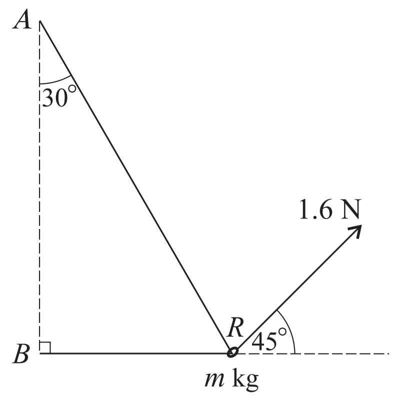
The Grange School
Maths Department

Mechanics 1
OCR Past Papers

1



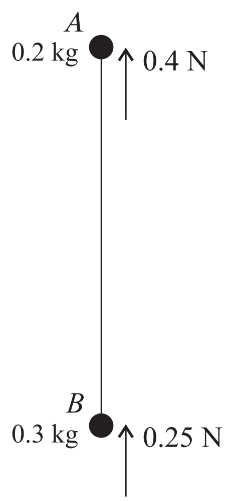
A light inextensible string has its ends attached to two fixed points A and B. The point A is vertically above B. A smooth ring R of mass m kg is threaded on the string and is pulled by a force of magnitude 1.6 N acting upwards at 45° to the horizontal. The section AR of the string makes an angle of 30° with the downward vertical and the section BR is horizontal (see diagram). The ring is in equilibrium with the string taut.

(i) Give a reason why the tension in the part AR of the string is the same as that in the part BR. [1]

(ii) Show that the tension in the string is 0.754 N, correct to 3 significant figures. [3]

(iii) Find the value of m. [3]

2



Particles A and B, of masses 0.2 kg and 0.3 kg respectively, are attached to the ends of a light inextensible string. Particle A is held at rest at a fixed point and B hangs vertically below A. Particle A is now released. As the particles fall the air resistance acting on A is 0.4 N and the air resistance acting on B is 0.25 N (see diagram). The downward acceleration of each of the particles is a m s^{-2} and the tension in the string is T N.

(i) Write down two equations in a and T obtained by applying Newton's second law to A and to B. [4]

(ii) Find the values of a and T. [3]

June 2005

3 Two small spheres P and Q have masses 0.1 kg and 0.2 kg respectively. The spheres are moving directly towards each other on a horizontal plane and collide. Immediately before the collision P has speed $4\,\text{m}\,\text{s}^{-1}$ and Q has speed $3\,\text{m}\,\text{s}^{-1}$. Immediately after the collision the spheres move away from each other, P with speed $u\,\text{m}\,\text{s}^{-1}$ and Q with speed $(3.5 - u)\,\text{m}\,\text{s}^{-1}$.

(i) Find the value of u. [4]

After the collision the spheres both move with deceleration of magnitude $5\,\text{m}\,\text{s}^{-2}$ until they come to rest on the plane.

(ii) Find the distance PQ when both P and Q are at rest. [4]

4 A particle moves downwards on a smooth plane inclined at an angle α to the horizontal. The particle passes through the point P with speed $u\,\text{m}\,\text{s}^{-1}$. The particle travels 2 m during the first 0.8 s after passing through P, then a further 6 m in the next 1.2 s. Find

(i) the value of u and the acceleration of the particle, [7]

(ii) the value of α in degrees. [2]

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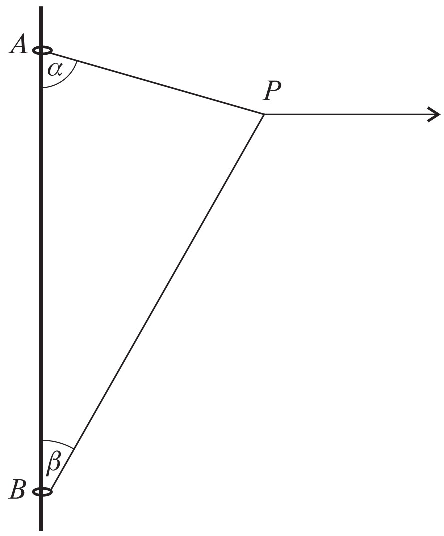


Two small rings A and B are attached to opposite ends of a light inextensible string. The rings are threaded on a rough wire which is fixed vertically. A is above B. A horizontal force is applied to a point P of the string. Both parts AP and BP of the string are taut. The system is in equilibrium with angle $BAP = \alpha$ and angle $ABP = \beta$ (see diagram). The weight of A is 2 N and the tensions in the parts AP and BP of the string are 7 N and T N respectively. It is given that $\cos\alpha = 0.28$ and $\sin\alpha = 0.96$, and that A is in limiting equilibrium.

(i) Find the coefficient of friction between the wire and the ring A. [7]

(ii) By considering the forces acting at P, show that $T\cos\beta = 1.96$. [2]

(iii) Given that there is no frictional force acting on B, find the mass of B. [3]

[Turn over

June 2005

6 A particle of mass 0.04 kg is acted on by a force of magnitude P N in a direction at an angle α to the upward vertical.

(i) The resultant of the weight of the particle and the force applied to the particle acts horizontally. Given that $\alpha = 20°$ find

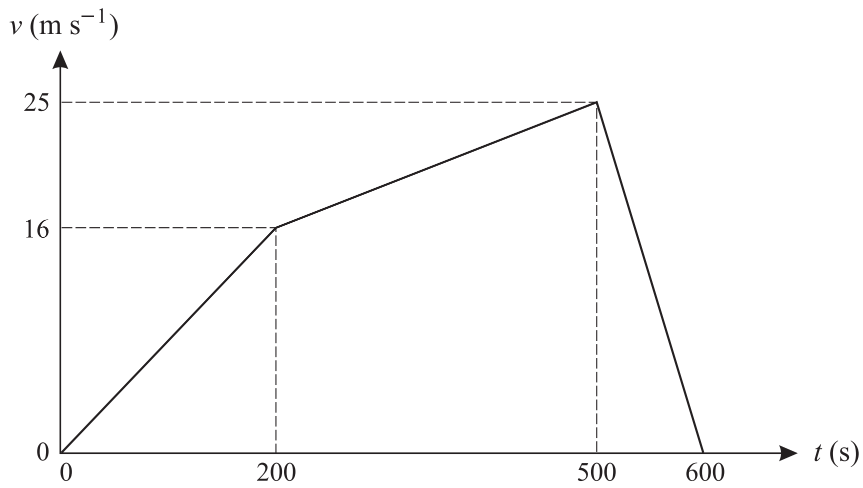
(a) the value of P, [3]

(b) the magnitude of the resultant, [2]

(c) the magnitude of the acceleration of the particle. [2]

(ii) It is given instead that $P = 0.08$ and $\alpha = 90°$. Find the magnitude and direction of the resultant force on the particle. [5]

7



A car P starts from rest and travels along a straight road for 600 s. The (t, v) graph for the journey is shown in the diagram. This graph consists of three straight line segments. Find

(i) the distance travelled by P, [3]

(ii) the deceleration of P during the interval $500 < t < 600$. [2]

Another car Q starts from rest at the same instant as P and travels in the same direction along the same road for 600 s. At time t s after starting the velocity of Q is $(600t^2 - t^3) \times 10^{-6}$ m s^{-1}.

(iii) Find an expression in terms of t for the acceleration of Q. [2]

(iv) Find how much less Q's deceleration is than P's when $t = 550$. [2]

(v) Show that Q has its maximum velocity when $t = 400$. [2]

(vi) Find how much further Q has travelled than P when $t = 400$. [6]

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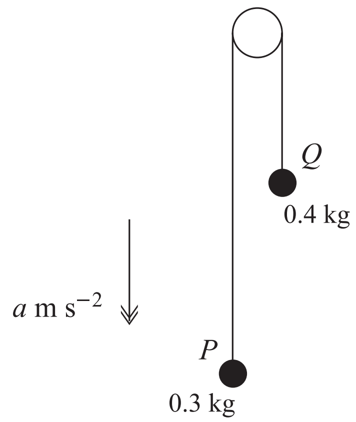


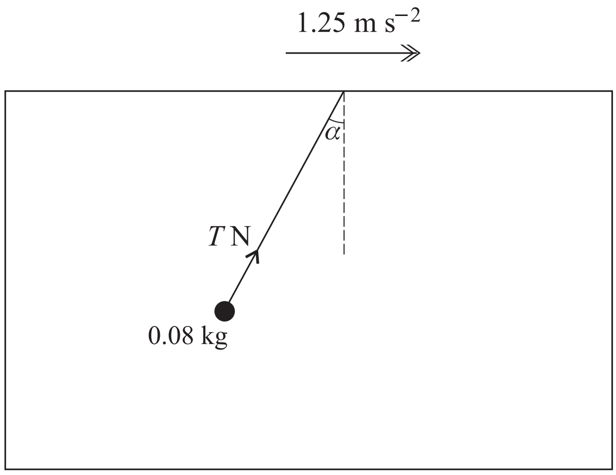
Particles P and Q, of masses 0.3 kg and 0.4 kg respectively, are attached to the ends of a light inextensible string. The string passes over a smooth fixed pulley. The system is in motion with the string taut and with each of the particles moving vertically. The downward acceleration of P is a m s^{-2} (see diagram).

(i) Show that $a = -1.4$. [4]

Initially P and Q are at the same horizontal level. P's initial velocity is vertically downwards and has magnitude 2.8 m s^{-1}.

(ii) Assuming that P does not reach the floor and that Q does not reach the pulley, find the time taken for P to return to its initial position. [3]

2



An object of mass 0.08 kg is attached to one end of a light inextensible string. The other end of the string is attached to the underside of the roof inside a furniture van. The van is moving horizontally with constant acceleration 1.25 m s^{-2}. The string makes a constant angle α with the downward vertical and the tension in the string is T N (see diagram).

