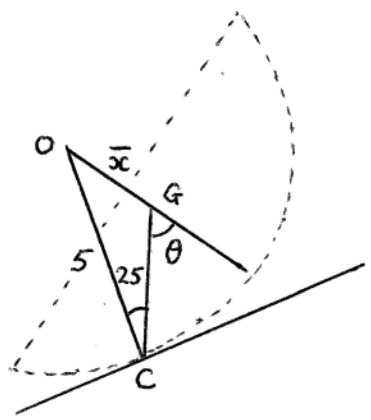
Question			Answer	Marks	Guidance	
1	(iv)		$\mathrm{T} = \mathrm{M}^{\alpha}\,\mathrm{L}^{\beta}\,(\mathrm{M\,L\,T}^{-2})^{\gamma}$			
			$\gamma = -\frac{1}{2}$	B1	CAO	
			$\alpha + \gamma = 0,\quad \beta + \gamma = 0$	M1	Considering powers of M or L	
			$\alpha = \frac{1}{2},\quad \beta = \frac{1}{2}$	A1A1	FT $\alpha = -\gamma,\ \beta = -\gamma$ (provided non-zero)	
				[4]		
1	(v)		$0.718 = k(8)^{\frac{1}{2}}(0.4)^{\frac{1}{2}}(125)^{-\frac{1}{2}}$	M1	Obtaining equation for k	Or using ratio and powers
			$k = 4.4875$			
			$t = (4.4875)(75)^{\frac{1}{2}}(3)^{\frac{1}{2}}(20)^{-\frac{1}{2}}$	M1	Obtaining expression for new time	Or $\times\left(\frac{75}{8}\right)^{\frac{1}{2}}\times\left(\frac{3}{0.4}\right)^{\frac{1}{2}}\times\left(\frac{20}{125}\right)^{-\frac{1}{2}}$
			New time is 15.1 s (3 sf)	A1	CAO *No penalty for using* $b = 1.2$ *and* $b = 9$	
				[3]		
2	(a)	(i)	$R\cos 18° = 800 \times 9.8$ $(R = 8243)$	M1	Resolving vertically	Might also include F
				M1	Horizontal equation of motion	Might also include F
			$R\sin 18° = 800 \times \dfrac{v^2}{45}$	A1		
			$\tan 18° = \dfrac{v^2}{45 \times 9.8}$			
			Speed is $12.0\ \mathrm{m\,s}^{-1}$ (3 sf)	A1		
				[4]		
2	(a)	(ii)		M1	Resolving vertically (three terms)	
			$R\cos 18° = F\sin 18° + 800 \times 9.8$	A1		
				M1	Horizontal equation (three terms)	
			$R\sin 18° + F\cos 18° = 800 \times \dfrac{15^2}{45}$	A1		
				M1	Obtaining a value for F or R	*Dependent on previous M1M1*
			Frictional force is 1380 N (3 sf)	A1		
			Normal reaction is 8690 N (3 sf)	A1		
				[7]		

Question			Answer	Marks	Guidance	
2	(b)			M1	Equation involving KE and PE	$h=2.1$ implies M1 a is length of the string
			$\frac{1}{2}m(7^2-2.8^2)=mg(a+a\cos\theta)$	A1	Correct equation involving a and θ	(Might use angle with downward vertical or horizontal)
			$a(1+\cos\theta)=2.1$			
				M1	Radial equation of motion	Might also involve T
			$mg\cos\theta=m\times\frac{2.8^2}{a}$	A1	Correct equation involving a and θ	
			$a\cos\theta=0.8$			
				M1	Eliminating θ or a	*Dependent on previous M1M1*
			Length of string is 1.3 m	A1		
			Angle with upward vertical is 52.0° (3 sf)	A1		A0 for 128° or 38°
				[7]		
3	(i)		$\dot{x}=-A\omega\sin(\omega t-\phi)$	B1		
			$\ddot{x}=-A\omega^2\cos(\omega t-\phi)$	M1	Obtaining second derivative	*Allow one error*
			$\ddot{x}=-\omega^2(x-c)$	E1	Correctly shown	
				[3]		
3	(ii)		$c=10$	B1		
			$A=6$	B1	Accept $A=-6$	
			$\frac{2\pi}{\omega}=10$	M1	Using $\frac{2\pi}{\omega}$	*Or other complete method for finding* ω
			$\omega=\frac{\pi}{5}$	A1	Accept $\omega=-\frac{\pi}{5}$	*Allow* $\frac{2\pi}{10}$ *etc*
			$x=16$ when $t=3 \Rightarrow 3\omega-\phi=0$	M1	Obtaining simple relationship between ϕ and ω. *NB* $\phi=3$ *is M0*	Or $x=10+6\cos\{\frac{\pi}{5}(t-3)\}$
			$\phi=\frac{3\pi}{5}$	A1	NB other values possible *If exact values not seen, give A0A1 for both* $\omega=0.63$ *and* $\phi=1.9$	e.g. $\phi=-\frac{7\pi}{5}$, $\phi=\frac{13\pi}{5}$, $x=10-6\cos(\frac{\pi}{5}t-\frac{8\pi}{5})$ etc
				[6]	*Max 5/6 if values are not consistent*	

