Answer **all** questions.

1 A hot air balloon is at rest on the ground. When the balloon is released, it rises to a height of 320 metres in 80 seconds. The balloon moves under the action of its weight and a vertical lift force. Assume that the balloon has a constant acceleration during this motion.

(a) Show that the acceleration of the balloon is $0.1\ \mathrm{m\,s^{-2}}$. *(3 marks)*

(b) Find the speed of the balloon when it reaches a height of 320 metres. *(2 marks)*

(c) The mass of the balloon is 450 kg. Show that the magnitude of the vertical lift force is 4500 N, correct to two significant figures. *(3 marks)*

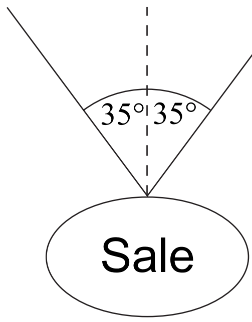
(d) After a while, the vertical lift force is reduced so that the balloon rises at a constant speed. State the magnitude of the vertical lift force when this is the case. *(1 mark)*

2 Two particles, A and B, are moving on a smooth horizontal surface. Particle A has mass 2 kg and velocity $\begin{bmatrix} 3 \\ -2 \end{bmatrix}\ \mathrm{m\,s^{-1}}$. Particle B has mass 3 kg and velocity $\begin{bmatrix} -4 \\ 1 \end{bmatrix}\ \mathrm{m\,s^{-1}}$. The two particles collide, and they coalesce during the collision.

(a) Find the velocity of the combined particles after the collision. *(3 marks)*

(b) Find the speed of the combined particles after the collision. *(2 marks)*

3 A sign, of mass 2 kg, is suspended from the ceiling of a supermarket by two light strings. It hangs in equilibrium with each string making an angle of 35° to the vertical, as shown in the diagram. Model the sign as a particle.



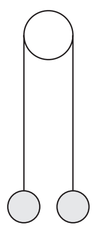
(a) By resolving forces horizontally, show that the tension is the same in each string. *(2 marks)*

(b) Find the tension in each string. *(5 marks)*

(c) If the tension in a string exceeds 40 N, the string will break.

Find the mass of the heaviest sign that could be suspended as shown in the diagram. *(3 marks)*

4 Two particles, of masses 3.45 kg and 1.45 kg, are connected by a light string that passes over a smooth peg. The particles are released from rest with the strings vertical, as shown in the diagram.



(a) By forming an equation of motion for each particle, show that the magnitude of the acceleration of each particle is $4\,\text{m}\,\text{s}^{-2}$. *(5 marks)*

(b) Find the tension in the string. *(2 marks)*

(c) Initially the particles are at the same level.

Find the speed of the heavier particle when it is 1 metre lower than the lighter particle. Assume that neither particle hits the floor or the peg. *(3 marks)*

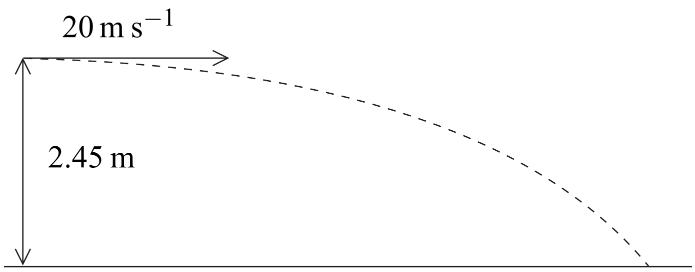
Turn over for the next question

5 An aeroplane flies in air that is moving due east at a speed of $V\,\mathrm{m\,s^{-1}}$. The velocity of the aeroplane relative to the air is $150\,\mathrm{m\,s^{-1}}$ due north. The aeroplane actually travels on a bearing of 030°.

(a) Show that $V = 86.6\,\mathrm{m\,s^{-1}}$, correct to three significant figures. *(2 marks)*

(b) Find the magnitude of the resultant velocity of the aeroplane. *(3 marks)*

6 A tennis ball is hit from a height of 2.45 metres above horizontal ground. Initially it travels horizontally at a speed of $20\,\mathrm{m\,s^{-1}}$, as shown in the diagram.



(a) Show that the time taken for the tennis ball to reach the ground is 0.707 seconds, correct to three significant figures. *(3 marks)*

(b) Find the horizontal distance travelled by the ball when it hits the ground. *(2 marks)*

(c) Find the angle between the velocity of the ball and the horizontal when the ball hits the ground. *(4 marks)*

7 A boat is initially at the origin, heading due east at $5\,\mathrm{m\,s^{-1}}$. It then experiences a constant acceleration of $(-0.2\mathbf{i} + 0.25\mathbf{j})\,\mathrm{m\,s^{-2}}$. The unit vectors $\mathbf{i}$ and $\mathbf{j}$ are directed east and north respectively.

(a) State the initial velocity of the boat as a vector. *(1 mark)*

(b) Find an expression for the velocity of the boat t seconds after it has started to accelerate. *(2 marks)*

(c) Find the value of t when the boat is travelling due north. *(3 marks)*

(d) Find the bearing of the boat from the origin when the boat is travelling due north. *(6 marks)*

END OF QUESTIONS

Answer **all** questions.

