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Examiners' Report
June 2019

IAL Physics WPH04 01

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Introduction

The assessment structure of Unit 4, "Physics on the Move" is the same as that of Units 1, 2 and 5. Section A consists of ten multiple choice questions and Section B contains a number of short answer questions followed by some longer, structured questions based on contexts of varying familiarity.

The contextual range of the paper allowed candidates of all abilities to demonstrate their knowledge and understanding of Physics.

Those less confident in the subject could complete calculations which involved simple substitution and limited rearrangement, including structured series of calculations, but could not always master calculations involving several steps or complications; such as taking into account the number of wires in a coil, or only being given the charge lost from a capacitor rather than the charge remaining. They demonstrated an understanding of the significant points in descriptions linked to standard situations; such as the standard model, the operation of an electron gun, and electromagnetic induction. Occasionally, however, they missed important details and did not set out their ideas in a logical sequence, sometimes quoting as many key points as they could remember without particular reference to the context.

More confident candidates were able to complete calculations with little to no difficulty; including most marking points in logically structured answers.

Section A

The multiple choice questions discriminated well, with performance improving across the ability range for all items. Candidates around the E grade boundary typically scored about 6 or 7 and more able candidates usually answered 8 or 9 correctly.

The percentages of correct responses for the whole cohort are shown in the table.

Question	Percentage of correct responses
1	58
2	94
3	67
4	88
5	83
6	80
7	90
8	66
9	38
10	93

More details on the rationale behind the marking of multiple choice questions can be found in the published mark scheme.

Question 11

The great majority of candidates were able to demonstrate the correct use of the Coulomb force equation by substitution of charge and distance, although very many used an incorrect value of *r*. Frequently seen incorrect values were 5, 6, 12 and 17 cm rather than 11 cm. A significant minority failed to show that *r* should be squared when they made their substitutions and candidates occasionally used the Boltzmann constant when substituting for *k*.

Candidates generally knew the direction, but a fair proportion omitted it or made suggestions such as upwards or downwards.

Occasionally, the unit was omitted or was incorrect; examples being T and Vm.

11 Calculate the electric field strength at a distance of 5.0 cm from the surface of a positively charged sphere.

diameter of sphere = 12 cm

charge on sphere = +34 nC

(3)

$E = \frac{F}{Q}$ $E = \frac{kQ}{r^2}$

$= \frac{8.99 \times 10^9 \times 34 \times 10^{-9}}{0.12}$

$= 2547.2\ NC^{-1}$

Magnitude of electric field strength = 2547 NC^{-1}

Direction of electric field strength = radially away from the sphere.

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Examiner Comments

1 mark.

The correct formula has been written but an incorrect value of *r* has been substituted. Although the formula says r^2, the substituted value has not been squared, so there is no credit for use of the formula.

The stated direction of the electric field is correct.

11 Calculate the electric field strength at a distance of 5.0 cm from the surface of a positively charged sphere.

diameter of sphere = 12 cm

charge on sphere = +34 nC

(3)

~~Eq = k~~ $F = Eq$ $F = \frac{kQq}{r^2}$

$Eq = \frac{kQq}{r^2}$ $E = \frac{kQ}{r^2}$ $\frac{8.99 \times 10^9 \times 34 \times 10^{-9}}{((6+5)/100)^2}$

$E = 2.53 \times 10^4$

Magnitude of electric field strength = $2.53 \times 10^4 NC^{-1}$

Direction of electric field strength = Outwards

ResultsPlus
Examiner Comments

3 marks.

This is a correctly calculated response.

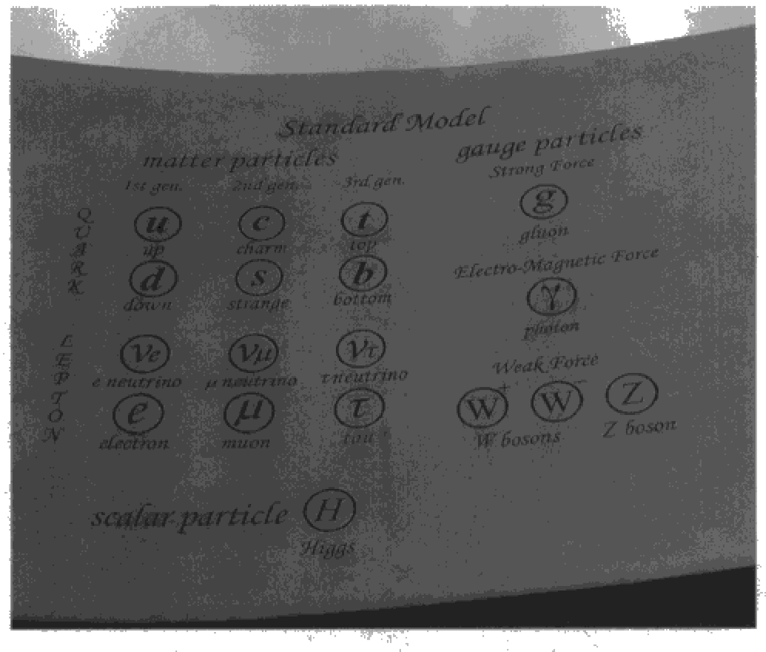
Question 12

Candidates seemed comfortable answering this longer question and the majority scored at least 3 marks. Among the most commonly awarded marks were those for the three quark structure of protons and neutrons, frequently quoted as uud and udd respectively; although not so frequently referred to as baryons. Some candidates ambiguously remarked that the baryons were made of "3 quarks or antiquarks" rather than the correct "3 quarks or 3 antiquarks".

A lack of detail meant that certain marks were awarded less frequently; mainly for failing to locate protons and neutrons in the nucleus and not comparing the size of the nucleus to the overall size of the atom. There were quite a few references to Rutherford’s alpha scattering experiment, prompted by the statement in the stem that ‘matter is mostly empty space’, but these were not credited without this comparison.

Some candidates misread “two first generation quarks” as “quarks from the first two generations”.

*12 The photograph shows part of a sculpture at the laboratories of the European Organization for Nuclear Research in Switzerland.



A teacher on a tour says to a group of students, "In fact, nearly all of the matter in that sculpture is made up of the two first generation quarks, in combinations called baryons, and one type of lepton. However, the matter is mostly empty space."

Explain this statement.

(6)

The standard model is a list of fundamental particles that form particles in an atom. These fundamental particles are split into two groups called quarks and leptons. There are baryons which are ~~particles~~ formed by a combination of 3 quarks. Leptons are fundamental particles such as electrons found orbiting the nucleus of an atom. An atom is mainly empty space due to the discoveries made by the alpha-scattering experiment.

ResultsPlus
Examiner Comments

3 marks.

This response gives details about baryon structure, the nature of electrons and their location on the atom, however, it does not address 'first generation' or nuclear structure. The statement about alpha scattering is not sufficient as an explanation of empty space because it does not refer to the size of the nucleus relative to the atom.

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Examiner Tip

Be sure to identify all key points in longer questions and address them in your response.

(6)

Matter, including the sculpture, is made of atoms. These have the structure of a nucleus and electrons orbiting the nucleus. The electron is the lepton the teacher is ~~refe~~ referring to.

