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Examiners' Report
June 2023

GCE Physics 9PH0 01

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June 2023

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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 employed including multiple choice, questions requiring a short explanation, calculations and 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 questions were set in a context eg question 11 was about an induction hob.

Almost all candidates demonstrated some sound algebraic skills. Most candidates could substitute the relevant numerical values into an equation and rearrange it successfully. Many of the calculations on this paper required at least two stages and many candidates responded to these well. There was good evidence for this in questions 13(a), 14(a)(i) and 16(b).

Question 17(a) was a demanding projectile question and many candidates showed an excellent understanding of this topic with the use of three separate equations to construct a well-sequenced answer and conclusion.

In previous years there has been inconsistent approaches to significant figures. This was much improved this year and most candidates retained the number of significant figures given in the question.

The indicative content question was about a d.c. motor. This was well-answered by many candidates and it demonstrated good written communication skills.

Question 17(b)(ii) exposed an area of the specification which was generally less understood. The question required the completion of a vector diagram. Similar questions have been set before but could be answered using a mathematical approach or a vector diagram. This question specified a vector diagram. Although a small minority of candidates were able to complete the diagram satisfactorily, many had little idea of how to begin. The most common answer was to draw a single line to represent two separate vectors. The front of the paper had specified a protractor. Candidates were required to use the protractor in this question and the evidence suggested most had a protractor.

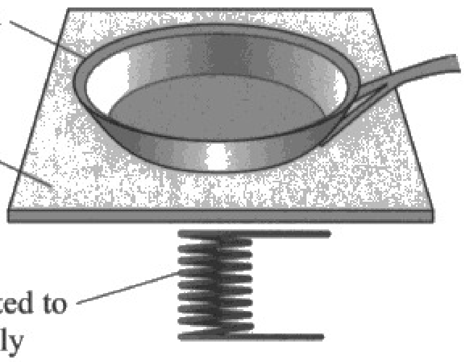
Question 18 included a spreadsheet model. The question didn't require specific spreadsheet skills. Scenarios in physics which involve a change in a quantity with time can be modelled using a spreadsheet. This can be a useful additional way to look at a topic.

Question 11 (a)

This question was about the application of Faraday's law. The use of the word "induction" in the stem of the question was a strong hint. Although the majority of candidates recognised that the question was about Faraday's law, a significant number missed the point and talked about heating in general terms or in relation to electrical heating.

Those candidates that did attempt to apply Faraday's law didn't always apply it to the context described in the question. Several answers described the changing magnetic field produced by the coil but didn't go on to discuss the effect of this field on the steel pan.

11 An induction hob consists of a coil beneath a sheet of ceramic material. The coil is connected to an alternating current (a.c.) supply as shown.



(a) A steel pan containing water is placed on the induction hob.

Explain why the pan becomes hot when the supply is switched on.

(4)

when the ac supply is switched on the free ions and electrons move through the coil as they collide with the lattice ions they transfer some energy as heat to the surroundings. This heat then reaches the ceramic material which will take in that heat and transfer it to its surroundings. As the pan is on the ceramic the steel pan will heat up. As the steel conducts heat. Electrons in steel increase vibrations.

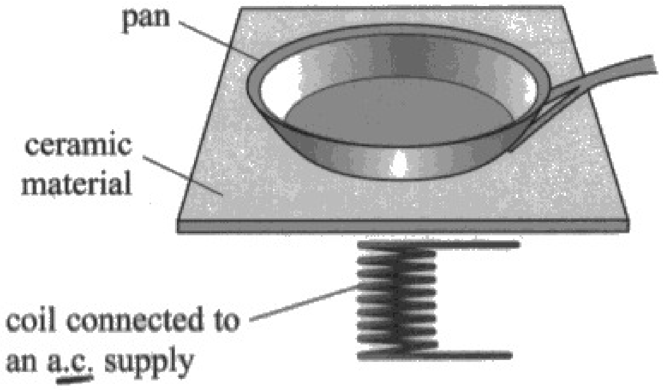
ResultsPlus Examiner Comments

This answer is an example of not recognising the application of Faraday's law.

ResultsPlus Examiner Tip

The word "induction" was provided as a strong hint.

11 An induction hob consists of a coil beneath a sheet of ceramic material. The coil is connected to an alternating current (a.c.) supply as shown.



(a) A steel pan containing water is placed on the induction hob.

Explain why the pan becomes hot when the supply is switched on.

(4)

- Current passes through coil
- EMF induced
- Electric field occurs
- work gets done on Pam causing it to heat up

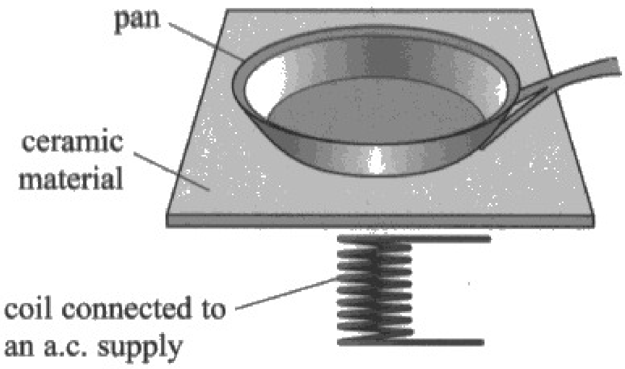
ResultsPlus
Examiner Comments

This answer recognised the hint in the question and wrote down "emf induced". It does not point out that the relevant induced emf will be in the steel pan. It then describes an electric field rather than a magnetic field.

ResultsPlus
Examiner Tip

Induction is a term used in relation to changing magnetic fields.

11 An induction hob consists of a coil beneath a sheet of ceramic material. The coil is connected to an alternating current (a.c.) supply as shown.



(a) A steel pan containing water is placed on the induction hob.

Explain why the pan becomes hot when the supply is switched on.

(4)

- As current passes through coil it generates a magnetic field. As it is alternating current, coil generates a changing magnetic field. Thus pan cuts through lines of flux or changing flux linkage. Which induces an emf and thus current on the pan. As there is emf/ current, ~~energy~~ it heats up pan due to pans resistance, thus making the pan hot.

ResultsPlus
Examiner Comments

This is a good answer. It describes the changing magnetic field "cutting" the steel pan and understands the idea of "linkage". It recognises that the induced emf will be in the steel pan and consequently a current for full credit.

Question 11 (b)

This part of the question was connected to Q11(a). A higher frequency will lead to a higher rate of change of magnetic field. This will lead to a larger value of induced emf and current in the pan.

(b) The a.c. supply to the coil in an induction hob has a much higher frequency than normal mains frequency.

Explain why this is an advantage in this case.

(2)

The induction hob will heat up faster, and will cool down faster, which reduces the chance of an injury, and will use less energy overall (more efficient).

ResultsPlus Examiner Comments

A number of answers associated the higher frequency with a faster rate of thermal energy transfer.

(b) The a.c. supply to the coil in an induction hob has a much higher frequency than normal mains frequency.

Explain why this is an advantage in this case.

(2)

There will be a more frequent transfer of energy, therefore the the pan will heat up quicker

ResultsPlus Examiner Comments

A number of answers referred to an increase in the rate of thermal energy transfer.

(b) The a.c. supply to the coil in an induction hob has a much higher frequency than normal mains frequency.

Explain why this is an advantage in this case.

(2)

The rate of changing magnetic flux is higher so ~~the force is higher~~ emf ~~is~~ is higher so the energy provided is high so a higher ~~the~~ temperature can be produced.

(Total for Question 11 = 6 marks)

ResultsPlus
Examiner Comments

This answer gets full credit. It refers to a higher rate of change of magnetic flux (or field) leading to an increase in induced emf.

Note that a complete explanation included an increase in current. Either reference to current or emf was acceptable for the second mark point.

Question 12 (a)

The first part of this question examined what is meant by a vector quantity. This was well-answered by almost all candidates.

12 An electrical conductor XY carries a current I as shown.

The current density j is defined as $j = \frac{I}{A}$ where A is the cross-sectional area of the conductor.

(a) Current density is a vector quantity.

State what is meant by a vector quantity.

(1)

A quantity having both a magnitude and a direction.

ResultsPlus
Examiner Comments

The most typical correct answer.

Question 12 (b)

Most candidates knew the appropriate equation to quote and often defined the symbols.

(b) I is constant but A decreases towards end Y.

Explain how this affects the drift velocity of the free electrons in the conductor.

(2)

- ~~electrons~~ there will be the same number of charge carriers in a smaller area
- the charge carrier density will increase and so will the frequency of collisions of free electrons
- therefore the drift velocity will decrease

ResultsPlus
Examiner Comments

Many answers incorrectly discussed collisions or thought the charge carrier density would change.

ResultsPlus
Examiner Tip

When questions ask how a quantity would change it is often a good idea to start by quoting the relevant equation.

(b) I is constant but A decreases towards end Y.

Explain how this affects the drift velocity of the free electrons in the conductor.

(2)

$I = nAvq$ if I is constant and so is the number of charge carriers and the charge itself if A decreases then the drift velocity of the electrons must increase to keep I constant

ResultsPlus Examiner Comments

A good answer for full credit.

Question 12 (c)

This part of the question was about showing that the units on one side of the equation should be the same as the other side. There were several ways to do this. The most straightforward way was to substitute the units V m^{-1} for the electric field strength.

If candidates substituted the units N C^{-1} for field strength this leads to a more protracted answer as shown by one of the examples below.

Many candidates did well with this question and those that took the longer route often did so successfully.

(c) The resistivity ρ of the conducting material is given by $\rho = \dfrac{E}{j}$

where E is the electric field strength.

Show that the units are the same on both sides of this equation.

(4)

$R = \dfrac{\rho l}{A}$ $\qquad \rho = \dfrac{RA}{l}$

$\rho = Rl$ $\qquad\qquad$ ~~$E = VA$~~ $\quad E = \dfrac{V}{d}$

$\rho = \Omega m$ $\qquad\qquad E = Vm^{-1}$

$\dfrac{Vm^{-1}}{I\,m^{-2}} = \Omega m$

$\Omega m = \Omega m$

ResultsPlus
Examiner Comments

This example illustrates the most straightforward method.

ResultsPlus
Examiner Tip

A good way to approach "units" questions is to write down an equation for the quantity being discussed. Then substitute the units as this answer demonstrates.

(c) The resistivity ρ of the conducting material is given by $\rho = \frac{E}{j}$

where E is the electric field strength.

Show that the units are the same on both sides of this equation.

(4)

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

$\rho = \frac{RA}{l} = \frac{VA}{Il}$ $\quad E = \frac{V}{d}$ $\quad j = \frac{I}{A}$

$\therefore \frac{VA}{Il} = \frac{VA}{Id} \Rightarrow \frac{RA}{l} = \frac{RA}{d}$

l and d have the same units ∴ the units are the same on each side.

∴ units are Ωm.

ResultsPlus
Examiner Comments

This answer illustrates how candidates could use a mix of equations and then units.

(c) The resistivity ρ of the conducting material is given by $\rho = \frac{E}{j}$ $= kgms^{-2}$

where E is the electric field strength.

Show that the units are the same on both sides of this equation.

(4)

ρ $R = \frac{\rho l}{A}$ ~~$E = kgm^2s^{-2}$~~ $j = \frac{I}{A} = \frac{A}{m^2} = Am^{-2}$

$\therefore \frac{RA}{l} = \rho$ $E = \frac{F}{Q}$

$\therefore \rho = \frac{kgm^2A^{-2}s^{-3} \times m^2}{m}$ $\therefore \frac{E}{j} = \frac{kgm^2s^{-2}}{Am^{-2}}$ $\therefore E = \frac{kgms^{-2}}{As}$

$\therefore \rho = kgm^3A^{-2}s^{-3}$ $\therefore = kgm^4A^{-1}s^{-2}$ $= kgms^{-2}A^{-1}$

$\frac{E}{j} = \frac{kgms^{-2}A^{-1}}{Am^{-2}}$ $= kgms^{-3}A^{-1}$

$\therefore \rho = kgm^3A^{-2}s^{-3}$ and $\frac{E}{j} = kgm^3A^{-2}s^{-3}$ $\frac{E}{j} = \frac{kgms^{-3}A^{-1}}{Am^{-2}}$

$\therefore = kgm^3s^{-3}A^{-2}$

$\therefore \rho = \frac{E}{j}$ $= kgm^3A^{-2}s^{-3}$

ResultsPlus
Examiner Comments

This answer successfully reduces the quantities to base units.

(c) The resistivity ρ of the conducting material is given by $\rho = \frac{E}{j}$

where E is the electric field strength.

Show that the units are the same on both sides of this equation.

(4)

$R = \frac{\rho l}{A} \Rightarrow \frac{RA}{l} = \rho$

• so units of resistivity (ρ) $= \Omega m^2 m^{-1} = \Omega m$ (ohmic meters)

but $\Omega = \frac{Jt}{A}$ → $\frac{Jtm}{A}$ = units

• $j = \frac{I}{A}$ so unit of j = Am^{-2}

• unit of E: $E = \frac{\quad}{At}$

units of

ResultsPlus Examiner Comments

This type of answer was quite common. It correctly finds the units of *J* and resistivity. It doesn't state the units of *E* so goes no further.

