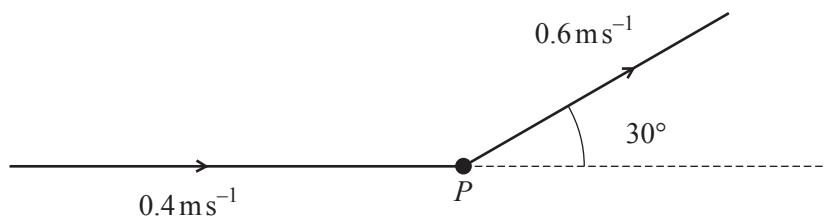




1



A particle  $P$  of mass  $0.3 \text{ kg}$  is moving with speed  $0.4 \text{ ms}^{-1}$  in a straight line on a smooth horizontal surface when it is struck by a horizontal impulse. After the impulse acts  $P$  has speed  $0.6 \text{ ms}^{-1}$  and is moving in a direction making an angle  $30^\circ$  with its original direction of motion (see diagram).

- (i) Find the magnitude of the impulse and the angle its line of action makes with the original direction of motion of  $P$ . [4]

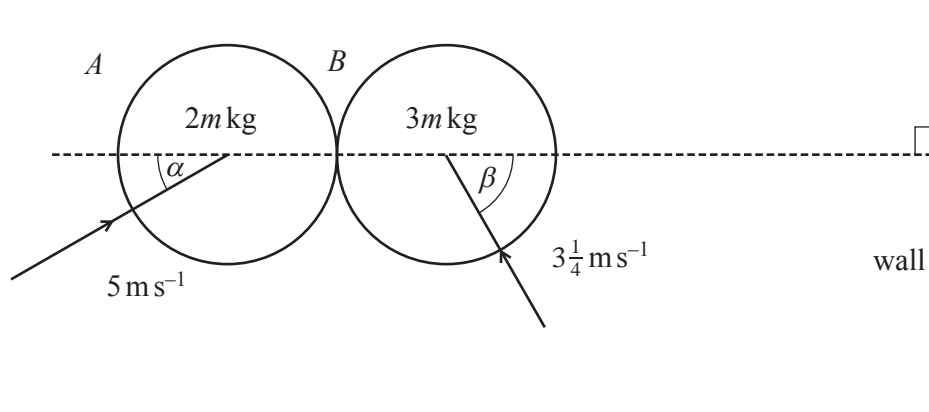
Subsequently a second impulse acts on  $P$ . After this second impulse acts,  $P$  again moves from left to right with speed  $0.4 \text{ ms}^{-1}$  in a direction parallel to its original direction of motion.

- (ii) State the magnitude of the second impulse, and show the direction of the second impulse on a diagram. [2]

- 2 A particle  $Q$  of mass  $0.2 \text{ kg}$  is projected horizontally with velocity  $4 \text{ ms}^{-1}$  from a fixed point  $A$  on a smooth horizontal surface. At time  $t \text{ s}$  after projection  $Q$  is  $x \text{ m}$  from  $A$  and is moving away from  $A$  with velocity  $v \text{ ms}^{-1}$ . There is a force of  $3 \cos 2t \text{ N}$  acting on  $Q$  in the positive  $x$ -direction.

- (i) Find an expression for the velocity of  $Q$  at time  $t$ . State the maximum and minimum values of the velocity of  $Q$  as  $t$  varies. [4]
- (ii) Find the average velocity of  $Q$  between times  $t = \pi$  and  $t = \frac{3}{2}\pi$ . [4]

3



Two uniform smooth spheres  $A$  and  $B$ , of equal radius, have masses  $2m \text{ kg}$  and  $3m \text{ kg}$  respectively. The spheres are approaching each other on a horizontal surface when they collide. Before the collision  $A$  is moving with speed  $5 \text{ ms}^{-1}$  in a direction making an angle  $\alpha$  with the line of centres, where  $\cos \alpha = \frac{4}{5}$ , and  $B$  is moving with speed  $3\frac{1}{4} \text{ ms}^{-1}$  in a direction making an angle  $\beta$  with the line of centres, where  $\cos \beta = \frac{5}{13}$ . A straight vertical wall is situated to the right of  $B$ , perpendicular to the line of centres (see diagram). The coefficient of restitution between  $A$  and  $B$  is  $\frac{2}{3}$ .

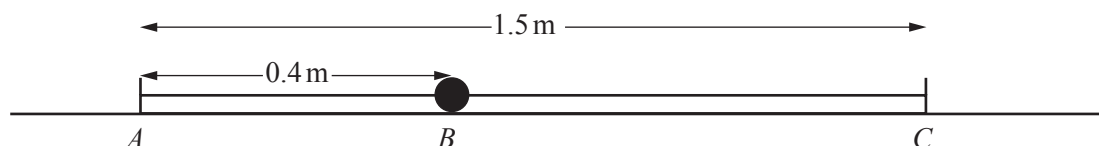
3

- (i) Find the speed of  $A$  after the collision. Find also the component of the velocity of  $B$  along the line of centres after the collision. [7]

$B$  subsequently hits the wall.

