EXPERT TUITION

Maths Questions By Topic:

Forces & Newton's Laws

A-Level Edexcel

0207 060 4494
www.expert-tuition.co.uk
online.expert-tuition.co.uk
enquiries@expert-tuition.co.uk
The Foundry, 77 Fulham Palace Road, W6 8JA

Table Of Contents

1.

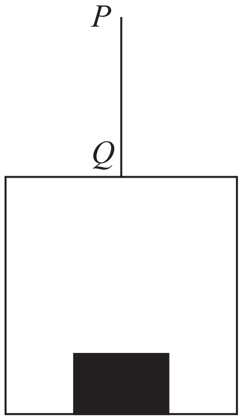

Figure 1

A vertical rope PQ has its end Q attached to the top of a small lift cage.

The lift cage has mass 40 kg and carries a block of mass 10 kg, as shown in Figure 1.

The lift cage is raised vertically by moving the end P of the rope vertically upwards with constant acceleration $0.2\,\text{m}\,\text{s}^{-2}$

The rope is modelled as being light and inextensible and air resistance is ignored.

Using the model,

(a) find the tension in the rope PQ

(3)

(b) find the magnitude of the force exerted on the block by the lift cage.

(3)

Question 1 continued

Question 1 continued

(Total for Question 1 is 6 marks)

2.

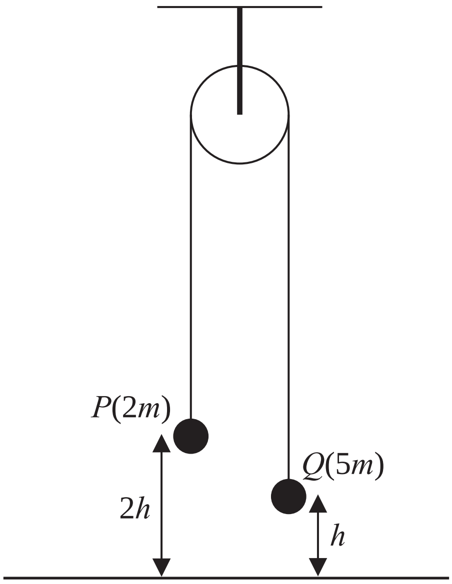

Figure 1

A ball P of mass $2m$ is attached to one end of a string.

The other end of the string is attached to a ball Q of mass $5m$.

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 $2h$ 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)

Question 2 continued

Question 2 continued

Question 2 continued

Question 2 continued

(Total for Question 2 is 13 marks)

3.

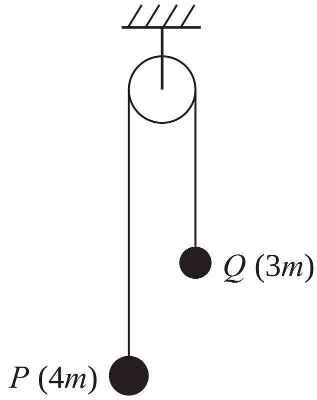

Figure 1

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)

Question 3 continued

Question 3 continued

Question 3 continued

(Total for Question 3 is 9 marks)

4. A particle P moves along a straight line such that at time t seconds, $t \geqslant 0$, after leaving the point O on the line, the velocity, $v\,\text{m s}^{-1}$, of P is modelled as

$$v = (7 - 2t)(t + 2)$$

(a) Find the value of t at the instant when P stops accelerating.

(4)

(b) Find the distance of P from O at the instant when P changes its direction of motion.

(5)

In this question, solutions relying on calculator technology are not acceptable.

Question 4 continued

Question 4 continued

(Total for Question 4 is 9 marks)

5.

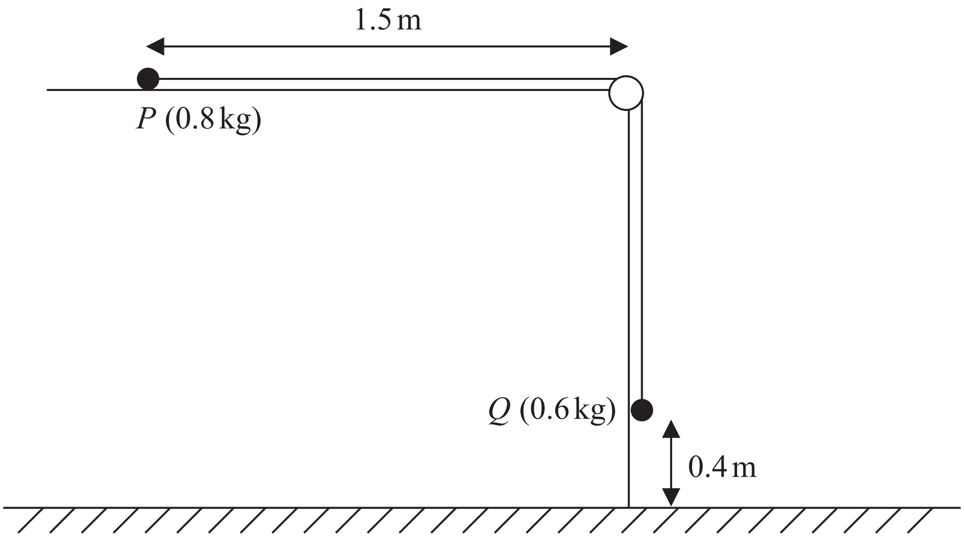

Figure 1

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 $4.2\,\text{m s}^{-2}$

(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)

Question 5 continued

Question 5 continued

Question 5 continued

(Total for Question 5 is 12 marks)

6.

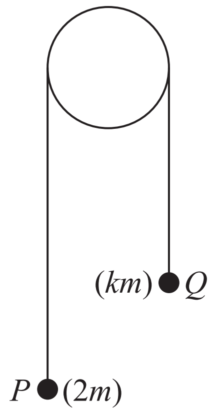

Figure 1

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)

Question 6 continued

Question 6 continued

(Total for Question 6 is 9 marks)

7.

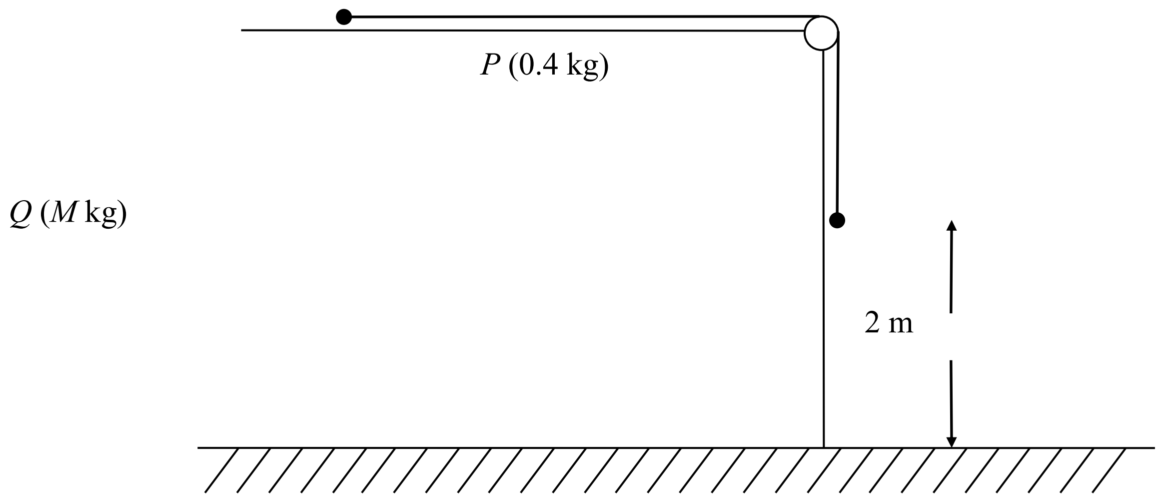

Figure 1

A ball, P, of mass 0.4 kg rests on a rough horizontal table and is attached to one end of a thin rope. The rope passes over a pulley which is fixed at the edge of the table. The other end of the rope is attached to another ball, Q, of mass M kg which hangs freely below the pulley, as shown in Figure 1.

The system is released from rest with the rope taut and with Q at a height of 2 m above the ground and Q moves downwards with acceleration 2.5 m s^{-2}. In the subsequent motion P does not reach the pulley before Q reaches the ground.

The balls are modelled as particles, the rope as a light and inextensible string and the pulley as being small and smooth. The total resistance to the motion of P is modelled as having constant magnitude 1.5 N. The acceleration due to gravity is modelled as being 10 m s^{-2}.

Using this model, find, to 2 significant figures,

(a) (i) the tension in the rope,

(ii) the value of M,

(6)

(b) the time, after release, for Q to hit the ground.

(2)

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

(1)

Question 7 continued

(Total for Question 7 is 9 marks)

8.

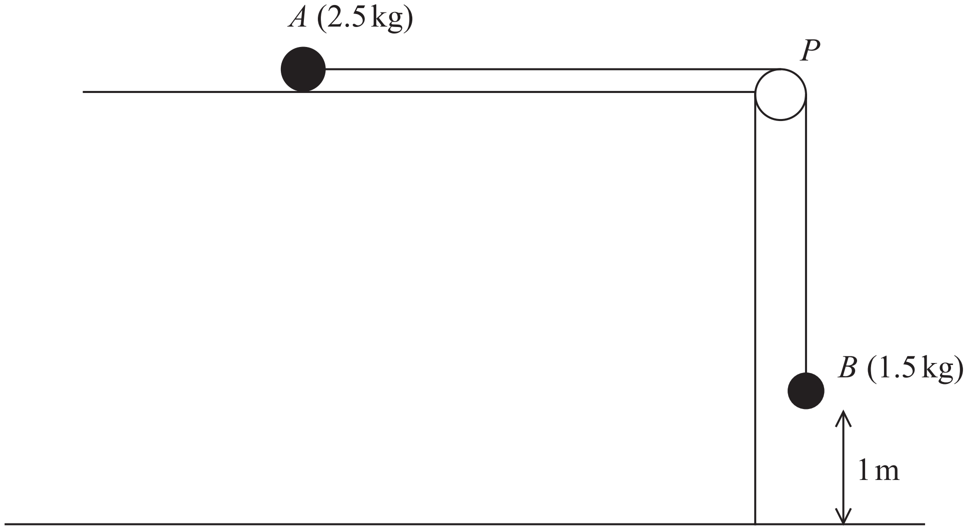

Figure 2

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)

Question 8 continued

Question 8 continued

Question 8 continued

(Total for Question 8 is 10 marks)

9.

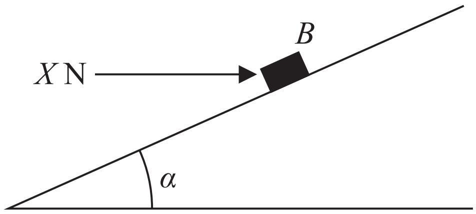

Figure 1

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

A small block B of mass 5 kg is held in equilibrium on the plane by a horizontal force of magnitude X newtons, as shown in Figure 1.

The force acts in a vertical plane which contains a line of greatest slope of the inclined plane.

The block B is modelled as a particle.

The magnitude of the normal reaction of the plane on B is 68.6 N.

Using the model,

(a) (i) find the magnitude of the frictional force acting on B,

(3)

(ii) state the direction of the frictional force acting on B.