(i) By applying Newton's second law horizontally to the object, find the value of $T \sin \alpha$. [2]

(ii) Find the value of T. [5]

Jan 2006

3 A motorcyclist starts from rest at a point O and travels in a straight line. His velocity after t seconds is $v\,\mathrm{m\,s^{-1}}$, for $0 \leqslant t \leqslant T$, where $v = 7.2t - 0.45t^2$. The motorcyclist's acceleration is zero when $t = T$.

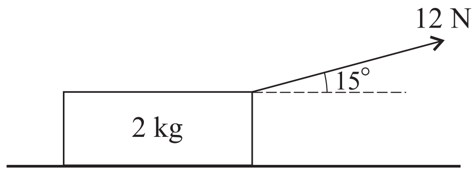
(i) Find the value of T. [4]

(ii) Show that $v = 28.8$ when $t = T$. [1]

For $t \geqslant T$ the motorcyclist travels in the same direction as before, but with constant speed $28.8\,\mathrm{m\,s^{-1}}$.

(iii) Find the displacement of the motorcyclist from O when $t = 31$. [6]

4



A block of mass 2 kg is at rest on a rough horizontal plane, acted on by a force of magnitude 12 N at an angle of 15° upwards from the horizontal (see diagram).

(i) Find the frictional component of the contact force exerted on the block by the plane. [2]

(ii) Show that the normal component of the contact force exerted on the block by the plane has magnitude 16.5 N, correct to 3 significant figures. [2]

It is given that the block is on the point of sliding.

(iii) Find the coefficient of friction between the block and the plane. [2]

The force of magnitude 12 N is now replaced by a horizontal force of magnitude 20 N. The block starts to move.

(iv) Find the acceleration of the block. [5]

5 A man drives a car on a horizontal straight road. At $t = 0$, where the time t is in seconds, the car runs out of petrol. At this instant the car is moving at $12\,\mathrm{m\,s^{-1}}$. The car decelerates uniformly, coming to rest when $t = 8$. The man then walks back along the road at $0.7\,\mathrm{m\,s^{-1}}$ until he reaches a petrol station a distance of 420 m from his car. After his arrival at the petrol station it takes him 250 s to obtain a can of petrol. He is then given a lift back to his car on a motorcycle. The motorcycle starts from rest and accelerates uniformly until its speed is $20\,\mathrm{m\,s^{-1}}$; it then decelerates uniformly, coming to rest at the stationary car at time $t = T$.

(i) Sketch the shape of the (t, v) graph for the man for $0 \leqslant t \leqslant T$. [Your sketch need not be drawn to scale; numerical values need not be shown.] [5]

(ii) Find the deceleration of the car for $0 < t < 8$. [2]

(iii) Find the value of T. [4]

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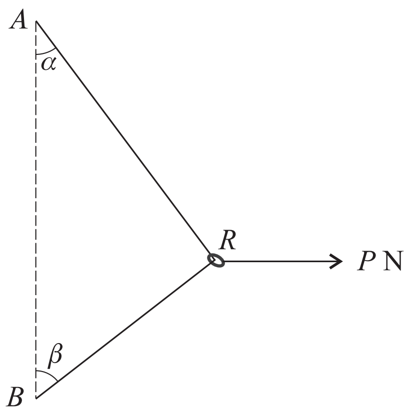

Fig. 1

A smooth ring R of weight W N is threaded on a light inextensible string. The ends of the string are attached to fixed points A and B, where A is vertically above B. A horizontal force of magnitude P N acts on R. The system is in equilibrium with the string taut; AR makes an angle α with the downward vertical and BR makes an angle β with the upward vertical (see Fig. 1).

(i) By considering the vertical components of the forces acting on R, show that $\alpha < \beta$. [3]

(ii)

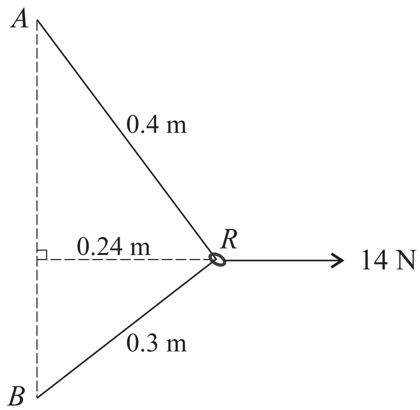

Fig. 2

It is given that when $P = 14$, $AR = 0.4$ m, $BR = 0.3$ m and the distance of R from the vertical line AB is 0.24 m (see Fig. 2). Find

(a) the tension in the string, [3]

(b) the value of W. [3]

(iii) For the case when $P = 0$,

(a) describe the position of R, [1]

(b) state the tension in the string. [1]

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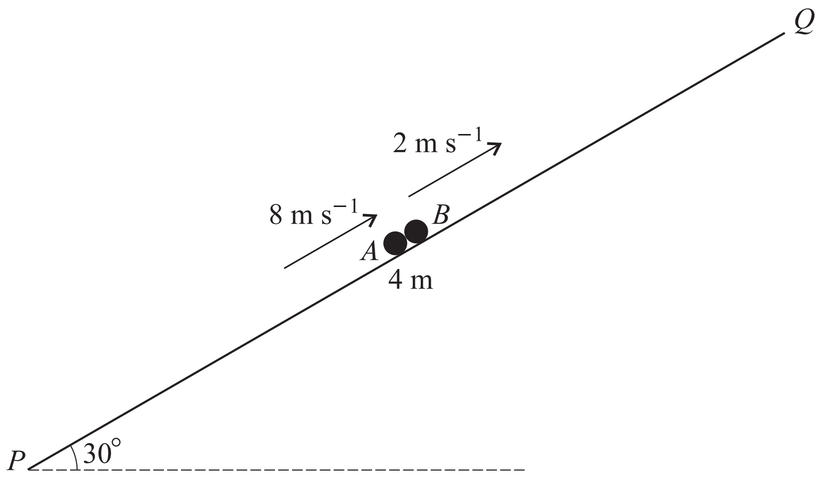
7



PQ is a line of greatest slope, of length 4 m, on a smooth plane inclined at 30° to the horizontal. Particles A and B, of masses 0.15 kg and 0.5 kg respectively, move along PQ with A below B. The particles are both moving upwards, A with speed 8 m s^{-1} and B with speed 2 m s^{-1}, when they collide at the mid-point of PQ (see diagram). Particle A is instantaneously at rest immediately after the collision.

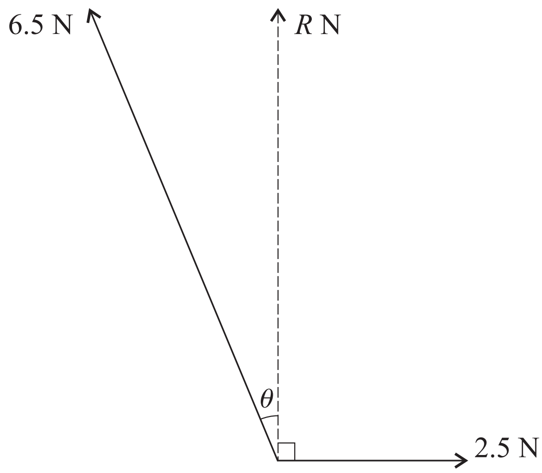
(i) Show that B does not reach Q in the subsequent motion. [8]

(ii) Find the time interval between the instant of A's arrival at P and the instant of B's arrival at P. [6]

June 2006

1 Each of two wagons has an unloaded mass of 1200 kg. One of the wagons carries a load of mass m kg and the other wagon is unloaded. The wagons are moving towards each other on the same rails, each with speed 3 m s^{-1}, when they collide. Immediately after the collision the loaded wagon is at rest and the speed of the unloaded wagon is 5 m s^{-1}. Find the value of m. [5]

2



Forces of magnitudes 6.5 N and 2.5 N act at a point in the directions shown. The resultant of the two forces has magnitude R N and acts at right angles to the force of magnitude 2.5 N (see diagram).

(i) Show that $\theta = 22.6^\circ$, correct to 3 significant figures. [3]

(ii) Find the value of R. [3]

3 A man travels 360 m along a straight road. He walks for the first 120 m at 1.5 m s^{-1}, runs the next 180 m at 4.5 m s^{-1}, and then walks the final 60 m at 1.5 m s^{-1}. The man's displacement from his starting point after t seconds is x metres.

(i) Sketch the (t, x) graph for the journey, showing the values of t for which $x = 120$, 300 and 360. [5]

A woman jogs the same 360 m route at constant speed, starting at the same instant as the man and finishing at the same instant as the man.

(ii) Draw a dotted line on your (t, x) graph to represent the woman's journey. [1]

(iii) Calculate the value of t at which the man overtakes the woman. [5]

June 2006

4 A cyclist travels along a straight road. Her velocity $v\,\mathrm{m\,s^{-1}}$, at time t seconds after starting from a point O, is given by

$$v = 2 \quad \text{for } 0 \leqslant t \leqslant 10,$$
$$v = 0.03t^2 - 0.3t + 2 \quad \text{for } t \geqslant 10.$$

(i) Find the displacement of the cyclist from O when $t = 10$. [1]

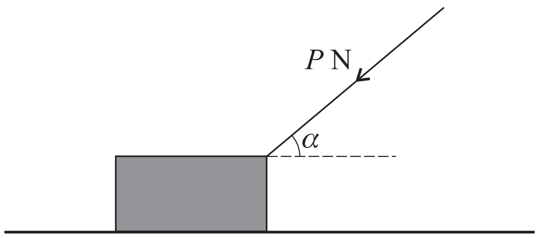
(ii) Show that, for $t \geqslant 10$, the displacement of the cyclist from O is given by the expression $0.01t^3 - 0.15t^2 + 2t + 5$. [4]

(iii) Find the time when the acceleration of the cyclist is $0.6\,\mathrm{m\,s^{-2}}$. Hence find the displacement of the cyclist from O when her acceleration is $0.6\,\mathrm{m\,s^{-2}}$. [5]

5 A block of mass m kg is at rest on a horizontal plane. The coefficient of friction between the block and the plane is 0.2.

