Examiners' Report
June 2025

GCE Physics 9PH0 01

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June 2025

Publications Code 9PH0_01_2506_ER

Introduction

This examination paper, 9PHO_01, examines about half of the Physics A level specification. The topics examined are mechanics, electric circuits, magnetic and electric fields, nuclear and particle physics.

The paper was completed fully by almost every candidate in the allotted time and candidates appeared to attempt every question.

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

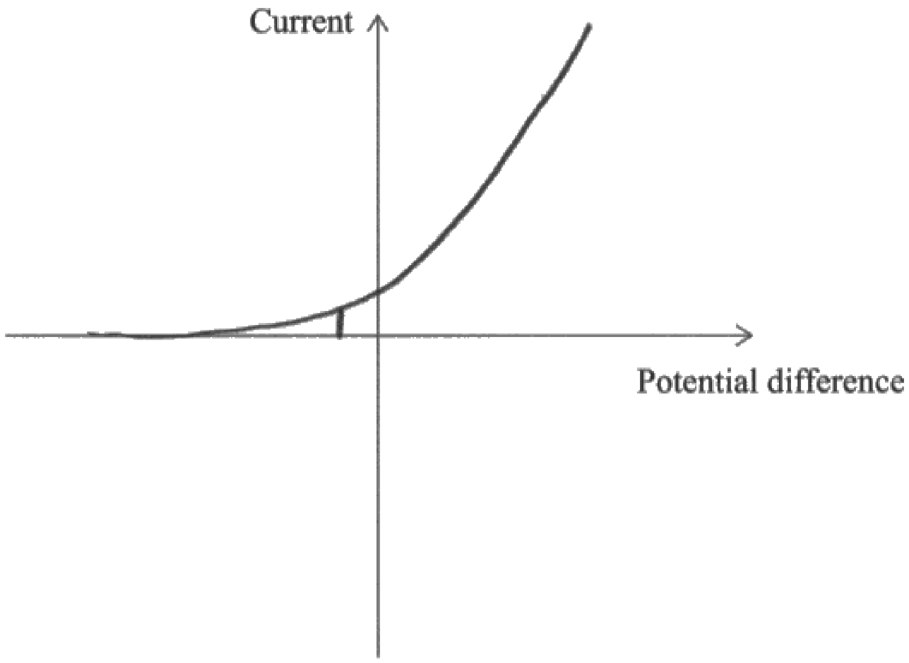
- a "show that" question should have the answer given to one extra significant figure compared to that given in the question. The numerical substitutions (including constants such as ε0) should be made clear.
- all numerical answers should have a unit.
- a "deduce" question usually requires a comparison of the candidate's answer with a piece of data given in the question.

Question 11(a)

This question examined the V-I characteristic of a diode. Most candidates knew this. A few candidates didn't complete the graph on the negative side of the axes. A few candidates drew the characteristic for a filament lamp.

11 Diodes are used in a variety of electrical circuits.

(a) Sketch the current-potential difference graph for a diode.

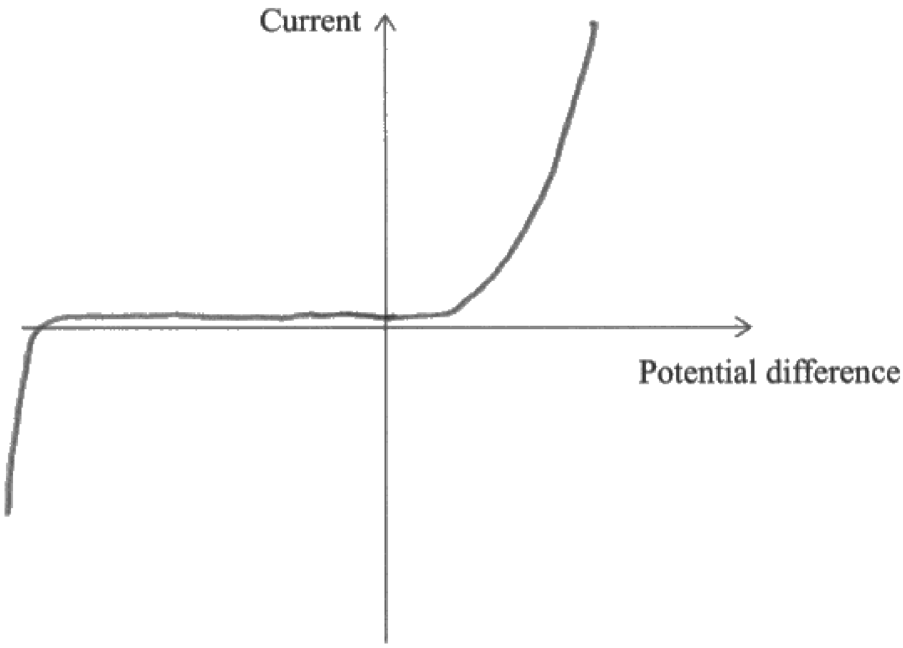


ResultsPlus
Examiner Comments

This line starts to increase significantly before a positive value of p.d. This meant it couldn't gain either mark.

11 Diodes are used in a variety of electrical circuits.

(a) Sketch the current-potential difference graph for a diode.



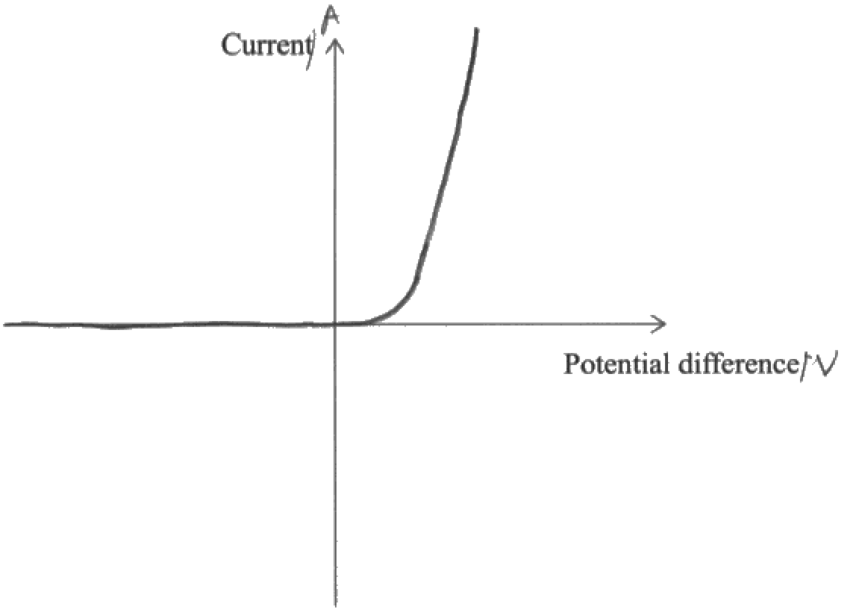
ResultsPlus Examiner Comments

A breakdown negative p.d. was acceptable for MP1 as this candidate illustrates. The line could be a curve as long as it starts to increase at a definite value of positive p.d. (rather than at the origin).

11 Diodes are used in a variety of electrical circuits.

(a) Sketch the current-potential difference graph for a diode.

(2)



ResultsPlus
Examiner Comments

A very well-drawn answer for full credit.

Question 11(b)

There were various methods that candidates could adopt to solve this question. They could either find the potential difference across the resistor and then use V=IR or they could calculate the total resistance of the circuit then the LED and subtract one from the other. A few candidates used the potential dividing equation.

(b) A package containing a light emitting diode (LED) is marked

"20 mA 3.2 V to operate normally".

A student uses a 5 V power supply of negligible internal resistance to operate the LED.

Calculate the resistance of a protective resistor required to operate the LED normally from this power supply.

$$R = \frac{V}{I} = \frac{5}{20 \times 10^{-3}} = 250\,\Omega$$

ResultsPlus
Examiner Comments

This answer was quite common. The resistance calculated is the total resistance of the circuit and gains MP2 only.

(b) A package containing a light emitting diode (LED) is marked

"20 mA 3.2 V to operate normally".

A student uses a 5 V power supply of negligible internal resistance to operate the LED.

Calculate the resistance of a protective resistor required to operate the LED normally from this power supply.

(3)

$V = 5 - 3.2 = 1.8\ A$

$I = 20 \times 10^{-3} = 0.02\ A$

$R = \frac{V}{I} = \frac{1.8}{0.02} = 90\ \Omega$

Resistance = $90\ \Omega$

ResultsPlus
Examiner Comments

This answer finds the potential difference across the resistor then uses V=IR for full credit.

(b) A package containing a light emitting diode (LED) is marked

"20 mA 3.2 V to operate normally".

A student uses a 5 V power supply of negligible internal resistance to operate the LED.

Calculate the resistance of a protective resistor required to operate the LED normally from this power supply.

(3)

$V = IR$ $\quad 3.2 = 0.002\ (R)$ $\quad R = 160\,\Omega$

~~5 = I (160Ω)~~

$5 = 0.02\ (R)$ $\quad R = 250$

$250 - 160 = 90$

Resistance = $90\,\Omega$

ResultsPlus
Examiner Comments

This answer finds the total resistance of the circuit and subtracts the resistance of the LED for full credit.

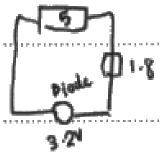
(b) A package containing a light emitting diode (LED) is marked

"20 mA 3.2 V to operate normally".

A student uses a 5 V power supply of negligible internal resistance to operate the LED.

Calculate the resistance of a protective resistor required to operate the LED normally from this power supply.

$5 - 3.2 = 1.8\,V$ m milli



$20\,mA = 20 \times 10^{-3} = 0.02\,A$

$R = IV$

$0.02 \times 1.8 = 0.036$

Resistance = 0.036 Ω

ResultsPlus
Examiner Comments

This answer finds the potential difference across the resistor (for MP1) but then uses an incorrect version of Ohm's law.

Question 12(a)

This question examined an understanding of the term "equilibrium". The two mark points are for "resultant force is zero" and "resultant moment about a point is zero".

Very few candidates would have been given the second mark point so the requirement "about a point" was relaxed. In future it would be worth ensuring that the full definition is learnt.

(a) State the two conditions needed for the arrangement to be in equilibrium.

(2)

· the clockwise moment around P due to the weight must equal the anticlockwise moment around P due to counterweight.
· the same sum of the vertical and horizontal forces (due to weight) must be equal respectively (net zero).

ResultsPlus
Examiner Comments

This has a fully expressed statement about moments for MP2. MP1 was only just given as the answer refers to forces and then, in brackets, states net zero. The net force is zero was accepted as an alternative.

(a) State the two conditions needed for the arrangement to be in equilibrium.

(2)

Both moments either side of pivot to be equal (clockwise = anticlockwise)
No other external forces acting, constant force / moment force is required

ResultsPlus
Examiner Comments

This answer gains MP2 for the bracketed "clockwise moments are equal to anticlockwise moments". No external forces was not an alternative to resultant force.

(a) State the two conditions needed for the arrangement to be in equilibrium.

(2)

- All forces are balanced so that there is no resultant force.
- The object is either at rest or ~~th~~ ~~consistant~~ at a constant velocity.

ResultsPlus
Examiner Comments

Some candidates used the word "balanced". This was not accepted for either mark point. This answer gains MP1 for "no resultant force".

Question 12(b)

This question examined the ability to take moments about the pivot. The complicating factors were a perpendicular component to consider and the answer required was a weight (not mass).

(b) Determine the weight of the counterweight.

Assume the mass of the lever-arm is negligible.

mass of pan = 260 g

(4)

$0{\cdot}04 \times 0{\cdot}26 =$ ↷ moment

$= 0{\cdot}0104$

$0{\cdot}0104 = 0{\cdot}18 \cos 80 \times X$

$x = \dfrac{0{\cdot}0104}{0{\cdot}18 \cos 80}$

$x = 0{\cdot}33$ kg (2sf)

Weight of counterweight = $0{\cdot}33$ kg (2sf)

ResultsPlus
Examiner Comments

This answer does everything correctly but forgets to convert the mass to a weight so gains MP1, MP2 and MP3.

(b) Determine the weight of the counterweight.

Assume the mass of the lever-arm is negligible.

