

7	<p>The only correct answer is D ($2 \times 9.11 \times 10^{-31} \times (3 \times 10^8)^2$)</p> <p>A is not correct because this does not consider the mass of the positron B is not correct because this uses the mass of a single proton / antiproton C is not correct because this gives uses the mass of a proton / antiproton</p>	1
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2	<p>The only correct answer is B (pion)</p> <p>A is not correct because a photon is a quantum of electromagnetic radiation C is not correct because a positron is a lepton D is not correct because a proton is a baryon</p>	1
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1	<p>The only correct answer is D (thermionic emission)</p> <p>A is not correct because it is not caused by beta decay B is not correct because it is not caused by excitation C is not correct because it is not caused by the photoelectric effect</p>	1
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4	<p>The only correct answer is C ($v \approx c$)</p> <p>A is not correct because the muons cannot travel faster than the speed of light B is not correct because muons cannot travel at the speed of light D is not correct because the muons would not experience relativistic effects with this speed</p>	1
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1	<p>A is the correct answer</p> <p>B is not correct because the number of neutrons N is on the top line C is not correct because Z is on the top line and N is on the bottom line D is not correct because Z is on the top line</p>	1
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5	<p>A is the only correct answer because the particles are accelerated by electric fields across the gap and magnetic fields in the dees</p> <p>B is not correct because the particles follow a semi-circular path of constant radius followed by a straight portion across the gap and then a semi-circular path of greater constant radius and so on C is not correct because the electric field changes direction when the particles are in the dees, not when the particles are in the gaps D is not correct because the magnetic field does not change direction</p>	1
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6	<p>D is the correct answer</p> <p>A is not correct because lepton number is not conserved B is not correct because charge is not conserved C is not correct because charge is not conserved</p>	1
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3	<p>The only correct answer is B (lepton , meson)</p> <p>A is not correct because alpha is not fundamental C is not correct because proton is not fundamental and electron is D is not correct because muon is fundamental</p>	1
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5	<p>The only correct answer is A (Strong electrostatic forces act on the alpha particles.)</p> <p>B is not correct because this does not explain large angle deflection C is not correct because this does not explain large angle deflection D is not correct because this does not explain large angle deflection</p>	1
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1	<p>The only correct answer is B (85 protons 128 neutrons)</p> <p>A is not correct because the number of protons is 85 and the neutron number is the mass number- the proton number.</p> <p>C is not correct because the number of protons is incorrect</p> <p>D is not correct because the number of neutrons is incorrect; it should be the mass number – the proton number</p>	1
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3	<p>The only correct answer is B because after emission the proton number is 18 and the nucleon number is 38</p> <p>A is not correct because after emission the proton number is 18 and the nucleon number is 38</p> <p>C is not correct because after emission the proton number is 18 and the nucleon number is 38</p> <p>D is not correct because after emission the proton number is 18 and the nucleon number is 38</p>	1
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1	B is the correct answer , as $N = A - Z$	1
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7	<p>The only correct answer is B because the mass in kg is given by</p> $\frac{6.5 \times 1.6 \times 10^{-13}}{(3 \times 10^8)^2}$ <p>A is not correct because this does not take account of the M in MeV</p> <p>C is not correct because multiplication and division are reversed</p> <p>D is not correct because multiplication and division are reversed</p>	1
