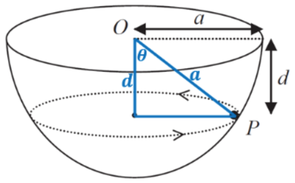
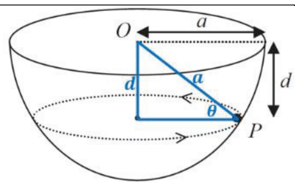
Question Number	Scheme	Marks
	$T\cos\alpha = mg$	M1A1
	$\frac{\lambda a}{4a}\times\frac{3}{5} = mg \Rightarrow \lambda = \frac{20mg}{3}$ *	A1* (4)
1(b)	$T\sin\alpha = kmg$	M1A1
	$\frac{20mg}{3}\times\frac{1}{4}\times\frac{4}{5} = kmg$	M1
	$k = \frac{4}{3}$	A1 (4)
		(8)
	Notes for question 1	
	Mark parts (a) and (b) together	
1(a)		
B1	Use of Hooke's Law	
M1	For a relevant equation in T. Must be dimensionally correct with the correct number of terms, condone sign errors and sin/cos confusion. Eg • Resolve vertically: $T\cos\alpha = mg$ • Parallel to string: $T = kmg\ \sin\alpha + mg\cos\alpha$ • Triangle of forces: $T = \sqrt{(mg)^2 + (kmg)^2}$	
A1	Correct unsimplified equation	
A1*	Given answer obtained from complete and correct working. Must include a line of working before reaching the given answer.	
1(b)		
M1	For a relevant equation in k (a second equation). Must be dimensionally correct with the correct number of terms, condone sign errors and sin/cos confusion. Eg • Resolve horiz: $T\sin\alpha = kmg$ • Perp to string: $mg\sin\alpha = kmg\cos\alpha$ • Triangle of forces: $\tan\alpha = \frac{kmg}{mg} = \frac{4}{3}$	
A1	Correct unsimplified equation	
M1	Complete method to produce an equation in k only (replace T and trig)	
A1	Any equivalent fraction. Accept 1.3 or better	
	Lami: $\frac{T}{\sin 90} = \frac{kmg}{\sin(180-\alpha)} = \frac{mg}{\sin(90+\alpha)}$ M0 for an EPE approach	

Question Number	Scheme		Marks
	 $\sin\theta = \frac{\sqrt{a^2-d^2}}{a} = \sqrt{\frac{a^2-d^2}{a^2}} = \sqrt{1-\frac{d^2}{a^2}}$	 $\cos\theta = \frac{\sqrt{a^2-d^2}}{a} = \sqrt{\frac{a^2-d^2}{a^2}} = \sqrt{1-\frac{d^2}{a^2}}$	
2(a)	$R\cos\theta = mg$	$R\sin\theta = mg$	M1A1
	$R = \frac{mga}{d}$		A1 (3)
2(b)	$R\sin\theta = \frac{mv^2}{r}$	$R\cos\theta = \frac{mv^2}{r}$	M1A1A1
	$\frac{mga}{d} \times \frac{\sqrt{a^2-d^2}}{a} = \frac{mv^2}{\sqrt{a^2-d^2}}$		DM1
	$v = \sqrt{\frac{g(a^2-d^2)}{d}}$		A1 (5)
			(8)
	Notes for question 2		
2(a)			
M1	Resolve vertically to form an equation with the correct number of terms and the correct structure. Dimensionally correct, condone sign errors and sin/cos confusion		
A1	Correct equation		
A1	Correct answer.		
2(b)			
M1	Form a horizontal equation of motion with the correct number of terms, condone sign errors and sin/cos confusion. Dimensionally correct. Accept $\frac{v^2}{r}$ or $r\omega^2$ for of acceleration. Condone use of *a* for radius at this point but M0 if *a* is used for acceleration.		
A1	Equation with at most one error. An error in the acceleration term is one error (incorrect form of acceleration or radius).		
A1	Correct equation (must use the correct form of acceleration and correct radius).		
DM1	Dependent on previous M. Eliminate *R* and trig to form an equation in *v*, *g*, *a* and *d*		
A1	Correct answer ISW		

