Examiners' Report
June 2012

GCE Physics 6PH04 01

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June 2012

Publications Code UA032783

Introduction

Candidates found this paper accessible and 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 shown in the more difficult content of the A2 specification and also in the demands of the questions. Some of the context questions such as Q16 were generally well answered with the candidates scoring well. Candidates need to read the questions carefully and think about the context before launching into their answers. Q15 was about an induction motor which requires a force in order to start moving. Many candidates treated it like a generator and assumed it was moving and cutting the flux which lost them marks. In the main calculations were well done across all ability ranges with the exception of Q13 where many candidates merely looked for a formula that had the terms given in the question, the de Broglie equation, and did not think about the conditions under which that equation could be used. The clue was that the question was worth 5 marks and any calculation scoring 5 or more marks will mean that there are several steps and more than one equation is required. Whenever a question asks for an explanation and numerical values have been given, then the marks will be dependent on a calculation having been done. Candidates need to remember that at A2 some of the questions can have a synoptic element and in this unit that is most likely to be from the AS mechanics. Q11 required the candidates to make a link between acceleration and a force (not often done) and in Q17, the projectile type motion of a charged particle in a magnetic field was required. Q12 required candidates to comment on a prediction and although three marks were obtained from calculations, the last mark was for a comment on the prediction and it was surprising how many candidates did not do this.

Section A

The multiple choice questions in Section A were accessible to candidates of all abilities.

question	topic	% correct	Most common incorrect response
1	nuclear structure	92	B
2	Kinetic energy variation with momentum	73	C
3	inelastic collisions	88	B
4	units	93	C
5	capacitor discharge	60	C
6	use of electrons to probe nucleus	50	D
7	work done on a particle in an electric field	66	D then A
8	comparison of magnetic flux linkage across 2 coils	78	all 3
9	pion decay	67	D
10	tube lengths of Linac	86	A then D

Question 11 (a)

This question required candidates to appreciate that if an object is accelerating, there must be a force acting. Generally most candidates managed to score one mark for the use of repel or repulsive force, however fewer were able to successfully link the force to acceleration. Most responses that did not score the second mark focussed on repulsion/ attraction or just stated that the positive charge caused the acceleration.

11 The positively charged particles in the solar wind are accelerating away from the Sun. Some scientists have therefore concluded that the Sun is positively charged.

(a) Explain this conclusion.

(2)

Iƒ the charged partcles are positive and the sun is positive the charges will repel each other as same charges repel and opposites attract, causing there to be a ƒorce repeling the positivly charged particle.

ResultsPlus

Examiner Comments

This answer focuses on the action between charged objects and does not refer to the acceleration at all.

ResultsPlus

Examiner Tip

Like charges repel and unlike charges attract is just one physics point and is not worth two marks.

The positively charged particles have a force acting on them to be accelerated. as the acceleration is away from the Sun it must be a repulsive force suggesting the Sun is positively charged.

ResultsPlus

Examiner Comments

A model answer with a logical reasoning

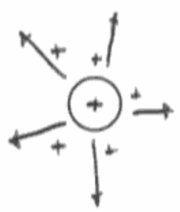
Question 11 (b)

The majority of candidates scored both marks for this section with most marks being lost through poor diagrams. Typical errors are not having straight lines, lines not being equi-spaced, lines not touching the circle or crossing in the middle of the circle. Candidates should be encouraged to draw just the four lines at right angles to each other.

(b) The circle below represents the Sun.

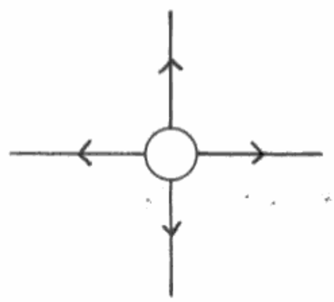
Complete the diagram to show the electric field produced by a positively-charged Sun.

(2)



ResultsPlus
Examiner Comments

This scores one mark only for the correct direction of the field. The other mark is lost for two reasons, the lines are not equi-spaced and they do not touch the circle.

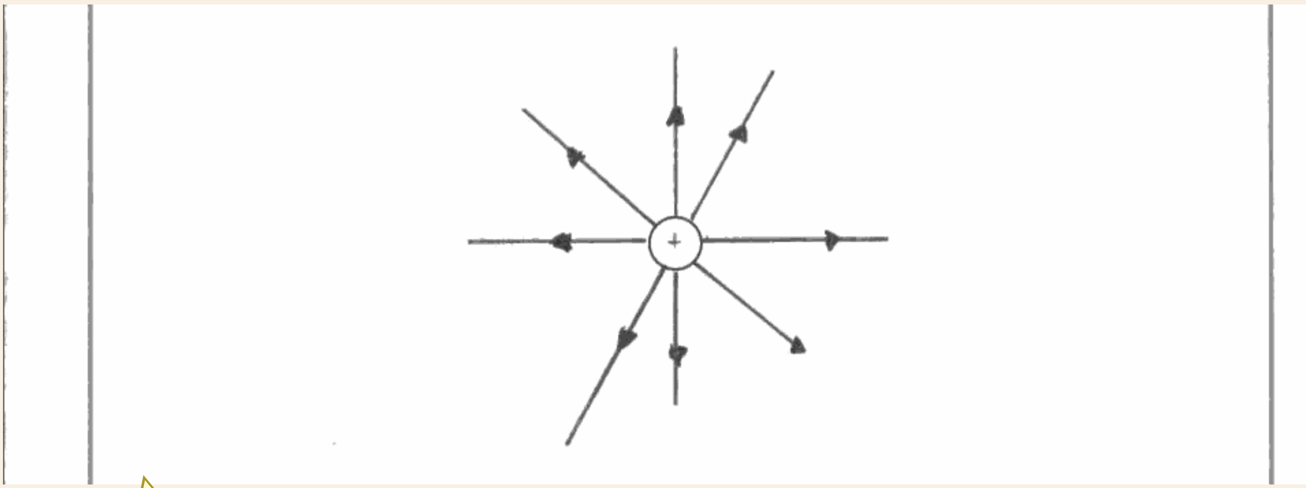


ResultsPlus
Examiner Comments

This scores both marks.

ResultsPlus
Examiner Tip

Four is the minimum number of lines required and can be accurately drawn. Note the use of a rule.



ResultsPlus
Examiner Comments

The lines are not equi-spaced and so a mark is lost.

Question 12

Most candidates recognised that conservation of momentum was the key to the analysis of the movement of the spacecraft with only a very small minority going on completely the wrong track of trying to conserve energy. The most successful candidates found the speed of the spacecraft rather than finding and comparing the momenta. Where candidates went wrong was in not realising that the conservation of momentum could be applied in isolation and they did not have to include the fact that the space craft was moving through space. Other candidates tried to include time which while successful for some did lead others to make mistakes. The question asked candidates to comment on the prediction and quite a significant number of candidates missed out on the last mark by failing to make a comment.

12 A spacecraft called Deep Space 1, mass 486 kg, uses an "ion-drive" engine. This type of engine is designed to be used in deep space.

The following statement appeared in a web site.

> The ion propulsion system on Deep Space 1 expels 0.13 kg of xenon propellant each day. The xenon ions are expelled from the spacecraft at a speed of 30 km s^{-1}. The speed of the spacecraft is predicted to initially increase by about 8 m s^{-1} each day.

