Question Number	Scheme	Marks
1(a)	$\int k(3-t^2)\mathrm{d}t$	M1
	$= k(3t - \frac{1}{3}t^3) + (C)$	A1
	$t = 0,\ v = 0 \Rightarrow C = 0$ **and** $t = 1.5,\ v = 13.5$ **OR** $\left[k(3t - \frac{1}{3}t^3)\right]_0^{1.5} = 13.5$ $\Rightarrow k(3\times1.5 - \frac{1}{3}\times1.5^3) = 13.5 \Rightarrow k = 4$*	A1*
		(3)
1(b)	$s = \int 4(3t - \frac{1}{3}t^3)\mathrm{d}t$	M1
	$s = 4(3\times\frac{1}{2}t^2 - \frac{1}{3}\times\frac{1}{4}t^4) = \frac{1}{3}t^2(18-t^2) + D$ **and** $t = 0,\ s = 0 \Rightarrow D = 0$ **OR** $s = \left[4(3\times\frac{1}{2}t^2 - \frac{1}{3}\times\frac{1}{4}t^4)\right]_0^t$ so $s = \frac{1}{3}t^2(18-t^2)$ * Accept any equivalent factorised form e.g. $s = \frac{(18-t^2)t^2}{3}$	A1*
		(2)
1(c)	$v = 0 \Rightarrow (k)(3t - \frac{1}{3}t^3) = 0$	M1
	$t = 3$	A1
	When $t = 3$, $s = 27$	M1
	Total distance = 54 (m)	A1
		(4)
	Notes for question 1	**(9)**
1(a)	M1 Integrate a wrt t, with both powers increasing by 1	
	A1 Correct integral	
	A1* $k = 4$ correctly obtained. $t = 0$ and $v = 0$ must be referred to but do not need to be actually substituted in. We must see the substitution of 1.5 and 13.5	
1(b)	M1 Integrate *their* v wrt t, with both powers increasing by 1, where v has come from a valid attempt at an integral of a. **N.B.** Allow without k being substituted.	
	A1* Given answer correctly obtained including "$s =$ " Must see reference to $t = 0$, $s = 0$ but do not need to be actually substituted in.	
1(c)	M1 Equate their v to 0 and solve for t	
	A1 cao	
	M1 Put their non-zero t, which must have come from $v = 0$, into s	

Question Number	Scheme	Marks
	A1 cao	
	N.B. $t = 3$ could come from a correct sketch of the graph of their v	

2.	$\frac{\mathrm{d}}{\mathrm{d}t}(4t^{\frac{1}{2}}\mathbf{i}-3t\mathbf{j})$	M1
	$2t^{-\frac{1}{2}}\mathbf{i}-3\mathbf{j}$	A1
	$t=4$: $\mathbf{i}-3\mathbf{j}$	M1
	$(6\mathbf{i}-3\mathbf{j})=3(\mathbf{v}-(\mathbf{i}-3\mathbf{j}))$	M1
	$\mathbf{v}=3\mathbf{i}-4\mathbf{j}$	A1
	Speed $=\sqrt{3^2+(-4)^2}=5\ (\mathrm{m\,s^{-1}})$	M1A1
		(7)
	Notes for question 2	
	N.B. Column vectors are acceptable throughout.	
2.	M1 for differentiating **r** wrt to t with both powers decreasing by 1, must be a vector. M0 if **i** or **j** is missing and never reappear(s).	
	A1 Correct vector	
	M1 for putting t = 4 in their **v,** allow a slip, must have **attempted** to differentiate e.g. $\mathbf{v}=\frac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$ seen.	
	M1 for use of impulse-momentum (M0 if g included or 3 missing) to form an equation in **v** only using their **u**, which must have come from an attempt at finding a **velocity** at t = 4. M0 if they use **r** at t = 4. Condone $(6\mathbf{i}-3\mathbf{j})=3((\mathbf{i}-3\mathbf{j})-\mathbf{v})$ and a slip.	
	A1 correct **v,** seen or implied**.**	
	M1 Use of Pythagoras on their **v**	
	A1 cao from a **correct v**	