(1)

The horizontal force of magnitude X newtons is now removed and B moves down the plane.

Given that the coefficient of friction between B and the plane is 0.5

(b) find the acceleration of B down the plane.

(6)

Question 9 continued

Question 9 continued

Question 9 continued

(Total for Question 9 is 10 marks)

10. [*In this question*, **i** *and* **j** *are horizontal unit vectors*.]

A particle P of mass 4 kg is at rest at the point A on a smooth horizontal plane.

At time $t = 0$, two forces, $\mathbf{F}_1 = (4\mathbf{i} - \mathbf{j})\,\text{N}$ and $\mathbf{F}_2 = (\lambda\mathbf{i} + \mu\mathbf{j})\,\text{N}$, where λ and μ are constants, are applied to P

Given that P moves in the direction of the vector $(3\mathbf{i} + \mathbf{j})$

(a) show that

$$\lambda - 3\mu + 7 = 0$$

(4)

At time $t = 4$ seconds, P passes through the point B.

Given that $\lambda = 2$

(b) find the length of AB.

(5)

Question 10 continued

Question 10 continued

Question 10 continued

(Total for Question 10 is 9 marks)

11.

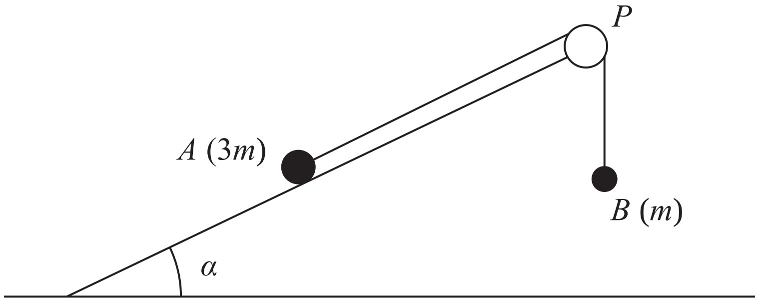

Figure 1

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)

Question 11 continued

Question 11 continued

Question 11 continued

(Total for Question 11 is 12 marks)

12. 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)

Question 12 continued

Question 12 continued

Question 12 continued

(Total for Question 12 is 9 marks)

13.

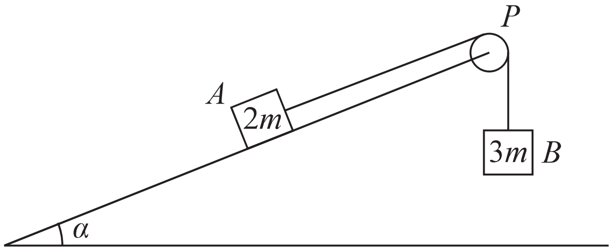

Figure 1

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 $\tan\alpha = \frac{5}{12}$

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 $\frac{2}{3}$

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 $T = \frac{12mg}{5}$

(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)

Question 13 continued

Question 13 continued

Question 13 continued

(Total for Question 13 is 12 marks)

14.

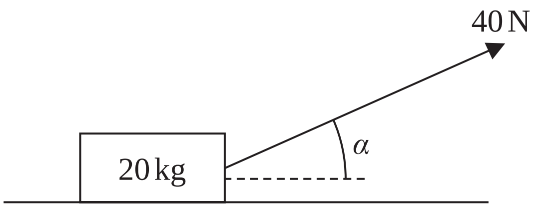

Figure 1

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.

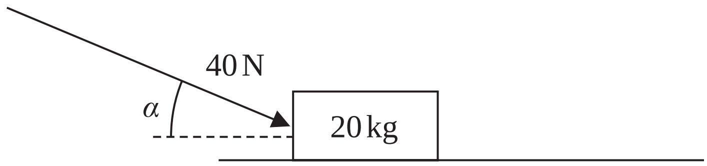

Figure 2

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

(2)

Question 14 continued

Question 14 continued

Question 14 continued

(Total for Question 14 is 8 marks)

15. A particle P moves under the action of a single force in such a way that at time t seconds, where $t \geq 0$, its velocity $\mathbf{v}$ m s^{-1} is given by

$$\mathbf{v} = (t^2 - 3t)\,\mathbf{i} - 12t\,\mathbf{j}$$

The mass of P is 0.5 kg.

Find the time at which the magnitude of the force acting on P is 6.5 N. **(7)**

Question 15 continued

(Total for Question 15 is 7 marks)

16.

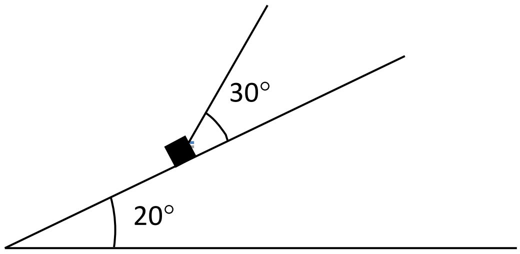

Figure 1

A small box of mass 3 kg moves on a rough plane which is inclined at an angle of 20° to the horizontal. The box is pulled up a line of greatest slope of the plane using a rope which is attached to the box. The rope makes an angle of 30° with the plane, as shown in Figure 1. The rope lies in the vertical plane which contains a line of greatest slope of the plane. The coefficient of friction between the box and the plane is 0.3. The tension in the rope is 25 N.

The box is modelled as a particle, the rope is modelled as a light inextensible string and air resistance is ignored.

Using the model,

(a) find the acceleration of the box.

(7)

(b) Suggest one improvement to the model that would make it more realistic.

(1)

The rope now breaks and the box slows down and comes to rest.

(c) Show that, after the box comes to rest, it immediately starts to move down the plane.

(3)

Question 16 continued

(Total for Question 16 is 11 marks)

17. 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)

Question 17 continued

(Total for Question 17 is 8 marks)

Leave blank

18.

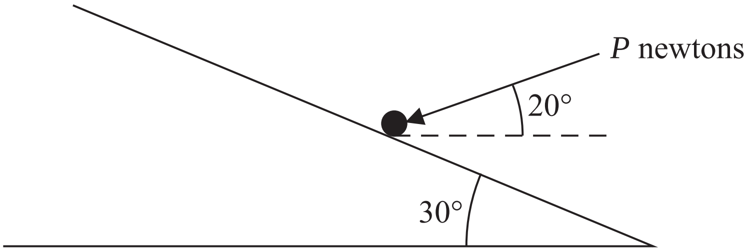

Figure 1

A particle of mass 2 kg lies on a rough plane. The plane is inclined to the horizontal at 30°. The coefficient of friction between the particle and the plane is $\frac{1}{4}$. The particle is held in equilibrium by a force of magnitude P newtons. The force makes an angle of 20° with the horizontal and acts in a vertical plane containing a line of greatest slope of the plane, as shown in Figure 1. Find the least possible value of P.

(10)

Leave blank

Question 18 continued

Leave blank

Question 18 continued

Leave blank

Question 18 continued

(Total 10 marks)

Leave blank

19.

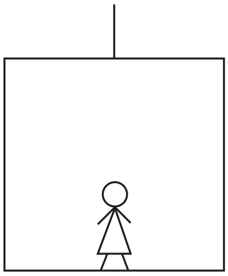

Figure 3

A lift of mass 250 kg is being raised by a vertical cable attached to the top of the lift. A woman of mass 60 kg stands on the horizontal floor inside the lift, as shown in Figure 3. The lift ascends vertically with constant acceleration $2\,\text{m}\,\text{s}^{-2}$. There is a constant downwards resistance of magnitude 100 N on the lift. By modelling the woman as a particle,

(a) find the magnitude of the normal reaction exerted by the floor of the lift on the woman.

(3)

The tension in the cable must not exceed 10 000 N for safety reasons, and the maximum upward acceleration of the lift is $3\,\text{m}\,\text{s}^{-2}$. A typical occupant of the lift is modelled as a particle of mass 75 kg and the cable is modelled as a light inextensible string. There is still a constant downwards resistance of magnitude 100 N on the lift.

(b) Find the maximum number of typical occupants that can be safely carried in the lift when it is ascending with an acceleration of $3\,\text{m}\,\text{s}^{-2}$.

(7)

Leave blank

Question 19 continued

Leave blank

Question 19 continued

Leave blank

Question 19 continued

(Total 10 marks)

Leave blank

20. [*In this question* **i** *and* **j** *are horizontal unit vectors due east and due north respectively*]

Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a particle P of mass 0.5 kg.

$\mathbf{F}_1 = (4\mathbf{i} - 6\mathbf{j})$ N and $\mathbf{F}_2 = (p\mathbf{i} + q\mathbf{j})$ N.

Given that the resultant force of $\mathbf{F}_1$ and $\mathbf{F}_2$ is in the same direction as $-2\mathbf{i} - \mathbf{j}$,

(a) show that $p - 2q = -16$

(5)

Given that $q = 3$

(b) find the magnitude of the acceleration of P,

(5)

(c) find the direction of the acceleration of P, giving your answer as a bearing to the nearest degree.

(3)

Leave blank

Question 20 continued

Leave blank

Question 20 continued

Leave blank

Question 20 continued

(Total 13 marks)

Leave blank

21.

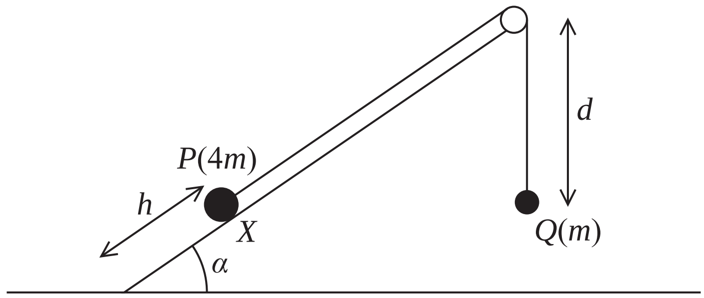

Figure 4

A particle P of mass $4m$ is held at rest at the point X on the surface of a rough inclined plane which is fixed to horizontal ground. The point X is a distance h from the bottom of the inclined plane. The plane is inclined to the horizontal at an angle α where $\tan\alpha = \frac{3}{4}$. The coefficient of friction between P and the plane is $\frac{1}{4}$. The particle P is attached to one end of a light inextensible string. The string 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 particle Q of mass m which hangs freely at a distance d, where $d > h$, below the pulley, as shown in Figure 4.

The string lies in a vertical plane through a line of greatest slope of the inclined plane. The system is released from rest with the string taut and P moves down the plane.

For the motion of the particles before P hits the ground,

(a) state which of the information given above implies that the magnitudes of the accelerations of the two particles are the same,

(1)

(b) write down an equation of motion for each particle,

(5)

(c) find the acceleration of each particle.

(5)

When P hits the ground, it immediately comes to rest. Given that Q comes to instantaneous rest before reaching the pulley,

(d) show that $d > \frac{28h}{25}$.

(5)

Leave blank

Question 21 continued

Leave blank

Question 21 continued

Leave blank

Question 21 continued

Leave blank

Question 21 continued

(Total 16 marks)

Leave blank

22. Three forces, $(15\mathbf{i} + \mathbf{j})$ N, $(5q\mathbf{i} - p\mathbf{j})$ N and $(-3p\mathbf{i} - q\mathbf{j})$ N, where p and q are constants, act on a particle. Given that the particle is in equilibrium, find the value of p and the value of q.