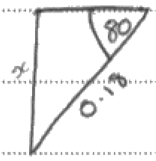
mass of pan = 260 g

(4)

$M(P): (0.04 \times 260 \times 9.81) = (W \times 0.18 \times \sin(80))$

$102.024 = 0.177\,W$

$W = 575.5438\,N$



$\sin(80) = \frac{x}{0.18}$

Weight of counterweight = 575.5 N

ResultsPlus
Examiner Comments

This answer incorrectly uses sin80 (rather than cos80) so does not use the perpendicular component. It gains MP1 and MP3.

(b) Determine the weight of the counterweight.

Assume the mass of the lever-arm is negligible.

mass of pan = 260 g

(4)

$260 g = 0.26 kg$

~~[illegible]~~ moments about P:

$((0.26 \times 9.81) \times 0.04) = (W_{l-a} \times 0.18 \cos 80)$

$W_{l-a} = \frac{0.102024}{(0.18 \cos 80)}$

$= 3.264 \ldots N$

Weight of counterweight = 3.26 N

ResultsPlus
Examiner Comments

This answer is fully correct and gains all four marks.

Question 12(c)

This question was one of the more demanding topics. It examined the understanding of angular displacement.

(c) An object is placed in the pan. The lever-arm moves along the scale.

Explain why the lever-arm pointer moves through a large distance whilst the pan moves a much shorter distance.

(2)

Pan is closer to the pivot, ~~wh~~ so it has a low moment. While lever-arm is more away from the pivot point, so it will be moving more.

ResultsPlus
Examiner Comments

Many candidates assumed this part was about moments. This answer does gain MP2 for the idea that the distance to the pivot is different for the pointer and pan.

ResultsPlus
Examiner Tip

Do not assume that every part of a question is on the same topic. In this case the first two parts examined moments and equilibrium. This section examines angular displacement.

(c) An object is placed in the pan. The lever-arm moves along the scale.

Explain why the lever-arm pointer moves through a large distance whilst the pan moves a much shorter distance.

(2)

- Because the lever arm is a fixed body, so the whole lever arm rotates. Hence, when an object is placed in the pan which causes the pan to move, the lever arm pointer moves as well.
- As the ~~p~~ distance from the pan to P is 0.04 and this is less than the distance from P to pointer, distance of arc length for P to pointer is greater, as angle θ remains the same, but r increases and arc length = θr.

(Total for Question 12 = 8 marks)

ResultsPlus
Examiner Comments

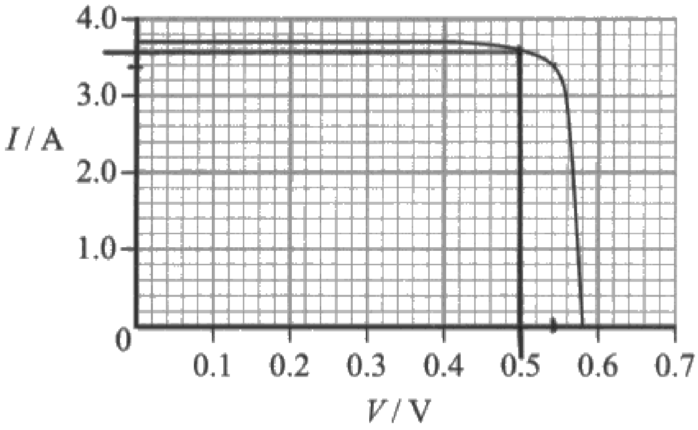
This answer is fully correct. It explains that the angle of rotation is the same for both. It is the distance from the pivot that is different so leads to a larger displacement.

Question 13(a)

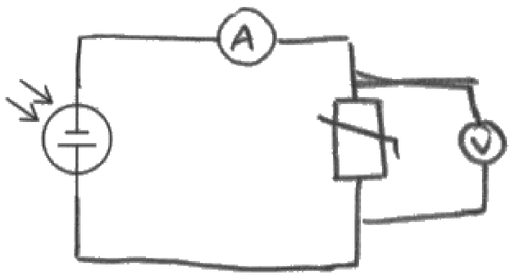
This question examined the use of circuit symbols and an understanding of how voltage - current data would be obtained.

13 Solar cells are being used in increasing numbers around the world.

The current *I* from a solar cell can be varied by connecting it to a variable resistor. The graph shows how *I* and the terminal potential difference *V* across a solar cell vary.



(a) Complete the circuit diagram below to show how the data for the graph could be obtained.



ResultsPlus
Examiner Comments

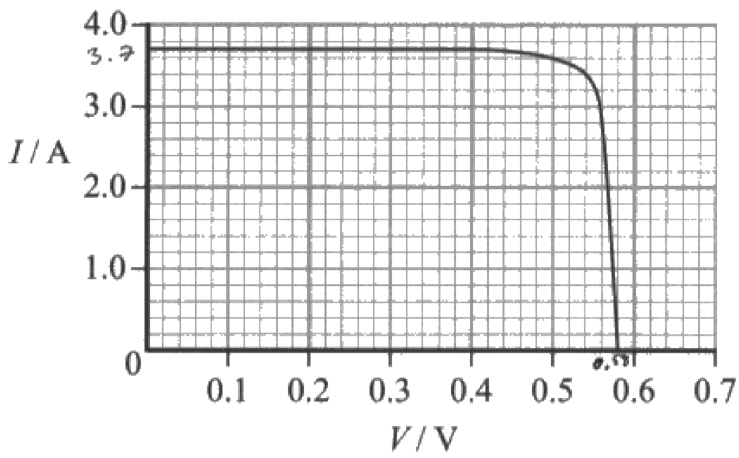
A number of candidates inserted a thermistor instead of a variable resistor. These answers could still gain MP1.

ResultsPlus
Examiner Tip

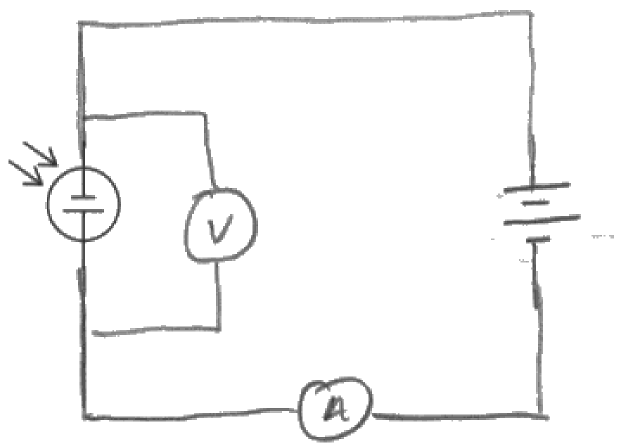
You should recall the symbols for all the electrical devices described in the specification.

13 Solar cells are being used in increasing numbers around the world.

The current I from a solar cell can be varied by connecting it to a variable resistor. The graph shows how I and the terminal potential difference V across a solar cell v



(a) Complete the circuit diagram below to show how the data for the graph could be obtained.



ResultsPlus
Examiner Comments

A number of candidates added an extra cell to the circuit rather than, or in addition to, a variable resistor. This answer still gains MP1.

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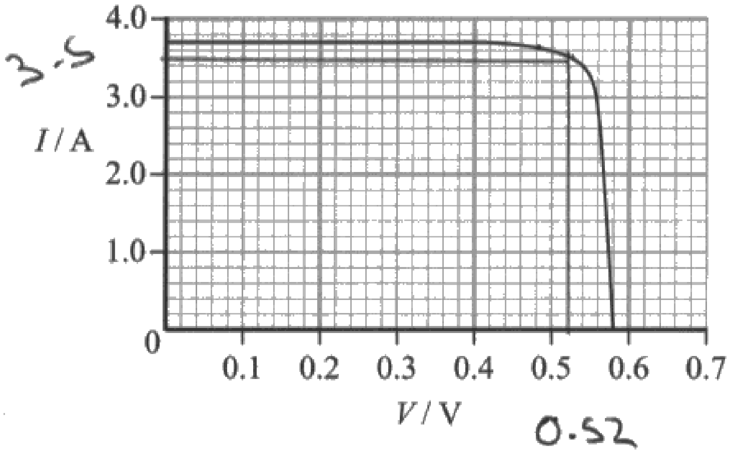
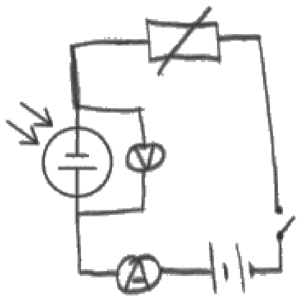


(a) Complete the circuit diagram below to show how the data for the graph could be obtained.



ResultsPlus
Examiner Comments

This answer has an incorrect symbol for a variable resistor. It has an extra cell. The switch was an acceptable item if used. This answer gains MP1.

Question 13(b)

This question has three parts.

Part (i) required candidates to use P = IV. The maximum power output is on the curve of the graph. A range of pairs of values for V and I were allowed between V = 0.5 and 0.55 V.

If the pair of values were not on this curve, then the answer could still gain MP1 for using the equation.

Part (ii) required candidates to calculate the power of sunlight arriving at the solar cell and then use the efficiency equation.

Part (iii) required candidates to understand that the EMF of a cell can be found from the graph. It is the value of terminal potential difference when there is no current ie 0.58 V.

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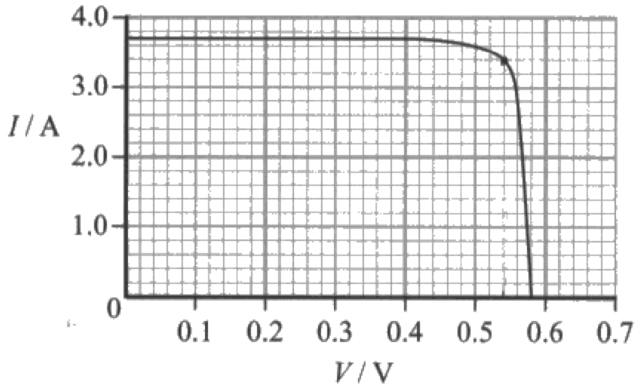
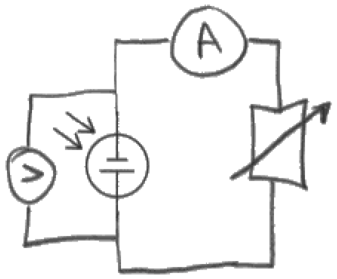
The current I from a solar cell can be varied by connecting it to a variable resistor. The graph shows how I and the terminal potential difference V across a solar cell vary.



(a) Complete the circuit diagram below to show how the data for the graph could be obtained.

(2)



(b) (i) Show that the maximum power output from the solar cell is about 2 W. You should use values from the graph.

(2)

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

$0.55\,V \times 3.5\,A = \frac{77}{40}\,W = 1.925\,W$

$1.925\,W \approx 2W$

$P = \frac{I_0 V_0}{2} = \frac{I_0}{\sqrt{2}} \times \frac{V_0}{\sqrt{2}}$

(ii) The area of the solar cell is 104 cm^2.

Determine the efficiency of the solar cell when operating at maximum power.

intensity of sunlight = 1000 W m^{-2}

(3)

$I = \frac{P}{A}$ Efficiency $= \frac{\text{power out}}{\text{power in}} \times 100$

$104\,cm^2 = 0.0104\,m^2 = A$ $I = 1000\,Wm^{-2}$

Power in $= IA = P = 0.0104(1000) = \frac{52}{5}W = 10.4W$

$(1cm = 0.01m)$ $0.1923 \times 100 = 19.23\%$

$\frac{2w}{10.4w} = \frac{5}{26} = 0.1923$

Efficiency = 19.2%

(iii) Calculate the internal resistance of the solar cell when operating at maximum power.

(3)

$V = I(R+r) = IR + Ir$

r = internal resistance

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

$\left(\frac{2}{I}\right)^2 / R = 2$

Internal resistance = ...

$\sqrt{2R} = \frac{2}{I}$

(Total for Question 13 = 10 marks)

$\frac{2\sqrt{2R}}{2R} = I = \frac{\sqrt{2R}}{R}$

$IR = \sqrt{2R}$

ResultsPlus
Examiner Comments

(i) – the pair of values for I and V in this answer were not a point on the curve. The equation was used so MP1 was given.

(ii) – this part is fully correct for full credit.

(iii) – although the candidate writes a correct equation it isn't used so gains 0 marks.

ResultsPlus
Examiner Tip

Take care when reading values from a graph.