3(a)	arc AB arc CD $AC+DB$ L Length : $\pi(2a)$ πa $2a$ $3\pi a+2a$ (mass) or ratios: 2π π 2 $3\pi+2$	B1
	Distance : $\frac{4a}{\pi}$ $\frac{2a}{\pi}$ 0 d from AB	B1
	$\pi(2a)\times\frac{4a}{\pi}-\pi a\times\frac{2a}{\pi}=(3\pi a+2a)d$	M1A1
	$*\,(d=)\frac{6a}{(3\pi+2)}$ **N.B.** Accept any equivalent form with whole numbers.	A1*
		(5)
3(b)	$\tan OAG\ (\alpha) = \dfrac{\frac{6a}{(3\pi+2)}}{2a}=\dfrac{3}{(3\pi+2)}$	B1
	$\tan\theta=\tan(45^o-\alpha)$ **or** $\tan(\theta+\alpha)=\tan 45^o$ **or** $\tan\alpha=\tan(45^o-\theta)$	M1
	$\tan\theta=\dfrac{1-\tan\alpha}{1+\tan\alpha}$ $\dfrac{\tan\theta+\tan\alpha}{1-\tan\theta\tan\alpha}=1$ $\tan\alpha=\dfrac{1-\tan\theta}{1+\tan\theta}$	**D**M1
	Substitute for $\tan\alpha$ e.g. $\tan\theta=\dfrac{1-\frac{3}{(3\pi+2)}}{1+\frac{3}{(3\pi+2)}}$	DM1
	$\tan\theta=\dfrac{3\pi-1}{3\pi+5}$ (must have π's and integers)	A1
	OR	
	Let F be on AE where GF is perpendicular to AE.	
	$GF=GE\sin 45^o$	B1
	$\tan\theta=\dfrac{GF}{AF}=\dfrac{GE\sin 45^o}{AE-GE\cos 45^o}$	M1
	$=\dfrac{(2a-\bar{x})\sin 45^o}{2a\sqrt{2}-(2a-\bar{x})\sin 45^o}$	**D**M1
	$=\dfrac{(2a-\bar{x})}{(2a+\bar{x})}$ where $\bar{x}=\dfrac{6a}{(3\pi+2)}$ is substituted in.	DM1
	$=\dfrac{3\pi-1}{3\pi+5}$	A1
		(5)
		(10)
	Notes for question 3	

3(a)	**N.B.** If they treat it as a lamina, can score max B0B0M1A0A0*	
	B1 Mass (length) ratios	
	B1 Distances from *AB* or a parallel axis	
	M1 Moments about *AB* or parallel axis, dimensionally correct, condone sign errors, using their 'masses' and distances, including all terms.	
	A1 Correct unsimplified equation **N.B**. Condone missing brackets on RHS here but penalise the A1*	
	A1* Given answer correctly obtained with no errors seen **N.B.** Need to see reference to *AC* and *DB*, either in the table or in the equation**.**	
3(b)	B1 Correct unsimplified expression for tan *OAG*, seen or implied **N.B.** B0 if they have *OAG* = θ	
	M1 Correct method seen or implied. May see arctan1 instead of 45° **N.B.** If their first line of working is: $\tan\theta = \tan 45^o - \tan\alpha$ oe, treat as a correct method but wrong formula.	
	DM1 Dependent on previous M for use of a correct formula used to give an equation in $\tan\theta$ and $\tan\alpha$ only	
	DM1 Dependent on previous M for substitution for **their** $\tan\alpha$ to give an equation in $\tan\theta$ only	
	A1 cao. Must be simplified.	

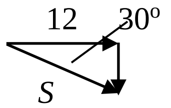
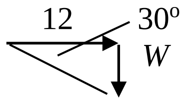
4(a)	$F=\dfrac{20000}{V}$	M1
	$F-750g\sin\alpha-200=0$	M1
	$\dfrac{20000}{V}-750g\sin\alpha-200=0$	A1
	Speed = 16 ($\mathrm{m\,s^{-1}}$)	A1
		(4)
4(b)	$D-750g\sin\alpha-200=750a$	M1
	$\dfrac{20000}{10}-750g\sin\alpha-200=750a$	A1A1
	$a=1$ ($\mathrm{m\,s^{-2}}$)	A1
		(4)
4(c)	$\frac{1}{2}\times750\times10^2-750gh=200d$	M1
	$\frac{1}{2}\times750\times10^2-750gd\sin\alpha=200d$ **OR** $\frac{1}{2}\times750\times10^2-750gh=200\times\frac{h}{\sin\alpha}$	A1A1
	$d=30$ (m)	A1
		(4)
		(12)
	Notes for question 4	
4(a)	M1 for use of $P=Fv$, condone wrong number of 0's	
	M1 for equation of motion with correct terms, condone sign errors and sin/cos confusion, F does not need to be substituted	
	A1 Correct equation in V and α	
	A1 cao **N.B.** Allow use of $-F$ and/or $-V$ throughout.	
4(b)	M1 for equation of motion with correct terms, condone sign errors and sin/cos confusion, D does not need to be substituted.	
	A1 correct equation in a only with at most one error	
	A1 correct equation in a	
	A1 cao	
4(c)	M1 for work-energy equation, dimensionally correct, with correct terms, condone sign errors and allow with h and d **N.B**. Treat use of 16 instead of 10 an A error. **N.B.** M0 for $\frac{1}{2}\times750\times10^2-750gh=200h$	
	A1 correct equation in d only or h only with at most one error	
	A1 correct equation in d only or h only	
	A1 cao	