(6)

Leave blank

Question 22 continued

(Total 6 marks)

Leave blank

23.

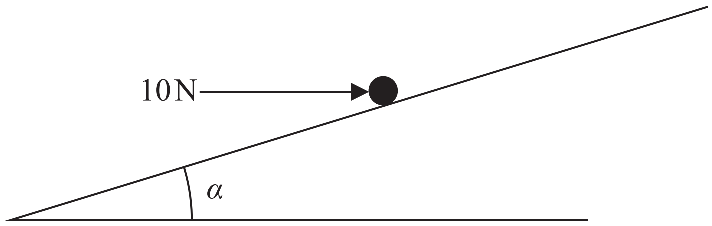

Figure 1

A particle P of mass 5 kg is held at rest in equilibrium on a rough inclined plane by a horizontal force of magnitude 10 N. 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 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 down the plane, find the value of μ.

(9)

Leave blank

Question 23 continued

Leave blank

Question 23 continued

Leave blank

Question 23 continued

(Total 9 marks)

24.

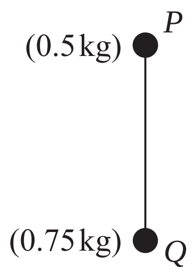

Figure 2

A vertical light rod *PQ* has a particle of mass 0.5 kg attached to it at *P* and a particle of mass 0.75 kg attached to it at *Q*, to form a system, as shown in Figure 2. The system is accelerated vertically upwards by a vertical force of magnitude 15 N applied to the particle at *Q*. Find the thrust in the rod.

(6)

Leave blank

Question 24 continued

(Total 6 marks)

EXPERT TUITION

Leave blank

25.

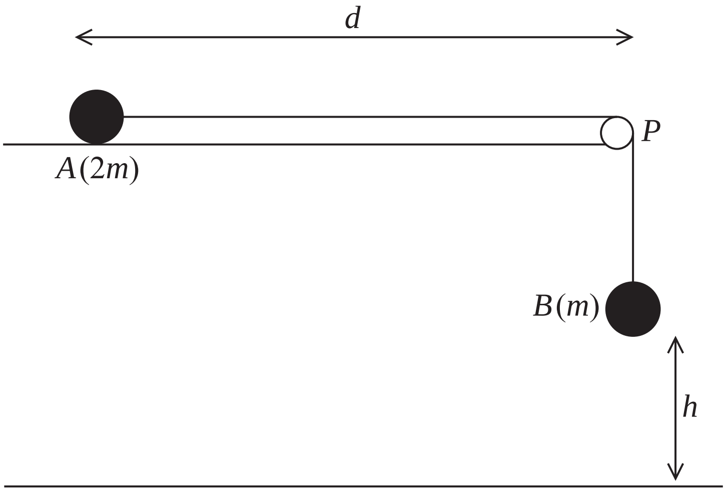

Figure 3

Two particles, A and B, have masses $2m$ and m respectively. The particles are attached to the ends of a light inextensible string. Particle A is held at rest on a fixed rough horizontal table at a distance d from a small smooth light pulley which is fixed at the edge of the table at the point P. The coefficient of friction between A and the table is μ, where $\mu < \frac{1}{2}$. The string is parallel to the table from A to P and passes over the pulley. Particle B hangs freely at rest vertically below P with the string taut and at a height h, ($h < d$), above a horizontal floor, as shown in Figure 3. Particle A is released from rest with the string taut and slides along the table.

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

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

(4)

(b) Hence show that, until B hits the floor, the acceleration of A is $\frac{g}{3}(1 - 2\mu)$.

(3)

(c) Find, in terms of g, h and μ, the speed of A at the instant when B hits the floor.

(2)

After B hits the floor, A continues to slide along the table. Given that $\mu = \frac{1}{3}$ and that A comes to rest at P,

(d) find d in terms of h.

(5)

(e) Describe what would happen if $\mu = \frac{1}{2}$

(1)

Leave blank

Question 25 continued

Leave blank

Question 25 continued

Leave blank

Question 25 continued

Leave blank

Question 25 continued

(Total 15 marks)

Leave blank

26.

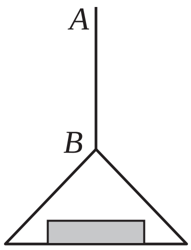

Figure 1

A vertical rope *AB* has its end *B* attached to the top of a scale pan. The scale pan has mass 0.5 kg and carries a brick of mass 1.5 kg, as shown in Figure 1. The scale pan is raised vertically upwards with constant acceleration 0.5 m s^{-2} using the rope *AB*. The rope is modelled as a light inextensible string.

(a) Find the tension in the rope *AB*.

(3)

(b) Find the magnitude of the force exerted on the scale pan by the brick.

(3)

(Total 6 marks)

EXPERT TUITION

Leave blank

27.

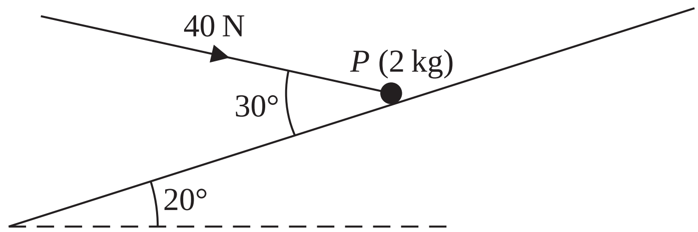

Figure 2

A particle P of mass 2 kg is held at rest in equilibrium on a rough plane by a constant force of magnitude 40 N. The direction of the force is inclined to the plane at an angle of 30°. The plane is inclined to the horizontal at an angle of 20°, 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.

(10)

Leave blank

Question 27 continued

(Total 10 marks)

Leave blank

28. Two forces $\mathbf{F}_1$ and $\mathbf{F}_2$ act on a particle P.

The force $\mathbf{F}_1$ is given by $\mathbf{F}_1 = (-\mathbf{i} + 2\mathbf{j})$ N and $\mathbf{F}_2$ acts in the direction of the vector $(\mathbf{i} + \mathbf{j})$.

Given that the resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ acts in the direction of the vector $(\mathbf{i} + 3\mathbf{j})$,

(a) find $\mathbf{F}_2$

(7)

The acceleration of P is $(3\mathbf{i} + 9\mathbf{j})$ m s^{-2}. At time $t = 0$, the velocity of P is $(3\mathbf{i} - 22\mathbf{j})$ m s^{-1}

(b) Find the speed of P when $t = 3$ seconds.

(4)

Leave blank

Question 28 continued

(Total 11 marks)

29.

Figure 3

Two particles P and Q have masses 1.5 kg and 3 kg respectively. The particles are attached to the ends of a light inextensible string. Particle P is held at rest on a fixed rough horizontal table. The coefficient of friction between P and the table is $\frac{1}{5}$. The string is parallel to the table and passes over a small smooth light pulley which is fixed at the edge of the table. Particle Q hangs freely at rest vertically below the pulley, as shown in Figure 3. Particle P is released from rest with the string taut and slides along the table.

Assuming that P has not reached the pulley, find

(a) the tension in the string during the motion,

(8)

(b) the magnitude and direction of the resultant force exerted on the pulley by the string.

(4)

Leave blank

Question 29 continued

(Total 12 marks)

30.

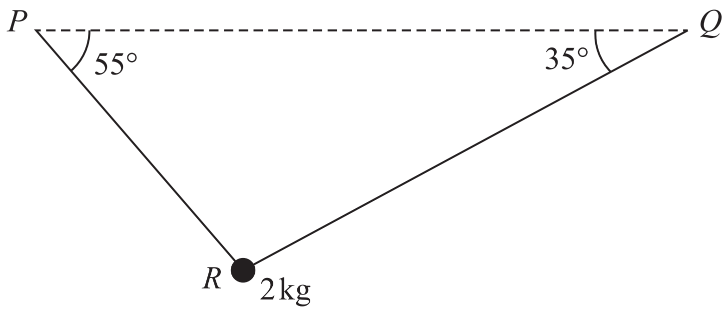

Figure 1

A particle of mass 2 kg is suspended from a horizontal ceiling by two light inextensible strings, *PR* and *QR*. The particle hangs at *R* in equilibrium, with the strings in a vertical plane. The string *PR* is inclined at 55° to the horizontal and the string *QR* is inclined at 35° to the horizontal, as shown in Figure 1.

Find

(i) the tension in the string *PR*,

(ii) the tension in the string *QR*.

(7)

Leave blank

Question 30 continued

(Total 7 marks)

EXPERT TUITION

Leave blank

31.

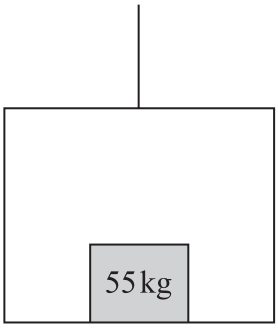

Figure 2

A lift of mass 200 kg is being lowered into a mineshaft by a vertical cable attached to the top of the lift. A crate of mass 55 kg is on the floor inside the lift, as shown in Figure 2. The lift descends vertically with constant acceleration. There is a constant upwards resistance of magnitude 150 N on the lift. The crate experiences a constant normal reaction of magnitude 473 N from the floor of the lift.

(a) Find the acceleration of the lift.

(3)

(b) Find the magnitude of the force exerted on the lift by the cable.

(4)

Leave blank

Question 31 continued

(Total 7 marks)

Leave blank

32.

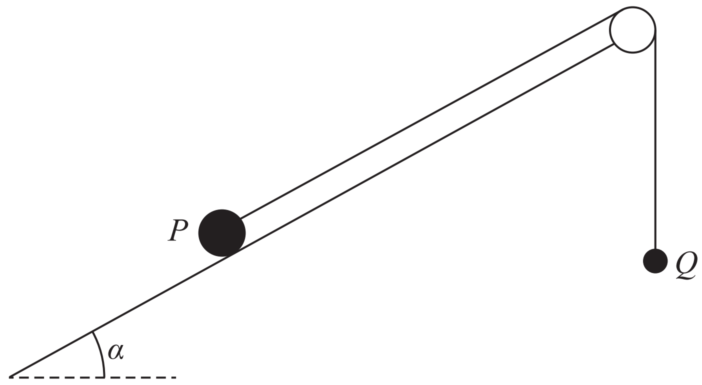

Figure 4

Two particles P and Q have mass 4 kg and 0.5 kg respectively. The particles are attached to the ends of a light inextensible string. Particle P is held at rest on a fixed rough plane, which is inclined to the horizontal at an angle α where $\tan \alpha = \frac{4}{3}$. The coefficient of friction between P and the plane is 0.5. The string lies along the plane and passes over a small smooth light pulley which is fixed at the top of the plane. Particle Q hangs freely at rest vertically below the pulley. The string lies in the vertical plane which contains the pulley and a line of greatest slope of the inclined plane, as shown in Figure 4. Particle P is released from rest with the string taut and slides down the plane.

Given that Q has not hit the pulley, find

(a) the tension in the string during the motion,

(11)

(b) the magnitude of the resultant force exerted by the string on the pulley.

(4)

Leave blank

Question 32 continued

(Total 15 marks)

Leave blank

33.