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8	<p>The only correct answer is D (The particles are accelerated by electric fields inside the dees.)</p> <p>A is not correct because this statement about cyclotrons is correct</p> <p>B is not correct because this statement about cyclotrons is correct</p> <p>C is not correct because this statement about cyclotrons is correct</p>	1
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10	<p>The only correct answer is C $\left(\frac{450 \times 10^9 \times 1.6 \times 10^{-19}}{(3.00 \times 10^8)^2} \right)$</p> <p>A is not correct because this uses MeV instead of GeV and suggests that only the mass-energy of one of the colliding particles has been conserved</p> <p>B is not correct because this uses MeV instead of GeV</p> <p>D is not correct because this suggests that the mass-energy in the interaction has been doubled</p>	1
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*16(a)	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Total marks awarded is the sum of marks for indicative content and the marks for structure and lines of reasoning.	<table border="1"> <thead> <tr> <th>IC points</th> <th>IC mark</th> <th>Max linkage mark</th> <th>Max final mark</th> </tr> </thead> <tbody> <tr><td>6</td><td>4</td><td>2</td><td>6</td></tr> <tr><td>5</td><td>3</td><td>2</td><td>5</td></tr> <tr><td>4</td><td>3</td><td>1</td><td>4</td></tr> <tr><td>3</td><td>2</td><td>1</td><td>3</td></tr> <tr><td>2</td><td>2</td><td>0</td><td>2</td></tr> <tr><td>1</td><td>1</td><td>0</td><td>1</td></tr> <tr><td>0</td><td>0</td><td>0</td><td>0</td></tr> </tbody> </table> <p>Indicative content:</p> <p>IC1 The p.d. provides an electric field</p> <p>IC2 The electric field accelerates the particles</p> <p>IC3 Electric field is between the tubes in a linac and between the dees in the cyclotron</p> <p>IC4 The p.d. is alternating so the particles are always accelerated</p> <p>IC5 In both machines the particles' paths get longer when not in the electric fields Or The time taken between leaving and entering the electric field in each machine is the same</p> <p>IC6 In both machines the frequency of the alternating p.d. is constant</p>	IC points	IC mark	Max linkage mark	Max final mark	6	4	2	6	5	3	2	5	4	3	1	4	3	2	1	3	2	2	0	2	1	1	0	1	0	0	0	0	<p>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> <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> <p>IC 3 allow electric field is across a gap</p> <p>IC 5 Accept references constant time in the dees and constant time in the tubes instead of the Electric field</p>	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		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	6
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16(b)(i)	Use of $V = \frac{W}{q}$ Uses 1.67×10^{-27} (kg) Uses $E_k = \frac{1}{2}mv^2$ $v = 1.8 \times 10^7$ (m s ⁻¹)	(1) (1) (1) (1)	<p>Example of calculation $W = 0.40 \times 10^6 \text{ V} \times 1.6 \times 10^{-19} \text{ C} \times 4 = 2.56 \times 10^{-13} \text{ J}$</p> $v = \sqrt{\frac{2.56 \times 10^{-13} \text{ (J)} \times 2}{1.67 \times 10^{-27} \text{ (kg)}}} = 1.75 \times 10^7 \text{ m s}^{-1}$	4
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16(b)(ii)	Use of $r = \frac{p}{\theta q}$ $v = 1.53 \times 10^7$ (m s ⁻¹) 1.8×10^7 (m s ⁻¹) > 1.5×10^7 (m s ⁻¹) so the increase in speed was not the same Or 2×10^7 (m s ⁻¹) > 1.5×10^7 (m s ⁻¹) so the increase in speed was not the same Or Correct conclusion based on comparison of candidate's calculated values (ecf from (a)(i) for the value of v)	(1) (1) (1)	<p>Example of calculation $p = 0.55 \text{ T} \times 1.6 \times 10^{-19} \text{ C} \times 0.29 \text{ m}$ $= 2.55 \times 10^{-20} \text{ kg m s}^{-1}$</p> $v = \frac{2.55 \times 10^{-20} \text{ kg m s}^{-1}}{1.67 \times 10^{-27} \text{ kg}} = 1.53 \times 10^7 \text{ m s}^{-1}$ <p>$1.75 \times 10^6 \text{ m s}^{-1} > 1.53 \times 10^7 \text{ m s}^{-1}$ so no, the increase in speed was not the same</p>	3
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21(a)	$u\bar{d}$ Or $d\bar{u}$ Or $u\bar{u}$ Or $d\bar{d}$	(1)	1
21(b)	<p>MAX 2 conservation laws (Conservation of) charge $-1 \rightarrow -1 + 0$ Dependent on MP1</p> <p>(Conservation of) lepton number $0 \rightarrow 1 + -1$ Dependent on MP3</p> <p>(Conservation of) baryon number $0 \rightarrow 0 + 0$ Dependent on MP5</p>	(1) (1) (1) (1) (1)	4

