1 A particle $P$ is projected with speed $15 \text{ m s}^{-1}$ at an angle of $60^\circ$ above the horizontal. Find the direction of motion of $P$ at the instant 0.9 s after projection. [4]

2 A particle $P$ of mass 0.3 kg is attached to one end of a light elastic string of natural length 0.6 m and modulus of elasticity 45 N. The other end of the string is attached to a fixed point $O$. The particle $P$ is released from rest at $O$ and falls vertically. Find the extension of the string when $P$ is at its lowest position. [4]

3 A ball is projected horizontally with speed $5 \text{ m s}^{-1}$ from the top of a tower which is 30 m high. The tower stands on horizontal ground.

   (i) Find the speed and direction of motion of the ball when it reaches the ground. [3]

   (ii) Calculate the distance from the foot of the tower to the point where the ball reaches the ground. [3]

4 A smooth hollow cylinder of internal radius 0.3 m is fixed with its axis vertical. One end of a light inextensible string of length 0.5 m is fixed to a point $A$ on the axis. The other end of the string is attached to a particle $P$ of mass 0.2 kg which moves in a horizontal circle on the surface of the cylinder (see diagram).

   (i) Find the tension in the string. [3]

   (ii) Find the least angular speed of $P$ for which the motion is possible. [2]

   (iii) Calculate the magnitude of the force exerted on $P$ by the cylinder given that the speed of $P$ is $1.8 \text{ m s}^{-1}$. [3]
One end of a light elastic string $S_1$ of modulus of elasticity 20 N and natural length 0.5 m is attached to a fixed point $O$. The other end of $S_1$ is attached to a particle $P$ of mass 0.4 kg. $P$ hangs in equilibrium vertically below $O$.

(i) Find the distance $OP$. \[2\]

The opposite ends of a light inextensible string $S_2$ of length $l$ m are now attached to $O$ and $P$ respectively. The elastic string $S_1$ remains attached to $O$ and $P$. The particle $P$ hangs in equilibrium vertically below $O$.

(ii) Find the tension in the inextensible string $S_2$ for each of the following cases:

(a) $l < 0.5$;
(b) $l > 0.6$;
(c) $l = 0.54$. \[4\]

In the case $l = 0.54$, the inextensible string $S_2$ suddenly breaks and $P$ begins to descend vertically.

(iii) Calculate the greatest speed of $P$ in the subsequent motion. \[3\]

A uniform solid cone of height 1.2 m and semi-vertical angle $\theta^\circ$ is divided into two parts by a cut parallel to and 0.4 m from the circular base. The upper conical part, $C$, has weight 16 N, and the lower part, $L$, has weight 38 N. The two parts of the solid rest in equilibrium with the larger plane face of $L$ on a horizontal surface and the smaller plane face of $L$ covered by the base of $C$ (see diagram).

(i) Calculate the distance of the centre of mass of $L$ from its larger plane face. \[3\]

An increasing horizontal force is applied to the vertex of $C$. Equilibrium is broken when the magnitude of this force first exceeds 4 N, and $C$ begins to slide on $L$.

(ii) By considering the forces on $C$,

(a) find the coefficient of friction between $C$ and $L$, \[1\]
(b) show that $\theta > 14.0$, correct to 3 significant figures. \[2\]

$C$ is removed and $L$ is placed with its curved surface on the horizontal surface.

(iii) Given that $L$ is on the point of toppling, calculate $\theta$. \[3\]
A small ball $B$ of mass 0.2 kg moves in a narrow fixed smooth cylindrical tube $OA$ of length 1 m, closed at the end $A$. When the ball has displacement $x$ m from $O$, it has velocity $v \text{ m s}^{-1}$ in the direction $OA$ and experiences a resisting force of magnitude $\frac{k}{1-x} \text{ N}$.

(i)

The tube is fixed in a horizontal position and $B$ is projected from $O$ towards $A$ with velocity $1.2 \text{ m s}^{-1}$ (see diagram). Given that $B$ comes to instantaneous rest after travelling 0.55 m, show that $k = 0.1803$, correct to 4 significant figures. [6]

(ii) The tube is now fixed in a vertical position with $O$ above $A$. The ball $B$ is released from rest at $O$. Calculate the speed of $B$ after it has descended 0.1 m. [4]