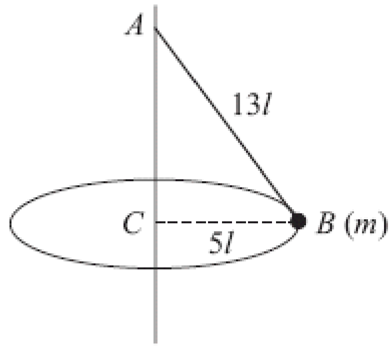
1.



A garden game is played with a small ball B of mass m attached to one end of a light inextensible string of length $13l$. The other end of the string is fixed to a point A on a vertical pole as shown in the diagram above. The ball is hit and moves with constant speed in a horizontal circle of radius $5l$ and centre C, where C is vertically below A. Modelling the ball as a particle, find

(a) the tension in the string,

(3)

(b) the speed of the ball.

(4)
(Total 7 marks)

2. A bend of a race track is modelled as an arc of a horizontal circle of radius 120 m. The track is not banked at the bend. The maximum speed at which a motorcycle can be ridden round the bend without slipping sideways is 28 m s^{-1}. The motorcycle and its rider are modelled as a particle and air resistance is assumed to be negligible.

(a) Show that the coefficient of friction between the motorcycle and the track is $\frac{2}{3}$.

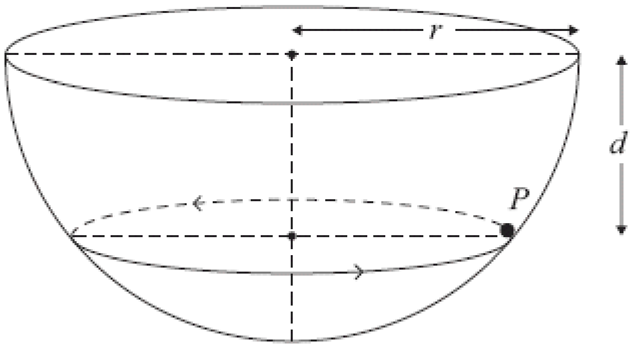
(6)

The bend is now reconstructed so that the track is banked at an angle α to the horizontal. The maximum speed at which the motorcycle can now be ridden round the bend without slipping sideways is 35 m s^{-1}. The radius of the bend and the coefficient of friction between the motorcycle and the track are unchanged.

(b) Find the value of tan α.

(8)
(Total 14 marks)

3.



A particle *P* of mass *m* moves on the smooth inner surface of a hemispherical bowl of radius *r*. The bowl is fixed with its rim horizontal as shown in the diagram above. The particle moves with constant angular speed $\sqrt{\left(\frac{3g}{2r}\right)}$ in a horizontal circle at depth *d* below the centre of the bowl.

(a) Find, in terms of *m* and *g*, the magnitude of the normal reaction of the bowl on *P*.

(4)

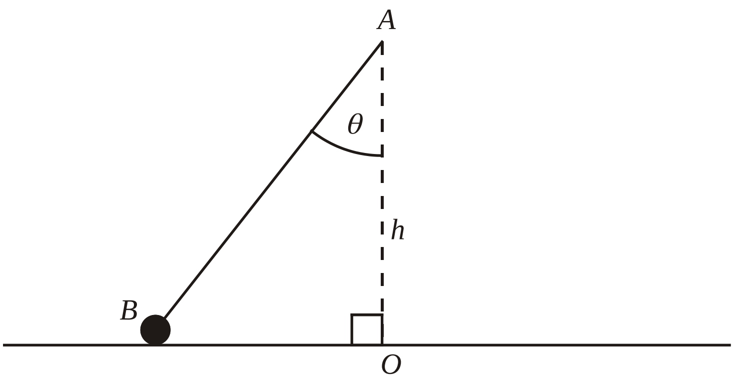
(b) Find d in terms of *r*.

(4)
(Total 8 marks)

4. A rough disc rotates about its centre in a horizontal plane with constant angular speed 80 revolutions per minute. A particle P lies on the disc at a distance 8 cm from the centre of the disc. The coefficient of friction between P and the disc is μ. Given that P remains at rest relative to the disc, find the least possible value of μ.

(Total 7 marks)

5.



The diagram above shows a particle B, of mass m, attached to one end of a light elastic string. The other end of the string is attached to a fixed point A, at a distance h vertically above a smooth horizontal table. The particle moves on the table in a horizontal circle with centre O, where O is vertically below A. The string makes a constant angle θ with the downward vertical and B moves with constant angular speed ω about OA.

(a) Show that $\omega^2 \le \frac{g}{h}$.

(8)

The elastic string has natural length h and modulus of elasticity 2 mg.

Given that $\tan\theta = \frac{3}{4}$,

(b) find ω in terms of g and h.

(5)
(Total 13 marks)

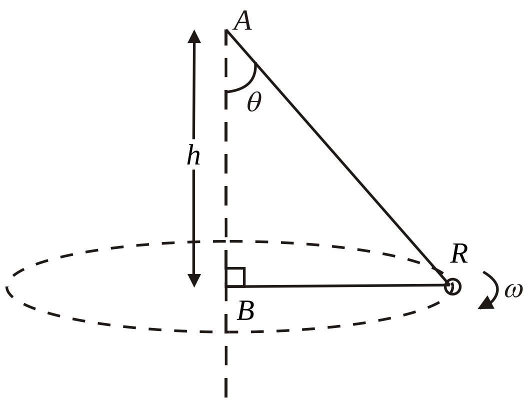
6. A light inextensible string of length l has one end attached to a fixed point A. The other end is attached to a particle P of mass m. The particle moves with constant speed v in a horizontal circle with the string taut. The centre of the circle is vertically below A and the radius of the circle is r.