Use a calculation to comment on the prediction made in this statement.

(4)

$0{\cdot}13 \times 30 \times 10^3 = 486 \times$ Velocity increase

$3900 = 486 V$

$\frac{3900}{486} = V$

$V = 8{\cdot}02\ \text{ms}^{-1}$

I would say this prediction is correct as momentum in the system is conserved. Therefore the momentum of the xenon ions will be equal to the momentum of the spacecraft. So when momentum is given to the xenon ions it will cause the spacecraft to move in the opposite direction so momentum is conserved.

(Total for Question 12 = 4 marks)

ResultsPlus
Examiner Comments

This was the most common choice of method. This answer scores all four marks. The comment is too long, all that is needed is the first sentence. The rest is a statement and explanation of the conservation of momentum.

ResultsPlus
Examiner Tip

A comment was needed but try to avoid writing overlong answers, as they don't necessarily gain extra marks.

12 A spacecraft called Deep Space 1, mass 486 kg, uses an "ion-drive" engine. This type of engine is designed to be used in deep space.

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Use a calculation to comment on the prediction made in this statement.

(4)

$F = \frac{\Delta p}{t} = ma \qquad a = \frac{\Delta p}{tm} \qquad m = 486$

$p = mv = 0.13 \times 30 \times 10^3 = 3900$ kg m s^{-1}

$F = \frac{\Delta p}{t} = \frac{3900}{t}$

$t = 24 \times 60 \times 60 = 86400$

$F = \frac{\Delta p}{t} \frac{3900}{86400} = 0.045$ N

$F = ma \quad a = \frac{F}{m} = \frac{0.045}{486} = 9.3 \times 10^{-5}$ m/s²

Prediction is incorrect

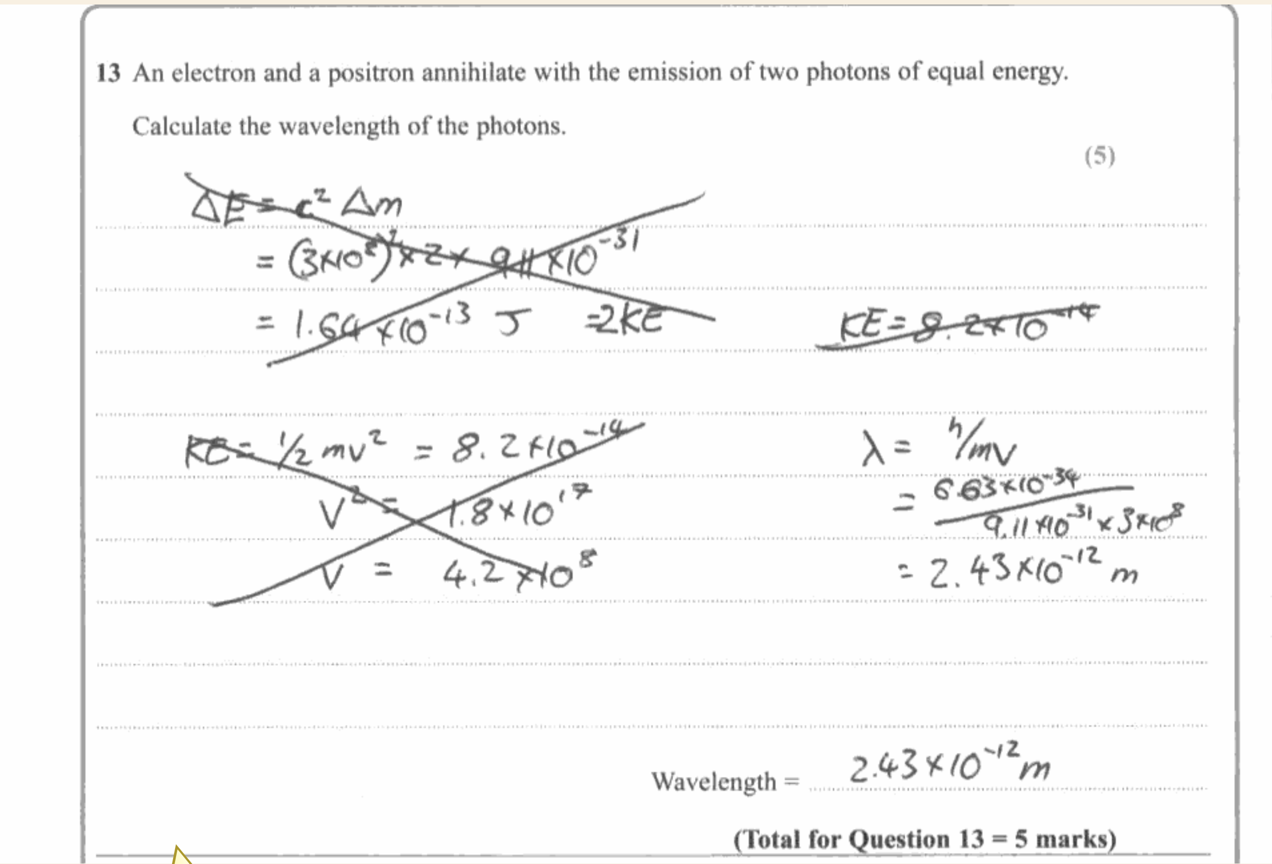
ResultsPlus

Examiner Comments

This candidate realises that momentum is involved but is trying to use force is equal to rate of change of momentum. Correct answers were seen using this method but a more complicated method gives more opportunities for candidates to go wrong.

Question 13

Too many candidates attempted to use the de Broglie wavelength equation without thinking about the situation and realising that it was inappropriate to use this equation. This equation gives the wavelength for a particle with a given momentum i.e. all the terms are properties of a single particle. It cannot be used for the annihilation of two particles and the production of two different particles. Candidates should have realised that 5 marks would not be awarded for a straight forward substitution into a single equation. Many candidates using this approach managed to score one or two marks at most. Some candidates used the mass of a proton as the mass of a positron. Candidates who did approach the question correctly usually went on to score 4 or the full 5 marks. There was some confusion over the factors of two so that a common wrong answer was half of the correct answer although we also saw double and quadruple answers.



13 An electron and a positron annihilate with the emission of two photons of equal energy.

Calculate the wavelength of the photons.

(5)

~~$\Delta E = c^2 \Delta m$~~

~~$= (3\times10^8)^2 \times 2 \times 9.11\times10^{-31}$~~

~~$= 1.64\times10^{-13}$ J $= 2KE$~~

~~$KE = 8.2\times10^{-14}$~~

~~$KE = \frac{1}{2}mv^2 = 8.2\times10^{-14}$~~

~~$v^2 = 1.8\times10^{17}$~~

~~$v = 4.2\times10^{8}$~~

$\lambda = h/mv$

$= \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times3\times10^8}$

$= 2.43\times10^{-12}$ m

Wavelength = 2.43×10^{-12} m

(Total for Question 13 = 5 marks)

ResultsPlus
Examiner Comments

An example of using the de Broglie formula.

