Question			Answer	Marks	Guidance	
1	(a)		$A\omega = 5.1$	B1		
				M1	Using $v^2 = \omega^2(A^2 - x^2)$	
			$4.5^2 = \omega^2(A^2 - 6^2)$	A1		
			$4.5^2 = 5.1^2 - 36\omega^2$ $\omega = 0.4$	M1	Eliminating A or ω	
			Period ($\frac{2\pi}{\omega}$) is $5\pi = 15.7$ s (3 sf)	A1		Allow 5π
			Amplitude (A) is 12.75 m	A1 **[6]**		
1	(b)	(i)	$[\,F\,] = \text{M L T}^{-2}$	B1		
			$[\,G\,] = \left[\frac{Fd^2}{m_1 m_2}\right] = \frac{\text{M L T}^{-2}\,\text{L}^2}{\text{M}^2}$	M1	Obtaining dimensions of G	
			$= \text{M}^{-1}\,\text{L}^3\,\text{T}^{-2}$	A1 **[3]**		
1	(b)	(ii)	$\text{T}^{-1} = (\text{M}^{-1}\,\text{L}^3\,\text{T}^{-2})^{\alpha}\,\text{M}^{\beta}\,\text{L}^{\gamma}$			
			$\alpha = \frac{1}{2}$	B1		
			$-\alpha + \beta = 0$	M1	Considering powers of M	
			$\beta = \frac{1}{2}$	A1		
			$3\alpha + \gamma = 0$	M1	Considering powers of L	
			$\gamma = -\frac{3}{2}$	A1 **[5]**		*All marks FT from wrong [G] if comparable. No FT within part* ***(ii)****.*

Question			Answer	Marks	Guidance	
1	(b)	(iii)		M1M1	For $\left(\frac{4.86\times10^{14}}{2500}\right)^{\pm\frac{1}{2}}$ and $\left(\frac{30000}{50}\right)^{\pm\frac{3}{2}}$	*Requires* $\beta\neq0,\ \gamma\neq0$
			$\omega=2.0\times10^{-6}\times\left(\frac{4.86\times10^{14}}{2500}\right)^{\frac{1}{2}}\times\left(\frac{30000}{50}\right)^{-\frac{3}{2}}$	A1	Correct equation for ω	*FT if comparable*
		OR	$2.0\times10^{-6}=k\times G^{\frac{1}{2}}\times2500^{\frac{1}{2}}\times50^{-\frac{3}{2}}$		M1 *Requires* $\beta\neq0$ *or* $\gamma\neq0$	
			$kG^{\frac{1}{2}}=1.414\times10^{-5}$		M1 *Requires* $\beta\neq0$ *and* $\gamma\neq0$	Condone the use of any value for G (including $G=1$)
			$\omega=1.414\times10^{-5}\times(4.86\times10^{14})^{\frac{1}{2}}\times30000^{-\frac{3}{2}}$		A1 Correct equation for ω	*FT if comparable*
			Angular speed is $6.0\times10^{-5}\ \text{rad s}^{-1}$	A1 **[4]**	CAO	
2	(a)	(i)		M1	Equation involving initial KE, final KE and attempt at PE	
			$\frac{1}{2}mv^2-\frac{1}{2}m(1.2)^2=mg(0.8-0.8\cos\frac{1}{6}\pi)$	A1		
			$v^2=3.5407$			
			Radial component $\left(\frac{v^2}{0.8}\right)$ is $4.43\ \text{m s}^{-2}$ (3 sf)	A1		
			$(\pm)mg\sin\frac{1}{6}\pi=ma_T$	M1	Allow M1 for $\cos\frac{1}{6}\pi$ used instead of $\sin\frac{1}{6}\pi$; but M0 for $a_T=mg\sin\frac{1}{6}\pi$	
			Tangential component is $4.9\ \text{m s}^{-2}$	A1 **[5]**	Allow $\frac{1}{2}g$	

