Question Number	Scheme	Marks
1(a)	$\frac{2\pi}{\omega}=4$	M1
	$\omega=\frac{\pi}{2}$	A1
	$2=a\frac{\pi}{2}\cos\left(\frac{\pi}{2}\times 0.5\right)\Rightarrow 2=a\frac{\pi}{2}\times\frac{1}{\sqrt{2}}$	M1
	$a=\frac{4\sqrt{2}}{\pi}$ m *	A1* (4)
1(b)	$v_{MAX}=\frac{4\sqrt{2}}{\pi}\times \text{their}\,\omega$	M1
	$2\sqrt{2}$ (m s^{-1})	A1 (2)
		(6)
	Notes for question 1	
1(a)	M1 Need to see this equation, as it's a 'show that'. Allow with 4 or T or in a rearranged form.	
	A1 seen	
	M1 Complete method to obtain an equation in a only Use of $x=a\sin\omega t$ to find x followed by $v^2=\omega^2\left(a^2-x^2\right)$ may be seen. (Use of $v=\pm a\omega\sin\omega t$ scores M0 (this implies $t=0$ at an end-point.)	
	A1* Correct answer correctly obtained	
1(b)	M1 Use of $a\omega$ with the given value of a	
	A1 Allow 2.8 or better. Ignore units but must be positive.	

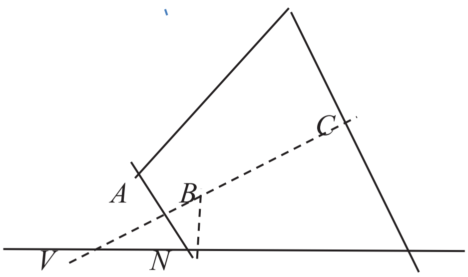
Question Number	Scheme	Marks
2(a)	$\frac{1}{\sqrt{(2x+1)}}=\frac{1}{3}\Rightarrow x=4$	M1A1
	$a=v\frac{dv}{dx}=\frac{1}{\sqrt{(2x+1)}}\times-\frac{1}{2}\times 2(2x+1)^{-\frac{3}{2}}\quad\left(=-(2x+1)^{-2}\right)$	M1A1
	$a=(-)\frac{1}{81}$	A1
	$\frac{2}{81}$ (N), 0.025or better	A1 (6)
2(b)	$t=\int\sqrt{(2x+1)}\ dx$	M1
	$t=\frac{2}{3}\times\frac{1}{2}(2x+1)^{\frac{3}{2}}+(C)$	A1
	Use of $t=0$, $x=0$ to obtain a value for C $(=-\frac{1}{3})$	M1
	Substitute $x=7.5$	dM1
	$t=21$	A1 (5)
		(11)
	Notes for question 2	
2(a)	M1 for putting $v=\frac{1}{3}$ and solving for $x$oe e.g. $(2x+1)=9$	
	A1 for $x=4$ oe	
	M1 for use of $v\frac{dv}{dx}$ with clear attempt at differentiation. (Power $-\frac{3}{2}$ needed	
	A1 for a correct unsimplified expression for a in terms of x only	
	A1 for a correct value for a (ignore sign)	
	A1 cao (must be positive)	
2(b)	M1 for use of $\frac{dx}{dt}=\frac{1}{\sqrt{(2x+1)}}$, separate variables and attempt to integrate. $k(2x+1)^{\frac{3}{2}}$ should be seen	
	A1 for correct unsimplified integration, C not needed.	
	If definite integration used, ignore limits for these 2 marks	
	M1 for use of initial conditions to find a value for C	
	dM1 dependent on first M1, for substituting in $x=7.5$ and evaluating	
	For definite integration award M1 for substitution of the lower limits and DM1 for substitutio of the upper limits.	
	A1 cao	

