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June 2022

GCE Physics 9PH0 01

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Introduction

This paper examined the following topics: working as a physicist, mechanics and further mechanics, electric circuits, electric and magnetic fields and nuclear and particle physics.

A range of question types were used including multiple choice, questions requiring a short explanation, calculations and at least one indicative response question worth 6 marks.

The paper had 90 marks and was allocated a time of 1 hour 45 minutes. There was little evidence of candidates running out of time.

Most question were set in a context, eg question 12 was about a cyclist and bicycle.

Almost all candidates demonstrated some sound algebraic skills. Most candidates could substitute numerical values into equations and then rearrange them. Some questions required graphical skills such as Q12(b)(i), Q14(b)(ii) and Q18(b)(iv). Many candidates were less confident using graphical skills. Candidates were confident with their use of units and their prefixes. There is still some confusion when dealing with significant figures. Answers should not be rounded off to a number of significant figures which is less than the data given in the question.

In previous years the indicative content question has proved challenging. The indicative content question, requiring an explanation of the operation of a LINAC, was well-answered by most candidates. The question required some extended writing. Many candidates responded well and demonstrated good written communication skills.

Questions make use of a command word. The most commonly used command words were "explain" and "calculate". It is pleasing to note that candidates are becoming familiar with these and consequently their performance is improving. There were few examples of questions being completely misinterpreted.

The front of this paper informed centres that a protractor would be required for the exam. A number of candidates did not appear to have brought or been given a protractor.

Question 11 (a)

This question could be solved by either considering gain in gravitational potential energy or by resolving forces along the slope. Work done and power could then be calculated.

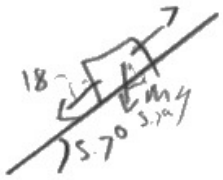
This example shows both approaches.

11 A student drives a go-kart up a slope.

(a) The slope is at an angle of 5.7° to the horizontal. The go-kart moves with a constant velocity of 2.8 m s^{-1}.

Calculate the power of the go-kart.

mass of go-kart and driver = 60 kg
resistive force on the go-kart = 18 N



(4)

$D = r + mg \sin 5.7$ ↑ 0.278

$D = 18 + 60 \times 9.81 \times \sin 5.7$

$D = 76.5$ N

$E_p = mgh$

$W = mgh$

77 N 2 s.f.

$W = 60 \times (9.81 + 18 \sin 5.7) \times 0.278$

190 W 2 s.f.

Power = 190 W 2 s.f.

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Examiner Comments

The resultant force has been correctly determined **down** the slope. This gains two marks, mark point 1 and 2 on the mark scheme for resolving forces.

The vertical height gained per second has also been calculated. This is mark point 1 on the first scheme.

The formula for gravitational potential energy has been written down but is incorrectly used.

This answer gains 2 marks on the mark scheme for resolving forces. This is equal to the tractive force on the go-kart.

If candidates have used a mix of approaches, then whichever scheme gives the most marks is used.

ResultsPlus
Examiner Tip

This answer illustrates how candidates can confuse two correct methods.

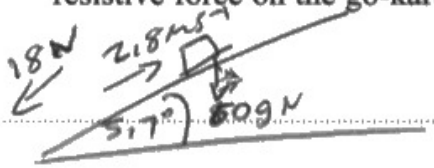
11 A student drives a go-kart up a slope.

(a) The slope is at an angle of 5.7° to the horizontal. The go-kart moves with a constant velocity of 2.8 m s^{-1}.

Calculate the power of the go-kart.

mass of go-kart and driver = 60 kg
resistive force on the go-kart = 18 N

(4)



$F = ma$ $Pt = W$ $W = Fs$

$60a - 18 = 0$ $a = \frac{\Delta v}{t}$

$F = ma$ $60a_N - 18_N = F$ $W = mg$

$60g \times \sin(5.7) = 60 \times 9.81 \times \sin(5.7) = 58.46\ N$

$56.46 - 18 = 38.46\ N$

ResultsPlus
Examiner Comments

The candidate has correctly calculated the component of weight acting parallel to the slope. The resistive force has then been subtracted as if the go-kart is travelling down the slope.

The go-kart is moving up the slope with a constant velocity. The resultant force along the slope on the kart must therefore be zero. The propulsion force must equal the component of weight plus the resistive force.

ResultsPlus
Examiner Tip

In mechanics questions check which way the object is moving.

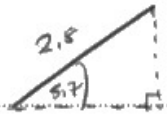
11 A student drives a go-kart up a slope.

(a) The slope is at an angle of 5.7° to the horizontal. The go-kart moves with a constant velocity of 2.8 m s^{-1}.

Calculate the power of the go-kart.

mass of go-kart and driver = 60 kg
resistive force on the go-kart = 18 N

(4)



Power = Force x velocity

horizontally : $2.8\cos 5.7 = 2.79$ m/s → moves 2.79 m in one second (→)

vertically : $2.8\sin 5.7 = 0.28$ m/s → moves 0.28 m in 1 second up

Power = $\frac{\text{Energy}}{\text{time}}$

↑ Energy = $60 \times 9.81 \times 0.28$

Energy = 164.8 J in 1 sec

→ Energy = F x D

Energy = $18 \times 2.79 = 50.22$ J in 1 sec

Total energy = $164.8 + 50.22 = 215$ J in one sec

Power = $\frac{E}{t}$

Power = $\frac{215}{1}$

Power = 215 W

Power = 215 W

ResultsPlus
Examiner Comments

This answer illustrates the energy approach to solving this problem for full credit.

ResultsPlus
Examiner Tip

Mechanics questions can often be solved by either a consideration of energy or resolving forces.

Question 11 (b)

This questions examined the use of the equation $P = I^2R$.

The most common errors were to substitute an incorrect power, omit the Ohms units or rearrange the equation incorrectly.

(b) The go-kart is powered by a battery connected to a motor. The rate of thermal energy transfer by the wiring in the motor is 55 W.

Calculate the resistance of the wiring in the motor.

current in motor = 24 A

(2)

$I = 24\ A$ $\quad P = I^2R$

$P = 55\ W$ $\quad \frac{P}{I^2} = R$

$\frac{55}{(24)^2} = R$ $\quad R = 0.0955$

Resistance of the wiring in the motor = 0.11 Ω

(Total for Question 11 = 6 marks)

ResultsPlus Examiner Comments

This is a more unusual error. The answer has been rounded off incorrectly.

ResultsPlus Examiner Tip

Leave the answer to more significant figures than strictly necessary rather than making a mistake with the rounding.

(b) The go-kart is powered by a battery connected to a motor. The rate of thermal energy transfer by the wiring in the motor is 55 W.

Calculate the resistance of the wiring in the motor.

current in motor = 24 A

(2)

$P = I^2 R$

$R = P/I^2 = 55/24^2 = 0.095\ \Omega$

Resistance of the wiring in the motor = $0.095\ \Omega$

ResultsPlus
Examiner Comments

This correct answer shows the most common way of solving this problem.

(b) The go-kart is powered by a battery connected to a motor. The rate of thermal energy transfer by the wiring in the motor is 55 W.

Calculate the resistance of the wiring in the motor.

current in motor = 24 A

(2)

$P = VI$ $V = \frac{P}{I}$

$V = 2.3\text{ V}$

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

$R = 0.095\ \Omega$

Resistance of the wiring in the motor = 0.095 Ω

(Total for Question 11 = 6 marks)

ResultsPlus
Examiner Comments

The problem can be solved in two stages as this example shows.

ResultsPlus
Examiner Tip

It is a good idea to show the substitution of data in formulas just in case you make a mistake in the calculation.

Question 12 (a)

This question is about completing a free-body force diagram.

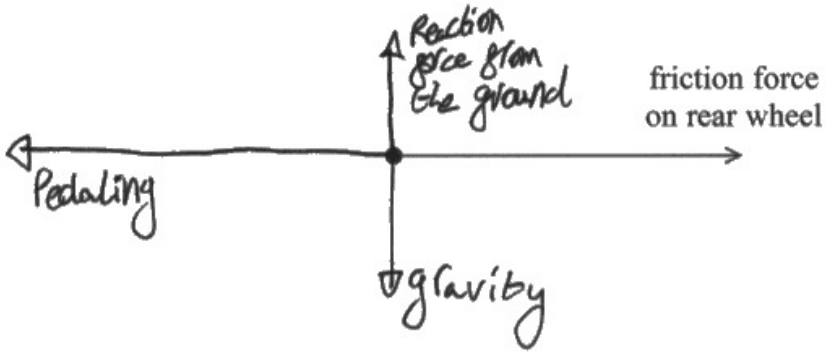
The cyclist is moving with a constant velocity so the horizontal arrows should be the same length (as should the vertical arrows). However, the mark scheme only required correct labelling of forces.

The most common error was to look at the label "friction force on rear wheel" and interpret that as the resistive or drag force on the bicycle. This force is the driving force.

12 The photograph shows a cyclist cycling at a constant velocity on horizontal ground.

(a) Complete the free-body force diagram to show the four forces acting on the bicycle. Treat the bicycle and cyclist as a single object. One force has been added for you.

(3)



ResultsPlus
Examiner Comments

There are two errors present.

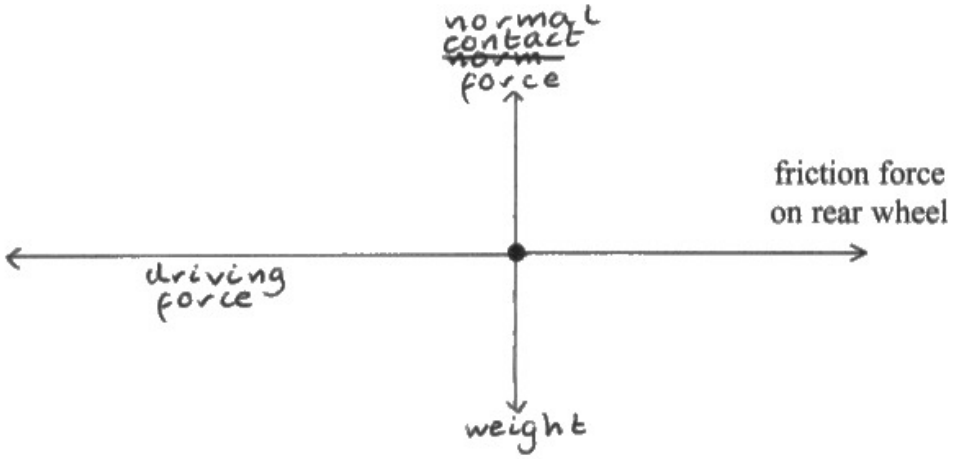
The force downwards is not gravity, it is weight.

The force to the left is the resistive force.

12 The photograph shows a cyclist cycling at a constant velocity on horizontal ground.

(a) Complete the free-body force diagram to show the four forces acting on the bicycle. Treat the bicycle and cyclist as a single object. One force has been added for you.

(3)



ResultsPlus
Examiner Comments

This illustrates the most common error. The resistive force to the left has been labelled "driving force" or similar.

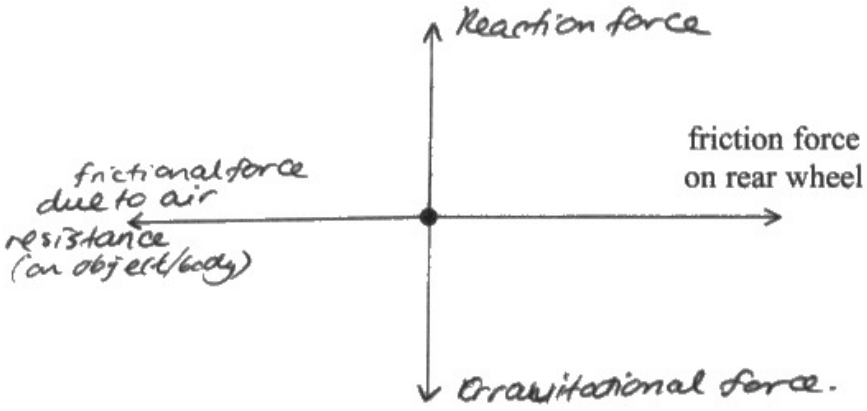
ResultsPlus
Examiner Tip

A clue was in the photograph showing the cyclist moving to the right.