Show that

$$gr^2 = v^2\sqrt{(l^2 - r^2)}.$$

(Total 9 marks)

7.



One end of a light inextensible string is attached to a fixed point A. The other end of the string is attached to a fixed point B, vertically below A, where $AB = h$. A small smooth ring R of mass m is threaded on the string. The ring R moves in a horizontal circle with centre B, as shown in the diagram above. The upper section of the string makes a constant angle θ with the downward vertical and R moves with constant angular speed ω. The ring is modelled as a particle.

(a) Show that $\omega^2 = \dfrac{g}{h}\left(\dfrac{1+\sin\theta}{\sin\theta}\right)$.

(7)

(b) Deduce that $\omega > \sqrt{\dfrac{2g}{h}}$.

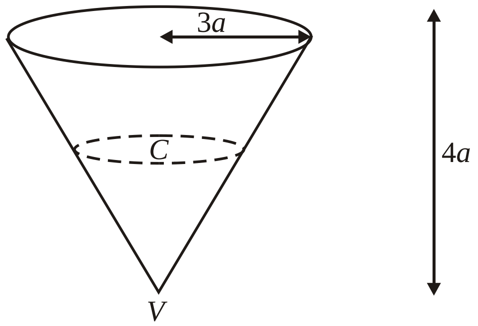
(2)

Given that $\omega = \sqrt{\frac{3g}{h}}$,

(c) find, in terms of m and g, the tension in the string.

(4)
(Total 13 marks)

8.

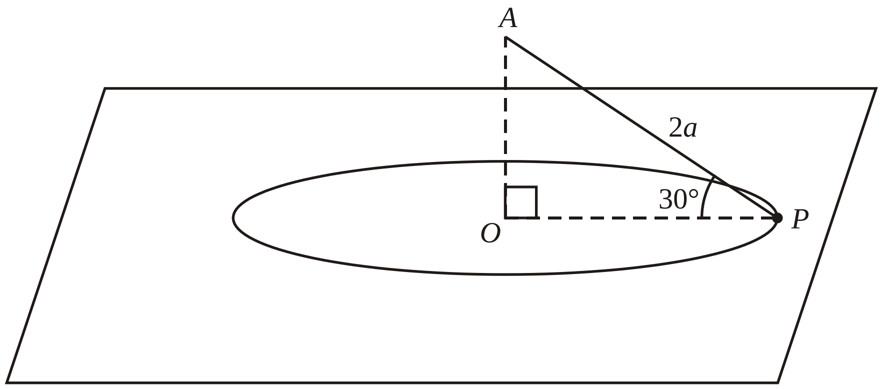


A hollow cone, of base radius $3a$ and height $4a$, is fixed with its axis vertical and vertex V downwards, as shown in the figure above. A particle moves in a horizontal circle with centre C, on the smooth inner surface of the cone with constant angular speed $\sqrt{\frac{8g}{9a}}$.

Find the height of C above V.

(Total 11 marks)

9.



A particle P of mass m is attached to one end of a light inextensible string of length $2a$. The other end of the string is fixed to a point A which is vertically above the point O on a smooth horizontal table. The particle P remains in contact with the surface of the table and moves in a circle with centre O and with angular speed $\sqrt{\left(\frac{kg}{3a}\right)}$, where k is a constant. Throughout the motion the string remains taut and $\angle APO = 30°$, as shown in the figure above.

(a) Show that the tension in the string is $\frac{2kmg}{3}$.

(3)

(b) Find, in terms of m, g and k, the normal reaction between P and the table.

(3)

(c) Deduce the range of possible values of k.

(2)

The angular speed of P is changed to $\sqrt{\left(\frac{2g}{a}\right)}$. The particle P now moves in a horizontal circle above the table. The centre of this circle is X.

(d) Show that X is the mid-point of OA.

(7)
(Total 15 marks)

10. A particle P of mass m moves on the smooth inner surface of a spherical bowl of internal radius r. The particle moves with constant angular speed in a horizontal circle, which is at a depth $\frac{1}{2}r$ below the centre of the bowl.

(a) Find the normal reaction of the bowl on P.

(4)

(b) Find the time for P to complete one revolution of its circular path.

(6)
(Total 10 marks)

11. A particle P of mass 0.5 kg is attached to one end of a light inextensible string of length 1.5 m. The other end of the string is attached to a fixed point A. The particle is moving, with the string taut, in a horizontal circle with centre O vertically below A. The particle is moving with constant angular speed 2.7 rad s^{-1}. Find

(a) the tension in the string,

(4)

(b) the angle, to the nearest degree, that AP makes with the downward vertical.

(3)
(Total 7 marks)

12. A rough disc rotates in a horizontal plane with constant angular velocity ω about a fixed vertical axis. A particle P of mass m lies on the disc at a distance $\frac{4}{3}a$ from the axis. The coefficient of friction between P and the disc is $\frac{3}{5}$. Given that P remains at rest relative to the disc,

(a) prove that $\omega^2 \leq \dfrac{9g}{20a}$.

