Examiners' Report
June 2023

International Advanced Level Physics WPH14 01

Introduction

The assessment structure of Unit 4: Further Mechanics, Fields and Particles is the same as that of Units 1, 2 and 5, consisting of Section A with ten multiple choice questions, and Section B with a number of short answer questions followed by some longer, structured questions based on contexts of varying familiarity.

This paper allowed candidates of all abilities to demonstrate their knowledge and understanding of Physics by applying them to a range of contexts with differing levels of familiarity.

Candidates at the lower end of the range could complete calculations involving simple substitution and limited rearrangement, including short structured series of calculations, but could not always tackle calculations involving several steps or other complications, such as using radius when told the diameter. They also knew some significant points in explanations linked to standard situations, such as electromagnetic induction and linear accelerators, but missed important details and did not always set out their ideas in a logical sequence, sometimes just quoting as many key points as they could remember from the mark schemes for previous papers without particular reference to the specific context.

Steady improvement was demonstrated in all of these areas through the range of increasing ability and at the higher end all calculations were completed faultlessly, with most points included in ordered explanations of the situations in the questions.

Question 11

Approaching half of the candidates scored full marks, with the great majority being awarded at least 4 marks. Those who were awarded 4 missed the reference to ‘equal and opposite’ charges and gave quark combinations for a meson and baryon which both had charge zero or used at least one of the quarks twice. A few students used a meson combination for the baryon and vice versa or the same type of combination twice.

11 In 2022, CERN announced the discovery of a new particle known as a pentaquark which is made of five quarks.

The table shows the charges on some quarks.

Quark	Charge / e
u	+2/3
d	−1/3
s	−1/3
c	+2/3

The five quarks in the pentaquark are c, $\bar{c}$, d, s and u.

Some scientists said the pentaquark is made of a meson and a baryon, held together by the attraction of their equal and opposite charges.

Determine the quark combination and charge of a meson and of a baryon that could make up the pentaquark.

Meson ~~Mes~~ Meson is made of one ~~quark~~ quark and an anti-quark.

Quark combination = d, $\bar{s}$

Charge = 0

Baryon Baryon is made of three quarks.

Quark combination = u, d, s

Charge = 0

ResultsPlus
Examiner Comments

3 marks. The correct type of quark combination has been used in each part with the charge corresponding to that of the chosen combination, so there is a mark for each part. The meson uses a quark that wasn't included in the list, so no more marks for the meson, but the baryon does only use the listed quarks, so there is a third mark there. The final mark is not awarded because the correct 5 quarks have not been used and the charges are not equal and opposite.

ResultsPlus
Examiner Tip

It may be a cliché but be sure to read the whole question. Highlighting or underlining important parts often helps. Here that would include the list of quarks and 'equal and opposite charges'.

11 In 2022, CERN announced the discovery of a new particle known as a pentaquark which is made of five quarks.

The table shows the charges on some quarks.

Quark	Charge / e
u	+2/3
d	−1/3
s	−1/3
c	+2/3

The five quarks in the pentaquark are c, $\bar{c}$, d, s and u.

Some scientists said the pentaquark is made of a meson and a baryon, held together by the attraction of their equal and opposite charges.

Determine the quark combination and charge of a meson and of a baryon that could make up the pentaquark.

Meson

structure : one quark and one anti-quark that should be $c\bar{c}$

charge : $\frac{2}{3} - \frac{2}{3} = 0$

Quark combination = $c\bar{c}$

Charge = 0 C

Baryon

structure : three quark or three anti-quark that should be uds

charge : $\frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0$

Quark combination = uds

Charge = ~~0 4~~ 0 C

ResultsPlus
Examiner Comments

4 marks. The quark combinations match the requirements for mesons and baryons and all of the quarks in the list have been used, but the charges are both zero, so that does not satisfy 'equal and opposite charges'.

Question 12 (a)

Fewer than a quarter of the candidates could not complete this straightforward derivation. The great majority were able to identify and equate the two relevant starting equations and complete the algebraic manipulation with ease. Some students did not introduce $p = mv$ sufficiently clearly, effectively skipping a step, and a surprisingly large number did not use $p = mv$ at all, leaving it as $r = mv/BQ$. Some students included sin q and not all of them realised that, while not incorrect, its value would be 1. A few others tried to work backwards from the stated equation, but without success.

12 A particle with charge Q and momentum p follows a circular path of radius r. The path is at right angles to a magnetic field of magnetic flux density B.

(a) Derive the following equation for the particle.

$$r = \frac{p}{BQ}$$

(2)

$\cancel{Bqv = mv}$ $\quad Bqv = \frac{mv^2}{r}$

$\Rightarrow rBqv = mv^2$

$\Rightarrow rBq = \frac{mv^{\cancel{2}}}{\cancel{v}}$

$\Rightarrow r = \frac{mv}{Bq}$

ResultsPlus
Examiner Comments

1 mark. Many responses were similar to this. The derivation is fine up to $r = mv/BQ$, but it stops there, without using $p = mv$ at all.

A derivation must end with the equation required being written down as the last step.

12 A particle with charge Q and momentum p follows a circular path of radius r. The path is at right angles to a magnetic field of magnetic flux density B.

(a) Derive the following equation for the particle.

$$r = \frac{p}{BQ}$$

(2)

$\frac{mv^2}{r} = qvB$ $\because mv = p$

$\frac{mv}{r} = qB$ $\therefore r = \frac{p}{BQ}$

$r = \frac{mv}{qB}$

ResultsPlus
Examiner Comments

This is very clear, with all three of the required initial equations shown.

Question 12 (b)

About half of the entry gained full credit for this multi-step calculation starting by converting Mev to J, but usually giving themselves an extra step by using kinetic energy to calculate velocity and then calculating momentum rather than using the direct relationship between kinetic energy and momentum. This extra step sometimes introduced errors, for example by forgetting the square root. The final part of the calculation required the use of charge = 2*e*, but some used *e*,4*e* or even just 2. The M in MeV was sometimes ignored and, oddly, a number of students used 0.96 m as the radius.

(b) The particle is an alpha particle of energy 5.4 MeV.

Calculate B.

mass of alpha particle = 6.64×10^{-27} kg
$r = 0.096$ m

(4)

~~$E_k = 5.4 \times 10^{6} \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19} = 1.38 \times 10^{-31}$ V~~

$5.4 \times 10^{6} \times 1.6 \times 10^{-19} = 8.64 \times 10^{-13}$ J

$8.64 \times 10^{-13} \div \frac{1}{2} \div (6.64 \times 10^{-27}) = 2.6 \times 10^{14}$, $v = 1.6 \times 10^{7}$ m/s

$p = mv = 6.64 \times 10^{-27} \times 1.6 \times 10^{7} = 1.06 \times 10^{-19}$ kg m/s

$0.096 = \dfrac{1.06 \times 10^{-19}}{1.6 \times 10^{-19} B}$, $B = 6.9$ wb

$B =$ 6.9 wb

ResultsPlus
Examiner Comments

3 marks. The method is correct, but the charge used is just *e* when it should be 2*e* for the alpha particle. This student has taken the extra step of calculating velocity from the kinetic energy when they could have used $E_k = p^2/2m$ and done it in one step.

(b) The particle is an alpha particle of energy 5.4 MeV.

Calculate B.

mass of alpha particle = 6.64×10^{-27} kg
$r = 0.096$ m

(4)

$E = m \times c^2$. $\quad E = 5.4 \times 10^6 \times (1.6 \times 10^{-19})$

$= 8.64 \times 10^{-13}$ J.

~~8.64×10^{-13}~~ $=$ $\quad E_k = \frac{p^2}{2m}$ $\quad = 8.64 \times 10^{-13} \times 2(6.64 \times 10^{-27})$

$r = \frac{p}{BQ}$. $\quad p^2 = 1.15 \times 10^{-38}$.

$= 1.07 \times 10^{-19}$ ~~ms~~ kgms^{-1}.

$r = 0.096 = \frac{(1.07 \times 10^{-19})}{B \times (2)}$. $\quad B = \frac{(1.07 \times 10^{-19})}{2 \times (0.096)} = 5.58 \times 10^{-19}$ T

$B = 5.58 \times 10^{-19}$ T.

ResultsPlus
Examiner Comments

2 marks. $E_k = p^2/2m$ has been used and momentum then apparently substituted into the correct equation, but the charge used is just 2 rather than 2e, so no more marks.

Question 13 (a)

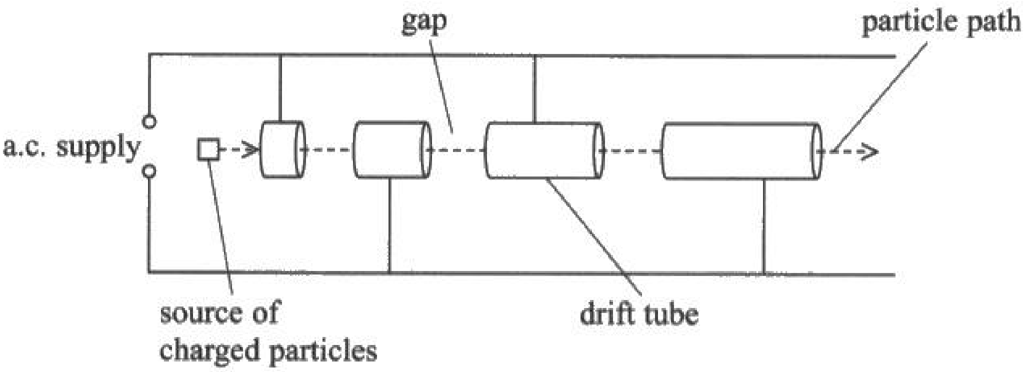
Many candidates used this question as an opportunity to give a well-rehearsed description of the operation of linear accelerators according to the mark scheme for similar questions on previous papers but did not give the wording of this question sufficient attention to see which aspect they were expected to address. Accordingly, a large proportion of candidates limited themselves to one or two marks because they did not refer to electric fields.

Whether they referred to the tubes or the gaps, there were some common points missing or lacking in detail. Candidates did not always state that the acceleration of the particles takes place in the gaps between the tubes, and some even said they accelerate between the gaps, i.e. in the tubes. For some reason a large proportion of the candidates refer very simply to electrons being attracted to the next tube by its opposite charge rather than stating that they are accelerated by the electric field between the tubes.

Candidates often took note of the question guidance and stated that the frequency of the a.c. supply is constant, although some just referred to a constant frequency and didn't say what it was that had a constant frequency and others didn't link it to the time spent in the tubes. The diagram reminded students that the length of the drift tubes, and the gaps between them, increased.

13 Linacs and cyclotrons both accelerate charged particles to very high speeds.

(a) The diagram shows a linac.



Explain the use of electric fields in a linac.

You should refer to the frequency of the a.c. supply.