ResultsPlus
Examiner Tip

The de Broglie formula applies to a single particle. Also this question has 5 marks. A substitution into an equation with no unit changes would have been worth 2 marks only.

$$E = \frac{hc}{\lambda}$$

$$E = mc^2$$

$$E = 2(9.11\times10^{-31}) \times (3\times10^{8})^2$$

$$= 1.6398\times10^{49}\ J$$

$$\lambda = \frac{hc}{1.6398\times10^{49}\ J}$$

$$= \frac{(6.63\times10^{-34}) \times (3\times10^{8})}{1.6\times10^{49}\ J}$$

$$= 1.21295\times10^{-74}$$

$$\lambda = h/p$$

$$\lambda = h/p_1+p_2$$

$$\lambda =$$

Wavelength = 1.2×10^{-74} m

(Total for Question 13 = 5 marks)

ResultsPlus
Examiner Comments

A correct method but the candidate has x2 in the energy calculation but forgets that this energy is used to produce two photons.

Although the de Broglie formula has been written down, the candidate does not use it and so we can ignore it.

ResultsPlus
Examiner Tip

Think before starting the calculation. You are finding the energy from two particles of the same mass and then dividing it equally between two photons. The calculation can be done without the use of the 2 factor.

Question 14

The reference to the bubble chamber in the stem of this question was intended to direct candidates to detectors and away from accelerators. The question was intended as a general question about any detector and was not meant to be specifically about bubble chambers. It is accepted that the question did cause some confusion and so the mark scheme was adjusted to allow four of the marks to be awarded from just a discussion of magnetic fields. The most common score for this question was two, one for identifying that electric fields accelerate the particles and one for magnetic fields being used to cause circular motion. Too many candidates spent too much time explaining about the orientation of the magnetic field, quoting Fleming's left hand rule and giving far too much detail about the set up rather than the actual role of the fields. Although a lot of responses hinted at being able to find out information about charge, mass etc., very few actually described what feature of the path would be measured/observed in order to calculate these values.

***14** A bubble chamber is a particle detector which makes use of electric and magnetic fields.

Explain the role of electric and magnetic fields in a particle detector.

(5)

The electric field in a particle detector creates an area with a uniform electric field (field strength is constant) so that a particle experiences a force. Negatively charged particles travel to the positive plate and ~~negatively~~ positively charged particles travel to the negative plate (able to determine the charge of a particle). Neutral particles leave no tracks. The magnetic ~~field~~ field creates a force that acts pependicular to the direction of current and field lines, which causes circular motion of the particles. Able to determine the mass of a particle from the size of its curvature path.

(Total for Question 14 = 5 marks)

ResultsPlus
Examiner Comments

This scores 3 marks. It correctly identifies that charge in the electric field is determined by the direction of deflection, that the magnetic field causes circular motion and that the curvature can be used to find the mass. No marks were awarded for the three and a half lines of the answer.

ResultsPlus
Examiner Tip

Explaining what is meant by a uniform field does not answer the question about the role of the fields in a detector.

Electric fields provide a force on charged particles which causes them to accelerate, where $F = \frac{E}{q}$.

Magnetic fields curve the path of charged particles produced in a collision. From the direction of the curve the sign of their charge can be determined. Also from the radius of their path their momentum can be determined from $r = \frac{p}{BQ}$. ~~Th~~ For the particles to have a curved path they must move at an angle θ to the magnetic field, ~~so that they make an angle θ with the field lines,~~ and

(Total for Question 14 = 5 marks)

here $F = Bqv\sin\theta$, where F is the force exerted on them. This force is a result of Fleming's Left Hand Rule, where a force is exerted on a moving charge in a magnetic field.

ResultsPlus

Examiner Comments

This scores 4 marks. Just saying that magnetic fields curve the path is not sufficient since electric fields can also curve a path. If this candidate had referred to circular motion or a centripetal force, this answer would have scored 5 marks.

The electric fields accelerate the particles up to high speeds by giving them energy ready for collisions with other particles.

Magnetic fields keep particles in a circular orbit by ~~given~~ giving them an acceleration, centrapetial acceleration which acts ~~the~~ to the centre of the circle.

ResultsPlus
Examiner Comments

This answer reflects the most common mark, scoring one mark for the electric field accelerating the particles and one for the circular motion for the magnetic fields.

ResultsPlus
Examiner Tip

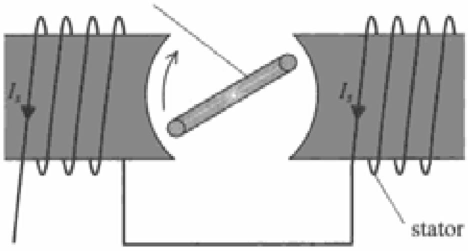
Five marks require 5 different physics points.

Question 15 (a) (i)

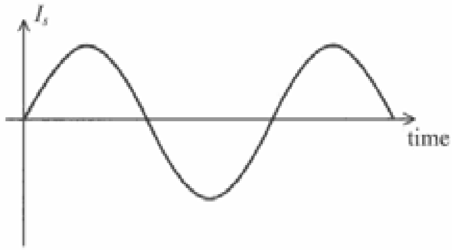
The induction motor is an example of a good context because it is something that candidates were not expected to have been taught but they should readily have been able to grasp the physics. Most candidates scored at least two marks. The common error was to think of this as a generator and not a motor. Candidates were required to recognise that the stator produces a magnetic field which is changing and that the field passes through the rotor coil inducing an e.m.f in the rotor. What happened was that many candidates described the situation in terms of the rotor cutting the magnetic field.

15 The diagram represents a simple induction motor. An alternating current I_s is supplied to a stationary coil (stator). This coil is wrapped around an iron core.

A rotating coil (rotor) is shown end on in the diagram.



(a) The graph shows the variation of the alternating current I_s with time.



*(i) Explain how current is induced in the rotor coil.

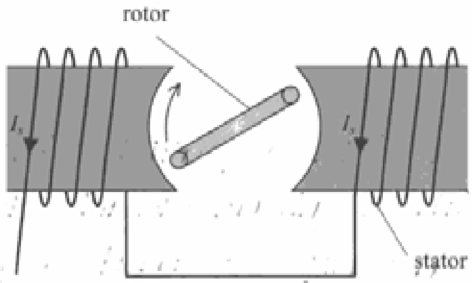
(4)

The alternating current (I_s) in the stationary coil produces an alternating (changing) magnetic field. As a result, the rotor is in a zone of changing magnetic flux (it experiences a change in magnetic flux), so an e.m.f. is induced across the rotor coil. This emf causes a current to flow in the coil (the induced current). The current is alternating because the magnetic field and thus the induced emf are alternating.

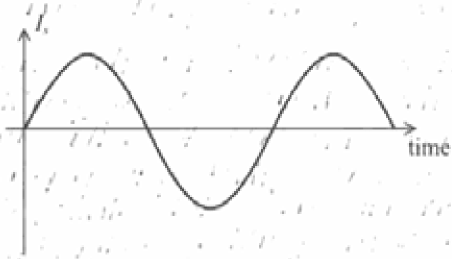
ResultsPlus

Examiner Comments

A rare example that scores four marks.



(a) The graph shows the variation of the alternating current I_s with time.



*(i) Explain how current is induced in the rotor coil.

(4)

A current is induced because the stationary coil wrapped around the iron core has a magnetic field. An emf is induced when the rotor (the conductor) moves through the magnetic field of the iron core wrapped in a coil. This is because the rotor cuts through the lines of flux, of the coil wrapped around the iron core, causing an emf to be induced. A current is then induced, if the wire is connected in a circuit with a p.d. .