1 A ball is released from rest at a height h metres above ground level. The ball hits the ground 1.5 seconds after it is released. Assume that the ball is a particle that does not experience any air resistance.

(a) Show that the speed of the ball is $14.7\,\mathrm{m\,s^{-1}}$ when it hits the ground. *(2 marks)*

(b) Find h. *(2 marks)*

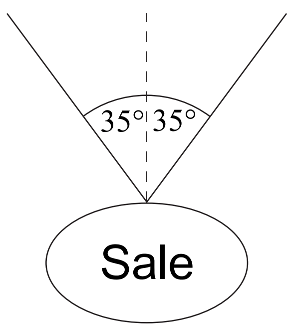
(c) Find the distance that the ball has fallen when its speed is $5\,\mathrm{m\,s^{-1}}$. *(3 marks)*

2 Two particles, A and B, are moving on a smooth horizontal surface. Particle A has mass 2 kg and velocity $\begin{bmatrix} 3 \\ -2 \end{bmatrix}\mathrm{m\,s^{-1}}$. Particle B has mass 3 kg and velocity $\begin{bmatrix} -4 \\ 1 \end{bmatrix}\mathrm{m\,s^{-1}}$. The two particles collide, and they coalesce during the collision.

(a) Find the velocity of the combined particles after the collision. *(3 marks)*

(b) Find the speed of the combined particles after the collision. *(2 marks)*

3 A sign, of mass 2 kg, is suspended from the ceiling of a supermarket by two light strings. It hangs in equilibrium with each string making an angle of 35° to the vertical, as shown in the diagram. Model the sign as a particle.

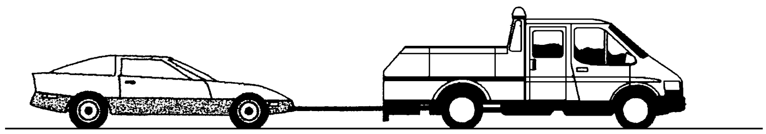


(a) By resolving forces horizontally, show that the tension is the same in each string. *(2 marks)*

(b) Find the tension in each string. *(5 marks)*

(c) If the tension in a string exceeds 40 N, the string will break. Find the mass of the heaviest sign that could be suspended as shown in the diagram. *(3 marks)*

4 A car, of mass 1200 kg, is connected by a tow rope to a truck, of mass 2800 kg. The truck tows the car in a straight line along a horizontal road. Assume that the tow rope is horizontal. A horizontal driving force of magnitude 3000 N acts on the truck. A horizontal resistance force of magnitude 800 N acts on the car. The car and truck accelerate at $0.4\,\mathrm{m\,s^{-2}}$.



(a) Find the tension in the tow rope. *(3 marks)*

(b) Show that the magnitude of the horizontal resistance force acting on the truck is 600 N. *(4 marks)*

(c) In fact, the tow rope is **not** horizontal. Assume that the resistance forces and the driving force are unchanged.

Is the tension in the tow rope greater or less than in part (a)?

Explain why. *(2 marks)*

5 An aeroplane flies in air that is moving due east at a speed of $V\,\mathrm{m\,s^{-1}}$. The velocity of the aeroplane relative to the air is $150\,\mathrm{m\,s^{-1}}$ due north. The aeroplane actually travels on a bearing of 030°.

(a) Show that $V = 86.6\,\mathrm{m\,s^{-1}}$, correct to three significant figures. *(2 marks)*

(b) Find the magnitude of the resultant velocity of the aeroplane. *(3 marks)*

Turn over for the next question

6 A box, of mass 3 kg, is placed on a slope inclined at an angle of 30° to the horizontal. The box slides down the slope. Assume that air resistance can be ignored.

(a) A simple model assumes that the slope is smooth.

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

(ii) Show that the acceleration of the box is $4.9\,\mathrm{m\,s^{-2}}$. *(2 marks)*

(b) A revised model assumes that the slope is rough. The box slides down the slope from rest, travelling 5 metres in 2 seconds.

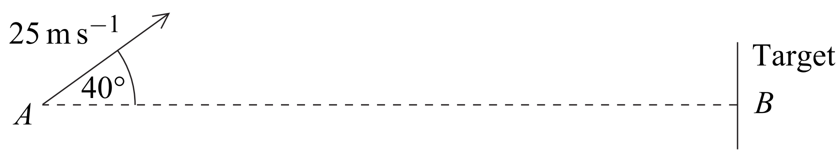
(i) Show that the acceleration of the box is $2.5\,\mathrm{m\,s^{-2}}$. *(2 marks)*

(ii) Find the magnitude of the friction force acting on the box. *(3 marks)*

(iii) Find the coefficient of friction between the box and the slope. *(5 marks)*

(iv) In reality, air resistance affects the motion of the box. Explain how its acceleration would change if you took this into account. *(2 marks)*

7 An arrow is fired from a point A with a velocity of $25\,\mathrm{m\,s^{-1}}$, at an angle of 40° above the horizontal. The arrow hits a target at the point B which is at the same level as the point A, as shown in the diagram.