(4)

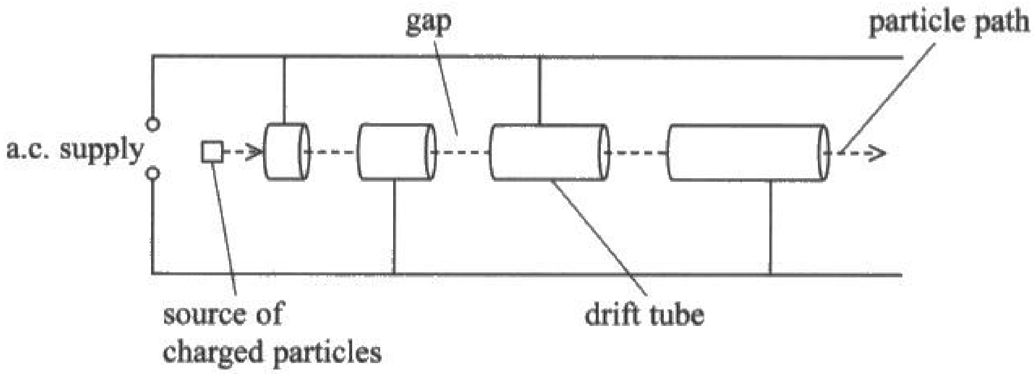
There is an alternating power supply between the tubes in the gaps. This provides an electric field. The electric field provides a force on the charged particles causing them to accelerate. Since the frequency of the a.c supply remains constant the particles need to spend the same time in ~~the~~ each tube so that it can reach the gaps when there is maximum p.d as there is no electrical field inside the tube.

ResultsPlus
Examiner Comments

2 marks. This gets the first two marks but doesn't explain the polarity change clearly enough and doesn't mention the increasing tube length at all.

13 Linacs and cyclotrons both accelerate charged particles to very high speeds.

(a) The diagram shows a linac.



Explain the use of electric fields in a linac.

You should refer to the frequency of the a.c. supply.

(4)

The a.c supply creates a p.d. ~~between~~ in the gaps between drift tubes. due to the existence of p.d. ~~an~~ an electric field created and charged particle experience electric field force while passing it. As $F=ma$, $a=\frac{F}{m}$, an acceleration would be gained by the charged particle while passing it. The particle travels at constant speed in the drift tubes, and they are designed to be increasingly longer to maintain the time travelling through each of them being constant. This is because the p.d needs to be reversed in this time period in order to provide continous acceleration instead of first accelerate then decelerate..., and the frequency of the a.c supply is constant, ~~each~~ as it is equal to $\frac{1}{T}$.

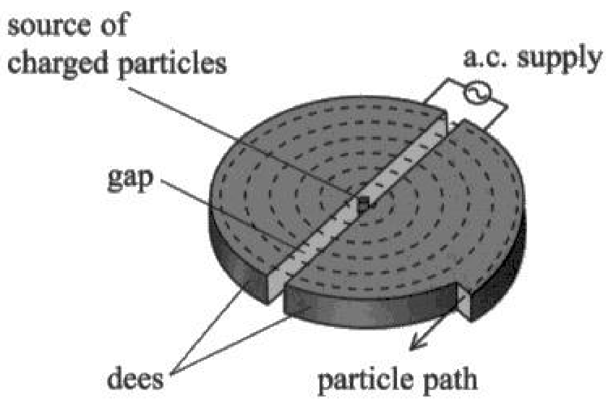
ResultsPlus
Examiner Comments

4 marks. An example of a full mark question. Note in the first line where between the gaps has been changed to between the tubes, correctly.

Question 13 (b)

The great majority indicated circular motion directly or by referring to centripetal force or acceleration. Only about a quarter specifically described the direction of the force. Many just referred to the direction of the field being at right angles to the motion and didn't mention the force.

(b) The diagram shows a cyclotron.



Explain why a magnetic field is applied at right angles to the dees in the cyclotron.

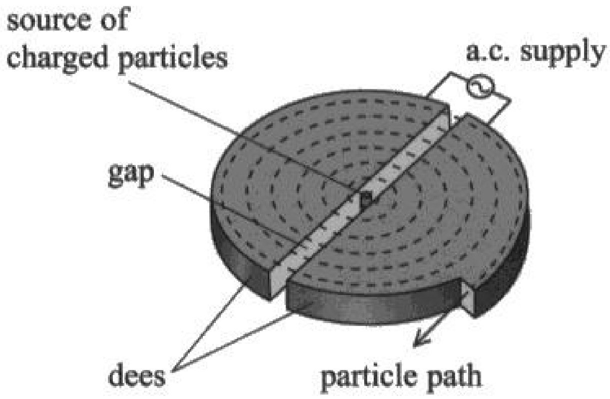
(2)

The magnetic field provides a force on the charged particle.
The field is applied at right ~~force is applied at righ~~ angles so that the magnetic
force applied on the charged particle is at right angles. This creates
a centripetal force which allows the particle to follow the circular path.

ResultsPlus
Examiner Comments

1 mark. This mentions force at right angles, but not right angles to velocity etc., so it only gets the mark for centripetal force for a circular path.

(b) The diagram shows a cyclotron.



Explain why a magnetic field is applied at right angles to the dees in the cyclotron.

(2)

The magnetic field is applied at right angles to the dees so particles experience centripetal force and moves in circular motion.

ResultsPlus
Examiner Comments

1 mark. The first line is just repeating the question, only mentioning field at right angles and not force, followed by the second mark.

Question 14

About a fifth of the entry successfully completed both parts of this question which required a sequence of fairly detailed calculations.

In part (a), nearly all of the students were able to show some understanding of the underlying principle of conservation of momentum, even if they didn't apply it in two dimensions. They could usually use trigonometric functions successfully to calculate components. A fair few students limited themselves to 4 marks by only calculating one of the required values; some calculated the correct magnitude but didn't go on to find the angle and, less frequently, some calculated the angle but didn't use it to find the magnitude.

A minority used the stated 'show that' angle to calculate momentum but were unable to access more than 4 marks if they approached it this way.

In part (b), students could generally use momentum and mass to calculate kinetic energy, although they did not always utilise the equation $E_k = p^2/2m$, instead calculating velocity as an intermediate step. Some used a component of momentum from part (a) rather than the actual particle momentum. A significant minority completed all calculations correctly but didn't make a clear conclusion including a comparison of the relative kinetic energy values.

A few showed 'squared' in their written equations but omitted it after substitution of neglected to square when using their calculator. The factor of 2 in the energy calculation was also missed by some.

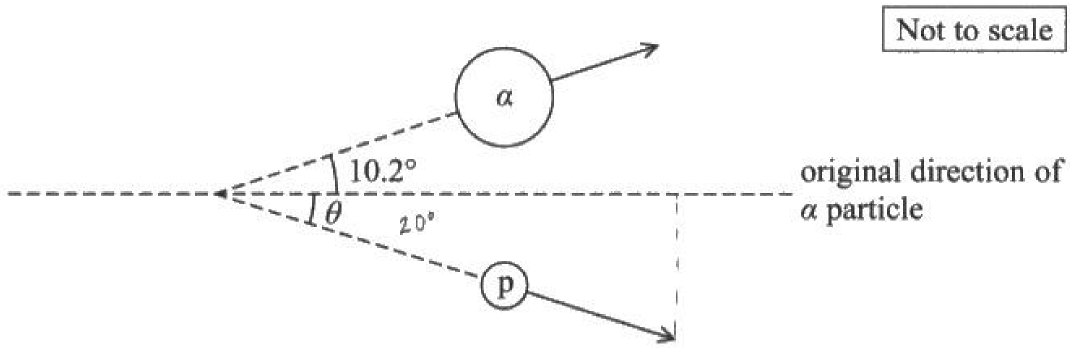
14 In the 1930s, scientists investigated collisions of alpha particles with protons to determine whether the collisions were elastic.

The diagrams show an alpha particle before and after a collision with a stationary proton.
The proton moves off at an angle θ to the original direction of the alpha particle.

<u>Before collision</u>

momentum of alpha particle = 1.26×10^{-19} N s

<u>After collision</u>



momentum of alpha particle = 8.06×10^{-20} N s

(a) Show that the momentum of the proton after the collision is about 5×10^{-20} N s at an angle θ, where θ is about 20°.

(6)

Momentum before = momentum after,

momentum before in vertical plane = 0

momentum after :

$0 = p_\alpha - p_p$

$\therefore p_\alpha = -p_p$

$(8.06 \times 10^{-20})(-\sin 10.2) = p_p \cancel{\sin 20°}$

thus $p_V = \cancel{4.17 \times 10^{-20} \text{ N s}^{-1}}$ 1.4273×10^{-20}

$\therefore$ Horisontal before = horisontal after

$1.26 \times 10^{-19} = 8.06 \times 10^{-20} \cos 10.4 + p \cancel{\cos 20°}$

$p_h = \cancel{4.97 \times 10^{-20} \text{ Ns}}$ 4.66×10^{-20}

$\cancel{\approx 5 \times 10^{-20} \text{ Ns}}$

final part

$p^2 = pv^2 + ph^2$

$= (1.4273 \times 10^{-20})^2 + (4.6 \times 10^{-20})^2$

$= 2.37 \times 10^{-39}$

$p = 4.87 \times 10^{-20}$ Ns

$\approx 5 \times 10^{-20}$ Ns

(b) Deduce whether the collision was elastic.

mass of alpha particle = 6.64×10^{-27} kg

(4)

Ek before $= \frac{1}{2}mv^2$

$= \frac{1}{2}(6.64 \times 10^{-27})(1.897 \times 10^7)^2$

$= 1.1955 \times 10^{-12}$ J

but $v = \dfrac{1.26 \times 10^{-19}}{6.64 \times 10^{-27}} = 1.897 \times 10^7 \text{ m s}^{-1}$

Ek after $= \frac{1}{2}mv^2 + \frac{1}{2}mv^2$

$= \frac{1}{2}(1.67 \times 10^{-27})(2.976 \times 10^7)^2 + \frac{1}{2}(6.64 \times 10^{-27})(1.2 \times 10^7)^2$

$V_{proton} = \dfrac{4.97 \times 10^{-20}}{1.67 \times 10^{-27}} = 2.976 \times 10^7 \text{ m s}^{-1}$

$V_\alpha = \dfrac{8.06 \times 10^{-20}}{6.64 \times 10^{-27}} = 1.21 \times 10^7 \text{ m s}^{-1}$

$= 7.395 \times 10^{-13} + 4.860 \times 10^{-13} = 1.23 \times 10^{-12}$ J

thus as Ek after $\neq$ Ek before, not elastic collision

Part (a) 4 marks, part (b) 4 marks.

(a) The momentum is calculated correctly, but there is no attempt at calculating the angle.

(b) This is completed fully, with a comparison of kinetic energies and a conclusion.