The nucleus is a very small (in size). About $\frac{1}{10,000}$ of the volume of an atom is occupied by the nucleus hence 99.99% ~~so~~ (most of ~~the atom~~) of the atom is empty space.

The nucleus contains protons and neutrons. These are baryons. Their internal structure is as follows:- proton = up+up+down quarks (udu) neutron = up+down+down quarks, (udd). Therefore ~~the most of~~ it is correct to say that the vast ~~ma~~ majority of matter comprises the 1st generation quarks (up quarks & down quarks).

ResultsPlus
Examiner Comments

6 marks.

This is a full mark response which has been structured logically and includes all key points.

Question 13 (a) (b)

A large majority worked through this question with no more than a single error, to achieve at least 5 marks out of 6, and many completed it correctly. The most common error was failing to take into account **two** photons, despite being told to assume that the photons are identical.

Some candidates forgot to multiply by *e,* or divided by *c* rather than c^2. Some were unsure of the method for part (b) and treated the photon as a particle with mass travelling at the speed of light, attempting to find the de Broglie wavelength. Those attempting this route sometimes used the mass of a proton, possibly mistaking it for photon, which does not have mass, or even used the mass of an electron.

13 The existence of the Higgs boson was confirmed in 2012.

The Higgs boson has no charge and a mass of 126 MeV/c^2.

(a) Calculate the mass of the Higgs boson in kg.

(3)

$$M = \frac{126 \times 10^6 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2} = 2.24 \times 10^{-28}$$

$$E = c^2 \times m$$

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

Mass = 2.24×10^{-28} kg

(b) In a video about the Higgs boson the following statement is made:

"The Higgs boson can decay in many ways. Sometimes the Higgs boson decays into two high energy photons."

Calculate the frequency of the photons. Assume the photons are identical.

(3)

$$v = \lambda f$$

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

$$f = \frac{v}{\frac{h}{p}} = v \times \frac{mv}{h} = \frac{mv^2}{h} = \frac{2.24 \times 10^{-28} \times (3 \times 10^8)^2}{6.63 \times 10^{-34}} = 3.041 \times 10^{22} \text{ Hz}$$

Frequency = 3.041×10^{22} Hz

ResultsPlus
Examiner Comments

(a) 3 marks.

(b) 0 marks.

In part (b) an attempt has been made to use the idea of the de Broglie wavelength but this is incorrect physics. This response uses the mass of the Higgs particle and assumes that it is travelling at the speed of light, which is not possible for a particle with mass.

ResultsPlus
Examiner Tip

Particles with mass cannot travel at the speed of light.

13 The existence of the Higgs boson was confirmed in 2012.

The Higgs boson has no charge and a mass of 126 MeV/c^2.

(a) Calculate the mass of the Higgs boson in kg.

(3)

$m = \frac{126 \times 10^{6} \times 1.6 \times 10^{-19}}{(3 \times 10^{8})^2} = 6.72 \times 10^{-20}$

Mass = 6.72×10^{-20} kg

(b) In a video about the Higgs boson the following statement is made:

"The Higgs boson can decay in many ways. Sometimes the Higgs boson decays into two high energy photons."

Calculate the frequency of the photons. Assume the photons are identical.

(3)

$\lambda = \frac{h}{p}$, $E = c^2 \Delta m$

$E = (3 \times 10^8)^2 (6.72 \times 10^{-20})$

$E = 6.048 \times 10^{-3}$

energy of 1 photon = 3.024×10^{-3} J

$E = hf$

$E/h = f$

$f = \frac{(3.024 \times 10^{-3})}{(6.63 \times 10^{-34})}$

$f = 4.561 \times 10^{30}$

Frequency = 4.56×10^{30} Hz

ResultsPlus

Examiner Comments

(a) 2 marks

(b) 3 marks

In part (a) the substitution is correct, including the power of 2, but, in the calculation, only *c* has been used and not c^2.

The incorrect answer from part (a) has been correctly used in part (b), so full marks have been awarded.

13 The existence of the Higgs boson was confirmed in 2012.

The Higgs boson has no charge and a mass of 126 MeV/c^2.

(a) Calculate the mass of the Higgs boson in kg.

(3)

~~u = 931.5 MeV / c²~~ mass $= \frac{126\times10^6 \times 1.6\times10^{-19}}{(3\times10^8)^2}$

$= 2.24\times10^{-28}$ kg

Mass = 2.24×10^{-28} kg

(b) In a video about the Higgs boson the following statement is made:

"The Higgs boson can decay in many ways. Sometimes the Higgs boson decays into two high energy photons."

Calculate the frequency of the photons. Assume the photons are identical.

(3)

$E = m.c^2$

$= 2.24\times10^{-28} \times (3\times10^8)^2$

$= (126\times10^6 \times 1.6\times10^{-19})$

$= 2.016\times10^{-11}$ J

$E = hf$

$f = \frac{E}{h} = \frac{2.016\times10^{-11}}{6.63\times10^{-34}}$

$f = 3.04\times10^{22}$ HZ

Frequency = 3.04×10^{22} HZ

ResultsPlus
Examiner Comments

(a) 3 marks

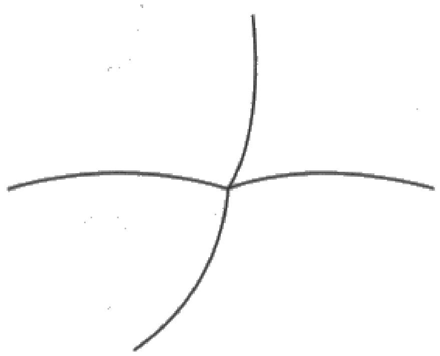
(b) 2 marks

Part (a) is correct but the response to (b) does not divide the energy between two separate photons.

Question 13 (c)

Less than half of the candidates gained any marks for this question, often for applying conservation of charge. Many candidates missed the information provided, stating that the Higgs particle is uncharged, and set out to prove that the commentary was correct and that they moved apart because they repelled each other, often stating as evidence that the radii of curvature for the particles were the same although they had no information about momentum. Many candidates failed to gain the second mark because they only referred to opposite directions and not opposite directions of curvature.

(c) The video shows the following diagram, which represents the decay of a Higgs boson. The lines are tracks of decay particles moving in a magnetic field perpendicular to the diagram.



The video commentary includes the statement:

"Sometimes the Higgs boson decays into four electrons."

Discuss this statement.

(3)

tracks are curving in different directions suggesting that two of the tracks are formed from oppositely charged particles.
All the tracks have the same radius of curvature.
Therefore all the decay particles have the same mass and magnitude of charge.
Decay particles could be 2 positrons and 2 electrons

ResultsPlus
Examiner Comments

2 marks.

In this answer the required reference to opposite curvature is made and suggested particles have been mentioned. No reference to conservation of charge has been made.

If the Higgs boson decayed into four electrons, charge wouldn't be conserved as the Higgs has 0 charge, yet four electrons would have $-4e$ charge in total. Thus, the higgs is more likely to produce 2 pairs of electrons and positrons - which are anti particles to electrons, with opposite ~~mass~~ charge and equal mass. Thus, charge would be conserved. As they travel in opposite directions, momentum would also be conserved.