12 The photograph shows a cyclist cycling at a constant velocity on horizontal ground.

(a) Complete the free-body force diagram to show the four forces acting on the bicycle. Treat the bicycle and cyclist as a single object. One force has been added for you.

(3)



ResultsPlus
Examiner Comments

This answer correctly shows all three forces.

Question 12 (b)(i)

This question examined the ability to sketch a velocity-time graph.

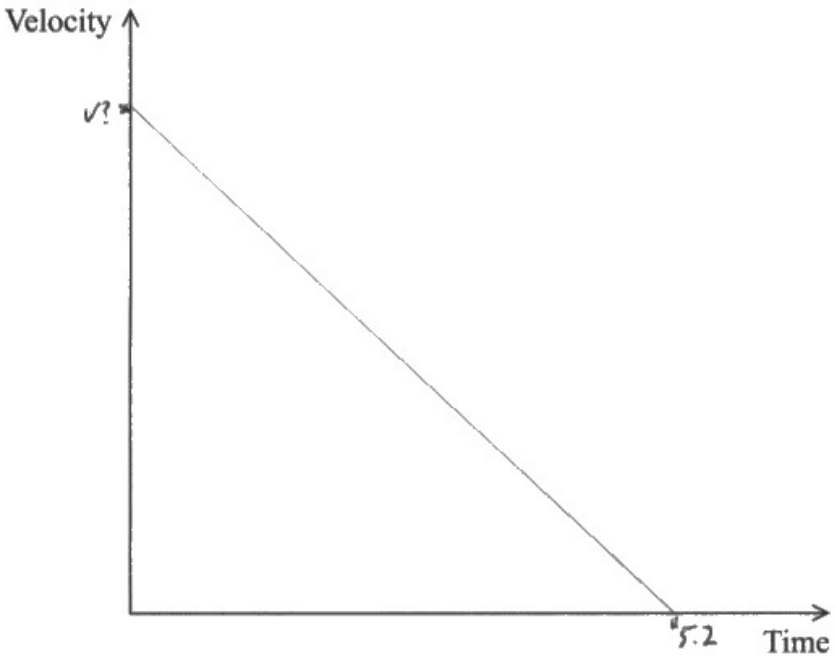
Some answers showed the motion before the brakes were applied as well as the period of deceleration. As long as this was clearly labelled it was fully credited.

(b) The cyclist stops pedalling and comes to rest in a time of 5.2 s.

(i) Sketch a graph to show how the cyclist's velocity changes during this time.

Assume the deceleration is constant.

(2)



ResultsPlus
Examiner Comments

The most common error was to forget the unit 's'.

ResultsPlus
Examiner Tip

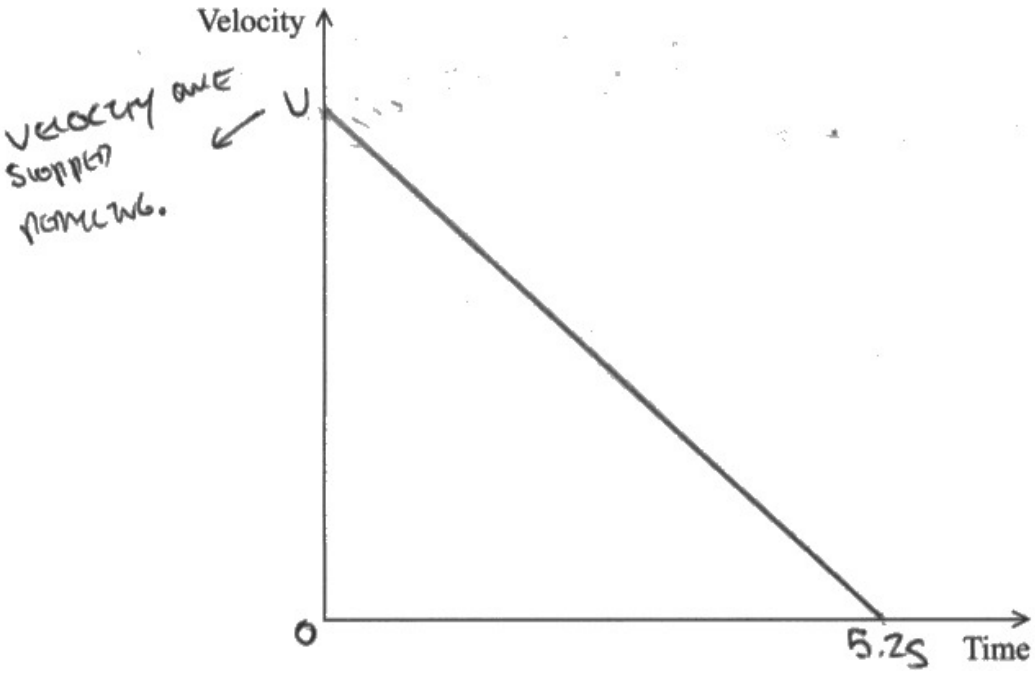
Graph axes almost always have units.

(b) The cyclist stops pedalling and comes to rest in a time of 5.2 s.

(i) Sketch a graph to show how the cyclist's velocity changes during this time.

Assume the deceleration is constant.

(2)



ResultsPlus
Examiner Comments

This answer is fully correct for both marks.

Question 12 (b)(ii)

This question could be solved in a number of different ways.

A graphical method could be employed making use of the sketch from Q12(b)(i) to calculate the initial velocity and acceleration.

The equations of motion could be used to calculate the initial velocity and acceleration.

An energy approach can be used along with the equation for work done.

This method appears to result in the correct answer. However, it is incorrect physics. It assumes the initial velocity, u, is zero which is not correct.

(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

mass of cyclist and bicycle = 28.0 kg

(4)

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

W

$7.8 = 0 + \frac{1}{2} \times a \times 5.2^2$

$\frac{2 \times 7.8}{5.2^2} = 0.5769 = 0.5a$

Average resistive force = 16 N

$0.5769 \times 28\,kg = 16.15\,N$ **(Total for Question 12 = 9 marks)**

$\simeq 16\,N$

ResultsPlus
Examiner Comments

The use of *F=ma* is correct and credited.

The final answer gains a mark.

(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

mass of cyclist and bicycle = 28.0 kg

(4)

$s = 7.8$
$u = x$
$v = 0$
$a = ?$
$t = 5.2$

$s = vt - \frac{1}{2}at^2$

$a = \frac{2(vt - s)}{t^2}$

$= \frac{2(0 - 7.8)}{5.2^2}$

$= -\frac{15}{26} = -0.5769$

$F = ma$

$= 28 \times \frac{15}{26}$

$= \frac{210}{13}$

$= 16.15$

Average resistive force = 16.2 N

(Total for Question 12 = 9 marks)

ResultsPlus
Examiner Comments

The equation used in this answer is not given in the specification. However, it is used correctly and is correct physics and is therefore fully credited.

(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

mass of cyclist and bicycle = 28.0 kg

(4)

$S = \frac{(U+V)t}{2}$ $V=0$ (rest)

$S = \frac{Ut}{2}$ $7.8 = \frac{Ut}{2}$ $Ut = 15.6$ $U = 3\,m/s$

$KE_{initial} = \frac{1}{2} \times 28 \times (3)^2$ Work done = KE

$= 126\,j$ $126 = F \times 7.8$ $F = 16.2\,N$

Average resistive force = 16.2N

ResultsPlus
Examiner Comments

This answer illustrates the energy approach.

ResultsPlus
Examiner Tip

An energy approach can be a useful alternative to some mechanics questions.

(ii) The cyclist travels 7.80 m while coming to rest.

Calculate the average resistive force on the cyclist and bicycle.

mass of cyclist and bicycle = 28.0 kg

(4)

7.8m $s = vt$ $s = ut + \frac{1}{2}at^2$

$S = \frac{1}{2}(ut + vt)$ $4.8 = u$

$7.8 = \frac{1}{2}(u(5.2) + (0t))$ $s = 3(t) + \frac{1}{2}(a)5.2^2$

$= \frac{1}{2}(5.2u)$ $7.8 = 3(5.2) + \frac{1}{2}(a)5.2^2$

$7.8 = 2.6u$ $7.8 = 15.6 + 13.52a$

$u = 3$ $a = -0.578$ $F = ma$ $F = 28(-0.578)$

Average resistive force = ≤ 16.2 N

(Total for Question 12 = 9 marks)

ResultsPlus
Examiner Comments

This answer illustrates the most commonly seen correct approach. It uses two equations of motion to firstly calculate initial velocity then acceleration.

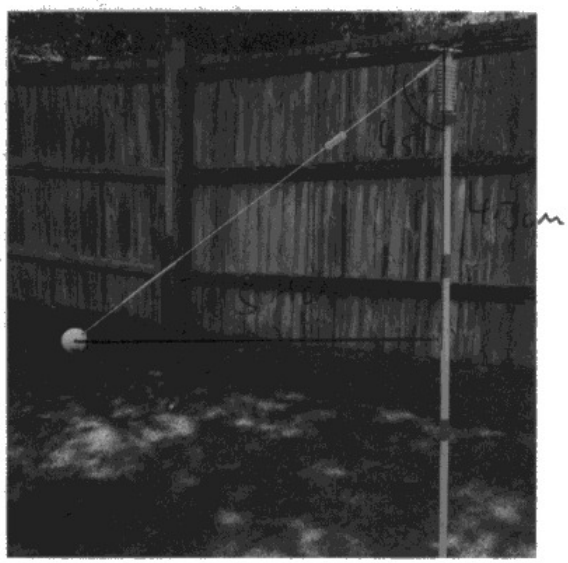
Question 13

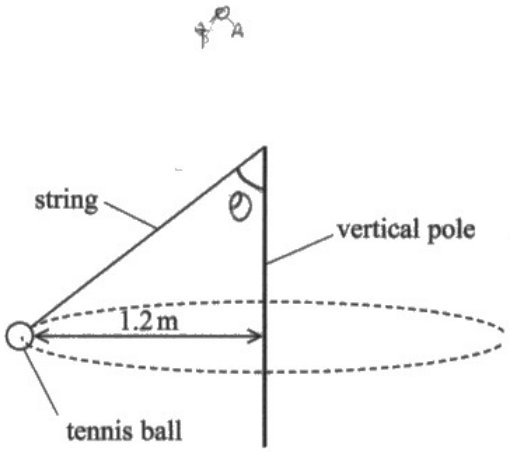
This question is sometimes referred to as a conical pendulum.

It examines circular motion equations.

A significant number of answers did not have a measured angle.

13 A 'tennis trainer' consists of a tennis ball suspended by a string from the top of a vertical pole. When the ball is hit it travels in a horizontal circle around the pole, as shown in both the photograph and the diagram.





The radius of the path of the ball is 1.2 m and the speed of the ball is 3.8 m s^{-1}.

Deduce whether these values are consistent with the angle between the string and the vertical pole shown in the photograph.