Question 13 (a)

This question examined reading a value from a log graph, using Ohm's law and understanding potential divider circuits when one resistor is variable.

Many candidates were able to do the calculation to show that p.d. across the fixed resistor is 0.7 V at the required light intensity.

Only a small minority of candidates continued and considered whether an increase in light intensity would keep the transistor on.

Some answers did not use the appropriate p.d. across a resistor or combination of resistors.

(a) Deduce whether this circuit responds as required.

(6)

The initial voltage is 7v   Resistance when the LDR is at 3C lux = 5CC

The Resistor is 333 Ω

V = I × R

$I = \frac{V}{R}$ $\frac{7}{333}$ = 0.021C

Series: I = I = I = ; V + V + V ; Rt = R = R + R

Parallel: V = V V ; 1/Rt = 1/R + 1/R

transistor = 333Ω

ResultsPlus Examiner Comments

This response suggests there is 7 V across the fixed resistor.

ResultsPlus Examiner Tip

Ohm's law will calculate the current if the p.d. across a resistor is known.

(a) Deduce whether this circuit responds as required.

(6)

When LDR reaches above 30 lux, resistence is 3000 Ω

Total resistence of circuit = 333 + 3000 = 3333 Ω

Current in the circuit: $\frac{7}{333}$ = 0·021

Voltage across resister = $7 \times \frac{333}{3333}$ = 0·699 V ≈ 0·7V

Yes, this circuit responds as required.

ResultsPlus Examiner Comments

This answer shows a typical correct calculation but does not check whether the transistor stays on if the light level increases.

(a) Deduce whether this circuit responds as required.

(6)

at light level = 30 lux, resistance = 3000 Ω

R_{LDR} : R_T

3000 : 333

p.d. across transistor = $7 \times \frac{333}{333+3000}$ = 0.69936... V

at 30 lux the potential difference across the ~~ut~~ input is 0.699V (3sf)

as the light level increases above 30 lux, the resistance of the LDR decreases ∴ the p.d. across the input increases as the ratio of its resistance increases, leading to the input p.d. of the transistor to be above 0.7V ∴ the circuit responds as required

ResultsPlus
Examiner Comments

This answer is complete. A correct calculation and a reasoned discussion about whether the transistor would stay on at higher light intensities.

Question 13 (b)

This question was well answered by most candidates. Answers either referred to free electrons or charge carriers. Either was acceptable but some candidates did not emphasise that there would be "more" free electrons.

(b) Explain how the resistance of the LDR changes as the light level increases. as required

(2)

As the light levels increase the electrons in the Ldr's lattice are exited and released and can now act as free electrons and carry a current

so light levels increase → more free electrons → lower resistance

ResultsPlus
Examiner Comments

This answer gets to the point after a while "so light levels increase so more free electrons".

(b) Explain how the resistance of the LDR changes as the light level increases.

(2)

The resistance decreases as more electrons become free charge carriers, allowing for easier charge transfer

ResultsPlus
Examiner Comments

The marks were given for mixing the terms free electrons and charge carriers.

ResultsPlus
Examiner Tip

Try to avoid "free charge carrier". A charge carrier is a free electron.

(b) Explain how the resistance of the LDR changes as the light level increases.

(2)

Resistance decreases as light level increases, they are inversely proportional.

ResultsPlus
Examiner Comments

The second mark point is dependent on the first. This answer therefore doesn't get one mark.

(b) Explain how the resistance of the LDR changes as the light level increases.

(2)

As photons of light are incident on the LDR free electrons on the surface of a metal surface are released, meaning more charge carriers are released increasing current, decreasing resistance

(Total for Question 13 = 8 marks)

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Examiner Comments

A small number of answers confused this with the photoelectric effect.

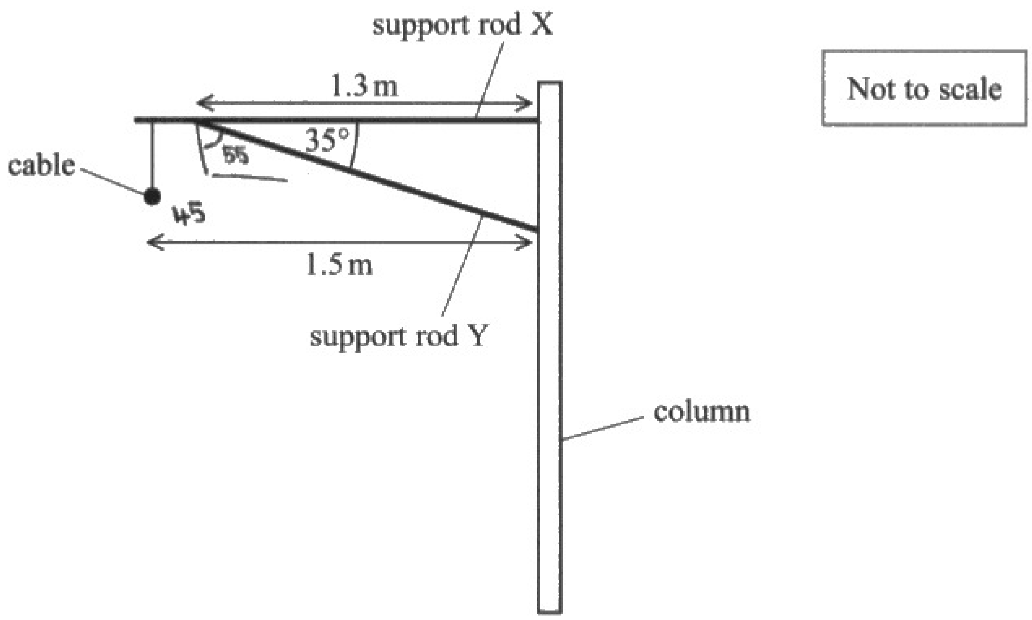
Question 14 (a)(i)

This questions involved taking moments about a point. It had the added challenge of a force (exerted by rod Y) which was not perpendicular to a marked distance on the diagram.

Almost all candidates gained some credit by attempting to take moments about the end of the rod.

14 Overhead electricity cables for railway lines are supported by structures like the one shown.

An electric cable of mass 45 kg is suspended from a support rod X. A second support rod Y is attached to X. X and Y are attached at one end to a column.



The masses of support rods X and Y are negligible.

(a) (i) Determine, by taking moments, the force exerted on rod X by rod Y.

(4)

45 x 9.81 = 441.45 N

1.5 x 441.45 = 662.175

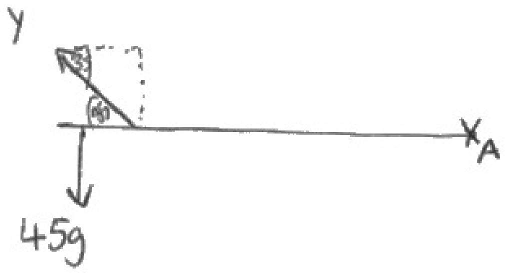
662.175 = 1.3 x unknown force

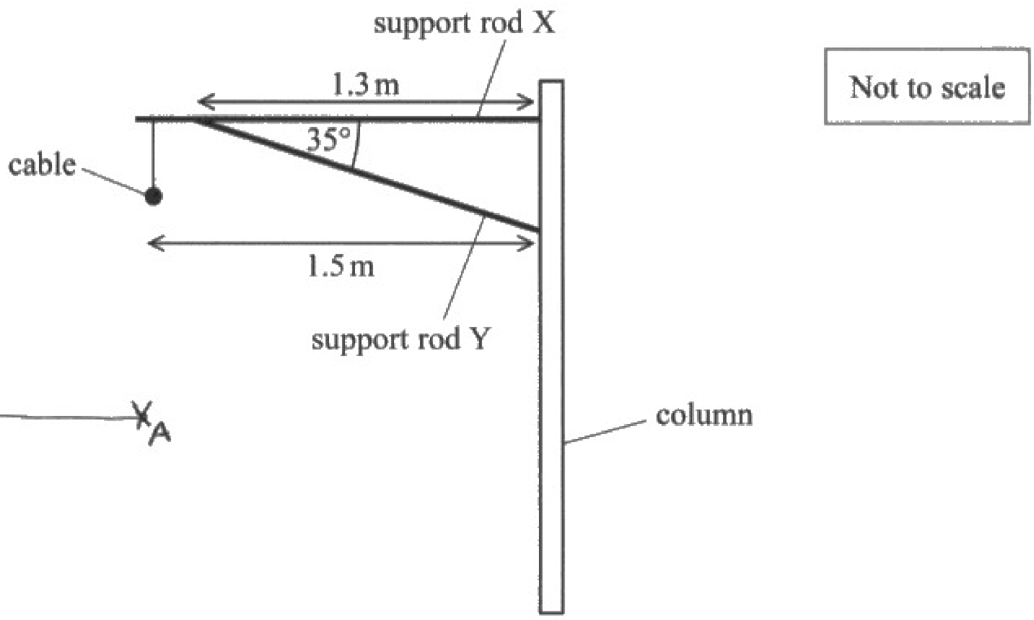
ResultsPlus Examiner Comments

This answer gains the first two marks. It determines a moment of weight around the end of the rod.

14 Overhead electricity cables for railway lines are supported by structures like the one shown.

An electric cable of mass 45 kg is suspended from a support rod X. A second support rod Y is attached to X. X and Y are attached at one end to a column.





The masses of support rods X and Y are negligible.

(a) (i) Determine, by taking moments, the force exerted on rod X by rod Y.

(4)

let Point A be the point of contact between rod X and column.

taking moments about A, clockwise = anticlockwise

$(Y \sin 35 \times 1.3) = (45g \times 1.5)$

$Y \sin 35 = \frac{662.175}{1.3}$

$Y = \frac{662.175}{1.3 \sin 35}$

$= 888.05144... \text{ N}$

Force = 890 N (2sf)

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Examiner Comments

This answer shows a fully correct approach for 4 marks.

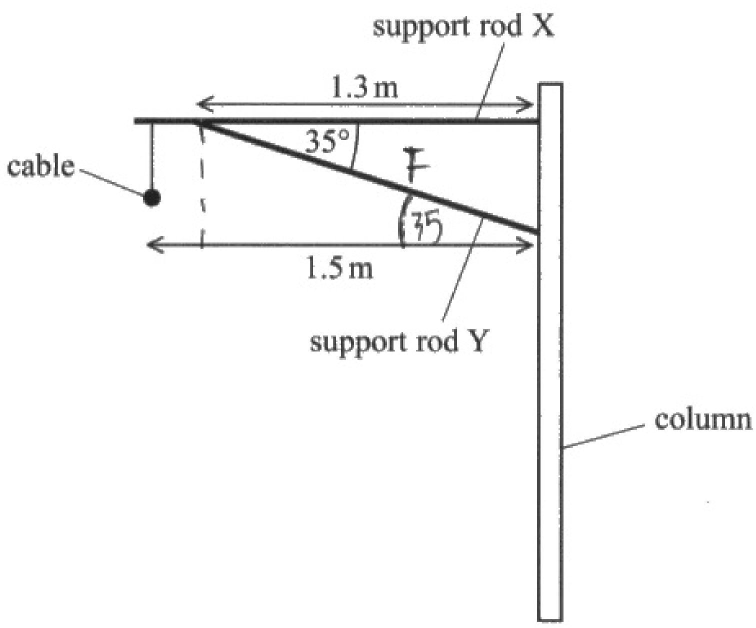
ResultsPlus
Examiner Tip

Note the perpendicular component of force to the distance "Ysin35".

14 Overhead electricity cables for railway lines are supported by structures like the one shown.

An electric cable of mass 45 kg is suspended from a support rod X. A second support rod Y is attached to X. X and Y are attached at one end to a column.

$45g - F_y = 0$



Not to scale

The masses of support rods X and Y are negligible.

(a) (i) Determine, by taking moments, the force exerted on rod X by rod Y.

(4)

$1.3 \times 45 \times g = 1.3 \times F \sin(35)$

$45g = F \sin 35$

$F_y = F \cos 35$ $\quad F = \frac{F_y}{\cos 35}$ $\quad 45g = \frac{F_y}{(\cos 35)} \times \sin 35$

$45g = F_y \times \tan 35$ $\quad F_y = \frac{45g}{\tan 35} = \frac{441.45}{0.7002}$

$= 630.456$

Force = 630 N

ResultsPlus
Examiner Comments

This answer is almost correct.

It converts the mass of cable to weight but it doesn't multiply it by the correct distance.

It does have the correct component of the force from Y and does multiply this by the correct distance, hence 3 marks.