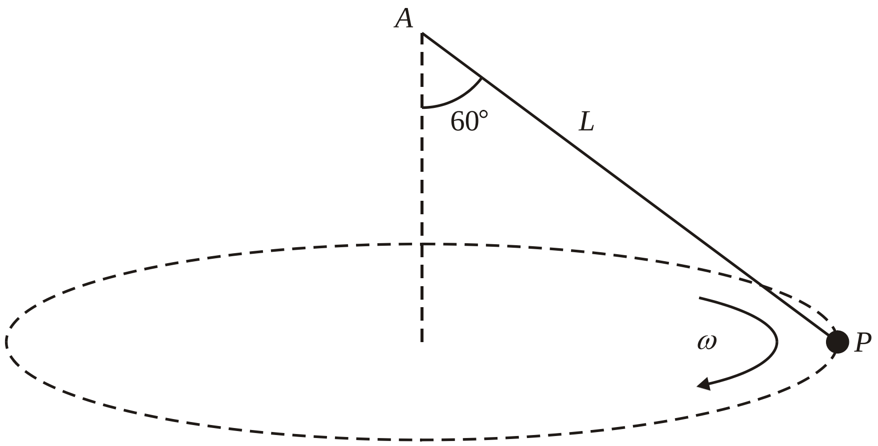
(4)

The particle is now connected to the axis by a horizontal light elastic string of natural length a and modulus of elasticity $2mg$. The disc again rotates with constant angular velocity ω about the axis and P remains at rest relative to the disc at a distance $\frac{4}{3}a$ from the axis.

(b) Find the greatest and least possible values of ω^2.

(7)
(Total 11 marks)

13.



A particle P of mass m is attached to one end of a light string. The other end of the string is attached to a fixed point A. The particle moves in a horizontal circle with constant angular speed ω and with the string inclined at an angle of 60° to the vertical, as shown in the diagram above. The length of the string is L.

(a) Show that the tension in the string is $2mg$.

(1)

(b) Find ω in terms of g and L.

(4)

The string is elastic and has natural length $\frac{3}{5}L$.

(c) Find the modulus of elasticity of the string.

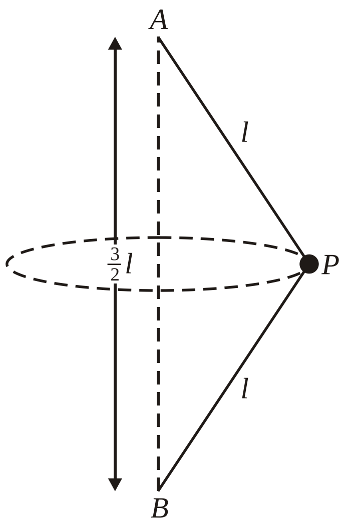
(2)
(Total 7 marks)

14. A car moves round a bend which is banked at a constant angle of 10° to the horizontal. When the car is travelling at a constant speed of 18 m s^{-1}, there is no sideways frictional force on the car. The car is modelled as a particle moving in a horizontal circle of radius r metres.

Calculate the value of r.

(Total 6 marks)

15.



A particle P of mass m is attached to the ends of two light inextensible strings AP and BP each of length l. The ends A and B are attached to fixed points, with A vertically above B and $AB = \frac{3}{2}l$, as shown in the diagram above. The particle P moves in a horizontal circle with constant angular speed ω. The centre of the circle is the mid-point of AB and both strings remain taut.

(a) Show that the tension in AP is $\frac{1}{6}m(3l\omega^2 + 4g)$.

(7)

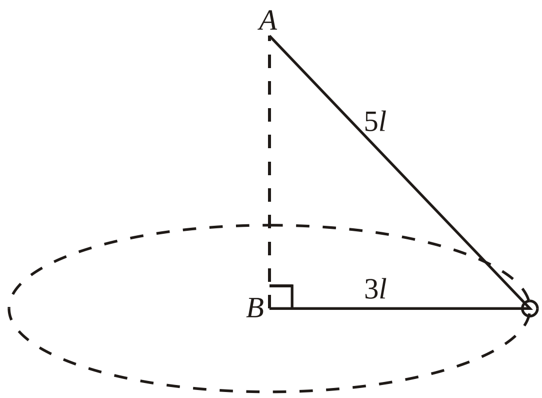
(b) Find, in terms of m, l, ω and g, an expression for the tension in BP.

(2)

(c) Deduce that $\omega^2 \geq \dfrac{4g}{3l}$.

(2)
(Total 11 marks)

16.



A light inextensible string of length $8l$ has its ends fixed to two points A and B, where A is vertically above B. A small smooth ring of mass m is threaded on the string. The ring is moving with constant speed in a horizontal circle with centre B and radius $3l$, as shown in the diagram above. Find

(a) the tension in the string,

(3)

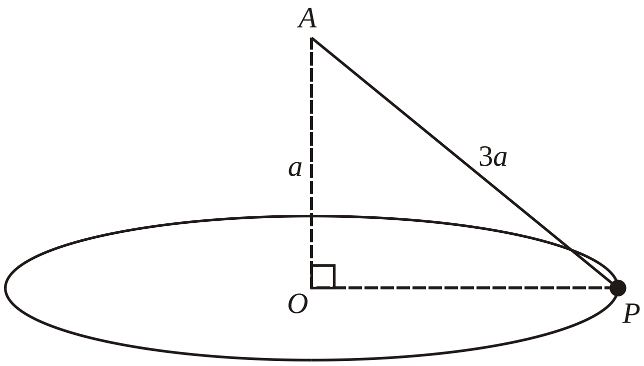
(b) the speed of the ring.

(5)

(c) State briefly in what way your solution might no longer be valid if the ring were firmly attached to the string.

(1)
(Total 9 marks)

17.



A particle P of mass m is attached to one end of a light inextensible string of length $3a$. The other end of the string is attached to a fixed point A which is a vertical distance a above a smooth horizontal table. The particle moves on the table in a circle whose centre O is vertically below A, as shown in the diagram above. The string is taut and the speed of P is $2\sqrt{(ag)}$.

