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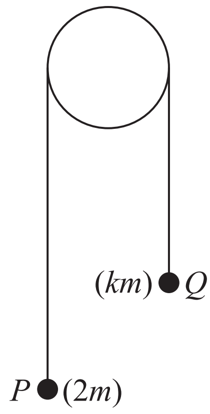

Figure 1

Two small balls, P and Q, have masses $2m$ and km respectively, where $k < 2$.
The balls are attached to the ends of a string that passes over a fixed pulley.
The system is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 1.

The system is released from rest and, in the subsequent motion, P moves downwards with an acceleration of magnitude $\frac{5g}{7}$

The balls are modelled as particles moving freely.
The string is modelled as being light and inextensible.
The pulley is modelled as being small and smooth.

Using the model,

(a) find, in terms of m and g, the tension in the string,

(3)

(b) explain why the acceleration of Q also has magnitude $\frac{5g}{7}$

(1)

(c) find the value of k.

(4)

(d) Identify one limitation of the model that will affect the accuracy of your answer to part (c).

(1)

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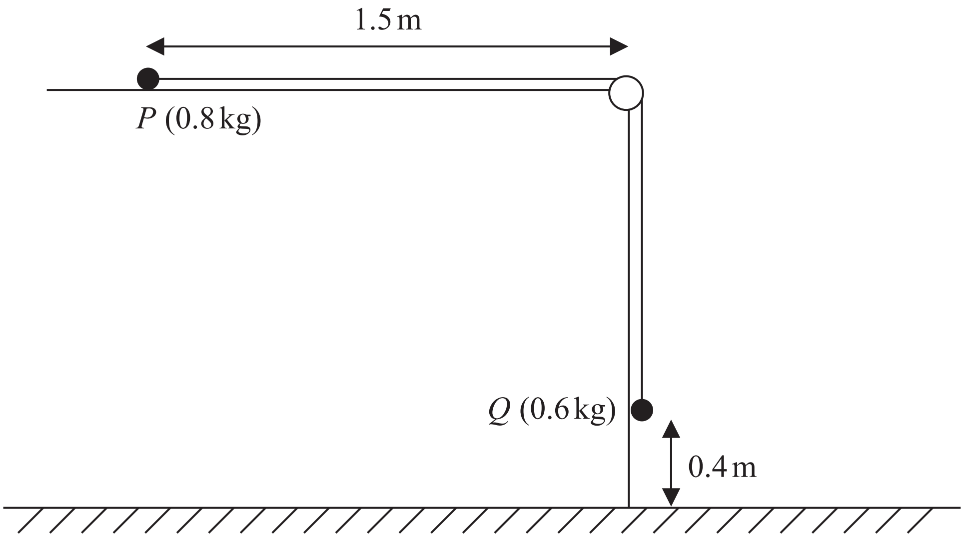

Figure 1

A small ball, P, of mass 0.8 kg, is held at rest on a smooth horizontal table and is attached to one end of a thin rope.

The rope passes over a pulley that is fixed at the edge of the table.

The other end of the rope is attached to another small ball, Q, of mass 0.6 kg, that hangs freely below the pulley.

Ball P is released from rest, with the rope taut, with P at a distance of 1.5 m from the pulley and with Q at a height of 0.4 m above the horizontal floor, as shown in Figure 1.

Ball Q descends, hits the floor and does not rebound.

The balls are modelled as particles, the rope as a light and inextensible string and the pulley as small and smooth.

Using this model,

(a) show that the acceleration of Q, as it falls, is $4.2\,\text{m}\,\text{s}^{-2}$

(5)

(b) find the time taken by P to hit the pulley from the instant when P is released.

(6)

(c) State one limitation of the model that will affect the accuracy of your answer to part (a).

(1)

2.

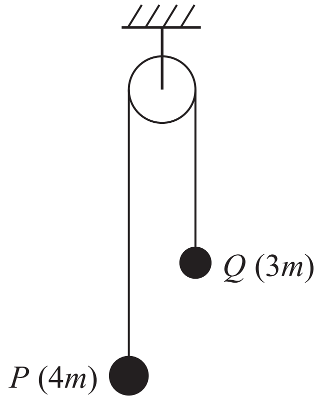

Figure 1

One end of a string is attached to a small ball P of mass $4m$.

The other end of the string is attached to another small ball Q of mass $3m$.

The string passes over a fixed pulley.

Ball P is held at rest with the string taut and the hanging parts of the string vertical, as shown in Figure 1.

Ball P is released.

The string is modelled as being light and inextensible, the balls are modelled as particles, the pulley is modelled as being smooth and air resistance is ignored.

(a) Using the model, find, in terms of m and g, the magnitude of the force exerted on the pulley by the string while P is falling and before Q hits the pulley.

(8)

(b) State one limitation of the model, apart from ignoring air resistance, that will affect the accuracy of your answer to part (a).

