

Mark Scheme

Q1.

Question Number	Answer	Mark
	C	1

Q2.

Question Number	Answer	Mark
	C	1

Q3.

Question Number	Answer	Mark
	A	1

Q4.

Question Number	Answer	Mark
	D	1

Q5.

Question Number	Answer	Mark
	C	1

Q6.

Question Number	Answer	Mark
	C	1

Q7.

Question Number	Acceptable answers	Additional guidance	Mark
	<p>The only correct answer is B</p> <p><i>A is not correct because a cyclotron uses a magnetic field</i></p> <p><i>C is not correct because a LINAC uses an electric field</i></p> <p><i>D is not correct because a LINAC does not use a magnetic field</i></p>	Cyclotron accelerated	1

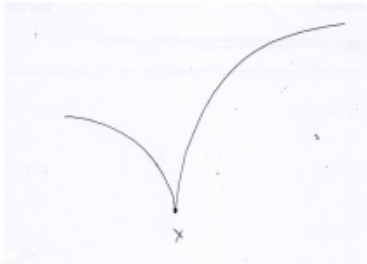
Q8.

Question Number	Answer	Mark
	D	1

Q9.

Question Number	Answer	Mark
	C	1

Q10.

Question Number	Answer	Mark
	<p>Diagram: Path curves in opposite sense (1)</p> <p>With a greater radius of curvature (1) [For Mp2 drawn line must start at X, upwards at less than 45° to vertical and go above printed line. Look at curvature close to X, do not penalise if later it curves more/less.]</p>  <p>Explanation: (these marks are independent of the diagram) (Antihelium) has opposite charge (to proton) Or reference to proton +ve and antihelium -ve (1)</p> <p>See $r = p/BQ$ (1)</p> <p>r is doubled Or p/Q is doubled (1)</p> <p>[equation may appear near diagram.]</p>	5
	Total for question	5

Q11.

Question Number	Answer	Mark
(a)	Only (moving) charged particles are deflected by a magnetic field (1) Or Only charged particles can be accelerated to produce a beam (1)	1
(b)	Into the page (1)	1
(c)	Use of $F = mv^2/r$ Or use of $r = p/BQ$ (1) Use of $F = Bqv$ Or use of $p = mv$ (1) $m = 6.64 \times 10^{-26}$ kg (1)	3
	<p><u>Example of calculation</u> $mv^2/r = Bqv$ $m = Bqr/v = (0.673 \text{ T} \times 1.6 \times 10^{-19} \text{ C} \times 7.40 \times 10^{-2} \text{ m}) / 1.20 \times 10^5 \text{ m s}^{-1}$ $m = 6.64 \times 10^{-26}$ kg</p>	
(d)	Semicircle drawn starting from same initial point and a smaller radius (1)	1
	Total for question	6

Q12.

Question Number	Answer	Mark
(a)	The idea that electron(s) have been removed/added from an atom/molecule/particle. (1)	1
(b)	Flemings left hand (rule) Or FLHR (1)	1
(c)	<p>Max 5</p> <p>Only charged particles leave a trail so photon is neutral (1) Or the two particles produced are charged because they leave a track</p> <p>Particles are oppositely charged because they curve/spiral in opposite directions (1) Or Particles are oppositely charged to conserve charge (1)</p> <p>(Applying FLHR) , top particle is positive and bottom one negative. (1)</p> <p>Because they have the same curvature/radius on the spirals Or because the paths have identical shape (1)</p> <p>Particles have the same momentum (1)</p> <p>The photon enters from the left because the (resultant) momentum afterwards is to the right.</p>	5
Total for question		7

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	<ul style="list-style-type: none"> The ions experience a force perpendicular to their velocity (and the magnetic field) (1) The (resultant) force on the ions causes an acceleration at right angles to their velocity (1) Or There is a magnetic force acting towards the centre of the path 	For velocity accept direction of motion or direction of travel	2

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	<ul style="list-style-type: none"> Use of $r = \frac{mv}{BQ}$ (1) $r = 0.23 \text{ m}$ (1) 	<p><u>Example of calculation:</u></p> $r = \frac{mv}{BQ}$ $= \frac{(34.97 \times 1.66 \times 10^{-27}) \text{ kg} \times 2.2 \times 10^5 \text{ ms}^{-1}}{0.35 \text{ T} \times 1.6 \times 10^{-19} \text{ C}} = 0.228 \text{ m}$	2

Question Number	Acceptable Answer	Additional Guidance	Mark
1 (iii)	<ul style="list-style-type: none"> path drawn with less curvature (less overall deflection) (1) 	MP1 awarded for path in the magnetic field	1

Question Number	Acceptable Answer	Additional Guidance	Mark
2 (iii)	<ul style="list-style-type: none"> ions are more massive (1) ions have the same charge so the radius of the path would be greater (1) 		2

Q14.