Question Number	Scheme	Marks
3(a)	$mg = \frac{kmg}{l}\frac{2l}{5}$	M1
	$k = \frac{5}{2}$ *	A1* (2)
3(b)	$mg - T = m\ddot{x}$	M1
	$mg - \frac{5mg}{2l}\left(x + \frac{2l}{5}\right) = m\ddot{x}$	DM1A1
	$-\frac{5g}{2l}x = \ddot{x}$, hence SHM.*	A1* (4)
3(c)	$\omega = \sqrt{\frac{5g}{2l}}$; $a = \frac{1}{4}l$	B1 **ft**; B1
	$v = a\omega = \frac{1}{4}l \times \sqrt{\frac{5g}{2l}}$	M1
	$\frac{1}{4}\sqrt{\frac{5gl}{2}}$ oe	A1 (4)
3(d)	$\frac{1}{4} \times \frac{2\pi}{\omega}$	M1
	$\frac{\pi}{2}\sqrt{\frac{2l}{5g}}$ oe	A1 **ft** (2)
		(12)
	Notes for question 3	
3(a)	M1 for $mg = T$ and use of Hooke's Law	
	A1* Given answer correctly obtained	
3(b)	M1 for equation of motion, dim correct with all necessary terms, allow a for acceleration and condone sign errors. Accept T or attempt at T, which may not have a variable extension.	
	DM1 for equation of motion, dim correct with correct terms, and use of Hooke's Law with a variable extension measured from E and now need $\ddot{x}$, condone sign errors. Depends on the first M mark; both M marks can be awarded together.	
	A1 for a correct unsimplified equation	
	A1* for a correct equation and conclusion	
3(c)	B1 ft for a dimensionally correct ω or ω^2, seen explicitly or used. B1 for $a = \frac{1}{4}l$	
	M1 for use of $v = a\omega$ or $v^2 = \omega^2\left(a^2 - x^2\right)$ with $x = 0$ later	
	A1 cao	
	Use of energy: B1 gain of GPE B1 either EPE M1 energy equation with change in GPE, change in EPE and KE. A1 cao	
3(d)	M1 for use of $\frac{1}{4} \times \frac{2\pi}{\omega}$	
	A1 cao	

Question Number	Scheme	Marks
4(a)	WD against air resistance $= kmga$; PE Gain $= \frac{1}{2}mga$; KE Gain $= \frac{1}{2}\times\frac{1}{2}m\times 3ag$	B2,1,0
	Initial EPE $= \frac{2mg}{4a}(2a)^2$; Final EPE $= \frac{2mg}{4a}a^2$	B1; B1
	$kmga = \frac{2mg}{4a}\left((2a)^2 - a^2\right) - \frac{1}{2}mga - \frac{1}{2}\times\frac{1}{2}m\times 3ag$	M1A1
	$k = \frac{1}{4}$ *	A1* (7)
4(b)	$\frac{1}{2}mg - \frac{1}{4}mg - T = 0$	M1
	$\frac{1}{2}mg - \frac{1}{4}mg - \frac{2mg}{2a}x = 0$	A1
	$x = \frac{1}{4}a$	A1
	$OB = \frac{9a}{4}$	A1 ft (4)
		(11)
	Notes for question 4	
4(a)	B2 for all 3 unsimplified terms. B1 B0 for 2 out of 3 corrrect	
	B1 for the initial EPE	
	B1 for the final EPE	
	M1 for the work-energy equation with all necessary terms, condone sign errors.	
	A1 for a correct equation.	
	A1* for the given answer correctly obtained. At least one step of working to be seen.	
4(b)	M1 for a vertical resolution with the correct terms (T does not need to be substituted) Must have acceleration = 0 for this mark	
	A1 for a correct equation with T replaced.	
	A1 cao	
	A1ft $2a$ + their x	
	Use of uniform aceleration equations scores 0/4	
	Alternative, using work-energy	
	M1 for an equation with GPE, EPE, KE and WD terms – all but KE using a variable distance (OB or the extension).	
	A1 correct equation	
	DM1 (A1 on e-pen) Obtain an expression for v^2 in terms of their unknown distance **and** find their distance when this is maximum by calculus or completing the square	
	A1 cao	

Question Number	Scheme	Marks
5(a)	$\cos\alpha = \frac{3}{5}$, where angle $ARP = \alpha$ oe	B1
	For R, ($\updownarrow$) $T_2 \cos\alpha = mg$ oe	M1
	$T_2 = \frac{5mg}{3}$ *	A1* (3)
5(b)	For P, ($\updownarrow$) $T_1 \cos\alpha - \frac{5mg}{3}\cos\alpha = mg$ or $T_1 \cos\alpha = 2mg$	M1A1
	Equation of motion: $T_1 \sin\alpha + \frac{5mg}{3}\sin\alpha = m(l\sin\alpha)\omega^2$ oe	M1A2,1,0
	$\omega = \sqrt{\frac{5g}{l}}$	A1
	Time $= \frac{2\pi}{\omega}$	M1
	$= 2\pi\sqrt{\frac{l}{5g}}$ oe	A1 (8)
		(11)
	Notes for question 5	
5(a)	B1 for sine or cosine of a relevant angle. May be seen in (b).	
	M1 for resolving vertically for the ring R, with usual rules	
	A1* for given answer correctly obtained.	
5(b)	M1 for resolving vertically for P, with usual rules. This may have been seen in (a) and **used** in (b)	
	A1 for a correct equation (trig does not need substituting)	
	M1 for horizontal equation of motion for P, with usual rules. The acceleration can be in either form and accept "r" for $l\sin\alpha$	
	A2 for a correct equation, give A1A0 for an equation with at most one error (allow the sines to have been cancelled)	
	A1 cao	
	M1 for a correct method	
	A1 cao	