ResultsPlus
Examiner Comments

2 marks

Conservation of charge has been addressed, together with possible particles, but the response only suggests opposite directions without reference to curvature.

Question 14 (a)

A third of candidates failed to gain any credit for this question for not following the instruction to describe the motion of both gliders. Others did not include sufficient detail about the direction; for example, in (i), stating that they moved in the same direction without specifying which direction this was.

(a) Describe the motion of glider A and glider B after the collision

(i) when $m_B < m_A$

(1)

A and B move in same direction. A was ~~sm~~ slower after the collision

(ii) when $m_B = m_A$

(1)

A stops moving, B moves with velocity same as A's initial velocity.

(iii) when $m_B > m_A$.

(1)

A rebounds, moving in ~~a~~ opposite direction

ResultsPlus
Examiner Comments

(i) 0 marks.

This states correctly that A and B move in the same direction but does not describe the direction.

(ii) 1 mark.

The direction has not been stated explicitly, but velocity includes direction, so the mark has been awarded.

(iii) 0 marks.

Only glider A has been described when the question requires a description for both.

(a) Describe the motion of glider A and glider B after the collision

(i) when $m_B < m_A$

(1)

The velocity of A is positive so it moves forward in the same direction with glider B.

(ii) when $m_B = m_A$

(1)

The velocity of A is 0, so it's stationary and the glider B would move forward

(iii) when $m_B > m_A$.

(1)

The velocity of A is negative so the A would recoil and move backwards whilst glider B moves forward.

ResultsPlus
Examiner Comments

(i) 1 mark.

(ii) 1 mark.

(iii) 1 mark.

This is an example of a correct response.

Question 14 (b)

A substantial majority completed both parts correctly and were awarded full marks. In part (i), some did not apply conservation of momentum correctly because the velocity of glider A was not indicated by use of a negative value. Others did not make a clear statement in conclusion for part (ii), however, candidates rarely scored fewer than 4 marks overall.

(b) (i) Calculate the velocity v_B of glider B after the collision when m_B = 1.4 kg. Do not assume that the collision is elastic.

(4)

~~$m_1v_1 = m_2v_2$~~

$m_1v_1 = -m_1v_1 + m_2v_2$

$-0.50 \times 0.28 + 1.4 \times V_B = 0.50 \times 0.60$

$-0.14 + 1.4 \times V_B = 0.3$

$= 0.44 = 1.4 \times V_B$

$V_B = 0.314285714 3\ ms^{-1}$

$V_B = 0.314\ ms^{-1}$

v_B = 0.314 ms^{-1}

(ii) Determine whether the collision was elastic when m_B = 1.4 kg.

(3)

$\frac{1}{2}mv^2 = \frac{1}{2}mv^2$ if is elastic

$\frac{1}{2} \times 0.5 \times 0.6^2 = \frac{1}{2} \times 1.4 \times 0.314^2$

$0.09\ J \neq 0.069$

Both K.E are different therefore the collision is not elastic

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Examiner Comments

(i) 4 marks.

This part is correct.

(ii) 2 marks

Here, the kinetic energy of glider A after the collision has not been included.

(b) (i) Calculate the velocity v_B of glider B after the collision when $m_B = 1.4\,kg$. Do not assume that the collision is elastic.

(4)

$p = mv$

$(0.5 \times 0.6) = (1.4 \times v_B) + (-0.28 \times 0.5)$

$1.4 v_B = 0.44$

$v_B = 0.31\ ms^{-1}$

$v_B =$ 0.31 ms^{-1}

(ii) Determine whether the collision was elastic when $m_B = 1.4\,kg$.

(3)

$E_k = \frac{1}{2}mv^2$ Initial $E_k = \frac{1}{2} \times 0.5 \times 0.6^2 = 0.09$

Final $E_k = (\frac{1}{2} \times 0.5 \times 0.28^2) + (\frac{1}{2} \times 1.4 \times 0.31^2)$

$= 0.09$

The initial E_k is equal to the final (0.09 = 0.09), so kinetic energy is conserved and it's an elastic collision.

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Examiner Comments

(i) 4 marks.

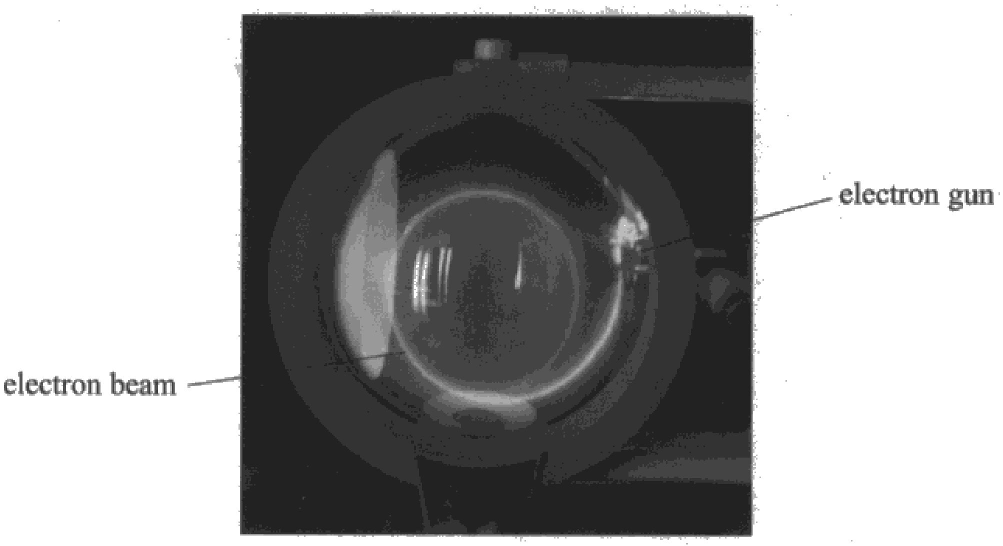
(ii) 3 marks.

In this response, both parts are correct.

Question 15 (a) (i)

While most candidates knew that thermionic emission was involved here, only about two thirds gained credit. Many did not correctly locate it in the filament, often saying that electrons were emitted from the anode which only accounted for electron emission. Few proceeded to explain the beam by referring to the acceleration of the electrons by the electric field. Many who did attempt this simply stated that electrons were attracted to the anode, which was not sufficient detail for the second mark. A number of candidates invoked the photoelectric effect.

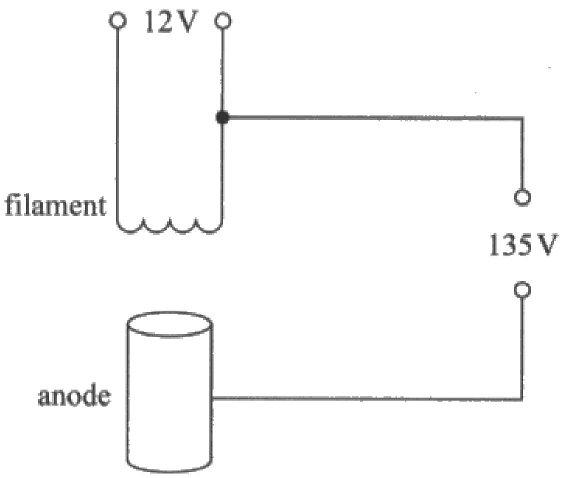
15 The photograph shows the path of an electron beam in a fine beam tube.



