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Examiners' Report
January 2011

GCE Physics 6PH04 01

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Introduction

This paper seemed more accessible to candidates than the previous ones, perhaps in part due to the fact that this is now the third paper that has been set for this unit. Most candidates who sat this paper were able to demonstrate their understanding of the full range of topics in this unit. The responses for all questions covered the full range of marks allowable with full marks being seen frequently for all question parts. Well prepared candidates appeared to be able to do well on any section. However in reality even good candidates dropped some marks but the section that this happened on was random, justifying that all parts of the paper were accessible. Where the more able candidates struggled was on the questions that required continuous prose i.e. questions 13 and 18.

Section A Multiple choice questions

These produce good discrimination with the E grade candidates usually scoring about 5 and the more able candidates often scoring the full 10 marks. The highest scoring questions were 2, 4 and 8. The lowest scoring questions were 3, 9 and 10.

Question 11 (a)

The vast majority of candidates knew that a 3 quark particle is a Baryon.

Question 11 (b)

This part was also answered well, although many candidates did not realise the need for a '+' sign on the charge. In this type of question, examiners will not take the absence of a sign to mean it is positive.

(b) Calculate the charge on the lambda particle.

(1)

$+\frac{2}{3} - \frac{1}{3} = +\frac{1}{3} + \frac{2}{3} = 1$

Charge = 1 unit of charge

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Examiner Comments

Note the lack of + sign.

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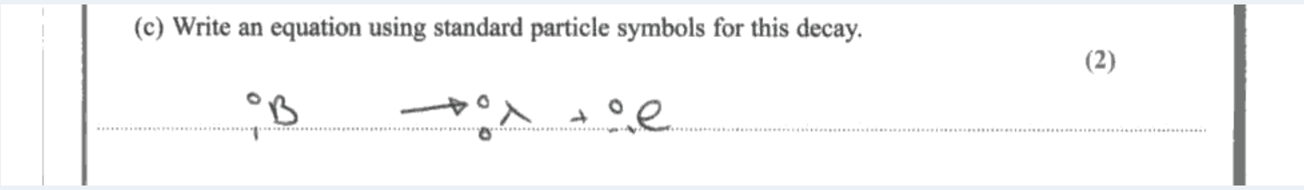
Examiner Tip

When identifying the charge on a particle, you must identify if it is positive, negative or has no charge.

Question 11 (c)

The question specifically told candidates to use standard particle symbols, however, many candidates did not seem familiar with standard symbols and added various symbols of their own e.g. a minus as a superscript or subscript next to an anti-proton symbol.


(c) Write an equation using standard particle symbols for this decay.

(2)

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Examiner Comments

Note the incorrect use of lambda symbol which was given in the question. The candidate also incorrectly worked out the charge on this particle (+).
The symbol for an anti proton is p bar.

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Examiner Tip

Learn the standard particle symbols and if one is given the question, copy if correctly.

(c) Write an equation using standard particle symbols for this decay.

(2)

~~B → p̄~~ $B^0 \rightarrow {}^{1}_{-1}\bar{p} + \Lambda^{+}$

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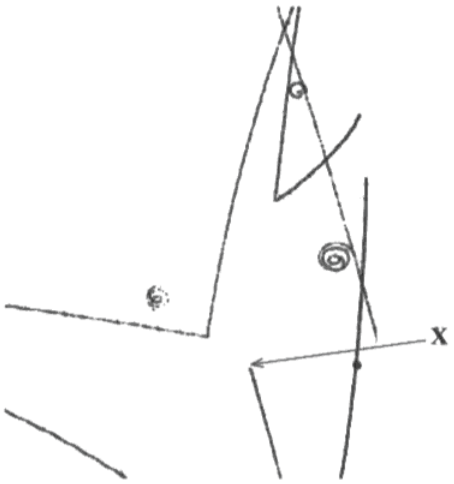
Examiner Comments

This candidate correctly worked out the charge on the lambda particle and indicated this correctly, but incorrectly added to the anti proton symbol.

Question 12

This question produced good discrimination between the candidates. Full marks could be scored from written text but those that added to the diagram, for instance, showing the neutral tracks, generally scored better. A number of candidates ignored the hint "with reference to the photograph" and tried to describe, often vaguely, various lines on the photograph. Some candidates commented on the curve of the lines and the spirals, this was not relevant to the question that was asked. Other candidates just reworded the question and made no reference to the photograph, whilst others wrote at length about bubble chambers.

*12 The photograph shows tracks produced by charged particles in a bubble chamber.



At X, an incoming charged particle interacts with a stationary proton to produce a neutral lambda particle and a neutral kaon particle. Both these particles later decay into other particles.

With reference to the photograph, describe and explain the evidence provided for this event.

(4)

You can see this in the photograph due the abrupt stop in the track where the particle gets anihilated. This means that when the negative particle hits the positive proton the charge becomes zero and can be no longer detected in the bubble chamber. Also you can see other particles "appear" from nothing due to the decay and the change in charge.

