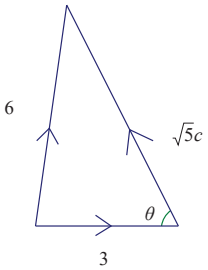
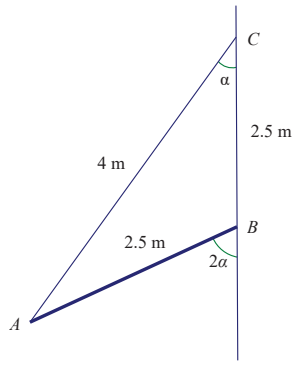
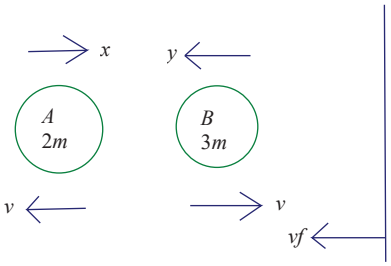
Q	Solution	Mark	Guidance
1a	$F = \mu R = \frac{1}{5}mg\cos\alpha$	B1	Seen or implied
	Work done = force x distance	M1	Correct method for work done against friction
	$= \frac{1}{5}mg \times \frac{12}{13} \times d = \frac{12}{65}mgd$ *	A1*	Obtain **given answer** from correct working.
		(3)	
1b	Work-energy equation	M1	All terms required and dimensionally correct. Condone sign errors and sin/cos confusion
	$\frac{1}{2}mv^2 = mg \times d \times \frac{5}{13} - \frac{12}{65}mgd \left(= \frac{13}{65}mgd\right)$	A1 A1	Unsimplified equation with at most one error Correct unsimplified equation
	$v = \sqrt{\frac{2gd}{5}}$	A1	Or exact equivalent e.g. $\sqrt{\frac{26}{65}gd}$, $\frac{1}{5}\sqrt{10gd}$ Accept $0.63\sqrt{gd}$ or better
		(4)	
		[7]	
2	Equation of motion down the slope	M1	First equation (either direction). Condone sign errors and sin/cos confusion
	$F_1 + 450g \times \frac{1}{15} - R = 450 \times 0.5$ $\left(\frac{P}{12} + 30g - R = 225\right)$ $\left(\frac{P}{12} - R = -69\right)$	A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation in P or F_1
	Equation of motion up the slope	M1	Second equation. Condone sin/cos confusion. Signs consistent with first equation and change in direction of motion
	$F_2 - 450g \times \frac{1}{15} - R = 450 \times -0.5$ $\left(\frac{P}{6} - 30g - R = -225\right)$ $\left(\frac{P}{6} - R = 69\right)$	A1	Correct unsimplified equation in P or F_2
	$F_1 = \frac{P}{12}$ or $F_2 = \frac{P}{6}\left(= \frac{2P}{12}\right)$	M1	Use of $P = Fv$ at least once
	Solve for P	DM1	Dependent on all previous M marks
	$\left(R = \frac{P}{8}\right)$ $P = 1660$ or $P = 1700$	A1	3 sf or 2 sf (follows use of 9.8) Allow 1.66 kW but not 1.66
		(8)	
		[8]	

3a	Use of $v = \dfrac{\mathrm{d}x}{\mathrm{d}t}$	M1	Recognisable attempt to differentiate the given expression
	$0 = 7t^{\frac{1}{2}}\left(t^2 - 5t + 4\right)$	DM1	Set $v = 0$ and solve for t Dependent on first M1
	$t = 1$ and $t = 4$	A1	Correct solution only
		(3)	
3b	$s = \lvert x_1 - x_0 \rvert + \lvert x_4 - x_1 \rvert$	M1	Correct strategy to find distance for their value(s) of t in $[0, 4]$ **Allow M1 if there is no change of direction in the interval**
	$= \left\lvert \dfrac{20}{3} - 0 \right\rvert + \left\lvert -\dfrac{128}{3} - \dfrac{20}{3} \right\rvert$	A1ft	Correct unsimplified expression for their distance (provided there was a change in direction in [0, 4]) **Clearly using $x(4) + 2x(1)$ but $x(4)$ miscalculated so correct combined expression never seen. M1 only**
	$= 56$	A1	Correct solution only
		(3)	
3c	Use of $a = \dfrac{\mathrm{d}v}{\mathrm{d}t}$	M1	Recognisable attempt to differentiate
	$a = \dfrac{35}{2} \times 4^{\frac{3}{2}} - \dfrac{105}{2} \times 4^{\frac{1}{2}} + 14 \times 4^{-\frac{1}{2}}$	M1	Substitute $t = 4$ in their a and simplify
	$= 42$	A1	Correct solution only
		(3)	
		[9]	

