

Q	Scheme	Marks	Notes
<b>1(a)</b>	Expression for total KE before collision	M1	Dimensionally correct. Condone confusion between before and after for $A$ . Allow if vectors seen in the working but the modulus is used correctly. The two parts must be added together Allow confusion of 2 kg and 3 kg
	$\frac{1}{2} \times 2 \times 5^2 + \frac{1}{2} \times 3 \times (3^2 + (-1)^2)$	A1	correct unsimplified expression
	= 40 (J)	A1	cao
		(3)	
<b>1(b)</b>	$2((3\mathbf{i} + 2\mathbf{j}) - 5\mathbf{j})$	M1	change in momentum of $A$ , must be a difference but allow subtraction in either order Must be using the correct mass, 2 kg
	= $(6\mathbf{i} - 6\mathbf{j})$ (N s)	A1	Cao The final answer should be in terms of $\mathbf{i}$ and $\mathbf{j}$ because this is asked for in the question. Accept $2(3\mathbf{i} - 3\mathbf{j})$ ISW
		(2)	
<b>1(c)</b>	impulse-momentum equation for $B$	M1	must use negative of their answer to (b) and the initial velocity of $B$ Must be using the correct mass, 3 kg  or CLM with correct terms (allow slip) and plus signs
	$3(\mathbf{v}_B - (3\mathbf{i} - \mathbf{j})) = (-6\mathbf{i} + 6\mathbf{j})$ or $2 \times 5\mathbf{j} + 3(3\mathbf{i} - \mathbf{j}) = 2(3\mathbf{i} + 2\mathbf{j}) + 3\mathbf{v}_B$	A1ft	correct unsimplified equation ft on their impulse from (b)
	$\mathbf{v}_B = (\mathbf{i} + \mathbf{j})$ ( $\text{m s}^{-1}$ )	A1	Cao Accept column vector ISW
		(3)	
		<b>(8)</b>	

Q	Scheme	Marks	Notes
2(a)	$\frac{3}{4}t = \sqrt{2t+1}$	M1	Equate the two expressions Allow M1 only if they verify that it works for $k = 4$
	$9t^2 - 32t - 16 = 0$	A1	Correct 3 term quadratic In $t$ or in $k$ . Any equivalent form without the root
	$t = 4$ or $-\frac{4}{9}$ , so $k = 4$ $k \geq 0$ *	A1*	<b>Given answer</b> for $k$ correctly explained The Q asks for an explanation, so they must explain why they reject the negative root.
		(3)	
2(b)	Differentiate $v$ to obtain $a$	M1	power decreasing by 1, condone incorrect chain rule
	$a = \frac{dv}{dt} = \frac{1}{2}(2t+1)^{-\frac{1}{2}} \times 2$	A1	Correct derivative (any equivalent form)
	When $t = 1.5$ , $a = 0.5$ ( $\text{m s}^{-2}$ )	A1	cao
		SC	Allow M1A1A0 for correct differentiation seen as part of a vector approach
		(3)	
2(c)	$x = \int \sqrt{2t+1} dt$	M1	Attempt to integrate: power increasing by 1 Must see working – the question excludes calculators for this step
	$= \frac{2}{3}(2t+1)^{\frac{3}{2}} \times \frac{1}{2} (+C)$	A1	Correct indefinite integral
	Correct use of correct limits	M1	Use of $t = 0$ , $x = 0$ and $t = 4$ as limits in a definite integral or to obtain the constant of integration and hence $x$ when $t = 4$ ( $C = -\frac{1}{3}$ ) “Correct use” means (value when 4 substituted) – (value when 0 substituted)
	$x = \frac{26}{3}$	A1	Accept 8.7 or better
	$\int \frac{3}{4}t dt$	M1	Attempt to integrate: power increasing by 1 Must see working – the question excludes calculators for this step NB It is correct to use <i>suvat</i> in place of this second interval, but if they do then M1 includes use of the correct initial speed ( $3 \text{ ms}^{-1}$ )
	$= \left[ \frac{3}{8}t^2 \right]_4^8$	A1	Correct definite integral. Accept $\frac{3 \times 64}{8} - \frac{3 \times 16}{8}$ or equivalent unsimplified expression
	Total = $\frac{80}{3}$ (m) (=18 (m))	A1	Accept 27 or better ( $26.\dot{6}$ )
		SC	Correct integration seen as part of a vector approach can score M1A1M0A0M1A0A0
		(7)	
		(13)	

