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

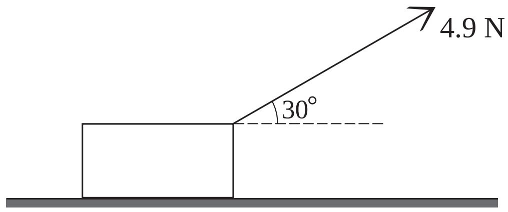
(a) the acceleration of the car and trailer, [4]

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

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

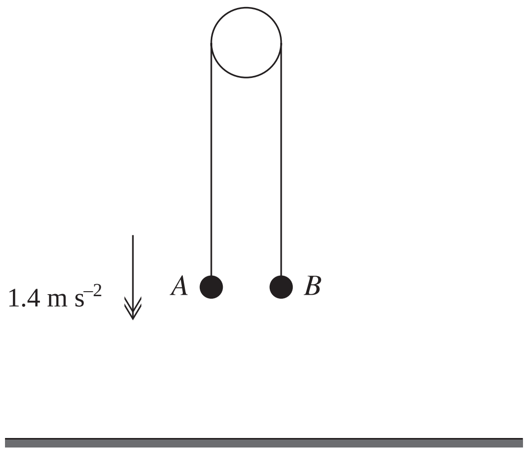
(a) the vertical component of the contact force between the floor and the block, and the magnitude of the frictional force, [5]

(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.]

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 $1.4\,\mathrm{m\,s^{-2}}$ 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]

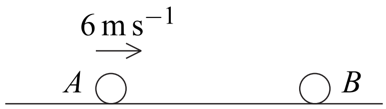
(v) The pulley has mass 0.5 kg, and is held in a fixed position by a light vertical chain. Calculate the tension in the chain

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

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

Answer **all** questions.

1 A particle A moves across a smooth horizontal surface in a straight line. The particle A has mass 2 kg and speed $6\,\mathrm{m\,s^{-1}}$. A particle B, which has mass 3 kg, is at rest on the surface. The particle A collides with the particle B.



(a) If, after the collision, A is at rest and B moves away from A, find the speed of B. *(3 marks)*

(b) If, after the collision, A and B move away from each other with speeds $v\,\mathrm{m\,s^{-1}}$ and $4v\,\mathrm{m\,s^{-1}}$ respectively, as shown in the diagram below, find the value of v.

(3 marks)

2 A girl throws a ball vertically upwards with a speed of $10.5\,\mathrm{m\,s^{-1}}$ and subsequently catches it at the same point from which it was thrown.

Find:

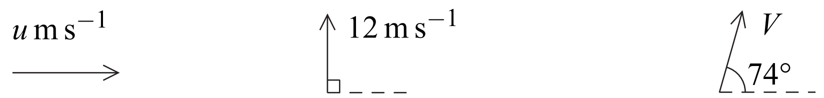
(a) the greatest height that the ball reaches above the point from which it is thrown; *(2 marks)*

(b) (i) the time that the ball takes to reach the greatest height; *(2 marks)*

(ii) the time between the ball being thrown and being caught. *(1 mark)*

3 Water flows in a constant direction at a constant speed of $u\,\text{m s}^{-1}$. A boat travels in the water at a speed of $12\,\text{m s}^{-1}$ relative to the water.

(a) The direction in which the boat travels relative to the water is perpendicular to the direction of motion of the water. The resultant velocity of the boat is $V\,\text{m s}^{-1}$ at an angle of 74° to the direction of motion of the water, as shown in the diagram.

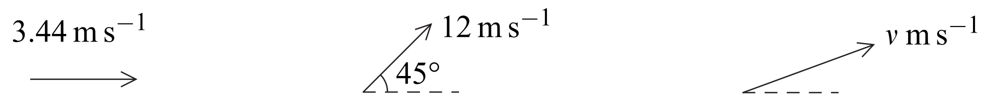


Velocity of the water | Velocity of the boat relative to the water | Resultant velocity of the boat

(i) Find V. *(2 marks)*

(ii) Show that $u = 3.44$, correct to three significant figures. *(3 marks)*

(b) The boat changes course so that it travels relative to the water at an angle of 45° to the direction of motion of the water. The resultant velocity of the boat is now of magnitude $v\,\text{m s}^{-1}$. The velocity of the water is unchanged, as shown in the diagram below.