4	Use of $\mathbf{I}=m(\mathbf{v}-\mathbf{u})$	M1	As a single vector equation or two separate equations.
	$c\begin{pmatrix}-1\\2\end{pmatrix}=\frac{3}{4}\mathbf{v}-\begin{pmatrix}3\\0\end{pmatrix}$ $\left(\mathbf{v}=\frac{4}{3}\begin{pmatrix}3-c\\2c\end{pmatrix}\right)$	A1	Any equivalent substituted form
	Use of Pythagoras	M1	
	$64=\frac{16}{9}\left((3-c)^2+4c^2\right)$	A1	Correct unsimplified equation in c or a component of $\mathbf{v}$. $\left(5a^2-32a=0 \text{ or } 5b^2-16b-192=0\right)$
	Simplify to 3 term quadratic and solve for c	M1	$5c^2-6c-27=0$
	$c=3 \quad \text{or} \quad c=-\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
4 Alt		M1 A1	Form vector triangle. Dimensionally correct Three correct lengths and $\lvert\cos\theta\rvert=\frac{1}{\sqrt{5}}$ seen or implied
	Use of cosine rule	M1	
	$36=9+5c^2-2\times3\sqrt{5}c\cos\theta$	A1	Correct unsimplified equation in c with $\cos\theta$ or their $\cos\theta$
	Rearrange as 3 term quadratic and solve for c.	M1	$5c^2-6c-27=0$
	$c=3 \quad \text{or} \quad c=-\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
		[6]	

5a			
	Moments about B:	M1	Dimensionally correct Condone sin/cos confusion and errors in angles OR: Correct moments equation and resolution Resolving where required
	$T\times 2.5\sin\alpha = 70\times 1.25\sin 2\alpha$ Or $T\times 2.5\sin\alpha = 70\times 2\sin\alpha$ Or use similar triangles $T\times\frac{3}{2} = 70\times\frac{6}{5}$	A1 A1	Unsimplified equation in α with at most one error Correct unsimplified equation in α
	$T = 70\times\frac{4}{5} = 56(\text{N})$ *	A1*	Obtain **given answer** from correct exact working and no errors seen
		(4)	
5b	Resolve horizontally:	M1	First equation
	$H = T\sin\alpha\,(=33.6(\text{N}))$	A1ft	Correct unsimplified equation
	Resolve vertically	M1	Second equation
	$V + T\cos\alpha = 70 \quad (V = 25.2(\text{N}))$	A1ft	Correct unsimplified equation
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
5balt	Resolve parallel to the rod:	M1	
	$H\sin 2\alpha + 70\cos 2\alpha = 56\cos\alpha + V\cos 2\alpha$	A1ft	$(24H - 7V = 630)$
	Resolve perpendicular to the rod:	M1	
	$70\sin 2\alpha = 56\sin\alpha + V\sin 2\alpha + H\cos 2\alpha$	A1ft	$(24V + 7H = 840)$
	$V = \mu H$	M1	Use of $F = \mu R$ with their V, H
	$\mu = \frac{3}{4}$	A1	Correct only (no subst for g required)
		(6)	
		[10]	

6a			
	$5mv = 2m\left(v-\left(-x\right)\right)$	M1	Use of $I = mv - mu$
	$x = \frac{3v}{2}$	A1	Seen or implied
	$5mv = 3m\left(v-\left(-y\right)\right)$ or $2mx - 3my = 3mv - 2mv$	M1	Use of $I = mv - mu$ or use of CLM
	$y = \frac{2v}{3}$	A1	Seen or implied
	$2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$	M1	Correct use of impact law (not necessarily with values in terms of v) **Allow $v - v$ on LHS**
	$e = \frac{12}{13}$	A1	0.92 or better
		(6)	
6b	Speed of B after collision with wall $= vf$	B1	Seen or implied
	$2\times\frac{1}{2}\times 3m\left(y^2-\left(vf\right)^2\right) = \frac{1}{2}\times 2m\left(x^2-v^2\right)$	M1	Use KE to form an equation in f. Condone use of change in KE rather than loss **Condone 2 on wrong side**
	$3\left(\frac{4}{9}-f^2\right) = \left(\frac{9}{4}-1\right)$	A1	Correct unsimplified equation for f
	$\left(f^2 = \frac{1}{36}\right)\quad f = \frac{1}{6}$	A1	cao NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.
		(4)	
		[10]	

