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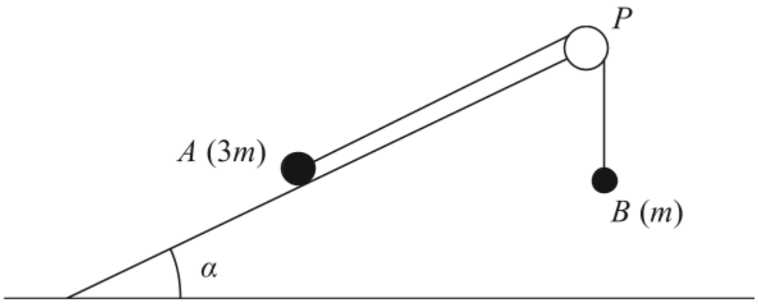

Figure 1

A small stone A of mass $3m$ is attached to one end of a string.

A small stone B of mass m is attached to the other end of the string.

Initially A is held at rest on a fixed rough plane.

The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

The string passes over a pulley P that is fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane.

Stone B hangs freely below P, as shown in Figure 1.

The coefficient of friction between A and the plane is $\frac{1}{6}$

Stone A is released from rest and begins to move down the plane.

The stones are modelled as particles.

The pulley is modelled as being small and smooth.

The string is modelled as being light and inextensible.

Using the model for the motion of the system before B reaches the pulley,

(a) write down an equation of motion for A

(2)

(b) show that the acceleration of A is $\frac{1}{10}g$

(7)

(c) sketch a velocity-time graph for the motion of B, from the instant when A is released from rest to the instant just before B reaches the pulley, explaining your answer.

(2)

In reality, the string is not light.

(d) State how this would affect the working in part (b).

(1)

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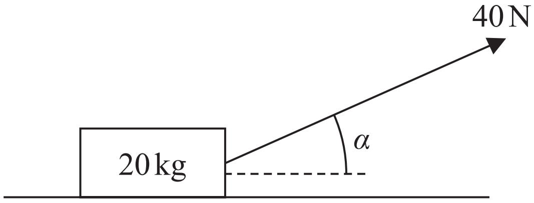

Figure 1

A wooden crate of mass 20 kg is pulled in a straight line along a rough horizontal floor using a handle attached to the crate.

The handle is inclined at an angle α to the floor, as shown in Figure 1, where $\tan\alpha = \frac{3}{4}$

The tension in the handle is 40 N.
The coefficient of friction between the crate and the floor is 0.14
The crate is modelled as a particle and the handle is modelled as a light rod.

Using the model,

(a) find the acceleration of the crate.

(6)

The crate is now pushed along the same floor using the handle. The handle is again inclined at the same angle α to the floor, and the thrust in the handle is 40 N as shown in Figure 2 below.

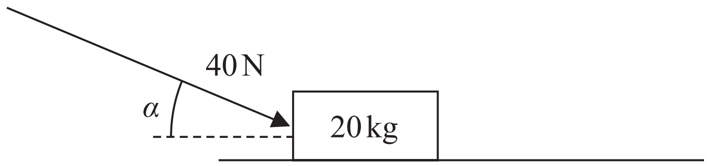

Figure 2

(b) Explain briefly why the acceleration of the crate would now be less than the acceleration of the crate found in part (a).

(2)

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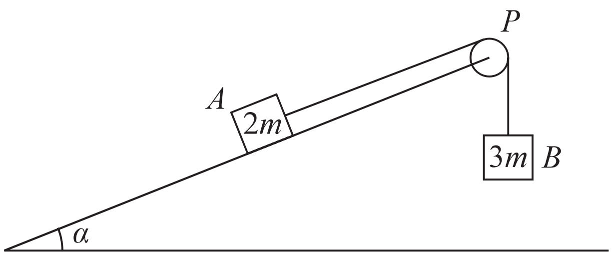

Figure 1

Two blocks, A and B, of masses $2m$ and $3m$ respectively, are attached to the ends of a light string.

Initially A is held at rest on a fixed rough plane.

The plane is inclined at angle α to the horizontal ground, where $\tan\alpha = \dfrac{5}{12}$

The string passes over a small smooth pulley, P, fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane. Block B hangs freely below P, as shown in Figure 1.

The coefficient of friction between A and the plane is $\dfrac{2}{3}$

The blocks are released from rest with the string taut and A moves up the plane.

The tension in the string immediately after the blocks are released is T.

The blocks are modelled as particles and the string is modelled as being inextensible.

