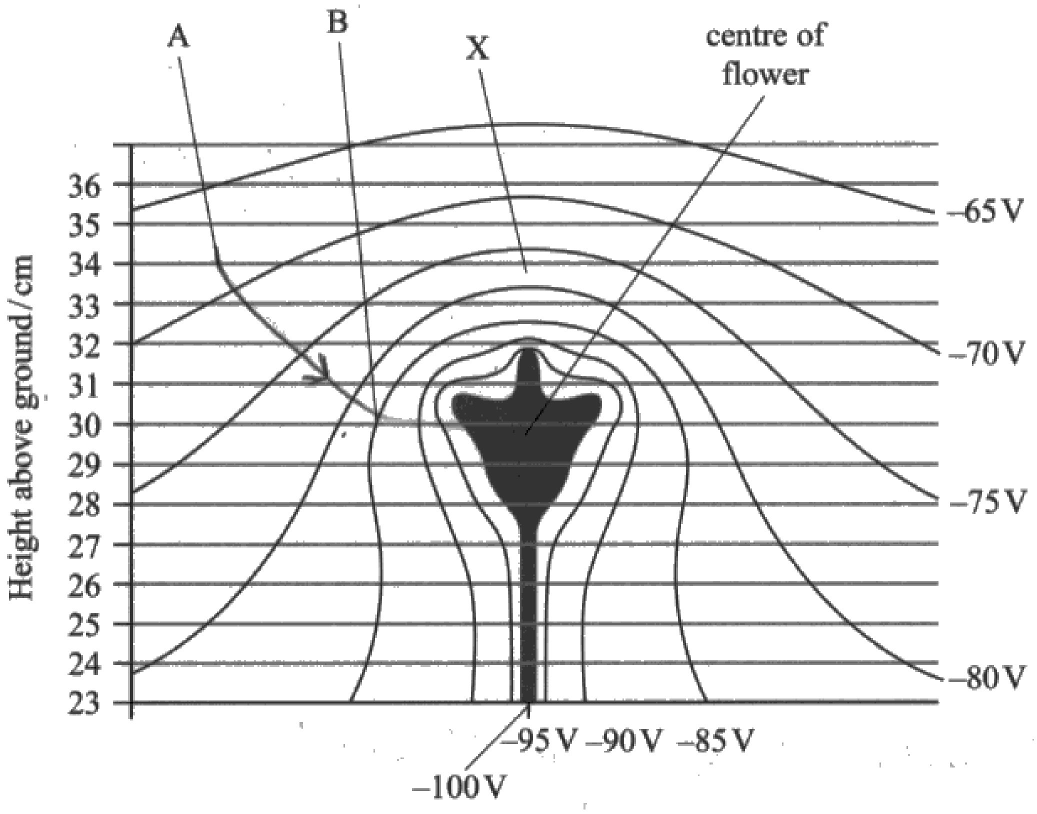
Question 13 (b) (ii)

Electric field lines should be perpendicular to lines of equipotential for mark point 1. Many candidates did appreciate this, and susequently gained this mark.

The arrow should be in the direction of force that a positive charge would experience. In this case, towards the negatively charged flower for mark point 2.

This answer gains both marks.

(b) The diagram shows lines of equipotential surrounding a flower.



(ii) Draw the electric field line between point A and point B on the diagram.

(2)

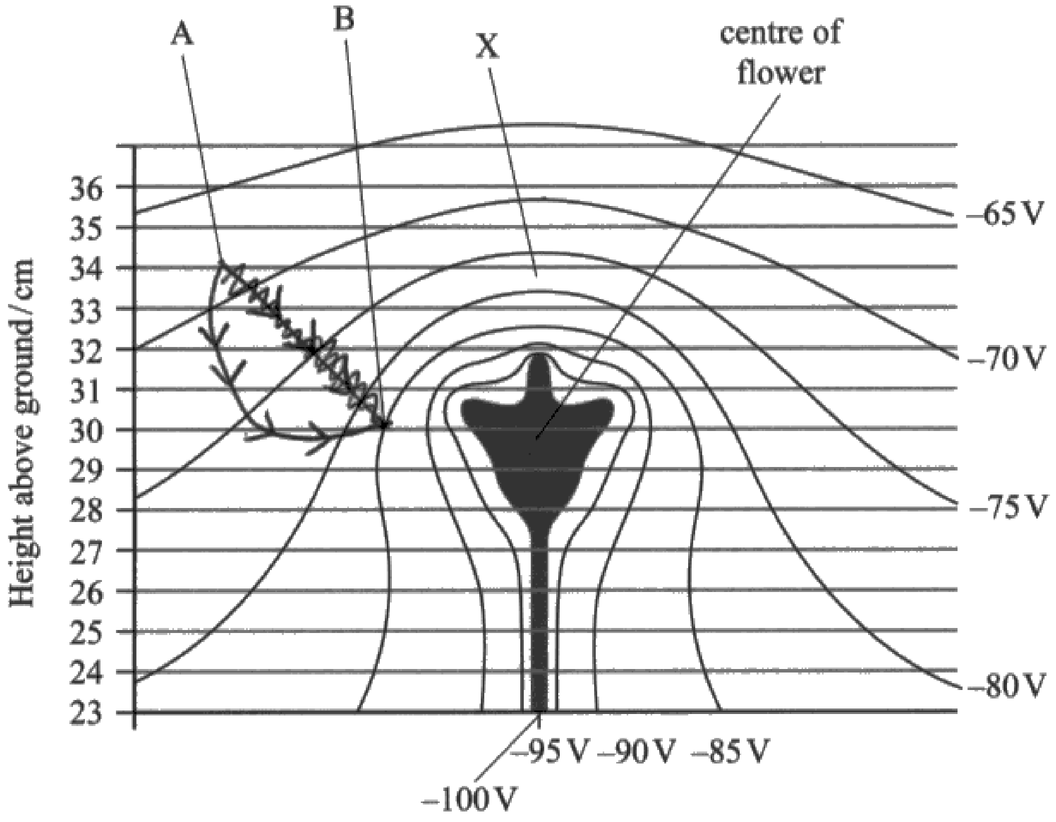
ResultsPlus
Examiner Comments

If the line had a curve then mark point 1 was given unless it curved the wrong way.

The arrow is correct for mark point 2.

This answer has a curved line but it is clearly not perpendicular to the equipotential lines.

(b) The diagram shows lines of equipotential surrounding a flower.



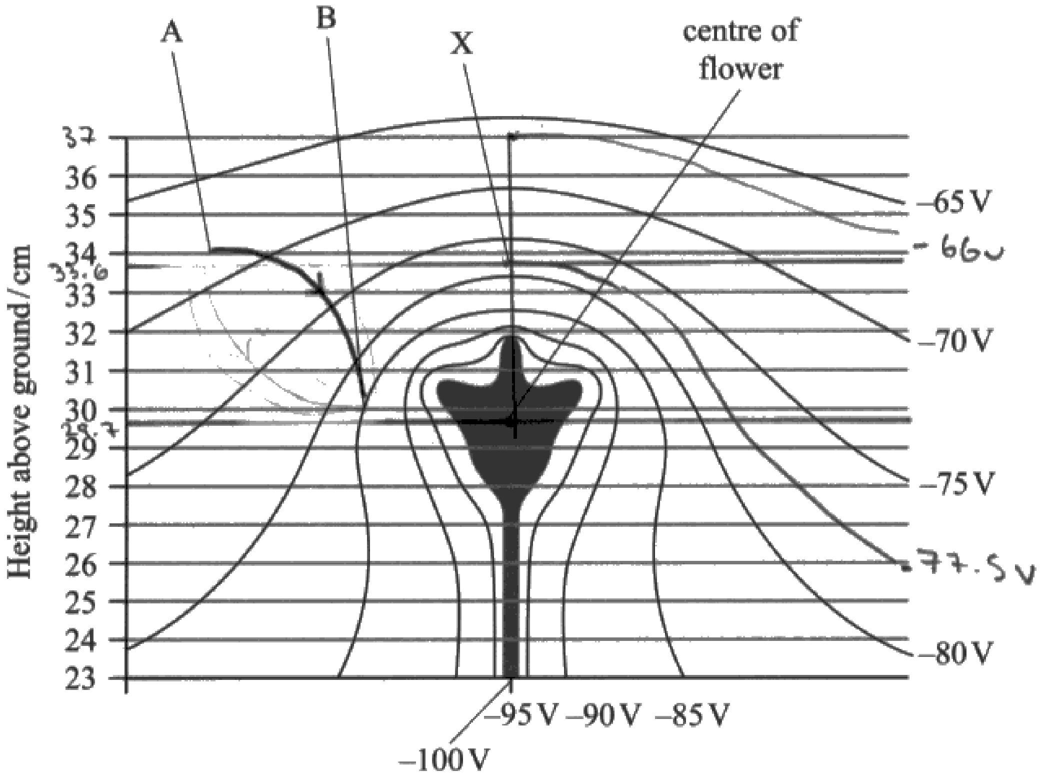
ResultsPlus
Examiner Comments

This line curves too much so that the line is clearly no longer perpendicular to the potential lines.

Mark point 2 only.

This line is clearly not perpendicular to the equipotential lines.

(b) The diagram shows lines of equipotential surrounding a flower. with a charge.



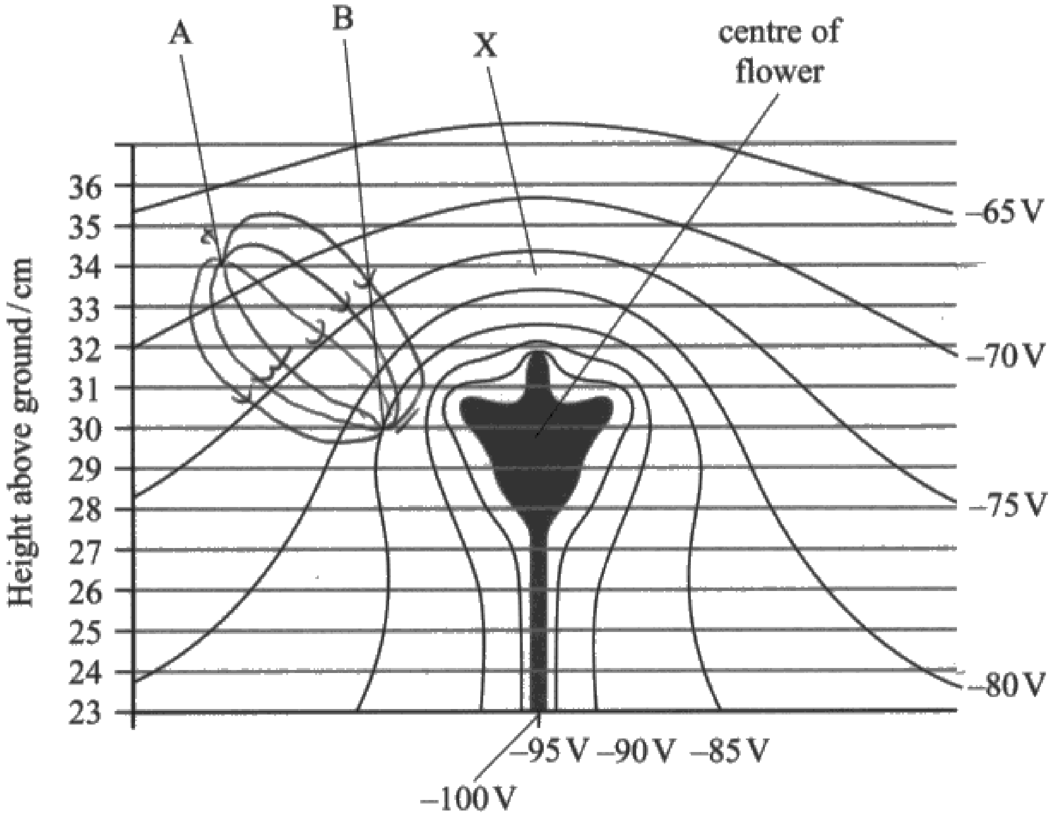
ResultsPlus Examiner Comments

This line curves the wrong way so the line is not perpendicular to the potential lines.

Mark point 2 only.

As a general rule, if a choice of answers are given by a candidate at GCE then the mark cannot be given.

(b) The diagram shows lines of equipotential surrounding a flower.



ResultsPlus
Examiner Comments

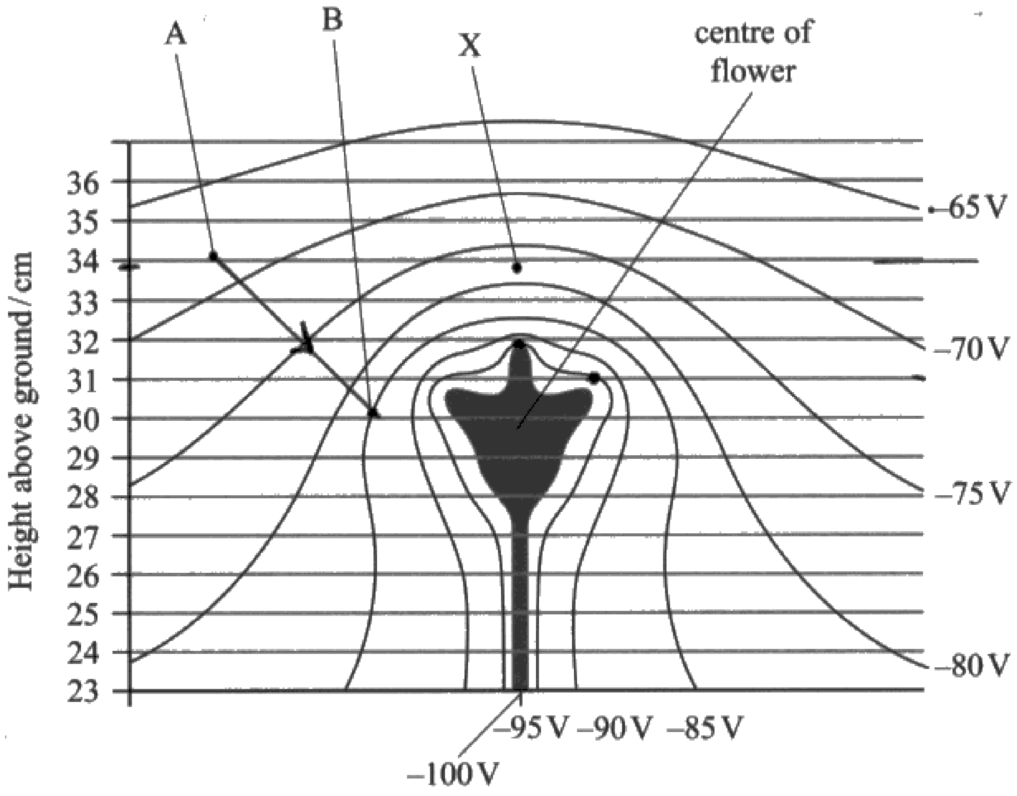
If more than one line is drawn then mark point 1 cannot be awarded. The question asked for **one** line.

ResultsPlus
Examiner Tip

You should not give a choice of answers in examinations.

A straight line will not be perpendicular to the equipotential lines in this context.

(b) The diagram shows lines of equipotential surrounding a flower.



ResultsPlus
Examiner Comments

Many candidates drew a straight line. This will not be perpendicular to the electric potential lines.

Mark point 2 only.

Question 13 (b) (iii)

Rearranging the equation gives the product V r = constant for a radial field. Any reference to determine this or attempt to calculate this product gained mark 1.

