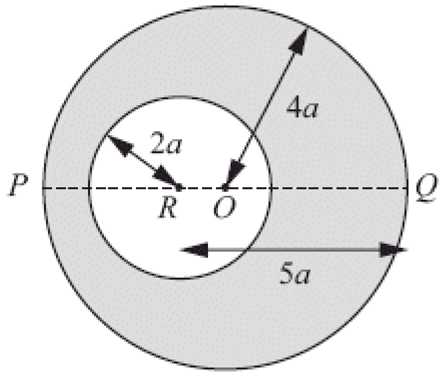
1.



A uniform circular disc has mass $4m$, centre O and radius $4a$. The line POQ is a diameter of the disc. A circular hole of radius $2a$ is made in the disc with the centre of the hole at the point R on PQ where $QR = 5a$, as shown in the diagram above.

The resulting lamina is free to rotate about a fixed smooth horizontal axis L which passes through Q and is perpendicular to the plane of the lamina.

(a) Show that the moment of inertia of the lamina about L is $69ma^2$.

(7)

The lamina is hanging at rest with P vertically below Q when it is given an angular velocity Ω. Given that the lamina turns through an angle $\frac{2\pi}{3}$ before it first comes to instantaneous rest,

(b) find Ω in terms of g and a.

(6)
(Total 13 marks)

2. A uniform lamina ABC of mass m is in the shape of an isosceles triangle with $AB = AC = 5a$ and $BC = 8a$.

(a) Show, using integration, that the moment of inertia of the lamina about an axis through A, parallel to BC, is $\frac{9}{2}ma^2$.

(6)

The foot of the perpendicular from A to BC is D. The lamina is free to rotate in a vertical plane about a fixed smooth horizontal axis which passes through D and is perpendicular to the plane of the lamina. The lamina is released from rest when DA makes an angle α with the downward vertical. It is given that the moment of inertia of the lamina about an axis through A, perpendicular to BC and in the plane of the lamina, is $\frac{8}{3}ma^2$.

(b) Find the angular acceleration of the lamina when DA makes an angle θ with the downward vertical.

(8)

Given that α is small,

(c) fin d an approximate value for the period of oscillation of the lamina about the vertical.

(2)
(Total 16 marks)

3. A uniform circular disc has mass m, centre O and radius $2a$. It is free to rotate about a fixed smooth horizontal axis L which lies in the same plane as the disc and which is tangential to the disc at the point A. The disc is hanging at rest in equilibrium with O vertically below A when it is struck at O by a particle of mass m. Immediately before the impact the particle is moving perpendicular to the plane of the disc with speed $3\sqrt{(ag)}$. The particle adheres to the disc at O.

(a) Find the angular speed of the disc immediately after the impact.

(5)

(b) Find the magnitude of the force exerted on the disc by the axis immediately after the impact.

(6)
(Total 11 marks)

4. A pendulum consists of a uniform rod AB, of length $4a$ and mass $2m$, whose end A is rigidly attached to the centre O of a uniform square lamina $PQRS$, of mass $4m$ and side a. The rod AB is perpendicular to the plane of the lamina. The pendulum is free to rotate about a fixed smooth horizontal axis L which passes through B. The axis L is perpendicular to AB and parallel to the edge PQ of the square.

(a) Show that the moment of inertia of the pendulum about L is $75ma^2$.

(4)

The pendulum is released from rest when BA makes an angle α with the downward vertical through B, where $\tan \alpha = \frac{7}{24}$. When BA makes an angle θ with the downward vertical through B, the magnitude of the component, in the direction AB, of the force exerted by the axis L on the pendulum is X.

(b) Find an expression for X in terms of m, g and θ.

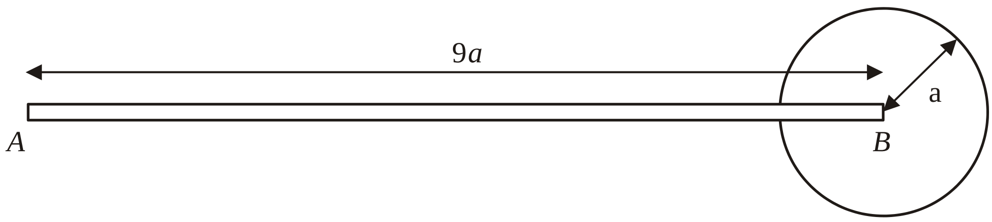
(9)

Using the approximation $\theta \approx \sin \theta$,

(c) find an estimate of the time for the pendulum to rotate through an angle α from its initial rest position.