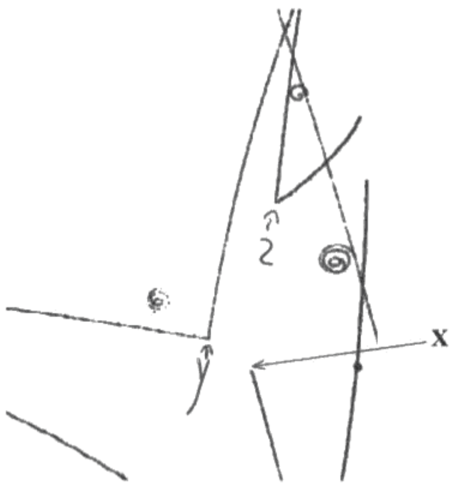
ResultsPlus Examiner Comments

The candidate could have labelled the diagram and drawn relevant ideas. This scored 2 marks for the idea of the abrupt end of the track and that neutral particles can not be detected but the rest is too vague for any credit.

ResultsPlus Examiner Tip

Sometimes additions to a diagram can be helpful.

*12 The photograph shows tracks produced by charged particles in a bubble chamber.



At X, an incoming charged particle interacts with a stationary proton to produce a neutral lambda particle and a neutral kaon particle. Both these particles later decay into other particles.

With reference to the photograph, describe and explain the evidence provided for this event.

(4)

The Bubble chamber detects Charged Particles, So before X Collides with a proton its path is shown, Once it has Collided and produced 2 neutral Particles they Cannot be detected, So the trace Disapears. Both these neutral particles Decay into charged Particles as Shown at Point y and z shown on the graph. These traces Show the Products of the Decay of the 2 neutral particles

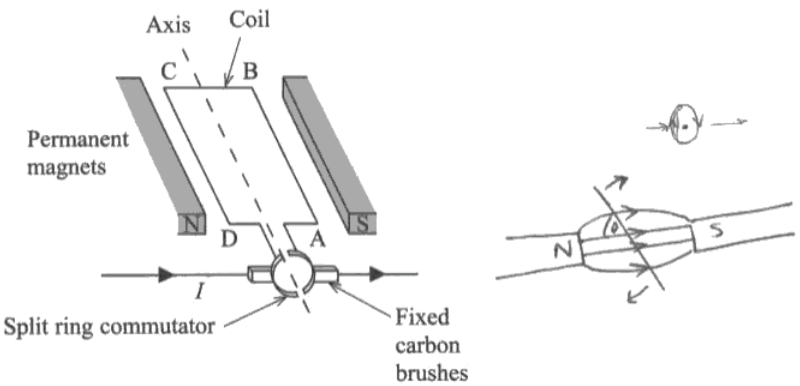
ResultsPlus Examiner Comments

This candidate identifies the two further points of interest and helpfully identifies them in the image.

Question 13 (a)

This question specifically told candidates to add to the diagram, but a number of candidates did not follow this instruction. Two correctly labelled arrows scored three of the four marks. Other candidates wrongly drew curved lines for force direction. The best answers showed directions of force on sides AB and DC. Some candidates understood this well and wrote clear explanations. Many wrote that the commutator kept the current in the same direction instead of explaining that it kept the current direction the same on left and right sides of the coil by reversing the current direction.

13 The simplified diagram shows a d.c. electric motor. The split ring commutator consists of two copper semicircular sections attached to either end of a coil. Fixed carbon brushes rub against, and make electrical connections to, the split ring commutator.



(a) Explain why the coil turns and why it continues to rotate. Add to the diagram to help your explanation.

(4)

There is a magnetic field between the two magnets, from north to south. When the current passes through the wire, it produces a magnetic field around the wire. The magnetic field around the wire interacts with the magnetic field between the magnets, and a force is applied to the wire, [illegible] causing the wire to rotate. When the wire has rotated, their is no longer a force, however the split ring has rotated, so the current is reversed through the wire, and a force is then applied to the wire, causing it to continue rotating. $F = BIl \sin\theta$

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Examiner Comments

The candidate refers to a force and a wire, but does not add to the diagram to show the direction of the forces or direction of rotation. This answer has a separate diagram showing the direction of the magnetic field, unfortunately the direction of the force on the current carrying wires is not shown. This scored 1 mark.

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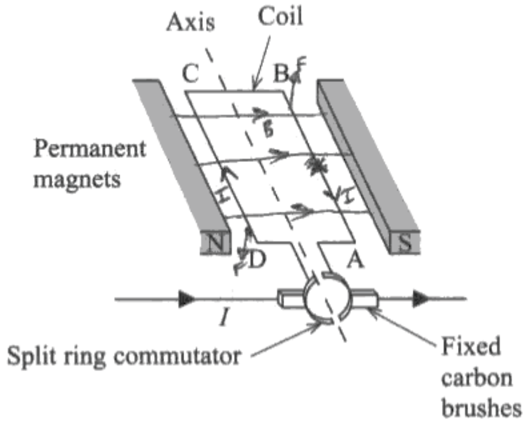
Examiner Tip

Read the question and follow the instructions.

13 The simplified diagram shows a d.c. electric motor. The split ring commutator consists of two copper semicircular sections attached to either end of a coil. Fixed carbon brushes rub against, and make electrical connections to, the split ring commutator.