Question Number	Scheme	Marks
3(a)	$v\dfrac{\mathrm{d}v}{\mathrm{d}x}=\dfrac{3\sqrt{x+1}}{4}$	M1
	$\dfrac{1}{2}v^2=\dfrac{1}{2}(x+1)^{\frac{3}{2}}\quad(+C)$	M1A1
	$x=15,\ v=8 \Rightarrow C=0$ so $v=(x+1)^{\frac{3}{4}}$ *	A1* (4)
3(b)	$\dfrac{\mathrm{d}x}{\mathrm{d}t}=(x+1)^{\frac{3}{4}}$	M1
	$4(x+1)^{\frac{1}{4}}=t\ (+C)$	M1A1
	$x=15,\ t=0 \Rightarrow C=8$ so $4v^{\frac{1}{3}}=t+8$	M1
	$t=4v^{\frac{1}{3}}-8$	A1 (5)
	OR	
	$\dfrac{\mathrm{d}v}{\mathrm{d}t}=\dfrac{3}{4}v^{\frac{2}{3}}$	M1
	$3v^{\frac{1}{3}}=\dfrac{3}{4}t\ (+C)$	M1A1
	$t=0,\ v=8 \Rightarrow C=6$ so $3v^{\frac{1}{3}}=\dfrac{3}{4}t+6$	M1
	$t=4v^{\frac{1}{3}}-8$	A1 (5)
		(9)
	Notes for question 3	
3(a)		
M1	Set up a differential equation in v and x only M0 if acceleration is $\frac{dv}{dx}$ or $\frac{dv}{dt}$ M0 if there is no differential equation eg starting with $\frac{1}{2}v^2=\int\frac{3\sqrt{x+1}}{4}\,dx$	
M1	Clear attempt to separate variables and integrate acceleration in terms of v and x. At least one of the powers must increase by 1.	
A1	Correct integration, condone missing + C	
A1*	Given answer obtained from complete and correct working. Must include use of the boundary conditions and the initial differential equation. A0 if +C is not dealt with correctly eg If +C is only considered *after* the square root.	
3(b)		
M1	Set up a differential equation in x and t only. Using the given answer in (a).	
M1	Clear attempt to separate the variables and integrate in terms of x and t. At least one of the powers must increase by 1	
A1	Correct integration, condone missing + C	
M1	Use of boundary conditions in an integrated equation and use of (a) to form an equation in v and t. M0 if boundary conditions are not used.	
A1	Correct answer	
	OR	
M1	Set up a differential equation in v and t only	

Question Number	Scheme	Marks
M1	Clear attempt to separate the variables and integrate in terms of v and t. At least one of the powers must increase by 1	
A1	Correct integration, condone missing + C	
M1	Use of boundary conditions in an integrated equation to form an equation in v and t. M0 if boundary conditions are not used.	
A1	Correct answer	

Question Number	Scheme	Marks
4(a)	$a = 3$ (m)	B1
	$\frac{38}{3} = \frac{2\pi}{\omega} \Rightarrow \omega = \frac{3\pi}{19}$	M1A1
	$x = -a\cos\omega t \Rightarrow v = a\omega\sin\omega t$ or similar	M1
	$v = 3 \times \frac{3\pi}{19}\sin\left(\frac{3\pi}{19} \times \frac{95}{60}\right)$	M1
	$= \frac{9\pi\sqrt{2}}{38}$, 1.1, 1.05, 1.052,… (m h^{-1})	A1 (6)
4(b)	$-1.5 = 3\cos\frac{3\pi t}{19}$	M1A1ft
	$t = \frac{38}{9}$ (h)	A1
	Time is 16:13 or 16:14	A1 (4)
		(10)
	Notes for question 4	
4(a)		
B1	$a = 3$ seen or implied	
M1	For use of $T = \frac{2\pi}{\omega}$ to give an equation in ω where $T = 2 \times \frac{19}{3}$ (double the time between 12:00 and 18:20). Condone use of $T = 760$ min or 45600 seconds.	
A1	A correct equation using hrs, min or seconds.	
M1	Form a relevant equation in v and t using their a and ω Eg • $x = -a\cos(\omega t) \Rightarrow v = a\omega\sin(\omega t)$ • $x = a\cos(\omega t) \Rightarrow v = -a\omega\sin(\omega t)$ • $x = a\cos(\omega t) = (2.12\ldots) \Rightarrow v^2 = \omega^2(a^2 - x^2)$	
M1	Use correct equation with an appropriate value of t	
A1	Correct answer, must be positve and must be in metres per hour.	
4(b)		
M1	A complete method to find the required time eg • Use of $-1.5 = a\cos\omega t$ to find required time is $\frac{1}{\omega}\cos^{-1}\left(\frac{x}{a}\right)$ • Use of $1.5 = a\sin\omega t$ to find required time is $\frac{1}{4}\text{Period} + \frac{1}{\omega}\sin^{-1}\left(\frac{x}{a}\right)$ • Use of $1.5 = a\cos\omega t$ to find required time is $\frac{1}{\omega}\cos^{-1}\left(\frac{x}{a}\right)$ subtracted from 18:20	
A1ft	A correct equation, ft on their a and ω $\frac{1}{4}\left(\frac{38}{3}\right) + \frac{1}{\omega}\sin^{-1}\left(\frac{x}{a}\right)$	
A1	A correct t value in hours or minutes or seconds $t = \frac{38}{9}$ (h) , $t = \frac{760}{3}$ (min) $t = 15200$ (s)	
A1	For the correct time . Accept 4.13pm or 4.14 pm or 16:13 or 16:14	