(i) When a horizontal force of magnitude 5 N acts on the block, the block is on the point of slipping. Find the value of m. [3]

(ii)



When a force of magnitude P N acts downwards on the block at an angle α to the horizontal, as shown in the diagram, the frictional force on the block has magnitude 6 N and the block is again on the point of slipping. Find

(a) the value of α in degrees,

(b) the value of P.

[8]

[Questions 6 and 7 are printed overleaf.]

[Turn over

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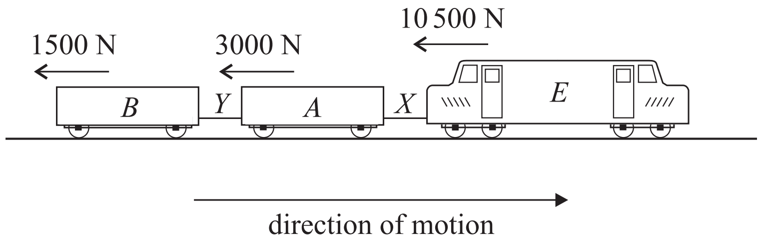
6



A train of total mass 80 000 kg consists of an engine E and two trucks A and B. The engine E and truck A are connected by a rigid coupling X, and trucks A and B are connected by another rigid coupling Y. The couplings are light and horizontal. The train is moving along a straight horizontal track. The resistances to motion acting on E, A and B are 10 500 N, 3000 N and 1500 N respectively (see diagram).

(i) By modelling the whole train as a single particle, show that it is decelerating when the driving force of the engine is less than 15 000 N. [2]

(ii) Show that, when the magnitude of the driving force is 35 000 N, the acceleration of the train is $0.25\ \text{m s}^{-2}$. [2]

(iii) Hence find the mass of E, given that the tension in the coupling X is 8500 N when the magnitude of the driving force is 35 000 N. [3]

The driving force is replaced by a braking force of magnitude 15 000 N acting on the engine. The force exerted by the coupling Y is zero.

(iv) Find the mass of B. [5]

(v) Show that the coupling X exerts a forward force of magnitude 1500 N on the engine. [2]

7 A particle of mass 0.1 kg is at rest at a point A on a rough plane inclined at 15° to the horizontal. The particle is given an initial velocity of $6\ \text{m s}^{-1}$ and starts to move up a line of greatest slope of the plane. The particle comes to instantaneous rest after 1.5 s.

(i) Find the coefficient of friction between the particle and the plane. [7]

(ii) Show that, after coming to instantaneous rest, the particle moves down the plane. [2]

(iii) Find the speed with which the particle passes through A during its downward motion. [6]

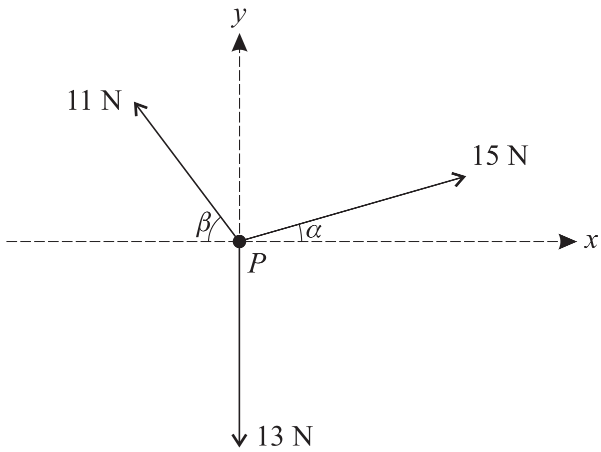
Jan 2007

1 A trailer of mass 600 kg is attached to a car of mass 1100 kg by a light rigid horizontal tow-bar. The car and trailer are travelling along a horizontal straight road with acceleration 0.8 m s^{-2}.

(i) Given that the force exerted on the trailer by the tow-bar is 700 N, find the resistance to motion of the trailer. [4]

(ii) Given also that the driving force of the car is 2100 N, find the resistance to motion of the car. [3]

2



Three horizontal forces of magnitudes 15 N, 11 N and 13 N act on a particle P in the directions shown in the diagram. The angles α and β are such that $\sin\alpha = 0.28$, $\cos\alpha = 0.96$, $\sin\beta = 0.8$ and $\cos\beta = 0.6$.

(i) Show that the component, in the y-direction, of the resultant of the three forces is zero. [4]

(ii) Find the magnitude of the resultant of the three forces. [3]

(iii) State the direction of the resultant of the three forces. [1]

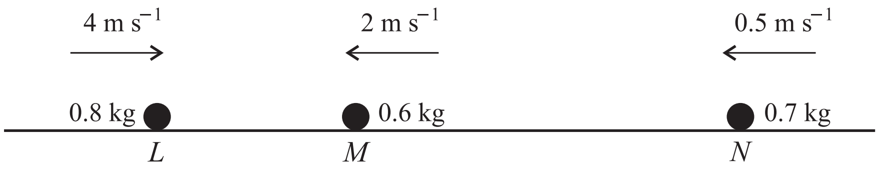
3

A block B of mass 0.4 kg and a particle P of mass 0.3 kg are connected by a light inextensible string. The string passes over a smooth pulley at the edge of a rough horizontal table. B is in contact with the table and the part of the string between B and the pulley is horizontal. P hangs freely below the pulley (see diagram).

(i) The system is in limiting equilibrium with the string taut and P on the point of moving downwards. Find the coefficient of friction between B and the table. [5]

(ii) A horizontal force of magnitude X N, acting directly away from the pulley, is now applied to B. The system is again in limiting equilibrium with the string taut, and with P now on the point of moving **upwards**. Find the value of X. [3]

4



Three uniform spheres L, M and N have masses 0.8 kg, 0.6 kg and 0.7 kg respectively. The spheres are moving in a straight line on a smooth horizontal table, with M between L and N. The sphere L is moving towards M with speed 4 m s^{-1} and the spheres M and N are moving towards L with speeds 2 m s^{-1} and 0.5 m s^{-1} respectively (see diagram).

(i) L collides with M. As a result of this collision the direction of motion of M is reversed, and its speed remains 2 m s^{-1}. Find the speed of L after the collision. [4]

(ii) M then collides with N.

(a) Find the total momentum of M and N in the direction of M's motion before this collision takes place, and deduce that the direction of motion of N is reversed as a result of this collision. [4]

(b) Given that M is at rest immediately after this collision, find the speed of N immediately after this collision. [2]

5 A particle starts from rest at a point A at time $t = 0$, where t is in seconds. The particle moves in a straight line. For $0 \leqslant t \leqslant 4$ the acceleration is $1.8t\text{ m s}^{-2}$, and for $4 \leqslant t \leqslant 7$ the particle has constant acceleration 7.2 m s^{-2}.

(i) Find an expression for the velocity of the particle in terms of t, valid for $0 \leqslant t \leqslant 4$. [3]

(ii) Show that the displacement of the particle from A is 19.2 m when $t = 4$. [4]

(iii) Find the displacement of the particle from A when $t = 7$. [5]

[Questions 6 and 7 are printed overleaf.]

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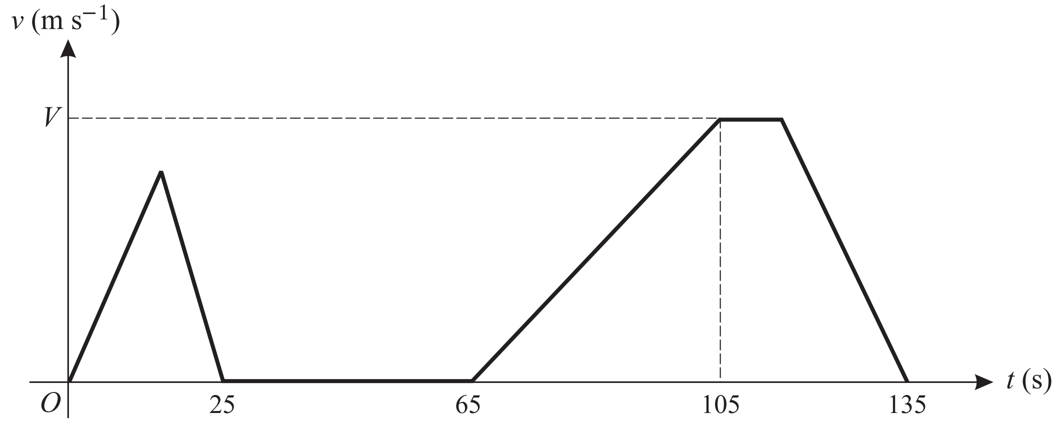
6



The diagram shows the (t, v) graph for the motion of a hoist used to deliver materials to different levels at a building site. The hoist moves vertically. The graph consists of straight line segments. In the first stage the hoist travels upwards from ground level for 25 s, coming to rest 8 m above ground level.

(i) Find the greatest speed reached by the hoist during this stage. [2]

The second stage consists of a 40 s wait at the level reached during the first stage. In the third stage the hoist continues upwards until it comes to rest 40 m above ground level, arriving 135 s after leaving ground level. The hoist accelerates at 0.02 m s^{-2} for the first 40 s of the third stage, reaching a speed of V m s^{-1}. Find

(ii) the value of V, [3]

(iii) the length of time during the third stage for which the hoist is moving at constant speed, [4]

(iv) the deceleration of the hoist in the final part of the third stage. [3]

7 A particle P of mass 0.5 kg moves upwards along a line of greatest slope of a rough plane inclined at an angle of 40° to the horizontal. P reaches its highest point and then moves back down the plane. The coefficient of friction between P and the plane is 0.6.