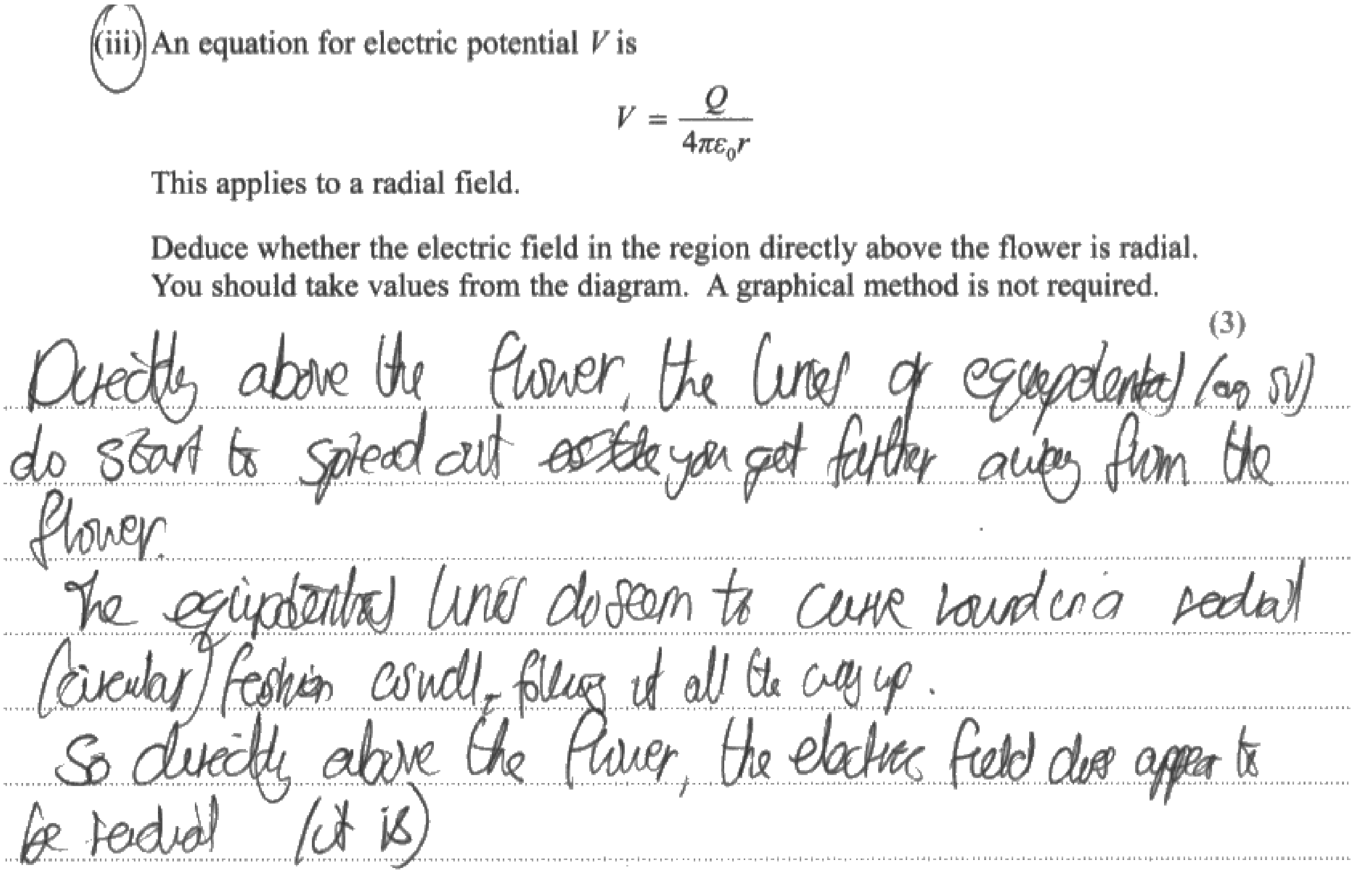
Using at least one pair of values of V and corresponding r from the diagram gained mark point 2, for example, (-)70 V and 6 cm. This mark point 2 allowed for a range of values of r .

A number of candidates did not 'measure' their r from the centre of the flower.

The third marking point was for taking a second pair of values and using both pairs to show that the product is not constant.

There were some very good answers to this question but many candidates often failed to use the starting point that the product Vr should be a constant.

The question says 'take values from the diagram'.



(iii) An equation for electric potential V is

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

This applies to a radial field.

Deduce whether the electric field in the region directly above the flower is radial.
You should take values from the diagram. A graphical method is not required.

(3)

Directly above the flower, the lines of equipotential (eg 5V) do start to spread out ~~as the~~ you get farther away from the flower.

The equipotential lines do seem to curve round in a radial (circular) fashion around, following it all the way up.

So directly above the flower, the electric field does appear to be radial (it is)

ResultsPlus
Examiner Comments

Some answers had no quantitative argument.

ResultsPlus
Examiner Tip

The question states 'take values from the diagram', so follow the advice provided.

This answer follows the mark scheme for full credit.

$V = \frac{KQ}{r}$ $V = \frac{K}{r}$ since Q is constant

~~$95 \times 2 = 190$~~ $95 \times 0.02 = 1.9$

~~$90 \times 2.1 = 189$~~ $90 \times 0.022 = 1.98$

~~$85 \times 2.5 = 212.5$~~ $85 \times 0.026 = 2.21$

K is not constant so the electric field in the region directly above the flower is not radial

ResultsPlus
Examiner Comments

A clear example of an answer which deserves full credit.

If a response contained a clear exanple of the product *Vr* being evaluated more than once, then the first mark was given.

$\frac{Vr}{k} = Q$ $k = 8.99 \times 10^9$

$\frac{0.335(-80)}{8.99 \times 10^9} = \boxed{-2.9 \times 10^{-9}}$ = similar value for charge

$\frac{0.35(-70)}{8.99 \times 10^9} = \boxed{-2.7 \times 10^{-9}}$

$Q = It$

ResultsPlus
Examiner Comments

There is an attempt to determine a product and this gains mark point 1.

The values are not correct so no further credit.

If a calculation containing *Vr* was only carried out with one set of data then mark point 1 was not given.

$E=VQ$ $V = \frac{Qk}{r}$

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

$-75\,V = \frac{Q\,(8.99\times10^{9})}{0.344} = 1.91\times10^{-10}\ C$

it isn't radical since the charge is bigger than $1.6\times10^{-19}\,C$

ResultsPlus
Examiner Comments

This type of answer was seen quite often.

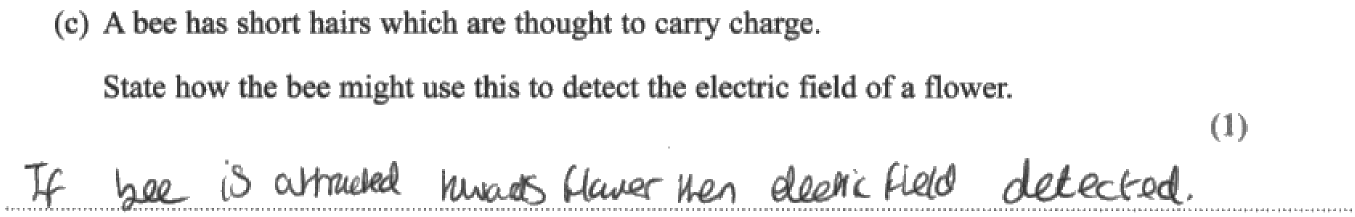
The candidate is not using *V r* is a constant so does not get mark point 1.

Question 13 (c)

The mark scheme point is that a charged hair will experience a force in the field.

The hair probably deflects or moves slightly and the bee detects that.

The mark is for the 'hair' experiencing the force, not the bee.



(c) A bee has short hairs which are thought to carry charge.

State how the bee might use this to detect the electric field of a flower.

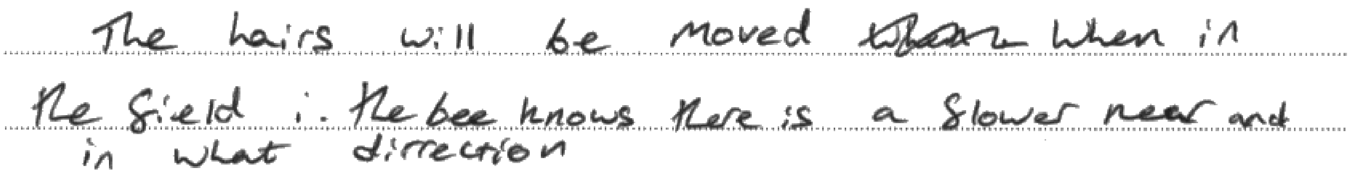
(1)

If bee is attracted towards flower then electric field detected.

ResultsPlus
Examiner Comments

A number of answers referred to the bee 'feeling a force' or being attracted towards the flower. This was not awarded any marks.

This answer refers to the 'hair'.



The hairs will be moved [illegible] when in the field ∴ the bee knows there is a flower near and in what direction

ResultsPlus
Examiner Comments

This answer just gets the mark for referring to movement of the hairs.

This answer refers to the force on the hair and achieves the mark.

The short hair migh repulle or attract dependin on thir charge.

ResultsPlus

Examiner Comments

This answer now refers to a force on the hair and gains the mark.

Question 13 (d)

This question required candidates to understand that a decreasing field strength will lead to equipotential lines being further apart.

Only 'further apart' or a phrase which can be interpreted as meaning the same thing can achieve this mark.

(d) When the bee is collecting nectar from the plant, the electric field strength decreases. It is thought that this warns other bees that the nectar supply is low.

State the effect of a decreased electric field strength on the equipotential lines.

(1)

No effect

ResultsPlus
Examiner Comments

Most answers fell into 'reduce the separation', no effect and further apart.

This achieves the mark.

The lines get further apart

ResultsPlus
Examiner Comments

This gains the mark scheme point.

They would move closer to the point charge as the electric potential of the field would decrease.

ResultsPlus
Examiner Comments

Any reference to 'closer' does not get credit.

The equipotential lines will have smaller, in magnitude, values of he potential.

ResultsPlus
Examiner Comments

The differences in potential between the lines is not changed by this description (ie could still be 5 V between each pair of lines).

Question 14 (a)

This question requires candidates to consider a situation and apply their physics to agree or disagree with a statement. There are two ways to go about the problem. The easier method involved energy transfer and work done by frictional forces between the table and a coin. Both methods are published in the mark scheme.

A more complicated method involved using a SUVAT equation $v^2 = u^2 + 2as$.

Noting that when the coin comes to halt v = 0.

So u = square root (2as).

This agrees with the statement if acceleration a is the same for different coins.

The second part of this argument involves friction F = km.

As F = km = ma the m's cancel and a is constant.

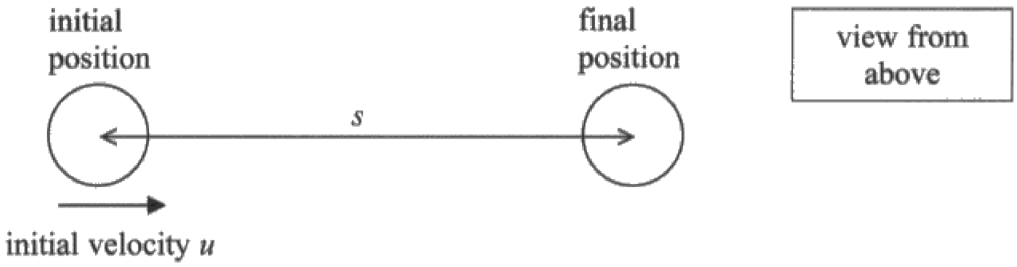
A final sentence along the lines of 'the student's statement should be correct'.

Candidates who used the energy approach usually gained high marks. Some candidates scored poorly by considering what was happening during the sharp tap. Some candidates approached the discussion as a critique of experimental methods and missed the point of the question. Some candidates misread the question and discussed the statement that frictional force is directly proportional to the mass of an object.

Some answers seemed to confuse more than one force acting on the coin.

14 A student carried out an experiment with coins.

(a) She gave a 2p coin a sharp tap, so that it slid along a horizontal surface and came to rest as shown.



The student recorded the distance *s* moved by the coin.

She then replaced the 2p coin with a 1p coin and repeated the process.

The student read that the frictional force between an object and a surface is directly proportional to the mass of the object. She suggested that, in her experiment, *u* is directly proportional to √*s* and is independent of the mass of the coin.

Discuss the validity of this suggestion.

(6)

Her suggestion is ~~not~~ valid because for the coin to stop that means that ~~her~~ there was a resultant force acting on it ~~on~~ in the opposite direction. The resultant force is equal to friction. Since both the resultant force and the friction are calculated using the mass, this means that the mass cancels ~~ot~~ out and it doesn't affect the acceleration. Therefore, since ~~[illegible]~~ ~~[illegible]~~ v=0 then $\cancel{v^2}^{0}=u^2+2as$ $u=\sqrt{2as}$ $u=\sqrt{-2a}\sqrt{s}$, since a is constant this mean that the graph of u against √s, will be a straight line through the origin which shows direct proportionality.

ResultsPlus
Examiner Comments

This gains mark point 1 and mark point 2.

Mark point 3 was given as there is some reference to friction stopping the coin.

Mark point 6 was given but mark point 4 and 5 were not explicit.

A number of answers correctly used SUVAT for the first two mark points but were unable to develop the argument further.

Frictional force = μR => where R is the normal Reaction. $R = w$ => $R = wg$ so since $R \propto m$ then it follows that Friction $\propto m$. $\overset{0}{\cancel{v}}{}^2 = u^2 + 2as$ => $u = \sqrt{-2as}$ => so $u \propto \sqrt{s}$, but also $u \propto \sqrt{a}$. And $a = \frac{F}{m}$ => which means that acceleration $\propto \frac{1}{m}$. Since $u \propto \sqrt{a}$ then $u \propto \frac{1}{w}$ so the student is partially correct

ResultsPlus
Examiner Comments

Mark points 1 and 2 were given.

Mark point 3 was not explicitly stated. There is no statement that friction slows the coin down.

Mark point 4 was given for use of *F=ma* and the answer just about infers that F is friction.

Total 3 marks.

A number of answers wrote down the correct SUVAT equation for mark point 1.

They then didn't make a clear link between *u* and *s* for mark point 2.

$\overset{0}{\cancel{v^2}} = u^2 + 2as$

$s = \frac{u^2}{-2a}$ a is constant

The validity of this suggestion is low as mass affects a lot the outcome of this experiment. As u stays constant and m increases (1p to 2p) then it means that ~~s~~ as m increases s will decrease. Resultant force will be much less if m increases as ~~g~~ ~~will~~ ~~also~~ there will be a greater force opposing the force applied by the student

ResultsPlus
Examiner Comments

Mark point 1 given.

Mark point 2 was not given as the answer becomes confused and does not clearly derive *u* = sqroot 2*as.*

$F = ma$ was often quoted but without any explanation.

This answer does state that F is friction so collects that mark point.

$\Sigma F = ma$

Friction $= ma$

$Fr \propto M$

$a = \frac{Fr}{M}$

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

$u = \sqrt{v^2 - 2as}$

According to this equation, u is not directly proportional to $\sqrt{s}$ and also it is not independant of the mass, as the acceleration in the equation is found by dividing friction with mass.

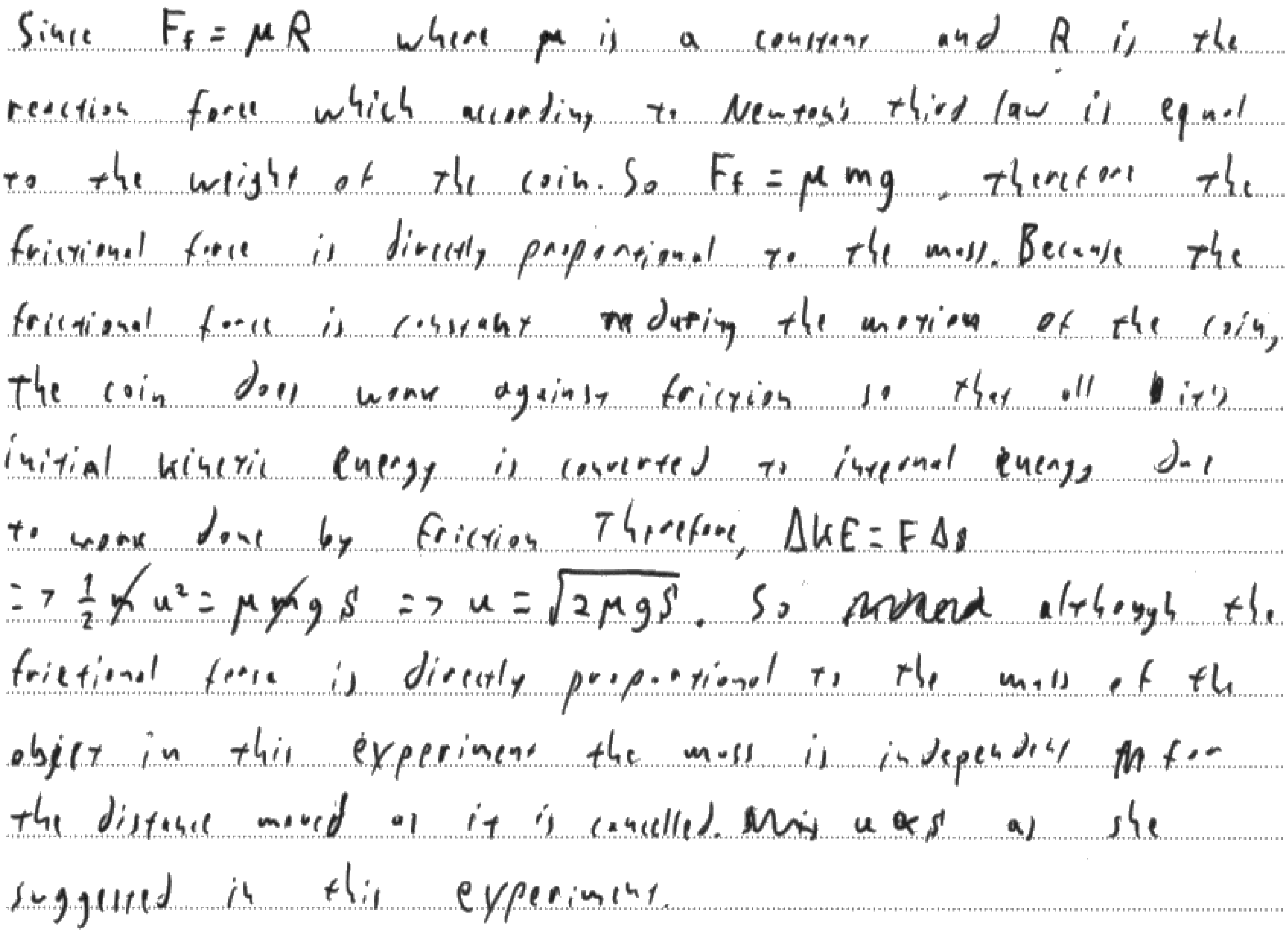
ResultsPlus
Examiner Comments

This answer gains mark point 1 but not 2.