(6)
(Total 19 marks)

5.



A pendulum P is modelled as a uniform rod AB, of length $9a$ and mass m, rigidly fixed to a uniform circular disc of radius a and mass $2m$. The end B of the rod is attached to the centre of the disc, and the rod lies in the plane of the disc, as shown in the diagram above. The pendulum is free to rotate in a vertical plane about a fixed smooth horizontal axis L which passes through the end A and is perpendicular to the plane of the disc.

(a) Show that the moment of inertia of P about L is $190ma^2$.

(4)

The pendulum makes small oscillations about L.

(b) By writing down an equation of motion for P, find the approximate period of these small oscillations.

(7)
(Total 11 marks)

6. A uniform square lamina $ABCD$, of mass $2m$ and side $3a\sqrt{2}$, is free to rotate in a vertical plane about a fixed smooth horizontal axis L which passes through A and is perpendicular to the plane of the lamina. The moment of inertia of the lamina about L is $24ma^2$.

The lamina is at rest with C vertically above A. At time $t = 0$ the lamina is slightly displaced. At time t the lamina has rotated through an angle θ.

(a) Show that

$$2a\left(\frac{d\theta}{dt}\right)^2 = g(1 - \cos\theta) .$$

(4)

(b) Show that, at time t, the magnitude of the component of the force acting on the lamina at A, in a direction perpendicular to AC, is $\frac{1}{2}mg\sin\theta$.

(7)

When the lamina reaches the position with C vertically below A, it receives an impulse which acts at C, in the plane of the lamina and in a direction which is perpendicular to the line AC. As a result of this impulse the lamina is brought immediately to rest.

(c) Find the magnitude of the impulse.

(5)
(Total 16 marks)

7. Four uniform rods, each of mass m and length $2a$, are joined together at their ends to form a plane rigid square framework $ABCD$ of side $2a$. The framework is free to rotate in a vertical plane about a fixed smooth horizontal axis through A. The axis is perpendicular to the plane of the framework.

(a) Show that the moment of inertia of the framework about the axis is $\frac{40ma^2}{3}$.

(5)

The framework is slightly disturbed from rest when C is vertically above A. Find

(b) the angular acceleration of the framework when AC is horizontal,

(3)

(c) the angular speed of the framework when AC is horizontal,

(3)

(d) the magnitude of the force acting on the framework at A when AC is horizontal.

(6)
(Total 17 marks)

8. A uniform square lamina $ABCD$, of mass m and side $2a$, is free to rotate in a vertical plane about a fixed smooth horizontal axis L which passes through A and is perpendicular to the plane of the lamina. The moment of inertia of the lamina about L is $\frac{8ma^2}{3}$.

Given that the lamina is released from rest when the line AC makes an angle of $\frac{\pi}{3}$ with the downward vertical,

(a) find the magnitude of the vertical component of the force acting on the lamina at A when the line AC is vertical.

(7)

Given instead that the lamina now makes small oscillations about its position of stable equilibrium,

(b) find the period of these oscillations.

(5)
(Total 12 marks)

9. A uniform lamina of mass m is in the shape of an equilateral triangle ABC of perpendicular height h. The lamina is free to rotate in a vertical plane about a fixed smooth horizontal axis L through A and perpendicular to the lamina.

(a) Show, by integration, that the moment of inertia of the lamina about L is $\frac{5mh^2}{9}$.

(9)

The centre of mass of the lamina is G. The lamina is in equilibrium, with G below A, when it is given an angular speed $\sqrt{\left(\frac{6g}{5h}\right)}$.

(b) Find the angle between AG and the downward vertical, when the lamina first comes to rest.

(5)

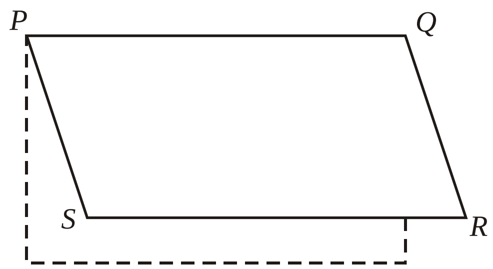
(c) Find the greatest magnitude of the angular acceleration during the motion.