(i) Show that the magnitude of the frictional force acting on P is 2.25 N, correct to 3 significant figures. [3]

(ii) Find the acceleration of P when it is moving

(a) up the plane,

(b) down the plane.

[4]

(iii) When P is moving up the plane, it passes through a point A with speed 4 m s^{-1}.

(a) Find the length of time before P reaches its highest point.

(b) Find the total length of time for P to travel from the point A to its highest point and back to A.

[8]

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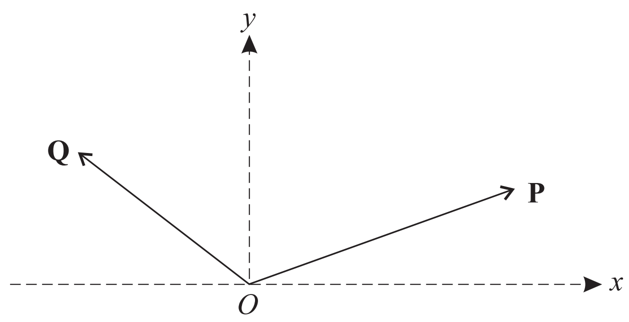
1

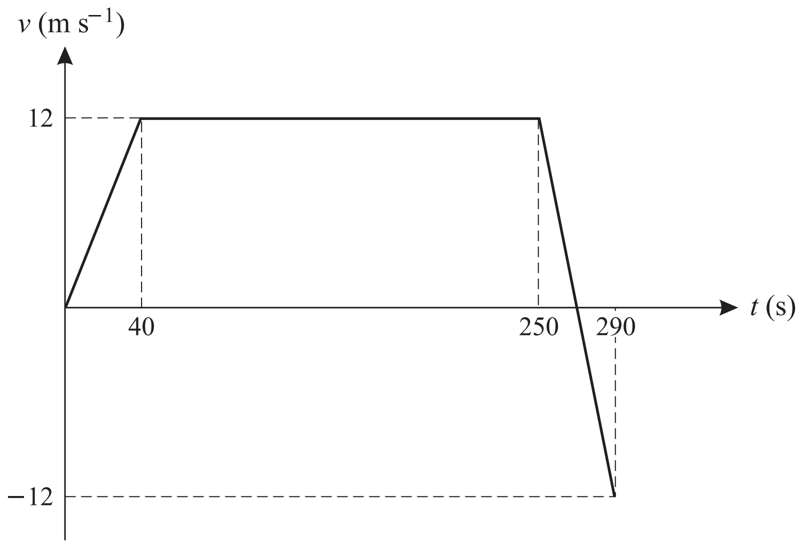


Two horizontal forces **P** and **Q** act at the origin O of rectangular coordinates Oxy (see diagram). The components of **P** in the x- and y-directions are 14 N and 5 N respectively. The components of **Q** in the x- and y-directions are -9 N and 7 N respectively.

(i) Write down the components, in the x- and y-directions, of the resultant of **P** and **Q**. [2]

(ii) Hence find the magnitude of this resultant, and the angle the resultant makes with the positive x-axis. [4]

2



A particle starts from the point A and travels in a straight line. The diagram shows the (t, v) graph, consisting of three straight line segments, for the motion of the particle during the interval $0 \leqslant t \leqslant 290$.

(i) Find the value of t for which the distance of the particle from A is greatest. [2]

(ii) Find the displacement of the particle from A when $t = 290$. [3]

(iii) Find the total distance travelled by the particle during the interval $0 \leqslant t \leqslant 290$. [2]

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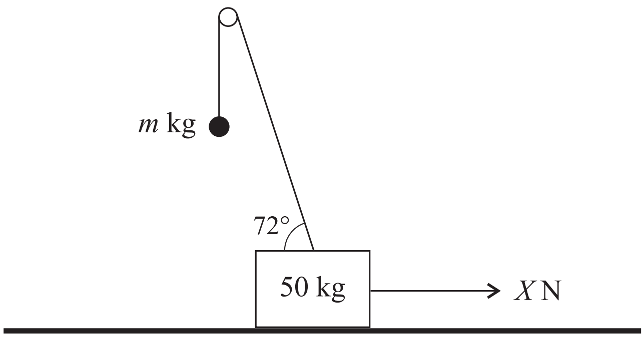
3



A block of mass 50 kg is in equilibrium on smooth horizontal ground with one end of a light wire attached to its upper surface. The other end of the wire is attached to an object of mass m kg. The wire passes over a small smooth pulley, and the object hangs vertically below the pulley. The part of the wire between the block and the pulley makes an angle of 72° with the horizontal. A horizontal force of magnitude X N acts on the block in the vertical plane containing the wire (see diagram).

The tension in the wire is T N and the contact force exerted by the ground on the block is R N.

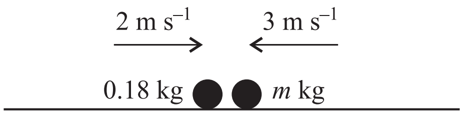
(i) By resolving forces on the block vertically, find a relationship between T and R. [2]

It is given that the block is on the point of lifting off the ground.

(ii) Show that $T = 515$, correct to 3 significant figures, and hence find the value of m. [4]

(iii) By resolving forces on the block horizontally, write down a relationship between T and X, and hence find the value of X. [2]

4



Two particles of masses 0.18 kg and m kg move on a smooth horizontal plane. They are moving towards each other in the same straight line when they collide. Immediately before the impact the speeds of the particles are $2\,\text{m s}^{-1}$ and $3\,\text{m s}^{-1}$ respectively (see diagram).

(i) Given that the particles are brought to rest by the impact, find m. [3]

(ii) Given instead that the particles move with equal speeds of $1.5\,\text{m s}^{-1}$ after the impact, find

(a) the value of m, assuming that the particles move in opposite directions after the impact, [3]

(b) the two possible values of m, assuming that the particles coalesce. [4]

June 2007

5 A particle P is projected vertically upwards, from horizontal ground, with speed $8.4\,\text{m s}^{-1}$.

(i) Show that the greatest height above the ground reached by P is 3.6 m. [3]

A particle Q is projected vertically upwards, from a point 2 m above the ground, with speed $u\,\text{m s}^{-1}$. The greatest height **above the ground** reached by Q is also 3.6 m.

(ii) Find the value of u. [2]

It is given that P and Q are projected simultaneously.

(iii) Show that, at the instant when P and Q are at the same height, the particles have the same speed and are moving in opposite directions. [6]

6 A particle starts from rest at the point A and travels in a straight line. The displacement s m of the particle from A at time t s after leaving A is given by

$$s = 0.001t^4 - 0.04t^3 + 0.6t^2, \quad \text{for } 0 \leqslant t \leqslant 10.$$

(i) Show that the velocity of the particle is $4\,\text{m s}^{-1}$ when $t = 10$. [3]

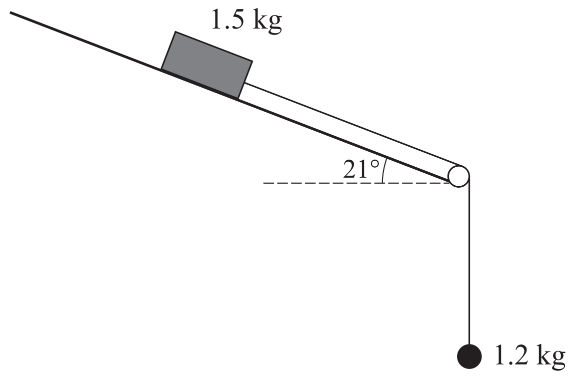
The acceleration of the particle for $t \geqslant 10$ is $(0.8 - 0.08t)\,\text{m s}^{-2}$.

(ii) Show that the velocity of the particle is zero when $t = 20$. [5]

(iii) Find the displacement from A of the particle when $t = 20$. [6]

June 2007

7



One end of a light inextensible string is attached to a block of mass 1.5 kg. The other end of the string is attached to an object of mass 1.2 kg. The block is held at rest in contact with a rough plane inclined at 21° to the horizontal. The string is taut and passes over a small smooth pulley at the bottom edge of the plane. The part of the string above the pulley is parallel to a line of greatest slope of the plane and the object hangs freely below the pulley (see diagram). The block is released and the object moves vertically downwards with acceleration $a\,\text{m}\,\text{s}^{-2}$. The tension in the string is T N. The coefficient of friction between the block and the plane is 0.8.

(i) Show that the frictional force acting on the block has magnitude 10.98 N, correct to 2 decimal places. [3]

(ii) By applying Newton's second law to the block and to the object, find a pair of simultaneous equations in T and a. [5]

(iii) Hence show that $a = 2.24$, correct to 2 decimal places. [2]

(iv) Given that the object is initially 2 m above a horizontal floor and that the block is 2.8 m from the pulley, find the speed of the block at the instant when

(a) the object reaches the floor, [2]

(b) the block reaches the pulley. [4]

Jan 2008

1 A man of mass 70 kg stands on the floor of a lift which is moving with an upward acceleration of $0.3\,\mathrm{m\,s^{-2}}$. Calculate the magnitude of the force exerted by the floor on the man. [4]

2 An ice skater of mass 40 kg is moving in a straight line with speed $4\,\mathrm{m\,s^{-1}}$ when she collides with a skater of mass 60 kg moving in the opposite direction along the same straight line with speed $3\,\mathrm{m\,s^{-1}}$. After the collision the skaters move together with a common speed in the same straight line. Calculate their common speed, and state their direction of motion. [5]

3 Two horizontal forces **X** and **Y** act at a point O and are at right angles to each other. **X** has magnitude 12 N and acts along a bearing of 090°. **Y** has magnitude 15 N and acts along a bearing of 000°.

