Examiners' Report
January 2013

GCE Physics 6PH04 01

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6PH04 01

This question paper discriminated well and candidates were able to apply their knowledge to a variety of styles of examination questions. Since this is an A2 paper, candidates should show progression from AS and this is reflected in the more difficult content of the A2 specification and also in the demands of the questions. Almost all candidates were able to start all of the questions, demonstrating some knowledge of all of the topics within this unit.

In a context-based question it is important for candidates to think clearly about the situation being considered and not to assume that it is one that they have met already. This applied specifically to Q13, regarding the varying reaction force on the path of the London Eye. Many candidates answered it as if it were a stone on a rope, moving in a vertical circle, confusing tension and contact force. Candidates need to be aware of 'making up data'. If the candidate selects the wrong formula to complete a calculation and there is a piece of data they require but is not given, they will generally assume a value. They should not do this, because any data they require will be given in the question. If this situation does occur, the correct thought-process should be that this is the wrong equation to use and that they need to think of another solution.

The multiple choice questions in section A were generally well-answered, with even the less-able candidates managing to achieve 6/7 marks.

Question	Topic	% correct	Most common incorrect response
1	Magnetic flux density units	78	C
2	Conservation of momentum	56	A
3	Electric field properties	88	C
4	Electric field strength	93	A
5	Vector quantities	46	B
6	Colliding spheres	78	A
7	Rate of change of momentum	82	A
8	Magnetic force on a conductor	92	B
9	Ratio of forces on charged particles	55	C
10	linac	96	-

Question 11 (a)

This question was generally well-answered. Most candidates understood the idea of a definite interaction between the alpha and the air molecules. Answers such as 'to prevent the alpha particles being ionised' or 'to make sure the alpha particles reach the gold', were not credited because both of these effects are a consequence of a collision. Other incorrect answers occurred when words such as 'interfere' or 'react' were used. These words have specific meanings, which are not to do with collisions. The examples included are of answers which did not score the mark.

11 Early in the twentieth century physicists observed the scattering of alpha particles after they had passed through a thin gold foil. This scattering experiment provided evidence for the structure of the atom.

(a) State why it is necessary to remove the air from the apparatus that is used for this experiment.

(1)

So that alpha particles do not collide with anything.

ResultsPlus

Examiner Comments

Although the candidate has understood the concept of collisions, this answer is not detailed enough. Reference needs to be made to the air molecules. The point of the experiment is to have a collision with a gold atom.

0 marks

11 Early in the twentieth century physicists observed the scattering of alpha particles after they had passed through a thin gold foil. This scattering experiment provided evidence for the structure of the atom.

(a) State why it is necessary to remove the air from the apparatus that is used for this experiment.

(1)

This could affect the alpha particles (make them change direction or lose energy) changing the results

ResultsPlus

Examiner Comments

This is grammatically a very poor answer because the candidate starts with *this.* It reads as though it is the removal of the air that could affect the alpha particles.

0 marks

ResultsPlus

Examiner Tip

Make sure your answer is clear.

11 Early in the twentieth century physicists observed the scattering of alpha particles after they had passed through a thin gold foil. This scattering experiment provided evidence for the structure of the atom.

(a) State why it is necessary to remove the air from the apparatus that is used for this experiment.

(1)

so that the air particles do not interfere with the alpha particles

ResultsPlus
Examiner Comments

Interfere is too vague a word, so this example again scores zero.

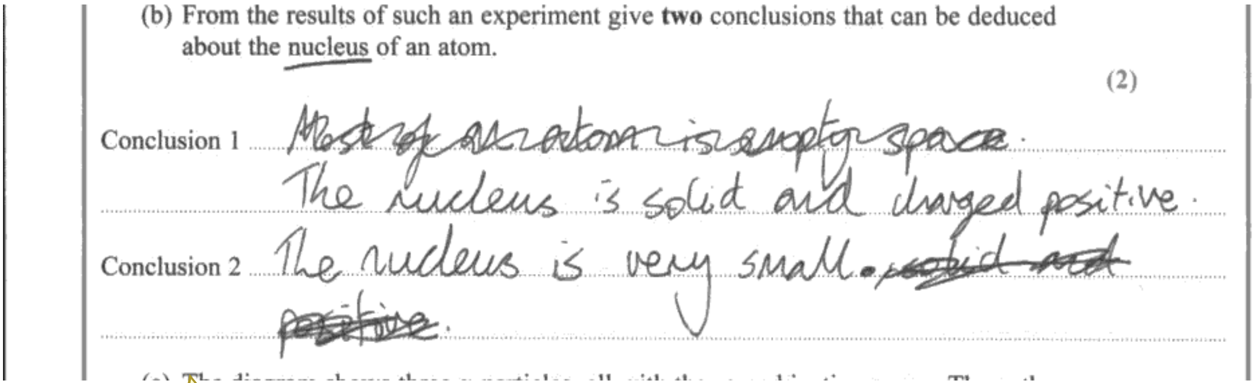
0 marks

Question 11 (b)

Candidates need to 'read the question'. The question was about the nucleus and not the atom. Although many candidates did score both marks, often marks were lost because the candidates were answering questions from previous papers.

A common wrong answer was ' the atom is mainly empty space.' Also, many candidates responded using the word 'it' and sometimes it was not clear to what they were referring. As a general rule, a reply such as 'it is charged' would be assumed to be a reference to the nucleus. However, a response such as 'it has a small central area containing all of the mass', is really an answer to a question about the atom.

Most candidates who scored the marks did so by referring to the nucleus being charged and most of the atom's mass being in the nucleus. It was not sufficient to say that the nucleus is small, because the atom is also small. Candidates needed to say that the nucleus was very much smaller than the atom.



(b) From the results of such an experiment give **two** conclusions that can be deduced about the nucleus of an atom.

(2)

Conclusion 1 Most of an atom is empty space.
The nucleus is solid and charged positive.

Conclusion 2 The nucleus is very small. ~~solid and positive~~.

ResultsPlus
Examiner Comments

Although Rutherford's experiment only established that the nucleus was charged, we treat as neutral the reference to positive. Only saying that the nucleus is very small is not sufficient, since the atom itself is very small. There needs to be a comparison with the atom itself.

0 marks

(b) From the results of such an experiment give **two** conclusions that can be deduced about the nucleus of an atom.

(2)

Conclusion 1 only the nuclea of an atom is charged

Conclusion 2 Atoms are mainly space and only the centre have mass.

ResultsPlus

Examiner Comments

This candidate seems to have forgotten that an atom has electrons as well as protons. The 2nd conclusion is about the atom and not the nucleus.

0 marks

ResultsPlus

Examiner Tip

Be careful to read the question. This one is about the nucleus, not the atom, so saying the atom is empty space is not telling the examiner anything about the nucleus.

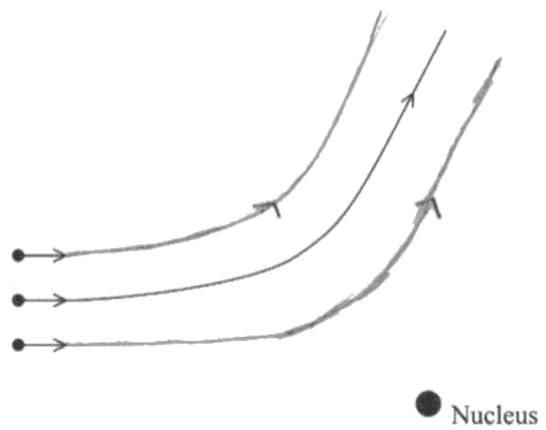
Question 11 (c)

The full range of marks was awarded for this section, with only the most able scoring all three marks. The most common errors were to have all three paths becoming parallel, or having the lower path curving downwards and back on itself. This shows an initial attraction, rather than repulsion. Those candidates who did have the lower path curving up and all three paths diverging, often started the deviation for the lower path too late. Again, it is about reading the question and thinking about what is being asked, rather than trying to reproduce a diagram seen in a text book.

(c) The diagram shows three α-particles, all with the same kinetic energy. The path followed by one of the particles is shown.

Add to the diagram to show the paths followed by the other two particles.

(3)



(Total for Question 11 = 6 marks)

ResultsPlus

Examiner Comments

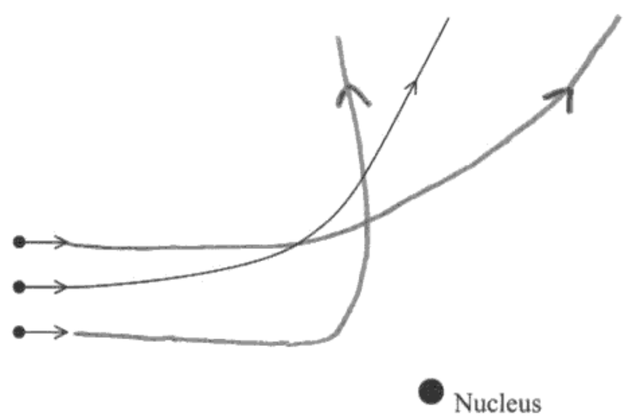
This type of response was seen quite often: the three particles have the same divergence.

0 marks

(c) The diagram shows three α-particles, all with the same kinetic energy. The path followed by one of the particles is shown.

Add to the diagram to show the paths followed by the other two particles.

(3)



ResultsPlus
Examiner Comments

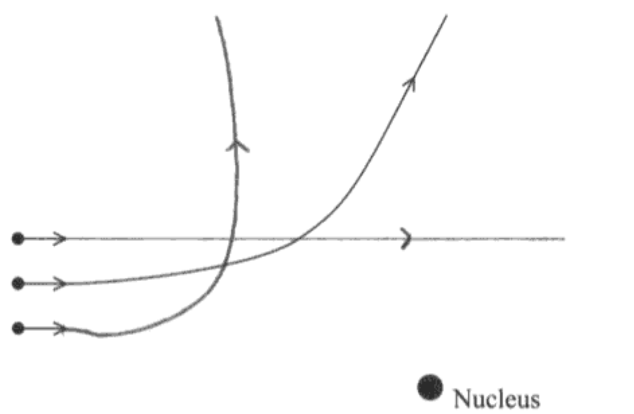
This response scored 2 marks but lost the 3rd mark because the bottom particle began curving too late.