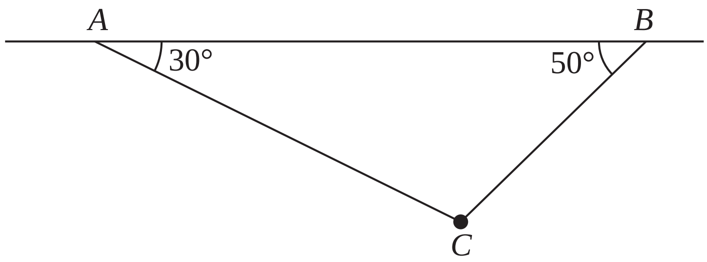

Figure 1

A particle of weight W newtons 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 AC and BC inclined to the horizontal at 30° and 50° respectively, as shown in Figure 1.

Given that the tension in BC is 6 N, find

(a) the tension in AC,

(3)

(b) the value of W.

(3)

(Total 6 marks)

EXPERT TUITION

Leave blank

34.

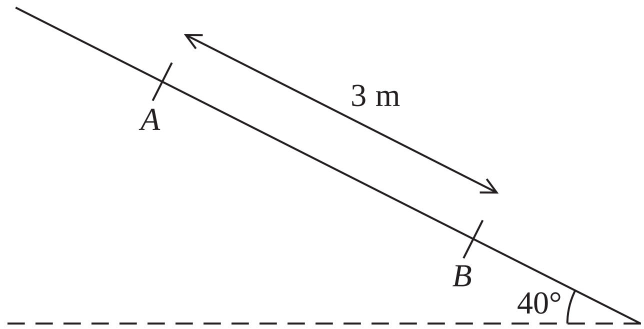

Figure 2

A rough plane is inclined at 40° to the horizontal. Two points A and B are 3 metres apart and lie on a line of greatest slope of the inclined plane, with A above B, as shown in Figure 2. A particle P of mass m kg is held at rest on the plane at A. The coefficient of friction between P and the plane is $\frac{1}{2}$. The particle is released.

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

(5)

(b) Find the speed of P at B.

(2)

Leave blank

Question 34 continued

(Total 7 marks)

EXPERT TUITION

Leave blank

35.

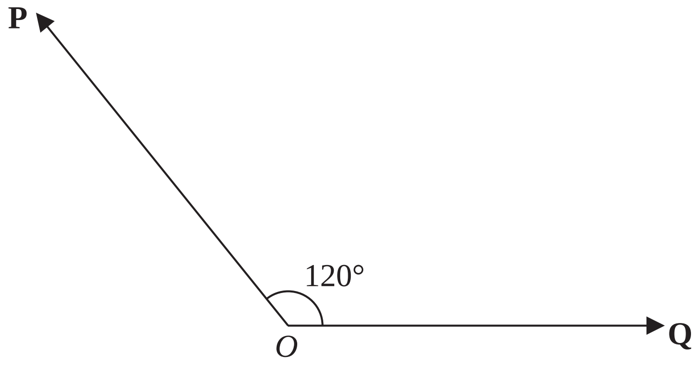

Figure 4

Two forces **P** and **Q** act on a particle at O. The angle between the lines of action of **P** and **Q** is 120° as shown in Figure 4. The force **P** has magnitude 20 N and the force **Q** has magnitude X newtons. The resultant of **P** and **Q** is the force **R**.

Given that the magnitude of **R** is $3X$ newtons, find, giving your answers to 3 significant figures

(a) the value of X,

(5)

(b) the magnitude of (**P** – **Q**).

(4)

Leave blank

Question 35 continued

(Total 9 marks)

36.

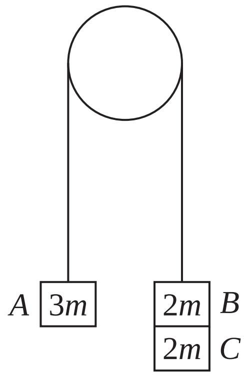

Figure 5

Three particles A, B and C have masses $3m$, $2m$ and $2m$ respectively. Particle C is attached to particle B. Particles A and B 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, as shown in Figure 5. The system is released from rest and A moves upwards.

(a) (i) Show that the acceleration of A is $\frac{g}{7}$

(ii) Find the tension in the string as A ascends.

(7)

At the instant when A is 0.7 m above its original position, C separates from B and falls away. In the subsequent motion, A does not reach the pulley.

(b) Find the speed of A at the instant when it is 0.7 m above its original position.

(2)

(c) Find the acceleration of A at the instant after C separates from B.

(4)

(d) Find the greatest height reached by A above its original position.

(3)

Leave blank

Leave blank

Question 36 continued

(Total 16 marks)

Leave blank

37.

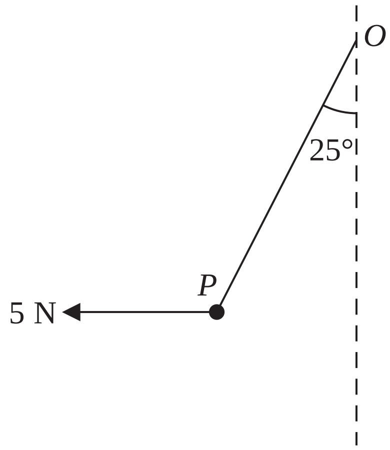

Figure 1

A particle P of weight W newtons is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point O. A horizontal force of magnitude 5 N is applied to P. The particle P is in equilibrium with the string taut and with OP making an angle of 25° to the downward vertical, as shown in Figure 1.

Find

(a) the tension in the string,

(3)

(b) the value of W.

(3)

Leave blank

Question 37 continued

(Total 6 marks)

Leave blank

38. Two forces $(4\mathbf{i} - 2\mathbf{j})$ N and $(2\mathbf{i} + q\mathbf{j})$ N act on a particle P of mass 1.5 kg. The resultant of these two forces is parallel to the vector $(2\mathbf{i} + \mathbf{j})$.

(a) Find the value of q.

(4)

At time $t = 0$, P is moving with velocity $(-2\mathbf{i} + 4\mathbf{j})$ m s^{-1}.

(b) Find the speed of P at time $t = 2$ seconds.

(6)

(Total 10 marks)

Leave blank

39.

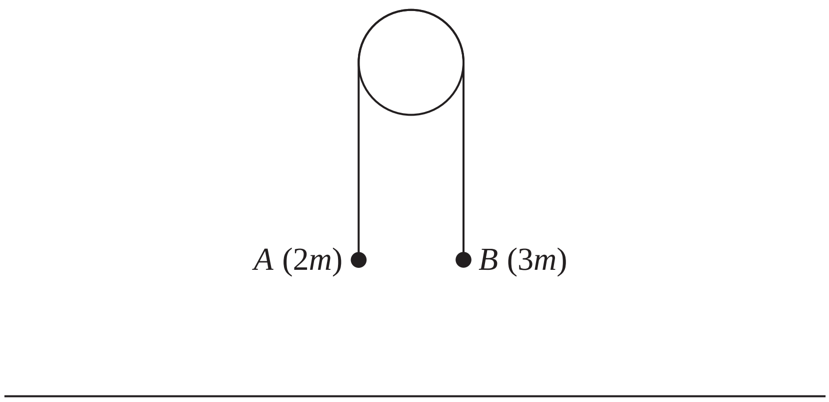

Figure 2

Two particles A and B have masses $2m$ and $3m$ respectively. 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 are vertical and A and B are above a horizontal plane, as shown in Figure 2. The system is released from rest.

(a) Show that the tension in the string immediately after the particles are released is $\frac{12}{5}mg$.

(6)

After descending 1.5 m, B strikes the plane and is immediately brought to rest. In the subsequent motion, A does not reach the pulley.

(b) Find the distance travelled by A between the instant when B strikes the plane and the instant when the string next becomes taut.

(6)

Given that $m = 0.5$ kg,

(c) find the magnitude of the impulse on B due to the impact with the plane.

(2)

Leave blank

Question 39 continued

(Total 14 marks)

Leave blank

40.

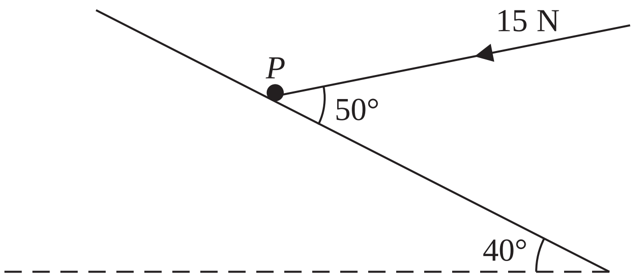

Figure 4

A particle P of mass 2.7 kg lies on a rough plane inclined at 40° to the horizontal. The particle is held in equilibrium by a force of magnitude 15 N acting at an angle of 50° to the plane, as shown in Figure 4. The force acts in a vertical plane containing a line of greatest slope of the plane. The particle is in equilibrium and is on the point of sliding down the plane.

Find

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

(4)

(b) the coefficient of friction between P and the plane.

(5)

The force of magnitude 15 N is removed.

(c) Determine whether P moves, justifying your answer.

(4)

Leave blank

Question 40 continued

(Total 13 marks)

EXPERT TUITION

Leave blank

41. A woman travels in a lift. The mass of the woman is 50 kg and the mass of the lift is 950 kg. The lift is being raised vertically by a vertical cable which is attached to the top of the lift. The lift is moving upwards and has constant deceleration of 2 m s^{-2}. By modelling the cable as being light and inextensible, find

(a) the tension in the cable,

(3)

(b) the magnitude of the force exerted on the woman by the floor of the lift.

(3)

(Total 6 marks)

42.

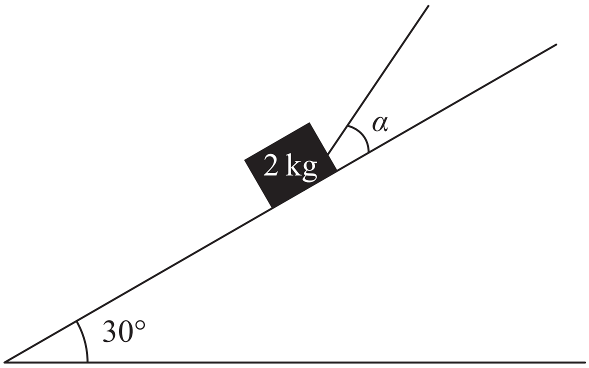

Figure 1

A box of mass 2 kg is held in equilibrium on a fixed rough inclined plane by a rope. The rope lies in a vertical plane containing a line of greatest slope of the inclined plane. The rope is inclined to the plane at an angle α, where $\tan \alpha = \frac{3}{4}$, and the plane is at an angle of 30° to the horizontal, as shown in Figure 1. The coefficient of friction between the box and the inclined plane is $\frac{1}{3}$ and the box is on the point of slipping up the plane. By modelling the box as a particle and the rope as a light inextensible string, find the tension in the rope.

(8)

Leave blank

Question 42 continued

(Total 8 marks)

EXPERT TUITION

Leave blank

43.