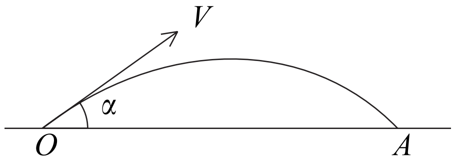


Velocity of the water | Velocity of the boat relative to the water | Resultant velocity of the boat

Find the value of v. *(4 marks)*

Turn over for the next question

4 A golf ball is projected from a point O with initial velocity V at an angle α to the horizontal. The ball first hits the ground at a point A which is at the same horizontal level as O, as shown in the diagram.



It is given that $V\cos\alpha = 6u$ and $V\sin\alpha = 2.5u$.

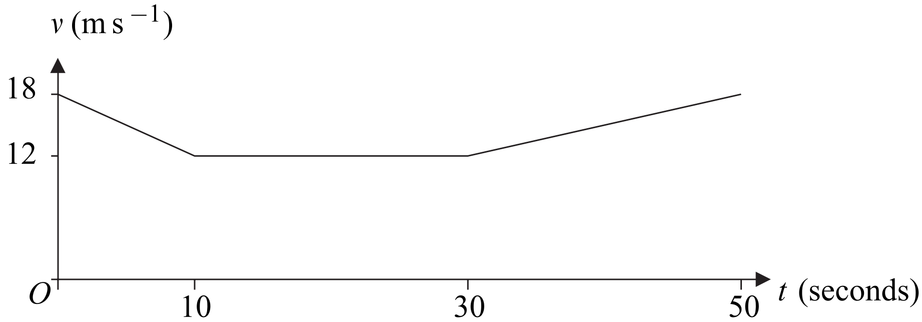
(a) Show that the time taken for the ball to travel from O to A is $\dfrac{5u}{g}$. *(4 marks)*

(b) Find, in terms of g and u, the distance OA. *(2 marks)*

(c) Find V in terms of u. *(2 marks)*

(d) State, in terms of u, the least speed of the ball during its flight from O to A. *(1 mark)*

5 The velocity–time graph below represents the three stages of the motion of a coach moving along a straight horizontal road. Initially the coach has velocity $18\,\text{m s}^{-1}$.



(a) During the first stage of the motion, the coach decelerates at a constant rate of $a\,\text{m s}^{-2}$ for 10 seconds until it reaches a velocity of $12\,\text{m s}^{-1}$.

(i) Find the value of a. *(2 marks)*

(ii) Find the distance that the coach travels during the 10 seconds. *(2 marks)*

(b) During the second stage of the motion, the coach travels for 20 seconds with constant velocity $12\,\text{m s}^{-1}$. Find the distance that the coach travels during these 20 seconds. *(1 mark)*

(c) During the third stage of the motion, the coach travels with constant acceleration, reaching a velocity of $18\,\text{m s}^{-1}$ after a further 20 seconds.

Find the average speed of the coach during the 50 seconds of the motion. *(4 marks)*

6 A builder ties two identical buckets, P and Q, to the ends of a light inextensible rope. He hangs the rope over a smooth beam so that the buckets hang in equilibrium, as shown in the diagram.

The buckets are each of mass 0.6 kg.

(a) (i) State the magnitude of the tension in the rope. *(1 mark)*

(ii) State the magnitude and direction of the force exerted on the beam by the rope. *(2 marks)*

(b) The bucket Q is held at rest while a stone, of mass 0.2 kg, is placed inside it. The system is then released from rest and, in the subsequent motion, bucket Q moves vertically downwards with the stone inside.

(i) By forming an equation of motion for each bucket, show that the magnitude of the tension in the rope during the motion is 6.72 newtons, correct to three significant figures. *(6 marks)*

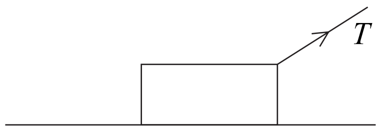
(ii) State the magnitude of the force exerted on the beam by the rope while the motion takes place. *(1 mark)*

Turn over for the next question

7 A crate is being pulled at constant speed across rough horizontal ground by a rope.

The crate is of weight 100 newtons and the frictional force between the crate and the ground is of magnitude 30 newtons.

