CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Units 2 & 3: Kinematics, Dynamics and Linear Momentum

Past Papers 2021 – 2025

QUESTION PAPER 46 Questions

Prepared by

Waseem Ahmad

A Level Physics Teacher

Author of ***Practical Mastery: Cambridge 9702 Paper 3***

www.examspath.com

Question 1

(a) Complete Table 1.1 by stating whether each of the quantities is a vector or a scalar.

Table 1.1

quantity	vector or scalar
acceleration	
power	
work	

(b) The variation with time *t* of the velocity *v* of an object is shown in Fig. 1.1.

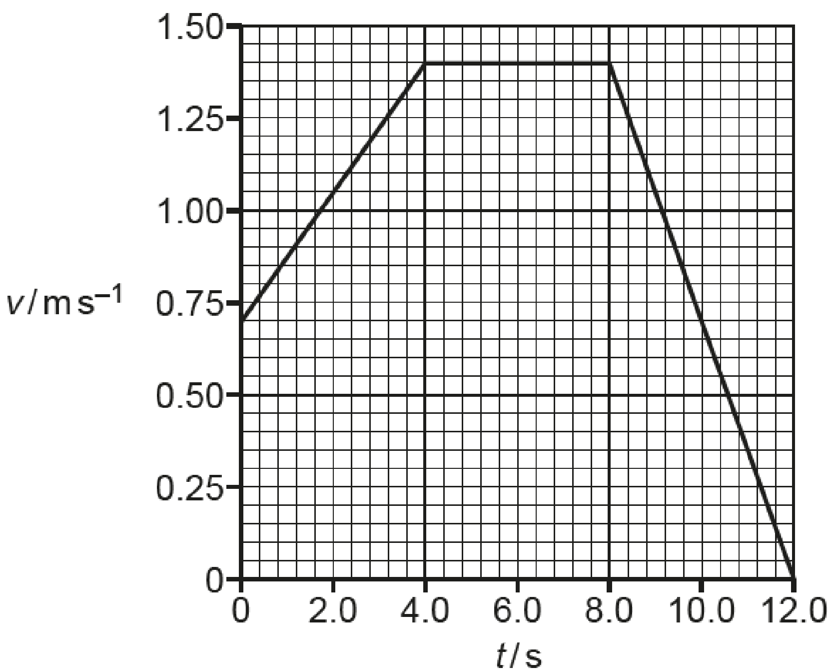


Fig. 1.1

(i) Determine the acceleration of the object from time $t = 0$ to time $t = 4.0\,\text{s}$.

acceleration = ... $m\,s^{-2}$ [2]

(ii) Determine the distance moved by the object from time $t = 0$ to time $t = 4.0\,s$.

distance = ... m [2]

(c) **(i)** Define *force*.

....

.... [1]

(ii) The motion represented in Fig. 1.1 is caused by a resultant force F acting on the object.

On Fig. 1.2, sketch the variation of F with time t from $t = 0$ to $t = 12.0\,s$.
Numerical values of F are not required.

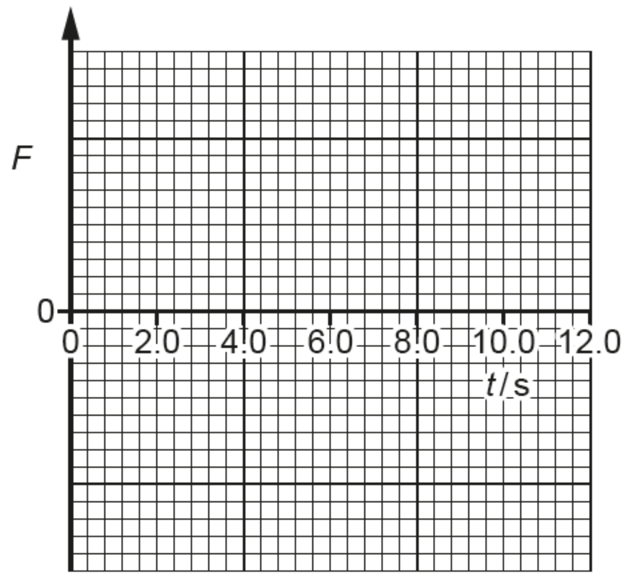


Fig. 1.2

[3]

[Total: 10]

Question 2

A ball is thrown vertically downwards to the ground, as illustrated in Fig. 2.1.

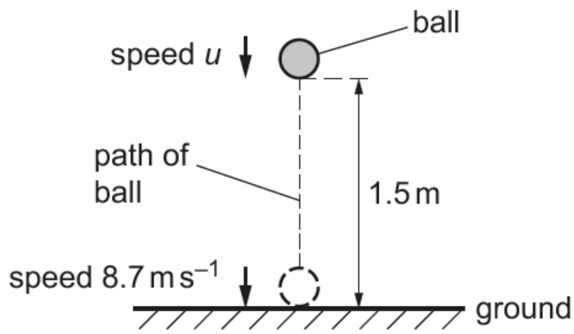


Fig. 2.1

The ball is thrown with speed u from a height of 1.5 m. The ball then hits the ground with speed 8.7 m s^{-1}. Assume that air resistance is negligible.

(a) Calculate speed u.

u = ... m s^{-1} [2]

(b) State how Newton's third law applies to the collision between the ball and the ground.

....

....

....

.... [2]

(c) The ball is in contact with the ground for a time of 0.091 s. The ball rebounds vertically and leaves the ground with speed 5.4 m s^{-1}. The mass of the ball is 0.059 kg.

(i) Calculate the magnitude of the change in momentum of the ball during the collision.

change in momentum = ... N s [2]

(ii) Determine the magnitude of the average resultant force that acts on the ball during the collision.

average resultant force = ... N [1]

(iii) Use your answer in **(c)(ii)** to calculate the magnitude of the average force exerted by the ground on the ball during the collision.

average force = ... N [2]

(d) The ball was thrown downwards at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the speed of the ball with time t from $t = 0$ to $t = T$. Numerical values are not required.

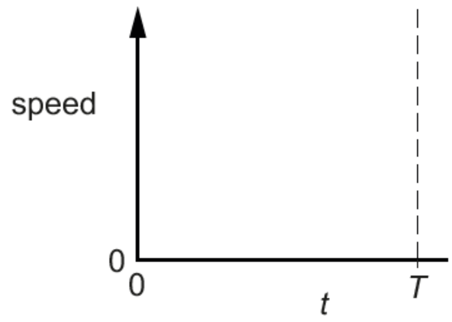


Fig. 2.2

[1]

(e) In practice, air resistance is not negligible.

State and explain the variation, if any, with time t of the gradient of the graph in **(d)** when air resistance is not negligible.

....

....

....

.... [2]

[Total: 12]

Question 3

(a) Define *acceleration*.

....

.... [1]

(b) A stone falls vertically from the top of a cliff. Fig. 2.1 shows the variation with time t of the velocity v of the stone.

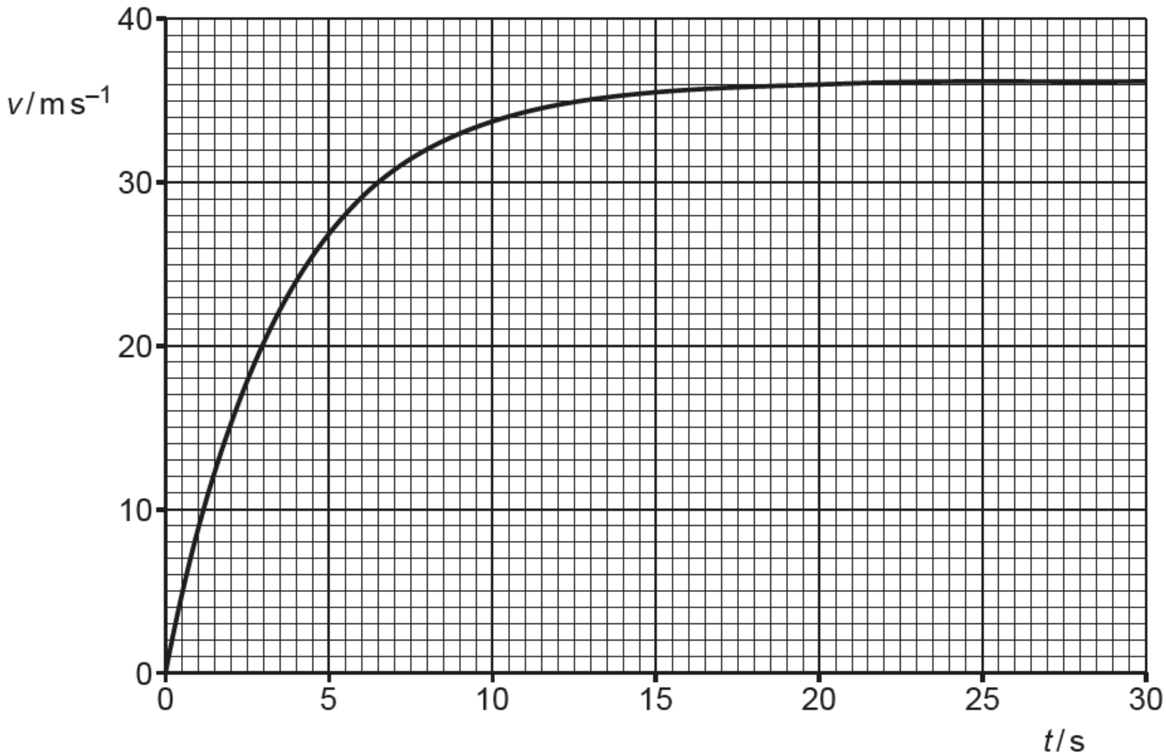


Fig. 2.1

(i) Explain, with reference to forces acting on the stone, the shape of the curve in Fig. 2.1.

....

....

....

....

.... [3]

(ii) Use Fig. 2.1 to determine the speed of the stone when the resultant force on it is zero.

speed = ... m s^{-1} [1]

Fig. 2.1

(i) Explain, with reference to forces acting on the stone, the shape of the curve in Fig. 2.1.

....

....

....

....

.... [3]

(ii) Use Fig. 2.1 to determine the speed of the stone when the resultant force on it is zero.

speed = ... $m\,s^{-1}$ [1]

(iii) Use Fig. 2.1 to calculate the approximate height through which the stone falls between $t = 0$ and $t = 30\,s$.

height = ... m [3]

(iv) On Fig. 2.2, sketch the variation with t of the acceleration a of the stone between $t = 0$ and $t = 30\,s$.

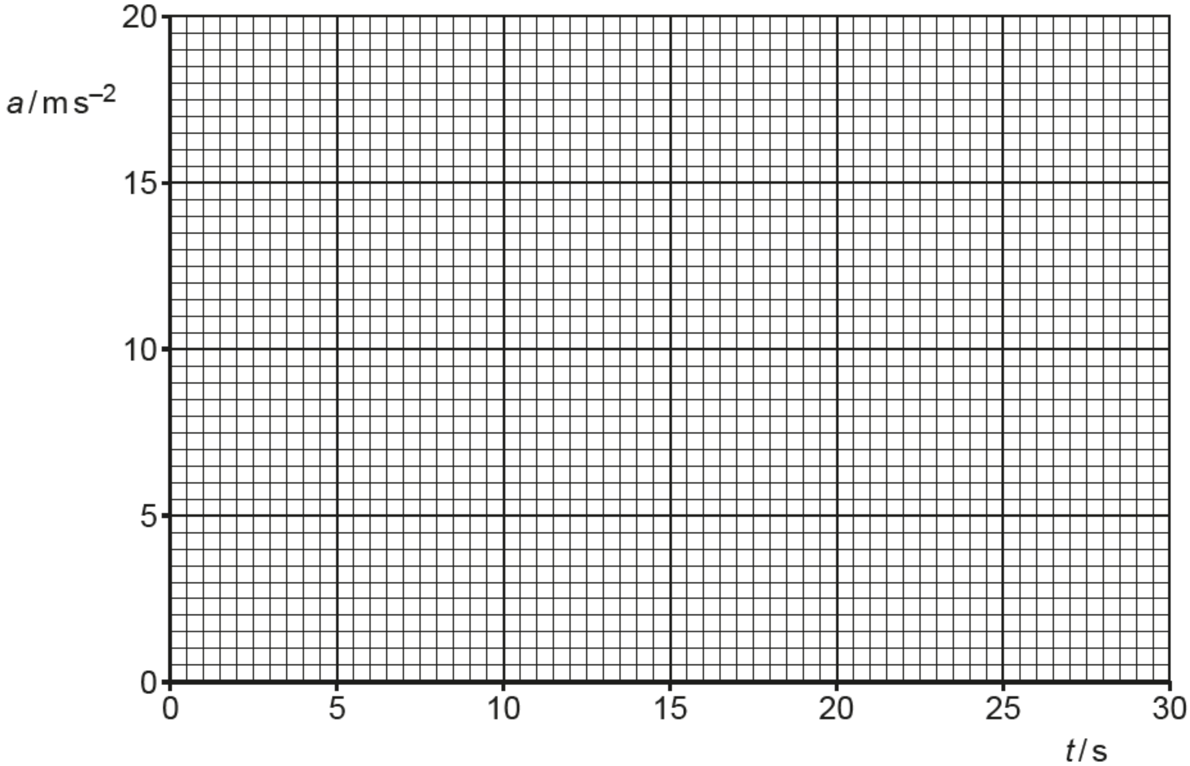


Fig. 2.2

[3]

[Total: 11]

Question 4

(a) Define *momentum*.

....

.... [1]

(b) Two balls X and Y, of equal diameter but different masses 0.24 kg and 0.12 kg respectively, slide towards each other on a frictionless horizontal surface, as shown in Fig. 2.1.

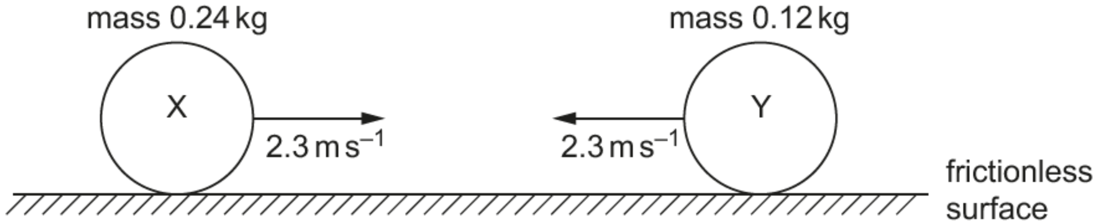


Fig. 2.1

Both balls have initial speed $2.3\,\text{m s}^{-1}$ before they collide with each other. Fig. 2.2 shows the variation with time t of the force F_Y exerted on ball Y by ball X during the collision.