(i) Calculate the magnitude and bearing of the resultant of **X** and **Y**. [6]

(ii) A third force **E** is now applied at O. The three forces **X**, **Y** and **E** are in equilibrium. State the magnitude of **E**, and give the bearing along which it acts. [2]

4 The displacement of a particle from a fixed point O at time t seconds is $t^4 - 8t^2 + 16$ metres, where $t \geqslant 0$.

(i) Verify that when $t = 2$ the particle is at rest at the point O. [5]

(ii) Calculate the acceleration of the particle when $t = 2$. [3]

5 A car is towing a trailer along a straight road using a light tow-bar which is parallel to the road. The masses of the car and the trailer are 900 kg and 250 kg respectively. The resistance to motion of the car is 600 N and the resistance to motion of the trailer is 150 N.

(i) At one stage of the motion, the road is horizontal and the pulling force exerted on the trailer is zero.

(a) Show that the acceleration of the trailer is $-0.6\,\mathrm{m\,s^{-2}}$. [2]

(b) Find the driving force exerted by the car. [3]

(c) Calculate the distance required to reduce the speed of the car and trailer from $18\,\mathrm{m\,s^{-1}}$ to $15\,\mathrm{m\,s^{-1}}$. [2]

(ii) At another stage of the motion, the car and trailer are moving down a slope inclined at 3° to the horizontal. The resistances to motion of the car and trailer are unchanged. The driving force exerted by the car is 980 N. Find

(a) the acceleration of the car and trailer, [4]

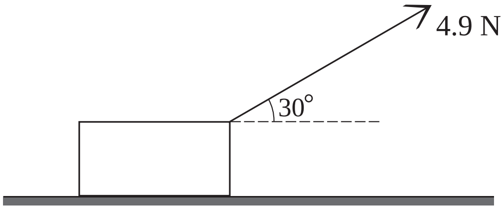
(b) the pulling force exerted on the trailer. [3]

Jan 2008

6 A block of weight 14.7 N is at rest on a horizontal floor. A force of magnitude 4.9 N is applied to the block.

(i) The block is in limiting equilibrium when the 4.9 N force is applied horizontally. Show that the coefficient of friction is $\frac{1}{3}$. [2]

(ii)



When the force of 4.9 N is applied at an angle of 30° above the horizontal, as shown in the diagram, the block moves across the floor. Calculate

(a) the vertical component of the contact force between the floor and the block, and the magnitude of the frictional force, [5]

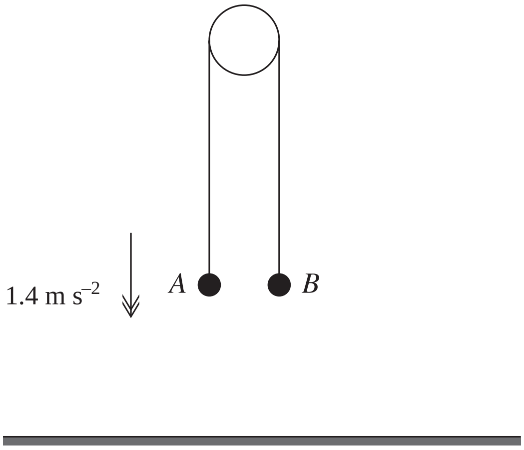
(b) the acceleration of the block. [5]

(iii) Calculate the magnitude of the frictional force acting on the block when the 4.9 N force acts at an angle of 30° to the upward vertical, justifying your answer fully. [4]

[Question 7 is printed overleaf.]

Jan 2008

7



Particles A and B are attached to the ends of a light inextensible string. The string passes over a smooth fixed pulley. The particles are released from rest, with the string taut, and A and B at the same height above a horizontal floor (see diagram). In the subsequent motion, A descends with acceleration $1.4\,\text{m}\,\text{s}^{-2}$ and strikes the floor 0.8 s after being released. It is given that B never reaches the pulley.

(i) Calculate the distance A moves before it reaches the floor and the speed of A immediately before it strikes the floor. [4]

(ii) Show that B rises a further 0.064 m after A strikes the floor, and calculate the total length of time during which B is rising. [4]

(iii) Sketch the (t, v) graph for the motion of B from the instant it is released from rest until it reaches a position of instantaneous rest. [2]

(iv) Before A strikes the floor the tension in the string is 5.88 N. Calculate the mass of A and the mass of B. [4]

(v) The pulley has mass 0.5 kg, and is held in a fixed position by a light vertical chain. Calculate the tension in the chain

(a) immediately before A strikes the floor, [2]

(b) immediately after A strikes the floor. [1]

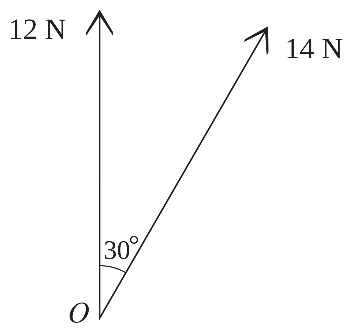
June 2008

1 A car of mass 900 kg is travelling in a straight line on a horizontal road. The driving force acting on the car is 600 N, and a resisting force of 240 N opposes the motion.

(i) Show that the acceleration of the car is $0.4\,\text{m s}^{-2}$. [2]

(ii) Calculate the time and the distance required for the speed of the car to increase from $5\,\text{m s}^{-1}$ to $9\,\text{m s}^{-1}$. [4]

2

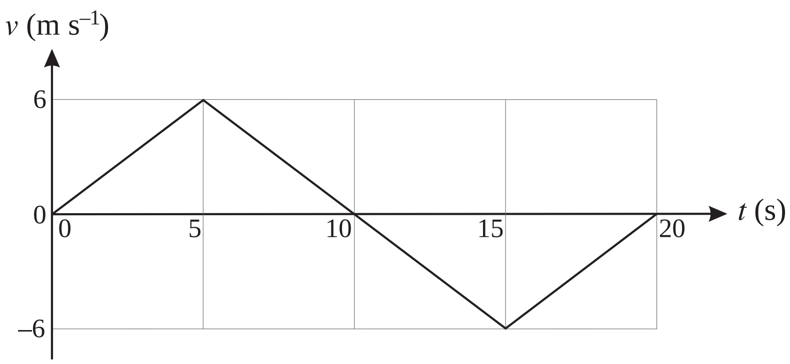


Two horizontal forces act at the point O. One force has magnitude 12 N and acts along a bearing of 000°. The other force has magnitude 14 N and acts along a bearing of 030° (see diagram).

(i) Show that the resultant of the two forces has magnitude 25.1 N, correct to 3 significant figures. [5]

(ii) Find the bearing of the line of action of the resultant. [3]

3



An athlete runs in a straight line from point A to point B, and back to point A. The diagram shows the (t, v) graph for the motion of the athlete. The graph consists of three straight line segments.

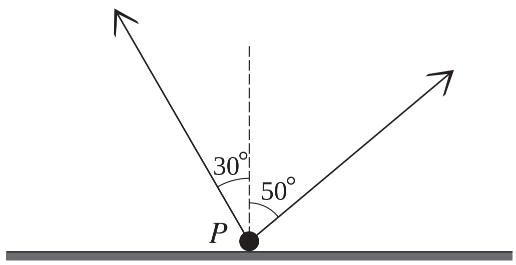
(i) Calculate the initial acceleration of the athlete. [2]

(ii) Calculate the total distance the athlete runs. [3]

(iii) Calculate the velocity of the athlete when $t = 17$. [3]

June 2008

4



A particle P of weight 30 N rests on a horizontal plane. P is attached to two light strings making angles of 30° and 50° with the upward vertical, as shown in the diagram. The tension in each string is 15 N, and the particle is in limiting equilibrium. Find

(i) the magnitude and direction of the frictional force on P, [3]

(ii) the coefficient of friction between P and the plane. [5]

5 A railway wagon A of mass 2400 kg and moving with speed $5\,\mathrm{m\,s^{-1}}$ collides with railway wagon B which has mass 3600 kg and is moving towards A with speed $3\,\mathrm{m\,s^{-1}}$. Immediately after the collision the speeds of A and B are equal.

(i) Given that the two wagons are moving in the same direction after the collision, find their common speed. State which wagon has changed its direction of motion. [5]

(ii) Given instead that A and B are moving with equal speeds in opposite directions after the collision, calculate

(a) the speed of the wagons,

(b) the change in the momentum of A as a result of the collision.

[5]

6 A model train travels along a straight track. At time t seconds after setting out from station A, the train has velocity $v\,\mathrm{m\,s^{-1}}$ and displacement x metres from A. It is given that for $0 \leqslant t \leqslant 7$

$$x = 0.01t^4 - 0.16t^3 + 0.72t^2.$$

After leaving A the train comes to instantaneous rest at station B.

(i) Express v in terms of t. Verify that when $t = 2$ the velocity of the train is $1.28\,\mathrm{m\,s^{-1}}$. [3]

(ii) Express the acceleration of the train in terms of t, and hence show that when the acceleration of the train is zero $t^2 - 8t + 12 = 0$. [3]

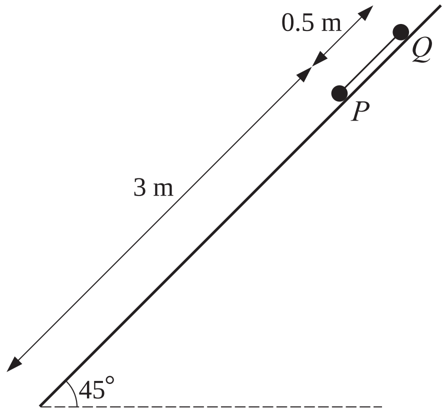
(iii) Calculate the minimum value of v. [4]

(iv) Sketch the (t, v) graph for the train, and state the direction of motion of the train when it leaves B. [4]

(v) Calculate the distance AB. [2]

June 2008

7



Two particles P and Q are joined by a taut light inextensible string which is parallel to a line of greatest slope on an inclined plane on which the particles are initially held at rest. The string is 0.5 m long, and the plane is inclined at 45° to the horizontal. P is below the level of Q and 3 m from the foot of the plane (see diagram). Each particle has mass 0.2 kg. Contact between P and the plane is smooth. The coefficient of friction between Q and the plane is 1. The particles are released from rest and begin to move down the plane.

