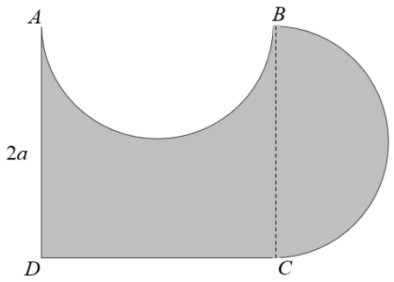
QUESTION NUMBER	SCHEME	MARKS
1	N.B. Calculator warning :' Not entirely'	
1(a)	Differentiate displacement to find an expression for velocity.	M1
	$v = 8t^3 - 42t^2 + 45t + 14$	A1
	Substitutes $t = 2$ to find $v = 0$ Or solves $v = 0$ to give $t = -\frac{1}{4}, 2, 3.5$ N.B. Only stating with no working t=2,v=0 or v=0,t=2 is A0	A1*
		(3)
1(b)	Complete method to find total distance = $\lvert x_2 - x_0 \rvert + \lvert x_3 - x_2 \rvert$	M1
	$\frac{95}{2}$ (m)	A1
		(2)
1(c)	Differentiates velocity $24t^2 - 84t + 45$	M1
	Substitute $t =$ 1.5 into differentiated expression	M1
	Correct **magnitude** of acceleration 27 (m s^{-2})	A1
		(3)
		(8)
	Notes for question	
1(a)		
M1	Differentiate given expression with at least two powers of t decreasing by 1.	
A1	Correct differentiated expression.	
A1*	Obtain t=2 from correct and complete working. If solving equation, and if any incorrect roots appear A0.	
1(b)		
M1	Complete method to find the total distance. Do not condone sign errors. (x_0=0 ,x_2=38, x_3=28.5)	
A1	Correct distance, must be positive	
1(c)		
M1	Differentiate velocity to find an expression for acceleration with at least two powers of t decreasing by 1.	
M1	Substitute 1.5 into their differentiated velocity.	
A1	Correct answer, must be positive.	

QUESTION NUMBER	SCHEME	MARKS
2		
2(a)	<table><tr><td></td><td>Mass ratio</td><td>Distance from AD</td></tr><tr><td>Square</td><td>$4a^2$</td><td>a</td></tr><tr><td>Semicircle removed</td><td>$\frac{\pi a^2}{2}$</td><td>a</td></tr><tr><td>Semicircle attached</td><td>$\frac{\pi a^2}{2}$</td><td>$\frac{4a}{3\pi}+2a$</td></tr><tr><td>Lamina</td><td>$4a^2$</td><td>$\bar{x}$</td></tr></table>	B1 (mass) B1 (distances)
	Moments equation about AD or a parallel axis	M1
	About AD $\left(4a^2\times a\right)-\left(\frac{\pi a^2}{2}\times a\right)+\frac{\pi a^2}{2}\left(\frac{4a}{3\pi}+2a\right)=4a^2\bar{x}$ About BC $4a^2(a)-\frac{\pi a^2}{2}(a)-\frac{\pi a^2}{2}\left(\frac{4a}{3\pi}\right)=4a^2(2a-\bar{x})$ About line joining midpoints of AB and DC $4a^2(0)-\frac{\pi a^2}{2}(0)+\frac{\pi a^2}{2}\left(a+\frac{4a}{3\pi}\right)=4a^2(\bar{x}-a)$	A1
	Obtain given answer from correct working. $\bar{x}=\frac{a}{24}(28+3\pi)$ *	A1*
		(5)
2(b)	Relevant moments equation	M1
	$T\times 2a=W\frac{a}{24}(28+3\pi)$	A1
	Second relevant equation	M1
	e.g. $5T=W+kW$	A1
	$k=\left(\frac{92+15\pi}{48}\right)$	A1
		(5)
		(10)
	Notes for question	
2(a)	**Vector form is acceptable for part a**	