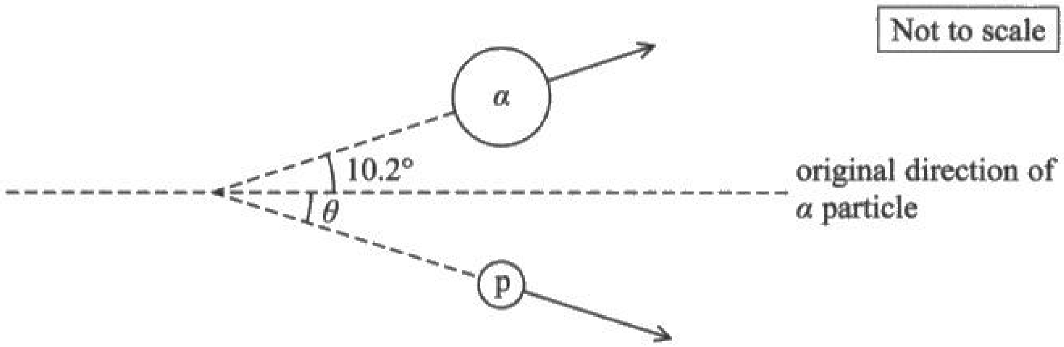
14 In the 1930s, scientists investigated collisions of alpha particles with protons to determine whether the collisions were elastic.

The diagrams show an alpha particle before and after a collision with a stationary proton.
The proton moves off at an angle θ to the original direction of the alpha particle.

Before collision

momentum of alpha particle = 1.26×10^{-19} N s

After collision



momentum of alpha particle = 8.06×10^{-20} N s

(a) Show that the momentum of the proton after the collision is about 5×10^{-20} N s at an angle θ, where θ is about 20°.

(6)

V : $8.06 \times 10^{-20} \times \sin(10.2°) = 1.43 \times 10^{-20}$ Ns

H : $8.06 \times 10^{-20} \times \cos(10.2°) = 7.93 \times 10^{-20}$ Ns

$\cancel{1.2e}$ $1.26 \times 10^{-19} - 7.93 \times 10^{-20} = 4.67 \times 10^{-20}$ Ns

$p = \sqrt{(1.43 \times 10^{-20})^2 + (4.67 \times 10^{-20})^2} = 4.88 \times 10^{-20}$ Ns $\approx 5 \times 10^{-20}$ Ns

$\theta = \tan^{-1}\left(\frac{1.43 \times 10^{-20}}{4.67 \times 10^{-20}}\right) = 17° \approx 20°$

(b) Deduce whether the collision was elastic.

mass of alpha particle = 6.64×10^{-27} kg

(4)

$E_k = \frac{p^2}{2m}$

$= \frac{(1.26 \times 10^{-19})^2}{2 \times 6.64 \times 10^{-27}} = \cancel{9.49 \times 10^{6}\ J}$ 1.2×10^{-20} J

$E_k = \frac{p^2}{2m}$

$= \frac{(8.06 \times 10^{-20})^2}{2 \times 6.64 \times 10^{-27}} = 4.87 \times 10^{-13}$ J

$E_k = \frac{p^2}{2m} = \frac{(4.88 \times 10^{-20})^2}{2 \times 1.67 \times 10^{-27}} = 7.13 \times 10^{-13}$ J

$4.89 \times 10^{-13} + 7.13 \times 10^{-13} = 1.2 \times 10^{-12}$ J

∴ The collision was elastic

(Total for Question 14 = 10 marks)

ResultsPlus
Examiner Comments

Part (a) 4 marks. Part (b) 3 marks.

(a) This is completed fully, for magnitude and angle.

(b) The calculation is complete and there is a conclusion, but the values have not been compared, so the last mark is not awarded.

ResultsPlus
Examiner Tip

Where you are asked to make a judgement or come to a conclusion by command words such as 'determine whether' or 'deduce whether', you must make a clear statement, including any values being compared. If it is a numerical comparison you must show all steps in your calculation.

Question 15 (a)

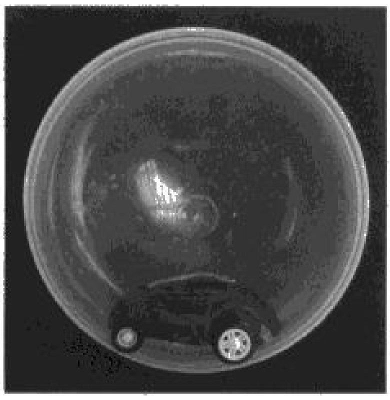
About a half of the students successfully completed the sequence of multi-step calculations to arrive at the correct radius value. A surprisingly large minority did not capitalise on this with a clear justification of their conclusion as to whether this was the radius or diameter, which could have been as simple as pointing out that 86 mm = 2 × 43 mm.

In part (i) very few were unable to apply the angular velocity equation, although some did not read the correct period from the graph. The great majority were then able to apply the centripetal force in part (ii), correctly substituting the force from the graph and their answer to part (i). Some students incorrectly converted 9.5 g, or just used 9.5, and some thought they needed to use weight at this stage.

Some students attempted the process in reverse, starting with a radius of 86 mm, but they were not generally able to draw a clear conclusion having calculated a force of 1.28 N.

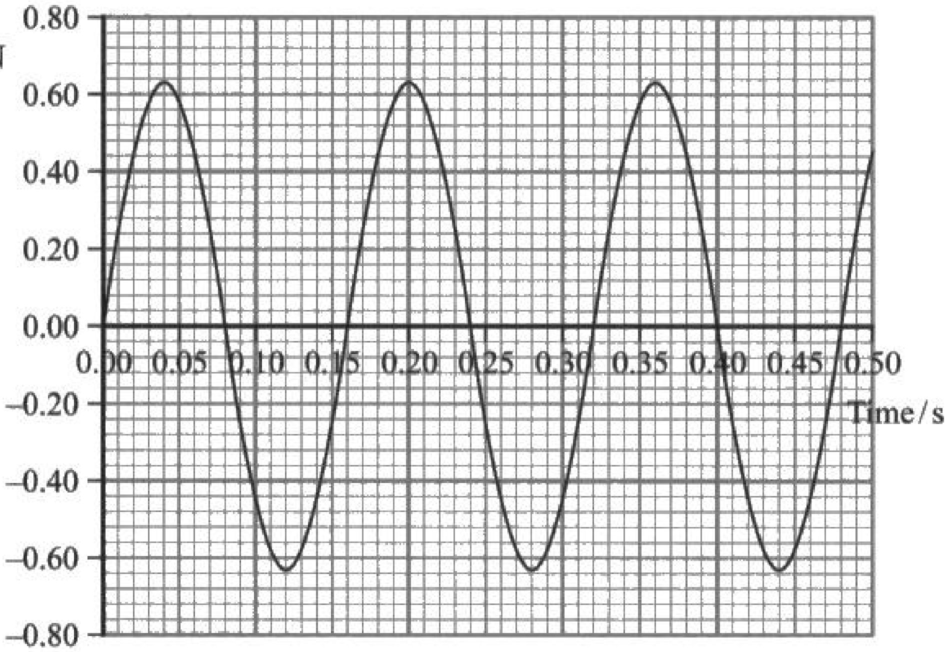
Some students read the force from the graph as 0.62 or 0.61 N because they assumed an incorrect increment for a small division without looking at the next marked scale value above their measured point.

15 The photograph shows a toy car inside a plastic ball. The car has an electric motor and follows a circular path in a vertical plane. The car travels at a constant speed.



A student determined how the resultant vertical force on the car varied over a period of time.

The graph shows the student's data. A positive value represents an upwards force.



(a) (i) Show that the angular velocity of the car's motion about the centre of the ball is about 40 radian s^{-1}.

(3)

$T = 0.16$ s

$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.16} = 39.3$ rad/s

(ii) The student took measurements of the ball and wrote down a value of 86 mm.

Deduce whether 86 mm was the radius or the diameter of the ball.

mass of car = 9.5 g

(4)

$F_c = 0.64\,N = m\frac{v^2}{r} = mr\omega^2$

$0.64 = 9.5\times10^{-3} \times r \times 39.3^2$

$r = 0.0436\ m = 43.6\ mm$

thus 86 ~~a~~ ~~so~~ is the diameter of the ball.

ResultsPlus

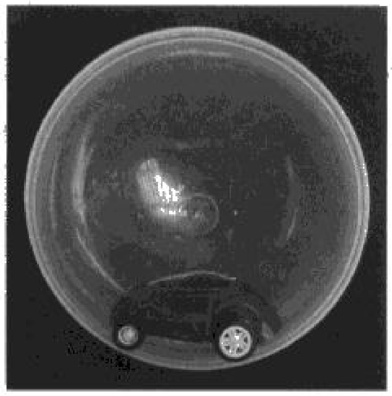
Examiner Comments

Part (i) 3 marks, part (ii) 3 marks.

(i) This has been completed with all of the required steps and substitutions shown clearly, with an answer to the required extra significant figure.

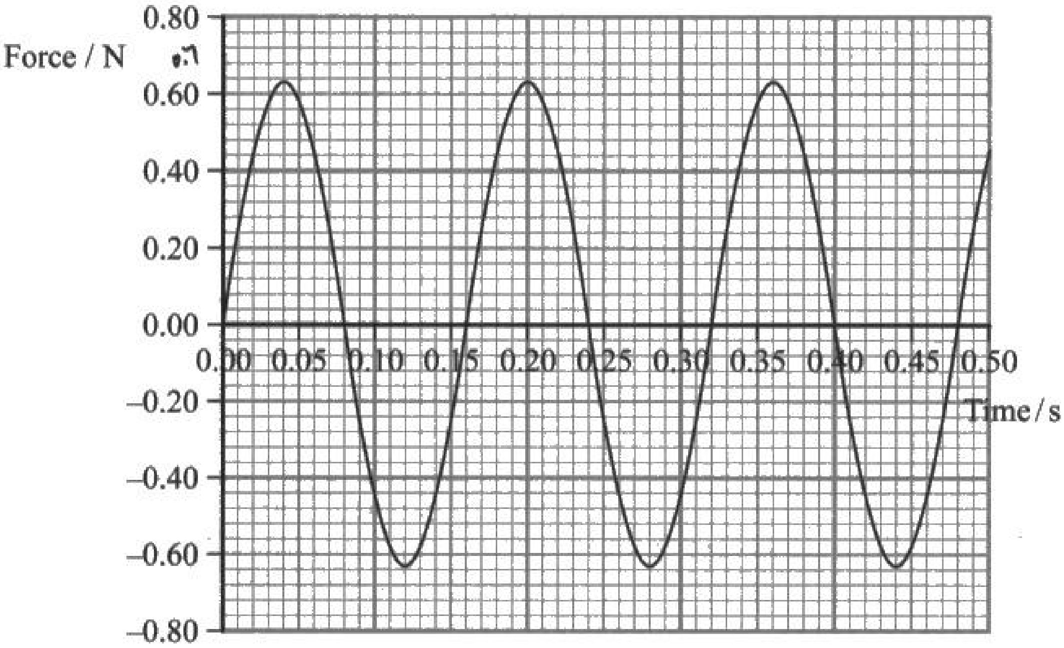
(ii) The calculation leads to a correct value of radius and a correct calculation, but there is not a comparison to the value of 86 mm in such a way as to justify the conclusion.