(a) Show that $T = \dfrac{12mg}{5}$

(8)

After B reaches the ground, A continues to move up the plane until it comes to rest before reaching P.

(b) Determine whether A will remain at rest, carefully justifying your answer.

(2)

(c) Suggest two refinements to the model that would make it more realistic.

(2)

1. A rough plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$

A brick P of mass m is placed on the plane.

The coefficient of friction between P and the plane is μ

Brick P is in equilibrium and on the point of sliding down the plane.

Brick P is modelled as a particle.

Using the model,

(a) find, in terms of m and g, the magnitude of the normal reaction of the plane on brick P

(2)

(b) show that $\mu = \frac{3}{4}$

(4)

For parts (c) and (d), you are not required to do any further calculations.

Brick P is now removed from the plane and a much heavier brick Q is placed on the plane.

The coefficient of friction between Q and the plane is also $\frac{3}{4}$

(c) Explain briefly why brick Q will remain at rest on the plane.

(1)

Brick Q is now projected with speed $0.5\,\text{m}\,\text{s}^{-1}$ down a line of greatest slope of the plane.

Brick Q is modelled as a particle.

Using the model,

(d) describe the motion of brick Q, giving a reason for your answer.

(2)

7. A rough plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$.

A particle of mass m is placed on the plane and then projected up a line of greatest slope of the plane.

The coefficient of friction between the particle and the plane is μ.

The particle moves up the plane with a constant deceleration of $\frac{4}{5}g$.

(a) Find the value of μ.

(6)

The particle comes to rest at the point A on the plane.

(b) Determine whether the particle will remain at A, carefully justifying your answer.

(2)

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1. A suitcase of mass 40 kg is being dragged in a straight line along a rough horizontal floor at constant speed using a thin strap. The strap is inclined at 20° above the horizontal. The coefficient of friction between the suitcase and the floor is $\frac{3}{4}$. The strap is modelled as a light inextensible string and the suitcase is modelled as a particle. Find the tension in the strap.

(7)

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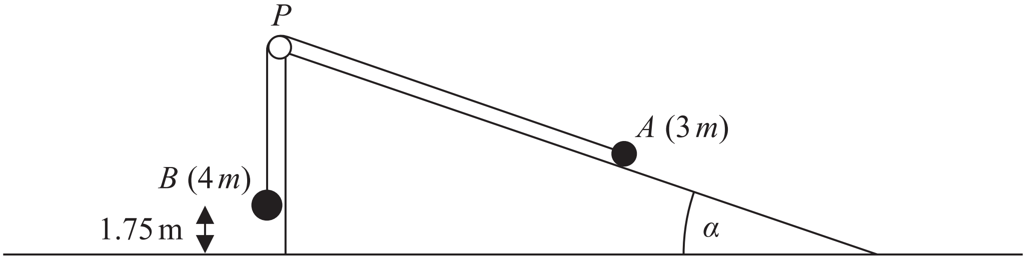

Figure 2

Figure 2 shows two particles A and B, of masses $3m$ and $4m$ respectively, attached to the ends of a light inextensible string. Initially A is held at rest on the surface of a fixed rough inclined plane. The plane is inclined to the horizontal at an angle α where $\tan\alpha = \frac{3}{4}$. The coefficient of friction between A and the plane is $\frac{1}{4}$. The string passes over a small smooth light pulley P which is fixed at the top of the plane. The part of the string from A to P is parallel to a line of greatest slope of the plane. The particle B hangs freely and is vertically below P. The system is released from rest with the string taut and with B at a height of 1.75 m above the ground. In the subsequent motion, A does not hit the pulley.

For the period before B hits the ground,

(a) write down an equation of motion for each particle.
(4)

(b) Hence show that the acceleration of B is $\frac{8}{35}g$.
(5)

(c) Explain how you have used the fact that the string is inextensible in your calculation.
(1)

When B hits the ground, B does not rebound and comes immediately to rest.