It also gets mark point 4 for $F = ma$ and F is friction.

Mechanics questions can usually be answered by an energy approach.

This answer efficiently gains all the marks.



Since $F_f = \mu R$ where μ is a constant and R is the reaction force which according to Newton's third law is equal to the weight of the coin. So $F_f = \mu mg$, therefore the frictional force is directly proportional to the mass. Because the frictional force is constant during the motion of the coin, the coin does work against friction so that all it's initial kinetic energy is converted to internal energy due to work done by friction. Therefore, $\Delta KE = F\Delta s$ $\Rightarrow \frac{1}{2}\cancel{m}u^2 = \mu\cancel{m}g s \Rightarrow u = \sqrt{2\mu g s}$. So although the frictional force is directly proportional to the mass of the object in this experiment the mass is independent for the distance moved as it is cancelled. Mia was as she suggested in this experiment.

Results Plus
Examiner Comments

This answer is a nice example of the energy transfer approach for full credit.

Question 14 (b)

This question tested conservation of momentum in 2 dimensions.

In Q14(b)(i) candidates had to calculate the momentum of both coins in the 'horizontal' direction. Mark point 1 and mark point 2.

Add these two momentums together and equate to the initial momentum of the 2p coin gained mark point 3.

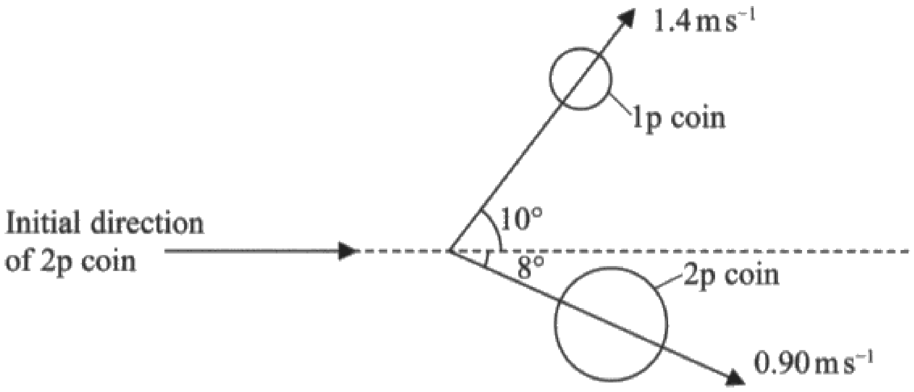
A correct answer gained mark point 4.

In Q14(b)(ii) the kinetic energy of each coin needs to be calculated before and after the collision. Mark point 1 was for any calculation of a kinetic energy.

Mark point 2 was for correct values and a conclusion.

A few responses recognised momentum conservation but did not use the components in the 'x' direction.

(b) She arranged a collision between a 2p coin and a stationary 1p coin. She noted the directions in which the coins moved after the collision and determined their velocities.



(i) Show that the velocity of the 2p coin just before the collision was about 2 m s^{-1}.

mass of 2p coin = 7.1 g

mass of 1p coin = 3.6 g

(4)

$m_1u_1 = m_1v_1 + m_2v_2$

$7.1 \times 10^{-3} \times x = 7.1 \times 10^{-3} \times 1.4 + 3.6 \times 10^{-3} \times 0.90$

$x = \frac{0.01318}{7.1 \times 10^{-3}}$

$v = 1.85\ ms^{-1}$

$v = 2 ms^{-1}$

(ii) Show that the collision was inelastic.

(2)

$\cos(10) \times 1.4 = 1.38$ total momentum before ≠ total momentum after

[illegible]

$\cos(8) \times 0.90 = 0.89$

ResultsPlus
Examiner Comments

This answer does not calculate the components in the horizontal direction.

This answer correctly follows the mark scheme for full credit.

(i) Show that the velocity of the 2p coin just before the collision was about 2 m s⁻¹.

B mass of 2p coin = 7.1 g

A mass of 1p coin = 3.6 g

(4)

X: $m_A \cancel{u_A}^{0} + m_B u_B = m_A v_A + m_B v_B$

$0.0071 u_B = 0.0036 \times 1.4 \cos 10° + 0.0071 \times 0.9 \cos 58°$

X: $V_B = 1.59 \, ms^{-1}$

(ii) Show that the collision was inelastic.

(2)

$E_{K_b} = \frac{1}{2} mv^2 = \frac{1}{2}(0.0071)(1.59)^2 = 8.98 \times 10^{-3} J$

$E_{K_A} = \frac{1}{2}(0.0071)(0.9)^2 + \frac{1}{2}(0.0036)(1.4)^2 = 6.40 \times 10^{-3} J$

$E_{K_{Bef}} \neq E_{K_{after}} \rightarrow$ Inelastic

ResultsPlus
Examiner Comments

This answer gains full credit for both parts.

A significant number of responses made the following error in calculating kinetic energies.

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

$(7.1u_1) + 3.\cancel{6\times0}^{0} = (7.1 \times 0.90\cos(8)) + (3.6 \times 1.4 \times \cos 10))$

$u_1 = \dfrac{6.33 + 4.96}{7.1}$

$u_1 = 1.59 \approx 2\,\text{ms}^{-1}$

(ii) Show that the collision was inelastic.

(2)

If inelastic $\frac{1}{2}mv_b^2 \neq \frac{1}{2}mv_A^2$

$\frac{1}{2}\left(\overset{0.0071}{\text{[illegible]}}\right) \times (1.59)^2 \overset{?}{=} \frac{1}{2}(0.0071)(0.90\cos8)^2 + \frac{1}{2}(0.0036)(1.4\cos10)^2$

$0.00897 \overset{?}{=} 0.0028198 + 0.00342$

$0.00897 \neq 0.0062398 \quad \therefore$ Inelastic

ResultsPlus

Examiner Comments

This answer gains full credit for Q14(b)(i).

In Q14(b)(ii) the horizontal components of velocity are used restricting the credit gained.

ResultsPlus

Examiner Tip

Kinetic energy is a scalar quantity. This means that it doesn't have a 'direction' and components are not relevant.

Question 15 (a)

This question required candidates to analyse a simple graph.

Mark point 2 was given for stating current = 0 for negative pd's.

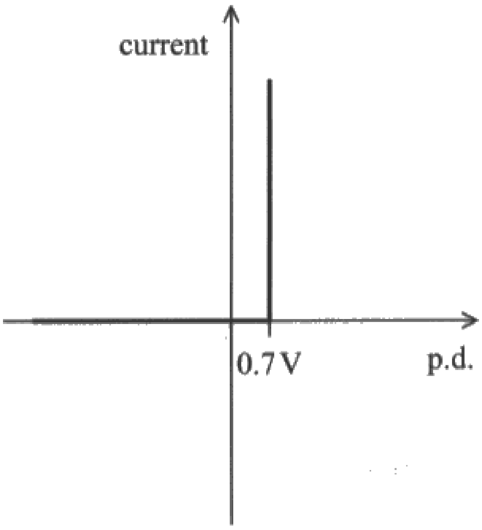
Mark point 1 was given for fully addressing positive pd's. Many candidates correctly stated that a current flowed when the pd was 0.7 V but did not say anything about what happens between 0 V and 0.7 V.

To gain mark point 2 the answer had to say something like the current is zero between 0 and 0.7 V and at 0.7 V there is a current.

Some candidates discussed the resistances involved - the question did not say 'explain' so this is not required.

This answer fully addresses both the full range of negative and positive pd's.

15 The graph shows how current varies with potential difference (p.d.) for an ideal diode.



$\uparrow R = \frac{V}{I\uparrow}$

(a) Describe how the current through this diode varies for positive p.d.s and negative p.d.s.

(2)

For negative p.ds there is infinite resistance ∴ current is 0.

For positive p.ds less than 0.7V current is also 0. ($R = \infty$)

For positive p.d.s greater than 0.7V which is the threshold voltage there is ~~resistance~~ current as we can see a vertical straight line at 0.7V.

ResultsPlus
Examiner Comments

This follows the mark scheme for 2 marks.

This answer does not describe what happens to the current for positive pd's.

Positive pd.s has currunt but
negative p.d.s has zero / no current
OR current cannot pass through
the negative pds

ResultsPlus
Examiner Comments

This gets mark point 2 for no current in negative pd's.

Some answers failed to address the question.

For positive p.d's at 0.7V, the current increases at the
same voltage. For negative p.d's theres no change (increase or
decrease). For ~~decreasing~~ increasing p.d above 0.7V, theres
a 0 + .

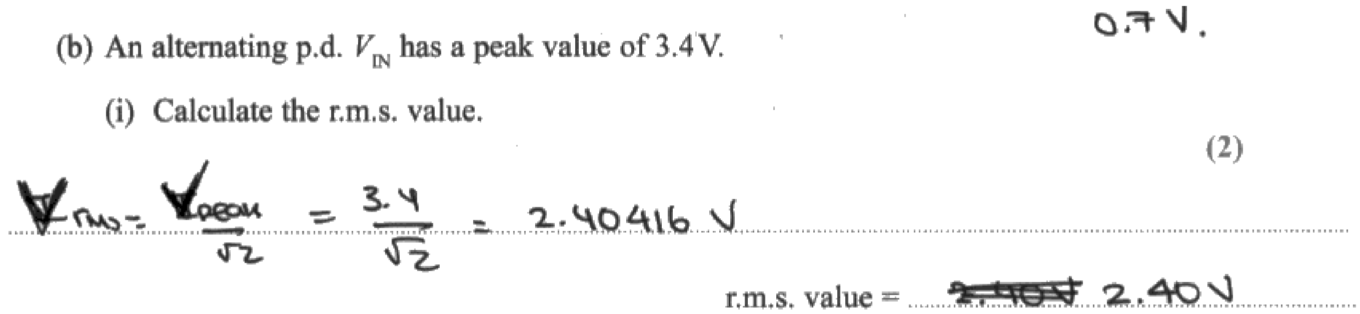
ResultsPlus
Examiner Comments

This answer doesn't actually state mark point 1 or 2.

Question 15 (b) (i)

This tested page 129 of the specification.

A straight forward calculation gaining full credit.



0.7 V.

(b) An alternating p.d. V_{IN} has a peak value of 3.4 V.

(i) Calculate the r.m.s. value.

(2)

$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{3.4}{\sqrt{2}} = 2.40416\ V$

r.m.s. value = ~~2.404~~ 2.40 V

ResultsPlus
Examiner Comments

This gains full credit.

Numerical answers need to be accompanied by the correct unit.

$\frac{3.4}{\sqrt{2}} = 2.4$

r.m.s. value = 2.4

ResultsPlus
Examiner Comments

The most common way to lose 1 mark was to forget the unit to the answer.

Question 15 (b) (ii)

This question tested page 35 of the specification.

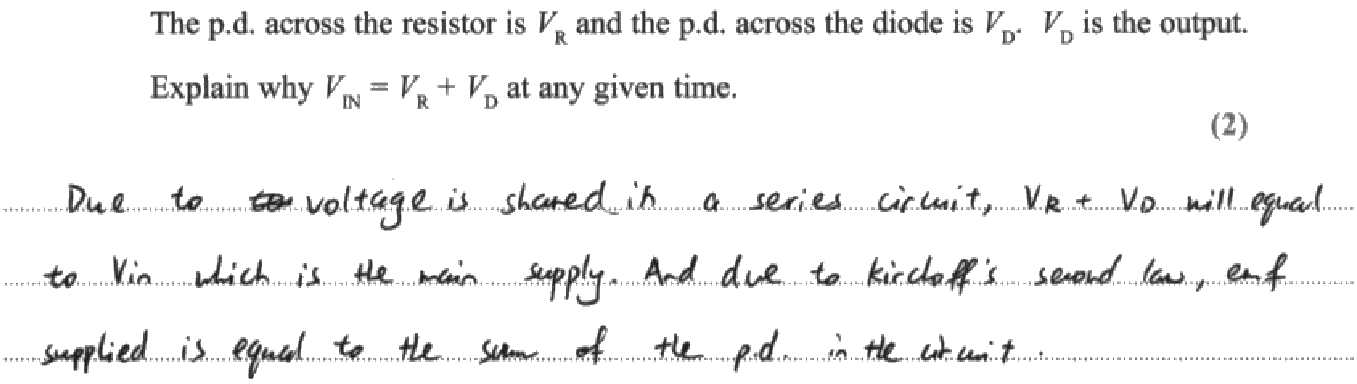
Many candidates answered this question superficially without addressing the command word 'explain'.

An initial reference to energy conservation (Kirchoff's law was also allowed) gained mark point 1.

The second mark (dependent on gaining mark point 1), was for a full description of the sum of pd's in a series circuit being equal to $V_{in.}$

The second mark point can be accessed only if mark point 1 is awarded.

Mark point 1 was awarded for either reference to energy conservation or to Kirchoff's law.



The p.d. across the resistor is V_R and the p.d. across the diode is V_D. V_D is the output.

Explain why $V_{IN} = V_R + V_D$ at any given time.

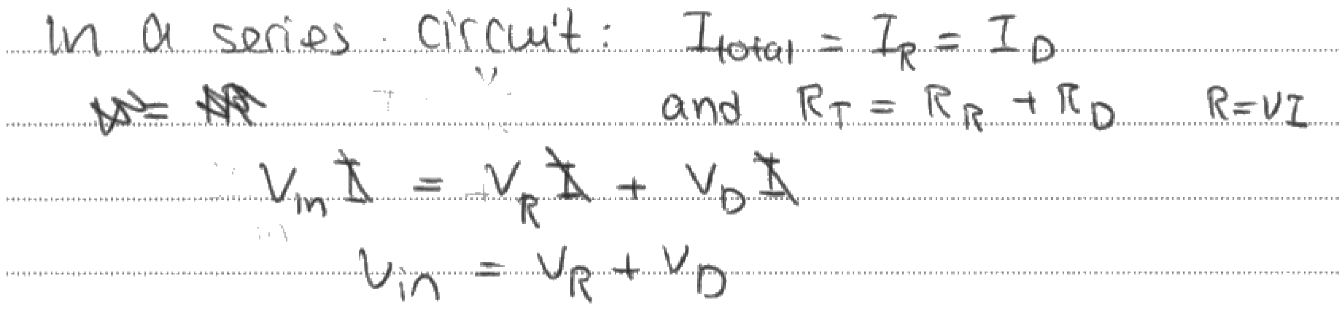
(2)

Due to ~~to~~ voltage is shared in a series circuit, $V_R + V_D$ will equal to Vin which is the main supply. And due to kirchoff's second law, emf supplied is equal to the sum of the p.d. in the circuit.

ResultsPlus
Examiner Comments

This answer gains both marks.

An alternative approach that was accepted, was to identify that the current would be the same in both components and that the power dissipated would equal the power in.



In a series circuit: $I_{total} = I_R = I_D$

~~W= AR~~ and $R_T = R_R + R_D$ $R=VI$

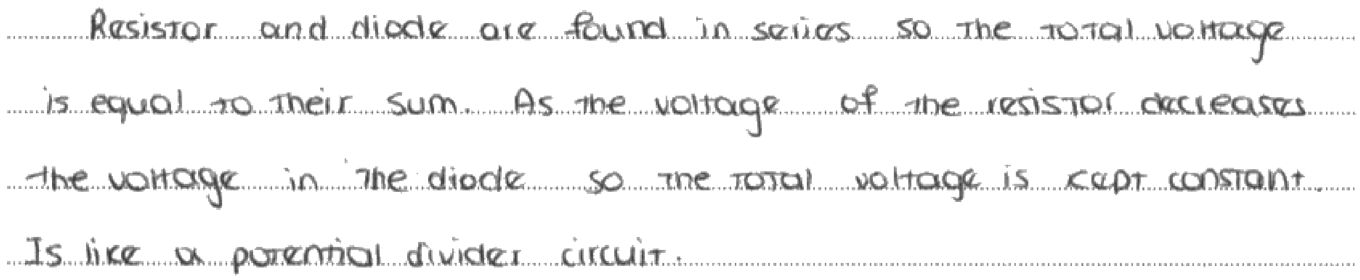
$V_{in} \cancel{I} = V_R \cancel{I} + V_D \cancel{I}$

$V_{in} = V_R + V_D$

ResultsPlus
Examiner Comments

This answer gains full credit for expressing the ideas in equations.

If mark point 1 is not given then mark point 2 could not be awarded.



Resistor and diode are found in series so the total voltage is equal to their sum. As the voltage of the resistor decreases the voltage in the diode so the total voltage is cept constant. Is like a potential divider circuit.

ResultsPlus
Examiner Comments

No mention of energy conservation or Kirchoff's laws so 0 marks.

o conservation of energy. $W = VQ$, $V = \frac{W}{Q}$

$W_{in} = W_R + W_D$

$V_{in}Q = V_RQ + V_DQ$ (charge equal at any point in a series circuit)

$\therefore V_{in} = V_R + V_D$

ResultsPlus
Examiner Comments

A good alternative for full credit.