2 marks

(c) The diagram shows three α-particles, all with the same kinetic energy. The path followed by one of the particles is shown.

Add to the diagram to show the paths followed by the other two particles.

(3)



(Total for Question 11 = 6 marks)

ResultsPlus
Examiner Comments

A three-mark answer.

3 marks

Question 12 (a)

Candidates scored very well, with the majority scoring full marks. When errors were made in the velocity calculation they were usually due to incorrect rearrangements of the formula at the start. The 'use of' mark at the beginning of most calculations is for substitution into a correct formula.

For weaker candidates, it is better to substitute into equations before they are rearranged. If they rearrange first (incorrectly) and then substitute, they will not receive the 'use of' mark. Examiners often saw $v = m\lambda/h$.

In the kinetic energy calculation, the common mistakes were either to fail to square the velocity if using KE = $mv^2/2$ or to multiply by e, instead of dividing.

12 The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that the de Broglie wavelength associated with it must be similar to the size of the atom which is of the order of 10^{-10} m.

(a) (i) Calculate the speed of an electron whose de Broglie wavelength is 1.00×10^{-10} m.

(3)

$\lambda = \frac{h}{p}$ $\qquad$ $p = mv$

$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{1 \times 10^{-10}}$ $\qquad$ $v = \frac{p}{m}$

$p = 6.63 \times 10^{-24}$ Ns $\qquad$ $v = \frac{6.63 \times 10^{-24}}{9.11 \times 10^{-31}}$

$v =$ [illegible] 7280000...

Speed = 7.28×10^{6} ms^{-1}

(ii) Calculate the kinetic energy of this electron in electronvolts.

(3)

$K.e. = \frac{1}{2} mv^2$

$= \frac{1}{2} \times 9.11 \times 10^{-31} \times (7.28 \times 10^{6})^2 = 2.4 \times 10^{-17}$ J

$\frac{2.4 \times 10^{-17}}{1.6 \times 10^{-19}} =$ [illegible] 150.8 eV

Kinetic energy = 151 eV

ResultsPlus

Examiner Comments

Responses like this were often seen: a perfect answer scoring all of the marks.

6 marks

12 The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that the de Broglie wavelength associated with it must be similar to the size of the atom which is of the order of 10^{-10} m.

(a) (i) Calculate the speed of an electron whose de Broglie wavelength is 1.00×10^{-10} m.

(3)

$p = mv$

$\lambda = 1 \times 10^{-10}$ $\quad\lambda = h/p$

$1.00 \times 10^{-10} = 6.63 \times 10^{-34}/p$

$p = 6.63 \times 10^{-44}$

$6.63 \times 10^{-44} = 9.11 \times 10^{-31} \times v \qquad v = 7.28$

Speed = 7.28×10^{-14} ms^{-1}

(ii) Calculate the kinetic energy of this electron in electronvolts.

(3)

$Ke = \frac{1}{2}mv^2 \qquad J \to eV$

$\times (3 \times 10^8)^2 \div eV.$

$Ke = \frac{1}{2} \times 9.11 \times (7.28 \times 10^{-14})^2$

$Ke = 2.41 \times 10^{-57} \times 3 \times 10^{8\,2} \div 1.6 \times 10^{-19}$

Kinetic energy = 1.36×10^{-21} eV

ResultsPlus

Examiner Comments

(a)(i) This candidate has made an error with the powers of ten in the calculation of momentum. It scores the two method marks but not the last answer mark.

(a)(i) The candidate could potentially score three marks here, using the value from (i), but in the energy calculation has missed the powers of ten off the mass of the electron. The candidate then multiplies by c^2, as well as dividing by e. The marks are independent, so this candidate scored one mark for dividing by e.

3 marks

12 The electron in a hydrogen atom can be described by a stationary wave which is confined within the atom. This means that the de Broglie wavelength associated with it must be similar to the size of the atom which is of the order of 10^{-10} m.

(a) (i) Calculate the speed of an electron whose de Broglie wavelength is 1.00×10^{-10} m.

(3)

$\lambda = h/p \quad \lambda = h/mv$

$mv = h/\lambda \quad v = \dfrac{6.63 \times 10^{-34}}{1.00 \times 10^{-10} \times 9.11 \times 10^{-31}}$

$v = \dfrac{h}{\lambda m} \quad = 7277716.795\ ms^{-1}$

Speed = $7.28 \times 10^{6}\ ms^{-1}$

(ii) Calculate the kinetic energy of this electron in electronvolts.

(3)

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

$= 0.5 \times 9.11 \times 10^{-31} \times 7.28 \times 10^{6}$

$= 3.315 \times 10^{-24}\ J$

convert to eV → $3.315 \times 10^{-24} \div 1.6 \times 10^{-19}$

$= 2.07187 \times 10^{-5}\ eV$

Kinetic energy = 2.07×10^{-5} eV

ResultsPlus

Examiner Comments

A common error in (ii). Despite writing $E_k = mv^2/2$ when substituting into the equation the candidate has forgotten to square the velocity. This scored 3 for (i) and 1 for (ii).

4 marks

ResultsPlus

Examiner Tip

Remember to learn the terms in equations.

Question 12 (b)

Since this question was about de Broglie, it was very surprising how few candidates thought to base their answer in terms of electron wavelength. The vast majority of candidates missed the point completely, and talked about attractive electrostatic forces between the protons and the electrons, the difficulties with the strong nuclear forces and many more inventive answers. Even those who did realise that it was about wavelengths, often scored only 1 mark, because they failed to say that the wavelength would have to be similar in size to the nucleus. It appeared that that was assumed, and candidates just commented on the wavelength being smaller.

(b) When β radiation was first discovered, it was suggested that there were electrons in the atomic nucleus, but it was soon realised that this was impossible because the energy of such an electron would be too great.

Suggest why an electron confined within a nucleus would have a much greater energy than the energy calculated in (a)(ii).

(2)

The de Broglie wavelength would have to be the same size as the nucleus, which is a lot smaller than the atom. A shorter wavelength means more energy. $E = hf$

ResultsPlus

Examiner Comments

A perfect answer that scores both marks. Very few of the candidates scored 2 marks and only a small number more scored 1 mark.

2 marks

This candidate does appreciate that the answer is to do with the associated de Broglie wavelength but fails to say that the wavelength is similar in size to the nucleus and so scored 1 mark.

(b) When β radiation was first discovered, it was suggested that there were electrons in the atomic nucleus, but it was soon realised that this was impossible because the energy of such an electron would be too great.

Suggest why an electron confined within a nucleus would have a much greater energy than the energy calculated in (a)(ii).

(2)

because if it was confined within a nucleus it would have to have a much shorter de broglie wavelength and ~~A~~ $v = \frac{h}{\lambda m}$ the shorter the wavelength the greater the velocity ∴ the greater the E_k

ResultsPlus
Examiner Comments

Think about the context of the question: the clue was in (a) where the electron of hydrogen was talked about.

1 mark

(b) When β radiation was first discovered, it was suggested that there were electrons in the atomic nucleus, but it was soon realised that this was impossible because the energy of such an electron would be too great.

Suggest why an electron confined within a nucleus would have a much greater energy than the energy calculated in (a)(ii).

(2)

nucleus is positive and held because of strong nuclear force. The electron would be attracted to the positive centre because it is negatively charged.

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Examiner Comments

A very frequent answer that scored no marks.

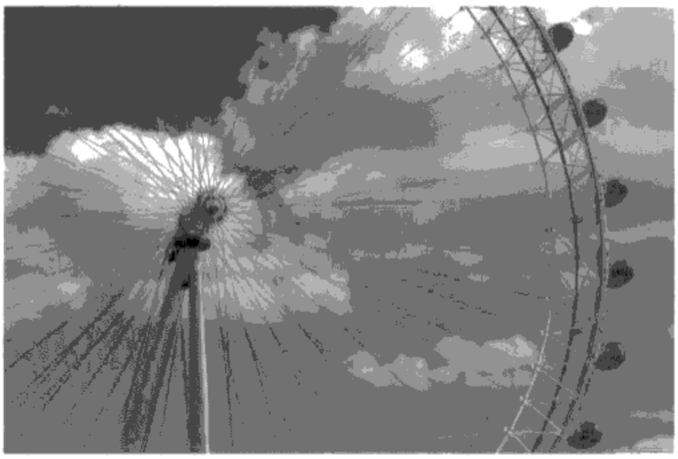
0 marks

Question 13 (a)

Again, there were many correct answers. Some candidates chose to calculate an angular velocity first and then calculate T. This is acceptable but candidates need to be aware of working with too few significant figures. Some used 0.004 rad s^{-1} instead of 0.00426 rad s^{-1}, leading to an answer that was outside the acceptable range.

Other candidates tried to incorporate 32, the number of capsules. Candidates need to remember that any data that they need they will be given, but that at A2, there may be some data in the question that they do not need to use.

13 The London Eye consists of a large vertical circle with 32 equally-spaced passenger cabins attached to it. The wheel rotates so that each cabin has a constant speed of 0.26 m s^{-1} and moves around a circle of radius 61 m.



(a) Calculate the time taken for each cabin to make one complete revolution.