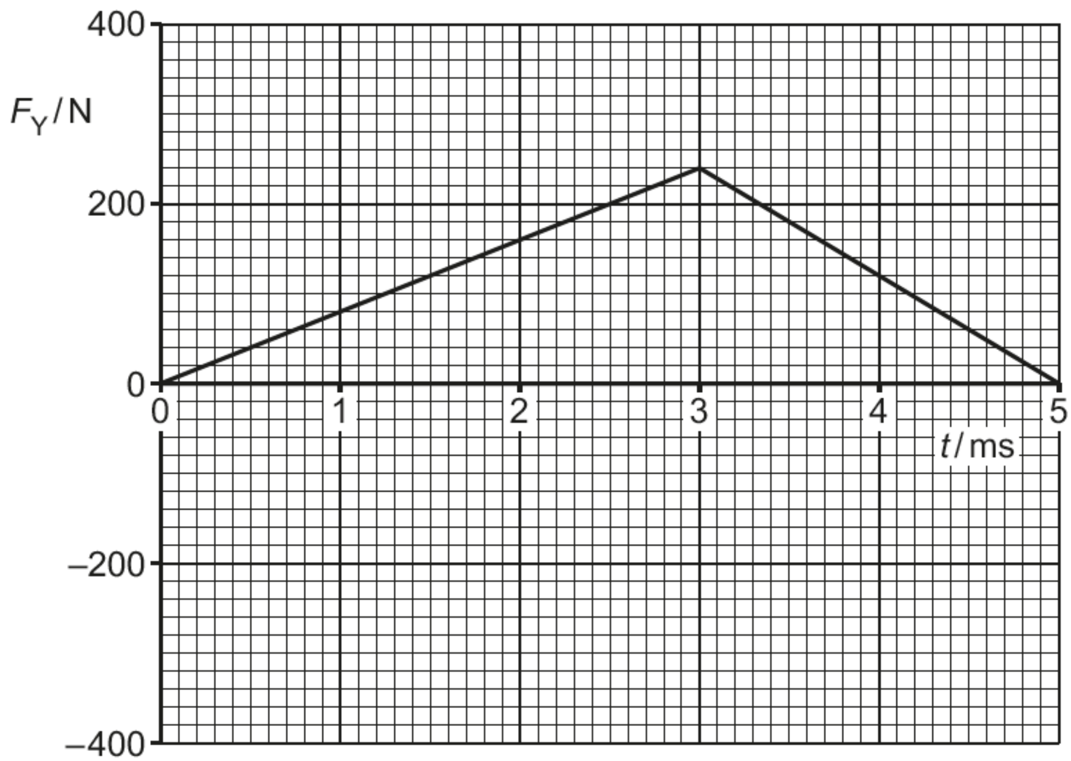


Fig. 2.2

(i) Calculate the kinetic energy of ball X before the collision.

kinetic energy = ... J [3]

(ii) The area enclosed by the lines and the time axis in Fig. 2.2 represents the change in momentum of ball Y during the collision.

Determine the magnitude of the change in momentum of ball Y.

change in momentum = ... N s [2]

(iii) Calculate the magnitude of the velocity of ball Y after the collision.

velocity = ... m s^{-1} [2]

(c) On Fig. 2.3, sketch the variation with time *t* of the force F_X exerted on ball X by ball Y during the collision in **(b)**.

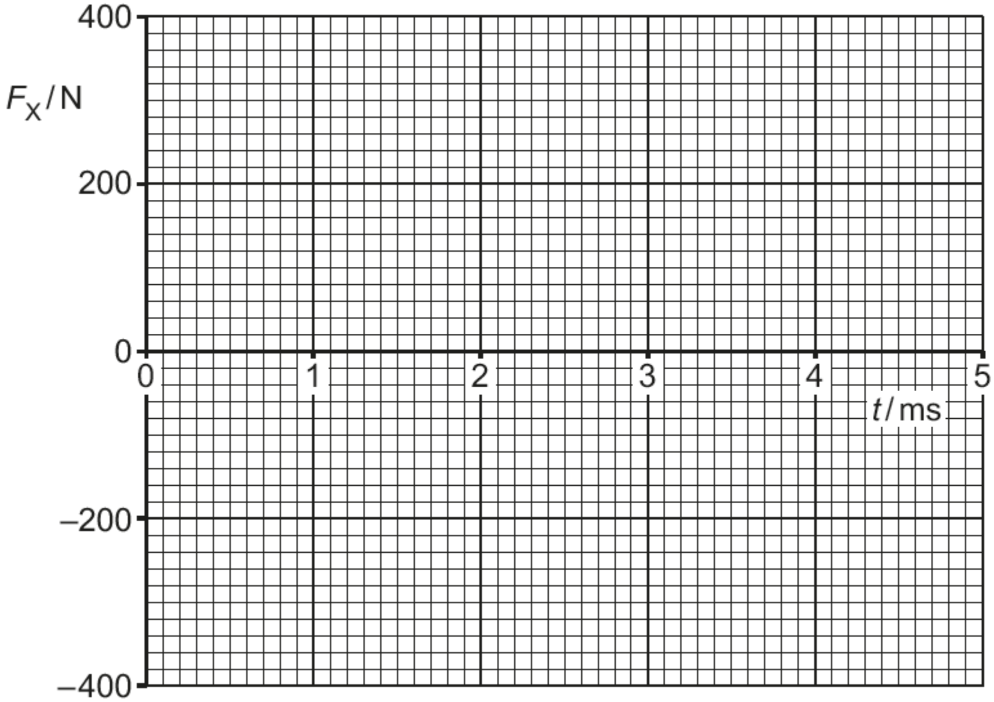


Fig. 2.3

[3]

[Total: 11]

Question 5

(a) Define *velocity*.

....

.... [1]

(b) A remote-controlled toy aircraft is flying horizontally in a wind. Fig. 3.1 shows the velocity vectors, to scale, of the wind and of the aircraft in still air.

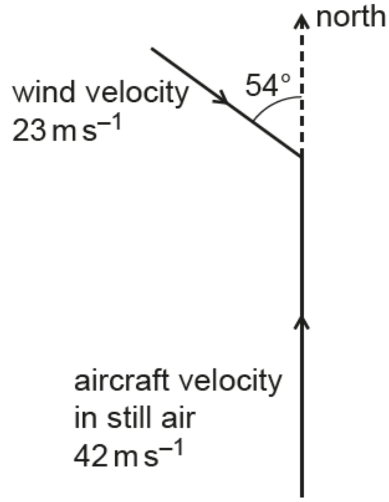


Fig. 3.1

The velocity of the aircraft in still air is $42\,\text{m}\,\text{s}^{-1}$ to the north. The velocity of the wind is $23\,\text{m}\,\text{s}^{-1}$ in a direction of 54° east of south.

Determine the magnitude of the resultant velocity of the aircraft.

magnitude of velocity = ... $\text{m}\,\text{s}^{-1}$ [2]

(c) The engine of the aircraft in **(b)** stops. The aircraft then glides towards the ground with a constant velocity at an angle θ to the horizontal, as illustrated in Fig. 3.2.

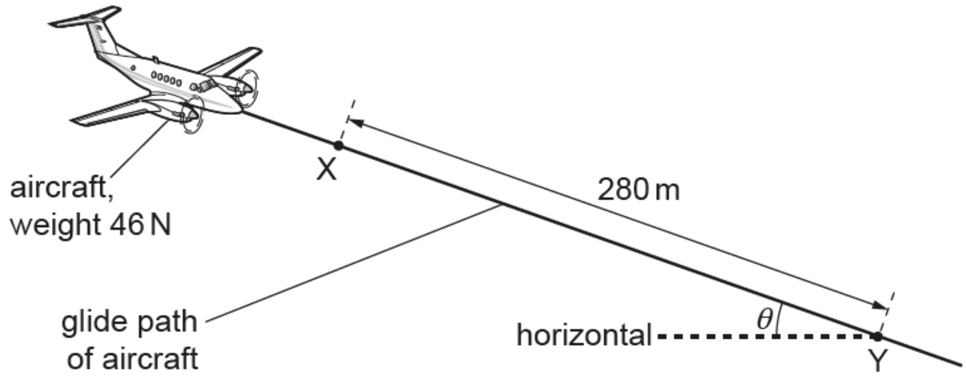


Fig. 3.2 (not to scale)

The aircraft has a weight of 46 N and travels a distance of 280 m from point X to point Y. The change in gravitational potential energy of the aircraft for its movement from X to Y is 6100 J.

Assume that there is now no wind.

(i) Calculate angle θ.

θ = ... ° [3]

(ii) Calculate the magnitude of the force acting on the aircraft due to air resistance.

force = ... N [2]

(d) The aircraft in **(c)** travels from X to Y in a time of 14 s. Fig. 3.3 shows that, as the aircraft travels from X to Y, it moves directly towards an observer who is standing on the ground.

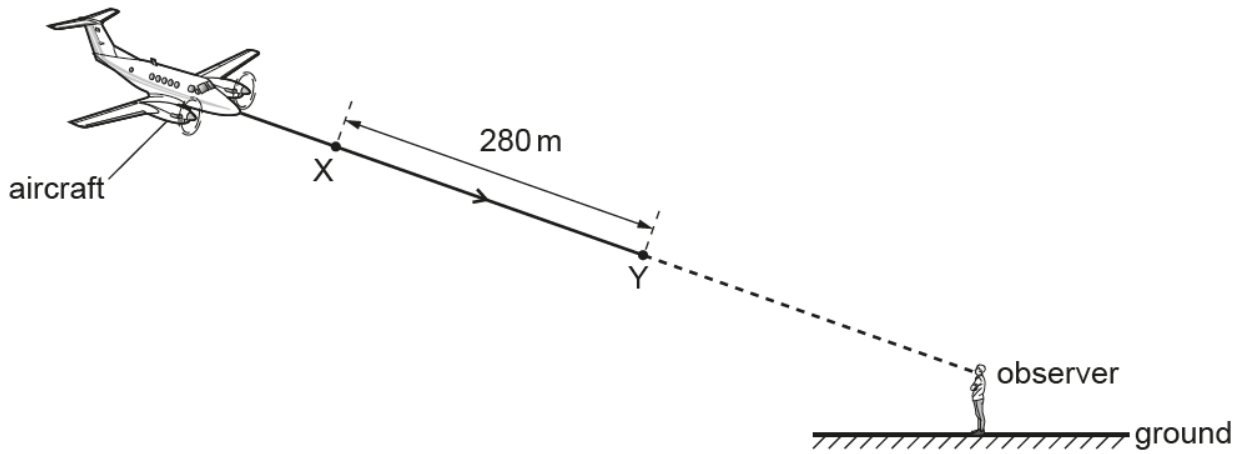


Fig. 3.3 (not to scale)

The aircraft emits sound as it travels from X to Y. The observer hears sound of frequency 450 Hz. The speed of the sound in the air is 340 m s^{-1}.

Calculate the frequency of the sound that is emitted by the aircraft.

frequency = ... Hz [3]

[Total: 11]

Question 6

Water leaves the end of a hose pipe at point P with a horizontal velocity of $6.6\,\mathrm{m\,s^{-1}}$, as shown in Fig. 2.1.

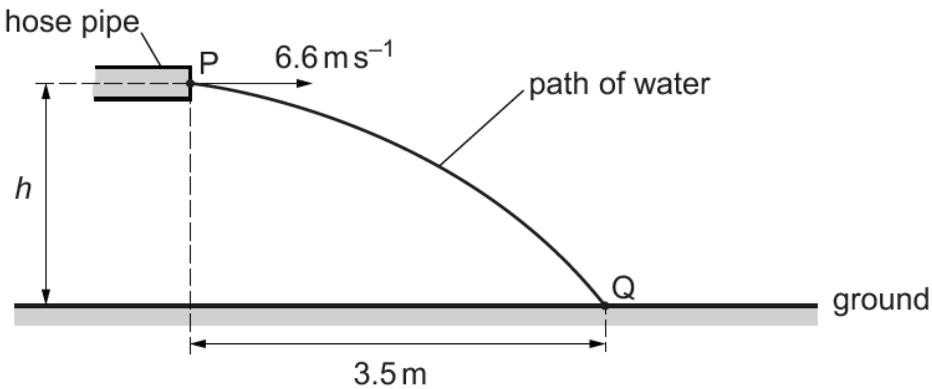


Fig. 2.1 (not to scale)

Point P is at height h above the ground. The water hits the ground at point Q. The horizontal distance from P to Q is 3.5 m.

Air resistance is negligible. Assume that the water between P and Q consists of non-interacting droplets of water and that the only force acting on each droplet is its weight.

(a) Explain, briefly, why the horizontal component of the velocity of a droplet of water remains constant as it moves from P to Q.

....

.... [1]

(b) Show that the time taken for a droplet of water to move from P to Q is 0.53 s.

[1]

(c) Calculate height h.

h = ... m [2]

(d) For the movement of a droplet of water from P to Q, state and explain whether the displacement of the droplet is less than, more than or the same as the distance along its path.

....

....

.... [1]

(e) Calculate the magnitude of the displacement of a droplet of water that moves from P to Q.

displacement = ... m [2]

[Total: 7]

(d) For the movement of a droplet of water from P to Q, state and explain whether the displacement of the droplet is less than, more than or the same as the distance along its path.

....

....

.... [1]

(e) Calculate the magnitude of the displacement of a droplet of water that moves from P to Q.

displacement = ... m [2]

[Total: 7]

Question 7

A jet of water hits a vertical wall at right angles, as shown in Fig. 3.1.

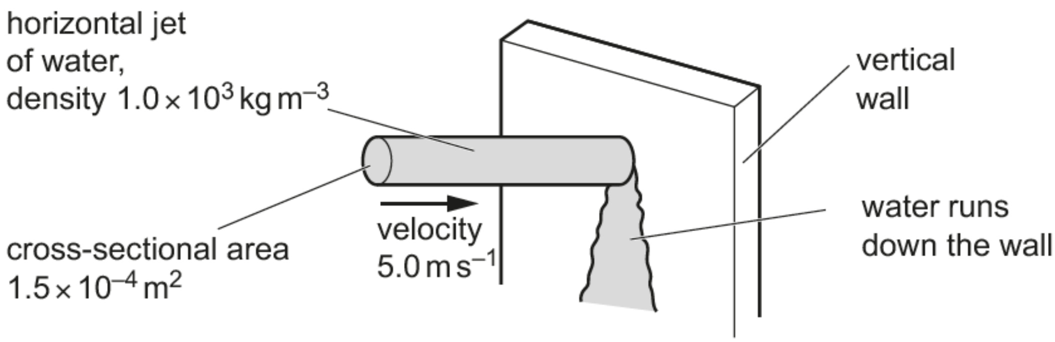


Fig. 3.1 (not to scale)

The water hits the vertical wall with a velocity of $5.0\,m\,s^{-1}$ in a horizontal direction. The cross-sectional area of the jet is $1.5 \times 10^{-4}\,m^2$. The density of the water is $1.0 \times 10^3\,kg\,m^{-3}$.

The water runs down the wall after hitting it.

(a) Show that, over a time of 1.6 s, the mass of water hitting the wall is 1.2 kg.

[2]

(b) Calculate:

(i) the decrease in the horizontal momentum of the mass of water in **(a)** due to hitting the wall

decrease in momentum = ... N s [1]

(ii) the magnitude of the horizontal force exerted on the water by the wall.

force = ... N [1]

(c) State and explain the magnitude of the horizontal force exerted on the wall by the water.

....

.... [1]

(d) Calculate the pressure exerted on the wall by the water.

pressure = ... Pa [2]

[Total: 7]

Question 8

(a) Define velocity.

....

.... [1]

(b) A rock of mass 7.5 kg is projected vertically upwards from the surface of a planet. The rock leaves the surface of the planet with a speed of $4.0\,\text{m}\,\text{s}^{-1}$ at time $t = 0$. The variation with time t of the velocity v of the rock is shown in Fig. 1.1.