15 The photograph shows a toy car inside a plastic ball. The car has an electric motor and follows a circular path in a vertical plane. The car travels at a constant speed.



A student determined how the resultant vertical force on the car varied over a period of time.

The graph shows the student's data. A positive value represents an upwards force.



(a) (i) Show that the angular velocity of the car's motion about the centre of the ball is about 40 radian s^{-1}.

(3)

from graph $T = 0.16\ s$.

$\omega = \frac{2\pi}{T} = 39.3$ radian s^{-1}

(ii) The student took measurements of the ball and wrote down a value of 86 mm.

Deduce whether 86 mm was the radius or the diameter of the ball.

mass of car = 9.5 g

(4)

$F = m\omega^2 r$.

$0.63\,N = 9.5 \times 10^{-3}\,kg \times (39.3\,radian\,s^{-1})^2\,r$.

$r = 0.043\,m \Rightarrow d = 0.086\,m$.

thus 86 mm was the diameter of the ball.

ResultsPlus
Examiner Comments

Part (i) 2 marks, part (ii) 4 marks

(i) The period has been taken correctly from the graph and the angular velocity calculated correctly, but in a show that question we expect to see full substitution to be able to award full marks.

(ii) The line saying r = 0.043 so d = 0.086 m was just sufficient justification for the correct conclusion for full marks.

ResultsPlus
Examiner Tip

In a 'show that' question, all values, including physical constants, must be substituted and the answer must be given to one significant figure more than the value quoted in the question.

Question 15 (b)

As well as their knowledge and understanding of forces in circular motion, this question assessed candidates' ability to give coherent and logically structured answers.

A fair few students seem to misunderstand what we mean when we refer to centripetal force, thinking it is a particular type of force you might find in a KS3 list with other forces such as magnetic, gravitational, friction etc. They do not appreciate that it is a term we use to describe the resultant force in a situation where circular motion occurs and that it may be due solely to a particular physical force and it may be due to more than one force acting on a body. In responses to this question, it was not unusual to see students treating the normal contact force and centripetal force interchangeably.

Students who drew diagrams often found it easier to interpret this situation even though the diagrams themselves did not gain credit. Similarly, students who did the best on this question wrote out clear equations, although some poorer answers also included equations, but not the correct ones.

As an illustration of the misunderstanding described above, some students wrote that the resultant force on the car equalled the sum of centripetal force and weight – necessarily incorrect as the resultant force was the centripetal force.

In responses to this question, the most common correct points were that the force exerted by the ball was greatest at the bottom and least at the top, something they could conclude from experience without needing any equations. Many could, however, support the conclusion with suitable equations. Quite a few got the times at these points reversed, and a surprising number only mentioned one time, whereas both times needed to be stated correctly to get that indicative content point. Similarly, some got the point for saying force was greatest at the bottom but did not say that force was least at the top.

Few candidates mentioned that centripetal force was constant, although that is central to any deductions from the equations.

Some of the students identified the times when the car was half way up or half way down.

*(b) The magnitude of the force exerted by the ball on the car was greatest at 0.04 s and least at 0.12 s.

Discuss the position of the car at these two times.

You should consider the forces acting on the car.
You do not need to do any further calculations.

(6)

the force was greatest at the bottom as the total force exerted was centripetal force plus the gravitanal force. $F_{bottom} = \frac{mv^2}{r} + mg$

And the force was the least at 0,12s because it was at the top and the total force exerted was the centripetal force minus the gravitanal force.

$F_{top} = \frac{mv^2}{r} - mg$

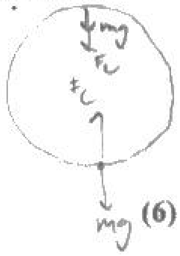
ResultsPlus
Examiner Comments

4 marks. Everything in this response is correct, and the equations clarify the written comments, but only one of the times is mentioned, despite the question saying to discuss the position at those two times. It is not sufficient to leave the examiner to conclude that part of the discussion is about the time not mentioned. There is no mention here of the constant centripetal force.

*(b) The magnitude of the force exerted by the ball on the car was greatest at 0.04 s and least at 0.12 s.

Discuss the position of the car at these two times.

You should consider the forces acting on the car.
You do not need to do any further calculations.



(6)

At t=0.04sec: $mg = F$

$F_c = \frac{mv^2}{r}$, $F_c = N - W$

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

At time 0.12 sec:

$F = N + W \Rightarrow \frac{mv^2}{r} - mg = N$

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

The force is least at 0.12 as the normal force exerted by the ball is lowest ~~at~~ when the car is at the top of the ball as the weight decreases the total force.
The force is highest at time 0.04 as the car is at the lowest and the ~~total~~ normal force ~~of~~ now equals the centripetal force and the weight of the car.

ResultsPlus
Examiner Comments

5 marks. This includes a diagram used by the student to interpret the situation at the top and bottom of the ball, along with accurate equations.

Only 5 marks are awarded because there is no reference to constant centripetal force.

ResultsPlus
Examiner Tip

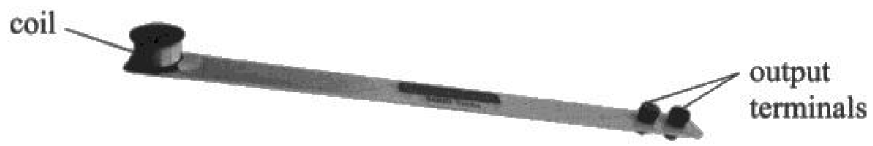
While diagrams may not, in themselves, be sufficient for marks they may help to interpret a situation.

Question 16 (a)

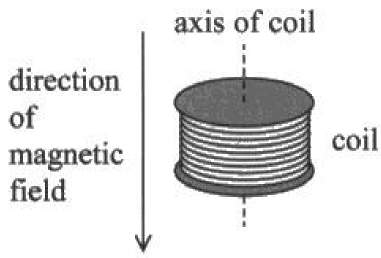
About half of the entry were able to quote the two lines seen in many prior mark schemes that a change in flux linkage induced an emf. About a third only got the mark for induces emf because of imprecise terminology, quite commonly referring to a change in flux rather than a change in flux linkage. Other errors were 'cuts magnetic flux linkage', 'produces an emf' and 'induces a current'.

16 A search coil is used to investigate magnetic fields.

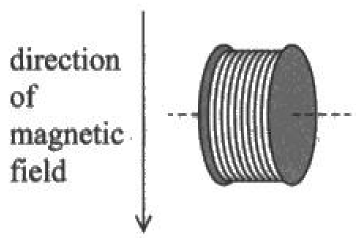
The search coil consists of a coil of thin copper wire connected to two output terminals, as shown.



A student placed the coil in a magnetic field with the axis parallel to the direction of the field, as shown.



The coil was rotated through 90° so the axis was perpendicular to the direction of the field, as shown.



As the coil was rotated, a potential difference (p.d.) was detected across the terminals.

(a) Explain why a p.d. was produced as the coil was rotated.

(2)

The was an induced current since the magnetic field causes the coil flux to change.

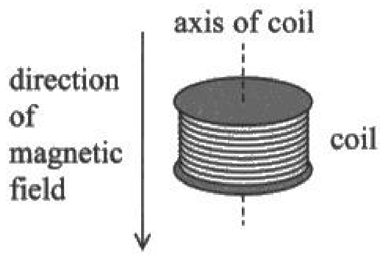
Examiner Comments

0 marks. Coil flux change isn't sufficient – we really need to see flux linkage for this version of the answer. This does not mention e.m.f.

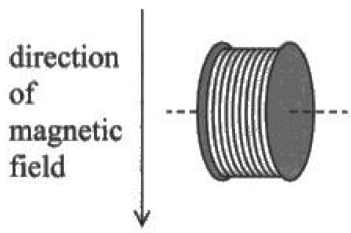
16 A search coil is used to investigate magnetic fields.

The search coil consists of a coil of thin copper wire connected to two output terminals, as shown.

A student placed the coil in a magnetic field with the axis parallel to the direction of the field, as shown.



The coil was rotated through 90° so the axis was perpendicular to the direction of the field, as shown.



As the coil was rotated, a potential difference (p.d.) was detected across the terminals.

(a) Explain why a p.d. was produced as the coil was rotated.

(2)

Because when it rotated, the flux linkage is cutting ~~the~~ through the magnetic field lines, and the p.d. ~~is~~ was produced.

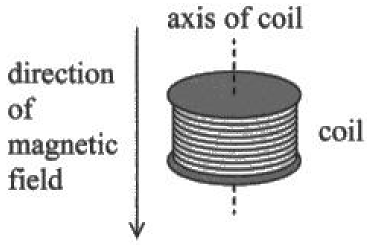
ResultsPlus
Examiner Comments

0 marks. The linkage cutting through the field lines is a confused combination of the two acceptable answers, followed by 'p.d. was produced', which is identical to the question.

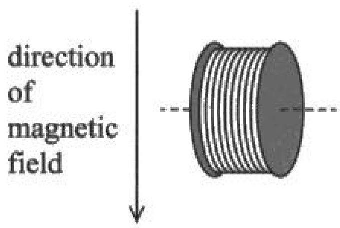
16 A search coil is used to investigate magnetic fields.

The search coil consists of a coil of thin copper wire connected to two output terminals, as shown.

A student placed the coil in a magnetic field with the axis parallel to the direction of the field, as shown.



The coil was rotated through 90° so the axis was perpendicular to the direction of the field, as shown.



As the coil was rotated, a potential difference (p.d.) was detected across the terminals.

(a) Explain why a p.d. was produced as the coil was rotated.

(2)

When the coil is rotated magnetic flux linkage changes from maximum to zero. Thus ~~a~~ emf is induced in the ~~co~~ coil and a potential different was detected across the terminals.

ResultsPlus
Examiner Comments

2 marks. This is an example of a good, full mark response.

Question 16 (b)

The great majority scored full marks for this question. Chief errors were in calculating area, such as using diameter rather than radius, using $2\pi r$ or power of ten errors in using 25 mm.