Question			Answer	Marks	Guidance	
2	(a)	(ii)	$\frac{1}{2}mv^2 - \frac{1}{2}m(1.2)^2 = mg(0.8 - 0.8\cos\theta)$	M1	Equation involving initial KE, final KE and attempt at PE in general position	θ between OP and upward vertical Allow *mgh* for PE if *h* is linked to θ in later work
				M1	Equation involving resolved component of weight and v^2 / r	
			$mg\cos\theta - R = \frac{mv^2}{0.8}$	A1	*R* may be omitted	
			Leaves surface when $R = 0$	M1	May be implied	e.g. Implied by $mg\cos\theta = \frac{mv^2}{0.8}$
			$v^2 - 1.44 = 2\times 9.8\times 0.8(1 - \frac{v^2}{7.84})$	M1	Obtaining equation in *v* or θ *Dependent on previous M1M1M1*	$\cos\theta = \frac{107}{147} = 0.728$ $\theta = 0.756$ rad or $43.3°$
			Speed is $2.39\ \mathrm{m\,s^{-1}}$	A1		
				[6]		
2	(b)		$T_R \sin\alpha + T_S \sin\beta = mg$	M1	Resolving vertically (three terms)	$\alpha = \mathrm{R\hat{Q}C} = 53.1°,\ \beta = \mathrm{S\hat{Q}C} = 16.3°$
			$0.8T_R + 0.28T_S = 0.9\times 9.8\ \ (= 8.82)$	A1	Allow $\sin 53.1°$, etc	
			$T_R\cos\alpha + T_S\cos\beta = m\frac{v^2}{r}$	M1	Horizontal equation of motion	Three terms, and v^2 / r
			$0.6T_R + 0.96T_S = 0.9\times\frac{5^2}{2.4}\ \ (= 9.375)$	A1		
				M1	Obtaining T_R or T_S	*Dependent on previous M1M1*
			Tension in string RQ is 9.737 N	A1		
			Tension in string SQ is 3.68 N	A1		
				[7]		

Question			Answer	Marks	Guidance	
3	(i)		Length of each string is 7.8 m	B1		
			$T = \frac{728}{6.4}(7.8 - 6.4)$	M1	Using Hooke's law	Must use extension
			Tension is 159.25 N	A1		
				[3]		
3	(ii)		$2T\cos\theta = mg$	M1	Resolving vertically	$\theta = \text{X}\hat{\text{P}}\text{M} = 67.4°$
			$2 \times 159.25 \times \frac{5}{13} = m \times 9.8$	A1	FT	
			$m = \frac{122.5}{9.8} = 12.5\text{ kg}$	E1	*Working must lead to 12.5 to 3 sf*	
				[3]		
3	(iii)		New length of each string is 7.5 m	M1	Hooke's law with new extension	
			$T = \frac{728}{6.4}(7.5 - 6.4) \quad (= 125.125)$	A1		
			$mg - 2T\cos\theta = ma$	M1	Vertical equation of motion (3 terms)	
			$12.5 \times 9.8 - 2 \times 125.125 \times 0.28 = 12.5a$	A1	FT for incorrect T	
			Acceleration is 4.19 m s^{-2} downwards (3 sf)	A1	*Some indication of downwards required*	
				[5]		
3	(iv)		At maximum speed, acceleration is zero Acceleration is zero in equilibrium position	B1	Mention of zero acceleration	*Reference to* $v^2 = \omega^2(A^2 - x^2)$, *SHM, etc, will usually be B0*
				[1]		

