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Examiners' Report
June 2015

GCE Physics 6PH04 01

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Introduction

This paper was generally well answered with candidates able to attempt all question parts and demonstrate a good understanding of the physics that was being tested. All of the question parts were accessible to the majority of candidates and all of the marks were awarded to some candidates. There were a number of question parts that were more challenging and these provided good discrimination across the paper.

For question 5 candidates chose the answers that had s^{-1} in the unit presumably because that implies a rate. For question 7 the common wrong answers involved a subtraction, probably based on the tension and weight being in opposite directions. For question 8 all three wrong answers were equally chosen. This was a calculation that candidates did not need to actually work out. If candidates substituted into $a = Ee/m$ and considered the powers of ten, it could only be answer D. For question 9 although energy is mentioned in A and B, there is no indication that all of the mass becomes energy so they are wrong. For question 10 although the LHC does allow protons to collide and the annihilation of protons and antiprotons, these collisions can occur at lower energies.

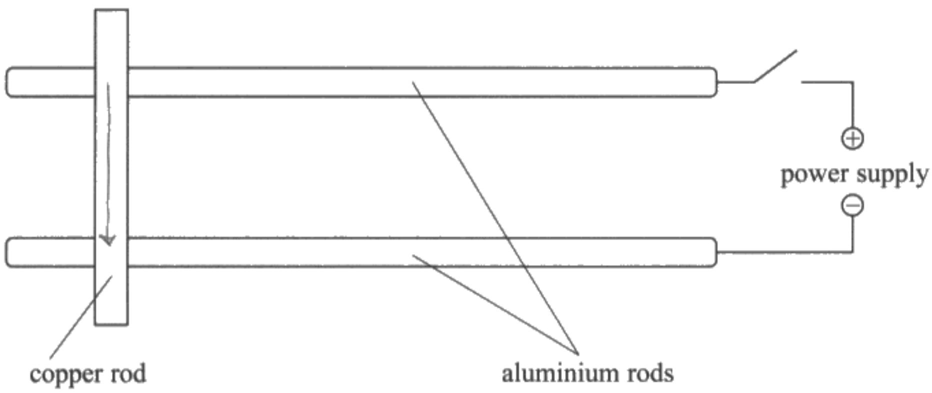
Question 11

This was a straightforward question at the start of the paper with 60% of candidates scoring all three marks and most candidates achieving some credit. Mistakes were more often made with the identification of current direction, the issue of electron flow and conventional current causing this problem. Candidates who thought that the current was in the reverse direction could still score the marks in (b) if their answer was consistent with their current direction. Descriptions of Fleming's left hand rule were not required but some candidates who wrote a correct description went on to get the direction of the field wrong.

SECTION B

Answer ALL questions in the spaces provided.

11 The apparatus shown in the diagram can be used to demonstrate that a force acts on a current-carrying conductor when the conductor is in a magnetic field.



The apparatus is placed in a magnetic field. When the switch is closed, the copper rod rolls along the aluminium rods.

(a) Add to the diagram to indicate the direction of the current in the copper rod. **(1)**

(b) State the direction of the magnetic field that will make the copper rod move to the right. **(2)**

The magnetic Should be out of the page. Using the right hand rule.

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Examiner Comments

This scored full marks with the marks for (a) being scored for the first five words. The explanation was perfectly correct but was not needed.

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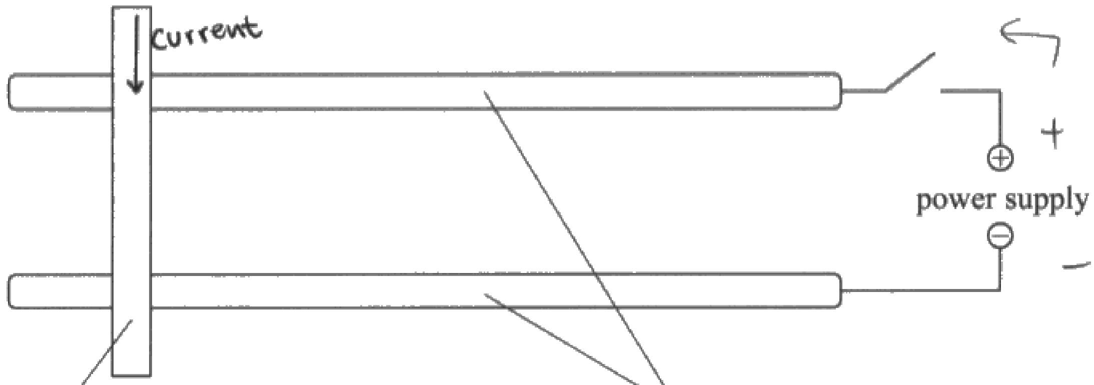
Examiner Tip

Notice the command words. State means that you do not have to write much and do not need to explain. All that was needed for the marks was the idea that the field was perpendicular to the field for one mark and into the page for the second mark. The answer written here would have been expected if the question has said 'state and explain...'

SECTION B

Answer ALL questions in the spaces provided.

11 The apparatus shown in the diagram can be used to demonstrate that a force acts on a current-carrying conductor when the conductor is in a magnetic field.



The apparatus is placed in a magnetic field. When the switch is closed, the copper rod rolls along the aluminium rods.

(a) Add to the diagram to indicate the direction of the current in the copper rod.

(1)

(b) State the direction of the magnetic field that will make the copper rod move to the right.

(2)

Magnetic field acts into the paper. By FLHR, the B-field must be perpendicular to the current and the force acting on it, as current is in direction of vertically down and force is acting horizontally to the right, magnetic field must be in a direction which goes into the page/paper.

(Total for Question 11 = 3 marks)

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Examiner Comments

This candidate had the current in the correct direction but did not apply Fleming's left hand rule correctly. Question (b) scored 1 mark for the idea that fields are perpendicular to both current and direction of motion.

Question 12 (a)

It is very pleasing to note that 94 % of the candidates were able to identify the π^- pion correctly.

Question 12 (b)

This is a standard unit conversion that continues to prove challenging for less successful candidates. The common errors are to fail to square the value *c*, to divide and later multiply by c^2 and to divide by *e* and multiply by c^2. In addition there is also the issue of unit conversion.

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

Calculate the mass of a pion in kg.

(3)

$E = mc^2$ $\quad 140\,MeV = mc^2$

$140{,}000{,}000 \times 1.6\times10^{-19} = 2.24\times10^{-11}\ J$

$1eV = 1.6\times10^{-19}$ $\quad m = \frac{2.24\times10^{-11}}{(9\times10^{16})}$

$m = 2.49\times10^{-28}\ kg$

Mass = 2.5×10^{-28} kg

(Total for Question 12 = 4 marks)

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Examiner Comments

This was an example of a correct answer that scored 3 marks

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

Calculate the mass of a pion in kg.

(3)

140 ~~MeV/c^2~~

$140 \times (3\times10^8)^2 = 1.26\times10^{19}$ MeV

$= 1.26 \times 10^{22}$ eV

1 eV = 1.6×10^{-19} J

1.26×10^{22} eV = 2.016

Mass = 2.02 kg

(Total for Question 12 = 4 marks)

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Examiner Comments

The candidate has wrongly multiplied by c^2 and, although it was not stated, multiplied by e so this scored zero.

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Examiner Tip

Be careful setting out calculations and do not write down as equal two numbers which obviously are not equal.

Question 13

This question started with a calculation in (a) and then went on to a description about the effect of changing a variable. 28% of candidates scored all 6 marks but the most common score was 4, with 2 marks lost in either part (a) or (b). The most common error in (a) was to omit 'g' when calculating the frictional force, so losing 2 marks. For less successful candidates marks were also lost due to poor rearranging of equations. For less successful candidates, it is better to substitute first and then rearrange, they will then get credit for substituting into a correct equation. If they substitute into an incorrect equation they will not score marks. A small number of candidates calculated the frictional force and then subtracted it from the weight and used that value in subsequent calculations. There were many well-argued answers for (b) showing a clear understanding that the time period was independent of the mass. However a significant number of answers thought that the time was different with the answers based on just considering the frictional force.

(a) Calculate the minimum time taken for one revolution of the roundabout if the child is not to slide off.

