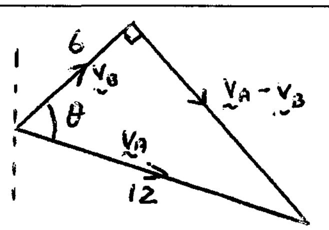
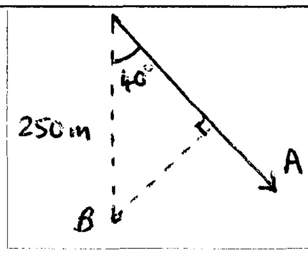
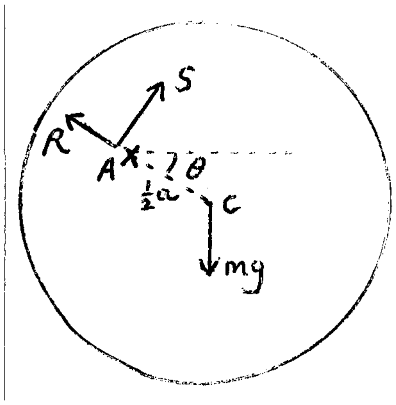
1 (i)	$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$, $180 = 25 \times 5 + \frac{1}{2}\alpha \times 25$ $\alpha = 4.4 \text{ rad s}^{-2}$	M1 A1 **2**	
(ii)	Moment $= I\alpha = 0.65 \times 4.4$ $= 2.86 \text{ N m}$	M1 A1 ft **2**	
2	Area $= \int_0^9 \sqrt{x}\,dx = \left[\frac{2}{3}x^{\frac{3}{2}}\right]_0^9 = 18$ $\int xy\,dx = \int_0^9 x^{\frac{3}{2}}\,dx = \left[\frac{2}{5}x^{\frac{5}{2}}\right]_0^9 = 97.2$ $\bar{x} = \frac{97.2}{18}$ $= \frac{27}{5} = 5.4$ $\int \frac{1}{2}y^2\,dx = \int_0^9 \frac{1}{2}x\,dx = \left[\frac{1}{4}x^2\right]_0^9 = 20.25$ $\bar{y} = \frac{20.25}{18}$ $= \frac{9}{8} = 1.125$	B1 B1 M1 A1 B1 M1 A1 **7**	For $\frac{2}{5}x^{\frac{5}{2}}$ For $\frac{1}{4}x^2$ (*or* $\frac{9}{2}y^2 - \frac{1}{4}y^4$)
3 (i)	$I = 0.02 + 0.12 = 0.14$ Period is $2\pi\sqrt{\frac{I}{mgh}} = 2\pi\sqrt{\frac{0.14}{1.5 \times 9.8 \times 0.2}}$ $= 1.37 \text{ s}$	B1 M1 A1 **3**	
(ii)	WD by couple is $3.2 \times \frac{1}{2}\pi$ $3.2 \times \frac{1}{2}\pi = 1.5 \times 9.8 \times 0.2 + \frac{1}{2}(0.14)\omega^2$ $\omega = 5.46 \text{ rad s}^{-1}$	B1 M1 A1 ft A1 **4**	For WD = PE + KE
4 (i)	 $\cos\theta = \frac{6}{12}$ $\theta = 60°$ Bearing of *B*'s velocity is $110 - 60 = 050°$	M1 A1 M1 A1 **4**	Relative velocity perpendicular to $\mathbf{v}_B$ Correct velocity triangle

(ii)	As viewed from B: 	M1 A1	Considering relative displacement Relative velocity on bearing 140°
	Shortest distance is $250 \sin 40$ $= 161$ m	M1 A1 **4**	

5	$m = \rho \int \pi y^2 \, dx = \rho\pi \int_0^{ka} a^2 e^{-\frac{2x}{a}} \, dx$	M1	Integral of $\left(e^{-\frac{x}{a}} \right)^2$ (when finding mass or volume)
	$= \rho\pi \left[-\frac{1}{2} a^3 e^{-\frac{2x}{a}} \right]_0^{ka}$	A1	For $\int e^{-\frac{2x}{a}} \, dx = -\frac{1}{2} a e^{-\frac{2x}{a}}$
	$= \frac{1}{2} \rho\pi a^3 (1 - e^{-2k})$	A1	For mass or volume
	$I = \int \frac{1}{2} \rho\pi y^4 \, dx$ $= \frac{1}{2} \rho\pi \int_0^{ka} a^4 e^{-\frac{4x}{a}} \, dx$	M1	Integral of y^4
		A1 ft	Correct integral expression (in terms of x)
	$= \frac{1}{2} \rho\pi \left[-\frac{1}{4} a^5 e^{-\frac{4x}{a}} \right]_0^{ka} = \frac{1}{8} \rho\pi a^5 (1 - e^{-4k})$	A1	
	$= \dfrac{\frac{1}{4} ma^2 (1 - e^{-4k})}{1 - e^{-2k}}$		
	$= \dfrac{\frac{1}{4} ma^2 (1 - e^{-2k})(1 + e^{-2k})}{1 - e^{-2k}} = \frac{1}{4} ma^2 (1 + e^{-2k})$	M1	*Dependent on previous M1M1*
		A1 (ag) **8**	*Intermediate step not required, provided no wrong working seen*

