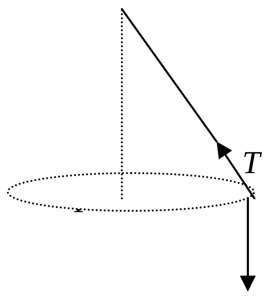
1.



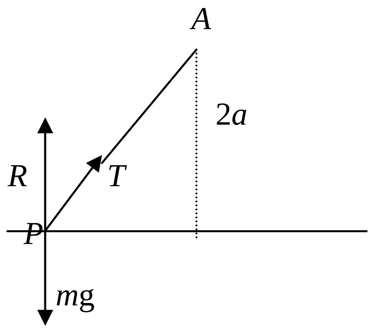
(a) (↕) $T\cos 60° = mg \Rightarrow T = 2mg$ *	B1	**(1)**
(b) (↔) $T\sin 60° = mr\omega^2$ [Omission of m is M0]	M1A1	
Attempt at $r = L\sin 60°$	M1	
($T\sin 60° = m\,L\sin 60°\,\omega^2$)		
$\omega = \sqrt{\dfrac{2g}{L}}$	A1	**(4)**
(c) Applying Hooke's Law: $2mg = \dfrac{\lambda}{(\frac{3}{5}L)}(L - \frac{2}{5}L)$; $\lambda = 3mg$	M1;A1	**(2)**
[L in denominator is M0]		
		[7]

2.

(a) Integration of $-4e^{-2t}$ w.r.t. t to give $v = 2e^{-2t}$ (+c)	B1	
Using initial conditions to find c (–1) or $v - 1 = \left[f(t)\right]_0^t$	M1	
$v = 2e^{-2t} - 1$ ms^{-1}	A1	**(3)**
(b) **Integrating** v w.r.t t ; $x = -e^{-2t} - t$ (+c)	M1;A1√	
Using t =0, x = 0 **and** finding value for c (c = 1)	M1	
Finding t when v = 0; t = ½ ln 2 or equiv., 0.347	M1;A1√	
[both f.t. marks dependent on v of form $ae^{-2t} \pm b$]		
x = ½ (1 – ln 2) m or 0.153 m(awrt)	A1	**(6)**
		[9]
[For A1, exact form must be two termed answer]		

3. (a)	$F = \dfrac{k}{x^2}$ [k may be seen as Gm_1m_2, for example]	M1
	Equating F to mg at $\boldsymbol{x = R}$, [$mg = \dfrac{k}{R^2}$]	M1
	Convincing completion [$k = mgR^2$] to give $F = \dfrac{mgR^2}{x^2}$ *	A1 **(3)**
	[Note: r may be used instead of x throughout, then $r \to x$ at end.]	
(b)	Equation of motion: $(m)a = (-)\dfrac{(m)gR^2}{x^2}$; $(m)v\dfrac{dv}{dx} = -\dfrac{(m)gR^2}{x^2}$	M1;M1
	Integrating: $\tfrac{1}{2}v^2 = \dfrac{gR^2}{x}$ $(+c)$ or equivalent	M1A1
	[S.C: Allow A1√ if A0 earlier due to "+" only]	
	Use of $v^2 = \dfrac{3gR}{2}$, $x = R$ to find c [$c = -\tfrac{1}{4}gR$] or use in def. int.	M1
	[Using $x = 0$ is M0] [$v^2 = \dfrac{2gR^2}{x} - \dfrac{gR}{2}$]	
	Substituting $x = 3R$ and finding V; $V = \sqrt{\dfrac{gR}{6}}$	M1;A1 **(7)**
	[Using $x = 2R$ is M0]	
	Alternative in (b)	**[10]**
	Work/energy $(-)\displaystyle\int_R^a \dfrac{mgR^2}{x^2}\,dx$; $= \tfrac{1}{2}mv^2 - \tfrac{1}{2}mu^2$	M1;M1
	Integrating: $\left[\dfrac{mgR^2}{x} - \dfrac{mgR^2}{R}\right] = \tfrac{1}{2}mv^2 - \tfrac{1}{2}m\dfrac{3gR}{2}$	M1A1M1
	Final 2 marks as scheme	M1A1
	[Conservation of energy scores 0]	

4. (a) Length of string = $\frac{10}{3}a$ B1



$\text{EPE} = \frac{\frac{1}{2}mg}{2a}(L-a)^2$ M1

$= \frac{49}{36}mga$ A1 **(3)**

(b) Energy equation: $\frac{1}{2}mv^2 + \frac{\frac{1}{2}mg}{2a}a^2 = \left(\frac{49}{36}mga\right)_C$ M1A1✩

$v = \frac{2}{3}\sqrt{5ga}$ or equivalent A1 **(3)**

(c) When string at angle θ to horizontal, length of string = $\frac{2a}{\sin\theta}$

$\Rightarrow$ Vert. Comp. of T, $T_V = T\sin\theta = \frac{mg}{2a}\left(\frac{2a}{\sin\theta} - a\right)\sin\theta$ M1A1

$= \frac{mg}{2}(2 - \sin\theta)$

($\updownarrow$) $R + T_V = mg$ and find R = …. M1

$R = mg - \frac{mg}{2}(2-\sin\theta) = \frac{mg}{2}\sin\theta$ A1

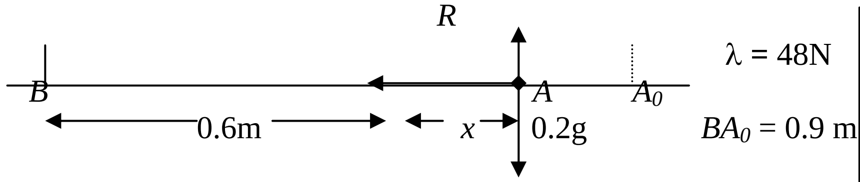
$\Rightarrow R > 0$ (as $\sin\theta > 0$), so stays on table A1 **(5)**