(b) Show that the initial value of magnetic flux in the coil is about 9×10^{-5} Wb.

diameter of coil = 25 mm
magnetic flux density = 0.18 T

(3)

$\phi = Ba$ $\qquad A = \overset{2}{4}\pi r^2$ $\qquad A = 2\pi\left(\frac{25\times10^{-3}}{2}\right)^2$

$\phi = (0.18)(9.82\times10^{-4})$ $\qquad A = 9.82\times10^{-4}$

$\phi = 1.77\times10^{-4}$

$\boxed{\phi = 1.8\times10^{-4}}$ /

ResultsPlus
Examiner Comments

1 mark. The formula for area is incorrect, introducing an extra factor of 2. A mark is awarded for applying knowledge and understanding of flux = *BA*.

(b) Show that the initial value of magnetic flux in the coil is about 9×10^{-5} Wb.

diameter of coil = 25 mm
magnetic flux density = 0.18 T

(3)

$\phi = BA$ $\qquad A = \pi r^2$ $\qquad r = \frac{25}{2}$

$= 0.18 \times \frac{\pi}{6400}$ $\qquad = \pi \times (0.0125)^2$ $\qquad = 12.5\text{mm}$

$= \frac{\pi}{6400}$ $\qquad = 0.0125\text{m}$

$= 8.84\times10^{-5}$ Wb $\qquad = 4.91\times10^{-4}$

$\approx 9\times10^{-5}$ Wb

ResultsPlus
Examiner Comments

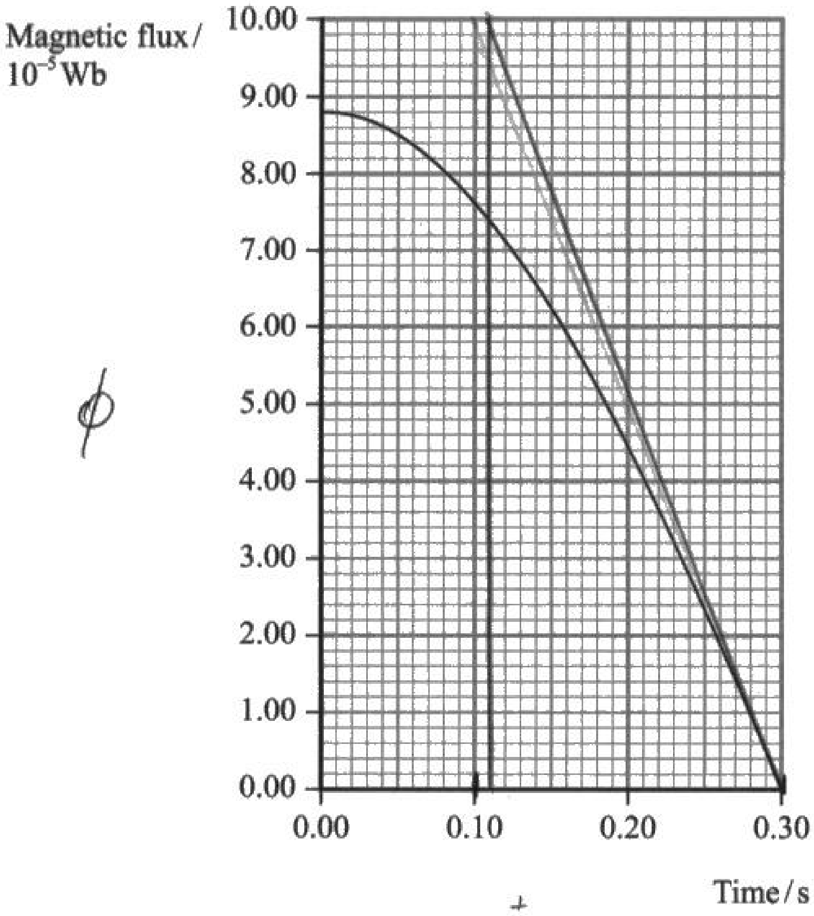
3 marks. A nice example of a full mark question.

Question 16 (c)

Students were generally able to identify the relevant equation and, having done so, many realised they needed to use the gradient of a tangent to the curve. They did not, however, all choose the point on the graph at 0.30 s, some choosing to draw their tangent at 0.00 s and others at a random point part way along the curve. Some didn't use a tangent at all but took the values at 0.00 s and 0.30 s. Whichever method was used, some students did not use the power of ten shown on the magnetic flux axis. The number of turns was usually applied correctly.

A substantial minority demonstrated a lack of understanding of the difference between magnetic flux density and magnetic flux because they included area in their calculation – even if they had used *BA* in part (b).

(c) The graph shows the magnetic flux in the coil while the coil was being rotated.



Determine the maximum p.d. produced across the terminals.

number of turns on coil = 5000

(4)

$\mathcal{E} = -\frac{d(N\phi)}{dt} = 5000 \times -\frac{dN}{dt}$

$= 5000 \times -$ gradient

gradient $= \Delta y / \Delta x = -10 / 0.19 = -52.6$

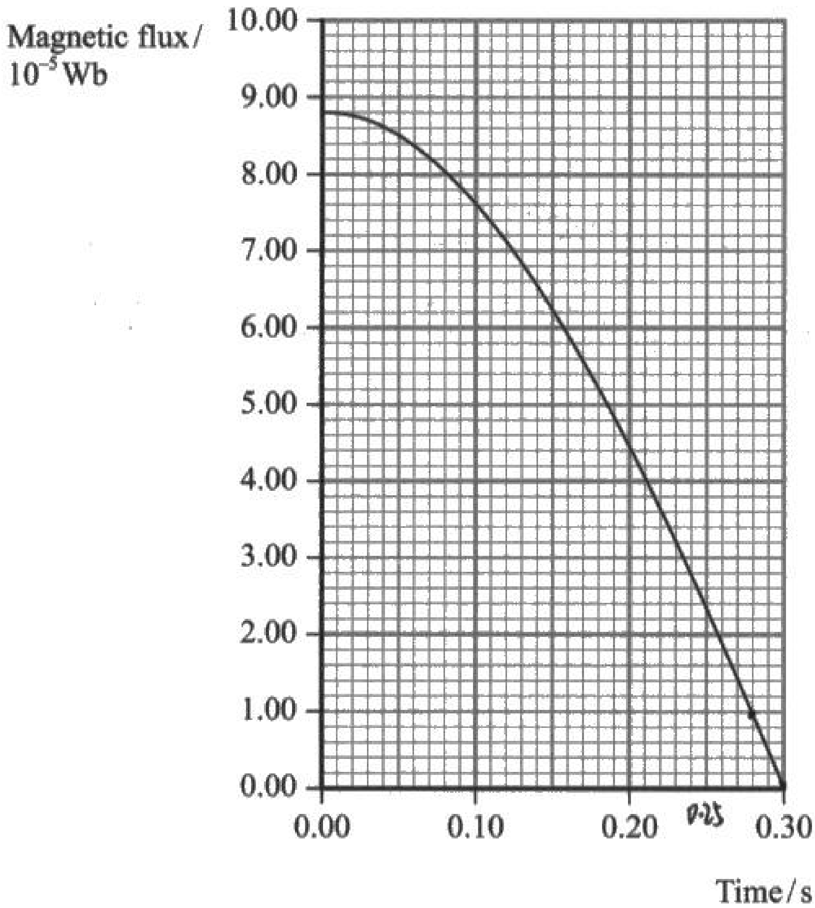
$5000 \times -(-52.6) = 5000 \times 52.6 = 2.63 \times 10^5$ V

Maximum p.d. = 2.6×10^5 V

ResultsPlus
Examiner Comments

3 marks. The correct method has been followed, but the power of ten on the magnetic flux axis has been ignored, so there is a large power of ten error in the final answer.

(c) The graph shows the magnetic flux in the coil while the coil was being rotated.



Determine the maximum p.d. produced across the terminals.

number of turns on coil = 5000

(4)

~~The~~ maximum magnitude of gradient. = $\frac{1 \times 10^{-5} \cancel{Wb}}{0.02}$

$= 5 \times 10^{-4}$.

$\varepsilon = -5000 \times 5 \times 10^{-4} = -2.5V$

Maximum p.d. = 2.5 V

ResultsPlus
Examiner Comments

4 marks. For the last twentieth of a second the line appears straight, and some students use points along this section of the line rather than drawing a tangent. This does lead to using a very small triangle, which increases the effect of uncertainties in reading the values and is more likely to produce an inaccurate answer.

In this case the answer was within range and full marks were awarded.

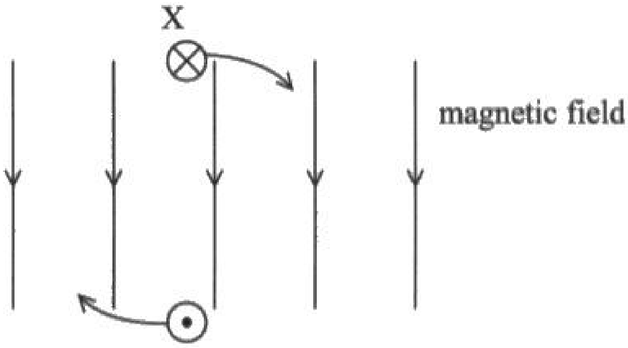
ResultsPlus
Examiner Tip

When the gradient of a graph is required, from a straight line graph directly or from the tangent to a curve, you should use the largest triangle possible to reduce the effect of uncertainties.

Question 16 (d)

About a third got a single mark and half that number gained some of the other marks. Some sort of statement of Lenz’s law was usually included, but frequently not quite correct, such as ‘a current is produced that opposes the magnetic field’. The mechanism for opposition to the change via the interaction between the magnetic field and the current was frequently ignored. Students who depended on the formula sheet to remind themselves of Lenz’s law tended to focus on the mechanism of electromagnetic induction, already assessed in part (a), if they didn’t pick up on the minus sign. Quite a few students thought they had been instructed to deduce the current that would make a motor turn in the direction shown and gave that as their final answer, even though they could have argued from that to find the required answer.

(d) The output terminals of the coil are connected together, while the coil is in the magnetic field. The diagram shows a cross-section through one turn of the coil. X is on one side of the coil.



The coil is rotated clockwise in the magnetic field, causing a current in the coil. The student states that the current at X is into the page.

Deduce whether the student's statement is correct.
You should refer to Lenz's law.

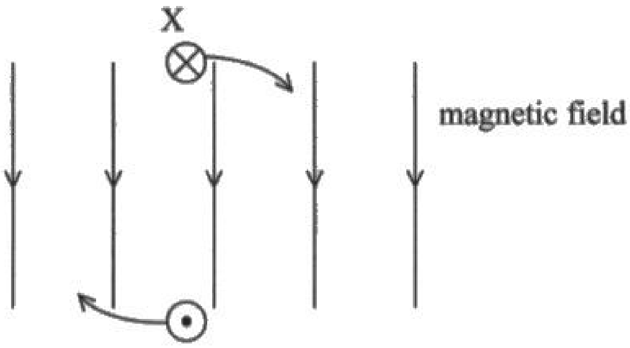
(4)

As the coil rotates, there is a change in magnetic flux linked with the coil. E.m.f is induced. ~~The~~ ~~that~~ As the coil move through the magnetic field a current is generated. According to lenz law the e.m.f is induced in such a way to oppose the motion of the coil. The force will act from the ~~lef~~ right side to the left side. Using flemings left hand rule, the current at X is into the page. Hence the student is correct.