ResultsPlus
Examiner Comments

A common type of answer where the candidate thinks that the e.m.f is induced by the rotor cutting the magnetic field rather than because it is in a changing magnetic field.

ResultsPlus
Examiner Tip

This question was about a motor and something has to happen to make it start moving. It is important to think about the situation and not rush into writing down your first thoughts. Many candidates treated this as a generator where the coil is initially made to rotate and so talking about the coil moving through the magnetic field is correct.

Question 15 (a) (ii)

The rotor then moves because there is a current in the rotor and it is in a magnetic field and so experiences a force. Candidates who had treated this as a generator struggled with this part because they invariably went down the wrong route of trying to apply Lenz's Law. Candidates who did think about what was causing the force often gave too vague an answer. There are two coils in this motor both of which have a current and so candidates needed to make it clear that they were talking about the rotor.

(ii) Explain why the rotor turns.

(2)

~~As ther~~ Due to Flemhings left hand rule, The force applied is perpendicular to the direction of the current. Magnetic filld into the Page. ~~therefore force~~

ResultsPlus

Examiner Comments

There are two conductors both in a magnetic field and so the candidate needed to make it clear that it was the current in the rotor, in a magnetic field that led to the force. This scored 1 mark.

Question 15 (a) (iii)

This question was generally well answered.

(iii) State **two** ways of making the rotor turn faster.

(2)

1 Increase the number of ~~co~~ stator coils.

2 Use a bigger current in the stator.

ResultsPlus

Examiner Comments

The majority of candidates scored 2 marks for an answer similar to this one.

Question 15 (b)

Another generally well answered part with more than half of candidates scoring the full 5 marks for a couple of straightforward calculations. Mistakes were made in converting the frequency in hertz to a time period or in using the wrong units for angular velocity. There was a unit conversion needed in the last part of this question which did cause a problem for a few candidates. The other challenge was having quoted the correct equation a = rω2 a number of candidates then forgot to square the ω thus losing two marks.

(b) An induction motor is used to rotate the turntable in a record deck. Long-play records require the turntable to rotate at 33 revolutions per minute.

(i) Calculate the angular velocity of the turntable.

(3)

33 revolutions $= 33 \times 2\pi = 66\pi$

$\omega = \frac{\theta}{t}$ ∴ $\omega = \frac{66\pi}{60} = \frac{11}{10}\pi = 3.46$ rads^{-1}

Angular velocity = 3.46 rads^{-1}

(ii) Calculate the acceleration of a speck of dust at the outside edge of a rotating record.

radius of record = 12.5 cm

(2)

$a = r\omega^2$

∴ $a = 12.5 \times (3.46)^2 = $ ~~178.2 ms^{-2}~~

$= 149.3$ ms^{-2}

Acceleration = ~~178.2 ms^{-2}~~ 149.3 ms^{-2}

(Total for Question 15 = 13 marks)

ResultsPlus

Examiner Comments

This candidate scores 3 marks for (i) but in (ii) forgets to convert cm to m and loses a mark.

ResultsPlus

Examiner Tip

Watch out for units in case there is a unit change to make in a calculation and also make sure you add a unit to any quantity that you have calculated.

(b) An induction motor is used to rotate the turntable in a record deck. Long-play records require the turntable to rotate at 33 revolutions per minute.

(i) Calculate the angular velocity of the turntable.

(3)

33 revolutions per 60 seconds

0.55 revolutions per second.

1 revolution = 2π radians

Angular velocity = 11.4 rad s⁻¹

Angular velocity = 11.4 rad s^{-1}

(> 5J)

(ii) Calculate the acceleration of a speck of dust at the outside edge of a rotating record.

radius of record = 12.5 cm

(2)

$a = r\omega^2$

$= 0.125 \times (11.4)^2$

= [illegible]

= 16.3

Acceleration = 16.3 m s^{-2}

ResultsPlus
Examiner Comments

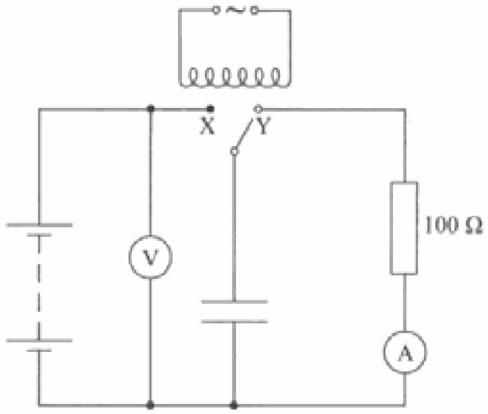
A common wrong answer, dividing 2π by 0.55 instead of multiplying. Error carried forward was applied to (ii) so this candidate scored 1 for (i) and 2 for (ii).

Question 16 (a) (i)

Question 16 as a whole was a well answered question with many candidates scoring more than 10 marks.

The most likely place where they would have lost a mark was in (a)(i). A quarter of candidates scored zero for this part because they made no attempt at any calculations. Students still need reminding that any explanation in a physics paper needs to be as quantitative as the question permits. A significant number of candidates did score 2 marks for calculating the time constant and the time period of the switch frequency. The third mark was for appreciating the significance that the capacitor had to discharge fully i.e. that one time constant wasn't enough. This mark was often most awarded to candidates who identified a discharge time equal to nRC where most chose a value of 5 for n. A large number of candidates merely commented that one time was smaller than the other rather than qualifying it as much /significantly smaller.

16 A student is investigating capacitors. She uses the circuit below to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of ±30%.



The switch flicks between contacts, X and Y, so that the capacitor charges and discharges *f* times per second.

(a) The capacitor must discharge fully through the 100 Ω resistor.

(i) Explain why 400 Hz is a suitable value for *f*.

(3)

$T = RC = 100 \times 2.2\times10^{-6} = 2.2\times10^{-4}$ s

∴ To fully discharge $= 5RC = 5 \times 2.2\times10^{-4}$
$= 1.1\times10^{-3}$ s

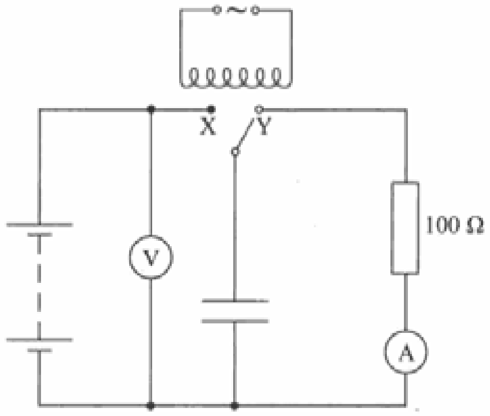
~~$\therefore f = \frac{1}{T} = \frac{1}{1.1\times10^{-3}} = 909.1$ Hz~~

Time take for $f = \frac{1}{400} = 2.5\times10^{-3}$ s ∴ it is longer than the time taken to discharge fully, so it is suitable.

ResultsPlus
Examiner Comments

A 3 mark answer that addresses the fact that the capacitor does not fully discharge in a time constant.

16 A student is investigating capacitors. She uses the circuit below to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of ±30%.



The switch flicks between contacts, X and Y, so that the capacitor charges and discharges f times per second.

(a) The capacitor must discharge fully through the 100 Ω resistor.

(i) Explain why 400 Hz is a suitable value for f.