The fine beam tube contains helium gas at very low pressure. When electrons strike the helium atoms the resulting excitation is responsible for the glow tracing the path of the electron beam.

The electron beam is emitted downwards from an electron gun.

(a) The electron gun contains a heated filament above an anode as shown. There is a potential difference of 135 V between the anode and the filament.



(i) Describe how the electron beam is produced.

(2)

Electron beam is produced from the heated filament. via thermionic emission process.

ResultsPlus
Examiner Comments

0 marks.

The response correctly identifies the heated filament as the source but only refers to the electron beam, which was already mentioned in the question, and not to the emission of electrons specifically.

The filament heats up due to the heating effect of the current through it, supplying kinetic energy to the electrons in the filament so that they have enough energy to overcome the ~~work function~~ minimum energy required to be ~~and are~~ released from the metal, and attracted to the anode

ResultsPlus
Examiner Comments

1 mark.

The thermionic emission process is described satisfactorily for 1 mark; however, stating that the electrons are attracted to the anode provides insufficient detail to explore the concept of the electric field accelerating electrons to form the beam.

The heated filament excite the electrons enough to leave the atom they were in (thermionic emission). They are then accelerated according to $a = \frac{EQ}{m}$ as a potential difference is applied which causes an electric field to form. Anode's positive while electrons are negative so the attraction causes a positive acceleration on all electrons, forming an electron beam

ResultsPlus
Examiner Comments

2 marks.

This is an example of a correct response.

Question 15 (a) (ii) - (bii)

Half of the entry worked through this sequence of two calculations and a derivation correctly to gain the full six marks.

In part (a)(ii) some candidates added the 12 V for the filament to the 135 V accelerating p.d., or subtracted it, and some omitted to multiply by the electron charge but, as it was a 'show that' question, most were able to go back and try again if they did not succeed the first time.

In part (b)(i) some candidates did not make it clear when $p = mv$ was being applied.

In part (b)(ii) the diameter was not always halved to find the radius and sometimes cm was not converted to m. Failing to include the unit T meant that some candidates were not awarded the second mark.

(ii) Show that the speed of the electrons leaving the electron gun is about $7 \times 10^6\,\text{m s}^{-1}$.

(2)

$E = QV = \frac{1}{2}mv^2$

$1.6 \times 10^{-19} \times (135 + 12) = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$

$v = 7.19 \times 10^6\ \text{m s}^{-1}$

(b) The electron beam follows the path shown in the photograph. A horizontal magnetic field is applied in the direction into the page.

(i) Show that a particle of momentum p follows a circular path of radius r given by

$$r = p/BQ$$

where Q is the charge on the particle and B is the magnetic flux density.

(2)

$F = BqV \qquad p = mv.$

~~$p = mat$~~

So $F = Bq\frac{p}{m}$

(ii) Calculate B.

diameter of circular path = 7.3 cm

(2)

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

$\frac{1}{2} \times 0.073 = \frac{9.11 \times 10^{-31} \times 7.19 \times 10^6}{B \times 1.6 \times 10^{-19}}$

$B = 1.12 \times 10^{-3}\ \text{T}$

$B = $ ....

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Examiner Comments

(a)(ii) 1 mark.

A mark has been awarded for substitution of suitable quantities into the correct formula, however, the magnitude of the p.d. is incorrect because the 12 V for the filament has been added.

(b)(i) 0 marks.

Only one force formula has been stated, so the candidate has been able to proceed no further without reference to centripetal force.

(b)(ii) 2 marks.

This is a correct response.

(ii) Show that the speed of the electrons leaving the electron gun is about $7 \times 10^6\,m\,s^{-1}$.

(2)

$E = V \times eV = 135 \times 1.6\times10^{-19} = 2.16\times10^{-17}\,J$

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

$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{2\times2.16\times10^{-17}}{9.11\times10^{-31}}}$

$= 6.89\times10^{6}\,ms^{-1}$

(b) The electron beam follows the path shown in the photograph. A horizontal magnetic field is applied in the direction into the page.

(i) Show that a particle of momentum p follows a circular path of radius r given by

$$r = p/BQ$$

where Q is the charge on the particle and B is the magnetic flux density.

(2)

magnetic force : $F = QvB$ centripetal force : $F = m\frac{v^2}{r}$

so $m\frac{v^2}{r} = QvB$

$mv^2 = QvB \cdot r$

$r = \frac{mv^2}{QvB} = \frac{mv}{BQ}$

as $p = mv$, $r = \frac{p}{BQ}$

(ii) Calculate B.

diameter of circular path = 7.3 cm

(2)

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

$B = \frac{p}{Qr} = \frac{mv}{Qr} = \frac{9.11\times10^{-31}\times6.89\times10^{6}}{1.6\times10^{-19}\times(7.3cm\div2)}$

$= 1.07\times10^{-3}\,NA^{-1}m^{-1}$

$B =$ ....

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Examiner Comments

(a)(ii) 2 marks.

A correct response.

(b)(i) 2 marks.

A correct response.

(b)(ii) 1 mark

This calculation is correct, but the unit stated is not correct, which is the derived unit tesla. The unit given is dimensionally correct, as can be seen by consideration of the formula $F = BIl$, but this non-standard format is not acceptable.

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Examiner Tip

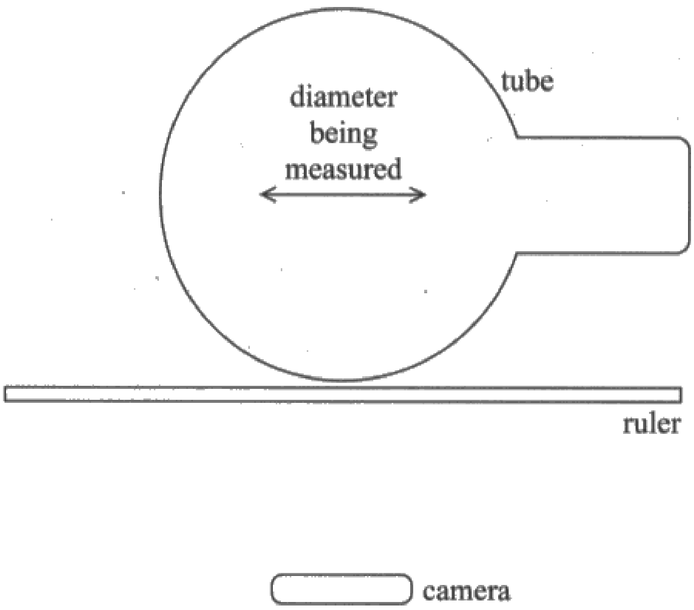
Use standard SI units with numerical answers.

Question 15 (c)

Only about a third of candidates scored on this Assessment Objective 3 question, either becuase of difficulty in visualising the situation or a lack of sufficient detail in their answers. They often referred to the camera making it ‘easier’ to take measurements, without suggesting how; such as by allowing magnification. Parallax was often identified as an issue, however, candidates often stated that parallax errors were avoided, when actually they were introduced by this arrangement. Those who recognised parallax errors as a problem generally did not explain how this method caused them. The resolution of a metre rule was often used in the answer, though many simply stated that a 1 mm scale introduced a large uncertainty, rather than comparing it to the known measurement of 7.3 cm to show that it actually represented a small percentage uncertainty.