Question Number	Scheme	Marks
5(a)	$\bar{x}=\dfrac{\pi\int_0^{4r} x\left(\frac{1}{4}x\right)^2 \mathrm{d}x}{\frac{4\pi r^3}{3}}$ or $\bar{x}=\dfrac{\pi\int_0^{4r} x\left(r-\frac{1}{4}x\right)^2 \mathrm{d}x}{\frac{4\pi r^3}{3}}$	M1A1
	$=\dfrac{3}{256r^3}\left[x^4\right]_0^{4r}$	A1
	$=3r$*	A1*
		(4)
5(b)	(table below)	B1 B1
	$\left(\frac{4\pi r^3}{3}\times 3r\right)-\left(\pi\left(\frac{1}{2}r\right)^2\times r\right)\left(4r-\frac{1}{2}r\right)=\left(\frac{4\pi r^3}{3}-\pi\left(\frac{1}{2}r\right)^2\times r\right)\bar{y}$	M1A1
	$\bar{y}=\dfrac{75}{26}r$ *	A1*
		(5)
5(c)	$\tan\alpha=\dfrac{r}{4r-\frac{75}{26}r}$	M1A1
	$\tan\alpha=\dfrac{26}{29}$	A1
		(3)
		(12)
	Notes for question 5	
5(a)		
M1	Correct method to find the distance of the centre of mass from vertex or plane face, using $\bar{x}=\dfrac{\pi\int_0^{4r} xy^2\mathrm{d}x}{\frac{4\pi r^3}{3}}$. The formula must be correct but allow a constant multiple if it appears in both numerator and denominator or cancelled π. The y	

Table for 5(b):

	Cone	Cylinder	S
Mass ratio	$\frac{4\pi r^3}{3}$	$\pi\left(\frac{1}{2}r\right)^2\times r$	$\left(\frac{4\pi r^3}{3}-\pi\left(\frac{1}{2}r\right)^2\times r\right)$
	$\frac{4}{3}$	$\frac{1}{4}$	$\frac{13}{12}$
Distance from vertex	$3r$	$\left(4r-\frac{1}{2}r\right)$	$\bar{y}$
Distance from plane face	r	$\frac{1}{2}r$	$\bar{y}$

Question Number	Scheme	Marks
	must be replaced with $y = \frac{1}{4}x$ or $y = r - \frac{1}{4}x$. Condone a gradient of $\pm\frac{r}{h}$ if h is later replaced with $4r$. There must be an attempt to integrate the numerator i.e. the power of x must increase by 1. The denominator of $\frac{4\pi r^3}{3}$ is given in the question. Condone sight of vol $= \pi\int_0^{4r}\left(\frac{1}{4}x\right)^2 \mathrm{d}x$ as denominator. Ignore limits for the method mark.	
A1	Correct equation for the distance of the centre of mass from vertex or plane face. $\bar{x} = \dfrac{\pi\int_0^{4r} x\left(\frac{1}{4}x\right)^2 \mathrm{d}x}{\frac{4\pi r^3}{3}}$ or $\bar{x} = \dfrac{\pi\int_0^{4r} x\left(r-\frac{1}{4}x\right)^2 \mathrm{d}x}{\frac{4\pi r^3}{3}}$ Ignore limits.	
A1	A correct expression for the distance of the centre of mass from vertex or plane face following integration and division by $\frac{4\pi r^3}{3}$. Limits must be correct at this point. $\frac{3}{256r^3}\left[x^4\right]_0^{4r}$ or $\frac{3}{4r^3}\left[\frac{r^2x^2}{2} - \frac{rx^3}{6} + \frac{x^4}{64}\right]_0^{4r}$	
A1*	Given answer obtained from complete and correct working. If distance is found from plane face this must be subtracted to find required distance.	
5(b)		
B1	Correct mass ratios	
B1	Correct distances (for their parallel axis) Ignore signs.	
M1	Form a moments equation with correct number of terms (allow about a parallel axis). Equation must be dimensionally correct (mass ratio × distance).	
A1	Correct unsimplified equation	
A1*	Given answer obtained from complete and correct working. Working should include a line of simplification. The simplification could occur between the moments equation and the given answer or in the initial stage eg in a table.	
5(c)		
M1	Use of tan to obtain an equation for a relevant angle, allow reciprocal $\dfrac{r}{4r - \frac{75}{26}r}$	
A1	For a correct equation, condone reciprocal.	
A1	Correct answer, $\tan\alpha = \frac{26}{29}$ o.e. Must be an exact value for $\tan\alpha$. A0 if they got straight to α.	