(4)

Maximum frictional force = $0.35 \times 20 \times 9.81 = 68.67$ N

Maximum centripedal force provide by frictional force = 68.67 N

$F = ma \quad a = r\omega^2$

$F = mr\omega^2$

$68.67 = 20 \times 0.8 \times \omega^2$

$\omega = 2.0716841$

$T = \frac{2\pi}{\omega} = \frac{2\pi}{2.0716841} = 3.03$ s

Minimum time = 3.03 s

(b) State and explain how this time would change if a child of larger mass sat at the same place on the roundabout.

(2)

As $F = mr\omega^2$ and F is given by frictional force, $F = 0.35 \times mg$ by combining two equations $mr\omega^2 = 0.35mg$, ~~0.35~~ $0.35g = r\omega^2$. Therefore mass is not include in the equation and the time taken $\left(\frac{2\pi}{\omega}\right)$ is independent of the mass, so the time taken will stay the same with a child of larger mass.

(Total for Question 13 = 6 marks)

ResultsPlus
Examiner Comments

A well laid out answer that scored full marks. The use of words to explain the calculation enable an examiner to follow the workings.

(a) Calculate the minimum time taken for one revolution of the roundabout if the child is not to slide off.

$r = 0.8 \quad f = 7 \quad m = 20$

(4)

Max friction force = $0.35 \times 20 = 7N$

$F = ma \quad a = F/m = \frac{7}{20} = 0.35 \, ms^{-2}$

$a = r\omega^2 \quad \omega = \sqrt{\frac{a}{r}} = \sqrt{\frac{0.35}{0.8}} = 0.6614 \, rads^{-1}$

$T = \frac{2\pi}{\omega} = \frac{2\pi}{0.6614} = 9.50 \, s$

Minimum time = 9.5 s

(b) State and explain how this time would change if a child of larger mass sat at the same place on the roundabout.

(2)

Child of larger mass has a greater maximum frictional force between them and roundabout. Therefore roundabout can accelerate faster without child falling off, hence shorter time period for one revolution.

(Total for Question 13 = 6 marks)

ResultsPlus

Examiner Comments

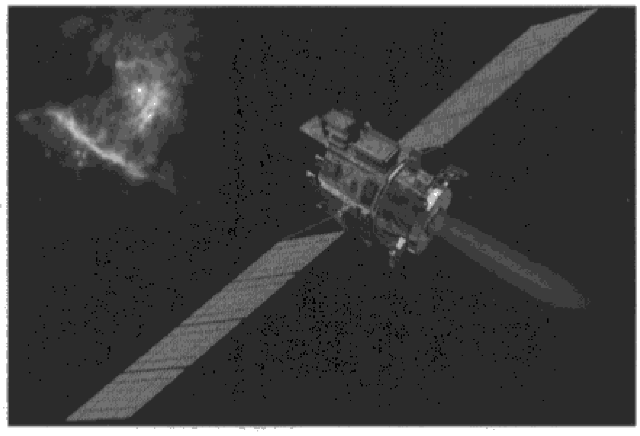
This was an example of the common wrong answer where the frictional force was written as 0.35 x 20 = 7N. If candidates are encouraged to use quantity algebra (as in the MS) where each quantity is written as a number and unit, this mistake might not have been made, i.e. F = 0.35 x 20 kg x 9.81 m s^{-2} = 68.7 N. If the candidate in this example had written kg, they might have thought twice about their answer.

For (b) another common wrong answer where the candidate only considers the frictional force.

Question 14

This question discriminated well with most candidates being able to state that momentum was conserved in this situation. The less successful candidates who just quoted the conservation of momentum without applying it did not score any marks. Most candidates were able to explain that the fuel tank moved away from the probe. However most candidates ignored the stem which told them clearly that the probe was moving, instead assuming that the initial momentum was zero. The majority of candidates attributed the increase in speed of the probe due to a reduction in its mass. Hardly any candidates appreciated that there were equal but opposite changes in momentum so only 2% of candidates scored full marks for this question. In general candidates had more difficulty in applying conservation of energy. Many focussed on kinetic energy not being conserved, some thought kinetic energy was conserved by treating it as a vector and some candidates thought that kinetic energy was converted to chemical energy, for the explosion to occur. In general there was a great deal of confusion between total energy kinetic energy and elastic and inelastic collisions. The most common score for the question was 3 marks.

***14** The photograph shows a probe moving in space.



Whilst moving, empty fuel tanks can be ejected by means of an explosion. This has the effect of increasing the speed of the probe.

Discuss whether conservation of momentum and conservation of energy apply in this situation and why the speed of the probe increases.

(6)

• Both momentum and energy are conserved in this situation.

$M_T V_T = M_P V_P + (M_F(-V_F))$, The fuel tank (F) is moving in the opposite direction

$M_T V_T = M_P V_P - M_F V_F$, the momentum before and after the explosion are the same

As the fuel tanks change from positive to negative velocity (+ve to the direction the probe originally moves)

As velocity of the probe without the fuel tanks must increase to conserve momentum,

• Energy cannot be made or destroyed, only converted from one form to another,

the chemical potential energy during the explosion is converted to a range of different energies, thermal, sound, light and kinetic energy. So its kinetic energy must increase

As the kinetic energy increases, while its mass is slightly decreased, must mean the speed of the probe increases $\uparrow K.E = \frac{1}{2} \downarrow m \uparrow v^2$, $(K.E = \frac{1}{2} mv^2)$

∴ This is why the speed of the probe increases after the explosion

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Examiner Comments

This was an example that scored 5 marks, just losing the mark for equal changes in momentum. In line 8 of the answer, we accepted that the 'it' is the probe although it would have been better if the word probe had been used there. There was no credit given for the equations since the terms were not defined but the words of the answer were clear enough for 5 marks to be awarded.

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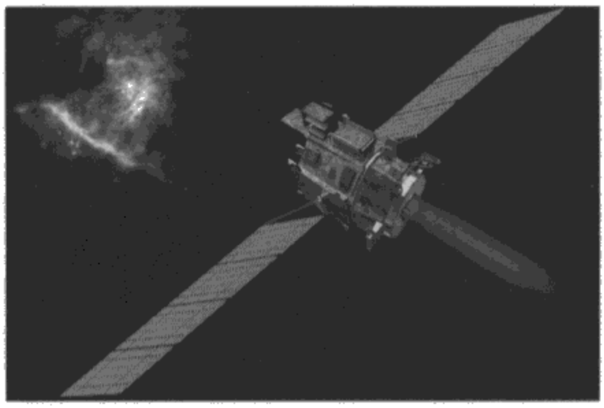
Examiner Tip

In a descriptive answer remember to define all symbols used. Also be careful in a long sentence to be sure that the subject of the sentence is clear to an examiner.

*14 The photograph shows a probe moving in space.



Whilst moving, empty fuel tanks can be ejected by means of an explosion. This has the effect of increasing the speed of the probe.

Discuss whether conservation of momentum and conservation of energy apply in this situation and why the speed of the probe increases.

(6)

Momentum is always conserved. ~~[illegible]~~ Before the explosion the toatal momentum is zero. When the fuel tank is edjected it has negative momentum and so the probe will move forward with positive momentum and so the speed will increase. ~~Momentum = mass x velocity and [illegible]~~ The probe and the fuel tank are different sizes and so this will be an inelastic collision and energy will not be conserved. Energy will be lost to things like heat when the ~~[illegible]~~ fuel tank rubs against the probe, when it is being edjected.

ResultsPlus

Examiner Comments

This was an example of where the candidate has ignored the probe moving in space. This also showed the confusion over energy because it stated that it was an inelastic collision so energy was not conserved.

Question 15

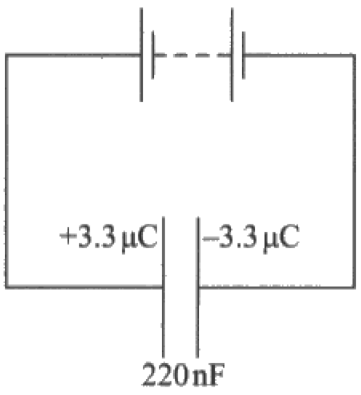
This question was marked as a single clip so there are only statistics for the question as a whole and not the individual sections. 60% of candidates scored in the range of 5 to 8 marks of the possible 12 with some candidates scoring all of the possible totals.(a) Many candidates were caught out by the charges being written on the plates of the capacitor and so they used 6.6 μC instead of 3.3 μC. This meant a loss of 2 marks in this section.