Find

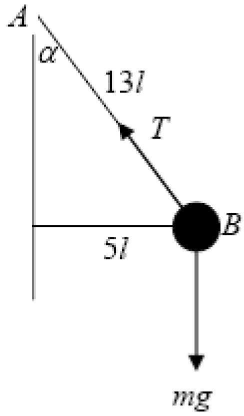
(a) the tension in the string,

(6)

(b) the normal reaction of the table on P.

(4)
(Total 10 marks)

1. (a)



$$\cos\alpha = \frac{12}{13}$$ B1

$R(\uparrow)$ $T\cos\alpha = mg$ M1

$$T \times \frac{12}{13} = mg$$

$$T = \frac{13}{12}mg$$ oe A1 3

(b) Eqn of motion $T\sin\alpha = m\dfrac{v^2}{5l}$ M1 A1

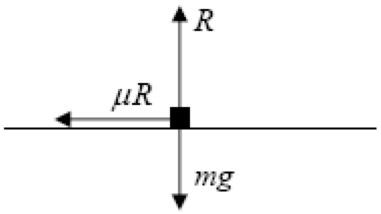
$$\frac{13mg}{12} \times \frac{5}{13} = m\frac{v^2}{5l}$$ M1 dep

$$v^2 = \frac{25gl}{12}$$

$v = \dfrac{5}{2}\sqrt{\dfrac{gl}{3}}$ $\left(\text{accept } 5\sqrt{\dfrac{gl}{12}} \text{ or } \sqrt{\dfrac{25gl}{12}} \text{ or any other equiv}\right)$ A1 4

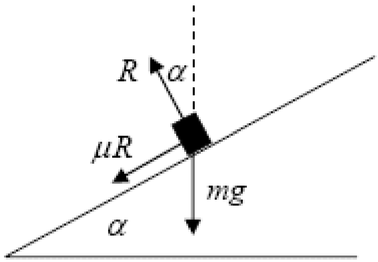
[7]

2. (a)



↑ $R = mg$		B1	
Use of limiting friction, $F_r = \mu R$		B1	
← $\mu R = \dfrac{m28^2}{120}$		M1 A1	
$\mu = \dfrac{28^2}{120 \times 9.8} = \dfrac{2}{3}$ *	cao	M1 A1	6

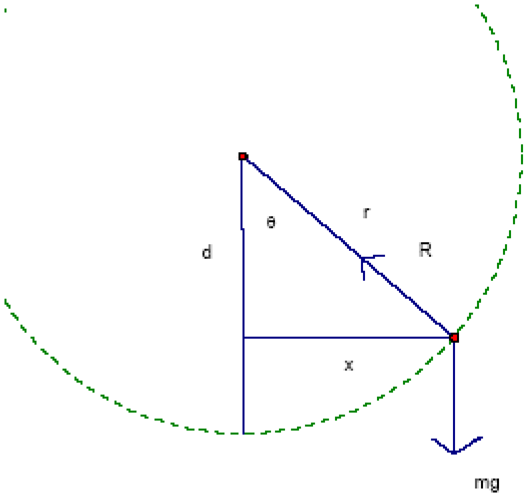
(b)



↑ $R\cos\alpha - \mu R\sin\alpha = mg$		M1 A1	
← $\mu R\cos\alpha + R\sin\alpha = \dfrac{mv^2}{r}$		M1 A1	
$\dfrac{\mu\cos\alpha + \sin\alpha}{\cos\alpha - \mu\sin\alpha} = \dfrac{v^2}{rg}$	Eliminating R	M1	
$\dfrac{2\cos\alpha + 3\sin\alpha}{3\cos\alpha - 2\sin\alpha} = \dfrac{25}{24}$	Substituting values	M1	
leading to $\tan\alpha = \dfrac{27}{122}$	awrt 0.22	M1 A1	8

[14]

3.



(a) $\leftrightarrow$ $R \sin \theta = mx\omega^2$ M1 A1

$R \times \frac{x}{r} = mx \times \frac{3g}{2r}$ M1

$R = \frac{3mg}{2}$ A1

(b) $\updownarrow$ $R \cos \theta = mg$ M1 A1

$\frac{3mg}{2} \times \frac{d}{r} = mg$ M1

$d = \frac{2}{3}r$ A1

[8]

4. $\omega = \frac{80 \times 2\pi}{60} \text{ rad s}^{-1} \left(= \frac{8\pi}{3} \approx 8.377\ldots \right)$ B1

Accept $v = \frac{16\pi}{75} \approx 0.67 \text{ ms}^{-1}$ as equivalent

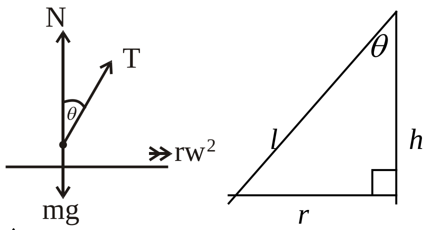
$(\uparrow)$ $R = mg$ B1

For least value of μ $(\leftarrow)$ $\mu mg = mr\omega^2$ M1 A1 = A1

$\mu = \frac{0.08}{9.8} \times \left(\frac{8\pi}{3}\right)^2 \approx 0.57$ accept 0.573 M1 A1

[7]