Question Number	Answer	Mark
	At X the idea that 2 particles are produced	(1)
	One is uncharged/neutral so no track	(1)
	charged particle has same charge as incident particle to conserve charge Or path of (new) charged particle changes to conserve momentum	(1)
	At Y Neutral particle decays into two charged particles.	(1)
	Tracks curve in opposite directions as particles oppositely charged. Or particles have (equal and) opposite charge to conserve charge Or particles have equal (magnitude of) momenta since their (radius of) curvature is the same.	(1)
		5

Q15.

Question Number	Acceptable answers	Additional guidance	Mark																												
*	<p>This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.</p> <table border="1"> <thead> <tr> <th>Number of indicative points seen in answer</th> <th>Number of marks awarded for indicative points</th> </tr> </thead> <tbody> <tr> <td>6</td> <td>4</td> </tr> <tr> <td>5-4</td> <td>3</td> </tr> <tr> <td>3-2</td> <td>2</td> </tr> <tr> <td>1</td> <td>1</td> </tr> <tr> <td>0</td> <td>0</td> </tr> </tbody> </table> <p>Indicative content</p> <ul style="list-style-type: none"> • There is an alternating p.d./E-field • P.d./E-field accelerates protons between dees • Magnetic field perpendicular to plane of dees • Proton path curved by magnetic field • As velocity of protons increases radius of path in dees increases • The time for which a proton is in a dee remains constant Or the frequency of p.d./E-field is constant 	Number of indicative points seen in answer	Number of marks awarded for indicative points	6	4	5-4	3	3-2	2	1	1	0	0	<p>Guidance on how the mark scheme should be applied: The mark for The following table shows how the marks should be awarded for structure and lines of reasoning</p> <table border="1"> <thead> <tr> <th></th> <th>Number of marks awarded for structure and lines of reasoning</th> </tr> </thead> <tbody> <tr> <td>Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout</td> <td>2</td> </tr> <tr> <td>Answer is partially structured with some linkages and lines of reasoning</td> <td>1</td> </tr> <tr> <td>Answer has no linkage between points and is unstructured</td> <td>0</td> </tr> </tbody> </table> <table border="1"> <thead> <tr> <th>Number of IC points</th> <th>Possible linkage marks</th> </tr> </thead> <tbody> <tr> <td>0, 1</td> <td>0</td> </tr> <tr> <td>2, 3</td> <td>1</td> </tr> <tr> <td>4, 5, 6</td> <td>2</td> </tr> </tbody> </table> <p>IC2 accept 'in the gap' for between dees. Accept increases E_x for accelerates</p> <p>IC3 accept vertical or upwards for perpendicular to plane.</p> <p>IC5 accept reference to $r = p/BQ$</p>		Number of marks awarded for structure and lines of reasoning	Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkage between points and is unstructured	0	Number of IC points	Possible linkage marks	0, 1	0	2, 3	1	4, 5, 6	2	6
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4, 5, 6	2																														

Q16.

Question Number	Answer	Mark
*	<p>(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)</p> <p>Alternating p.d. max 2</p> <p>Electric field/ p.d. accelerates particles Or Electric field /p.d. gives particles energy (1)</p> <p>Constant time period Or constant frequency (1)</p> <p>Polarity of dees switches every half cycle Or P.d. switches every half cycle (1)</p> <p>Magnetic field max 2</p> <p>Magnetic field/force at right angles to particles path (1)</p> <p>Maintains circular motion (whilst in dees) Or Experiences centripetal force/acceleration (whilst in dees) (1)</p> <p>Radius of circle increases as particles get faster (1)</p>	4
	Total for question	4

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	<ul style="list-style-type: none"> • Use of $W = QV$ (1) • Use of $KE = \frac{1}{2}mv^2$ (1) • Use of $m = 1.66 \times 10^{-27} \text{ kg}$ (1) • $v = 2.16 \times 10^5 \text{ (m s}^{-1}\text{)}$ (1) 	<p><u>Example of calculation:</u></p> $\frac{1}{2}mv^2 = eV$ $\therefore v = \sqrt{\frac{2 \times 1.6 \times 10^{-19} \text{ C} \times 8.5 \times 10^3 \text{ V}}{(34.97 \times 1.66 \times 10^{-27}) \text{ kg}}} = 2.16 \times 10^5 \text{ m s}^{-1}$	4

Q18.