(a) State **two** assumptions that you should make in order to model the motion of the arrow. *(2 marks)*

(b) Show that the time that it takes for the arrow to travel from A to B is 3.28 seconds, correct to three significant figures. *(4 marks)*

(c) Find the distance between the points A and B. *(2 marks)*

(d) State the magnitude and direction of the velocity of the arrow when it hits the target. *(2 marks)*

(e) Find the minimum speed of the arrow during its flight. *(2 marks)*

8 A boat is initially at the origin, heading due east at $5\,\text{m}\,\text{s}^{-1}$. It then experiences a constant acceleration of $(-0.2\mathbf{i} + 0.25\mathbf{j})\,\text{m}\,\text{s}^{-2}$. The unit vectors $\mathbf{i}$ and $\mathbf{j}$ are directed east and north respectively.

(a) State the initial velocity of the boat as a vector. *(1 mark)*

(b) Find an expression for the velocity of the boat t seconds after it has started to accelerate. *(2 marks)*

(c) Find the value of t when the boat is travelling due north. *(3 marks)*

(d) Find the bearing of the boat from the origin when the boat is travelling due north. *(6 marks)*

END OF QUESTIONS

Practice 3

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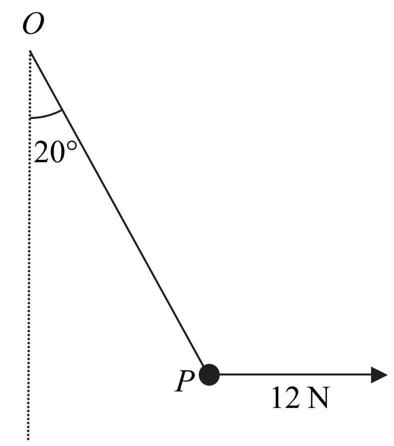
1. **Figure 1**



A particle P is attached to one end of a light inextensible string. The other end of the string is attached to a fixed point O. A horizontal force of magnitude 12 N is applied to P. The particle P is in equilibrium with the string taut and OP making an angle of 20° with the downward vertical, as shown in Figure 1.

Find

(a) the tension in the string,

(3)

(b) the weight of P.

(4)

Leave blank

2. Two particles A and B, of mass 0.3 kg and m kg respectively, are moving in opposite directions along the same straight horizontal line so that the particles collide directly. Immediately before the collision, the speeds of A and B are 8 m s^{-1} and 4 m s^{-1} respectively. In the collision the direction of motion of each particle is reversed and, immediately after the collision, the speed of each particle is 2 m s^{-1}. Find

(a) the magnitude of the impulse exerted by B on A in the collision,

(3)

(b) the value of m.

(4)

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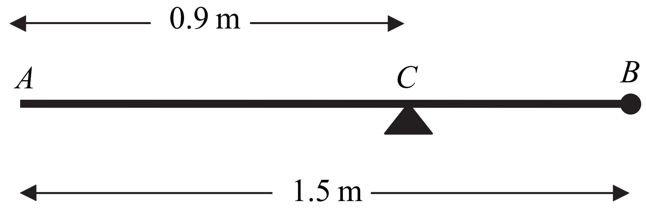
3.

Figure 2



A uniform rod AB has length 1.5 m and mass 8 kg. A particle of mass m kg is attached to the rod at B. The rod is supported at the point C, where $AC = 0.9$ m, and the system is in equilibrium with AB horizontal, as shown in Figure 2.

(a) Show that $m = 2$.

(4)

A particle of mass 5 kg is now attached to the rod at A and the support is moved from C to a point D of the rod. The system, including both particles, is again in equilibrium with AB horizontal.

(b) Find the distance AD.

(5)

Leave blank

4. A car is moving along a straight horizontal road. At time $t = 0$, the car passes a point A with speed 25 m s^{-1}. The car moves with constant speed 25 m s^{-1} until $t = 10$ s. The car then decelerates uniformly for 8 s. At time $t = 18$ s, the speed of the car is V m s^{-1} and this speed is maintained until the car reaches the point B at time $t = 30$ s.

(a) Sketch, in the space below, a speed–time graph to show the motion of the car from A to B.
(3)

Given that $AB = 526$ m, find

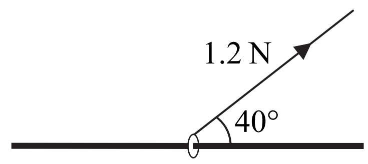
(b) the value of V,
(5)

(c) the deceleration of the car between $t = 10$ s and $t = 18$ s.
(3)

Leave blank

5.

Figure 3



A small ring of mass 0.25 kg is threaded on a fixed rough horizontal rod. The ring is pulled upwards by a light string which makes an angle 40° with the horizontal, as shown in Figure 3. The string and the rod are in the same vertical plane. The tension in the string is 1.2 N and the coefficient of friction between the ring and the rod is μ. Given that the ring is in limiting equilibrium, find

(a) the normal reaction between the ring and the rod,

(4)

(b) the value of μ.