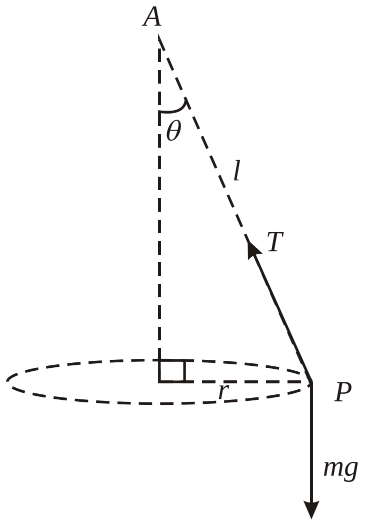
5. (a)



	$\uparrow T\cos\theta + N = Mg$ **(1)**	M1A1	
	$\rightarrow T\sin\theta = mr\omega^2$ **(2)**	M1A1	
	$\sin\theta = \frac{r}{l}$ from **(2)** $T = ml\omega^2$		
	sub into **(1)** $ml\cos\theta\,\omega^2 + N = mg$	M1	
	$N = mg - mh\omega^2$	A1	
	Since in contact with table $N \geq \mathbf{0}$ $\therefore$ $\omega^2 \leq \frac{g}{h}$ *	M1A1 cso	8
(b)	$r : h : l = 3 : 4 : 5$ $\therefore$ extension $= \frac{h}{4}$	B1	
	$T = \frac{2mg}{h} \times \frac{h}{4} = \frac{mg}{2}$	M1A1	
	$T = ml\omega^2 = \frac{5mh}{4}\omega^2$ $\quad \omega = \sqrt{\frac{2g}{5h}}$	M1A1	5

[13]

6.



$\uparrow T\cos\theta = mg$		M1A1	
$\leftarrow T\sin\theta = \dfrac{mv^2}{r}$		M1A1	
$\tan\theta = \dfrac{r}{\sqrt{(l^2 - r^2)}}$	or equivalent	M1A1	
$\tan\theta = \dfrac{v^2}{rg}$	Eliminating T	M1	
$\dfrac{r}{\sqrt{(l^2 - r^2)}} = \dfrac{v^2}{rg}$	Eliminating θ	M1	
$gr^2 = v^2\sqrt{(l^2 - r^2)}$ *	cso	A1	9

[9]

7. (a)

$\updownarrow T\cos\theta = mg$		B1	
$\leftrightarrow T + T\sin\theta = mr\omega^2$	(3 terms)	M1A1	
$r = h\tan\theta$		B1	
$\dfrac{mg}{\cos\theta}(1+\sin\theta) = \dfrac{m\omega^2 h\sin\theta}{\cos\theta}$	(eliminate r)	M1	
$\underline{\omega^2 = \dfrac{g}{h}\left(\dfrac{1+\sin\theta}{\sin\theta}\right)}$ (*)	(solve for ω^2)	M1A1	7

Allow first B1M1A1 if assume different tensions (so next M1 is effectively for eliminating r **and** T.

(b) $\omega^2 = \frac{g}{h}\left(\frac{1}{\sin\theta}+1\right) > \frac{2g}{h}\,(\sin\theta < 1) \Rightarrow \omega > \sqrt{\frac{2g}{h}}$ (*) M1A1 2

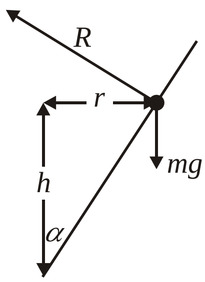
M1 requires a *valid* attempt to derive an *inequality* for ω.
(Hence putting $\sin\theta = 1$ immediately into expression of ω^2
[assuming this is the critical value] is M0.)

(c) $\frac{3g}{h} = \frac{g}{h}\left(\frac{1+\sin\theta}{\sin\theta}\right) \Rightarrow \sin\theta = \frac{1}{2}$ M1 A1

$T\cos\theta = mg \Rightarrow \underline{T = \frac{2\sqrt{3}}{3}mg}$ or $\underline{1.15mg}$ (awrt) M1A1 4

[13]

8.



$\tan\alpha = \frac{3}{4}$ or equivalent B1

$\tan\alpha = \frac{r}{h}$ or $\frac{r}{h} = \frac{3a}{4a}$ B1

R(↑) R sin α = mg $\left(R = \frac{5}{3}mg\right)$ M1 A1

R(→) R cos α = $mr\omega^2$ M1 A1

$= mr\frac{8g}{9a}\left(R = \frac{10mrg}{9a}\right)$ A1

$\tan\alpha = \frac{9a}{8r}\left(\frac{5}{3}mg = \frac{100mrg}{9a}\right)$ Eliminating R M1 A1

$\left(\frac{3}{4} = \frac{9a}{8r} \Rightarrow r = \frac{3}{2}a\right)$

$h = \frac{r}{\tan\alpha} = \frac{3a}{2} \times \frac{4}{3} = 2a$ M1 A1

[11]

9. (a) N2L U $T\cos 30° = m\,(2a\cos 30°)\left(\dfrac{kg}{3a}\right)$ M1 A1

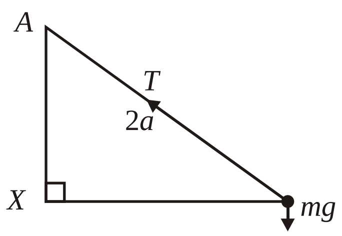
$T = \dfrac{2kmg}{3}$ ∗ cso A1 3

(b) i $R = mg - T\sin 30°$ M1 A1

$= mg\left(1 - \dfrac{k}{3}\right)$ A1 3

(c) $(R \mid 0) \Rightarrow k \mid 3$ ignore $k > 0$, accept $k < 3$ M1 A1 2

(d)



N2L U $T\cos\theta = m\,(2a\cos\theta)\left(\dfrac{2g}{a}\right)$ M1 A1

$(T = 4mg)$

i $T\sin\theta = mg$ M1

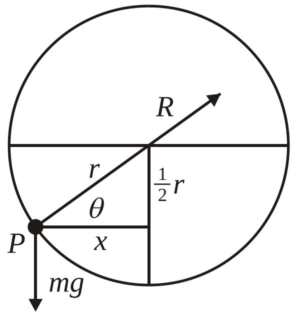
Eliminating T M1

$AX = 2a\sin\theta = \dfrac{1}{2}a$ A1

$AO = 2a\sin 30° = a \Rightarrow AX = \dfrac{1}{2}AO$, as required cso B1, A1 7

[15]

10.