Question 14 (a)(ii)

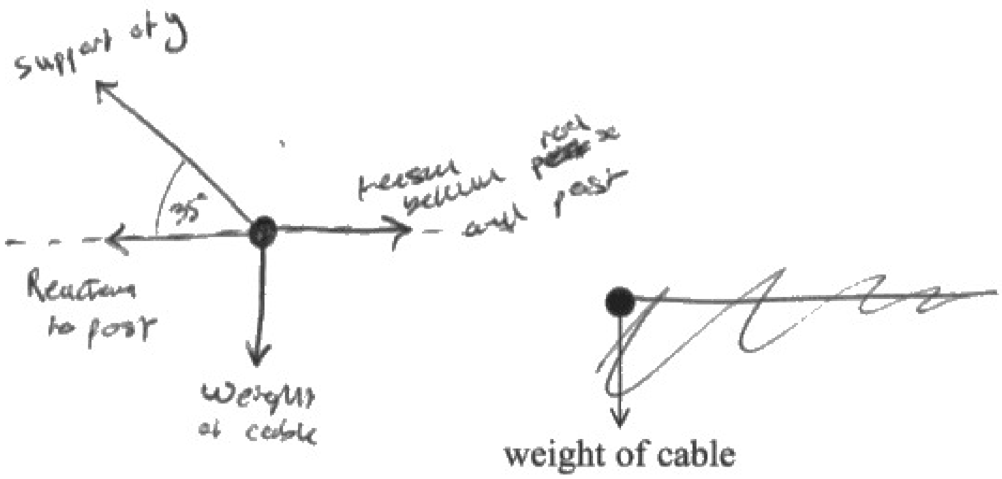
This free-body force diagram was only completed successfully by a minority of candidates.

The forces were those exerted on rod X. A number of candidates drew this force acting in the opposite direction, or to the right rather than upper left.

The third force, from the column on X, should be in a direction to create equilibrium.

(ii) Complete the free-body force diagram for support rod X.

(2)



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Examiner Comments

This diagram has a correct force from Y on X.

However it has two further forces from the column.

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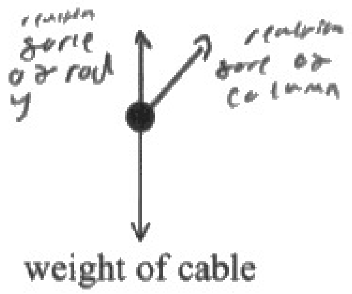
Examiner Tip

It is a good idea to label an angle with a value, as this candidate has done, especially if you are not very good at using a protractor.

(ii) Complete the free-body force diagram for support rod X.

(2)

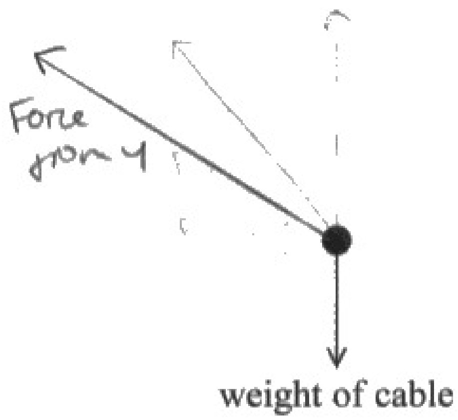


ResultsPlus
Examiner Comments

Many answers had a vertical force from Y on X.

(ii) Complete the free-body force diagram for support rod X.

(2)



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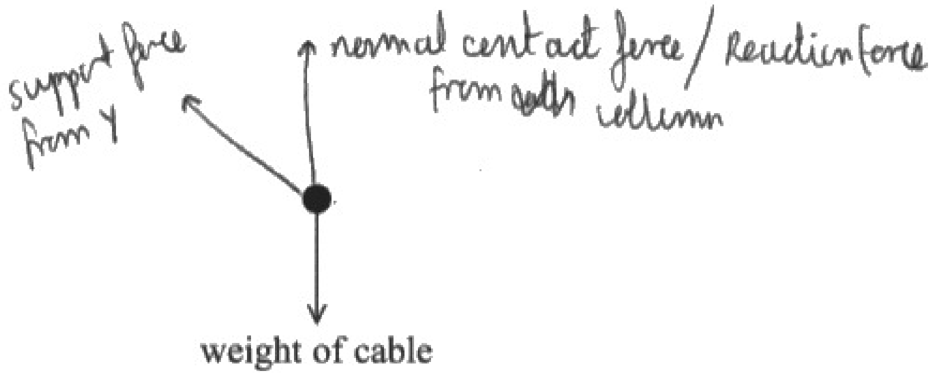
Examiner Comments

This diagram only just got the first mark. The angle of the force (35) to the horizontal has been drawn with little accuracy.

(ii) Complete the free-body force diagram for support rod X.

(2)



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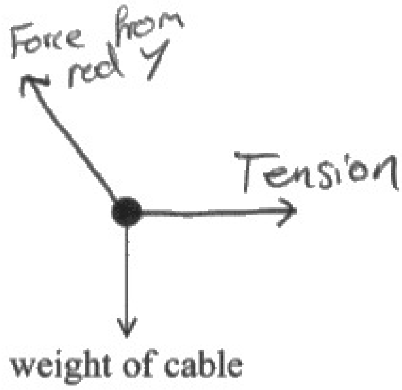
Examiner Comments

The force from Y is just about within tolerance for the first mark.

The force from the column could not produce an equilibrium.

(ii) Complete the free-body force diagram for support rod X.

(2)



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Examiner Comments

The angle of the force from Y is out of tolerance.

The force from the column could produce an equilibrium so gains mark point 2.

Question 14 (b)

This question examined whether candidates knew the mathematical relationship known as the inverse square law.

The typical approach was to find the product $E\,d^2$ for both sets of data and see if the constant was the same.

(b) A website gives a value of the electric field strength E, at two distances from the electric cable.

Distance / m	E / N C^{-1}
3	1200
25	100

Deduce whether these data are consistent with an inverse square law.

(3)

$E \propto \frac{1}{d^2}$

$1200 \propto \frac{1}{3^2}$ → ratio of 133

$100 \propto \frac{1}{25^2}$ → ratio of 0.16

the data is not consistent!

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Examiner Comments

This answer divides E by d^2 rather than finds the product.

(b) A website gives a value of the electric field strength E, at two distances from the electric cable.

Distance / m	E / NC^{-1}
3	1200
25	100

Deduce whether these data are consistent with an inverse square law.

(3)

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

$V = Ed$

$V_1 = 1200 \times 3 = 3600$

$V_2 = 100 \times 25 = 2500$

~~kE =~~ 2 ~~50~~ $2500 = k^2\, 3600$

This follow $E = k\frac{Q}{r^2}$ since k and Q are both constant.

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Examiner Comments

This answer uses an inversely proportional relationship rather than an inverse square law.

(b) A website gives a value of the electric field strength E, at two distances from the electric cable.

Distance / m	E / N C^{-1}
3	1200
25	100

Deduce whether these data are consistent with an inverse square law.

(3)

If $E \propto \frac{1}{d^2}$ then Ed^2 is constant

$1200 \times 3^2 = 10800\ \text{N m}^2\text{C}^{-1}$

$100 \times 25^2 = 62500\ \text{N m}^2\text{C}^{-1}$

Ed^2 is not constant so the cable doesn't follow an inverse square law

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Examiner Comments

This answer is fully correct and achieves all 3 marks.

Question 15 (a)(i)

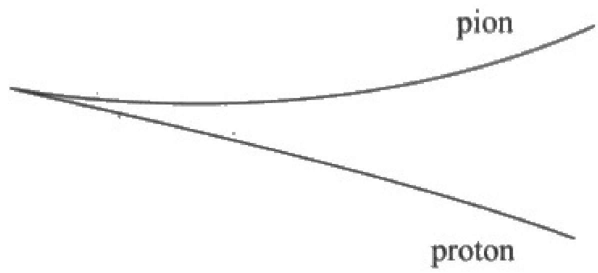
The question asked why the delta particle could be assumed to be neutral from the evidence in the diagram.

Some candidates discussed this without any reference to the diagram.

Most candidates wrote the straightforward response "there is no track".

15 A delta particle decays into a proton and a pion.

(a) The diagram shows tracks in a particle detector formed when the delta particle decays.



(i) State why it can be concluded from the diagram that the delta particle is neutral.

(1)

Charge must be conserved and the proton is positive so pion must be negative so delta must be neutral. Both move in opposite direction so must be opposite

ResultsPlus
Examiner Comments

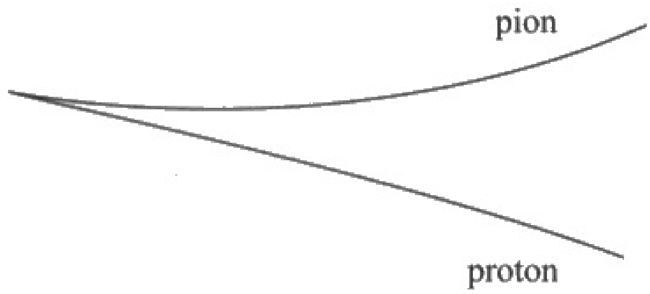
The two tracks **curve** in opposite directions. They do not move in opposite directions. In fact, initially, they are moving in almost the same direction.

ResultsPlus
Examiner Tip

Be careful with the wording you use to describe particle tracks.

15 A delta particle decays into a proton and a pion.

(a) The diagram shows tracks in a particle detector formed when the delta particle decays.



(i) State why it can be concluded from the diagram that the delta particle is neutral.

(1)

~~(a) It doesn't ionise~~

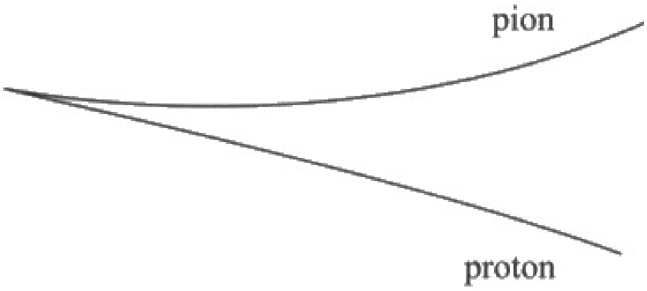
Has no particle track and the pion and proton have opposing curvatures

ResultsPlus
Examiner Comments

This answer would get the mark for both of the reasons stated.

15 A delta particle decays into a proton and a pion.

(a) The diagram shows tracks in a particle detector formed when the delta particle decays.



(i) State why it can be concluded from the diagram that the delta particle is neutral.

(1)

There is no track shown for the delta particle

ResultsPlus
Examiner Comments

A straightforward and correct answer.

Question 15 (a)(ii-iii)

The most common method was to state that a proton is positive.

As the delta is neutral, charge conservations means that the pion is negative.

The same conclusion can be reached by discussing the opposite curvatures of the proton and pion.

(ii) Deduce the charge on the pion. **(2)**

Δ proton μ

Conservation of Q 0 → +1 + ?

in order for charge to be conserved, the charge on the pion must be -1

(iii) Complete the particle equation for the decay of the delta (Δ^0) particle. **(1)**

$\Delta^0 \rightarrow p^+ + \mu^-$

ResultsPlus
Examiner Comments

If the answer to Q15(a)(ii) was written in numerical form as a charge conservation equation then the marks were awarded as long as it was clear.

A small minority of candidates did not know the symbol for a pion (in part (iii)).

(ii) Deduce the charge on the pion.

(2)

Proton ~~char~~ charge = +1

~~as~~ ~~the~~ delta particle is neutral

=> Pion charge = -1

delta (0) → Pion (-1) + Proton (+1)

(iii) Complete the particle equation for the decay of the delta (Δ^0) particle.

(1)

$\Delta^0 \rightarrow \pi^- + p^+$

ResultsPlus
Examiner Comments

A good answer for both parts of the question.

ResultsPlus
Examiner Tip

Note that the p symbol for a proton does not need a plus sign. This was not penalised.

Question 15 (a)(iv)

This question tested whether candidates could apply conservation of baryon number.

An answer such as "the proton is a baryon so the delta must be a baryon" was too vague. This type of answer needed to also point out that the pion is not a baryon.

(iv) State why the delta particle must be classified as a baryon based on the evidence of its decay.

(1)

The ~~baryon nut~~ number of baryons after Δ's decay is 1 so the Δ^0 particle must be a baryon.

ResultsPlus
Examiner Comments

This answer makes it clear that there is one baryon after the decay, so the delta is a baryon.

(iv) State why the delta particle must be classified as a baryon based on the evidence of its decay.

(1)

because its made of three quarks and there are no antiquarks or

ResultsPlus
Examiner Comments

A number of answers were side-tracked by explaining what the quark structure of a baryon is.

(iv) State why the delta particle must be classified as a baryon based on the evidence of its decay.
(1)

proton is a lepton and Pion is baryon so ~~so for~~ so baryon number to balance delta must be a baryon

ResultsPlus
Examiner Comments

A small number of responses indicated that the standard model had not been learnt.

Question 15 (a)(v)

This question was about the application of the equation $p = Bqr$. The proton has a larger radius track than the pion.

Some candidates referred to "more curved" or "less curved" but it was then easier to get the answer the wrong way round.

(v) Explain how the momentum of the proton compares with the momentum of the pion.

(3)

Since proton will have a greater radius of curvature than pion, due to equation $r = P/BQ \rightarrow P = rBq$, as proton has a greater radius, it will also have a greater momentum than pion as it has a lower radius value.

ResultsPlus
Examiner Comments

An answer pointing out the equation, the larger radius track and correct conclusion for full credit.

ResultsPlus
Examiner Tip

It is a good idea to define the other terms in the equation, B and Q, or at least point out that they are constant.

(v) Explain how the momentum of the proton compares with the momentum of the pion.

(3)

The momentum ~~p~~ of ~~pr~~ the proton is much larger then the momentum of the pion as it is affected by electric field much less.