(6)

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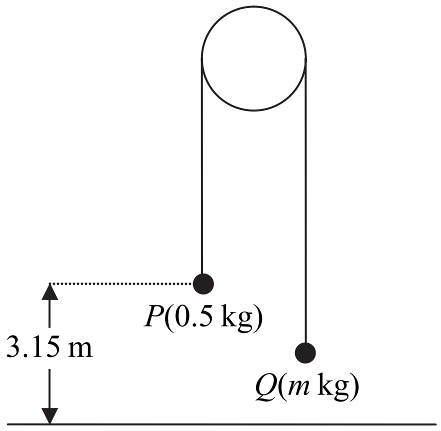
6.

Figure 4



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

(a) Show that the acceleration of P as it descends is 2.8 m s^{-2}.
(3)

(b) Find the tension in the string as P descends.
(3)

(c) Show that $m = \frac{5}{18}$.
(4)

(d) State how you have used the information that the string is inextensible.
(1)

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

(e) Find the time between the instant when P strikes the ground and the instant when the string becomes taut again.
(6)

Leave blank

7. A boat B is moving with constant velocity. At noon, B is at the point with position vector $(3\mathbf{i} - 4\mathbf{j})$ km with respect to a fixed origin O. At 1430 on the same day, B is at the point with position vector $(8\mathbf{i} + 11\mathbf{j})$ km.

(a) Find the velocity of B, giving your answer in the form $p\mathbf{i} + q\mathbf{j}$.
(3)

At time t hours after noon, the position vector of B is $\mathbf{b}$ km.

(b) Find, in terms of t, an expression for $\mathbf{b}$.
(3)

Another boat C is also moving with constant velocity. The position vector of C, $\mathbf{c}$ km, at time t hours after noon, is given by

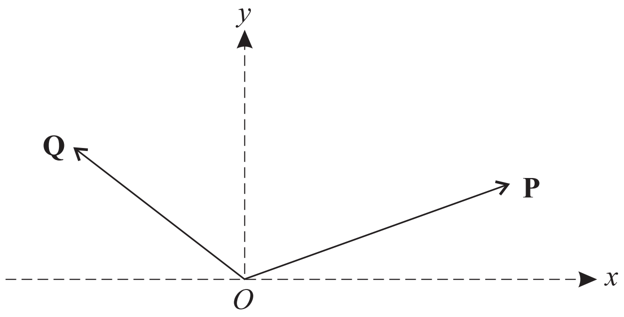
$$\mathbf{c} = (-9\mathbf{i} + 20\mathbf{j}) + t(6\mathbf{i} + \lambda\mathbf{j}),$$

where λ is a constant. Given that C intercepts B,

(c) find the value of λ,
(5)

(d) show that, before C intercepts B, the boats are moving with the same speed.
(3)

1

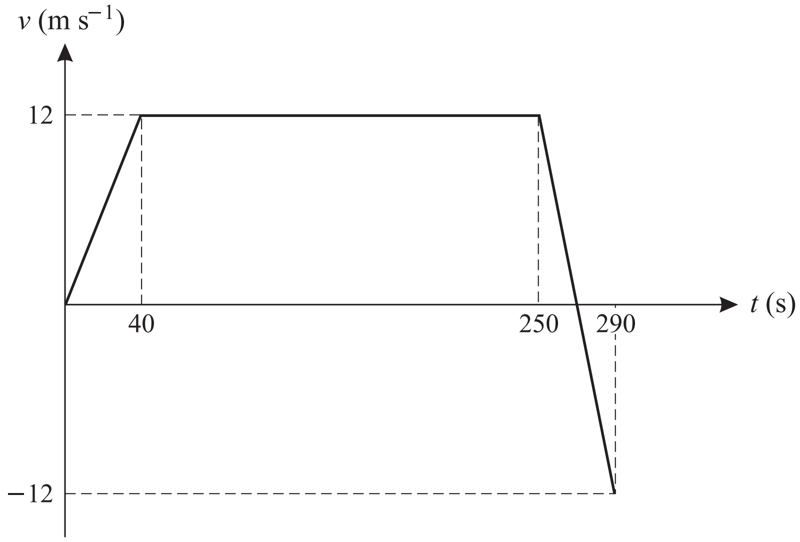


Two horizontal forces **P** and **Q** act at the origin O of rectangular coordinates Oxy (see diagram). The components of **P** in the x- and y-directions are 14 N and 5 N respectively. The components of **Q** in the x- and y-directions are −9 N and 7 N respectively.

(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



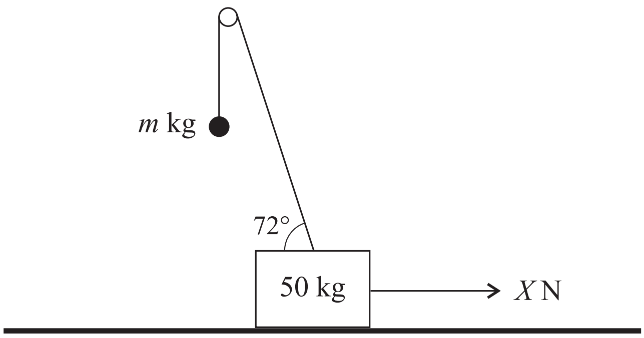
A particle starts from the point A and travels in a straight line. The diagram shows the (t, v) graph, consisting of three straight line segments, for the motion of the particle during the interval $0 \leqslant t \leqslant 290$.