(2)

r = 61 v = 0.26 $\frac{61\text{m}}{0.26\text{ms}^{-1}}$

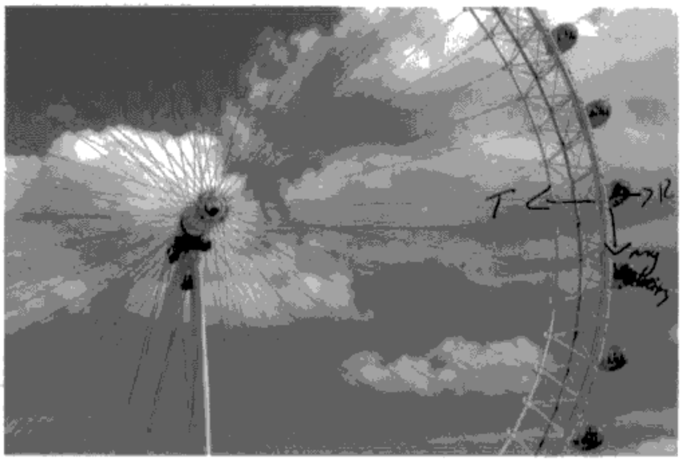
Time = 234.6s

ResultsPlus
Examiner Comments

This is a typical wrong answer where the candidate has used time = distance/speed using the radius, instead of the circumference. This scored zero.

0 marks

13 The London Eye consists of a large vertical circle with 32 equally-spaced passenger cabins attached to it. The wheel rotates so that each cabin has a constant speed of 0.26 m s^{-1} and moves around a circle of radius 61 m.



(a) Calculate the time taken for each cabin to make one complete revolution.

(2)

circumference = $2\pi r$ $= 102\pi$ ... $\frac{102\pi}{0.26} = 1232.47...$ s

Time = 1232 s

ResultsPlus
Examiner Comments

Arithmetic error, 2 x 61 = 122 not 102. This candidate has used the correct formula and scored 1 mark.

1 mark

ResultsPlus
Examiner Tip

Take care with simple arithmetic, careless slips lose marks.

Question 13 (b)

Generally correctly answered - candidates were helped because there was no need to rearrange the equation. The common error, when made, was to forget to square the velocity thus losing both marks.

(b) Calculate the centripetal force acting on each cabin.

mass of cabin = 9.7×10^3 kg

(2)

$F = \frac{mv^2}{r} = \frac{9.7 \times 10^3 \times 0.26^2}{61} = 1.07495082 \times 10^{-5}$

Centripetal force = 1.07×10^{-5} N (3s.f.)

ResultsPlus

Examiner Comments

All the substitutions are correct and velocity is squared. However, this candidate has made a power of ten error, so loses the answer mark but receives the method mark.

1 mark

ResultsPlus

Examiner Tip

Think about the answer: just looking at the order of magnitudes on the LHS, it is clear that the power of ten is wrong on the RHS.

(b) Calculate the centripetal force acting on each cabin.

mass of cabin = 9.7×10^3 kg

(2)

$F = \frac{mv^2}{r}$ $F = m\omega^2 r$

$F = \frac{9.7 \times 10^3 \times (0.26)}{61} = 41.3N$

Centripetal force = 41.3N

ResultsPlus

Examiner Comments

A typical wrong answer, the formula used is correct but the velocity has not been squared.

0 marks

ResultsPlus

Examiner Tip

Having written the correct formula, take time to ensure that it has been used properly.

Question 13 (c) (i)

Nearly all candidates scored this mark.

Question 13 (c) (ii)

Whereas candidates were able to show the direction of the centripetal force on the diagram, the majority of candidates showed no understanding of the fact that this is a resultant force, in this case, of the weight and normal contact force. Also, many candidates thought that the problem was like that of an object being swung on a rope in a vertical circle. This meant that many candidates said that the maximum reaction force was at the top and the minimum at the bottom. Even those who did correctly identify the maximum force at the bottom, invariably went on to talk about the centripetal force as an actual physical force.

Overall, this was a very poorly-answered question, showing a very poor understanding of what is admittedly a very difficult topic.

*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)

At A the contact force is at a minimum as $F_c = Mg - R$ at A (where R is the contact force) so for there to be a resultant (centripetal) force, R must be smaller than mg (which is constant).

At C the contact force is at a maximum as at C: $F_c = R - Mg$ so for a resultant centripetal force to act towards the circle centre, R must be greater than mg.

ResultsPlus

Examiner Comments

An example of a full 4-mark answer, which was only achieved by a very few candidates. Rather more scored 3 marks, but usually lost the 4th mark because their answer did not make it clear that the centripetal force is not an *actual* force, but the name given to the *resultant* force of the weight and normal contact force.

4 marks

*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)

At the top of ~~the cabin~~ the circle the contact force is going to be at at its ~~greatest~~ least as you have both the centripetal force and the person's weight acting in a downward direction.* The bottom of the circle would experience the ~~least~~ greatest force as both the resultant and the centripetal force are pushing upwards onto the person.

ResultsPlus

Examiner Comments

This response scored one mark for the positions of max and min forces but the reasoning is incorrect. This candidate clearly thinks that the centripetal force is a physical force.

1 mark

*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)

The normal contact force will be the greatest at C because $R = \frac{Mv^2}{r} + Mg$ ~~at point C~~ where R is the normal contact force. ~~The norm~~

~~Here the normal~~

The normal contact force will be the least at point A ~~B~~. ~~At point B they there will be no contact force as mg and weight of the cabin and the centripetal force is balance is equal.~~ The normal contact force at A will ~~B~~ be $R = mg - \frac{mv^2}{r}$

ResultsPlus

Examiner Comments

This scores 3 marks but does not identify clearly that the centripetal force is a resultant force.

3 marks

*(ii) As the person in a cabin moves around the circle, the normal contact force between the person and the cabin varies.

State the position at which this force will be a maximum and the position at which it will be a minimum. Explain your answers.

(4)

At A both the ~~[illegible]~~ weight and the tension are acting in the same direction. Thus the force will be maximum at point A. At C the weight ~~[illegible]~~ is acting down and the tension up in the opposite direction. Therefore these forces oppose each other and the normal contact force is at a minimum at C.

At B the forces are ~~[illegible]~~ applied in different directions ~~[illegible]~~ aswell but do not oppose each other.

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Examiner Comments

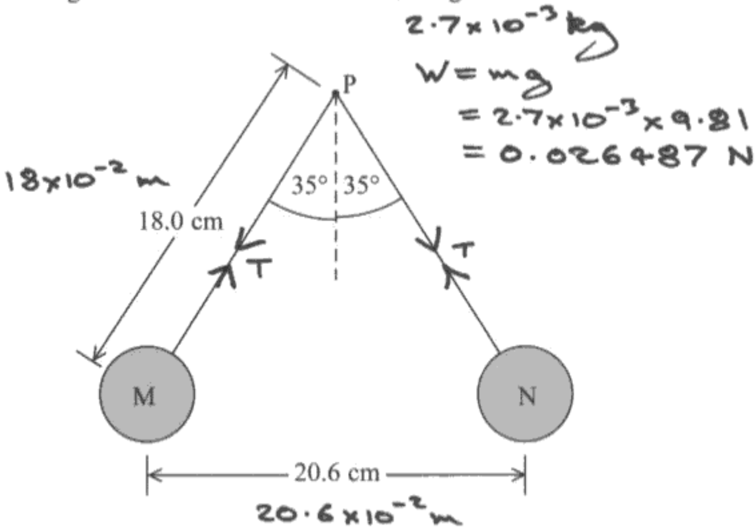
A frequently-seen answer, where the candidate is thinking about an object on a rope. This scores zero.

0 marks

Question 14 (a)

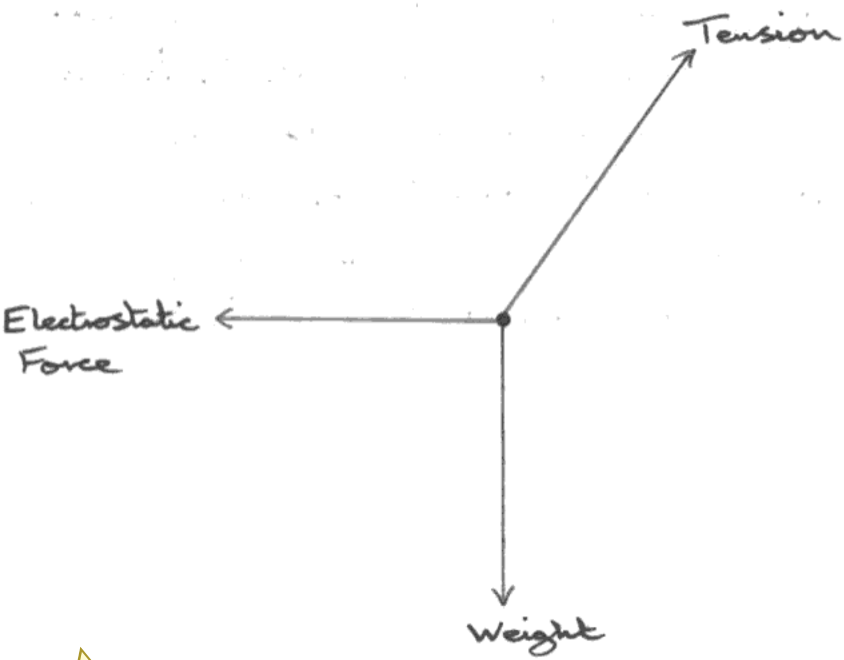
The diagrams were generally good with most candidates understanding that a free-body diagram should only show the forces acting on one object and that it should be the forces, and not the components of the forces.

14 Two identical table tennis balls, M and N, are attached to non-conducting threads and suspended from a point P. The balls are each given the same positive charge and they hang as shown in the diagram. The mass of each ball is 2.7 g.



(a) Draw a free-body force diagram for ball M, label your diagram with the names of the forces.

(2)



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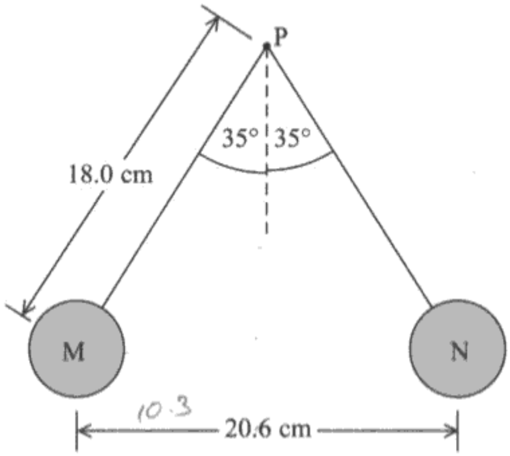
Examiner Comments

An excellent diagram that scores both marks.

