Question Number	Scheme	Marks
6 **(a)**	$\frac{1}{2}mv^2 - \frac{1}{2}m\left(\frac{ag}{5}\right) = mga(1-\cos\theta)$	M1A1A1
	$v^2 = 2ag + \frac{ag}{5} - 2ag\cos\theta = \frac{ag}{5}(11 - 10\cos\theta)$ *	A1 (4)
(b)	$mg\cos\alpha \ (-R) = m\frac{v^2}{a}$	M1A1
	$g\cos\alpha = \frac{g}{5}(11 - 10\cos\alpha)$ or sub $\cos\alpha = \frac{v^2}{ag}$ in energy equation	M1 A1
	$\cos\alpha = \frac{11}{15}$	
	P leaves the sphere with speed $\sqrt{\frac{ag}{5}\left(11 - \frac{22}{3}\right)} = \sqrt{\frac{11ag}{15}}$	DM1A1 (6)
(c)	Horiz comp = $\sqrt{\frac{11ag}{15}} \times \cos\alpha = \sqrt{\frac{11ag}{15}} \times \frac{11}{15}$	M1
	By cons of energy from top: $2mag = \frac{1}{2}mV^2 - \frac{1}{2}m\frac{ag}{5}$	M1
	$V^2 = \frac{21ag}{5}$	A1
	$\cos\theta = \sqrt{\frac{11ag}{15}} \times \frac{11}{15} \times \sqrt{\frac{5}{21ag}} = \sqrt{\frac{11}{63}} \times \frac{11}{15} = 0.30642...$	M1
	$\theta = 72.155...$ Accept 72° or better	A1 (5)
		[15]
(a)	M1 **Energy** equation from start to general position - must have 2 KE terms and a loss of PE A1 LHS correct A1 RHS correct A1cso re-arrange to the given result	

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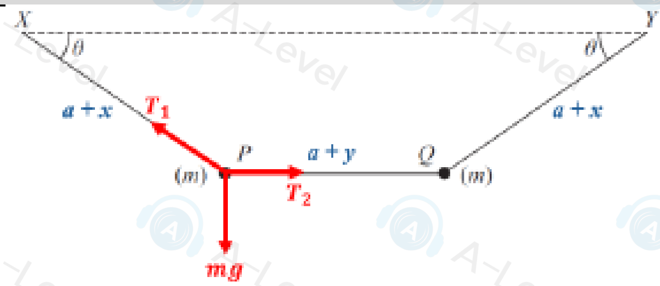
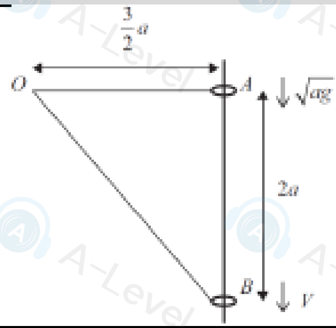
2		
	First relevant force equation	M1
	Correct unsimplified equation Relevant force equations: • Horiz $T_1\cos\theta = T_2$ Vert $T_1\sin\theta = mg$ or $2T_1\sin\theta = 2mg$ • // $T_1 = T_2\cos\theta + mg\sin\theta$ Perp $T_2\sin\theta = mg\cos\theta$ (accept $T_2\tan\theta = mg$) • Lami $\dfrac{T_2}{\sin(90+\theta)} = \dfrac{mg}{\sin(180-\theta)} = \dfrac{T_1}{\sin 90}$ $\dfrac{T_2}{\cos\theta} = \dfrac{mg}{\sin\theta} = \dfrac{T_1}{\sin 90}$ It may be useful to note the simplified expressions for tensions are $T_1 = \dfrac{5mg}{3}$, $T_2 = \dfrac{4mg}{3}$ but need not be seen explicitly.	A1
	Second relevant force equation	M1
	Correct unsimplified equation	A1
	Hooke's Law for either tension $T_1 = \dfrac{\frac{20mg}{7}x}{a}$ or $T_2 = \dfrac{\frac{20mg}{7}y}{a}$	B1
	Solve their relevant force equation(s) and HL to find x or y	M1
	$x = \dfrac{7a}{12}$, $y = \dfrac{7a}{15}$	A1 A1
	$(XY =)\ 2(a+x)\cos\theta + (a+y)$	DM1
	$= 4a$	A1
		(10)
	Notes for question 2	
M1	First relevant force equation. All required forces present with no extras, condone sign errors and sin/cos confusion. M0 if $T_{XP} = T_{PQ}$ or $T_{PQ} = T_{QY}$. Condone W instead of mg.	
A1	Correct unsimplified equation. Condone W instead of mg.	