(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.

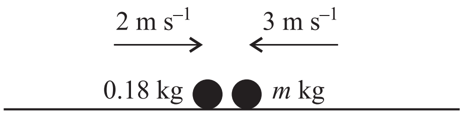
(i) By resolving forces on the block vertically, find a relationship between T and R. [2]

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 $2\,\text{m s}^{-1}$ 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]

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

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

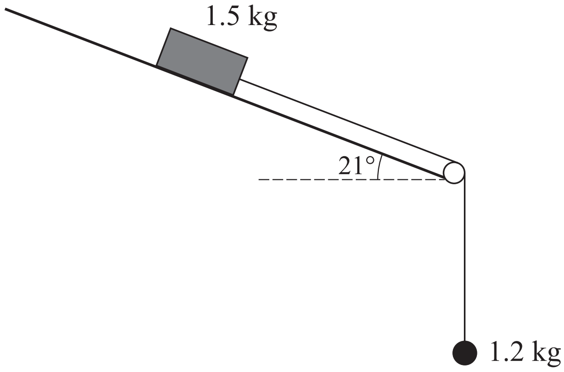
(i) Show that the velocity of the particle is $4\,\mathrm{m\,s^{-1}}$ when $t = 10$. [3]

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

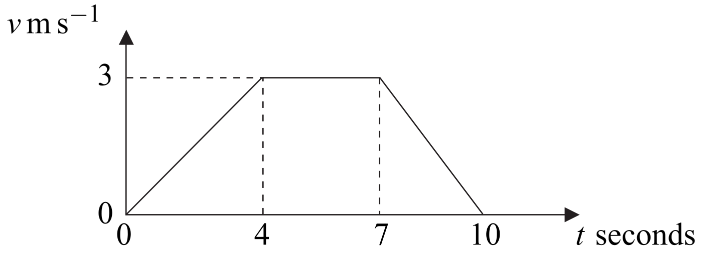
(iv) Given that the object is initially 2 m above a horizontal floor and that the block is 2.8 m from the pulley, find the speed of the block at the instant when

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

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

Answer **all** questions.

1 The diagram shows a velocity–time graph for a lift.

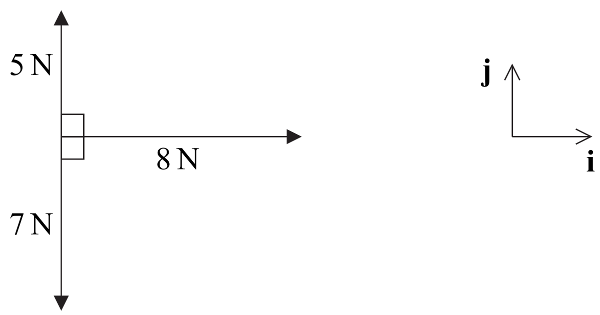


(a) Find the distance travelled by the lift. *(3 marks)*

(b) Find the acceleration of the lift during the first 4 seconds of the motion. *(1 mark)*

(c) The lift is raised by a single vertical cable. The mass of the lift is 400 kg. Find the tension in the cable during the first 4 seconds of the motion. *(3 marks)*

2 The diagram shows three forces and the perpendicular unit vectors **i** and **j**, which all lie in the same plane.



(a) Express the resultant of the three forces in terms of **i** and **j**. *(2 marks)*

(b) Find the magnitude of the resultant force. *(2 marks)*

(c) Draw a diagram to show the direction of the resultant force, and find the angle that it makes with the unit vector **i**. *(3 marks)*

3 Two particles, A and B, are connected by a light inextensible string, which passes over a smooth peg. Particle A is on a rough horizontal surface and has mass 3 kg. Particle B hangs freely, as shown in the diagram, and has mass 2 kg. The coefficient of friction between A and the horizontal surface is μ.

The particles are released from rest and move with a constant acceleration of magnitude $0.9\,\text{m s}^{-2}$.

(a) Find the tension in the string. *(3 marks)*

(b) Draw and label a diagram to show the forces acting on particle A. *(1 mark)*

(c) Calculate the magnitude of the normal reaction force acting on A. *(1 mark)*

(d) Find the magnitude of the friction force that acts on A. *(2 marks)*

(e) Find μ. *(2 marks)*

4 An aeroplane is travelling due north at $180\,\text{m s}^{-1}$ relative to the air. The air is moving north-west at $50\,\text{m s}^{-1}$.

(a) Find the magnitude of the resultant velocity of the aeroplane. *(4 marks)*

(b) Find the direction of the resultant velocity, giving your answer as a three-figure bearing to the nearest degree. *(4 marks)*

5 A ball is kicked so that it leaves a horizontal surface, at the point A, travelling at $16\,\text{m s}^{-1}$ and at an angle θ above the horizontal. The ball hits the surface again 2 seconds later, at the point B. Assume that the ball is a particle that moves only under the influence of gravity.