(a) $\sin\theta = \frac{\frac{1}{2}r}{r} = \frac{1}{2}$ $(\Rightarrow \theta = 30°)$ B1

$\uparrow R\sin\theta = mg$ M1 A1

$R = 2\text{mg}$ A1 4

(b) $\rightarrow R\cos\theta = mx\omega^2$ M1 A1

$= m(r\cos\theta)\omega^2$ A1

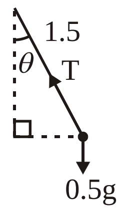
$\omega = \left(\frac{2g}{r}\right)^{\frac{1}{2}}$ A1

$T = \frac{2\pi}{\omega} = 2\pi\left(\frac{r}{2g}\right)^{\frac{1}{2}}$ or exact equivalent M1 A1 6

Note: $x = \frac{\sqrt{3}}{2}r$

[10]

11. (a)



$r = 1.5\sin\theta$ B1

$T\sin\theta = mrw^2$ M1A1

$T\sin\theta = 0.5 \times 1.5\sin\theta \times 2.7^2$

$T = \underline{5.4675\text{ N}}$ A1 4

(AWRT 5.5 N)

(b) $T\cos\theta = 5$ M1 A1

$\cos\theta = \dfrac{0.5g}{5.4675}$

$\underline{\theta = 26°}$ A1 3

(nearest degree)

[7]

12. (a) $(\uparrow)$, $R = mg$ B1

$m\dfrac{4a}{3}\omega^2$ (seen and used) B1

$m\dfrac{4a}{3}\omega^2 \le \dfrac{3}{5}mg$ M1

$\omega^2 \le \dfrac{9g}{20a}$ (*) A1 c.s.o 4

(b) $T = \dfrac{2mg}{a}\dfrac{a}{3} = \dfrac{2mg}{3}$ B1

$(\rightarrow)$, $\dfrac{3}{5}mg + \dfrac{2mg}{3} \underset{=}{\ge} m\dfrac{4a}{3}\omega_{max}^2$ M1 A1 f.t

$\dfrac{19g}{20a} = \omega_{max}^2$ A1

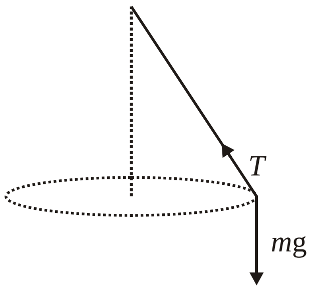
$(\rightarrow)$, $-\dfrac{3}{5}mg + \dfrac{2mg}{3} \underset{=}{\le} m\dfrac{4a}{3}\omega_{min}^2$ M1 A1 f.t

$\dfrac{g}{20a} = \omega_{min}^2$ A1 7

If only one answer, must be clear whether max or min for final A1

[11]

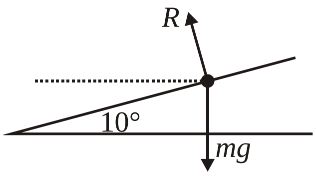
13.



(a)	($\updownarrow$) $T\cos60° = mg \Rightarrow T = 2mg$ *	B1	1
(b)	($\leftrightarrow$) $T\sin60° = mr\omega^2$	M1A1	
	$r = L\sin60°$	B1	
	$\omega = \sqrt{\dfrac{\mathbf{2g}}{\boldsymbol{L}}}$	A1	4
(c)	Applying Hooke's Law: $2mg = \dfrac{\lambda}{(\frac{3}{5}L)}(L - \dfrac{3}{5}L)$; λ 3mg	M1;A1	2

[7]

14.

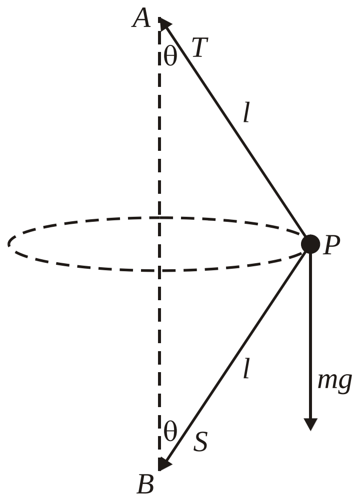


($\updownarrow$) $R\cos10° = mg$	M1 A1	
($\leftrightarrow$) $R\sin10° = \dfrac{mv^2}{r}$	M1 A1 ft	
[A1 ft on sin/cos mix]		
Solving for r: $r = \left[\dfrac{18^2}{g\tan10^\circ}\right]$	M1	
$r = 190$ (m) [Accept 187, 188]	A1	6

[Resolving along slope: mg sin10° = $\dfrac{m(18)^2}{r}$ *cos10°,* M2A1A1 *ft, then M1 A1]*

[6]

15. (a)