(d) Find the distance travelled by A from the instant when the system is released to the instant when A first comes to rest.
(7)

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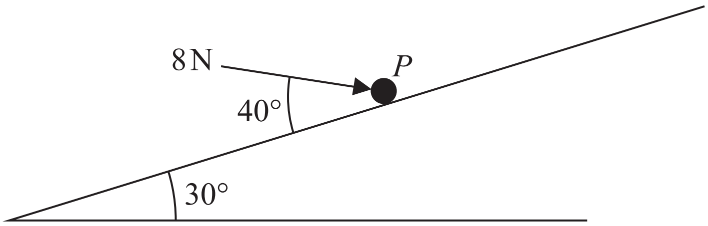

Figure 2

A particle P of mass 0.5 kg is at rest on a rough plane which is inclined to the horizontal at 30°. The particle is held in equilibrium by a force of magnitude 8 N, acting at an angle of 40° to the plane, as shown in Figure 2. The line of action of the force lies in the vertical plane containing P and a line of greatest slope of the plane. The coefficient of friction between P and the plane is μ. Given that P is on the point of sliding up the plane, find the value of μ.

(9)

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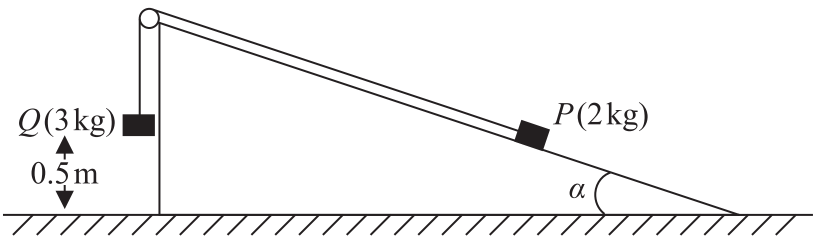

Figure 3

Two particles P and Q have masses 2 kg and 3 kg respectively. The particles are attached to the ends of a light inextensible string. The string passes over a smooth light pulley which is fixed at the top of a rough plane. The plane is inclined to horizontal ground at an angle α, where $\tan \alpha = \frac{3}{4}$. Initially P is held at rest on the inclined plane with the part of the string from P to the pulley parallel to a line of greatest slope of the plane. The particle Q hangs freely below the pulley at a height of 0.5 m above the ground, as shown in Figure 3. The coefficient of friction between P and the plane is μ. The system is released from rest, with the string taut, and Q strikes the ground before P reaches the pulley. The speed of Q at the instant when it strikes the ground is 1.4 m s^{-1}.

(a) For the motion before Q strikes the ground, find the tension in the string.

(5)

(b) Find the value of μ.

(8)

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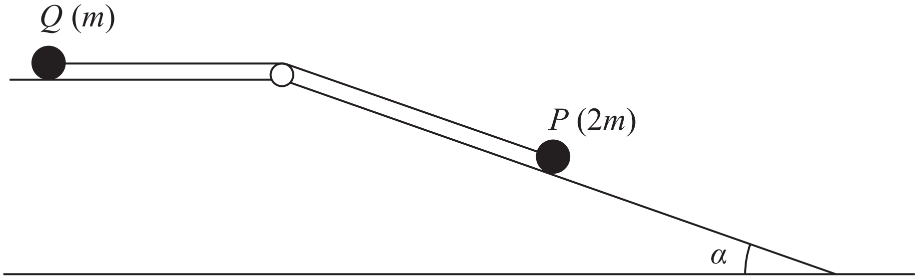

Figure 4

Two particles, P and Q, with masses $2m$ and m respectively, are attached to the ends of a light inextensible string. The string passes over a small smooth pulley which is fixed at the edge of a rough horizontal table. Particle Q is held at rest on the table and particle P is on the surface of a smooth inclined plane. The top of the plane coincides with the edge of the table. The plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$, as shown in Figure 4. The string lies in a vertical plane containing the pulley and a line of greatest slope of the plane. The coefficient of friction between Q and the table is $\frac{1}{2}$. Particle Q is released from rest with the string taut and P begins to slide down the plane.

(a) By writing down an equation of motion for each particle,

(i) find the initial acceleration of the system,

(ii) find the tension in the string.

(10)

Suppose now that the coefficient of friction between Q and the table is μ and when Q is released it remains at rest.

(b) Find the smallest possible value of μ.