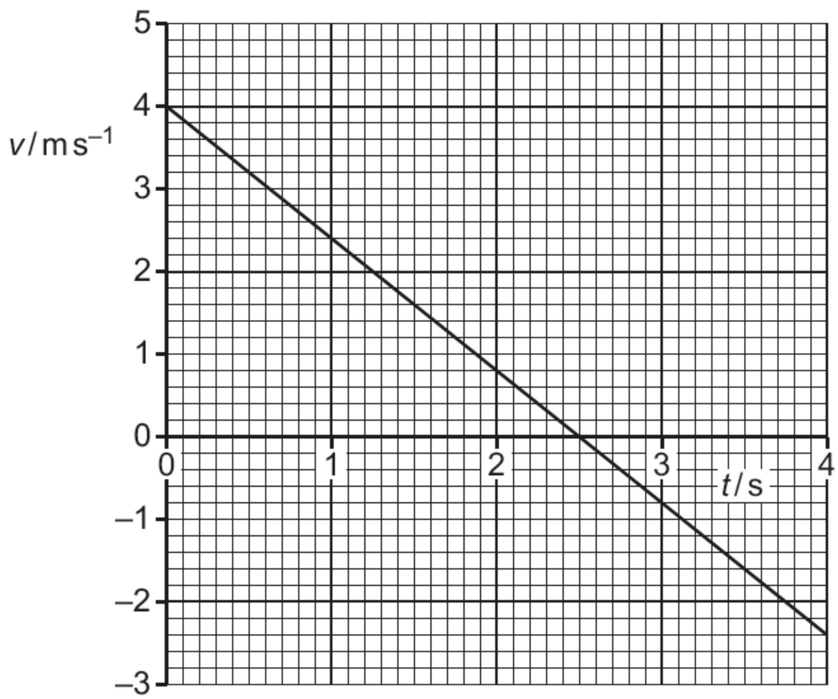


Fig. 1.1

Assume that the planet does not have an atmosphere and that the viscous force acting on the rock is always zero.

(i) Determine the height of the rock above the surface of the planet at time $t = 4.0\,s$.

height = ... m [3]

(ii) Determine the change in the momentum of the rock from time $t = 0$ to time $t = 4.0\,s$.

change in momentum = ... N s [2]

(iii) Determine the weight W of the rock on this planet.

W = ... N [2]

(c) In practice, the planet in **(b)** does have an atmosphere that causes a viscous force to act on the moving rock.

State and explain the variation, if any, in the resultant force acting on the rock as it moves vertically upwards.

....

....

....

.... [2]

[Total: 10]

Question 9

A sphere is attached by a metal wire to the horizontal surface at the bottom of a river, as shown in Fig. 2.1.

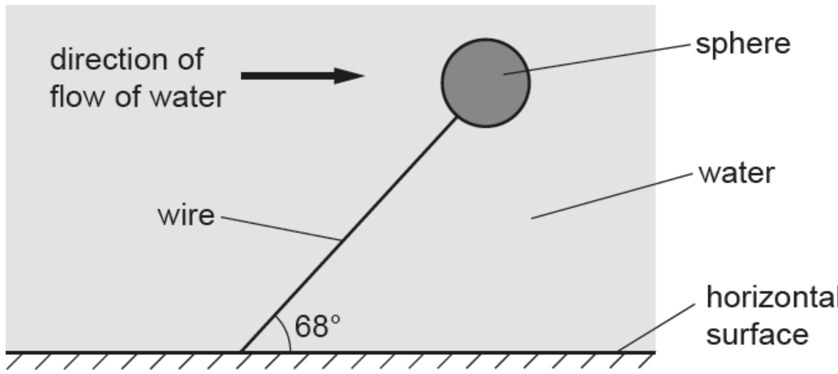


Fig. 2.1 (not to scale)

The sphere is fully submerged and in equilibrium, with the wire at an angle of 68° to the horizontal surface. The weight of the sphere is 32 N. The upthrust acting on the sphere is 280 N. The density of the water is $1.0 \times 10^3\,\text{kg}\,\text{m}^{-3}$.

Assume that the force on the sphere due to the water flow is in a horizontal direction.

(a) By considering the components of force in the vertical direction, determine the tension in the wire.

tension = ... N [2]

(b) For the sphere, calculate:

(i) the volume

volume = ... m^3 [1]

(ii) the density.

density = ... $kg\,m^{-3}$ [2]

(c) The centre of the sphere is initially at a height of 6.2 m above the horizontal surface. The speed of the water then increases, causing the sphere to move to a different position. This movement of the sphere causes its gravitational potential energy to decrease by 77 J.

Calculate the final height of the centre of the sphere above the horizontal surface.

height = ... m [3]

(d) The extension of the wire increases when the sphere changes position as described in **(c)**. The wire obeys Hooke's law.

(i) State a symbol equation that gives the relationship between the tension *T* in the wire and its extension *x*. Identify any other symbol that you use.

....

.... [1]

(ii) Before the sphere changed position, the initial elastic potential energy of the wire was 0.65 J. The change in position of the sphere causes the extension of the wire to double.

Calculate the final elastic potential energy of the wire after the sphere has changed position.

final elastic potential energy = ... J [2]

[Total: 11]

Question 10

A man standing on a wall throws a small ball vertically upwards with a velocity of $5.6\,\text{m}\,\text{s}^{-1}$. The ball leaves his hand when it is at a height of 3.1 m above the ground, as shown in Fig. 3.1.

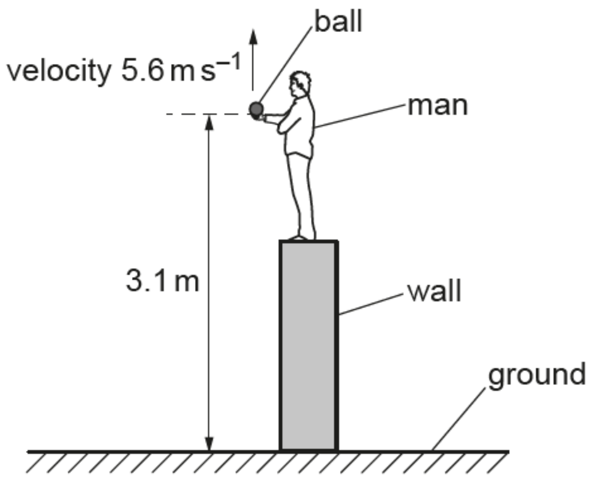


Fig. 3.1 (not to scale)

Assume that air resistance is negligible.

(a) Show that the ball reaches a maximum height above the ground of 4.7 m.

[2]

(b) The man does not catch the ball as it falls.

Calculate the time taken for the ball to fall from its maximum height to the ground.

time taken = ... s [2]

(c) The ball leaves the man's hand at time $t = 0$ and hits the ground at time $t = T$.

On Fig. 3.2, sketch a graph to show the variation of the velocity v of the ball with time t from $t = 0$ to $t = T$. Numerical values of v and t are not required. Assume that v is positive in the upward direction.

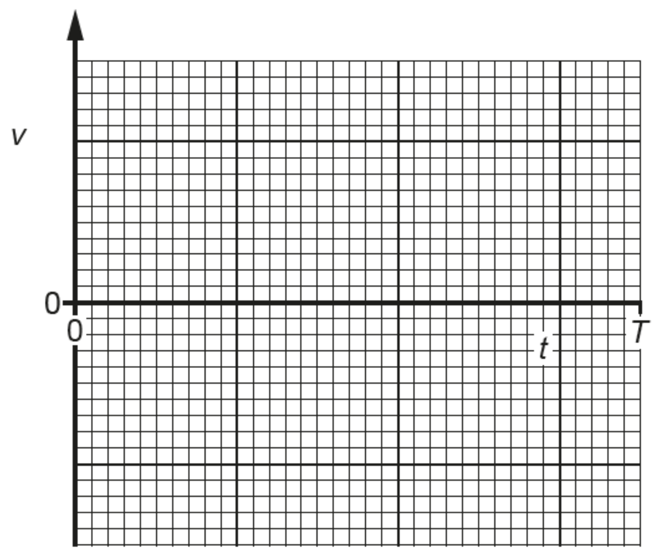


Fig. 3.2

[3]

(d) State what is represented by the gradient of the graph in **(c)**.

.... [1]

(e) The man now throws a second ball with the same velocity and from the same height as the first ball. The mass of the second ball is greater than that of the first ball. Assume that air resistance is still negligible.

For the first and second balls, compare:

(i) the magnitudes of their accelerations

.... [1]

(ii) the speeds with which they hit the ground.

.... [1]

[Total: 10]

Question 11

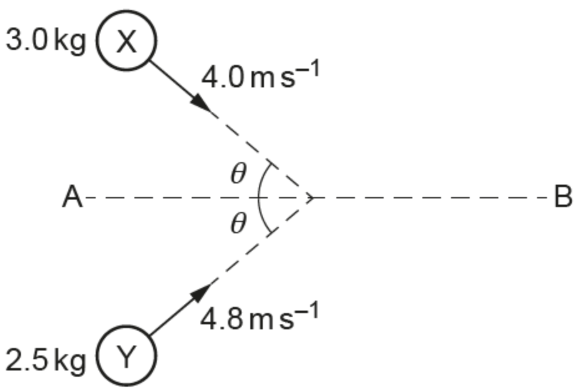
(a) State the principle of conservation of momentum.

....

....

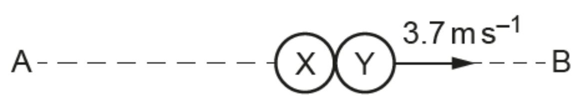
.... [2]

(b) Two balls, X and Y, move along a horizontal frictionless surface, as shown from above in Fig. 4.1.



before collision

Fig. 4.1 (not to scale)



after collision

Fig. 4.2 (not to scale)

Ball X has a mass of 3.0 kg and a velocity of 4.0 m s^{-1} in a direction at angle θ to a line AB. Ball Y has a mass of 2.5 kg and a velocity of 4.8 m s^{-1} in a direction at angle θ to the line AB.

The balls collide and stick together. After colliding, the balls have a velocity of 3.7 m s^{-1} along the line AB on the horizontal surface, as shown in Fig. 4.2.

(i) By considering the components of the momenta along the line AB, calculate θ.

θ = ... ° [3]

(ii) By calculation of kinetic energies, state and explain whether the collision of the balls is inelastic or perfectly elastic.

....

.... [2]

[Total: 7]

Question 12

An archer releases an arrow towards a target at a velocity of $65.0\,\text{m s}^{-1}$ at an angle of 4.30° above the horizontal, as shown in Fig. 2.1.

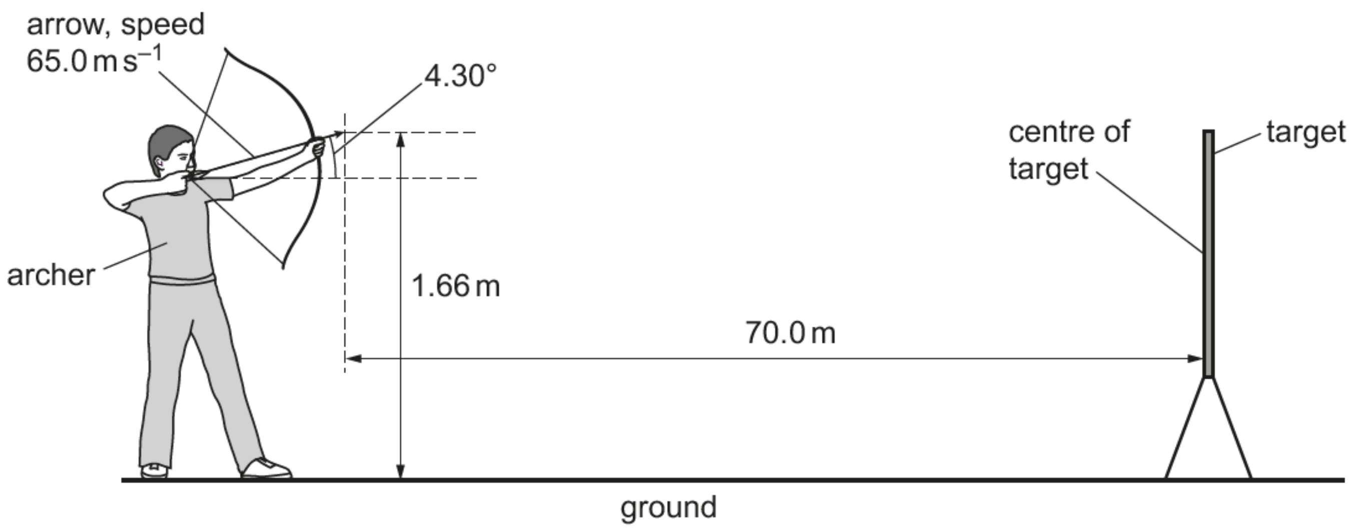


Fig. 2.1 (not to scale)

When released, the tip of the arrow is a horizontal distance of 70.0 m from the target and 1.66 m above the horizontal ground.

The arrow hits the centre of the target.

Assume that air resistance is negligible and that all the mass of the arrow is at its tip.

(a) Show that the time taken for the arrow to reach the target is 1.08 s.

[2]

(b) Calculate the height of the centre of the target above the ground.

height above ground = ... m [3]

(c) By considering energy changes, state and explain how the final kinetic energy of the arrow as it hits the target compares with its initial kinetic energy immediately after release. A numerical calculation is not required.

....

....

....

.... [2]

[Total: 7]

Question 13

(a) Define velocity.

....

.... [1]

(b) A constant driving force of 2400 N acts on a car of mass 1200 kg. The car accelerates from rest in a straight line along a horizontal road.

Assume that the resistive forces acting on the car are negligible.

(i) Calculate the acceleration of the car.

acceleration = ... $m\,s^{-2}$ [1]

(ii) On Fig. 3.1, sketch a graph showing the variation with time *t* of the velocity *v* of the car for the first 20 seconds of its motion.

Label this line A.

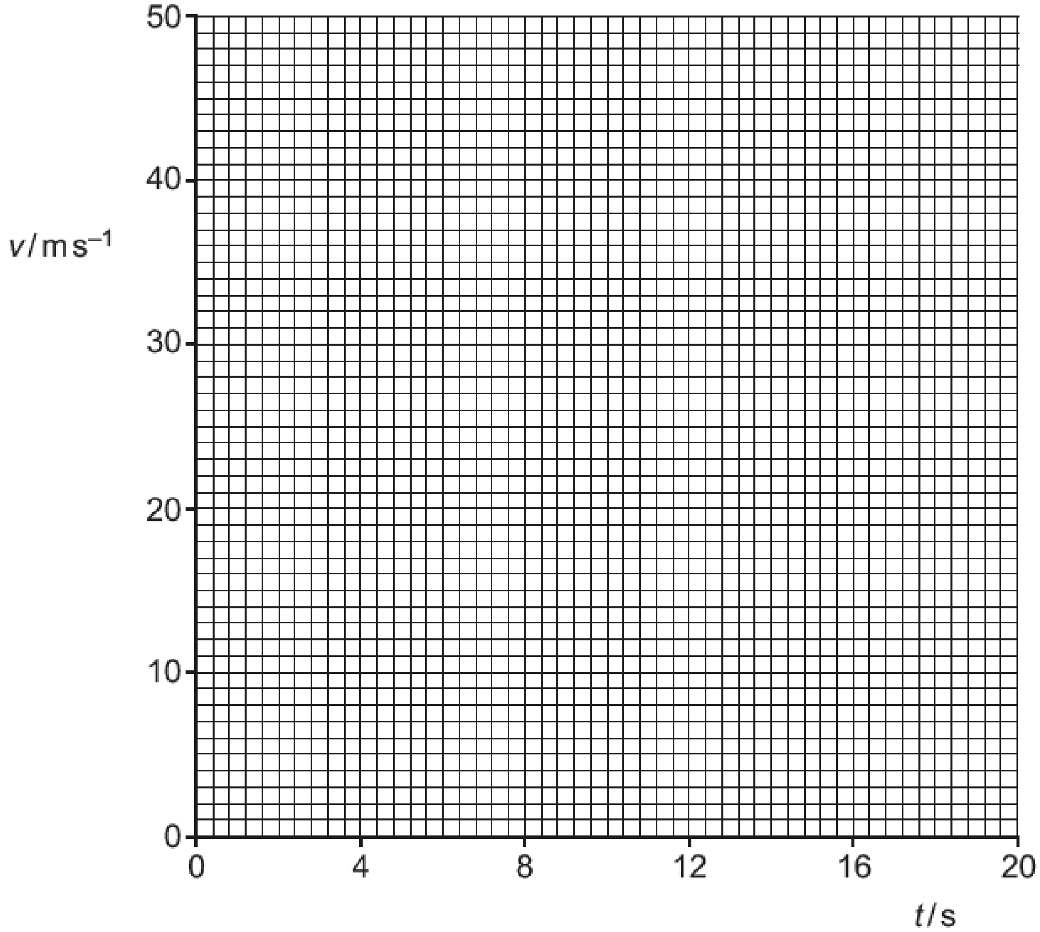


Fig. 3.1

[2]

(c) In reality, a resistive force due to air resistance acts on the car in **(b)**. This resistive force increases with speed until it becomes equal in magnitude to the driving force at time t = 12 s.

