Year 1 Chapter 10: Forces and Motions
(Pulleys – 2 Vertical Particles)

Q1.

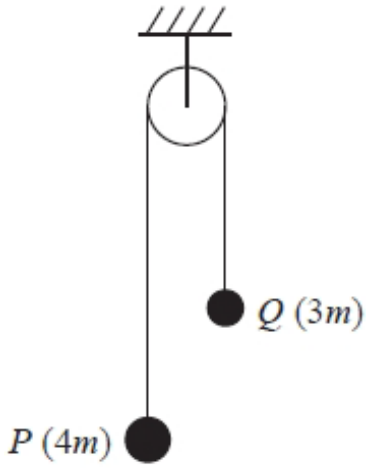


Figure 1

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)

(Total for question = 9 marks)

Q2.

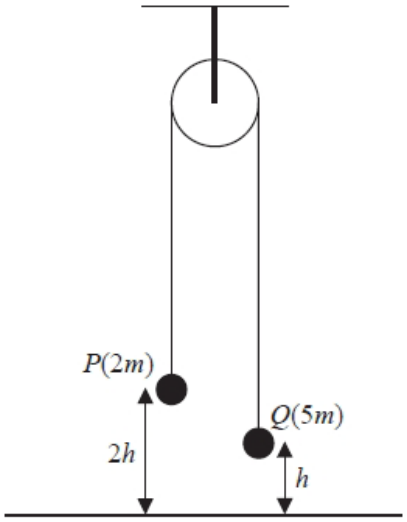


Figure 1

A ball *P* of mass 2*m* is attached to one end of a string. The other end of the string is attached to a ball *Q* of mass 5*m*. The string passes over a fixed pulley. The system is held at rest with the balls hanging freely and the string taut.

The hanging parts of the string are vertical with *P* at a height 2*h* above horizontal ground and with *Q* at a height *h* above the ground, as shown in Figure 1.

The system is released from rest. In the subsequent motion, *Q* does not rebound when it hits the ground and *P* does not hit 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. Air resistance is modelled as being negligible.

Using this model,

(a) (i) write down an equation of motion for *P*,

(ii) write down an equation of motion for *Q*,

(4)

(b) find, in terms of *h* only, the height above the ground at which *P* first comes to instantaneous rest.

(7)

(c) State one limitation of modelling the balls as particles that could affect your answer to part (b).

(1)

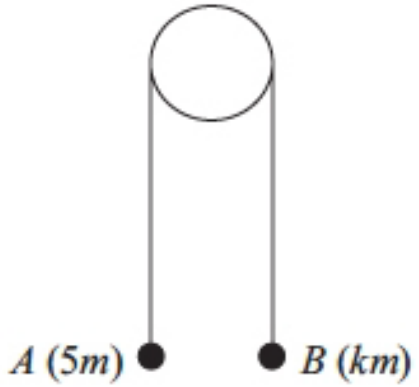
In reality, the string will not be inextensible.

(d) State how this would affect the accelerations of the particles.

(1)

(Total for question = 13 marks)

Q3.



Two particles A and B have masses $5m$ and km respectively, where $k < 5$. 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, the hanging parts of the string vertical and with A and B at the same height above a horizontal plane, as shown in above. The system is released from rest. After release, A descends with acceleration $\frac{1}{4}g$.

(a) Show that the tension in the string as A descends is $\frac{15}{4}mg$.

(3)

(b) Find the value of k.

(3)

(c) State how you have used the information that the pulley is smooth.

(1)

After descending for 1.2 s, the particle A reaches the plane. It is immediately brought to rest by the impact with the plane. The initial distance between B and the pulley is such that, in the subsequent motion, B does not reach the pulley.

(d) Find the greatest height reached by B above the plane.

(7)

(Total 14 marks)

Q4.

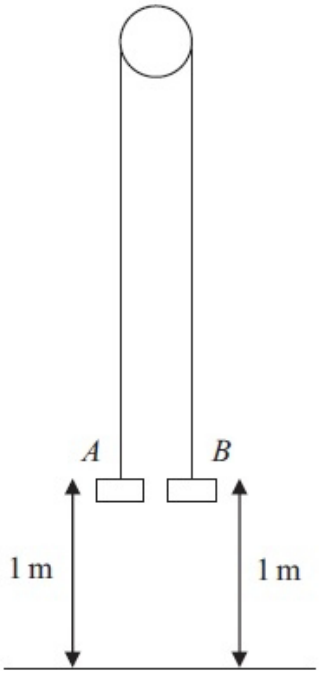


Figure 3

Two particles *A* and *B* have mass 0.4 kg and 0.3 kg respectively. The particles are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed above a horizontal floor. Both particles are held, with the string taut, at a height of 1m above the floor, as shown in Figure 3. The particles are released from rest and in the subsequent motion *B* does not reach the pulley.

(a) Find the tension in the string immediately after the particles are released.

(6)

(b) Find the acceleration of *A* immediately after the particles are released.

(2)

When the particles have been moving for 0.5 s, the string breaks.

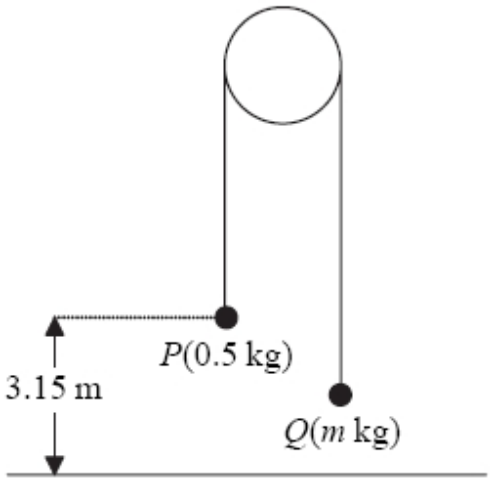
(c) Find the further time that elapses until B hits the floor.

(9)

(Total 17 marks)

Q5.

Figure 4



Two particles P and Q have mass 0.5 kg and m kg respectively, where $m < 0.5$. The particles are connected by a light inextensible string which passes over a smooth, fixed pulley. Initially P is 3.15 m above horizontal ground. The particles are released from rest with the string taut and the hanging parts of the string vertical, as shown in Figure 4. After P has been descending for 1.5 s, it strikes the ground. Particle P reaches the ground before Q has reached the pulley.

(a) Show that the acceleration of P as it descends is 2.8 m s^{-2}.

(3)

(b) Find the tension in the string as P descends.

(3)

(c) Show that $m = \frac{5}{18}$.

(4)

(d) State how you have used the information that the string is inextensible.

(1)

When P strikes the ground, P does not rebound and the string becomes slack. Particle Q then moves freely under gravity, without reaching the pulley, until the string becomes taut again.

(e) Find the time between the instant when P strikes the ground and the instant when the string becomes taut again.

(6)

(Total 17 marks)