$(\updownarrow)$ $(T-S)\cos\theta = mg$	M1 A1	
$(\leftrightarrow)$ $(T+S)\sin\theta = mr\omega^2$	M1 A1 ft	
$= m(l\sin\theta)\omega^2$	A1	
Finding T in terms of l, m, ω^2 and g	M1	
$T = \frac{1}{6}m(3l\omega^2 + 4g)$ (*)	A1	7

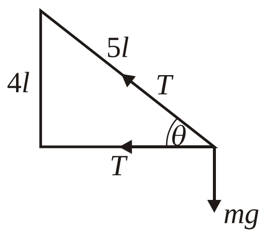
(b) Finding S: $S = \frac{1}{6}m(3l\omega^2 - 4g)$ — M1 A1 — 2

any correct form

(c) Setting $S \geq 0$; $\omega^2 \geq \dfrac{4g}{3l}$ (*) (no wrong working seen) — M1 A1 — 2

[11]

16. (a)

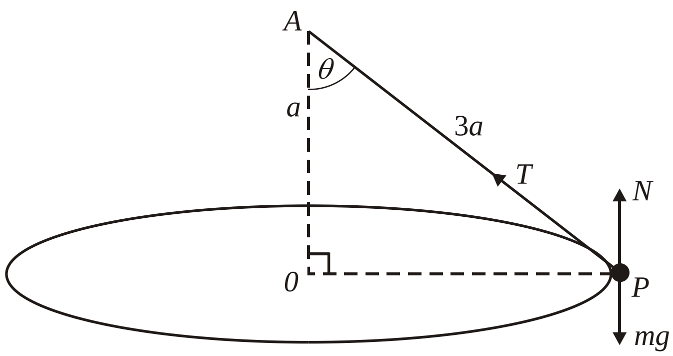


3, 4, 5 Δ	B1	
R(↑) $T\sin\theta = mg$	M1	
$T = \dfrac{5mg}{4}$	A1	3

(b)	R ($\leftarrow$) $T + T\cos\theta = \dfrac{mv^2}{3l}$	M1 A2	
	$\dfrac{8}{5} \times \dfrac{5mg}{4} = \dfrac{mv^2}{3l}$	M1	
	$v = \sqrt{6gl}$	A1	5
(c)	Could not assume tensions same	B1	1

[9]

17.



$OP = a\sqrt{8}$	B1	
$R(\leftarrow)$: $T\sin\theta = \dfrac{mv^2}{a\sqrt{8}}$	M1 A1	
$T\,\dfrac{\sqrt{8}a}{3a} = \dfrac{m \times 4ga}{a\sqrt{8}}$ (sin θ)	B1 ft	
$\Rightarrow\ T = \dfrac{3mg}{2}$	M1 A1	6
$R(\uparrow)$: $T\cos\theta + N = mg$	M1 A1	
$\Rightarrow N = mg - \frac{3}{2}mg \times \frac{1}{3} = \frac{1}{2}mg$	M1 A1	4

[10]

1. For the overwhelming majority this provided a very straightforward introduction leading to full marks. Mistakes made by the weakest students, both here and elsewhere, revealed their lack of understanding of different areas of the syllabus and their reliance on standard equations. In particular, some seemed intent on using SHM wherever they felt a familiar formula seemed applicable.

2. Almost all candidates achieved full marks in part (a) but a few lost the last mark for using decimals through their working. The given answer was a fraction and once accuracy has been lost through the use of decimals it cannot be regained. Part (b) proved to be much more of a challenge. The majority seemed to be trying to resolve horizontally and vertically as they produced a correct horizontal equation (M1A1) but their second equation was often $R = mg\cos\theta$ (M0A0). Some even used $R = mg$, as they had in part (a). Others produced correct horizontal and vertical equations (M1A1M1A1) but then included $R = mg\cos\theta$ or $R = mg$ to aid elimination of R. This made their solution invalid and no further marks could be gained. A few candidates attempted to resolve parallel and perpendicular to the plane but did not realise that both of these equations needed a component of the acceleration.

3. Some candidates found this question to be very straightforward and gave very neat concise solutions to both parts. However, that was not so in the majority of cases. Many produced horizontal and vertical equations with correct components of the reaction. However, not all knew what to do with these equations and no further work was shown. Frequently candidates equated the horizontal component of the reaction to $mr\omega^2$ (where r was the given radius of the bowl). Most of these candidates then found $\tan\theta = \frac{3}{2}$ and linked back to the reaction and d (in terms of r) via $\sin\theta$ and $\cos\theta$. As they thought that r was the horizontal radius (rather than the radius of the bowl) they also used $\theta = \frac{r}{d}$ to arrive at what appeared to be a correct result. Few marks could be awarded, however, for work which was based on such a serious initial error. Some candidates simply wrote down $F = mr\omega^2 = \dfrac{3mg}{2}$, which is a correct equation, although it was often not clear that the candidates really understood this. Many could not produce any equations to enable d to be found or even revealed their lack of understanding by proceeding to treat $\dfrac{3mg}{2}$ as a component of the required reaction.

4. Candidates seemed to have great difficulty changing from revolutions per minute to radians per second. This seemed to be wrong at least as often as it was correct. A surprising number of solutions involved inequalities, not always the correct way round. Unfortunately, some gave their final answer as an inequality and so failed to answer the question as set. Many did not notice that the distance was given in centimetres and so used 8 instead of 0.08 in their calculation. Those who knew how to tackle this question produced succinct solutions.