(a) Show that $\theta = 37.8°$, correct to three significant figures. *(3 marks)*

(b) Find the time for which the ball is more than 2 metres above the surface. *(5 marks)*

Turn over for the next question

6 The unit vectors **i** and **j** are directed east and north respectively. A helicopter moves horizontally with a constant acceleration of $(-0.4\mathbf{i} + 0.5\mathbf{j})\,\mathrm{m\,s^{-2}}$. At time $t = 0$, the helicopter is at the origin and has velocity $20\mathbf{i}\,\mathrm{m\,s^{-1}}$.

(a) Write down an expression for the velocity of the helicopter at time t seconds. *(2 marks)*

(b) Find the time when the helicopter is travelling due north. *(3 marks)*

(c) Find an expression for the position vector of the helicopter at time t seconds. *(2 marks)*

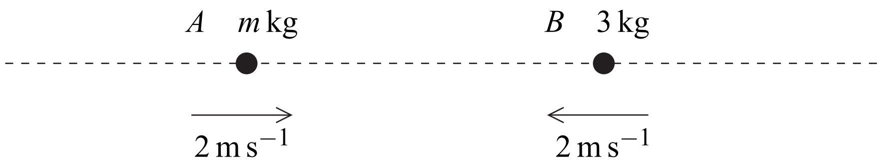
(d) When $t = 100$:

(i) show that the helicopter is due north of the origin; *(3 marks)*

(ii) find the speed of the helicopter. *(3 marks)*

7 Two particles, A and B, are travelling towards each other along a straight horizontal line.

Particle A has velocity $2\,\mathrm{m\,s^{-1}}$ and mass m kg.
Particle B has velocity $-2\,\mathrm{m\,s^{-1}}$ and mass 3 kg.



The particles collide.

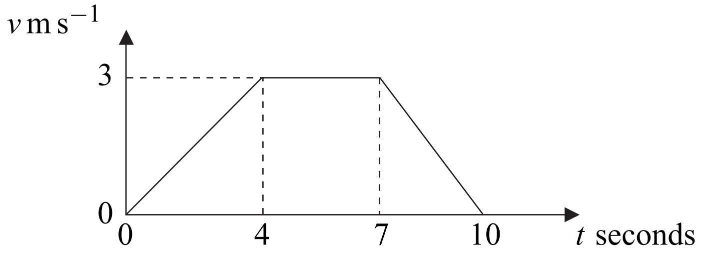
(a) If the particles move in opposite directions after the collision, each with speed $0.5\,\mathrm{m\,s^{-1}}$, find the value of m. *(3 marks)*

(b) If the particles coalesce during the collision, forming a single particle which moves with speed $0.5\,\mathrm{m\,s^{-1}}$, find the two possible values of m. *(5 marks)*

END OF QUESTIONS

Answer **all** questions.

1 The diagram shows a velocity–time graph for a lift.

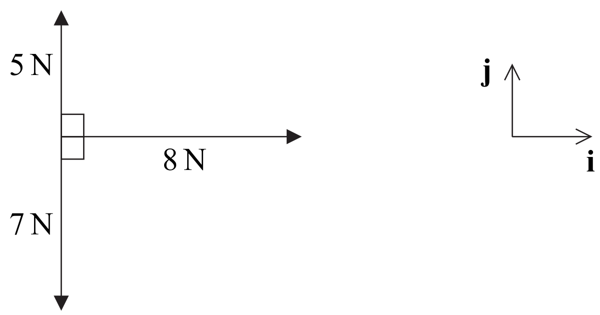


(a) Find the distance travelled by the lift. *(3 marks)*

(b) Find the acceleration of the lift during the first 4 seconds of the motion. *(1 mark)*

(c) The lift is raised by a single vertical cable. The mass of the lift is 400 kg. Find the tension in the cable during the first 4 seconds of the motion. *(3 marks)*

2 The diagram shows three forces and the perpendicular unit vectors **i** and **j**, which all lie in the same plane.

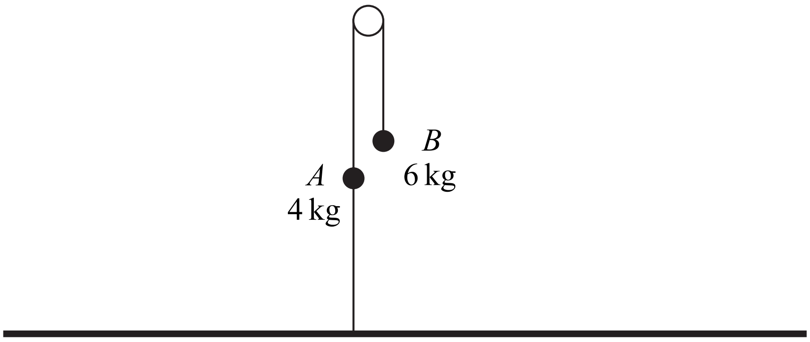


(a) Express the resultant of the three forces in terms of **i** and **j**. *(2 marks)*

(b) Find the magnitude of the resultant force. *(2 marks)*

(c) Draw a diagram to show the direction of the resultant force, and find the angle that it makes with the unit vector **i**. *(3 marks)*

3 Two particles, A and B, have masses 4 kg and 6 kg respectively. They are connected by a light inextensible string that passes over a smooth fixed peg. A second light inextensible string is attached to A. The other end of this string is attached to the ground directly below A. The system remains at rest, as shown in the diagram.