(a) Explain why the coil turns and why it continues to rotate. Add to the diagram to help your explanation.

(4)

As current flows through the coil, from D to A, a force acts on the coil at 90°. As the magnetic field goes from N to S, we can see, from Flemming's left hand rule, that the direction of the force on the left part of the coil is downwards. This causes the coil to turn anti-clockwise. When the coil has turned 180°, the direction of the current in the magnetic field would be reversed, producing a force trying to turn the coil clockwise. By using a split ring commutator, the current through the coil oscillates so the direction of current in the magnetic field remains the same. This means the force continues to turn the coil anticlockwise.

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Examiner Comments

Good use of the diagram.

Question 13 (b)

Most candidates realised that an opposing e.m.f. was produced, but the descriptions given were poor. Candidates need to realise that when there are four marks they should make four different physics points, none of which should be a repeat of what they have been told in the question. Candidates who realised that this was about lenz's law sometimes lost marks by refereing to field lines instead of flux or induced current rather than induced e.m.f. Quite a few candidates though that this was a heating effect due to current flow and resistance increasing or friction at the commutators.

If there are 4 marks there should be at least four good points to make.

*(b) When the motor is first switched on the current *I* is large. As the coil turns faster, the current decreases.

Explain these observations.

(4)

Because its an inverse proportion law, as the time taken to cut field lines decrease, $\frac{d\phi}{dt}$ will increase so the induced current has to decrease because of lenzs law and faradays law combination.

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Examiner Comments

Lenz's law is about the cutting of flux lines. This candidate scores 1 mark for mentioning Lenz's law.

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Examiner Tip

If you realise that a question is about Lenz's law, remember to talk about flux not fields and also mention induced e.m.f.

*(b) When the motor is first switched on the current I is large. As the coil turns faster, the current decreases.

Explain these observations.

(4)

The current is large at the beginning because the magnetic field generated around the coil will be relatively small and the coil will travel slowly. Therefore, the rate of change of flux linkage will be low and no additional large emf will be induced (in accordance with Faraday's law). However, as it begins to move faster, there will be a greater rate of change of magnetic flux linkage : $-\frac{N d\Phi}{dt}$, as t is ~~greater~~ smaller. In accordance with Faraday's law, this will induce an emf in the coil which is proportionately large. Due to Lenz's law, the ~~effect~~ direction of this emf will be such as to oppose the change producing it – so the induced emf will cause a current to flow which generates a magnetic field around the

(Total for Question 13 = 8 marks)

coil, opposing the other magnetic field. This means the current in the wire will flow in two directions giving a net effect of slower moving electrons and therefore less current. This is because of a greater resistance.

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Examiner Comments

This answer is fully developed. The candidate notes the effect of induced e.m.f. and describes this thoroughly.

Question 14 (a)

(a) What is meant by a fundamental particle?

(1)

Smaller ~~[illegible]~~ particles that make up the protons and neutrons

(b) Sketch the electric field around a muon.

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Examiner Comments

Although this is factually correct, the answer does not describe what is meant by fundamental.

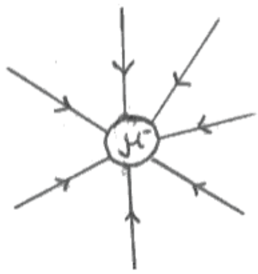
Although most candidates scored this mark, the most common error was to say 'smallest particle'.

Question 14 (b)

A lot of candidates scored full marks. Those that didn't, need to remember to use a ruler for this type of diagram, with equispaced lines and an arrow to show the direction of the field. Sometimes candidates end up with non equispaced lines because they try to draw too many. Four lines are sufficient.

(b) Sketch the electric field around a muon.

(3)



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Examiner Comments

These lines are not equispaced.

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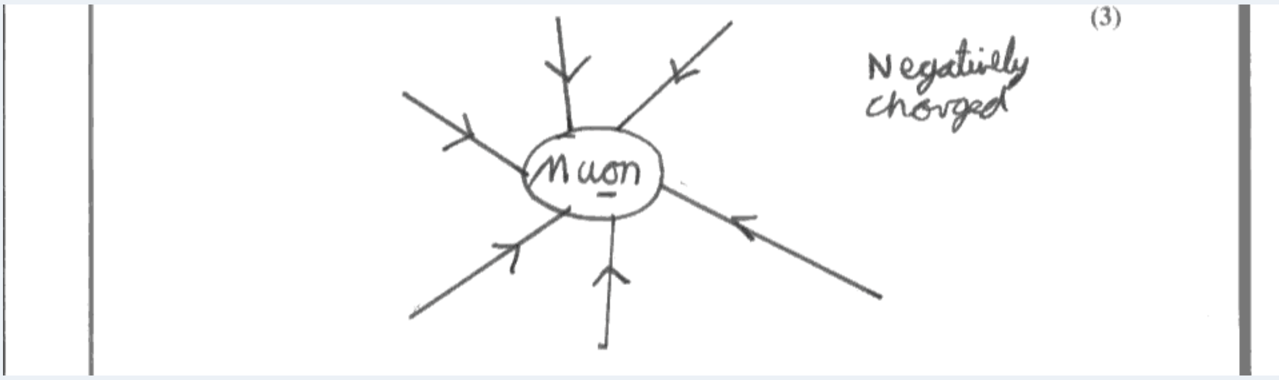
Examiner Tip

Make sure field lines are drawn with a ruler and are equispaced if appropriate. Limit yourself to 4 lines.