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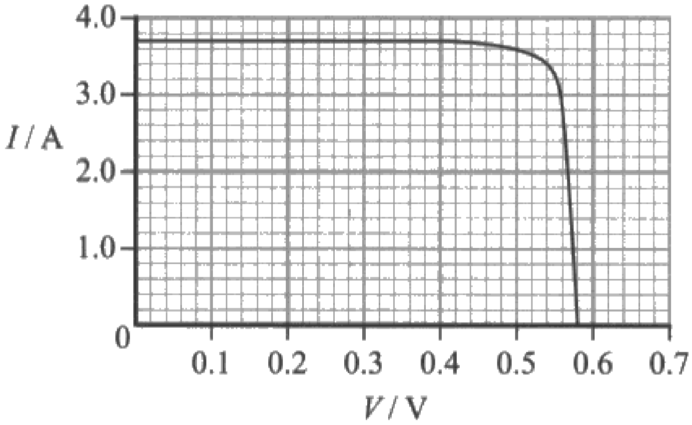
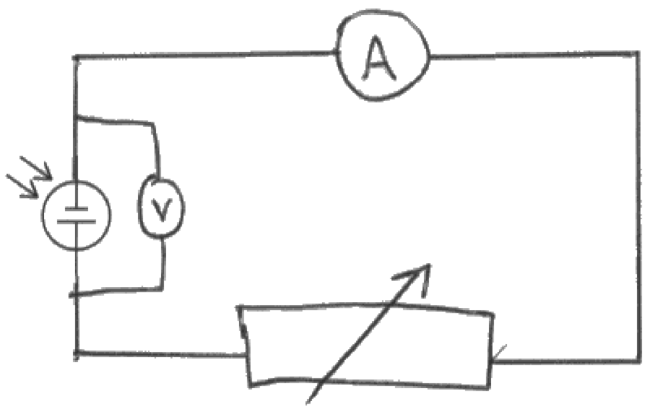
The current I from a solar cell can be varied by connecting it to a variable resistor. The graph shows how I and the terminal potential difference V across a solar cell vary.



(a) Complete the circuit diagram below to show how the data for the graph could be obtained.



(b) (i) Show that the maximum power output from the solar cell is about 2 W. You should use values from the graph.

$P = VI$

$3.70 \times 0.58 = 2.146 \simeq 2A$

(ii) The area of the solar cell is 104 cm^2.

Determine the efficiency of the solar cell when operating at maximum power.

intensity of sunlight = 1000 W m^{-2}

(3)

$104 \times 10^{-4}\ m^2$ $\quad$ $104 \times 10^{-4} \times 1000 = 10.4\ W$

$\frac{2.146}{10.4} = 0.206$

Efficiency = 20.6 %

(iii) Calculate the internal resistance of the solar cell when operating at maximum power.

(3)

$V = \mathcal{E} - Ir$ $\quad$ $P = VI$

~~3.70 = E - 0.~~ $\quad$ $\frac{10.4}{3.7} = 2.81$

$0.58 = \mathcal{E} - 3.7 \times r$

$0.58 = 2.81 - 3.7 \times r$

Internal resistance = 0.61 Ω

(Total for Question 13 = 10 marks)

ResultsPlus
Examiner Comments

(i) – the pair of values for V and I are the intercept values and do not correspond to each other. It gains MP1 only.

(ii) – this part was fully correct.

(iii) – the emf is not written as 0.58 V. A value of V is 0.58 V so MP1 is not credited. A value of p.d. is calculated (the E -V) across the internal resistance so MP2 is given.

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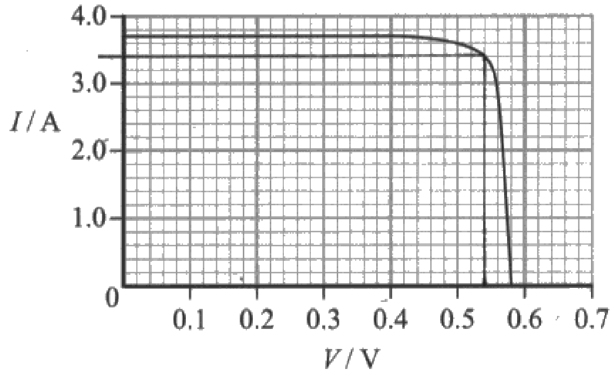
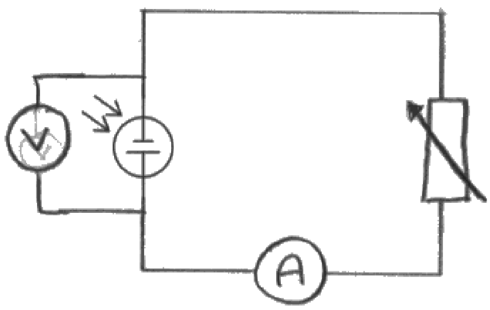
The graph shows how I and the terminal potential difference V across a solar cell vary.



1.936
~~0.1836~~
1.48

(a) Complete the circuit diagram below to show how the data for the graph could be obtained.

(2)



(b) (i) Show that the maximum power output from the solar cell is about 2 W. You should use values from the graph.

(2)

$P = VI$

$= 0.54 \times 3.4 = 1.836\ \text{W} \approx 2\ \text{W}$

(ii) The area of the solar cell is 104 cm^2.

Determine the efficiency of the solar cell when operating at maximum power.

intensity of sunlight = 1000 $W m^{-2}$

(3)

$I = \frac{P}{A}$ ~~$= \frac{1.836 W}{(104 \times 10^{-2})^2} = 1.697 W m^{-3}$~~

$P = I \times A = 1000 \times (104 \times 10^{-2})^2 = 1081.6 W$

~~$\frac{1.697}{1000} \times 100 = 0.1697\%$~~

~~$= 0.170\%$ (3sf)~~

$\frac{1.836}{1081.6} \times 100 = 0.169\%$

$= 0.170\%$

Efficiency = 0.170 %

(iii) Calculate the internal resistance of the solar cell when operating at maximum power.

(3)

~~$V = \mathcal{E} - Ir$~~

$R = \frac{V}{I} = \frac{0.54}{3.4} = 0.15882 \Omega$

$V = \mathcal{E} - Ir$

ResultsPlus
Examiner Comments

(i) – the values of V and I lie on the curve of the graph and this part gains full credit.

(ii) – the area is squared so the use of P = IA cannot be awarded. The efficiency equation is used correctly with the output of the cell as the numerator for MP2 only.

(iii) – no credit in this answer.

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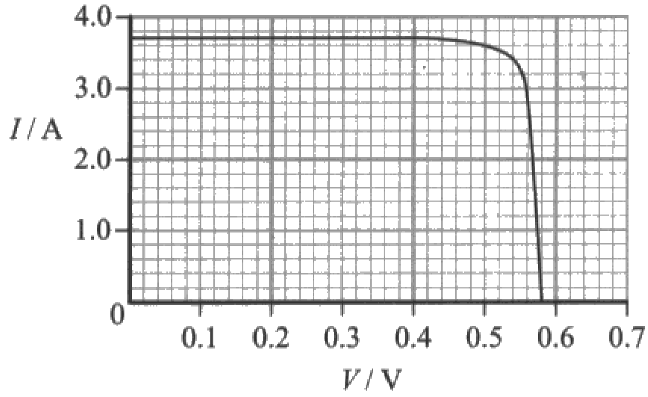
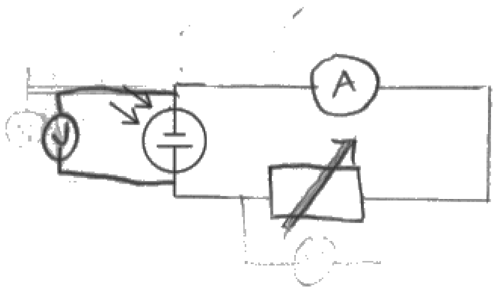


(a) Complete the circuit diagram below to show how the data for the graph could be obtained.

(2)



(b) (i) Show that the maximum power output from the solar cell is about 2 W. You should use values from the graph.

(2)

$P = IV$, P_{max} = Area ≈ 3.7×0.58

$= 2.146$ W

≈ 2 W

(ii) The area of the solar cell is 104 cm^2.

Determine the efficiency of the solar cell when operating at maximum power.

intensity of sunlight = 1000 W m^{-2}

(3)

$P = IA = (104 \div 100^2) \times 1000$

$= 10.4$

$\frac{2}{10.4} \times 100 = 19.2\%$ (3 s.f.)

Efficiency = 19.2%

(iii) Calculate the internal resistance of the solar cell when operating at maximum power.

(3)

$P = I^2R = VI$ $\quad \varepsilon = 0.58$

• lost Power is 8.25 W $\quad = 3.7x$

$P = I^2 R = 8.25$

$R = \frac{8.25}{3.7^2} = 0.6\,\Omega$

Internal resistance = 0.6 Ω

ResultsPlus
Examiner Comments

(i) – the values of V and I do not correspond to a point on the graph so MP1 only.

(ii) – Full credit.

(iii) – the emf is correctly written as 0.58 V for MP1. There is nothing further to credit.

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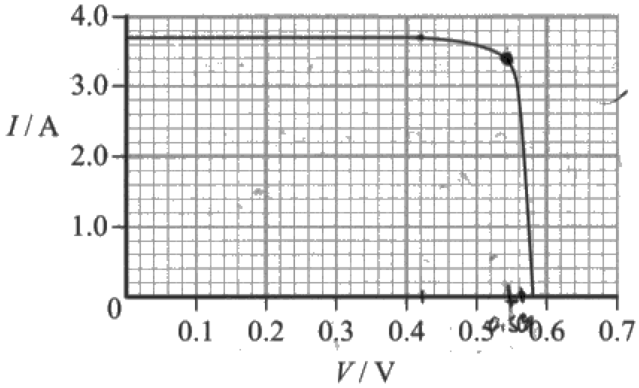
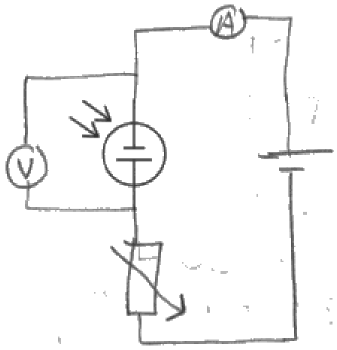


$\varepsilon = V + Ir$

$V = \varepsilon - Ir$

(a) Complete the circuit diagram below to show how the data for the graph could be obtained.

(2)



(b) (i) Show that the maximum power output from the solar cell is about 2 W. You should use values from the graph.

(2)

$P = IV$

~~$= 3.7 \times 0.42$~~

$= 3.64 \times 0.54$

$= 1.944 \text{ W} \approx 2 \text{ W}$

836

(ii) The area of the solar cell is 104 cm². $= 0.0104 m^2$

Determine the efficiency of the solar cell when operating at maximum power.

intensity of sunlight = 1000 W m⁻²

(3)

$I = \frac{P}{A}$

$P = IA$

$= 1000 \times 0.0104$

$= 10.4 W$

$\text{efficiency} = \frac{\text{useful output}}{\text{total input}}$

$= \frac{1.944}{10.4}$

$= \cancel{0.18692}... \ 0.1765..$

Efficiency = ~~0.187~~ 0.177

(iii) Calculate the internal resistance of the solar cell when operating at maximum power.

(3)

$\varepsilon = V + Ir$

$V = \varepsilon - Ir$

$Ir = \varepsilon - V$

$\cancel{I = \frac{\varepsilon}{R} - \frac{V}{r}}$

$\varepsilon = V$ when $I = 0 = 0.58 V$

$Ir = \varepsilon - V$

$3.4r = 0.58 - 0.564$

$r = 0.01176..$

Internal resistance = 0.012Ω

ResultsPlus
Examiner Comments

All parts of this answer are fully correct. Although their previous value of power out from (i) appears in the efficiency equation in (ii) the candidate has actually used their correct value. Either way this would be acceptable as it would have been an error carried forward.