(i) Show that the magnitude of the frictional force acting on Q is 1.386 N, correct to 4 significant figures. [2]

(ii) Show that the particles accelerate at $3.465\ \text{m s}^{-2}$, correct to 4 significant figures, and calculate the tension in the string. [5]

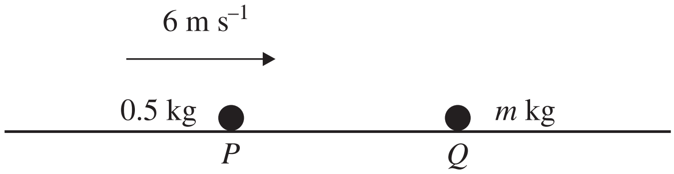
(iii) Calculate the speed of the particles at the instant when Q reaches the initial position of P. [2]

At the instant when Q reaches the initial position of P, Q becomes detached from the string and the two particles travel independently to the foot of the plane.

(iv) Show that Q descends at constant speed, and calculate the time interval between the arrival of P and the arrival of Q at the foot of the plane. [7]

Jan 2009

1



A particle P of mass 0.5 kg is travelling with speed 6 m s^{-1} on a smooth horizontal plane towards a stationary particle Q of mass m kg (see diagram). The particles collide, and immediately after the collision P has speed 0.8 m s^{-1} and Q has speed 4 m s^{-1}.

(i) Given that both particles are moving in the same direction after the collision, calculate m. **[3]**

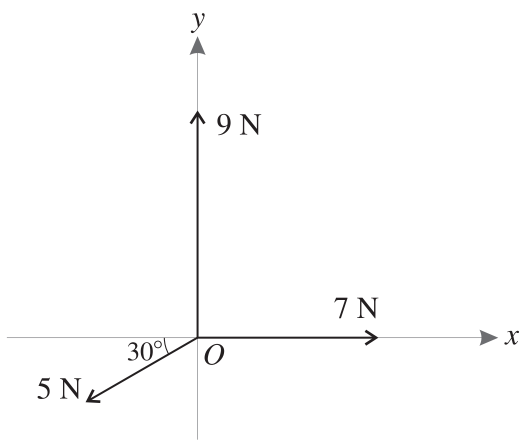
(ii) Given instead that the particles are moving in opposite directions after the collision, calculate m. **[3]**

2 A trailer of mass 500 kg is attached to a car of mass 1250 kg by a light rigid horizontal tow-bar. The car and trailer are travelling along a horizontal straight road. The resistance to motion of the trailer is 400 N and the resistance to motion of the car is 900 N. Find both the tension in the tow-bar and the driving force of the car in each of the following cases.

(i) The car and trailer are travelling at constant speed. **[3]**

(ii) The car and trailer have acceleration 0.6 m s^{-2}. **[6]**

3



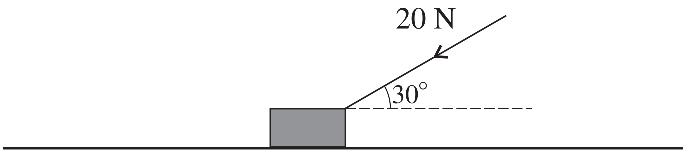
Three horizontal forces act at the point O. One force has magnitude 7 N and acts along the positive x-axis. The second force has magnitude 9 N and acts along the positive y-axis. The third force has magnitude 5 N and acts at an angle of 30° below the negative x-axis (see diagram).

(i) Find the magnitudes of the components of the 5 N force along the two axes. **[2]**

(ii) Calculate the magnitude of the resultant of the three forces. Calculate also the angle the resultant makes with the positive x-axis. **[6]**

Jan 2009

4



A block of mass 3 kg is placed on a horizontal surface. A force of magnitude 20 N acts downwards on the block at an angle of 30° to the horizontal (see diagram).

(i) Given that the surface is smooth, calculate the acceleration of the block. **[3]**

(ii) Given instead that the block is in limiting equilibrium, calculate the coefficient of friction between the block and the surface. **[5]**

5 A car is travelling at $13\,\mathrm{m\,s^{-1}}$ along a straight road when it passes a point A at time $t = 0$, where t is in seconds. For $0 \leqslant t \leqslant 6$, the car accelerates at $0.8t\,\mathrm{m\,s^{-2}}$.

(i) Calculate the speed of the car when $t = 6$. **[5]**

(ii) Calculate the displacement of the car from A when $t = 6$. **[5]**

(iii) Three (t, x) graphs are shown below, for $0 \leqslant t \leqslant 6$.

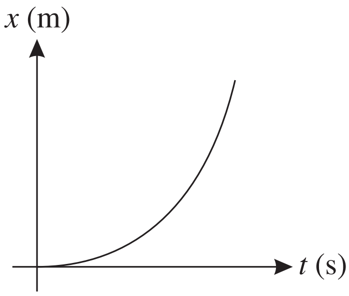


Fig. 1

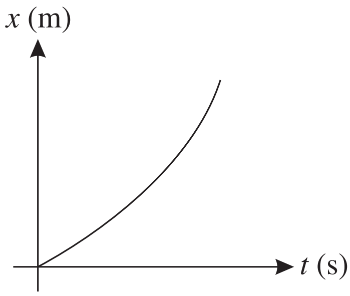


Fig. 2

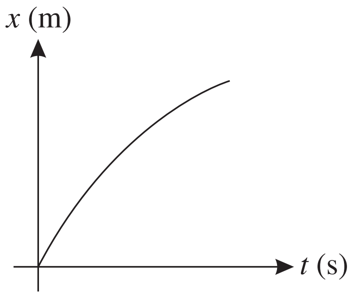


Fig. 3

(a) State which of these three graphs is most appropriate to represent the motion of the car. **[1]**

(b) For each of the two other graphs give a reason why it is not appropriate to represent the motion of the car. **[2]**

[Questions 6 and 7 are printed overleaf.]

Jan 2009

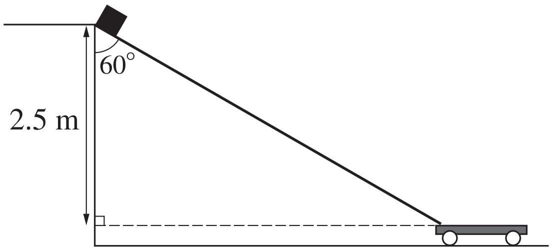
6 Small parcels are being loaded onto a trolley. Initially the parcels are 2.5 m above the trolley.

(i) A parcel is released from rest and falls vertically onto the trolley. Calculate

(a) the time taken for a parcel to fall onto the trolley, **[2]**

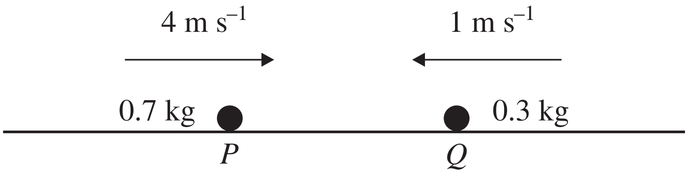
(b) the speed of a parcel when it strikes the trolley. **[2]**

(ii)



Parcels are often damaged when loaded in the way described, so a ramp is constructed down which parcels can slide onto the trolley. The ramp makes an angle of 60° to the vertical, and the coefficient of friction between the ramp and a parcel is 0.2. A parcel of mass 2 kg is released from rest at the top of the ramp (see diagram). Calculate the speed of the parcel after sliding down the ramp. **[9]**

7



Two particles P and Q have masses 0.7 kg and 0.3 kg respectively. P and Q are simultaneously projected towards each other in the same straight line on a horizontal surface with initial speeds of 4 m s^{-1} and 1 m s^{-1} respectively (see diagram). Before P and Q collide the only horizontal force acting on each particle is friction and each particle decelerates at 0.4 m s^{-2}. The particles coalesce when they collide.

(i) Given that P and Q collide 2 s after projection, calculate the speed of each particle immediately before the collision, and the speed of the combined particle immediately after the collision. **[6]**

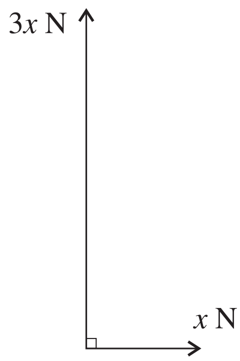
(ii) Given instead that P and Q collide 3 s after projection,

(a) sketch on a single diagram the (t, v) graphs for the two particles in the interval $0 \leqslant t < 3$, **[3]**

(b) calculate the distance between the two particles at the instant when they are projected. **[6]**

June 2009

1



Two perpendicular forces have magnitudes x N and $3x$ N (see diagram). Their resultant has magnitude 6 N.