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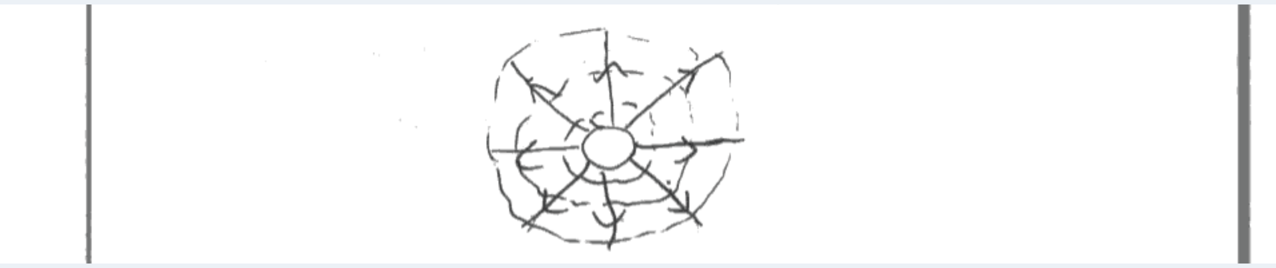
Examiner Comments

These lines are not radial (or equal spaced).



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Examiner Comments

These are not drawn straight.

Question 14 (c)

Some candidates worked backwards. They worked out the "mass of an electron" by dividing the mass of the muon by 200. This gained 2 marks. When a question says "show that" the candidates must calculate the answer which they can then check is about 200.

(c) The mass of a muon is 106 MeV/c^2. Show that its mass is about 200 times that of an electron.

(3)

$106 \times 10^6 \text{ eV} \times 1.6 \times 10^{-19} = 1.696 \times 10^{-11}$

$\frac{1.696 \times 10^{-11}}{(3 \times 10^8)^2} = 1.88 \times 10^{-28} \text{ kg}$

$E_m = 9.11 \times 10^{-31} \text{ kg}$

$9.11 \times 10^{-31} \times 200 = 1.822 \times 10^{-28} \text{ kg}$

$\approx 1.88 \times 10^{-28} \text{ kg}$

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Examiner Comments

The candidate should have divided the mass of the electron into that of the muon and shown that their answer is about 200 (206).

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Examiner Tip

In a 'show that' question, do not work backwards. i.e. don't start with the 200 and end up with a muon mass near 106 MeV/c^2.

Question 14 (d)

Generally, this was well answered with many candidates scoring full marks. Where errors were made, it was often that having correctly identified the r^2 in the equation, candidates forgot to actually square their value. Similarly, some candidates doubled the charge instead of squaring it.

(d) Calculate the electric force between the muon and proton in the muonic hydrogen atom.

distance between muon and proton = 2.7×10^{-13} m

(2)

$$F = \frac{kQ_1Q_2}{r^2} = \frac{(8.99\times10^{9})(1.6\times10^{-19})(1.6\times10^{-19})}{2.7\times10^{-13}}$$

$$= 8.52 \times 10^{-16}$$

Electric force = 8.52×10^{-16} N

ResultsPlus

Examiner Comments

An example of a candidate who doesn't square r.

(d) Calculate the electric force between the muon and proton in the muonic hydrogen atom.

distance between muon and proton = 2.7×10^{-13} m

(2)

$Q_p = 1.6 \times 10^{-19}$ C $Q_m = -1.6 \times 10^{-19}$ C $k = \frac{1}{4\pi\varepsilon}$

$F = k\frac{Q_p Q_m}{r^2}$ $= \frac{1}{4\pi \times 8.85 \times 10^{-12}}$

$= \frac{1.112 \times 10^{-10} \times 1.6 \times 10^{-19} \times -1.6 \times 10^{-19}}{(2.7 \times 10^{-13})^2}$ $= 1.112 \times 10^{-10}$

$= -3.91 \times 10^{-23}$ N

-ve ∴ repelling each other

Electric force = -3.91×10^{-23} N

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Examiner Comments

The candidate has calculated a wrong value of k rather than use the value given on the data sheet. This scores 1 mark.

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Examiner Tip

Candidates should be familiar with the data provided.

Question 14 (e)

This was a synoptic element requiring candidates to recall emission of photons from excited energy levels from unit 2. Those that realised this generally scored two marks, but not many candiates related the large energy difference needed to produce X-rays.

(e) Emission line spectra in the X-ray region of the electromagnetic spectrum can be detected from muonic hydrogen atoms.

Outline the atomic processes that produce emission spectra and suggest why they are X-rays in this case. ?

(3)

They have a short life (similar to x rays) and decay to electrons. The relatively large mass (compared to an electron) would cause a significant amount of radiation when decaying, and due to this mass difference the energy of the radiation would be very high (like xray).

