1(a)(i)	[Force] $= \mathrm{M\,L\,T^{-2}}$ [Power] = [Force] $\times$ [Distance] $\div$ [Time] = [Force] $\times \mathrm{L\,T^{-1}}$ $= \mathrm{M\,L^2\,T^{-3}}$	B1 M1 A1 **3**	or [Energy] $= \mathrm{M\,L^2\,T^{-2}}$ or [Energy] $\times \mathrm{T^{-1}}$
(ii)	$[\mathrm{RHS}] = \dfrac{(\mathrm{L})^3(\mathrm{L\,T^{-1}})^2(\mathrm{M\,L^{-3}})}{\mathrm{M\,L^2\,T^{-3}}}$ $= \mathrm{T}$ [LHS] = L so equation is not consistent	B1B1 M1 A1 E1 **5**	For $(\mathrm{L\,T^{-1}})^2$ and $(\mathrm{M\,L^{-3}})$ Simplifying dimensions of RHS With all working correct (cao) *SR* '... $\mathrm{L} = \frac{28}{9}\pi\,\mathrm{T}$, so inconsistent ' can earn B1B1M1A1E0
(iii)	[RHS] needs to be multiplied by $\mathrm{L\,T^{-1}}$ which are the dimensions of *u* Correct formula is $x = \dfrac{28\pi r^3 u^3 \rho}{9P}$	M1 A1 A1 cao **3**	RHS must appear correctly
	OR $x = k\,r^{\alpha} u^{\beta} \rho^{\gamma} P^{\delta}$ M1 $\beta = 3$ A1 $x = \dfrac{28\pi r^3 u^3 \rho}{9P}$ A1		Equating powers of one dimension
(b)(i)	Elastic energy is $\frac{1}{2} \times 150 \times 0.8^2$ $= 48$ J	M1 A1 **2**	*Treat use of modulus* $\lambda = 150$ N *as MR*
(ii)	In extreme position, length of string is $2\sqrt{1.2^2 + 0.9^2}$ $(= 3)$ elastic energy is $\frac{1}{2} \times 150 \times 1.4^2$ $(= 147)$ By conservation of energy, $147 - 48 = \frac{1}{2} \times m \times 10^2$ Mass is 1.98 kg	B1 M1 M1 A1 A1 **5**	for $\sqrt{1.2^2 + 0.9^2}$ or 1.5 or 3 allow M1 for $(2\times)\frac{1}{2} \times 150 \times 0.7^2$ Equation involving EE and KE

2 (a)(i)	Vertically, $T\cos 55° = 0.6 \times 9.8$ Tension is 10.25 N	M1 A1 **2**	
(ii)	Radius of circle is $r = 2.8\sin 55° \quad (= 2.294)$	B1	
	Towards centre, $T\sin 55° = 0.6 \times \dfrac{v^2}{2.8\sin 55°}$	M2	Give M1 for one error
	OR $T\sin 55° = 0.6 \times (2.8\sin 55°) \times \omega^2$ M1 $\omega = 2.47$ $v = (2.8\sin 55°)\,\omega$ M1		or $T = 0.6 \times 2.8 \times \omega^2$ *Dependent on previous M1*
	Speed is 5.67 m s^{-1}	A1 **4**	
(b)(i)	Tangential acceleration is $r\alpha = 1.4 \times 1.12$ $F_1 = 0.5 \times 1.4 \times 1.12$ $= 0.784\text{ N}$ Radial acceleration is $r\omega^2 = 1.4\omega^2$ $F_2 = 0.5 \times 1.4\omega^2$ $= 0.7\omega^2\text{ N}$	M1 A1 M1 A1 **4**	*SR* $F_1 = -0.784,\ F_2 = -0.7\omega^2$ *penalise once only*
(ii)	Friction $F = \sqrt{F_1^{\,2} + F_2^{\,2}}$ Normal reaction $R = 0.5 \times 9.8$ About to slip when $F = \mu \times 0.5 \times 9.8$ $\sqrt{0.784^2 + 0.49\omega^4} = 0.65 \times 0.5 \times 9.8$ $\omega = 2.1$	M1 M1 A1 A1 A1 cao **5**	For LHS and RHS *Both dependent on M1M1*
(iii)	$\tan\theta = \dfrac{F_1}{F_2}$ $= \dfrac{0.784}{0.7 \times 2.1^2}$ Angle is $14.25°$	M1 A1 A1 **3**	Allow M1 for $\tan\theta = \dfrac{F_2}{F_1}$ etc Accept 0.249 rad