Question			Answer	Marks	Guidance	
3	(iii)		Maximum speed is $A\omega$	M1	Or e.g. evaluating $\dot{x}$ when $t = 5.5$	
			Maximum speed is $\frac{6\pi}{5}$ or $3.77\ \text{m s}^{-1}$ (3 sf)	A1	FT is $\lvert A\omega \rvert$ (must be positive)	
				[2]		
3	(iv)		When $t = 0$, height is 8.15 m (3 sf)	B1	FT is $c + A\cos\phi$ (provided $4 < x < 16$)	Must use radians
			$v = -\frac{6\pi}{5}\sin(\frac{\pi t}{5} - \frac{3\pi}{5})$	M1	Or $v^2 = \left(\frac{\pi}{5}\right)^2 (6^2 - 1.854^2)$	*Allow one error in differentiation*
			When $t = 0$, velocity is $3.59\ \text{m s}^{-1}$ (3 sf)	A1	FT is $A\omega\sin\phi$ (must be positive)	($\phi = 3$ gives $x = 4.06$, $v = 0.532$)
				[3]		
3	(v)		When $t = 0$, $x = 8.146$			
			When $t = 14$, $x = 14.854$	M1	Finding x when $t = 14$	Correct (FT) value, or evidence of substitution, required ($\phi = 3$ gives $x = 15.3$)
				M1	$(16 - 14.854)$ used	Requires $4 < x(14) < 16$
			$(16 - 8.146) + 12 + 12 + (16 - 14.854)$	M1	Fully correct strategy	Also requires $4 < x(0) < 16$
			Distance is 33 m	A1	CAO	
				[4]		

Question			Answer	Marks	Guidance	
4	(a)		$A=\int_0^9 (3-\sqrt{x})\,dx$	M1		
			$=\left[\, 3x-\frac{2}{3}x^{\frac{3}{2}} \,\right]_0^9 \quad (=9)$	A1	For $3x-\frac{2}{3}x^{\frac{3}{2}}$	
			$A\bar{x}=\int xy\,dx=\int_0^9 x(3-\sqrt{x})\,dx$	M1	For $\int xy\,dx$	
			$=\left[\, \frac{3}{2}x^2-\frac{2}{5}x^{\frac{5}{2}} \,\right]_0^9 \quad (=24.3)$	A1	For $\frac{3}{2}x^2-\frac{2}{5}x^{\frac{5}{2}}$	
			$\bar{x}=\frac{24.3}{9}=2.7$	A1		
			$A\bar{y}=\int \frac{1}{2}y^2\,dx=\int_0^9 \frac{1}{2}(3-\sqrt{x})^2\,dx$	M1	For $\int \ldots y^2\,dx$	Or $\int_{(0)}^{(3)} (3-y)^2\,y\,dy$
				M1	Expanding (three terms) and integrating *(allow one error)*	
			$=\left[\, \frac{9}{2}x-2x^{\frac{3}{2}}+\frac{1}{4}x^2 \,\right]_0^9 \quad (=6.75)$	A1	For $\frac{9}{2}x-2x^{\frac{3}{2}}+\frac{1}{4}x^2$	Or $\frac{9}{2}y^2-2y^3+\frac{1}{4}y^4$
			$\bar{y}=\frac{6.75}{9}=0.75$	A1		
				[9]		

Question			Answer	Marks	Guidance	
4	(b)	(i)	$V=\int_2^5 \pi(25-x^2)\,\mathrm{d}x$	M1	For $\int ...(25-x^2)\,\mathrm{d}x$	
			$=\pi\left[\ 25x-\frac{1}{3}x^3\ \right]_2^5 \quad (=36\pi\ )$	A1	For $25x-\frac{1}{3}x^3$	
			$V\bar{x}=\int \pi xy^2\,\mathrm{d}x=\int_2^5 \pi x(25-x^2)\,\mathrm{d}x$	M1	For $\int xy^2\,\mathrm{d}x$	
			$=\pi\left[\ \frac{25}{2}x^2-\frac{1}{4}x^4\ \right]_2^5 \quad \left(=\frac{441\pi}{4}\ \right)$	A1	For $\frac{25}{2}x^2-\frac{1}{4}x^4$	
			$\bar{x}=\frac{\frac{441}{4}\pi}{36\pi}=\frac{49}{16} \quad (=3.0625)$	A1	Accept 3.1 from correct working	
				[5]		
4	(b)	(ii)		M1	CG is vertical *(may be implied)*	Lenient, if CG drawn. Needs to be quite accurate if CG not drawn
				M1	Using triangle OGC *or equivalent*	
			$\frac{\sin\theta}{5}=\frac{\sin 25°}{\bar{x}}$	M1		
			$\theta=43.6°$	A1	Accept art 43° or 44° from correct work FT is $\sin^{-1}\left(\frac{2.113}{\bar{x}}\right)$	Provided $2.113<\bar{x}<5$
				[4]		