Question Number	Answer	Mark
1(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**
1(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**
1(c)	$4mg - mg$ OR $3mg$ **(1)** $(m)v^2 / r$ seen **(1)** Answer = 110 (m) **(1)** Eg $3mg = mv^2 / r$ $r = (57)^2 / 3g$	**3**
1(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 $(57)^2 - 9.81x139$	**2**
1(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**

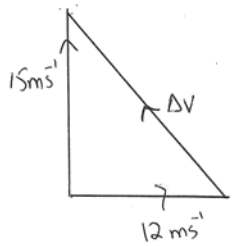
Question Number	Answer	Mark
2(a)*	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Measurement of appropriate quantity e.g .height /distance /time (1) Calculate speed or inferred by an equation (1) Speed on impact (1) Statement of how method shows 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(a)	Use of $v = 2\pi r/t$ **Or** $v = r\omega$ **and** $T = 2\pi/\omega$ $t = 1.5 \times 10^3$ s [24.6 minutes] Example of calculation $t = 2\pi r/v$ $t = (2\pi \times 61\text{ m}) / 0.26\text{ m s}^{-1}$ $t = 1473$ s	**(1)** **(1)**	**2**
3(b)	Use of $F = mv^2/r$ $F = 11$ N Example of calculation $F = 9.7 \times 10^3\text{ kg} \times (0.26\text{ m s}^{-1})^2 / 61\text{ m}$ $F = 10.7$ N	**(1)** **(1)**	**2**
3(c)(i)	Three arrows all pointing to the centre of the circle (accept free hand and lines of varying length)	**(1)**	**1**
***3(c)(ii)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Maximum at C / bottom **and** Minimum at A / top At C contact/reaction force (R) greater than weight (accept $R - W = mv^2/r$ or $R = W + mv^2/r$) At A contact/reaction force is less than the weight. (accept $W - R = mv^2/r$ or $R = W - mv^2/r$) Any statement that centripetal force / acceleration is provided by weight/reaction **Or** centripetal force is the resultant force This is a qwc question so a bald statement of the equations can score the marks but to get full marks there must be clear explanation in words.	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for question		**9**

Question Number	Answer		Mark
4(a)(i)	R cos 62º = mg **Or** R sin 28º = mg R = 1670 (N) Example of calculation	**(1)** **(1)**	**2**
4(a)(ii)	Use of force component **and** acceleration = force/mass a = 18.4 m s^{-2} (show that value gives 18.8 m s^{-2}) Example of calculation a = 1670 N cos 28º / 80 kg a =18.4 m s^{-2}	**(1)** **(1)**	**2**
4(a)(iii)	Use of $a = v^2/r$ (do not credit if g is used) v = 9.6 m s^{-1} ecf answer to (a)(ii) (show that value gives 9.7 m s^{-1}) example of calculation $v = \sqrt{}$(18.4 m s^{-2} × 5.0 m) v = 9.6 m s^{-1}	**(1)** **(1)**	**2**
4(b)	Use of speed = distance /time v = 13 m s^{-1} example of calculation v = 24 × 2π × 5.0 m / 60 s v = 12.56 m s^{-1}	**(1)** **(1)**	**2**
4(c)	Child's mass/weight is less (than adult) The smaller the mass, the smaller the force the rider experiences (since they experience the same acceleration) **Or** the push of the pad is less **Or** Centre of mass of child is lower (than adult) Distance to centre is smaller so force is less	**(1)** **(1)** **(1)** **(1)**	**2**
	Total for Question		**10**