ResultsPlus
Examiner Comments

Without achieving mark point 1 or 2, mark point 3 could not be awarded.

This answer also displays a misunderstanding of the role of electric fields in particle detectors.

(v) Explain how the momentum of the proton compares with the momentum of the pion.

(3)

The ~~pion~~ proton appears to have greater momentum than the pion because it has a smaller radius of curvature. This shows us that the pion will lose energy quicker than the proton

ResultsPlus
Examiner Comments

Some candidates incorrectly associated a less curved path with a smaller radius.

ResultsPlus
Examiner Tip

A "flatter" curve has a large radius.

(v) Explain how the momentum of the proton compares with the momentum of the pion.

(3)

After the decay, the 2 particles gain the same momentum but, since the pion has a greater mass, it will have a lower velocity.

ResultsPlus
Examiner Comments

Answers that tried to consider momentum conservation will not be able to answer this particular question.

Momentum is conserved, the momentum of the delta will equal the sum of the initial momentum of the proton and pion.

This doesn't help to compare the momentum of the proton and pion, which is why a magnetic field is applied in a detector.

Question 15 (b)(i)

Conversions from MeV/c^2 to kg or vice versa are now well done by the vast majority of candidates.

(b) The mass of the delta particle is 1232 MeV/c^2.

$E = mc^2$

(i) Calculate the mass of the delta particle in kg.

$\frac{E}{c^2} = m$

(3)

1232×10^6

$1232 \times (3 \times 10^{-8})^2 = 35.696 \times 10^{17}$ 1.1088×10^{26} MeV

$1.1088 \times 10^{26} \times 1.6 \times 10^{-19} = 17740800$ J 1.6×10^{-19}

$\frac{17740800}{(3 \times 10^8)^2} = 1.9712 \times 10^{-10}$

Mass = 1.97×10^{-10} kg

ResultsPlus
Examiner Comments

This answer appears to convert eV to J correctly. It gets into a muddle applying $m = E/c^2$.

(b) The mass of the delta particle is 1232 MeV/c^2.

(i) Calculate the mass of the delta particle in kg.

(3)

~~1232×~~

$$\frac{1.232 \times 10^{9} \times 1.6 \times 10^{-19}}{(300000000)^2} = 2.190222 \times 10^{-27}$$

Mass = 2.19×10^{-27} kg

ResultsPlus
Examiner Comments

Correctly done for full credit.

Question 15 (b)(ii)

This question examined the application of delta$E$ = deltamc^2.

The rest mass of the delta is more than the total rest mass of the proton and pion.

The loss in mass has been converted to kinetic energy of the decay products.

Note that the delta particle would have some kinetic energy and this would also have been passed to the decay products. This wasn't required for the marks as the question concentrated on the mass difference.

(ii) The mass of the proton is 939 MeV/c^2 and the mass of the pion is 139 MeV/c^2.

Explain why the sum of the masses of the two particles after the decay is not equal to the mass of the delta particle.

(3)

Decay has meant that some energy has been converted to mass. Does not abide by
$\Delta e = \Delta m \times c^2$ conservation of mass.
Therefore mass of delta particle is less than the sum of the proton and pion mass.

ResultsPlus
Examiner Comments

This quotes the relevant equation. However it suggests that energy has been converted to mass because the mass of the products is more than the mass of the delta particle.

(ii) The mass of the proton is 939 MeV/c^2 and the mass of the pion is 139 MeV/c^2.

Explain why the sum of the masses of the two particles after the decay is not equal to the mass of the delta particle.

(3)

The mass of the Proton added to the mass of the Pion after both have decayed does not equal to the mass of the delta Particle. This is because as the Proton and Pion decayed they lost some mass. This means that, when added back together they have less mass than origionally.

ResultsPlus
Examiner Comments

This answer finally states that the mass of the decay products is less than the delta particle.

ResultsPlus
Examiner Tip

It is often easier to use a numerical argument if available. The mass difference is 154 MeV/c^2.

(ii) The mass of the proton is 939 MeV/c^2 and the mass of the pion is 139 MeV/c^2.

Explain why the sum of the masses of the two particles after the decay is not equal to the mass of the delta particle.

(3)

$939 + 139 = 1078 \quad 1078 < 1232$

some of the mass of the delta particle will convert to energy according to $E = mc^2$ the ~~po~~ delta particle will have kinetic energy which needs to be conserved.

ResultsPlus
Examiner Comments

This gets most of the answer correct. However it doesn't state that the energy will be in the form of kinetic energy of the decay particles.

ResultsPlus
Examiner Tip

Note that the candidate has written E = mc^2. The "deltas" are omitted. This wasn't penalised but the "deltas" are important and their meaning should be understood and included.

(ii) The mass of the proton is 939 MeV/c^2 and the mass of the pion is 139 MeV/c^2.

Explain why the sum of the masses of the two particles after the decay is not equal to the mass of the delta particle.

(3)

~~Rest mass~~ Energy and momentum is conserved in the decay. ~~Rest mass~~ Energy of Δ^0 is 1232 MeV, and the total energy of proton and pion is 939+139 = 1078 MeV according to $E = mc^2$. Since ~~momentum~~ proton and pion conserve ~~have~~ momentum and travel after decay, so the lost in mass converted into the kinetic energy of two decay particles according to $\Delta E = \Delta mc^2$.

(Total for Question 15 = 14 marks)

ResultsPlus
Examiner Comments

This answer gets across that it is a loss in mass and has some calculations to go with it. The equation is quoted and that the mass will become kinetic energy of the decay products.

It also discusses momentum conservation which will apply but wasn't required in this answer.

Question 16 (a)

The indicative content question was about a d.c. motor.

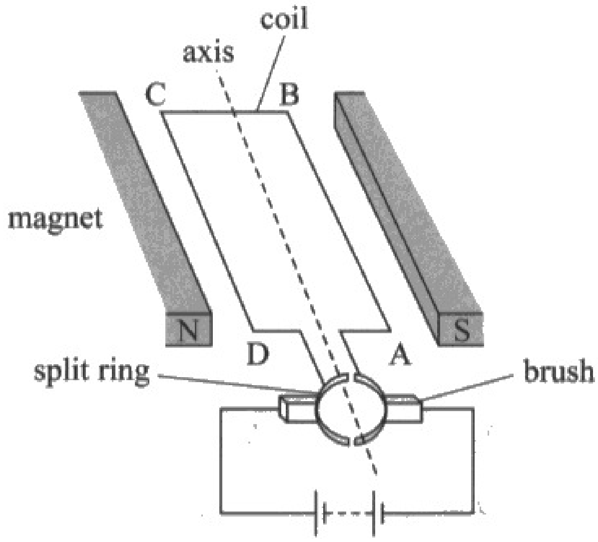
The first three indicative content points were about applying Fleming's left hand rule to this diagram.

The fourth was for explaining that the moment of the two forces (or couple) will cause rotation.

The last two points were for explaining the action of the split ring.

16 Electric vehicles use a direct current (d.c.) electric motor powered by a battery for propulsion. A simplified diagram of a d.c. electric motor is shown.

A split ring consists of two semi-circular sections that are attached to a coil. The coil is labelled ABCD. Two brushes, made of carbon, rub against and make electrical contact with the split ring.



*(a) Describe how this arrangement can lead to the coil rotating.

(6)

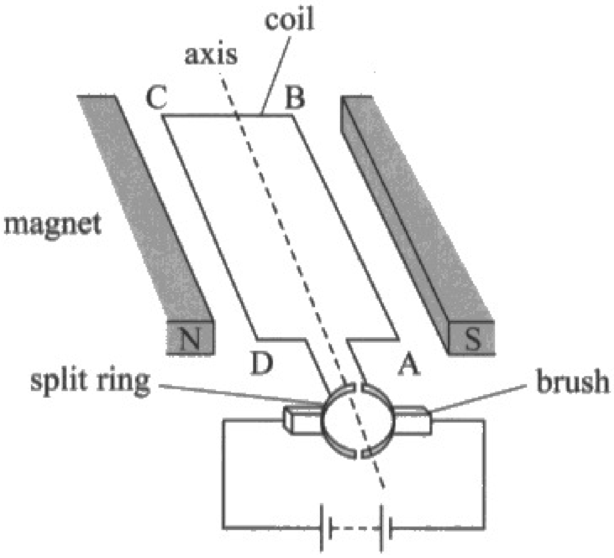
As the brushes rub the split ring, it causes the circuit to be complete. Therefore e.m.f is induced across the whole circuit/coil. ~~This~~ As Faraday's law states, an e.m.f is induced when the magnetic field ~~flux~~ is cut/ experiences a change in flux. When an e.m.f is induced, Lenz's law states a current will also be induced, opposing the change that created it. Therefore, if an e.m.f is induced as field is cut, the current will ~~try to~~ oppose this change in flux, causing the coil to rotate as the current travels in the opposite direction to the e.m.f.

ResultsPlus
Examiner Comments

Some candidates described the action of a dynamo rather than a motor.

16 Electric vehicles use a direct current (d.c.) electric motor powered by a battery for propulsion. A simplified diagram of a d.c. electric motor is shown.

A split ring consists of two semi-circular sections that are attached to a coil. The coil is labelled ABCD. Two brushes, made of carbon, rub against and make electrical contact with the split ring.



*(a) Describe how this arrangement can lead to the coil rotating.

(6)

The coil above ~~devices~~ is placed within a magnetic field travelling from ~~North to South.~~ the north terminus to the south terminus. When a potential difference is applied accross the battery, a direct current will be transferred into the ~~current~~, coil via the brushes. The current in the coil ~~with~~ will create a force, F=BILsin30, which will change and the coil will ~~become~~ begin to rotate as a result of Flemings left hand rule. The side DC will begin to move upwards in thed diagram, and the line AB will move downwards. The coil will begin to turn clockwise as the diagram faces. As the coil turns, the changing magnetic flux will induce an e.m.f. and an alternating current. As the rate of change of flux increases the coil will rotate faster about the axis.

ResultsPlus
Examiner Comments

A number of answers did not specify the direction of the current in the coil.

This answer has the second indicative point for force on a current in a magnetic field.

There is no attempt to explain the split ring.

*(a) Describe how this arrangement can lead to the coil rotating.

(6)

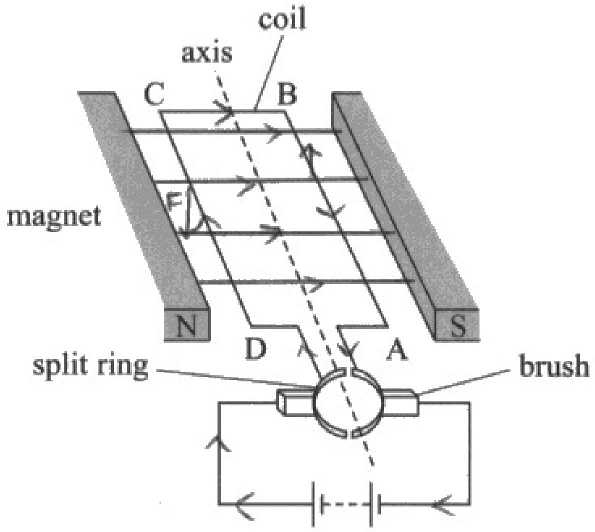
~~a~~ When the brushes rub against the split ring it generates a current that will travel in the direction of D to C and B to A. ~~From~~ Using Flemings left hand rule ~~a~~ I know that with the current going D to C a force ~~of~~ will be acting downwards and will spin the coil until the split ring no longer connects to the ~~a~~ brushes the force will stop and ~~the~~ it will allow the coil to turn more than ~~over a~~ ~~coil~~ 180° whilst from D to C there is a downwards force from B to A there is an upwards force causing the entire coil to rotate.

ResultsPlus
Examiner Comments

This answer has the first three indicative points.

16 Electric vehicles use a direct current (d.c.) electric motor powered by a battery for propulsion. A simplified diagram of a d.c. electric motor is shown.

A split ring consists of two semi-circular sections that are attached to a coil. The coil is labelled ABCD. Two brushes, made of carbon, rub against and make electrical contact with the split ring.



*(a) Describe how this arrangement can lead to the coil rotating.

(6)

From d.c. electric motor, when the brushes make contact with split ring, a current passes through into the coil. Magnetic field (uniform) has north to south direction. As current flows from D to C, the current and magnetic field are perpendicular ∴ a magnetic force acts on wire → using Fleming's left hand rule, force acts downwards on coil. When current travels from C to B, the magnetic field and current are parallel (0°) => no force acts on wire. From B to A, current is in opposite direction (to C to D) => upward force acts on wire. This causes coil to rotate anticlockwise. Split ring and contacts touch every half turn → ~~reversing current~~ rotates same way (reverses current in opposite direction).

ResultsPlus
Examiner Comments

This is a very well-explained answer. The diagram has been added to and labelled.

Five indicative points are present. The only one missing is the comment about moments causing a rotation.

ResultsPlus
Examiner Tip

In questions where a diagram has been provided it is acceptable to add to the diagram but make sure you label things clearly.

Question 16 (b)

This question expected the use of equations with energy and power.

There was a lengthier way of finding the kinetic energy by deriving the equation for kinetic energy from first principles.