(a) (i) Write down the tension in the string connecting A and B. *(1 mark)*

(ii) Find the tension in the string connecting A to the ground. *(3 marks)*

(b) The string connecting particle A to the ground is cut. Find the acceleration of A after the string has been cut. *(5 marks)*

4 An aeroplane is travelling due north at $180\,\mathrm{m\,s^{-1}}$ relative to the air. The air is moving north-west at $50\,\mathrm{m\,s^{-1}}$.

(a) Find the magnitude of the resultant velocity of the aeroplane. *(4 marks)*

(b) Find the direction of the resultant velocity, giving your answer as a three-figure bearing to the nearest degree. *(4 marks)*

5 The unit vectors $\mathbf{i}$ and $\mathbf{j}$ are directed east and north respectively. A helicopter moves horizontally with a constant acceleration of $(-0.4\mathbf{i} + 0.5\mathbf{j})\,\mathrm{m\,s^{-2}}$. At time $t = 0$, the helicopter is at the origin and has velocity $20\mathbf{i}\,\mathrm{m\,s^{-1}}$.

(a) Write down an expression for the velocity of the helicopter at time t seconds. *(2 marks)*

(b) Find the time when the helicopter is travelling due north. *(3 marks)*

(c) Find an expression for the position vector of the helicopter at time t seconds. *(2 marks)*

(d) When $t = 100$:

(i) show that the helicopter is due north of the origin; *(3 marks)*

(ii) find the speed of the helicopter. *(3 marks)*

6 A block, of mass 5 kg, slides down a rough plane inclined at 40° to the horizontal. When modelling the motion of the block, assume that there is no air resistance acting on it.

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

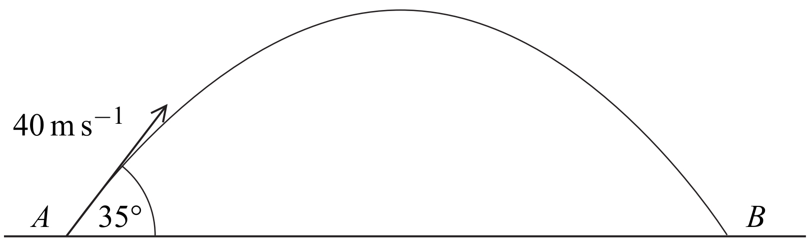
(b) Show that the magnitude of the normal reaction force acting on the block is 37.5 N, correct to three significant figures. *(2 marks)*

(c) Given that the acceleration of the block is $0.8\,\mathrm{m\,s^{-2}}$, find the coefficient of friction between the block and the plane. *(6 marks)*

(d) In reality, air resistance does act on the block. State how this would change your value for the coefficient of friction and explain why. *(2 marks)*

7 A ball is hit by a bat so that, when it leaves the bat, its velocity is $40\,\mathrm{m\,s^{-1}}$ at an angle of 35° above the horizontal. Assume that the ball is a particle and that its weight is the only force that acts on the ball after it has left the bat.

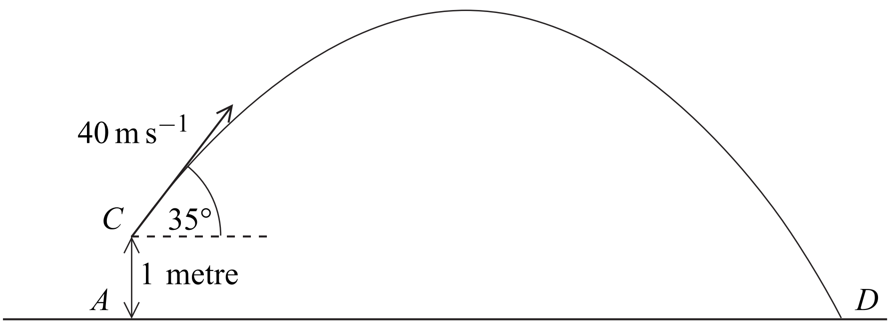
(a) A simple model assumes that the ball is hit from the point *A* and lands for the first time at the point *B*, which is at the same level as *A*, as shown in the diagram.



(i) Show that the time that it takes for the ball to travel from *A* to *B* is 4.68 seconds, correct to three significant figures. *(4 marks)*

(ii) Find the horizontal distance from *A* to *B*. *(2 marks)*

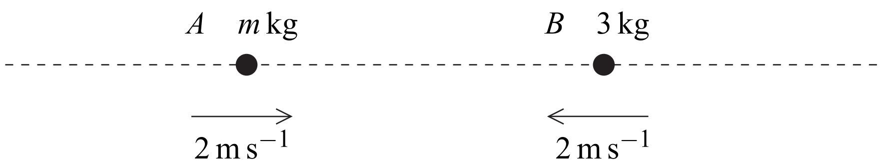
(b) A revised model assumes that the ball is hit from the point *C*, which is 1 metre above *A*. The ball lands at the point *D*, which is at the same level as *A*, as shown in the diagram.