5(a)	$\rightarrow u$ $\rightarrow 0$ $P\ (2m)$ $Q\ (m)$ $\rightarrow v_Q$ $\rightarrow v_P$ $\rightarrow v_Q$ $fv_Q \leftarrow$	
	CLM: $2mu = 2mv_P + mv_Q$	M1A1
	NEL: $eu = -v_P + v_Q$	M1A1
	$(v_Q =)\ \dfrac{2(1+e)u}{3}$ *	A1*
		(5)
5(b)	e.g. $v_P = \dfrac{2(1+e)u}{3} - eu \quad \left(= \dfrac{u}{3}(2-e)\right)$	B1
	KE After $= \dfrac{1}{2}\times 2m\left(\dfrac{u}{3}(2-e)\right)^2 + \dfrac{1}{2}m\left(\dfrac{2(1+e)u}{3}\right)^2$	M1A1
	KE Loss $= \dfrac{1}{2}\times 2mu^2 -$ their KE after	DM1
	$= \dfrac{1}{3}(1-e^2)mu^2$ so $k = \dfrac{1}{3}$	A1
		(5)
5(c)	$\dfrac{8mu}{9} = m\times\dfrac{2(1+e)u}{3}$ **OR** $-\dfrac{8mu}{9} = 2m\left(\dfrac{u}{3}(2-e)-u\right)$	M1
	$e = \dfrac{1}{3}$	A1
		(2)
5(d)	$\dfrac{2(1+e)uf}{3}$ seen or implied, e does not need to be substituted.	B1
	$\dfrac{2\left(1+\text{"}\frac{1}{3}\text{"}\right)uf}{3} =$ their speed of P, with their value of e used to give an equation in f **only**.	M1
	$f = \dfrac{5}{8}$ or 0.625	A1
		(3)
		(15)
	Notes for question 5	
5(a)	**N.B.** Mark CLM equation first.	
	M1 for a CLM equation, dimensionally correct with correct no. of terms, condone sign errors, consistent extra g's or cancelled m's	
	A1 for a correct equation	
	M1 for a NEL equation, with e on the correct side, condone sign errors	
	A1 for a correct equation, consistent with the CLM equation.	
	A1* for given answer correctly obtained, with at least one line of intermediate working. **N.B.** Allow any fully factorised equivalent form.	
5(b)	B1 for a correct unsimplified expression in e and u for v_P seen or	

	implied.	
	M1 for correct unsimplified expression, using **their** v_P and the **given** v_Q for KE after (must be adding the KE's)	
	A1 for a correct unsimplified expression for the KE After	
	DM1 for $\left(\frac{1}{2}\times 2mu^2 -\text{ their KE after}\right)$ using their v_P and the **given** v_Q, condone Final KE – Initial KE.	
	A1 Accept 0.33 or better. **N.B.** Must be from correct working.	
5(c)	M1 for a **correct** impulse-momentum equation for either Q or P i.e. do NOT condone sign errors.	
	A1 Accept 0.33 or better.	
5(d)	B1 cao	
	M1 for equating their speeds of P and Q, with their e substituted, to give an equation **in *f* only**, allow slip when substituting in their e value, provided the method is clear. **N.B**. Must be using a value of e where $0 < e \leqslant 1$	
	A1 Accept 0.63	