Question Number	Answer	Mark
(i)	Outward spiral from centre in either direction, minimum of two complete loops (1)	1
(ii)	Direction consistent with diagram: Clockwise path, field out of page Anticlockwise path, field into page (1)	1
(iii)	Electric field/p.d. between dees causes (resultant) force/acceleration Proton makes half a revolution in half a cycle of the a.c. Or facing dee (always) negative when proton reaches gap. Or whenever the proton gets to a gap, the p.d. has reversed (1) k.e./speed (only) increases each time the proton crosses the gap Or work done by the field in the gap increases the k.e. (1)	3
(iv)	$Bev = mv^2/r$ Or $r = p/Be$ $v = 2\pi r/T$ $T = 1/f$ (seeing $f = v/(2\pi r)$ scores MP2 & 3) Or $Bev = mr\omega^2$ $v = r\omega$ $\omega = 2\pi f$ (seeing $v/r = 2\pi f$ scores MP2 & 3) (1) (1) (1) (1) (1) (1)	3
(v)	Use of $B = 2\pi fm/e$ with mass of proton $f = 1.8 \times 10^4$ Hz (1) (1) <u>Example of calculation</u> $f = eB/2\pi m$ $f = (1.6 \times 10^{-19} \text{ C} \times 1.2 \times 10^{-3} \text{ T}) / (2\pi \times 1.67 \times 10^{-27} \text{ kg})$ $f = 1.8 \times 10^4$ Hz	2

Q19.

Question Number	Answer	Mark
* (a)	<p>(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate)</p> <p>Electric field Provides a force on the proton/particle (1) Which accelerate the proton/particle Or gives energy to the protons/particles (1)</p> <p>Magnetic field Provides a force on a moving proton Or Provides a force at right angles to the direction of motion (of the protons) (1) Acts as a centripetal force Or produces circular motion (1)</p> <p>Additional detail about either field E field across gap only Or The idea that the E field is reversed /alternates every half cycle Or B field perpendicular to the Dees (1)</p> <p>(this mark may be awarded from a diagram)</p>	5
(b)	<p>Division by e (ignore powers of 10 error) (1) multiplication by c^2 (1) Mass = 0.14 (GeV/c²) (1)</p> <p><u>Example of calculation</u> Mass = $(2.5 \times 10^{-28} \text{ kg} \times 9 \times 10^{16} \text{ m}^2 \text{ s}^{-2}) / 1.6 \times 10^{-19} \text{ C}$ Mass = $0.14 \times 10^9 \text{ eV}/c^2 = 0.14 \text{ GeV}/c^2$</p>	3
(c)	<p>2/3 charge of a proton Or 2/3 charge of a positron (1) Or 2/3 <u>positive</u> value of the charge on an electron Or $2/3e^+$</p>	1

(d)(i)	<table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Particle</th> <th>Quark combination</th> </tr> </thead> <tbody> <tr> <td>K⁻</td> <td>$\bar{u} s$ (1)</td> </tr> <tr> <td>K⁺</td> <td>$u \bar{s}$ (1)</td> </tr> <tr> <td>K⁰</td> <td>$\bar{d} s$ or $d \bar{s}$ (1)</td> </tr> </tbody> </table>	Particle	Quark combination	K ⁻	$\bar{u} s$ (1)	K ⁺	$u \bar{s}$ (1)	K ⁰	$\bar{d} s$ or $d \bar{s}$ (1)	3
Particle	Quark combination									
K ⁻	$\bar{u} s$ (1)									
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K ⁰	$\bar{d} s$ or $d \bar{s}$ (1)									
(d)(ii)	<p>Mass-energy is conserved Or a comment about $E = m c^2$ (1) Appropriate reference to colliding particles having mass and kinetic energy The extra mass comes from the <u>kinetic</u> energy. (1)</p>	3								
Total for question		15								

