

Question Number	Scheme	Marks	Notes
2a			
	Resolve vertically	M1	Need all terms. Dimensionally correct. Condone sign error and sine / cosine confusion
	$R + T \sin \theta = mg$ $\left(R + \frac{4}{5}T = mg \right)$	A1	Correct unsimplified equation
	Equation for circular motion	M1	Dimensionally correct. Condone sign error and sine / cosine confusion
	$T \cos \theta = m \times 3a\omega^2$ $\left(\frac{3}{5}T = m \times 3a\omega^2 \right)$	A1	Correct unsimplified equation
	Substitute $\omega = \frac{1}{4} \sqrt{\frac{g}{a}}$ and obtain R	M1	As far as an equation in R, m and g
	$R = \frac{3mg}{4}$	A1	Or exact equivalent
		(6)	
2b	Use $mg - T \sin \theta > 0$ to obtain ω	M1	
	$\omega < \frac{1}{2} \sqrt{\frac{g}{a}} *$	A1*	Given answer from correct working
		(2)	
		[8]	

Question Number	Scheme	Marks	Notes
3a	Use $\frac{dv}{dt} = \frac{dv}{dx} \times \frac{dx}{dt}$	M1	Use of chain rule or $\frac{d}{dx} \left(\frac{1}{2}v^2 \right)$
	Correct method for $\frac{dv}{dx}$	M1	Correct quotient rule or equivalent (allow one slip)
	Correct derivative	A1	e.g. $\frac{8x}{3+x^2} \times \frac{8(3+x^2)-16x^2}{(3+x^2)^2}$
	Substitute $x = 3$ into their derivative	DM1	Dependent on the first M1
	Obtain $\frac{2}{3}(\text{ms}^{-2})$	A1	Must be positive. Accept 0.67 or better
		(5)	
3b	$\frac{dx}{dt} = \frac{8x}{3+x^2}$	M1	Use of $v = \frac{dx}{dt}$
	$\int \frac{3+x^2}{8x} dx = \int 1 dt \quad \left(= \int \frac{3}{8x} + \frac{x}{8} dx \right)$	M1	Separate and attempt integration (as far as 2 terms of the correct form)
	$\frac{3}{8} \ln x + \frac{1}{16} x^2 = t (+C)$	A1	Correct integration. Allow if "+ C" not seen
	Use $x = 1$ when $t = 2$ to obtain C	M1	In an expression containing at least 2 of $p \ln x, qx^2, rt$
	$t = \frac{5}{2} + \frac{3}{8} \ln 3$	A1	Or exact equivalent
		(5)	
		[10]	

Question Number	Scheme				Marks	Notes	
4a		H-sphere	Cylinder	Cone	S	B1 B1	
	Mass	$18\pi a^3$	$81\pi a^3$	$18\pi a^3$	$81\pi a^3$		
	To O	$9a + \frac{9a}{8}$	$\frac{9a}{2}$	$\frac{3a}{2}$	d		
	Moments about a horizontal axis through O				M1	Or a parallel axis. Dimensionally consistent. Need all terms. Condone sign errors.	
	$18 \times \frac{81a}{8} + 81 \times \frac{9a}{2} - 18 \times \frac{3a}{2} = 81d$				A1	Correct unsimplified equation for their axis.	
	$\frac{2079}{4}a = 81d \Rightarrow d = \frac{77a}{12}$ *				A1*	Obtain given answer from correct working	
					(5)		
4b	Moments about toppling point, or equivalent complete method				M1	Dimensionally consistent. Using $9a$ and $3a$	
	$9aH = 3aW \Rightarrow H = \frac{1}{3}W$				A1		
					(2)		
					[7]		
5	Moments about B				M1	Dimensionally correct. Condone sine / cosine confusion	
	$Mg \times \frac{3l}{2} \sin 2\theta = T \cos \theta \times 3l$				A1 A1	Unsimplified equation in T or <i>their</i> T with at most one error. Correct unsimplified equation in T or <i>their</i> T	
	$T = \frac{5Mgx}{8 \times 2l}$				M1	Correct use of Hooke's Law seen or implied.	
	$Mg \times \frac{3l}{2} \times 2 \sin \theta \cos \theta = \frac{5Mgx}{16l} \cos \theta \times 3l$ $\left(\sin \theta = \frac{5x}{16l} \right)$				M1	Substitute for T and use double angle formula to obtain equation in x , l and θ	
	$(\sin \theta =) \frac{l + \frac{1}{2}x}{3l} = \frac{5x}{16l}$				M1	Use trig to form an equation in x and l	
	$\Rightarrow 16l + 8x = 15x \Rightarrow x = \frac{16l}{7}$ *				A1*	Obtain given answer from correct working.	
					(7)		
					[7]		