The tension in the rope is of magnitude T newtons.



(a) Draw and label a diagram to show all the forces acting on the crate. *(1 mark)*

(b) The coefficient of friction between the crate and the ground is 0.5. Show that the normal reaction force between the crate and the ground is 60 newtons. *(2 marks)*

(c) Explain why the horizontal component of the tension in the rope is 30 newtons. *(2 marks)*

(d) Find the value of T. *(4 marks)*

(e) Find the angle that the rope makes with the horizontal. *(3 marks)*

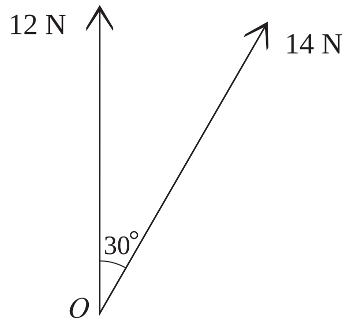
END OF QUESTIONS

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 $0.4\,\mathrm{m\,s^{-2}}$. [2]

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

2

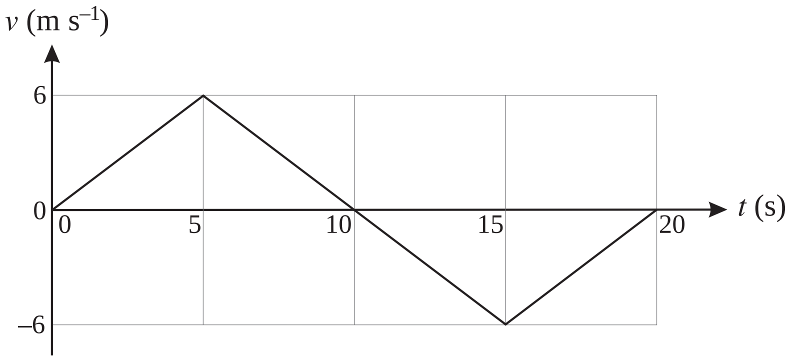


Two horizontal forces act at the point O. One force has magnitude 12 N and acts along a bearing of 000°. The other force has magnitude 14 N and acts along a bearing of 030° (see diagram).

(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



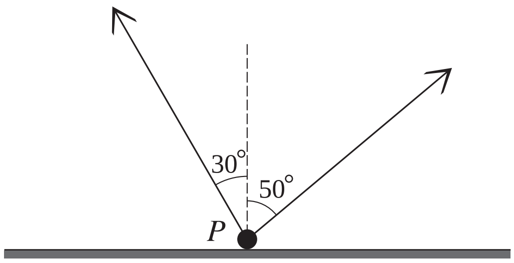
An athlete runs in a straight line from point A to point B, and back to point A. The diagram shows the (t, v) graph for the motion of the athlete. The graph consists of three straight line segments.

(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]

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]

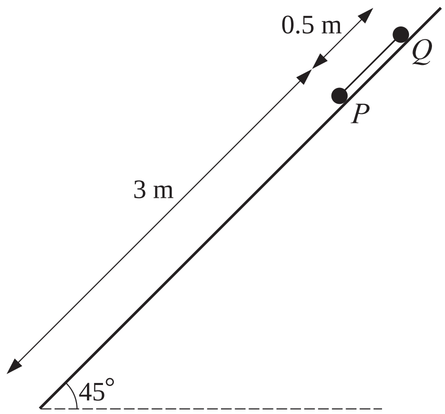
(iii) Calculate the minimum value of v. [4]

(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]

[Turn over

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 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]

Answer **all** questions.

1 A small stone is dropped from a high bridge and falls vertically.

(a) Find the distance that the stone falls during the first 4 seconds of its motion. *(3 marks)*

(b) Find the speed of the stone when it has been falling for 4 seconds. *(2 marks)*

2 A car travels along a straight horizontal road. The motion of the car can be modelled as three separate stages.

During the first stage, the car accelerates uniformly from rest to a velocity of $10\,\mathrm{m\,s^{-1}}$ in 6 seconds.