Question			Answer	Marks	Guidance	
3	(v)		Change of PE is $12.5\times9.8\times3 \quad (=367.5)$	B1		
			Initial EE is $2\times\frac{728\times0.8^2}{2\times6.4} \quad (=72.8)$	B1	Allow one string (36.4)	
			Final EE is $2\times\frac{728\times1.4^2}{2\times6.4} \quad (=222.95)$	B1	Allow one string (111.475)	
				M1	Equation involving KE, PE and EE	
			$\frac{1}{2}(12.5)v^2-367.5+222.95=72.8$	A1	FT from any B0 above All signs must be correct	*All terms must be non-zero*
			Maximum speed is 5.90 m s^{-1} (3 sf)	A1	CAO	
				[6]		
4	(a)		$V=\int_0^h \pi(y^{\frac{1}{4}})^2\,dy$	M1	For $\int\ldots(y^{\frac{1}{4}})^2\,dy$	
			$=\pi\left[\frac{2}{3}y^{\frac{3}{2}}\right]_0^h \quad (=\frac{2}{3}\pi h^{\frac{3}{2}})$	A1	For $\frac{2}{3}y^{\frac{3}{2}}$	
			$V\bar{y}=\int\pi x^2y\,dy=\int_0^h\pi y^{\frac{1}{2}}y\,dy$	M1	For $\int x^2y\,dy$	
			$=\pi\left[\frac{2}{5}y^{\frac{5}{2}}\right]_0^h \quad (=\frac{2}{5}\pi h^{\frac{5}{2}})$	A1	For $\frac{2}{5}y^{\frac{5}{2}}$	
			$\bar{y}=\frac{\frac{2}{5}\pi h^{\frac{5}{2}}}{\frac{2}{3}\pi h^{\frac{3}{2}}}=\frac{3}{5}h$	A1		
				[5]		

Question			Answer	Marks	Guidance	
4	(b)	(i)	$A = \int_0^4 (x + \sqrt{x})\,dx$	M1	For $\int (x + \sqrt{x})\,dx$	
			$= \left[\frac{1}{2}x^2 + \frac{2}{3}x^{\frac{3}{2}} \right]_0^4 \quad (= \frac{40}{3})$	A1	For $\frac{1}{2}x^2 + \frac{2}{3}x^{\frac{3}{2}}$	
			$A\bar{x} = \int xy\,dx = \int_0^4 x(x + \sqrt{x})\,dx$	M1	For $\int xy\,dx$	
			$= \left[\frac{1}{3}x^3 + \frac{2}{5}x^{\frac{5}{2}} \right]_0^4 \quad (= \frac{512}{15})$	A1	For $\frac{1}{3}x^3 + \frac{2}{5}x^{\frac{5}{2}}$	
			$\bar{x} = \frac{\frac{512}{15}}{\frac{40}{3}} = \frac{64}{25} = 2.56$	E1		
			$A\bar{y} = \int \frac{1}{2}y^2\,dx = \int_0^4 \frac{1}{2}(x + \sqrt{x})^2\,dx$	M1	For $\int ... y^2\,dx$	
			$= \left[\frac{1}{6}x^3 + \frac{2}{5}x^{\frac{5}{2}} + \frac{1}{4}x^2 \right]_0^4 \quad (= \frac{412}{15})$	A1A1	For $\frac{1}{6}x^3 + \frac{2}{5}x^{\frac{5}{2}} + \frac{1}{4}x^2$	Give A1 for two correct terms
			$\bar{y} = \frac{\frac{412}{15}}{\frac{40}{3}} = \frac{103}{50} = 2.06$	A1		
				[9]		

Question			Answer	Marks	Guidance	
4	(b)	(ii)	Area of B is $24-\frac{40}{3}=\frac{32}{3}$ $\frac{32}{3}\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}+\frac{40}{3}\begin{pmatrix}2.56\\ 2.06\end{pmatrix}=24\begin{pmatrix}2\\ 3\end{pmatrix}$ $\begin{pmatrix}\bar{x}\\ \bar{y}\end{pmatrix}=\begin{pmatrix}1.3\\ 4.175\end{pmatrix}$	M1 M1 A1 A1	CM of composite body Correct strategy CAO FT requires $0<\bar{y}<6$	(One coordinate sufficient) *FT is* $6.75-1.25\bar{y}_A$ *No FT from wrong area*
		OR	$\int \frac{1}{4}\left(\sqrt{1+4y}-1\right)^2 y\,\mathrm{d}y$ *or* $\int x(6-x-\sqrt{x})\,\mathrm{d}x$ *or* $\int \frac{1}{32}\left(\sqrt{1+4y}-1\right)^4 \mathrm{d}y$ *or* $\int \frac{1}{2}(6-x-\sqrt{x})(6+x+\sqrt{x})\,\mathrm{d}x$ $\bar{x}=1.3,\quad \bar{y}=4.175$		M1 For any one of these M1 For one successful integration A1A1	
				[4]		