(b) A lot of the candidates were able to manipulate the exponential equation but a common wrong error was to find the time for the charge to fall to 80% of its initial value instead of the 20% required. Another 2 mark loss. Careful reading of the question is needed. The less successful candidates do struggle with the exponential equation and continue to confuse the symbol C for coulombs and the symbol C for capacitance.

(c) This was generally poorly answered with candidates struggling to explain and be confident in terms of what had changed. Many candidates chose to use $W= QV/2$ which is perhaps the easier equation to work with. However they assumed that V remained constant and argued that the times would be equal. Candidates who chose to use $W = Q^2 /2C$ did have only one variable to deal with but struggled to explain the significance of halving a term that is squared.Other candidates went for the scatter gun approach, i.e. write down every equation that relates to capacitors and energy and hope for the best. This did not get any credit.

(d) The question asked for the advantages of the data logger to record the results. Therefore the fact that the computer could draw a graph had nothing to do with recording the results and so was not credited. Answers to questions about data loggers must answer the question asked and relate to the specific experiment. Human reaction time is not an issue in this experiment since you are not regularly starting and stopping a stopwatch. That would be an issue in an oscillation type experiment. The one advantage of data loggers that does apply to all experiments is that there is an increased rate of taking readings. Just saying a data logger can take lots of results is not enough. In this capacitor discharge experiment it is the taking of synchronous readings that is the advantage. No credit is given for general statements such as more accurate, more precise, etc.

15 A capacitor is charged by a battery as shown in the circuit diagram.



(a) Calculate the e.m.f. of the battery and the energy stored in the charged capacitor.

(4)

$Q = 6.6\,\mu C$ $\quad C = \frac{Q}{V}$

$C = 220\,nF$ $\quad V = \frac{Q}{C}$

$= \frac{6.6 \times 10^{-6}}{220 \times 10^{-9}}$

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

$= \frac{1}{2} \times 220 \times 10^{-9} \times 30^2$ $\quad = 30$

E.m.f. = 30V

Energy = 9.9×10^{-5} J

(b) The capacitor is disconnected from the battery and discharged through a 20 MΩ resistor.

Calculate the time taken for 80% of the charge on the capacitor to discharge through the resistor.

(3)

$0.2 Q_0 = Q_0 e^{-\frac{t}{RC}}$

$0.2 = e^{-t/RC}$

$\ln(0.2) = -\frac{t}{RC}$

$t = -RC\ln(0.2)$

$= -20 \times 10^{6} \times 220 \times 10^{-9} \times \ln(0.2)$

$= 7.08s$

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Examiner Comments

The common wrong answer for (a) where double charge has been used, 2 marks awarded. (b) is correct for all 3 marks, finding the time when the charge is 20% of its original value.

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Examiner Tip

Remember that when there is a charge Q on a capacitor, it means +Q on one plate and -Q on the other plate.

Read the question; the exponential equation gives you how much charge is on the capacitor after a certain time. The question asked for how long for the capacitor to lose 80% of its charge, i.e. it has 20% left.

(c) Use an equation to explain whether the time taken for the capacitor to lose half its energy is greater or less than the time taken to lose half its charge.

(3)

~~Use half of charge: $t = -RC\ln\left(\frac{Q}{Q_0}\right)$~~

$E = \frac{QV}{2}$ Both charge and ~~voltage~~ potential difference decrease over time. Therefore, energy would become half of its original value first, so would take less time.

(d) A student carries out an experiment to record data so that she can plot a graph of potential difference against time as the capacitor discharges.

State **two** advantages of using a datalogger rather than a voltmeter and stopwatch to record this data.

(2)

- A data logger can record results at very small intervals very quickly
- A datalogger removes the error that would be introduced by the reaction time of the student.

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Examiner Comments

(c) A clear answer that scored 3 marks.

(d) 1 mark awarded for the recording results at very small intervals

(c) Use an equation to explain whether the time taken for the capacitor to lose half its energy is greater or less than the time taken to lose half its charge.

(3)

does $\frac{1}{2}E = \frac{1}{2}Q$ for t

If so at 7.08 s , $E = \frac{1}{2} \times 9.9 \times 10^{-5} = 4.95 \times 10^{-5}$

(d) A student carries out an experiment to record data so that she can plot a graph of potential difference against time as the capacitor discharges.

State **two** advantages of using a datalogger rather than a voltmeter and stopwatch to record this data.

(2)

Excludes human errors in recording time and human errors in time delay.

Volt meter and stopwatch method may need more than one ~~sec~~ person to be accurate but data logger can be opperated by one person.

(Total for Question 15 = 12 marks)

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Examiner Comments

No marks awarded for (c), many candidates did not know how to approach this question part.

(d) A mark was given for the idea that two people are needed for the stopwatch and voltmeter; it conveys the right idea about synchronous readings.

Question 16 (a)

This is a standard definition which all candidates are capable of learning. All of the reasons why candidates did not score both marks were seen; produced not induced, voltage or current instead of e.m.f, no indication of rate or time, just writing the equation without defining symbols and woolly answers relating to a conductor's movement and magnetic fields. 53% scored 2 marks, 30% scored 1 mark and 17% scored 0.

16 (a) State Faraday's law of electromagnetic induction.

(2)

The emf induced is proportional to the rate of change of flux linkage.

ResultsPlus
Examiner Comments

This was a model answer which scored 2 marks.

ResultsPlus
Examiner Tip

Learn your definitions.

16 (a) State Faraday's law of electromagnetic induction.

(2)

The induced emf is directly propotional to flux linkage.

ResultsPlus
Examiner Comments

This response was awarded 1 mark for induced e.m.f. but no indication of rate or time.

ResultsPlus
Examiner Tip

Learn your definitions.

16 (a) State Faraday's law of electromagnetic induction.

(2)

The magnitude of the emf produced is proportional to the rate of change of magnetic flux linkage.

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Examiner Comments

No induced mentioned so 1 mark for the rate of change of flux linkage.

ResultsPlus

Examiner Tip

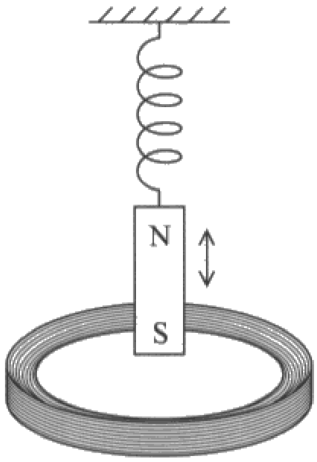
Learn your definitions.

Question 16 (b)

Candidates need to read the question and answer accordingly. The defintion in (a) clued candidates into the question being about electromagnetic induction which meant we had lots of flux cutting. What the examiners were looking for was that the copper, which wasn't moving, was in a changing magnetic field. The majority of candidates focussed on the direction change of motion altering the direction change of the current as the reason for the a.c. Hardly any candidates referred to the magnitude of the e.m.f./current depending on the speed of the magnet or the rate of change of flux linkage, so MP4 was hardly ever awarded.

The decision was made that, for this paper, we would not insist on the closed loop (hence it is in brackets on the MS) but in future exams it could be expected. This meant that 2 and 3 were the most commonly awarded marks with only 3% scoring all 4 marks.

*(b) A magnet is attached to the end of a spring as shown in the diagram.



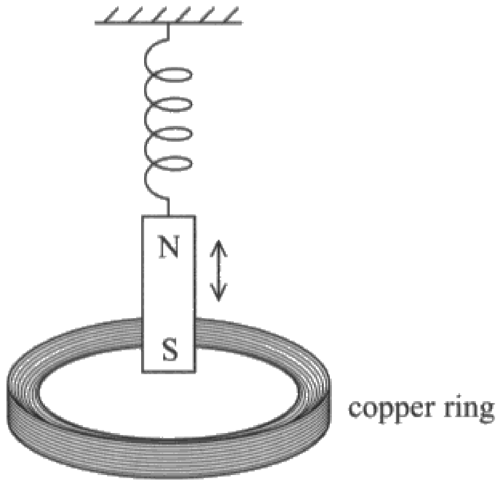
The magnet is displaced vertically and released so that it oscillates.
Explain why this produces an alternating current in the copper ring.