ResultsPlus
Examiner Comments

3 marks. MP1 is given for 'according to Lenz's law the emf is induced in such a way as to oppose the motion of the coil'. MP2 is not awarded. It is not clear that the force is produced because of the interaction of the current and field. MP3 is awarded for the force will act from the right side to the left side (the sense of direction is clear) and an indication that FLHR applies here. MP4 is awarded as the response indicates that the current is into the page and therefore the student's statement is correct.

(d) The output terminals of the coil are connected together, while the coil is in the magnetic field. The diagram shows a cross-section through one turn of the coil. X is on one side of the coil.



The coil is rotated clockwise in the magnetic field, causing a current in the coil.
The student states that the current at X is into the page.

Deduce whether the student's statement is correct.
You should refer to Lenz's law.

(4)

According to Lenz's law, induced current in the magnetic field will cause a force to oppose the coil's motion. So the coils rotates clockwise, the force acts on the coils to move anti -clockwise.

At X, the force is towards to left.

According to left hand law, the current is into the page.

The student is correct.

ResultsPlus Examiner Comments

4 marks. There is a clear statement that the induced current is a magnetic field so a force will be produced so MP2 was awarded. MP1 is clear in the first two lines. MP3 is given for force to left and applying the left hand rule. MP4 is given as the current is said to be into the page and the appropriate conclusion has been drawn.

Question 17 (a)

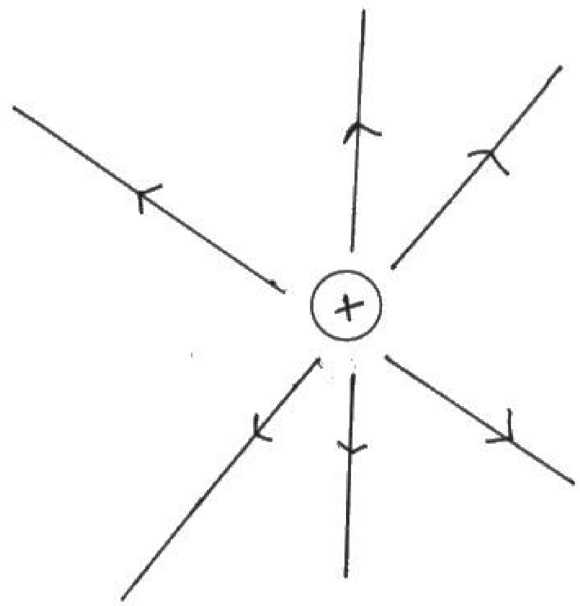
A minority of candidates failed to score here, with more than two thirds getting two marks and half of the entry getting all three marks. Those who knew the general pattern required failed to score for a few main reasons – drawing lines that were plainly not straight, irregularly spaced lines, particularly when the number of lines was odd, and lines not starting from the surface of the sphere. Those using 4 or 8 lines were most likely to be correct, but the more lines were included the harder it was to ensure that they were evenly spaced. The arrows were rarely incorrect.

On the whole, students drawing four lines at right angles found it the easiest to ensure equal spacing. It is also worth pointing out that the front of the paper says a ruler is required for a reason and it isn't just for lines on graphs.

Quite a few students drew equipotentials as well as field lines and only gained marks if they labelled them appropriately to indicate that they knew which was which. A few students found a way to draw a uniform field for the sphere.

(a) Complete the diagram to show the electric field around a positively charged sphere.

(3)

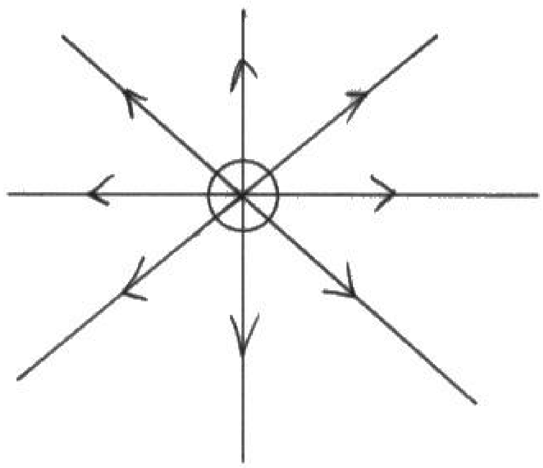


ResultsPlus
Examiner Comments

1 mark. Only the arrows gain credit here as the lines do not meet the surface and they are not evenly spaced.

(a) Complete the diagram to show the electric field around a positively charged sphere.

(3)

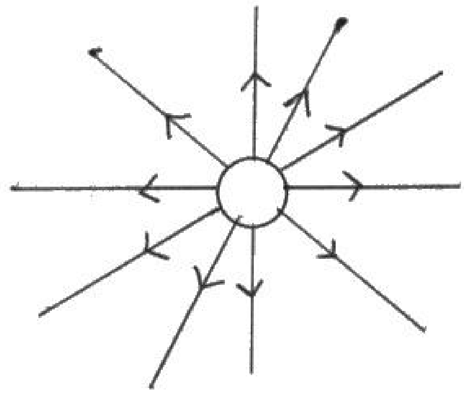


ResultsPlus
Examiner Comments

2 marks. This does not get 3 marks because the lines originate at the centre, but there is no electric field inside a charged sphere.

(a) Complete the diagram to show the electric field around a positively charged sphere.

(3)

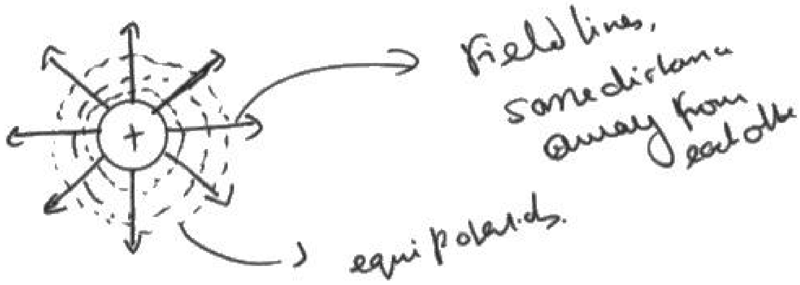


ResultsPlus
Examiner Comments

2 marks. These lines are not equally spaced – made more difficult by using 10 rather than 4 or 8.

(a) Complete the diagram to show the electric field around a positively charged sphere.

(3)



ResultsPlus
Examiner Comments

3 marks. This diagram was seen fairly often, but without the labels, in which case it got no marks. Students who drew equipotentials only got no marks and it is not the responsibility of the examiner to determine which is the correct answer when two are given.

Question 17 (b)

Almost half of the entry successfully completed all three parts of this question which required a linked sequence of fairly detailed calculations.

In part (i) the great majority were able to select the correct equation and calculate the answer. Some, however, used *E* = *V/d* and some squared *r*. There was a scattering of power of ten errors from the radius and some candidates made errors in rearrangement.

This question started with 'show that', which means that the relevant steps must be shown in full, including substitution of all data, and the calculation of the final answer to one significant figure more than the quoted value. In this case, some did not get full credit because they did not substitute values fully, usually through leaving the Coulomb constant as *k*.

Part (ii) had two steps, but students were generally more familiar with this than using potential. They were generally able to work through to the end, using the charge given in part (i) if they hadn't been able to calculate it.

Some students used the Coulomb equation with the distance between the plates as *r*.

Part (iii), while often well done, was the most difficult part for many, often using the force from part (ii) as the tension or simply applying trigonometrical functions incorrectly, including attempting to find components of weight even though it is clearly not the largest force.

(b) (i) Show that the charge on the sphere is about 10 nC.

potential at surface of sphere = 5000 V
radius of sphere = 20 mm

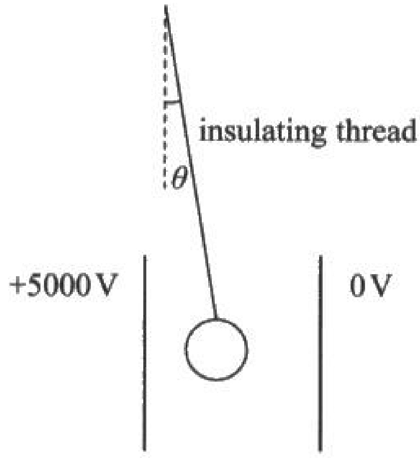
(2)

$E = \frac{V}{d}$ $\quad E = \frac{KQ}{r^2}$ $\quad E = \frac{5000}{0.02} = 2.5 \times 10^5\ \mathrm{Vm^{-1}}$

$Q = \frac{\cancel{E}r^2}{K} = \frac{2.5 \times 10^5 \times (0.02)^2}{8.99 \times 10^9} = 1.1 \times 10^{-8}\ \mathrm{C}$

$= \underline{11\mathrm{nC}}$

(ii) The sphere moves away from the positive plate and comes to rest at an angle θ to the vertical.



Show that the horizontal force on the sphere is about 5×10^{-4} N.

distance between plates = 10.5 cm

(3)

$E = \frac{V}{d} = \frac{5000}{0.105} = 4.76 \times 10^{4}\ \text{V m}^{-1}$

$F = EQ = 4.76 \times 10^{4} \times 1.1 \times 10^{-8} = \underline{5.2 \times 10^{-4}\ \text{N}}$

(iii) Show that θ is about 1°.

mass of sphere = 2.7 g

(3)

$\cancel{5 \times 10^{-4} \sin\theta = 2.7 \times 10^{-3} \times 9.81 \cos\theta}$

$W = mg = 2.7 \times 10^{-3} \times 9.81 = 0.0265$

$5 \times 10^{-4} \sin\theta = \cancel{2.7 \times 10^{-3}}\ 0.0265 \cos\theta$

$\tan\theta = \frac{0.0265}{5 \times 10^{-4}} \Rightarrow \theta = \tan^{-1}\left(\frac{0.0265}{5 \times 10^{-4}}\right) = 88.9^{\circ}$

$90 - 88.9 = \underline{1.1^{\circ}}$

ResultsPlus
Examiner Comments

Part (i) 0 marks. This looks like the correct answer, but it is a 'show that' question, and the method is required. This starts off using *E* = *V/d*, which is not relevant because it is for a uniform field. It may have been intended as *E* = *V/r*, which could be a route, but that must be made clear for 'show that', using the standard symbols, or at least the same symbols throughout. Here we are left to puzzle out whether *d* and *r* are the same thing.

Part (ii) 3 marks. Fully correct answer.

