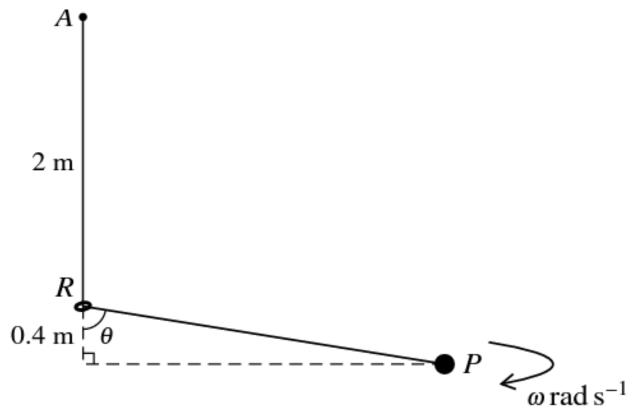
Circular Motion 2

Q1.



One end of a light elastic string with modulus of elasticity 15 N is attached to a fixed point A which is 2 m vertically above a fixed small smooth ring R. The string has natural length 2 m and it passes through R. The other end of the string is attached to a particle P of mass m kg which moves with constant angular speed ω rad s^{-1} in a horizontal circle which has its centre 0.4 m vertically below the ring. PR makes an acute angle θ with the vertical (see diagram).

(i) Show that the tension in the string is $\frac{3}{\cos\theta}$ N and hence find the value of m. [4]

(ii) Show that the value of ω does not depend on θ. [4]

It is given that for one value of θ the elastic potential energy stored in the string is twice the kinetic energy of P.

(iii) Find this value of θ. [4]

Q2.

A horizontal disc with a rough surface rotates about a fixed vertical axis which passes through the centre of the disc. A particle P of mass 0.2 kg is in contact with the surface and rotates with the disc, without slipping, at a distance 0.5 m from the axis. The greatest speed of P for which this motion is possible is 1.5 m s^{-1}.

(i) Calculate the coefficient of friction between the disc and P. [2]

P is now attached to one end of a light elastic string, which is connected at its other end to a point on the vertical axis above the disc. The tension in the string is equal to half the weight of P. The disc rotates with constant angular speed ω rad s^{-1} and P rotates with the disc without slipping. P moves in a circle of radius 0.5 m, and the taut string makes an angle of 30° with the horizontal.

(ii) Find the greatest and least values of ω for which this motion is possible. [5]

(iii) Calculate the value of ω for which the disc exerts no frictional force on P. [2]

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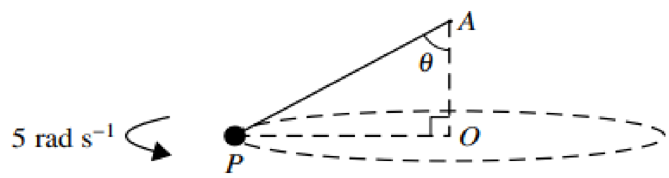
Q3.



One end of a light inextensible string is attached to a fixed point A and the other end of the string is attached to a particle P. The particle P moves with constant angular speed $5\,\text{rad}\,\text{s}^{-1}$ in a horizontal circle which has its centre O vertically below A. The string makes an angle θ with the vertical (see diagram). The tension in the string is three times the weight of P.

(i) Show that the length of the string is 1.2 m. [3]

(ii) Find the speed of P. [4]

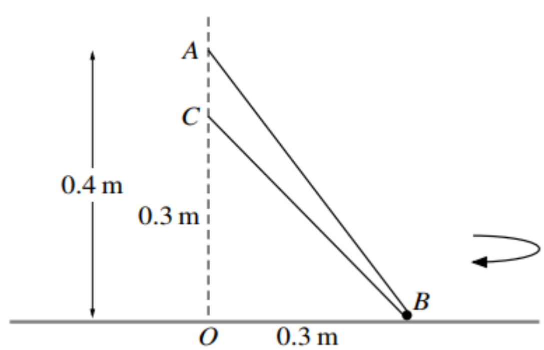
Q4.