(4)

The movement of the magnet passes a magnetic field across the ring each time it oscillates. This causes a change in magnetic flux which induces an e.m.f and therefore current flows in the copper ring. Each time the magnet bounces it goes up and down, and as the e.m.f opposes the motion of field, the current in the ring will alternate +ve and -ve.

ResultsPlus
Examiner Comments
An example that scored 3 marks, no reference to the magnitude of the e.m.f.

*(b) A magnet is attached to the end of a spring as shown in the diagram.



The magnet is displaced vertically and released so that it oscillates.
Explain why this produces an alternating current in the copper ring.

(4)

Copper ring produces an alternating magnetic field. When the magnet is displaced vertically it cuts the magnetic field lines which produces an alternating emf which induces an alternating current in the copper ring. Lenz's law states the induced emf causes a current to flow in such a direction as to oppose the change in flux linkage that created it. $\varepsilon = -\frac{\Delta N\Phi}{\Delta t}$

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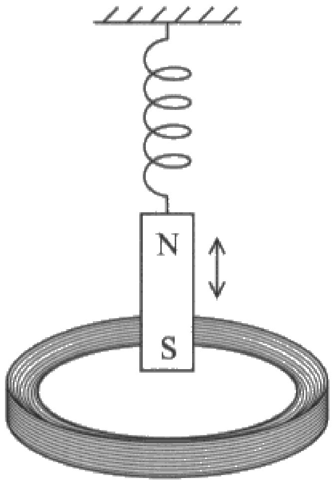
Examiner Comments

The copper will produce a magnetic field when there is a current flowing but not initially. There was enough in the answer to be able to award MP1. Induced current was not a replacement for induced e.m.f and also the answer referenced to Lenz's law but did not say what that meant in terms of current direction. This scored 1 mark.

*(b) A magnet is attached to the end of a spring as shown in the diagram.



The magnet is displaced vertically and released so that it oscillates.
Explain why this produces an alternating current in the copper ring.

(4)

When the magnet is travelling downwards, it induced an emf in one derection around the copper ring as it is travelling towards the center. When it passes through it is moving away and therefore an emf is induced in the opposite derection. This continuous change in movement relative to the copper ring produces an alternating current

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Examiner Comments

This scored 2 marks for the induced e.m.f. and the opposite directions.

Question 16 (c)

There was a noticeable difference between the candidates who understood the relationship between flux density and flux linkage and those who didn't. The latter either dividing the flux density by the area or leaving the area out entirely and thinking that the rate of change of flux density was the induced e.m.f. itself. Candidates who understood the relationship could do the calculation easily and so the most common marks were 4 or 0. For those in between, a frequent error was to use circumference instead of area. Also candidates do not seem to bother about ridiculous answers; 66 000 A was seen. A good exam technique is to take time to assess an answer and if ridiculous look for an error that caused it.

(c) The average vertical component of the magnetic flux density through the coil varies at a maximum rate of 0.035 T s^{-1}.
Calculate the maximum current in the copper ring.

radius of copper ring = 5.0 cm
resistance of copper ring = $6.7 \times 10^{-5}\ \Omega$

(4)

$\varepsilon = \frac{d(BAN)}{dt}$ $\quad \varepsilon = 0.035 \times (5\times10^{-2})^2\pi$

$= 2.75\times10^{-4}$ V

$V = IR \quad I = \frac{2.75\times10^{-4}}{6.7\times10^{-5}} = 4.1$ A

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Examiner Comments

This was a model answer which was clearly laid out and scored 4 marks.

(c) The average vertical component of the magnetic flux density through the coil varies at a maximum rate of 0.035 T s^{-1}.
Calculate the maximum current in the copper ring.

radius of copper ring = 5.0 cm
resistance of copper ring = $6.7 \times 10^{-5}\ \Omega$

(4)

$R = \frac{V}{I} \quad I = \frac{V}{R} = \frac{0.035}{6.7\times10^{-5}} = 522$ A

ResultsPlus
Examiner Comments

An example where rate of change of flux density was assumed to be the e.m.f. This scored 0 marks.

ResultsPlus
Examiner Tip

Look at the marks, a 4 mark calculation will have at least two steps. This answer as written could not possibly be worth 4 marks.

(c) The average vertical component of the magnetic flux density through the coil varies at a maximum rate of 0.035 T s^{-1}.
Calculate the maximum current in the copper ring.

radius of copper ring = 5.0 cm
resistance of copper ring = 6.7×10^{-5} Ω

(4)

$I = \frac{V}{R}$ $V = \frac{d(N\phi)}{dt}$

$V = 5.0\times10^{-2} \times 2\pi \times 0.035$

$= 0.0110\,V$

$I = \frac{V}{R} = \frac{0.0110}{6.7\times10^{-5}} = 164\,A$

ResultsPlus
Examiner Comments

This candidate found a circumference instead of an area. This scored MP3 for the use of $V = IR$ since the candidate used a calculated value of V.

Question 17 (a)

Some candidates found this extremely difficult mainly because they did not seem to know what was meant by base units. 70% of candidates scored 0 or 1. Many answers were left in terms of Newtons and if they did write kg m s^{-2} as the base units for force, they left charge as C or wrote it as A s^{-1}. A knowledge of base units is fundamental to physics and it is expected that all candidates know these units and can work with them.

30% of candidates could express the N and C in base units and so scored 2 marks but half of those were unable to rearrange the units to give the correct answer.

17 (a) Coulomb's law for the force F between point charges Q_1 and Q_2, which are a distance r apart, is given by

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Express the unit of ε_0 in base units.

(3)

$$4\pi\varepsilon_0 r^2 f = Q_1 Q_2$$

$$\varepsilon_0 = \frac{Q_1 Q_2}{r^2 f} = \frac{(As)(As)}{(m)^2 (kgms^{-2})}$$

$$= kg^{-1} A^2 m^{-3} s^4$$

ResultsPlus
Examiner Comments

This was a correct answer which scored all 3 marks.

ResultsPlus
Examiner Tip

Learn your base units and practice rearranging equations.

17 (a) Coulomb's law for the force F between point charges Q_1 and Q_2, which are a distance r apart, is given by

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Express the unit of ε_0 in base units.

(3)

$\varepsilon_0 = \frac{Q_1 Q_2}{4\pi F r^2}$

ε_0 units $= N^{-1} m^{-2} C^2$

ResultsPlus

Examiner Comments

This was a common wrong answer.

ResultsPlus

Examiner Tip

Look at the marks, this answer cannot be worth 3 marks, which is the clue that more work needs to be done.

17 (a) Coulomb's law for the force F between point charges Q_1 and Q_2, which are a distance r apart, is given by

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$$

Express the unit of ε_0 in base units.

(3)

$\frac{kgm}{s^2} = \frac{A^2 s^2}{m^2 \varepsilon} \Rightarrow \varepsilon = $ ~~$\frac{A^2}{kgm^3}$~~ $\frac{A^2}{kgm^3}$

ResultsPlus

Examiner Comments

This response was not very well laid out but using the equation given, the units for force and charge were correct but the rearranging was wrong.

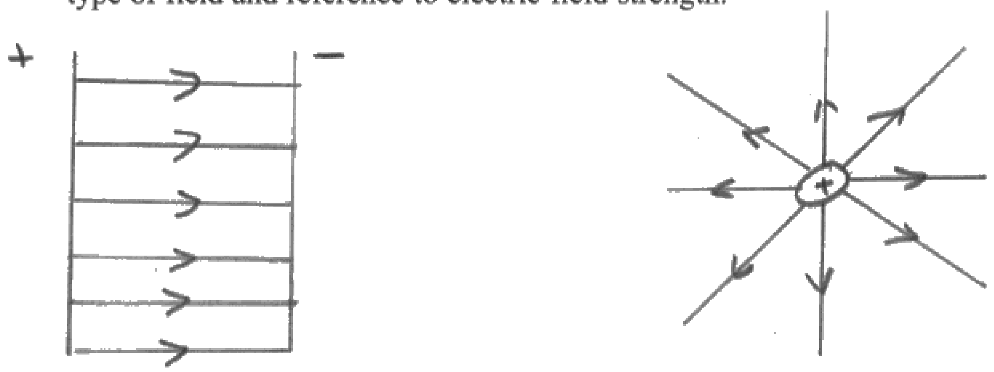
Question 17 (b)

This was generally well answered with 80% of candidates scoring 3, 4 or 5 marks. The most frequently lost mark was for the description of the electric field strength between parallel plates. Many chose to say that it was constant. This implied that it was not changing over time and was not telling us that all of the points have the same value. Candidates need to be told to say that the value of the field is the same at all points in the field. Also marks were lost by omitting the word strength and just referring to field or force. The diagrams were generally good enough for the first two marking points but some marks were lost due to careless errors, asymmetry, lines not touching the plates, lines nowhere near straight etc. Also the more lines candidates draw the more likely they are to have uneven gaps etc. A minimum of 4 is needed for the radial field and 3 for the parallel plates field.

