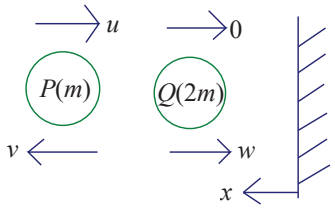
Q	Scheme	Marks	Notes
1(a)	Expression for total KE before collision	M1	Dimensionally correct. Condone confusion between before and after for A . Allow if vectors seen in the working but the modulus is used correctly. The two parts must be added together Allow confusion of 2 kg and 3 kg
	$\frac{1}{2}\times 2\times 5^2+\frac{1}{2}\times 3\times(3^2+(-1)^2)$	A1	correct unsimplified expression
	$=40$ (J)	A1	cao
		(3)	
1(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 **i** and **j** because this is asked for in the question. Accept $2(3\mathbf{i}-3\mathbf{j})$ ISW
		(2)	
1(c)	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)
	$\mathbf{v}_B=(\mathbf{i}+\mathbf{j})$ (m s^{-1})	A1	Cao Accept column vector ISW
		(3)	
		(8)	

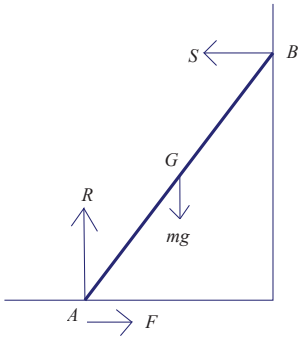
Q	Scheme	Marks	Notes
2(a)	$\frac{3}{4}t = \sqrt{2t+1}$	M1	Equate the two expressions Allow M1 only if they verify that it works for $k = 4$
	$9t^2 - 32t - 16 = 0$	A1	Correct 3 term quadratic In t or in k. Any equivalent form without the root
	$t = 4$ or $-\frac{4}{9}$, so $k = 4$ $k \geqslant 0$ *	A1*	**Given answer** 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 $t = 1.5$, $a = 0.5$ (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 $t = 4$ $\left(C = -\frac{1}{3}\right)$ "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 *suvat* in place of this second interval, but if they do then M1 includes use of the correct initial speed (3 ms^{-1})
	$= \left[\frac{3}{8}t^2\right]_4^8$	A1	Correct definite integral. Accept $\frac{3\times64}{8} - \frac{3\times16}{8}$ or equivalent unsimplified expression
	Total = $\frac{80}{3}$ (m) (=18 (m))	A1	Accept 27 or better $\left(26.\dot{6}\right)$
		SC	Correct integration seen as part of a vector approach can score M1A1M0A0M1A0A0
		(7)	
		(13)	