Part (iii) 1 mark. MP1 only. Sin and cos should only be applied as multipliers to find components of tension, which is the hypotenuse in this triangle of forces. It doesn't necessarily affect the answer much because it is a small angle, which is why this looks correct.

(b) (i) Show that the charge on the sphere is about 10 nC.

potential at surface of sphere = 5000 V
radius of sphere = 20 mm

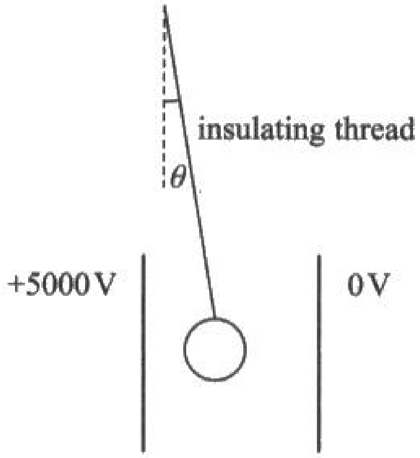
(2)

$5000 = \frac{kQ}{r}$ $\quad V = \frac{kQ}{r}$

$5000 = \frac{kQ}{0.02}$

$Q = 11.1 \times 10^{-9} \rightarrow 11 nC$

(ii) The sphere moves away from the positive plate and comes to rest at an angle θ to the vertical.



Show that the horizontal force on the sphere is about 5×10^{-4} N.

distance between plates = 10.5 cm

(3)

$E = \frac{V}{d} = \frac{5000}{0.105} = 47.6 \times 10^3$

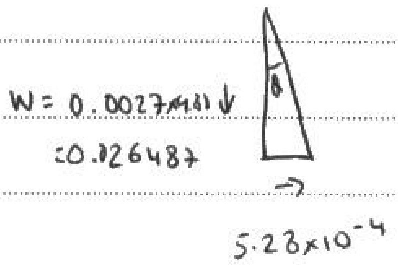
$E = \frac{F}{Q}$ $F = 47.6 \times 10^3 \times 11.1 \times 10^{-9}$

$= 5.28 \times 10^{-4}$ N

(iii) Show that θ is about 1°.

mass of sphere = 2.7 g

(3)



$\tan\theta = \frac{5.28 \times 10^{-4}}{0.026487}$

$\theta = 1.14°$

ResultsPlus
Examiner Comments

Part (i) 1 mark. The working is correct, as is the answer, but this is a 'show that' question so all working must be clear. The value for *k*, the Coulomb constant, has not been substituted.

Part (ii) 3 marks. Fully correct response.

Part (iii) 3 marks. Fully correct answer. This is a 'show that' question, and the triangle of forces has been used to show the origin of the equation using tan.

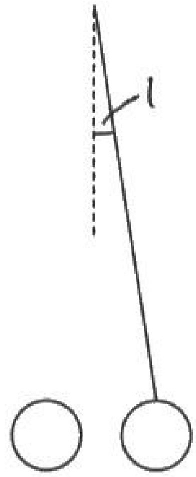
Question 17 (c)

This was well answered, with well over half getting full marks. Errors included forgetting to take a square root, using $2Q$ instead of Q^2, or just forgetting the square, and the usual range of power of ten errors.

(c) A second identical charged sphere is held in a fixed position.

The first sphere, attached to the insulating thread, is placed near to the fixed sphere.

The spheres exert a repulsive force on each other.



The force between the spheres is 5.0×10^{-4} N.

Calculate the distance between the centres of the spheres.

charge on each sphere = 12 nC

(3)

$F = k\frac{Q_1 Q_2}{r^2}$

$5 \times 10^{-4} = \frac{8.99 \times 10^9 \times 12 \times 10^{-6} \times 12 \times 10^{-6}}{r^2}$

$r = \sqrt{\frac{8.99 \times 10^9 \times 12 \times 10^{-6} \times 12 \times 10^{-6}}{5 \times 10^{-4}}}$ $r = 50.88\text{ m}$

Distance between centres of spheres = ...

ResultsPlus
Examiner Comments

2 marks. The method is correct, but nanometres have been interpreted as micrometres, leading to a power of ten error.

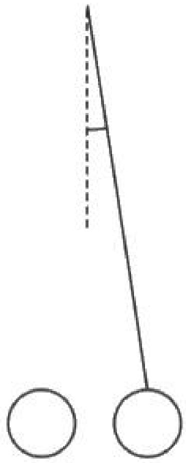
ResultsPlus
Examiner Tip

Be sure to know the standard SI prefixes and be able to apply the correct power of ten – this is frequently required in this paper with eV, F and Ω.

(c) A second identical charged sphere is held in a fixed position.

The first sphere, attached to the insulating thread, is placed near to the fixed sphere.

The spheres exert a repulsive force on each other.



The force between the spheres is 5.0×10^{-4} N.

Calculate the distance between the centres of the spheres.

charge on each sphere = 12 nC

(3)

$F = k\frac{Q_1 Q_2}{r^2}$

$5 \times 10^{-4} = \frac{8.99 \times 10^{9} \times (12 \times 10^{-9})^2}{r^2}$

$r = 2.59 \times 10^{-3}$ m

Distance between centres of spheres = 2.59×10^{-3} m

ResultsPlus
Examiner Comments

2 marks. The correct equation has been used and the substitution is correct and r^2 has been calculated correctly but given as the final answer r without taking the square root.

ResultsPlus
Examiner Tip

When using an equation with a power term, e.g. r^2, don't forget to square the term or to take the square root as appropriate.

Question 18 (a)

More students got full marks than any other mark here. Quite a lot of students did not draw the best fit straight line, but just used values taken from the points. This was the third question requiring a ruler and some students may well not have had one. Some didn’t realise that the graph values were logarithms and took logarithms of the logarithms.

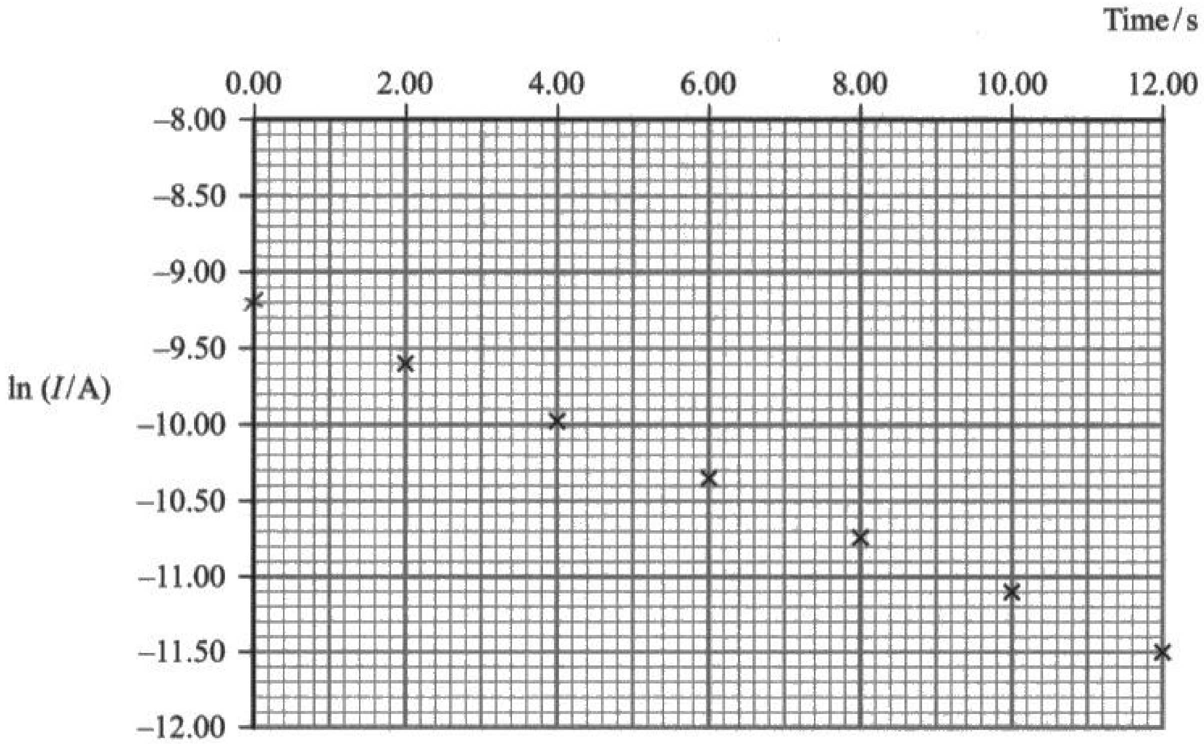
Some students did not gain full credit because they gave their answer as 22 microfarads without an additional significant figure.

18 A student planned to use a capacitor in a timing circuit.

The capacitor was connected in series with a resistor to determine the capacitance of the capacitor.

The capacitor was charged while measuring the current I in the circuit.

The following graph was plotted.



(a) The value marked on the capacitor is 22 μF.

Show that this value is correct.

resistance of resistor = 240 kΩ

(4)

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

$\ln I = \ln I_0 - \frac{t}{RC}$

$\cancel{\ln(-11.5) = \ln(-9.6) - \left(\frac{10}{240000 \times C}\right)}$ $-11.5 = -9.6 - \frac{10}{240000 \times C}$

$\cancel{-\frac{10}{240000 \times C} = \ln \left(\frac{-11.6}{-9.6}\right)}$ $\frac{10}{240000 \times C} = -9.6 - -11.5$