Mark point 2 required a full description including the word 'series' or reference to a closed loop.

According to kirchoff's first law the total voltages in the circuit will equal to the voltage of the voltage supply for energy to be conserved.

ResultsPlus
Examiner Comments

Mark point 1 given, but 'series' missing, so mark point 2 not given.

Question 15 (b) (iii)

This question proved to be very demanding.

It involved using the graph given at the start of the question.

When the pd V_{in} is positive across the diode then the pd across the diode is 0.7 V for all values of V_{in} greater than 0.7 V. From 0.01 to 0.09 s the value of V_D is 0.7 V.

When the pd V_{in} is negative the first graph tells us that current is zero. This means that the pd across the resistor must also be zero as V=IR.

If $V_R = 0$ then $V_{in} = V_D$. The graph of V_D follows the curve of V_{in} from 0.1 to 0.2 s.

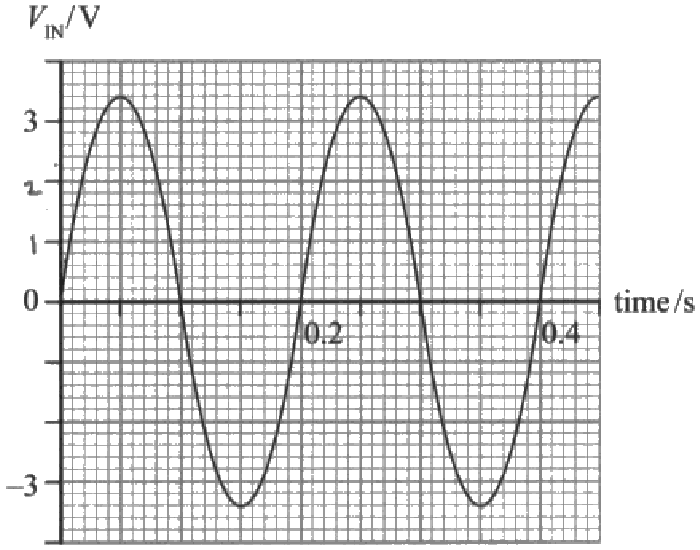
A reasonable amount of candidates gained one mark for either recognising half sine waves or a 0.7 V value in the output, but it was rare to see both.

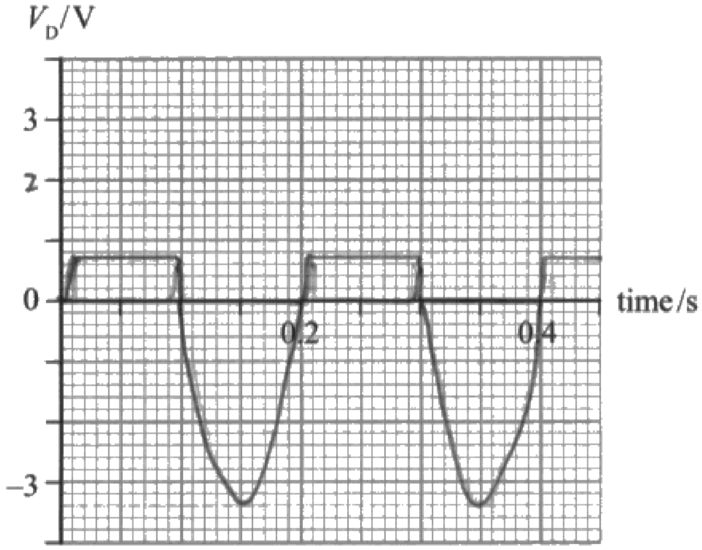
This answer follows the mark scheme for full credit.

(iii) The graph shows how V_{IN} varies with time.

Sketch a graph of V_D against time using the axes provided below.

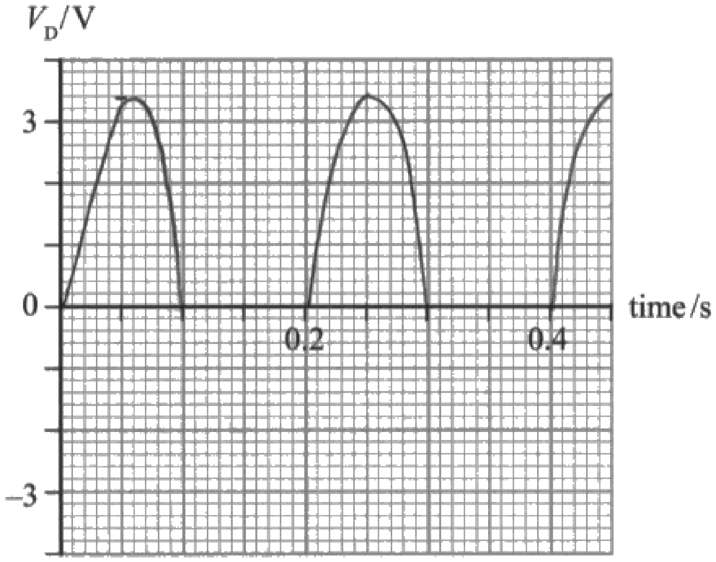
(3)





ResultsPlus
Examiner Comments

This answer shows all the points in the mark scheme.



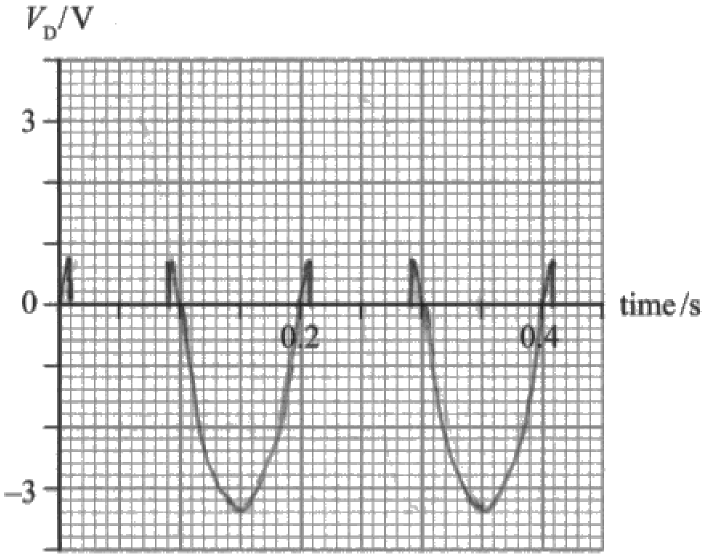
ResultsPlus
Examiner Comments

Mark point 1 was given for alternate cycles of the sine wave. If they were in the wrong place or positive, the mark was still awarded.

ResultsPlus
Examiner Tip

Mark point 1 was given for any alternate half cycle curves of the input pd.

A degree of flexibility was given to the '0.7 V' sections.

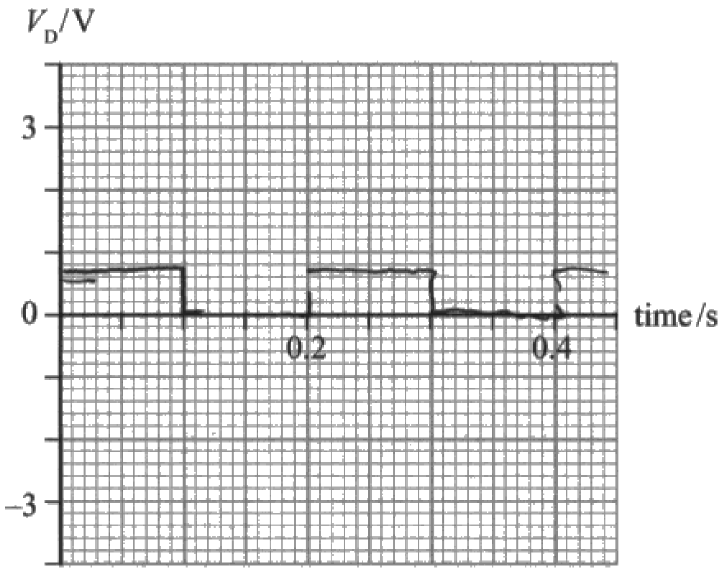


ResultsPlus
Examiner Comments

This answer gains all 3 marks as there is a correct set of half cycle sinusoidal waves.

There was also enough evidence of the 0.7 V to collect full credit.

This answer has the 0.7 V lines in the correct position, but if they had been in the second half of each cycle the mark should be awarded.



ResultsPlus
Examiner Comments

This answer has the 0.7 V part of the graph correct.

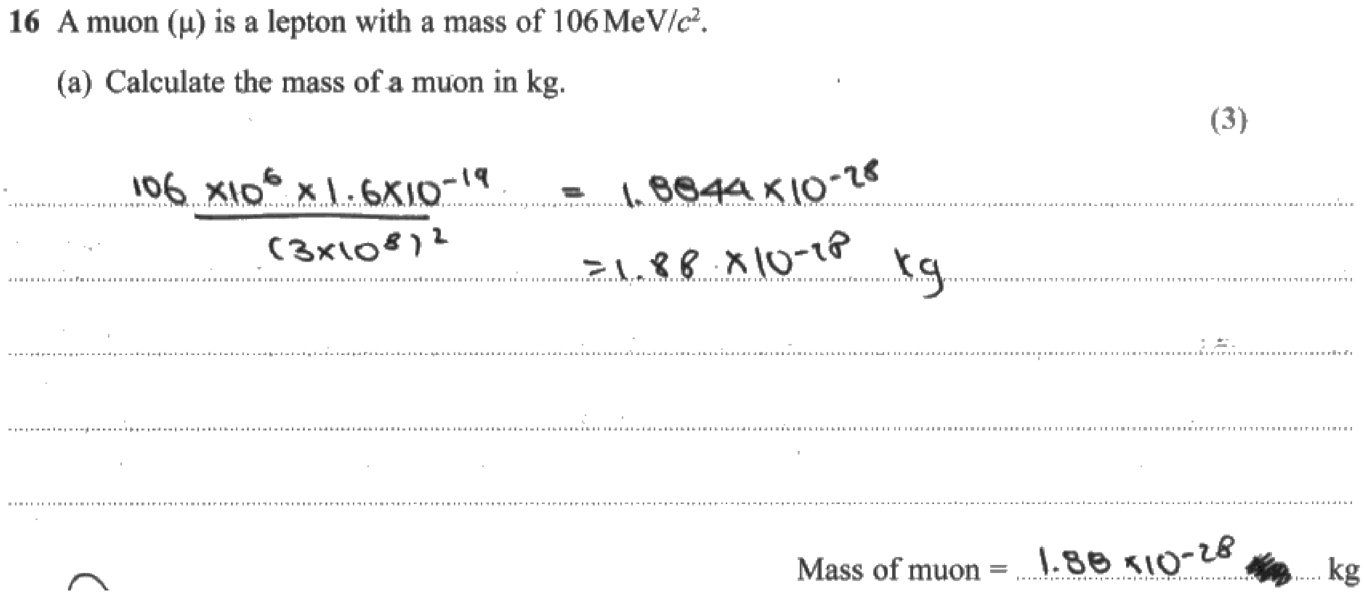
Question 16 (a)

This question required a conversion from MeV/c^2 to kg.

This was carried out competently by the vast majority of candidates.

A few answers muddled M (10^6) or forgot to square *c*.

This follows the mark scheme.



16 A muon (μ) is a lepton with a mass of 106 MeV/c^2.

(a) Calculate the mass of a muon in kg.

(3)

$\frac{106 \times 10^6 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2} = 1.8844 \times 10^{-28}$

$= 1.88 \times 10^{-28}$ kg

Mass of muon = 1.88×10^{-28} kg

ResultsPlus
Examiner Comments

An answer that follows the mark scheme for full credit.

Some responses incorrectly used a variety of different constants from the data page.

$106 \times 10^{6} \times 9.11 \times 10^{-31} = 9.66 \times 10^{-23}$ kg

Mass of muon = $9.66 \times 10^{-2\,3}$ kg

ResultsPlus
Examiner Comments

This answer assumes that MeV/c^2 are electron numbers.

A few candidates did not know G, M, k abbreviations against units.

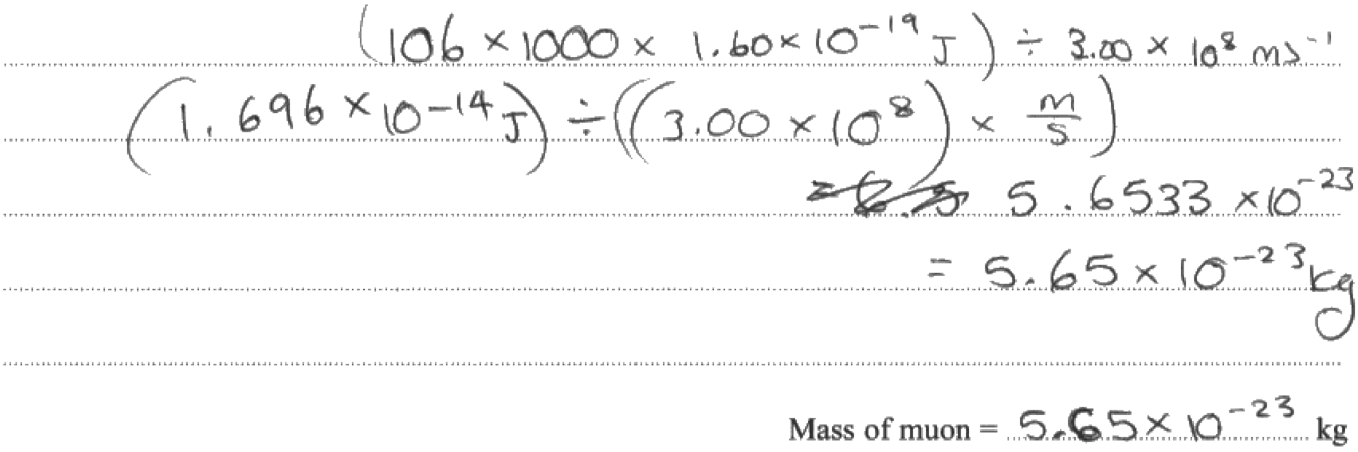
$106 \text{MeV}/c^2 = \dfrac{106 \times 10^{9} \times e}{c^2}$ kg

Mass of muon = 1.89×10^{-25} kg

ResultsPlus
Examiner Comments

This answer suggests M is 10^9 so gains 2 marks.

A common mistake was to write down the square of the speed of light, but forget to actually do it with the calculator.



$(106 \times 1000 \times 1.60 \times 10^{-19} J) \div 3.00 \times 10^{8} ms^{-1}$

$(1.696 \times 10^{-14} J) \div ((3.00 \times 10^{8}) \times \frac{m}{s})$

$= \cancel{6.5}\ 5.6533 \times 10^{-23}$

$= 5.65 \times 10^{-23} kg$

Mass of muon = 5.65×10^{-23} kg

ResultsPlus
Examiner Comments

This answer forgets to square *c* but still converts eV correctly for 1 mark.

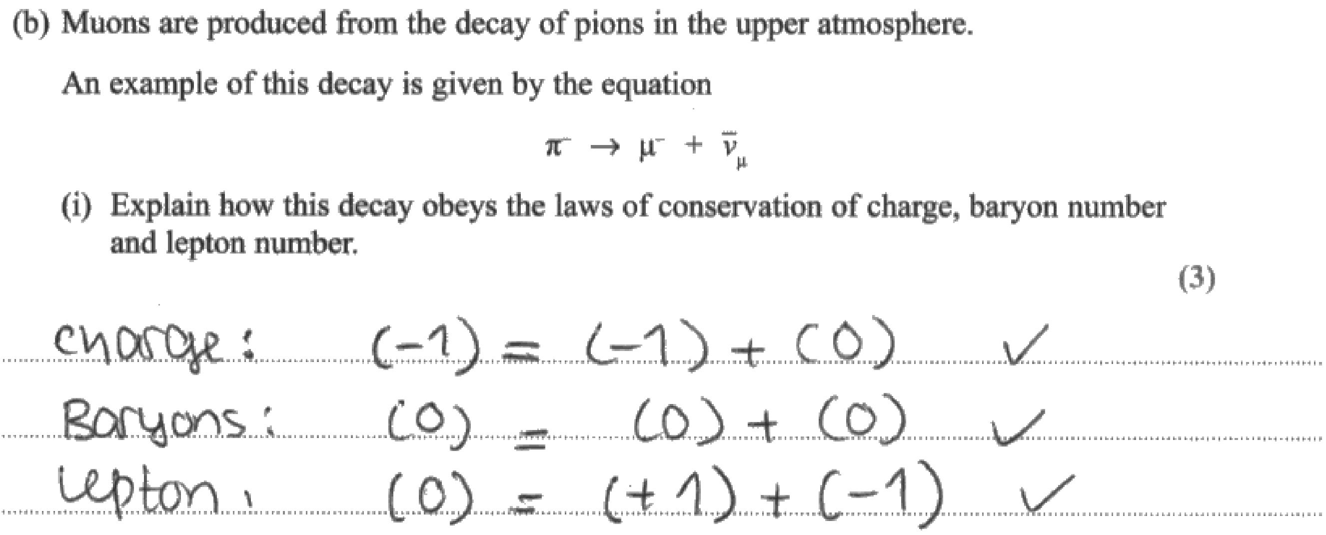
Question 16 (b) (i)

This question tested page 142 of the specification.

