Question	Evidence	1-4 marks	5-6 marks	7-8 marks
1(a)	As the 2 g red puck approaches, electrostatic repulsion will cause it to slow down and the 4 g blue puck to start moving. The 4 g will accelerate in the original direction and the 2 g will stop and recoil in the opposite direction.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND/OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	At closest approach, the relative velocity of the pucks must be zero. So both will have the same velocity with respect to the track. Conservation of momentum $m_{2g}v_{2g} = (m_{2g} + m_{4g})v_c$ $v_c = 42 / 6 = 7 \text{ m s}^{-1}$			
(c)	At 10 m, the electrostatic potential energy is $\frac{kQQ}{r} = 9\times10^9 \times \frac{(1.5\times10^{-6})^2}{10} = 2.02\times10^{-3}$ J Kinetic energy is $\frac{1}{2}\times2\times10^{-3}\times21^2 = 441\times10^{-3}$ J			
(d)	Total energy is conserved. Original KE = KE_{2g} at closest + KE_{4g} at closest + electric potential energy $\frac{1}{2}\times2\times10^{-3}\times21^2 = \left(\frac{1}{2}\times2\times10^{-3}\times7^2\right)$ $+\left(\frac{1}{2}\times4\times10^{-3}\times7^2\right)+\frac{1.5\times10^{-6}\times1.5\times10^{-6}\times9\times10^9}{d}$ $(441-49-98)\times10^{-3} = 0.294 = \frac{0.02025}{d}$ $d = 0.069\,\text{m}$			
(e)	The collision is elastic $2\times21 = 2v_R + 4v_B$ (conservation of momentum) $^1/_2\times2\times21^2 = {}^1/_2\times2\times v_R^2 + {}^1/_2\times4\times v_B^2$ (conservation of kinetic energy) (and taking the original electric PE as zero) From 1st equation: $2v_R = 2\times21 - 4v_B \Rightarrow 4v_R^2 = (2\times21-4v_B)^2$ Using 2nd: $2\times21^2 = \frac{(2\times21-4v_B)^2}{2}+8v_B^2$ $2\times2\times21^2 = (2\times21)^2 - 336v_B + 16v_B^2 + 8v_B^2$ $336v_B = 24v_B^2$ $v_{Blue} = 14\,\text{m s}^{-1}$ $v_{Red} = -7\,\text{m s}^{-1}$			

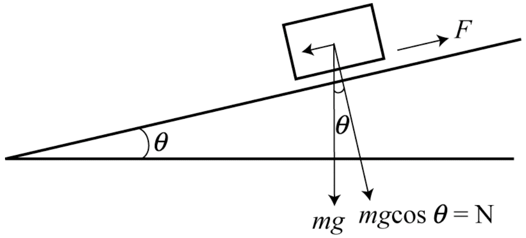
Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
2 (a)	By conservation of momentum: Before: ((6 +(–2.5)),(0 + 2.5)) = (3.5,2.5) After: (1.5 + (5 × V_x),3 + (5 × V_y)) 5V_x = (3.5 – 1.5) = 2.0 V_x = 0.40 5V_y = (2.5 – 3.0) = –0.5 V_y = –0.1	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	Kinetic energy before $=\left(\frac{1}{2}\times3.0\times2^2\right)+\left(\frac{1}{2}\times5.0\times\left(\frac{\sqrt{2}}{2}\right)^2\right)$ = 7.25 J Kinetic energy after $=\left(\frac{1}{2}\times3.0\times\sqrt{1.25}^2\right)$ $+\left(\frac{1}{2}\times5.0\times\left(\sqrt{0.17}\right)^2\right)=2.30$ J $KE_{before} \neq KE_{after}$; therefore collision is inelastic. The "missing" energy will have been converted into heat energy in the collision and into rotation KE with the discs spinning.			
(c)	The linear motions will be in straight lines as there are no external forces acting. The collision will have applied equal but opposite forces to each disc. Because angular momentum is conserved (no external torques) in the system the discs must rotate. M1 (3.0 kg – assuming it is uniform) will be rotating 1.67 times the angular velocity of M2 (5.0 kg– assuming it is uniform).			
(d)	The discs are originally neutral, so their motion through the electric field before the collision is not affected by the field. M_1 is positive after the collision, and will move in a parabola towards the right. M_2 is negative after the collision, and will slow down, reverse direction, and move towards the left, also following a parabolic path.			