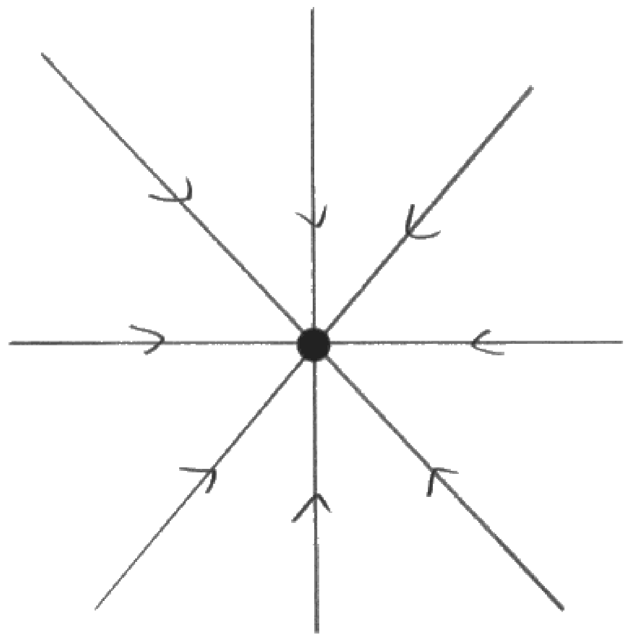
Question 14(a)

This question examined a radial electric field.

14 Flowers can attract bees by being colourful or by producing a scent. Some flowers also attract bees by producing an electric field.

so attracted

(a) Draw the electric field around a negative point charge. +



ResultsPlus
Examiner Comments

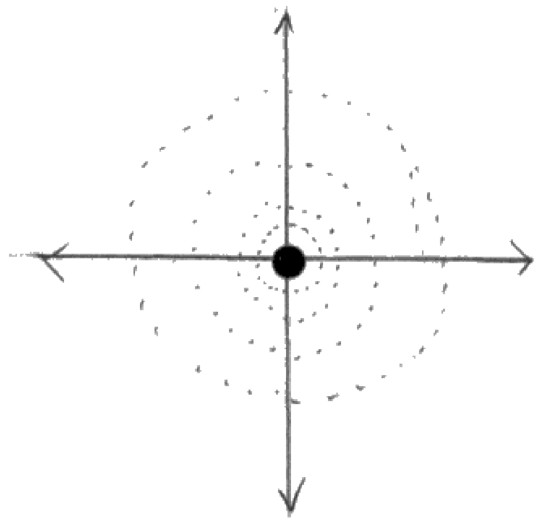
The direction is correct for MP2. The lines are not equispaced so does not gain MP1.

ResultsPlus
Examiner Tip

Take care when drawing field lines. If they are meant to be equispaced take extra care to ensure they are, ie the diagonals should be drawn at 45°.

14 Flowers can attract bees by being colourful or by producing a scent. Some flowers also attract bees by producing an electric field.

(a) Draw the electric field around a negative point charge.

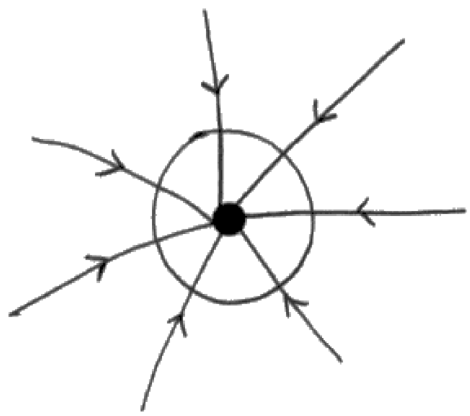


ResultsPlus
Examiner Comments

The arrow is in the wrong direction but does get MP1 as 4 lines drawn this way is a sensible way to indicate this field.

14 Flowers can attract bees by being colourful or by producing a scent. Some flowers also attract bees by producing an electric field.

(a) Draw the electric field around a negative point charge.

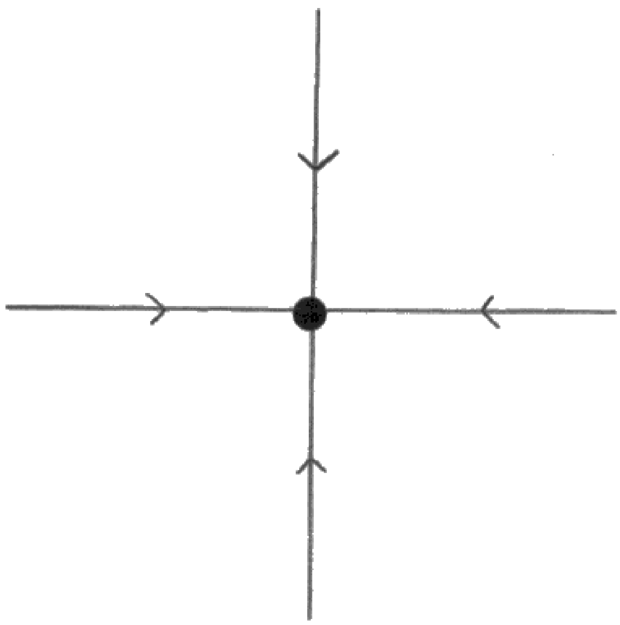


ResultsPlus
Examiner Comments

These lines have not been drawn with a ruler so cannot be equispaced. The arrow direction gains MP2.

14 Flowers can attract bees by being colourful or by producing a scent. Some flowers also attract bees by producing an electric field.

(a) Draw the electric field around a negative point charge.



ResultsPlus
Examiner Comments

A fully correct answer for full credit.

Question 14(b)

This question examined the equations associated with radial electric fields.

Part (i) is a "show that" so the value of εo should be shown as a substitution. The answer should be given to one extra significant figure than in the question.

Part (ii) is a "deduce" question. A comparison should be made with data given in the question and a comment made about the statement.

(b) When a bee gets close to a flower it can detect the electric field. The charge on the flower acts as a point charge at the centre of the flower.

(i) At a distance of 0.06 m from the centre of a particular flower the potential is –16 V.

Show that the charge on this flower is about –0.1 nC.

(3)

$E = \frac{V}{d} \Rightarrow \cancel{\frac{V}{d} = \frac{-16V}{4\pi\varepsilon_0 V}}$

$E = \frac{-16V}{0.06m} = -\frac{800}{3}\ V/m$

$Q = 4\pi\varepsilon_0 r^2 \times E$

$= 4 \times \pi \times 8.85 \times 10^{-12}\ F/m \times (0.06m)^2 \times -\frac{800}{3}\ V/m$

$= -1.067... \times 10^{-10}\ C$

$\cancel{= -0.1067 \times 10}$

(ii) The minimum field strength that a bee can detect is $120\,\text{V m}^{-1}$.

A teacher suggests that bees can detect the field when they are closer than 10 cm from the flower in (b)(i).

Deduce whether this suggestion is correct.

(3)

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

$$= \sqrt{\frac{1.067 \times 10^{-16}\,C}{4\pi \times 8.85 \times 10^{-12}\,F/m \times 120\,V/m}}$$

$= 0 \ldots m = 0.089\,m \simeq 0.09\,m \Rightarrow$ The teacher is right.

ResultsPlus Examiner Comments

(i) – this answer uses E = V/d which is for uniform fields so is an error of Physics. The only mark that might still be awarded was the conversion from C to nC but this is omitted.

(ii) – the calculation is correct for MP1 and MP2. The candidate does not compare the value with that given in the question. If the candidate had said the teacher was incorrect it would have gained MP3 as it follows from their answer that at 10 cm the field strength would not be large enough.

ResultsPlus Examiner Tip

In "show that" questions you should present your answer to one extra significant figure to that given in the question.

(b) When a bee gets close to a flower it can detect the electric field. The charge on the flower acts as a point charge at the centre of the flower.

(i) At a distance of 0.06 m from the centre of a particular flower the potential is –16 V.

Show that the charge on this flower is about –0.1 nC.

(3)

$r = 0.06$

$V = 16\,V$

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

$$-16 = \frac{Q}{4\pi\varepsilon_0 (0.06)}$$

$$= Q = -1.067 \times 10^{-10} = -0.1067\,nC$$

$$= -0.11\,nC \approx -0.1\,nC.$$

(ii) The minimum field strength that a bee can detect is 120 V m⁻¹.

A teacher suggests that bees can detect the field when they are closer than 10 cm from the flower in (b)(i).

Deduce whether this suggestion is correct.

(3)

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

$$120 = \frac{16}{d}$$

$d = 0.133$

$= 0.13\,m$

The teacher is correct in their suggestion, the bee can detect the field at 13cm ~~ab~~ and smaller. 10cm < 13cm.

ResultsPlus
Examiner Comments

(i) – the value of εo is not substituted so this does not gain MP1. The candidate does get the correct answer, converts it to nC and presents it to 2 significant figures as appropriate for a "show that" question for MP2 and MP3.

(ii) – the uniform field equation is used so cannot gain MP1 or MP2. However, the candidate has compared the values and given an opinion about the statement so this gains MP3.

(b) When a bee gets close to a flower it can detect the electric field. The charge on the flower acts as a point charge at the centre of the flower.

(i) At a distance of 0.06 m from the centre of a particular flower the potential is –16 V.

Show that the charge on this flower is about –0.1 nC.

$V = \frac{Q}{4\pi\varepsilon_0 r}$ $-16 = \frac{Q}{4\pi(8.85\times10^{-12})(0.06)}$

$-16\times4\pi(8.85\times10^{-12})(0.06) = Q = -1.1\times10^{-10}$

$= -0.11\,nC$

(ii) The minimum field strength that a bee can detect is 120 V m⁻¹.

A teacher suggests that bees can detect the field when they are closer than 10 cm from the flower in (b)(i). / 9cm

0.1m

0.09m

Deduce whether this suggestion is correct.

(3)

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

10cm away = $\frac{-0.11\times10^{-9}}{4\pi(8.85\times10^{-12})(0.1)^2} = 99\ Vm^{-1}$

9cm away = $\frac{-0.11\times10^{-9}}{4\pi(8.85\times10^{-12})(0.09)^2} = 120\ Vm^{-1}$

9.9cm away → 100 Vm⁻¹

the electric field strength 10cm away is on 99Vm⁻¹, which is less than the minimum field strength a bee can detect, so ~~the suggestion~~

the electric field strength 9cm away is 120Vm⁻¹, so the suggestion is incorrect for values between 9cm and 10cm away.

ResultsPlus
Examiner Comments

This answer is fully correct for both parts. In part (ii) they have done more than necessary. After the first calculation they could have made the observation that the field strength is not strong enough at 10 cm and therefore the teacher is incorrect.

Question 14(c)

This question examined the idea that only a charged particle in an electric field will be subjected to a force.

(c) It is suggested that the hairs on a bee deflect slightly when close to the flower.

Explain what would cause a hair to deflect in an electric field.

(2)

~~charged bodies~~ ~~charged particles on hairs~~
~~experience a force in an electric field~~
hairs are charged. Charged particles in an
electric field experience a force so hairs will deflect

ResultsPlus Examiner Comments

This answer is fully correct for 2 marks.

(c) It is suggested that the hairs on a bee deflect slightly when close to the flower.

Explain what would cause a hair to deflect in an electric field.

(2)

• In an ~~the~~ electric field charged particles experience a force.
• If the charge on bee's hair is ~~+ve~~ positive then there
will be an electrostatic attraction between the hair and the
negative charge on the flower.

ResultsPlus Examiner Comments

Even without the first sentence, which gains MP2, the rest of this answer gains both marks for saying the hair is charged (MP1) and that if it is positive, it will be attracted to the negative charge of the flower (MP2).

(c) It is suggested that the hairs on a bee deflect slightly when close to the flower.

Explain what would cause a hair to deflect in an electric field.

(2)

The hairs on a bee must be slightly negative, therefore once it gets close to the flower the negative field would deflect the hairs a bit.

ResultsPlus
Examiner Comments

This answer gains MP1. The answer doesn't make clear that the negatively charged hairs would be repelled by the negatively charged flower or that there is always a force on a charged particle in an electric field.

(c) It is suggested that the hairs on a bee deflect slightly when close to the flower.

Explain what would cause a hair to deflect in an electric field.

(2)

If the hairs on a bee are slightly charged they would be affected by the field. They would be deflected if the charge is the same on both the hair and in the field so they repel.

ResultsPlus
Examiner Comments

This answer gains MP1. It then suggests that if the hairs are negatively charged, they would be repelled by the negative charge of the flower for MP2.

Question 15(a)(b)

This question examined the candidate's knowledge of particle symbols and the application of the conservation of charge and baryon number.