(3)

$2.2\mu F$ $\quad Q = Q_0 e^{-t/RC}$.

$RC = 100 \times 2.2\times10^{-6} = 2.2\times10^{-4}$ s.

$(2.2\times10^{-6} + 2.2\times10^{-6} \times 30\%) = 2.86\times10^{-6}$ F.

$\therefore RC = 100 \times 2.86\times10^{-6} = 2.86\times10^{-4}$ s.

$f = 400$ Hz. $T = \frac{1}{f} = \frac{1}{400} = 2.5\times10^{-3}$.

ResultsPlus

Examiner Comments

The most common mark for this section was 2. This candidate has used the +30% value of capacitance which does not gain credit and has just found the time constant and the time period.

ResultsPlus

Examiner Tip

Remember that if numerical values are given, they should be used to inform your explanation. Calculations are expected.

Question 16 (a) (ii)

Candidates must realise that when they are asked to show that an equation is correct, they must explain clearly all of the steps that they are taking and not leave it to the examiner to work out. To score three marks the examiners needed to see C=QV Q = It and t = 1/f as clear distinct statements. More than half of candidates did score the full three marks but many got to C = It/V and then just wrote down the equation as given in the paper without justifying it by saying t = 1/f.

(ii) Show that the capacitance C can be given by

$$C = \frac{I}{fV}$$

where I is the reading on the ammeter and V is the reading on the voltmeter.

(3)

$C = \frac{Q}{V} = \frac{It}{V} = \frac{I}{fV}$ $\quad Q = It$

$f = \frac{1}{t}$

ResultsPlus
Examiner Comments

This scores 3 marks because the candidate has written the two relevant equations on the right hand side.

ResultsPlus
Examiner Tip

When you are given an equation and are asked to show that it is correct, make sure that you write down clearly all of the equations you are using. Make it clear or marks might not be awarded.

Question 16 (a) (iii)

As was expected a significant number of the candidates scored both of the marks for this calculation. For those that did not, the challenge was in realising that the frequency to be used was on the previous page or that the formula to be used was in the previous part of the question.

(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

$$C = \frac{5.4 \times 10^3}{5 \times 400} = 2.7\ F$$

$C =$ 2.7 Farads.

ResultsPlus
Examiner Comments

This is an example of a candidate not scoring two marks due to misunderstanding of mA.

ResultsPlus
Examiner Tip

Suffixes should be learnt.

(2)

$$\frac{5.4 \times 10^{-3}}{400 \times 5} = 2.7 \times 10^{-6}$$

$c =$ 2.7×10^{-6}

ResultsPlus
Examiner Comments

A mark is lost for missing unit.

ResultsPlus
Examiner Tip

Remember to add a unit to all calculations.

Question 16 (a) (iv-b)

Q16(a)(iv) was another example of where a calculation was needed to support the explanation and this was in fact what nearly all of the students did. The majority of candidates worked out the maximum value of capacitance and showed that this was more than their calculated value in (iii). Others found the % difference and compared it to the 30% and nearly all candidates did make a comment regarding the consistency of the tolerance. As with Q15(b) a number of candidates write the correct equation E = 1/2 CV2 and then fail to square their V thus losing both marks.

(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

$C = \frac{5.4 \times 10^{-3}}{5 \times 400}$

$= 2.7 \times 10^{-6}$

$C = 2.7 \times 10^{-6}$ F

(iv) Explain whether you think this value is consistent with the tolerance given for this capacitor.

(2)

yes it is tolerant as ±30% would range the capacitance between 1.54 μF and 2.86μF ~~which~~ And our calculated capacitance is 2.7μF which is within that range.

(b) Calculate the energy stored on the capacitor when it is charged to a potential difference of 5.0 V.

(2)

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

$= \frac{1}{2} I t V^2$

$= \frac{1}{2} \times 5.4 \times 10^{-3} \times \frac{1}{400} \times 5^2$

$= 1.6875 \times 10^{-4}$

Energy = 1.7×10^{-4} J.

ResultsPlus
Examiner Comments

This scores both marks for (iii) but for (b) tries to use the formula that is on the formula sheet and cannot convert to a useful one.

ResultsPlus
Examiner Tip

Energy in a capacitor can be expressed in three differnt ways so practice substituting from C =Q/V into the energy equation.

(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

$C = \left(5.4 \times 10^{-3} / 400 \times 5 \right) = 2.7 \times 10^{-6}$ F

C = 2.7×10^{-6} F

(iv) Explain whether you think this value is consistent with the tolerance given for this capacitor.

(2)

the capacitor has capacitance 2.2μF = 2.2×10^{-6} F

$2.7 \times 10^{-6} > 2.2 \times 10^{-6}$, thus, the calculated value is inconsistent, the capacitor is not sufficient to hold that amount of charge or voltage. Or it can be inferred that label on the capacitor is wrong!

(b) Calculate the energy stored on the capacitor when it is charged to a potential difference of 5.0 V.

(2)

~~W=~~ $W = \frac{1}{2} CV^2 = \frac{1}{2} \times (2.7 \mu F) \times (5)^2$

= ~~2.25×10⁻⁵ J~~

= ~~3.4×10~~ $= 3.375 \times 10^{-5}$ J

Energy = 3.4×10^{-5} J

$C = Q/V$ $Q = It$

$= \frac{It}{V}$ $t = 1/f$

$\frac{I}{Vf}$

ResultsPlus

Examiner Comments

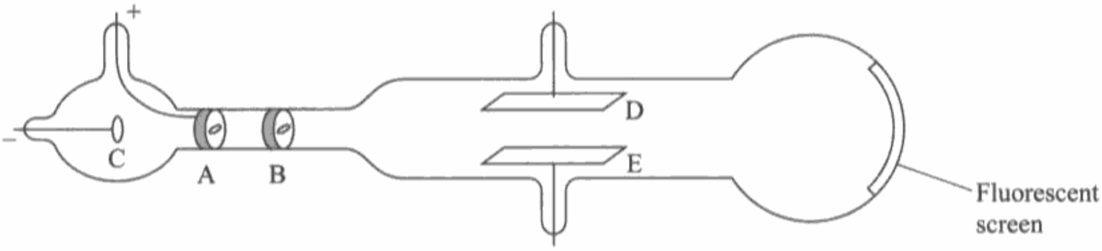
This candidate probably doesn't understand what is meant by tolerance. Since the stem of the question does refer to tolerance, as a reminder to turn back to the start of the question where the value was given.

Question 17 (a)

If candidates recognised this as an example of thermionic emission they generally scored both marks. Unfortunately quite a few saw the words metal disc and immediately wrote about the photoelectric effect.

17 J J Thomson is credited with the discovery of the electron. He measured the 'charge to mass ratio' *e/m* for the electron, using the apparatus shown.

electron beam



A metal disc at C emits electrons. A positively-charged disc at A accelerates the electrons along the tube. Slits in A and B produce a narrow horizontal beam of electrons. An electric field is produced between plates D and E, which can be used to deflect the beam vertically. The final position of the beam is shown on a fluorescent screen at the end of the tube.

(a) Describe how a metal disc can be made to emit electrons.

(2)

If you heat a metal disc ~~enough~~ then you are giving free electrons within the metal energy. If you heat them enough then they will gain enough energy to leave the metal disc by thermionic emission.

ResultsPlus
Examiner Comments

The majority of candidates scored both marks for answers similar to this one.

