Question Number	Answer		Mark
1(a)	Conversion of MeV to J Use of $E_k = ½ mv^2$ Max velocity = 4.1×10^6 (m s^{-1}) Example of calculation $v = \sqrt{\frac{2 \times 1.2\text{Mev} \times 1.6 \times 10^{-13}\text{J}}{14 \times 1.66 \times 10^{-27}\text{kg}}}$ velocity = 4.06×10^6 m s^{-1}	**(1)** **(1)** **(1)**	**3**
1(b)(i)	Correct momentum of any particle seen e.g. N*ux* (must contain *u*) Correct equation from conservation of momentum (allow even if *u* not shown) Rearrange for z (dependent on second mark) Example of calculation N*ux* = 14*uy* + N*uz* N*z* = N*x* - 14*y*	**(1)** **(1)** **(1)**	**3**
1(b)(ii)	Kinetic energy is conserved	**(1)**	**1**
1(b)(iii)	See ½ *Nux*^{2} **Or** ½ *Nuz*^{2} **Or** ½ *14uy*^{2} Clear statement that E_k nitrogen atom = E_k neutron before – E_k neutron after **Or** E_k nitrogen atom = E_k lost by neutron	**(1)** **(1)**	**2**
1(c)(i)	Use of equation, N in the denominator must be included, given with $y = 3.0 \times 10^7$ **Or** $y = 4.1 \times 10^6$ In equation given use of: N + 1 with $y = 3.0 \times 10^7$ **Or** N + 14 with $y = 4.1 \times 10^6$ In equation given use of: N + 1 with $y = 3.0 \times 10^7$ **And** N + 14 with $y = 4.1 \times 10^6$ Example of calculation For hydrogen $2Nx = 3.0 \times 10^7$ (N + 1) For nitrogen $2Nx = 4.1 \times 10^6$ (N + 14) Equating gives 4.1×10^6 (N + 14) = 3.0×10^7 (N + 1) (so N = 1.06)	**(1)** **(1)** **(1)**	**3**
1(c)(ii)	Collision might not be elastic **Or** Speed (of particles) approaches speed of light (so mass increases)	**(1)**	**1**
	Total for question		**13**

Question Number	Answer	Mark
2(a)	Baryon (1)	**1**
2(b)	(+2/3 -1/3 + 2/3) = +1 / +1e / +e / (+)1.6 × 10^{-19} C (1) [Do not allow 1, 1e, e]	**1**
2(c)	($B^0 \rightarrow$) [No mark for LHS but must have an equation X = Y + Z] For RHS Λ^+ only [do not credit alternatives e.g. λ^+] (1) $\bar{p}$ only [do not credit alternatives e.g. p^-, $\bar{p}^{+/-}$] (1)	**2**
	Total for question	**4**

Question Number	Answer	Mark
3*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) (After X) no tracks / track ceases (at X) / tracks can't be seen (after X) (1) [allow lines for tracks] (so) uncharged/neutral particles produced OR only charged particles give tracks . (1) At least one of the correct further events identified. [i.e. at the 'V' points] [in words or on diagram] (1) Both of the correct further events identified.	**4**
	Total for question	**4**

Question Number	Answer	Mark
4(a)	Cannot be split further/has no internal structure / not made up of other particles (1)	**1**
4(b)	At least 4 radial straight lines [drawn with a ruler, need not touch particle] (1) Equispaced [very closely by eye] (1) Arrow pointing inwards (1) [ignore any words and mark the diagram only]	**3**
4(c)	Convert MeV to J [$\times 1.6 \times 10^{-13}$] (1) Divide by c^2 [$\div 9 \times 10^{16}$] (1) answer 205 - 214 (1) [Reverse calculation from 200 loses the third mark] <u>Example of calculation</u> 106 MeV = 106 x 1.6 x10^{-13} J = 106 x 1.6 x10^{-13} J / (3 x 10^8 m s^{-1})^2 ratio = 1.88 x 10^{-28} kg / 9.11 x 10^{-31} kg [May convert electron to 0.51 MeV]	**3**
4(d)	Use of $F = q^2/4\pi\varepsilon_0 r^2$ or $F = kq^2/r^2$ with $q = 1.6 \times 10^{-19}$ and $r = 2.7 \times 10^{-13}$ [ignore power of 10 error] (1) F = (-) 3.2×10^{-3} N (1) <u>Example of calculation</u> $F = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2}) (1.6 \times 10^{-19} \text{ C})^2 / (2.7 \times 10^{-13} \text{ m})^2$	**2**
4(e)	Mention of energy levels/states (1) Muon/electron jumps down / drops down /returns to original state (1) Large ΔE / large photon energy (hf) (1)	**3**
	Total for question	**12**

5(i)	C
5(ii)	A
5(iii)	D

Question Number	Answer	Mark
6(a)	$u\bar{d}$ identified **(1)**	**1**
6(b)	Conversion of G **(1)** Conversion of either eV or divided by c^2 **(1)** 2.5×10^{-28} (kg) **(1)** eg $m = 0.14 \times 10^9 \times 1.6 \times 10^{-19} \ / \ 9 \times 10^{16}$	**3**
6(c)	QWC i and iii – Spelling of technical terms must be correct and the answer must be organised in a logical sequence Electric fields: Electric field provides force on the charge/proton **(1)** gives energy to /work done / $E = qV$/ accelerate protons **(1)** Magnetic fields: Force on moving charge/proton **(1)** Produces circular path/centripetal force **(1)** labelled diagram showing Dees with E field indicated across gap OR B field through Dees (1) E field is reversed/alternates (1)	**QWC** **4** **1 max**
6(d)	QWC i and iii – Spelling of technical terms must be correct and the answer must be organised in a logical sequence	**QWC**

	momentum **(1)** Zero / negligible momentum before **(1)** To conserve momentum **(**fragments go in all directions) **(1)**	**3**
	Total for question	**12**

Question Number	Answer		Mark
***7**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) **Max 6** **Fixed target** There is momentum before the collision so there must be momentum after the collision. So particle(s) created must have some kinetic energy So not all KE converted to mass **Colliding beams** (If particles have the same mass and speed), total initial momentum is zero Momentum after collision will be zero If one stationary particle is created All of the kinetic energy of the particle is converted to mass	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**6**
	Total for question		**6**

Question Number	Answer		Mark
8(a)	The wavelength (associated) with a particle/electron with a given momentum **Or** $\lambda = h/p$ all terms defined	**(1)** **(1)** **(1)** **(1)**	**2**
8(b)(i)	Use of $E_k = eV$ Use of $E_k = p^2/2m$ **Or** use of $E_k = mv^2/2$ **and** $p = mv$ Momentum = 1.21×10^{-23} kg m s^{-1} <u>Example of calculation</u> $E_k = 1.6 \times 10^{-19}$ C× 500 V $p^2 = 2\ m\ E_k = 2 \times 9.11 \times 10^{-31}$ kg × $(1.6 \times 10^{-19} \times 500)$ J $p = 1.21 \times 10^{-23}$ kg m s^{-1}	**(1)** **(1)** **(1)**	**3**
8(b)(ii)	Use of $\lambda = h/p$ $\lambda = 5.49 \times 10^{-11}$ m (ecf value of p from (i)) (show that value gives 6.63×10^{-11} m) <u>Example of calculation</u> $p = 6.63 \times 10^{-34}$ J s / 1.21×10^{-23} kg m s^{-1} $\lambda = 5.49 \times 10^{-11}$ m	**(1)** **(1)**	**2**
	Total for question		**7**