2 marks

14 Two identical table tennis balls, M and N, are attached to non-conducting threads and suspended from a point P. The balls are each given the same positive charge and they hang as shown in the diagram. The mass of each ball is 2.7 g.



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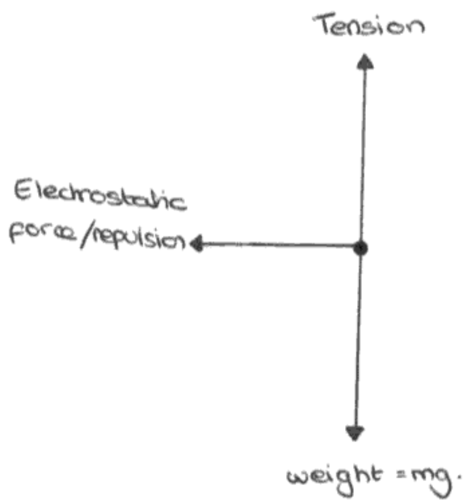
(2)



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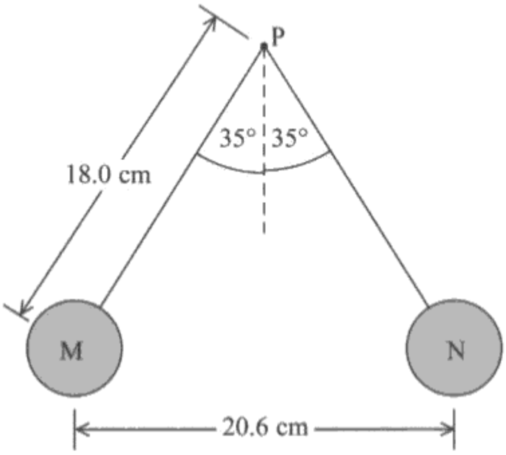
Examiner Comments

Although a tension force has been drawn, it is not in the correct direction and so this scores 1 mark for two correct forces.

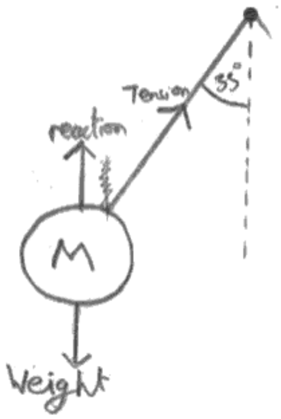
1 mark

14 Two identical table tennis balls, M and N, are attached to non-conducting threads and suspended from a point P. The balls are each given the same positive charge and they hang as shown in the diagram. The mass of each ball is 2.7 g.



(a) Draw a free-body force diagram for ball M, label your diagram with the names of the forces.

(2)



ResultsPlus
Examiner Comments

The electric force has been omitted. If only the weight and tension had been drawn, this would have scored 1 mark but that mark is lost because of the extra reaction force.

0 marks

Question 14 (b)

A lot of candidates scored all three marks in (i) but did not realise in (ii) that they needed to resolve horizontally to find the electric force. They assumed that they had to use $F = Q_1 Q_2 / kr^2$ and either gave up or invented a charge to use. They then in (iii), used that force to arrive at the charge that they invented in (ii). A nice circular argument that meant they lost several marks. The use $F = Q_1 Q_2 / kr^2$ was quite challenging for some candidates. There was a lot of confusion between Q^2 and $2Q$ and many candidates did not know what to use for *r.* Many candidates think of *r* as a radius and so tried to use 18 cm, the length of the thread, or they halved the 20.6 cm.

As well as these errors, there were also a lot of calculator mistakes, so that the last mark of (iii) was often lost.

(b) (i) Show that the tension in one of the threads is about 3×10^{-2} N. (3)

Weight = 0.026N

Tension = 0.026 ÷ cos 35

Tension = 0.032 N

(ii) Show that the electrostatic force between the balls is about 2×10^{-2} N. (2)

$F = \frac{kQ_1Q_2}{r^2}$ $F = \frac{(9\times10^9)\times(1.6\times10^{-19})\times(1.6\times10^{-19})}{0.206^2}$ $= 5.429 \times 10^{-27}$

(iii) Calculate the charge on each ball. (3)

$E = \frac{F}{Q}$

Charge = ...

ResultsPlus

Examiner Comments

The candidate successfully resolves vertically to find the tension, scoring 3 marks for (i) but fails to resolve for (ii) meaning that no more marks are scored.

3 marks

(b) (i) Show that the tension in one of the threads is about 3×10^{-2} N. (3)

$T\cos 35^\circ = mg \Rightarrow mg = 2.7(9.81) \times 10^{-3}$

$= 26.46 \text{ N} \times 10^{-3}$

$\therefore T = \frac{mg}{\cos 35} = \frac{26.46 \times 10^{-3}}{\cos 35} \Rightarrow T = 32.3 \times 10^{-3}$ N

$\therefore T = 3.23 \times 10^{-2}$ N

(ii) Show that the electrostatic force between the balls is about 2×10^{-2} N. (2)

$\Rightarrow F = T\sin 35$

$= (3.23 \times 10^{-2})\sin 35 = 1.85 \times 10^{-2}$ N

$\approx 2 \times 10^{-2}$ N $\therefore F = 1.85 \times 10^{-2}$ N

(iii) Calculate the charge on each ball. (3)

$F = \frac{kQ_1Q_2}{r^2}$, $Q_1 = Q_2$ $\therefore F = \frac{kQ^2}{r^2}$

$\Rightarrow 1.85 \times 10^{-2} = \frac{kQ^2}{(20.68 \times 10^{-2})^2} \Rightarrow Q^2 = \frac{(1.85 \times 10^{-2})(20.68 \times 10^{-2})^2}{8.99 \times 10^{9}} = 8.73 \times 10^{-14}$ C

Charge = 8.73×10^{-14} C

ResultsPlus
Examiner Comments

(i) and (ii) score full marks. In (iii) the candidate has forgotten to take the square root of their answer so scores 2 marks.

7 marks

ResultsPlus
Examiner Tip

Putting a square root sign around the calculation would have acted as a prompt to take the square root.

(iii) Calculate the charge on each ball. (3)

$E_g = mgh$

$= (2.7\times10^{-3})\times(9.81)\times[(18\times10^{-2}) - (18\times10^{-2})\cos 35]$

$= 8.6\times10^{-4}\,J$

$E = \frac{F}{Q}$ $\quad 8.6\times10^{-4} = \frac{2\times10^{-2}}{Q}$

$Q = 23.2\,c$

Charge = 23.2c

ResultsPlus

Examiner Comments

In (iii) this candidate is confusing E for electric field with E for energy and scores no marks.

5 marks

ResultsPlus

Examiner Tip

Make sure that you know the meaning of all of the symbols used in physics.

(iii) Calculate the charge on each ball. (3)

$F = \frac{k Q_1 Q_2}{r^2}$ $\quad \frac{(2\times10^{-2})\times(10.3^2)}{2(8.99\times10^9)} = Q$

$F = \frac{8.99\times10^9 \times Q_1 Q_2}{10.3^2}$ $\quad Q = 1.18\times10^{-10}\,C$

Charge = 1.18×10^{-10} C

ResultsPlus

Examiner Comments

A common error, Q_1Q_2 treated as 2Q. Distance left as cm so this scores zero marks.

0 marks

Question 14 (c)

The question was looking for evidence of an understanding of Newton's 3rd law. There were a number of vague or ambiguous answers that did not score a mark, but there were also a surprising number of answers specifically saying that the balls would hang at different angles to the vertical, because ball M would exert a larger force on ball N.

(c) State and explain what would have happened if the charge given to ball M was greater than the charge given to ball N.

(2)

Both balls would move an equal distance further as the force experienced by both balls under Coulomb's law is equal and opposite, despite the difference in charge

ResultsPlus
Examiner Comments

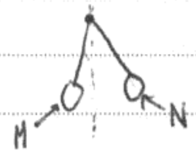
A full 2-mark answer with a clear understanding of the situation.

2 marks

(c) State and explain what would have happened if the charge given to ball M was greater than the charge given to ball N.

(2)

If charge on M was greater than charge on N, they would still have a similar radius between them (depending on the change of charge) but M would be more vertical and N would be more horizontal.



ResultsPlus
Examiner Comments

A clearly wrong answer, where the candidate has no understanding of the forces in this situation.

0 marks

(c) State and explain what would have happened if the charge given to ball M was greater than the charge given to ball N.

(2)

The ball N would experience a greater repulsive force from ball M. Therefore the ~~At~~ ball N will repel further. ~~and the angle~~

ResultsPlus

Examiner Comments

Everything in this answer is correct, but without a reference to ball M, it scores zero.

0 marks

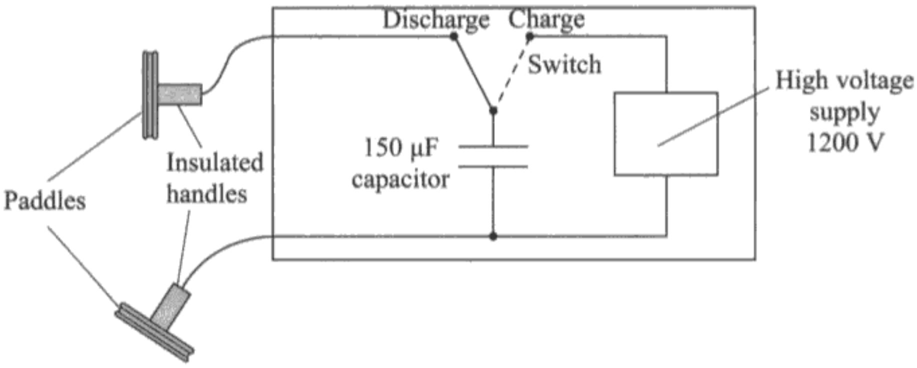
Question 15 (a) (b)

A straightforward calculation to start this question, although some candidates still made the mistake of confusing C for 'charge' instead of 'capacitance'.