Question 17 (b)

The justification of the equation given was considerably more difficult than the one in Q16 and this was reflected in the candidates ' performance where many scored no marks. This and subsequent parts provided discrimination at the top of the ability range but left weaker candidates scoring very low marks. Again, candidates need to realise that they must set out clearly the steps they are going through. Candidates need to realise that they were dealing with motion in two directions with time as a link, similar to projectiles. This lack of appreciation of the projectile type path led to a whole range of messy and confused algebra leading to a fudged result. It is an understanding of how this equation is derived that is required later in the question in (e)(ii).

(b) The length of plates D and E is l. Thomson deduced that the vertical component v_v of velocity gained by the electrons as they leave the plates is given by

$$v_v = \frac{Ee}{m} \times \frac{l}{v}$$

where E is the electric field strength between the plates and v is the velocity with which the electrons entered the field.

Show that this expression is correct.

(3)

$F = Eq$ and $a = \frac{F}{m}$, so $a = \frac{Eq}{m}$

q for an electron is e, so $a = \frac{Ee}{m}$

$v = u + at$, and time in between the plates $= \frac{l}{v}$

initial vertical velocity, $u = 0$, so $v_v = a \times \frac{l}{v}$

$\therefore \; v_v = \frac{Ee}{m} \times \frac{l}{v}$

ResultsPlus

Examiner Comments

This candidate has started sensibly with F = Eq and A= F/m and so arrives at the first part of the equation. Then applies an equation of motion but importantly realises that the time comes from the horizontal motion and clearly states t = l/v. This scores 3 marks and is an example of an excellent, well laid out answer.

(3)

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

$F = ma \Rightarrow \frac{F}{m} = a$

$(ms^{-1}) = \frac{(NC^{-1})(C)}{m(kg)} \times \frac{m}{m(s^{-1})} \Rightarrow \frac{(m)}{(s)} = \frac{(N)(C)}{(kg)(C)} \times \frac{m(s)}{m}$

$\frac{(m)}{(s)} = \frac{(N)}{(kg)} \times (s)$ $\quad F = ma \Rightarrow (N) = (kg)(m)(s^{-2})$

$\Rightarrow \frac{(m)}{(s)} = \frac{(kg)(m)(s)}{(kg)(s^2)} \Rightarrow \frac{(m)}{(s)} = \frac{(m)}{(s)}$

(c) Thomson determined the angle θ at which the beam was deflected

ResultsPlus

Examiner Comments

This candidate doesn't even substitute for F = EQ into F=ma and clearly has not made the link between horizontal and vertical motion. Showing that the equation is dimensionally correct is not sufficient.

ResultsPlus

Examiner Tip

Remember that an electron moving into an electric field at right angles to its velocity is an example of a projectile type question.

Question 17 (c)

The angle cannot be measured directly but Thomson needed it for his calculations and it was found by using the trigonometric function tan with two lengths that could be measured. The majority of candidates thought that it was somehow calculated from a variety of equations and even when they realised it was to do with measuring two lengths, the descriptions were poor so they often only scored one mark and this was for the sue of tan θ.

(c) Thomson determined the angle θ at which the beam was deflected.

Suggest how this angle could be determined.

(3)

Measure the distance (d_1) from the ~~P~~plates D and E to the center of the flurescent sreen measure ~~for dist~~ distance (d_2) from the center of the flurescent sceen to where the electron landed and use ~~pythagron~~ pythgaros theorm to work out θ $\left(\tan\theta = \frac{d_2}{d_1}\right)$

ResultsPlus
Examiner Comments

A good example that scores all three marks.

(3)

using $F = Bqv \sin\theta$ and reargeing it to $\sin^{-1}\left(\frac{F}{Bqv}\right) = \theta$ the angle is found

The velocity can be found in x and y (i and j) componat form and the angle can be worked out using pythagroces. V_V is known from the equation and V_H is close to the speed of light.

ResultsPlus
Examiner Comments

A lot of the candidates wanted to calculate the angle from a formula which did not get any credit. This candidate goes on to use velocities but just saying 'using pythagorus' is not sufficient detail. Similarly, just saying 'use trigonometry' is not sufficient.

Question 17 (d)

To score the marks candidates again needed to set out clear unambiguous steps. Comparison of the two equations showed clearly that the first had been divided by v. In order to score any marks candidates needed to establish that tan θ = vertical velocity/ horizontal velocity.

(d) The angle θ is also given by

$$\tan\theta = \frac{Ee}{m} \times \frac{l}{v^2}$$

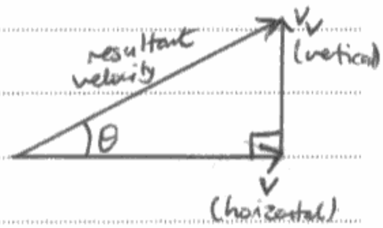
Show that this equation is correct.

(2)

$\tan\theta = \frac{v_v}{v}$ (see diagram)

$= \dfrac{\left(\frac{Ee}{m} \times \frac{l}{v}\right)}{v} = \frac{Ee}{m} \times \frac{l}{v} \times \frac{1}{v}$

$= \frac{Ee}{m} \times \frac{l}{v^2}$



ResultsPlus
Examiner Comments

A clear answer, with tan θ = v_v/v clearly identified as is the divison by v so this scored 2 marks.

Question 17 (e) (i)

More than half of candidates scored this mark. The examiners were looking for the idea that the electric force that provided the vertical acceleration could be replace by a different force, in this case a magnetic force. Quite a number of candidates said that the electric field had been replaced by a magnetic field which missed the idea of the use of force that the fields provide.

(e) Thomson replaced the electric field with a uniform magnetic field which acted over the same length as the plates. He adjusted the flux density B to obtain the same deflection on the screen.

For this arrangement he assumed that the vertical component of velocity gained by the electrons as they leave the plates is given by

$$v_v = \frac{Bev}{m} \times \frac{l}{v}$$

(i) Thomson just replaced the term eE in the equation in part (b) with Bev.

Suggest why he did this.

(1)

As eE is equal to the force for electric fields, and for magnetic fields F = Bev, they can be replaced without changing the rest of the equation.

ResultsPlus
Examiner Comments

Quite a wordy answer but this candidate has clearly understood that one force is being replaced with another force, so that the equation is dimensionally correct.

(e) Thomson replaced the electric field with a uniform magnetic field which acted over the same length as the plates. He adjusted the flux density B to obtain the same deflection on the screen.

For this arrangement he assumed that the vertical component of velocity gained by the electrons as they leave the plates is given by

$$v_v = \frac{Bev}{m} \times \frac{l}{v}$$

(i) Thomson just replaced the term eE in the equation in part (b) with Bev.

Suggest why he did this.

(1)

A uniform electric field has the same force throughout the field.

ResultsPlus
Examiner Comments

This is just a definition of a uniform field and does not answer the question.

ResultsPlus
Examiner Tip

For this question, you need to remember how the equation was derived.

Question 17 (e) (ii)

To answer this part candidates had to think again about how the equation had been derived. Very few candidates scored both marks and only a small number scored 1 mark, usually for identifying that the magnetic force would give a different path. They were unable to think of the consequence of this when the equation was derived i.e. that the horizontal velocity would not remain constant so that t = l/v was no longer applicable.

