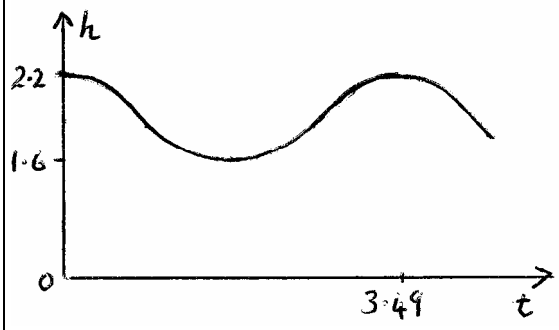
1(a)(i)	[Velocity] $= \mathrm{L\,T^{-1}}$ [Acceleration] $= \mathrm{L\,T^{-2}}$ [Force] $= \mathrm{M\,L\,T^{-2}}$ [Density] $= \mathrm{M\,L^{-3}}$ [Pressure] $= \mathrm{M\,L^{-1}\,T^{-2}}$	B1 B1 B1 B1 B1 **5**	*(Deduct 1 mark if answers given as* $\mathrm{ms^{-1}}$, $\mathrm{ms^{-2}}$, $\mathrm{kg\,ms^{-2}}$ *etc)*
(ii)	$[P] = \mathrm{M\,L^{-1}\,T^{-2}}$ $[\frac{1}{2}\rho v^2] = (\mathrm{M\,L^{-3}})(\mathrm{L\,T^{-1}})^2$ $= \mathrm{M\,L^{-1}\,T^{-2}}$ $[\rho g h] = (\mathrm{M\,L^{-3}})(\mathrm{L\,T^{-2}})(\mathrm{L}) = \mathrm{M\,L^{-1}\,T^{-2}}$ All 3 terms have the same dimensions	M1 A1 A1 E1 **4**	Finding dimensions of 2nd or 3rd term Allow e.g. 'Equation is dimensionally consistent' following correct work
(b)(i)		M1 A1 **2**	For a 'cos' curve (starting at the highest point) Approx correct values marked on both axes
(ii)	Period $\frac{2\pi}{\omega} = 3.49$ $\omega = 1.8$ $h = 1.9 + 0.3\cos 1.8t$	M1 A1 M1 F1 **4**	Accept $\frac{2\pi}{3.49}$ For $h = c + a\cos/\sin$ with either $c = \frac{1}{2}(1.6 + 2.2)$ or $a = \frac{1}{2}(2.2 - 1.6)$
(iii)	When $h = 1.7$, float is 0.2 m below centre Acceleration is $\omega^2 x = 1.8^2 \times 0.2$ $= 0.648\,\mathrm{m\,s^{-2}}$ upwards	M1A1 A1 cao **3**	Award M1 if there is at most one error
	OR When $h = 1.7$, $\cos 1.8t = -\frac{2}{3}$ ($1.8t = 2.30$, $t = 1.28$) Acceleration $\ddot{h} = -0.3 \times 1.8^2 \cos 1.8t$ M1 $= -0.3 \times 1.8^2 \times (-\frac{2}{3})$ A1 $= 0.648\,\mathrm{m\,s^{-2}}$ upwards A1 cao		

2 (i)	$R\cos 60 = 0.4 \times 9.8$ Normal reaction is 7.84 N	M1 A1 **2**	Resolving vertically (e.g. $R\sin 60 = mg$ is M1A0 $R = mg\cos 60$ is M0)
(ii)	$R\sin 60 = 0.4 \times \dfrac{v^2}{2.7\sin 60}$ Speed is $6.3\,\text{m s}^{-1}$	M1 M1 A1 A1 cao **4**	Horizontal equation of motion Acceleration $\dfrac{v^2}{r}$ (M0 for $\dfrac{v^2}{2.7}$)
	OR $R\sin 60 = 0.4 \times (2.7\sin 60)\omega^2$ $\omega = 2.694$ $v = (2.7\sin 60)\omega$ Speed is $6.3\,\text{m s}^{-1}$	M1 A1 M1 A1 cao	Horizontal equation of motion or $R = 0.4 \times 2.7 \times \omega^2$ For $v = r\omega$ (M0 for $v = 2.7\omega$)
(iii)	By conservation of energy, $\frac{1}{2} \times 0.4 \times (9^2 - v^2) = 0.4 \times 9.8 \times (2.7 + 2.7\cos\theta)$ $81 - v^2 = 52.92 + 52.92\cos\theta$ $v^2 = 28.08 - 52.92\cos\theta$	M1 A1 A1 **3**	Equation involving KE and PE Any (reasonable) correct form e.g. $v^2 = 81 - 52.92(1 + \cos\theta)$
(iv)	$R + 0.4 \times 9.8\cos\theta = 0.4 \times \dfrac{v^2}{2.7}$ $R + 3.92\cos\theta = \dfrac{0.4}{2.7}(28.08 - 52.92\cos\theta)$ $R + 3.92\cos\theta = 4.16 - 7.84\cos\theta$ $R = 4.16 - 11.76\cos\theta$	M1 A1 M1 A1 E1 **5**	Radial equation with 3 terms Substituting expression for v^2 *SR* If θ is taken to the downward vertical, maximum marks are: M1A0A0 in (iii) M1A1M1A1E0 in (iv)
(v)	Leaves surface when $R = 0$ $\cos\theta = \dfrac{4.16}{11.76}$ $v^2 = 28.08 - 52.92 \times \dfrac{4.16}{11.76}$ $(= 9.36)$ Speed is $3.06\,\text{m s}^{-1}$	M1 A1 M1 A1 cao **4**	 *Dependent on previous M1* or using $mg\cos\theta = \dfrac{mv^2}{r}$