(i) On Fig. 3.1, sketch a second line to show the variation with time t of the velocity v of the car for the first 20 seconds of its motion. Label this line B. [3]

(ii) At time t = 20 s, the driving force is increased to 3000 N and remains constant at this value.

Describe how the velocity of the car changes due to this increase in the driving force.

....

....

....

.... [2]

[Total: 9]

Question 14

A steel ball is projected horizontally from the top of a table, as shown in Fig. 2.1.

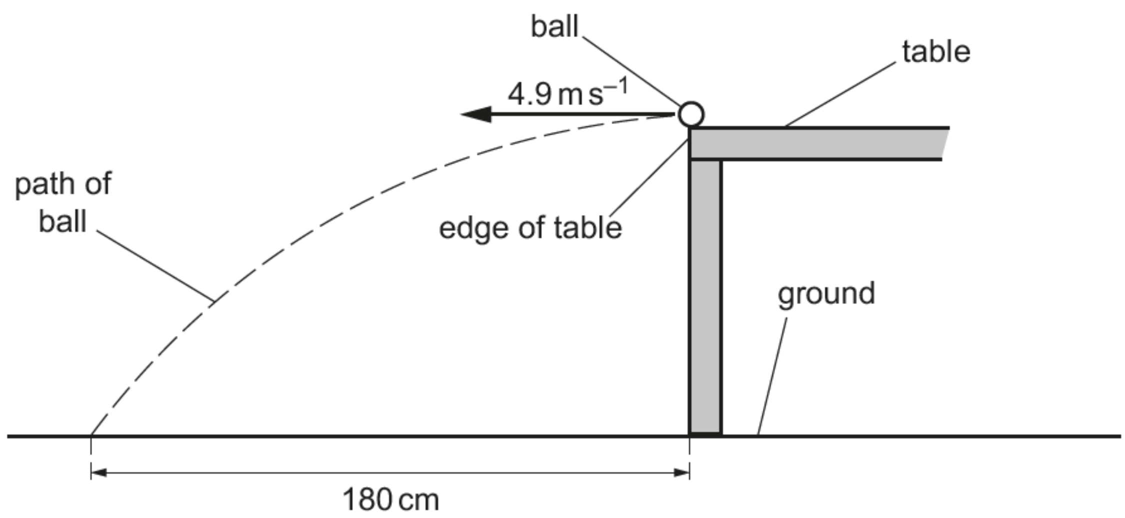


Fig. 2.1 (not to scale)

The ball is projected horizontally at a speed of 4.9 m s^{-1}. The ball lands on the ground a horizontal distance of 180 cm from the edge of the table.

Assume that air resistance is negligible.

(a) **(i)** Calculate the time taken for the ball to reach the ground.

time = ... s [1]

(ii) Calculate the vertical component of the velocity of the ball as it hits the ground.

velocity = ... $m\,s^{-1}$ [2]

(iii) Determine the magnitude and the angle to the horizontal of the velocity of the ball as it hits the ground.

magnitude of velocity = ... $m\,s^{-1}$

angle to the horizontal = ... °

[3]

(b) The ball is projected by means of a compressed spring which is attached to a fixed block as shown in Fig. 2.2.

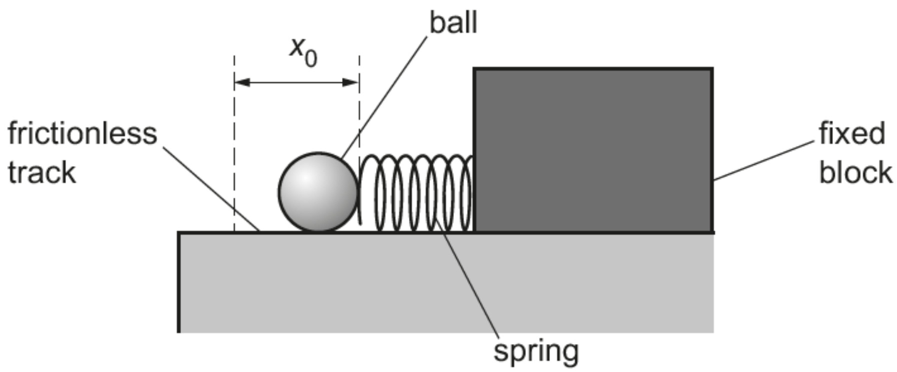


Fig. 2.2

The ball is placed on a frictionless track in front of the spring. The ball is then pulled back so that the spring has compression x_0.

When the spring is released, the ball is projected horizontally as shown in Fig. 2.3.

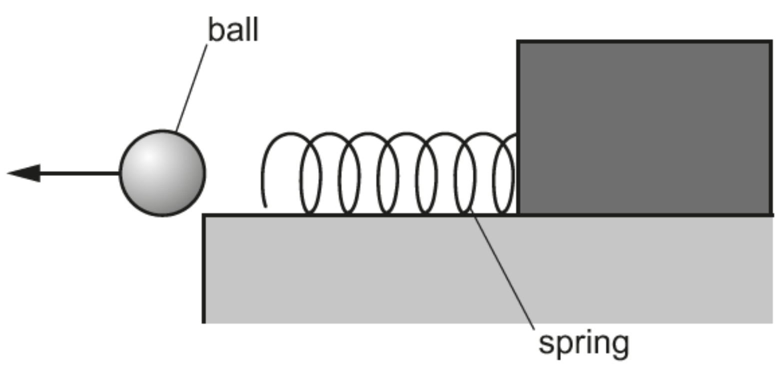


Fig. 2.3

The variation with compression x of the applied force F for the spring is shown in Fig. 2.4.

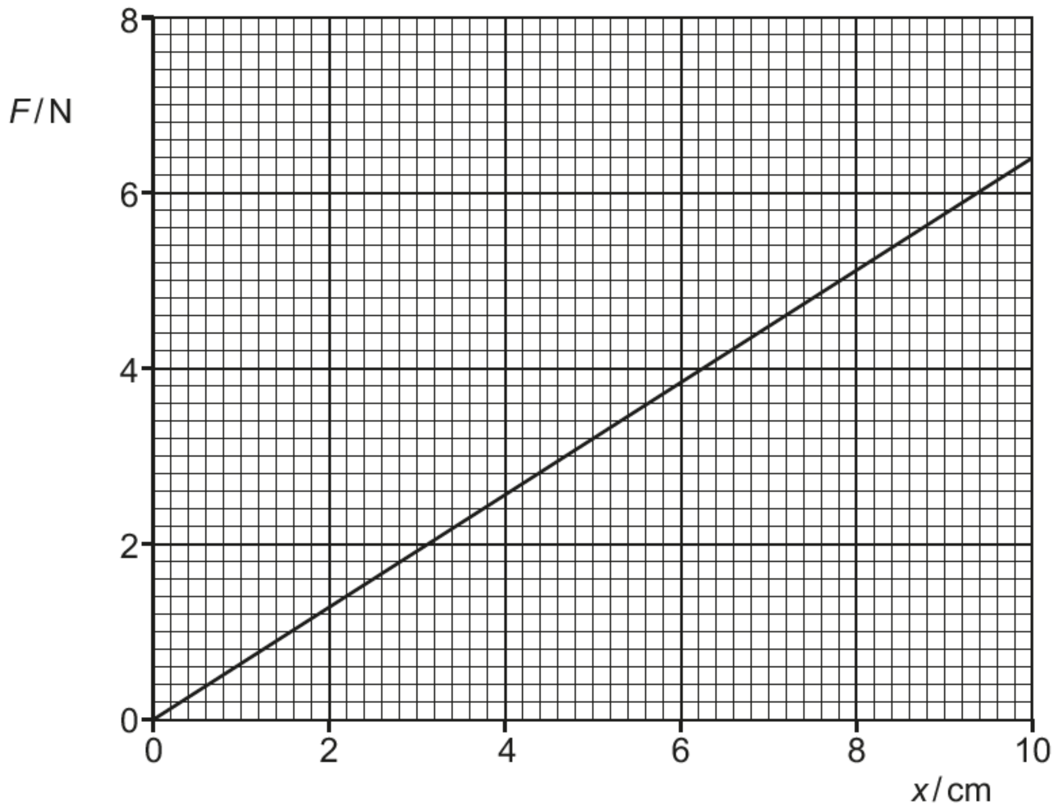


Fig. 2.4

The ball is a uniform sphere of steel of diameter 0.016 m and mass 0.017 kg.

(i) Calculate the density of the steel.

density = ... $kg\,m^{-3}$ [3]

(ii) All of the elastic potential energy in the spring is converted into kinetic energy of the ball. The speed of the ball as it leaves the spring is 4.9 m s^{-1}.

Show that the maximum elastic potential energy of the spring is 0.20 J.

[2]

(iii) Use Fig. 2.4 to determine the spring constant *k* of the spring.

k = ... N m^{-1} [2]

(iv) Use your answer in **(b)(iii)** and the value of energy given in **(b)(ii)** to determine the compression x_0 of the spring.

x_0 = ... m [2]

(c) The steel ball is replaced by a polystyrene ball of the same diameter but of much lower mass. The spring is given compression x_0 and is then released.

Air resistance on this ball is **not** negligible after it leaves the spring.

Explain:

(i) why this ball leaves the spring with a greater speed than that of the steel ball

....

....

.... [1]

(ii) why this ball takes a longer time to reach the ground than the steel ball.

....

....

.... [1]

[Total: 17]

Question 15

A spherical balloon is filled with a fixed mass of gas. A small block is connected by a string to the balloon, as shown in Fig. 2.1.

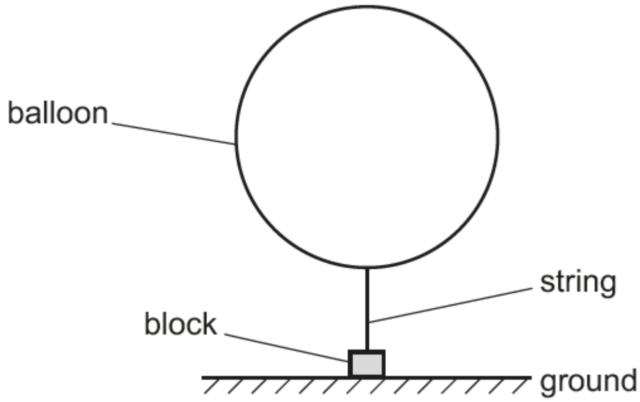


Fig. 2.1 (not to scale)

The block is held on the ground by an external force so that the string is vertical. The density of the air surrounding the balloon is 1.2 kg m^{-3}. The upthrust acting on the balloon is 0.071 N. The upthrust acting on the string and block is negligible.

(a) By using Archimedes' principle, calculate the radius *r* of the balloon.

r = ... m [2]

(b) The total weight of the balloon, string and block is 0.053 N.

The external force holding the block on the ground is removed so that the released block is lifted vertically upwards by the balloon.

Calculate the acceleration of the block immediately after it is released.

acceleration = ... $m\,s^{-2}$ [3]

(c) The balloon continues to lift the block. The string breaks as the block is moving vertically upwards with a speed of $1.4\,m\,s^{-1}$. After the string breaks, the detached block briefly continues moving upwards before falling vertically downwards to the ground. The block hits the ground with a speed of $3.6\,m\,s^{-1}$.

Assume that the air resistance on the block is negligible.

(i) By considering the motion of the block after the string breaks, calculate the height of the block above the ground when the string breaks.

height = ... m [2]

(ii) The string breaks at time $t = 0$ and the block hits the ground at time $t = T$.

On Fig. 2.2, sketch a graph to show the variation of the velocity v of the block with time t from $t = 0$ to $t = T$.

Numerical values of t are not required. Assume that v is positive in the upward direction.

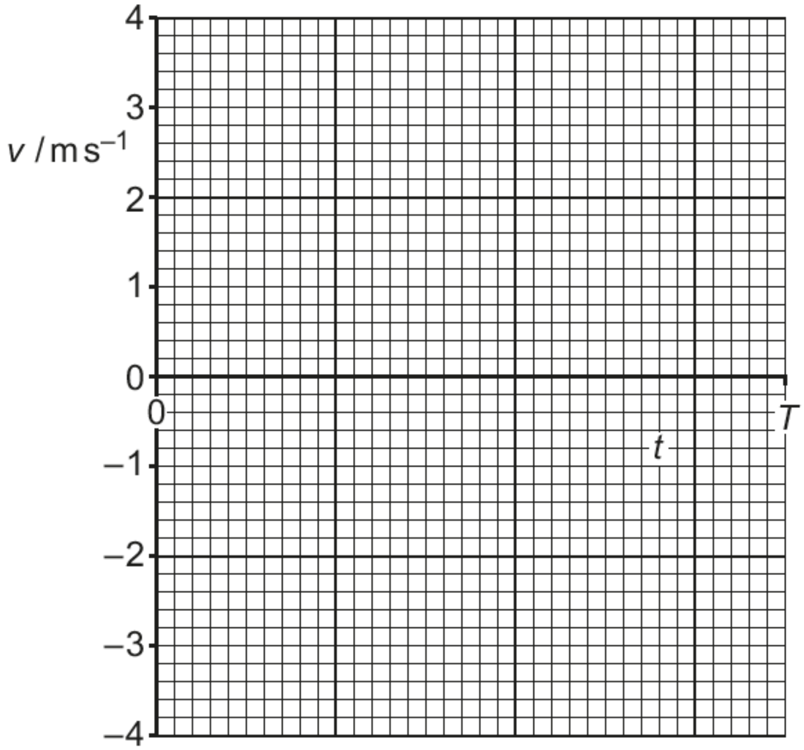


Fig. 2.2

[2]

[Total: 9]

Question 16

The engine of a toy rocket pushes gases vertically downwards and this results in the rocket accelerating vertically upwards from the ground.

The rocket starts to move from rest at time $t = 0$. The variation with time t of the vertical velocity v of the rocket for the first 0.30 s of the flight is shown in Fig. 2.1.