During the second stage, the car travels with a constant velocity of $10\,\mathrm{m\,s^{-1}}$ for a further 4 seconds.

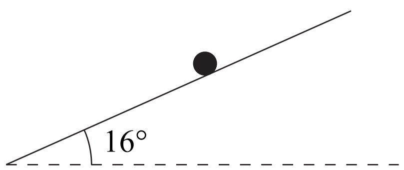
During the third stage of the motion, the car travels with a uniform retardation of magnitude $0.8\,\mathrm{m\,s^{-2}}$ until it comes to rest.

(a) Show that the time taken for the **third** stage of the motion is 12.5 seconds. *(2 marks)*

(b) Sketch a velocity–time graph for the car during the three stages of the motion. *(4 marks)*

(c) Find the total distance travelled by the car during the motion. *(3 marks)*

3 A stone rests in equilibrium on a rough plane inclined at an angle of 16° to the horizontal, as shown in the diagram. The mass of the stone is 0.5 kg.



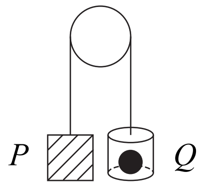
(a) Draw a diagram to show the forces acting on the stone. *(1 mark)*

(b) Show that the magnitude of the frictional force acting on the stone is 1.35 newtons, correct to three significant figures. *(3 marks)*

(c) Find the magnitude of the normal reaction force between the stone and the plane. *(2 marks)*

(d) Hence find an inequality for the value of μ, the coefficient of friction between the stone and the plane. *(2 marks)*

4 A block P is attached to a can Q by a light inextensible string. The string hangs over a smooth peg so that P and Q hang freely, as shown in the diagram.



The block P and the can Q each has mass 0.2 kg. The can Q contains a small stone of mass 0.1 kg. The system is released from rest and the can Q and the stone move vertically downwards.

(a) By forming two equations of motion, show that the magnitude of the acceleration of P and Q is $1.96\,\text{m}\,\text{s}^{-2}$. *(5 marks)*

(b) Find the magnitude of the reaction force between the can and the stone. *(3 marks)*

5 The points A and B have position vectors $(3\mathbf{i} + 2\mathbf{j})$ metres and $(6\mathbf{i} - 4\mathbf{j})$ metres respectively. The vectors $\mathbf{i}$ and $\mathbf{j}$ are in a horizontal plane.

(a) A particle moves from A to B with constant velocity $(\mathbf{i} - 2\mathbf{j})\,\text{m}\,\text{s}^{-1}$. Calculate the time that the particle takes to move from A to B. *(3 marks)*

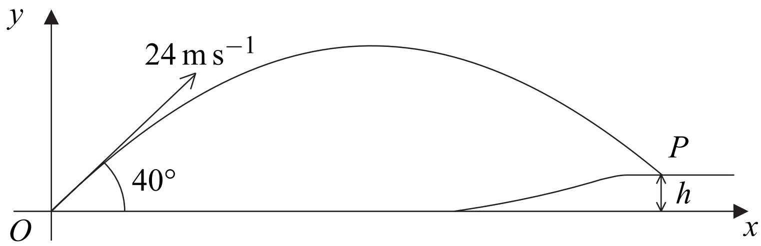
(b) The particle then moves from B to a point C with a constant acceleration of $2\mathbf{j}\,\text{m}\,\text{s}^{-2}$. It takes 4 seconds to move from B to C.

(i) Find the position vector of C. *(4 marks)*

(ii) Find the distance AC. *(2 marks)*

Turn over for the next question

6 A golf ball is struck from a point O with velocity $24\,\text{m s}^{-1}$ at an angle of $40°$ to the horizontal. The ball first hits the ground at a point P, which is at a height h metres above the level of O.



The horizontal distance between O and P is 57 metres.

