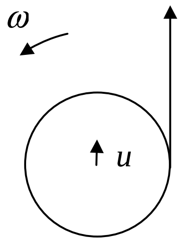
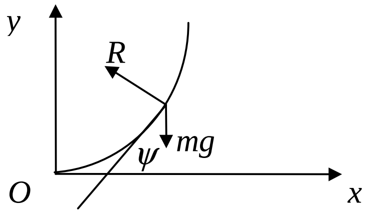
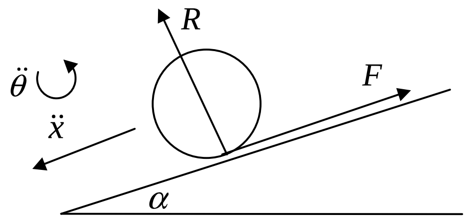
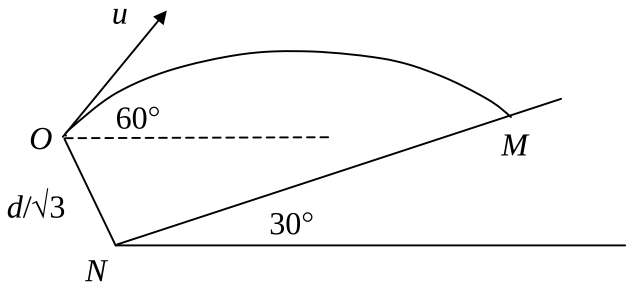
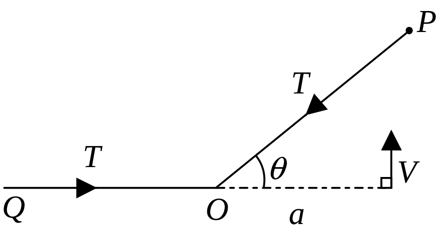
Question Number	Scheme	Marks
1.		
	$J = mu$	B1
	$Ja = \frac{1}{2}ma^2\omega$	M1 A1
	$2u = a\omega$ Eliminating J	M1
	Speed of P is $u + a\omega = 3u$	M1
	Speed of O is one third speed of P *	A1 <u>6</u> **6**
2.		
	Energy $\frac{1}{2}mv^2 = mg\left(\frac{3}{2} - \frac{3}{8}\right)$	M1 A1
	$v^2 = \frac{9g}{4}$	A1
	Radial $R - mg\cos\psi = \frac{mv^2}{\rho}$ $\left(= \frac{m \times \frac{9g}{4}}{\frac{125}{48}} = \frac{108}{125}mg\right)$	M1 A1
	At A $\tan\psi = \frac{dy}{dx} = \frac{3}{4}x = \frac{3}{4}$	M1 A1
	$\cos\psi = \frac{4}{5}$	A1
	$R = \frac{4}{5}mg + \frac{108}{125}mg$	M1
	$= \frac{208}{125}mg$ $1.664mg$	A1 <u>10</u> **10**

Question Number	Scheme	Marks
3. (a)	$\frac{dr}{d\theta} = \frac{\dot{r}}{\dot{\theta}} = \frac{4\cos\theta}{(3-2\sin\theta)^2}$	M1 A1
	$r = \int \frac{4\cos\theta}{(3-2\sin\theta)^2}\,d\theta$	M1
	$= \frac{2}{3-2\sin\theta} \quad (+C)$	M1 A1
	$r = \frac{2}{3}, \theta = 0 \quad \Rightarrow \quad C = 0$	M1
	$r = \frac{2}{3-2\sin\theta}$	A1 7
(b)	$\dot{r} = \frac{dr}{dt} = 4\cos\theta$	
	$\ddot{r} = -4\sin\theta.\dot{\theta}$	M1 A1
	$t = 0, \theta = 0 \quad \Rightarrow \quad \ddot{r} = 0$	A1
	Also $r = \frac{2}{3}, \dot{\theta} = 9$	
	Magnitude of radial component is $\left\|\ddot{r} - r\dot{\theta}^2\right\| = \left\|0 - \frac{2}{3}\times 9^2\right\| = 54 \quad (\text{m s}^{-2})$	M1 A1 5 **12**

Question Number	Scheme	Marks
4. (a)	Mass/unit area $= \dfrac{M}{\pi\left(b^2 - a^2\right)}$ $(= \rho, \text{say})$	B1
	$I = \frac{1}{2}\left(\pi b^2 \rho\right) b^2 - \frac{1}{2}\left(\pi a^2 \rho\right) a^2$	M1 A1
	$= \dfrac{\pi\rho}{2}\left(b^4 - a^4\right)$	
	$= \dfrac{\pi}{2} \times \dfrac{M}{\pi\left(b^2 - a^2\right)} \times \left(b^4 - a^4\right) = \dfrac{1}{2} M\left(a^2 + b^2\right)$ * cso	A1 <u>4</u>
(b)		
	LM $Mg\sin\alpha - F = M\ddot{x}$	M1 A1
	AM $F \times b = \frac{1}{2} M\left(a^2 + b^2\right)\ddot{\theta}$	M1 A1
	Condition for rolling $x = b\theta \Rightarrow \ddot{x} = b\ddot{\theta}$	
	$F = \dfrac{1}{2} M \dfrac{a^2 + b^2}{b^2} \ddot{x}$ Eliminating $\ddot{\theta}$	M1
	$g\sin\alpha - \dfrac{a^2 + b^2}{2b^2}\ddot{x} = \ddot{x}$ Eliminating F	M1
	$\ddot{x} = \dfrac{2b^2 \sin\alpha}{3b^2 + a^2} g$	A1
	✓ "$s = ut + \frac{1}{2}at^2$" $d = \dfrac{1}{2} \times \dfrac{2b^2\sin\alpha}{3b^2 + a^2} gT^2$	M1
	$gT^2 \sin\alpha = d\left(3 + \dfrac{a^2}{b^2}\right)$ * cso	A1 <u>9</u> **13**