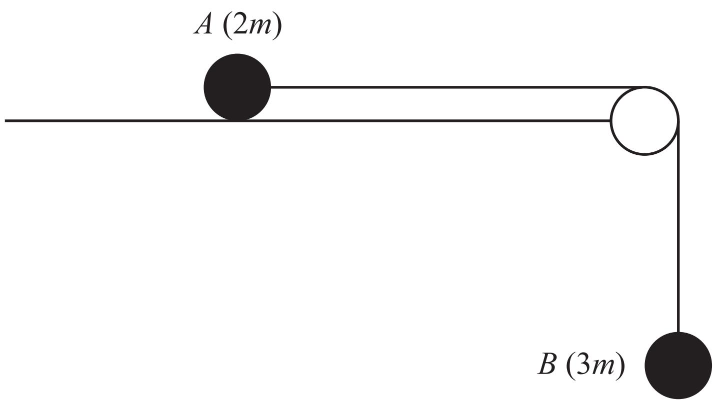

Figure 2

Two particles A and B have masses $2m$ and $3m$ respectively. The particles are attached to the ends of a light inextensible string. Particle A is held at rest on a smooth horizontal table. The string passes over a small smooth pulley which is fixed at the edge of the table. Particle B hangs at rest vertically below the pulley with the string taut, as shown in Figure 2. Particle A is released from rest. Assuming that A has not reached the pulley, find

(a) the acceleration of B,

(5)

(b) the tension in the string,

(1)

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

(4)

Leave blank

Question 43 continued

(Total 10 marks)

Leave blank

44.

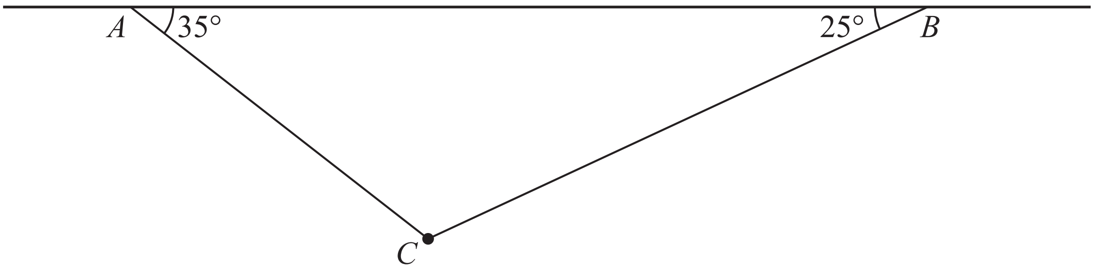

Figure 1

A particle of weight 8 N is attached at C to the ends of two light inextensible strings AC and BC. The other ends, A and B, are attached to a fixed horizontal ceiling. The particle hangs at rest in equilibrium, with the strings in a vertical plane. The string AC is inclined at 35° to the horizontal and the string BC is inclined at 25° to the horizontal, as shown in Figure 1. Find

(i) the tension in the string AC,

(ii) the tension in the string BC.

(8)

(Total 8 marks)

Leave blank

45.

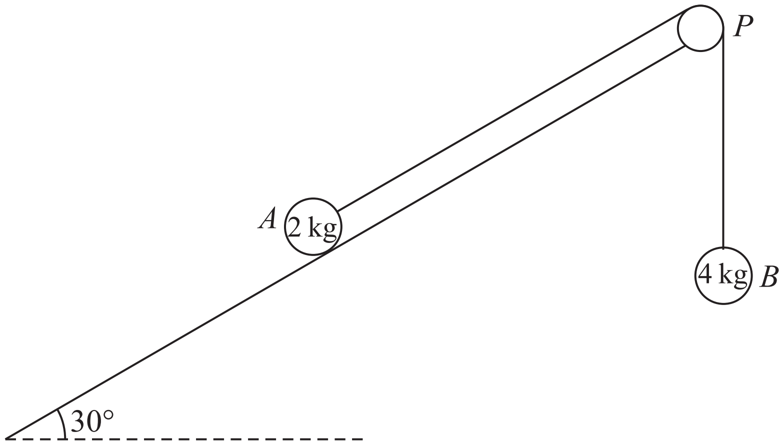

Figure 2

A fixed rough plane is inclined at 30° to the horizontal. A small smooth pulley P is fixed at the top of the plane. Two particles A and B, of mass 2 kg and 4 kg respectively, are attached to the ends of a light inextensible string which passes over the pulley P. The part of the string from A to P is parallel to a line of greatest slope of the plane and B hangs freely below P, as shown in Figure 2. The coefficient of friction between A and the plane is $\frac{1}{\sqrt{3}}$. Initially A is held at rest on the plane. The particles are released from rest with the string taut and A moves up the plane.

Find the tension in the string immediately after the particles are released.

(9)

Leave blank

Question 45 continued

(Total 9 marks)

46.

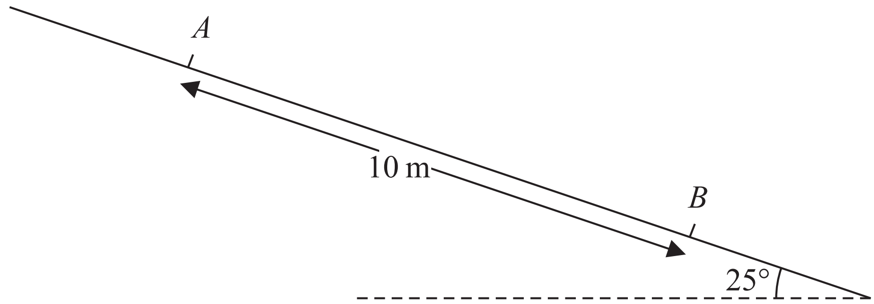

Figure 3

A particle P of mass 0.6 kg slides with constant acceleration down a line of greatest slope of a rough plane, which is inclined at 25° to the horizontal. The particle passes through two points A and B, where AB = 10 m, as shown in Figure 3. The speed of P at A is 2 m s^{-1}. The particle P takes 3.5 s to move from A to B. Find

(a) the speed of P at B,

(3)

(b) the acceleration of P,

(2)

(c) the coefficient of friction between P and the plane.

(5)

Leave blank

Question 46 continued

(Total 10 marks)

47.

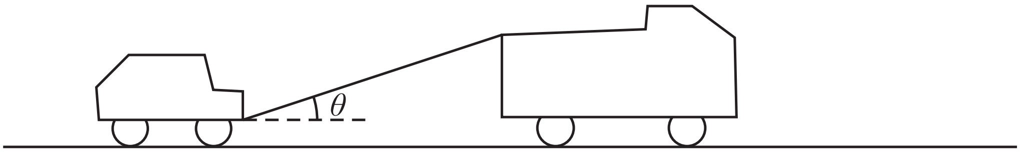

Figure 4

A truck of mass 1750 kg is towing a car of mass 750 kg along a straight horizontal road. The two vehicles are joined by a light towbar which is inclined at an angle θ to the road, as shown in Figure 4. The vehicles are travelling at 20 m s^{-1} as they enter a zone where the speed limit is 14 m s^{-1}. The truck's brakes are applied to give a constant braking force on the truck. The distance travelled between the instant when the brakes are applied and the instant when the speed of each vehicle is 14 m s^{-1} is 100 m.

(a) Find the deceleration of the truck and the car.

(3)

The constant braking force on the truck has magnitude R newtons. The truck and the car also experience constant resistances to motion of 500 N and 300 N respectively. Given that $\cos \theta = 0.9$, find

(b) the force in the towbar,

(4)

(c) the value of R.

(4)

Leave blank

Leave blank

Question 47 continued

(Total 11 marks)

48. A particle P of mass 2 kg is attached to one end of a light string, the other end of which is attached to a fixed point O. The particle is held in equilibrium, with OP at 30º to the downward vertical, by a force of magnitude F newtons. The force acts in the same vertical plane as the string and acts at an angle of 30º to the horizontal, as shown in Figure 3.

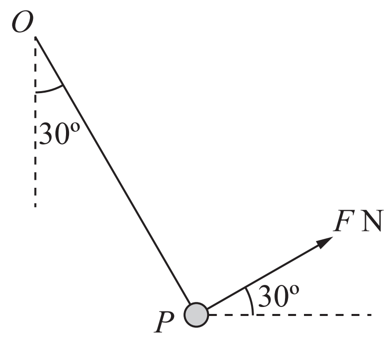

Figure 3

Find

(i) the value of F,

(ii) the tension in the string.

(8)

Leave blank

Question 48 continued

(Total 8 marks)

Leave blank

49. A lifeboat slides down a straight ramp inclined at an angle of 15º to the horizontal. The lifeboat has mass 800 kg and the length of the ramp is 50 m. The lifeboat is released from rest at the top of the ramp and is moving with a speed of 12.6 m s^{-1} when it reaches the end of the ramp. By modelling the lifeboat as a particle and the ramp as a rough inclined plane, find the coefficient of friction between the lifeboat and the ramp.

(9)

(Total 9 marks)

Leave blank

50.

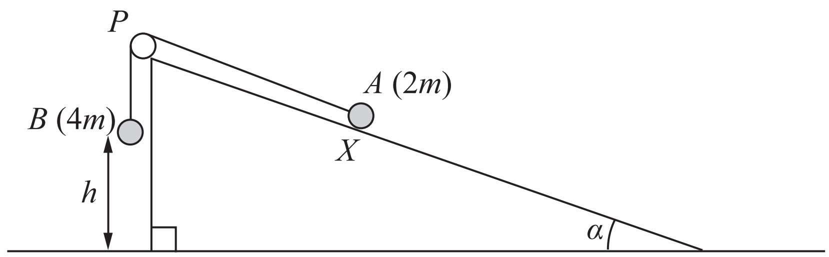

Figure 5

Figure 5 shows two particles *A* and *B*, of mass 2*m* and 4*m* respectively, connected by a light inextensible string. Initially *A* is held at rest on a rough inclined plane which is fixed to horizontal ground. 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 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 and *B* hangs vertically below *P*. The system is released from rest with the string taut, with *A* at the point *X* and with *B* at a height *h* above the ground.

For the motion until *B* hits the ground,

(a) give a reason why the magnitudes of the accelerations of the two particles are the same,

(1)

(b) write down an equation of motion for each particle,

(4)

(c) find the acceleration of each particle.

(5)

Particle *B* does not rebound when it hits the ground and *A* continues moving up the plane towards *P*. Given that *A* comes to rest at the point *Y*, without reaching *P*,

(d) find the distance *XY* in terms of *h*.

(6)

Leave blank

Question 50 continued

(Total 16 marks)

Leave blank

51.

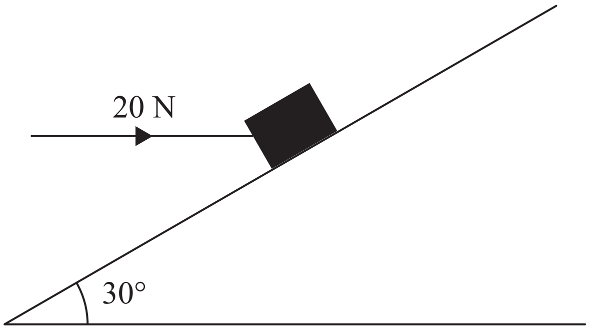

Figure 2

A box of mass 5 kg lies on a rough plane inclined at 30° to the horizontal. The box is held in equilibrium by a horizontal force of magnitude 20 N, as shown in Figure 2. The force acts in a vertical plane containing a line of greatest slope of the inclined plane.
The box is in equilibrium and on the point of moving down the plane. The box is modelled as a particle.