(b) Electric fields are caused by both point charges and by parallel plates with a potential difference across them.

Describe the difference between the electric field caused by a point charge and the electric field between parallel plates. Your answer should include a diagram of each type of field and reference to electric field strength.

(5)



The eletic field produced between ~~two~~ two plates depends on the potential difference between the plates. The eletic field strength for two ~~para~~ parallel plates is constant ~~throughout~~ anywhere in the field. The point charge has ~~an~~ an electric field which is a radial so it follows an inverse square law so moving away from it greatly decreases the strength. The general strength is dependent on it's charge.

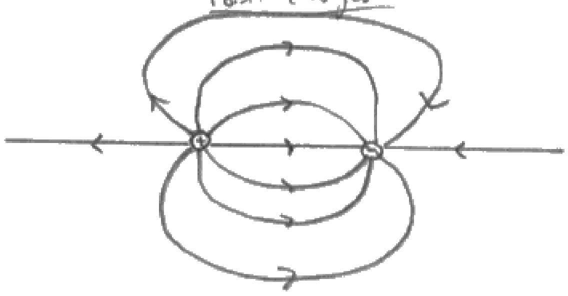
ResultsPlus

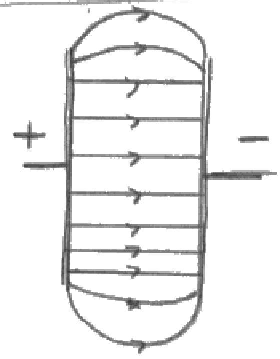
Examiner Comments

This response scored 4 marks, good diagrams but referred to a constant field between the plates.

(b) Electric fields are caused by both point charges and by parallel plates with a potential difference across them.

Describe the difference between the electric field caused by a point charge and the electric field between parallel plates. Your answer should include a diagram of each type of field and reference to electric field strength. **(5)**





$E = V/d$

$E = F/Q$

The electric field caused by a point charge acts radially outwards. On the other hand the electric field between two parallel plates is direct between the two. Efs on the plates is proportional to distance whereas on the point charge it is constant. The fields are uniform on both.

ResultsPlus Examiner Comments

The point charge diagram was wrong because it was not one point charge. This scored 2 marks, MP1 and MP3. The words scored nothing, as there was no mention of electric field strength, inverse square law etc.

ResultsPlus Examiner Tip

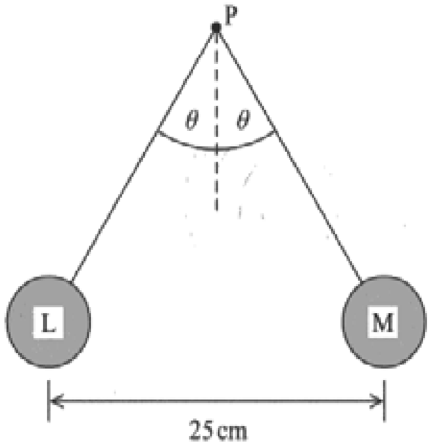
Read the question carefully. Although point charges (plural) are mentioned in the stem, the question is about the field caused by a (singular) point charge.

Question 17 (c)

This was quite a stretching calculation involving the use of Coulomb's law, either resolving forces or Pythagoras and trigonometric functions as well as unit conversions. What was really pleasing was that 50% of the candidates scored the full 6 marks. Significantly, another 15% scored the 4 method marks and the reason they did not get the final answer was because they either halved the separation, i.e. used 12.5 cm instead of 25 cm or having found the electric force, then proceeded to use half of that value. It is noticeable that candidates who really did not know how to do this type of calculation ended up writing equations with numbers but no symbols so it was very difficult to be able to give any credit. A few words like 'weight =....' help tremendously. The Pythagoras method was more common but most candidates made a good attempt. Other than the mistakes already identified, others were failing to square the separation or the charge, resolving incorrectly, getting tan the wrong way round and omitting the *g* in *W* = *mg.* What never fails to amaze me is that when doing a calculation with Coulomb's law, candidates use Boltzmann's constant for *k*.

(c) Two small spheres L and M are attached to non-conducting threads and suspended from a point P. Each sphere is given an equal positive charge of 4.0×10^{-7} C. The spheres hang in equilibrium as shown in the diagram.

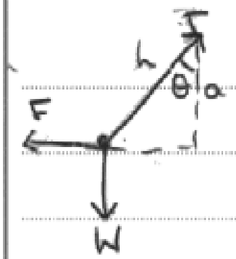
The mass of each sphere is 2.7 g.



By considering the forces acting on one of the spheres, calculate the tension in the thread and the angle θ.

$\cos\theta = \frac{W}{T}$ $\quad \sin\theta = \frac{F}{T}$

(6)



$W = T\cos\theta \qquad F = T\sin\theta$

$(2.7\times10^{-3})g = T\cos\theta \qquad F = \frac{kQ_1Q_2}{r^2} = \frac{8.99\times10^{9} \times (4\times10^{-7})^2}{(0.25)^2}$

$0.026N = T\cos\theta$ ① $\qquad = 0.023N$

$0.023N = T\sin\theta$ ②

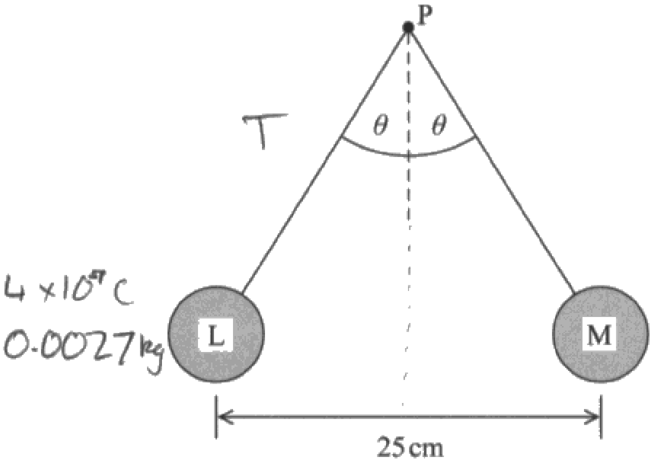
② ÷ ① $\quad \frac{0.023}{0.026} = \tan\theta \quad \therefore \theta = 41.5°$

$T = \frac{0.023}{\sin\theta}$

ResultsPlus
Examiner Comments
This was a model answer resolving forces, it scored all 6 marks.

(c) Two small spheres L and M are attached to non-conducting threads and suspended from a point P. Each sphere is given an equal positive charge of 4.0×10^{-7} C. The spheres hang in equilibrium as shown in the diagram.

The mass of each sphere is 2.7 g.



By considering the forces acting on one of the spheres, calculate the tension in the thread and the angle θ.