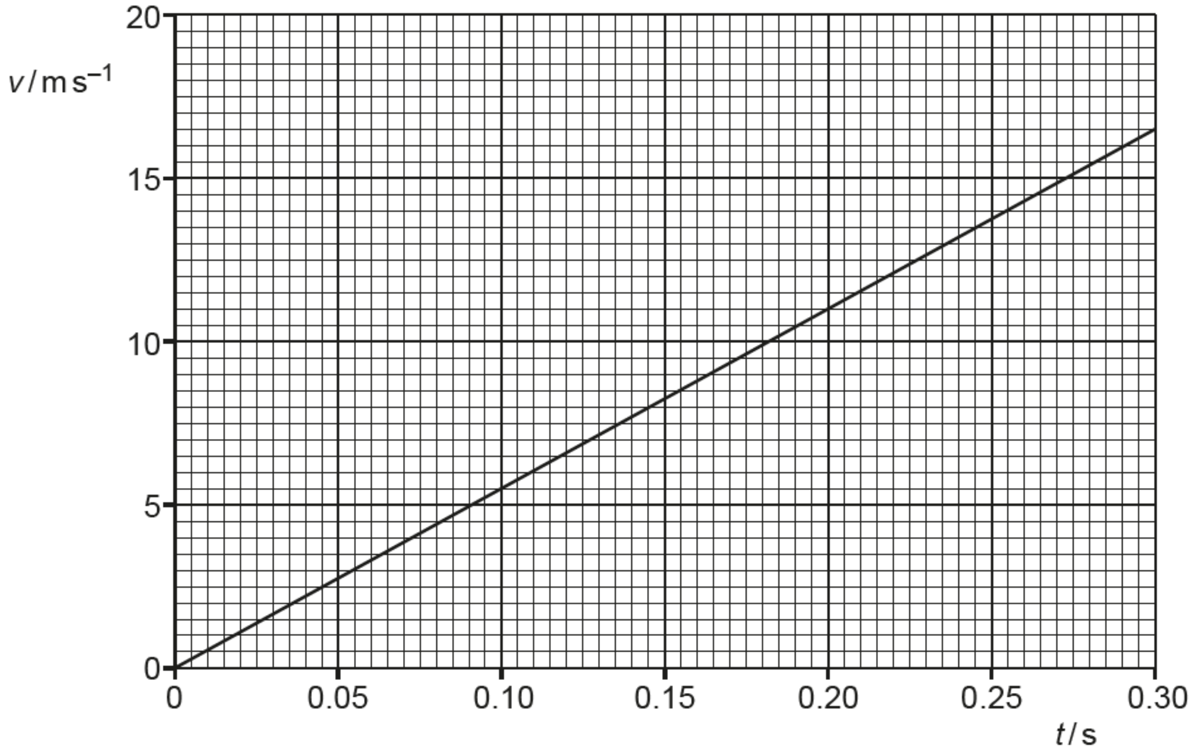


Fig. 2.1

As the rocket moves, the thrust force T provided by the rocket engine is 16 N.
Assume that the mass of the rocket is constant for this part of its flight.

Assume that air resistance is negligible.

(a) For this part of the rocket's flight:

(i) show that the acceleration of the rocket is 55 m s^{-2}

[1]

(ii) state an expression for the resultant force F experienced by the rocket in terms of the thrust force T and the weight W of the rocket

[1]

(iii) calculate the mass of the rocket.

mass = ... kg [2]

(b) At time t = 0.30 s, a small piece of metal separates from the rocket.

Calculate:

(i) the height of the rocket above the ground at t = 0.30 s

height = ... m [2]

Question 17

Two blocks slide directly towards each other along a frictionless horizontal surface, as shown in Fig. 4.1. The blocks collide and then move as shown in Fig. 4.2.

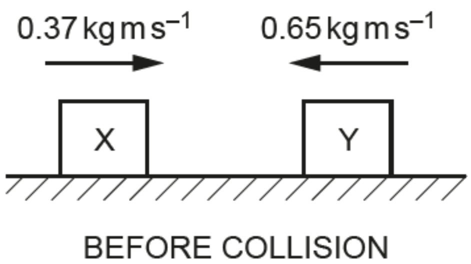


Fig. 4.1

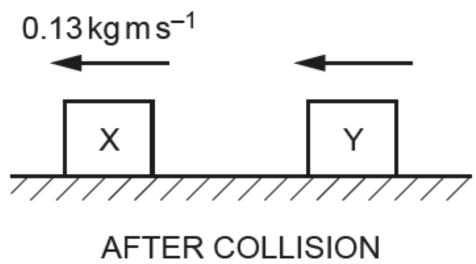


Fig. 4.2

Block X initially moves to the right with a momentum of $0.37\,\mathrm{kg\,m\,s^{-1}}$. Block Y initially moves to the left with a momentum of $0.65\,\mathrm{kg\,m\,s^{-1}}$. After the blocks collide, block X moves to the left back along its original path with a momentum of $0.13\,\mathrm{kg\,m\,s^{-1}}$. Block Y also moves to the left after the collision.

(a) Block X has an initial kinetic energy of 0.30 J.

Calculate the mass of block X.

mass = ... kg [3]

(b) Determine the magnitude of the momentum of block Y after the collision.

momentum = ... $\mathrm{kg\,m\,s^{-1}}$ [1]

(c) Block X exerts an average force of 7.7 N on block Y during the collision.

Calculate the time that the blocks are in contact with each other.

time = ... s [2]

[Total: 6]

Question 18

A block is pulled in a straight line along a rough horizontal surface by a varying force *X*, as shown in Fig. 3.1.

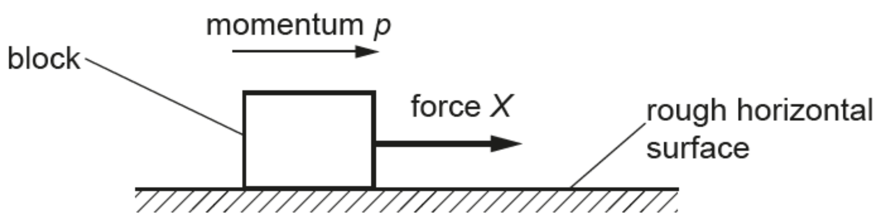


Fig. 3.1

Air resistance is negligible. Assume that the frictional force exerted on the block by the surface is constant and has magnitude 2.0 N.

The variation with time *t* of the momentum *p* of the block is shown in Fig. 3.2.

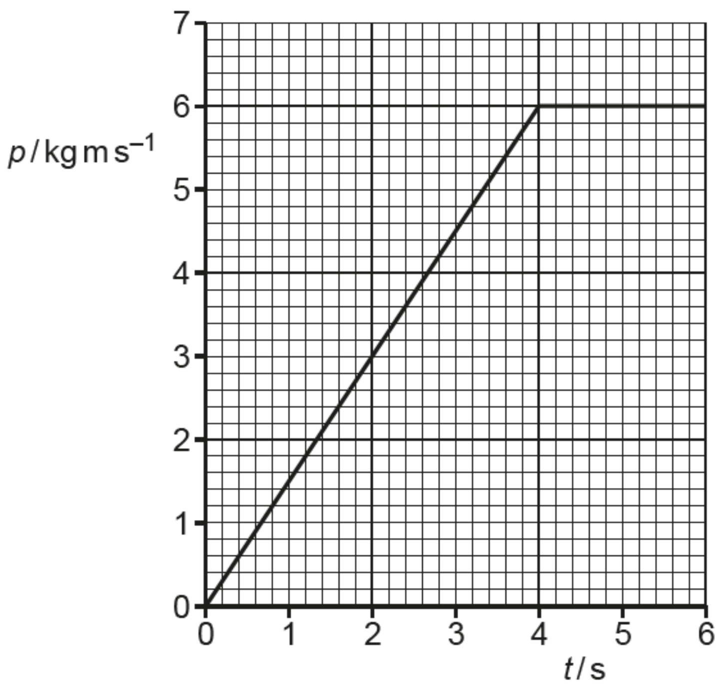


Fig. 3.2

(a) State Newton's second law of motion.

....

.... [1]

(b) Use Fig. 3.2 to determine, for the block at time t = 2.0 s, the magnitude of:

(i) the resultant force on the block

resultant force = ... N [1]

(ii) the force X.

X = ... N [1]

(c) On Fig. 3.3, sketch a graph to show the variation of force X with time t from t = 0 to t = 6.0 s.

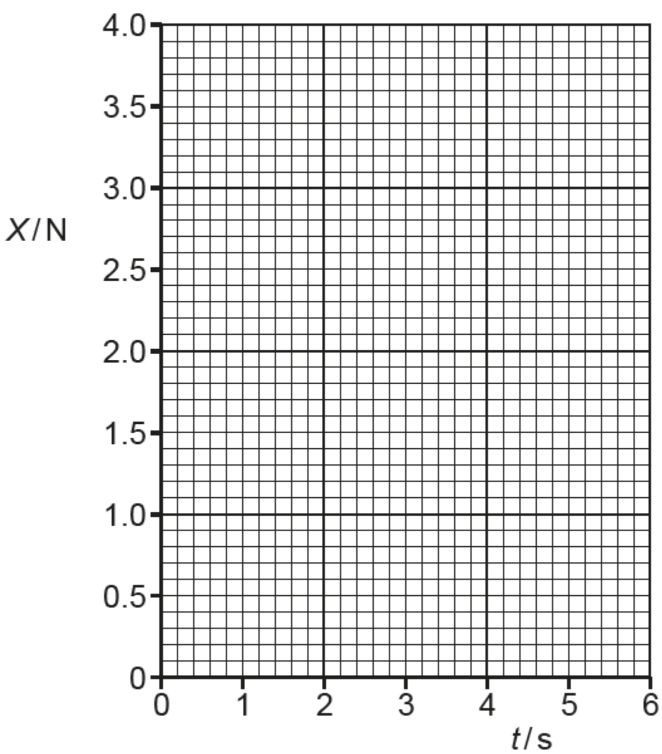


Fig. 3.3

[3]

[Total: 6]

Question 19

A block is pulled by a force *X* in a straight line along a rough horizontal surface, as shown in Fig. 3.1.

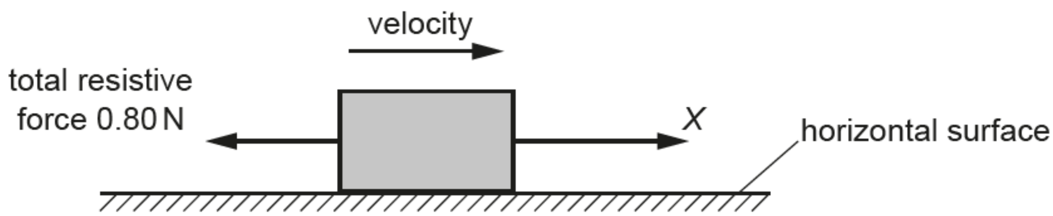


Fig. 3.1

Assume that the total resistive force opposing the motion of the block is 0.80 N at all speeds of the block.

The variation with time *t* of the magnitude of the force *X* is shown in Fig. 3.2.

The variation with time *t* of the magnitude of the force *X* is shown in Fig. 3.2.

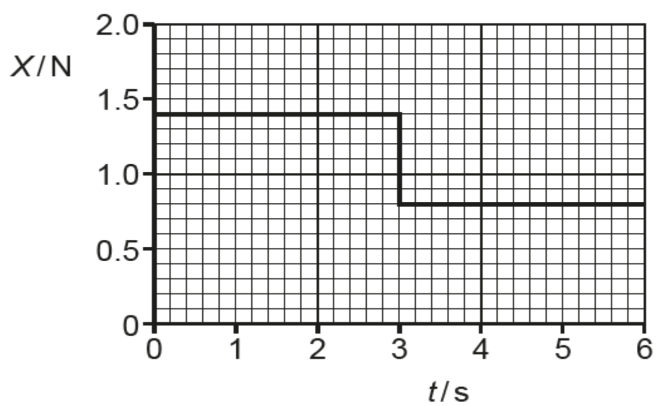


Fig. 3.2

(a) **(i)** Define force.

....

.... [1]

(ii) Determine the change in momentum of the block from time t = 0 to time t = 3.0 s.

change in momentum = ... $kg\,m\,s^{-1}$ [2]

(b) **(i)** Describe and explain the motion of the block between time t = 3.0 s and time t = 6.0 s.

....

....

....

.... [2]

(ii) Force X produces a total power of 2.0 W when moving the block between time t = 3.0 s and time t = 6.0 s.

Calculate the distance moved by the block during this time interval.

distance = ... m [3]

(c) The block is at rest at time $t = 0$.

On Fig. 3.3, sketch a graph to show the variation of the momentum of the block with time t from $t = 0$ to $t = 6.0$ s.
Numerical values of momentum are not required.

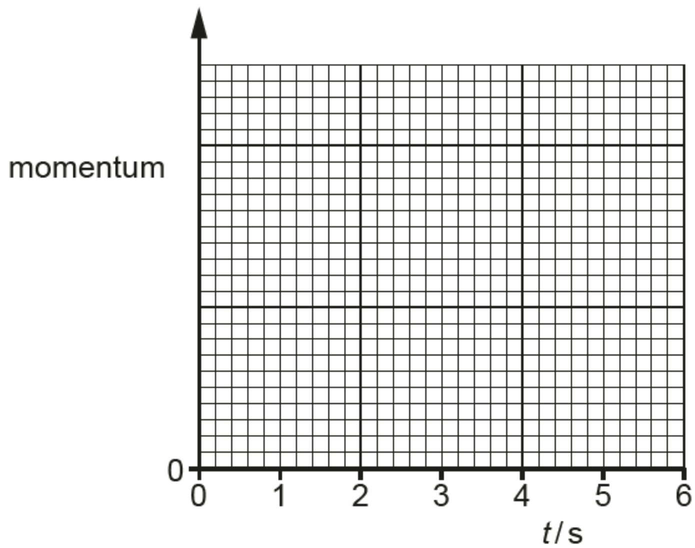


Fig. 3.3

[2]

[Total: 10]

Question 20

A well has a depth of 36 m from ground level to the surface of the water in the well, as shown in Fig. 1.1.

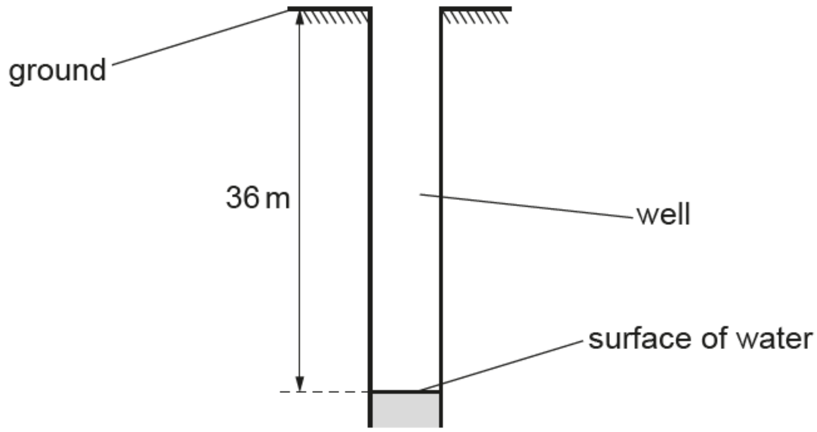


Fig. 1.1 (not to scale)

A student wishes to find the depth of the well. The student plans to drop a stone down the well and record the time taken from releasing the stone to hearing the splash made by the stone as it enters the water.

(a) Assume that air resistance is negligible and that the stone is released from rest.

Calculate the time taken for the stone to fall from ground level to the surface of the water.

time = ... s [2]

(b) The time recorded by the student using a stop-watch is not equal to the time in **(a)**.

Suggest **three** possible reasons, other than the effect of air resistance, for this difference.

1 ....

....

2 ....

....

3 ....

....
[3]

(c) The student repeats the experiment three times and uses the results to calculate the depth of the well. The values are shown in Table 1.1.

Table 1.1

	1st experiment	2nd experiment	3rd experiment
depth/m	54.4	53.9	54.1

The true depth of the well is 36.0 m. Explain why these results may be described as precise but not accurate.