(a) Show that the time that the ball takes to travel from O to P is 3.10 seconds, correct to three significant figures. *(3 marks)*

(b) Find the value of h. *(3 marks)*

(c) (i) Find the speed with which the ball hits the ground at P. *(5 marks)*

(ii) Find the angle between the direction of motion and the horizontal as the ball hits the ground at P. *(2 marks)*

7 Two particles, A and B, are moving on a smooth horizontal surface.

The particle A has mass m kg and is moving with velocity $\begin{bmatrix} 5 \\ -3 \end{bmatrix}\,\text{m s}^{-1}$.

The particle B has mass 0.2 kg and is moving with velocity $\begin{bmatrix} 2 \\ 3 \end{bmatrix}\,\text{m s}^{-1}$.

(a) Find, in terms of m, an expression for the total momentum of the particles. *(2 marks)*

(b) The particles A and B collide and form a single particle C, which moves with velocity $\begin{bmatrix} k \\ 1 \end{bmatrix}\,\text{m s}^{-1}$, where k is a constant.

(i) Show that $m = 0.1$. *(3 marks)*

(ii) Find the value of k. *(3 marks)*

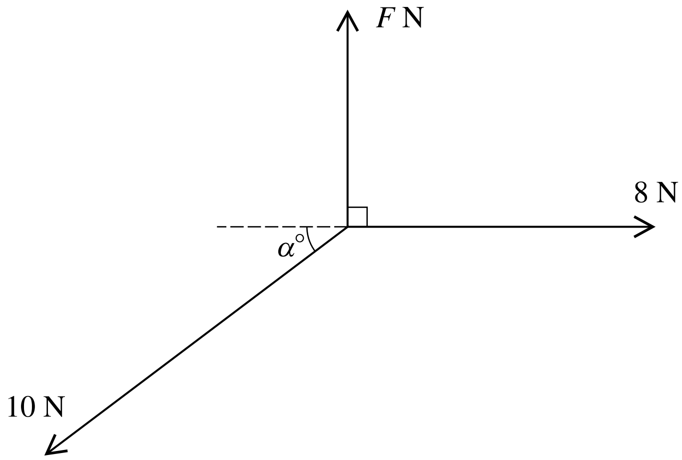
END OF QUESTIONS

1 Two particles P and Q are projected directly towards each other on a smooth horizontal surface. P has mass 0.5 kg and initial speed $2.4\,\mathrm{m\,s^{-1}}$, and Q has mass 0.8 kg and initial speed $1.5\,\mathrm{m\,s^{-1}}$. After a collision between P and Q, the speed of P is $0.2\,\mathrm{m\,s^{-1}}$ and the direction of its motion is reversed. Calculate

(i) the change in the momentum of P, **[2]**

(ii) the speed of Q after the collision. **[4]**

2



Three horizontal forces of magnitudes F N, 8 N and 10 N act at a point and are in equilibrium. The F N and 8 N forces are perpendicular to each other, and the 10 N force acts at an obtuse angle $(90 + \alpha)^\circ$ to the F N force (see diagram). Calculate

(i) α, **[3]**

(ii) F. **[3]**

3 A particle is projected vertically upwards with velocity $5\,\mathrm{m\,s^{-1}}$ from a point 2.5 m above the ground.

(i) Calculate the speed of the particle when it strikes the ground. **[3]**

(ii) Calculate the time after projection when the particle reaches the ground. **[3]**