(b) An advert for an electric car has the following information:

- electric motor can develop up to 390 kW output power
- car achieves a velocity of 28 m s^{-1} from rest in 4.0 s at maximum power

Calculate the work done by resistive forces when the car accelerates to a velocity of 28 m s^{-1} from rest in 4.0 s.

mass of car = 1950 kg

(3)

$K_e = \frac{1}{2}mv^2 = 0.5 \times 1450 \times 28^2 = 764400$ J

$P = \frac{E}{T}$ $\quad 340000 = \frac{x}{4}$ $\quad x = 1560000$ J

$\therefore$ $1560000 - 764400 = 795600$ J = Resistive forces

Work done by resistive forces = 796 000 J

ResultsPlus Examiner Comments

A fully correct answer based on the use of energy equations.

ResultsPlus Examiner Tip

When a question refers to work done, the use of an approach based on energy is likely to be more straightforward.

(b) An advert for an electric car has the following information:

- electric motor can develop up to 390 kW output power   P
- car achieves a velocity of 28 m s^{-1} from rest in 4.0 s at maximum power   V

Calculate the work done by resistive forces when the car accelerates to a velocity of 28 m s^{-1} from rest in 4.0 s.

mass of car = 1950 kg   M

(3)

$P = \frac{W}{t}$

390000 × 4 = W

W = 1.56 × 10^{6} J

Work done by resistive forces = ...

ResultsPlus
Examiner Comments

A number of answers either just calculated the energy output of the motor (as in this case) or the kinetic energy gained.

(b) An advert for an electric car has the following information:

- electric motor can develop up to 390 kW output power
- car achieves a velocity of $28\,m\,s^{-1}$ from rest in 4.0 s at maximum power

Calculate the work done by resistive forces when the car accelerates to a velocity of $28\,m\,s^{-1}$ from rest in 4.0 s.

mass of car = 1950 kg

(3)

390 kW power — Force = mass × acceleration

$28\,ms^{-1}$ in 4 s — $1950 \times \left(\frac{28}{4}\right) = 13650\,N$

$W = F\Delta s$ — $s = ut + \frac{1}{2}at^2$

$s = \frac{1}{2} \times \left(\frac{28}{4}\right) \times 16 = 56\,m$

$13650 \times 56 = 764400\,J$

Work done by resistive forces = [illegible]

ResultsPlus
Examiner Comments

This answer has determined the kinetic energy of the car from first principles.

(b) An advert for an electric car has the following information:

- electric motor can develop up to 390 kW output power
- car achieves a velocity of $28\,m\,s^{-1}$ from rest in 4.0 s at maximum power

Calculate the work done by resistive forces when the car accelerates to a velocity of $28\,m\,s^{-1}$ from rest in 4.0 s.

mass of car = 1950 kg

$P = 390 \times 10^3\,W$

$v = 28\,ms^{-1}$ → $a = \frac{\Delta v}{t} = \frac{28}{4} = 7\,ms^{-2}$ (3)

$t = 4s$

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

$a = 7\,ms^{-2}$

$t = 4s$

$u = 0\,ms^{-1}$

$v = 28\,ms^{-1}$

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

$s = 0 + \frac{1}{2}(7)(4)^2$

$= \frac{1}{2}(7)(16)$

$= 56m$

$Pt = E$

$(390 \times 10^3) \times (4) = 1560000$

$1560000 - 1071252$

$= 488748J$

$W = F\Delta s$

$W = 19130 \times 56$

$W = 1071252\,J$

$1950 \times 9.81 = 19130N$

Work done by resistive forces = 488,748 J

489,000 J

ResultsPlus
Examiner Comments

Many of the attempts to determine the kinetic energy from first principles contained a mistake.

This attempt calculates the force using *mg* rather than *ma*.

Question 16 (c)

This question was marked by using either of two approaches.

An energy approach: explaining that more energy would be transferred internally in the battery, the battery becomes less efficient and needs to be charged more frequently.

A force/power argument: explaining that the terminal p.d. would decrease, the current would decrease so there would be less power output or less acceleration.

(c) A website suggests that 'fast-charging' the battery in an electric vehicle can increase the internal resistance of the battery.

Explain why an increase in internal resistance of a battery is a disadvantage.

(3)

Increase the internal resistance on a motor would decrease the potential difference. so ~~That would mean the total circuit~~ in ~~the battery will have lower be P=VI~~ so a ~~dec~~

The decrease in potential difference also decreases the total current. P=VI so if these go lower total power will be lower so car will move slower making it a disadvantage

ResultsPlus
Examiner Comments

This answer is close to three marks for the force/power approach.

It was expected that candidates would refer to **terminal** p.d. The p.d. across the internal resistance would increase.

This answer gains mark points 2 and 3.

ResultsPlus
Examiner Tip

Use correct terminology, when discussing internal resistance of a battery. Make sure you use "terminal potential difference" to be clear you are describing the output or useful p.d.

(c) A website suggests that 'fast-charging' the battery in an electric vehicle can increase the internal resistance of the battery.

Explain why an increase in internal resistance of a battery is a disadvantage.

(3)

With an increased internal resistance, more work is done against the resistance inside the cell (caused by electrons colliding with atoms inside); volts are 'lost' as a result, (there is a p.d across the internal resistance) which decreases the terminal potential difference. Therefore, this is a disadvantage as a higher proportion of the electrical energy is wasted rather than usefully used, decreasing the efficiency and potentially costing more per unit of useful work transferred.

(Total for Question 16 = 12 marks)

ResultsPlus
Examiner Comments

This answer used the energy approach and gains the first two mark points for describing the increase in energy transferred within the battery.

It then gives a good alternative answer for the third mark point: costs more per unit of useful work transferred.

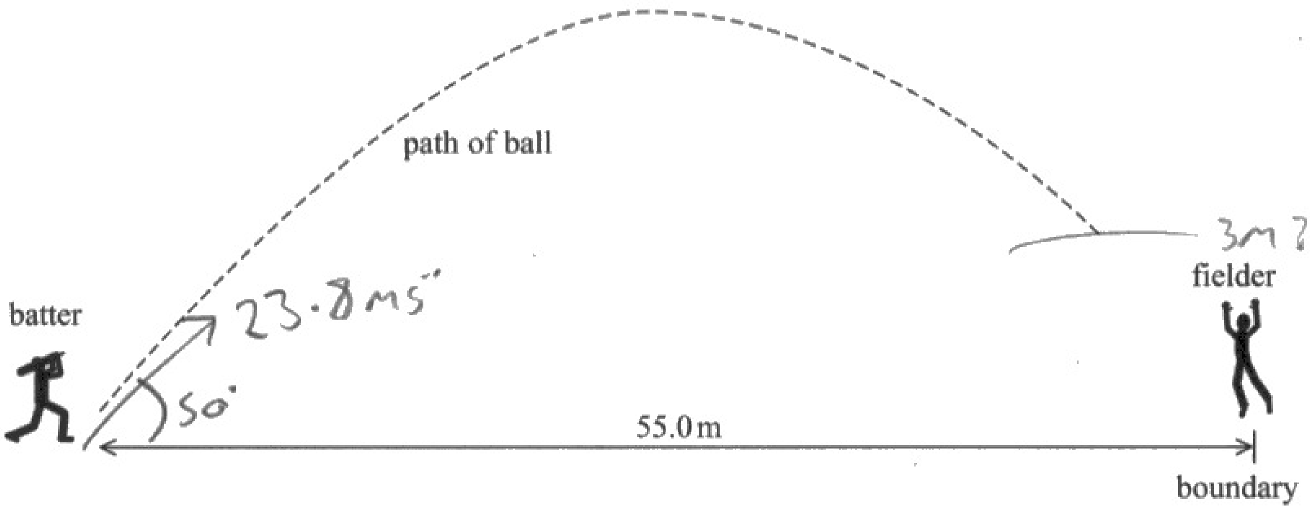
Question 17 (a)

This question tested the candidates skills at solving a projectile problem.

There are a few different ways to approach this question but the most common way was to determine the time of flight of the ball to the boundary.

Then to use $s = ut - 1/2at^2$ to predict the height of the ball at the boundary and decide whether it was within range of the fielder.

17 In cricket a fielder is often placed at the boundary edge as shown. If the fielder catches the ball, the batter is out.



The fielder is 55.0 m away from the batter. The fielder can catch the ball providing the ball is less than three metres above the height at which it was hit.

The ball is hit with a velocity of $23.8\,m\,s^{-1}$ and at an angle of 50.0° to the horizontal.

(a) Deduce whether the fielder can catch the ball in this case.

(5)

v↑ = 23.8 sin 50

v → = 23.8 cos 50

s = 3m
u = 23.8 sin 50
v = x
a = −g
t ?

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

$3 = ut + \frac{1}{2}(-g)t^2$

$\frac{g}{2}t^2 - ut + 3 = 0$

t = 3.54 or ~~t = 0.173~~

$s = \frac{d}{t}$ d = s × t = 23.8 cos 50 × 3.54 = 54.2

~~B~~ d < 55 ∴ fielder can catch the ball

ResultsPlus
Examiner Comments

This method was relatively unusual. It determines the horizontal distance to the ball when the height is 3m.

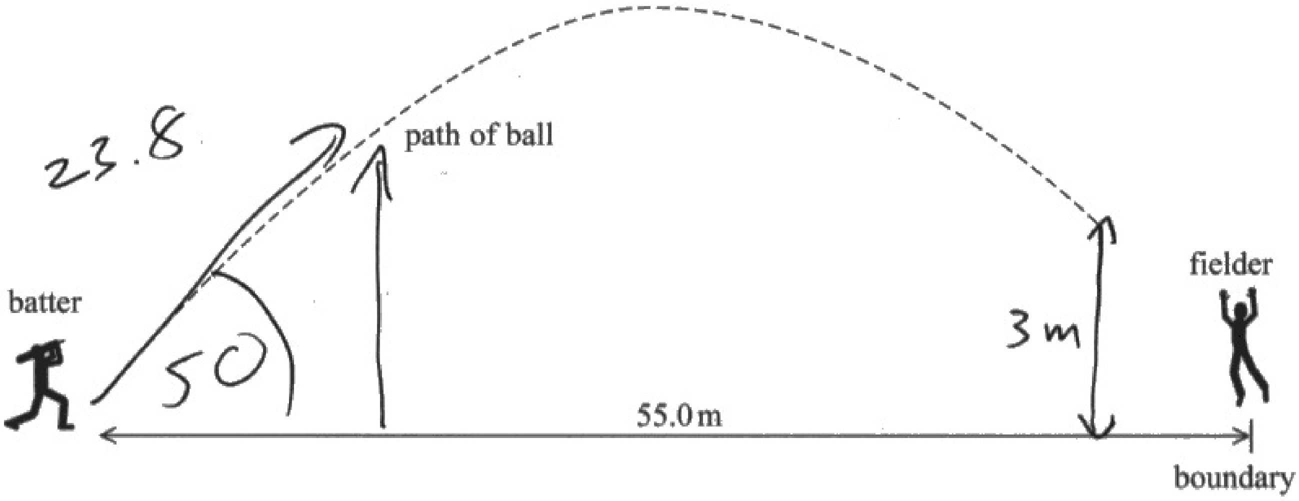
This gains all the marks except for the conclusion mark.

For this mark it needed to be clear that beyond the calculated distance the height would decrease and therefore the fielder would be able to catch it.

ResultsPlus
Examiner Tip

State the reason for your conclusion clearly.

17 In cricket a fielder is often placed at the boundary edge as shown. If the fielder catches the ball, the batter is out.



The fielder is 55.0 m away from the batter. The fielder can catch the ball providing the ball is less than three metres above the height at which it was hit.

The ball is hit with a velocity of 23.8 m s^{-1} and at an angle of 50.0° to the horizontal.

(a) Deduce whether the fielder can catch the ball in this case.

(5)

↑+

Vert:

$s = ?$

$a = -9.81$

$u = 23.8 \sin 50$

$t = 3.595\,s$

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

$= (23.8 \sin 50)(3.595) + \frac{1}{2}(-9.81)(3.595)^2$

$= 2.15\,m < 3\,m$

So fielder can catch ball

Horiz:

$v = 23.8 \cos 50$

$s = 55$

$t = ?$

$v = \frac{s}{t}$

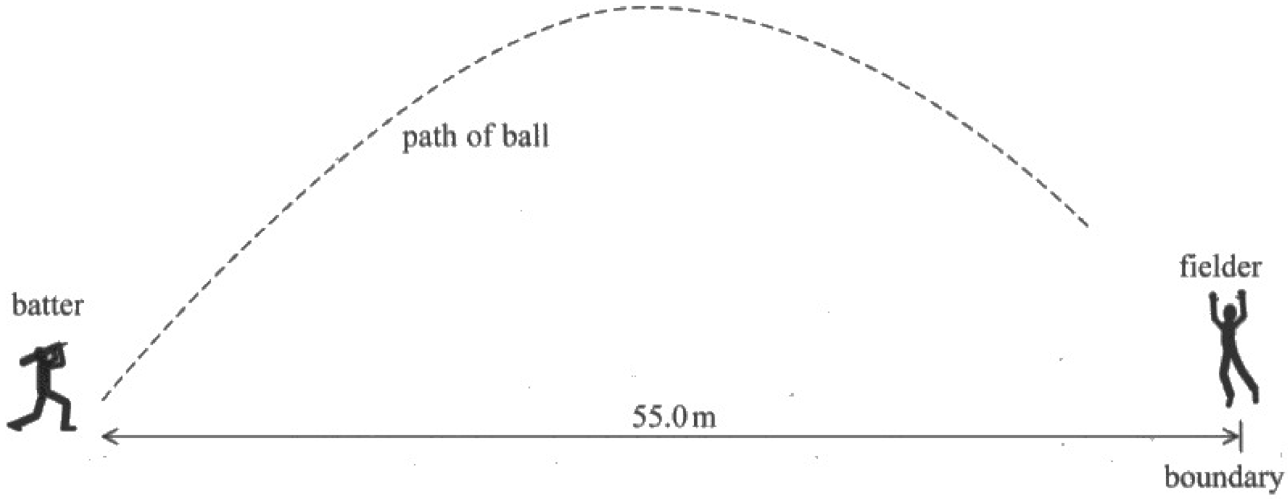
$t = \frac{55}{23.8 \cos 50}$

$t = 3.595\,s$

ResultsPlus
Examiner Comments

This shows the most common method correctly for full credit.