Find the time that it takes for the ball to travel from *C* to *D*. *(6 marks)*

8 Two particles, A and B, are travelling towards each other along a straight horizontal line.

Particle A has velocity $2\,\mathrm{m\,s^{-1}}$ and mass m kg.
Particle B has velocity $-2\,\mathrm{m\,s^{-1}}$ and mass 3 kg.



The particles collide.

(a) If the particles move in opposite directions after the collision, each with speed $0.5\,\mathrm{m\,s^{-1}}$, find the value of m. *(3 marks)*

(b) If the particles coalesce during the collision, forming a single particle which moves with speed $0.5\,\mathrm{m\,s^{-1}}$, find the two possible values of m. *(5 marks)*

END OF QUESTIONS

Practice 7

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1. Two particles P and Q have mass 0.4 kg and 0.6 kg respectively. The particles are initially at rest on a smooth horizontal table. Particle P is given an impulse of magnitude 3 N s in the direction PQ.

(a) Find the speed of P immediately before it collides with Q.

(3)

Immediately after the collision between P and Q, the speed of Q is 5 m s^{-1}.

(b) Show that immediately after the collision P is at rest.

(3)

Leave blank

2. At time $t = 0$, a particle is projected vertically upwards with speed u m s^{-1} from a point 10 m above the ground. At time T seconds, the particle hits the ground with speed 17.5 m s^{-1} . Find

(a) the value of u,

(3)

(b) the value of T.

(4)

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

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

(2)

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

(3)

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

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

(3)

Leave blank

4. A car is moving along a straight horizontal road. The speed of the car as it passes the point *A* is 25 m s^{-1} and the car maintains this speed for 30 s. The car then decelerates uniformly to a speed of 10 m s^{-1}. The speed of 10 m s^{-1} is then maintained until the car passes the point *B*. The time taken to travel from *A* to *B* is 90 s and *AB* = 1410 m.

(a) Sketch, in the space below, a speed-time graph to show the motion of the car from *A* to *B*.

(2)

(b) Calculate the deceleration of the car as it decelerates from 25 m s^{-1} to 10 m s^{-1}.

(7)

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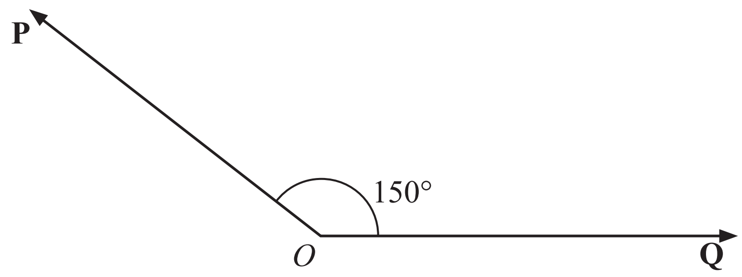

Figure 1

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

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

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

(4)

(b) the value of X.

(5)

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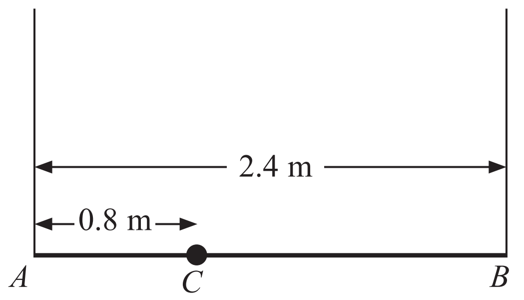

Figure 2

A plank AB has mass 12 kg and length 2.4 m. A load of mass 8 kg is attached to the plank at the point C, where $AC = 0.8$ m. The loaded plank is held in equilibrium, with AB horizontal, by two vertical ropes, one attached at A and the other attached at B, as shown in Figure 2. The plank is modelled as a uniform rod, the load as a particle and the ropes as light inextensible strings.

(a) Find the tension in the rope attached at B.

(4)

The plank is now modelled as a non-uniform rod. With the new model, the tension in the rope attached at A is 10 N greater than the tension in the rope attached at B.

(b) Find the distance of the centre of mass of the plank from A.

(6)

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7.

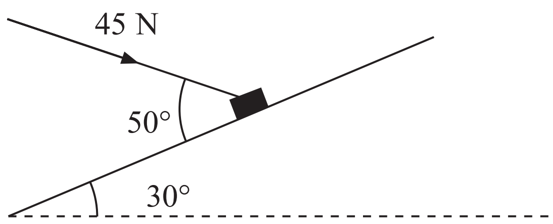

Figure 3

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

(a) the magnitude of the normal reaction of the plane on the package,
(5)

(b) the coefficient of friction between the plane and the package.
(6)

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8.

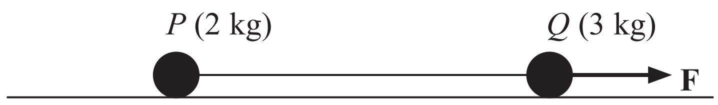

Figure 4

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

(a) the acceleration of Q,
(2)

(b) the value of μ,
(4)

(c) the tension in the string.
(4)

(d) State how in your calculation you have used the information that the string is inextensible.
(1)

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

(e) Find the time between the instant that the force is removed and the instant that Q comes to rest.
(4)