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Examiner Comments

A common wrong answer where the candidate thinks there is a decay process involved. The answer required a discussion of energy levels.

(e) Emission line spectra in the X-ray region of the electromagnetic spectrum can be detected from muonic hydrogen atoms.

Outline the atomic processes that produce emission spectra and suggest why they are X-rays in this case.

(3)

When electrons gain energy to get to an energy level then ~~ret~~ drop back down to their original energy level they release a 'packet of energy' or photon with a certain energy in this case they are x-rays as alot of energy is being released.

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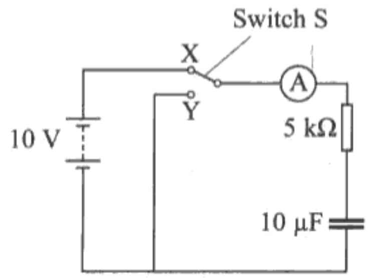
Examiner Comments

An example of an excelent answer that scores all three marks.

Question 15 (a) (i)

Most candidates scored one mark for the idea of the capacitor discharging, but the idea that this does not happen instantly was not well expressed.



(a) (i) She moves switch S from X to Y. Explain what happens to the capacitor.

(2)

~~The capacitor discharges~~

current flows through the circuit and is used up by the resistor causing the capacitor to discharge

(ii) On the axis below, sketch a graph to show how the current in the ammeter

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Examiner Comments

The idea of capacitor discharge is here but not the idea that there is a time factor involved.

Question 15 (a) (ii-iii)

Many candidates showed an exponential shape and correctly indicated the initial current. Candidates need to know the characteristics of exponential decay and make them clear in an answer i.e. they should start on the y-axis but should not touch the X-axis. Many did not indicate any value of time, while others omitted units from the axes making any values meaningless. Part (iii) was very poorly answered with very few candidates realising that the charging capacitor actually follows a similar pattern for current (but negative), most thought the current was now an exponential increase.

(ii) On the axis below, sketch a graph to show how the current in the ammeter varies with time from the moment the switch touches Y. Indicate typical values of current and time on the axes of your graph.

(3)

$V = IR$

$I = V/R$

$I = 10/5000$

$I = 2 \times 10^{-3}$ A

$= 2$ mA

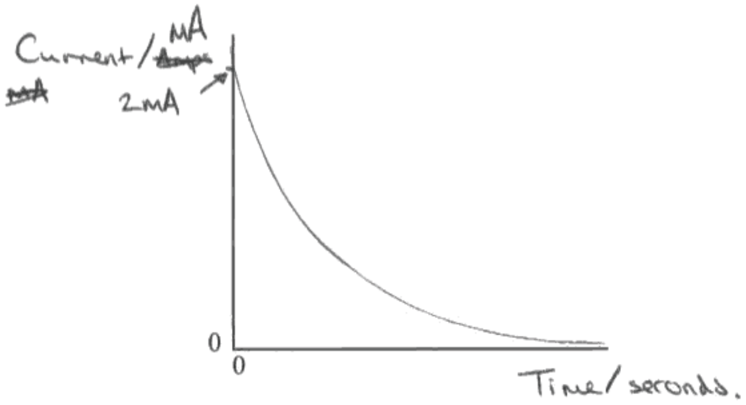
$Q = VC$

$Q = 10 \times 10 \times 10^{-6}$

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

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

$0 = 10 \times 10^{-5} e^{-t/5000 \times 10 \times 10^{-6}}$



(iii) Describe how the graph would appear when the switch is moved back to X.

(2)

Exactly the ~~same~~ opposite, as time increases current would increase.

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Examiner Comments

The candidate should have added a value to the time axis. many calculated the time constant (0.05 s) and put this on the appropriate place on the time axis. This scored 2 for the general shape and the intial current value. Calculating the time constant and adding this value to approximately the right point on the time axis would have given the third mark
In part (iii) many thought the current would increase.

Question 15 (b)

The calculation of energy stored in the capacitor was generally well answered.

Question 15 (c)

Whilst there were a lot of fully correct answers, the common error was due to a misreading of the question. Candidates reading it as a p.d. of 0.07 V rather than a ratio of its maximum value.

(c) The student wants to use this circuit to produce a short time delay, equal to the time it takes for the potential difference across the capacitor to fall to 0.07 of its maximum value.

Calculate this time delay.

(2)

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

$0.7 = 10e^{-t/5000 \times 10\times10^{-6}}$

$0.7 = 10e^{-t/0.05}$

$0.07 = e^{-t/0.05}$

$-t/0.05 = \ln 0.07$

$-t = \frac{\ln 0.07}{0.05}$

$-t = -53.1852...$

$t = 53.2s$

Time delay = 53.2s

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Examiner Comments

This candidate got the right ratio but has slipped up when rearranging the formula.

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Examiner Tip

Read the question carefully.

Question 16 (a)

This produced quite a range of answers. A lot of candidates are now giving sensible comparative answers e.g. “most” alphas go straight through, “very few” are deflected through very large angles etc. Some answers contatined far too much detail e.g. expalining what Rutherford’s nuclear model was, rather than just the observations. Examiners were looking for the comparative statements e.g. most, some or few and very few as the three categoreies. Most lost marks were due to poor expression rather than misunderstanding.