[Alternative final 3 marks: As θ increases so T_V decreases M1

Initial T_V (string at β to hor.) = $\frac{7}{10}mg$ A1

$\Rightarrow T_V \le \frac{7}{10}mg < mg$, so stays on table A1] **[11]**

5. (a)



Applying Hooke's Law correctly : e.g. $T = \dfrac{48x}{0.6}$	M1
Equation of motion: (–) T = 0.2 $\ddot{x}$	M1
Correct equation of motion: e.g. $-\dfrac{48x}{0.6} = 0.2\ \ddot{x}$	A1
Writing in form $\ddot{x} = -\,\omega^2\ x$, and stating motion is SHM	A1√
Period = $\dfrac{2\pi}{\omega} = \dfrac{2\pi}{20} = \dfrac{\pi}{10}$ * (no incorrect working seen)	A1 **(5)**
[If measure x from B or A, final 2 marks only available if equation of motion is reduced to $\ddot{X} = -\,\omega^2\ X$]	
(b) max $v = aw$ with values substituted; = 0.3 x 20 = 6 ms^{-1}	M1A1**(2)**
(c) Using $x = 0.3\cos 20t$ or $x = 0.3\sin 20T$	M1
Using x = 0.15 to give either cos 20t = ½ or sin 20T = ½	M1
Either $t = \dfrac{\pi}{60}, \dfrac{5\pi}{60}$ or $T = \dfrac{\pi}{120}$	A1
Complete method for time:	
$t_2 - t_1$, or $\dfrac{\pi}{10} - 2t_1$, or $2(\dfrac{\pi}{40} + T)$	M1
Time = $\dfrac{\pi}{15}$ s (must be in terms of π)	A1 **(5)**
	[12]

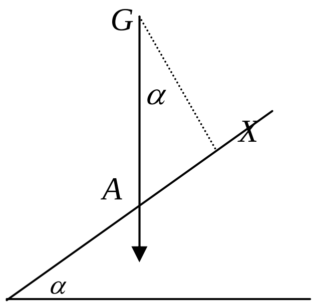
6. (a)

	Cylinder	Hemisphere	S	
Masses	$(\rho)\pi(2a)^2(\frac{3}{2}a)$	$(\rho)\frac{2}{3}\pi a^3$	$(\rho)(\frac{16}{3}\pi a^3)$	M1A1
	$[6\pi a^3]$ [18]	[2]	[16]	
Distance of CM from O	$\frac{3}{4}a$	$\frac{3}{8}a$	$\bar{x}$	B1B1

Moments equation: $6\pi a^3(\frac{3}{4}a) - \frac{2}{3}\pi a^3(\frac{3}{8}a) = \frac{16}{3}\pi a^3\,\bar{x}$ M1

$\bar{x} = \frac{51}{64}a$ A1 **(6)**

(b)



G above "A" seen or implied M1

or $mg\sin\alpha\,(GX) = mg\cos\alpha\,(AX)$

$\tan\alpha = \dfrac{AX}{XG} = \dfrac{2a}{\frac{3}{2}a - \bar{x}}$ M1

$[GX = \frac{3}{2}a - \frac{51}{64}a = \frac{45}{64}a,\ \tan\alpha = \dfrac{128}{45}]$ $\alpha = 70.6°$ A1 **(3)**

(c) Finding F and R **:** $R = mg\cos\beta,\ \ F = mg\sin\beta$ M1

Using $F = \mu R$ and finding $\tan\beta$ [= 0.8] M1

$\beta = 38.7°$ A1 **(3)**

[12]

7. (a) Energy: $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mga\sin\theta$	M1	
$v^2 = \frac{3}{2}ga + 2ga\sin\theta$	A1	**(2)**
(b) Radial equation: $T - mg\sin\theta = m\dfrac{v^2}{a}$	M1A1	
$T = \dfrac{3mg}{2}(1 + 2\sin\theta)$ any form	A1☆	**(3)**
(c) Setting $T = 0$ and solving trig. equation; $(\sin\theta = -\frac{1}{2}) \Rightarrow \theta = 210°$ *	M1;A1	**(2)**
(d) Setting $\boldsymbol{v} = \mathbf{0}$ in (a) and solving for θ	M1	
$\sin\theta = -\frac{3}{4}$ so not complete circle	A1	**(2)**
OR Substituting $\theta = 270°$ in (a); $v^2 < 0$ so not possible to complete		
(e) No change in PE $\Rightarrow$ no change in KE (Cof E) so $v = u$	B1	**(1)**
(f) When string becomes slack, $V^2 = \frac{1}{2}ga$ [$\sin\theta = -\frac{1}{2}$ in (a)]	B1☆	
Using fact that horizontal component of velocity is unchanged	M1	
$\sqrt{\dfrac{ga}{2}}\cos 60^\circ = \sqrt{\dfrac{3ga}{2}}\cos\phi$		
$\cos\phi = \sqrt{\dfrac{1}{12}} \Rightarrow \phi = 73.2°$	M1A1	**(4)**
		[14]