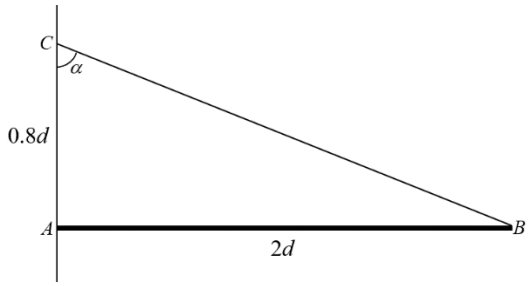
B1	Correct mass ratios for all 4 sections.	
B1	Correct distances for square and two semicircle sections measured from their moments line. (or shape to LHS of BC and semicircle)	
M1	Moments taken about AD or a parallel axis. Dimensionally correct equation. All terms required. 'a^2's may have been cancelled. LHS correct and RHS uses their $\bar{x}$.	
A1	Correct unsimplified equation in terms of a, $\bar{x}$ and π.	
A1*	Obtain given answer from correct working. At least one stage of simplification must be seen. Must be factorised with Allow$(28+3\pi)$ and $(3\pi+28)$	
2(b)		
M1	Form a moments equation about AD or a parallel axis. Dimensionally correct equation. All terms required.	
A1	Correct unsimplified equation. Allow in terms of $\bar{x}$. Accept decimal form for $\bar{x}$	
M1	Second relevant equation (moments or vertical equilibrium). Dimensionally correct equation. All terms required.	
A1	Correct unsimplified equation. Accept decimal form for $\bar{x}$ Other possible moments equations include: About B: $4T\times 2a - kW\times 2a - W\left(2a-\bar{x}\right)=0$ About midpoint AB: $4T\times a - kWa - W\left(\bar{x}-a\right) - Ta = 0$ About G: $4T\,\bar{x} - kW\,\bar{x} = T\left(2a-\bar{x}\right)$	
A1	Cao Accept equivalent forms in the form $p + q\pi$, but must be **exact**	

QUESTION NUMBER	SCHEME	MARKS
3	Accept column vectors throughout this question	
3(a)	Complete method to find greatest height (h) e.g. $0 = 14^2 + 2(-g)h$	M1
	$h = 10$	A1
		(2)
3(b)	Vertical component $v = 14 - g(2.4)$	M1
	Use Pythagoras to find Speed = $\sqrt{8^2 + (14 - 2.4g)^2}$	M1
	12.4 or 12 (ms^{-1})	A1
		(3)
3(c)	Relevant equation in t formed using vertical motion. e.g. $3 = 14t + \frac{1}{2}(-g)t^2$	M1 A1
	Use Horizontal motion to find the required distance $8t$	M1
	8x 2.6..	A1
	21 or 21.0 (m)	A1
		(5)
	ALT method forming trajectory equation	
	Relevant equation in t and y formed using vertical motion. $y = 14t - \frac{1}{2}gt^2$	M1
	Form relevant horizontal equation in x and t $x = 8t$	M1
	Eliminate t to form correct equation in x and y $y = 14 \times \frac{x}{8} - \frac{1}{2}g\left(\frac{x}{8}\right)^2$	A1
	Substitute y=3 into correct equation and solve for x	A1
	21 or 21.0 (m)	A1
		(5)
	ALT method using Energy	
	Vertically: $\frac{1}{2}(m)(14^2 - v^2) = 3(m)g$	M1
	Form vertical suvat equation in their v and t $v = 14 - gt$	M1
	$\sqrt{\frac{686}{5}} = 14 - gt$	A1