Question Number	Scheme	Marks
3		
	Attempt to find final extension: $\sqrt{\left(\left(\frac{3a}{2}\right)^2+(2a)^2\right)}\ -a$	M1
	Method to find at least one expression for EPE	M1
	Two correct expressions for EPE (final and initial) $\frac{mg}{2a}\left(\frac{3a}{2}\right)^2,\ \frac{mg}{2a}\left(\frac{a}{2}\right)^2$	A1
	GPE Loss = $mg\times 2a$	B1
	Use of conservation of mechanical energy	M1
	$mg\times 2a+\frac{1}{2}mag+\frac{mg}{2a}\left(\frac{a}{2}\right)^2=\frac{1}{2}mV^2+\frac{mg}{2a}\left(\frac{3a}{2}\right)^2$ $\left(2mga+\frac{1}{2}mag+\frac{mga}{8}=\frac{1}{2}mV^2+\frac{9mga}{8}\right)$	A1
	$(V=)\ \sqrt{3ag}$	A1
		(7)
	Notes for question 3	
M1	Complete method to find the final extension (their *OB* – *a*). May see use of the 3,4,5 triangle or Pythagoras to find *OB*. May be implied by a correct final extension.	
M1	Method using EPE formula at least once. EPE must have the form $\frac{\lambda x^2}{ka}$ where λ is modulus of elasticity, x is their extension and k is a constant (condone $k=1$).	
A1	Two correct expressions for EPE	
B1	GPE term seen or implied	
M1	Use of the principle of conservation of mechanical energy. All required terms present and of the correct structure with no extras (2 EPE, 2KE, GPE). Condone sign errors. Note there are different rearrangements. For example, Initial = Final $\quad mg\times 2a+\frac{1}{2}mag+\frac{mg}{2a}\left(\frac{a}{2}\right)^2=\frac{1}{2}mV^2+\frac{mg}{2a}\left(\frac{3a}{2}\right)^2$	

Question Number	Scheme	Marks
5(a)	$0.4\ddot{x} = -\frac{k}{x^2}$	M1
	$0.4v\frac{dv}{dx} = -\frac{k}{x^2}$	M1
	$0.2v^2 = \int -kx^{-2}dx$	
	$0.2v^2 = \frac{k}{x}\ (+c)$	dM1A1ft
	$x = 2,\ v = 5 \Rightarrow 5 = \frac{k}{2} + c$	dM1
	$x = 5,\ v = 2 \Rightarrow 0.8 = \frac{k}{5} + c$	A1
	$4.2 = k\left(\frac{1}{2} - \frac{1}{5}\right)$	dM1
	$k = 14$	A1 cso (8)
(b)	$c = 5 - 7 = -2$	
	$0.2v^2 = \frac{14}{x} - 2$	M1A1ft
	$v = 0 \Rightarrow x = 7$	dM1A1 cso(4) [12]

(a)M1 Form an equation of motion, minus sign may be missing.

M1 Writing the acceleration in the form $v\frac{dv}{dx}$ These two M marks may be awarded together.

Can be implied by $\frac{1}{2}mv^2$ after integrating.

dM1 Attempt to integrate both sides of the equation wrt x Depends on both M marks above

A1ft Correct integration with correct signs. Constant may be missing. Follow through a missing minus sign.

NB For the first 4 marks m or 0.4 may be used

dM1 Substitute either $x = 2,\ v = 5$ or $x = 5,\ v = 2$ Depends on all M marks above.

A1 Both substitutions made and 2 correct equations in k and c found

dM1 Solve these simultaneous equations to obtain a value for k. Solving 1 linear equation (as c was omitted) scores M0. Depends on all M marks above.

A1 Correct value of k obtained.

(b)

M1 Obtain a value of c and form an expression for v^2. (Often seen in (a); award marks if (b) is attempted.)

A1ft Correct expression for v^2. Follow through $k = -14$ which gives $c = -5$

dM1 Substitute $v = 0$ in their expression for v^2 and solve for x

A1cso Correct value of x obtained.