(4)

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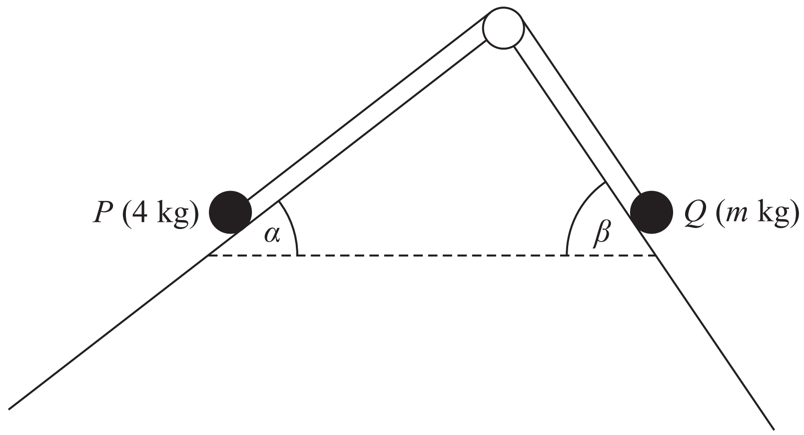

Figure 3

A particle P of mass 4 kg is attached to one end of a light inextensible string. A particle Q of mass m kg is attached to the other end of the string. The string passes over a small smooth pulley which is fixed at a point on the intersection of two fixed inclined planes. The string lies in a vertical plane that contains a line of greatest slope of each of the two inclined planes. The first plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$ and the second plane is inclined to the horizontal at an angle β, where $\tan\beta = \frac{4}{3}$. Particle P is on the first plane and particle Q is on the second plane with the string taut, as shown in Figure 3.

The first plane is rough and the coefficient of friction between P and the plane is $\frac{1}{4}$. The second plane is smooth. The system is in limiting equilibrium.

Given that P is on the point of slipping down the first plane,

(a) find the value of m,

(10)

(b) find the magnitude of the force exerted on the pulley by the string,

(4)

(c) find the direction of the force exerted on the pulley by the string.

(1)

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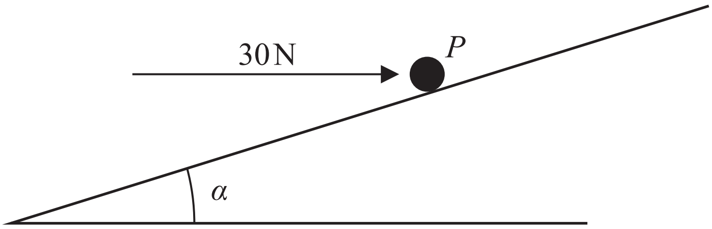

Figure 1

A particle P of mass 2 kg is pushed by a constant horizontal force of magnitude 30 N up a line of greatest slope of a rough plane. The plane is inclined to the horizontal at an angle α, where $\tan \alpha = \frac{3}{4}$, as shown in Figure 1. The line of action of the force lies in the vertical plane containing P and the line of greatest slope of the plane. The particle P starts from rest. The coefficient of friction between P and the plane is μ. After 2 seconds, P has travelled a distance of 5.5 m up the plane.

(a) Find the acceleration of P up the plane.

(2)

(b) Find the value of μ.

(8)

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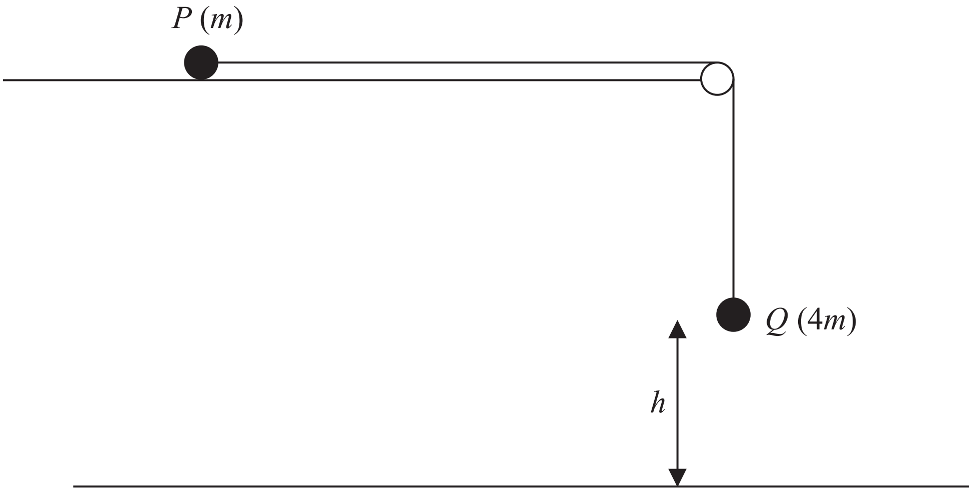

Figure 3

Two particles P and Q have masses m and $4m$ respectively. The particles are attached to the ends of a light inextensible string. Particle P is held at rest on a rough horizontal table. The string lies along the table and passes over a small smooth light pulley which is fixed at the edge of the table. Particle Q hangs at rest vertically below the pulley, at a height h above a horizontal plane, as shown in Figure 3. The coefficient of friction between P and the table is 0.5. Particle P is released from rest with the string taut and slides along the table.