(6)

$mg = T\cos\theta$

$9.21 \times 10^{-6} = T\sin\theta$

Force on sphere $= \frac{kQ_1Q_2}{r^2} = \frac{kQ^2}{r^2}$

$= \frac{(8.99 \times 10^9) \times (4 \times 10^{-7})^2}{12.5^2} =$ ~~9.21×10^{-22}~~

$= 9.21 \times 10^{-6}$ N

$0.0027 \times 9.81 = 0.026487$ N

$= 0.026$ (2sf)

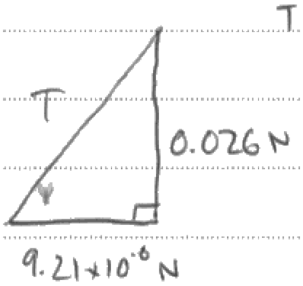
~~$\frac{mg}{T} = \cos\theta$~~

~~$\frac{0.026}{0.026} = \cos\theta$~~

Pythagoras: $0.026^2 + (9.21 \times 10^{-6})^2 = T^2$

$T^2 = 0.000676$

$T = 0.026$ N



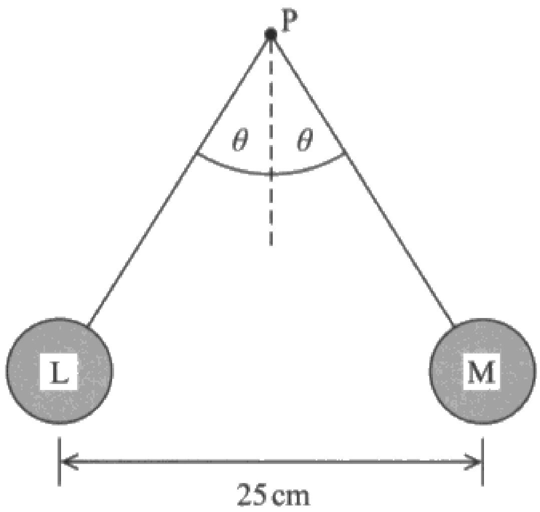
Tension = 0.026 N

ResultsPlus
Examiner Comments

This was an example that used Pythagoras but made the mistake of using 12.5 cm and also not converting to metres, hence the very small value of the electric force. The candidate did write a correct tan equation for their calculated values so this scored the 4 method marks.

(c) Two small spheres L and M are attached to non-conducting threads and suspended from a point P. Each sphere is given an equal positive charge of 4.0×10^{-7} C. The spheres hang in equilibrium as shown in the diagram.

The mass of each sphere is 2.7 g.



By considering the forces acting on one of the spheres, calculate the tension in the thread and the angle θ.

(6)

$F = \frac{kQ_1Q_2}{r^2}$ $F = \frac{1.38 \times 10^{-23} (4 \times 10^{-7} C)(4 \times 10^{-7} C)}{(0.25)^2}$

$F = 3.$

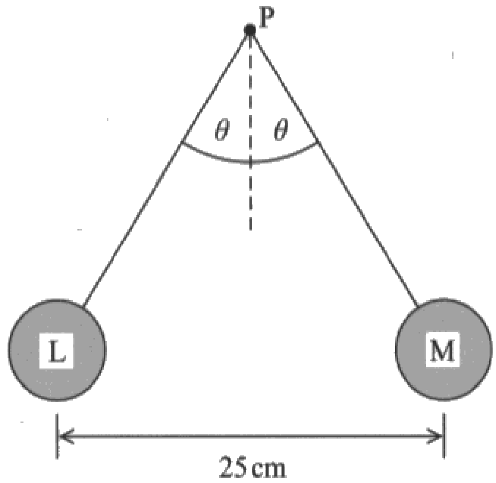
ResultsPlus

Examiner Comments

This example has been added as proof that some candidates do use Boltzmann's constant for the value for *k.*

(c) Two small spheres L and M are attached to non-conducting threads and suspended from a point P. Each sphere is given an equal positive charge of 4.0×10^{-7} C. The spheres hang in equilibrium as shown in the diagram.

The mass of each sphere is 2.7 g.



By considering the forces acting on one of the spheres, calculate the tension in the thread and the angle θ.

(6)

25 cm = 0.25 m $\quad F_E = \frac{k Q_1 Q_2}{r^2}$

$= \frac{8.99 \times 10^9 \times (4.0 \times 10^{-7})^2}{0.25^2}$

$= 2.30 \times 10^{-4}$ N

$F_E = \frac{2.30 \times 10^{-4}}{2} = 1.15 \times 10^{-4}$ N

2.7 g = 2.7×10^{-3} kg $\quad F = mg = (2.7 \times 10^{-3}) \times 9.81 = 2.65 \times 10^{-4}$ N

$\tan\theta = \frac{1.15 \times 10^{-4}}{2.65 \times 10^{-4}}$

$\theta = 23.5°$

$T^2 = W^2 + Fe^2$

$T = \sqrt{(2.65 \times 10^{-4})^2 + (1.15 \times 10^{-4})^2}$

$= 2.89 \times 10^{-4}$ N //

Tension = 2.89×10^{-4} N

θ = 23.5°

ResultsPlus
Examiner Comments

This candidate found the electric force and then divided it by 2, obviously forgetting all about N3. It still scored the 4 method marks but lost the answer marks.

ResultsPlus
Examiner Tip

This is an example of a well laid out answer that the examiner can easily follow and is able to award marks for.

Question 18 (a) (iii)

In 18(a)(i) most candidates had correctly drawn a spiral with increasing radius showing the proton passing through the gaps many times. However, when answering this question hardly any made any reference to repeat crossing of the gap so very few candidates scored 3 marks. In fact the most common mark scored was 1, usually for the idea of the field/p.d. causing an acceleration. The description of the changing polarity of the dees was poor and as mentioned already, hardly any made reference to an increase in KE each time the protons went through the gap. Most candidates attempted to explain about the changing polarity but their answers were too general or vague. Some thought the switching occurred when the proton was in the middle of the gap. Ideally we would have liked to see a clear statement about the proton repeatedly going through the gap, each time with an increase in KE but this time we accepted any reference to going through the gap more than once.

(iii) Explain how the kinetic energy of the protons is increased as they follow the path you have shown.

(3)

The potential difference between the Dee's creates a force onto the proton because it is positively charged. Because of F=ma the proton is accelerated across the gap. Because a force is acting on the proton and it accelerates it is moving faster meaning it has gained kinetic energy. Every time the proton gets ~~the~~ to the gap the p.d is reversed so that the proton can again be acted on by a force from the electric field.

ResultsPlus
Examiner Comments

An example not seen very often of a 3 mark answer. Awarded because the last sentence began 'every time.......'

(iii) Explain how the kinetic energy of the protons is increased as they follow the path you have shown.

(3)

Every time they cross the gap between the dees they are accelerated by the potential difference as it exerts a force on them, the more times they go round the faster they will go. By increasing their speed you increase their kinetic energy as $E_k = \frac{1}{2}mv^2$.

ResultsPlus
Examiner Comments

This scored the accelerating mark and the repetition mark but no mention of the changing polarity of the dees.

(iii) Explain how the kinetic energy of the protons is increased as they follow the path you have shown.

(3)

The protons kinetic energy is increased because they are accelerated by the ~~magneti~~ electric field between the 2 dees. The protons are attracted to ~~an~~ the dee of opposite charge. As the proton completes half a revolution the potential difference alternates so the proton is attracted to the next dee and kinetic energy increases more. $E = QV = \frac{1}{2}mv^2$

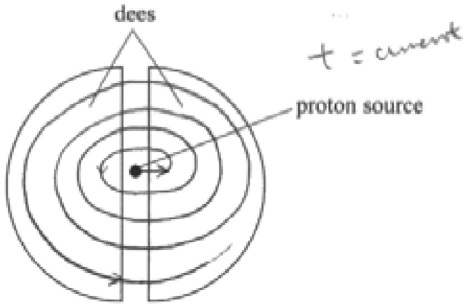
ResultsPlus
Examiner Comments

This also scored 2 marks, this time for the accelerating and the polarity of the dees.

Question 18 (a) (i-ii)

Nearly all candidates managed to draw a spiral with the minimum of two complete revolutions and about half of them correctly identified the direction of the field that was consistent with their spiral, either clockwise or anticlockwise.

18 (a) A cyclotron is a particle accelerator which can be used to accelerate protons. The cyclotron consists of two semicircular electrodes called 'dees'. An alternating potential difference is applied across the gap between the dees. A uniform magnetic field is applied at right angles to the plane of the dees.



(i) Complete the diagram to show the path of the protons.

(1)

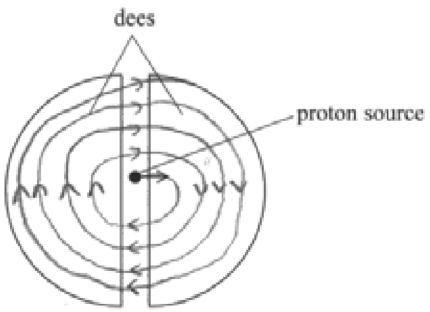
(ii) State the direction of the magnetic field needed in order to produce the path you have sketched.

ResultsPlus

Examiner Comments

Most candidates drew a clockwise spiral but this one was anticlockwise with the correct direction of field so it scored both marks.