(1)

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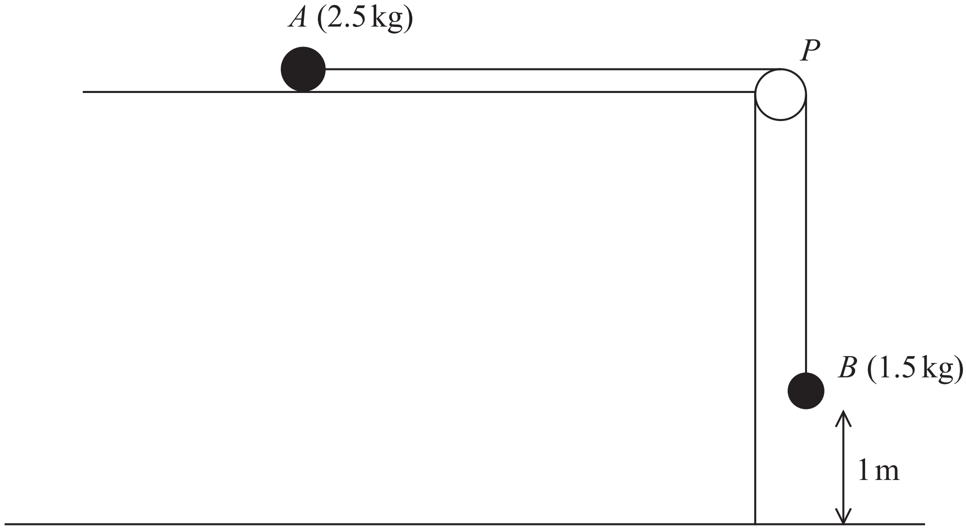

Figure 2

A small ball A of mass 2.5 kg is held at rest on a rough horizontal table.

The ball is attached to one end of a string.

The string passes over a pulley P which is fixed at the edge of the table. The other end of the string is attached to a small ball B of mass 1.5 kg hanging freely, vertically below P and with B at a height of 1 m above the horizontal floor.

The system is release from rest, with the string taut, as shown in Figure 2.

The resistance to the motion of A from the rough table is modelled as having constant magnitude 12.7 N. Ball B reaches the floor before ball A reaches the pulley.

The balls are modelled as particles, the string is modelled as being light and inextensible, the pulley is modelled as being small and smooth and the acceleration due to gravity, g, is modelled as being $9.8\,\text{m s}^{-2}$.

(a) (i) Write down an equation of motion for A.

(ii) Write down an equation of motion for B.

(4)

(b) Hence find the acceleration of B.

(2)

(c) Using the model, find the time it takes, from release, for B to reach the floor.

(2)

(d) Suggest two improvements that could be made in the model.

(2)

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2. [*In this question* **i** *and* **j** *are perpendicular unit vectors in a horizontal plane.*]

Three forces, $(-10\mathbf{i} + a\mathbf{j})$ N, $(b\mathbf{i} - 5\mathbf{j})$ N and $(2a\mathbf{i} + 7\mathbf{j})$ N, where a and b are constants, act on a particle P of mass 3 kg. The acceleration of P is $(3\mathbf{i} + 4\mathbf{j})$ m s^{-2}

(a) Find the value of a and the value of b.

(5)

At time $t = 0$ seconds the speed of P is u m s^{-1} and at time $t = 4$ seconds the velocity of P is $(20\mathbf{i} + 20\mathbf{j})$ m s^{-1}

(b) Find the value of u.

(4)

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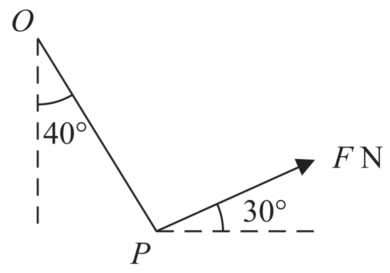

Figure 1

A particle P of weight 5 N is attached to one end of a light string. The other end of the string is attached to a fixed point O. A force of magnitude F newtons is applied to P. The line of action of the force is inclined to the horizontal at 30° and lies in the same vertical plane as the string. The particle P is in equilibrium with the string making an angle of 40° with the downward vertical, as shown in Figure 1.

Find

(i) the tension in the string,

(ii) the value of F.

(7)

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3. A block A of mass 9 kg is released from rest from a point P which is a height h metres above horizontal soft ground. The block falls and strikes another block B of mass 1.5 kg which is on the ground vertically below P. The speed of A immediately before it strikes B is 7 m s^{-1}. The blocks are modelled as particles.

(a) Find the value of h.

(2)

Immediately after the impact the blocks move downwards together with the same speed and both come to rest after sinking a vertical distance of 12 cm into the ground. Assuming that the resistance offered by the ground has constant magnitude R newtons,

(b) find the value of R.