(i) Calculate x. **[3]**

(ii) Find the angle the resultant makes with the smaller force. **[3]**

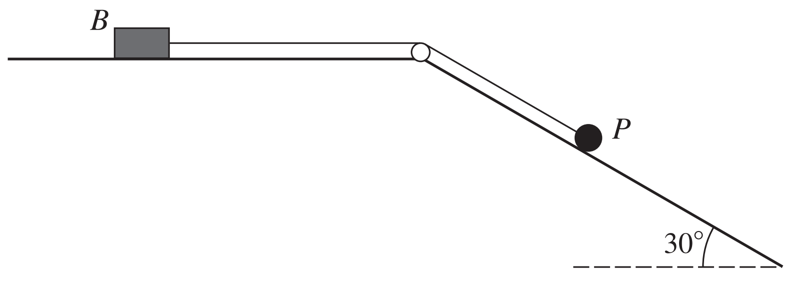
2 The driver of a car accelerating uniformly from rest sees an obstruction. She brakes immediately bringing the car to rest with constant deceleration at a distance of 6 m from its starting point. The car travels in a straight line and is in motion for 3 seconds.

(i) Sketch the (t, v) graph for the car's motion. **[2]**

(ii) Calculate the maximum speed of the car during its motion. **[3]**

(iii) Hence, given that the acceleration of the car is $2.4\ \text{m s}^{-2}$, calculate its deceleration. **[4]**

3



The diagram shows a small block B, of mass 3 kg, and a particle P, of mass 0.8 kg, which are attached to the ends of a light inextensible string. The string is taut and passes over a small smooth pulley. B is held at rest on a horizontal surface, and P lies on a smooth plane inclined at 30° to the horizontal. When B is released from rest it accelerates at $0.2\ \text{m s}^{-2}$ towards the pulley.

(i) By considering the motion of P, show that the tension in the string is 3.76 N. **[4]**

(ii) Calculate the coefficient of friction between B and the horizontal surface. **[5]**

June 2009

4 An object is projected vertically upwards with speed $7\,\text{m}\,\text{s}^{-1}$. Calculate

(i) the speed of the object when it is 2.1 m above the point of projection, **[3]**

(ii) the greatest height above the point of projection reached by the object, **[3]**

(iii) the time after projection when the object is travelling downwards with speed $5.7\,\text{m}\,\text{s}^{-1}$. **[3]**

5 **(i)**

Fig. 1

A particle P of mass 0.5 kg is projected with speed $6\,\text{m}\,\text{s}^{-1}$ on a smooth horizontal surface towards a stationary particle Q of mass m kg (see Fig. 1). After the particles collide, P has speed $v\,\text{m}\,\text{s}^{-1}$ in its original direction of motion, and Q has speed $1\,\text{m}\,\text{s}^{-1}$ more than P. Show that $v(m + 0.5) = -m + 3$. **[3]**

(ii)

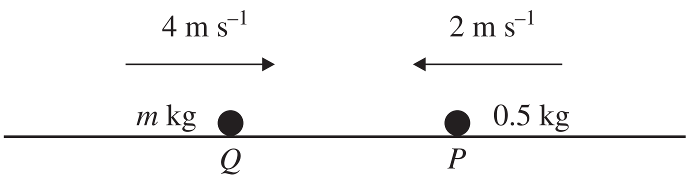


Fig. 2

Q and P are now projected towards each other with speeds $4\,\text{m}\,\text{s}^{-1}$ and $2\,\text{m}\,\text{s}^{-1}$ respectively (see Fig. 2). Immediately after the collision the speed of Q is $v\,\text{m}\,\text{s}^{-1}$ with its direction of motion unchanged and P has speed $1\,\text{m}\,\text{s}^{-1}$ more than Q. Find another relationship between m and v in the form $v(m + 0.5) = am + b$, where a and b are constants. **[4]**

(iii) By solving these two simultaneous equations show that $m = 0.9$, and hence find v. **[4]**

[Questions 6 and 7 are printed overleaf.]

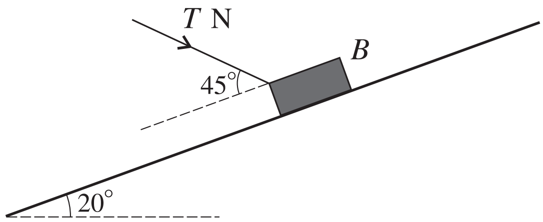
June 2009

6 A block B of weight 10 N is projected down a line of greatest slope of a plane inclined at an angle of 20° to the horizontal. B travels down the plane at constant speed.

(i) (a) Find the components perpendicular and parallel to the plane of the contact force between B and the plane. **[2]**

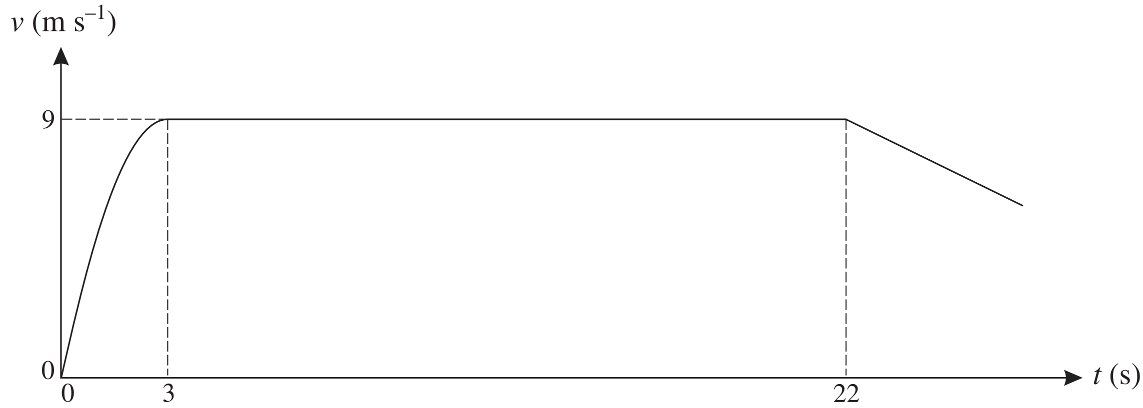
(b) Hence show that the coefficient of friction is 0.364, correct to 3 significant figures. **[2]**

(ii)



B is in limiting equilibrium when acted on by a force of T N directed towards the plane at an angle of 45° to a line of greatest slope (see diagram). Given that the frictional force on B acts down the plane, find T. **[7]**

7



A sprinter S starts from rest at time $t = 0$, where t is in seconds, and runs in a straight line. For $0 \leqslant t \leqslant 3$, S has velocity $(6t - t^2)$ m s^{-1}. For $3 < t \leqslant 22$, S runs at a constant speed of 9 m s^{-1}. For $t > 22$, S decelerates at 0.6 m s^{-2} (see diagram).

(i) Express the acceleration of S during the first 3 seconds in terms of t. **[2]**

(ii) Show that S runs 18 m in the first 3 seconds of motion. **[5]**

(iii) Calculate the time S takes to run 100 m. **[3]**

(iv) Calculate the time S takes to run 200 m. **[7]**

1 A particle P is projected vertically downwards from a fixed point O with initial speed $4.2\,\text{m s}^{-1}$, and takes 1.5 s to reach the ground. Calculate

(i) the speed of P when it reaches the ground, **[2]**

(ii) the height of O above the ground, **[2]**

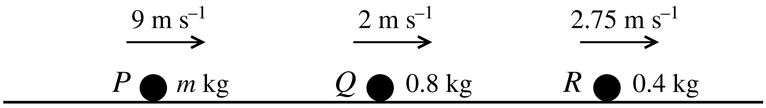
(iii) the speed of P when it is 5 m above the ground. **[2]**

2 Two horizontal forces of magnitudes 12 N and 19 N act at a point. Given that the angle between the two forces is 60°, calculate

(i) the magnitude of the resultant force, **[5]**

(ii) the angle between the resultant and the 12 N force. **[3]**

3



Three particles P, Q and R, are travelling in the same direction in the same straight line on a smooth horizontal surface. P has mass m kg and speed $9\,\text{m s}^{-1}$, Q has mass 0.8 kg and speed $2\,\text{m s}^{-1}$ and R has mass 0.4 kg and speed $2.75\,\text{m s}^{-1}$ (see diagram).

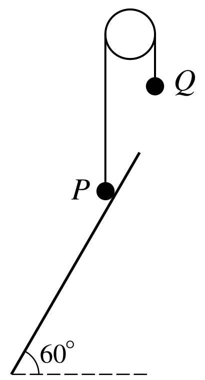
(i) A collision occurs between P and Q, after which P and Q move in opposite directions, each with speed $3.5\,\text{m s}^{-1}$. Calculate

(a) the value of m, **[4]**

(b) the change in the momentum of P. **[2]**

(ii) When Q collides with R the two particles coalesce. Find their subsequent common speed. **[3]**

4



Particles P and Q, of masses 0.4 kg and 0.3 kg respectively, are attached to the ends of a light inextensible string. The string passes over a smooth fixed pulley and the sections of the string not in contact with the pulley are vertical. P rests in limiting equilibrium on a plane inclined at 60° to the horizontal (see diagram).

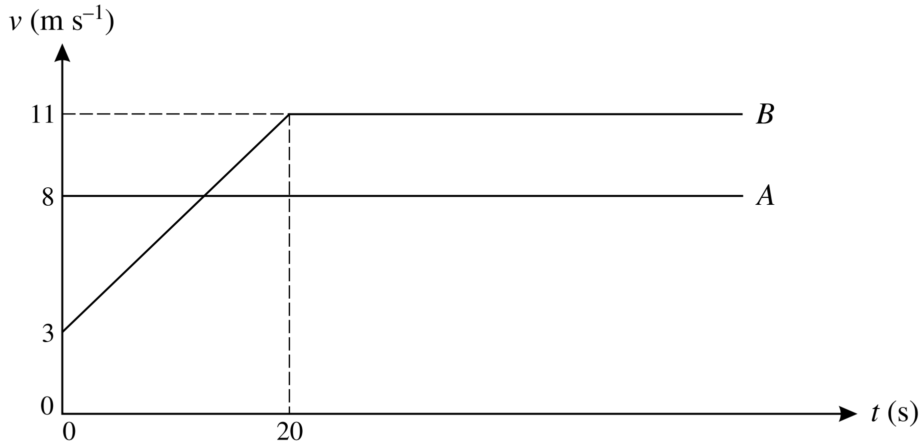
(i) (a) Calculate the components, parallel and perpendicular to the plane, of the contact force exerted by the plane on P. **[4]**

(b) Find the coefficient of friction between P and the plane. **[2]**

P is held stationary and a particle of mass 0.2 kg is attached to Q. With the string taut, P is released from rest.