18 (a) A cyclotron is a particle accelerator which can be used to accelerate protons. The cyclotron consists of two semicircular electrodes called 'dees'. An alternating potential difference is applied across the gap between the dees. A uniform magnetic field is applied at right angles to the plane of the dees.



(i) Complete the diagram to show the path of the protons.

(1)

(ii) State the direction of the magnetic field needed in order to produce the path you have sketched.

(1)

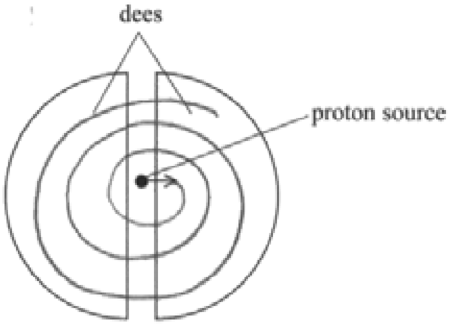
Out of the page.

ResultsPlus

Examiner Comments

This was a correct response for a clockwise spiral.

18 (a) A cyclotron is a particle accelerator which can be used to accelerate protons. The cyclotron consists of two semicircular electrodes called 'dees'. An alternating potential difference is applied across the gap between the dees. A uniform magnetic field is applied at right angles to the plane of the dees.



(i) Complete the diagram to show the path of the protons.

(1)

(ii) State the direction of the magnetic field needed in order to produce the path you have sketched.

(1)

into the page

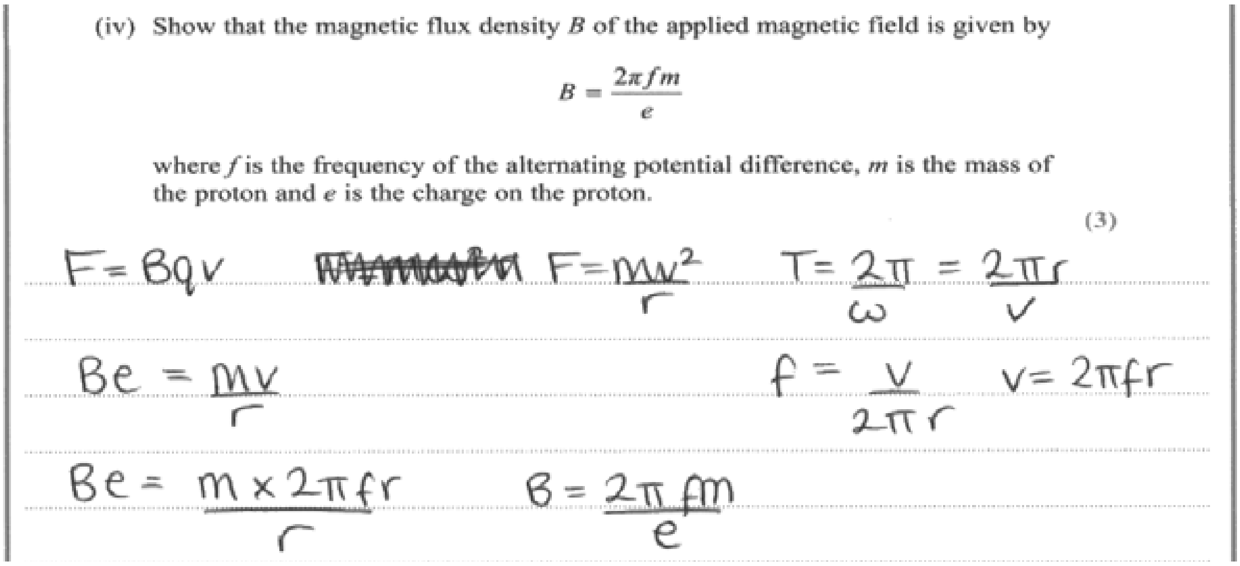
ResultsPlus

Examiner Comments

The common wrong answer, scored 1 mark for the spiral but the field was in the wrong direction.

Question 18 (a) (iv)

Some candidates did not know where to begin with this question and so scored zero marks. However those candidates who started with one of the two equations given in the MS went on to score all 3 marks. It was impossible to separate those who really knew what they were doing from the ones who effectively worked backwards from the given equation.


(iv) Show that the magnetic flux density B of the applied magnetic field is given by

$$B = \frac{2\pi f m}{e}$$

where f is the frequency of the alternating potential difference, m is the mass of the proton and e is the charge on the proton.

(3)

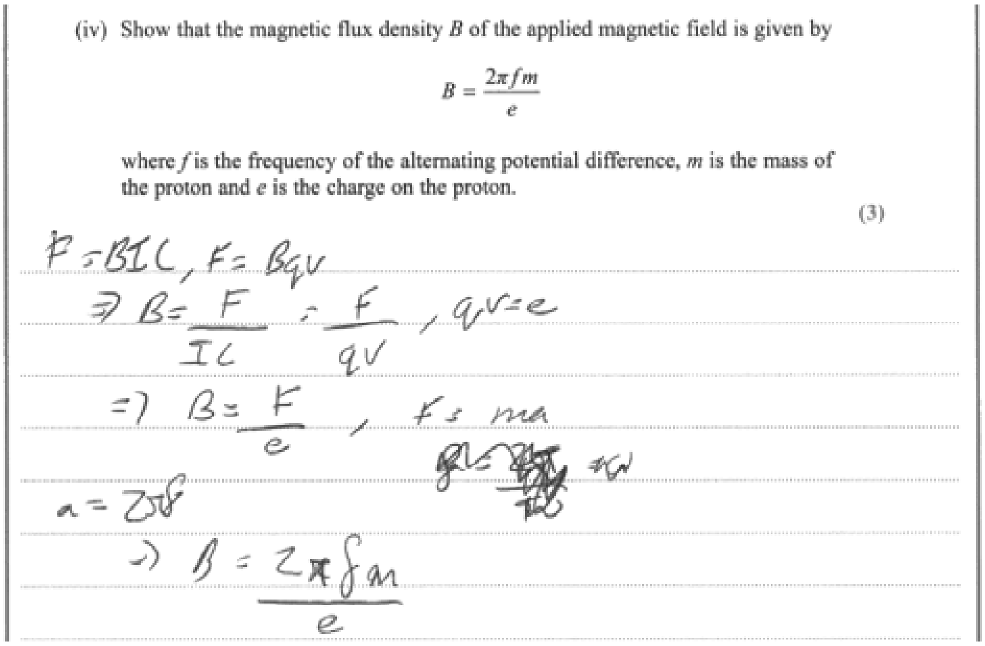
$F = Bqv$ $F = \frac{mv^2}{r}$ $T = \frac{2\pi}{\omega} = \frac{2\pi r}{v}$

$Be = \frac{mv}{r}$ $f = \frac{v}{2\pi r}$ $v = 2\pi f r$

$Be = \frac{m \times 2\pi f r}{r}$ $B = \frac{2\pi fm}{e}$

ResultsPlus
Examiner Comments

A well-presented answer where the candidate linked the force on the proton to the centripetal expression and worked through on the RHS to derive $v = 2\pi fr$. It scored 3 marks.


(iv) Show that the magnetic flux density B of the applied magnetic field is given by

$$B = \frac{2\pi f m}{e}$$

where f is the frequency of the alternating potential difference, m is the mass of the proton and e is the charge on the proton.

(3)

$F = BIl$, $F = Bqv$

$\Rightarrow B = \frac{F}{Il} = \frac{F}{qv}$, $qv = e$

$\Rightarrow B = \frac{F}{e}$, $F = ma$

$a = 2\pi f$

$\Rightarrow B = \frac{2\pi fm}{e}$

ResultsPlus
Examiner Comments

An example that scored zero marks, there were a number of different equations used but the candidate did not make any progress.

(iv) Show that the magnetic flux density B of the applied magnetic field is given by

$$B = \frac{2\pi f m}{e}$$

where f is the frequency of the alternating potential difference, m is the mass of the proton and e is the charge on the proton.

(3)

$F = Bev \qquad F_c = \frac{mv^2}{r}$

$Bev = \frac{mv^2}{r} \qquad \frac{v}{r} = \omega$

$Bev = m\omega v$

$B = \frac{m\omega}{e} \qquad \omega = 2\pi f$

$B = \frac{2\pi f m}{e}$ //

ResultsPlus

Examiner Comments

Another 3 mark answer, this one used ω instead

Question 18 (a) (v)

For 70% of the candidates this was a straightforward calculation using the equation given in (a)(iv). However most of the rest of the candidates chose to use the mass of an electron rather than the mass of the proton and so scored zero.