Q	Scheme			Marks	Notes
3(a)	Large disc	Small disc	Template	B1	correct area ratios and distances seen or implied Allow + $kr$ or $-kr$
	$\pi R^2$	$\pi r^2$	$\pi R^2 - \pi r^2$		
	0	$R - r$	$\pm kr$		
	Moments about axis through $X$			M1	Or moments about a parallel axis. Need all terms but condone sign errors Do not need to see the zero term Dimensionally consistent Could be part of a vector equation
	$(0 \times \pi R^2) - \pi r^2 \times (R - r) = (\pi R^2 - \pi r^2) \times (-kr)$ Moments about the left-hand end of the diameter through $X$ and $Y$ gives: $\pi R^2 \cdot R - \pi r^2 (2R - r) = \pi (R^2 - r^2) (R - kr)$			A1	Correct unsimplified equation Do not need to see the zero term Must be using $-kr$ (unless they have changed the sign on the left-hand side)
	$r = \frac{k}{1-k} R$ *			A1*	Obtain <b>given answer</b> from correct working e.g. via $\frac{r}{R+r} = k$
					If they use $\bar{x}$ in place of $\pm kr$ and never substitute $\pm kr$ they can score B0M1A0A0
				(4)	
3(b)	$0 < \frac{k}{1-k} R < R$			M1	use of correct inequality
	$(0 <) k < (1-k) \Rightarrow (0 <) k < \frac{1}{2}$			A1	Correct only Only need the right-hand value. A0 with an incorrect left hand value
				(2)	
3(c)	$k = \frac{4}{9} \Rightarrow r = \frac{4}{5} R$			B1	Seen or implied (this mark could be implied by the correct expression for $\tan \alpha$ in terms of $k$ )
	$\tan \alpha = \frac{R}{kr} \left( = \frac{R}{\frac{4}{9} \times \frac{4}{5} R} = \frac{45}{16} \right)$ $\left( \tan \alpha = \frac{1-k}{k^2} \right)$			M1	Correct use of trig in a correct triangle Available for finding $90 - \alpha$
	$\alpha = 70^\circ$			A1	or better (70.426...) Accept 109.6, 250.4 and 289.6
				(3)	

Q	Scheme	Marks	Notes
3(d)	Moments about an axis through $P$	M1	dimensionally consistent, condone sign errors and missing $g$ throughout The equation should be of the form $M_1gR = Mg \times \text{a distance (in } r \text{ or } R)$ Moments about any other axis requires use of the forces acting at $P$
	$M(P), M_1gR = Mg \times \frac{4}{9}r$ <p style="text-align: center;">Or <math>M_1gR = Mg \times \frac{16}{45}R</math></p>	A1	correct unsimplified equation in $r$ and / or $R$
	$M_1 = \frac{16}{45}M$	A1	Accept $0.36 M$ or better
		(3)	
		(12)	

Q	Scheme	Marks	Notes
4(a)	$F = \frac{1}{7} \times mg \cos \alpha \left( = \frac{1}{7} \times mg \times \frac{4}{5} \right)$	M1	condone sin/cos confusion
	$= \frac{4mg}{35} *$	A1*	obtain <b>given answer</b> from correct working Correct trig value must be seen as it is a given answer – could be against the Q
		(2)	
4(b)	Energy equation: PE gain + WD against Fr = KE lost or equivalent	M1	NB: The question tells them to use work-energy. Need all terms, dimensionally correct but condone sign errors. Condone sine / cosine confusion
	$\frac{4mgd}{35} + mgd \sin \alpha = \frac{1}{2} m \times 10ag$	A1	unsimplified equation with at most one error
	Or $\frac{4mgd}{35} + mgd \times \frac{3}{5} = \frac{1}{2} m \times 10ag$	A1	correct unsimplified equation
	$d (= AB) = 7a$	A1	cao
		(4)	
4(c)	Energy equation	M1	NB: The question tells them to use work-energy. Need all terms, dimensionally correct but condone sign errors
	$\frac{4mg}{35} \times 14a = \frac{1}{2} m \times 10ag - \frac{1}{2} mV^2$	A1ft	unsimplified equation with at most one error, ft on their AB
	or $\frac{4mg}{35} \times 7a = mg \times 7a \times \frac{3}{5} - \frac{1}{2} mV^2$	A1ft	correct unsimplified equation
	or $\frac{4mg}{35} \times d = mg \times d \times \frac{3}{5} - \frac{1}{2} mV^2$		Allow A1A1 if they have substituted for g
	$V = \sqrt{\frac{34ag}{5}}$	A1	accept $2.6\sqrt{ag}$ , $\sqrt{6.8ag}$ or better. Accept $\sqrt{\frac{170ag}{25}}$
		(4)	
		(10)	