6 (i)			
	$I = \frac{1}{2}ma^2 + m(\frac{1}{2}a)^2$	M1	Using parallel axes rule
	$= \frac{3}{4}ma^2$	A1	
	$mg(\frac{1}{2}a\cos\theta) = I\alpha = (\frac{3}{4}ma^2)\alpha$	M1	Or differentiating the energy equation
	$\alpha = \dfrac{2g\cos\theta}{3a}$	A1 (ag) **4**	
(ii)	$\frac{1}{2}I\omega^2 = mg(\frac{1}{2}a\sin\theta)$	M1 A1	Using $\frac{1}{2}I\omega^2$
	$\omega = \sqrt{\dfrac{4g\sin\theta}{3a}}$	A1 **3**	
(iii)		B1	For radial acc'n of C is $(\frac{1}{2}a)\omega^2$
	$R - mg\sin\theta = m(\frac{1}{2}a)\omega^2$	M1	$\pm R \pm mg\sin\theta = mr\omega^2$ *or* $kma\omega^2$ (with numerical k)
	$R = \frac{5}{3}mg\sin\theta$	A1	
		B1	For transverse acc'n of C is $(\frac{1}{2}a)\alpha$
	$mg\cos\theta - S = m(\frac{1}{2}a)\alpha$	M1	*as above*
	$S = \frac{2}{3}mg\cos\theta$	A1 **6**	Direction must be clear *Equations involving horizontal and vertical components can earn B1M1B1M1*
	OR $S(\frac{1}{2}a) = I_G\alpha$ M1 $S(\frac{1}{2}a) = (\frac{1}{2}ma^2)\alpha$ A1 $S = \frac{2}{3}mg\cos\theta$ A1		Must use I_G

7 (i)	$RB^2 = a^2 + (2a)^2 - 2(a)(2a)\cos(\theta + \frac{1}{4}\pi)$ $= 5a^2 - 4a^2(\cos\theta\cos\frac{1}{4}\pi - \sin\theta\sin\frac{1}{4}\pi)$ $= a^2(5 - 2\sqrt{2}\cos\theta + 2\sqrt{2}\sin\theta)$	M1 A1 (ag) **2**	
(ii)	$V = -mg(2a\sin\theta) + \frac{mg\sqrt{2}}{2a} \times RB^2$ $= \frac{5}{2}\sqrt{2}mga - 2mga\cos\theta$ $\frac{dV}{d\theta} = 2mga\sin\theta$ When $\theta = 0$, $\frac{dV}{d\theta} = 0$, hence equilibrium $\frac{d^2V}{d\theta^2} = 2mga\cos\theta$ When $\theta = 0$, $\frac{d^2V}{d\theta^2} = 2mga > 0$, hence stable	M1 A1 M1 A1 M1 A1 **6**	Considering PE and EE Correctly shown or other method for max / min Correctly shown
(iii)	KE is $\frac{1}{2}m(2a\dot{\theta})^2$ $\frac{5}{2}\sqrt{2}mga - 2mga\cos\theta + 2ma^2\dot{\theta}^2 = E$ Differentiating w.r.t. t, $2mga\sin\theta\dot{\theta} + 4ma^2\dot{\theta}\ddot{\theta} = 0$ $\ddot{\theta} = -\frac{g}{2a}\sin\theta$	B1 M1 M1 A1	 Requires fully correct working
	OR $(mg\cos\theta - T\sin\phi)(2a) = I\ddot{\theta}$, where $T = \frac{mg\sqrt{2}(RB)}{a}$ and $\frac{\sin\phi}{a} = \frac{\sin(\theta + \frac{1}{4}\pi)}{RB}$ M2 $\ddot{\theta} = -\frac{g}{2a}\sin\theta$ A2		or $mg\cos\theta - T\sin\phi = m(2a\ddot{\theta})$ Give A1 if just one minor error
	Period is $2\pi\sqrt{\frac{2a}{g}}$	B1 ft **5**	ft provided that k is in terms of a and g only