(v) In a particular cyclotron B is 1.2 mT. 1.2×10^{-3}
Calculate the frequency f of the alternating potential difference.

(2)

$Be = 2\pi f m$ $\qquad \frac{Be}{2\pi m} = f \qquad \frac{1.2\times10^{-3} \times 1.6\times10^{-19}}{(2\pi \times 9.11\times10^{-31})}$

$f = 33543087$

$= 3.35 \times 10^7$

$f =$ 34MHz

ResultsPlus
Examiner Comments
The whole of question 18 was about the acceleration of protons in a cyclotron, the word proton is used five times in the question before candidates get to this calculation. This was an example of a candidate who used the mass of an electron.

(v) In a particular cyclotron B is 1.2 mT.
Calculate the frequency f of the alternating potential difference.

(2)

$B = 2\pi$ $\qquad f = \frac{Be}{2\pi m} = \frac{1.2\times10^{6} \times 1.6\times10^{-19}}{2\pi \times 1.67\times10^{-27}} = 1.83\times10^{13}$

$f =$ 1.83×10^{13}

ResultsPlus
Examiner Comments
Correct mass given but milli and mega units confused and no unit for the answer. This response scored 1 mark.

(v) In a particular cyclotron B is 1.2 mT.
Calculate the frequency f of the alternating potential difference.

$\therefore B = \frac{2\pi f m}{e}$

(2)

$f = \frac{Be}{2\pi m} = \frac{1.2\times10^{-3} \times 1.6\times10^{-19}}{2\pi \times 1.67\times10^{-27}}$

$= 18.3$ kHz (3SF)

$f =$ 18.3 kHz

ResultsPlus

Examiner Comments

An example that scored both marks.

ResultsPlus

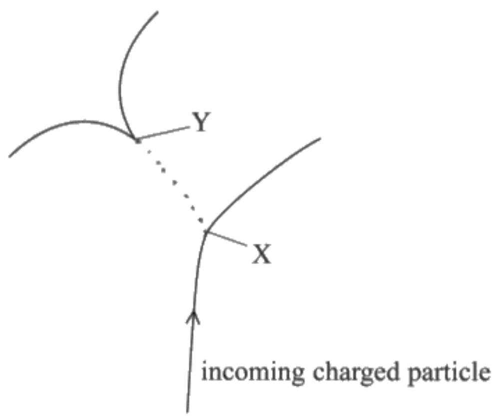
Examiner Tip

Be careful when selecting data from the table, make sure you choose the right value to use.

Question 18 (b)

Candidates generally scored well on this section with 3 and 4 being the most commonly awarded marks. The effect at Y was better described than the effect at X. The most frequently awarded mark was for there being two charged particles produced at Y. The easiest way to get the next marking point was to say this was due to conservation of charge since the particle arriving at Y was neutral. Many chose to answer in terms of the paths but did not get credit if they said the paths were in opposite directions, since the two particles paths are continually changing direction. Also an alarming number of candidates stated that because the paths had the same radii the particles had the same mass rather than the same momentum. At Y candidates were able to identify that two particles had been produced and that one was neutral because there was no path. It was MP3 that was the lowest scoring mark because it was necessary to talk about before and after the collision. Most responses were in terms of conservation of charge or momentum for the new particles without any reference to the incoming particle. It is surprising how many candidates thought that the two particles produced at Y went off in opposite directions.

(b) The diagram shows the tracks produced in a bubble chamber.



At X an incoming charged particle interacts with a stationary proton.

Describe and explain what can be deduced about the interaction at X and subsequent events. You may add to the diagram to help your answer.

(5)

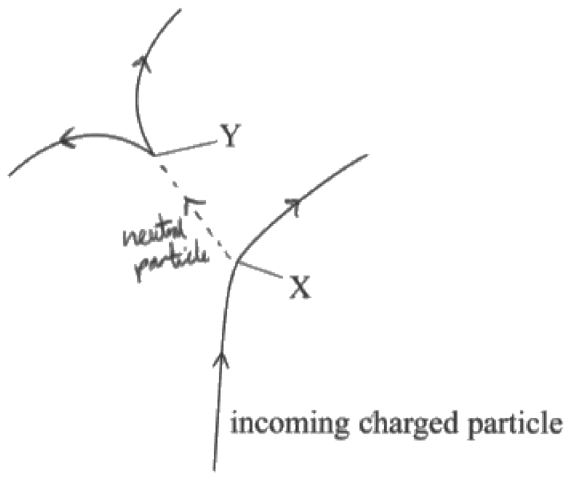
At x the collision between the charged particle and the stationary particle gave off a charged particle as shown and a uncharged particle, this can be seen by the addition of the dotted line. this uncharged particle then decayed into two seperate particles at Y, it can be deduced that these two particles have ~~the~~ equal but opposite charges and the same mass. this is because their paths are identicle but in opposite directions

ResultsPlus

Examiner Comments

This scored 2 marks for two particles at X and 2 charged particles at Y. There was no mention that the neutral particle doesn't leave a track and this was an example of paths in opposite directions. Candidates need to say that the paths curve in opposite directions.

(b) The diagram shows the tracks produced in a bubble chamber.



At X an incoming charged particle interacts with a stationary proton.

Describe and explain what can be deduced about the interaction at X and subsequent events. You may add to the diagram to help your answer.

(5)

At X, the charged particle decays into a neutral particle as there is no track ~~and~~ ~~and interacts~~ due to interaction of the proton and produces a charged particle with the same charge as the sum of the two initial particles as charge is conserved.

The neutral particle goes ~~to~~ to the left to conserve momentum as the charged particle goes to the right.

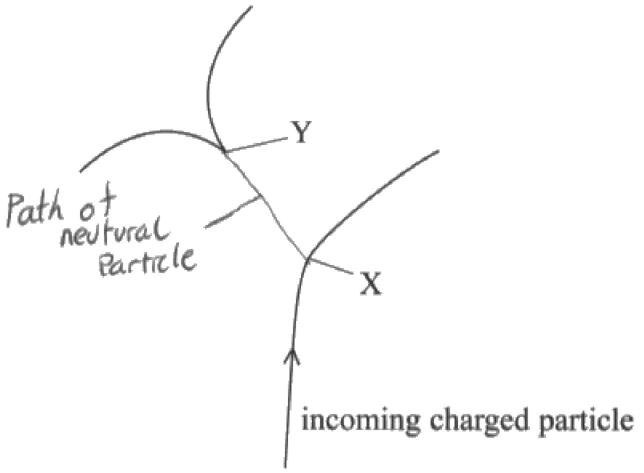
The neutral particle decays into two charged particles as two tracks appear and the charges are opposite to each other as they curve in the opposite directions. They are ~~likely to be the same~~ a particle and antiparticle pair as they have the same curvature.

ResultsPlus

Examiner Comments

An example of a script that scored 5 marks.

(b) The diagram shows the tracks produced in a bubble chamber.



At X an incoming charged particle interacts with a stationary proton.

Describe and explain what can be deduced about the interaction at X and subsequent events. You may add to the diagram to help your answer.

(5)

tracks in bubble chambers are caused by charged particles, at X a charged particle at high energies interacts with a stationary proton as a result another charged particle is emmitted along with a nutural particle, we can know that the neutural particle is unstable because it rapidly decays into two charged particles with opposite charges, we know that they are oppositely charged because charge is conserved and the parent had charge 0 $0 = (+1) + (-1)$

ResultsPlus
Examiner Comments

This scored 3 marks for the two particles at Y and the two charged particles oppositely charged to conserve charge at X. Although there was reference to bubbles being formed by charged particles, candidates need to make a clear statement about neutral particles not leaving a track.

Paper Summary

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

- learn the base units and practice rearranging equations
- in calculations, use words to explain what you are calculating, don't just write a series of numbers
- in context questions, answer in terms of the context and not in general terms
- be familiar with the formula and data sheet, *k* is used as the symbol for boltzmann's constant and for the constant in Coulomb's Law
- when writing descriptive answers use short sentences and check that the subject of the sentence is clear to the examiner who will be reading it.

Grade Boundaries

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