Question Number	Answer	Mark	
(a)	4 is the number of nucleons Or number of neutrons and protons Or mass number Or nucleon number	(1)	2
	2 is the number of protons Or proton number Or atomic number	(1)	
(b)(i)	(The particles are moving) close to the speed of light	(1)	1
(b)(ii)	To create particle /antimatter Or To allow (large) repulsive forces to be overcome Or To break the particles (into their constituents)	(1)	1
(b)(iii)	Mass = 4u (accept use of 4m _p) Use of $E = mc^2$ Division by e Mass = 3.74 (GeV/c ²) (use of mass of proton instead of u → 3.76 GeV/c ²) <u>Example of calculation</u> mass = $4 \times 1.66 \times 10^{-27} \text{ kg} = 6.64 \times 10^{-27} \text{ kg}$ $mc^2 = 6.64 \times 10^{-27} \text{ kg} \times (3 \times 10^8 \text{ m s}^{-1})^2 = 6.0 \times 10^{-10} \text{ J}$ $6.0 \times 10^{-10} \text{ J} / 1.6 \times 10^{-19}$ Mass = 3.74 GeV/c ²	(1) (1) (1) (1)	4
(b)(iv)	They meet matter (helium nuclei) and <u>annihilate</u>	(1)	1
(b)(v)	Use of $E = hf$ ecf E from (iii)	(1)	2
	Frequency = $9.02 \times 10^{23} \text{ Hz}$ (using 3.74 GeV/c ²) (3.76 GeV/c ² → $9.07 \times 10^{23} \text{ Hz}$ 4 GeV/c ² → $9.65 \times 10^{23} \text{ Hz}$) (half or double these values, due to a stray 2 can score 1st mark) (use of $\lambda = h/p$ scores 0) <u>Example of calculation</u> $f = 3.74 \times 10^9 \times 1.6 \times 10^{-19} \text{ J} / 6.63 \times 10^{-34} \text{ Js}$ $f = 9.02 \times 10^{23} \text{ Hz}$	(1)	
(c)(i)	<u>Quark and antiquark</u>	(1)	1
(c)(ii)	\bar{p} consists of $\bar{u} \bar{u} \bar{d}$	(1)	4
	$-\frac{2}{3}e -\frac{2}{3}e + \frac{1}{3}e = -e$ must be consistent with structure of \bar{p}	(1)	
	\bar{n} consists of $\bar{d} \bar{d} \bar{u}$	(1)	
	$+\frac{1}{3}e + \frac{1}{3}e - \frac{2}{3}e = 0$ must be consistent with structure of \bar{n}	(1)	
	(The sum must be clearly shown for marks 2 & 4)		

Question Number	Acceptable Answers	Additional guidance	Mark
a	<ul style="list-style-type: none"> fundamental – quarks and leptons (1) Baryons made of 3 q (1) Mesons made of quark and antiquark (1) 6 quark Or 6 leptons (1) Each particle has an antiparticle (1) 	<p>MP2 and 3 could be given for a named particle and its quark composition</p> <p>Can be inferred if either set named</p>	5

Question Number	Acceptable Answers	Additional guidance	Mark
b	<ul style="list-style-type: none"> Use of $\Delta E = \Delta mc^2$ (1) Conversion of J to eV (1) mass = 120 GeV/c² (1) 	<p>Example of calculation:</p> $E = 2.2 \times 10^{-25} \text{ kg} \times (3.0 \times 10^8)^2 (\text{ms}^{-1})^2$ $E = 1.98 \times 10^{-8} \text{ J}$ $E = 1.98 \times 10^{-8} \text{ J} \div 1.6 \times 10^{-19} \text{ J eV}^{-1}$ $E = 124 \times 10^9 \text{ eV}$	3

Question Number	Acceptable Answers	Additional guidance	Mark
c(i)	<ul style="list-style-type: none"> Energy (of protons) converted to mass (of Higgs) Or Energy is required to overcome electrostatic repulsion between protons (1) Reference to $E = mc^2$ (can be written in any form) (1) Because c^2 is very large (E must be large) Or Higgs particle is massive so needs a lot of energy to create it (1) 	<p>Alternative based on numerical values: Observation that Higgs mass is 120 GeV/c² This requires an energy of at least 120 GeV Each beam of protons would need an energy of at least 60 GeV</p>	3
c(ii)	<ul style="list-style-type: none"> Use of circumference = $2\pi r$ (1) Use of $p = Bqr$ (1) $p = 5.7 \times 10^{-15} \text{ N s}$ (1) 	<p>Example of calculation:</p> $r = 27000 \div 2\pi$ $r = 4300 \text{ m}$ $p = 8.3 \text{ T} \times 1.6 \times 10^{-19} \text{ C} \times 4300 \text{ m}$ $p = 5.7 \times 10^{-15} \text{ N s}$	3
ciii	0 (1)	zero	1

Question Number	Acceptable Answers	Additional guidance	Mark
d	<ul style="list-style-type: none"> High speeds Or relativistic (1) Mass (of proton) increases (1) Or this equation is only valid at non-relativistic speeds 	Alt: speeds close to speed of light	2