17 In cricket a fielder is often placed at the boundary edge as shown. If the fielder catches the ball, the batter is out.



The fielder is 55.0 m away from the batter. The fielder can catch the ball providing the ball is less than three metres above the height at which it was hit.

The ball is hit with a velocity of 23.8 m s^{-1} and at an angle of 50.0° to the horizontal.

(a) Deduce whether the fielder can catch the ball in this case.

(5)

$V_y = 23.8 \times \sin(50)$

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

$3 = 23.8\sin(50)t + \frac{1}{2}(-9.81)t^2$

$0 = 23.8(\sin(50)t) - \frac{9.81}{2}t^2 - 3$

t = 0.17256s & 3.544 s => Times when ball is 3m above the ground.

Ignore 0.17256s as this is when ball just leaves the bat. When t = 3.544s

$s = V_x \times t$ $\quad V_x = 23.8 \sin 50$

$S = 23.8 \cos(50) \times 3.544$

$s = 54.224$ m (3 d.p)

As 54.224 m is less than 55 m the fielder can catch the ball.

ResultsPlus
Examiner Comments

This method was relatively unusual.

The time taken to reach a height of 3m is calculated using
$s = ut - 1/2at^2$.

The time is then used to calculate the horizontal distance the ball travels.

ResultsPlus
Examiner Tip

This conclusion is only just enough. It would have been clearer to have said "as the ball actually travels a little further to the boundary the fielder will be able to catch it as the ball continues to fall".

Question 17 (b)(i-ii)

The first part of this question was to calculate the momentum of the ball after being hit using *mv.*

The second part was to complete the vector diagram to determine the momentum of the bat after the hit.

Some candidates did not appear to know how to start the question and left it blank.

Many candidates completed a triangle. Usually their third side was unlabelled.

Only a minority of candidates realised that there were two objects moving before the collision and the same two objects were moving after the collision. These two objects, the bat and the ball, would need two vector lines.

(b) The ball was bowled. Just after the bat hit the ball, the ball had a velocity of 23.8 m s^{-1} at an angle of 50° to the horizontal.

(i) Show that the magnitude of the momentum of the ball, after it was hit, was about 3.3 N s.

mass of cricket ball = 0.140 kg

(1)

$|mv| = 0.14|v| = 0.14 \times \sqrt{(23.8\sin 50)^2 + (23.8\cos 50)^2} = 23.8\ ms^{-1}$

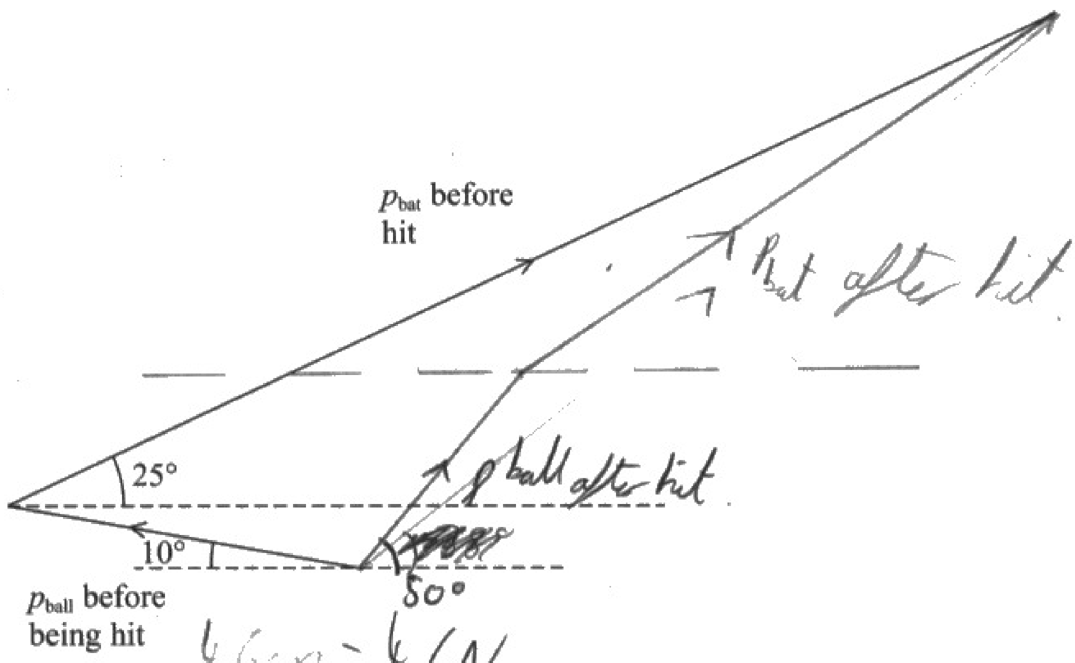
$0.14 \times 23.8 = 3.332\ kg\,ms^{-1} \approx 3.3$ ~~N~~ Ns

(ii) The vector diagram below shows, accurately to scale, the momentum of the ball and the momentum of the bat before the hit.

Determine, by completing the vector diagram, the momentum of the bat after it hit the ball.

momentum of bat before hitting ball = 15.0 N s at 25° to the horizontal
momentum of ball before hitting bat = 4.6 N s at 10° to the horizontal

(5)



4.6cm = 4.6Ns
15cm = 15Ns
10.5cm = 10.5Ns

Momentum of bat after hitting ball = ~~10.5Ns~~ 8.3Ns

at an angle of 34° to the horizontal

ResultsPlus
Examiner Comments

A fully correct, labelled vector diagram.

(b) The ball was bowled. Just after the bat hit the ball, the ball had a velocity of 23.8 m s^{-1} at an angle of 50° to the horizontal.

(i) Show that the magnitude of the momentum of the ball, after it was hit, was about 3.3 N s.

mass of cricket ball = 0.140 kg

(1)

23.8 × 0.14 = 3.332 Ns

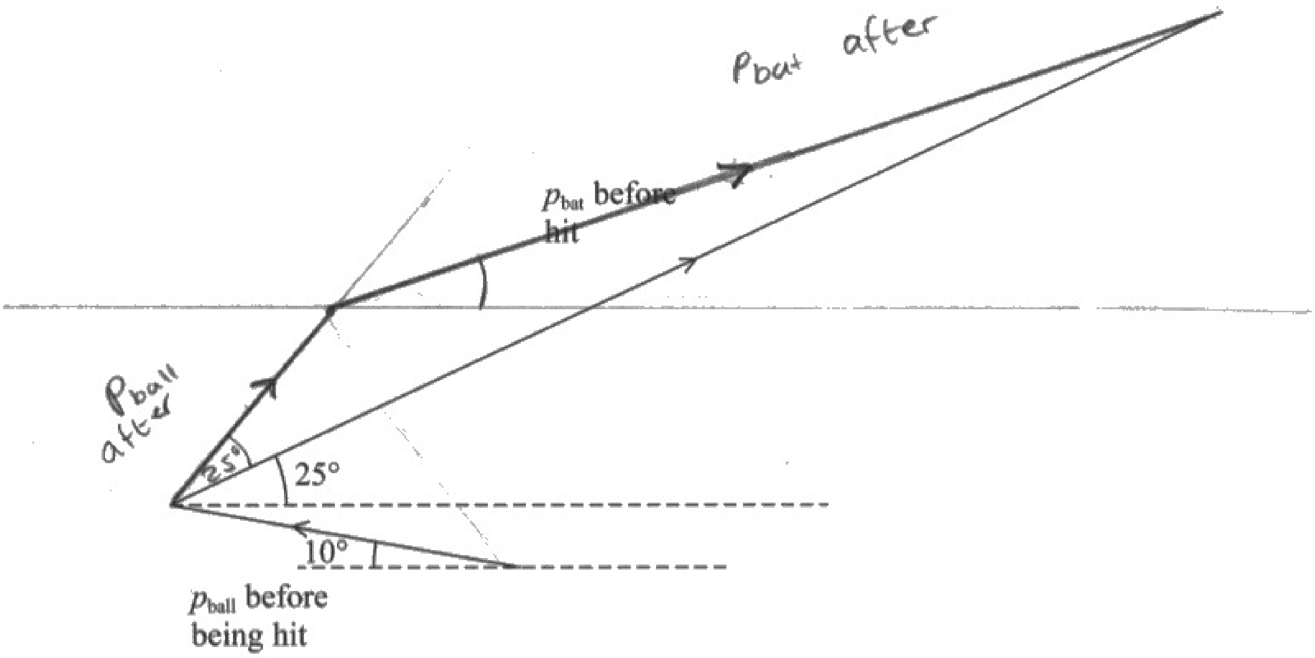
≈ 3.3 Ns

(ii) The vector diagram below shows, accurately to scale, the momentum of the ball and the momentum of the bat before the hit.

Determine, by completing the vector diagram, the momentum of the bat after it hit the ball.

momentum of bat before hitting ball = 15.0 N s at 25° to the horizontal
momentum of ball before hitting bat = 4.6 N s at 10° to the horizontal

(5)



Momentum of bat after hitting ball = 12.2 N

at an angle of 18° to the horizontal

ResultsPlus
Examiner Comments

This candidate has realised there are two objects moving after the collision.

The mistake was not to start either of their vector lines at the point where the vector for the ball before starts.

(b) The ball was bowled. Just after the bat hit the ball, the ball had a velocity of 23.8 m s^{-1} at an angle of 50° to the horizontal.

(i) Show that the magnitude of the momentum of the ball, after it was hit, was about 3.3 N s.

mass of cricket ball = 0.140 kg

(1)

23.8 × 0.140 = 3.3312 3.33 Ns ≈ 3.3 Ns

p = mv

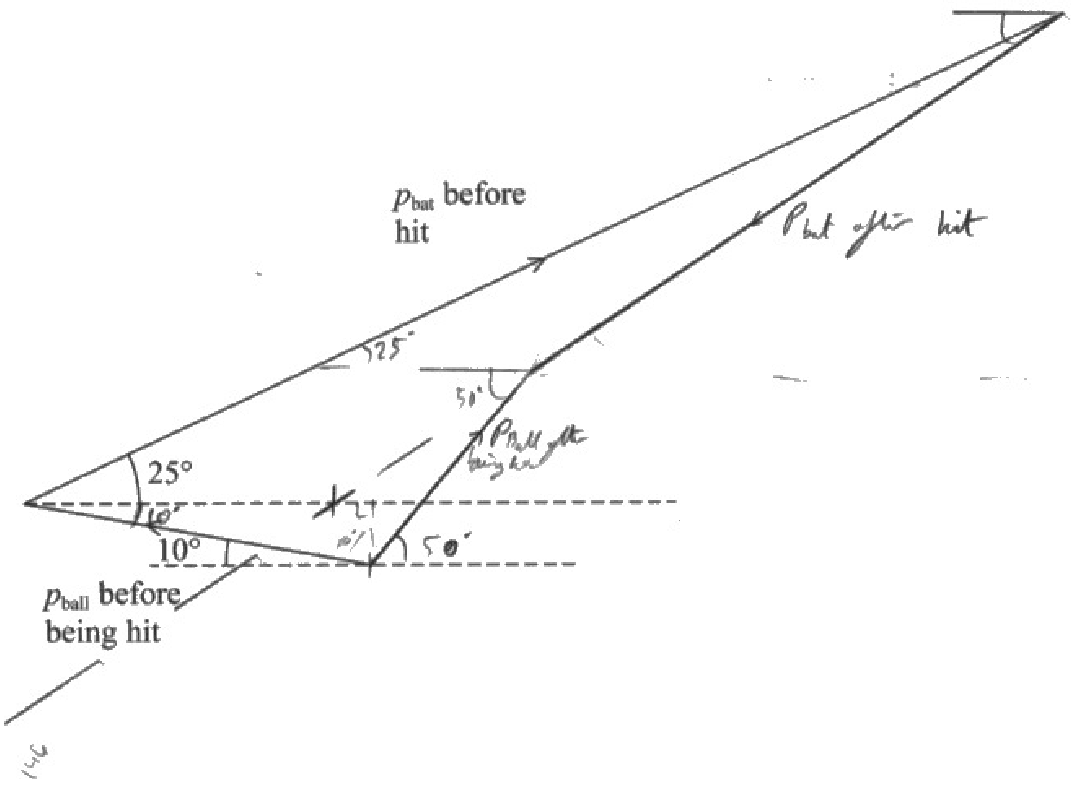
(ii) The vector diagram below shows, accurately to scale, the momentum of the ball and the momentum of the bat before the hit.