15 A sigma (Σ^+) particle is a baryon. It can decay into a positive pion and a neutron.

(a) Complete the particle equation for this decay.

(2)

$$\Sigma^+ \rightarrow \pi^+ + n$$

(b) Explain whether the conservation laws of charge and baryon number are obeyed for this decay.

(2)

yes, the sigma is a bargon and the neutron is a baryon, and the pion is not, so there is a bayon number of 1 on each side.

ResultsPlus
Examiner Comments

Part (a) gains 2 marks for the correct use of symbols. Some examples of incorrect symbols that were seen were: N for neutron, p for pion. In part (b) there is a good explanation of the application of baryon number for 1 mark.

15 A sigma (Σ^+) particle is a baryon. It can decay into a positive pion and a neutron.

(a) Complete the particle equation for this decay.

(2)

$$\Sigma^+ \rightarrow \pi^+ + n^0$$

(b) Explain whether the conservation laws of charge and baryon number are obeyed for this decay.

(2)

Charge is conserved as there is a charge of +1 before and after the decay (+1 → +1).

Baryon number is conserved as there are the same number of baryons before and after the decay.

ResultsPlus
Examiner Comments

The equation is written correctly. The neutron does not need the "0" but this was allowed. The conservation of charge did not gain a mark because the candidate did not make it clear that the pion was +1 charge and the neutron is not charged. The conservation of baryon number did not gain a mark because the answer is not clear that the pion is not a baryon and the neutron is a baryon.

ResultsPlus
Examiner Tip

A useful format to use when answering this type of conservation law question is the following: Σ π + + n charge +1 +1 + 0 so +1 = +1 charge conserved.

15 A sigma (Σ^+) particle is a baryon. It can decay into a positive pion and a neutron.

(a) Complete the particle equation for this decay.

(2)

$\Sigma^+ \rightarrow \pi^+ + n$

(b) Explain whether the conservation laws of charge and baryon number are obeyed for this decay.

(2)

$\Sigma^+ \quad \pi^+ \quad n$

Charge = 1 → 1 + 0 1 = 1 ∴ Charge is conserved

Baryon number = 1 → 0 + 1 1 = 1 ∴ Baryon number is conserved

Both laws are obeyed for this decay

ResultsPlus Examiner Comments

This answer is fully correct and uses the tip explained above.

Question 15(c)

This question examined the knowledge that a baryon is 3 quarks (not antiquarks) and that the charge of the quarks must add to +1.

(c) The table summarises the charges for three types of quark.

Quark	Charge/e
u	+2/3
d	−1/3
s	−1/3

The sigma particle has one strange quark within its structure.

Deduce the quark structure for Σ^+

(2)

3 quarks, +1 charge

$-\frac{1}{3}$ ~~a~~ $+\frac{2}{3} + \frac{2}{3} = 1$

$\therefore$ Σ^+ containing one strange quark,

and 2 up (u) quarks

s, u, u

ResultsPlus
Examiner Comments

This example neatly shows how the candidate has arrived at the quark combination.

(c) The table summarises the charges for three types of quark.

Quark	Charge/*e*
u	+2/3
d	−1/3
s	−1/3

The sigma particle has one strange quark within its structure.

Deduce the quark structure for Σ^+

(2)

$(-1/3) + (1/3) + (2/3)$

$s \quad \bar{d} \quad u$

$s\bar{d}u$

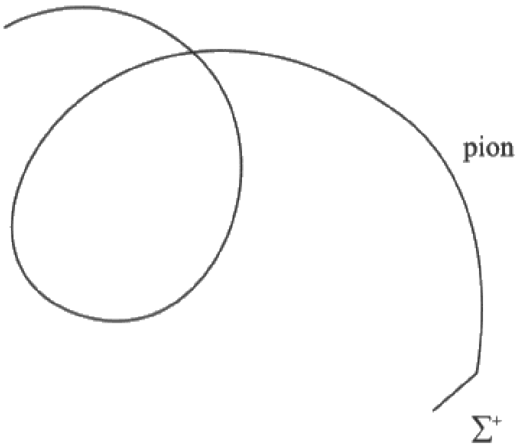
ResultsPlus
Examiner Comments

This answer gains 1 mark for a three "quark" combination. The baryon must consist of quarks, not antiquarks.

Question 15(d)i

This question examined the idea that neutral particles do not leave a track in a particle detector.

(d) The diagram shows tracks in a particle detector associated with this decay.



(i) State why the neutron does not leave a track.

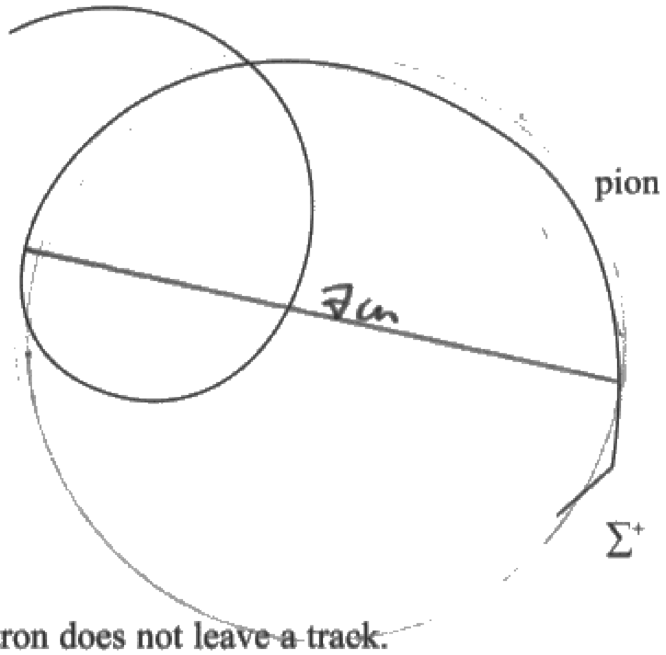
(1)

it isn't moving at a high enough speed, the magnetic field provides centripetal force and slows it down

ResultsPlus
Examiner Comments

This answer does not point out the neutron is not charged.

(d) The diagram shows tracks in a particle detector associated with this decay.



(i) State why the neutron does not leave a track.

It has 0 charge, so it does not ionise.

ResultsPlus
Examiner Comments

This answer gains 1 mark.

Question 15(d)ii

This question examined the use of $r = p/BQ$.

The value of radius had to be measured from the detector image.

It had to be adjusted for scale.

The values needed to be substituted into the equation above to give a value of B with units T.

(ii) The initial momentum of the positive pion is 1.1×10^{-19} N s. The scale of the diagram is 1 cm represents 15 cm.

p

Determine the magnitude of the magnetic flux density acting perpendicularly to the tracks.

(4)

$F = \frac{mv^2}{r}$, $F = Bqv \Rightarrow \frac{mv^{\cancel{2}}}{r} = Bq\cancel{v}$

$p = Bqr$

$r = 3.2\text{cm}$ on image

$= 3.2 \times 15$ in reality

$= 48\text{cm}$ in reality

$B = \frac{p}{qr}$

$= \frac{1.1 \times 10^{-19}\ \text{N s}}{1 \times 0.48}$

$= 2.3 \times 10^{-19}$ T

Magnetic flux density = 2.3×10^{-19} T

ResultsPlus
Examiner Comments

This gains MP1 and MP2 for measuring the radius and scaling it. It does not gain the use of equation mark as Q is substituted as 1.

ResultsPlus
Examiner Tip

Make sure you use the numerical value of charge, in C, when using this equation.

(ii) The initial momentum of the positive pion is 1.1×10^{-19} N s. The scale of the diagram is 1 cm represents 15 cm.

Determine the magnitude of the magnetic flux density acting perpendicularly to the tracks.

(4)

$r = \dfrac{p}{BQ} \rightarrow B = \dfrac{p}{BQr}$ $\quad 5 \times 15 = 75\text{ cm}$

$B = \dfrac{1.1 \times 10^{-19}}{1.6 \times 10^{-19} \times (75 \times 10^{-2})}$

$= 0.916$

Magnetic flux density = 0.916 T

ResultsPlus Examiner Comments

This answer is fully correct.

(ii) The initial momentum of the positive pion is 1.1×10^{-19} N s. The scale of the diagram is 1 cm represents 15 cm.

$F = \text{kg m}$

Determine the magnitude of the magnetic flux density acting perpendicularly to the tracks.

(4)

$F = BQv$

$B = \dfrac{F}{Qv} = \dfrac{\text{kg m s}^{-2}}{\text{C m s}^{-1}}$

$r = \dfrac{p}{BQ}$ $\quad B = \dfrac{p}{rQ}$ $\quad t^{1} = \text{kg C}^{-1}\text{s}^{-3}$

$r = 3.5 \times 15 = 52.5\text{ cm} = 0.525\text{ m}$

$B = \dfrac{1.1 \times 10^{-19}}{0.525 \times 1.60 \times 10^{-19}} = 1.3095$

1.31

ResultsPlus
Examiner Comments

This answer would gain full marks except the wrong unit is stated on the answer line.

ResultsPlus
Examiner Tip

Always write the units to each numerical answer.

Question 16

This question examined momentum conservation and elastic or inelastic collisions.

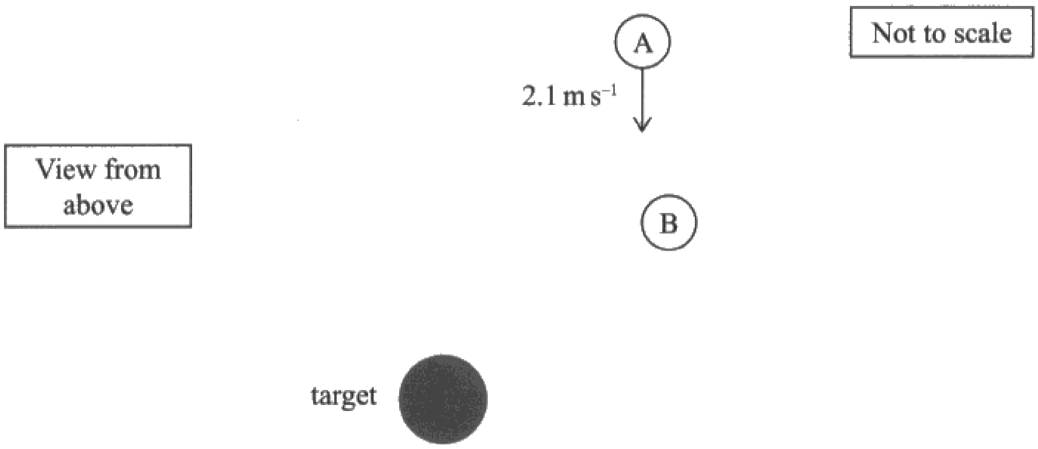
Part (a)(ii) was a "deduce" question which means that a number of approaches could be used. For the final mark, a conclusion was required as to whether the candidate agreed or disagreed with the statement.

The quickest way to do this question was using a scaled drawing. This was only seen in about 1 in 100 responses.

16 Curling is a sport played on ice. Players slide stones made of granite along the ice. The aim of the sport is to slide a stone into a circular area called the target.

The diagram below shows two stones, A and B. Each stone has a mass of 18 kg.

Stone A is moving with a velocity of 2.1 m s^{-1}, as shown. B is initially stationary.



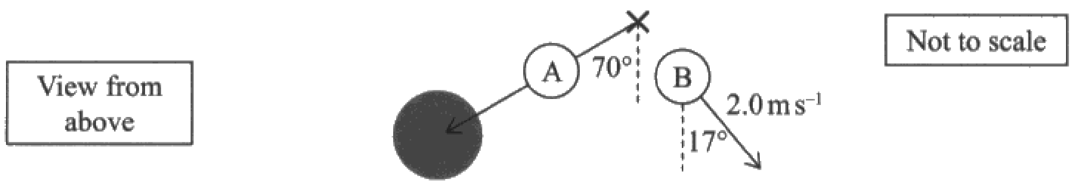
(a) (i) Show that the momentum of A is about 40 N s.

(2)

$p = mv \rightarrow \therefore 18 \times 2.1 = 37.8\ \text{Ns}$

(ii) Stone A collides with stone B.

The diagram below shows the velocity of stone B after the collision. The point of collision is marked ×.



$V\cos\theta = \cancel{A}$

V

Deduce whether stone A moves in the direction shown after the collision.