Question Number	Scheme	Marks	Notes
6a	Moments about the y-axis	M1	Use of $\int xy dx$. Limits not needed. Powers going up by 1
	$\int_{-2}^4 \frac{1}{4}x^3 + 2x dx = \left[\frac{1}{16}x^4 + x^2 \right]_{-2}^4$	A1	Correct integration and correct limits seen
	$\bar{x} = \frac{\left[\frac{1}{16}x^4 + x^2 \right]_{-2}^4}{18}$	M1	Use of $\bar{x} = \frac{\int xy dx}{18}$
	$= \frac{27}{18} = \frac{3}{2}$ *	A1*	Obtain given answer from correct working
		(4)	
6b	Moments about the x axis	M1	$\int \frac{1}{2}y^2 dx = \frac{1}{2} \int \frac{x^4}{16} + x^2 + 4 dx$ Correct squaring. Powers going up by 1. Condone if the half is missing.
	$\frac{1}{2} \left[\frac{x^5}{80} + \frac{x^3}{3} + 4x \right]_{-2}^4$	A1	Correct integration and correct limits seen or implied
	$\bar{y} = \frac{\frac{1}{2} \left[\frac{x^5}{80} + \frac{x^3}{3} + 4x \right]_{-2}^4}{18}$	M1	Use of $\bar{y} = \frac{\frac{1}{2} \int y^2 dx}{18}$
	$\bar{y} = \frac{153}{5 \times 18} = \frac{17}{10}$ *	A1*	Obtain given answer from correct working
		(4)	
6c	Correct use of trig to find tangent of a relevant angle	M1	e.g. $\tan \theta = \frac{4 - \frac{3}{2}}{6 - \frac{17}{10}}$
	$\tan \theta = \frac{25}{43}$	A1	
		(2)	
		[10]	

Question Number	Scheme	Marks	Notes
7a	$\text{EPE at } B = \frac{18Mg \times (2a)^2}{5 \times 6a}$	M1	Correct form for EPE seen or implied. Allow if correct formula stated but slip in substitution.
	Work-energy equation	M1	Need all terms. Dimensionally correct. Condone sign errors
	$Mg \times 2a + \frac{1}{2}Mv^2 = \frac{18Mg \times (2a)^2}{5 \times 6a}$	A1	Correct unsimplified equation
	$v = \sqrt{\frac{4ag}{5}}$	A1	Accept exact equivalent or $0.89\sqrt{ag}$ or better
		(4)	
7b	Work-energy equation	M1	Need all terms. Dimensionally correct. Condone sign errors.
	$\frac{18Mg \times 4a^2}{5 \times 6a} = Mg(2a + x) + \frac{18Mg \times x^2}{5 \times 6a}$ or $\frac{1}{2}M \times \text{their } \frac{4ag}{5} = Mgx + \frac{18Mg \times x^2}{5 \times 6a}$ $(3x^2 + 5ax - 2a^2 = 0)$	A1 A1	Unsimplified equation in one unknown length with at most one error Correct unsimplified equation in one unknown length
	$x = \frac{a}{3} \Rightarrow \text{distance from } A = \frac{8a}{3}$	A1	$2.7a$ or better
		(4)	
		[8]	

Question Number	Scheme	Marks	Notes
8a	Conservation of energy from A to general position	M1	Need all terms. Dimensionally correct. Condone sign errors and sine / cosine confusion
	$\frac{1}{2}m \times 4ag + mg \times 4a \cos \theta = \frac{1}{2}mv^2$	A1	Correct unsimplified equation
	Equation for circular motion	M1	Need all terms. Dimensionally correct. Condone sign errors and sine / cosine confusion
	$T - mg \cos \theta = \frac{mv^2}{4a}$	A1	Correct unsimplified equation
	Eliminate v^2 and solve for T	DM1	Dependent on both preceding M marks
	$\frac{mv^2}{4a} = T - mg \cos \theta = mg + 2mg \cos \theta$ $\Rightarrow T = mg(1 + 3 \cos \theta)$ *	A1*	Obtain given answer from correct working.
		(6)	
8b	Substitute $\theta = 0$ in the energy equation	M1	Or equivalent method to obtain the speed
	$4amg + 8amg = mv^2 \Rightarrow v = \sqrt{12ag}$	A1	$3.5\sqrt{ag}$ or better
		(2)	
8c	Conservation of energy from A to C	M1	Or equivalent. Need all terms. Dimensionally correct. Condone sign errors
	$\frac{1}{2}m \times 4ag + mg \times 2a = \frac{1}{2}mv^2$	A1	Correct unsimplified equation
	$w = \sqrt{8ag}$	A1	Or exact equivalent
		(3)	
8d	Speed of $P = 2\sqrt{ag}$	B1	Seen or implied
	Equation of motion: $T + mg = \frac{mv^2}{2a} \left(= \frac{m \times 4ag}{2a} \right)$	M1	Need all terms, with <i>their</i> v substituted. Condone sign errors.
	$T = mg$	A1	cso
		(3)	
		[14]	