Question Number	Scheme	Marks
6(a)	$\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mga(\cos\alpha - \cos\theta)$	M1A2,1,0
	$v^2 = u^2 + \frac{2ag}{5}(4 - 5\cos\theta)$ *	A1* (4)
6(b)	$T + mg\cos\theta = \frac{mv^2}{a}$ (T may be omitted here)	M1A2,1,0
	Use of $T = 0$ and substitute for v^2 and u^2	DM1
	$mg\cos\beta = \frac{m}{a}\left(\frac{6ag}{5} + \frac{2ag}{5}(4 - 5\cos\beta)\right)$	A1
	$\cos\beta = \frac{14}{15}$ (0.93 or better)	A1 (6)
		(10)
	Notes for question 6	
6(a)	M1 for an energy equation with the 2 KE terms and 2 PE terms. $\cos\alpha$ must be seen.	
	A2 for a correct equation, A1A0 for an equation with at most one error	
	A1* for the given answer correctly obtained.	
6(b)	M1 for an equation of motion towards O with all necessary terms, condone sign errors and sin/cos confusion mg must be resolved	
	A2 for a correct equation (allow – T), A1A0 for an equation with at most one error	
	DM1 for use of $T = 0$ and substitute for v^2 and u^2 to obtain an equation in $\cos\beta$ Depends on the first M mark of (b)	
	A1 Correct unsimplified equation following substitution	
	A1 cao	

Question Number	Scheme	Marks
7(a)	$\bar{x} = \dfrac{\int_0^h x\left(\frac{rx}{h}\right)^2 \mathrm{d}x}{\int_0^h \left(\frac{rx}{h}\right)^2 \mathrm{d}x}$ (Allow volume of cone formula quoted with π in the numerator)	M1DM1
	$= \dfrac{\left[\frac{x^4}{4}\right]_0^h}{\left[\frac{x^3}{3}\right]_0^h}$ oe	A1
	$= \dfrac{3h}{4}$ *	A1* (4)
7(b)		F	C	C' | Distance: $\bar{y}$; $\frac{1}{4}h$; $\frac{2h}{3}+\left(\frac{1}{4}\times\frac{h}{3}\right)$ $\left(=\frac{3h}{4}\right)$ Mass ratio: 26; 27; 1; oe	B1 B1
	$26\bar{y} = \frac{1}{4}h\times 27 - \left[\frac{2h}{3}+\left(\frac{1}{4}\times\frac{h}{3}\right)\right]\times 1$	M1A1ft
	$\bar{y} = \frac{3}{13}h$ *	A1* (5)
7(c)		
	For equilibrium, $\bar{y} = \frac{3}{13}h \le CB$ oe	M1
	$\frac{AB}{AN} = \frac{AN}{AV} \Rightarrow AB = \frac{1}{3}r\times\frac{r}{h} = \frac{r^2}{3h}$ oe	M1A1
	So, for equilibrium, $\frac{3}{13}h \le \frac{2}{3}h - \frac{r^2}{3h}$	M1
	$13r^2 \le 17h^2$ *	A1* (5)
		(14)

Question Number	Scheme	Marks
	Notes for question 7	
7(a)	M1 for use of $\int_0^h xy^2 \mathrm{d}x$ (Attempt at integration required)	
	DM1 for use of $\bar{x} = \dfrac{\int_0^h x\left(\frac{rx}{h}\right)^2 \mathrm{d}x}{\int_0^h \left(\frac{rx}{h}\right)^2 \mathrm{d}x}$ Depends on M mark above	
	A1 for $= \dfrac{\left[\frac{x^4}{4}\right]_0^h}{\left[\frac{x^3}{3}\right]_0^h}$	
	A1* for given answer correctly obtained. Upper limit(s) must be substituted.	
7(b)	B1 for distances from larger plane face or any parallel axis	
	B1 for mass (volume) ratios	
	M1 for moments about larger plane face or any parallel axis	
	A1ft for a correct equation, follow through their distances and masses	
	A1* for given answer correctly obtained. At least one step in the working from the equation must be seen.	
7(c)	M1 for overall method using a suitable inequality – may be comparing lengths or angles. If the limiting case is used this mark (and the final A mark) can only be awarded if a reason for the direction of the inequality is seen (eg $\bar{y} \leqslant CB$)	
	M1 for finding a length appropriate for their method	
	A1 for a correct relevant distance in terms of r and h	
	M1 for producing an inequality in r and h, must be right way round	
	A1* for correctly showing given inequality. At least one step in the working from their previous inequality must be seen.	