Determine, by completing the vector diagram, the momentum of the bat after it hit the ball.

momentum of bat before hitting ball = 15.0 N s at 25° to the horizontal
momentum of ball before hitting bat = 4.6 N s at 10° to the horizontal

Scale: 1cm = 1 Ns

(5)



180 - 146 = 34°

Momentum of bat after hitting ball = 8.45 Ns

at an angle of 34° to the horizontal

ResultsPlus
Examiner Comments

This answer has a small error – it is the direction of the arrow on their p_{bat} after vector.

However the answer satisfies all the mark scheme points to collect full credit because their other arrow is correct.

ResultsPlus
Examiner Tip

Remember to label vectors and add the arrow.

(b) The ball was bowled. Just after the bat hit the ball, the ball had a velocity of 23.8 m s^{-1} at an angle of 50° to the horizontal.

(i) Show that the magnitude of the momentum of the ball, after it was hit, was about 3.3 N s.

mass of cricket ball = 0.140 kg

(1)

p = mv

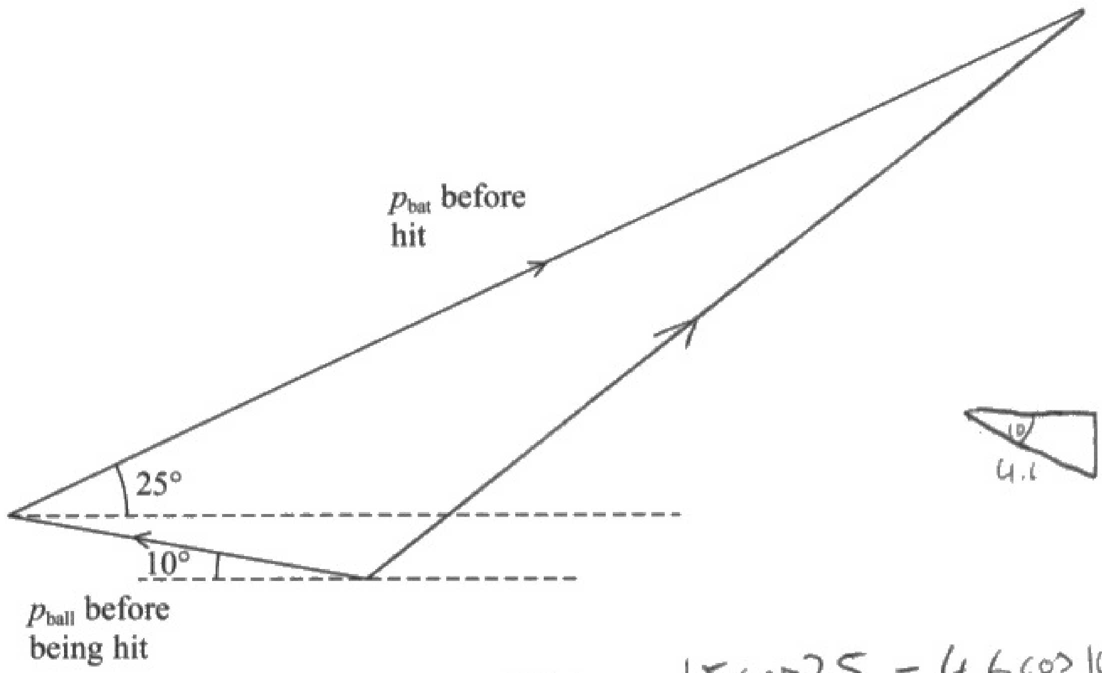
0.14 × ~~23.8~~ 23.8 = 3.332 Ns close to 3Ns

(ii) The vector diagram below shows, accurately to scale, the momentum of the ball and the momentum of the bat before the hit.

Determine, by completing the vector diagram, the momentum of the bat after it hit the ball.

momentum of bat before hitting ball = 15.0 N s at 25° to the horizontal
momentum of ball before hitting bat = 4.6 N s at 10° to the horizontal

(5)



15N

15cos25 − 4.6cos10
=

Momentum of bat after hitting ball = 9.06 Ns

at an angle of 34° to the horizontal

ResultsPlus
Examiner Comments

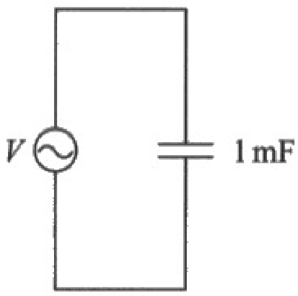
This is an example of completing a vector triangle. No label added.

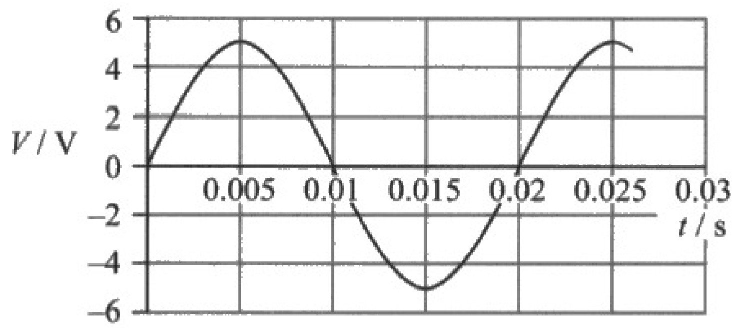
These could usually gain 1 mark by using the scale correctly, in this case the number in the answer line does not correspond to using the correct scale.

Question 18 (a)(i)

This question tested the use of the root mean square equation. A rare mistake was to forget the unit.

18 The circuit shows a 1 mF capacitor connected to an a.c. supply. The graph shows how the potential difference V varies with time t.





(a) (i) Calculate the root-mean-square potential difference.

(1)

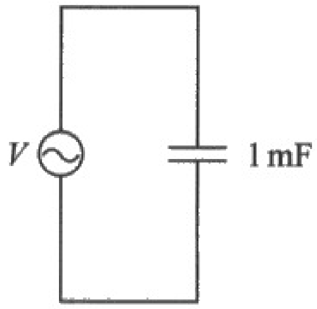
[illegible] $\frac{V_0}{\sqrt{2}}$ $\frac{5}{\sqrt{2}}$ [illegible] 3.54

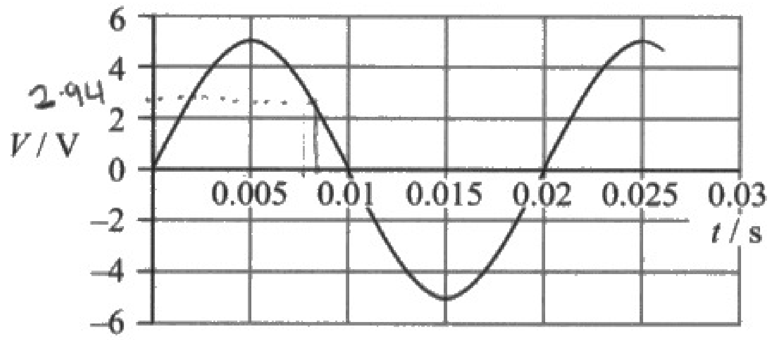
Root-mean-square potential difference = ...

ResultsPlus
Examiner Comments

Don't forget units. It especially seems to happen in very straightforward calculations.

18 The circuit shows a 1 mF capacitor connected to an a.c. supply. The graph shows how the potential difference V varies with time t.





(a) (i) Calculate the root-mean-square potential difference. **(1)**

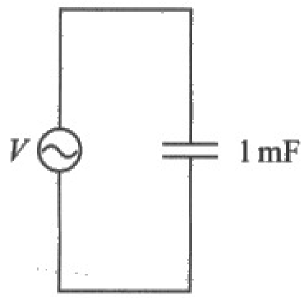
$\frac{0.01}{\sqrt{2}} = 7.07 \times 10^{-3}$

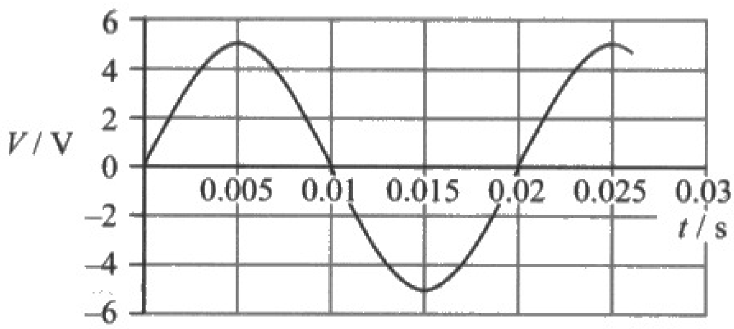
Root-mean-square potential difference = 7.07×10^{-3}

ResultsPlus
Examiner Comments

This is the rms value of time period.

18 The circuit shows a 1 mF capacitor connected to an a.c. supply. The graph shows how the potential difference V varies with time t.





(a) (i) Calculate the root-mean-square potential difference.

(1)

$5 \times \frac{1}{\sqrt{2}} = 3.54$ V

Root-mean-square potential difference = 3.54 V

ResultsPlus
Examiner Comments

Most candidates correctly determined the value and unit.

Question 18 (a)(ii)

This question was about recognising:

- that the 5 in the equation was to increase the amplitude to the peak value of *V*.
- that a sine wave normally has a period of 2pi so to convert that to a time period of 0.02 s, 50 x 2pi t as the frequency is 50 Hz or 50 x 0.02 =1.

(ii) The formula used to generate this graph is $V = 5\sin(100\pi t)$

Explain why this formula leads to the graph above.

(3)

the sin function gives the graph an oscilating ~~t~~ pattern, The 5 increase V_{max} from 1 to 5, V_{min} from -1 to -5. A full cycle of a sin graph is 2π and of the graph shown is 0.02 $\frac{2\pi}{0.02} = 100\pi$

ResultsPlus
Examiner Comments

This answer was convincing for all 3 marks.

(ii) The formula used to generate this graph is $V = 5\sin(100\pi t)$

Explain why this formula leads to the graph above.

(3)

· Since the maximum value of Sin(100πt) = 1, the maximum value of V will be 5 and hence the peak ~~voltage~~ p.d. on the graph is 5V

· ~~The sine~~ Sin(100πt) gives the sinusoidal shape of the graph

· The coefficient of t (100π) applies a transformation the graph in the t direction, changing the time period from 2π seconds to 0.02s $\left(\frac{2\pi}{100\pi} = 0.02s\right)$

ResultsPlus
Examiner Comments

A good, clearly explained answer for full credit.

(ii) The formula used to generate this graph is $V = 5\sin(100\pi t)$

Explain why this formula leads to the graph above.

(3)

The coefficient of 5 means that $V_0 = 5$ as shown in the graph.
The $100\pi t$ in the sin means that there will be ~~$\frac{2\pi}{100\pi}$~~ ~~200.5~~ $\frac{100\pi}{2\pi}$ oscillations per second, $= 50$ oscillations per second. This implies that the time period for 1 oscillation $= \frac{1}{50}$ s $= 0.02$ s as we can see in the graph

ResultsPlus
Examiner Comments

A slightly different but equally convincing explanation for full credit.

(ii) The formula used to generate this graph is $V = 5\sin(100\pi t)$

Explain why this formula leads to the graph above.

(3)

As the maximum amplitude is 5V, so multiply sine graph by 5. Sine graph usually repeats every ~~360~~ 2π radians, so by multiplying t by π, it gives only integer values ON THE ~~GRHA~~ GRAPH. Also by multiplying by 100, it divides by 100 on the graph.

ResultsPlus
Examiner Comments

This gains the first two mark points for *V* max = 5 and for the idea of a normal sin graph having a period of 2pi.

(ii) The formula used to generate this graph is $V = 5\sin(100\pi t)$

Explain why this formula leads to the graph above.

(3)

the normal maximum of a Sin graph is 1 so multiplying by 5 gives a peak value of 5 and by multiplying time by 100π, you make the graph more frequent so it is more comparable to frequency of potential difference alternating. Sin graphs can be both positive and negative

ResultsPlus
Examiner Comments

This gains the mark point only for *V* peak = 5V.

Question 18 (b)(i)

This section of questions was linked to a spreadsheet.

This part examined a simple equation: $Q = CV$.

Candidates did have to state "where C = 0.001 F" or something similar for the second mark.

(b) A spreadsheet is used to model how the current I in the 1 mF capacitor varies with t. Six rows of the spreadsheet are shown below.

	A	B	C	D	E	F	G
	t / s	Δt / s	V / V	$Q_{initial}$ / C	Q_{final} / C	ΔQ / C	I / A
7	0.0050	0.0010	5.00	0.00476	0.00500	0.00024	0.24
8	0.0060	0.0010	4.76	0.00500	0.00476	–0.00024	–0.24
9	0.0070	0.0010	4.05	0.00476	0.00405	–0.00071	–0.71
10	0.0080	0.0010	2.94	0.00405	0.00294	–0.00111	–1.11
11	0.0090	0.0010	1.55	0.00294	0.00155	–0.00139	–1.39
12	0.0100	0.0010	0	0.00155	0.00000	–0.00155	–1.55

(i) Explain how cell E10 has been calculated.