16 (a) Describe the key observations of the alpha particle scattering experiments which led to Rutherford’s nuclear model of the atom.

(3)

The key observations included that the majority of the ^4_2He particles passed straight through the gold foil, indicating the atom is most empty space. Some of the ^4_2He particles were reflected back (greater than 90°). Therefore the centre of the atom must be small, but with a large mass and positive charge in order to repel the ^4_2He. Rutherford called the centre of the atom the nucleus

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Examiner Comments

The word majority is not enough - it is the vast majority or better still 'most'. Some reflected back is not good enough, it needs to be very few.....This candidate obviously has a good idea of what is happening but does not score any marks.

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Examiner Tip

This type of question on Rutherford’s scattering experiment is likely to appear regularly and the answer could be learnt by candidates.

16 (a) Describe the key observations of the alpha particle scattering experiments which led to Rutherford's nuclear model of the atom.

(3)

When α particles were fired at a thin sheet of gold foil, most passed through unaffected but some particles were deflected at large angles, some even back in the direction in which they had come from. This showed that the atom must mainly be made up of empty space but with a positively charged dense mass in the centre.

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Examiner Comments

Many candidates did not specify that "very few" are deflected through large angles. A number of answers blurred the distinction between at least two from straight though, small angle deflection and large angle deflection.

Question 16 (b) (i)

Many candidates gave a good brief description of a LINAC. Most mentioned tubes of increasing length but some candidates weren't sure if there were tubes or electrodes. A few forgot to mention the alternating potential difference while others refererd to an alternating current which was not accepted.

Some candidates confused the different accelerators and talked about magnetic fields in place of electric fields.

(b) Experiments at Stanford University's linear accelerator (linac) accelerate electrons up to energies of 20 GeV.

(i) State the main features of a linac.

(3)

A linear consists of very long tubes with ~~element~~ electrodes inside in a varying magnetic field. Because they are so large they take up lots of space. A high frequency, alternating voltage is in the tubes, this changes the charge of the electrodes so that the particle that is being accelerated is always attracted to the next electrode, therefore increasing its speed so it is accelerated. Because the particle is getting faster, but we want to keep it in the electrode for the same space of time we have to increase the length of the electrode. It can only get up to 20 GeV as after this energy begins to be converted to mass so it is harder to accelerate. If you want higher energies you can use a syncocyclotron.

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Examiner Comments

This answer confuses the tubes and electrodes. They are one and the same.

Question 16 (b) (ii-iii)

In part (ii), quite a few candidates were able to complete this calulcation correctly. Others were unable to convert GeV into Joules (unit 2 knowledge and needed for particle physics) while some attempted the calculation without using the equation given in the question. Some candidates who could do the calculation lost the third mark because of the omission of a unit for the wavelength. In part (iii) we required a comparative reference between wavelength and nuclear structure. It was not enough to say the wavelength has to be small. Some candidates compared the wavelength to atomic, rather than nuclear, structure.

(ii) Calculate the de Broglie wavelength of 20 GeV electrons. At these energies, the following relativistic equation applies $E = pc$.

(3)

$\lambda = \frac{h}{p}$ $p = \frac{E}{c} = \frac{20\times10^9}{3\times10^8} = 66.67$ ~~Bed~~ $\frac{eV}{c}$

$\frac{6.63\times10^{-34}}{66.67} = 9.945\times10^{-36}$

De Broglie wavelength = 9.9×10^{-36} $\frac{Jc}{eVs}$

(iii) Suggest why these electrons would be particularly useful for investigating nuclear structure.

(1)

The electron wavelength is tiny

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Examiner Comments

A number of candidates forgot to change GeV to Joules.

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Examiner Tip

make sure you can convert between the units . e.g. eV and Joules

Question 16 (b) (iv)

A lot of candidates did realise, that the evidence suggested that the proton was not uniform, but very few made any reference to the quark structure of protons. Quite a few answers were given in terms of the structure of a hydrogen atom and the spaces between the protons in hydrogen so another example of when candidates need to read the question carefuuly and answer the question that is asked.

Question 16 (b) (v)

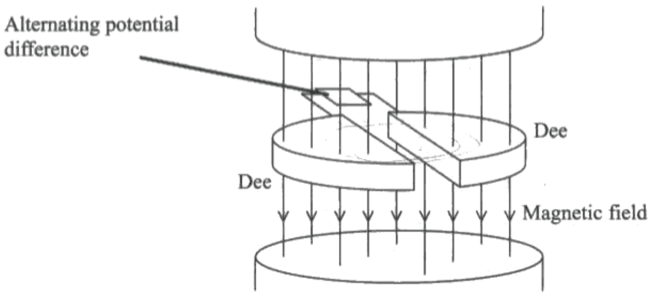
This was answered well with most candidates able to define an inelastic collision.