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
THREE (a)(i)	$mgL = \frac{1}{2}mv^2 \qquad v^2 = 2gL$ $T = mg + \frac{mv^2}{L} = mg + 2mg = 3mg$	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(ii)	The square of the speed reached increases as the length of the rope increases, and so the centripetal force (the tension) should also increase. But the centripetal force required is also reduced in direct proportion to the increase in radius of the motion. These factors exactly cancel each other, leading to a constant maximum tension.			
(b)(i)	$T = kx$ $T = mg + \frac{mv^2}{L+x}$ $T(L+x) - mg(L+x) = mv^2$ Energy $mg(L+x) = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$ $2mg(L+x) = mv^2 + kx^2 = T(L+x) - mg(L+x) + Tx$ $3mg(L+x) = T(L+2x)$ $T = \frac{3mg(L+x)}{L+2x}$			
(ii)	The maximum velocity reached is less for the rubber than for the rope because some of the transferred GPE is taken up as elastic PE in the stretched rubber. This reduces the required centripetal force, reducing the required tension.			

Q	Evidence	1–4 Below Schol	5–6 Scholarship	7–8 Outstanding
4 (a)	Conservation of momentum $2.2 \times 8.33 = 2.2 \times V + 1.5 \times 5.55$ $V = 4.546$ (speed of model truck after collision) Kinetic Energy lost $\frac{1}{2} \times 2.2 \times 8.33^2 - \frac{1}{2} \times 2.2 \times 4.546^2 - \frac{1}{2} \times 1.5 \times 5.55^2$ $= 30.49$ J This is the work done in crushing the model car: $30.49 = Fd$ $d = \frac{30.49}{500} = 0.061$ m	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. AND / OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND / OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	Assumption is that all of the lost KE goes into deformation. Because a lot of KE will be lost to frictional heat between the tyres and the surface, it is therefore invalid. Conservation of momentum is conserved only if we include all the bodies involved – that should also include the Earth due to the frictional forces involved.			
(c)	Impulse = Change of momentum $500 \times t = 1.5 \times 5.55$ $t = 0.017$ s			
(d)	If two vehicles without crumple zones collide, large forces / accelerations will be produced that are dangerous to the passengers.			
(e)	The seat belt prevents a person from moving within the vehicle. The person must slow down with the vehicle, which slows "gradually" because the crumple zones take appreciable time to compress. The seat belt gives the person no other option than to lose their momentum slowly along with the vehicle. Since the impulse required is fixed (by the original momentum of the moving person), any increase in the timespan of the collision will result in smaller forces having to be applied, meaning reduced accelerations and less damage to the person. Also… the seat belt is broad so the restraining forces on the person are spread over a considerable area, resulting in lower peak pressures and therefore less damage to the person.			