Question Number	Scheme	Marks
6(a)	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mgr(1-\cos\theta)$	M1A2
	$mg\cos\theta = \frac{mv^2}{r}$	M1A1
	Eliminate v^2 and solve for $\cos\theta$	M1
	$\cos\theta = \frac{2gr+u^2}{3gr}$ *	A1*
		(7)
6(b)	$\cos\theta = \frac{4}{5}$	B1
	$v^2 = rg\cos\theta \quad \left(v = \sqrt{\frac{4rg}{5}}\right)$	M1
	Horiz cpt at C: $H = v\cos\theta$ $\left(H = \frac{4}{5}\sqrt{\frac{4rg}{5}} = \sqrt{\frac{64rg}{125}}\right)$	
	Vert cpt at C: $V = \sqrt{(v\sin\theta)^2 + 2gr\cos\theta}$ $\left(V = \sqrt{\frac{236rg}{125}}\right)$	
	Speed at C: W where A to C: $\frac{1}{2}m\left(W^2 - \frac{2gr}{5}\right) = mgr$ **OR** B to C: $\frac{1}{2}m\left(W^2 - v^2\right) = mgr\cos\theta$ $\left(W = \sqrt{\frac{12rg}{5}}\right)$	M1 M1
	$\tan\alpha = \frac{V}{H} = \frac{\sqrt{W^2 - H^2}}{H} = \frac{V}{\sqrt{W^2 - V^2}}$	DM1
	$= \frac{\sqrt{59}}{4}$	A1
		(6)
		(13)
	Notes for question 6	
6(a)		
M1	Use conservation of energy to form a dimensionally correct equation. All terms present and no extras. Condone sign errors and sin/cos confusion. Anything that should be resolved has been resolved.	
A1	An unsimplified equation with at most one error.	
A1	A correct unsimplified equation.	
M1	Use N2L to form an equation of motion towards O. Equation must be dimensionally correct. All terms present and no extras. Condone sign errors and sin/cos confusion. Anything that should be resolved has been resolved Allow this mark with or without R.	

Question Number	Scheme	Marks
	Condone $\pm \text{R} + mg\cos\theta = \dfrac{mv^2}{r}$	
A1	Correct equation ($R = 0$ must be used now at some point) A0 if R never becomes 0	
M1	Solve to find an expression for $\cos\theta$ in terms g, r and u	
A1*	Given answer obtained from correct and complete working. Working should include a line with v^2 eliminated before reaching the given answer.	
6(b)		
B1	For $\cos\theta = \dfrac{4}{5}$ seen or implied	
M1	Solve to find v in terms of g, r and θ	
M1	Correct method to find at least **one** of H, V or W in terms of g, r and θ Condone finding H^2 , V^2 or W^2 Equation must be dimensionally correct. All terms present and no extras. Condone sign errors and sin/cos confusion. Anything that should be resolved has been resolved. M0: If they use the speed from (a) instead of v	
M1	Correct method to find any **two** of H, V or W in terms of g, r and θ Condone finding H^2 , V^2 or W^2 Equation must be dimensionally correct. All terms present and no extras. Condone sign errors and sin/cos confusion. Anything that should be resolved has been resolved. M0: If they use the speed from (a) instead of v	
DM1	Dependent on previous two M's. Complete method to find $\tan\alpha$ Condone if they go straight to $\alpha = \tan^{-1}(\ldots)$ and never state $\tan\alpha = \ldots$	
A1	A correct value for $\tan\alpha$ $\dfrac{\sqrt{59}}{4}$ Accept any equivalent surd, eg $\sqrt{\dfrac{59}{16}}$ but must be exact. A0 if they go straight to α and never find $\tan\alpha$	