15 A defibrillator is a machine that is used to correct an irregular heartbeat or to start the heart of someone who is in cardiac arrest.

The defibrillator passes a large current through the heart for a short time.

The machine includes a high voltage supply which is used to charge a capacitor. Two defibrillation 'paddles' are placed on the chest of the patient and the capacitor is discharged through the patient.



(a) The 150 μF capacitor is first connected across the 1200 V supply.

Calculate the charge on the capacitor.

(2)

$Q = CV$ ~~Q~~ $= 150 \times 10^{-6} \times 1200 = 0.18$

Charge = 0.18 C

(b) Calculate the energy stored in the capacitor.

(2)

$W = \frac{1}{2} QV = \frac{1}{2} \times 0.18 \times 1200$

$= 108$

Energy stored = 108 J

ResultsPlus

Examiner Comments

The majority of candidates scored both marks for (a) and (b), as in this example.

4 marks

(a) The 150 μF capacitor is first connected across the 1200 V supply.

Calculate the charge on the capacitor.

(2)

$Q = CV$

$Q = 150 \times 10^{-6} \times 1{,}200$

Charge = 0.18 A

ResultsPlus

Examiner Comments

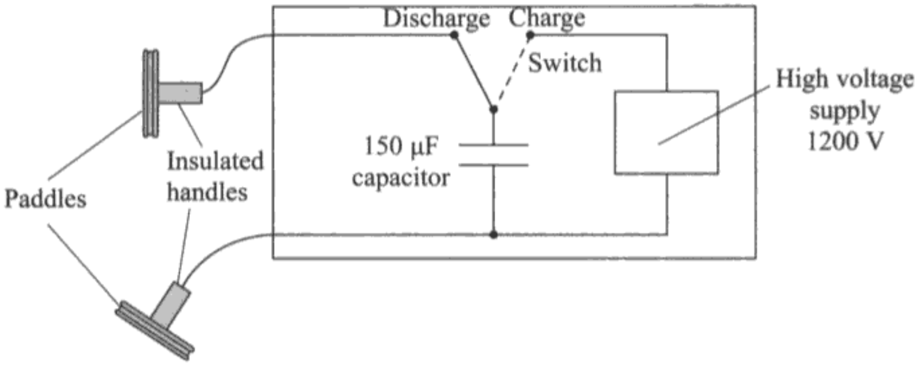
(a) A careless error with units loses a mark.

3 marks

15 A defibrillator is a machine that is used to correct an irregular heartbeat or to start the heart of someone who is in cardiac arrest.

The defibrillator passes a large current through the heart for a short time.

The machine includes a high voltage supply which is used to charge a capacitor. Two defibrillation 'paddles' are placed on the chest of the patient and the capacitor is discharged through the patient.



(a) The 150 μF capacitor is first connected across the 1200 V supply.

Calculate the charge on the capacitor.

(2)

$C = Q/V$

$\therefore C = 150/1200$

Charge = 0.125 farads

(b) Calculate the energy stored in the capacitor.

(2)

Energy stored = $\frac{1}{2}$ QV   Q = 150   V = 1200

⇒ (150 x 1200) ÷ 2

Energy stored = 90,000 J

ResultsPlus

Examiner Comments

When candidates did lose marks it was usually the mistake seen here. They think that C is the symbol for charge and therefore use the value of capacitance for Q, in the formula.

0 marks

ResultsPlus

Examiner Tip

Learn the symbols carefully and remember that C is used for capacitance and Q for charge.

0 marks

Question 15 (c) (i)

A very straightforward resistance calculation, which nearly all of the candidates answered correctly.

Question 15 (c) (ii)

Most candidate scored at least one mark for an attempt to use RC. The most common error was for candidates not to think about the question and because 'three quarters' was in the question, they assumed that Q was $0.75Q_0$.

(c) When the capacitor discharges there is an initial current of 14 A in the chest of the patient.

(i) Show that the electrical resistance of the body tissue between the paddles is about 90 Ω.

(1)

~~$I = I_0 e^{t/RC}$~~ ~~14 = 14e~~ $V = IR \quad R = \frac{V}{I} = \frac{1200}{14} = 85.7\,\Omega$

(ii) Calculate the time it will take for three quarters of the charge on the capacitor to discharge through the patient.

(3)

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

$\frac{3}{4} = e^{-t/RC}$

$\ln \frac{3}{4} = -t/RC$

$t = -RC \ln \frac{3}{4} = -(85.7...)(150\times10^{-6}) \ln \frac{3}{4} = 3.69876... \times 10^{-3}$ s

$= 3.7\times10^{-3}$ s

Time = 3.7×10^{-3} s

ResultsPlus
Examiner Comments

A frequent answer, where candidates did not read the question carefully and realise that if three-quarters of the charge has discharged, then the charge on the capacitor is one-quarter Q_0.

1 mark

ResultsPlus
Examiner Tip

Read the question carefully.

(c) When the capacitor discharges there is an initial current of 14 A in the chest of the patient.

(i) Show that the electrical resistance of the body tissue between the paddles is about 90 Ω.

(1)

$V = IR, \quad \frac{V}{I} = R = \frac{1200}{14} = 86\,\Omega$

(ii) Calculate the time it will take for three quarters of the charge on the capacitor to discharge through the patient.

(3)

$Q = Q_0 e^{-t/RC}$ $\quad 0.18 - (\frac{3}{4} \times 0.18) = 0.045$

$0.045 = 0.18\, e^{-t/86 \times 150 \times 10^{-6}}$

$\ln\left(\frac{0.045}{0.18}\right) = \frac{-t}{0.0129} \cdot \ln e$

$t = 0.018\,s$

Time = 0.018 s

ResultsPlus

Examiner Comments

This answer scores the full 3 marks. A lot of candidates used this method and calculated the charge, rather than used Q_0 and $0.25Q_0$. Doing an unnecessary extra calculation means that errors might be introduced which would lose marks.

3 marks

(c) When the capacitor discharges there is an initial current of 14 A in the chest of the patient.

(i) Show that the electrical resistance of the body tissue between the paddles is about 90 Ω.

(1)

$\frac{1200}{14} = 85.7\ \Omega$

(ii) Calculate the time it will take for three quarters of the charge on the capacitor to discharge through the patient.

(3)

$85.7 \times 150 \times 10^{-6} \times 1.6 \times 10^{-19} \times 0.75$

Time = 1.5426×10^{-21} s

ResultsPlus

Examiner Comments

This candidate has multiplied four numbers together with no indication of what is being found. The fact that the value for R and C appears in this calculation is not enough to justify the use of RC mark.

0 marks

ResultsPlus

Examiner Tip

Use words or symbols to explain what you are trying to do.

Question 15 (c) (iii)

This is another example of candidates needing to think about the context of the question. This was about a defibrillator, which is charged before applying it to the patient. The constant is therefore the charge. Quite a few candidates thought that an initial greater current meant that more charge could flow.

(iii) Body resistance varies from person to person. If the body resistance was lower, the initial current would be greater.

State how this lower body resistance affects the charge passed through the body from the defibrillator.

(1)

Q = I·t , if the resistance is lower, causes the current increase, according to Q = It , if time remains the same, the amount of charge passes through the body will be greater .

(Total for Question 15 = 9 marks)

ResultsPlus

Examiner Comments

A frequent wrong answer: the candidate states that if resistance decreases, current increases but does not realise that there is a fixed amount of charge. The candidate uses Q = It with T constant to justify a larger charge for a larger current.

0 marks

(iii) Body resistance varies from person to person. If the body resistance was lower, the initial current would be greater.

State how this lower body resistance affects the charge passed through the body from the defibrillator.

(1)

The charge would pass through the body more quickly.

ResultsPlus

Examiner Comments

An example of an answer that scores the mark.

1 mark

Question 16 (a)

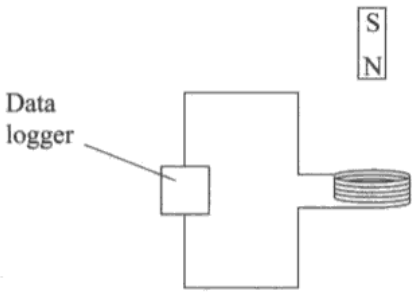
This was a very good question that discriminated well, with the full range of marks being awarded.

At the simplest level, candidates just mentioned the change of flux and Faraday's law. The more able candidates appreciated that the difference in shape of the two parts of the graph was due to the magnet accelerating. They were then able to score well on this question.

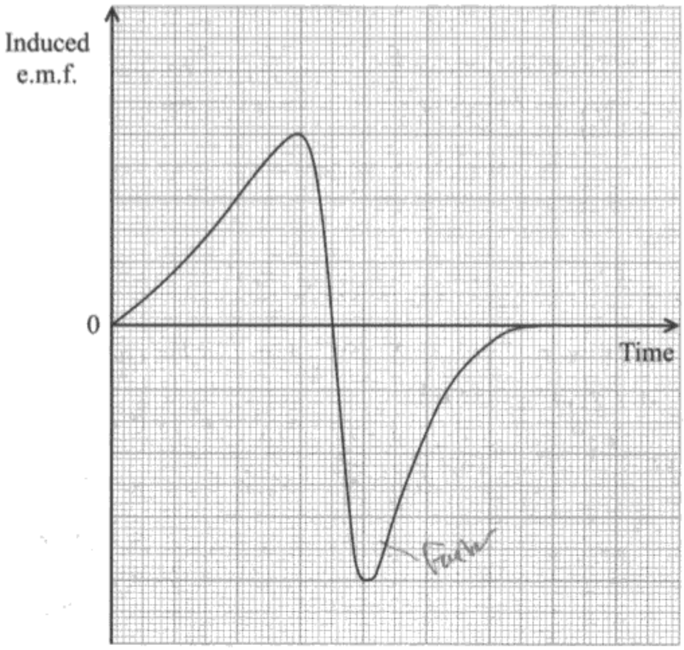
A few candidates missed the idea of magnetic flux and just went on to try to explain why the e.m.f. varied.