$a = \frac{3.8^2}{1.2} = 12.03$

$W = \sqrt{\frac{12.03}{1.2}} = 3.17$

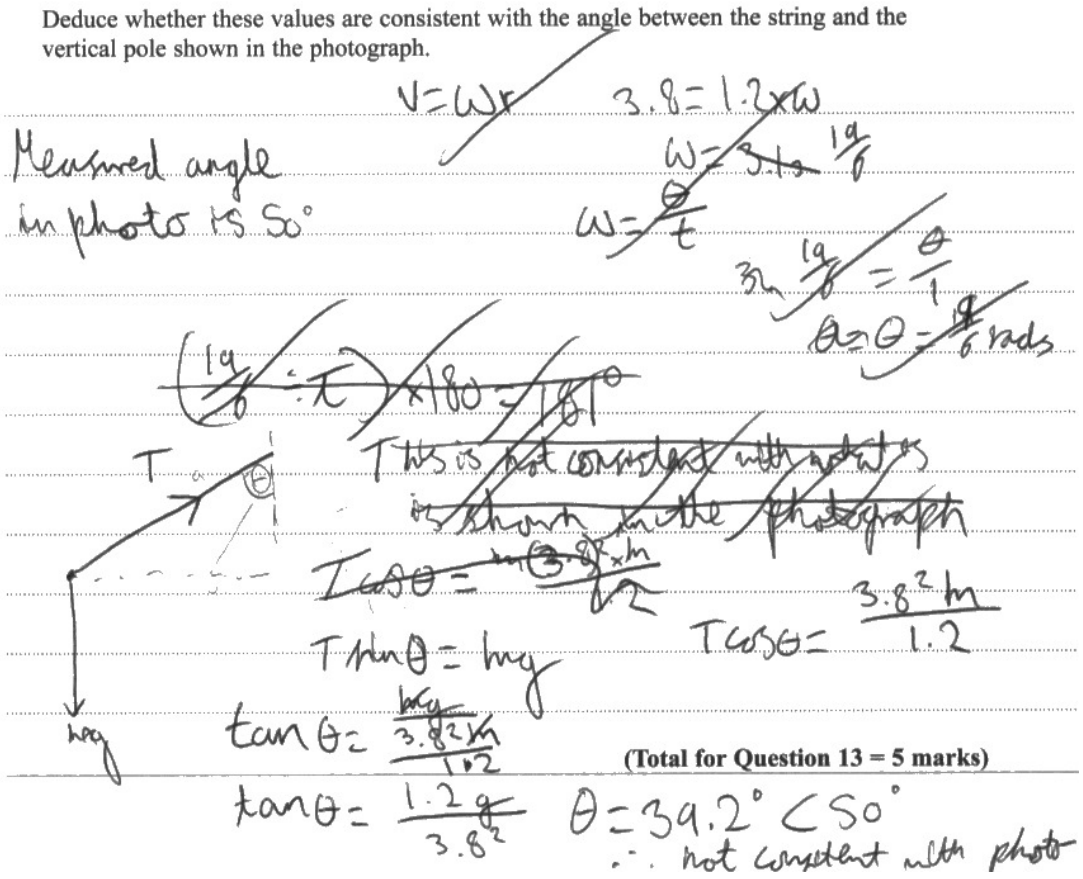
$1.2 / \tan 45 = 1.2\text{m}$

The angle would require the distance between the tennis ball and pole be the same both horizontally and vertically which is not shown in the photograph.

ResultsPlus
Examiner Comments

This answer does show a calculated value of acceleration towards the centre of the circle. This gains mark point 4.

Deduce whether these values are consistent with the angle between the string and the vertical pole shown in the photograph.



(Total for Question 13 = 5 marks)

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Examiner Comments

This candidate has measured the correct angle between the string and the vertical.

They then use the angle between the string and the horizontal for their analysis.

This analysis is correct but predicts the angle between the string and the horizontal so gains 4 marks overall.

ResultsPlus
Examiner Tip

Take care with angles when resolving.

Deduce whether these values are consistent with the angle between the string and the vertical pole shown in the photograph.

measured angle = 53°

$\frac{mv^2}{r} = T\sin\theta$ $\quad mg = T\cos\theta$

$T = \frac{mg}{\cos\theta}$

$\frac{mv^2}{r} = \frac{mg\sin\theta}{\cos\theta}$ $\quad \frac{v^2}{r} = g\tan\theta$ $\quad \theta = \tan^{-1}\left(\frac{v^2}{gr}\right)$

$\theta = \tan^{-1}\left(\frac{3.8^2}{9.81 \times 1.2}\right) = 50.81° \simeq 51°$

51° is approximately close to 53°, so the values are consistent with the photograph.

(Total for Question 13 = 5 marks)

ResultsPlus
Examiner Comments

This response is fully correct.

Question 14 (a)(i)

This question examined $f = 1/T$ and presented few difficulties to the vast majority of candidates.

14 Power supplies provide either alternating or direct currents and potential differences.

(a) A power supply produces an alternating potential difference (p.d.). The p.d. has a period of 0.02 s and a peak value of 4.0 V.

(i) Calculate the frequency of the supply.

(1)

$\frac{4}{0.02} = 200$

Frequency = ...

ResultsPlus Examiner Comments

This answer confuses the two pieces of data given in the question.

14 Power supplies provide either alternating or direct currents and potential differences.

(a) A power supply produces an alternating potential difference (p.d.). The p.d. has a period of 0.02 s and a peak value of 4.0 V.

(i) Calculate the frequency of the supply.

(1)

$\frac{1}{0.02} = 50$

Frequency = 50

ResultsPlus Examiner Comments

Omission of the unit.

ResultsPlus Examiner Tip

Make sure your calculation answers have a unit.

Question 14 (a)(ii)

This question examines the use of *V* rms = *V*o/√2.

(ii) Calculate the root-mean-square p.d. (2 s.f.)

(1)

$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{4.0}{\sqrt{2}} = 2.82...V$

Root-mean-square p.d. = 2.8 V (2 s.f.)

ResultsPlus Examiner Comments

This answer has the value 2.82 V (note that the correct value to 3 significant figures is 2.83).

The candidate has then noted that the data is given to 2 significant figures (4.0) and rounded off to two significant figures.

ResultsPlus Examiner Tip

You will not be penalised for leaving an answer to too many significant figures, but it is good practise to round off to the same number of significant figures as the data supplied.

(ii) Calculate the root-mean-square p.d.

(1)

$V = \frac{4}{\sqrt{2}} = 2\sqrt{2}$

Root-mean-square p.d. = $2\sqrt{2}$ V

ResultsPlus
Examiner Comments

When asked to calculate a value. You must calculate it and not leave it in surd form.

Question 14 (b)(i)

This question examined the knowledge of the basic function of a diode. Many candidates started with "a diode lets current travel in one direction" and this was given credit. The candidates then had to describe how this arrangement of diodes created a direct current from an alternating current. Many answers failed to express this clearly and succinctly. The end result was often a muddle or a contradiction and difficult to award marks.

(i) Explain the operation of this circuit. Your answer should refer to D_1, D_2, D_3 and D_4. (3)

Voltage comes out on the top and goes through D_2, past x and splits through the resistor and the voltmeter. D_1 makes sure it doesn't go the wrong way. The voltmeter needs to be in parallel. So the circuit is completed it goes back and through D_4. When current is changed it goes through D_3. The diode D_4 makes sure it doesn't go the wrong way. It passes X, past Y voltmeter and resistor, y but this then goes through D_1, as it wants to complete the circuit.

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Examiner Comments

This answer does a good job of conveying the route of the current through D2 and back through D4. It gains mark point 2.

(i) Explain the operation of this circuit. Your answer should refer to D_1, D_2, D_3 and D_4.

(3)

There is an alternating potential difference the diodes only allow current through them in one direction, therefore the diode channel the potential difference that is across through the diode. The resistor only receives current from X because current is unable to flow from Vin directly to Y. As the potential difference is passed through the capacitor D_2 ensures any current flows to X,

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Examiner Comments

This answer has marking points 1 and 3.

The discussion about the diodes themselves is not sufficient for mark point 2.

(i) Explain the operation of this circuit. Your answer should refer to D_1, D_2, D_3 and D_4.

(3)

The diodes always direct the current so that it travels from X to Y through R. This is because D_1 and D_4 block the current flow from going towards Y no matter what direction it is coming from, and D_2 and D_3 ~~allow~~ direct it through towards X. Therefore a positive V_{out} will always be read despite the alternating current because the current always travels from X to Y

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Examiner Comments

This answer gains marking point 3 with a clear statement about the resulting direction of current from X to Y.

The discussion about the diodes is clearly presented and just sufficient to award mark point 2.

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Examiner Tip

Make sure you do not contradict yourself. This answer keeps the description simple and clear.

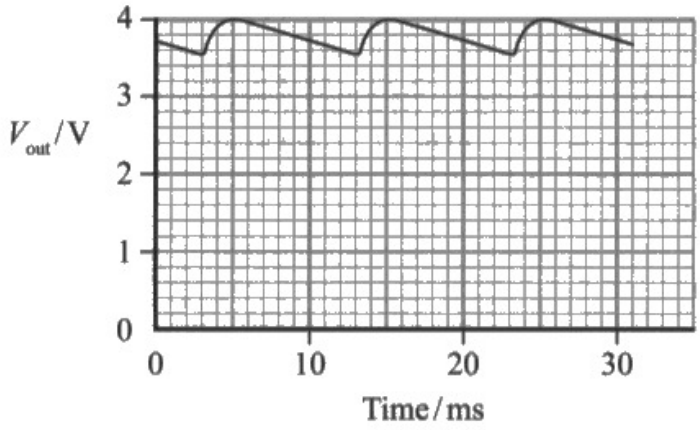
Question 14 (b)(ii)

This question examined capacitor discharge through a resistor. The expected method was to take two values of p.d. and a time difference from the discharge part of the graph and use the exponential discharge equation.

There is an alternate method which could be used correctly to determine *C*. This uses *V=IR*, *Q=IT* and *Q=CV.* It needs a clear understanding of difference in p.d. Δ*V* to obtain the correct answer.

(ii) A capacitor is added between points X and Y in the circuit.

The new graph of V_{out} against time is shown below.



Determine a value for the capacitance of the capacitor.

resistance of R = 2.2 kΩ

(3)

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

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

$I = \frac{4}{2.2 \times 10^{3}}$

$I = 1.82 \times 10^{-3}$ A

$I = \frac{Q}{t}$

$Q = I \times t$

$Q = 1.82 \times 10^{-3} \times 15$

$Q = 0.027C$

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

$C = \frac{0.03}{4}$

$C = 7.5 \times 10^{-3}$ farads

Capacitance = 7.5×10^{-3} farads

ResultsPlus
Examiner Comments

This answer starts well using $I=V/R$ to predict a current.

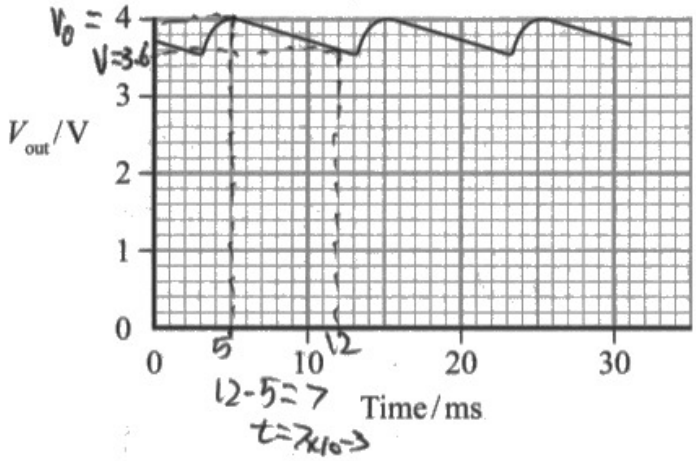
The value of time in $Q=It$ should be taken from the discharge section of the graph which has a maximum of 8 ms.

This time should then correspond to a difference in p.d. from the start of the discharge (4 V) to the end of the time period which would be 0.4 V if 8 ms was chosen.

This collects mark point 1.

(ii) A capacitor is added between points X and Y in the circuit.