(ii) Calculate the tension in the string and the acceleration of the particles. **[4]**

5



The (t, v) diagram represents the motion of two cyclists A and B who are travelling along a horizontal straight road. At time $t = 0$, A, who cycles with constant speed 8 m s^{-1}, overtakes B who has initial speed 3 m s^{-1}. From time $t = 0$ B cycles with constant acceleration for 20 s. When $t = 20$ her speed is 11 m s^{-1}, which she subsequently maintains.

(i) Find the value of t when A and B have the same speed. **[3]**

(ii) Calculate the value of t when B overtakes A. **[5]**

(iii) On a single diagram, sketch the (t, x) graphs for the two cyclists for the time from $t = 0$ until after B has overtaken A. **[3]**

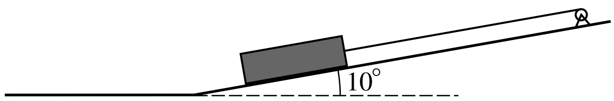
6 A swimmer C swims with velocity $v\,\mathrm{m\,s^{-1}}$ in a swimming pool. At time t s after starting, $v = 0.006t^2 - 0.18t + k$, where k is a constant. C swims from one end of the pool to the other in 28.4 s.

(i) Find the acceleration of C in terms of t. **[2]**

(ii) Given that the minimum speed of C is $0.65\,\mathrm{m\,s^{-1}}$, show that $k = 2$. **[5]**

(iii) Express the distance travelled by C in terms of t, and calculate the length of the pool. **[5]**

7



A winch drags a log of mass 600 kg up a slope inclined at 10° to the horizontal by means of an inextensible cable of negligible mass parallel to the slope (see diagram). The coefficient of friction between the log and the slope is 0.15, and the log is initially at rest at the foot of the slope. The acceleration of the log is $0.11\,\mathrm{m\,s^{-2}}$.

(i) Calculate the tension in the cable. **[5]**

The cable suddenly breaks after dragging the log a distance of 10 m.

(ii) (a) Show that the deceleration of the log while continuing to move up the slope is $3.15\,\mathrm{m\,s^{-2}}$, correct to 3 significant figures. **[2]**

(b) Calculate the time taken, after the cable breaks, for the log to return to its original position at the foot of the slope. **[9]**

<u>June 2010</u>

1 A block B of mass 3 kg moves with deceleration $1.2\,\mathrm{m\,s^{-2}}$ in a straight line on a rough horizontal surface. The initial speed of B is $5\,\mathrm{m\,s^{-1}}$. Calculate

(i) the time for which B is in motion, **[2]**

(ii) the distance travelled by B before it comes to rest, **[2]**

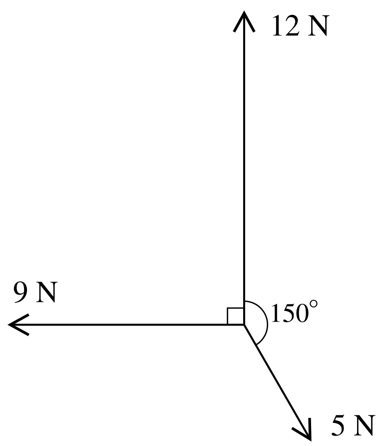
(iii) the coefficient of friction between B and the surface. **[4]**

2 Two particles P and Q are moving in opposite directions in the same straight line on a smooth horizontal surface when they collide. P has mass 0.4 kg and speed $3\,\mathrm{m\,s^{-1}}$. Q has mass 0.6 kg and speed $1.5\,\mathrm{m\,s^{-1}}$. Immediately after the collision, the speed of P is $0.1\,\mathrm{m\,s^{-1}}$.

(i) Given that P and Q are moving in the same direction after the collision, find the speed of Q. **[4]**

(ii) Given instead that P and Q are moving in opposite directions after the collision, find the distance between them 3 s after the collision. **[5]**

3



Three horizontal forces of magnitudes 12 N, 5 N, and 9 N act along bearings 000°, 150° and 270° respectively (see diagram).

(i) Show that the component of the resultant of the three forces along bearing 270° has magnitude 6.5 N. **[2]**

(ii) Find the component of the resultant of the three forces along bearing 000°. **[2]**

(iii) Hence find the magnitude and bearing of the resultant of the three forces. **[5]**

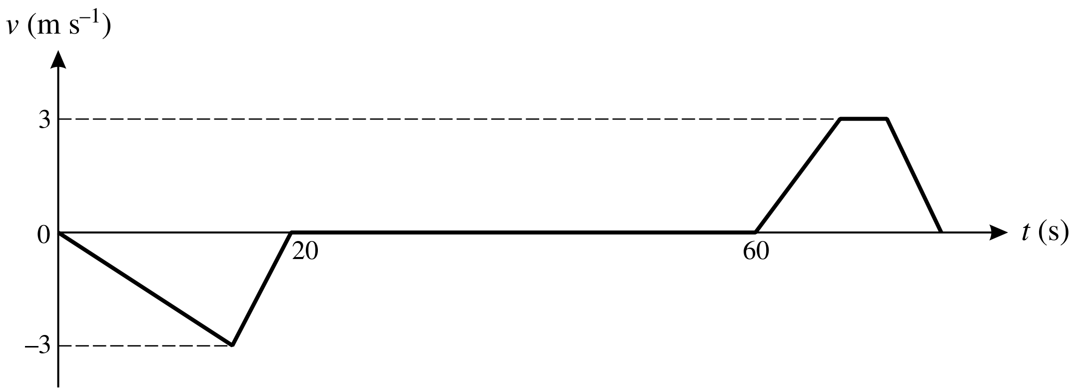
4 A particle P moving in a straight line has velocity $v\,\mathrm{m\,s^{-1}}$ at time t s after passing through a fixed point O. It is given that $v = 3.2 - 0.2t^2$ for $0 \leqslant t \leqslant 5$. Calculate

(i) the value of t when P is at instantaneous rest, **[2]**

(ii) the acceleration of P when it is at instantaneous rest, **[3]**

(iii) the greatest distance of P from O. **[5]**

5



The diagram shows the (t, v) graph for a lorry delivering waste to a recycling centre. The graph consists of six straight line segments. The lorry reverses in a straight line from a stationary position on a weighbridge before coming to rest. It deposits its waste and then moves forwards in a straight line accelerating to a maximum speed of $3\,\text{m}\,\text{s}^{-1}$. It maintains this speed for 4 s and then decelerates, coming to rest at the weighbridge.

(i) Calculate the distance from the weighbridge to the point where the lorry deposits the waste. **[2]**

(ii) Calculate the time which elapses between the lorry leaving the weighbridge and returning to it. **[4]**

(iii) Given that the acceleration of the lorry when it is moving forwards is $0.4\,\text{m}\,\text{s}^{-2}$, calculate its final deceleration. **[3]**

6 A block B of mass 0.85 kg lies on a smooth slope inclined at 30° to the horizontal. B is attached to one end of a light inextensible string which is parallel to the slope. At the top of the slope, the string passes over a smooth pulley. The other end of the string hangs vertically and is attached to a particle P of mass 0.55 kg. The string is taut at the instant when P is projected vertically downwards.

(i) Calculate

(a) the acceleration of B and the tension in the string, **[5]**

(b) the magnitude of the force exerted by the string on the pulley. **[2]**

The initial speed of P is $1.3\,\text{m}\,\text{s}^{-1}$ and after moving 1.5 m P reaches the ground, where it remains at rest. B continues to move up the slope and does not reach the pulley.

(ii) Calculate the total distance B moves up the slope before coming instantaneously to rest. **[6]**

[Question 7 is printed overleaf.]

June 2010

7

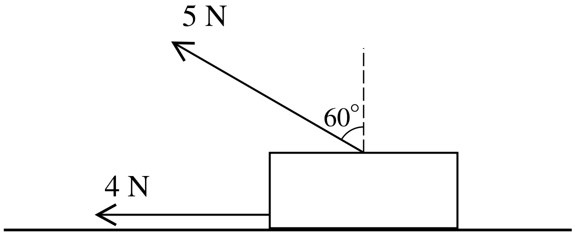


Fig. 1

A rectangular block B of weight 12 N lies in limiting equilibrium on a horizontal surface. A horizontal force of 4 N and a coplanar force of 5 N inclined at 60° to the vertical act on B (see Fig. 1).

(i) Find the coefficient of friction between B and the surface. **[6]**

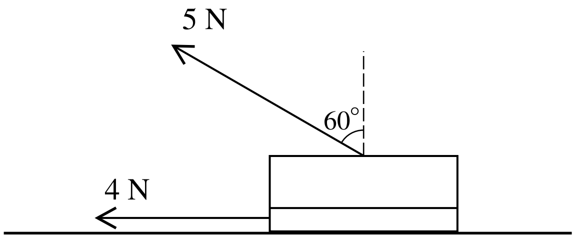


Fig. 2

B is now cut horizontally into two smaller blocks. The upper block has weight 9 N and the lower block has weight 3 N. The 5 N force now acts on the upper block and the 4 N force now acts on the lower block (see Fig. 2). The coefficient of friction between the two blocks is μ.

(ii) Given that the upper block is in limiting equilibrium, find μ. **[2]**

(iii) Given instead that $\mu = 0.1$, find the accelerations of the two blocks. **[6]**