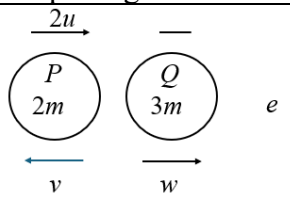
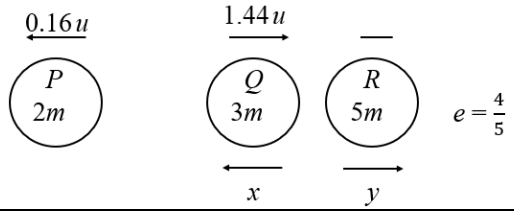
	8x2.6…	A1
	21 or 21.0 (m)	A1
		(5)
		(10)
	Notes for question	
3(a)		
M1	Complete method to find greatest height. Condone sign errors.	
A1	cao	
3(b)		
M1	Complete method to find the vertical component at t=2.4 Condone sign errors.	
M1	Use of Pythagoras with both components to find speed	
A1	Correct answer, 2/3sf	
3(c)		
M1	Relevant equation formed using vertical motion. Condone sign errors.	
A1	Correct unsimplified equation(s). (Note t = 2.62 (3sf) but does not need to be seen for this mark)	
M1	Use horizontal motion to find the required distance	
A1	Uses 'larger' t=2.6...to calculate distance AB	
A1	Correct answer with 2 or 3sf. Accept 21, 21.0.	
	Alt method Trajectory **Enter marks in correct M and A spaces**	
M1	Relevant equation formed in t and y using vertical motion.	
M1	Form relevant horizontal equation in x and t	
A1	Eliminate t to form correct equation in x and y	
A1	Substitute t=3 into correct equation and solve for x	
A1	Correct answer with 2 or 3sf. Accept 21, 21.0.	
	Alt method Energy	
M1	Form (vertical) energy equation,m's may have been cancelled and 8^2 may have been added to both velocity parts	
M1	Form vertical suvat equation in their v and t	
A1	Substitute correct value for v ($\sqrt{\frac{686}{5}}$=11.71..) and solve for t	
A1	Uses t=2.62...to calculate distance AB	
A1	Correct answer with 2 or 3sf. Accept 21, 21.0.	

QUESTION NUMBER	SCHEME	MARKS
4		
4(a)	Equation of motion	M1
	$D-30=70(0.4)$	A1
	Use of $P=D\times 5$	M1
	$P=290$ (W)	A1
		(4)
4(b)	At least one correct KE term $\frac{1}{2}\times 70\times 8^2$ $\frac{1}{2}\times 70\times 5^2$	M1
	Work done against resistance = 250×30	B1
	Work-energy equation	M1
	$70gH=\frac{1}{2}\times 70\times 8^2-\frac{1}{2}\times 70\times 5^2+250\times 30$	A1
	$H=13$ or 12.9 (m)	A1
		(5)
4(c)	Total work done	M1
	$70g(200\sin 5°)+(30\times 200)$	A1
	18000 (J)	A1
		(3)
		(12)
	Notes for question	
4(a)		
M1	Equation of motion. Dimensionally correct with all required terms and no extras.	
A1	Correct unsimplified equation.	
M1	Use of $P=D\times 5$	
A1	Correct answer, 290 (W)	
4(b)		
M1	At least one KE term correctly formed.	
B1	Expression seen for work done against resistance.	
M1	Work-energy equation. Dimensionally correct with all required terms and no extras or double counting. Mass must be replaced with 70. Condone sign errors.	
A1	Correct unsimplified equation.	
A1	Correct answer, 2/3sf	
4(c)		
M1	Expression for total work done. Dimensionally correct with all required terms and **no extras or double counting.** Mass must be replaced with 70. (the 200 may be used as 8x25)	
A1	Correct unsimplified expression for total work done.	
A1	Correct answer, 2/3sf	
	N.B. Penalise accuracy only once in entire question. **N.B**. Answers only in part a) M0A0M0A0, part b) M0B0M0A0 and in part c) M1A1A1	