Question 17 (a)

Whilst a lot of candidates recognised that the magnetic field caused circular motion, only the more able candidates talked about the force being perpendicular to the moving charged particles. A number of candidates thought, incorrectly, that the function of the magnetic field was to give the protons a spiral track.

Another question in which adding to the diagram helps the answer in most cases.Candidates were expected to point out that the function was to bend the path into a circle.

17 (a) A cyclotron can be used to accelerate charged particles.



Explain the purpose of the magnetic field in a cyclotron. You may add to the diagram if you wish.

(2)

The magnetic field keeps the charged particls on the right course. That keeps the charged particle going round in gradually increasing circle.

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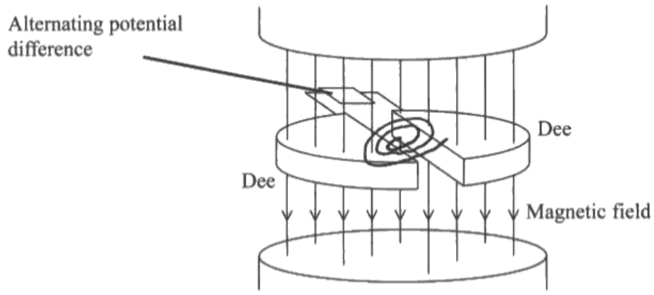
Examiner Comments

The reference to increasing circles is taken to mean spirals which is incorrect.

17 (a) A cyclotron can be used to accelerate charged particles.



Explain the purpose of the magnetic field in a cyclotron. You may add to the diagram if you wish.

(2)

The magnetic field provides a force on the charged particle which is centripetal and makes it follow a circular path.

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Examiner Comments

This scores 1 for the centripetal force but it omits reference to it being due to the fact that the force is at right angles to the particle's motion.

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Examiner Tip

It is because the force is at right angles tom the motion that there is a centriptal force and this is an essential part of the explanation.

Question 17 (b) (i)

A lot of very untidy difficult to mark answers were produced. Teachers do need to to spend some time expalining to candidates how to answer this type of question. It helps greatly if a few words are added to the argument, because often there was no well expalined thread to the derivation. The derivation was often incomplete, fudged or blank.

(b) A beam of low-speed protons are introduced into a cyclotron.

(i) Show that the number of revolutions per second, f, completed by the protons is given by

$$f = \frac{eB}{2\pi m}$$

where e is the electronic charge
B is the uniform magnetic flux density within the cyclotron
m is the mass of the proton.

(3)

$\omega = \frac{T}{2\pi}$ $\quad T = 2\pi\omega$ $\quad \frac{1}{f} = 2\pi\omega$ $\quad f = \frac{1}{2\pi\omega}$

$F = BeV$ $\quad mr\omega^2 = BeV$ $\quad \omega^2 = \frac{BeV}{mr}$ $\quad \frac{V}{r} = \omega$ $\quad \omega^2 = \frac{Be\omega}{m}$ $\quad \omega = \frac{Be}{m}$

$f = \frac{1}{2\pi\left(\frac{Be}{m}\right)}$

$f = \frac{Be}{2\pi M}$

ResultsPlus Examiner Comments

It looks convincing but T does not equal 2πω.

(b) A beam of low-speed protons are introduced into a cyclotron.

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$$f = \frac{eB}{2\pi m}$$

where e is the electronic charge
B is the uniform magnetic flux density within the cyclotron
m is the mass of the proton.

(3)

$T = 2\pi/\omega$ $\quad T = \frac{2\pi r}{V}$

$F = Mv^2r = Bqv$ $\quad v = \omega r$ $\quad \frac{v}{r} = \omega$ $\quad \frac{1}{\omega} = \frac{r}{v}$

$Mv^2r = Bqv$

$Mvr = Bq$ $\quad q = e.$

$Mvr = Be$

$v = \frac{Be}{Mr}$

$T = \frac{1}{f}$ $\quad f = \frac{V}{2\pi r}$

$f = \frac{\frac{Be}{Mr}}{2\pi r} = \frac{eB}{2\pi M}$

ResultsPlus Examiner Comments

The error here is mrv²

Question 17 (b) (ii)

A number of answers suggested that candidates thought acceleration took place within the Dees. Even when it was correctly identified as between the Dees, few candidates could articulate clearly why the potential difference needs to alternate.

(ii) An alternating potential difference is placed across the two dees to increase the energy of the protons.

Explain why the potential difference that is used is alternating.

(2)

This changes the poles of the dees to be positive or negative. They alternate at the correct rate to attract and repel the protons so the protons do not lose momentum

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Examiner Comments

This candidate is not explicit about where the proton is given energy.

Question 17 (b) (iii)

The relativistic effect was not always identified, and those that did realise that the mass would increase, did not use their knowledge of the equation used earlier to say that the frequency would decrease. In fact many thought that the frequency would increase because the protons were going faster.

+vely charged.

(iii) Initially, whilst the proton speeds are low, the frequency at which the potential difference has to alternate is constant.

Explain how the frequency must change as the protons gain more and more energy.

(2)

as the energy increases increases they travel faster so the frequency must be increased so that they still travel the same distance before the polarity is reversed and the proton is attracted to the other dee.

