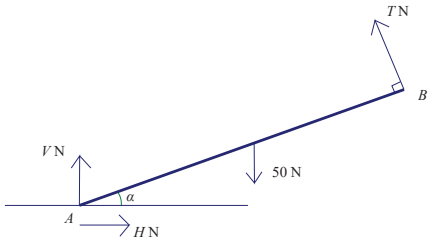
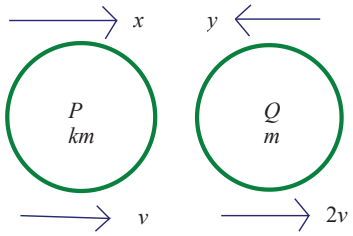
Q	Solution	Mark	Guidance
1a			**Allow column vectors.**
	Use of $\mathbf{v}=\dfrac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$	M1	Powers going down by 1. At least 2 powers going down .
	$\mathbf{v}=\left(3t^2-8\right)\mathbf{i}+\left(t^2-2t+2\right)\mathbf{j}$	A1	Any equivalent form
	Use of $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Powers going down by 1. At least 2 powers going down .
	$\mathbf{a}=6t\mathbf{i}+\left(2t-2\right)\mathbf{j}$	A1	Any equivalent form
	$=24\mathbf{i}+6\mathbf{j}\left(\mathrm{m\,s^{-2}}\right)$	A1	Must see acceleration stated as a correct simplified vector. ISW
		[5]	
1b	Direction $2\mathbf{i}+\mathbf{j}$	M1	Form equation in t or T only using direction. Condone use of 2 on the wrong side. Using their **v**
	$\Rightarrow\left(3T^2-8\right)=2\left(T^2-2T+2\right)$ $\left(T^2+4T-12=0\right)$	A1ft	Correct unsimplified **equation** in t or T. **Solving not required for the M1** Follow their **v**: **i** component = 2(**j** component)
	$T=2$	A1	Only Do not need to see method of solution.
		[3]	
		(8)	

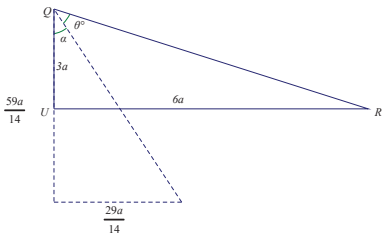
2a	Speed after first collision $=\frac{2}{3}u$	B1	Seen or implied (possibly on diagram)
	Speed after second collision $=\frac{4}{9}u$	B1	Seen or implied (possibly on diagram)
	Correct method for total time	M1	Correct formula, dimensionally correct and including all 3 elements.
	$T_1=\frac{d}{u}+\frac{3d}{\frac{2}{3}u}+\frac{2d}{\frac{4}{9}u}\quad\left(=\frac{d}{u}+\frac{9d}{2u}+\frac{18d}{4u}\right)$	A1	Correct unsimplified expression for T_1
	$T_1=\frac{10d}{u}$	A1	Correct single term. Allow unsimplified fraction e.g. $T_1=\frac{40d}{4u}$
		[5]	
2b	$T_2=\frac{10d}{\frac{4}{9}u}=\frac{45d}{2u}\quad\left(T_2=\frac{9}{4}T_1\right)$	B1ft	Follow through is on their T_1 and / or their $\frac{4}{9}u$ Any equivalent form e.g $\frac{90d}{4u}$.
		[1]	
		(6)	

3			**Allow column vectors**
	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting
	$(\mathbf{I} =) \pm 0.5\left((4-\lambda)\mathbf{i} + (-\lambda)\mathbf{j}\right)$	A1	Accept $\pm$ correct unsimplified expression on right hand side. (Ignore the left hand side) Allow $2\mathbf{i} - \frac{\lambda}{2}(\mathbf{i}+\mathbf{j})$ or equivalent
	Use of magnitude to form an equation in one variable	M1	Correct use of Pythagoras
	$\frac{5}{2} = \frac{1}{4}\left((4-\lambda)^2 + (-\lambda)^2\right)$	A1ft	Follow their **I**
	$0 = 2\lambda^2 - 8\lambda + 6 \quad (= (2\lambda - 6)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied). Not necessarily stated "= 0" From $\mathbf{I} = a\mathbf{i} + b\mathbf{j}$ can obtain $4a^2 - 8a + 3 = 0$ or $4b^2 + 8b + 3 = 0$ Dependent on the preceding M1 **Solving not required for the M1.**
	$\lambda = 3$ and $\lambda = 1$	A1cso	**From correct solution only.** Do not need to see method of solution.
		[6]	
3alt	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ to form a vector triangle	M1	
	Triangle with sides of length $\sqrt{\frac{5}{2}}$, $\lvert 2\mathbf{i}\rvert$ and $\left\lvert \frac{\lambda}{2}(\mathbf{i}+\mathbf{j}) \right\rvert$	A1	
	Use of cosine rule with $45°\left(\frac{\pi}{4}\right)$	M1	
	$\frac{5}{2} = 2^2 + \left(\frac{\lambda}{2}\right)^2 \times 2 - 2 \times 2 \times \frac{\lambda}{2}\sqrt{2}\cos 45°$	A1ft	Correct unsimplified equation Follow their magnitudes
	$0 = \lambda^2 - 4\lambda + 3 \quad (= (\lambda - 3)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied) Dependent on the preceding M1
	$\lambda = 3$ and $\lambda = 1$	A1	Correct solution only
		[6]	
		(6)	