3 (i)	$T_{AP} = \frac{1323}{3} \times 2 \quad (= 882)$ $T_{BP} = \frac{1323}{4.5} \times 2.5 \quad (= 735)$ $T_{AP} - mg - T_{BP} = 882 - 15 \times 9.8 - 735 = 0$ so P is in equilibrium	B1 B1 E1 **3**	
	OR $\frac{1323}{3}(\text{AP} - 3) = \frac{1323}{4.5}(\text{BP} - 4.5) + 15 \times 9.8$ B2 $\text{AP} + \text{BP} = 12$ and solving, $\text{AP} = 5$ E1		Give B1 for one tension correct
(ii)	Extension of AP is $5 - x - 3 = 2 - x$ $T_{AP} = \frac{1323}{3}(2 - x) = 441(2 - x)$ Extension of BP is $7 + x - 4.5 = 2.5 + x$ $T_{BP} = \frac{1323}{4.5}(2.5 + x) = 294(2.5 + x)$	E1 B1 B1 **3**	
(iii)	$441(2 - x) - 15 \times 9.8 - 294(2.5 + x) = 15\frac{d^2x}{dt^2}$ $\frac{d^2x}{dt^2} = -49x$ Motion is SHM with period $\frac{2\pi}{\omega} = \frac{2\pi}{7} = 0.898 \text{ s}$	M1 A1 M1 A1 **4**	Equation of motion involving 3 forces Obtaining $\frac{d^2x}{dt^2} = -\omega^2 x \ (+c)$ Accept $\frac{2}{7}\pi$
(iv)	Centre of motion is AP = 5 If minimum value of AP is 3.5, amplitude is 1.5 Maximum value of AP is 6.5 m	B1 **1**	
(v)	When $\text{AP} = 4.1, \quad x = 0.9$ Using $v^2 = \omega^2(A^2 - x^2)$ $v^2 = 49(1.5^2 - 0.9^2)$ Speed is 8.4 m s^{-1}	M1 A1 A1 **3**	Accept ± 8.4 or -8.4
	OR $x = 1.5\sin 7t$ When $x = 0.9, \ 7t = 0.6435 \quad (t = 0.0919)$ $v = 7 \times 1.5\cos 7t$ M1 $= 10.5\cos(0.6435)$ A1 $= 8.4$ A1		or $x = 1.5\cos 7t$ or $7t = 0.9273 \quad (t = 0.1325)$ or $v = -7 \times 1.5\sin 7t$ $= (-)\,10.5\sin(0.9273)$

(vi)	$x = 1.5\cos 7t$	M1 A1	For $\cos(\sqrt{49}\,t)$ or $\sin(\sqrt{49}\,t)$ or $x = 1.5\sin 7t$ *M1A1 above can be awarded in (v) if not earned in (vi)*
	When $1.5\cos 7t = 0.5$	M1	or other fully correct method to find the required time e.g. $0.400 - 0.224$ or $0.224 - 0.049$
	Time taken is 0.176 s	A1 **4**	Accept 0.17 or 0.18

4 (i)	$\int \pi y^2\,dx = \int_1^4 \pi x\,dx$ $= \left[\frac{1}{2}\pi x^2\right]_1^4 = 7.5\pi$ $\int \pi x y^2\,dx$ $= \int_1^4 \pi x^2\,dx \quad = \left[\frac{1}{3}\pi x^3\right]_1^4 \quad (= 21\pi)$ $\bar{x} = \frac{21\pi}{7.5\pi}$ $= 2.8$	M1 A1 M1 A1 M1 A1 **6**	π *may be omitted throughout*
(ii)	Cylinder has mass $3\pi\rho$ Cylinder has CM at $x = 2.5$ $(4.5\pi\rho)\bar{x} + (3\pi\rho)(2.5) = (7.5\pi\rho)(2.8)$ $\bar{x} = 3$	B1 B1 M1 A1 E1 **5**	Or volume 3π Relating three CMs (ρ *and / or* π *may be omitted)* or equivalent, e.g. $\bar{x} = \frac{(7.5\pi\rho)(2.8) - (3\pi\rho)(2.5)}{7.5\pi\rho - 3\pi\rho}$ Correctly obtained
(iii)(*A*)	Moments about A, $S \times 3 - 96 \times 2 = 0$ $S = 64$ N Vertically, $R + S = 96$ $R = 32$ N	M1 A1 M1 A1 **4**	Moments equation or another moments equation *Dependent on previous M1*
(*B*)	Moments about A, $S \times 3 - 96 \times 2 - 6 \times 1.5 = 0$ Vertically, $R + S = 96 + 6$ $R = 35$ N, $S = 67$ N	M1 A1 A1 **3**	Moments equation Both correct
	OR Add 3 N to each of *R* and *S* M1 $R = 35$ N, $S = 67$ N A2		*Provided* $R \neq S$ Both correct