Q	Scheme	Marks	Notes
5(a)			
	Use of CLM (or equal and opposite impulses):	M1	correct no. of terms, dim correct, condone sign errors
	$mu = -mv + 2mw$	A1	Or equivalent
	Use of NEL:	M1	correct way round, condone sign errors
	$eu = v + w$	A1	Or equivalent
	Solve for $v$	DM1	Dependent on both preceding M marks
	$v = \frac{u(2e-1)}{3}$	A1	Or equivalent
	$v$ consistently in the wrong direction gives $v = \frac{u(1-2e)}{3}$		Mark as a misread and allow M1A0M1A0M1A1, but full marks if they later take account of the change in direction to give the correct final answer
	If the direction of $v$ is correct in one equation and incorrect in the other then mark as seen		
		(6)	
5(b)	NEL at the wall: $x = \frac{1}{3}w$	B1	Allow + / -: they might be working with velocities
	$w = \frac{u(e+1)}{3}$	B1	Or equivalent expression for $w$
	$\frac{1}{3} \times \frac{u(e+1)}{3} > \frac{u(2e-1)}{3}$	M1	use of <i>their</i> $x > \text{their } v$
	$e < \frac{4}{5}$	A1	cao
	$\frac{1}{2} < e < \frac{4}{5}$	A1	cao
		(5)	
		(11)	

Q	Scheme	Marks	Notes
6(a)			
	$F = \frac{1}{3}R$	B1	For a correct statement seen anywhere e.g. on a diagram
either	Horizontal forces: $S = F (= \frac{1}{3}mg)$	B1	
	Equation for M(A)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone $a$ missing throughout.
	$S \times 2a \cos \alpha = mga \sin \alpha$	A1	Correct unsimplified
or	$R = mg$	B1	
	Equation for M(B)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone $a$ missing throughout.
	$F \times 2a \cos \alpha + mga \sin \alpha = R \times 2a \sin \alpha$	A1	Correct unsimplified
or	$S = F (= \frac{1}{3}mg)$	B1	
	Equation for M(G)	M1	need correct terms, condone sign errors and sin/cos confusion. Condone $a$ missing throughout.
	$Fa \cos \alpha + Sa \cos \alpha = mga \sin \alpha$	A1	Correct unsimplified
SC	$S = F (= \frac{1}{3}mg)$ or $R = mg$ and no moments equation	B1	And no further marks
	Solve for $\tan \alpha$	M1	
	$\tan \alpha = \frac{2}{3}^*$	A1*	Obtain given answer from correct working
SC	A candidate who never uses $g$ can score B1B0M1A0M1A0		
		(6)	

Q	Scheme	Marks	Notes
6(b)			
	A good starting point for marking part (b) is to count the number of terms in the moments equation		
<b>either</b>	Use of $R = mg$ and $M(A)$	M1	
	$N = S = \frac{1}{3}mg$	A1	Correct only
	Resolve horizontally: $kmg = \frac{1}{3}R + N$ and solve for $k$	DM1	Dependent on the moments equation need correct terms, condone sign errors
	$k = \frac{2}{3}$	A1	correct equation
		(4)	
<b>or</b>	$M(A)$ and	M1	need correct terms, condone sign errors and sin/cos confusion. Condone $a$ missing throughout.
	$mga \sin \alpha = N \times 2a \cos \alpha$	A1	Correct unsimplified equation
	Resolve horizontally: $kmg = \frac{1}{3}R + N$ and use $R = mg$ and $\tan \alpha = \frac{2}{3}$ to solve for $k$	DM1	Dependent on the moments equation need correct terms, condone sign errors OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
<b>or</b>	$M(B)$ ,	M1	need correct terms, condone sign errors and sin/cos confusion. Condone $a$ missing throughout.
	$mga \sin \alpha + kmg \times 2a \cos \alpha$ $= R \times 2a \sin \alpha + \frac{1}{3}R \times 2a \cos \alpha$	A1	
	Use of $R = mg$ and $\tan \alpha = \frac{2}{3}$ to solve for $k$	DM1	Dependent on the moments equation OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
		(4)	
<b>or</b>	$M(G)$ ,	M1	need correct terms, condone sign errors and sin/cos confusion
	$Na \cos \alpha + kmg a \cos \alpha = Ra \sin \alpha + Fa \cos \alpha$	A1	Correct unsimplified equation
	Resolve horizontally: $kmg = \frac{1}{3}R + N$ and use $R = mg$ and $\tan \alpha = \frac{2}{3}$ to solve for $k$	DM1	Dependent on the moments equation need correct terms, condone sign errors OR could use a second moments equation
	$k = \frac{2}{3}$	A1	Correct only
		(10)	