Some candidates spent a long time on Lenz's law and which end of the coil was a north pole etc, and were convinced that because of this the magnet would slow down as it passed through the coil. These candidates showed a lack of appreciation of the relative sizes of the forces.

16 A teacher demonstrates electromagnetic induction by dropping a bar magnet through a flat coil of wire connected to a data logger.



The data from the data logger is used to produce a graph of induced e.m.f. across the coil against time.



*(a) Explain the shape of the graph and the relative values on both axes.

(6)

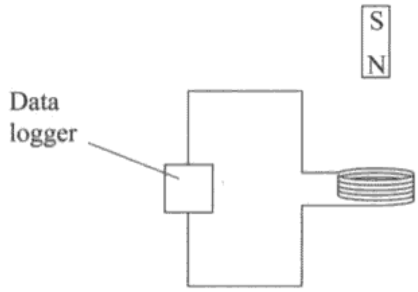
As the magnet goes through the coil, the flux linkage changes over time and e.m.f is induced. The vertical line on the graph represents the change in direction of induced e.m.f. When the magnet leaves the coil, higher e.m.f is induced because the magnet is travelling faster ~~secure~~ which causes greater change in flux likage.
The gradient is not constant because the velocity at which the magnet travels through the coil changes.
The magnet accelerates with acceleration of g (9.81ms⁻²)

ResultsPlus
Examiner Comments

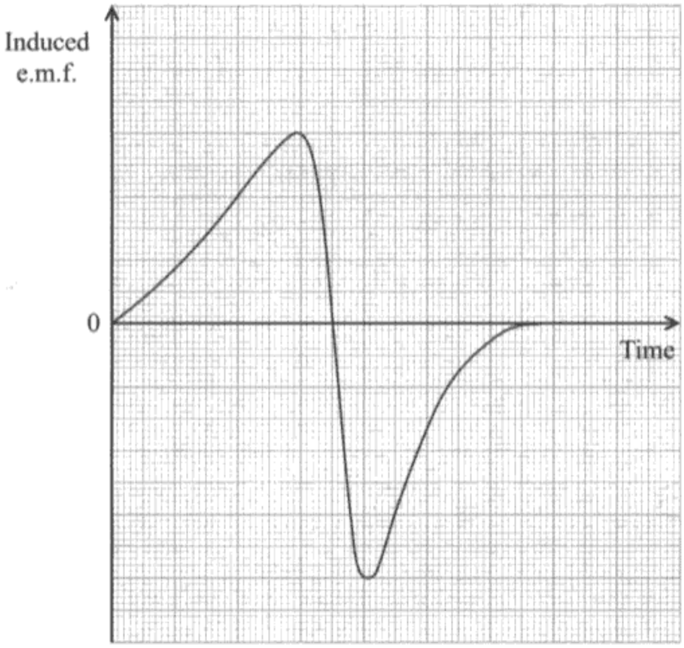
This scores 3 marks: flux changing, magnet accelerating and a larger e.m.f. as magnet leaves the coil. The statement about the vertical line showing change of direction of e.m.f. was not linked to the magnet passing through the coil and so did not gain a mark.

3 marks

16 A teacher demonstrates electromagnetic induction by dropping a bar magnet through a flat coil of wire connected to a data logger.



The data from the data logger is used to produce a graph of induced e.m.f. across the coil against time.



*(a) Explain the shape of the graph and the relative values on both axes.

(6)

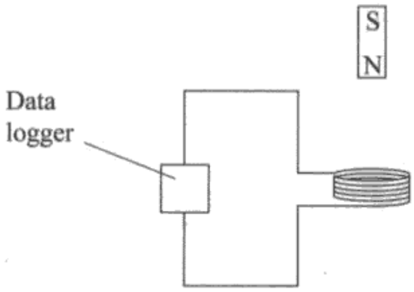
as the magnet falls the coil cuts a greater amount of lines of magnetic flux per unit time as it is accelerating ~~inducing~~ causing the increase in emf, when the magnet is in the coil for a brief time there is no change in magnetic flux so the emf drops to zero it then reaches a more -ve value in a faster time as will it is still accelerating $\frac{N(\Delta\Phi)}{\Delta t}$ is greater more lines of flux are cut in the same unit time, when the magnet reaches a distance too far the emf drops to zero as the lines of flux no longer interact due to the distance, the second emf is -ve as moving away from the coil

ResultsPlus
Examiner Comments

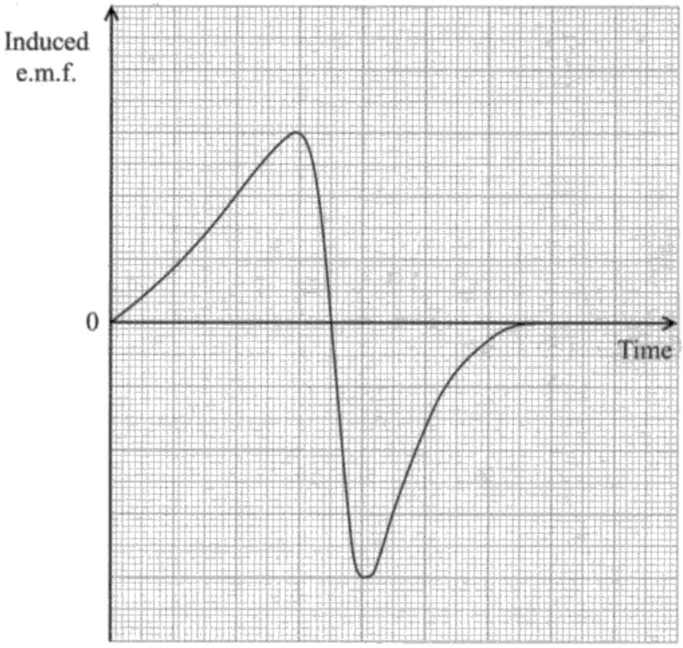
An example that scores 6 marks: *a faster time* was accepted as meaning *a shorter time*.

3 marks

16 A teacher demonstrates electromagnetic induction by dropping a bar magnet through a flat coil of wire connected to a data logger.



The data from the data logger is used to produce a graph of induced e.m.f. across the coil against time.



*(a) Explain the shape of the graph and the relative values on both axes.

(6)

- When the magnet ~~approaches~~ starts to enter the coil, there is a change in flux so an emf is induced due to Faraday's Law. Therefore the emf on the graph ~~graph~~ gradually increases over time - shown on y-axis.
- When the magnet reaches the middle of the coil and passes through, ~~and~~ an emf is induced in the opposite direction due to the south pole which changes the emf.

Due to Lenz's Law, the emf opposes the source which created the emf. On the graph, the value for emf is shown on the negative y-axis.
Once the magnet leaves the coil, flux is no longer changing and the emf induced gradually reduces to zero. The graph is steeper on the negative y-axis as the velocity of the magnet increases and the rate of change of flux is greater.

ResultsPlus
Examiner Comments

This scored 3 marks. One for the idea of flux changing - although Faraday is mentioned, the law is not quoted. The response mentions the e.m.f. increasing but does not relate it to the magnet approaching the coil.

The 2nd mark is for the idea of the direction of the e.m.f. changing, as the magnet goes through the coil.

The 3rd mark is for stating that the magnet's speed increases but the reference to the graph being steeper is not enough, because we do not know to which part of the graph the candidate is referring.

3 marks

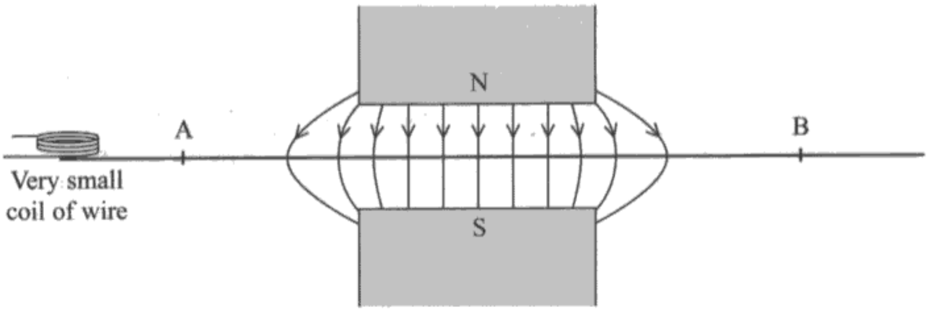
Question 16 (b)

Quite a few candidates had no understanding of this situation and drew one large single pulse. There were similarities with (a) and a number of candidates copied the graph from (a) and scored 2 marks.

Those that had probably identified the acceleration in (a), realised that because of the constant velocity in (b) the two peaks would be equal in size thus scoring 3 marks. Only the more able candidates realised that because of the relative sizes of the magnetic field and coil, there would be a region of zero e.m.f. in the middle.

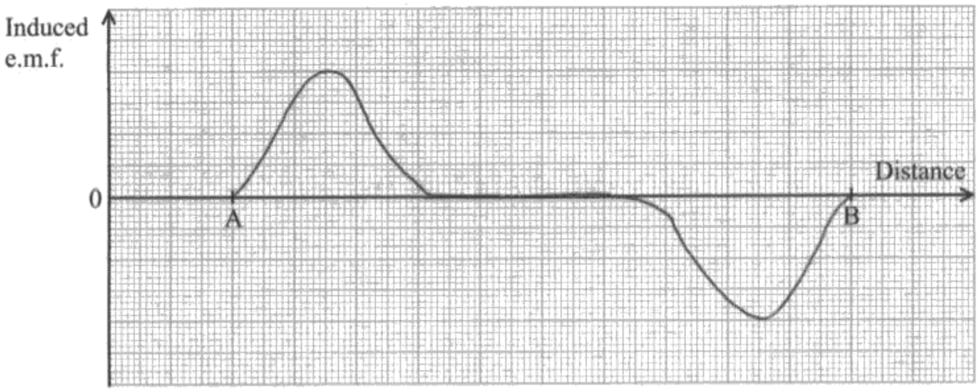
(b) The teacher then sets up another demonstration using a large U-shaped magnet and a very small coil of wire which is again connected to a data logger.