....

....

....

.... [2]

[Total: 7]

Question 21

A sphere floats in equilibrium on the surface of sea water of density $1050\,kg\,m^{-3}$, as shown in Fig. 2.1.

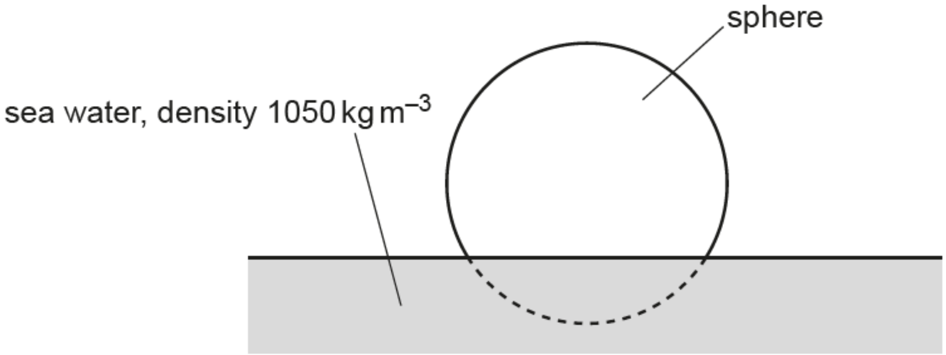


Fig. 2.1

(a) 21% of the volume of the sphere is below the surface of the water.

Calculate the density of the sphere.

density = ... $kg\,m^{-3}$ [2]

(b) The sphere is now held so that its entire volume is below the surface of the water. The sphere is then released.

(i) Calculate the initial acceleration of the sphere.

acceleration = ... $m\,s^{-2}$ [3]

(ii) The sphere accelerates upwards but remains entirely below the surface of the water.

State and explain what happens to the acceleration of the sphere as its velocity begins to increase.

....

....

....

.... [3]

[Total: 8]

Question 22

(a) State the principle of conservation of momentum.

....

....

.... [2]

(b) A firework is initially stationary. It explodes into three fragments A, B and C that move in a horizontal plane, as shown in the view from above in Fig. 3.1.

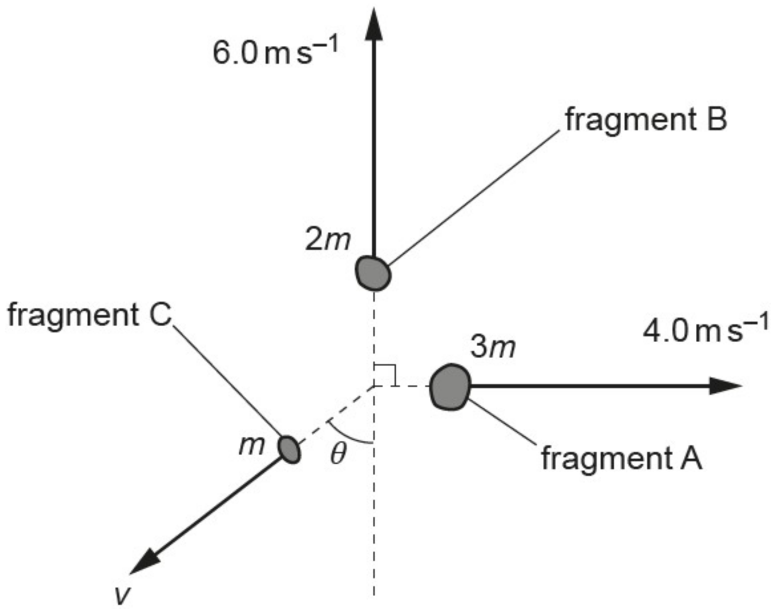


Fig. 3.1

Fragment A has a mass of 3*m* and moves away from the explosion at a speed of $4.0\,\text{m}\,\text{s}^{-1}$.

Fragment B has a mass of 2*m* and moves away from the explosion at a speed of $6.0\,\text{m}\,\text{s}^{-1}$ at right angles to the direction of A.

Fragment C has a mass of *m* and moves away from the explosion at a speed *v* and at an angle θ as shown in Fig. 3.1.

Calculate:

(i) the angle θ

θ = ...° [3]

(ii) the speed *v*.

v = ... $\text{m}\,\text{s}^{-1}$ [2]

The firework in **(b)** contains a chemical that has mass 5.0 g and has chemical energy per unit mass $700\,\text{J}\,\text{kg}^{-1}$. When the firework explodes, all of the chemical energy is transferred to the kinetic energy of fragments A, B and C.

(i) Show that the total chemical energy in the firework is 3.5 J.

[1]

(ii) Calculate the mass m.

m = ... kg [3]

[Total: 11]

Question 23

A hot-air balloon floats just above the ground. The balloon is stationary and is held in place by a vertical rope, as shown in Fig. 2.1.

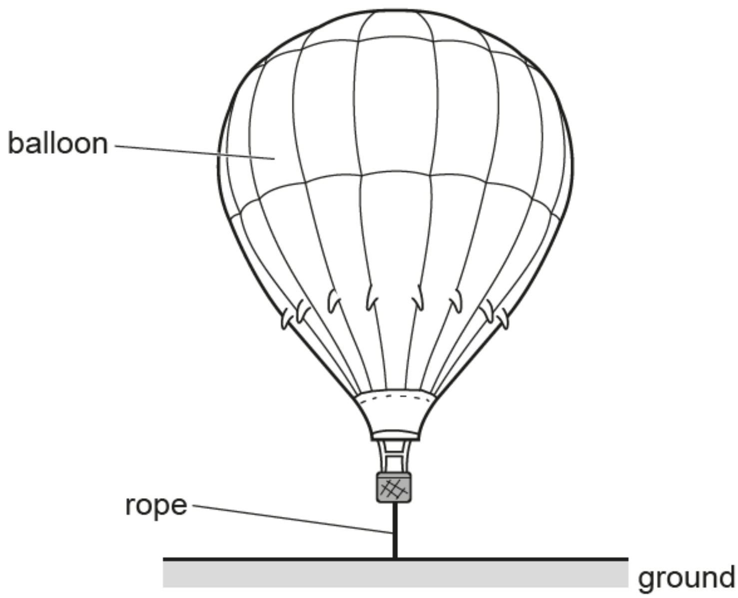


Fig. 2.1

The balloon has a weight W of 3.39×10^4 N. The tension T in the rope is 4.00×10^2 N.
Upthrust U acts on the balloon.
The density of the surrounding air is $1.23\,\text{kg}\,\text{m}^{-3}$.

(a) **(i)** On Fig. 2.1, draw labelled arrows to show the directions of the three forces acting on the balloon. [2]

(ii) Calculate the volume, to three significant figures, of the balloon.

volume = ... m^3 [3]

(iii) The balloon is released from the rope.

Calculate the initial acceleration of the balloon.

acceleration = ... $m\,s^{-2}$ [3]

(b) The balloon is stationary at a height of 500 m above the ground. A tennis ball is released from rest and falls vertically from the balloon.

A passenger in the balloon uses the equation $v^2 = u^2 + 2as$ to calculate that the ball will be travelling at a speed of approximately $100\,m\,s^{-1}$ when it hits the ground.

Explain why the actual speed of the ball will be much lower than $100\,m\,s^{-1}$ when it hits the ground.

....

....

....

.... [3]

(c) Before the balloon is released, the rope holding the balloon has a strain of 2.4×10^{-5}. The rope has an unstretched length of 2.5 m. The rope obeys Hooke's law.

(i) Show that the extension of the rope is 6.0×10^{-5} m.

[1]

(ii) Calculate the elastic potential energy E_P of the rope.

E_P = ... J [2]

(iii) The rope holding the balloon is replaced with a new one of the same original length and cross-sectional area. The tension is unchanged and the new rope also obeys Hooke's law.

The new rope is made from a material of a lower Young modulus.

State and explain the effect of the lower Young modulus on the elastic potential energy of the rope.

....

....

.... [2]

[Total: 16]

Question 24

A trolley A moves along a horizontal surface at a constant velocity towards another trolley B which is moving at a lower constant speed in the same direction. Fig. 3.1 shows the trolleys at time $t = 0$.

Fig. 3.1

Table 3.1 shows data for the trolleys.

Table 3.1

trolley	mass / kg	initial speed / $m\,s^{-1}$
A	0.25	0.48
B	0.75	0.12

The two trolleys collide elastically and then separate. Resistive forces are negligible.

Fig. 3.2 shows the variation with time t of the velocity v for trolley B.

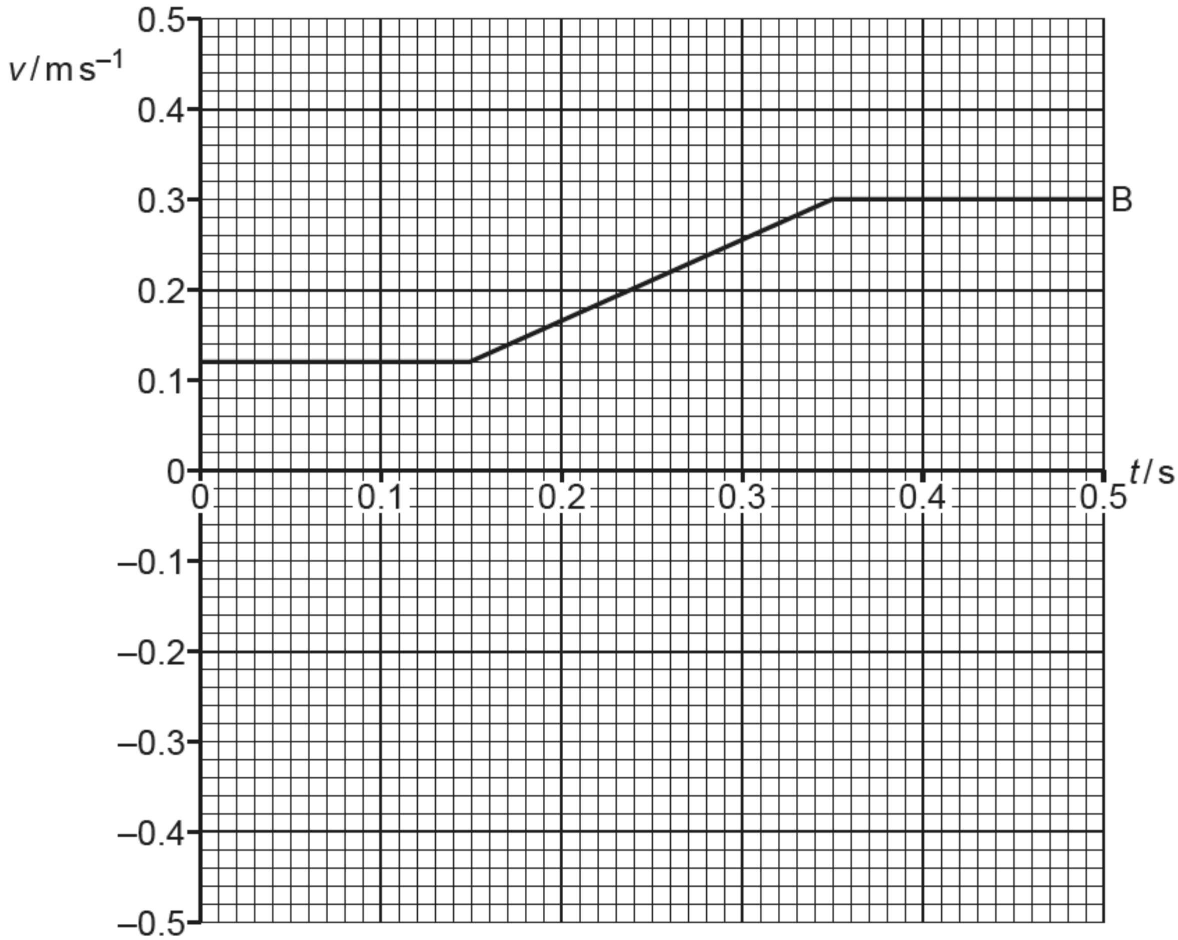


Fig. 3.2

(a) State what is represented by the area under a velocity–time graph.

.... [1]

(b) Use Table 3.1 and Fig. 3.2 to determine:

(i) the acceleration of trolley B during the collision

acceleration of B = ... $m\,s^{-2}$ [2]

(ii) the magnitude and direction of the final velocity of trolley A.

magnitude = ... $m\,s^{-1}$

direction ....

[3]

(c) On Fig. 3.2, sketch the variation of the velocity of trolley A with time t from $t = 0$ to $t = 0.50\,s$.

[3]

[Total: 9]

Question 25

(a) In the following list, underline **all** quantities that are SI base quantities.

charge   electric current   force   time   [1]

(b) Under certain conditions, the distance *s* moved in a straight line by an object in time *t* is given by

$$s = \tfrac{1}{2}at^2$$

where *a* is the acceleration of the object.

State **two** conditions under which the above expression applies to the motion of the object.

1 ....

2 ....
[2]

(c) The variation with time *t* of the velocity *v* of a car that is moving in a straight line is shown in Fig. 1.1.

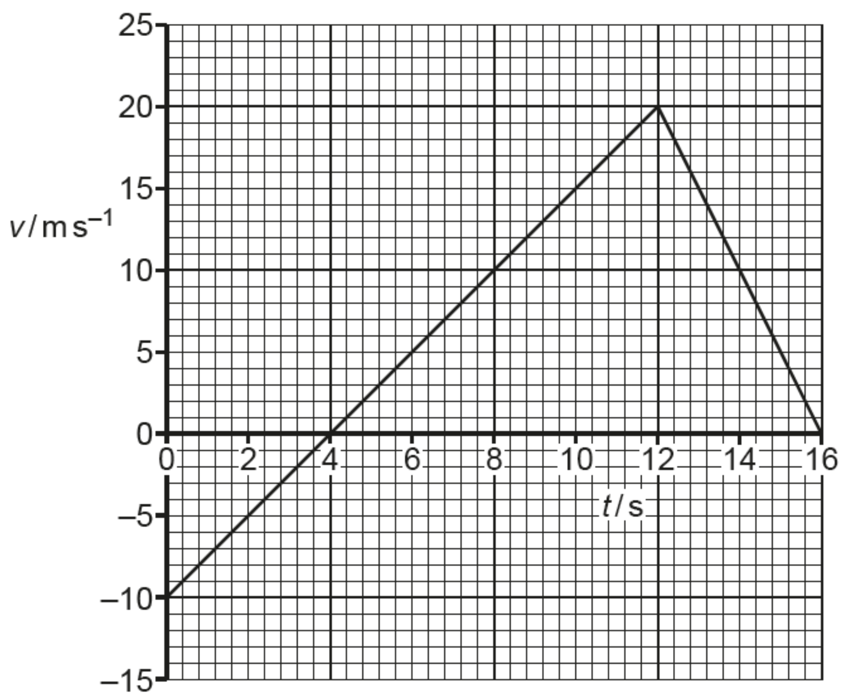


Fig. 1.1

(i) Compare, qualitatively, the acceleration of the car at time t = 8.0 s and at time t = 14.0 s in terms of:

- magnitude

....

....

- direction.

....

....

[2]

(ii) Determine the magnitude of the acceleration of the car at time t = 4.0 s.

acceleration = ... $m\,s^{-2}$ [2]

(iii) The car is at point X at time t = 0.

Determine the magnitude of the displacement of the car from X at time t = 12.0 s.

displacement = ... m [2]

[Total: 9]

Question 26

A high-altitude balloon is stationary in still air. A solid sphere is suspended from the balloon by a string, as shown in Fig. 2.1.

