1(a)(i)	$\mathrm{M\,L\,T^{-2}}$	B1 **1**	Allow $\mathrm{kg\,m\,s^{-2}}$
(ii)	$(\mathrm{T}) = (\mathrm{M\,L\,T^{-2}})^{\alpha}\ (\mathrm{L})^{\beta}\ (\mathrm{M\,L^{-1}})^{\gamma}$ Powers of M: $\alpha + \gamma = 0$ of L: $\alpha + \beta - \gamma = 0$ of T: $-2\alpha = 1$ $\alpha = -\frac{1}{2}$, $\beta = 1$, $\gamma = \frac{1}{2}$	B1 M1 M2 A2 **6**	For $\mathrm{M\,L^{-1}}$ For three equations Give M1 for one equation Give A1 for one correct
(iii)	$kF_1^{\alpha} l_1^{\beta} \sigma^{\gamma} = kF_2^{\alpha} l_2^{\beta} \sigma^{\gamma}$ $F_1^{-\frac{1}{2}}\, l_1 = F_2^{-\frac{1}{2}}\, l_2$	M1 A1	Equation relating F_1, F_2, l_1, l_2
	OR $F^{\alpha} l^{\beta}$ is constant M1 F is proportional to l^2 A1		or equivalent
	$F_2 = 90 \times \dfrac{2.0^2}{1.2^2}$ $= 250$ (N)	M1 A1 **4**	
(b)(i)	$\dfrac{2\pi}{\omega} = 0.01$ $\omega = 200\pi$ Maximum speed is $A\omega = 0.018 \times 200\pi$ $= 11.3$ $(\mathrm{m\,s^{-1}})$	B1 M1 A1 **3**	Accept 3.6π
(ii)	Using $v^2 = \omega^2 (A^2 - x^2)$ $8^2 = (200\pi)^2 (0.018^2 - x^2)$ $x = 0.0127$ (m)	M1 M1 A1 A1 **4**	Substituting values
	OR $v = 3.6\pi \cos(200\pi t) = 8$ M1 when $200\pi t = 0.785$ A1 $(t = 0.001249)$ $x = 0.018 \sin(200\pi t) = 0.018 \sin(0.785)$ M1 $= 0.0127$ A1		*Condone the use of degrees in this part*

2 (a)	$\omega = \frac{2\pi}{2.4\times10^6}$ $(=2.618\times10^{-6})$ Acceleration $a = r\omega^2$ (or $\frac{v^2}{r}$) $= 2.604\times10^{-3}$ Force is $ma = 7.5\times10^{22}\times2.604\times10^{-3}$ $=1.95\times10^{20}$ (N)	B1 M1 M1 A1 **4**	or $v = \frac{2\pi\times3.8\times10^8}{2.4\times10^6}$ $(=994.8)$ M0 for $F - mg = ma$ etc Accept 1.9×10^{20} or 2.0×10^{20}
(b)(i)	Change in PE is $mg(3.5-4\sin\theta)$ By conservation of energy $\frac{1}{2}mv^2 = mg(3.5-4\sin\theta)$ $v^2 = 68.6-78.4\sin\theta$	B1 M1 A1 **3**	or as separate terms Accept $7g-8g\sin\theta$
(ii)	$0.2\times9.8\sin\theta - R = 0.2\times\frac{v^2}{4}$ $1.96\sin\theta - R = 0.05(68.6-78.4\sin\theta)$ $R = 5.88\sin\theta - 3.43$	M1 M1 A1 E1 **4**	Radial equation of motion (3 terms) Substituting from part (i) Correctly obtained
(iii)	When $\theta = 40°$, $v^2 = 18.21$ Radial acceleration is $\frac{v^2}{4} = 4.55$ (m s^{-2}) Tangential acceleration is $9.8\cos40$ $= 7.51$ (m s^{-2})	M1 A1 M1 A1 **4**	or $0.2g\sin40 - R = ma$ Accept 4.5 or 4.6 M0 for $a = mg\cos40$ etc
(iv)	Leaves surface when $R = 0$ $\sin\theta = \frac{3.43}{5.88}$ $\theta = 35.7°$	M1 M1 A1 cao **3**	Accept $36°$, 0.62 rad