(5)

momentum before = momentum after

~~46~~ 37.8 kg m s^{-1} = 18 × v ~~+~~ + 18 × 2 cos ~~8~~17

37.8 = 18 × v + 18 × 1.9 →

~~37~~ 37.8 = 18v + 34.427

$\frac{37.8 - 34.427}{18} = 0.18\ \text{m s}^{-1}$ 3

~~0.18~~ ~~0.18 = cos θ~~

$\frac{0.18}{\cos 70} = 0.526\ \text{m s}^{-1}$

The stone does move in the direction shown

(b) Stone A comes to rest 1.9 m from X. The deceleration of the stone on the ice is 0.10 m s^{-2}.

Deduce whether the collision was elastic.

(4)

$\frac{1}{2}mv^2 = \frac{1}{2}mv^2 + \frac{1}{2}mv^2$ W = Fs

$\frac{1}{2}mv^2 = \frac{1}{2}(18 \times (2.1)^2)$ W = mas

18 × 0.10 × 1.9 = 3.42

39.69 = 3.42 + $\frac{1}{2}$ 18 × (2)^2

~~39.69 = 3.42 + $\frac{1}{2}$ 18 × (2)^2~~   39.69 = 3.42 + 36

~~39.69 = 3.42~~   ↳ 39.69 = 39.42

Kinetic energy is conserved, the

ResultsPlus
Examiner Comments

The answer in (a)(ii) only applies momentum conservation in the NS or vertical direction. This type of answer could only gain a maximum of 2 marks for finding a correct vertical component and then applying momentum conservation in the vertical direction. Part (b) was carried out successfully except that the unit J was required somewhere in the paragraph and is absent.

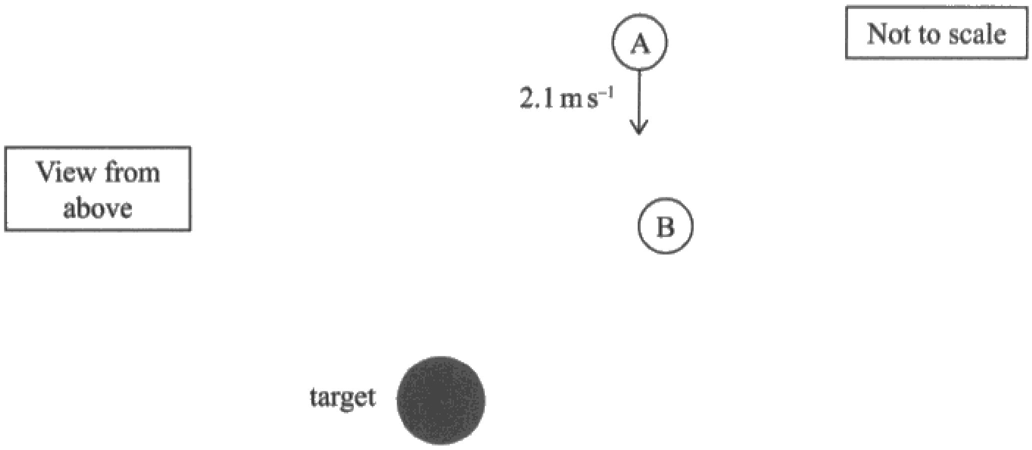
ResultsPlus
Examiner Tip

Don’t forget units to numerical answers.

16 Curling is a sport played on ice. Players slide stones made of granite along the ice. The aim of the sport is to slide a stone into a circular area called the target.

The diagram below shows two stones, A and B. Each stone has a mass of 18 kg.

Stone A is moving with a velocity of 2.1 m s^{-1}, as shown. B is initially stationary.



(a) (i) Show that the momentum of A is about 40 N s.

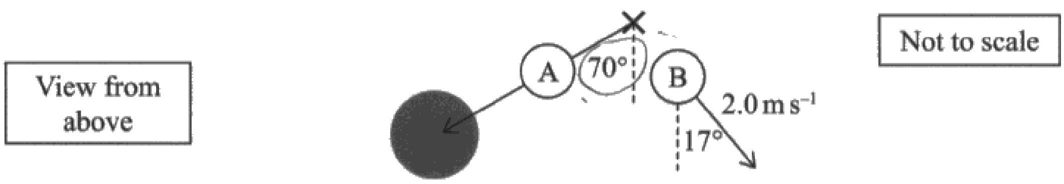
(2)

$p = mv$ ~~$W = mg = 18 \times 9.81 = 176.58$ N~~

$p = \cancel{176.58}\ 18 \times 2.1 = \cancel{370.818}\ 37.8$ Ns ≈ 40 Ns

(ii) Stone A collides with stone B.

The diagram below shows the velocity of stone B after the collision. The point of collision is marked ✕.



Deduce whether stone A moves in the direction shown after the collision.

(5)

Momentum before = momentum after

$0 \times 18 + 37.8 = (2.0\cos(17) \times 18) + 18 \times v_A$

$37.8 - 34.4269712l = 18 \times v_A$

$3.373028785 = 18 v_A$

$0.1873904881 = v_A$

$V_A = v\cos(70) = 0.1873904881$

$v = \frac{0.1873904881}{\cos(70)}$

$v = 0.5478931336\ ms^{-1}$

$\therefore$ Yes it does at $0.548\ ms^{-1}$ (3sf)

(b) Stone A comes to rest 1.9 m from X. The deceleration of the stone on the ice is $0.10\,m\,s^{-2}$.

Deduce whether the collision was elastic.

(4)

$E_k = \frac{1}{2}mv^2$ A before: $E_k = \frac{1}{2} \times 18 \times 2.1^2 = 39.69\,J$

~~A after: $E_k = \frac{1}{2}$~~

$s = 1.9\,m$

$u = ~~0.548~~ ?$

$v = 0\ ms^{-1}$

$a = -0.10\,ms^{-2}$

$t = \times$

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

$0 = u^2 + 2(-0.10)(1.9)$

$u = \sqrt{0.38}$

$u = 0.6164414003\ ms^{-1}$

A after: $E_k = \frac{1}{2} \times 18 \times (0.6164414003\cos 70)^2 = 0.40006\,J$

B after: $E_k = \frac{1}{2} \times 18 \times (2\cos(17))^2 = 32.9227$ ~~J it was not as kinetic energy was not conserved~~

(Total for Question 16 = 11 marks)

$39.69\,J \neq 32.9227 - 0.40006$

$\therefore$ It is not elastic as kinetic energy was not conserved.

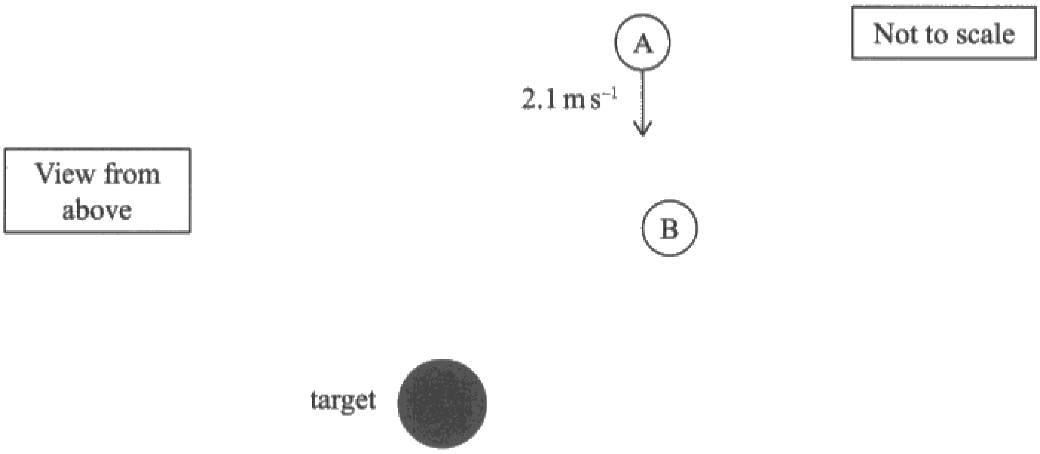
ResultsPlus
Examiner Comments

The answer to (a)(ii) only applies momentum conservation in the vertical direction. In part (b) the value of kinetic energy for stone A, after the collision, is incorrectly calculated. This results in 3 marks.

16 Curling is a sport played on ice. Players slide stones made of granite along the ice. The aim of the sport is to slide a stone into a circular area called the target.

The diagram below shows two stones, A and B. Each stone has a mass of 18 kg.

Stone A is moving with a velocity of $2.1\,\text{m}\,\text{s}^{-1}$, as shown. B is initially stationary.



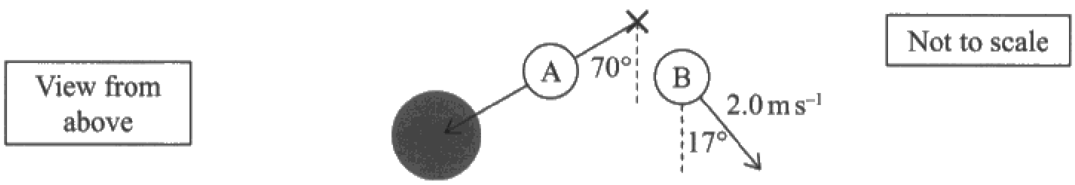
(a) (i) Show that the momentum of A is about 40 N s.

(2)

$p_A = 18 \times 2.1 = 37.8$ Ns

(ii) Stone A collides with stone B.

The diagram below shows the velocity of stone B after the collision. The point of collision is marked ✕.



Deduce whether stone A moves in the direction shown after the collision.

(↓) $m v_A = \cancel{m v_A + m} \; m V_A \cos\theta + m V_B \cos 17°$

$2.1 = V_A \cos\theta + 2\cos 17° \quad \ldots (1)$

(→) $0 = V_A \sin\theta + 2\sin 17° \quad \ldots (2)$

$V_A \cos\theta = 0.187, \quad V_A \sin\theta = -0.585$

$\cancel{v_A = \sqrt{0.187^2 + 0.585^2} = 0.614}$

$\tan\theta = \frac{-0.585}{0.187} \Rightarrow \theta = 72.3° \approx 73°$

Stone A moves in the direction shown.

(b) Stone A comes to rest 1.9 m from X. The deceleration of the stone on the ice is $0.10\,\text{m}\,\text{s}^{-2}$.

Deduce whether the collision was elastic.

$v^2 = u^2 + 2as$. A: $s = 1.9$ $a = -0.1$ $v = 0$

$0 = u^2 + 2(-0.1)(1.9)$ $t = x$ $u = \cancel{0.614}$?

$u = 0.616 \Rightarrow V_A = 0.616$

Initial KE $= \frac{1}{2}(18)(2.1)^2 = 39.69$ J.

Final KE $= \frac{1}{2}(18)(2^2 + 0.616^2) = 39.42$ J

about equal.

The collision was elastic.

ResultsPlus
Examiner Comments

This answer is fully correct. It assumes the angle is θ and then solves simultaneous equations to calculate the value as 72°.

ResultsPlus
Examiner Tip

It is a "deduce" question so compare your answer and state a conclusion.

Question 17(a)

This question is called the indicative content question. It is marked slightly differently. Indicative points are required and, if they are linked correctly by the candidate, they translate to marks. The linking does not have to be sophisticated. This question examined the application of Faraday's and Lenz's laws. Most candidates explained that there would be an induced emf and that this would result in a current in the disc. This is an example of linking the indicative points.

*(a) Explain why the aluminium disc rotates in the same direction as the magnet.

(6)

according to lenzs law, ~~a~~ a force opposes motion of a current in a magnetic field, because the magnet rotates, the aluminium disc opposes that motion due to its free electrons which acts a ~~[illegible]~~ force from the disc to the magnet, due to Newtons third law, the magnet will also act a force upon the aluminium disc rotating it in the same direction as the magnet

ResultsPlus
Examiner Comments

This answer misses the essential principles being examined. The question expects a discussion using Faraday's and Lenz's laws.

*(a) Explain why the aluminium disc rotates in the same direction as the magnet.

(6)

Len's Law states that induced e.m.f is always in such a direction as to oppose a change that caused it. The changing magnetic field means that the flux linkage is constantly changing and this causes e.m.f. If the coil is a part of the speedometer, then induced current will flow in the same direction in the magnet. By using Fleming's left hand rule where there is a magnetic force on a ~~carrying~~ current carrying wire, there is external magnetic field, which is why it flows perpendicular to induced current, as the same direction as the magnetic field.