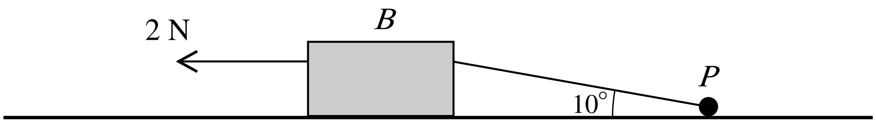
(iii) Sketch on separate diagrams

(a) the (t, v) graph,

(b) the (t, x) graph,

representing the motion of the particle. **[4]**

4

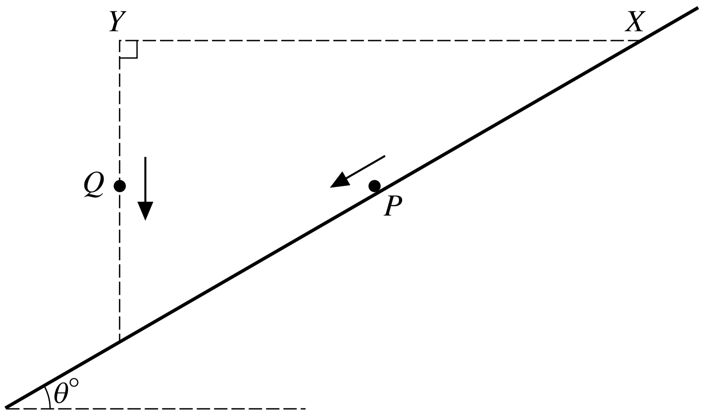


A block B of mass 0.8 kg and a particle P of mass 0.3 kg are connected by a light inextensible string inclined at $10°$ to the horizontal. They are pulled across a horizontal surface with acceleration $0.2\,\mathrm{m\,s^{-2}}$, by a horizontal force of 2 N applied to B (see diagram).

(i) Given that contact between B and the surface is smooth, calculate the tension in the string. **[3]**

(ii) Calculate the coefficient of friction between P and the surface. **[7]**

5



X is a point on a smooth plane inclined at $\theta°$ to the horizontal. Y is a point directly above the line of greatest slope passing through X, and XY is horizontal. A particle P is projected from X with initial speed $4.9\,\mathrm{m\,s^{-1}}$ down the line of greatest slope, and simultaneously a particle Q is released from rest at Y. P moves with acceleration $4.9\,\mathrm{m\,s^{-2}}$, and Q descends freely under gravity (see diagram). The two particles collide at the point on the plane directly below Y at time T s after being set in motion.

(i) **(a)** Express in terms of T the distances travelled by the particles before the collision. **[3]**

(b) Calculate θ. **[2]**

(c) Using the answers to parts **(a)** and **(b)**, show that $T = \frac{2}{3}$. **[3]**

(ii) Calculate the speeds of the particles immediately before they collide. **[3]**

6 The velocity $v\,\mathrm{m\,s^{-1}}$ of a particle at time t s is given by $v = t^2 - 9$. The particle travels in a straight line and passes through a fixed point O when $t = 2$.

(i) Find the displacement of the particle from O when $t = 0$. **[4]**

(ii) Calculate the distance the particle travels from its position at $t = 0$ until it changes its direction of motion. **[6]**

(iii) Calculate the distance of the particle from O when the acceleration of the particle is $10\,\mathrm{m\,s^{-2}}$. **[5]**

[Question 7 is printed overleaf.]

7 A particle P of mass 0.6 kg is projected up a line of greatest slope of a plane inclined at 30° to the horizontal. P moves with deceleration $10\,\mathrm{m\,s^{-2}}$ and comes to rest before reaching the top of the plane.

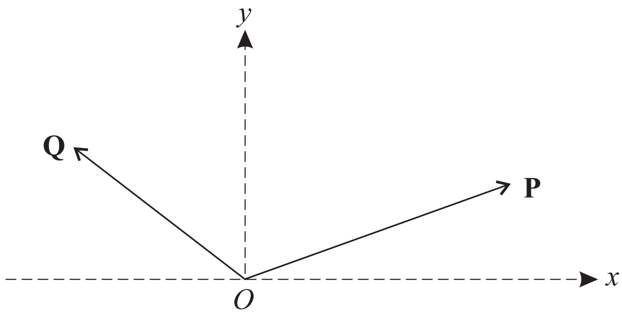
(i) Calculate the frictional force acting on P, and the coefficient of friction between P and the plane. **[7]**

(ii) Find the magnitude of the contact force exerted on P by the plane and the angle between the contact force and the upward direction of the line of greatest slope,