QUESTION NUMBER	SCHEME	MARKS
5	Accept column vectors throughout the question.	
	Velocity in component form eg $\mathbf{v}=(v\cos 45°)\mathbf{i}\pm(v\sin 45°)\mathbf{j}$ OR $\mathbf{v}=\lambda\mathbf{i}\pm\lambda\mathbf{j}$	M1 A1
	Change in momentum in vector form $0.5\mathbf{v}-0.5(6\mathbf{i})$	M1 A1
	Use of magnitude of impulse to form an equation **in one unknown**. eg $\frac{3\sqrt{2}}{2}=\sqrt{(0.5v\cos 45°-3)^2+(0.5v\sin 45°)^2}$ OR $\frac{3\sqrt{2}}{2}=\sqrt{(0.5\lambda-3)^2+(0.5\lambda)^2}$	M1 A1
	$-\frac{3}{2}\mathbf{i}+\frac{3}{2}\mathbf{j}$ $-\frac{3}{2}\mathbf{i}-\frac{3}{2}\mathbf{j}$	A1 A1
		(8)
	Notes for question	
	Accept column vectors throughout the question.	
M1	Velocity after impact as components in variable form.	
A1	Correct unsimplified expressions Eg $\mathbf{v}=(v\cos 45)\mathbf{i}\pm(v\sin 45)\mathbf{j}$ or $\mathbf{v}=\lambda\mathbf{i}\pm\lambda\mathbf{j}$	
M1	$m(\mathbf{v}-\mathbf{u})$ used in vector form.	
A1	Correct unsimplified expression, $0.5\mathbf{v}-0.5(6\mathbf{i})$	
M1	Use of magnitude of **impulse** to form an equation in one unknown. Eg $\frac{3\sqrt{2}}{2}=\sqrt{(0.5v\cos 45°-3)^2+(0.5v\sin 45°)^2}$ $(\Rightarrow v=3\sqrt{2})$ Or $\frac{3\sqrt{2}}{2}=\sqrt{(0.5\lambda-3)^2+(0.5\lambda)^2}$ $(\Rightarrow \lambda=3)$	
A1	Correct unsimplified equation.	
A1	At least one correct expression for impulse must be in $p\mathbf{i}+q\mathbf{j}$ form for this mark	
A1	Two correct expressions for impulse. Do not penalise lack of $p\mathbf{i}+q\mathbf{j}$ form twice.	
	N.B. Case1: If solution appears as per scheme, then full marks possible **Case 2**: If no ± in line one but two solutions emerge at end, then full marks available **Case 3**: If only one sign used in line one, and only one solution appears at end, then max M1A0M1A1 M1A1A1A0	

QUESTION NUMBER	SCHEME	MARKS
6		
6(a)	A complete method to find an equation in T, m, g, k (and α).	M1
	E.g. Moments about A $(T\cos\alpha\times 2d)=(mg\times d)+(kmg\times 2d)$	A1, A1
	$T=\dfrac{mg\sqrt{29}}{4}(2k+1)$ *	A1*
		(4)
6(b)	Vertical equation	M1
	Correct equation Eg Vertical equilibrium $Y+T\cos\alpha=mg+kmg$	A1
	Horizontal equation	M1
	Correct equation Eg Horizontal equilibrium $X=T\sin\alpha$	A1
	Use of $\tan\theta=\dfrac{Y}{X}$ to form an equation in k only	M1
	$k=\dfrac{11}{10}$ or 1.1	A1
		(6)
		(10)
	Notes for question	
6(a)		
M1	A complete method to find an equation in T, m, g, k and α or size of angle at B,*say* β. Dimensionally correct with all required terms. Condone sign errors and sin/cos confusion. 'g' missing, count as one accuracy error	
A1	Correct unsimplified equation(s) with at most one error.	
A1	Correct unsimplified equation(s).	
A1*	Complete method to substitute trig and correctly obtain the given answer. At least one line of working between the equation and the given answer. Note: $\cos\alpha=\dfrac{2}{\sqrt{29}}$, $\sin\alpha=\dfrac{5}{\sqrt{29}}$, $\tan\alpha=\dfrac{5}{2}$ $\sin\beta=\cos\alpha$, $\cos\beta=\sin\alpha$, $\tan\beta=\dfrac{2}{5}$ Allow factor as $(2k+1)$ or $(1+2k)$	
6(b)		