The north pole is vertically above the south pole and the coil is moved along the line AB which is midway between the poles. The magnetic field due to the U-shaped magnet has been drawn. The plane of the coil is horizontal.



Sketch a graph to show how the e.m.f. induced across the coil varies as the coil moves from A to B at a constant speed.

(4)



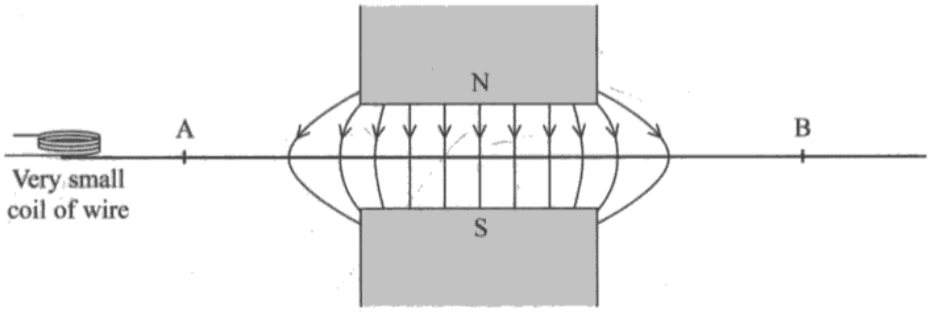
ResultsPlus
Examiner Comments

A correct answer that scores 4 marks.

4 marks

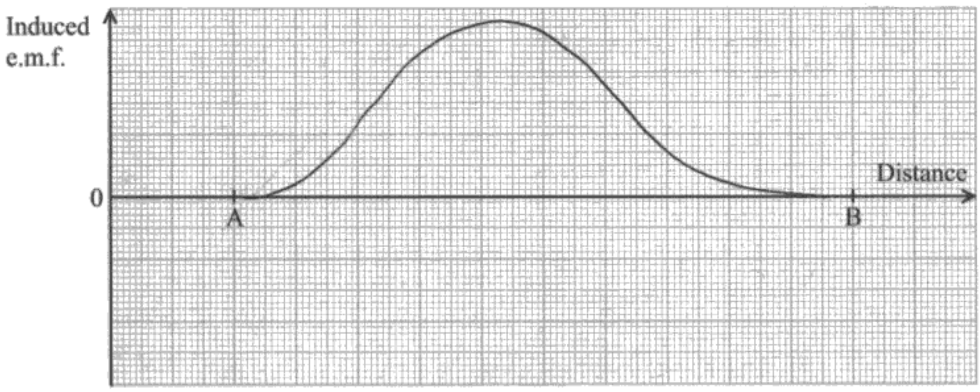
(b) The teacher then sets up another demonstration using a large U-shaped magnet and a very small coil of wire which is again connected to a data logger..

The north pole is vertically above the south pole and the coil is moved along the line AB which is midway between the poles. The magnetic field due to the U-shaped magnet has been drawn. The plane of the coil is horizontal.



Sketch a graph to show how the e.m.f. induced across the coil varies as the coil moves from A to B at a constant speed.

(4)



ResultsPlus

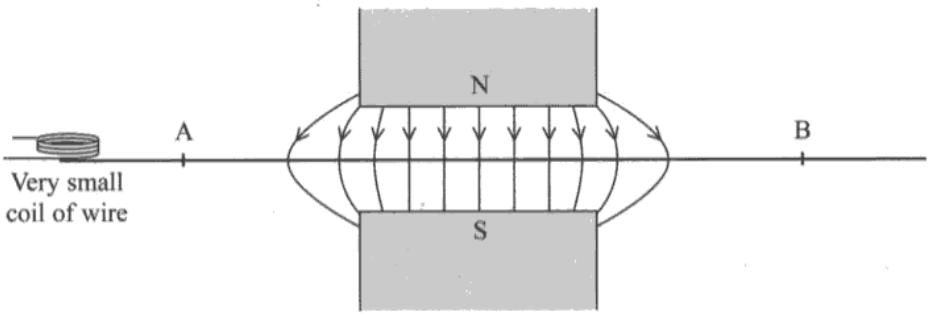
Examiner Comments

A frequent answer that scored zero marks. The candidate did not see the similarities between parts (a) and (b).

0 marks

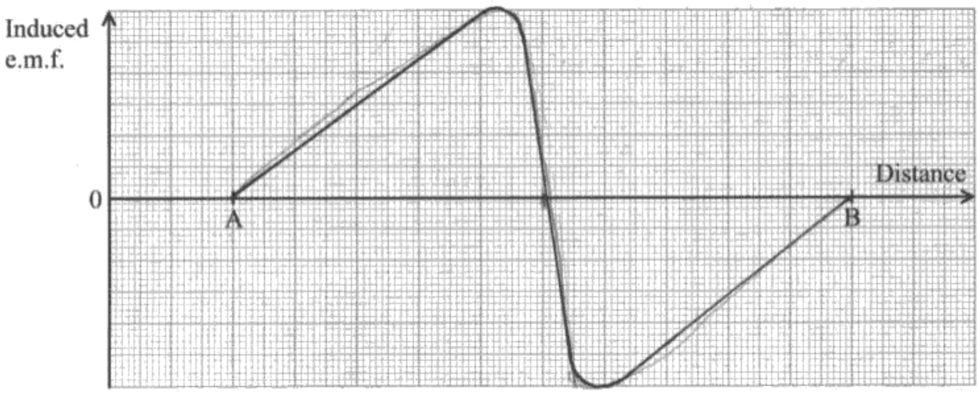
(b) The teacher then sets up another demonstration using a large U-shaped magnet and a very small coil of wire which is again connected to a data logger.

The north pole is vertically above the south pole and the coil is moved along the line AB which is midway between the poles. The magnetic field due to the U-shaped magnet has been drawn. The plane of the coil is horizontal.



Sketch a graph to show how the e.m.f. induced across the coil varies as the coil moves from A to B at a constant speed.

(4)



ResultsPlus

Examiner Comments

This candidate has probably realised the similarities between the question parts and has effectively copied the graph from (a), but has correctly made the two peaks of the same height. This scores 3 marks.

3 marks

Question 17 (a)

This question was generally well-answered, as expected. Where mistakes were made, it was in thinking that 4 was the atomic number (probably confusion with atomic mass) and in not realising that it is a number and not an actual mass.

17 In 2011 physicists at the Relativistic Heavy Ion Collider (RHIC) announced the creation of nuclei of anti-helium-4 which consists of anti-protons and anti-neutrons instead of protons and neutrons.

(a) 'Ordinary' helium-4 is written as $^{4}_{2}He$.

What do the numbers 4 and 2 represent?

(2)

The number of protons and neutrons there are present in the atom.

ResultsPlus
Examiner Comments

A vague answer that scored no marks.

0 marks

17 In 2011 physicists at the Relativistic Heavy Ion Collider (RHIC) announced the creation of nuclei of anti-helium-4 which consists of anti-protons and anti-neutrons instead of protons and neutrons.

(a) 'Ordinary' helium-4 is written as $^{4}_{2}He$.

What do the numbers 4 and 2 represent?

(2)

4 represents the ~~proton~~ mass number

~~2 represents the mass number of mass of~~ helium 4 ~~element~~

2 represents the number of electrons.

ResultsPlus
Examiner Comments

This scored 1 mark for the mass number, but although in a neutral atom the number of electrons is the same as the proton number, this is a wrong answer when the question is asking about the creation of nuclei.

1 mark

Question 17 (b) (i)

Although many got this right, quite a few candidates said that it was for speeds greater than the speed of light, whilst others thought that it was to do with how something relates to something else.

(b) In the RHIC experiment, nuclei of gold $^{197}_{79}Au$ travelling at speeds greater than 2.99×10^8 m s^{-1}, in opposite directions, collided, releasing energies of up to 200 GeV. After billions of collisions, 18 anti-helium nuclei had been detected.

(i) What is meant by 'relativistic' in the collider's name?

(1)

Travelling at speeds greater than the speed of light (3.00×10^8 ms^{-1})

ResultsPlus

Examiner Comments

Examiners would have expected all candidates to know that this is not possible. Zero marks.

0 marks

(b) In the RHIC experiment, nuclei of gold $^{197}_{79}Au$ travelling at speeds greater than 2.99×10^8 m s^{-1}, in opposite directions, collided, releasing energies of up to 200 GeV. After billions of collisions, 18 anti-helium nuclei had been detected.

(i) What is meant by 'relativistic' in the collider's name?

(1)

As speed increases mass increases as well, $E = mc^2$

ResultsPlus

Examiner Comments

This is a true statement but it occurs at all speeds and not just relativistic ones so it does not gain the mark.

0 marks

Question 17 (b) (ii)

Another good-scoring question, although it was an opportunity for some candidates to try to get annihilation into the answers. Others said that it was in order to get particles close to the speed of light.

(ii) State why it is necessary to use very high energies in experiments such as these.

(1)

to break the strong molecular forces holding atoms together.

ResultsPlus
Examiner Comments

Another example of a candidate not thinking about the question, which is this case is about nuclei not atoms. Therefore, talking about strong atomic bonds is inappropriate and scores 0.

0 marks

(ii) State why it is necessary to use very high energies in experiments such as these.

(1)

High energies are needed for particles with larger mass' to be produced.

ResultsPlus
Examiner Comments

An example of an answer that scored the mark.