7a	Use of $\dfrac{2a\times\frac{1}{2}}{3\times\frac{\pi}{6}}\left(=\dfrac{2a}{\pi}\right)$	B1	Seen or implied
	Moments about *EC*:	M1	Dimensionally correct Condone use of a parallel axis
	$ad\times\dfrac{d}{2}=\dfrac{1}{6}\pi a^2\times\dfrac{2a}{\pi}\times\sin\dfrac{\pi}{6}$	A1	Correct unsimplified equation
	$\Rightarrow\left(d^2=\dfrac{a^2}{3}\right)\quad a=\sqrt{3}d$ *	A1*	Obtain **given answer** from correct working
		(4)	
7b	Mass ratios $\dfrac{a^2}{\sqrt{3}}:\dfrac{\pi a^2}{6}:\dfrac{a^2}{\sqrt{3}}+\dfrac{\pi a^2}{6}$	B1	Or equivalent. Seen or implied
	Moments about *BC*	M1	Dimensionally correct Condone use of a parallel axis
	$\dfrac{1}{\sqrt{3}}\times\dfrac{a}{2}+\dfrac{\pi}{6}\times\dfrac{2a}{\pi}\times\dfrac{\sqrt{3}}{2}=\left(\dfrac{1}{\sqrt{3}}+\dfrac{\pi}{6}\right)y$	A1ft	Correct unsimplified. Follow their $\dfrac{2a}{\pi}$
	Distance from *BC* = $y=\dfrac{6a}{6+\sqrt{3}\pi}$	A1	Or equivalent $\left(y=\dfrac{6d}{2\sqrt{3}+\pi}\right)$
	Use of trig to find a relevant angle	M1	
	$\tan\beta^{C}=\dfrac{6}{6+\sqrt{3}\pi}\times\sqrt{3}\qquad\left(\dfrac{\bar{y}}{d}\right)$	A1ft	Or equivalent correct unsimplified equation for the required angle
	$\beta=0.737\quad(0.74)$	A1	0.74 or better $42.2°$ implies correct method
		(7)	
		[11]	

8a	Conservation of energy	M1	Need all three terms and dimensionally correct. Condone sign errors.
	$\frac{1}{2}m\times10^2+mgh=\frac{1}{2}m\times18^2$	A1	Correct unsimplified equation
	$h=11.4 \quad (11)$	A1	3 sf or 2 sf only $\left(\text{not } \frac{80}{7}\right)$
		(3)	
8b	Vertical distance	M1	Complete method using *suvat* to find angle of projection
	$10\sin\alpha\times2.5-\frac{1}{2}g\times2.5^2=-11.4$	A1ft	Follow their h
	$\alpha=50.2°$ or $10\sin\alpha=v_V=7.7678....$	A1	$50°$ or better (50.1618…) Accept $50.3°$ from11.4 Seen or implied Might see $\sin\alpha=\frac{43}{56}$ or $v_V=\frac{215}{28}$
	Horizontal distance $=10\cos\alpha\times2.5$ or $\sqrt{100-v_V{}^2}\times2.5$	M1	
	$=16.0 \quad (16)\,(\text{m})$	A1	3 sf or 2 sf only
		(5)	
8c	Using energy: $\frac{1}{2}m\times64+mgs=\frac{1}{2}m\times100$	M1	Complete method to find height above A
	$s=1.8367...$	A1	1.8 or better
	Use of suvat to form equation in t	M1	
	$1.84=10\sin50.2\times t-4.9t^2$	A1	Correct unsimplified equation
	Solve for t and find difference between roots	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$T=0.98$ or 0.978	A1	2 sf or 3 sf
		(6)	
8c alt	Use of Pythagoras	M1	Complete method to find vertical component of speed
	Vertical speed $\sqrt{64-(10\cos\alpha)^2}=4.8...$	A1	Awrt 4.8 or better
	Use of $10\sin\alpha-gt=\pm v$ to find t	M1	
	$\begin{cases}10\sin50.2°-gt_1=4.8\\10\sin50.2-gt_2=-4.8\end{cases}$	A1	Correct unsimplified equations Could also find time to top
	$T=t_2-t_1=1.27..-0.29..$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$=0.98$ or 0.978	A1	Final answer. 2 sf or 3 sf
		(6)	
8calt	Use of Pythagoras to form quadratic in t	M1	
	$(10\sin\theta-gt)^2+(10\cos\theta)^2=64$	A1	

	Simplify and substitute for trig	M1	
	$36+9.8^2t^2-150.5t=0$	A1	
	$T=t_2-t_1=1.27..-0.29..$	DM1	Complete method to find the required time Dependent on 2 previous M marks
	$=0.98$ or 0.978	A1	Final answer. 2 sf or 3 sf
		[14]	