3 (i)	$\frac{\lambda}{15} \times 0.8 = 12 \times 9.8$ $\lambda = 2205$ (N)	M1 E1 **2**	
(ii)	$\frac{2205}{15} \times 5 - 12 \times 9.8 = 12a$ $a = 51.45$ (m s^{-2})	M1 A1 A1 **3**	Equation of motion including tension Accept 51 or 52
(iii)	Loss of EE is $\frac{1}{2} \times \frac{2205}{15} \times 5^2$ $(= 1837.5)$	M1 A1	Calculating elastic energy
	By conservation of energy $12 \times 9.8 \times h = 1837.5$ $h = 15.625$ OA $= 20 - h = 4.375$ (m)	M1 F1 A1 **5**	Equation involving EE and PE
	OR $12 \times 9.8 \times 5 + \frac{1}{2} \times 12 \times v^2 = 1837.5$ M1 $v^2 = 208.25$ $0 = 208.25 - 2 \times 9.8 \times H$ F1 $H = 10.625$ OA $= 15 - H = 4.375$ (m) A1		Equation involving EE, PE and KE
(iv)	$T = \frac{2205}{15}(0.8 + x)$ $12 \times 9.8 - \frac{2205}{15}(0.8 + x) = 12\frac{\mathrm{d}^2 x}{\mathrm{d}t^2}$ $\frac{\mathrm{d}^2 x}{\mathrm{d}t^2} = -12.25x$	B1 M1 A1 E1 **4**	or $T = \frac{\lambda}{l}(x_0 + x)$ Equation of motion with three terms or $mg - \frac{\lambda}{l}(x_0 + x) = m\frac{\mathrm{d}^2 x}{\mathrm{d}t^2}$ provided that $mg = \frac{\lambda}{l}x_0$ appears somewhere Correctly obtained *No marks for just writing* $-\frac{2205}{15}x = 12\frac{\mathrm{d}^2 x}{\mathrm{d}t^2}$ *or just using the formula* $\omega^2 = \frac{\lambda}{ml}$ *If x is clearly measured upwards, treat as a mis-read*
(v)	$x = 4.2\cos(3.5t)$ Rope becomes slack when $x = -0.8$ $4.2\cos(3.5t) = -0.8$ $t = 0.504$ (s)	M1 A1 M1 A1 **4**	For $\cos(\sqrt{12.25}\,t)$ or $\sin(\sqrt{12.25}\,t)$ Accept 0.50 or 0.51

4 (i)	$\int y\,dx = \int_0^2 (4-x^2)\,dx \quad = \left[4x - \tfrac{1}{3}x^3\right]_0^2 \quad (= \tfrac{16}{3})$	B1	
	$\int xy\,dx = \int_0^2 x(4-x^2)\,dx$	M1	
	$= \left[2x^2 - \tfrac{1}{4}x^4\right]_0^2 \quad (=4)$	A1	
	$\bar{x} = \dfrac{4}{\frac{16}{3}}$	M1	
	$= 0.75$	E1	Correctly obtained
	$\int \tfrac{1}{2}y^2\,dx = \int_0^2 \tfrac{1}{2}(16 - 8x^2 + x^4)\,dx$	M1	
	$= \left[8x - \tfrac{4}{3}x^3 + \tfrac{1}{10}x^5\right]_0^2 \quad (= \tfrac{128}{15})$	A1	
	OR $\int yx\,dy = \int_0^4 y\sqrt{4-y}\,dy$ M1		Valid method of integration
	$= \left[-\tfrac{2}{3}y(4-y)^{\frac{3}{2}} - \tfrac{4}{15}(4-y)^{\frac{5}{2}}\right]_0^4$ A1		or $\left[-\tfrac{8}{3}(4-y)^{\frac{3}{2}} + \tfrac{2}{5}(4-y)^{\frac{5}{2}}\right]_0^4$
	$\bar{y} = \dfrac{\frac{128}{15}}{\frac{16}{3}}$	M1	
	$= 1.6$	E1 **9**	Correctly obtained *SR* If $\tfrac{1}{2}$ is omitted, marks for $\bar{y}$ are M1A0M0E0
(ii)	$\bar{x} = \dfrac{12\times 0 + 6.5\times 0.75 + 6.5\times 2.75}{12 + 6.5 + 6.5}$	M1 M1	For $6.5\times 0.75 + 6.5\times 2.75$ Using $\left(\sum m\right)\bar{x} = \sum mx$
	$= \dfrac{22.75}{25} = 0.91$	A1	
	$\bar{y} = \dfrac{12\times 0 + 6.5\times 1.6 + 6.5\times 1.6}{25}$	M1	Using $\left(\sum m\right)\bar{y} = \sum my$
	$= \dfrac{20.8}{25} = 0.832$	A1 **5**	
(iii)		M1 M1	For CM vertically below A For trig in a triangle containing θ, or finding the gradient of AG
	$\tan\theta = \dfrac{2 - 0.91}{4 - 0.832} \quad (= \dfrac{1.09}{3.168})$	A1	Correct expression for $\tan\theta$ or $\tan(90-\theta)$
	$\theta = 19.0°$	A1 **4**	Accept 0.33 rad