The new graph of V_{out} against time is shown below.



Determine a value for the capacitance of the capacitor.

resistance of R = 2.2 kΩ

(3)

$V = V_0 e^{\frac{-t}{RC}}$

$3.6 = 4\, e^{\frac{-7\times10^{-3}}{2.2\times10^{3}C}}$

$\ln\left(\frac{3.6}{4}\right) = \frac{-7\times10^{-3}}{2.2\times10^{3}C}$

$C = \frac{-7\times10^{-3}}{2.2\times10^{3}\times\ln\left(\frac{3.6}{4}\right)}$

$= 3.02\times10^{-5}\,F$

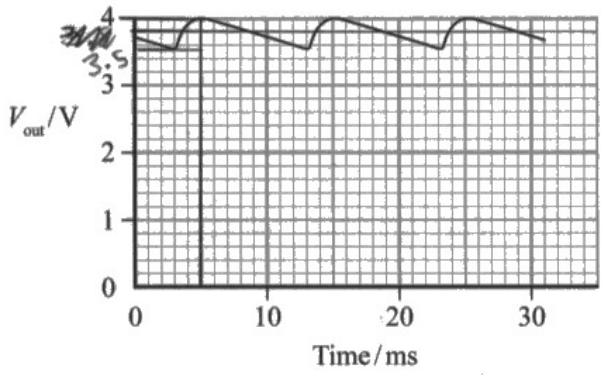
Capacitance = 3×10^{-5} F

ResultsPlus
Examiner Comments

This answer is fully correct.

(ii) A capacitor is added between points X and Y in the circuit. D_2.

The new graph of V_{out} against time is shown below.



Determine a value for the capacitance of the capacitor.

resistance of R = 2.2 kΩ

(3)

$W = \frac{1}{2}QV = VQ$

$V = V_0 e^{-t/RC}$ $V = 4$ $V_0 = 3.5$

$\frac{V}{V_0} = \frac{V_0}{V} = e^{t/RC}$ $t = 2$ s

$\frac{3.5}{4} = e^{\frac{2}{2.2\times10^3 C}}$

$\ln\left(\frac{3.5}{4}\right) = \frac{2}{2.2\times10^3 C}$

$C = \frac{2}{2.2\times10^3 \ln\left(\frac{3.5}{4}\right)}$ Capacitance = 6800 μF

ResultsPlus
Examiner Comments

This answer has *V*o = 3.5 V and *V* = 4 V which are the wrong way round. The initial p.d. is 4 V and the final p.d. is 3.5 V. The time difference between these values is 8 ms not 2 s.

However, the candidate has substituted values into the exponential equation and gains mark point 2.

ResultsPlus
Examiner Tip

Be clear in capacitor-resistor questions whether it is discharge or charge that is required.

Question 15 (a)

The indicative content (IC) question was to explain how electrons are accelerated in a LINAC. There are six indicative content points (IC) and these could be expressed in a variety of ways. Some candidates chose to add a diagram and this was also assessed.

This candidate has used bullet points which can add clarity.

15 A series of experiments was carried out in the 1970s to investigate the structure of protons using the linac at Stanford, USA.

***(a)** Explain how an electron is accelerated in a linac.

(6)

- alternating electric field
- charged partide enters (electron)
- between tubes force is applied to the particle ~~caus~~ due to alternating electric field hence it is accelerated between the tubes
- ~~due to time be~~
- for time ~~t of be~~ in each tube to be constant, length of tubes must increase along the linac
- ~~electron is~~
- electron is attracted to positive electric field hence accelerates
- electron is repelled upon leaving tube due to negative electric field, hence accelerates

ResultsPlus
Examiner Comments

IC1 tubes; IC2 accelerated by an electric field; IC3 between tubes.

IC5 alternating electric field and IC6 length of tubes and time are all present.

It is coherently communicated so this gained 3 IC marks + 2 linkage marks = 5 marks.

15 A series of experiments was carried out in the 1970s to investigate the structure of protons using the linac at Stanford, USA.

*(a) Explain how an electron is accelerated in a linac.

(6)

an electron gun is at one end of the linac and through thermionic emission, electrons are released into the linac. the drift tubes inside of the linear are connected to a high voltage alternating power supply. with the drift tubes being oppositly charged to the ones directly next to them. This creats a potential difference between the drift tubes which creates an electric field between the drift tubes. the electron is attracted to the posetive charge of the next drift tube and due to the electric field, is accelerated across the gap. Wher it gains energy and velocity. because the velocity of the electron is increasing between drift tubes, & the length of drift tubes increases along the linac. as $v = a/t$, and this allows the frequency of the alternating voltage supply to stay constant. meaning by the end of the linac, the electon will have gained alot of energy. and therefore, velocity.

ResultsPlus
Examiner Comments

This gains all indicative content (IC) points.

IC4 (adjacent tubes are connected to opposite terminals of a power supply or have opposite polarity) was frequently missed.

However, this answer has "the drift tubes are oppositely charged to the ones directly next to them" for IC 4.

So it gained all IC points: 4 marks + 2 linkage marks = 6 marks.

ResultsPlus
Examiner Tip

Indicative content questions have a maximum of 6 indicative content points.

Question 15 (b)

This question examined specification point 136: understand why high energies are required to investigate the structure of nucleons.

A high-energy electron beam will have a large momentum and therefore a small de Broglie wavelength. The wavelength needs to be at least as small as the size of the particles that are to be investigated.

(b) The electron leaves the accelerator with a high energy.

Explain why electrons need high energies to investigate the structure of a proton.

(2)

$E = mc^2$

High energy needed to transfer into equal parts matter and anti matter.

ResultsPlus
Examiner Comments

Many candidates confused this question. It is not about why high energy is required to create particles in nuclear experiments.

(b) The electron leaves the accelerator with a high energy.

Explain why electrons need high energies to investigate the structure of a proton.

(2)

Electrons need high energies because as they get close to the protons, the opposite charge repels them, so high energy is needed to overcome the repulsion force.

ResultsPlus
Examiner Comments

A number of answers suggested that opposite charged particles will repel when in fact they would attract.

(b) The electron leaves the accelerator with a high energy.

Explain why electrons need high energies to investigate the structure of a proton.

(2)

As the wavelength of ~~the~~ the electron needs to be similar to the size of ~~prot~~ proton constituents (qua).
So very small wavelength required.
$\lambda = \frac{h}{p}$ so for very small λ, very high momentum required, so very high velocity. Which requires very high energy.

ResultsPlus
Examiner Comments

An answer that gains full credit.

Question 15 (c)(i)

This question required a knowledge of base units.

(c) An electron leaves the accelerator with a momentum of 20 GeV/c.

(i) Explain, with reference to base units, why GeV/c can be used as a unit of momentum.

(2)

GeV => J -> $kgms^{-2} \cdot m$ ($WD = F \cdot d$) ∴ eV => kgm^2s^{-2}

$c = ms^{-1}$

∴ GeV/c => $\frac{kgm^2s^{-2}}{ms^{-1}} = kgms^{-1}$ => $m \cdot v$ = momentum.

Since the base units are the same, they represent the same measurement (momentum)

ResultsPlus
Examiner Comments

A fully correct answer.

(c) An electron leaves the accelerator with a momentum of 20 GeV/c.

(i) Explain, with reference to base units, why GeV/c can be used as a unit of momentum.

(2)

1 ~~$E = mc^2$~~ ~~$E = m^2c^2$~~ if E given in ~~J~~ eV ~~$mc = p$~~

2. $m \cdot c = p$ 3. $E = mpc \therefore p = \frac{E}{c}$ as $E = GeV$

4. $p = \frac{GeV}{c}$

ResultsPlus
Examiner Comments

This answer does not refer to or use base units.

ResultsPlus
Examiner Tip

Follow any instruction in the question. If it says, "with reference to...." make sure that this is included in your answer.

(c) An electron leaves the accelerator with a momentum of 20 GeV/c.

$\frac{1}{2}mv^2$ ~~$kgms^{-1}$~~ $kgms^{-1}$

(i) Explain, with reference to base units, why GeV/c can be used as a unit of momentum.

(2)

$p = mv = kgms^{-1} = $ ~~J~~ J

$GeV/c = J$

$\therefore \quad GeV/ = kgms^{-1} = J$

ResultsPlus
Examiner Comments

If the answer had stated that momentum had the base units $kgms^{-1}$ then it would gain 1 mark.

This answer muddles this by also saying these base units are the units of energy which is incorrect.

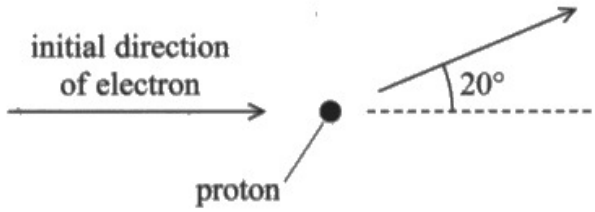
The base units of energy are kgm^2s^{-2}.

Question 15 (c)(ii)

This question examined conservation of momentum in two dimensions. A common mistake was to assume the proton was undeflected and would continue along the dotted line.

Both the electron and proton will move off at an angle to the dotted line after the collision.

(ii) An electron with initial momentum 20 GeV/c collides with a stationary proton. After the collision the electron is deflected by an angle of 20° as shown and its momentum is 9.1 GeV/c. The momentum of the proton after the collision is 11.9 GeV/c.



Deduce whether the law of conservation of momentum is obeyed.

(3)

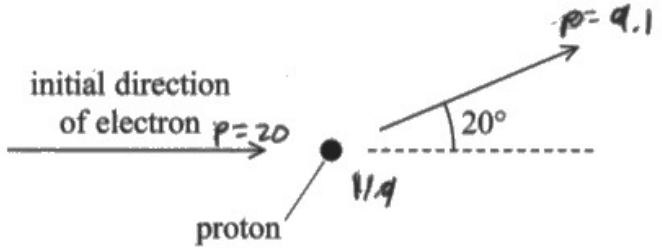
The law of conservation of momentum is obeyed As the momentum before the collision is equivalent to the momentum after the collision

$20\ \frac{GeV}{c} + 0\ \frac{GeV}{c} = 9.1\ \frac{GeV}{c} + 11.9\ \frac{GeV}{c}$

ResultsPlus Examiner Comments

This answer takes no account of the components of momentum in the x or y direction after the collision.

(ii) An electron with initial momentum 20 GeV/c collides with a stationary proton. After the collision the electron is deflected by an angle of 20° as shown and its momentum is 9.1 GeV/c. The momentum of the proton after the collision is 11.9 GeV/c.



Deduce whether the law of conservation of momentum is obeyed.

(3)

p=20 p=0

Before

p = 20

p=9.1

p=9.1cos(20)

=8.5512

After

p = 11.9+8.55

= 20.45

9.1

20

p=9.1cos(20)

=8.55GeV/c

Momentum is not conserved

ResultsPlus
Examiner Comments

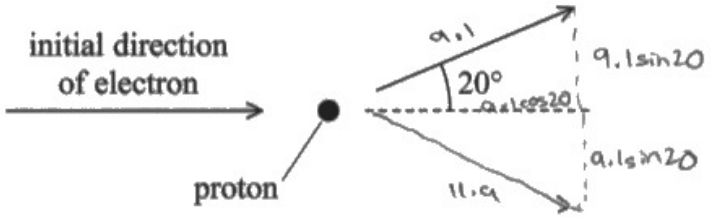
The most common mistake was to assume the proton was travelling along the dotted line after the collision. This cannot be true as momentum in the y direction must be conserved.

This answer has correctly expressed the x direction component of the electron for mark point 1.

ResultsPlus
Examiner Tip

Remember the law of conservation of momentum applies in any direction as well as the "obvious" one.