It would have benefitted candidates to refer back to the photograph in the stem of Q15, as a minority of candidates referred to difficulty in capturing an image of the beam. Despite knowledge of the very high speed of the electrons, and the clear reference to ‘photograph’ rather than 'video’, some seemed to think that the motion of individual electrons was being filmed.

(c) The diameter of the circular path was measured by holding a metre rule in front of the tube and taking a photograph, as shown.



Discuss the suitability of this method.

(2)

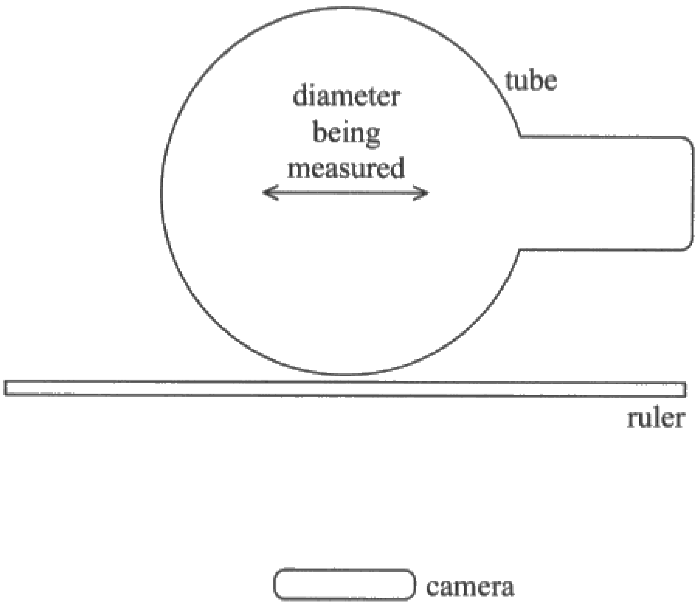
No, it is not a good method, the precision of metre rule is ~~a~~ 1mm which is very high. this will give greater percentage uncertainty, so not accurate. Also may have parallax error to increase the random error. better use a venier callipers.

ResultsPlus
Examiner Comments

0 marks.

This answer contains elements of accuracy but does not include the required detail. It begins by referring to high precision but then suggests it will lead to a large percentage uncertainty rather than the actual small percentage uncertainty. It correctly states that there may be parallax error but doesn't say how this is caused. There is also a suggestion of an improved method without providing any detail.

(c) The diameter of the circular path was measured by holding a metre rule in front of the tube and taking a photograph, as shown.



Discuss the suitability of this method.

(2)

The resolution of a metre rule is 0.1 cm

% U = $\frac{0.1 \times 2}{7.3}$ x100 = 2.7% The % uncertainty is 2.7%

because two readings must be taken than subtracted to ~~get~~ calculate the diameter. This ~~is~~ value is ~~a~~ small and ~~so~~ thus suitable.

ResultsPlus
Examiner Comments

1 mark.

Here, the percentage uncertainty in using a metre rule for this length is correcly calculated and described, gaining 1 mark, however, no other factors have ben considered.

Question 15 (d)

Again, about a third of the entry achieved at least 1 mark for this question. While many referred to the link between elctrons losing energy and diameter of the path, something already used in the earlier calculations, few candidates suggested a mechanism for energy loss and so did not gain credit. Very few seemed aware of the emission of radiation by accelerated charges, so those who did gain this mark usually did so by reference to energy loss by collisions, even though electrons would not continue in the beam along the same path after such a collision.

The 'decreasing intensity' was not often addressed, candidates seemingly not realising that it was part of the question.

(d) Suggest why the electron beam continues along a path of decreasing diameter with decreasing intensity.

(2)

$r = \frac{mv}{Bq}$, since ~~$v\downarrow$, $r\downarrow$~~ V decreases, radius decreases

ResultsPlus
Examiner Comments

0 marks.

This response makes a clear connection between decreasing speed and decreasing diameter, with reference to the relevant formula, but does not suggest a mechanism for the decreasing speed.

(d) Suggest why the electron beam continues along a path of decreasing diameter with decreasing intensity.

(2)

1. The electron cause ionisation ~~[crossed out]~~ with ~~[crossed out]~~ helium atom
2. so the electron lose energy
3. therefore E_k is decreasing and momentum is decreasing
4. $r = \frac{mv}{Bq}$, so radius decreases

ResultsPlus
Examiner Comments

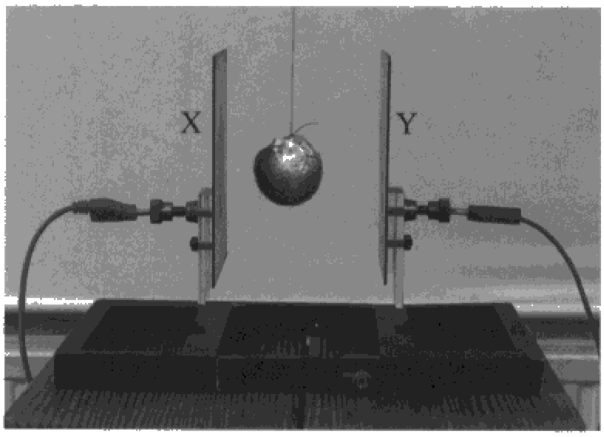
1 mark

In this response a clear sequence of ideas between an energy decreasing mechanism and decreasing diameter has been made. The question requires a suggestion for decreasing diameter and for decreasing intensity, however, so only the first mark is awarded.

Question 16 (a) (i)

Candidates rarely failed to gain credit for their diagrams, however, points of detail sometimes prevented the award of one mark. Candidates did not always use a ruler to ensure that lines perpendicular to the plates were spread evenly. Occasionally, candidates omitted the arrows or drew them in the wrong direction.

16 The photograph shows an arrangement for investigating charge, known as the "shuttling ball".

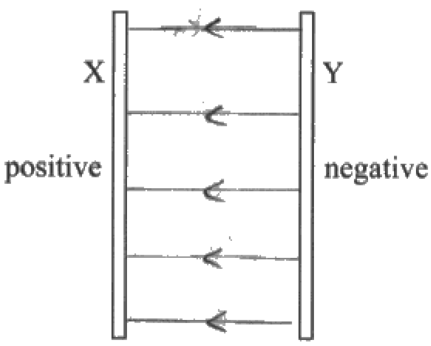


A ball coated in conducting material is suspended, on a very long insulating thread, between metal plates.

A potential difference (p.d.) is applied across the plates so that plate X is positively charged and plate Y is negatively charged. When the ball is touched against plate Y it gains a negative charge and is attracted to plate X. When the ball touches plate X the charge is transferred, the ball becomes positively charged and is attracted to plate Y. The ball continually moves between the plates. Assume that the presence of the ball does not affect the field of the plates.

(a) (i) Sketch the field between the plates on the diagram below.