4	Use of $F = \frac{P}{v}$	M1	Formula with a speed substituted correctly At least once.
	Equation for horizontal motion	M1	Dimensionally correct in P or F. Condone sign errors. Need all terms
	$\frac{P}{15} - R = -0.2 \times 900 \quad \left(\frac{P}{15} - R = -180\right)$	A1	Correct unsimplified equation in P and R
	Equation for motion down hill	M1	Dimensionally correct in P or F_D. Condone sign errors. Condone sin / cos confusion. Need all terms. M0 if using F(down) = F(horizontal)
	$F_D + 900g \times \sin\theta - R = 900 \times 0.4$	A1	Unsimplified equation in F_D or P and R with at most one error.
	$\left(\frac{P}{12} + 30g - R = 360\right) \quad \left(\frac{P}{12} = R + 66\right)$	A1	Correct unsimplified equation in (P and) R with trig substituted. e.g. $\frac{5}{4}(R - 180) = 360 - 30g + R$
	Solve for R	DM1	Dependent on the 3 preceding M marks. Condone slips in the algebra.
	$R = 1160 \quad \text{or} \quad R = 1200$	A1	3 sf or 2 sf only NB the answer follows the use of 9.8, so a final answer 1164 is A0. Clear use of 9.81 is a rubric infringement. It gives $(P = 14742 \text{ and}) \; R = 1162.8$ and scores a maximum of 7/8 (final A0)
		[8]	
		(8)	
	Some candidates work through with the two driving forces. They score M1M1 as above A1 for 4 x F(down) = 5 x F(horizontal) or equivalent M1A1 as above A1 for Correct unsimplified equation in R e.g. $\frac{5}{4}(R - 180) = 360 - 30g + R$ M1A1 as above		

5a			
	Moments about A	M1	Dimensionally correct equation i.e. force x distance = force x distance. Condone sin/cos confusion Mark 50*g* as an accuracy error
	$4T = 2\cos\alpha \times 50$ $\left(= 2\times\frac{4}{5}\times 50\right)$	A1	Correct unsimplified equation. Need to see $\cos\alpha$ **OR** $\frac{4}{5}$ Might see LHS = $T\cos\alpha\times 4\cos\alpha + T\sin\alpha\times 4\sin\alpha$
	$T = 20$ *	A1*	Obtain **given answer** from correct working. Must see $\frac{4}{5}$ used correctly.
		[3]	
5b	Resolve horizontally	M1	Condone sin/cos confusion
	$H = T\sin\alpha$	A1	Correct equation
	Resolve vertically	M1	Need all 3 terms. Condone sign error and sin/cos confusion.
	$T\cos\alpha + V = 50$	A1	Correct equation
	Either or both of the above equations could be replaced by a moments equation e.g. $\mathrm{M}(B): 4\cos\alpha\times V = 4\sin\alpha\times H + 2\cos\alpha\times 50$ or by resolving perpendicular & parallel to the rod: $T + V\cos\alpha = 50\cos\alpha + H\sin\alpha$ & $50\sin\alpha = H\cos\alpha + V\sin\alpha$		
	Use $F = \mu R$ to form an equation in μ	M1	$(H = \mu V)$ Used, not just stated i.e. they must get as far as substituting their values.
	$\mu = \frac{6}{17}$	A1	$\mu = 0.35$ or better Accept $\frac{12}{34}$
		[6]	
		(9)	

6a			
	They need to form three equations, one of which must be the impact law. Mark them as you see them, so the first M1A1 on epen is available for the first equation seen, the second M1A1is for the second equation seen etc. If there are more than 3 equations, mark this as multiple attempts and all the marks for the equations actually used in the solution. **Treat the second and third A marks as follow through marks if they are substituting values they have already found.**		
	Use of $I = mv - mu$ for P or Q	M1	Dimensionally correct. Need all terms. M0 if m is missing on RHS
	$5mv = m\left(2v - \left(-y\right)\right)$ or $-5mv = km\left(v - x\right)$	A1	Correct unsimplified equation
	Use of CLM or second use of $I = mv - mu$	M1	Dimensionally correct. Need all terms. In CLM allow cancelled m and extra common factor (eg g) throughout
	$kmx - my = kmv + 2mv$ $(kx - y = kv + 2v)$ or $-5mv = km\left(v - x\right)$	A1	Correct unsimplified equation
	Use of impact law	M1	Must be used with e on the correct side. Condone sign errors
	$2v - v = \frac{1}{5}\left(x + y\right)$	A1	Correct unsimplified equation
	$y = 3v$	A1	cao
	$x = 2v$	A1	cao
	$k = 5$	A1	cao
		[9]	
6b	KE lost	M1	Dimensionally correct. Accept change in KE. Not scored until they form the complete substituted equation.
	$= \frac{1}{2} \times km\left(x^2 - v^2\right) + \frac{1}{2} \times m\left(y^2 - 4v^2\right)$ $\left(= \frac{15}{2}mv^2 + \frac{5}{2}mv^2\right)$	A1ft	Correct unsimplified expression. Follow their x, y, k Condone sign change without explanation. $\left(\text{KE before} = 14.5mv^2\right.$ $\left.\text{KE after} = 4.5mv^2\right)$
	$= 10mv^2$	A1	Only
		[3]	
		(12)	