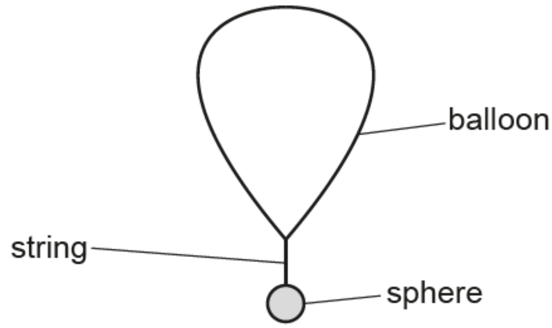


Fig. 2.1 (not to scale)

The volume of the balloon is $7.5\,m^3$. The total weight of the balloon, string and sphere is 65 N. The upthrust acting on the string and sphere is negligible.

(a) Calculate the density of the air surrounding the balloon.

density = ... $kg\,m^{-3}$ [2]

(b) The string breaks, releasing the sphere.

(i) State the magnitude of the acceleration of the sphere immediately after the string breaks.

acceleration = ... $m\,s^{-2}$ [1]

(ii) State and explain the variation, if any, in the magnitude of the acceleration of the sphere when it is moving downwards **before** it reaches terminal (constant) velocity.

....

....

....

....

....

....

.... [3]

(c) The sphere has a mass of 4.0 kg.

Calculate the total resistive force acting on the sphere at the instant when its acceleration is $1.9\,\mathrm{m\,s^{-2}}$.

resistive force = ... N [2]

[Total: 8]

Question 27

(a) A ball Y moves along a horizontal frictionless surface and collides with a ball Z, as illustrated in the views from above in Fig. 4.1 and Fig. 4.2.

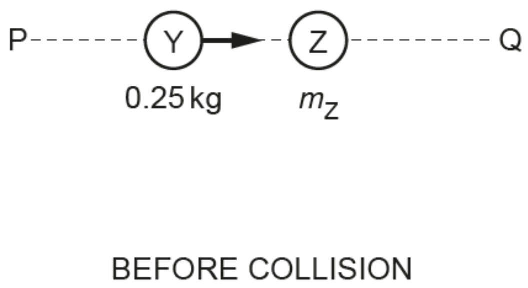


Fig. 4.1 (not to scale)

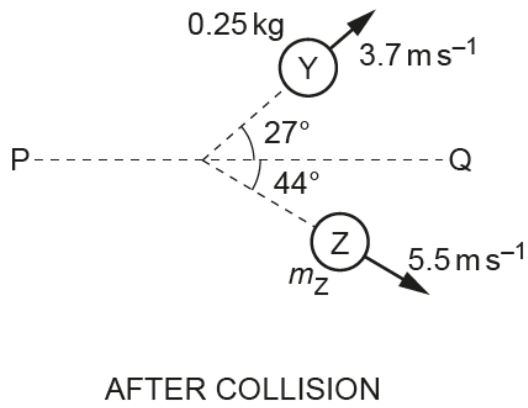


Fig. 4.2 (not to scale)

Ball Y has a mass of 0.25 kg and initially moves along a line PQ.
Ball Z has a mass m_Z and is initially stationary.

After the collision, ball Y has a final velocity of 3.7 m s^{-1} at an angle of 27° to line PQ and ball Z has a final velocity of 5.5 m s^{-1} at an angle of 44° to line PQ.

(i) Calculate the component of the final momentum of ball Y in the direction perpendicular to line PQ.

component of momentum = ... N s [2]

(ii) By considering the component of the final momentum of each ball in the direction perpendicular to line PQ, calculate m_Z.

m_Z = ... kg [1]

(iii) During the collision, the average force exerted on Y by Z is F_Y and the average force exerted on Z by Y is F_Z.

Compare the magnitudes and directions of F_Y and F_Z. Numerical values are not required.

magnitudes: ....

directions: ....
[2]

(b) Two blocks, A and B, move directly towards each other along a horizontal frictionless surface, as shown in the view from above in Fig. 4.3.

Fig. 4.3

The blocks collide perfectly elastically. Before the collision, block A has a speed of $4\,\text{m}\,\text{s}^{-1}$ and block B has a speed of $6\,\text{m}\,\text{s}^{-1}$. After the collision, block B moves back along its original path with a speed of $2\,\text{m}\,\text{s}^{-1}$.

Calculate the speed of block A after the collision.

speed = ... $\text{m}\,\text{s}^{-1}$ [1]

[Total: 6]

Question 28

A ball on horizontal ground is kicked towards a vertical wall. Fig. 2.1 shows the path of the ball.

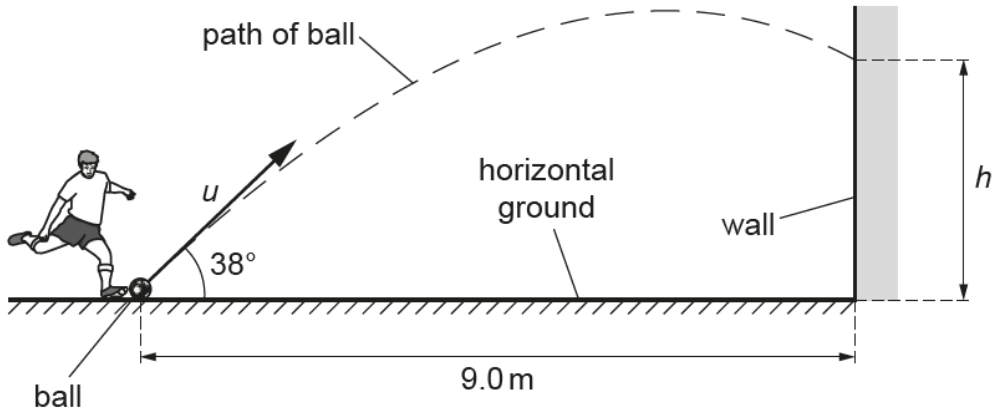


Fig. 2.1 (not to scale)

The ball has an initial velocity u at an angle of 38° to the ground. The ball travels a horizontal distance of 9.0 m before striking the wall at a height h above the ground. The horizontal component u_H of the initial velocity of the ball is 9.5 m s^{-1}.

Air resistance is negligible.

(a) **(i)** Show that the time t for the ball to reach the wall is 0.95 s.

[1]

(ii) Calculate the vertical component u_V of the initial velocity of the ball.

u_V = ... m s^{-1} [2]

(iii) Determine h.

h = ... m [2]

(b) The speed of the ball just after striking the wall is less than its speed just before striking the wall.

State what this indicates about the nature of the collision of the ball with the wall.

....

.... [1]

[Total: 6]

Question 29

(a) State the conditions for a system to be in equilibrium.

....

....

.... [2]

(b) Fig. 3.1 shows an airship in flight. The airship is propelled by identical fans that can be angled to control the motion of the airship.

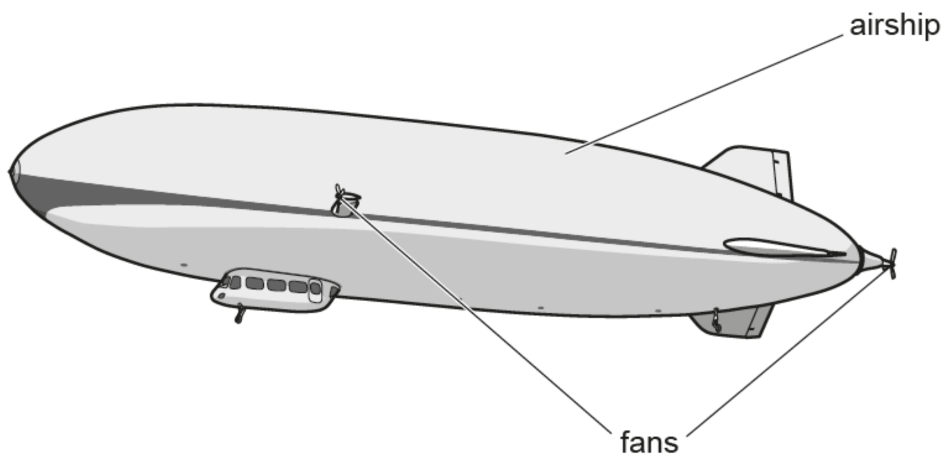


Fig. 3.1

The upthrust on the airship is 93 000 N.
The density of the surrounding air is 1.2 kg m^{-3}.

(i) Calculate the volume of air displaced by the airship.

volume = ... m^3 [1]

(ii) When fully loaded, the weight of the airship is greater than the upthrust.
To maintain horizontal flight, the fans provide a total vertical force of 3.0×10^{3} N upwards on the airship.

Calculate the mass of the airship.

mass = ... kg [2]

(c) At a certain time, the airship in **(b)** is stationary. The thrust force exerted by a fan on the airship is 2800 N.

To produce this force, a mass of 64 kg of air is propelled through the blades of the fan in a time of 0.50 s. Assume that this air is initially stationary at the entrance to the fan.

Calculate:

(i) the change in momentum Δp of the air propelled through the fan blades in this time

Δp = ... kg m s^{-1} [2]

(ii) the speed of the air as it leaves the fan

speed = ... m s^{-1} [2]

(iii) the total kinetic energy of this air due to its movement through the fan.

kinetic energy = ... J [2]

[Total: 11]

Question 30

(a) Define acceleration.

....

.... [1]

(b) An Olympic diver stands on a platform above a pool of water, as shown in Fig. 2.1.

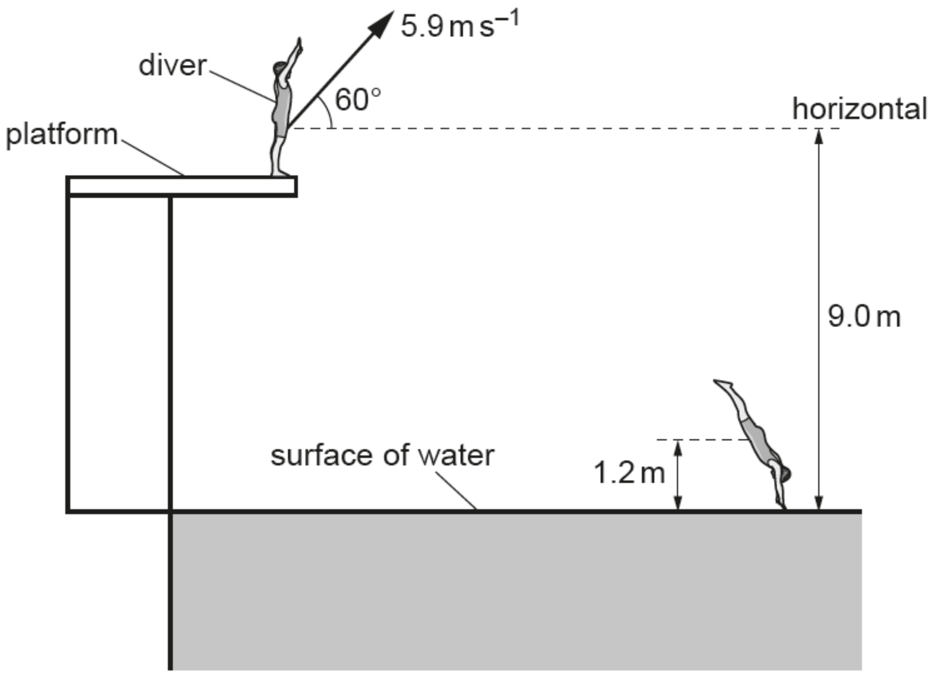


Fig. 2.1 (not to scale)

When the diver is on the platform his centre of gravity is a vertical height of 9.0 m above the surface of the water. The diver jumps from the platform with a velocity of $5.9\,\text{m}\,\text{s}^{-1}$ at an angle of 60° to the horizontal.

Air resistance is negligible.

When the diver hits the surface of the water, his centre of gravity is a vertical height of 1.2 m above the surface of the water.

Calculate the speed of the diver at the instant he hits the surface of the water.

speed = ... $m\,s^{-1}$ [3]

(c) The diver in **(b)** enters the water and decelerates.

(i) Describe and explain the variation of the viscous drag force acting on the diver in the water as he moves downwards.

....

....

....

.... [2]

(ii) The diver has a volume of $7.5 \times 10^{-2}\,m^3$. The density of the water is $1.0 \times 10^3\,kg\,m^{-3}$.

Show that the upthrust acting on the diver when he is entirely underwater is 740 N.

[1]

(iii) At a particular instant when the diver is entirely underwater his horizontal velocity is zero. The viscous drag force acting on him at this instant is 950 N vertically upwards. The diver has mass 78 kg.

Determine the magnitude and direction of the acceleration of the diver.

acceleration = ... $m\,s^{-2}$

direction ....

[4]

[4]

[Total: 11]

Question 31

The drag force F_D acting on an object falling through air is given by

$$F_D = \frac{1}{2} C\rho A v^2$$

where A is the cross-sectional area of the object,
v is the velocity of the object in the air,
ρ is the density of the air and
C is a constant called the drag coefficient.

(a) Use SI base units to show that the drag coefficient has no units.

[3]

(b) Fig. 1.1 shows a sphere falling at terminal velocity in air.

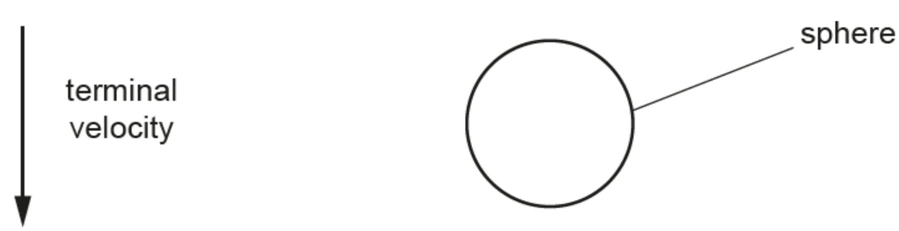


Fig. 1.1

Assume that the upthrust on the sphere is negligible.

On Fig. 1.1, draw and label arrows to show the directions of the **two** forces acting on the sphere. [2]

(c) The mass of the sphere is 49 g.

Calculate the drag force F_D acting on the sphere.

F_D = ... N [2]

(d) The sphere is falling in air at a terminal velocity of 25 in SI base units.
The density of the air is 1.2 in SI base units.
The diameter of the sphere is 0.060 in SI base units.

Use your answer in **(c)** to calculate the drag coefficient C for the sphere.

C = ... [3]

[Total: 10]

Question 32

(a) Define velocity.

....

.... [1]

(b) A student throws a ball over a vertical wall of height *h*, as shown in Fig. 2.1.