Find

(a) the magnitude of the normal reaction of the plane on the box,

(4)

(b) the coefficient of friction between the box and the plane.

(5)

Leave blank

Question 51 continued

(Total 9 marks)

Leave blank

52. A particle P is projected vertically upwards from a point A with speed u m s^{-1}. The point A is 17.5 m above horizontal ground. The particle P moves freely under gravity until it reaches the ground with speed 28 m s^{-1}.

(a) Show that $u = 21$

(3)

At time t seconds after projection, P is 19 m above A.

(b) Find the possible values of t.

(5)

The ground is soft and, after P reaches the ground, P sinks vertically downwards into the ground before coming to rest. The mass of P is 4 kg and the ground is assumed to exert a constant resistive force of magnitude 5000 N on P.

(c) Find the vertical distance that P sinks into the ground before coming to rest.

(4)

Leave blank

Question 52 continued

(Total 12 marks)

Leave blank

53.

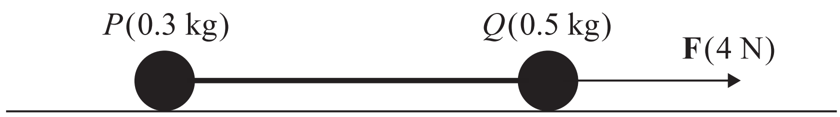

Figure 3

Two particles P and Q, of mass 0.3 kg and 0.5 kg respectively, are joined by a light horizontal rod. The system of the particles and the rod is at rest on a horizontal plane. At time $t = 0$, a constant force **F** of magnitude 4 N is applied to Q in the direction PQ, as shown in Figure 3. The system moves under the action of this force until $t = 6$ s. During the motion, the resistance to the motion of P has constant magnitude 1 N and the resistance to the motion of Q has constant magnitude 2 N.

Find

(a) the acceleration of the particles as the system moves under the action of **F**,
(3)

(b) the speed of the particles at $t = 6$ s,
(2)

(c) the tension in the rod as the system moves under the action of **F**.
(3)

At $t = 6$ s, **F** is removed and the system decelerates to rest. The resistances to motion are unchanged. Find

(d) the distance moved by P as the system decelerates,
(4)

(e) the thrust in the rod as the system decelerates.
(3)

Leave blank

Question 53 continued

(Total 15 marks)

Leave blank

54. A car of mass 1000 kg is towing a caravan of mass 750 kg along a straight horizontal road. The caravan is connected to the car by a tow-bar which is parallel to the direction of motion of the car and the caravan. The tow-bar is modelled as a light rod. The engine of the car provides a constant driving force of 3200 N. The resistances to the motion of the car and the caravan are modelled as constant forces of magnitude 800 newtons and R newtons respectively.

Given that the acceleration of the car and the caravan is $0.88\,\text{m}\,\text{s}^{-2}$,

(a) show that $R = 860$,

(3)

(b) find the tension in the tow-bar.

(3)

(Total 6 marks)

Leave blank

55. Three forces $\mathbf{F}_1$, $\mathbf{F}_2$ and $\mathbf{F}_3$ acting on a particle P are given by

$$\mathbf{F}_1 = (7\mathbf{i} - 9\mathbf{j})\text{ N}$$
$$\mathbf{F}_2 = (5\mathbf{i} + 6\mathbf{j})\text{ N}$$
$$\mathbf{F}_3 = (p\mathbf{i} + q\mathbf{j})\text{ N}$$

where p and q are constants.

Given that P is in equilibrium,

(a) find the value of p and the value of q.

(3)

The force $\mathbf{F}_3$ is now removed. The resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ is $\mathbf{R}$.
Find

(b) the magnitude of $\mathbf{R}$,

(2)

(c) the angle, to the nearest degree, that the direction of $\mathbf{R}$ makes with $\mathbf{j}$.

(3)

(Total 8 marks)

56.

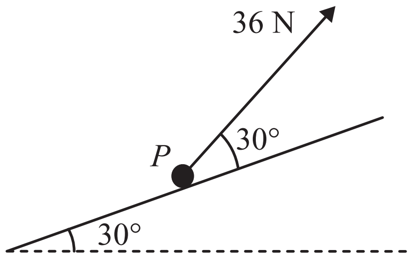

Figure 2

A particle P of mass 4 kg is moving up a fixed rough plane at a constant speed of $16\,\text{m}\,\text{s}^{-1}$ under the action of a force of magnitude 36 N. The plane is inclined at 30° to the horizontal. The force acts in the vertical plane containing the line of greatest slope of the plane through P, and acts at 30° to the inclined plane, as shown in Figure 2. The coefficient of friction between P and the plane is μ. Find

(a) the magnitude of the normal reaction between P and the plane,

(4)

(b) the value of μ.

(5)

The force of magnitude 36 N is removed.

(c) Find the distance that P travels between the instant when the force is removed and the instant when it comes to rest.

(5)

Leave blank

Question 56 continued

(Total 14 marks)

57.

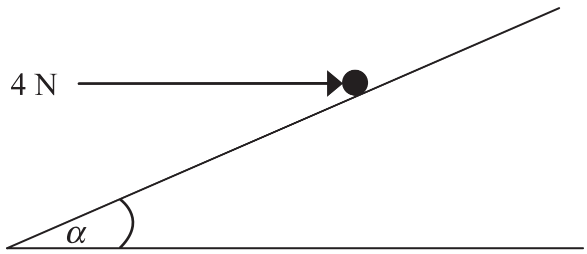

Figure 1

A particle of weight W newtons is held in equilibrium on a rough inclined plane by a horizontal force of magnitude 4 N. The force acts in a vertical plane containing a line of greatest slope of the inclined plane. The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$, as shown in Figure 1.

The coefficient of friction between the particle and the plane is $\frac{1}{2}$.

Given that the particle is on the point of sliding down the plane,

(i) show that the magnitude of the normal reaction between the particle and the plane is 20 N,

(ii) find the value of W.

(9)

Leave blank

Question 57 continued

(Total 9 marks)

Leave blank

58.

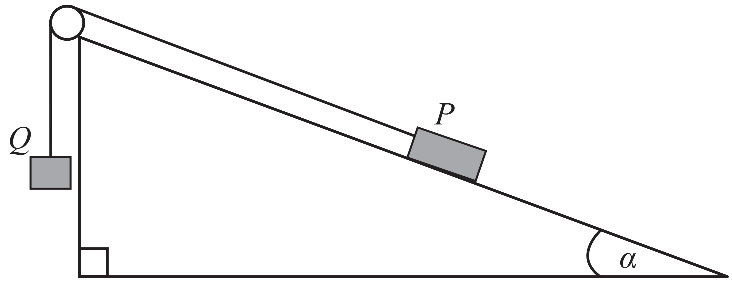

Figure 2

Two particles P and Q have masses 0.3 kg and m 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 at the top of a fixed rough plane. The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$. The coefficient of friction between P and the plane is $\frac{1}{2}$.

The string lies in a vertical plane through a line of greatest slope of the inclined plane. The particle P is held at rest on the inclined plane and the particle Q hangs freely below the pulley with the string taut, as shown in Figure 2.

The system is released from rest and Q accelerates vertically downwards at 1.4 m s^{-2}. Find

(a) the magnitude of the normal reaction of the inclined plane on P,

(2)

(b) the value of m.

(8)

When the particles have been moving for 0.5 s, the string breaks. Assuming that P does not reach the pulley,

(c) find the further time that elapses until P comes to instantaneous rest.

(6)

EXPERT TUITION

Leave blank

Question 58 continued

(Total 16 marks)

Leave blank

59. A particle P of mass 2 kg is moving under the action of a constant force $\mathbf{F}$ newtons. The velocity of P is $(2\mathbf{i}-5\mathbf{j})$ m s^{-1} at time $t=0$, and $(7\mathbf{i}+10\mathbf{j})$ m s^{-1} at time $t=5$ s.

Find

(a) the speed of P at $t=0$,

(2)

(b) the vector $\mathbf{F}$ in the form $a\mathbf{i}+b\mathbf{j}$,

(5)

(c) the value of t when P is moving parallel to $\mathbf{i}$.

(4)

Leave blank

Question 59 continued

(Total 11 marks)

Leave blank

60.

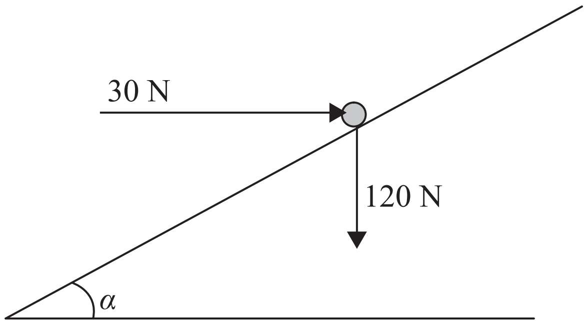

Figure 2

A particle of weight 120 N is placed on a fixed rough plane which is inclined at an angle α to the horizontal, where $\tan\alpha = \frac{3}{4}$.

The coefficient of friction between the particle and the plane is $\frac{1}{2}$.

The particle is held at rest in equilibrium by a horizontal force of magnitude 30 N, which acts in the vertical plane containing the line of greatest slope of the plane through the particle, as shown in Figure 2.

(a) Show that the normal reaction between the particle and the plane has magnitude 114 N.
(4)

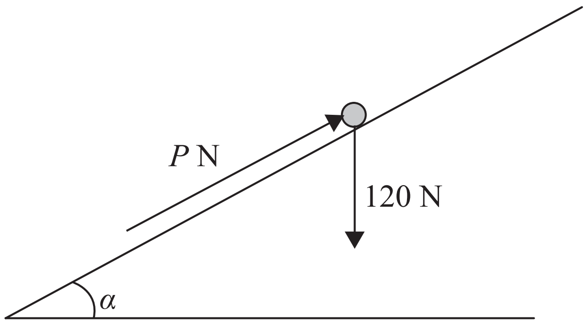

Figure 3

The horizontal force is removed and replaced by a force of magnitude *P* newtons acting up the slope along the line of greatest slope of the plane through the particle, as shown in Figure 3. The particle remains in equilibrium.

(b) Find the greatest possible value of *P*.
(8)

(c) Find the magnitude and direction of the frictional force acting on the particle when $P = 30$.
(3)

EXPERT TUITION

Leave blank

Question 60 continued

(Total 15 marks)

61.