(ii) An electron with initial momentum 20 GeV/c collides with a stationary proton. After the collision the electron is deflected by an angle of 20° as shown and its momentum is 9.1 GeV/c. The momentum of the proton after the collision is 11.9 GeV/c.



Deduce whether the law of conservation of momentum is obeyed.

(3)

Conservation of momentum has not been obeyed as momentum is a vector quantity so while the total magnitude of the momen for p to be conserved, vertical components of electron and proton after collision must add to 0. $\therefore P_v = 9.1\sin 20$ for proton

Proton horizontal $= \sqrt{11.9^2 - (9.1\sin 20)^2} = 11.486$ GeV/c

$\therefore$ Total momentum $= 9.1\cos 20 + 11.486 = 20.0$ GeV $\therefore$ conservation of

ResultsPlus
Examiner Comments

There were various alternative methods to solve the problem.

ResultsPlus
Examiner Tip

This fully correct answer calculates the momentum of the proton in the x direction after the collision. It then calculates the momentum of the proton in the y direction after the collision and finds the resultant momentum of the proton after the collision and compares with 11.9 GeV/c.

Question 15 (c)(iii)

An inelastic collision is one in which the total kinetic energy is not conserved.

(iii) The collisions between electrons and the protons in these experiments are sometimes inelastic.

State what is meant by an inelastic collision.

(1)

Momentum is conserved but kinetic energy is not conserved

ResultsPlus Examiner Comments

This was given the mark but "inelastic" does not refer to momentum.

(iii) The collisions between electrons and the protons in these experiments are sometimes inelastic.

State what is meant by an inelastic collision.

(1)

Not- all energy is conserved, some is wasted

ResultsPlus Examiner Comments

Some answers omitted "kinetic".

(iii) The collisions between electrons and the protons in these experiments are sometimes inelastic.

State what is meant by an inelastic collision.

(1)

Kinetic energy is not conserved.

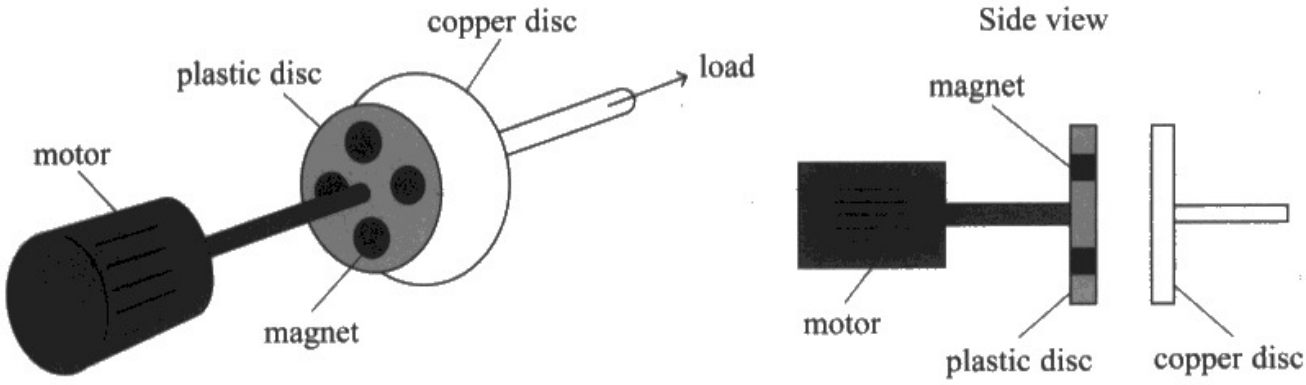
ResultsPlus Examiner Comments

This was credited although it would be helpful to add the word "total".

Question 16 (a)(i)

This question examines the application of Faraday's law of electromagnetic induction. The rotating magnets embedded in the plastic disk will cause a changing magnetic flux in the copper disc and induce an emf.

16 A device called a clutch can be used to connect a motor to a load. The diagram shows a design called an eddy current clutch.



Several magnets are embedded in the plastic disc and it is rotated by the motor.

(a) (i) Explain why a current is induced in the copper disc when the motor is switched on.

(2)

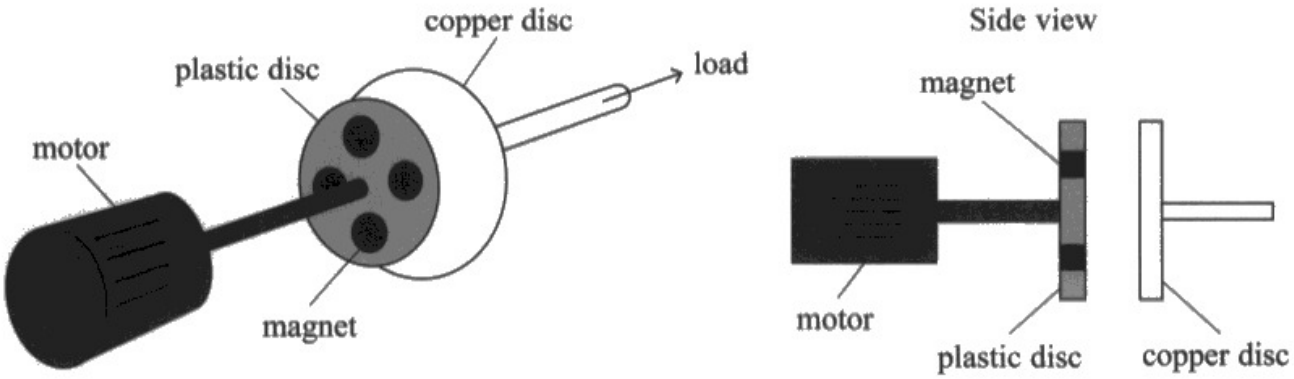
When the motor is switched on, the magnets rotate. Hence, the copper disc experiences changing flux linkage. By Faraday's law, there is an EMF induced in the copper disc, proportional to the rate of change of flux linkage. Since electrons can flow in the copper disc, a current is induced.

ResultsPlus
Examiner Comments

Either magnetic flux or flux linkage was accepted for mark point 1.

This answer covers both mark points.

16 A device called a clutch can be used to connect a motor to a load. The diagram shows a design called an eddy current clutch.



Several magnets are embedded in the plastic disc and it is rotated by the motor.

(a) (i) Explain why a current is induced in the copper disc when the motor is switched on.

(2)

a current is induced because a magnetic feild is created this magnetic feild acts perpendicular to particles and creates movement

ResultsPlus
Examiner Comments

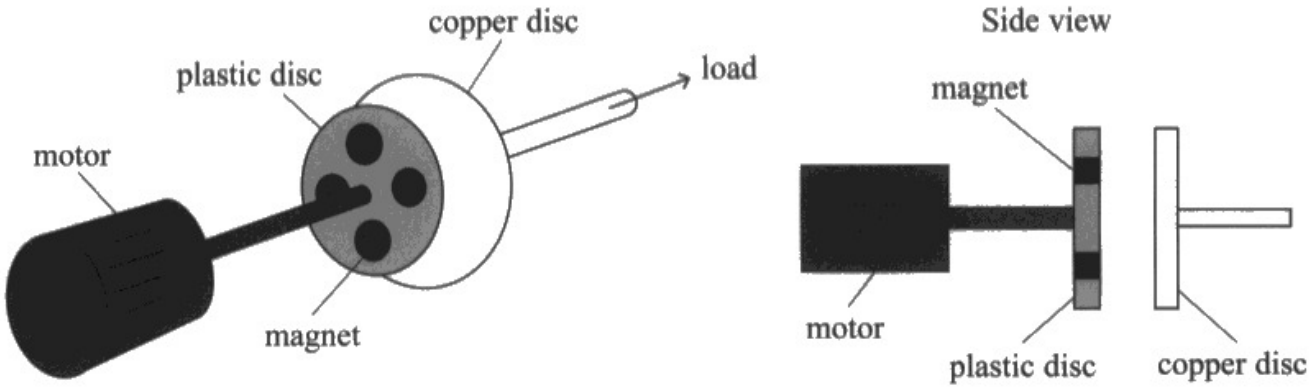
This answer does not mention "change" or magnetic flux for mark point 1.

It does not state induced emf for mark point 2.

ResultsPlus
Examiner Tip

Faraday's law is likely to be examined on this paper – make sure you know how to express it in words.

16 A device called a clutch can be used to connect a motor to a load. The diagram shows a design called an eddy current clutch.



Several magnets are embedded in the plastic disc and it is rotated by the motor.

(a) (i) Explain why a current is induced in the copper disc when the motor is switched on.

(2)

When the motor is switched on it performs motion, which interacts with the magnetic field of the magnet to induce a current (perpendicular to the magnetic field).

ResultsPlus
Examiner Comments

This answer does not state change in magnetic flux or cutting magnetic field lines for mark point 1.

It does not state induced emf for mark point 2.

Question 16 (a)(ii)

This question examines an understanding of Lenz's law. The copper disc will rotate in the **same** direction as the magnets. Lenz's law states that the result will be to oppose the change that created it. In this case the motion of the copper disc will be to try and reduce the rate of change in magnetic flux. It will achieve this by rotating in the same direction. If it could rotate in the same direction at the same rate the change in flux would become zero.

(ii) Explain, using Lenz's law, why the copper disc rotates.

(3)

Lenz's law opposes the force created by the change in flux which leads to ~~rotation~~ rotation in opposite direction to the motor

ResultsPlus
Examiner Comments

Many candidates confused the words in Lenz's law. This is a good example of this, "opposes the change in flux" would gain mark point 3.

(ii) Explain, using Lenz's law, why the copper disc rotates. copper disk.

(3)

The change in flux linkage induces an emf in the copper this drives a current through the copper which ~~opposes the change in~~ creates a force to oppose the magnetic flux linkage that caused it, this force rotates the disk.

ResultsPlus
Examiner Comments

This answer comes close but doesn't say which way the disc rotates. Note that the "force opposes the magnetic flux" rather than the **change** in magnetic flux.

It wasn't clear that the force results from a current within a magnetic field (mark point 2).

(ii) Explain, using Lenz's law, why the copper disc rotates.

(3)

According to Lenz's laws, the induced emf will cause a current to flow in a direction to oppose the changing magnetic flux, produce a magnetic flux which opposes the changing flux. A force is applied to the spinning magnetics, which sets up a Newton's 3rd laws pair, causing the copper disc to spin in the same direction as the magnets.

ResultsPlus
Examiner Comments

This answer was judged to cover all three marking points.

Question 16 (b)

This question examined angular velocity equations.

(b) The motor rotates at 500 revolutions per minute.

Calculate the angular speed ω of the motor.

(2)

500 rev per min => $\frac{25}{3}$ rev per second = freq

$\frac{1}{freq} = T = 0.12$ $2\pi T = \omega = 0.754$ rad s^{-1}

$\omega =$ 0.754 rad s^{-1}

ResultsPlus Examiner Comments

The angular velocity equation is incorrectly written down in this example.

ResultsPlus Examiner Tip

This equation is provided at the back of the exam paper. Don't risk writing it down from memory unless you are certain.

(b) The motor rotates at 500 revolutions per minute.

Calculate the angular speed ω of the motor.

(2)

500/60 = f = 8.3 Hz $\frac{1}{f} = T = 0.12s$ $T = \frac{2\pi}{\omega}$ $\omega = \frac{2\pi}{T}$

$2\pi / 0.12 = 52.4$

$\omega =$ 52.4 rad s^{-1}

ResultsPlus Examiner Comments

Correct use of angular velocity equation in this answer.

Question 16 (c)

The first mark scheme point was to note that the two variables are approximately proportional. This can be explained because if angular velocity is increased then the rate of change of flux will increase. This will induce a larger current within the disc and hence the force should increase.

(c) The table shows how the turning effect exerted on a load varies with ω for a particular distance between the copper disc and the plastic disc.