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Examiner Comments

A common wrong answer, the assumption being made that if it travels faster, the frequency must increase.

(iii) Initially, whilst the proton speeds are low, the frequency at which the potential difference has to alternate is constant.

Explain how the frequency must change as the protons gain more and more energy.

(2)

When the particles ~~reach~~ approach the speed of light they become relativistic and as $E_k = \frac{1}{2}mV^2$ and the speed cannot increase speed of light they gain mass and as $f = \frac{eB}{2\pi m}$ when the mass changes so does the frequency

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Examiner Comments

An answer that shows that the candidate does not know whether the frequency increases or decreases, so plays safe by just saying it changes, which is effectively repeating the question. Scores 1 mark for the relativistic effects.

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Examiner Tip

No marks are given for repeating the question. This candidate would have been better guessing whether the frequency increases or decreases.

Question 17 (c)

A number of candidates failed to spot the clue in the question about circular motion and leapt into imaginative and prosaic flights of imagination. Quite a large number of candidates decided that this was the relativistic effect rather than the previous part. This was generally not well answered.

(c) In the Large Hadron Collider at CERN, protons follow a circular path with speeds close to the speed of light. X-rays can be produced by free protons which are accelerating.

Explain why this provides a source of X-rays even though the speeds of the protons are constant.

(2)

The protons are still being put through large potential differences and are ~~fy~~ effectively now gaining mass as well as speed. This relativistic mass is where the energy for the X-rays comes from.

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Examiner Comments

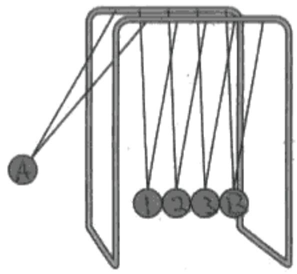
This was actually part of the answer to the previous question.

Question 18 (a)

This proved extremely challenging. Candidates needed to focus on what they were asked i.e. how to investigate if momentum is conserved. What ever the context, this requires knowledge of masses and velocity just before the collision. Candidates wanted to measure the mass despite being told the balls were identical and/or were not specific about finding a velocity on impact. Very few candidates had any idea about how to actually make relevant measurements. Confusion between average velocity calculations and really wanting the velocity at collision. Many candidates omitted to explain what would be expected from the two balls of equal mass if momentum is conserved.

18 A student is using a 'Newton's Cradle'. This consists of a set of identical solid metal balls hanging by threads from a frame so that they are in contact with each other.

She initially pulls one ball to the side as shown.



She releases the ball, it collides with the nearest stationary ball and stops. The ball furthest to the right immediately moves away. The middle three balls remain stationary.

*(a) Explain what measurements the student would take and describe how she would use them to investigate whether momentum had been conserved in this event.

(4)

p = mv , for ~~mo~~ p to be conserved mv must equal mv after. The velocity of the resting balls would be 0 ms⁻¹ to start with so intial p would equal the mass of ball A times the velocity of Ball A. Therefore she must measure the mass and the velocity of Ball A ~~exactly~~ before the collision. She then needs to measure the mass and velocity of Ball B after the collision. To calculate if momentum is conserved.

P_A must equal P_B

$m_A v_A = m_B v_B$

If they are equal, momentum has been conserved.

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Examiner Comments

Many candidates stated measure velocity - how? They might have mentioned height and use of PE - KE formula. They might have mentioned distance - time methods although this could yield average velocity or they could have discussed light gates and diameter of ball.

- She would need to measure the mass of the balls (~~assuming they are all of equal mass~~), and the velocity at the time of the first collision (this could be determined by ~~finding~~ measuring the height dropped from, the length of the thread from which the ball hangs, and the time taken for it to fall).
- It would then be possible to calculate the momentum of the first ball, and, once the momentum of the end ball is found they can be compared.
- Alternately, one could assume that if momentum were conserved ~~and a ba~~ when ball A (see diagram) was dropped from height h, ball E would also reach height h.

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Examiner Comments

This answer correctly identifies the best measurement to take i.e. height of ball. It doesn't then suggest the GPE to KE method to calculate the velocity of the ball at impact.

Question 18 (b)

Not surprisingly, candidates struggled to express this well. A lot of candidates did realise what was happening here, but did not express themselves clearly. A number of answers completely omitted the word "kinetic" with ambiguous phrases such as "energy is lost". Candidates should be giving answers such as 'energy is lost as heat and sound'.

(b) The student makes the following observations:

- the ball on the right returns and collides with a similar result; this repeats itself a number of times
- after a while, the middle balls are also moving
- shortly afterwards, the balls all come to rest.

Discuss these observations in terms of energy.

(3)

Ideally no energy would be lost and it would continue forever but in reality energy is lost in the collisions. Some energy would be lost in heat and some energy would be lost in sound. Air resistance will also slow the balls down. The middle balls will start to move if there is any slight impurity in the connection. Eg. if the ball does not hit square onto the next ball. These will cause slight differences which will be increased over time. Eventually they will lose all energy and come to rest.

(Total for Question 18 = 7 marks)

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Examiner Comments

The word kinetic needed appropriately to be inserted.

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