(ii) Give **two** reasons why the equation $v_v = \frac{Bev}{m} \times \frac{l}{v}$ is **not** correct.

(2)

1 because if B is perpendicular to the current it will produce a motion of the electrons in a circular path.

2 Because the velocities cancel each other out? so the units wouldn't be homogenous.

(Total for Question 17 = 13 marks)

ResultsPlus

Examiner Comments

A typical answer from a candidate who scored 1 mark which was for identifying that the B field would produce circular motion.

Question 18 (a)

Overall candidates scored better on question18 than they did on question 17 with the weaker candidates being able to score quite a few of the marks whilst the question still provided discrimination across the ability range.In (a) we were looking for the idea of symmetry in the standard quark-lepton model. We were happy to accept the idea that the quarks come in pairs e.g. up and down, charm and strange etc. but it would seem that many candidates could be confused by thinking that pairs mean quark and antiquark.

18 (a) Physicists were able to confidently predict the existence of a sixth quark. State why.

(1)

As it would make it symmetrical, e.g. top + bottom, up + down, strange and charm.

ResultsPlus
Examiner Comments

A very full answer, just the reference to symmetry was sufficient.

(1)

As the standard model has a strong pattern of symmetry to it, so there would be a sixth quark paired to the fifth.

ResultsPlus
Examiner Comments

Another good answer

ResultsPlus
Examiner Tip

You need to be clear that quarks come in pairs i.e. up and down, strange and charm, bottom and top. As well as these 2 quarks there are 6 antiquarks so an up quark can be thought of as a pair with the up antiquark. Care is needed in particle physics when talking about pairs.

Question 18 (b) (i)

Similar questions have appeared on previous papers and we will accept the idea that a particle and its antiparticle have opposite charges. Ideally it should be charge of the same magnitude but with the opposite sign. It seems to be accepted that the phrase 'opposite charges' is sufficient. We also accepted the charge on the proton is +1 and on the antiproton -1. However that is not true of 'different charges' or 'one is positive and one is negative'. The majority of the candidates did score both marks but this is a definition that all candidates could learn.

(b) The mass of the top quark was determined by an experiment. Collisions between protons and anti-protons occasionally produce two top quarks.

(i) How do the properties of a proton and an anti-proton compare? **(2)**

Mass etc.

They have all the same properties except the charge which will be different.

ResultsPlus
Examiner Comments

Mass is the only property that is the same. It is not enough to say that the charges will be different.

ResultsPlus
Examiner Tip

The statement: A particle and its antiparticle have the same mass but opposite charges, should be learnt.

(2)

proton has +1 charge anti proton has -1 and they are opposite in every way

ResultsPlus
Examiner Comments

One mark for the charges being +1 and -1 but no mention of mass.

(b) The mass of the top quark was determined by an experiment. Collisions between protons and anti-protons occasionally produce two top quarks.

(i) How do the properties of a proton and an anti-proton compare?

(2)

a proton consists of an uud sequence of quarks when an antiproton consis of $\bar{u}\bar{u}\bar{d}$ so they have an opposite charge

ResultsPlus

Examiner Comments

Giving the quark composition is not comparing the properties of the particles.

Question 18 (b) (ii)

Particle collisions is an example of conservation of momentum and candidates need to understand that this underpins all collisions. One mark was available just for stating that momentum had to be conserved but a significant number of candidates tried to answer in terms of conservation of energy or like charges repelling. Most candidates who did realise that momentum had to be conserved failed to make the comment that the initial momentum was zero.

(ii) After the collision the two top quarks move in opposite directions with the same speed.

Explain why.

(2)

Because Energy is conserved between the annihilation of the proton and anti-proton causing the same speed and the opposite directions is a result of opposing charges.

ResultsPlus
Examiner Comments

This response scores 1 mark.

ResultsPlus
Examiner Tip

The conservation of momentum is the starting point for all collisions.

Conservation of momentum.

Zero overall momentum to begin with, so to conserve momentum they move at equal speed but with opposite direction.

ResultsPlus
Examiner Comments

An example of an answer that score both marks.

top quarks have like charges so they repel.
They move at same speed because momentum is conserved.

ResultsPlus

Examiner Comments

A significant number of candidates thought that charges repelling was significant. The most common mark awarded for this section was 1 for at least recognising that momentum is conserved.

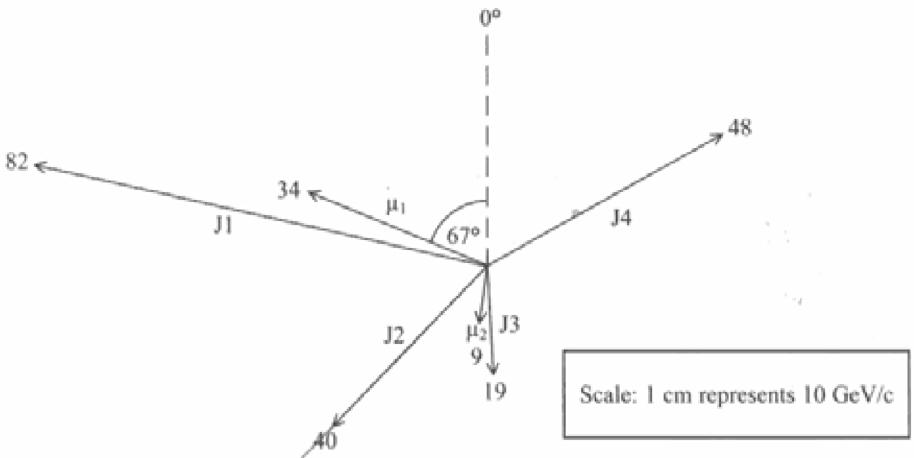
Question 18 (c) (i)

The specification requires candidates to use and convert between the non SI units used in particle physics. Candidates needed to start with either a statement that mass is measured in GeV/c2 or energy is measured in GeV and them use a momentum equation to arrive at the unit of momentum.

(c) The two top quarks decay rapidly into two muons and four jets of particles. These can be detected and their momenta measured.

The diagram shows an end-on view of the directions of the four jets (J1 to J4) of particles. The two muons are shown as μ_1 and μ_2. A muon neutrino is also produced but cannot be detected, so is **not** shown. Each momentum is measured in GeV/c.

The magnitude of the momentum for each particle or 'jet' is shown by the number printed at the end of each arrow.



(i) Explain why GeV/c is a valid unit for momentum. (2)

because $e=mc^2$ GeV is a unit of energy and c is speed so $p=mv$ $e=c \times mv$ so $\frac{e}{c}=mv$ so $\frac{GeV}{c}$ = momentum

ResultsPlus
Examiner Comments

Not many candidates scored this mark but this is an example of what was expected. This one starts with a statement that GeV is a unit of energy and then works through momentum and energy equations to justify the unit. It was perhaps easier to start with mass being measured in GeV/c^2 and using p =mv.