(3)
(Total 17 marks)

10. A uniform lamina of mass m is in the shape of a rectangle $PQRS$, where $PQ = 8a$ and $QR = 6a$.

(a) Find the moment of inertia of the lamina about the edge PQ.

(2)



The flap on a letterbox is modelled as such a lamina. The flap is free to rotate about an axis along its horizontal edge PQ, as shown in the diagram above. The flap is released from rest in a horizontal position. It then swings down into a vertical position.

(b) Show that the angular speed of the flap as it reaches the vertical position is $\sqrt{\left(\frac{g}{2a}\right)}$.

(3)

(c) Find the magnitude of the vertical component of the resultant force of the axis PQ on the flap, as it reaches the vertical position.

(4)
(Total 7 marks)

11. A uniform sphere, of mass m and radius a, is free to rotate about a smooth fixed horizontal axis L which forms a tangent to the sphere. The sphere is hanging in equilibrium below the axis when it receives an impulse, causing it to rotate about L with an initial angular velocity of $\sqrt{\dfrac{18g}{7a}}$.

Show that, when the sphere has turned through an angle θ,

(a) the angular speed ω of the sphere is given by $\omega^2 = \dfrac{2g}{7a}(4 + 5\cos\theta)$,

(5)

(b) the angular acceleration of the sphere has magnitude $\dfrac{5g}{7a}\sin\theta$.

(2)

(c) Hence find the magnitude of the force exerted by the axis on the sphere when the sphere comes to instantaneous rest for the first time.

(10)
(Total 17 marks)

1. (a)

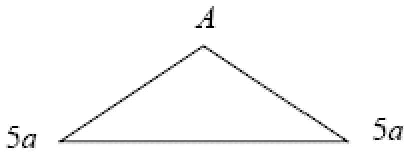
Mass of disc removed = m	B1	
$\frac{1}{2}4m(4a)^2 + 4m(4a)^2$	M1 A1	
$\frac{1}{2}m(2a)^2 + m(5a)^2$	M1 A1	
$I = \frac{1}{2}4m(4a)^2 + 4m(4a)^2 - (\frac{1}{2}m(2a)^2 + m(5a)^2)$	DM1	
$= 69ma^2$ *	A1	7

(b)

$4m.0 = 3m\bar{x} - ma$	M1	
$\bar{x} = \frac{1}{3}a$ (from O)	A1	
$\frac{1}{2}69ma^2\Omega^2 = 3mg(4a - \frac{1}{3}a)(1 - \cos\frac{2\pi}{3})$	M1 A2	
$\Omega = \sqrt{\frac{11g}{23a}}$	A1	6

[13]

2. (a)



$\delta A = \frac{8x}{3}\delta x$	M1 A1	
$\delta m = \frac{8x}{3}\delta x.\frac{m}{12a^2}$ or $\delta m = \frac{8x}{3}\delta x.\rho$	DM1	
$\delta I = \frac{8x}{3}\delta x.\frac{m}{12a^2}x^2 \quad (= \frac{2m}{9a^2}x^3\delta x)$	A1	
$I = \int_0^{3a} \frac{2m}{9a^2}x^3 \, dx$	M1	
$= \frac{2m}{9a^2}\left[\frac{x^4}{4}\right]_0^{3a}$		
$= \frac{9ma^2}{2}$*	A1	6

(b) $I_A = \dfrac{9ma^2}{2} + \dfrac{8ma^2}{3} = \dfrac{43ma^2}{6}$ (perp axes rule) M1 A1