(a) Find, in terms of mg, the tension in the string while both particles are moving.

(8)

The particle P does not reach the pulley before Q hits the plane.

(b) Show that the speed of Q immediately before it hits the plane is $\sqrt{1.4gh}$

(2)

When Q hits the plane, Q does not rebound and P continues to slide along the table. Given that P comes to rest before it reaches the pulley,

(c) show that the total length of the string must be greater than $2.4h$

(6)

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3. A particle P of mass 1.5 kg is placed at a point A on a rough plane which is inclined at 30° to the horizontal. The coefficient of friction between P and the plane is 0.6

(a) Show that P rests in equilibrium at A.

(5)

A horizontal force of magnitude X newtons is now applied to P, as shown in Figure 1. The force acts in a vertical plane containing a line of greatest slope of the inclined plane.

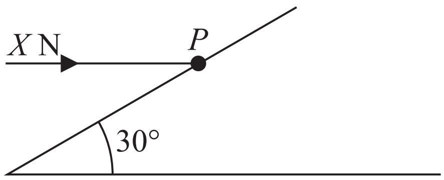

Figure 1

The particle is on the point of moving up the plane.

(b) Find

(i) the magnitude of the normal reaction of the plane on P,

(ii) the value of X.

(7)

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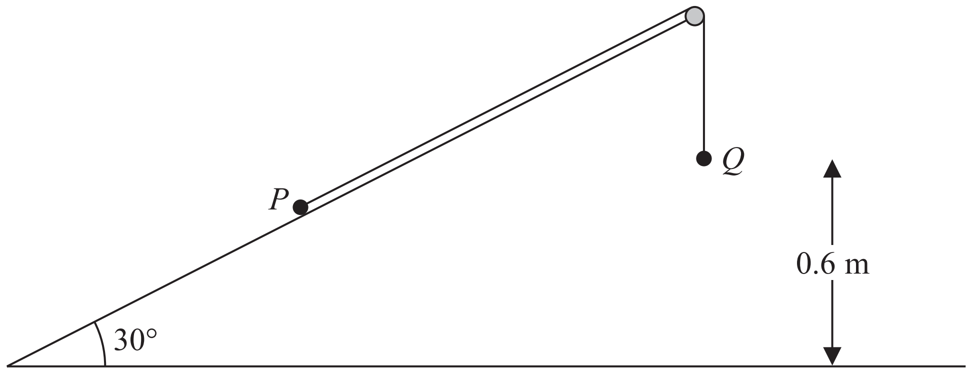

Figure 3

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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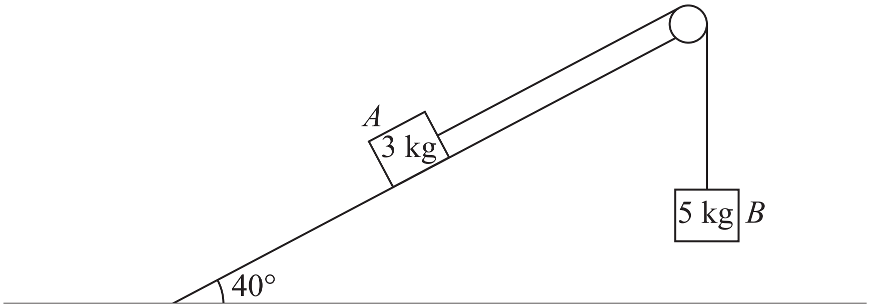

Figure 4

One end of a light inextensible string is attached to a block *A* of mass 3 kg. Block *A* is held at rest on a smooth fixed plane. The plane is inclined at 40° to the horizontal ground. The string lies along a line of greatest slope of the plane and passes over a small smooth pulley which is fixed at the top of the plane. The other end of the string is attached to a block *B* of mass 5 kg. Block *B* hangs freely at rest below the pulley, as shown in Figure 4. The system is released from rest with the string taut.

By modelling the two blocks as particles,

(a) find the tension in the string as *B* descends.
(6)

After falling for 1.5 s, block *B* hits the ground and is immediately brought to rest. In its subsequent motion, *A* does not reach the pulley.