ResultsPlus
Examiner Tip

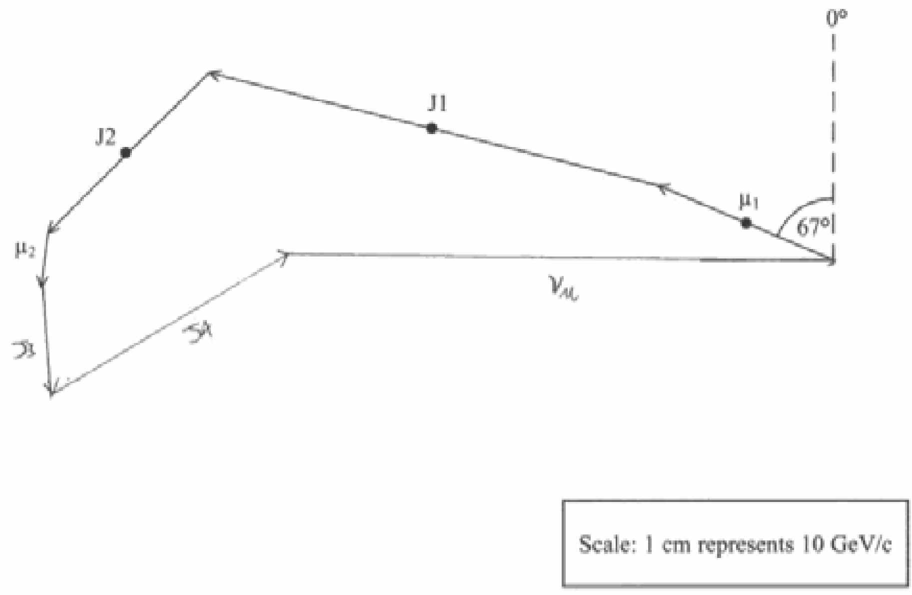
It is essential in particle physics that you know that the if the rest mass of a particle is 100 GeV/c^2, its energy is 100 GeV and its momentum is 100 GeV/c.

Question 18 (c) (ii-vi)

Q18(c)(ii) It was pleasing to see how many candidates knew that a closed polygon of vectors was required. Strictly speaking arrow heads should have been drawn on the vectors but this time we did not penalise candidates if they were missing. There were, not unexpectedly, some candidates who did not realise that the last neutrino's momentum was required to close the polygon. More care could have been taken by some candidates to draw the vectors accurately and where this was poorly done their answer to part (iii) was usually out of the accepted range. Q18(c)(iv) This was generally well answered with most candidates adding the seven vectors although some candidates added six vectors, randomly omitting one of the medium ones because this gave an answer very close to 300. Q18(c)(v) A lack of understanding of the equivalence of the particle units meant that very few candidates scored this mark. They often divided the 300 GeV by two, which is all they had to do, and then proceeded to divide by c2. Q18(c)(vi) Another example of where the specification is poorly understood by many candidates. Not many candidates seemed to realise that the top quark is massive in particle terms and that the difficulty in finding it was to do with the high energies required. Consequently many told us that the difficulty in finding it was due to its mass being so small.

(ii) The vector diagram shown below is **not** complete. Add to the diagram arrows to represent the momenta of J3 and J4.

(2)



(iii) Complete the diagram to determine the magnitude of the momentum of the muon neutrino.

(1)

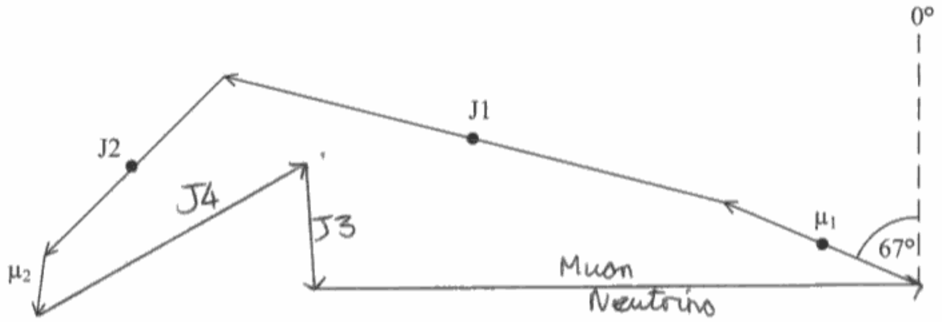
Momentum = 98 GeV/c.

ResultsPlus
Examiner Comments

A good example of what was expected for (ii) and (iii) with vectors drawn accurately and the candidate understanding the concept of the closed polygon.

(ii) The vector diagram shown below is **not** complete. Add to the diagram arrows to represent the momenta of J3 and J4.

(2)



Scale: 1 cm represents 10 GeV/c

(iii) Complete the diagram to determine the magnitude of the momentum of the muon neutrino.

(1)

Momentum = 97 GeV/c.

(iv) Show that the total energy of all the products of this event is about 300 GeV.

(1)

Muon J3 J4 μ2 Muon

97+20+48+10 97+34+82+40+9+19+48 = 329 GeV

329 GeV total energy

(v) Deduce the mass of a top quark in GeV/c^2.

(1)

329 GeV = mc^2 $m = 3.656 \times 10^{-15} \frac{GeV}{c^2}$

(vi) Suggest why it took a long time to find experimental evidence for the top quark.

(2)

This is quite a small mass, therefore it will have been more difficult to detect. Also as it decays into a neutrino, it appears to lose energy and could be thought of as an anomaly.

(Total for Question 18 = 14 marks)

ResultsPlus
Examiner Comments

An alternative way of scoring the three marks for (ii) and (iii) which is reversing the order of J3 and J4.

(iv) Show that the total energy of all the products of this event is about 300 GeV.
(1)

Total momentum vectors = 31.9 cm

31.9 cm × 10 GeV cm⁻¹ = 319 GeV

(v) Deduce the mass of a top quark in GeV/c^2.
(1)

~~300/2 ... 150 GeV/c²~~

319/2 = 160 GeV/c²

(vi) Suggest why it took a long time to find experimental evidence for the top quark.
(2)

High energy accelerators were not available until recently, so energies high enough for the formation of the heavy top quarks were not attainable, and hence the top quarks could not be formed as their rest mass energy could not be reached

(Total for Question 18 = 14 marks)

ResultsPlus
Examiner Comments

There is no indication of how the answer to (iv) was arrived at so no mark awarded, although this is a mark that most candidates did score.

A rare example of a candidate who gets a mark for (v). Generally candidates do not appreciate the equivalence of the particle physics units.

In (vi) there is a correct statement about the high energy required but although the mass is referenced it says that the rest mass couldn't be reached which is not telling us that the mass is large.

(iv) Show that the total energy of all the products of this event is about 300 GeV.

(1)

48+19+9+40+82+35+97 =330

≃300 GeV

(v) Deduce the mass of a top quark in GeV/c^2.

(1)

$\Rightarrow$ 330 GeV/c = p of two top quarks.

$\Rightarrow$ 165 GeV/c^2

(vi) Suggest why it took a long time to find experimental evidence for the top quark.

(2)

Very large mass and thus very high energies needed to create it since $E=mc^2$.

ResultsPlus

Examiner Comments

An example of a candidate who scored all of the marks for these question parts.

There were 7 marks available for (ii) to (vi) and more than half of candidates scored 3, 4 or 5 marks, although only a very small number scored all 7 marks.

Paper Summary

Key points to help students improve their performance are:

- Think carefully before applying the first equation that comes to hand. Some calculations are multi-stepped. Look at the marks available.
- Thoroughly learn key facts and definitions.
- Read the questions carefully and answer the question that is being asked.
- For context based questions, always think for a moment before starting to answer the question.
- Remember that if an explain question has numerical values, then calculations are more than likely required.

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