$I_A = I_G + m(2a)^2$ (parallel axes rule) DM1 A1

$I_D = I_G + ma^2$ (parallel axes rule) A1

$I_D = \dfrac{43ma^2}{6} - 3ma^2 = \dfrac{25ma^2}{6}$ A1

$mga\sin\theta = -\dfrac{25ma^2}{6}\ddot{\theta}$ M1

$\ddot{\theta} = -\dfrac{6g}{25a}\sin\theta$ A1 8

(c) For small θ, $\ddot{\theta} = -\dfrac{6g}{25a}\theta$ SHM M1

$T = 2\pi\sqrt{\dfrac{25a}{6g}} = 5\pi\sqrt{\dfrac{2a}{3g}}$ A1 2

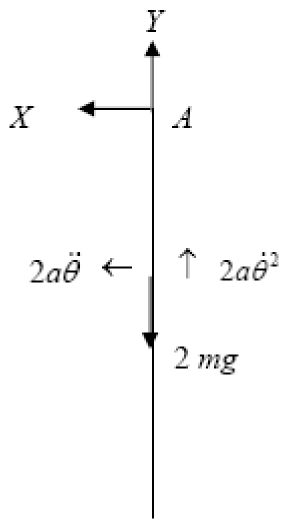
[16]

3. (a) MI of disc about $L = \dfrac{1}{4}m(2a)^2 + m(2a)^2 = 5ma^2$ M1 A1

CAM: $m3\sqrt{ag}.2a = (5ma^2 + m(2a)^2)\omega$ M1 A1 ft

$\omega = \dfrac{2}{3}\sqrt{\dfrac{g}{a}}$ A1 5

(b)



$M(A),\ 0 = I\ddot{\theta}$ B1

$\ddot{\theta} = 0$

$R(\leftarrow), X = 2m2a\ddot{\theta} = 0$ B1

$R(\uparrow), Y - 2mg = 2m2a\dot{\theta}^2$ M1 A1

$Y = 2mg + 4ma\dfrac{4g}{9a}$ DM1

$= \dfrac{34mg}{9}$ A1 6

[11]

4. (a) $\dfrac{1}{3}2m(4a)^2 + \dfrac{1}{12}4ma^2 + 4m(4a)^2$ B1 M1 A1

$= \dfrac{32}{3}ma^2 + \dfrac{1}{3}ma^2 + 64ma^2$

$= 75ma^2$ * A1 4

(b) $\dfrac{1}{2}\ 75ma^2\omega^2 = 2mg2a(\cos\theta - \cos\alpha) + 4mg4a(\cos\theta - \cos\alpha)$ M1 A2

$a\omega^2 = \dfrac{8}{15}g(\cos\theta - \dfrac{24}{25}) = \dfrac{8}{375}g(25\cos\theta - 24)$ A1

$X - 6mg\cos\theta = 2m2a\omega^2 + 4m4a\omega^2 = 20ma\omega^2$ M1 A2

$X = 6mg\cos\theta + 20m\dfrac{8}{375}g(25\cos\theta - 24)$ D M1

$= \dfrac{50mg\cos\theta}{3} - \dfrac{256mg}{25}$ A1 9

(c) $-2mg\ 2a\sin\theta - 4mg\ 4a\sin\theta = 75ma^2\ddot{\theta}$ M1 A1

$\ddot{\theta} = -\dfrac{4g}{15a}\sin\theta$ A1

$\approx -\dfrac{4g}{15a}\theta$, SHM M1

Time = $\dfrac{1}{4}2\pi\sqrt{\dfrac{15a}{4g}}$ M1

$\dfrac{\pi}{4}\sqrt{\dfrac{15a}{g}}$ A1 6

[19]

5. (a) $I = \dfrac{1}{3}m(9a)^2 + \dfrac{1}{2}2ma^2 + 2m(9a)^2$ M1A1A1

$= 27ma^2 + ma^2 + 162ma^2$

$= 190ma^2$ A1 4

(b) $M(L)$,

$mg\,\dfrac{9a}{2}\sin\theta + mg9a\sin\theta = -190ma^2\ddot{\theta}$ M1 A2

$\ddot{\theta} = -\dfrac{9g}{76a}\sin\theta$

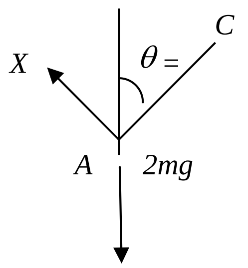
For small θ, $\sin\theta \approx \theta$, M1

$\Rightarrow \ddot{\theta} = -\dfrac{9g}{76a}\theta$ so S.H.M. A1

Period = $2\pi\sqrt{\dfrac{76a}{9g}} = \dfrac{4\pi}{3}\sqrt{\dfrac{19a}{g}}$ DM1 A1 7

[11]

6. (a)