ResultsPlus
Examiner Comments

This answer gives a generalised statement of Lenz's law. This did not gain credit. An application of Lenz's law to explain why the disc moved in the same direction as the magnet was required. The answer then mentions a changing magnetic field (IC1) causing an emf. The indicative content point 2 is "induced emf". Causing emf alone would not gain IC2 however the candidate did refer to induced emf earlier so IC2 was recognised. The answer then refers to current (IC3). There is a good explanation of a force acting on a current within a magnetic field for IC4. These points are well-linked and translate to 4 marks.

ResultsPlus
Examiner Tip

Questions on Faraday's and Lenz's laws are frequently examined on this paper. You should explain how these laws apply to the situation that is described in the question.

*(a) Explain why the aluminium disc rotates in the same direction as the magnet.

(6)

When the magnet rotates, ~~it causes a~~ ~~aa~~ ~~change~~ ~~to~~ ~~change~~ ~~the aluminium disc to experience~~
there is a change in magnetic flux that the aluminium disc experiences, so an emf is induced in the aluminium ~~shaft~~ disc, equal to the rate of change of magnetic flux, according to faradays law. According to lenz's law this induced ~~change~~ ~~to~~ emf acts to oppose the change that is causing it, which is the magnet rotating. So, to oppose this change, the aluminium coil rotates the same direction as the magnet to reduce the rate of change in flux that it experiences, so less emf is induced, therefore opposing the change that induces the emf.

ResultsPlus

Examiner Comments

This answer contains "changing magnetic flux induces an emf" for both IC1 and IC2. The answer then has a generalised statement of Lenz's law but continues to apply it to the context described in the question. The phrase "reduce the (rate of) change of flux (linkage)" gains IC5 and linking that with "Lenz's law" gains IC6. These points are well-linked so gain 4 marks.

Question 17(b)

This question required candidates to refer to "angular" velocity which is measured by the speedometer. "Angular" velocity is a technical term required by the specification. Many answers referred to circular or rotational speeds and were not credited.

Stronger answers usually used the equation v = rω within the explanation.

Some answers compared the number of turns that a smaller wheel would do. However, they didn't add "for a set distance" so these answers were not credited.

(b) The road speed of the bicycle should be displayed by the speedometer.

Explain why the displayed speed can **not** be accurate, as bicycles can have different wheel diameters.

(2)

because a smaller diameter would mean a smaller circumference so the ~~bicycle~~ ~~wy~~ axle would rotate more for the same change in distance giving a inflated speed and [illegible]

ResultsPlus
Examiner Comments

This answer gains MP1 in the second mark scheme. It does not mention angular velocity.

(b) The road speed of the bicycle should be displayed by the speedometer.

Explain why the displayed speed can **not** be accurate, as bicycles can have different wheel diameters.

(2)

$v = \omega r$, even if the angular speed that the dial is displaying is constant, the radius of the wheel can vary so the linear velocity will also ~~the~~ vary.

ResultsPlus
Examiner Comments

This answer uses the equation to explain that a different radius would lead to a different (road) speed. It also states that the dial (speedometer) measures angular velocity for 2 marks.

ResultsPlus
Examiner Tip

If you think an equation can be used to help with an explanation – use it.

(b) The road speed of the bicycle should be displayed by the speedometer.

Explain why the displayed speed can **not** be accurate, as bicycles can have different wheel diameters.

(2)

A larger wheel will ~~have~~ not have to turn ~~to~~ as much to travel the same distance as a smaller wheel. This means a smaller wheel will turn faster ~~to~~ to create the same road speed but showing a greater displayed speeds

ResultsPlus
Examiner Comments

This answer conveys the idea that different sized wheels will rotate a different number of times over a fixed distance. This is MP1 of the second scheme. It doesn't get a second mark because it doesn't mention angular velocity.

Question 17(c)

This question could be solved in two ways. Candidates could use conservation of energy or resolving forces. Very few candidates could use conservation of energy correctly in this situation. The cycle travels at a constant velocity up the slope. This means that the kinetic energy is not changing and therefore does not figure in conservation of energy statements.

This is a "deduce" question. This means that a comparison of values and a conclusion are required.

(c) A cyclist has a constant speed of $8.3\,m\,s^{-1}$ on a flat road. The cyclist generates an average power of 190 W. The total mass of the cyclist and bicycle is 75 kg.

The cyclist comes to a hill of gradient 1 in 20, as shown.

The cyclist now generates an average power of 330 W. The speed decreases to a constant value which the speedometer suggests is $5.6\,m\,s^{-1}$.

Deduce ~~whether the speedometer is accurate~~.

Assume resistive forces are constant.

$20^2 + 1^2 = 401$

$\sqrt{401} = 20$

$a^2 + b^2 = c^2$

(4)

$E_k = \frac{1}{2}mv^2$ $E_p = mgh$ $E_k = \frac{1}{2} \times 75 \times 8.3^2$ ~~= 2583.3~~

$P = \frac{E}{t}$ ~~$P \times t = E$~~ $= 2583.375$

$t = \frac{E}{P}$ ~~$E_k = \frac{1}{2}$~~

$E_p = 75 \times 9.81 \times$

$E_k = \frac{1}{2} \times 75 \times 5.6 = 1176$

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

$2583.375 = 75 \times 9.81 \times 1 \rightarrow 735.75$

$t = \frac{2583.375}{330} = 7.83\,s$

(Total for Question 17 = 12 marks)

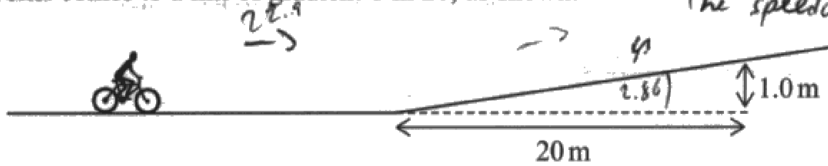
ResultsPlus
Examiner Comments

This is a good example of an incorrect application of conservation of energy. The candidate writes KE = PE as an equation. The kinetic energy is not changing in this particular scenario so it cannot account for the gain in potential energy. The only mark that can be credited is the use of the equation for gravitational potential energy.

(c) A cyclist has a constant speed of $8.3\,\text{m}\,\text{s}^{-1}$ on a flat road. The cyclist generates an average power of 190 W. The total mass of the cyclist and bicycle is 75 kg.

both the angular velocity and radius due to $v = \omega r$. The speedometer will not be able to display the correct speed.

The cyclist comes to a hill of gradient 1 in 20, as shown.



The cyclist now generates an average power of 330 W. The speed decreases to a constant value which the speedometer suggests is $5.6\,\text{m}\,\text{s}^{-1}$.

Deduce whether the speedometer is accurate.

Assume resistive forces are constant.

$\tan\theta = \frac{1}{20}$

$\theta = 2.86$

(4)

$W = Fs$ $\quad P = \frac{W}{t}$ $\quad E_k = \frac{1}{2}mv^2$ $\quad d = st$

$Pt = Fs$ $\quad E_k = \frac{1}{2} \times 75 \times 8.3^2$ $\quad d =$

$P = Fv$ $\quad E_k = \cancel{28}\ 2583$

$P = 190 = F \times 8.3$ $\quad 2583 = KE_A + GPE_A$

$F = 22.9$ $\quad 2583 = \frac{1}{2} \times 75v^2 + \cancel{m}\,75 \times 9.81 \times 1$

$v^2 = 49.26$

$v = 7$ $\quad \therefore$ The speedometer is inaccurate

$7 \neq 5.6$

ResultsPlus
Examiner Comments

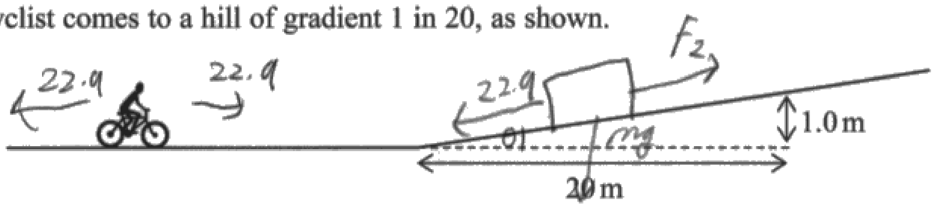
This answer starts well. It calculates the resistive force acting on the cycle for MP1. It then writes KE = KE + GPE which is not correct for this situation. It should have continued Work done by cyclist = gain in GPE + work done against resistive forces (per second). This answer gained a second mark for the use of the GPE formula.

ResultsPlus
Examiner Tip

The correct use of the Law of conservation of energy is a useful tool to solve mechanics questions.

(c) A cyclist has a constant speed of $8.3\,\mathrm{m\,s^{-1}}$ on a flat road. The cyclist generates an average power of 190 W. The total mass of the cyclist and bicycle is 75 kg.

The cyclist comes to a hill of gradient 1 in 20, as shown.



The cyclist now generates an average power of 330 W. The speed decreases to a constant value which the speedometer suggests is $5.6\,\mathrm{m\,s^{-1}}$.

Deduce whether the speedometer is accurate.

Assume resistive forces are constant.

(4)

$P = FV$

$F = \frac{P}{V}$

$F = \frac{190}{8.3}$

$F = 22.9\,N$

$R = F$ as constant speed so $R = 22.89\,N$

5

θ (slope) $= \tan^{-1}\left(\frac{1}{20}\right)$

$= 2.86^{\circ}$

constant speed

So $F_2 = R + mg\sin\theta$

$F_2 = 22.89 + 75 \times 9.81 \times \sin(2.86)$

$F_2 = 59.6\,N$

$P = FV$

$V = \frac{P}{F}$

$V = \frac{330}{59.6}$

$V = 5.5\,\mathrm{ms^{-1}}$

So the speedometer is approximately accurate

ResultsPlus
Examiner Comments

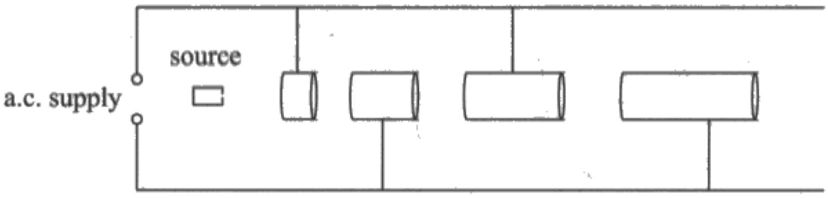
This answer gains full credit. It resolves forces along the slope. It starts by calculating the resistive force acting on the cyclist. Note that a conclusion is required by this type of question.

Question 18(a)

This question asks why the tubes in a LINAC particle accelerator become longer. Many candidates wasted some of their time explaining the accelerator principles rather than directly answering this question.

18 At the Facility for Rare Isotope Beams (FRIB) isotopes of elements that do not occur naturally can be produced.

(a) FRIB contains a linear accelerator. The initial section of the accelerator is shown.



Explain why the tubes get progressively longer.

(4)

electrons gains speed as move through the accelerator.
time spent is tubes in the same.
Speed = $\frac{\text{distance}}{\text{speed}}$ so the ~~th~~ tubes will get progressively longer. as the electron accelerates through ~~the~~ the accelerator.
frequency of ac is constant.

ResultsPlus
Examiner Comments

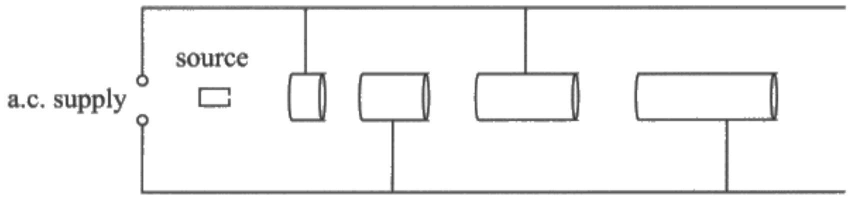
This gains 3 marks for MP1, MP3 and MP4. The formula $v = d / t$ needed to be rearranged into a form which suited the context.

ResultsPlus
Examiner Tip

If you are using a standard equation to help your discussion, then rearrange the formula to make the subject of the equation the quantity you are focusing on.