(2)

by using the discharge formula for charge

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

ResultsPlus
Examiner Comments

Some candidates tried to use an exponential equation.

ResultsPlus
Examiner Tip

As cell E10 is being calculated try using your method. If it is correct it should produce the number in cell E10.

(b) A spreadsheet is used to model how the current I in the 1 mF capacitor varies with t. Six rows of the spreadsheet are shown below.

	A	B	C	D	E	F	G
	t / s	Δt / s	V / V	$Q_{initial}$ / C	Q_{final} / C	ΔQ / C	I / A
7	0.0050	0.0010	5.00	0.00476	0.00500	0.00024	0.24
8	0.0060	0.0010	4.76	0.00500	0.00476	–0.00024	–0.24
9	0.0070	0.0010	4.05	0.00476	0.00405	–0.00071	–0.71
10	0.0080	0.0010	2.94	0.00405	0.00294	–0.00111	–1.11
11	0.0090	0.0010	1.55	0.00294	0.00155	–0.00139	–1.39
12	0.0100	0.0010	0	0.00155	0.00000	–0.00155	–1.55

(i) Explain how cell E10 has been calculated.

(2)

Q initial + ΔQ

Q initial + (0.01 × −1.11) = ΔQ Final

ResultsPlus
Examiner Comments

A basic idea of a spreadsheet is that a calculation of a cell is based on the use of numbers from previous cells. This answer cannot be correct as it uses a number from a cell which will be calculated after E10, ie F10.

(b) A spreadsheet is used to model how the current I in the 1 mF capacitor varies with t. Six rows of the spreadsheet are shown below.

	A	B	C	D	E	F	G
	t / s	Δt / s	V / V	$Q_{initial}$ / C	Q_{final} / C	ΔQ / C	I / A
7	0.0050	0.0010	5.00	0.00476	0.00500	0.00024	0.24
8	0.0060	0.0010	4.76	0.00500	0.00476	–0.00024	–0.24
9	0.0070	0.0010	4.05	0.00476	0.00405	–0.00071	–0.71
10	0.0080	0.0010	2.94	0.00405	0.00294	–0.00111	–1.11
11	0.0090	0.0010	1.55	0.00294	0.00155	–0.00139	–1.39
12	0.0100	0.0010	0	0.00155	0.00000	–0.00155	–1.55

(i) Explain how cell E10 has been calculated.

(2)

$Q = CV$

$Q = 1 \times 10^{-3} \times 2.94 = 0.00294$

ResultsPlus
Examiner Comments

A fully correct answer for 2 marks.

(b) A spreadsheet is used to model how the current I in the 1 mF capacitor varies with t. Six rows of the spreadsheet are shown below.

	A	B	C	D	E	F	G
	t / s	Δt / s	V / V	$Q_{initial}$ / C	Q_{final} / C	ΔQ / C	I / A
7	0.0050	0.0010	5.00	0.00476	0.00500	0.00024	0.24
8	0.0060	0.0010	4.76	0.00500	0.00476	–0.00024	–0.24
9	0.0070	0.0010	4.05	0.00476	0.00405	–0.00071	–0.71
10	0.0080	0.0010	2.94	0.00405	0.00294	–0.00111	–1.11
11	0.0090	0.0010	1.55	0.00294	0.00155	–0.00139	–1.39
12	0.0100	0.0010	0	0.00155	0.00000	–0.00155	–1.55

(i) Explain how cell E10 has been calculated.

(2)

0.001 x 2.94 = 0.00294

Q = VΔt

ResultsPlus
Examiner Comments

The value (0.001 s) in cell B10 also looks as if it might have been used.

The equation Q = V delta t is not dimensionally correct, so this is an error of Physics.

Question 18 (b)(ii)

This question is similar to Q18(b)(i).

The relevant equation is *I* = delta *Q*/ delta *t*.

The spreadsheet accentuates the need for the correct "Q" and "t". Just Q and/or t on their own are not correct.

(ii) State the formula used to calculate cell G11.

(1)

$I = I_0 e^{-\frac{t}{RC}}$

ResultsPlus
Examiner Comments

As in the last question, a number of answers contained exponential equations.

ResultsPlus
Examiner Tip

The point of using a spreadsheet is that it removes the need for exponential equations.

Using a small enough interval of time for each row will produce an equivalent set of values compared to using an exponential model.

(ii) State the formula used to calculate cell G11.

(1)

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

ResultsPlus
Examiner Comments

This is incorrect as the current is equal to the change in charge divided by an interval of time.

The "deltas" are important.

ResultsPlus
Examiner Tip

Using a spreadsheet as a model for various situations in Physics is a great way to learn and understand more detail.

(ii) State the formula used to calculate cell G11. [illegible]

(1)

$I = \frac{dQ}{dt} = \frac{F11}{B11}$

ResultsPlus
Examiner Comments

d or delta was perfectly acceptable.

This candidate also explains which cells are used to calculate cell G11. This would have been acceptable in its own right.

Question 18 (b)(iii)

This final question on the spreadsheet examined the use of any of the "energy stored by a capacitor" equations.

As the question asked for the maximum energy, candidates needed to look for the correct row in the table.

The vast majority of candidates recognised this corresponded to 5 V. Some did not use the correct "Q" ie charge on the capacitor.

(iii) Calculate the maximum energy stored on the capacitor.

(2)

$W = \frac{1}{2}QV = \frac{1}{2} \times 0.00500 \times 5 = 0.0125\,J$

Maximum energy stored on the capacitor = 0.0125 J

ResultsPlus
Examiner Comments

This method is perfectly correct for full credit.

(iii) Calculate the maximum energy stored on the capacitor.

(2)

$W = \frac{1}{2}CV^2$

$= \frac{1}{2} \times 1 \times 10^{-3} \times 5^2 = 0.0125\,J$

Maximum energy stored on the capacitor = 0.0125 J

ResultsPlus
Examiner Comments

Most candidates quoted and used this equation. This answer is fully correct.

(iii) Calculate the maximum energy stored on the capacitor.

(2)

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

$C = \frac{Q}{\frac{W}{Q}}$ $W = \frac{Q^2}{C} = \frac{0.00476^2}{1\times10^{-3}} = 0.02J$

$CW = Q^2$

Maximum energy stored on the capacitor = 0.02J

ResultsPlus
Examiner Comments

This answer uses a correct equation. But it uses an incorrect value of charge from the spreadsheet. This value is not the maximum charge (0.005 C) at this potential difference.

Question 18 (c)

This final question proved challenging for many candidates.

The current and potential difference graphs both show changes in sign from + to – .

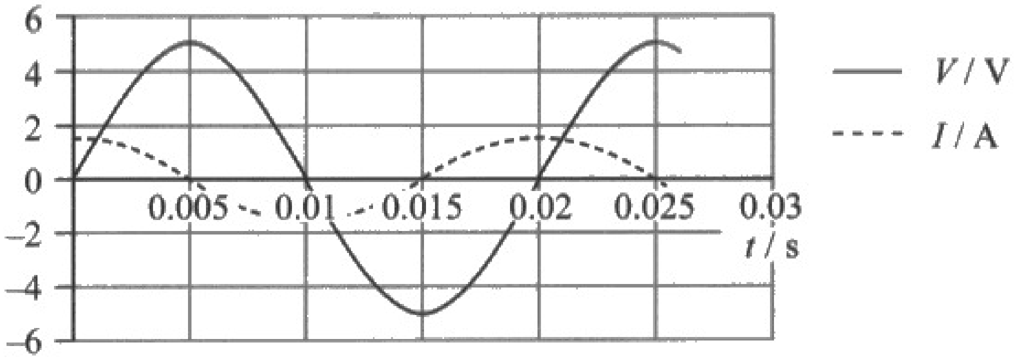
Note that although both are initially +, after 0.005 s, the pd is + but the current is – .

Power therefore changes sign and does so every quarter cycle.

Sometimes the capacitor is storing energy and sometimes it dissipates it.

Overall the two cancel and there is no net dissipation (or storing) of power in the capacitor.

(c) The spreadsheet data are used to plot a graph to show how I varies with t. This is shown as a dashed line below.



The corresponding graph of V against t is also shown as a continuous line.

Deduce whether the capacitor dissipates power over one cycle of the a.c. supply.

(4)

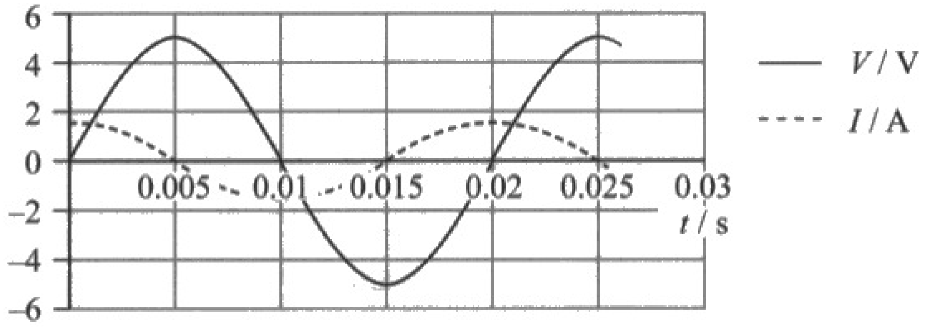
$P = IV$

The capacitor will not dissipate power over one cycle of the a.c supply as seen on the graph. When V is maximum, this is at points where I is 0 and when I is maximum, V is 0. Therefore they are out of phase with each other and so as per equation $P = IV$, this means no power is dissipated.

ResultsPlus
Examiner Comments

A number of answers went one step further than the example above and went on to say that no power is dissipated by the capacitor over a cycle. This then gained mark point 4.

(c) The spreadsheet data are used to plot a graph to show how I varies with t. This is shown as a dashed line below.



The corresponding graph of V against t is also shown as a continuous line.

Deduce whether the capacitor dissipates power over one cycle of the a.c. supply.

(4)

P=VI

when potential difference is at maximum the current is 0. So there is 0 power at those points. when the potential difference is increasing current decreases so there is power at these points. when potential difference is 0 current is at maximum so no power at those points.

(Total for Question 18 = 13 marks)

TOTAL FOR PAPER = 90 MARKS

only power when current and potential difference are increasing or decreasing.

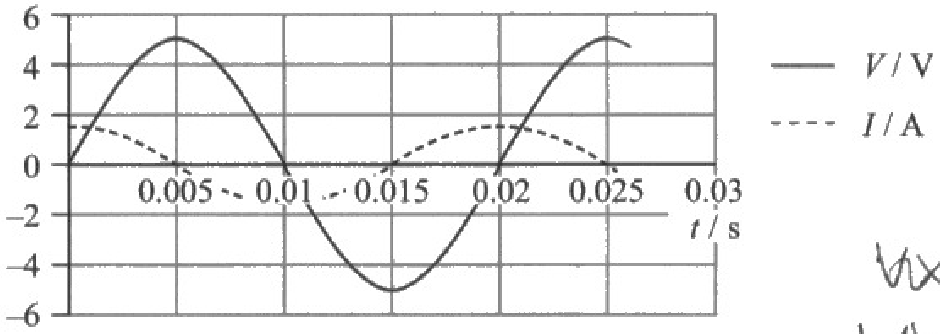
ResultsPlus
Examiner Comments

Some candidates offered answers in which they attempted to use *P* = *IV* with a pair of corresponding values of *V* and *I*.

These answers could usually gain two marks (mark point 1 and mark point 2).

They often involved recognising that *I* = 0 when *V* is a maximum (or vice versa).

(c) The spreadsheet data are used to plot a graph to show how I varies with t. This is shown as a dashed line below.



VxIxt
Vt = Area
It = Area

The corresponding graph of V against t is also shown as a continuous line.

Deduce whether the capacitor dissipates power over one cycle of the a.c. supply.

(4)

One Cycle = 0·02s.

Power dissipated = IV

Vt = Area between bold line and axis
It = Area between dotted line and axis.
∴ Power = Area between bold line and dotted line

(Total for Question 18 = 13 marks)

TOTAL FOR PAPER = 90 MARKS

Because both Curves are Symmetrical above and below time axis from 0s → 0·02s, total Area between lines = 0.
∴ No Power dissipated

ResultsPlus
Examiner Comments

Very few answers explained the situation convincingly however this example is a very good answer.

An alternative to substituting values into $P = IV$ for mark point 2 was to recognise the symmetry of the graph(s).

The examiner then considered that this answer says enough about the area above and below the line to recognise the idea of positive and negative power.

It gained full credit.

Paper Summary

Based on their performance on this paper, candidates should:

- Remember that energy can provide an alternative approach when solving a mechanics question.
- Write down the relevant equation when carrying out a calculation and then substitute the numerical values, before rearranging the equation.
- Consider that momentum conservation questions can be solved elegantly using a labelled, vector diagram. This method is usually quicker than a calculation.
- Note that free-body force diagrams are not as straightforward as people think.
- Consider that spreadsheets can be an interesting way to model a number of scenarios in Physics.

Grade boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

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