(a) when P is in motion, **[5]**

(b) when P is at rest. **[2]**

1

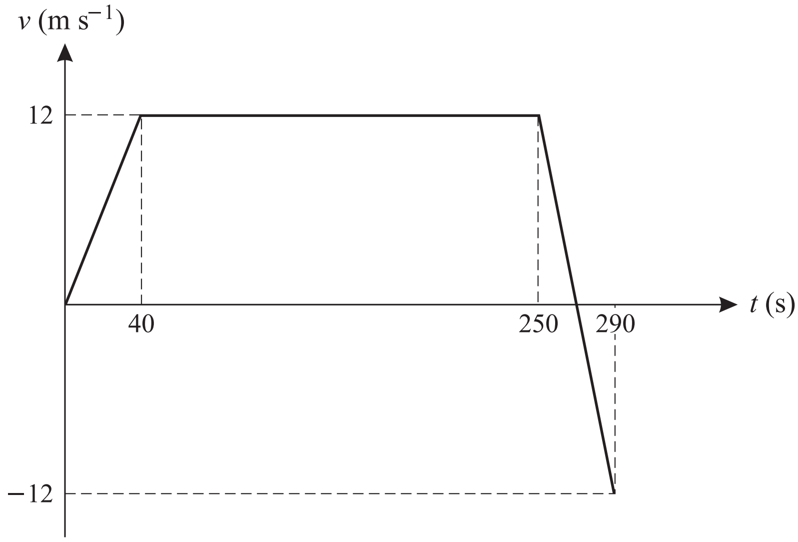


Two horizontal forces **P** and **Q** act at the origin O of rectangular coordinates Oxy (see diagram). The components of **P** in the x- and y-directions are 14 N and 5 N respectively. The components of **Q** in the x- and y-directions are -9 N and 7 N respectively.

(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



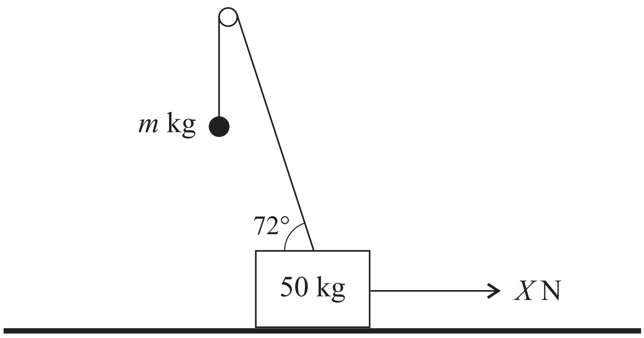
A particle starts from the point A and travels in a straight line. The diagram shows the (t, v) graph, consisting of three straight line segments, for the motion of the particle during the interval $0 \leqslant t \leqslant 290$.

(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]

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.

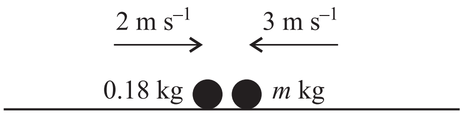
(i) By resolving forces on the block vertically, find a relationship between T and R. [2]

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 $2\,\mathrm{m\,s^{-1}}$ and $3\,\mathrm{m\,s^{-1}}$ 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 $1.5\,\mathrm{m\,s^{-1}}$ 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]

[Turn over

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

(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 $u\,\mathrm{m\,s^{-1}}$. 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

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

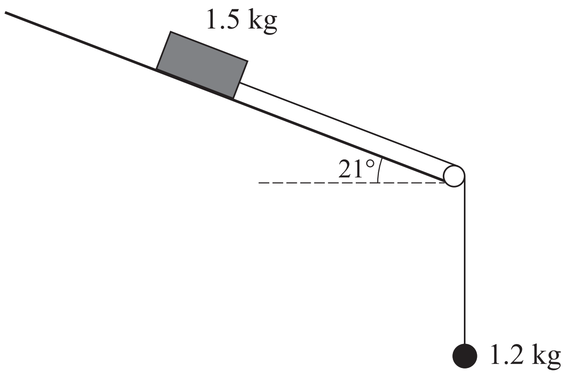
(i) Show that the velocity of the particle is $4\,\mathrm{m\,s^{-1}}$ when $t = 10$. [3]

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

(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]

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 $a\,\text{m s}^{-2}$. 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]

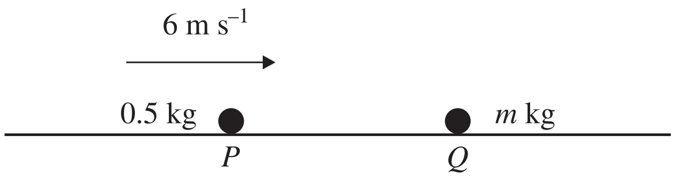
(iii) Hence show that $a = 2.24$, correct to 2 decimal places. [2]