ω/rad s^{-1}	Turning effect/N cm
52.4	1.0
104.7	2.0
157.1	2.8

Explain the trend shown by the data.

(4)

We can see that as the ~~or~~ meter spins faster, the turning effect increases, however it is not a linear increase. This is because Faraday's law tells us that the increase in angular velocity creates a larger induced emf, as the rate of change of B increases. This will increase the opposing effect by the induced emf., which in this case is the turning effect. So the increase in rate of change of magetic field, creates a larger turning effect.

ResultsPlus
Examiner Comments

This answer covers both mark point 2 and mark point 3.

(c) The table shows how the turning effect exerted on a load varies with ω for a particular distance between the copper disc and the plastic disc.

ω / rad s^{-1}	Turning effect / N cm
52.4	1.0
104.7	2.0
157.1	2.8

Explain the trend shown by the data.

(4)

$\frac{52.4}{1} = 52.4$ $\frac{1.0}{52.4} = 0.01908$

$\frac{104.7}{2.0} = 52.35$ $\frac{2.0}{104.7} = 0.01910$

$\frac{157.1}{2.8} = 56.1$ $\frac{2.8}{157.1} = 0.01782$

The range in values is only 1.28×10^{-3}, showing little difference.

The turning effect / Ncm increases linearly, and in direct proportion with the angular speed in rads^{-1}, as they all experience a constant value when divided. similar

ResultsPlus
Examiner Comments

Some answers completed a numerical discussion of the relationship and gained one mark.

(c) The table shows how the turning effect exerted on a load varies with ω for a particular distance between the copper disc and the plastic disc.

ω/rad s^{-1}	Turning effect/N cm = moment
52.4	1.0
104.7	2.0
157.1	2.8

Explain the trend shown by the data.

(4)

Trend shows that increasing ω increases turning effect proportionally. As ω is increased the rate of change of magnetic flux linkage through copper is greater as ε or emf induced emf is greater as $\varepsilon = -N\frac{d\phi}{dt}$ as t is shortened for each revolution ε increases, there fore the induced current through coil is increased and so the opposing force from the currents magnetic field and the permanent magnetic field increases ∴ the turning effect is greater.

(Total for Question 16 = 11 marks)

ResultsPlus
Examiner Comments

This answer was judged to contain all four marking points for full credit.

Question 17 (a)

The process of writing a nuclear equation is well understood by most candidates. There were very few candidates that didn't use the symbol π. A few candidates couldn't or forgot to mark the charge on the pion as +.

17 A cosmic ray, consisting of a fast-moving proton, collides with a proton within the nucleus of an atom in the upper atmosphere. Three particles, a proton, a neutron and a pion result from the collision.

(a) Write a particle equation for this collision.

(2)

$p + p \rightarrow p + n + \pi^+$

ResultsPlus
Examiner Comments

Correct for full credit.

17 A cosmic ray, consisting of a fast-moving proton, collides with a proton within the nucleus of an atom in the upper atmosphere. Three particles, a proton, a neutron and a pion result from the collision.

(a) Write a particle equation for this collision.

(2)

$p \rightarrow p + n + \pi^-$

ResultsPlus
Examiner Comments

Some candidates only started with one proton. The negative charge is also incorrect even from an error carried forward point of view.

17 A cosmic ray, consisting of a fast-moving proton, collides with a proton within the nucleus of an atom in the upper atmosphere. Three particles, a proton, a neutron and a pion result from the collision.

(a) Write a particle equation for this collision.

(2)

$p^+ + p^+ \rightarrow p^+ + n + \pi^+$

ResultsPlus
Examiner Comments

Some candidates showed all the charges on the particles which is sensible and helps to work out whether the charge balances for the whole equation.

ResultsPlus
Examiner Tip

Indicate all the charges on a nuclear equation. It helps you to check for conservation of charge.

Question 17 (b)

This question examines that baryons are three quarks and mesons are a quark-antiquark pair.

(b) The table shows the properties of two quarks.

Quark	Charge/*e*
u	+2/3
d	−1/3

Give the quark structure for each of the particles produced by this collision.

(3)

A proton has 2 u quarks and 1 d quark

a neutron has 2 d quarks and 1 u quark.

a pion has 3 u quarks.

ResultsPlus
Examiner Comments

The most common mistake was to get the pion (meson) incorrect.

(b) The table shows the properties of two quarks.

Quark	Charge/*e*
u	+2/3
d	−1/3

Give the quark structure for each of the particles produced by this collision.

(3)

u u d = proton

u d d = neutron

u d = measons

The pion (meson) is a quark-antiquark pair.

Check that the charges add up. In this case to +1.

Question 17 (c)

This question examined the conversion between eV and kg. This specification point is now well-understood by the vast majority of candidates.

(c) The mass of a pion is 140 MeV/c^2.

Calculate the mass of the pion in kg.

(3)

$e = mc^2$ $m = \frac{e}{c^2}$ $e = mc^2$

$\frac{140 \times 10^6 \times 1.6 \times 10^{-19}}{} = 2.24 \times 10^{-11}$ kg

Mass = ~~2.2410~~ 2.24×10^{-11} kg

ResultsPlus Examiner Comments

This gains mark point 1 for converting eV to J.

(c) The mass of a pion is 140 MeV/c^2.

Calculate the mass of the pion in kg.

(3)

$\frac{140 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2} =$

Mass = 2.49×10^{-28} kg

ResultsPlus Examiner Comments

Completely correct for full marks.

(c) The mass of a pion is 140 MeV/c^2.

Calculate the mass of the pion in kg.

(3)

$\frac{140 \times 10^6}{(3.00 \times 10^8)^2} = 1.553... \times 10^{-9}$

Mass = 1.55×10^{-9} kg

This gained mark point 2 for attempting to convert J to kg by dividing by c^2.

Question 17 (d)

This question examined the mass-energy conservation principle and the ability to discuss it using quantities measured in eV and eV/c^2. There were two aspects to this question.

Applying mass-energy conservation, the extra mass after the collision is the pion which has a mass of 140 MeV/c^2. This extra mass will require the initial proton to have a kinetic energy of 140 MeV.

However, momentum conservation tells us that as the initial moving proton has momentum so the three particles must have momentum after. As they have momentum, they must also have kinetic energy. If the initial proton had just 140 MeV of energy, then all of it would be required to create the pion and the resulting three particles would have no kinetic energy. These three particles must have some kinetic energy so more than 140 MeV is required.

(d) The mass of a neutron is about the same as the mass of a proton. A student suggests that the minimum kinetic energy the cosmic ray proton would need to create the pion in this collision is 140 MeV.

Discuss whether this suggestion is correct. Your answer should include reference to the laws of conservation of momentum and conservation of energy.

(4)

The students suggestion would satisfy the conservation of energy as all of the kinetic energy of the proton would be transferred to the mass of the pion. However, as a result, this means none of the 3 produ particles produced by the collision can have any kinetic energy (else conservation of energy would be violated). ∴ none of the resulting particles (momentum after = 0) would have a momentum. This, as a result, violates the conservation of momentum because there is a momentum before the collision from the fast moving particle. ∴ it is impossible for momentum before = momentum after. Therefore, the suggestion is incorrect.

(Total for Question 17 = 12 marks)

ResultsPlus
Examiner Comments

This gains mark point 1 and mark point 3.

(d) The mass of a neutron is about the same as the mass of a proton. A student suggests that the minimum kinetic energy the cosmic ray proton would need to create the pion in this collision is 140 MeV.

Discuss whether this suggestion is correct. Your answer should include reference to the laws of conservation of momentum and conservation of energy.

(4)

momentum before = m after ✓ energy before = e after

m_1u_1 ✓ = $m_1v_1 + m_1v_2 + m_2v_3$ ✓ conservation of momentum

The suggestion is incorrect as the minimum kinetic energy of the proton before has to be greater than 140 MeV in order to allow for the 3 particles to travel with a velocity. With 140 MeV, the particle will collide with no energy left over for KE, then (meaning Energy is conserved) by now momentum is not conserved. Hence it has to be greater than 140 MeV.

ResultsPlus
Examiner Comments

This gains mark point 3 and 4.

ResultsPlus
Examiner Tip

The question said using conservation of momentum (which is clearly discussed in this answer) and energy.

It would be worth making two subtitles: momentum and energy to ensure both are fully discussed.

(d) The mass of a neutron is about the same as the mass of a proton. A student suggests that the minimum kinetic energy the cosmic ray proton would need to create the pion in this collision is 140 MeV.

Discuss whether this suggestion is correct. Your answer should include reference to the laws of conservation of momentum and conservation of energy.

(4)

$E = mc^2$, $p = mv$

the statement is correct as the mass of a pion is 140 MeV, therefore 140 MeV/c^2 needed

ResultsPlus
Examiner Comments

This muddle discussing energy in MeV/c^2 and mass in MeV was common.

(d) The mass of a neutron is about the same as the mass of a proton. A student suggests that the minimum kinetic energy the cosmic ray proton would need to create the pion in this collision is 140 MeV.

Discuss whether this suggestion is correct. Your answer should include reference to the laws of conservation of momentum and conservation of energy.

(4)

- In particle collisions, mass-energy is always conserved, therefore if the cosmic ray proton had 140MeV of kinetic energy, there would be enough energy for the creation of a pion.
- But, if all energy ~~is used in~~ converted into the mass of a pion, then there is no additional energy for kinetic energy, or movement of the product particles.
- If all the product particles have 0 kinetic energy, then momentum will not be conserved.
- Therefore more than 140 MeV would be needed.

ResultsPlus
Examiner Comments

This answer gains marking points 1, 3 and 4.

(d) The mass of a neutron is about the same as the mass of a proton. A student suggests that the minimum kinetic energy the cosmic ray proton would need to create the pion in this collision is 140 MeV.

Discuss whether this suggestion is correct. Your answer should include reference to the laws of conservation of momentum and conservation of energy.

(4)

→ ~~The momentum before the collision is greater than 0 Ns because one of the fast moving proton.~~

→ The suggestion is incorrect.

→ ~~The energy (rest mass) of~~ while the proton produced has its rest mass energy

→ The rest mass energy of the two initial protons will match the rest mass energy of the proton and neutron produced. But, to conserve energy, ~~the (rest~~ some of the KE in the ~~initial~~ initial collision (the KE of the fast moving proton) must be used to ~~create~~ produce the mass of the π^+ (through $\Delta E = \Delta mc^2$)

(Total for Question 17 = 12 marks)

→ However, due to the law of ~~energy~~ conservation of momentum (momentum (vector sum) before = momentum (vector sum) after) is a constant vector in a closed system where no external forces act), the products must be moving / have a momentum > 0 Ns as the ~~pion~~ initial momentum was > 0 Ns).

→ Therefore, the products must have some KE

→ As energy (rest mass + KE) is conserved, the minimum amount of KE needed by the fast moving proton would have to be greater than the rest mass of the ~~π~~ pion to account for the KE)

Energy before = energy after

Energy before = energy

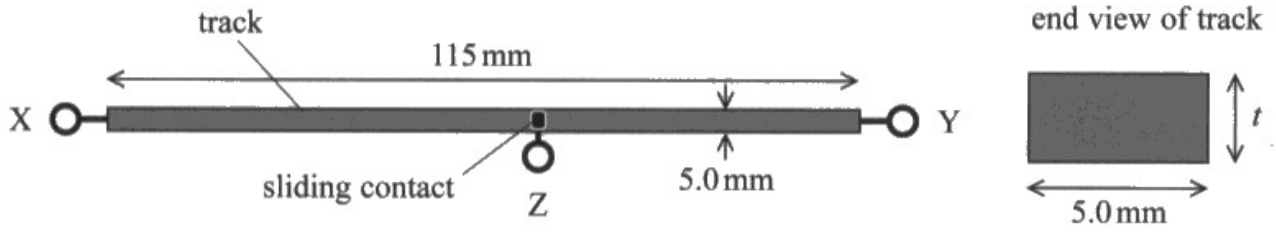
ResultsPlus
Examiner Comments

This answer gains full credit.