$\dfrac{1}{2}24ma^2\dot{\theta}^2 = 2mg.3a(1 - \cos\theta)$ M1A1A1

$2a\dot{\theta}^2 = g(1 - \cos\theta)$ A1 4

(b) (↘)

$2mg\sin\theta - X = 2m3a\cos\theta$ M1A2

$M(L)$, $2mg.3a\sin\theta = 24ma^2\ddot{\theta}^2$ M1A1

$\Rightarrow X = 2mg\sin\theta - 6ma\left(\dfrac{g\sin\theta}{4a}\right)$ DM1

$= \dfrac{mg\sin\theta}{2}$* A1 7

(c) $\theta = \pi : 2a\dot{\theta}^2 = g(1-\cos\pi)$ M1

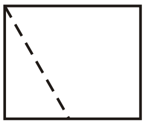
$\dot{\theta} = \sqrt{\frac{g}{a}}$ A1

$6a.I = 24ma^2\sqrt{\frac{g}{a}}$ M1A1

$\Rightarrow I = 4m\sqrt{ag}$ A1 5

[16]

7. (a)



$I_{AB} = 2 \times \frac{4}{3}ma^2 + m(2a)^2 = \frac{20}{3}ma^2$ M1 A1 A1

(BC, AD) (CD)

By ⊥r axis: $I_A = 2 \times \frac{20}{3}ma^2 = \underline{\frac{40}{3}ma^2}$ M1 A1 5

[<u>or</u> $I_A = 2 \times \frac{4}{3}ma^2, +2(\frac{1}{3}ma^2 + 5ma^2)$ M1, M1 A1 A1

(AB, AD) (BC, CD)

$= \underline{\frac{40}{3}ma^2}$ A1

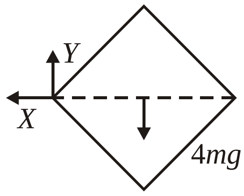
(b) M(A) $\frac{40ma^2}{3}\ddot{\theta} = 4mg.a\sqrt{2}$ M1 A1

$\ddot{\theta} = \underline{\frac{3g\sqrt{2}}{10a}}$ A1 3

(c) $\frac{1}{2}.\frac{40ma^2}{3}\dot{\theta}^2 = 4mg.a\sqrt{2}$ M1 A1

$\dot{\theta} = \sqrt{\frac{3g\sqrt{2}}{5a}}$ A1 3

(d)



R(←) $X = 4ma\sqrt{2}\dot{\theta}^2$ M1

$= 4ma\ \sqrt{2}.\dfrac{3g\sqrt{2}}{5a} = \dfrac{24mg}{5}$ A1

R(↑) $4mg - Y = 4ma\sqrt{2}\ddot{\theta}$ M1

$Y = 4mg - 4ma\sqrt{2}.\dfrac{3g\sqrt{2}}{10a}$

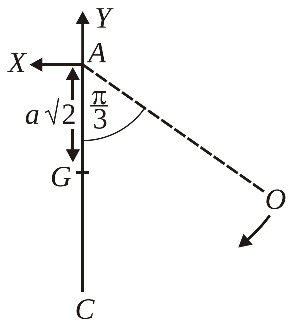
$Y = \dfrac{8mg}{5}$ A1

$R = \sqrt{(X^2 + Y^2)} = \dfrac{8mg}{5}\sqrt{(1^2 + 3^2)}$ M1

$= \underline{\dfrac{8\sqrt{10}}{5}mg}$ A1 6

[17]

8. (a)



Energy: $\dfrac{1}{2}.\dfrac{8ma^2}{3}\dot{\theta}^2 = mga\sqrt{2}\left(1 - \cos\dfrac{\pi}{3}\right)$ M1 A1

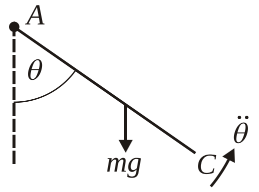
$\Rightarrow\ \underline{\dot{\theta}^2 = \dfrac{3g\sqrt{2}}{8a}}$ A1

$R\uparrow$: $\gamma - mg = ma\sqrt{2}\dot{\theta}^2$ M1 A1

$= ma\sqrt{2}.\dfrac{3g\sqrt{2}}{8a}$ M1

$\Rightarrow \underline{\gamma = \dfrac{7mg}{4}}$ A1 7

(b)