One end of a light inextensible string of length 0.5 m is attached to a fixed point A. The other end of the string is attached to a particle P of weight 6 N. Another light inextensible string of length 0.5 m connects P to a fixed point B which is 0.8 m vertically below A. The particle P moves with constant speed in a horizontal circle with centre at the mid-point of AB. Both strings are taut.

(i) Calculate the speed of P when the tension in the string BP is 2 N. [5]

(ii) Show that the angular speed of P must exceed $5\,\text{rad}\,\text{s}^{-1}$. [3]

Q5.



A light inextensible string passes through a small smooth bead B of mass 0.4 kg. One end of the string is attached to a fixed point A 0.4 m above a fixed point O on a smooth horizontal surface. The other end of the string is attached to a fixed point C which is vertically below A and 0.3 m above the surface. The bead moves with constant speed on the surface in a circle with centre O and radius 0.3 m (see diagram).

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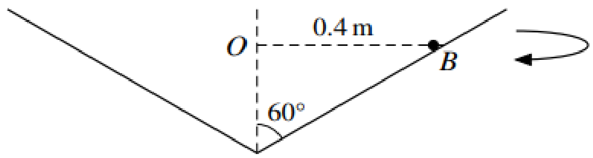
(i) Given that the tension in the string is 2 N, calculate

(a) the angular speed of the bead, [3]

(b) the magnitude of the contact force exerted on the bead by the surface. [2]

(ii) Given instead that the bead is about to lose contact with the surface, calculate the speed of the bead. [4]

Q6.



A small ball B of mass 0.5 kg moves in a horizontal circle with centre O and radius 0.4 m on the smooth inner surface of a hollow cone fixed with its vertex down. The axis of the cone is vertical and the semi-vertical angle is 60° (see diagram).

(i) Show that the magnitude of the force exerted by the cone on B is 5.77 N, correct to 3 significant figures, and calculate the angular speed of B. [4]

One end of a light elastic string of natural length 0.45 m and modulus of elasticity 36 N is attached to B. The other end of the string is attached to the point on the axis 0.3 m above O. The ball B again moves on the surface of the cone in the same horizontal circle as before.

(ii) Calculate the speed of B. [6]

Q7.

A particle P of mass 0.15 kg is attached to one end of a light elastic string of natural length 0.4 m and modulus of elasticity 12 N. The other end of the string is attached to a fixed point A. The particle P moves in a horizontal circle which has its centre vertically below A, with the string inclined at $\theta°$ to the vertical and $AP = 0.5$ m.

(i) Find the angular speed of P and the value of θ. [5]

(ii) Calculate the difference between the elastic potential energy stored in the string and the kinetic energy of P. [4]

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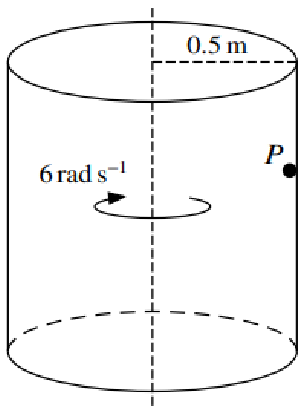
Q8.

A particle P of mass 0.2 kg moves with speed $4\ \text{m s}^{-1}$ and angular speed $5\ \text{rad s}^{-1}$ in a horizontal circle on a smooth surface. P is attached to one end of a light elastic string of natural length 0.6 m. The other end of the string is attached to the point on the surface which is the centre of the circular motion of P.

(i) Find the radius of this circle. [1]

(ii) Find the modulus of elasticity of the string. [4]

Q9.



A hollow cylinder with a rough inner surface has radius 0.5 m. A particle P of mass 0.4 kg is in contact with the inner surface of the cylinder. The particle and cylinder rotate together with angular speed $6\ \text{rad s}^{-1}$ about the vertical axis of the cylinder, so that the particle moves in a horizontal circle (see diagram). Given that P is about to slip downwards, find the coefficient of friction between P and the surface of the cylinder. [4]