M1	Resolve vertically. Dimensionally correct with all terms required. Condone sign errors and sin/cos confusion. Must be using correct angle	
A1	Correct unsimplified equation. Allow for Y downwards ie +/-Y	
M1	Resolve horizontally. Dimensionally correct with all terms required. Condone sign errors and sin/cos confusion. Must be using correct angle.	
A1	Correct unsimplified equation.	
M1	Use of $\tan\theta = \frac{Y}{X}$ to form an equation in k only, so +/-1/8 or +/-8 must have been used. Allow for Y downwards ie -Y/X, consistent with first use of their Y	
A1	Correct value for k. Must be **exact**.	
	N.B For X and Y allow use of $R\cos\theta$ and $R\sin\theta$ or N and μN	

QUESTION NUMBER	SCHEME	MARKS
7	N.B. throughout this question refer to diagram for the direction of speeds and then apply to equations. N.B. Correct mass-speed pairings are needed for all M marks	
		
7(a)	CLM	M1
	$2m(2u) = 2m(-v) + 3m(w)$	A1
	Use of impact law	M1
	$e(2u) = w + v$	A1
	$w = \frac{4u}{5}(e+1)$ *	A1*
		(5)
7(b)	Find an expression involving v , e and u	M1
	Correct expression Eg $v = \frac{2u}{5}(3e-2)$	A1
	Use $v > 0$ to form an inequality in e, $\Rightarrow \quad \frac{2}{3} < e \leq 1$	A1
		(3)
7(c)	Use of Impulse-momentum	M1
	$\frac{108mu}{25} = 3m \times \frac{4u}{5}(e+1)$	A1
	$e = \frac{4}{5}$ *	A1*
		(3)
7(d)		
	$v = 0.16u$, 4/25u Allow +/-	B1
	Use of CLM with their v $3m(1.44u) = 3m(-x) + 5m(y)$ $3m\left(\frac{4u}{5}(e+1)\right) = 3m(-x) + 5m(y)$	M1

	Use of impact law with their v $0.8(1.44u) = x + y$ $e\left(\frac{4u}{5}(e+1)\right) = x + y$	M1
	Correct expression $x = 0.18u$ o.e.	A1
	Compare the speed of P after the first collision with the speed of Q after the second collision. ($v = 0.16u$ and $x = 0.18u$)	dM1
	Since $0.18u > 0.16u$ a third collision will occur (between P and Q)	A1
		(6)
		(17)
	Notes for question	
7(a)		
M1	Equation for CLM. Dimensionally correct, all terms required. Condone sign errors.	
A1	Correct unsimplified equation.	
M1	Use of impact law. Condone sign errors but must be used the right way round.	
A1	Correct unsimplified equation, signs consistent with CLM.	
A1*	Obtain given answer from correct working. Must be factorised with $(e+1)$ for this mark. Allow $(1+e)$	
7(b)		
M1	Find an expression involving their v_p after the first collision with u and e only for their direction	
A1	Correct unsimplified expression for v_p after the first collision with u and e for their direction.	
A1	Use the direction of P and their expression for v to form a correct inequality in e, both ends required.	
7(c)		
M1	Use of impulse-momentum equation. Dimensionally correct, condone sign errors.	
A1	Correct unsimplified equation.	
A1*	Obtain given answer from complete and correct working. At least one line of working form equation to answer as a 'Show that'	
7(d)		
B1	Correct expression seen for speed of Q after the first collision. Allow $-0.16u$,$-4/25u$	
M1	Form relevant CLM equation using given answer from (a). Dimensionally correct, all terms required. Condone sign errors. No need for e to be replaced.	
M1	Use of impact law with given answer from (a). Condone sign errors but must be used the right way round. No need for e to be replaced.	

A1	Correct expression from correct working for the speed and direction of Q after the second collision, e must be replaced. Allow +/- answer o.e	
dM1	Compare the speed of P after the first collision with the speed of Q after the second collision ($v = 0.16u$ and $x = 0.18u$) Dependent on two previous M marks. Velocities must have been found in terms of u prior awarding this mark	
A1	Cso. Since $0.18u > 0.16u$ a second collision could occur between P and Q	
	N.B. if all that is seen is '. ($v = 0.16u$ and $x = 0.18u$) and then so second collision'. This is M0A0 as no comparison has occurred.	