- (ii) Explain why  $A$  and  $B$  will have a second collision if the coefficient of restitution between  $B$  and the wall is sufficiently large. Find the set of values of the coefficient of restitution for which this second collision will occur. [3]

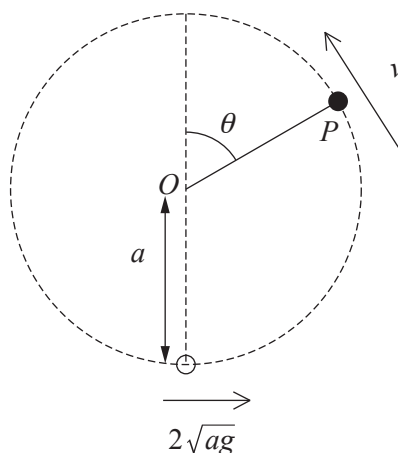
4



$A$  and  $C$  are two fixed points, 1.5 m apart, on a smooth horizontal plane. A light elastic string of natural length 0.4 m and modulus of elasticity 20 N has one end fixed to point  $A$  and the other end fixed to a particle  $B$ . Another light elastic string of natural length 0.6 m and modulus of elasticity 15 N has one end fixed to point  $C$  and the other end fixed to the particle  $B$ . The particle is released from rest when  $ABC$  forms a straight line and  $AB = 0.4$  m (see diagram).

Find the greatest kinetic energy of particle  $B$  in the subsequent motion. [7]

5



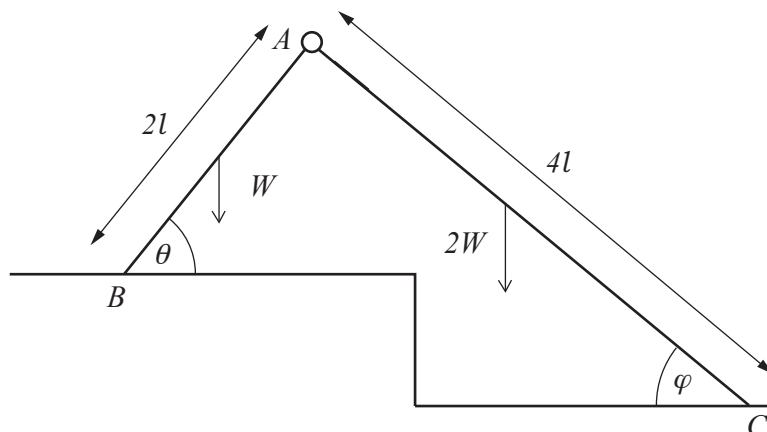
One end of a light inextensible string of length  $a$  is attached to a fixed point  $O$ . A particle  $P$  of mass  $m$  is attached to the other end of the string and hangs at rest.  $P$  is then projected horizontally from this position with speed  $2\sqrt{ag}$ . When the string makes an angle  $\theta$  with the upward vertical  $P$  has speed  $v$  (see diagram). The tension in the string is  $T$ .

- (i) Find an expression for  $T$  in terms of  $m$ ,  $g$  and  $\theta$ , and hence find the height of  $P$  above its initial level when the string becomes slack. [6]

$P$  is now projected horizontally from the same initial position with speed  $U$ .

- (ii) Find the set of values of  $U$  for which the string does not remain taut in the subsequent motion. [5]

6



Two uniform rods  $AB$  and  $AC$  are freely jointed at  $A$ . Rod  $AB$  is of length  $2l$  and weight  $W$ ; rod  $AC$  is of length  $4l$  and weight  $2W$ . The rods rest in equilibrium in a vertical plane on two rough horizontal steps, so that  $AB$  makes an angle of  $\theta$  with the horizontal, where  $\sin \theta = \frac{4}{5}$ , and  $AC$  makes an angle of  $\varphi$  with the horizontal, where  $\sin \varphi = \frac{3}{5}$  (see diagram). The force of the step acting on  $AB$  at  $B$  has vertical component  $R$  and horizontal component  $F$ .

(i) By taking moments about  $A$  for the rod  $AB$ , find an equation relating  $W$ ,  $R$  and  $F$ . [3]

(ii) Show that  $R = \frac{73}{50}W$ , and find the vertical component of the force acting on  $AC$  at  $C$ . [6]

(iii) The coefficient of friction at  $B$  is equal to that at  $C$ . Given that one of the rods is on the point of slipping, explain which rod this must be, and find the coefficient of friction. [4]

7 A particle  $P$  of mass  $m$  kg is attached to one end of a light elastic string of modulus of elasticity  $24mg$  N and natural length  $0.6$  m. The other end of the string is attached to a fixed point  $O$ ; the particle  $P$  rests in equilibrium at a point  $A$  with the string vertical.

(i) Show that the distance  $OA$  is  $0.625$  m. [2]

Another particle  $Q$ , of mass  $3m$  kg, is released from rest from a point  $0.4$  m above  $P$  and falls onto  $P$ . The two particles coalesce.

(ii) Show that the combined particle initially moves with speed  $2.1 \text{ m s}^{-1}$ . [3]

(iii) Show that the combined particle initially performs simple harmonic motion, and find the centre of this motion and its amplitude. [5]

(iv) Find the time that elapses between  $Q$  being released from rest and the combined particle first reaching the highest point of its subsequent motion. [7]

### END OF QUESTION PAPER

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