(2)



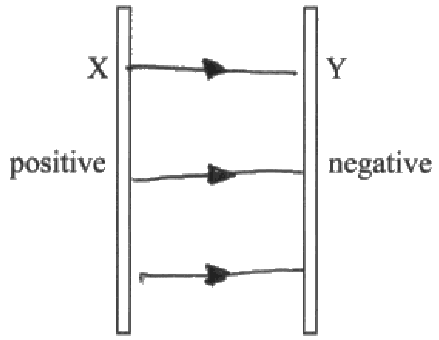
ResultsPlus
Examiner Comments

0 marks.

Here, the lines are not evenly spaced, not all are straight, and the arrows are in the wrong direction.

ResultsPlus
Examiner Tip

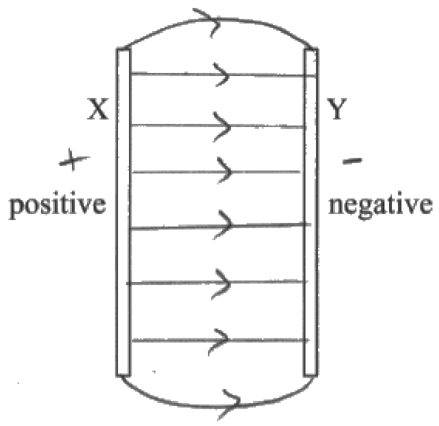
When a diagram is required, ensure that you are precise.



ResultsPlus
Examiner Comments

1 mark.

In this example the lines are crooked and do not all touch the plates but the arrows are in the correct direction.



ResultsPlus
Examiner Comments

2 marks.

An exemplary answer.

Question 16 (a) (ii)

A substantial number of candidates successfully described the uniform field, although they did not all successfully link this by use of $F = EQ$ to the constant force; many just stating it was so.

(ii) Explain why the charged ball experiences a horizontal force of constant magnitude while it is between the plates.

(2)

The is an uniform electric field between the plates. The electric field is a region where a small positive charge experiences a force thus the charged ball experiences a force perpendicular to the plates. The magnitude is constant as the electric field is constant, $\vec{E} = \frac{V}{d}$.

ResultsPlus
Examiner Comments

1 mark.

The uniform field is described but the force of constant magnitude is not explained, the question essentially being repeated.

(ii) Explain why the charged ball experiences a horizontal force of constant magnitude while it is between the plates.

(2)

The electric field between X and Y is a uniform electric field

$\because E = \frac{V}{d}$, the electric field strength is constant.

$\because F = EQ$, Q is constant

$\therefore$ the force which the charged ball experiences is of constant magnitude

ResultsPlus
Examiner Comments

2 marks.

This is a good example of a correct answer which describes all of the steps in a logical sequence.

Question 16 (b)

Taking part (b) as a whole, the majority of candidates gained at least 6 marks out of 10.

Part (i) presented few difficulties, however, a significant number of candidates attemped, incorrectly, to solve part (ii) by using equations for circular motion. Some were not awarded the final mark for failing to include the unit for their momentum value. In part (iii), some candidates who applied the rate of change of momentum did not complete the calculation correctly, only including the difference between the ball moving and coming to rest without considering the motion in the opposite direction. The unit of force was sometimes not included.

(b) The ball is initially at rest touching plate Y. After it leaves plate Y the ball accelerates uniformly from plate Y to plate X.

mass of ball = 2.7 g

(i) Show that the acceleration is about $0.2\,m\,s^{-2}$.

distance between plates = 9.5 cm
p.d. between plates = 5000 V
charge on ball = 11 nC

(4)

$F = ma = Eq = \frac{V}{d}q$

$ma = \frac{Vq}{d}$

$2.7\times10^{-3}a = \frac{5000\times11\times10^{-9}}{9.5\times10^{-2}}$

$a = 0.21\,ms^{-2}$

(ii) Calculate the momentum of the ball as it reaches plate X.

diameter of ball = 4.0 cm

(3)

$V^2 - u^2 = 2as$

$V^2 = 2\times0.21\times(9.5-2.0)\times10^{-2}$

$V = 0.18\,ms^{-1}$

$P = mV = 2.7\times10^{-3}\times0.18 = 4.8\times10^{-4}\,Ns$

Momentum = $4.8\times10^{-4}\,Ns$

(iii) The ball is in contact with plate X for 0.95 ms.
Calculate the average force acting on the ball during this time.
Assume that the ball hits the plate and leaves the plate at the same speed.

(3)

$\Delta F = \frac{\Delta P}{t} = \frac{4.8 \times 10^{-4}}{0.95 \times 10^{-3}} = 0.51$ N

Average force = 0.51 N

ResultsPlus
Examiner Comments

(i) 4 marks.

(ii) 2 marks.

(iii) 1 mark.

Part (i) has been completed correctly but in part (ii) only the radius of the ball has been subtracted from the plate separation to give an incorrect distance moved. In part (iii) the change of momentum in coming to rest has been used, failing to take into account the change required to move with the original speed in the opposite direction.

(b) The ball is initially at rest touching plate Y. After it leaves plate Y the ball accelerates uniformly from plate Y to plate X.

mass of ball = 2.7 g

(i) Show that the acceleration is about $0.2\,m\,s^{-2}$.

distance between plates = 9.5 cm
p.d. between plates = 5000 V
charge on ball = 11 nC

(4)

$F = EQ$, $E = \frac{V}{d}$

so $F = \frac{QV}{d} = \frac{11nC \times 5000V}{9.5cm} = 5.79 \times 10^{-4} N$

as $F = ma$, $a = \frac{F}{m} = \frac{5.79 \times 10^{-4} N}{2.7g} = 0.214 ms^{-2}$

(ii) Calculate the momentum of the ball as it reaches plate X.

diameter of ball = 4.0 cm

(3)

$a = 0.214 ms^{-2}$ $u = 0 ms^{-1}$, $s = 9.5cm - 4cm = 5.5cm = 0.055m$

$v^2 = u^2 + 2as$

$v = \sqrt{u^2 + 2as} = \sqrt{0^2 + 2 \times 0.214 \times 0.055} = 0.154 ms^{-1}$

$p = mv = 2.7g \times 0.154 ms^{-1} = 4.15 \times 10^{-4} kgms^{-1}$

Momentum = ...

(iii) The ball is in contact with plate X for 0.95 ms.
Calculate the average force acting on the ball during this time.
Assume that the ball hits the plate and leaves the plate at the same speed.

(3)

$\Delta p = mv - mu$ ~~mu...~~

$= 2.7g \times 0.154\,ms^{-1} - 2.7g \times (-0.154\,ms^{-1})$

$= 8.29 \times 10^{-4}\,kg\,ms^{-1}$

$\Delta p = F\Delta t$

$F = \frac{\Delta p}{\Delta t} = \frac{8.29 \times 10^{-4}\,kg\,ms^{-1}}{0.95\,ms} = 0.873\,N$

Average force = ...

ResultsPlus
Examiner Comments

(i) 4 marks.

(ii) 3 marks.