(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]

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]**

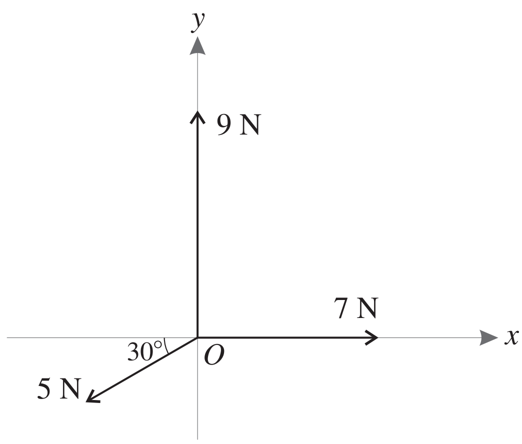
(ii) Given instead that the particles are moving in opposite directions after the collision, calculate m. **[3]**

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

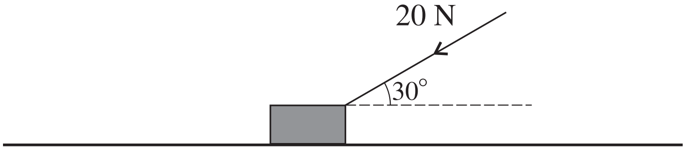


Three horizontal forces act at the point O. One force has magnitude 7 N and acts along the positive x-axis. The second force has magnitude 9 N and acts along the positive y-axis. The third force has magnitude 5 N and acts at an angle of 30° below the negative x-axis (see diagram).

(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]**

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 $0 \leqslant t \leqslant 6$.

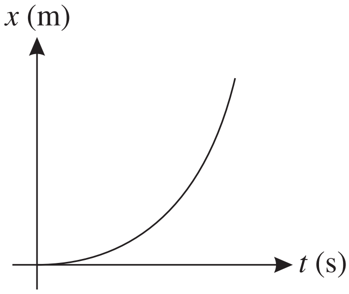


Fig. 1

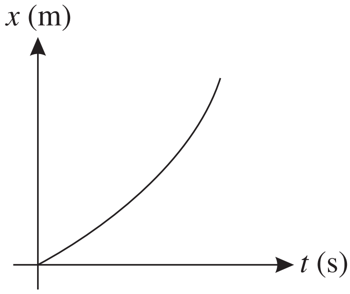


Fig. 2

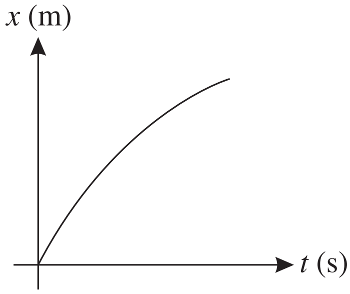


Fig. 3

(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.]

Turn over

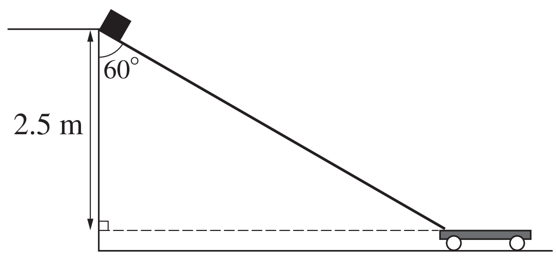
6 Small parcels are being loaded onto a trolley. Initially the parcels are 2.5 m above the trolley.

(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]**

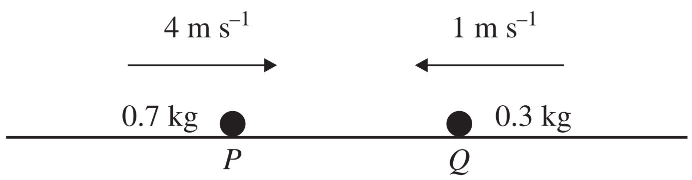
(b) the speed of a parcel when it strikes the trolley. **[2]**

(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]**