Question 18 (a)

This question examined the use of the resistivity equation for a conductor with rectangular cross-sectional area.

18 A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.



The length of the track is 115 mm and the width is 5.0 mm.

(a) The resistance of the track between terminal X and terminal Y is 12.0 kΩ.

Calculate the thickness t of the track.

resistivity of track material = 0.49 Ω m

(3)

$\rho = \frac{RA}{L}$

$A = \frac{\rho L}{R}$ $\quad \frac{0.49 \times (115 \times 10^{-3})}{12000} = 4.6958 \times 10^{-6}\ m^2$

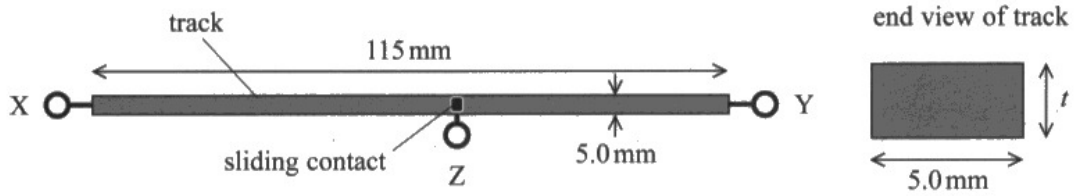
$A = \frac{\pi d^2}{4}$ $\quad \sqrt{\frac{4.6958 \times 4}{\pi}} = d$ $\quad d = 2.445 \times 10^{-3}\ m$

$t = 2.45 \times 10^{-3}\ m$

ResultsPlus
Examiner Comments

This answer assumes the cross-sectional area is a circle but still gets mark point 2.

18 A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.



The length of the track is 115 mm and the width is 5.0 mm.

(a) The resistance of the track between terminal X and terminal Y is 12.0 kΩ.

Calculate the thickness t of the track.

resistivity of track material = 0.49 Ωm

(3)

115×10^{-3} m $\quad 5 \times 10^{-3}$ $\quad 12 \times 10^{3}\,\Omega$ $\quad \rho = 0.49$

$5 \times 10^{-3} t = \dfrac{0.49 \times (115 \times 10^{-3})}{12{,}000}$ $\quad t = \dfrac{0.49 (115 \times 10^{-3})}{12{,}000} \div 5 \times 10^{-3}$

$t = 9.39 \times 10^{-9}$

$t = 9.4 \times 10^{-9}$

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

$12{,}000 = \dfrac{0.49 \times (115 \times 10^{-3})}{(5 \times 10^{-3} \times t)}$

$R \propto L$

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

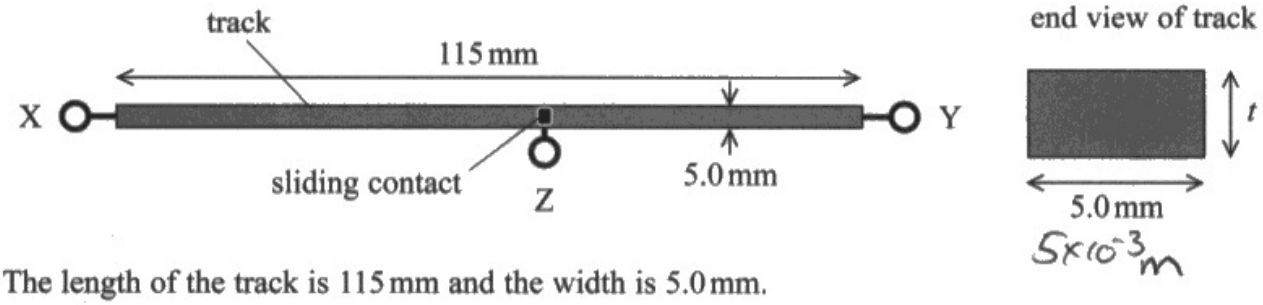
ResultsPlus
Examiner Comments

This answer omits the units so loses the final mark point.

ResultsPlus
Examiner Tip

Don't forget numerical answers will have units.

18 A potential divider circuit may contain a component known as a potentiometer. One type of potentiometer consists of a track with terminals X and Y at either end. There is a sliding contact that can move along the track connected to a terminal Z as shown.



5×10^{-3} m

The length of the track is 115 mm and the width is 5.0 mm.

(a) The resistance of the track between terminal X and terminal Y is 12.0 kΩ.

Calculate the thickness t of the track.

resistivity of track material = 0.49 Ω m

(3)

$12000 = \frac{0.49 \times 0.115}{A}$

$A = \frac{0.49 \times 0.115}{12000}$

$= 4.69583 \times 10^{-6}\ m^2$

$4.69... \times 10^{-6} = 5 \times 10^{-3}\ t$ $\quad t = 9.391... \times 10^{-4}\ m \approx 0.94\ mm\ (2sf)$

$t =$ 0.94 mm (2sf)

ResultsPlus
Examiner Comments

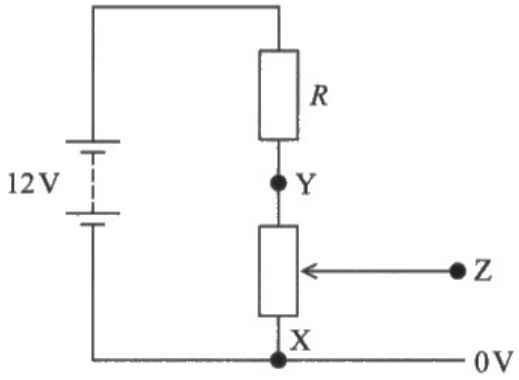
A fully correct answer.

Question 18 (b)(i)-(ii)

Q18(b)(i) examines the idea that the p.d. along a length of conductor is proportional to the length along it.

Q18(b)(ii) examines the analysis of a series circuit.

(b) The potentiometer is used to monitor the displacement of a moving tool on a machine in a production line. The tool is attached to the sliding contact. The potentiometer is connected to a resistor of resistance R and a potential difference is applied as shown. The tool moves through a maximum displacement of 60 mm from end X, producing a maximum potential difference of 5.0 V between Z and X.



(i) Show that the potential difference between X and Y is about 10 V.

(2)

0 → 0 ; 60 → 5 ; 115 → x

$5/60 = 1/12$

$x = 1/12 \times 115 = 9.58\ V$ ($\approx 10V$)

(ii) Calculate the value of R.

(3)

$V = IR$, $I = V/R = 9.58/12000 = 7.99 \times 10^{-4}\ A$

$12 - 9.58 = 2.42\ V$

$V = IR$

$R = V/I = 2.42/7.99 \times 10^{-4} = 3030.26...$

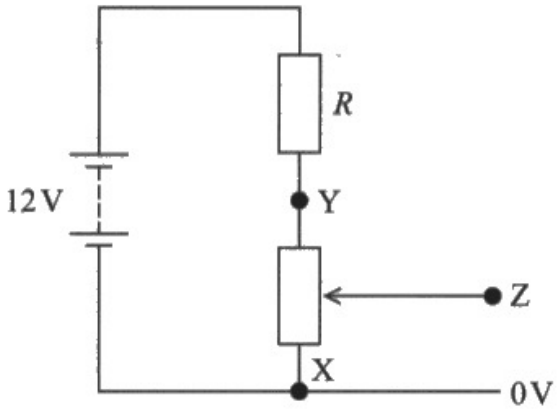
$= 3030\ \Omega$

$R =$ 3030 Ω

ResultsPlus
Examiner Comments

This answer gains full credit for Q18(b)(i) and Q18(b)(ii). The method employed in Q18(b)(ii) is to determine the current and apply $V=I\,R$ to calculate the resistance.

(b) The potentiometer is used to monitor the displacement of a moving tool on a machine in a production line. The tool is attached to the sliding contact. The potentiometer is connected to a resistor of resistance R and a potential difference is applied as shown. The tool moves through a maximum displacement of 60 mm from end X, producing a maximum potential difference of 5.0 V between Z and X.



(i) Show that the potential difference between X and Y is about 10 V.

(2)

Approx
60% Halfway, so pd between Z and X is $\frac{5}{2} = 2.5\,V$

$12 - 2.5 = 9.5 \approx 10\,V$

(ii) Calculate the value of R.

(3)

$V = IR$

$12 = 5 = 7$

$12 =$

$R =$ 28.8 Ω

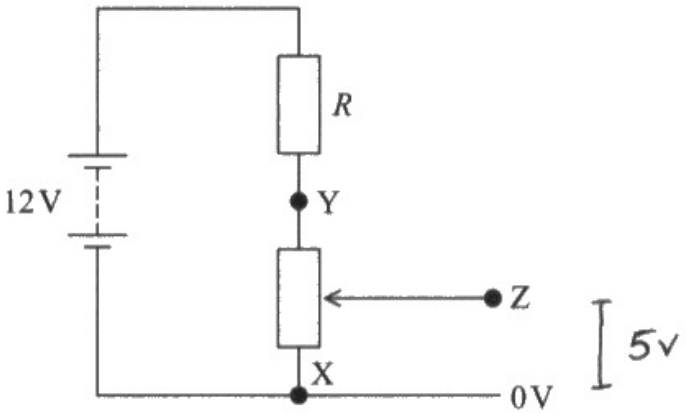
ResultsPlus
Examiner Comments

Q18(b)(i) This answer was seen a number of times with slight variations. The candidate has approximated the position of the divider as half way rather than using the lengths given in the question. This normally leads to an answer of 10 V. This answer further confuses the points and the potential differences.

ResultsPlus
Examiner Tip

In a "show that" question your answer will round off to the value given in the question. If your answer is equal to the "show that" value, then something is wrong.

(b) The potentiometer is used to monitor the displacement of a moving tool on a machine in a production line. The tool is attached to the sliding contact. The potentiometer is connected to a resistor of resistance R and a potential difference is applied as shown. The tool moves through a maximum displacement of 60 mm from end X, producing a maximum potential difference of 5.0 V between Z and X.



(i) Show that the potential difference between X and Y is about 10 V.

(2)

$V_{IN} = V_{OUT} \times \left(\frac{R_2}{R_1 + R_2}\right)$

$5 = V_{OUT} \times \left(\frac{6260.9}{12000}\right)$

$V_{OUT} = 9.58\,V$

$\therefore$ V between X and Y = 9.6V

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

$= \frac{0.49 \times \frac{60}{1000}}{4.6958 \times 10^{-6}}$

$= 6260.9$

(ii) Calculate the value of R.

(3)

$V_{IN} = V_{OUT} \times \left(\frac{R_2}{R_1 + R_2}\right)$

$12 = (12 - 9.6) \times \left(\frac{R_2}{6260.9 + R_2}\right)$

$\frac{R_2}{6260.9 + R_2} = 5$

$R_2 = 31304.5 + 5R$

$|R_2| = 7826\,\Omega$

$R_2 = 7800\,\Omega$

$R =$ 7800 Ω ~~7826 Ω~~

ResultsPlus
Examiner Comments

Q18(b)(i) is an unusual approach but is correct.

In Q18(b)(ii) the potential difference (12 – 9.6) across *R* is found for mark point 1. There are then two mistakes with the ratio of p.d.s to the ratio of resistances.

Mistake 1. The ratio is inverted incorrectly: the (12 – 9.6) should correspond to $R_{(2)}$ rather than $R_1 + R_2$.

Mistake 2. The 12 V must correspond to the total series resistance which is 12000 Ω + *R*.

ResultsPlus
Examiner Tip

Be clear to use the potential difference and corresponding resistance.

Question 18 (b)(iii)

This question examines the concept of internal resistance of a battery and the use of associated terms such as terminal potential difference.