M(L): $-mga\sqrt{2}\sin\theta = \frac{8}{3}ma^2\ddot{\theta}$ M1 A1 A1

For small $\theta \sin\theta \cong \theta$

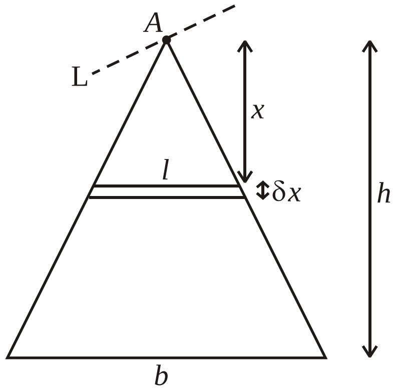
$\Rightarrow\ -\frac{3g\sqrt{2}}{8a}\dot{\theta} \cong \ddot{\theta}$ M1

Approx SHM

$\Rightarrow$ period $= 2\pi\sqrt{\frac{8a}{3g\sqrt{2}}}$ A1 5

[12]

9. (a)



$$\frac{l}{x} = \frac{b}{h}\left(= \frac{2}{\sqrt{3}}\right)$$ M1

$$\Rightarrow l = \frac{bx}{h} = \frac{2x}{\sqrt{3}}$$ A1

$$\rho = \frac{m}{\frac{1}{2}bh} = \frac{2m}{bh}$$

$$\delta m = \frac{bx}{h}.\delta x.\frac{2m}{bh} = \frac{2m}{bh} = \frac{2m}{h^2}x\delta x$$ M1

$$\delta T_L \cong \frac{1}{3}\delta m\left(\frac{l}{2}\right)^2 + \delta m x^2$$ M1 M1 A1

$$= \frac{1}{12}(l^2 + 12x^2)\delta m$$

$$= \frac{1}{12}\left(\frac{4x^2}{3} + 12x^2\right)\frac{2mx}{h^2}\delta x$$

$$= \frac{80}{36}\frac{m}{h^2}x^3\delta x$$

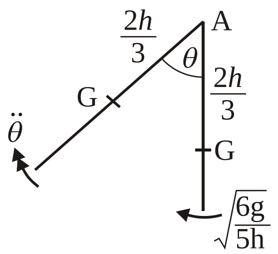
$$= \frac{20}{9}\frac{m}{h^2}x^3\delta x$$ A1

$$I_L = \frac{20}{9}\frac{m}{h^2}\int_0^h x^3\delta x$$ M1

$$= \frac{20}{9}\frac{m}{h^2}.\frac{h^4}{4}$$

$$= \frac{5mh^2}{9} \quad (*)$$ A1 9

(b)



Energy:

$\frac{1}{2}.\frac{5m}{9}h^2\dot{\theta}^2 = mg\frac{2h}{3}(1-\cos\theta)$

$\Rightarrow \frac{1}{2}.\frac{5mh^2}{9}\frac{6g}{5h} = mg\frac{2h}{3}(1-\cos\theta)$ M1 A1 A1

$\cos\theta = \frac{1}{2}$ M1

$\underline{\theta = \frac{\pi}{3}}$ (60°) A1 5

(c) $M(A)$: $-mg.\frac{2h}{3}\sin 60 = \frac{5mh^2}{9}\ddot{\theta}$ M1 A1ft on θ

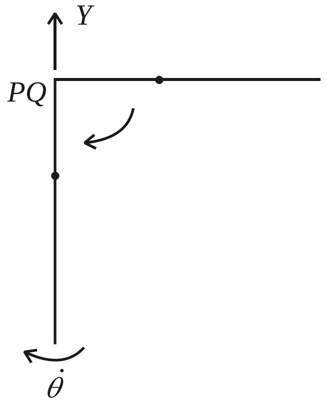
(max L^r acc^n when at rest)

$\left|\ddot{\theta}\right|_{\max} = \frac{3\sqrt{3g}}{5h}$ A1 3

[17]

10. (a) $I_{PQ} = \frac{4}{3}m(3a)^2 = \underline{12\ ma^2}$ M1 A1 2

(b)



Energy: $\frac{1}{2} \times 12\ ma^2 \times \dot{\theta}^2 = mg \times 3a$ M1 A1 ft