21(c)	Conversion of eV to J	(1)	3
	Use of $\Delta E = c^2 \Delta m$	(1)	
	$m = 1.9 \times 10^{-28}$ (kg)	(1)	
	<u>Example of calculation</u>		
	$m = 106 \text{ MeV} \times 10^6 \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 1.70 \times 10^{-11} \text{ J}$		
	$m = \frac{1.70 \times 10^{-11} \text{ J}}{(3.0 \times 10^8)^2} = 1.88 \times 10^{-28} \text{ kg}$		

21(d)	(When $v = 0.99c$) relativistic effects will be significant	(1)	2
	Or (When $v = 0.99c$) time dilation occurs		
	The lifetime (of high energy pions) would be longer (than for pions at rest)		
	MP2 dependent on MP1	(1)	

14(a)	The (metal in the) filament is heated (by the current)	(1)	2
	The electrons are released by <u>thermionic emission</u>	(1)	

14(b)	Use of $p = \frac{h}{\lambda}$	(1)	4
	Use of $E_k = \frac{p^2}{2m}$ Or $p=mv$ and $E_k = \frac{1}{2}mv^2$	(1)	
	Use of $V = \frac{w}{q}$	(1)	
	$V = 2100 \text{ V}$	(1)	
	<u>Example of calculation</u>		
	$p = \frac{6.63 \times 10^{-34} \text{ J s}}{2.65 \times 10^{-11} \text{ m}} = 2.50 \times 10^{-23} \text{ kg m s}^{-1}$		
	$E_k = \frac{(2.50 \times 10^{-23} \text{ kg m s}^{-1})^2}{2 \times 9.11 \times 10^{-31} \text{ kg}} = 3.44 \times 10^{-16} \text{ J}$		
	$V = \frac{3.44 \times 10^{-16} \text{ J}}{1.6 \times 10^{-19} \text{ C}} = 2147 \text{ V}$		

17(a)	Spiral path (of increasing radius) in the Dees (allow straight line in the gap)	(1)	2
	Anticlockwise spiral (MP2 dependent on MP1)	(1)	

17(b)	Use of $f = \frac{Bq}{2\pi m}$ Use of $T = 1/f$ $T = 6.0 \times 10^{-8} \text{ s}$ <u>Example calculation:</u> $f = \frac{0.55 \times 1.6 \times 10^{-19}}{2\pi \times 1.67 \times 10^{-27}} = 8.39 \times 10^6 \text{ Hz}$ $T = \frac{1}{8.39 \times 10^6} = 1.19 \times 10^{-7} \text{ s}$ Time in one Dee $\frac{1.19 \times 10^{-7} \text{ s}}{2} = 5.96 \times 10^{-8} \text{ s}$	(1) (1) (1)	3
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14(a)	Baryon: 3 quarks (or 3 antiquarks) Meson: a quark and an antiquark	(1) (1)	2
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14(b)(i)	Identifies charges (of quark) $(+2e/3)$ and (charge of lepton) $(+1)e$	(1)	5
	Identifies a quark with $+2/3$ charge (u,c,t)	(1)	
	Identifies an anti-lepton with charge $+1$ (e^+ , μ^+ , τ^+ - accept bar notation)	(1)	
	Baryon number = $1/3$	(1)	
	Lepton number = -1	(1)	
<u>Example of calculation</u> $+5e/3 = +2e/3 + 1e$			

14(b)(ii)	Use of eV to J conversion	(1)	3
	Use of $\Delta E = c^2 \Delta m$	(1)	
	$m = 2.7 \times 10^{-24}$ (kg) (2 sf)	(1)	
	<u>Example of calculation</u> $(2 \times 6.8 \times 10^{12} \text{ eV} \times 1.6 \times 10^{-19} \text{ V}) \times 11 / 100 = 2.39 \times 10^{-7} \text{ J}$ $m = 2.39 \times 10^{-7} \text{ J} / (3.00 \times 10^8 \text{ m s}^{-1})^2 = 2.66 \times 10^{-24} \text{ kg}$		

14(b)(iii)	Reasonable suggestion, such as:		1
	• Leptoquarks must have a mass greater than 2.7×10^{-24} kg (ecf from (b)(ii))	(1)	
	• Its mass is too high	(1)	
	• Energy needed is too high	(1)	
	• The energy of the collision is too low	(1)	