Q	Scheme	Marks	Notes
7(a)	Horizontal distance	M1	equation with correct terms, condone sign errors
	$2ut = 80$	A1	correct equation
	Vertical distance or vertical speed	M1	equation with correct terms, condone sign errors
	$0 = ut - \frac{1}{2}gt^2$	A1	correct equation in $t$ Alternatives include $-u = u - gt$ or $0 = u - g\frac{1}{2}t$
	Solve for $u$ (e.g. $u \times \frac{80}{2u} = \frac{1}{2}g \frac{80^2}{4u^2}$ )	DM1	Dependent on the two previous M marks
	$u = 14^*$	A1*	obtain <b>given answer</b> correctly
If they consistently have $u$ horizontal and $2u$ vertically, then mark as a misread. M1A0M1A0M1A1 Fortuitously, they do obtain the given answer			
		(6)	
7(b)	$v^2 = (7\sqrt{17})^2 - 28^2$	M1	form an equation in $v$ only ( $v$ is vertical component)
	$\Rightarrow v = 7$ (or $-7$ )	A1	second value not needed
	Use of <i>suvat</i> to find the required time Check their logic. Have they found the time speed is $< 7\sqrt{17}$ or the time the speed is $> 7\sqrt{17}$ ?	DM1	Dependent on the first M mark. Complete method to obtain the required time. condone sign errors
	$7 = 14 - gt \Rightarrow t = \frac{5}{7} = 0.71\dots$	A1	Obtain a relevant value of $t$
	Total time = $2 \times \frac{5}{7} = 1.4$ or $1.43$ (s)	A1	For the required time to 2 sf or 3 sf A0 for $\frac{10}{7}$ ; follows the use of an approximate value for $g$
	The misread from (a) will give $v = \pm\sqrt{637} = \pm 7\sqrt{13}$ ( $\pm 25.2$ ), critical value of time $t = 0.282$ , required time $0.56$ (s)		No further penalty for the misread if the penalty is already applied in (a)
		(5)	

<b>7(b) alt</b>	$\frac{1}{2}m(28^2 + 14^2) - \frac{1}{2}m(7\sqrt{17})^2 = mgh$	M1	form an equation in $h$ only
	$\Rightarrow h = 7.5$	A1	Correct only
	Use of <i>suvat</i> to find the required time Check their logic. Have they found the time speed is $< 7\sqrt{17}$ or the time the speed is $> 7\sqrt{17}$ ?	DM1	Dependent on the first M mark. Complete method to obtain the required time, condone sign errors
	$7.5 = 14t - \frac{1}{2} \times 9.8t^2 \Rightarrow t = \frac{5}{7}, t = \frac{15}{7}$	A1	Obtain at least one relevant value for $t$
	Total time = $\frac{20}{7} - \left(\frac{15}{7} - \frac{5}{7}\right) = 1.4$ or 1.43(s)	A1	For the required time to 2 sf or 3 sf A0 for $\frac{10}{7}$ ; follows the use of an approximate value for $g$
	The misread from (a) will give the same value for $h$ (7.5), $t = 5.43$ and $t = 0.28$ , so required time 0.56 (s)		
		(5)	
<b>7b alt</b>	Use $7\sqrt{17}$ to form an equation in $t$ only	M1	
	$\Rightarrow 7\sqrt{17} = \sqrt{(14 - gt)^2 + 28^2}$	A1	Or equivalent
	Solve to find the required time Check their logic. Have they found the time speed is $< 7\sqrt{17}$ or the time the speed is $> 7\sqrt{17}$ ?	DM1	Dependent on the first M mark. Complete method to obtain the required time, condone sign errors
	$147 = 2gt - g^2t^2 \Rightarrow t = \frac{5}{7}, t = \frac{15}{7}$	A1	Obtain at least one relevant value for $t$
	Total time = $\frac{20}{7} - \left(\frac{15}{7} - \frac{5}{7}\right) = 1.4$ or 1.43(s)	A1	For the required time to 2 sf or 3 sf A0 for $\frac{10}{7}$ ; follows the use of an approximate value for $g$
		(5)	
		<b>(11)</b>	