5. It was disappointing to note how many candidates missed the point of the mechanics in part (a) of this question. Certainly having a reaction force from contact with the table was an irritation to them so much so that they either ignored it all together or put it in and then said $N = 0$. The actual condition of finding an expression for N and using $N \geq 0$ was lost on too many.
Most preferred part (b) where they could simply find some set values and plug in results. The ones who did this part incorrectly were usually those who had insisted that $T \cos \theta = mg$ in part (a) and hence it also applied in part (b).

Most preferred part (b) where they could simply find some set values and plug in results. The ones who did this part incorrectly were usually those who had insisted that $T \cos \theta = mg$ in part (a) and hence it also applied in part (b). They used it to find an incorrect value of T to use in $T \sin \theta = mr\omega^2$. The relating of 3:4:5 to a given side of h was often dubious with h being missed out of some lengths and some careless trigonometry was also seen. Candidates often stopped at ω^2 and so lost the final mark.

6. This proved to be the easiest question on the paper and full marks were very common. Those who failed to complete the question nearly always had the resolutions correct but failed to spot the trigonometric relation between the lengths. Methods of solution using a centrifugal force were very uncommon.

7. Parts (a) and (c) were generally well done. In part (b), a fully justified derivation of the given answer was only rarely seen. Most assumed that they could put the maximum value of $\sin \theta = 1$ directly into the expression obtained in (a) without any more discussion.

8. This question was a very good discriminator. There were many excellent concise solutions leading quickly to full marks. However there was also a substantial minority of students who failed to get started. Inadequate diagram often led to candidates confusing an angle with its complementary angle and this led to errors in resolution. A common error was to assume that the line of action of the reaction went through the centre of the circular end of the cone. In resolving, the vertical equation was more often incorrect than the horizontal equation. $R = mg$, $R = mg \cos \alpha$ and $R = mg \sin \alpha$ were all common errors. An unexpected feature of the responses was, for the first time for some years in any numbers, to see some students using centrifugal or, even, centripetal forces. Such methods were not envisaged when this set of mechanics specifications were designed but, if used correctly, are accepted.

9. For a significant number of relatively weak candidates this question ensured a respectable mark. If conical pendulum methods were well known, it proved very straightforward and large numbers of candidates gained full marks. However, the "show that" in part (a) threw many, who were not entirely happy with this topic, completely off track. It was very clear to many that $m\omega^2 \times 2a$ gave the right numerical answer, so they decided that this must be the right way to do the question. It was very common to see a solution which had started with $T\cos 30 = m\omega^2 \times 2a$ continue with the cos 30 scribbled out. This then had further implications in part (c) where the candidates used the method which had "worked" in part (a) and failed to resolve here also. This betrayed a complete lack of understanding and justifiably led to the loss of a significant number of marks. There was further evidence in this question of inadequate "showing" by able students when answers are printed. Calculation of length *OA* as *a* was almost trivial but needed to be shown not assumed. Perfect solutions which ended up saying $OX = a/2$, so *X* is the mid-point of *OA* were not uncommon.

10. Although the general principles involved in this question were usually well understood, many errors of detail were seen. Many assumed *r* to be the radius of the circle rather than the sphere. This led to an incorrect angle in (a) and a significant oversimplification of the question in (b). A common error in (b), even among those who realised in (a) that *r* was the radius of the sphere, was to fail to calculate the radius of the circle. Almost all of those who could find the angular velocity knew how to convert this to the time for a complete revolution.

11. This proved to be a good start for most candidates although a few used $r = 1.5$ and a significant number failed to give the answer in part (b) to the nearest degree.

12. Part (a) was reasonably well done by most but the second part was challenging. The use of "centripetal force" continues to cause much confusion. The most frequent errors in (b) were (i) using only one of the equations T ± F= mrω2, and then failing to indicate whether their answer was the maximum or minimum. (ii) putting F = 0 to find the minimum value and (iii) being unable to find or making an error with the extension of the elastic string. In (b) some candidates drew the diagram as a conical pendulum and wasted a great deal of time trying to solve the unsolvable.

13. Although the answer was given in part (a) it is still good to report that all but a handful of candidates gained the mark. Part (b) was generally well answered, although $T = mr\omega^2$, $T\sin 60° = mL\omega^2$, and errors in eliminating *r*, were occasionally seen. Probably the most common error in this question occurred in part (c), where *L*, instead of $\frac{3}{5}L$, was often seen in the denominator of Hooke's law.

14. This question was well answered by the majority of candidates, who frequently scored 5 or 6 marks, the loss of the final mark for giving an answer to more than 3 significant figures. Some candidates did use equations showing serious errors in the mechanics, like $R = mg \cos 10°$ and $mg \sin 10° = m\frac{v^2}{r}$; invariably these errors meant that a maximum of 2 marks was available.

15. All but the weakest candidates, who considered the strings separately, made some progress in this question. Some were handicapped by mixing up sine and cosine, by not eliminating r successfully, and by arithmetic errors in finding trigonometric ratios. In parts (a) and (c) given results had to be derived and, as usual, they often emerged from incorrect working. In part (c) it was quite common to see T_1 (top string) ≥ 0, or $T_1 + T_2 \geq 0$ used as the condition for deriving the result.

16. The majority scored well on part (a) although many calculated an angle rather than using the 3-4-5 triangle. There were some who resolved incorrectly, either using the wrong trig. ratio or worse, trying to resolve along the string, forgetting that there is an acceleration component in that direction. In the second part a large number of candidates included only one tension, usually the one in the upper part of the string, in their equation of motion but then went on, in the final part, to correctly state that, if the particle were attached to the string, the tensions in the two portions of the string would be different.

17. No Report available for this question.