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

(3)

Because there is an internal resistance and this causes there to be lost volts and as a result of this the max. out is slightly less than 5.0V.

ResultsPlus
Examiner Comments

This answer gains mark point 1 and mark point 2.

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

(3)

- because of the internal resistance ~~exists~~ in the battery
- $\mathcal{E} = V + Ir$
- the internal resistance creates a voltage seperate from the potentiometer meaning it's less than 5V.

ResultsPlus
Examiner Comments

This gains mark point 1. Had the equation been rearranged so it was clear that *V* (the terminal potential difference) was being referred to, it would have been awarded mark point 3.

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

(3)

The battery will have internal resistance so there are 'lost volts' used from the e.m.f overcoming this internal resistance. This means the terminal potential difference available to the circuit also decreases ∴ Maximum output from the potentiometer is lower. The connecting wires will also have resistance.

ResultsPlus
Examiner Comments

All points made so full credit awarded.

(iii) When the circuit is assembled, using the correctly calculated resistance value and a battery of e.m.f. 12 V, it is found that the maximum output from the potentiometer is slightly less than 5.0 V.

Explain why the maximum output is slightly less than predicted.

(3)

the internal resistance of the battery causes heat and a reduced output voltage so you are calculating with a too large value

ResultsPlus
Examiner Comments

This gains mark point 1. The "output voltage" is not enough for mark point 3.

ResultsPlus
Examiner Tip

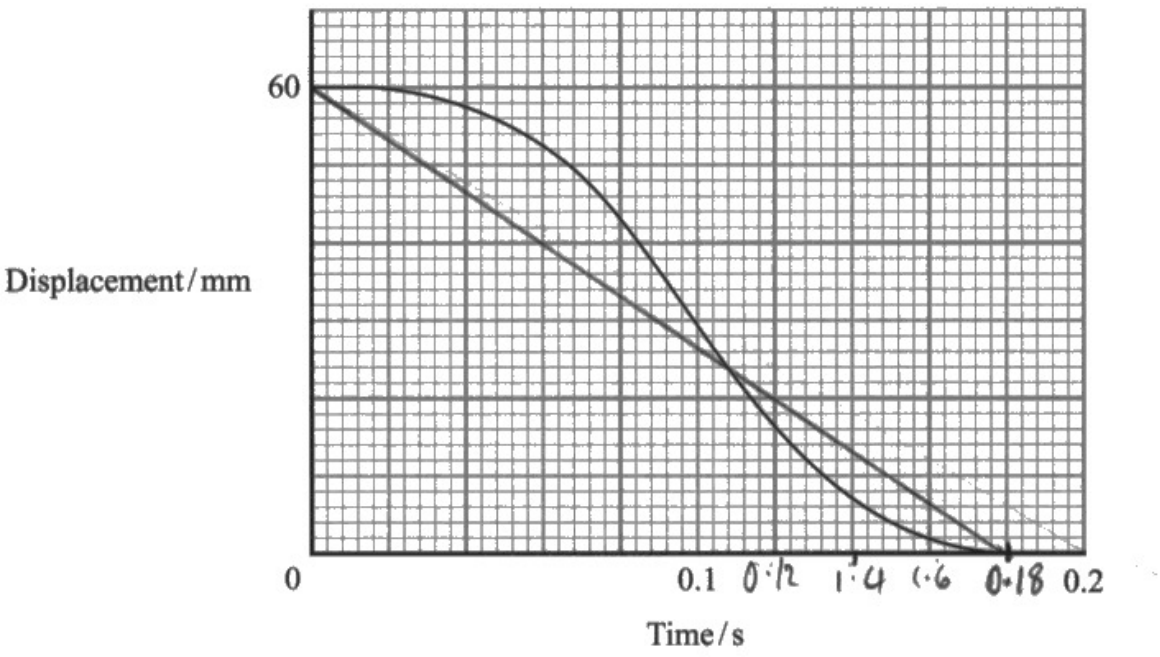
Use technical terminology, in this case "terminal potential difference", as it is defined in the specification.

Question 18 (b)(iv)

This question examined features of a distance-time graph. The gradient of this graph gave the velocity at that particular moment.

(iv) The tool on the machine should not travel with a speed any larger than $0.8\,m\,s^{-1}$.

The graph shows how the displacement varies with time for the downward stroke of the moving tool.



Deduce whether this speed is exceeded by the moving tool.

(4)

d/t $d = 60mm$

$d = 60 \times 10^{-3}$

$t = 0.165$

$\frac{60 \times 10^{-3}}{0.18} = 0.333$

$0.33 < 0.8$

therefore the speed wasn't exceeded by moving tool

(Total for Question 18 = 15 marks)

ResultsPlus
Examiner Comments

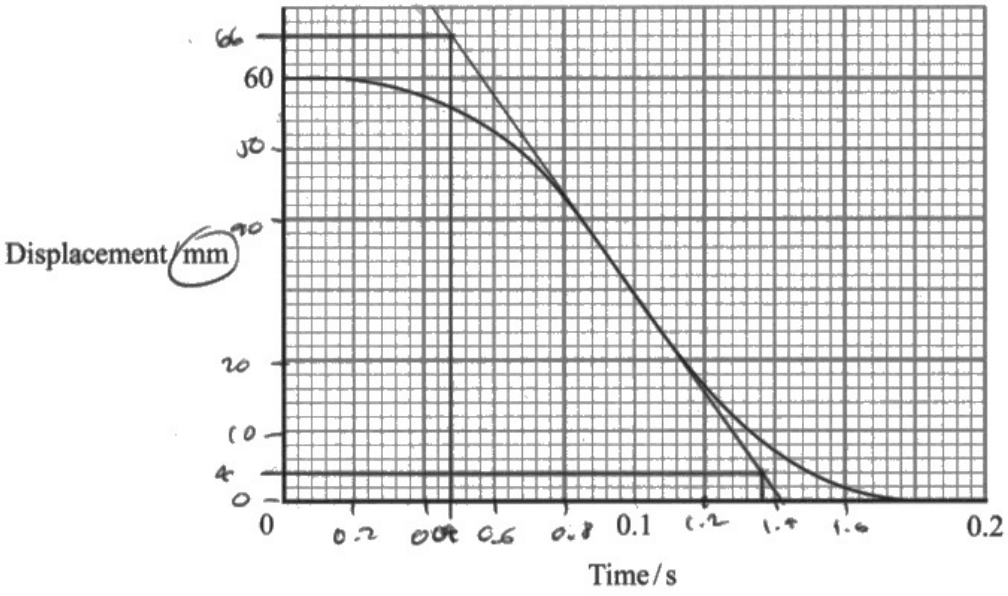
This is an attempt to find an average gradient (velocity) for the whole time period. It was given mark point 3.

ResultsPlus
Examiner Tip

Remember the gradient of the tangent on a distance-time graph gives velocity.

(iv) The tool on the machine should not travel with a speed any larger than $0.8\,m\,s^{-1}$.

The graph shows how the displacement varies with time for the downward stroke of the moving tool.



Deduce whether this speed is exceeded by the moving tool.

(4)

velocity = gradient of st graph

gradient = $\frac{\Delta y}{\Delta x}$ = $\frac{(66-4)\times10^{-3}}{0.048-0.136}$

= $-0.704\,54$

So max speed = $0.705\,ms^{-1}$ (3sf)

so the speed of moving tool does not exceed $0.8\,ms^{-1}$ as $0.705 < 0.8$

ResultsPlus
Examiner Comments

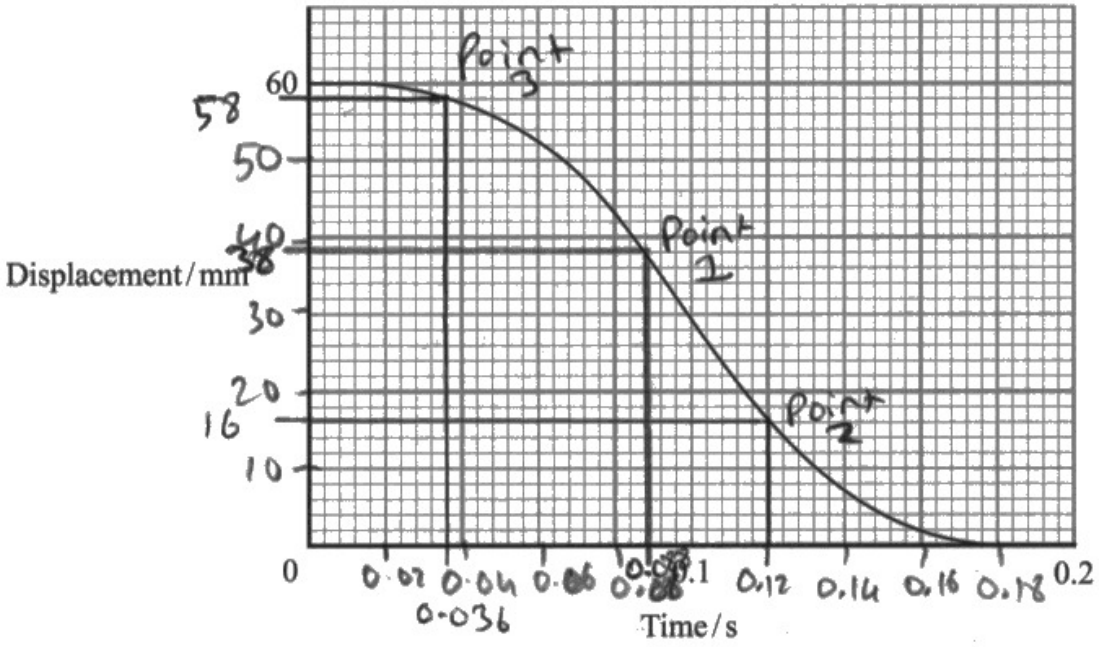
This answer gains full credit.

ResultsPlus
Examiner Tip

Note that in a deduce question you should compare your answer with the one given in the question.

(iv) The tool on the machine should not travel with a speed any larger than $0.8\,m\,s^{-1}$.

The graph shows how the displacement varies with time for the downward stroke of the moving tool.



Deduce whether this speed is exceeded by the moving tool.

(4)

Speed = $\frac{\text{displacement}}{\text{time}}$ 38mm = 0.038 m

Point 1 => speed = $\frac{0.038}{0.088}$ = 0.4318... ms^{-1}

Point 2 => speed = $\frac{0.016}{0.12}$ = 0.1333... ms^{-1}

Point 3 => speed = $\frac{0.058}{0.036}$ = 1.611 ms^{-1}

∴ At no point the speed 0.8 ms^{-1} is exceeded by the moving tool.

(Total for Question 18 = 15 marks)

TOTAL FOR PAPER = 90 MARKS

Point 1 to point 2 => $\frac{0.038 - 0.016}{0.12 - 0.088}$ = 0.6875 ms^{-1}

Point 3 to point 1 => $\frac{0.058 - 0.038}{0.088 - 0.036}$ = 0.385 ms^{-1}

Point 3 to point 2 => $\frac{0.058 - 0.016}{0.12 - 0.036}$ = 0.5 ms^{-1}

∴ The speed isn't exceeded by the moving tool

ResultsPlus
Examiner Comments

This answer attempts to calculate various gradients (mark point 3) without using a tangent. Because there is a choice of answers for the maximum velocity, mark point 4 cannot be awarded.

Paper Summary

Based on their performance on this paper, candidates should:

- improve on their graphical skills, such as how to use a tangent to find a gradient at a particular time.
- remember that energy can often be used as an alternative approach to solving mechanics questions.
- improve their understanding of Lenz's law. It appeared to have been rote learnt but not necessarily understood.
- not round off answers unnecessarily to one significant figure.
- distinguish and be able to discuss energy measured in eV and mass measured in eV/c^2.

Grade boundaries

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