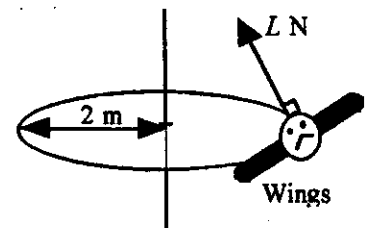


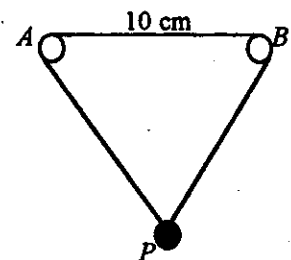
Take $g = 9.8 \text{ ms}^{-2}$ and give all answers correct to 3 significant figures where necessary.

1. A bird of mass 0.5 kg , flying around a vertical feeding post at a constant speed of 6 ms^{-1} , banks its wings to move in a horizontal circle of radius 2 m . The aerodynamic lift L newtons is perpendicular to the bird's wings, as shown. Modelling the bird as a particle, find, to the nearest degree, the angle that its wings make with the vertical.



(7 marks)

2. A thin elastic string, of modulus $\lambda \text{ N}$ and natural length 20 cm , passes round two small, smooth pegs A and B on the same horizontal level to form a closed loop. $AB = 10 \text{ cm}$. The ends of the string are attached to a weight P of mass 0.7 kg . When P rests in equilibrium, APB forms an equilateral triangle.



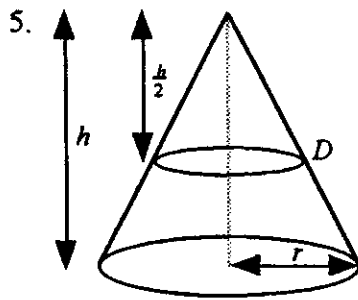
- (a) Find the value of λ . **(6 marks)**
 (b) State one assumption that you have made about the weight P , explaining how you have used this assumption in your solution. **(1 mark)**

3. A particle P of mass 0.5 kg moves along a straight line. When P is at a distance $x \text{ m}$ from a fixed point O on the line, the force acting on it is directed towards O and has magnitude $\frac{8}{x^2} \text{ N}$. When $x = 2$, the speed of P is 4 ms^{-1} . Find the speed of P when it is 0.5 m from O . **(8 marks)**

4. A particle P of mass $m \text{ kg}$ is attached to one end of a light elastic string of natural length l and modulus of elasticity $\lambda \text{ N}$. The other end of the string is attached to a fixed point O . P is released from rest at O and falls vertically downwards under gravity. The greatest distance below O reached by P is $2l \text{ m}$.

- (a) Show that $\lambda = 4mg$. **(3 marks)**
 (b) Find, in terms of l and g , the speed with which P passes through the point A , where

$$OA = \frac{5l}{4} \text{ m}. \quad \textbf{(6 marks)}$$



A uniform solid right circular cone has height h and base radius r . The top part of the cone is removed by cutting through the cone parallel to the base at a height $\frac{h}{2}$.

- (a) Show that the centre of mass of the remaining solid is at a height $\frac{11h}{56}$ above the base, along its axis of symmetry. (7 marks)

The remaining part of the solid is suspended from the point D on the circumference of its smaller circular face, and the axis of symmetry then makes an angle α with the vertical, where

$$\tan \alpha = \frac{1}{2}.$$

- (b) Find the value of the ratio $h : r$. (5 marks)

6. A light elastic string, of natural length l m and modulus of elasticity $\frac{mg}{2}$ newtons, has one end fastened to a fixed point O . A particle P , of mass m kg, is attached to the other end of the string. P hangs in equilibrium at the point E , vertically below O , where $OE = (l + e)$ m

- (a) Find the numerical value of the ratio $e : l$. (2 marks)

P is now pulled down a further distance $\frac{3l}{2}$ m from E and is released from rest.

In the subsequent motion, the string remains taut. At time t s after being released, P is at a distance x m below E .

- (b) Write down a differential equation for the motion of P and show that the motion is simple harmonic. (4 marks)

- (c) Write down the period of the motion. (2 marks)

- (d) Find the speed with which P first passes through E again. (2 marks)

- (e) Show that the time taken by P after it is released to reach the point A above E , where

$$AE = \frac{3l}{4} \text{ m, is } \frac{2\pi}{3} \sqrt{\frac{2l}{g}} \text{ s.} \quad (5 \text{ marks})$$

7. A particle P is attached to one end of a light inextensible string of length l m. The other end of the string is attached to a fixed point O . When P is hanging at rest vertically below O , it is given a horizontal speed u ms^{-1} and starts to move in a vertical circle.

Given that the string becomes slack when it makes an angle of 120° with the downward vertical through O ,

- (a) show that $u^2 = \frac{7gl}{2}$. (10 marks)

- (b) Find, in terms of l , the greatest height above O reached by P in the subsequent motion.

(7 marks)