Many candidates did well on this question and answered it by writing the numbers before and after, as shown here:

For charge: -1 = -1 + 0

Candidates could answer this type of question most efficiently with a simple numerical layout as shown here.



(b) Muons are produced from the decay of pions in the upper atmosphere.

An example of this decay is given by the equation

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

(i) Explain how this decay obeys the laws of conservation of charge, baryon number and lepton number.

(3)

charge: $(-1) = (-1) + (0)$ ✓

Baryons: $(0) = (0) + (0)$ ✓

lepton: $(0) = (+1) + (-1)$ ✓

ResultsPlus
Examiner Comments

This answer gains full credit.

ResultsPlus
Examiner Tip

Use a number method as shown here.

Some answers lacked sufficient detail.

~~Muons~~ Pions have a negative charge and ~~Both~~ the ~~[illegible]~~ μ also has a negative charge but the $\bar{\nu}$ doesnt, it has ~~a~~ no charge ~~neutral~~ which means both sides ~~[illegible]~~ have the same charge meaning it obeys the law.

ResultsPlus
Examiner Comments

This answer addresses charge, however, it does not state that the charge before is -1. Negatively charged is not detailed enough to gain the mark.

Note also that some candidates wrote 'the charge after is also -1'. The mark is for explicitly pointing out that the charge after is -1 + 0

Some responses did not specifically state the baryon number.

None of the particles in this decay are baryons, therefore baryon number is conserved. Both the pion and muon have a ~~negative cha~~ charge of negative one and the ~~antimuon~~ antimuon neutrino has no charge, therefore charge is conserved. the pion isn't a lepton and has no lepton number, the muon has a lepton number of one and the ~~A~~ antimuon neutrino has a lepton number of negative one, therefore lepton number is conserved.

ResultsPlus
Examiner Comments

This answer did not gain the mark for addressing baryon number.

The question asked candidates to consider baryon number. There needed to be some statement within the answer that it is 0.

Question 16 (b) (ii)

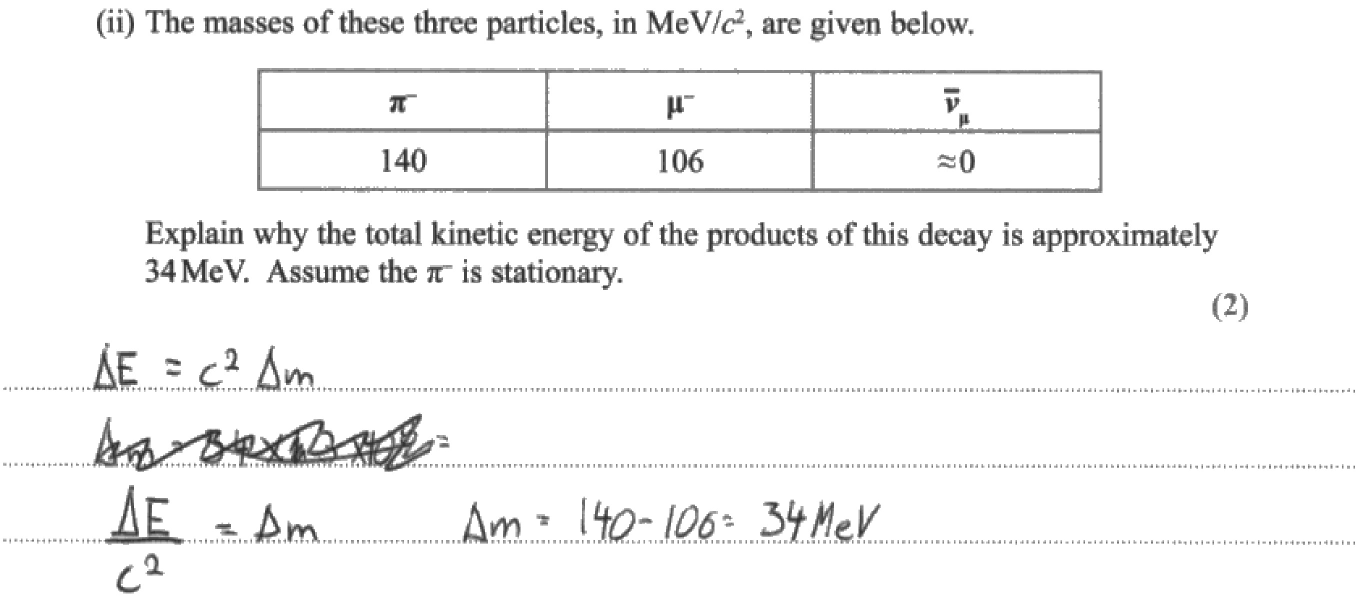
This question proved quite demanding.

It is about mass-energy conservation.

140 -106 = 34 MeV/c^2 is the mass difference for mark point 1. The unit was not required but some answers confused units (eg referring to mass in MeV energy).

According to $E = \Delta mc^2$ this mass will be converted to an energy of 34 MeV achieved mark point 2.

Units of energy and mass in this question were often confused.



(ii) The masses of these three particles, in MeV/c^2, are given below.

π^-	μ^-	$\bar{\nu}_\mu$
140	106	≈ 0

Explain why the total kinetic energy of the products of this decay is approximately 34 MeV. Assume the π^- is stationary.

(2)

$\Delta E = c^2 \Delta m$

~~$\Delta m = 34 \times$ [illegible]~~ =

$\frac{\Delta E}{c^2} = \Delta m$ $\Delta m = 140 - 106 = 34$ MeV

ResultsPlus
Examiner Comments

This answer gains mark point 1.

Note that it confuses the units of mass - suggesting they are MeV.

The equation is written out but with no explanation.

This response gains some credit but doesn't link ideas together in order to gain full marks.

$\Delta E = \Delta m c^2$ $\Delta E = \Delta m c^2$

$\Delta m = 140 - 106 = 34 \frac{MeV}{c^2}$ $= 34 \frac{meV}{c^2}$

mass deficit = 34 MeV/c^2

ResultsPlus
Examiner Comments

This answer gains mark point 1.

It quotes the relevant equation but doesn't finish off by explaining why the energy will be 34 MeV.

A good answer.

$\mu^- + \bar{\nu}_\mu$ mass: 106 MeV/c^2

π^- mass = 140 MeV/c^2

$\Delta m = 140 - 106 = 34$ meV/c^2

$\Delta E = c^2 \Delta m = c^2 \times 34 MeV/c^2 = 34$ MeV.

ResultsPlus
Examiner Comments

This gains mark point 1.

It also gains mark point 2 and points out how the unit of mass changes to a unit of energy.

Take note of the prompt 'explain'.

Because 140 - 106 gives 34 MeV.

ResultsPlus
Examiner Comments

Many candidates observed the difference in numbers gave the answer 34, but failed to provide an explanation.

ResultsPlus
Examiner Tip

Your answer should include some degree of explanation as stated within the question.

This candidate understands the difference in units but doesn't explain the value.

change in mass between pion and products is $140 - 106 = 34 \frac{MeV}{c^2}$

$34 \frac{MeV}{c^2}$ is equal to kinetic energy of 34 MeV

ResultsPlus
Examiner Comments

This answer gains mark point 1.

It does not explain why the mass difference results in energy.

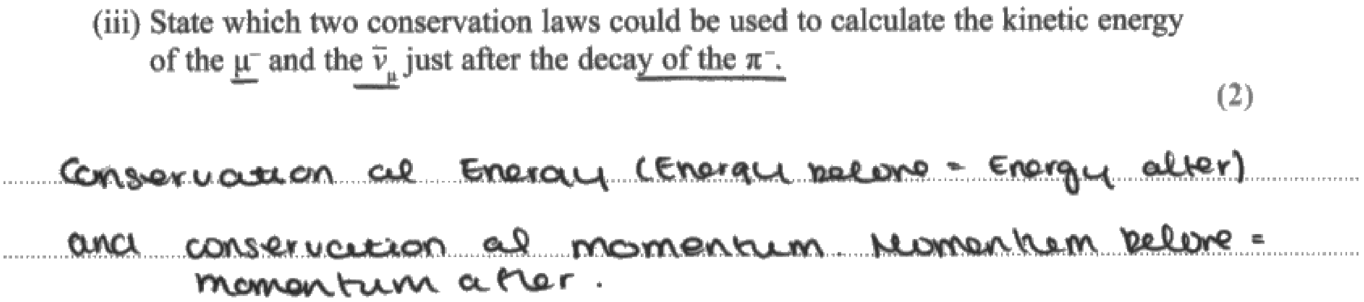
Question 16 (b) (iii)

This question required two laws: the law of conservation of momentum and the law of conservation of mass-energy.

The second conservation law should be spelt as 'mass-energy' to avoid confusion with the mechanics law which has its own conservation of energy.

Conservation of mass-energy is required.

Conservation of energy in mechanics is a different application.



(iii) State which two conservation laws could be used to calculate the kinetic energy of the μ^- and the $\bar{\nu}_\mu$ just after the decay of the π^-.

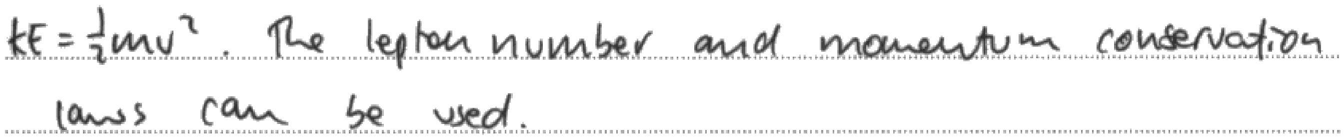
(2)

Conservation of Energy (Energy before = Energy after) and conservation of momentum. Momentum before = momentum after.

ResultsPlus
Examiner Comments

An example of 'conservation of energy' which was not acceptable.

The law of conservation of momentum was usually included but a significant number of responses mentioned a variety of other irrelevant laws.



$KE = \frac{1}{2}mv^2$. The lepton number and momentum conservation laws can be used.

ResultsPlus
Examiner Comments

A number of other laws were sometimes incorrectly quoted (eg law of conservation of charge, etc).

Conservation of mass means something different in chemistry so 'mass-energy' was required.

Mass ~~of~~ must be conserved between the process of the decay

Velocity must be conserved between the process of the decay.

ResultsPlus
Examiner Comments

'Mass-energy' was required for the mark.

A good answer for both marks.

Conservation of ~~ene~~ mass-energy and conservation of momentum

ResultsPlus
Examiner Comments

This answer follows the mark sceme for both marks.

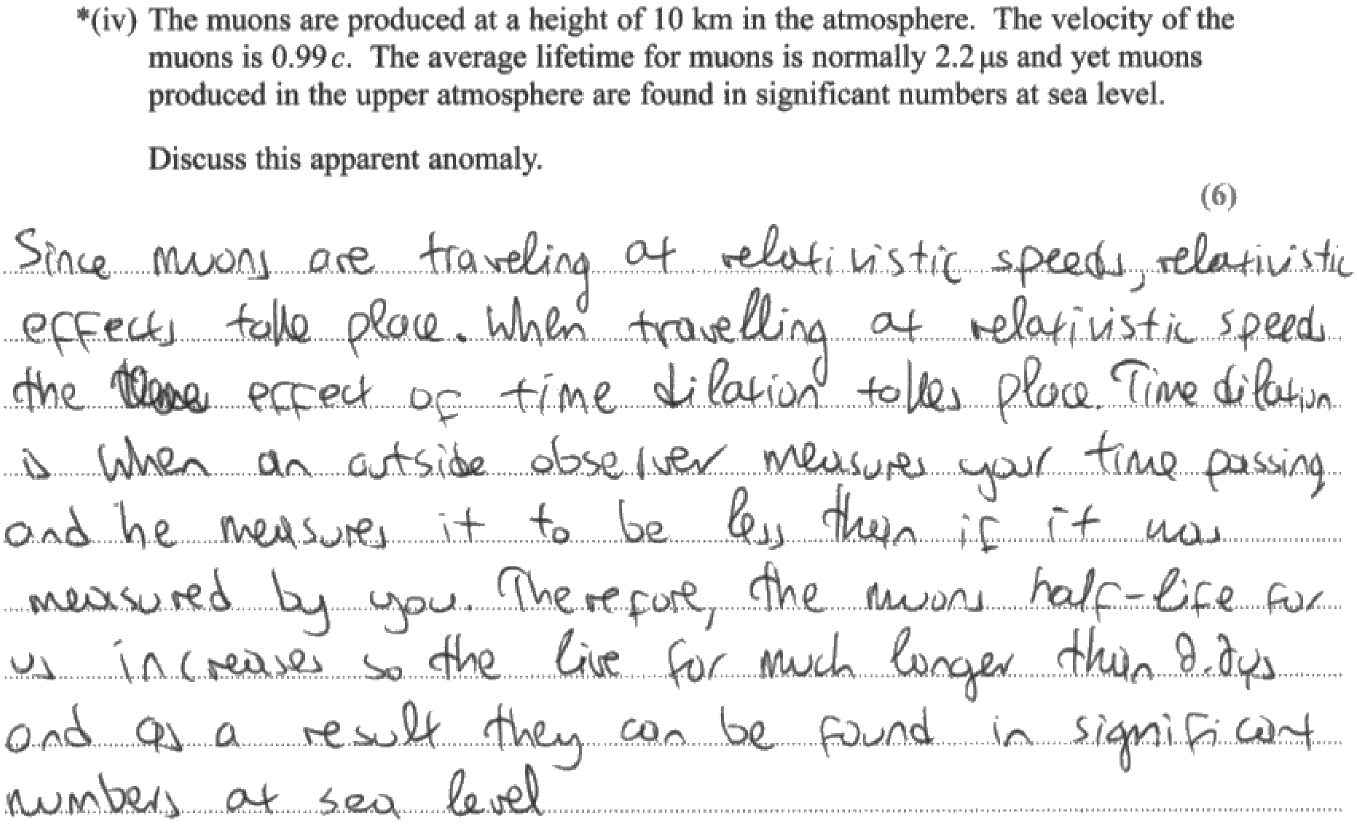
Question 16 (b) (iv)

This question covered page 139 of the specification.

Three indicative points are connected with using speed = distance/time and the data given in the question.

The other three points are to do with relativistic increase in particle lifetime, coupled with an appropriate concluding remark about particle lifetime.

This answer covered the qualitative aspects of the discussion but not the quantitative.



*(iv) The muons are produced at a height of 10 km in the atmosphere. The velocity of the muons is $0.99c$. The average lifetime for muons is normally 2.2 μs and yet muons produced in the upper atmosphere are found in significant numbers at sea level.

Discuss this apparent anomaly.

(6)

Since muons are traveling at relativistic speeds, relativistic effects take place. When travelling at relativistic speeds the effect of time dilation takes place. Time dilation is when an outside observer measures your time passing and he measures it to be less then if it was measured by you. Therefore, the muons half-life for us increases so the live for much longer than 2.2μs and as a result they can be found in significant numbers at sea level

ResultsPlus
Examiner Comments

This answer covered the indicative points 4, 5 and 6 but did not address the data given in the question.

ResultsPlus
Examiner Tip

If numbers are given in the question try and use them.

This answer contained the relevant point that the muon is travelling at a relativistic speed.

Since the muons are at relativistic speeds (nearly $3x10^8$), Their mass must change at such high velocities. Muons are also not fundamental particles. This means they could be produced in other ways. Since they move in such high speeds, It is possible for them to move to sea level within their very short lifetime. Due to $E=mc^2$, They have very high energies in numbers aswell due to c being so large.