Question Number	Scheme	Marks
7(a)	$\frac{1}{2}mU^2 - \frac{1}{2}mv^2 = \frac{2mgx^2}{2l}$	M1 A1A1
	$v^2 = U^2 - \frac{2gx^2}{l}$ *	A1* (4)
7(b)	$2v\frac{\mathrm{d}v}{\mathrm{d}x} = -\frac{4gx}{l}$	M1A1
	$\ddot{x} = -\frac{2g}{l}x$, SHM $\left(\omega = \sqrt{\frac{2g}{l}}\right)$	A1
	Period $= \frac{2\pi}{\omega} = \pi\sqrt{\frac{2l}{g}}$ *	DM1A1* (5)
7(c)	$\sqrt{\frac{gl}{2}} = a\sqrt{\frac{2g}{l}}$ **OR** $0 = \frac{gl}{2} - \frac{2ga^2}{l}$	M1
	$a = \frac{1}{2}l$	A1
	time from $x = a$ to $x = \frac{1}{4}l$, t given by: $\frac{1}{4}l = \frac{1}{2}l\cos\sqrt{\frac{2g}{l}}t$	M1
	$t = \frac{\pi}{3}\sqrt{\frac{l}{2g}}$	A1
	Time $= \frac{1}{4}$period + time from $x = a$ to $x = \frac{1}{4}l$	M1
	$= \frac{5\pi}{6}\sqrt{\frac{l}{2g}}$	A1 (6)
		(15)
	Notes for question 7	
7(a)		
M1	Use conservation of energy equation with 2KE terms and 1EPE term. Note there are rearrangements. Dimensionally correct, terms of the correct structure, condone sign errors. EPE of the form $\frac{1}{2}k\,x^2$	
A1	For an unsimplified equation with at most one error	
A1	For a correct unsimplified equation	
A1*	Given answer obtained from complete and correct working. Must include a line of working before reaching the given answer.	
7(b)	Note: In (b) it is possible to score M1A1A0 DM1A1*	
M1	For differentiating wrt x . Powers of v and x to reduce by 1 and $\frac{dv}{dx}$ seen. M0 for an approach that does not involve differentiating with respect to x eg N2L	
A1	A correct differentiated equation	
A1	Correct SHM equation. Must use $\ddot{x}$ for acceleration **and** conclude SHM.	
DM1	Dependent on previous M. Correct use of period $= \frac{2\pi}{\omega}$	

Question Number	Scheme	Marks
A1*	Given answer correctly obtained. Must include a line of working between $\ddot{x} = -\omega^2 x$ and the given answer. Eg $\text{period} = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{2g}{l}}} = \pi\sqrt{\frac{2l}{g}}$ Or $\omega = \sqrt{\frac{2g}{l}}$, $\text{period} = 2\pi\sqrt{\frac{l}{2g}} = \pi\sqrt{\frac{2l}{g}}$	
7(c)		
M1	For use of $U = a\omega$ OR energy equation with $v = 0$ and $x = a$ to find the amplitude.	
A1	For correct amplitude, $\frac{l}{2}$	
M1	For a complete method to find the partial time with their calculated a and their ω • Use of $x = a\cos(\omega t)$ where $\frac{1}{4}l = \frac{1}{2}l\cos\sqrt{\frac{2g}{l}}t$ to give a partial time. • Use of $x = a\sin(\omega t)$ where $\frac{1}{4}l = \frac{1}{2}l\sin\sqrt{\frac{2g}{l}}t$ to give a partial time.	
A1	For a correct partial time • Use of $x = a\cos(\omega t) \Rightarrow t = \frac{1}{\omega}\frac{\pi}{3}$ • Use of $x = a\sin(\omega t) \Rightarrow t = \frac{1}{\omega}\frac{\pi}{6}$ or $\frac{1}{\omega}\frac{5\pi}{6}$	
M1	For a complete method to find the total time • Using $x = a\cos(\omega t)$ Total time $= \frac{1}{4}\text{period} + \text{time from } x = a \text{ to } x = \frac{1}{4}l$ $= \frac{1}{4}\pi\sqrt{\frac{2l}{g}} + \frac{\pi}{3}\sqrt{\frac{l}{2g}}$ • Using $x = a\sin(\omega t)$ with $\frac{1}{\omega}\frac{5\pi}{6}$ Total time $= \frac{1}{\omega}\frac{5\pi}{6}$ • Using $x = a\sin(\omega t)$ with $\frac{1}{\omega}\frac{\pi}{6}$ Total time $= \frac{1}{2}\text{period} - \text{time from } x = 0 \text{ to } x = \frac{1}{4}l$ Total time $= \frac{1}{2}\pi\sqrt{\frac{2l}{g}} - \frac{\pi}{6}\sqrt{\frac{l}{2g}}$	
A1	Correct answer of $\frac{5\pi}{6}\sqrt{\frac{l}{2g}} = \frac{5\pi}{3}\sqrt{\frac{l}{8g}} = \pi\sqrt{\frac{25l}{72g}}$ o.e	