Question Number	Answer		Mark
5(a)(i)	Correct equation to show conservation of momentum Correctly works through to show $v = 0$ Example of calculation Momentum before = Momentum after $(20\ 000\ kg \times 4.5\ m\ s^{-1}) + (60\ 000 \times 1.5\ m\ s^{-1})$ $= (60\ 000\ kg \times 3.0\ m\ s^{-1}) + (20\ 000\ kg \times v)$ $180\ 000\ kg\ m\ s^{-1} = 180\ 000\ kg\ m\ s^{-1} + 20\ 000\ kg \times v$	**(1)** **(1)**	**2**
(a)(ii)	Horizontal line at $v = 4.5\ m\ s^{-1}$ **and** **Either** negative gradient line for a collision time the same as for the heavier truck. **Or** negative gradient line passing through midpoint of collision	**(1)**	**1**
(a)(iii)	Use of $F = \Delta(mv) / \Delta t$ for either truck $F = 900\ 000$ N Example of calculation For the heavier truck $F = [(60\ 000\ kg \times 3.0\ m\ s^{-1}) - (60\ 000 \times 1.5\ m\ s^{-1})] / 0.1\ s$ $F = (-)\ 900\ 000$N	**(1)** **(1)**	**2**
(b)(i)	Kinetic energy is conserved	**(1)**	**1**
(b)(ii)	Recognises need to use $E_k = mv^2/2$ Calculation of E_k halfway at 0.050 s after collision begins [if graphs cross at a different point both velocities must be used] Calculation of E_k after collision = 270 000 J Example of calculation E_k halfway $= (20\ 000\ kg \times (2.25\ m\ s^{-1})^2)/2 + (60\ 000\ kg \times (2.25\ m\ s^{-1})^2)/2$ $= 203\ 000$ J E_k after $= (60\ 000\ kg \times (3.0\ m\ s^{-1})^2)/2 + 0$ $= 270\ 000$ J	**(1)** **(1)** **(1)**	**3**
(b)(iii)	Elastic (potential) energy is stored in the buffers/ springs ['lost' as elastic energy is not sufficient]	**(1)**	**1**
	Total for Question		**10**

Question Number	Answer		Mark
6(a)	Velocity/direction changing **Or** (object is) accelerating Force towards centre (of circle)	**(1)** **(1)**	**2**
***(b)(i)**	(QWC – Work must be clear and organised in a logical manner using technical wording where appropriate) Identifies a horizontal component of lift **Or** refers to $L \sin \theta$ Which acts as a centripetal force **Or** which provides a centripetal acceleration **Or** force perpendicular to velocity of plane so acts to centre (of circle) (MP2 **dependent mark** and only awarded for reference to a horizontal force)	 **(1)** **(1)**	**2**
(b)(ii)	Resolve vertically $L\cos \theta = mg$ Resolve horizontally $L\sin \theta = mv^2/r$ Use their value of L in their horizontal equation **Or** uses $\tan \theta = v^2/rg$ r = 1.6 km <u>Example of calculation</u> $L\cos \theta = mg$ $L = 2.4 \times 10^6$ kg × 9.81 kg N^{-1} / cos 25° = 2.6×10^7 N horizontally $L\sin \theta = mv^2/r$ $r = mv^2 / L\sin \theta = 2.4 \times 10^6$ kg × 85^2 m^2 s^{-2} / 2.6×10^7 N × sin 25° r = 1578 m	**(1)** **(1)** **(1)** **(1)**	**4**
	Total for Question		**8**

Question Number	Answer	Mark
7(a)	Sum of momenta before (collision) = sum of momenta after (collision) **Or** the total momentum before (a collision) = the total momentum after (a collision) **Or** total momentum remains constant **Or** the momentum of a system remains constant **(1)** Provided no external/unbalanced/resultant force acts **Or** in a closed/isolated system **(1)**	**2**
7(b)	Force equals rate of change of momentum **Or** force is proportional to rate of change of momentum **Or** $F = \Delta(mv)/\Delta t$ with terms defined **Or** $F = \Delta p/\Delta t$ with terms defined **(1)**	**1**
7(c)(i)	Line at right angles to drawn vector, arrow upwards and labelled. **(1)** Resultant vector joined and arrow in correct direction. **(1)** **Correct diagram**  **Wrong direction (**vector addition rather than subtraction: can score 1 mark here but allow full ecf in (c)(ii)  	**2**
7(c)(ii)	Use of Pythagoras **Or** trig. **(1)** Change in velocity = 19 m s^{-1} **(1)** Direction 51° from horizontal. **(1)** (accept $\theta = 51°$ if θ correctly added to diagram) <u>Example of calculation</u> $\Delta v = \sqrt{15^2 + 12^2}$ Δv = 19.2 m s^{-1} Tan θ = 15/12 θ = 51°	**3**
7(c)(iii)	Use of $p=mv$ **and** $F = \Delta p/t$ **(1)** F = 7100 N or 7200 N ecf their value from (c)(ii) **(1)** <u>Example of calculation</u> $F = \Delta p/t$ F = 1500 kg × 19.2 m s^{-1} / 4.0 s 7200 N	**2**
	Total for Question	**10**