Question Number	Scheme	Marks
5. (a)		
	$u = 2\sqrt{(gd)}$	
	↖ $-d\sqrt{3} = u\sin 30°t - \frac{1}{2}g\cos 30°t^2$	M1
	$g\sqrt{3}t^2 - 4\sqrt{(gd)}t - 4d\sqrt{3} = 0$	M1 A1
	$t = \frac{4\sqrt{(gd)} \pm \sqrt{(16gd + 48gd)}}{2g\sqrt{3}} = \left(\frac{12d}{g}\right)^{\frac{1}{2}}$	M1 A1
	↗ $MN = u\cos 30°t, -\frac{1}{2}g\sin 30°t^2$	M1 A1, A1
	$= 2\sqrt{(gd)} \times \frac{\sqrt{3}}{2} \times \left(\frac{12d}{g}\right)^{\frac{1}{2}} - \frac{g}{4} \times \frac{12d}{g}$	
	$= 6d - 3d = 3d$ * cso	A1 <u>9</u>
(b)	↗ $v_x = u\cos 30° - g\sin 30° \times \left(\frac{12d}{g}\right)^{\frac{1}{2}}$	M1 A1
	$= 2\sqrt{(gd)} \times \frac{\sqrt{3}}{2} - \frac{g}{2} \times \left(\frac{12d}{g}\right)^{\frac{1}{2}} = 0$	A1
	$\Rightarrow$ strikes plane at *M* in direction perpendicular to plane	
	$e = 1$ $\Rightarrow$ component ⊥r to plane is unchanged in magnitude	M1
	$\Rightarrow$ retraces path and returns to *O* * cso	A1 <u>5</u> **14**
	Alternative for last two marks of (b)	
	At *M* $v_y = u\sin 30° - g\cos 30° \times \left(\frac{12d}{g}\right)^{\frac{1}{2}} = 2\sqrt{(gd)}$ NB $v_y = u$	
	Time for *MN* ↙ $3d = \frac{1}{2}g\sin 30°t^2 \Rightarrow t^2 = \frac{12d}{g}$ NB same as in (a)	
	↖ $s = 2\sqrt{(gd)}\left(\frac{12d}{g}\right)^{\frac{1}{2}} - \frac{1}{2}g\frac{\sqrt{3}}{2} \times \frac{12d}{g} = d\sqrt{3}$, as required	M1 A1

Question Number	Scheme	Marks
6. (a)	 P, transverse $0 = m\frac{1}{r}\frac{\mathrm{d}}{\mathrm{d}t}\left(r^2\dot{\theta}\right)$	M1
	$r^2\dot{\theta} = h = a^2 \times \frac{V}{a} = aV$ * cso	M1 A1 <u>3</u>
(b)	For Q $T = m\ddot{r}$	B1
	For P, radial $-T = m\left(\ddot{r} - r\dot{\theta}^2\right)$	M1 A1
	$2\ddot{r} = r\dot{\theta}^2$ Eliminating T	M1
	$2\frac{\mathrm{d}^2 r}{\mathrm{d}t^2} = r \times \frac{a^2V^2}{r^4} = \frac{a^2V^2}{r^3}$ * cso	M1 A1 <u>6</u>
(c)	$2\frac{\mathrm{d}}{\mathrm{d}r}\left(\frac{1}{2}\dot{r}^2\right) = \frac{a^2V^2}{r^3} \Rightarrow \dot{r}^2 = \int \frac{a^2V^2}{r^3}\mathrm{d}r$	M1 A1
	$= -\frac{a^2V^2}{2r^2} \quad (+C)$	A1
	$\dot{r} = 0, r = a \Rightarrow C = \frac{V^2}{2}$	M1
	$\left(\frac{\mathrm{d}r}{\mathrm{d}t}\right)^2 = \frac{V^2}{2r^2}\left(r^2 - a^2\right)$ * cso	A1 <u>5</u>
	(d) $\frac{\mathrm{d}r}{\mathrm{d}t} = \frac{V}{r\sqrt{2}}\sqrt{\left(r^2 - a^2\right)} \Rightarrow \int \frac{r}{\sqrt{\left(r^2 - a^2\right)}}\mathrm{d}r = \int \frac{V}{\sqrt{2}}\mathrm{d}t$	M1
	$\sqrt{\left(r^2 - a^2\right)} = \frac{V}{\sqrt{2}}t \quad (+C)$	M1 A1
	$t = 0, r = a \Rightarrow C = 0, \Rightarrow t = \frac{\sqrt{2}\sqrt{\left(r^2 - a^2\right)}}{V}$	B1
	$r = 2a \Rightarrow T = \frac{a\sqrt{6}}{V}$	M1 A1 <u>6</u> **20**