18 At the Facility for Rare Isotope Beams (FRIB) isotopes of elements that do not occur naturally can be produced.

(a) FRIB contains a linear accelerator. The initial section of the accelerator is shown.



Explain why the tubes get progressively longer.

(4)

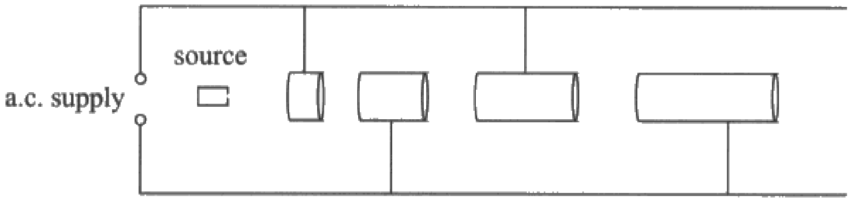
- the particles are accelerating
- but the frequency of the ac power supply is constant
- ~~and th~~ so the particles must spend the same length of time in each tube
- so the tubes must get longer to accommodate

ResultsPlus
Examiner Comments

This answer refers to the particles accelerating. This information was given in the question "...linear accelerator". The candidates were expected to state that the velocity of the particles increases. This answer gains MP1 and MP4.

18 At the Facility for Rare Isotope Beams (FRIB) isotopes of elements that do not occur naturally can be produced.

(a) FRIB contains a linear accelerator. The initial section of the accelerator is shown.



Explain why the tubes get progressively longer.

(4)

The a.c. supply has a fixed frequency therefore as $f = \frac{1}{T} \rightarrow T = 1/f$ the time period between ~~other~~ current reversals is constant. As ~~the~~ $t = S/v$ ~~&the~~ and velocity of isotopes is increasing due to electric field acceleration, the length of the tube must increase as $S \propto V$, to maintain a constant time period of isotopes in the drift tubes so that the current is reversed at correct time to accelerate them between the drift tubes.

ResultsPlus Examiner Comments

This answer gains all four marking points.

Question 18(b)i

This question examines the units MeV and the ability to use them. Many candidates tried to convert values into Joules but then often made mistakes. This isn't required if the candidate continues to use an energy in MeV.

(b) A uranium atom ($^{238}_{92}U$) has 80 electrons removed. The uranium ion is then accelerated between two adjacent tubes until its kinetic energy is 200 MeV per nucleon.

(i) Calculate the accelerating potential difference.

(4)

$Q = 80 \times 1.6\times10^{-19} = 1.28\times10^{-17}$ C

$E_k = 200$ MeV $= 3.2\times10^{-11}$ J

$m = 238 \times 1.66\times10^{-27} = 3.9508\times10^{-25}$ kg

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

$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2\times3.2\times10^{-11}}{3.9508\times10^{-25}}} = 1.27\times10^{7}$ ms^{-1}

$V = \frac{kQ}{r} = \frac{8.99\times10^{9}\times1.28\times10^{-17}}{59.967} = 1.92\times10^{-9}$ V

$r = \sqrt{\frac{kQ}{E}}$

$E = \frac{V}{d}$ 59.966 $V = Ed$

$E = \frac{kQ}{r^2}$ $\frac{V}{d} = \frac{F}{Q}$

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

Potential difference = 1.92×10^{-9} V

ResultsPlus
Examiner Comments

This answer recognises that the charge on the Uranium ion will be 80e for MP1. The candidate also recognises that the nucleon number is 238 by using it to calculate a mass of the ion. The mass of the ion was not required for this calculation, but it does enable the answer to gain MP3. The candidate converts into J and subsequently makes mistakes but has gained 2 marks – MP1 and MP3.

(b) A uranium atom ($^{238}_{92}U$) has 80 electrons removed. The uranium ion is then accelerated between two adjacent tubes until its kinetic energy is 200 MeV $\boxed{\text{per nucleon.}}$

(i) Calculate the accelerating potential difference.

(4)

charge becomes $+80 \times 1.6 \times 10^{-19}$

$V = \frac{W}{Q}$ $\quad W = 200\text{ MeV} \times (238+92-80)$

$\cancel{V = \frac{200\times10^{6} \times 1.6\times10^{-19}}{80 \times 1.6\times10^{-19}} = 2.5\times10^{6}\text{ V}}$ $\quad = 200\text{ MeV} \times 250$

$= 50\,000\text{ MeV}$

with $V = \frac{W}{Q}$, $V = 625 \times 10^{6}\text{ V}$

Potential difference = $\cancel{2.5\times10^{6}\text{ V}}$ $625 \times 10^{6}\text{ V}$

ResultsPlus
Examiner Comments

This answer was commonly seen. The candidate recognises that the charge on the uranium ion will be 80e for MP1. The candidate uses V = W/Q for MP2 but has converted into J which was not required. The candidate has a mixture of numbers in a bracket that means it is impossible to understand whether they appreciate that 238 is the nucleon number so MP3 is not given.

(b) A uranium atom ($^{238}_{92}U$) has 80 electrons removed. The uranium ion is then accelerated between two adjacent tubes until its kinetic energy is 200 MeV per nucleon.

(i) Calculate the accelerating potential difference.

Q of U Ion : $12 \cdot 1.6\times10^{-19} = 1.92\times10^{-18}$

E_k in J : $200\times10^{6}\times1.6\times10^{-19} = 3.2\times10^{-11}$

$V = \frac{3.2\times10^{-11}}{1.92\times10^{-18}}$

$V = 1.67\times10^{7}$

ResultsPlus
Examiner Comments

This candidate incorrectly states the charge on the ion is 12e. They use V = W/Q for MP2.

(b) A uranium atom ($^{238}_{92}U$) has 80 electrons removed. The uranium ion is then accelerated between two adjacent tubes until its kinetic energy is 200 MeV per nucleon.

(i) Calculate the accelerating potential difference.

(4)

KE: 200MeV/nucleon $\times 238 = 47600$ MeV

$\times 10^6 = 4.76 \times 10^{10}$ eV

$\times 1.6 \times 10^{-19} = 7.616 \times 10^{-9}$ J

P.E → KE

$VQ = KE$ $\quad VQ = 7.616 \times 10^{-9}$

$V = \dfrac{7.616 \times 10^{-9}}{80(1.6 \times 10^{-19})} = 595 \times 10^6$ V

Potential difference = 600×10^6 V

ResultsPlus Examiner Comments

This answer converts eV to J. It also calculates the charge on the ion in C. This can gain full credit although it takes extra time compared with the mark scheme example.

ResultsPlus Examiner Tip

Correct understanding of the use of units such as MeV can simplify accelerator questions considerably.

Question 18(b)ii

This question makes use of the kinetic energy equation. It is a "show that" question. Candidates were expected to show a substitution of the atomic mass unit in their equation. They had to express their answer to at least one extra significant figure.

(ii) Show that the uranium ions will reach a velocity of about 65% of the speed of light.

(3)

$E_k = \frac{p^2}{m} \Rightarrow E_k = \frac{m^2v^2}{2m}$ $\qquad E_k = \frac{1}{2}mv^2$

$\sqrt{\frac{2E_k}{m}} = v \qquad v = \sqrt{\frac{2 \times 3.2\times10^{-11}}{92 \times 1.67\times10^{-27}}} = 2.04 \times 10^6$

proton number $= 92$

$m = 92 \times 1.67\times10^{-27} = 1.54\times10^{-25}$ kg

ResultsPlus Examiner Comments

The energy of 3.2 x 10^{-11} is correctly calculated by converting 200 MeV to J so gains MP1. The kinetic equation uses a value of proton mass rather than u but this was allowed for MP2. The mass of the ion is found by using 238 rather than the proton number.

ResultsPlus Examiner Tip

Remember to show all substitutions in "show that" questions.

(ii) Show that the uranium ions will reach a velocity of about 65% of the speed of light.

$$E = mv^2$$

$$200 \times 10^6 = 1.67 \times 10^{-27} \times 238 \times V^2$$

$$V^2 = \frac{200 \times 10^6}{1.67 \times 10^{-27} \times 238}$$

ResultsPlus
Examiner Comments

This answer forgets the 1/2 so cannot gain MP2. They do not convert MeV into J so do not gain MP1.

(ii) Show that the uranium ions will reach a velocity of about 65% of the speed of light.

(3)

$\frac{1}{2}mv^2 \quad m = \cancel{238} \; 1.66\times10^{-27}$

$m = {}^{238}_{92}u = 238 \; 1.66\times10^{-27}\,\text{kg} = \cancel{3.9508\times10^{-25}\,\text{kg}}$

$200\times10^{6}\times1.6\times10^{-19} = \frac{1}{2}\times \overset{1.66\times10^{-27}}{\cancel{3.9508\times10^{-25}}}\times v^2$

$v^2 = \cancel{[illegible]} \; \cancel{1.6199} \; 3.855\times10^{16}$

$v = \cancel{[illegible]} \; \cancel{[illegible]} \; 1.964\times10^{8}$

$\frac{1.964\times10^{8}}{3\times10^{8}}\times100 = 65.45\% \approx 65\%$

ResultsPlus
Examiner Comments

This gains full credit. Note that the 238 nucleons effectively cancels out if placed on both sides of the equation. The answer is presented to more than 2 significant figures.

Question 18(c)

This question examined the appreciation of nucleon and proton numbers.

Uranium has a high ratio of neutrons compared to protons.

When it decays to produce products they will be neutron rich as the example of Mg shows.

(c) When a uranium ion hits a target at this speed the ion is likely to break up and produce smaller elements. One particular isotope produced in this way is ${}^{40}_{12}\mathrm{Mg}$. The naturally occurring common stable isotope of magnesium is ${}^{24}_{12}\mathrm{Mg}$.

Explain why the break-up of ${}^{238}_{92}\mathrm{U}$ is likely to produce unusual isotopes such as ${}^{40}_{12}\mathrm{Mg}$.

U Has a very high velocity, ~~so isotopes~~ ~~produced~~ and mass so isotopes produced from this will also have a higher mass

ResultsPlus
Examiner Comments

Many candidates did not recognise the clue given by the information about magnesium. They often then discussed velocities or energies.

(c) When a uranium ion hits a target at this speed the ion is likely to break up and produce smaller elements. One particular isotope produced in this way is $^{40}_{12}Mg$. The naturally occurring common stable isotope of magnesium is $^{24}_{12}Mg$.

Explain why the break-up of $^{238}_{92}U$ is likely to produce unusual isotopes such as $^{40}_{12}Mg$.

(2)

Because uranium is unstable and has a high mass number compared to atomic number so it is likely to produce isotopes of a simular manor such as $^{40}_{12}Mg$ with a high mass number compared to atomic number.

(Total for Question 18 = 12 marks)

ResultsPlus
Examiner Comments

This candidate appears to have recognised what the topic is about. They do not tell us what the mass numbers and atomic numbers represent.

ResultsPlus
Examiner Tip

The specification bullet point expects candidates to understand the meaning of these numbers. Where possible consider which part of the specification is being examined.

(c) When a uranium ion hits a target at this speed the ion is likely to break up and produce smaller elements. One particular isotope produced in this way is ${}^{40}_{12}\mathrm{Mg}$. The naturally occurring common stable isotope of magnesium is ${}^{24}_{12}\mathrm{Mg}$.

Explain why the break-up of ${}^{238}_{92}\mathrm{U}$ is likely to produce unusual isotopes such as ${}^{40}_{12}\mathrm{Mg}$.

(2)

Uranium ~~is~~ ~~alost~~ has much ~~more~~ ~~?ittealy~~ more neutrons than protons this means when it breaks up it is much more likely to produce a heavier ~~particle~~ isotope with many more neutrons

(Total for Question 18 = 13 marks)

ResultsPlus
Examiner Comments

This answer appreciates the ratio of neutrons to protons for MP1. They then state that products are likely to be neutron-rich for full credit.

Paper Summary

Based on their performance on this paper, candidates should:

- Identify and then write down the equation for a numerical question.
- Show all substitutions in an equation, including constants.
- Rearrange the equation, if needed, to make the unknown quantity the subject.
- Note that "deduce" questions require a comparison of the candidate’s answer with that given in the question and also a conclusion.
- Make sure you have all the equipment listed in the "requirements section" of the examination paper.
- Not expect every section of a particular question to be on the same topic.
- Remember to add a unit to each of the numerical answers.

Grade boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link: https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html

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