Question Number	Answer	Mark
1(a)	(Total / sum of) Kinetic energy conserved	**(1)**
1(b)	These diagrams could appear in part c and should be credited in (b)  [allow first mark for any triangle or parallelogram ie do not insist on right angle] right angle labelled or approximately by eye / diagonal should be labelled "before" or "initial" or appropriately recognisable as incoming particle	**(1)** **(1)**
1(c)	KE as formula eg ½ mu^2 = ½ mv^2 + ½ ms^2 / p^2 /2m = p^2 /2m + p^2 /2m Recognition of "Pythagoras"	**(1)** **(1)**
1(d)(i)	Electric field Does work on proton/applies a force /repel/attract qV / Fd / Eq	**(1)** **(1)** **(1)**
1(d)(ii)	Mass of incoming proton larger (than rest mass) Due to moving near speed of light/high speed/high energy/relativistic Alt answer : image not in plane of two protons after the event	**(1)** **(1)** **(2)** **(max 2)**
1(e)	Out of the plane of paper	**(1)**
	Total for question	**11**

Question Number	Answer	Mark
2(a)*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Measurement of appropriate quantity e.g .height /distance /time (1) Calculate speed or inferred by an equation (1) Speed on impact (1) Statement of how method shows momentum has been conserved (1) [must include correct mention of mass and velocity] [correct description of measuring velocity directly with a sensor scores first two marks]	**4**
2(b)	Collisions inelastic / KE is transferred in collisions (1) to internal energy (of balls) [allow heat] / to KE of middle balls/to sound (1) Eventually stops because **all** energy is transferred (1)	**3**
	Total for question	**7**

Question Number	Answer		Mark
***3**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) No external/unbalanced/resultant force so momentum of system is conserved Rocket gains momentum in backward direction Module gains equal amount of momentum in forward direction Kinetic energy of the system increases (Some) chemical energy converted to KE **Alternative mark scheme** if candidate presumes that the initial total momentum is zero (Max 4) No external/unbalanced/resultant force so momentum of system is conserved Rocket and module have equal amount of momentum and move in opposite directions (after separation) Kinetic energy of the system increases (Some) chemical energy converted to KE	**(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)** **(1)**	**5**
	Total for question		**5**

Question Number	Answer		Mark
4(a)	Velocity/direction changing **Or** (object is) accelerating Force towards centre of circle	**(1)** **(1)**	**2**
4(b)	High(er) speed means large(r) force **Or** small(er) radius means large(r) force (For sharp bends) centripetal/resultant/required <u>force</u> would need to be greater than maximum frictional force **Or** (for sharp bends) friction cannot provide the (required) centripetal/resultant force	**(1)** **(1)**	**2**
4(c)(i)	Resolving forces vertically $\underline{N} \sin\theta = mg$ Resolving forces horizontally $\underline{N} \cos\theta = mv^2/r$ Division of vertical equation by horizontal equation to get correct answer	**(1)** **(1)** **(1)**	**3**
4(c)(ii)	Use of $\tan\theta = gr/v^2$ $\theta = 57^\circ$ <u>Example of calculation</u> $\tan\theta = (9.81\ \text{m s}^{-2} \times 18.7\ \text{m})/ (11.0\ \text{m s}^{-1})^2$ $\theta = 56.6^\circ$	**(1)** **(1)**	**2**
	Total for question		**10**

Question Number	Answer	Mark
5(a)(i)	Outward spiral from centre in either direction, minimum of two complete loops **(1)**	**1**
5(a)(ii)	Direction consistent with diagram: Clockwise path, field out of page Anticlockwise path, field into page **(1)**	**1**
5(a)(iii)	Electric field/p.d. between dees causes (resultant) force/acceleration **(1)** 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**
5(a)(iv)	$Bev=mv^2/r$ **Or** $r=p/Be$ **(1)** $v=2\pi r/T$ **(1)** $T=1/f$ (seeing $f=v/(2\pi r)$ scores MP2 & 3) **(1)** **Or** $Bev=mr\omega^2$ **(1)** $v=r\omega$ **(1)** $\omega=2\pi f$ (seeing $v/r=2\pi f$ scores MP2 & 3) **(1)**	**3**
5(a)(v)	Use of $B=2\pi fm/e$ with mass of proton **(1)** $f=1.8\times10^4$ Hz **(1)** <u>Example of calculation</u> $f=eB/2\pi m$ $f=(1.6\times10^{-19}\text{ C}\times1.2\times10^{-3}\text{ T})/(2\pi\times1.67\times10^{-27}\text{kg})$ $f=1.8\times10^4$ Hz	**2**
5(b)	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**
	Total for question	**15**

6(i)	C	**1**
6(ii)	A	**1**
6(iii)	D	**1**

Question Number	Answer	Mark
7(a)	Use of $F=mv/t$ or $F = ma$ **(1)** Answer = 2.0×10^5 N **(1)** Eg F = 12000 x 57 / 3.5	**2**
7(b)	Arrow down labelled mg / W **(1)** Arrow up labelled eg R / reaction / force from seat **(1)** Equal length vertical arrows from a clear single point / centre of mass and "bottom" **(1)**	**3**
7(c)	$4mg - mg$ OR $3mg$ **(1)** $(m)v^2 / r$ seen **(1)** Answer = 110 (m) **(1)**	**3**
	Eg $3mg = mv^2 / r$ $r = (57)^2 / 3g$	
7(d)	Use of KE / PE conservation **(1)** Answer = 23 (m s^{-1}) **(1)** Eg ½ $m(57)^2$ = ½ $mv^2 + mg139$ v^2 = ½ $(57)^2 - 9.81 \times 139$	**2**
7(e)	Using $(m)g$ only **(1)** Answer r = 54 m [allow ecf] **(1)** **Eg** $mg = mv^2 / r$ $r = (23)^2 / 9.81$	**2**
	Total for question	**12**

Question Number	Answer	Mark
***8**	(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. **(1)** So particle(s) created must have some kinetic energy **(1)** So not all KE converted to mass **(1)** **Colliding beams** (If particles have the same mass and speed), total initial momentum is zero **(1)** Momentum after collision will be zero **(1)** If one stationary particle is created **(1)** All of the kinetic energy of the particle is converted to mass **(1)**	**6**
	Total for question	**6**