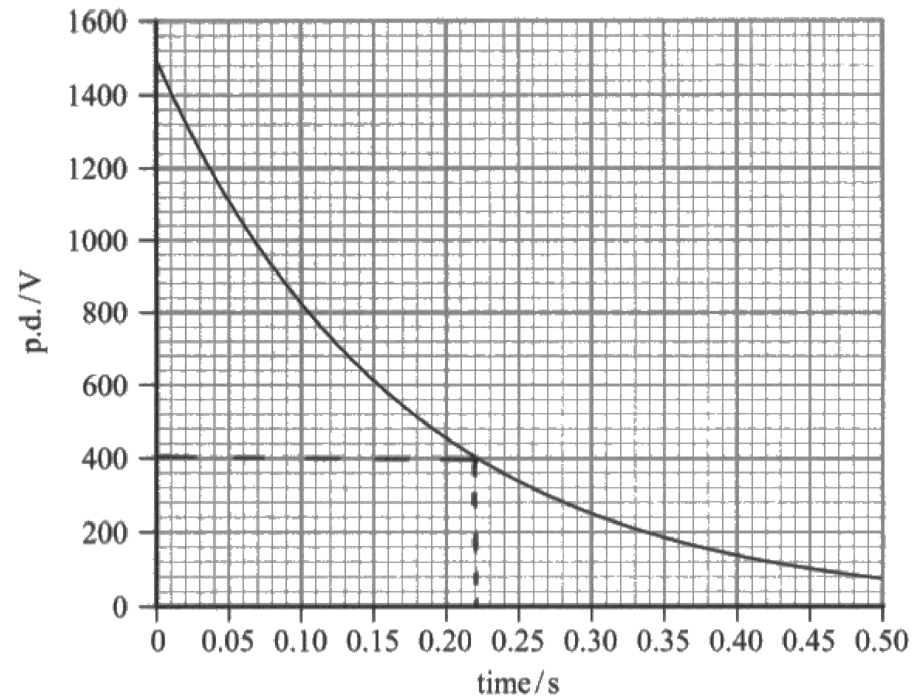
(iii) 3 marks.

This response is a very good example and correct in every part.

Question 17 (a)

This is not an unprecedented question, however, only a small proportion of candidates gave answers in sufficient detail to gain credit. Many just assumed that, as the graph was not linear, it must show exponential decay, and stated the features of such a graph; such as the p.d. decreasing by equal fractions in equal times or using it to determine the time constant. They did not say how they would obtain data from the graph to demonstrate whether it did show an exponential decrease in p.d.

While some candidates gained credit for stating that they would plot a graph of ln(*V*) against *t* and that it should produce a straight line graph, they did not often refer to the negative gradient.



(a) Describe how a graph of p.d. against time can be used to show that the racquet contained a capacitor. Your answer should not include calculations.

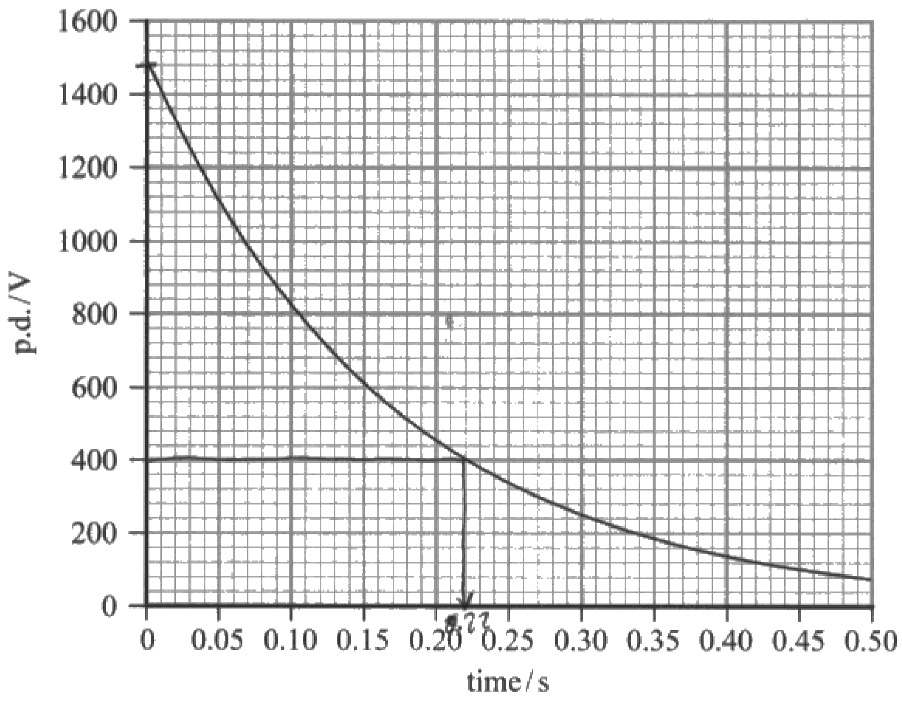
(2)

By using the formula $V = V_0 e^{-t/RC}$, and ~~xxxx~~
~~rearranging the values~~ ~~$\ln V = \ln V_0 + -t/RC$~~
~~and comparing it to $y = mx + c$, multiply the v~~
we can see that the graph is decreasing exponentially,
so a capacitor must be present.

ResultsPlus
Examiner Comments

0 marks.

In this response, the candidate quotes the exponential decay formula and suggests, correctly, that exponential decay would be evidence of the presence of a capacitor in the circuit. There is no suggestion, however, of a method to test, using values from the graph, whether the decay is, in fact, exponential.



(a) Describe how a graph of p.d. against time can be used to show that the racquet contained a capacitor. Your answer should not include calculations.

(2)

- By $V = V_0 e^{-\frac{t}{RC}}$, ~~or~~ ressistance affects the time taken for capacitor to discharge
- $\ln V = \ln V_0 \times -\frac{t}{RC}$ if we plot the graph of $\ln V$ against t the gradient of that graph would be $-\frac{1}{RC}$, proving that graph of potential difference against tim will ~~have~~ be exponential.

ResultsPlus
Examiner Comments

2 marks.

In this response, the candidate correctly identifies a graph which could be plotted using the data provided from the graph in the question and explains how the new graph would be used to verify that exponential decay has taken place.

Question 17 (b)

This 8 mark sequence of calculations proved straightforward to most candidates, with a majority scoring full marks. Parts (i) and (ii) were 'show that' questions so candidates knew when they needed to try again. Some candidates encountered difficulty with the SI prefixes for 'micro' and 'nano'.

In part (i), all of the methods shown in the mark scheme were used, with more using two pairs of values from the graph than a time constant method even though it required a more complicated calculation.

In part (ii), most candidates adopted the anticipated approach of calculating the charge on the capacitor, however, some calculated the p.d. that would be needed to provide the maximum charge, which was accepted with a suitable justification.

In part (iii) there were some errors with squaring, depending on the energy formula used. A number of candidates used the value of charge stated in part (ii) as the capacitance in part (iii).

(b) (i) Show that the capacitor has a capacitance of about 10 nF. Use values from the graph.

resistance of resistor = 12 MΩ

(4)

$I = V/R \quad = 1500\,V / 12\times10^6\,\Omega$

$= 1.25\times10^{-4}\,A$

$Q = It$

$= 1.25\times10^{-4} \times 0.5$

$= 6.25\times10^{-5}\,C$

$C = Q/V$

$= \frac{6.25\times10^{-5}}{1500}$

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

$\ln(80) = \ln(1500) - 0.50/12\times10^6 \times C$

$C = \frac{-0.50}{-2.9 \times 12\times10^6}$

$= 1.4\times10^{-8}\,F \quad = 14\,nF$

(ii) To ensure safety for humans, the maximum allowed stored charge for a fly zapper is 45 μC.