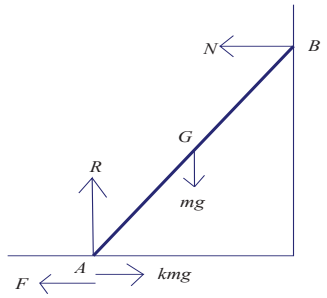
Q	Scheme	Marks	Notes
3(a)	<table><tr><td>Large disc</td><td>Small disc</td><td>Template</td></tr><tr><td>πR^2</td><td>πr^2</td><td>$\pi R^2 - \pi r^2$</td></tr><tr><td>0</td><td>$R-r$</td><td>$\pm kr$</td></tr></table>	B1	correct area ratios and distances seen or implied Allow + *kr* or -*kr*
	Moments 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
	$(0\times\pi R^2)-\pi r^2\times(R-r)=\left(\pi R^2-\pi r^2\right)\times(-kr)$ Moments about the left-hand end of the diameter through X and Y gives: $\pi R^2.R-\pi r^2\left(2R-r\right)=\pi\left(R^2-r^2\right)\left(R-kr\right)$	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)
	$r=\dfrac{k}{1-k}R$ *	A1*	Obtain **given answer** from correct working e.g. via $\dfrac{r}{R+r}=k$
			If they use $\bar{x}$ in place of $\pm kr$ and never substitute $\pm kr$ they can score B0M1A0A0
		(4)	
3(b)	$0<\dfrac{k}{1-k}R<R$	M1	use of correct inequality
	$(0<)k<(1-k)\Rightarrow(0<)k<\dfrac{1}{2}$	A1	Correct only Only need the right-hand value. A0 with an incorrect left hand value
		(2)	
3(c)	$k=\dfrac{4}{9}\Rightarrow r=\dfrac{4}{5}R$	B1	Seen or implied (this mark could be implied by the correct expression for tanα in terms of *k*)
	$\tan\alpha=\dfrac{R}{kr}\quad\left(=\dfrac{R}{\frac{4}{9}\times\frac{4}{5}R}=\dfrac{45}{16}\right)$ $\left(\tan\alpha=\dfrac{1-k}{k^2}\right)$	M1	Correct use of trig in a correct triangle Available for finding 90 - α
	$\alpha=70^{\circ}$	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 $M_1gR = Mg$ x a distance(in r or R) Moments about any other axis requires use of the forces acting at P
	$\text{M}(P),\ M_1gR = Mg \times \frac{4}{9}r$ Or $M_1gR = Mg \times \frac{16}{45}R$	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)	$F = \frac{1}{7} \times mg\cos\alpha \quad \left(= \frac{1}{7} \times mg \times \frac{4}{5}\right)$	M1	condone sin/cos confusion
	$= \frac{4mg}{35}$ *	A1*	obtain **given answer** 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
	$\frac{4mgd}{35} + mgd\sin\alpha = \frac{1}{2}m \times 10ag$ Or $\frac{4mgd}{35} + mgd \times \frac{3}{5} = \frac{1}{2}m \times 10ag$	A1 A1	unsimplified equation with at most one error 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
	$\frac{4mg}{35} \times 14a = \frac{1}{2}m \times 10ag - \frac{1}{2}mV^2$ or $\frac{4mg}{35} \times 7a = mg \times 7a \times \frac{3}{5} - \frac{1}{2}mV^2$ or $\frac{4mg}{35} \times d = mg \times d \times \frac{3}{5} - \frac{1}{2}mV^2$	A1ft A1ft	unsimplified equation with at most one error, ft on their AB correct unsimplified equation Allow A1A1 if they have substitued 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 *their* $x >$ *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: $S = F\ \left(=\frac{1}{3}mg\right)$	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	$S = F\ \left(=\frac{1}{3}mg\right)$	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	$S = F\left(=\frac{1}{3}mg\right)$ 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		
either	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)	
or	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
or	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)	
or	M(G),	M1	need correct terms, condone sign errors and sin/cos confusion
	$Na\cos\alpha + kmga\cos\alpha = Ra\sin\alpha + Fa\cos\alpha$	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 $\left(\text{e.g. } u \times \frac{80}{2u} = \frac{1}{2}g\frac{80^2}{4u^2}\right)$	DM1	Dependent on the two previous M marks
	$u = 14$*	A1*	obtain **given answer** 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 *suvat* 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
	$7 = 14 - gt \Rightarrow t = \frac{5}{7} = 0.71...$	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 $v = \pm\sqrt{637} = \pm 7\sqrt{13}$ (± 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)	

7(b) alt	$\frac{1}{2}m(28^2+14^2)-\frac{1}{2}m(7\sqrt{17})^2=mgh$	M1	form an equation in h only
	$\Rightarrow h=7.5$	A1	Correct only
	Use of *suvat* 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
	$7.5=14t-\frac{1}{2}\times 9.8t^2 \quad \Rightarrow t=\frac{5}{7}, t=\frac{15}{7}$	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)	
7b alt	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
	$147=2gt-g^2t^2 \quad \Rightarrow t=\frac{5}{7}, t=\frac{15}{7}$	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)	
		(11)	