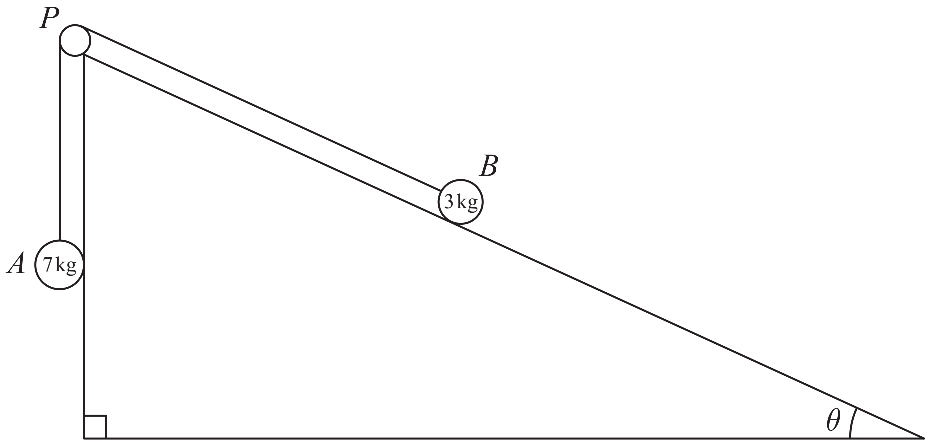

Figure 4

Two particles A and B, of mass 7 kg and 3 kg respectively, are attached to the ends of a light inextensible string. Initially B is held at rest on a rough fixed plane inclined at angle θ to the horizontal, where $\tan \theta = \frac{5}{12}$. The part of the string from B to P is parallel to a line of greatest slope of the plane. The string passes over a small smooth pulley, P, fixed at the top of the plane. The particle A hangs freely below P, as shown in Figure 4. The coefficient of friction between B and the plane is $\frac{2}{3}$. The particles are released from rest with the string taut and B moves up the plane.

(a) Find the magnitude of the acceleration of B immediately after release.

(10)

(b) Find the speed of B when it has moved 1 m up the plane.

(2)

When B has moved 1 m up the plane the string breaks. Given that in the subsequent motion B does not reach P,

(c) find the time between the instants when the string breaks and when B comes to instantaneous rest.

(4)

Leave blank

Question 61 continued

(Total 16 marks)

EXPERT TUITION

Leave blank

62.

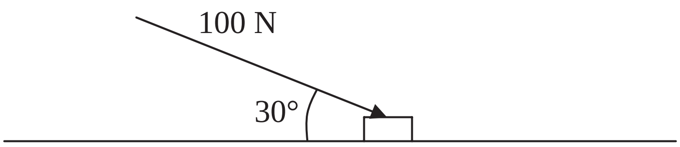

Figure 1

A small box is pushed along a floor. The floor is modelled as a rough horizontal plane and the box is modelled as a particle. The coefficient of friction between the box and the floor is $\frac{1}{2}$. The box is pushed by a force of magnitude 100 N which acts at an angle of 30° with the floor, as shown in Figure 1.

Given that the box moves with constant speed, find the mass of the box.

(7)

(Total 7 marks)

63.

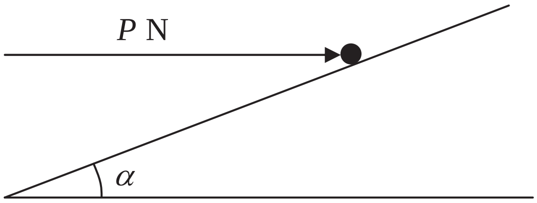

Figure 2

A particle of mass 0.4 kg is held at rest on a fixed rough plane by a horizontal force of magnitude P newtons. The force acts in the vertical plane containing the line of greatest slope of the inclined plane which passes through the particle. The plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$, as shown in Figure 2.

The coefficient of friction between the particle and the plane is $\frac{1}{3}$.

Given that the particle is on the point of sliding up the plane, find

(a) the magnitude of the normal reaction between the particle and the plane,

(5)

(b) the value of P.

(5)

Leave blank

Leave blank

Question 63 continued

(Total 10 marks)

Leave blank

64.

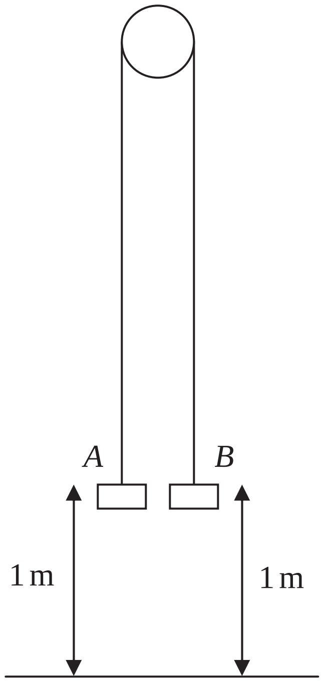

Figure 3

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 1 m 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)

Leave blank

Question 64 continued

(Total 17 marks)

Leave blank

65.

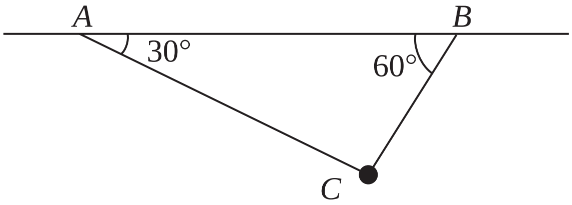

Figure 1

A particle of mass m kg 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 AC and BC inclined to the horizontal at 30° and 60° respectively, as shown in Figure 1.

Given that the tension in AC is 20 N, find

(a) the tension in BC,

(4)

(b) the value of m.

(4)

(Total 8 marks)

Leave blank

66. A particle of mass 0.8 kg is held at rest on a rough plane. The plane is inclined at 30° to the horizontal. The particle is released from rest and slides down a line of greatest slope of the plane. The particle moves 2.7 m during the first 3 seconds of its motion. Find

(a) the acceleration of the particle,

(3)

(b) the coefficient of friction between the particle and the plane.

(5)

The particle is now held on the same rough plane by a horizontal force of magnitude X newtons, acting in a plane containing a line of greatest slope of the plane, as shown in Figure 3. The particle is in equilibrium and on the point of moving up the plane.

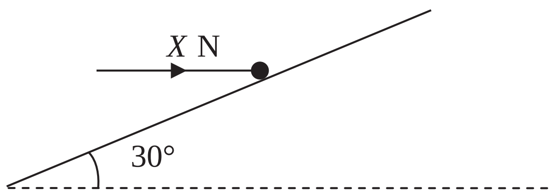

Figure 3

(c) Find the value of X.

(7)

Leave blank

Question 66 continued

(Total 15 marks)

67.

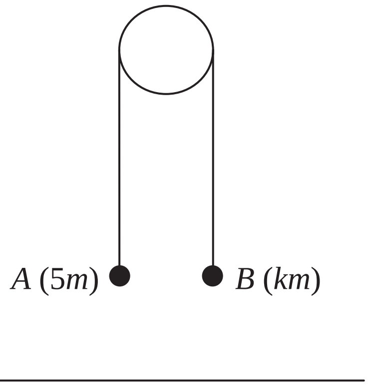

Figure 4

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 Figure 4. 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)

Leave blank

Question 67 continued

(Total 14 marks)

EXPERT TUITION

Leave blank

68. A particle is acted upon by two forces $\mathbf{F}_1$ and $\mathbf{F}_2$, given by

$\mathbf{F}_1 = (\mathbf{i} - 3\mathbf{j})$ N,

$\mathbf{F}_2 = (p\mathbf{i} + 2p\mathbf{j})$ N, where p is a positive constant.

(a) Find the angle between $\mathbf{F}_2$ and $\mathbf{j}$.

(2)

The resultant of $\mathbf{F}_1$ and $\mathbf{F}_2$ is $\mathbf{R}$. Given that $\mathbf{R}$ is parallel to $\mathbf{i}$,

(b) find the value of p.

(4)

(Total 6 marks)

Leave blank

69. A small brick of mass 0.5 kg is placed on a rough plane which is inclined to the horizontal at an angle θ, where $\tan\theta = \frac{4}{3}$, and released from rest. The coefficient of friction between the brick and the plane is $\frac{1}{3}$.

Find the acceleration of the brick.

(9)

(Total 9 marks)

Leave blank

70.

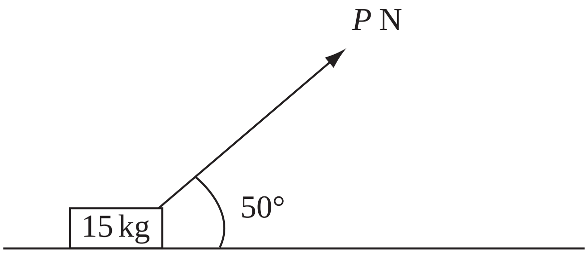

Figure 1

A small box of mass 15 kg rests on a rough horizontal plane. The coefficient of friction between the box and the plane is 0.2. A force of magnitude P newtons is applied to the box at 50° to the horizontal, as shown in Figure 1. The box is on the point of sliding along the plane.

Find the value of P, giving your answer to 2 significant figures.

(9)

(Total 9 marks)

Leave blank

71. A car of mass 800 kg pulls a trailer of mass 200 kg along a straight horizontal road using a light towbar which is parallel to the road. The horizontal resistances to motion of the car and the trailer have magnitudes 400 N and 200 N respectively. The engine of the car produces a constant horizontal driving force on the car of magnitude 1200 N. Find

(a) the acceleration of the car and trailer,

(3)

(b) the magnitude of the tension in the towbar.

(3)

The car is moving along the road when the driver sees a hazard ahead. He reduces the force produced by the engine to zero and applies the brakes. The brakes produce a force on the car of magnitude F newtons and the car and trailer decelerate. Given that the resistances to motion are unchanged and the magnitude of the thrust in the towbar is 100 N,

(c) find the value of F.

(7)

Leave blank

Question 71 continued

(Total 13 marks)

Leave blank

72.

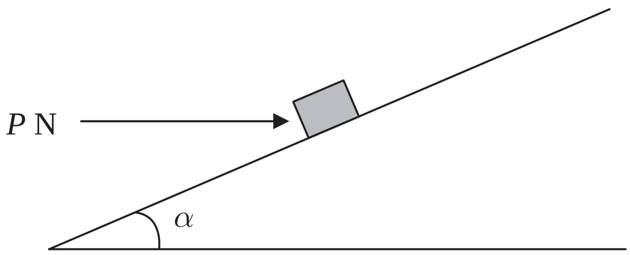

Figure 2

A small package of mass 1.1 kg is held in equilibrium on a rough plane by a horizontal force. The plane is inclined at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$. The force acts in a vertical plane containing a line of greatest slope of the plane and has magnitude P newtons, as shown in Figure 2.

The coefficient of friction between the package and the plane is 0.5 and the package is modelled as a particle. The package is in equilibrium and on the point of slipping down the plane.

(a) Draw, on Figure 2, all the forces acting on the package, showing their directions clearly.

(2)

(b) (i) Find the magnitude of the normal reaction between the package and the plane.

(ii) Find the value of P.

(11)

EXPERT TUITION

Leave blank

Question 72 continued

(Total 13 marks)

Leave blank

73. Two forces, $(4\mathbf{i} - 5\mathbf{j})$ N and $(p\mathbf{i} + q\mathbf{j})$ N, act on a particle P of mass m kg. The resultant of the two forces is $\mathbf{R}$. Given that $\mathbf{R}$ acts in a direction which is parallel to the vector $(\mathbf{i} - 2\mathbf{j})$,

(a) find the angle between $\mathbf{R}$ and the vector $\mathbf{j}$,

(3)

(b) show that $2p + q + 3 = 0$.

(4)

Given also that $q = 1$ and that P moves with an acceleration of magnitude $8\sqrt{5}$ m s^{-2},

(c) find the value of m.

(7)

Leave blank

Question 73 continued

(Total 14 marks)

Leave blank

74.