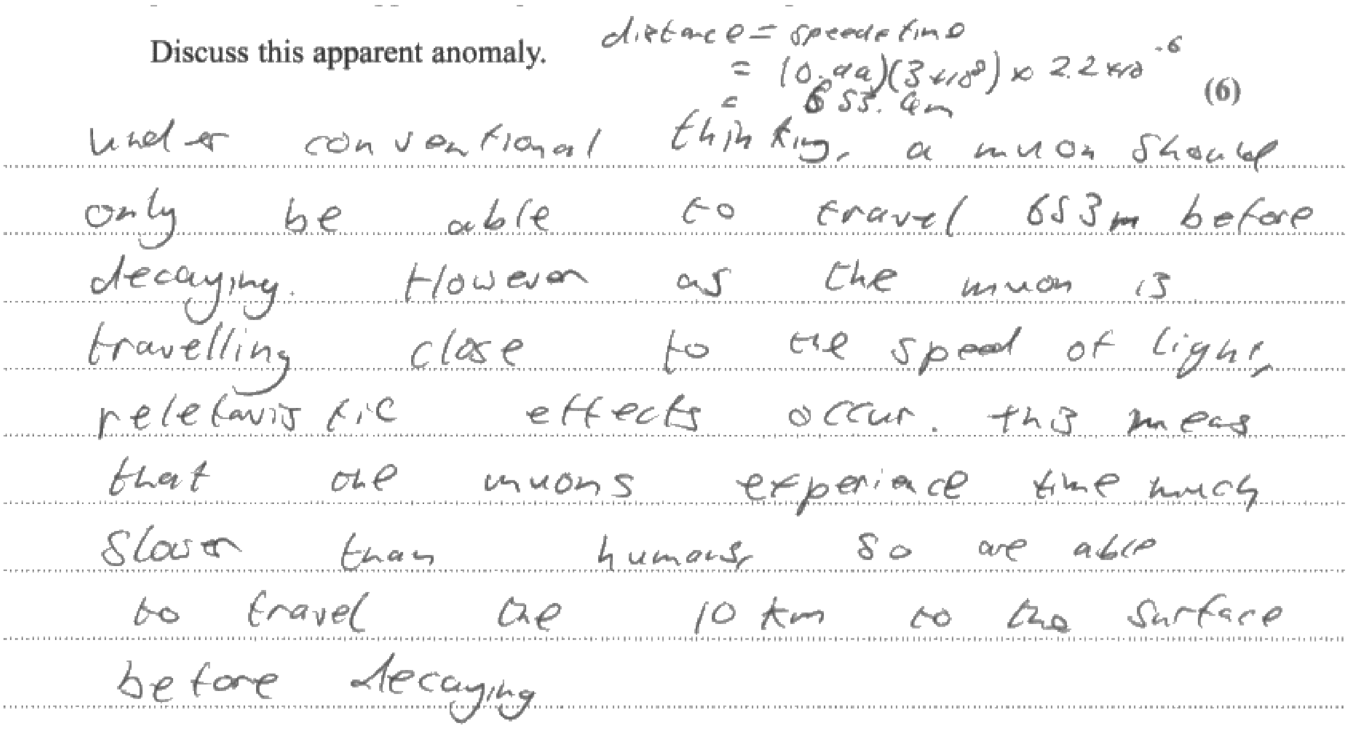
ResultsPlus

Examiner Comments

This answer contains the observation that the muons are travelling at relativistic speeds.

It gains 1 mark.

This was a good answer covering almost all the mark points except the last one.



Discuss this apparent anomaly.

distance = speed × time

$= (0.99)(3 \times 10^8) \times 2.2 \times 10^{-6}$

$= 653.4m$

(6)

under conventional thinking, a muon should only be able to travel 653m before decaying. However as the muon is travelling close to the speed of light, relativistic effects occur. this means that the muons experience time much slower than humans, so are able to travel the 10 km to the surface before decaying

ResultsPlus

Examiner Comments

This answer has all the initial five indicative content points.

It doesn't quite state the effect on muon lifetime so gained 5 marks.

A significant number of responses made use of the data but didn't comment further in a relevant way.

The muons have a very high velocity ~~so~~ even ~~to~~ though they have a very small life time their ~~spee~~ velocity allows them to travel to sea ~~a~~ easily. $0.99c = 297 \times 10^6$ ms^{-1} $297 \times 10^6 \times 2.2 \times 10^{-6} = 653.4$ meters is the distance a muon ~~ca~~ can travel before the average lifetime is over.

ResultsPlus
Examiner Comments

This answer contains indicative points 1 and 2.

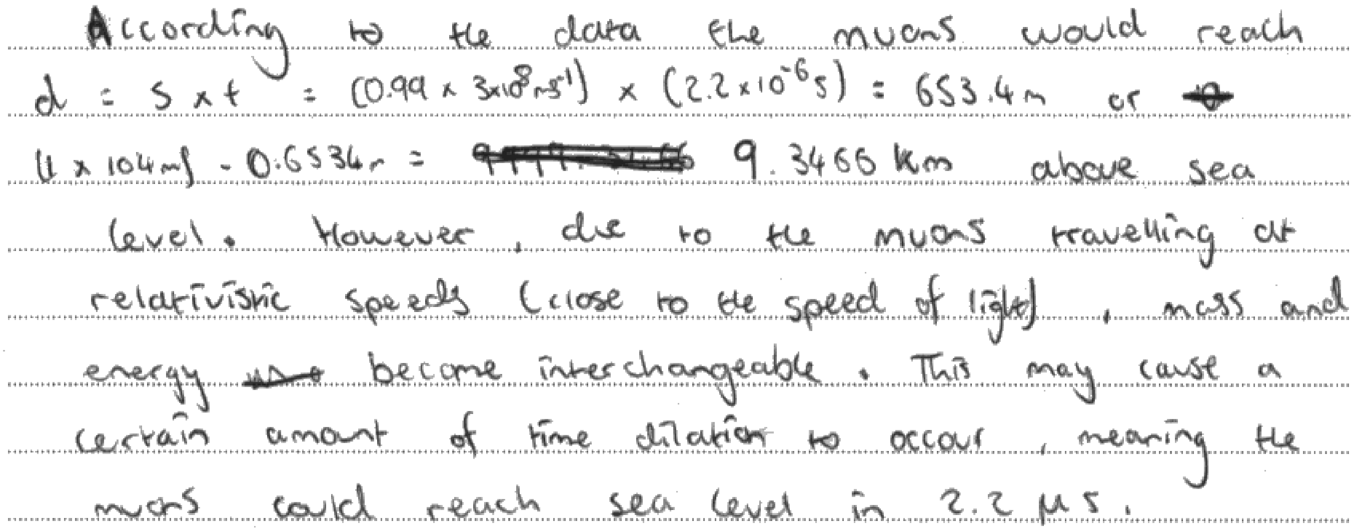
An excellent answer for full credit.

~~The muons~~ For a muon to reach 10km in 2.2μs it would have to be moving at $45.45\times10^{9}\,ms^{-1}$ which is faster than the speed of light (not possible). The anomaly that's occuring is time dilation which is occuring due to the muon travelling at near relativistic speeds (.99c). This means ~~the~~ although a muon only lasts 2.2μs to us for the muon it's around much longer $(\overset{\times10^{3}}{10}/(.99\times3\times10^{8}))$ at around 33.7μs. Time is stretched relatively to the muon due to its high velocity

ResultsPlus
Examiner Comments

This answer was judged to contain all six indicative points.

This response scored well but some candidates became distracted with 'increase in mass' arguments.



According to the data the muons would reach $d = s \times t = (0.99 \times 3\times10^8 ms^{-1}) \times (2.2\times10^{-6}s) = 653.4m$ or ~~0~~ (1 x 104m) - 0.6534m = 9.3466 km above sea level. However, due to the muons travelling at relativistic speeds (close to the speed of light), mass and energy ~~was~~ become interchangeable. This may cause a certain amount of time dilation to occour, meaning the muons could reach sea level in 2.2 μs.

ResultsPlus
Examiner Comments

This answer contains indicative points 1 and 2 for the calculation.

It then contains indicative points 4 and 5.

Question 17 (a)

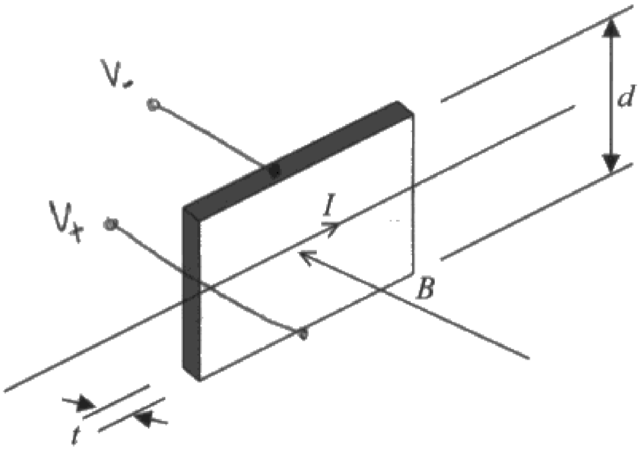
This question required more than 'Flemings left hand rule', which effectively gained mark point 2.

The other observation required for mark point 1 was that the current and magnetic field were not parallel. This was most commonly gained by stating that the current and the magnetic field are perpendicular.

This answer contains both aspects for full credit.

17 Tiny sensors in smartphones could be used to determine the position of the phone on the Earth's surface by measuring the Earth's magnetic flux density.

A current I and a magnetic field of flux density B are applied to a slice of semiconductor as shown. The slice has thickness t and depth d.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

(a) Explain why electrons will collect at the top edge of the slice.

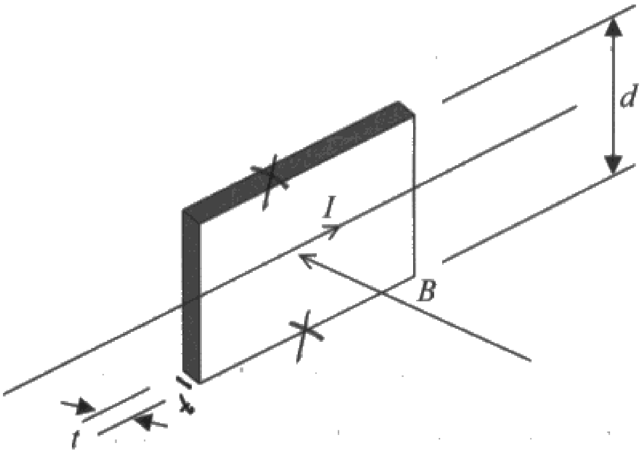
(2)

According to Flemming's LHR the ~~flow~~ magnetic field ~~through~~ perpendicular to the current causes the electrons found in I to experience a force perpendicular to the plane of the current. The electrons are deposited of the top edge and ∴ the bottom edge becomes charge carriers free and positively charged.

ResultsPlus
Examiner Comments

This answer contains both mark points.

Many candidates mentioned Flemings left hand rule for mark point 2 but didn't explain that I and B are non-parallel.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

(a) Explain why electrons will collect at the top edge of the slice.

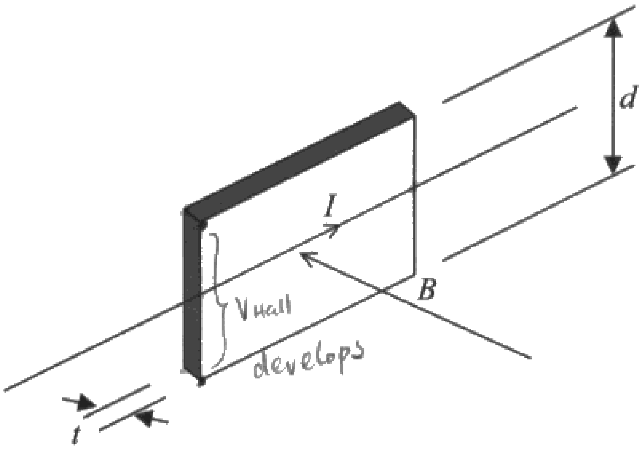
(2)

Based on Flemings lefthand Rule, a force is created on the electrons that pushes them towards the top edge.

ResultsPlus
Examiner Comments

Many answers only mentioned Flemings left hand rule for mark point 2.

Candidates could gain mark point 1 by referring carefully to the diagram to convey perpendicularity.



Electrons collect at the top edge of the slice and the bottom edge becomes positively charged. As a result a potential difference known as a Hall voltage V_{HALL} develops.

(a) Explain why electrons will collect at the top edge of the slice.

(2)

Due to Fleming's Left hand rule, current is from left to right, magnetic field density is inwards, the force will be upwards and electrons will be pushed towards the top edge of the slice.

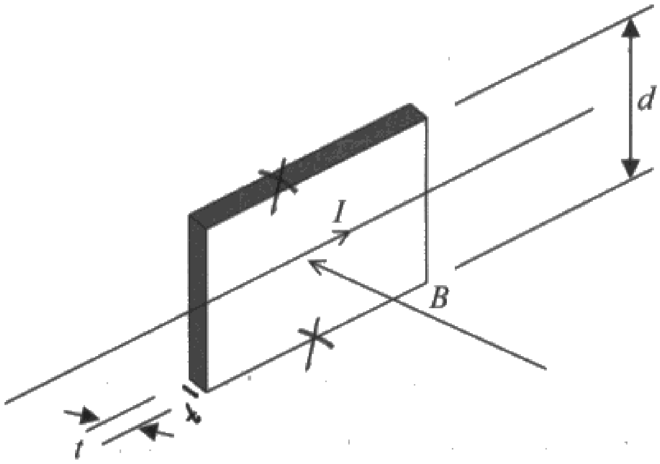
ResultsPlus
Examiner Comments

Reference to the directions of B and I on the diagram was acceptable.

Question 17 (b)

This question tested candidates' ability to read the information given and work in three dimensions to visualise the situation.

The Hall voltage develops between the top and bottom of the slice.



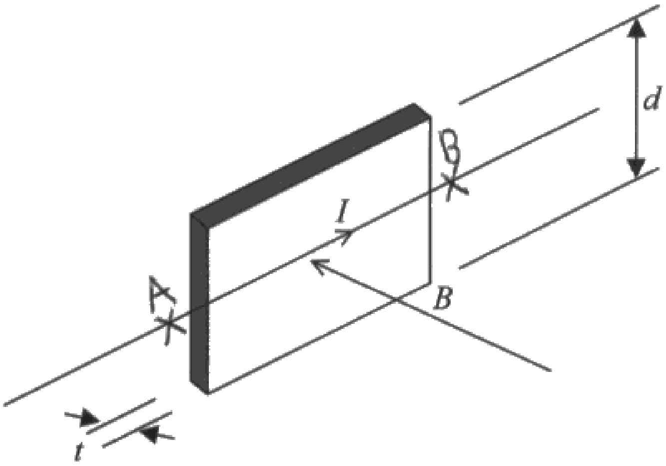
(b) Add to the diagram to show clearly two points between which V_{HALL} develops.

(1)

ResultsPlus
Examiner Comments

The question asked for two points and these are marked clearly for full credit.

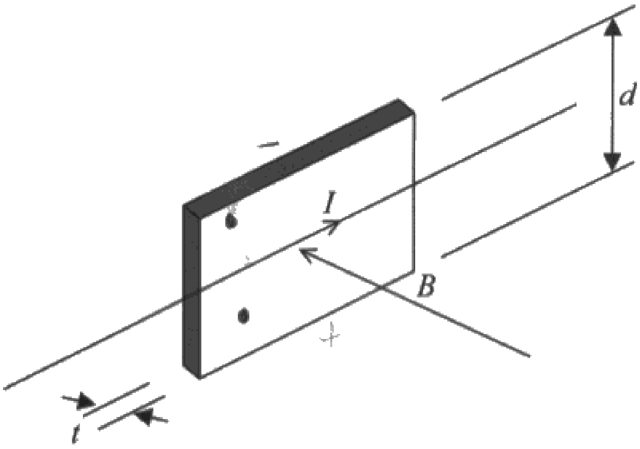
These points could be determined by careful reading of the question.



ResultsPlus
Examiner Comments

The two points are marked along the wrong direction.

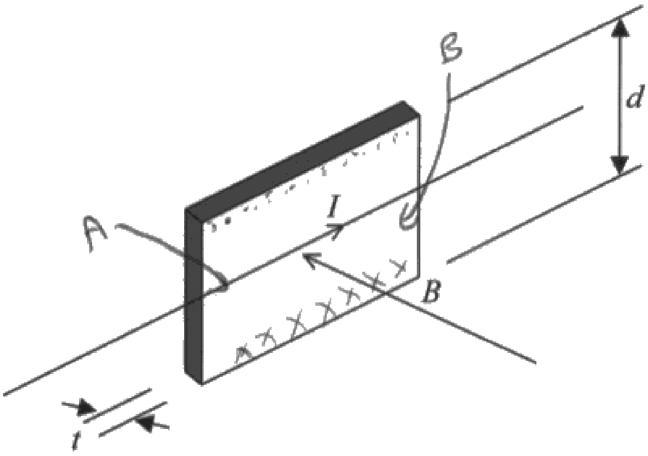
Be accurate when marking points, lines, etc, on a diagram.



ResultsPlus
Examiner Comments

These two points are not marked at the 'top' and 'bottom' of the slice.

Candidates should not present a choice at GCE.



ResultsPlus
Examiner Comments

Credit cannot be given if a choice of more than 2 (and in this case several) points are drawn.

ResultsPlus
Examiner Tip

At GCE, candidates should avoid presenting a choice unless the question explicitly asks for this.

Question 17 (c)

This question asked candidates to derive an equation. The question stated 'until the force on a moving electron due to a magnetic field is equal to the force on the electron due to the electric field'. In order to give candidates the starting point of $F = Bqv = Eq$. This was mark point 1.