Show that this racquet operates within the safe limit.

(2)

$C = Q/V$

$1.4\times10^{-8} = 45\times10^{-6}/V$

$V =$

(iii) Calculate the energy stored on the fully charged capacitor.

(2)

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

$= \frac{1}{2} \times 1.4\times10^{-8} \times 1500^2$

$= 0.016\,J$

Energy = 0.016 J

ResultsPlus
Examiner Comments

(i) 4 marks.

(ii) 1 mark.

(iii) 2 marks.

Part (i) is a correct example of the use of values from the graph.

The correct formula has been used in part (ii), but the calculation has not been completed. This would have shown that a value of over 3000 V would be required.

Part (iii) is correct.

(b) (i) Show that the capacitor has a capacitance of about 10 nF. Use values from the graph.

resistance of resistor = 12 MΩ

(4)

37% V_0 = 552V

according to the graph,

t = 0.17s

$\tau = RC$

$0.17 = 12 \times 10^6 C$

$C = 1.4 \times 10^{-8}$ F

so C is about 10nF.

(ii) To ensure safety for humans, the maximum allowed stored charge for a fly zapper is 45 µC.

Show that this racquet operates within the safe limit.

(2)

$Q = CV_0$ according to the graph, $V_0 = 1492$V

$= 1.4 \times 10^{-8} \times$ ~~1490~~ 1492

$= 2.09 \times 10^{-5}$ C

2.09×10^{-5} C < 4.5×10^{-5} C, so it's safe.

(iii) Calculate the energy stored on the fully charged capacitor.

(2)

$W = \frac{1}{2} QV$

$= \frac{1}{2} \times 2.09 \times 10^{-5} \times 1492$

$= 0.0156$ J

Energy = 0.0156 J

ResultsPlus
Examiner Comments

(i) 4 marks

(ii) 2 marks

(iii) 2 marks

This is an example of the use of 37% of V_0 to determine the time constant. All parts of the response are correct.

Question 17 (c)

This is not an uncommon question but it was answered with insufficient detail. Under half of the answers were awarded a mark, with a small proportion of those candidates gaining the second mark.

Many candidates appeared to have an answer ready for dataloggers, irrespective of the context. Thus, in this question about measurements being taken over half a second, many referred to a datalogger being used to take measurements over a much longer period of time than a human could manage.

A large number stated that a datalogger was'more accurate', although the digital meters to which it was being compared could provide equally accurate measurements.

There were frequent references to avoiding human reaction time, but these were not contextualized by saying that many measurements could be taken in a short time or with a suitable statement relating to simultaneous measurements. Of those who mentioned simultaneous reading, many were general and did not state that these were readings of time and p.d.

(c) The p.d. falls to about 5% of its initial value in less than half a second.

Explain why the measurements were made using a data logger rather than a digital voltmeter and a timer.

(2)

To eliminate reaction time. Also it would cause inaccuracy when voltmeter and timer need to be recorded at the same time in such short period.

ResultsPlus
Examiner Comments

0 marks.

This is a typical response. It shows some idea of the situation but does not express it in enough detail. Eliminating reaction time is not sufficient and, although there is a link to simultaneous readings, we required the quantities rather than the instruments, which were easily gleaned from the question. The response stated that they needed to be recorded at the same time but did not specify that a person could not do this or that a datalogger could.

(c) The p.d. falls to about 5% of its initial value in less than half a second.

Explain why the measurements were made using a data logger rather than a digital voltmeter and a timer.

(2)

because ~~#~~ a human can't record all these datas in less than half a second data assures ~~a~~ higher accuracy for spontenous data.

ResultsPlus
Examiner Comments

1 mark

This candidate has correctly identified the ability of the datalogger to record a large number of readings in a short space of time.

Question 17 (d)

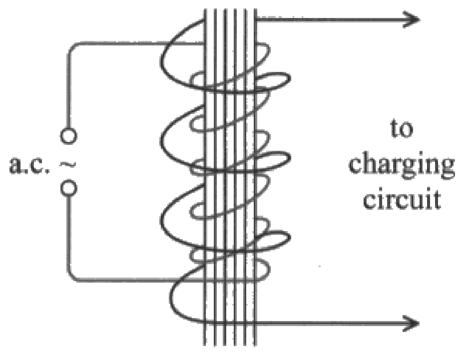
Two thirds of the candidates were awarded at least 2 marks, most commonly for stating that there was an induced e.m.f. and for reference to a current in a closed circuit. About half gained a third mark.

As has been the case with similar questions in the past, the identification of the cause of the change in magnetic flux linkage within this specific context can cause difficulty for some; many here did not refer to the varying current causing an alternating magnetic field. Others did not make specific reference to the change in magnetic flux linkage with the second coil.

Some candidates omitted the word 'magnetic' when referring to fields or field lines.

*(d) The capacitor is charged using a 5 V battery.

A circuit in the racquet produces a small alternating p.d. This circuit is connected to a coil wound around an iron core. A second coil around the core is connected to the capacitor charging circuit, as shown in the diagram.



Explain how this arrangement causes a current in the capacitor charging circuit.

(4)

The first coil which connected to the AC powersupply will produce an alternating magnetic field in iron core. According to the Fraday's law $\varepsilon = \frac{-dN\phi}{dt}$, the coil to the charging circuit will produce an ~~alternating p.d~~ induced e.m.f. According Lenz's law, the charging coil will form an magnetic field which is opposed to creating it. Also, the charging circuit is a closed circuit, the induced current formed.

ResultsPlus
Examiner Comments

3 marks

This response identifies the varying magnetic field, the induced e.m.f. and the current due to a complete circuit. Although the Faraday's law formula is quoted, a statement is required about the change in magnetic flux linkage in the context of the question to be able to score for marking point 2.

- The alternating current around the iron core ~~from the~~ (1st ~~wire~~ coil) produces an alternating magnetic field.
- The second ~~wire~~ coil (connected to charging circuit) cuts the magnetic field
- Because the magnetic field is alternating the 2nd coil is experiencing a rate of change ~~in~~ in magnetic flux linkage $\left(\varepsilon = \frac{-d(N\phi)}{dt}\right)$ which induces Emf.
- Because an Emf is induced in a closed circuit a current is created.

ResultsPlus
Examiner Comments

4 marks

All of the required points are shown within context and set out in a logical fashion.

Paper Summary

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

- Check that quantitative answers represent sensible values and go back over calculations when they do not
- Learn standard descriptions of physical processes, such as electromagnetic induction, and be able to apply them with sufficient detail to specific situations; identifying the parts of the general explanation required to answer the particular question
- Whenever you are given the diameter of a circle or sphere, look carefully to decide whether you need to use the radius in the following calculation
- Be sure to know the standard SI prefixes and be able to apply the correct power of ten
- Remember that particles with mass cannot travel at the speed of light and that photons do not have mass
- Remember that physical quantities have a magnitude and a unit and both must be given in answers to numerical questions
- When substituting in an equation with a power term, eg v^2, do not omit the index
- Where you are asked to "determine whether", you must make a clear statement, including any values, when reaching a conclusion

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