(8)

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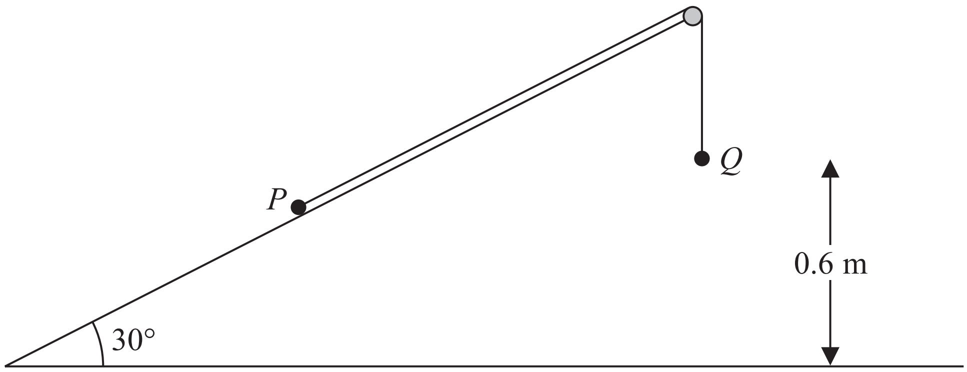

Figure 3

Two particles P and Q, of mass 2 kg and 3 kg respectively, are connected by a light inextensible string. Initially P is held at rest on a fixed smooth plane inclined at 30° to the horizontal. The string passes over a small smooth fixed pulley at the top of the plane. The particle Q hangs freely below the pulley and 0.6 m above the ground, as shown in Figure 3. The part of the string from P to the pulley is parallel to a line of greatest slope of the plane. The system is released from rest with the string taut.

For the motion before Q hits the ground,

(a) (i) show that the acceleration of Q is $\frac{2g}{5}$,

(ii) find the tension in the string.

(8)

On hitting the ground Q is immediately brought to rest by the impact.

(b) Find the speed of P at the instant when Q hits the ground.

(2)

In its subsequent motion P does not reach the pulley.

(c) Find the total distance moved up the plane by P before it comes to instantaneous rest.

(4)

(d) Find the length of time between Q hitting the ground and P first coming to instantaneous rest.

(2)

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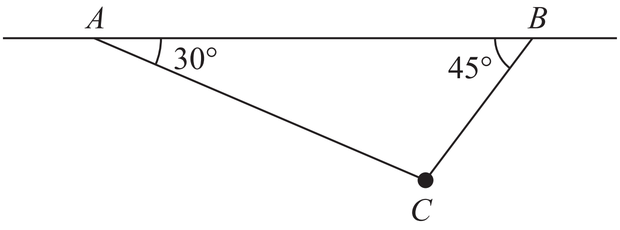

Figure 1

A particle of weight W is attached at C to two light inextensible strings AC and BC. The other ends of the strings are attached to fixed points A and B on a horizontal ceiling. The particle hangs in equilibrium with the strings in a vertical plane and with AC and BC inclined to the horizontal at 30° and 45° respectively, as shown in Figure 1.

Find, in terms of W,

(i) the tension in AC,

(ii) the tension in BC.

(7)

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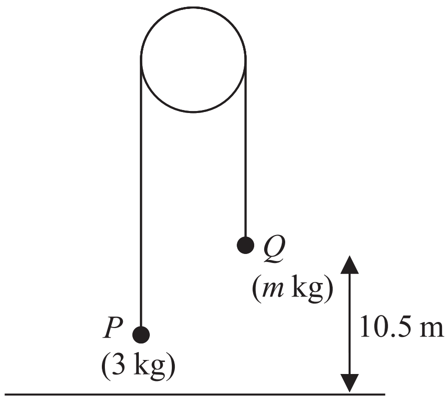

Figure 5

Two particles P and Q have masses 3 kg and m kg respectively ($m > 3$). The particles are connected by a light inextensible string which passes over a smooth light fixed pulley. The system is held at rest with the string taut and the hanging parts of the string vertical. The particle Q is at a height of 10.5 m above the horizontal ground, as shown in Figure 5. The system is released from rest and Q moves downwards. In the subsequent motion P does not reach the pulley. After the system is released, the tension in the string is 33.6 N.

(a) Show that the magnitude of the acceleration of P is 1.4 m s^{-2}.

(3)

(b) Find the value of m.

(3)

The system is released from rest at time $t = 0$. At time T_1 seconds after release, Q strikes the ground and does not rebound. The string goes slack and P continues to move upwards.

(c) Find the value of T_1

(3)

At time T_2 seconds after release, P comes to instantaneous rest.

(d) Find the value of T_2

(3)

At time T_3 seconds after release ($T_3 > T_1$) the string becomes taut again.

(e) Sketch a velocity-time graph for the motion of P in the interval $0 \leqslant t \leqslant T_3$

(2)

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1. A truck of mass 2400 kg is pulling a trailer of mass M kg along a straight horizontal road. The tow bar, connecting the truck to the trailer, is horizontal and parallel to the direction of motion. The tow bar is modelled as being light and inextensible. The resistance forces acting on the truck and the trailer are constant and of magnitude 400 N and 200 N respectively. The acceleration of the truck is $0.5\ \mathrm{m\,s^{-2}}$ and the tension in the tow bar is 600 N.

(a) Find the magnitude of the driving force of the truck.

(3)

(b) Find the value of M.

(3)

(c) Explain how you have used the fact that the tow bar is inextensible in your calculations.

(1)