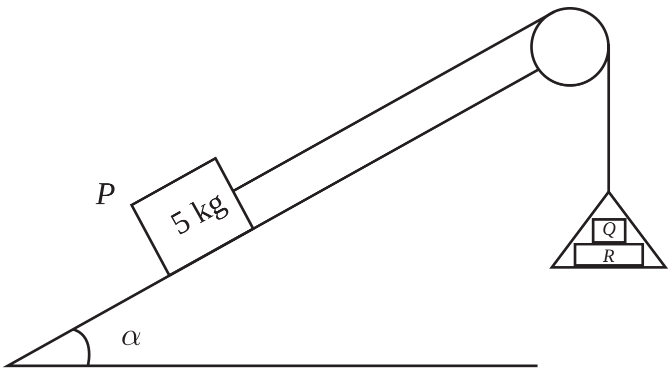

Figure 3

One end of a light inextensible string is attached to a block P of mass 5 kg. The block P is held at rest on a smooth fixed plane which is inclined to the horizontal at an angle α, where $\sin\alpha = \frac{3}{5}$. The string lies along a line of greatest slope of the plane and passes over a smooth light pulley which is fixed at the top of the plane. The other end of the string is attached to a light scale pan which carries two blocks Q and R, with block Q on top of block R, as shown in Figure 3. The mass of block Q is 5 kg and the mass of block R is 10 kg. The scale pan hangs at rest and the system is released from rest. By modelling the blocks as particles, ignoring air resistance and assuming the motion is uninterrupted, find

(a) (i) the acceleration of the scale pan,

(ii) the tension in the string,

(8)

(b) the magnitude of the force exerted on block Q by block R,

(3)

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

(5)

Leave blank

Question 74 continued

(Total 16 marks)

Leave blank

75. A particle P of mass 0.4 kg moves under the action of a single constant force $\mathbf{F}$ newtons. The acceleration of P is $(6\mathbf{i} + 8\mathbf{j})$ m s^{-2} . Find

(a) the angle between the acceleration and $\mathbf{i}$,

(2)

(b) the magnitude of $\mathbf{F}$.

(3)

At time t seconds the velocity of P is $\mathbf{v}$ m s^{-1} . Given that when $t = 0$, $\mathbf{v} = 9\mathbf{i} - 10\mathbf{j}$,

(c) find the velocity of P when $t = 5$.

(3)

(Total 8 marks)

76.

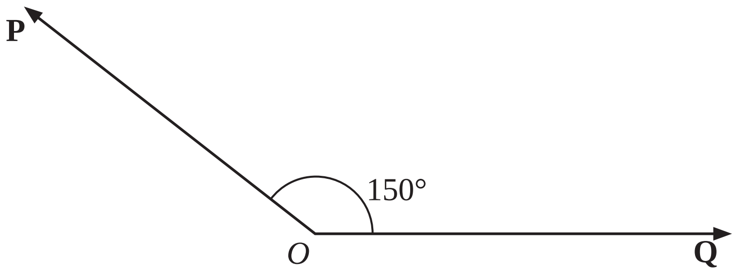

Figure 1

Two forces **P** and **Q** act on a particle at a point *O*. The force **P** has magnitude 15 N and the force **Q** has magnitude *X* newtons. The angle between **P** and **Q** is 150°, as shown in Figure 1. The resultant of **P** and **Q** is **R**.

Given that the angle between **R** and **Q** is 50°, find

(a) the magnitude of **R**,

(4)

(b) the value of *X*.

(5)

(Total 9 marks)

Leave blank

77.

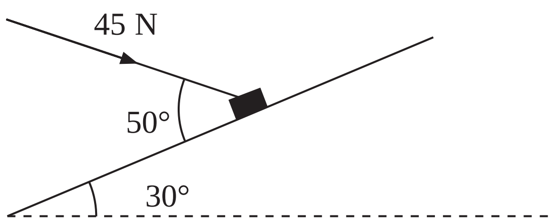

Figure 3

A package of mass 4 kg lies on a rough plane inclined at 30° to the horizontal. The package is held in equilibrium by a force of magnitude 45 N acting at an angle of 50° to the plane, as shown in Figure 3. The force is acting in a vertical plane through a line of greatest slope of the plane. The package is in equilibrium on the point of moving up the plane. The package is modelled as a particle. Find

(a) the magnitude of the normal reaction of the plane on the package,

(5)

(b) the coefficient of friction between the plane and the package.

(6)

Leave blank

Leave blank

Question 77 continued

(Total 11 marks)

78.

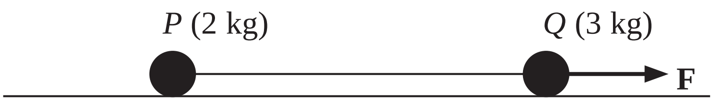

Figure 4

Two particles P and Q, of mass 2 kg and 3 kg respectively, are joined by a light inextensible string. Initially the particles are at rest on a rough horizontal plane with the string taut. A constant force **F** of magnitude 30 N is applied to Q in the direction PQ, as shown in Figure 4. The force is applied for 3 s and during this time Q travels a distance of 6 m. The coefficient of friction between each particle and the plane is μ. Find

(a) the acceleration of Q,

(2)

(b) the value of μ,

(4)

(c) the tension in the string.

(4)

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

(1)

When the particles have moved for 3 s, the force **F** is removed.

(e) Find the time between the instant that the force is removed and the instant that Q comes to rest.

(4)

Leave blank

Question 78 continued

(Total 15 marks)

Leave blank

79.

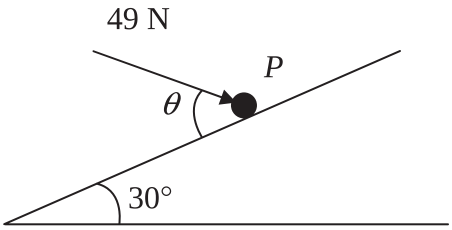

Figure 1

A particle P of mass 6 kg lies on the surface of a smooth plane. The plane is inclined at an angle of 30° to the horizontal. The particle is held in equilibrium by a force of magnitude 49 N, acting at an angle θ to the plane, as shown in Figure 1. The force acts in a vertical plane through a line of greatest slope of the plane.

(a) Show that $\cos\theta = \frac{3}{5}$.

(3)

(b) Find the normal reaction between P and the plane.

(4)

The direction of the force of magnitude 49 N is now changed. It is now applied horizontally to P so that P moves up the plane. The force again acts in a vertical plane through a line of greatest slope of the plane.

(c) Find the initial acceleration of P.

(4)

Leave blank

Question 79 continued

(Total 11 marks)

EXPERT TUITION

Leave blank

80.

Figure 3

Two particles A and B, of mass m and $2m$ respectively, are attached to the ends of a light inextensible string. The particle A lies on a rough horizontal table. The string passes over a small smooth pulley P fixed on the edge of the table. The particle B hangs freely below the pulley, as shown in Figure 3. The coefficient of friction between A and the table is μ. The particles are released from rest with the string taut. Immediately after release, the magnitude of the acceleration of A and B is $\frac{4}{9}g$. By writing down separate equations of motion for A and B,

(a) find the tension in the string immediately after the particles begin to move,

(3)

(b) show that $\mu = \frac{2}{3}$.

(5)

When B has fallen a distance h, it hits the ground and does not rebound. Particle A is then a distance $\frac{1}{3}h$ from P.

(c) Find the speed of A as it reaches P.

(6)

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

(1)

EXPERT TUITION

Leave blank

Question 80 continued

(Total 15 marks)

Leave blank

81. A particle P of mass 0.5 kg moves under the action of a single force **F** newtons. At time t seconds, $t \geqslant 0$, P has velocity **v** m s^{-1}, where

$$\mathbf{v} = (4t - 3t^2)\mathbf{i} + (t^2 - 8t - 40)\mathbf{j}$$

(a) Find

(i) the magnitude of **F** when $t = 3$

(ii) the acceleration of P at the instant when it is moving in the direction of the vector $-\mathbf{i} - \mathbf{j}$.

(9)

When $t = 1$, P is at the point A. When $t = 2$, P is at the point B.

(b) Find, in terms of **i** and **j**, the vector $\overrightarrow{AB}$.

(5)

Leave blank

Question 81 continued

Leave blank

Question 81 continued

Leave blank

Question 81 continued

(Total 14 marks)

82.

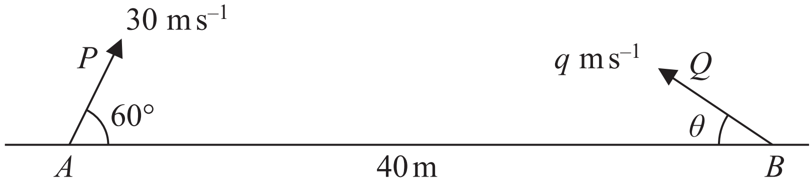

Figure 4

The points A and B lie 40 m apart on horizontal ground. At time $t = 0$ the particles P and Q are projected in the vertical plane containing AB and move freely under gravity. Particle P is projected from A with speed 30 m s^{-1} at 60° to AB and particle Q is projected from B with speed q m s^{-1} at angle θ to BA, as shown in Figure 4.

At $t = 2$ seconds, P and Q collide.

(a) Find

(i) the size of angle θ,

(ii) the value of q.

(6)

(b) Find the speed of P at the instant before it collides with Q.

(5)

Leave blank

Question 82 continued

Leave blank

Question 82 continued

Leave blank

Question 82 continued

(Total 11 marks)

Leave blank

83.

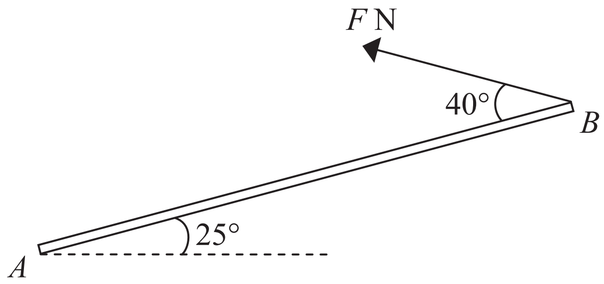

Figure 1

A uniform rod AB, of mass 5 kg and length 4 m, has its end A smoothly hinged at a fixed point. The rod is held in equilibrium at an angle of 25° above the horizontal by a force of magnitude F newtons applied to its end B. The force acts in the vertical plane containing the rod and in a direction which makes an angle of 40° with the rod, as shown in Figure 1.

(a) Find the value of F.

(4)

(b) Find the magnitude and direction of the vertical component of the force acting on the rod at A.

(4)

Leave blank

Question 83 continued

(Total 8 marks)

Leave blank

84. A particle P of mass 0.5 kg is moving under the action of a single force $\mathbf{F}$ newtons. At time t seconds,

$$\mathbf{F} = (6t - 5)\,\mathbf{i} + (t^2 - 2t)\,\mathbf{j}.$$

The velocity of P at time t seconds is $\mathbf{v}$ m s^{-1}. When $t = 0$, $\mathbf{v} = \mathbf{i} - 4\mathbf{j}$.

(a) Find $\mathbf{v}$ at time t seconds.

(6)

When $t = 3$, the particle P receives an impulse $(-5\mathbf{i} + 12\mathbf{j})$ N s.

(b) Find the speed of P immediately after it receives the impulse.

(6)

Leave blank

Question 84 continued

EXPERT TUITION

Leave blank

Question 84 continued

Leave blank

Question 84 continued

(Total 12 marks)