3 (i)	Tension is $637 \times 0.1 = 63.7$ N Energy is $\frac{1}{2} \times 637 \times 0.1^2$ $= 3.185$ J	B1 M1 A1 **3**	
(ii)	Let θ be angle between RA and vertical $\cos\theta = \frac{5}{13}$ ($\theta = 67.4°$) $T\cos\theta = mg$ $63.7 \times \frac{5}{13} = m \times 9.8$ Mass of ring is 2.5 kg	B1 M1 A1 E1 **4**	Resolving vertically
(iii)	Loss of PE is $2.5 \times 9.8 \times (0.9 - 0.5)$ EE at lowest point is $\frac{1}{2} \times 637 \times 0.3^2$ (= 28.665) By conservation of energy, $2.5 \times 9.8 \times 0.4 + \frac{1}{2} \times 2.5u^2 = \frac{1}{2} \times 637 \times 0.3^2 - 3.185$ $9.8 + 1.25u^2 = 25.48$ $u^2 = 12.544$ $u = 3.54$	M1 A1 M1 A1 M1 F1 A1 cao **7**	Considering PE or PE at start and finish Award M1 if not more than one error Equation involving KE, PE and EE
(iv)	From lowest point to level of A, Loss of EE is 28.665 Gain in PE is $2.5 \times 9.8 \times 0.9 = 22.05$ Since $28.665 > 22.05$, Ring will rise above level of A	M1 M1 M1 A1 cao **4**	EE at 'start' and at level of A PE at 'start' and at level of A (For M2 it must be the same 'start') Comparing EE and PE *(or equivalent,* *e.g.* $\frac{1}{2}mu^2 + 3.185 = mg \times 0.5 + \frac{1}{2}mv^2$ *)* Fully correct derivation
			SR If 637 is used as modulus, maximum marks are: (i) B0M1A0 (ii) B1M1A1E0 (iii) M1A1M1A1M1F1A0 (iv) M1M1M1A0

4 (a)	Area is $\int_0^2 x^3\,\mathrm{d}x = \left[\frac{1}{4}x^4\right]_0^2 = 4$	B1	
	$\int x\,y\,\mathrm{d}x = \int_0^2 x^4\,\mathrm{d}x$	M1	
	$= \left[\frac{1}{5}x^5\right]_0^2 = 6.4$	A1	
	$\bar{x} = \frac{6.4}{4} = 1.6$	A1	
	$\int \frac{1}{2}y^2\,\mathrm{d}x = \int_0^2 \frac{1}{2}x^6\,\mathrm{d}x$	M1	Condone omission of $\frac{1}{2}$
	$= \left[\frac{1}{14}x^7\right]_0^2 = \frac{64}{7}$	A1	
	$\bar{y} = \frac{\int \frac{1}{2}y^2\,\mathrm{d}x}{\int y\,\mathrm{d}x}$	M1	
	$= \frac{\frac{64}{7}}{4} = \frac{16}{7}$	A1 **8**	Accept 2.3 from correct working
(b)(i)	Volume is $\int \pi\,y^2\,\mathrm{d}x = \int_1^2 \pi(4-x^2)\,\mathrm{d}x$	M1	*π may be omitted throughout*
	$= \pi\left[4x - \frac{1}{3}x^3\right]_1^2 = \frac{5}{3}\pi$	A1	For $\frac{5}{3}$
	$\int \pi\,x\,y^2\,\mathrm{d}x = \int_1^2 \pi\,x(4-x^2)\,\mathrm{d}x$	M1	
	$= \pi\left[2x^2 - \frac{1}{4}x^4\right]_1^2 = \frac{9}{4}\pi$	A1	For $\frac{9}{4}$
	$\bar{x} = \frac{\int \pi\,x\,y^2\,\mathrm{d}x}{\int \pi\,y^2\,\mathrm{d}x}$	M1	
	$= \frac{\frac{9}{4}\pi}{\frac{5}{3}\pi} = \frac{27}{20} = 1.35$	E1 **6**	Must be fully correct
(ii)	Height of solid is $h = 2\sqrt{3}$	B1	
	$T\,h = mg \times 0.35$	M1	Taking moments
	$F = T = 0.101mg,\quad R = mg$	F1	
	Least coefficient of friction is $\frac{F}{R} = 0.101$	A1 **4**	Must be fully correct (e.g. A0 if $m = \frac{5}{3}\pi$ is used)