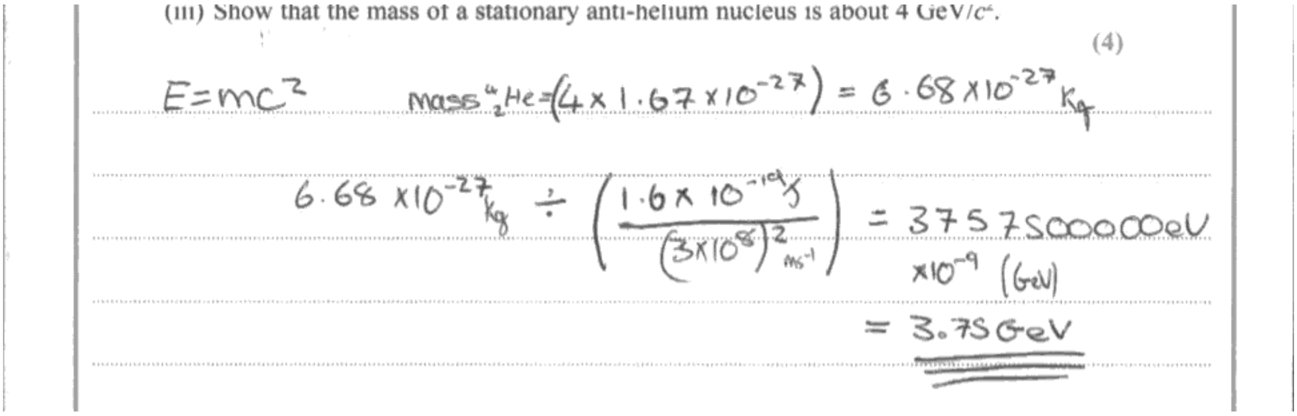
1 mark

Question 17 (b) (iii)-(b) (v)

(iii) This is another question where not all of the data is needed in calculations but is there in order to set the context. Many candidates were able to do the unit conversion, having realised that they needed to start with 4u as the mass of the anti-helium nucleus. Candidates who did not realise this, had difficulties. Some tried to use the 200 GeV, leading to a score of zero. Others started with the 4 GeV and worked backwards, to a mass in kg and a comparison with 4u. If this was done completely it scored only 3 marks, because the candidate had not done what the question had asked. In 'show that' questions, candidates must work towards the 'show that' value that is quoted and not away from it. Candidates are generally very good at showing their answers to 'show that' questions to one more significant figure.

(iv) This was the candidates' opportunity to talk about annihilation. However, candidates need to realise that annihilation does not just happen; it has to happen with something.

(v) This was not generally well-answered, although there were far fewer attempts to use the de Broglie wavelength compared with last June. Not many candidates realised that having found the rest mass as 3.74 GeV/c^2, the energy was 3.74 GeV. This meant that they started the whole calculation all over again, often making mistakes with rearranging the equations. Those who had not used the 200GeV earlier, often used it in this part.



(iii) Show that the mass of a stationary anti-helium nucleus is about 4 GeV/c^2.

(4)

$E=mc^2$ mass ${}^4_2He = (4 \times 1.67 \times 10^{-27}) = 6.68 \times 10^{-27}$ kg

6.68×10^{-27} kg $\div \left(\frac{1.6 \times 10^{-19} J}{(3 \times 10^8)^2 \, ms^{-1}}\right) = 3757500000 eV$

$\times 10^{-9}$ (GeV)

$= 3.75 GeV$

(iv) State why the small number of anti-helium nuclei produced only survive for a fraction of a second.

(1)

The have no over charge so cannot be contained. They will anhiallate because they are anti-particles.

(v) A slow moving anti-helium nucleus meets a slow moving helium nucleus. If they were to combine to produce 2 high energy gamma rays, calculate the frequency of each gamma ray.

(2)

$E = hf$ $E = mc^2$ $f = \frac{mc^2}{h} = \frac{(2 \times (6.68 \times 10^{-27})) \times (3 \times 10^8)^2}{6.63 \times 10^{-34}}$

$E = 1.20 \times 10^{-9}$ J

$= 1.81 \times 10^{24}$ Hz

$v = f\lambda$

Frequency = 1.81×10^{24} Hz

ResultsPlus

Examiner Comments

(iii) A well-laid out 4 mark answer.

(iv) No mark, because there is no indication of what the particle is annihilating with.

(v) Use of E = mc² is correct and the candidate has multiplied by two, but forgotten then to halve the energy for each gamma ray so that the answer is twice the correct answer.

6 marks

ResultsPlus

Examiner Tip

In questions like this where two particles annihilate to form two gamma rays, it is easiest to omit the use of the 2 completely.

(iii) Show that the mass of a stationary anti-helium nucleus is about 4 GeV/c^2.

(4)

$E = mc^2$

$= (2 \times 1.67 \times 10^{-27}) \times (3 \times 10^8)^2$

$= 3 \times 10^{-10}$ J

$3 \times 10^{-10} \div 1.6 \times 10^{-19}$

$= 1.9$ GeV $\times 2$

$= 3.8$ GeV

mass $= \frac{3.8 \text{ GeV}}{c^2}$

ResultsPlus
Examiner Comments

This candidate clearly starts off with just two particles in the nucleus and arrives at an answer of 1.9 GeV, scoring two marks for the two conversion steps.

The random multiplying by 2 is assumed to be because the candidate realises that their answer is about half of the 'show that' value. This receives no credit.

3 marks

ResultsPlus
Examiner Tip

In a 'show that' question, if you do not obtain the correct answer, look back at your method to see if you can find the error. Do not just multiply by the right number to obtain the value you need.

(iii) Show that the mass of a stationary anti-helium nucleus is about 4 GeV/c^2.

(4)

$M = 4 \times u = 1.66 \times 10^{-27} \times 4$

$= 6.64 \times 10^{-27}$ kg

$\frac{6.64 \times 10^{-27} \times (3.0 \times 10^8)^2}{1.6 \times 10^{-19}} = 3.7 \times 10^9$ eV/c^2

$= 3.7$ GeV/c^2

(iv) State why the small number of anti-helium nuclei produced only survive for a fraction of a second.

(1)

Anti helium particles annihilate very easily and quickly

(v) A slow moving anti-helium nucleus meets a slow moving helium nucleus. If they were to combine to produce 2 high energy gamma rays, calculate the frequency of each gamma ray.

(2)

$\Delta E = c^2 \Delta m = (3 \times 10^8)^2 \times (4 \times 1.66 \times 10^{-27})$

$= 5.976 \times 10^{-10}$

$E = hf$, so $f = \frac{5.976 \times 10^{-10}}{6.63 \times 10^{-34}} = 9.0 \times 10^{23}$ Hz

Frequency = 9.0×10^{23} Hz

ResultsPlus
Examiner Comments

(iii) and (v) score full marks but again, in (iv), the candidate does not say what the antiparticles annihilate with.

6 marks

Question 17 (c) (i)

This was generally well-done although an answer such as *it is made of two quarks, a quark and an antiquark* did seem a little confusing to read - but was given credit.

(c) There are two families of hadrons, called baryons and mesons. Baryons such as protons are made of three quarks.

(i) Describe the structure of a meson.

(1)

Mesons are composed of two quarks. Usually a quark and anti-quark

ResultsPlus
Examiner Comments

This response did not receive the mark because the use of the word 'usually' implies that sometimes it might not be a quark and an antiquark.

0 marks

ResultsPlus
Examiner Tip

Keep your answers simple. All that is needed as an answer is 'one quark and one antiquark'.

(c) There are two families of hadrons, called baryons and mesons. Baryons such as protons are made of three quarks.

(i) Describe the structure of a meson.

(1)

Mesons are made up of quarks and antiquarks

ResultsPlus
Examiner Comments

Another answer that did not receive the mark because it refers to plurals of quarks and antiquarks.

0 marks

Question 17 (c) (ii)

This question was again generally well-answered, with a significant number of candidates achieving 4 marks. It was the last question on the paper so candidates knew how much time they had left. The majority of candidates felt that they had to give full details of the proton and the neutron, as well as the antiparticles that were requested.

Some candidates did not appreciate the need to demonstrate the three charges adding up to 0 or 1, so only scored 2 of the marks. Other candidates were under the impression that the quark content of the neutron could be the same as the anti-neutron, because the charge on both is zero. This showed a fundamental lack of understanding of the nature of matter and antimatter. As often happens, marks were also lost due to careless errors, omitting the 'anti' in front of proton but then giving the correct quark content for an antiproton.

(ii) Up quarks have a charge of +2/3e and down quarks a charge of –1/3e.
Describe the quark composition of anti-protons and anti-neutrons and use this to deduce the charge on each of these particles.

(4)

proton is $\bar{u}\bar{u}\bar{d}$ so has a charge of −1e

neutron is $\bar{d}\bar{d}\bar{u}$ so has a charge of Øe

ResultsPlus
Examiner Comments

A 2-mark answer for the quark composition only.

2 marks

(ii) Up quarks have a charge of +2/3e and down quarks a charge of –1/3e.
Describe the quark composition of anti-protons and anti-neutrons and use this to deduce the charge on each of these particles.

(4)

A ~~pr~~ proton has quark structure uud.
A neutron has quark structure udd.
Therefore, $\bar{p} = \bar{u}\bar{u}\bar{d}$, and $\bar{n} = \bar{u}\bar{d}\bar{d}$.

$\bar{p} = \frac{-2}{3} + \frac{-2}{3} + \frac{+1}{3} = -1e.$

$\bar{n} = \frac{-2}{3} + \frac{+1}{3} + \frac{+1}{3} = 0e.$

So an anti-proton has −1e charge, and an anti-neutron is neutral.

ResultsPlus
Examiner Comments

An example of a 4-mark answer.
4 marks

Paper Summary

Key points to help candidates improve their performance are

- Read the questions carefully and answer the question that is asked.
- For context-based questions, always think for a moment before starting to answer the question. At the end of the question think again about the context - it might be relevant.
- Remember that not all data given in a question has to be used but all data that is needed will be given.

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