6(a)	M(A), $S\times 1.5a = mga\cos\theta$	M1A1
	$S = \dfrac{2mg\cos\theta}{3}$ * **N.B.** Allow RHS in any equivalent form with the same terms in any order.	A1*
		(3)
6(b)	$V = mg - S\cos\theta$	M1A1
	$*V = \dfrac{mg}{3}(3-2\cos^2\theta)$	A1*
		(3)
6(c)	$\dfrac{4}{7}V$ seen or implied	B1
	Horizontal: $F = S\sin\theta$ Other possible equations: Perp to rod: $F\cos\theta + V\sin\theta = mg\sin\theta$ Parallel to rod: $F\sin\theta + mg\cos\theta = V\cos\theta + S$ M(B): $F\times 2a\sin\theta + mga\cos\theta = V\times 2a\cos\theta + S\times 0.5a$ M(C): $F\times 1.5a\sin\theta + mg\times 0.5a\cos\theta = V\times 1.5a\cos\theta$ M(G): $Fa\sin\theta + S\times 0.5a = Va\cos\theta$	M1A1
	e.g. $\dfrac{4}{7}\times\dfrac{mg}{3}(3-2\cos^2\theta) = \dfrac{2mg\cos\theta}{3}\times\sin\theta$	DM1
	Divide by $\cos^2\theta$ to produce an equation in $\tan\theta$	**DM**1
	$6\tan^2\theta - 7\tan\theta + 2 = 0$	A1
		(6)
		(12)
	Notes for question 6	
6(a)	M1 for moments about A equation, dimensionally correct, correct no. of terms, condone sin/cos confusion and sign errors **N.B.** M0 if a's missing	
	A1 for a correct equation (allow a different letter for S e.g. R_C provided it's clear that $R_C = S$)	
	A1* for given answer correctly obtained including "$S =$ "but not necessarily in the final line of working..	
6(b)	M1 for resolving vertically, correct no. of terms, condone sin/cos confusion and sign errors	
	A1 for a correct equation (allow a different letter for V e.g. R_A provided it's clear that $R_A = V$)	
	A1* for obtaining the given answer from fully correct working including " $V =$ .." but not necessarily in the final line of working. **N.B.** If S is never seen, can score max M1A1A0*	
6(c)	**N.B.** The first 3 marks below can be earned if the 'equations' appear in (a) or (b).	

	B1 $\frac{4}{7}V$ seen or implied	
	M1 for another equation: either resolving or taking moments, correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors	
	A1 for a correct equation	
	DM1, dependent on previous M, for substituting for V and S and using $F=\frac{4}{7}V$ to give an equation in θ and m or g or both only	
	DM1, dependent on previous M, for dividing by $\cos^2\theta$ and using $\sec^2\theta = 1+\tan^2\theta$ to produce an equation in $\tan\theta$	
	A1 for answer, or an integer multiple of answer, correctly obtained **N.B.** Allow the terms in a different order.	

7(a)	Use of conservation of energy	M1
	$\frac{1}{2}m\times 20^2-\frac{1}{2}mv^2=mg\times 11$	A1
	$\frac{1}{2}m\times 20^2-\frac{1}{2}m\left(V^2+(2V)^2\right)=mg\times 11$	A1
	$V=6$ *	A1*
		(4)
7(b)	At A,  $S=\frac{12}{\cos 30^o}$ $(8\sqrt{3})$	M1A1
	$\frac{1}{2}m\times 20^2-\frac{1}{2}mS^2=mgH$ (from O to A) OR $\frac{1}{2}mS^2-\frac{1}{2}m\times(6^2+12^2)=mgh$ (from ht. 11m to A)	M1A1
	Solve for H or h (0.6)	DM1
	H = 10 m (2sf)	A1
		(6)
	OR	
	At A,  $W=12\tan 30^o$ $(4\sqrt{3})$ (**OR**: $12=S\cos 30^o$ **AND** $W=S\sin 30^o$)	M1A1
	$W^2=\left(20\times\frac{4}{5}\right)^2-2gH$ (from O to A) **OR** $W^2=\left(20^2-12^2\right)-2gH$ (from O to A) **OR** $W^2=6^2-2gs$ (from ht. 11m to A) **N.B.** All 3 equations are using positive UP	M1A1
	Solve for H (10.4) OR $s=-0.6$ so height is $11-0.6=10.4$	DM1
	Height is 10 m (2sf)	A1
		(6)
		(10)
	Notes for question 7	
7(a)	M1 for an energy equation, dimensionally correct with correct terms, condone sign errors **N.B.** M0 if not using energy. **N.B.** If clearly using V, must include both horizontal and vertical cpts.	
	A1 correct equation in v May find v first: $(v^2=180)$	
	A1 correct equation in V then $V^2+(2V)^2=180$	
	A1* for correct given answer correctly obtained, by putting g = 10,	

	cancelling m's and solving for V.	
7(b)	M1 for using perpendicularity at A to find S, the speed at A Condone sin/cos confusion.	
	A1 for correct unsimplified speed	
	M1 for complete method using energy to find an equation in S and H, or S and h, correct no. of terms, condone sign errors	
	A1 correct equation **without *S* replaced**	
	DM1, dependent on both M marks, solve for H	
	A1 cao	
	OR	
	M1 for using perpendicularity at A to find W, the vertical velocity component at A. Condone $30^o / 60^o$ confusion.	
	A1 for correct unsimplified vertical component. Allow + or $-$.	
	M1 for complete method using *suvat* to find an equation in W and H, condone sign errors, **N.B.** They may find t first and then use that to form this equation.	
	A1 correct equation **without *W* replaced**	
	DM1, dependent on both M marks, solve for H	
	A1 cao	