$C = 2.192982456 \times 10^{-5}$

$= 21.9 \times 10^{-6}$ F

$= 21.9\ \mu F$

$\approx 22\ \mu F$

ResultsPlus
Examiner Comments

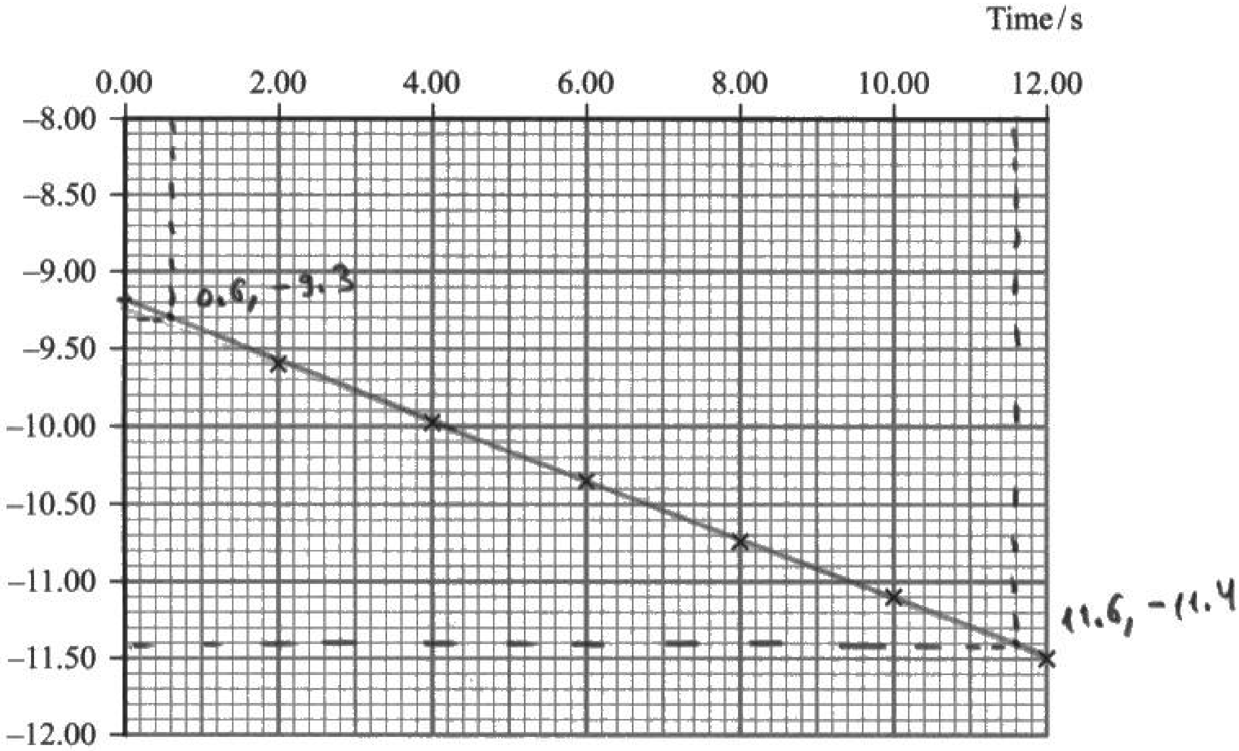
3 marks. The substitution of values in the correct equation leads to the correct value, but the values have been taken from points rather than from a line. The first mark is not awarded because a line of best fit has not been drawn.

18 A student planned to use a capacitor in a timing circuit.

The capacitor was connected in series with a resistor to determine the capacitance of the capacitor.

The capacitor was charged while measuring the current I in the circuit.

The following graph was plotted.



(a) The value marked on the capacitor is 22 μF.

Show that this value is correct.

resistance of resistor = 240 kΩ

(4)

$\ln I = \ln I_0 - \frac{1}{RC} \times t$

$m = \frac{-11.4 - (-9.3)}{11.6 - 0.6} = -0.191$

$-\frac{1}{RC} = -0.191$

$\frac{1}{240 \times 10^3 \times C} = 0.191$

$C = 2.18 \times 10^{-5} = 21.8\ \mu F \approx 22\ \mu F$

ResultsPlus
Examiner Comments

4 marks. This is an example of a full mark response. It is not clear why some students drew a full best fit straight line but chose points near to the ends but not at the ends for the values for the gradient.

Question 18 (b)

Almost half of the entry gained at least half of the marks for these three linked sections requiring a series of multi-step calculations.

Part (i) was a fairly standard gravitational potential energy to kinetic energy calculation. Some students arrived at the correct answer applying *suvat*, but this is incorrect physics because acceleration is not constant.

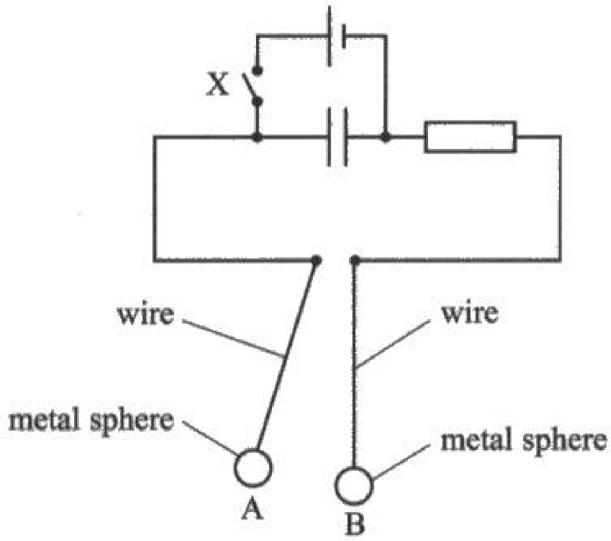
Students could generally select the capacitor discharge equation in exponential or logarithmic form for part (ii), although not all who started with the former proceeded correctly to the latter because they didn't include ln in the calculation.

Some used the resistance from part (a) rather than the value stated here.

In part (iii), the calculation of $W = mg$ was the most scored part of the whole of question 18. Not all students knew what to do thereafter, however, but those who thought to calculate momentum were able to apply the impulse concept to calculate the average force. Not all went on to gain the fourth mark because they didn't include a suitable comparison.

(b) The capacitor was used in a circuit to time a collision between two identical metal spheres.

The spheres were suspended from wires. The wires were connected to the circuit, as shown.



When the wires hang vertically the spheres are in contact and the discharging circuit is complete.

Switch X was closed to charge the capacitor. The switch was then opened and sphere A was released.

Sphere A collided with sphere B.

While the spheres were in contact, the capacitor partially discharged.

Sphere B moved to the right. The maximum height h of sphere B above its starting position was measured.

(i) Calculate the maximum speed of sphere B after the collision.

$h = 1.1\,\text{cm}$
mass of sphere B = 28 g

(3)

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

$v = \sqrt{2gh}$

$= \sqrt{2 \times 9.81 \times (0.011\,\text{m})}$

$= 0.46\,\text{ms}^{-1}$

Maximum speed = $0.46\,\text{ms}^{-1}$

(ii) Calculate the time for which the spheres were in contact.

resistance in circuit = 49 Ω
potential difference across capacitor before collision = 6.18 V
potential difference across capacitor after collision = 5.43 V
capacitance of capacitor = 22 μF

(2)

$\ln V = \ln V_0 - \frac{t}{RC}$

$\cancel{\ln\left(\frac{6.18V}{5.43V}\right)}$ $\ln\left(\frac{5.43V}{6.18V}\right) = \cancel{\frac{t}{RC}} - \frac{t}{49\Omega \times 22 \times 10^{-6} F}$

$t = 1.39 \times 10^{-4} s$

Time spheres in contact = 1.4×10^{-4} s

(iii) The student stated that the average force acting on sphere B cannot be more than the weight of sphere A.

Deduce whether this statement is correct.

mass of each sphere = 28 g

(4)

Impulse on B = $(0.028\ kg)(0.46\ ms^{-1})$

$= 0.0129\ kg\ ms^{-1}$

$0.0129\ kg\ ms^{-1} = F(1.4 \times 10^{-4} s)$

$F = 92\ N$

ResultsPlus
Examiner Comments

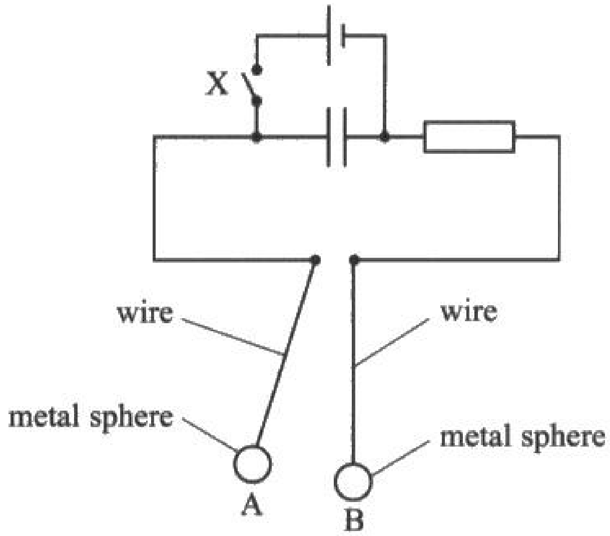
Part (i) 3 marks, part (ii) 2 marks, part (iii) 3 marks.

Parts (i) and (ii) are fully correct.

In part (iii) the calculations are all correct but there is no final conclusion.

(b) The capacitor was used in a circuit to time a collision between two identical metal spheres.

The spheres were suspended from wires. The wires were connected to the circuit, as shown.



When the wires hang vertically the spheres are in contact and the discharging circuit is complete.

Switch X was closed to charge the capacitor. The switch was then opened and sphere A was released.

Sphere A collided with sphere B.

While the spheres were in contact, the capacitor partially discharged.

Sphere B moved to the right. The maximum height *h* of sphere B above its starting position was measured.

(i) Calculate the maximum speed of sphere B after the collision.

$h = 1.1\,\text{cm}$
mass of sphere B = 28 g

(3)

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

$\frac{v^2}{2} = 9.81\,(1.1 \times 10^{-2})$

$v = 0.465\ \text{m s}^{-1}$ (cor. to 3 sig. fig.)

Maximum speed = $0.465\ \text{m s}^{-1}$

(ii) Calculate the time for which the spheres were in contact.

resistance in circuit = 49 Ω
potential difference across capacitor before collision = 6.18 V
potential difference across capacitor after collision = 5.43 V
capacitance of capacitor = 22 μF

(2)

$\ln 5.43 = \ln 6.18 - \frac{t}{22 \times 10^{-6} \times 49}$

$t = 1.39 \times 10^{-4}$ s (cor. to 3 sig. fig.)

Time spheres in contact = 1.39×10^{-4} s

(iii) The student stated that the average force acting on sphere B cannot be more than the weight of sphere A.

Deduce whether this statement is correct.

mass of each sphere = 28 g

(4)

$(F_{avg})(t) = \Delta(mv) = 28 \times 10^{-3} \times (v - 0)$

$F_{avg} = 93.35\ldots$ N

weight of sphere A $= 9.81 \times 28 \times 10^{-3} = 0.274\ldots$ N

∴ The statement is wrong.

ResultsPlus Examiner Comments

3,2,3

Paper Summary

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

- In questions with a specific answer line for a numerical value, you will not be awarded the final mark for a calculation if the unit is not included.
- Learn standard descriptions of physical processes, such as electromagnetic induction and linacs, and be able apply them with sufficient detail to specific situations, identifying the parts of the general explanation required to answer the particular question.
- Questions may be similar to something you have seen in a previous paper, but they are unlikely to be identical. Beware of giving a prepared answer to a different question.
- Where you are asked to make a judgement or come to a conclusion by command words such as ‘determine whether’, you must make a clear statement, including any values being compared.
- When you do not get the correct final answer, you may still be awarded marks for your working. For this mark to be awarded, there must be full substitution of values, including all constants, into a correct equation; there must be one unknown only.
- While physics formulae are provided in the exam, the formulae for the circumference and radius of a circle and area and volume of a sphere must be remembered.
- Physical quantities have a magnitude and a unit, and both must be given in answers to numerical questions for the final mark to be awarded.