(b) Find the speed of *B* at the instant it hits the ground.
(3)

(c) Find the total distance moved up the plane by *A* before it comes to instantaneous rest.
(5)

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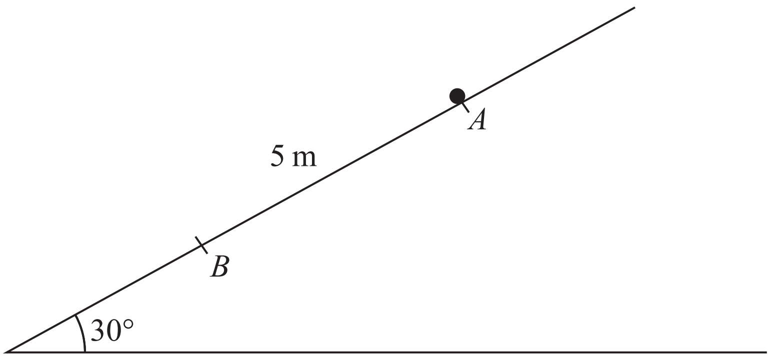

Figure 3

A particle P of mass 4 kg is held at rest at the point A on a rough plane which is inclined at 30° to the horizontal. The point B lies on the line of greatest slope of the plane that passes through A. The point B is 5 m down the plane from A, as shown in Figure 3. The coefficient of friction between the plane and P is 0.3

The particle is released from rest at A and slides down the plane.

(a) Find the speed of P at the instant it reaches B.

(7)

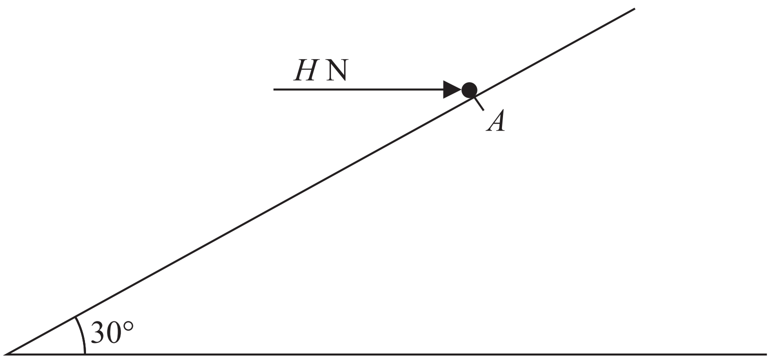

Figure 4

The particle is now returned to A and is held in equilibrium by a horizontal force of magnitude H newtons, as shown in Figure 4. The line of action of the force lies in the vertical plane containing the line of greatest slope of the plane through A. The particle is on the point of moving up the plane.

(b) Find the value of H.

(7)

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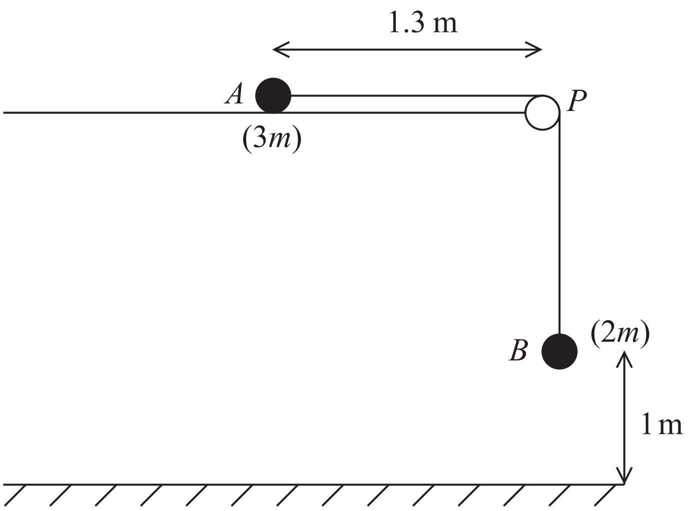

Figure 3

A particle A of mass $3m$ is held at rest on a rough horizontal table. The particle is attached to one end of a light inextensible string. The string passes over a small smooth pulley P which is fixed at the edge of the table. The other end of the string is attached to a particle B of mass $2m$, which hangs freely, vertically below P. The system is released from rest, with the string taut, when A is 1.3 m from P and B is 1 m above the horizontal floor, as shown in Figure 3.

Given that B hits the floor 2 s after release and does not rebound,

(a) find the acceleration of A during the first two seconds,
(2)

(b) find the coefficient of friction between A and the table,
(8)

(c) determine whether A reaches the pulley.
(6)