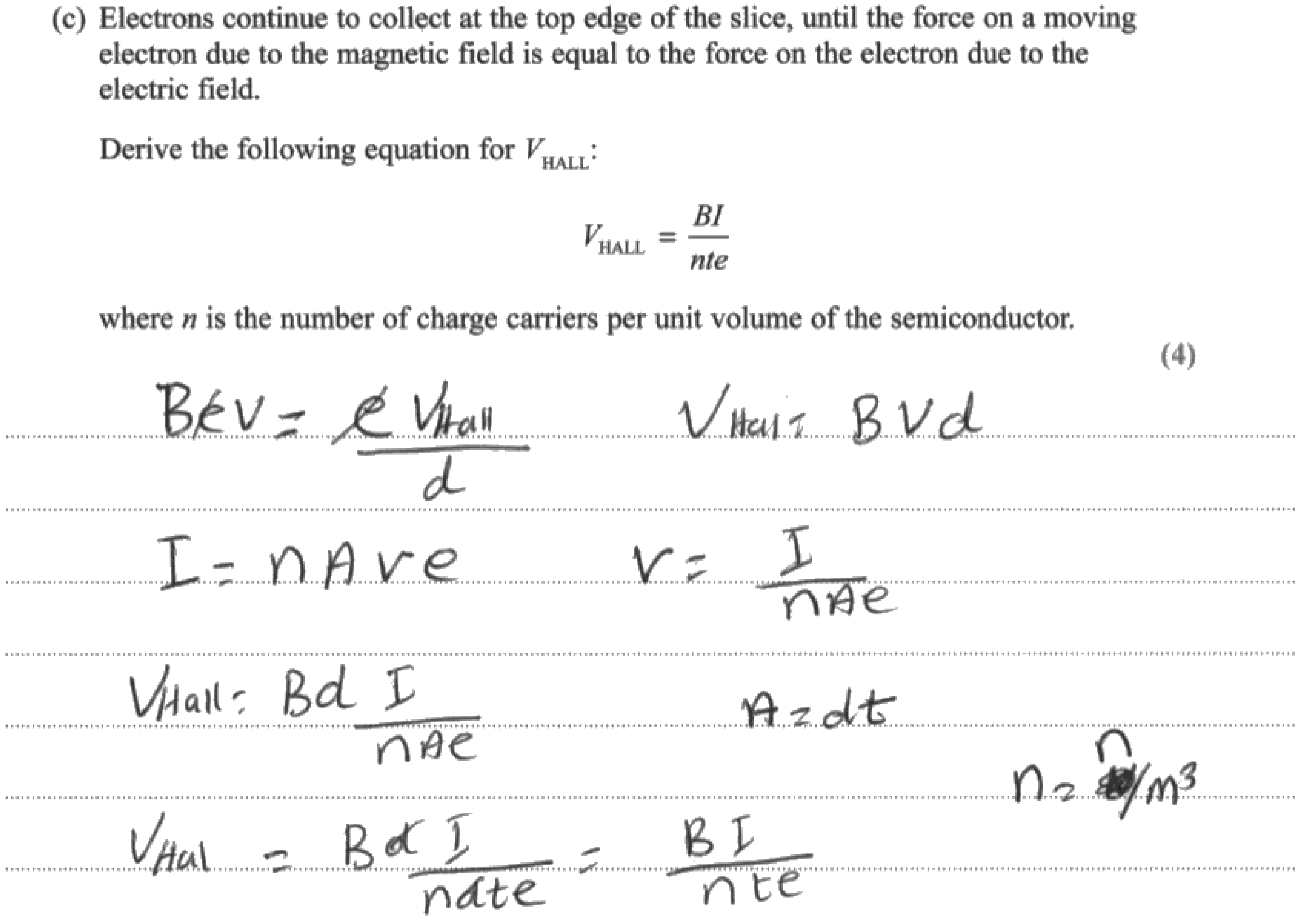
However, many candidates started with $F = BIl = Eq$. This was also awarded mark point 1, and whilst it can lead to a correct derivation most answers of this type did not understand that q would be the total charge in a length of wire l.

The second mark point on either scheme was for substituting $E = V/d$.

The third mark point, if candidates started with $F = Bqv$, was for using the drift velocity equation $v = I/nqA$.

The fourth mark point was for finalising the equation required using Area = $d \times t$.

An excellent response using the prompt within the question.



(c) Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for V_{HALL}:

$$V_{HALL} = \frac{BI}{nte}$$

where n is the number of charge carriers per unit volume of the semiconductor.

(4)

$Bev = \frac{e V_{Hall}}{d}$ $V_{Hall} = BVd$

$I = nAve$ $v = \frac{I}{nAe}$

$V_{Hall} = Bd\frac{I}{nAe}$ $A = dt$

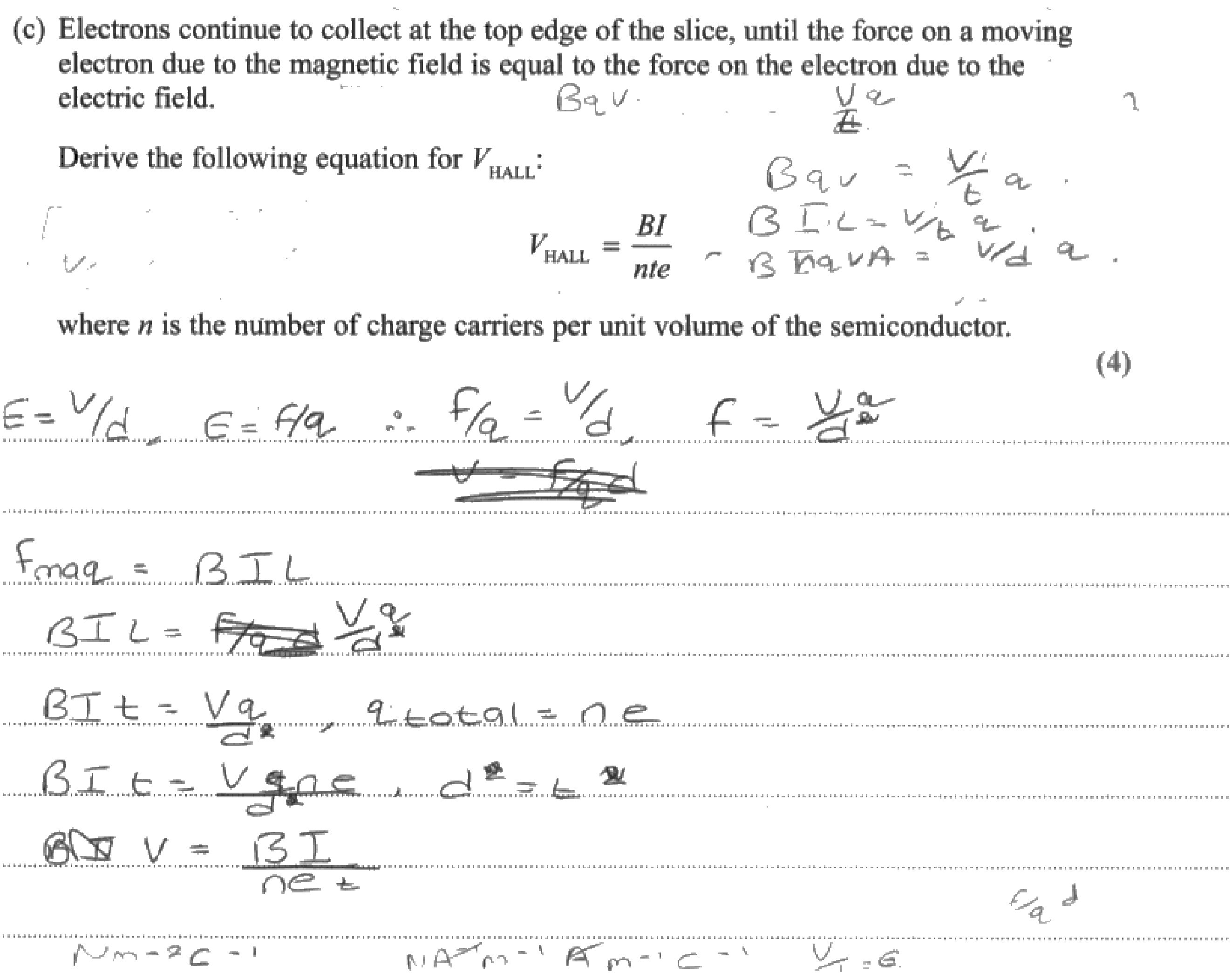
$n = n/m^3$

$V_{Hal} = \frac{BdI}{ndte} = \frac{BI}{nte}$

ResultsPlus
Examiner Comments

This a fully correct derivation using $F = Bqv = Eq$

This response uses the *F=BiI* route but gets muddled with total charge in the wire.



(c) Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Bqv . $\frac{V}{\cancel{t}}q$

Derive the following equation for V_{HALL}:

$$V_{HALL} = \frac{BI}{nte}$$

$Bqv = \frac{V}{t}q$.

$BIL = V/t\ q$.

$BnqvA = V/d\ q$.

where *n* is the number of charge carriers per unit volume of the semiconductor.

(4)

$E = V/d$, $E = F/q$ ∴ $F/q = V/d$, $F = \frac{V}{d}q$

~~$V = F/q\,d$~~

$F_{mag} = BIL$

$BIL = \cancel{F/q\,d}\ \frac{V}{d}q$

$BIt = \frac{Vq}{d}$, $q_{total} = ne$

$BIt = \frac{V\cancel{q}ne}{d}$, $d = t$

$V = \frac{BI}{net}$

$F/q\ d$

$Nm^{-2}C^{-1}$ $NA^{-1}m^{-1}$ $Am^{-1}C^{-1}$ $V/I = \Omega$

ResultsPlus

Examiner Comments

This answer gets mark points 1 and 2.

Using the F = BIl route.

The answer replaces length *l* with thickness *t* which is incorrect. It also states total charge = *ne* which is also incorrect so cannot collect any further credit.

Force due to magnetic field $= BI\ell$ $E = \frac{F}{Q}$

Electrostatic force $= EQ$ $E = \frac{V}{d}$

$= \frac{VQ}{d}$ where Q = total charge

equating: $BI\ell = \frac{V_{HALL}\,Q}{d}$ $= N \times e$

$\frac{BI\ell d}{Q} = V_{HALL}$ $\ell d = \text{Area} = \frac{d\ell t}{nt}$

$\frac{BI\cancel{N}}{nt \times \cancel{N}e} = V_{HALL}$ Volume $= d \times \ell \times t$

$V_{HALL} = \frac{BI}{nte}$ number of total charge carriers $= n \times V$

$N = nd\ell t \Rightarrow \ell d = \frac{N}{nt}$

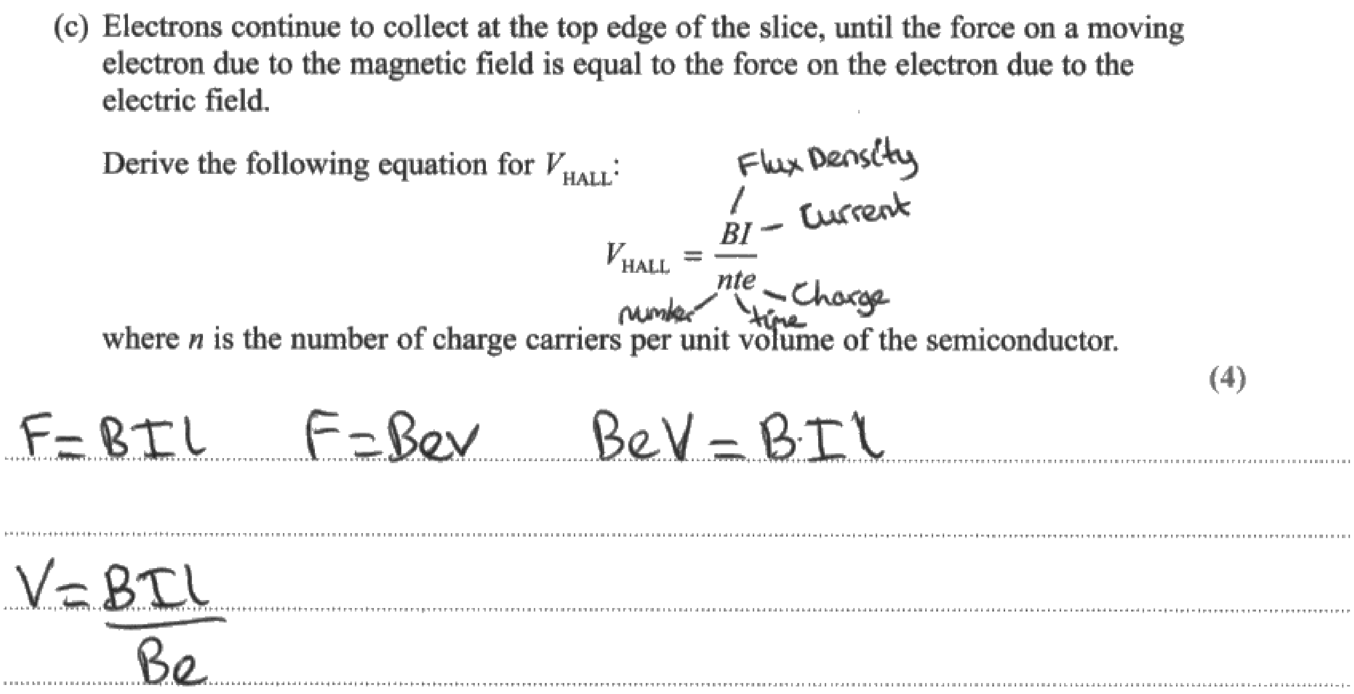
ResultsPlus

Examiner Comments

This candidate uses *F* = *BIl* = *EQ* and appreciates that Q is a total charge rather than the charge on an electron.

It is a convoluted method, but does go on to correctly derive the equation for full credit.

Some answers did not reference an electric field force on the electron so couldn't access any marks.



(c) Electrons continue to collect at the top edge of the slice, until the force on a moving electron due to the magnetic field is equal to the force on the electron due to the electric field.

Derive the following equation for V_{HALL}:

$$V_{\text{HALL}} = \frac{\overset{\text{Flux Density}}{B}I \text{ - Current}}{\underset{\text{number}}{n}\underset{\text{time}}{t}e \text{ - Charge}}$$

where n is the number of charge carriers per unit volume of the semiconductor.

(4)

$F = BIl$ $F = Bev$ $BeV = B \cdot Il$

$$V = \frac{BIl}{Be}$$

ResultsPlus

Examiner Comments

There is no reference to the force on the electron due to the electric field. This answer does not get any credit.

Question 17 (d)

Most answers followed two approaches. Some candidates chose to use base units whilst some used derived units.

The derived unit approach usually involved stating equivalent units to Volts as J/C or Nm/C for mark point 1.

Candidates then made use of a substitution for $B = F/Il$ and cancelled the I's. This gained mark point 2.

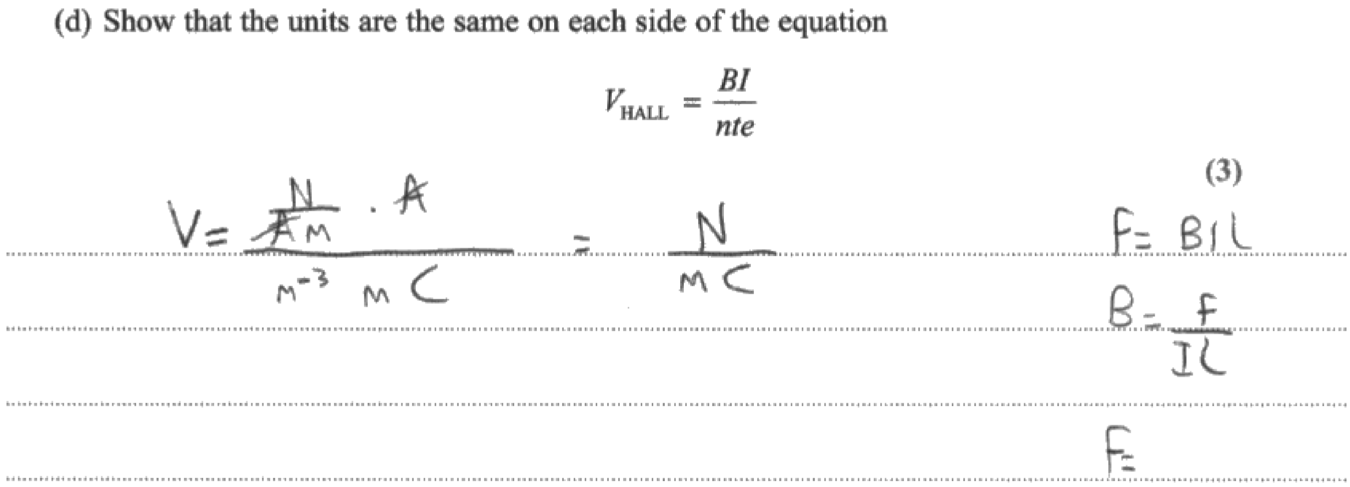
Replace the unit of F - N, n - m^{-3}, t and l with m and e with C. Simplifying leaves Nm/C for mark point 3.

Alternatively, the base unit approach usually started with Volts as kgm^{2}s^{-2} / C . Whilst C is not a base unit, this is not penalised as the question did not stipulate a specific method.

Substitution for $B = F/Il$ was commonly seen and again cancelling the current I.

Force would be replaced by its base units of kgms^{-2} and then n - m^{-3}, t and l with m and e with C.

This answer shows an approach using derived units.