$\Rightarrow \underline{\dot{\theta} = \sqrt{\left(\frac{g}{2a}\right)}}$ (*) A1 3

(c) $R(\uparrow)$: $Y - mg = m \times 3a\dot{\theta}^2$ M1 A1

$Y = \text{mg} + \text{m} \times 3\text{a} \times \frac{g}{2a} = \underline{\frac{5}{2}mg}$ M1 A1 4

[9]

11. (a) MI of sphere about $L = \frac{2}{5}ma^2 + ma^2 = \frac{7}{5}ma^2$ B1

Energy: $\frac{1}{2}\times\frac{7}{5}ma^2 \times \frac{18g}{7a} - \frac{1}{2}\times\frac{7}{5}ma^2 \times \omega^2 = mga(1 - \cos\theta)$M1 A2, 1, 0

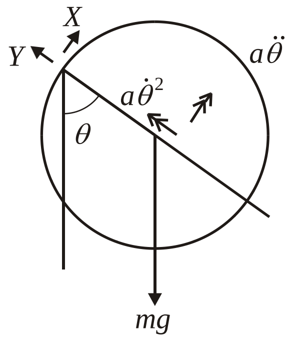
$\Rightarrow \frac{7}{10}a\omega^2 = \frac{8}{10}g + g\cos\theta$

$\omega^2 = \frac{g}{7a}(8 + 10\cos\theta) = \frac{2g}{7a}(4 + 5\cos\theta)$ A1 5

(b) $\frac{7}{5}ma^2\ddot{\theta} = -mga\sin\theta \Rightarrow \ddot{\theta} = -\frac{5g}{7a}\sin\theta$ M1 A1 2

[or $2\omega\dot{\omega} = -\frac{10g}{7a}\sin\theta \times \omega \Rightarrow \dot{\omega} = -\frac{5g}{7a}\sin\theta$]

(c)



$\dot{\theta} = 0$ when $\cos\theta = -\frac{4}{5}$ B1

$Y - mg\cos\theta = ma\dot{\theta}^2$ M1

$\dot{\theta} = 0$, $\cos\theta = -\frac{4}{5} \Rightarrow Y = -\frac{4mg}{5}$ M1 A1

$X - mg\sin\theta = ma\ddot{\theta}$ M1

$\dot{\theta} = 0$ and $\cos\theta = -\frac{4}{5} \Rightarrow \sin\theta = \frac{3}{5}$ M1

$\Rightarrow \ddot{\theta} = -\frac{3g}{7a}$

$\Rightarrow X = \frac{3mg}{5} - \frac{3mg}{7} = \frac{6mg}{35}$ A1

Magnitude of force = $\sqrt{(X^2 + Y^2)}$ M1

$= \text{mg}\left[\left(\frac{6}{35}\right)^2 + \left(\frac{4}{5}\right)^2\right]^{\frac{1}{2}}$

$\approx 0.818\,mg$ A1 10

[17]

1. In part (a) many correct solutions were seen. Errors arose in the use of the parallel axes rule. Despite distances being quite clearly given and marked on the diagram some candidates attempted to use $3a$, perhaps misreading the question. A few failed to use the parallel axes rule at all. It was surprising to see such basic errors in what was a fairly standard problem involving a change of axis for a moment of inertia.

In part (b) most candidates realised that an energy equation was required. A surprisingly large number, however, failed to realise that the position of the centre of mass for the lamina was required in the calculation of Potential Energy. Another common error was to use $4mg$ rather than $3mg$ for the weight of the lamina. It was surprising to see a number misquoting the expression for Kinetic Energy – sometimes omitting the $\frac{1}{2}$ or failing to square the Ω.

2. This question proved to be too difficult for many. Few completely correct solutions were seen.

Part (a) was very poorly answered. In order to find the mass of a strip, the ratio of base to height of the triangle was required. The height was easily found using a 3, 4,5 triangle yet a number of candidates made errors here with $\frac{3}{5}$ rather than $\frac{4}{3}$ seen quite often. Many candidates were unable to use appropriate methods for calculating the moment of inertia of a strip about the required axis through *A*. Many tried to use an axis through *BC* instead. A number used an incorrect density, failing to understand that *m* was the mass for the whole triangle and not half of it. Methods used were often very difficult to follow. There was often little indication of what the candidate was trying to do.