7a	<table><tr><td></td><td>*PQUV*</td><td>*URST*</td><td>*QRU*</td><td>total</td></tr><tr><td>Mass ratio</td><td>$9a^2$</td><td>$36a^2$</td><td>$18a^2$</td><td>$63a^2$</td></tr><tr><td>Displacement From *QT*</td><td>$-\frac{3a}{2}$</td><td>$3a$</td><td>$2a$</td><td>d</td></tr></table>	B1 B1	Correct mass ratios (1:4:2:7) Correct displacements from *QT* or a parallel axis seen or implied. Signs consistent
	Equation for moments about *QT* $18\times 2a+36\times 3a-9\times\frac{3a}{2}=63d$ $\left(4a+12a-\frac{3a}{2}=7d\right)$	M1 A1	(or a parallel axis) Dimensionally correct. Condone sign errors Or equivalent Correct unsimplified equation Check consistent in *a*.
	$d=\frac{29a}{2}\Big/7\left(=\frac{261a}{2}\Big/63\right)=\frac{29a}{14}$ *	A1*	Obtain **given answer** from correct working. Need to see at least one interim step with all the *a* terms collected. Check *a* is in final answer.
		[5]	
7b	Condone if "*a*" is missing throughout the working in part (b) because they have not been asked for the distance here.		
	Vertical distances from *Q*: $\frac{3a}{2}, 6a\left(=3a+3a\right), 2a, \left(v\right)$ From *T*: $7.5a, 3a, 7a$	B1	Seen or implied
	Equation for moments about *PQ*	M1	(Or a parallel axis) Dimensionally correct. Condone sign errors
	$9\times\frac{3a}{2}+18\times 2a+36\times 6a=63v$ $\left(\frac{3a}{2}+2\times 2a+4\times 6a=7v\right)$	A1	Correct unsimplified equation
	$v=\frac{59a}{14}$ $\left(\frac{67}{14}a \text{ above } T, \frac{17}{14}a \text{ below } U\right)$	A1	$4.2a$ or better (4.214…)
	The working for (a) and (b) might be combined in a vector equation. The marks for (b) are scored if the work is used in (b).		
			
	$\tan\alpha=\frac{29}{59}$ $\left(=26.175...°\right)$	M1	Use trig and their *v* to find a relevant angle Allow for $90°-26.17...°$

	$\theta° = \tan^{-1} 2 - \tan^{-1}\left(\frac{29}{59}\right)$	M1	Use their v to find the required angle $(63.43..° - 26.175..°)$
	$\theta = 37.3$	A1	37 or better
		[7]	
		(12)	
8a	Normal reaction between P and the ramp $= 3g\cos\alpha \quad \left(= \frac{18g}{\sqrt{37}} = 29.0\right)$	B1	cao ISW
	Use of $F = \frac{3}{4}R$	M1	$\frac{3}{4} \times$ their R (Must have an R)
	Work done $= 4F$	M1	Their F (Must have an F)
	$= 87.0\,(87)\,(\text{J})$	A1	3 sf or 2 sf only (follows 9.8) do not allow $\frac{54}{\sqrt{37}}g$ (this is an acceleration)
		[4]	
8b	Work-energy equation	M1	**M0 if not using work-energy**. All terms required. Condone sign errors Condone sin/cos confusion
	$\frac{1}{2} \times 3U^2 - \text{their(a)} - 3g \times 4\sin\alpha = \frac{1}{2} \times 3 \times 25$	A1ft A1ft	Unsimplified equation with at most one error. Follow their (a) Correct unsimplified equation Follow their (a)
	$U = 9.79$ or $U = 9.8$	A1	3 sf or 2 sf only (follows 9.8)
		[4]	
8c	Time taken:	M1	Complete method using *suvat* and $u = 5$ to form an equation in t only
	$-4\sin\alpha = (5\sin\alpha)t - \frac{1}{2}gt^2$ $\left(4.9\sqrt{37}t^2 - 5t - 4 = 0\right)$	A1	Correct unsimplified equation for t.
	$t = 0.45969....$	A1	Seen or implied
	Horizontal distance	M1	Complete method using *suvat* and $u = 5$
	$= (5\cos\alpha)t \quad \left(= \frac{30}{\sqrt{37}}t\right)$	A1ft	Follow their t
	$= 2.27$ or 2.3 (m)	A1	3 sf or 2 sf only
		[6]	
	Alternative: First M1A1 as above Second M1A1 as above Second A1 correct quadratic in horizontal distance e.g. $\frac{37\times4.9}{35\times25}d^2 - \frac{1}{6}d - \frac{4}{\sqrt{37}} = 0$ Final A1 as above		
		(14)	