(d) Show that the units are the same on each side of the equation

$$V_{\text{HALL}} = \frac{BI}{nte}$$

(3)

$$V = \frac{\frac{N}{\cancel{A}m} \cdot \cancel{A}}{m^{-3} \; m \; C} = \frac{N}{mC}$$

$F = BIL$

$B = \frac{F}{IL}$

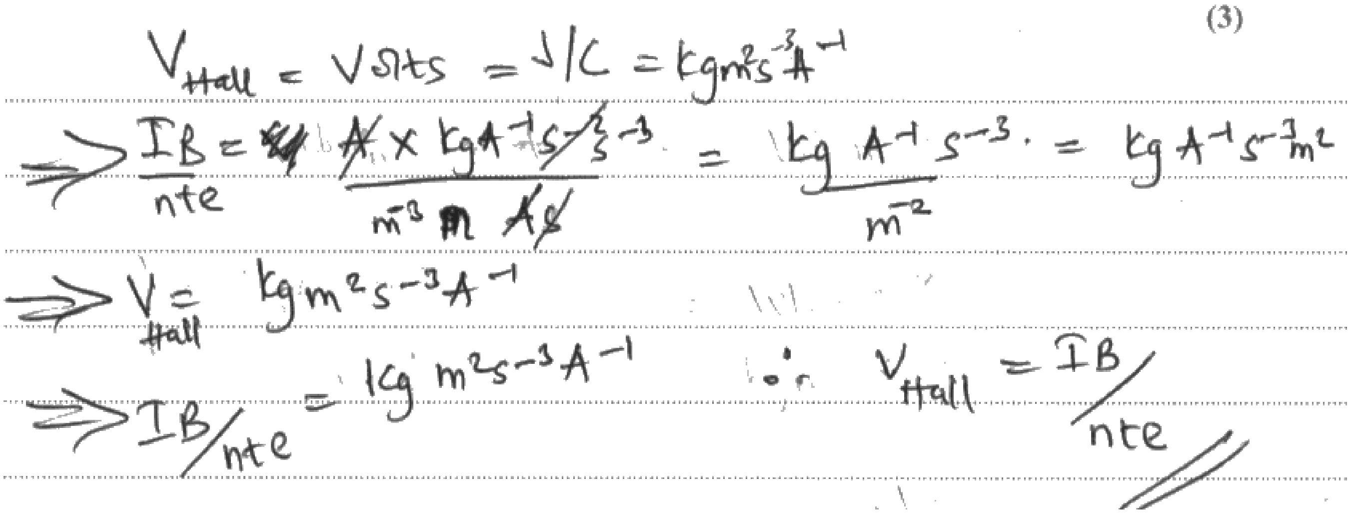
$F =$

ResultsPlus
Examiner Comments

This answer gains mark point 2 on either scheme. Substitution or use of $B=F/Il$ as units N/Am and cancelling A.

Note also an error: m^{-3}xmxm is m^{-1} not m.

This answer shows a base unit approach.



(3)

V_{Hall} = Volts = J/C = $kg\,m^2 s^{-3} A^{-1}$

$\Rightarrow \frac{IB}{nte} = \frac{\cancel{A} \times kg\,A^{-1} \cancel{s^{-2}}\, s^{-3}}{m^{-3}\, m\, \cancel{As}} = \frac{kg\,A^{-1} s^{-3}}{m^{-2}} = kg\,A^{-1} s^{-3} m^2$

$\Rightarrow V_{Hall} = kg\,m^2 s^{-3} A^{-1}$

$\Rightarrow IB/nte = kg\,m^2 s^{-3} A^{-1}$ $\therefore$ $V_{Hall} = IB/nte$

ResultsPlus
Examiner Comments

The candidate writes the base units of volts for mark point 1 - this mark is actually just for the base unit of energy which is contained within the first line.

The candidate has then replaced the quantities on the right hand side with their base units and simplifies for full credit.

This answer shows a base unit approach. It doesn't achieve full credit because the candidate doesn't substitute the correct units for *n*.

(3)

$$B = \frac{kgms^{-2}}{A \times m}$$

$$BI = \frac{kgms^{-2} \times A}{A \times m} \qquad \frac{kgs^{-2}}{Cm^{-3} \times m \times C} = kgm^{-2}s^{-2}C^{2} \qquad V = \frac{W}{Q}$$

$$= kgs^{-2} \qquad V = \frac{kgms^{-2} \times m}{C}$$

$$= kgm^{2}s^{-2}C^{-1}$$

ResultsPlus

Examiner Comments

This answer is a base unit approach.

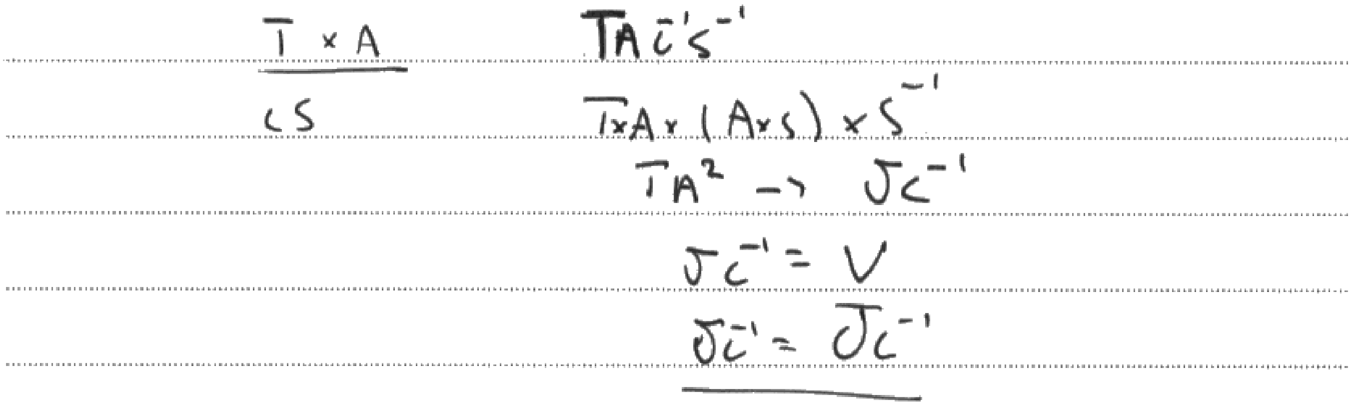
It gains the first two marking points.

The candidate makes a mistake with the units of *n* (Cm^{-3}) and then can't get agreement on both sides of the equation.

The units of *n* were often a stumbling block.

A few answers used the units Wb on both the left, and right hand side of the equation, and this can lead to an agreement.

This answer used Tesla and then went no further.



$\frac{T \times A}{cS}$

$TAc^{-1}s^{-1}$

$T \times A \times (A \times s) \times S^{-1}$

$TA^2 \rightarrow Jc^{-1}$

$Jc^{-1} = V$

$\underline{Jc^{-1} = Jc^{-1}}$

ResultsPlus
Examiner Comments

This answer replaces Magnetic field strength *B* with Tesla. This approach usually didn't lead anywhere.

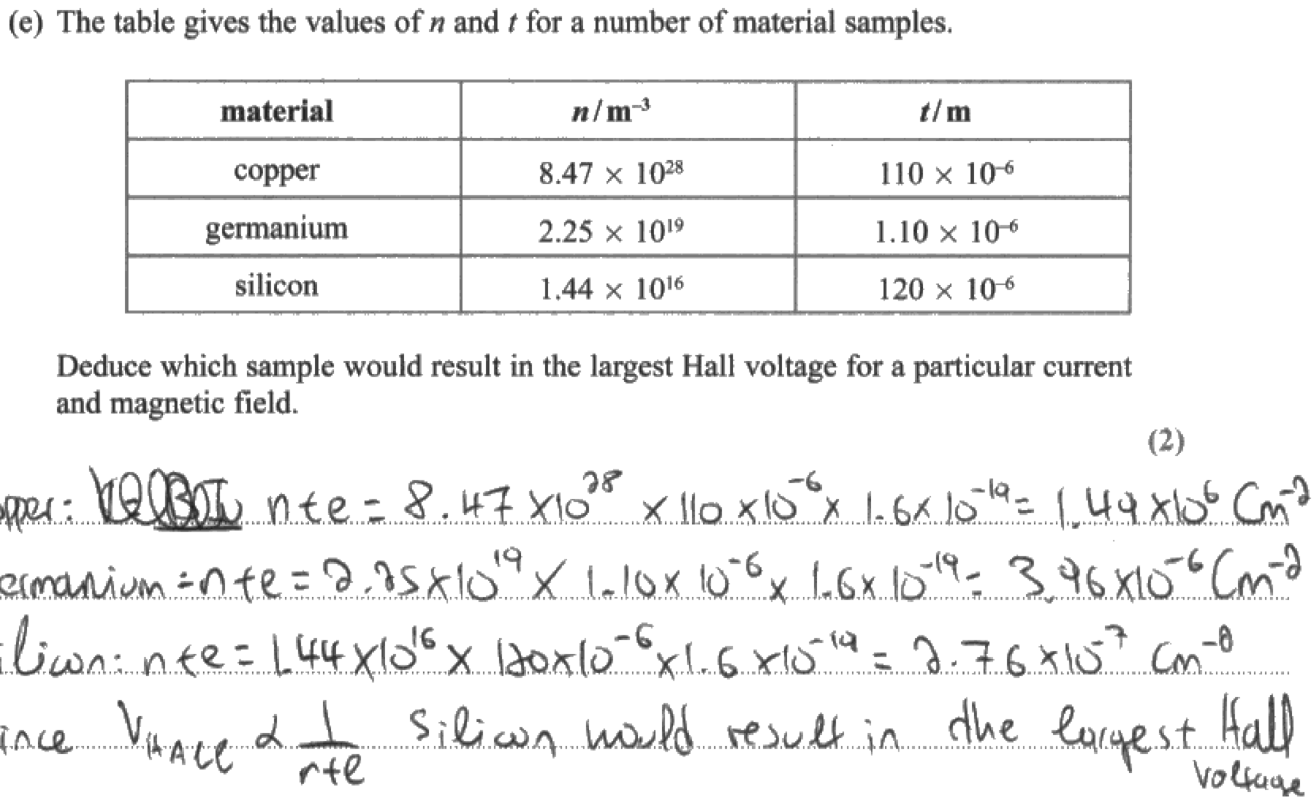
The mark gained was for V = J/C.

Question 17 (e)

The simplest way to tackle this question was to look at the Hall voltage equation. The Hall voltage will increase if *nt* is reduced.

Find the product nt for each material and the smallest value will give the largest Hall voltage.

Answers including constants within the calculation were given full credit.



(e) The table gives the values of *n* and *t* for a number of material samples.

material	n / m^{-3}	t / m
copper	8.47×10^{28}	110×10^{-6}
germanium	2.25×10^{19}	1.10×10^{-6}
silicon	1.44×10^{16}	120×10^{-6}

Deduce which sample would result in the largest Hall voltage for a particular current and magnetic field.

(2)

Copper: $nte = 8.47 \times 10^{28} \times 110 \times 10^{-6} \times 1.6 \times 10^{-19} = 1.49 \times 10^{6}$ Cm^{-2}

Germanium: $nte = 2.25 \times 10^{19} \times 1.10 \times 10^{-6} \times 1.6 \times 10^{-19} = 3.96 \times 10^{-6}$ Cm^{-2}

Silicon: $nte = 1.44 \times 10^{16} \times 120 \times 10^{-6} \times 1.6 \times 10^{-19} = 2.76 \times 10^{-7}$ Cm^{-2}

Since $V_{HALL} \propto \frac{1}{nte}$ Silicon would result in the largest Hall voltage

ResultsPlus
Examiner Comments

Some candidates included the charge *e*. This made the answer longer but the method is still correct for full credit.

Some answers made numerical errors with the calculation. If it lead to an incorrect conclusion then this was penalised.

$V = \frac{BI}{nte}$

$nxt: C = 9.32\times10^{24}$

$G = 2.48\times10^{13}$

$S = 1.45\times10^{12}$

Germanium since nxt is the smallest and when dividing by the smallest nxt, you get the max.

ResultsPlus
Examiner Comments

Some candidates made a mistake in one of the calculations. The essential method was rewarded with 1 mark.

This answer is well organised and straight forward.

$8.47\times10^{28} \times 110\times10^{-6} = 9.317\times10^{24}$

$2.25\times10^{19} \times 1.10\times10^{-6} = 2.475\times10^{13}$

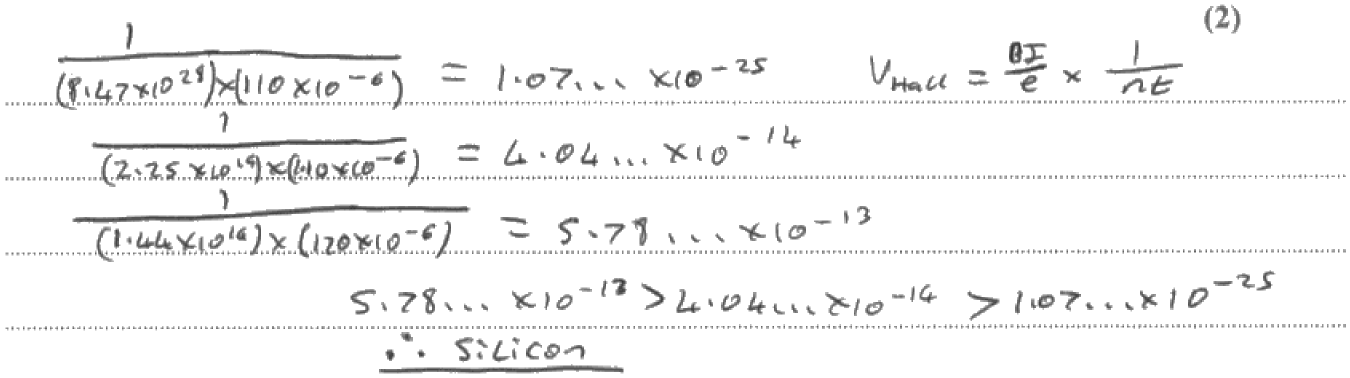
$1.99\times10^{16} \times 120\times10^{-5} = 1.728\times10^{12}$

∴ Silicon

ResultsPlus
Examiner Comments

This answer shows the most direct way to achieve both marks.

Some answers referred and calculated the reciprocal of *nt*. This answer shows this approach and gains full credit.



(2)

$\frac{1}{(8.47\times10^{28})\times(110\times10^{-6})} = 1.07\ldots\times10^{-25}$ $\quad V_{Hall} = \frac{BI}{e}\times\frac{1}{nt}$

$\frac{1}{(2.25\times10^{19})\times(110\times10^{-6})} = 4.04\ldots\times10^{-14}$

$\frac{1}{(1.44\times10^{16})\times(120\times10^{-6})} = 5.78\ldots\times10^{-13}$

$5.78\ldots\times10^{-13} > 4.04\ldots\times10^{-14} > 1.07\ldots\times10^{-25}$

$\therefore$ Silicon

ResultsPlus
Examiner Comments

This answer calculates 1/*nt*. The candidate understands the relevance of the reciprocal to achieve full credit.

Question 17 (f)

This question tested page 14 of the specification.

Magnetic flux density is an unusual vector quantity.

The first mark was gained by using tan^{-1} of the ratio of the flux densities and the second mark for the angle to the horizontal.

This answer follows the mark scheme.

(f) Two sensors in the smartphone were used to determine the horizontal component B_H and the vertical component B_V of the Earth's magnetic flux density.

Calculate the angle of the Earth's magnetic field to the horizontal.

$B_H = 19.0\,\mu T$

$B_V = 49.0\,\mu T$

(2)

$$\tan\theta = \frac{49\times10^{-6}}{19\times10^{-6}}$$

$\theta = 68.8059 = 68.8°$

Angle = 68.8 °

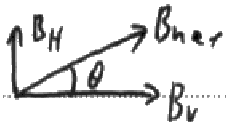
ResultsPlus

Examiner Comments

This shows a correct answer for full credit.

This answer calculates the wrong angle.

(2)



$\theta = \tan^{-1}\left(\frac{B_H}{B_v}\right)$

$\theta = \tan^{-1}\left(\frac{19.0\times10^{-6}}{49.0\times10^{-6}}\right) = 21.2°$

Angle = 21.2°

ResultsPlus
Examiner Comments

This gains one mark. This angle is between the resultant and the vertical.

A few candidates used sin or cos incorrectly as shown here.

$B_H = 19.0\,\mu T$ 19.0×10^{-6}

$B_V = 49.0\,\mu T$ 49.0×10^{-6}

(2)

$F = BIL\sin\theta$ s^oH c^aH T^oA

$\sin\theta = \frac{F}{BIL}$

$\theta = \sin^{-1}\left(\frac{F}{BIL}\right)$

$\sin\left(\frac{19\times10^{-6}}{49\times10^{-6}}\right) = 6.76\times10^{-3}$

$= 6.8\times10^{-3}$

$\sin\left(\frac{49\times10^{-6}}{19\times10^{-6}}\right) \approx 0.044$

$\approx \underline{0.04}$ Angle =

ResultsPlus
Examiner Comments

Some candidates muddled sin or cos for tan.

Others used tan rather than $\tan^{-1}$.

Paper Summary

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

- The use of 'explain' as a prompt in a question means that the answer requires more than a superficial response.
- The use of log-log scales is a requirement at GCE.
- Some answers lend themselves to simple summaries, such as, conservation laws of charge, baryon and lepton number.
- Numerical data given in a question is there to be used and commented on.
- If invited to comment on a graph, then comment fully on all the aspects shown.
- In mechanics questions, an energy approach can sometimes be the most straightforward way to achieve full credit.

Grade Boundaries

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

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