For part (b), very many thought that $\frac{8}{3}ma^2$ was the moment of inertia required in their solution. Very few realised that they needed to use this, together with the answer from part (a), and the perpendicular axes rule. Of those who did, few appreciated that they also needed to use the parallel axes rule, in order to find the moment of inertia about the axis required. Using their moment of inertia, in an equation of motion, to find the angular acceleration also proved to be a stumbling block for many, with $2a$ rather than a often seen. A significant number chose, instead, to differentiate an energy equation and both methods were generally used correctly by those who got this far.

In part (c) many candidates failed to write down the actual SHM equation for $\ddot{\theta}$ in terms of θ before writing down the periodic time, thereby losing all the marks.

3. A fairly high number of good attempts to this question were seen.

In part (a) most candidates used the correct moment of inertia for an axis tangential to the disc and some did then use the perpendicular axes rule followed by the parallel axes rule. Only a few, erroneously, used an axis perpendicular to the disc. Most of the errors in this part then resulted from trying to use energy conservation for an inelastic impact where energy was *not* conserved. Conservation of angular momentum was required here and those who used this were generally successful in scoring most of the available marks.

Very few completely correct solutions were seen to part (b). Some attempted to use energy conservation again. Of those who correctly realised that equations of motion were required, there were very many incomplete solutions with only a very small number correctly justifying the fact that the horizontal component of the force required was zero. Of those who correctly followed through a vertical equation of motion, quite a number failed to include the mass of the particle to make the total mass $2m$.

4. The weakness of candidates when answering questions about rotational mechanics was shown by the large number who only attempted part (a) of this question. This sometimes involved blatant "fudging".

In part (b), the attempt at the energy equation was often reasonable, but using Newton's second law along the rod often contained dimensional errors, such as multiplying the component of the weight by a distance.

In the final part it was necessary to obtain an expression for the angular acceleration either by taking moments or by differentiating the energy equation from part (b). Without this starting point, it was not possible to use the approximation $\theta \approx \sin\theta$ and so few marks could be obtained. There are still a number of candidates who learn a formula for the period of a compound pendulum and this should be strongly discouraged as the questions are usually designed to test understanding and the ability to work from 1st principles.

5. The vast majority of candidates successfully reached the required answer in part (a). In part (b), many candidates took moments as was intended. However, there were as usual candidates who ignored the instruction to write down an equation of motion for *P*, instead quoting a formula for the period, which gained no credit. Candidates should be reminded that the SHM formula should contain a minus sign. A few candidates interpreted "equation of motion" as an instruction to use Newton's second law.

6. Most candidates were successful with part (a), but often had little success with the later parts. Candidates who used moments in part (b) often seemed to assume that the moment of the weight had the opposite sign to $\ddot{\theta}$, as is often the case. An omission of a 2 from $2mg$ could easily lead erroneously to the printed answer. A selection of invalid methods were used in trying to find the impulse in part (c). These included impulse = change in angular momentum (rather than moment of impulse) and impulse = change in linear momentum.

7. Most could find the moment of inertia in part (a) correctly. However, there were many mistakes in parts (b) and (c). Many failed to consider an equation of rotational motion in part (b); and although most realised that they could do part (c) easiest by considering energy, there were a number of mistakes in dealing with the distances involved. Part (d) was generally approached correctly, but often incorrect previous answers led to an incorrect answer here as well.

8. Better candidates did very well in this question but others had a general idea of the methods but could not implement them correctly. The most common errors were: in (a), not using the motion of the centre of mass and using $Y - mg\cos(\pi/3)$ instead of $Y - mg$. and in (b), omitting the negative sign in the equation of motion. Candidates should not quote the formula for the period of oscillation – they should always work from first principles.

9. Part (a) proved to be beyond the majority of candidates. The proof was not well known and most candidates could not find the moment of inertia of an elementary strip. Use of the parallel and perpendicular axis theorems was needed but they were rarely seen. However, marks were gained in (b) and (c) since the inertia was given although candidates often lost marks because they used mgh instead of $2mgh/3$ in the potential energy term and in the angular equation of motion.

10. This proved to be a very straightforward question for the vast majority of candidates and full marks here were regularly obtained. It was very pleasing to note the clear understanding shown of the general principles involved.

11. No Report available for this question.