Question	Evidence	1-4 marks	5-6 marks	7-8 marks
5 (a)	$v^2 = 2gh$ $D\text{i (drop)} = \frac{1}{2}gt^2$ $D\text{ii (rise)} = v\,t - \frac{1}{2}gt^2$ $h = D\text{i} + D\text{ii} = v \,.\, t$ (works dimensionally) $t = \dfrac{h}{v}$ Sub into $D\text{i} = \dfrac{1}{2}\dfrac{gh^2}{v^2}$ $D\text{i} = \dfrac{\frac{1}{2}gh^2}{2gh} = \dfrac{1}{4}h$	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems AND/OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. AND/OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)	One starts off fast and loses speed – the other starts slow and gains speed. By the time they meet, the fast starting one must have done most of the traveling. They cross ¾ the way up. When they meet both have been traveling for the same time. The fast moving one must have traveled a greater distance.			
(c)	$mv = MV - \dfrac{mv}{3}$ $\dfrac{4mv}{3M} = V$ $\dfrac{1}{2}mv^2 = \dfrac{1}{2}MV^2 + \dfrac{1}{2}\dfrac{mv^2}{9}$ $\dfrac{8mv^2}{9} = \dfrac{M \cdot 16m^2v^2}{9M^2}$ $8mv^2 = \dfrac{16m^2v^2}{M}$ $M = 2m$			
(d)	<u>Collision 1</u>: B hits C Momentum $4 = V_B + V_C$ Restitution $0.4 = \dfrac{V_C - V_B}{4-0}$ $V_C - V_B = 1.6$ Gives $2\,V_C = 5.6$ $V_C = 2.8$ m s^{-1} and $V_B = 1.2$ m s^{-1} <u>Collision 2</u>: A hits B Momentum $4 + 1.2 = V_A + V_B = 5.2$ Restitution $0.4 = \dfrac{V_B - V_A}{4-1.2}$ $V_B - V_A = 1.12$ Gives $2\,V_B = 6.32$ $V_B = 3.16$ m s^{-1} and $V_A = 2.04$ ms^{-1} (this is the final velocity for Ball A) <u>Collision 3</u>: B hits C Momentum $3.16 + 2.8 = 5.96 = V_B + V_C$ Restitution $0.4 = \dfrac{V_C - V_B}{3.16-2.8}$ $V_C - V_B = 0.144$ Gives $2\,V_C = 6.104$ $V_C = 3.052$ m s^{-1} and $V_B = 2.908$ m s^{-1} Since the masses are the same the conservation of momentum can be written as the conservation of velocity. Those three answers add up to 8… the starting total velocity.			

Question	Typical evidence that will be awarded one mark (if applicable)	Typical evidence that will be awarded two marks	
6(a)		Initial momentum $= 2.20\times10^4 \times 1.25$ $= 2.75\times10^4\,\mathrm{kg\,m\,s^{-1}}$ no external forces act so momentum conserved. $\therefore$ final momentum of wagon $= 2.75\times10^4\,\mathrm{kg\,m\,s^{-1}}$ velocity of wagon $= \frac{p}{m} = \frac{2.75\times10^4\,\mathrm{kg\,m\,s^{-1}}}{3.7\times10^4\,\mathrm{kg}}$ $= 0.74\,\mathrm{m\,s^{-1}}$	2
(b)		If zero friction then momentum conserved. As the superphosphate falls out the mass of the wagon decreases. However, the velocity of the wagon doesn't increase as the falling phosphate has a horizontal velocity and therefore momentum. It is only when the phosphate hits the ground that it loses its momentum i.e. the wagon is losing mass and losing momentum but maintaining a constant velocity. (Alternative approach is to consider the net force in the x direction, which is zero and therefore the acceleration is zero.)	2
(c)	Award 1 mark if used faster speed. Final answer will be closer to 1.1×10^7 kg.	volume of wagon $= 1.5\times1.5\times$ length mass per wagon (assume full wagon) $= 1.5\times10^4 = \rho V = 1.1\times10^3\times1.5\times1.5\times$ length $\therefore$ length $= 6.06\,\mathrm{m}$ If moving at $0.74\,\mathrm{m\,s^{-1}}$ time to fill 1 wagon $= \frac{d}{v} = \frac{6.06}{0.74} = 8.2\,\mathrm{s}$ in one hour can fill n wagons $n = \frac{60\times60}{8.2} = 440$ wagons therefore mass per hour $= 440\times1.5\times10^4$ $= 6.6\times10^6\,\mathrm{kg}$	2

Question	Typical evidence that will be awarded one mark (if applicable)	Typical evidence that will be awarded two marks	
(d)		 Forces balanced for zero acceleration. $N = mg\cos\theta$ $F = mg\sin\theta = \mu N$ $mg\sin\theta = \mu mg\cos\theta$ $\mu = \tan\theta$ $\theta = \tan^{-1}(0.005)$ $\theta = 0.29^{\circ}$	2