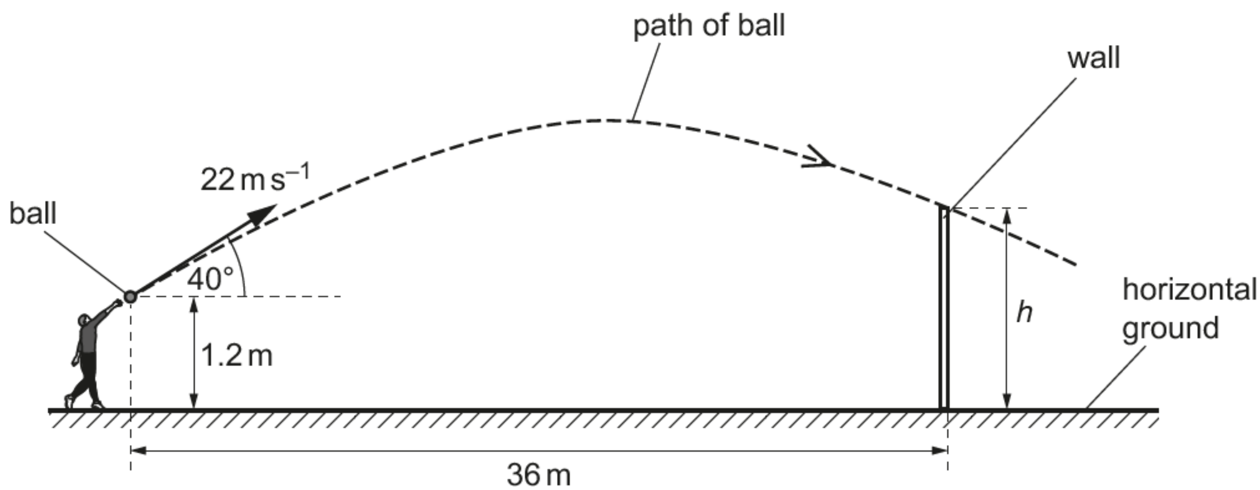


Fig. 2.1 (not to scale)

The ball leaves the hand of the student at a height of 1.2 m above the horizontal ground.
The ball has an initial velocity of $22\,m\,s^{-1}$ at an angle of 40° to the horizontal.
The wall is a horizontal distance of 36 m from where the student releases the ball.

Air resistance is negligible.

(i) Determine the time taken for the ball to reach the wall.

time taken = ... s [2]

(ii) Calculate the vertical component *u* of the initial velocity of the ball.

u = ... m s^{-1} [1]

(iii) The ball just goes over the wall.

Calculate the height *h* of the wall.

h = ... m [3]

[Total: 7]

Question 33

(a) State the principle of conservation of momentum.

....

....

.... [2]

(b) An object of mass $2m$ is travelling at a speed of $5.0\,\text{m}\,\text{s}^{-1}$ in a straight line. It collides with an object of mass $3m$ which is initially stationary, as shown in Fig. 3.1.

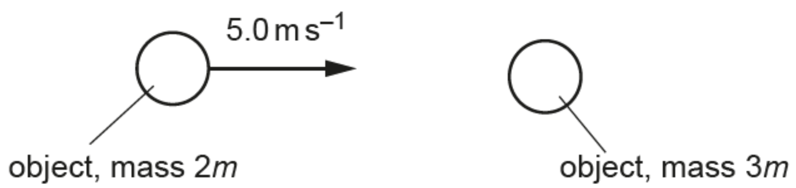


Fig. 3.1

After the collision, the object of mass $2m$ moves with velocity v at an angle of 30° to its original direction of motion.

The object of mass $3m$ moves with velocity w also at an angle of 30°, as shown in Fig. 3.2.

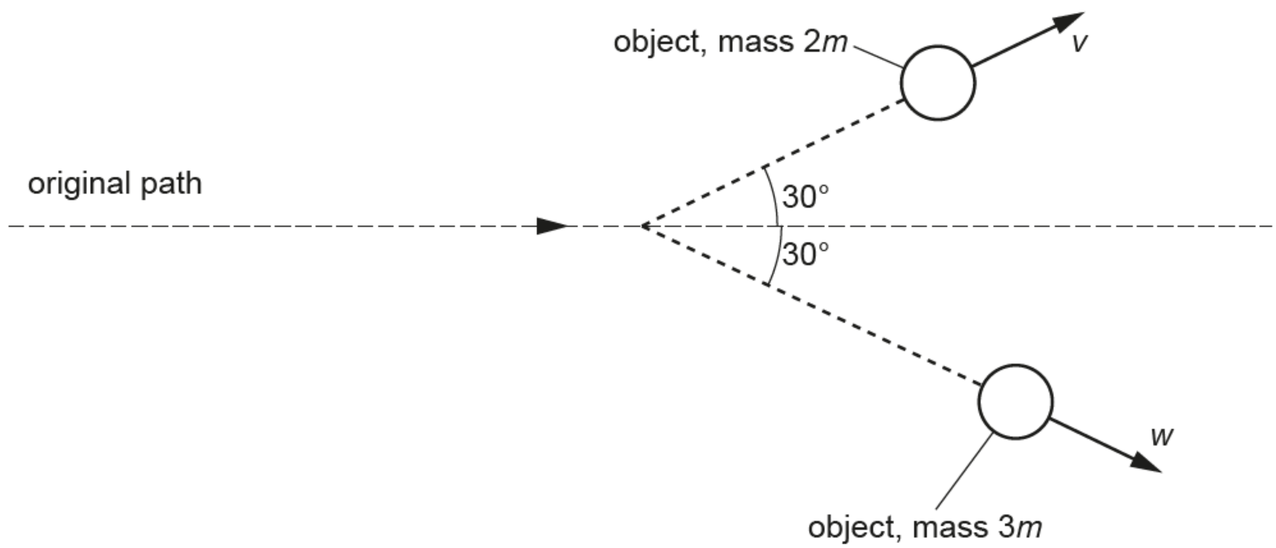


Fig. 3.2

By considering the conservation of momentum in two dimensions, calculate the magnitudes of v and w.

v = ... m s^{-1}

w = ... m s^{-1}
[4]

(c) An object of mass 4.2 kg is travelling in a straight line at a speed of $6.0\,\text{m s}^{-1}$. The object is brought to rest in a distance of 0.050 m by a constant force.

Calculate the magnitude of this force.

force = ... N [3]

[Total: 9]

Question 34

A skydiver jumps from an aircraft at time t = 0 and falls vertically downwards. The variation with t of her velocity v is shown in Fig. 2.1.

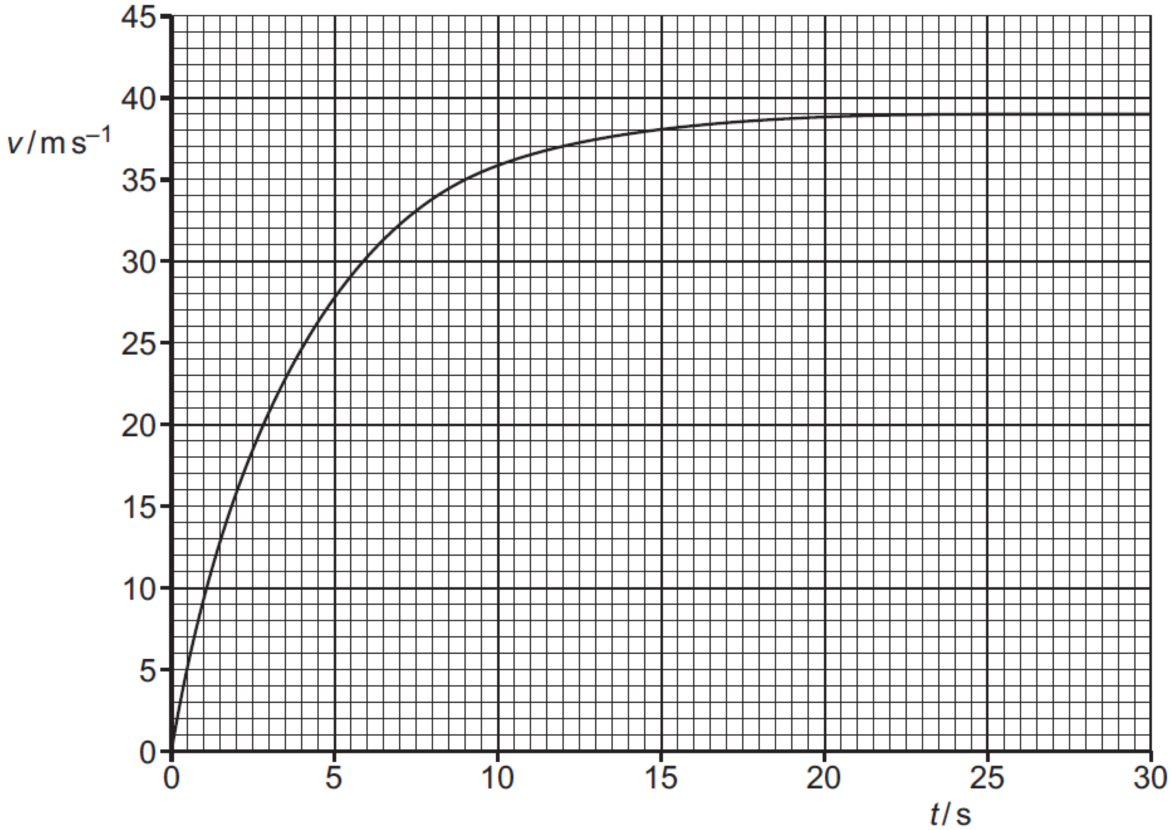


Fig. 2.1

(a) **(i)** Using Fig. 2.1, state the terminal velocity of the skydiver.

terminal velocity = ... m s^{-1} [1]

(ii) By drawing a suitable line on Fig. 2.1, determine the acceleration of the skydiver at time t = 9.0 s.

acceleration = ... m s^{-2} [2]

(b) The mass of the skydiver and her equipment is 68 kg. The upthrust on the skydiver is negligible.

After reaching terminal velocity, the skydiver opens her parachute at time t_1. A total drag force of 1800 N acts on the skydiver.

Determine the magnitude and direction of the acceleration of the skydiver at time t_1.

acceleration = ... $m s^{-2}$

direction = ...
[3]

(c) The parachute is fully open at time t_2. At a later time t_3 the skydiver reaches a constant velocity of $5.7 m s^{-1}$.

(i) Describe and explain the variation with time of the magnitude of her acceleration between time t_2 and time t_3.

....

....

....

....

.... [2]

(ii) Calculate the change in momentum of the skydiver between time t_1 and time t_3.

change in momentum = ... Ns [2]

[Total: 10]

Question 35

(a) Define displacement from a point.

....

.... [1]

(b) An object is projected horizontally at a speed of $6.0\,\mathrm{m\,s^{-1}}$ from a slope, as shown in Fig. 2.1.

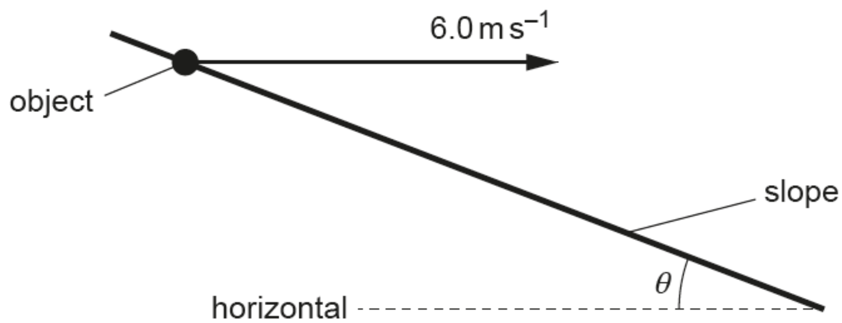


Fig. 2.1 (not to scale)

The slope is at an angle θ to the horizontal. Air resistance is negligible.

The object lands on the slope a time of 0.71 s later and stops without rolling or bouncing.

(i) Determine the horizontal distance travelled by the object.

distance = ... m [1]

(ii) Determine the vertical distance travelled by the object.

distance = ... m [2]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to calculate θ.

θ = ... ° [2]

(iv) Determine the magnitude of the displacement of the object from its original position.

displacement = ... m [2]

(v) By considering energy, calculate the speed of the object just before it lands.

speed = ... $m\,s^{-1}$ [3]

[Total: 11]

Question 36

(a) Define linear momentum.

....

.... [1]

(b) A car of mass 1800 kg is moving in a straight line. Fig. 2.1 shows the variation with time *t* of the momentum *p* of the car.

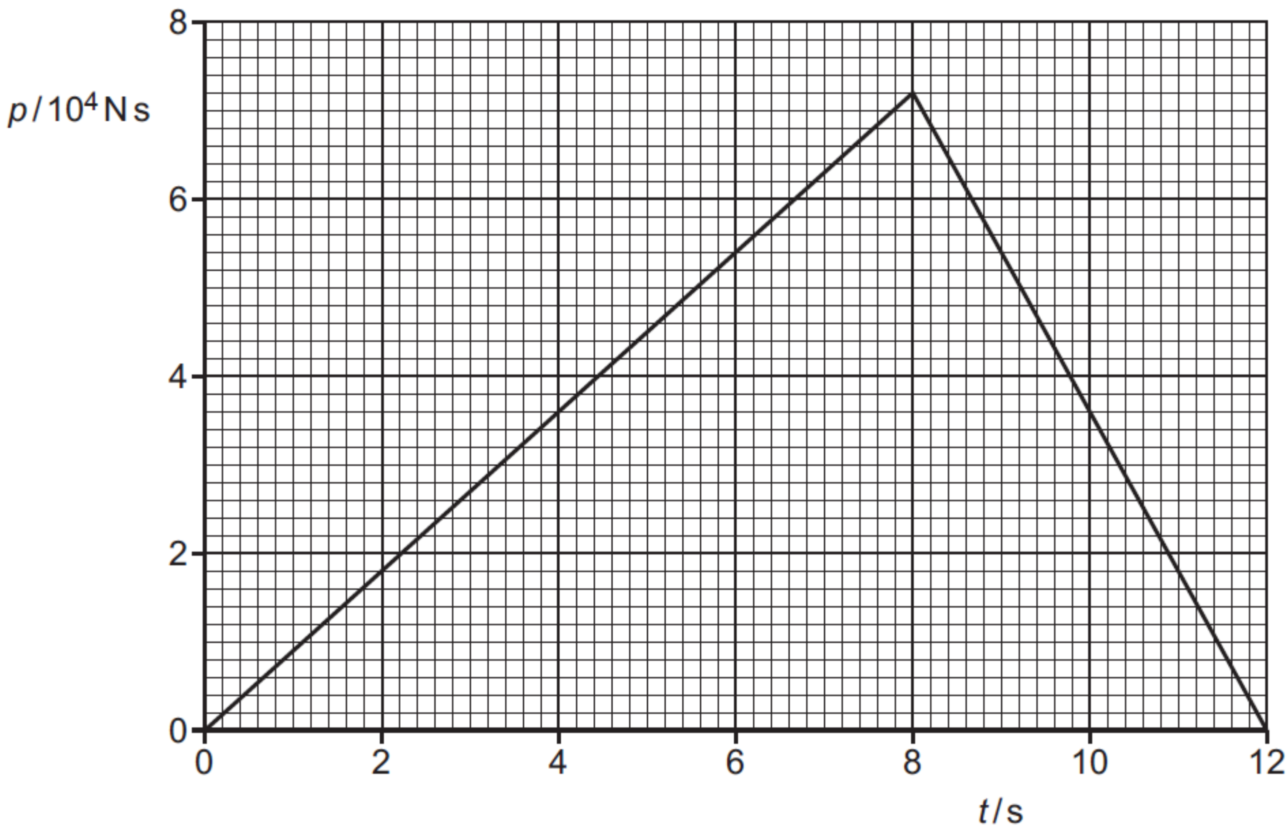


Fig. 2.1

(i) Calculate the maximum speed reached by the car.

maximum speed = ... $m\,s^{-1}$ [1]

(ii) Calculate the maximum kinetic energy of the car.

maximum kinetic energy = ... J [2]

(iii) Show that the acceleration of the car at time t = 4.0 s is 5.0 $m\,s^{-2}$.

[2]

(iv) Determine the distance travelled by the car between times t = 0 and t = 12.0 s.

distance = ... m [2]

(c) On Fig. 2.2, sketch the variation with time *t* of the acceleration *a* of the car in **(b)** from *t* = 0 to *t* = 12.0 s.

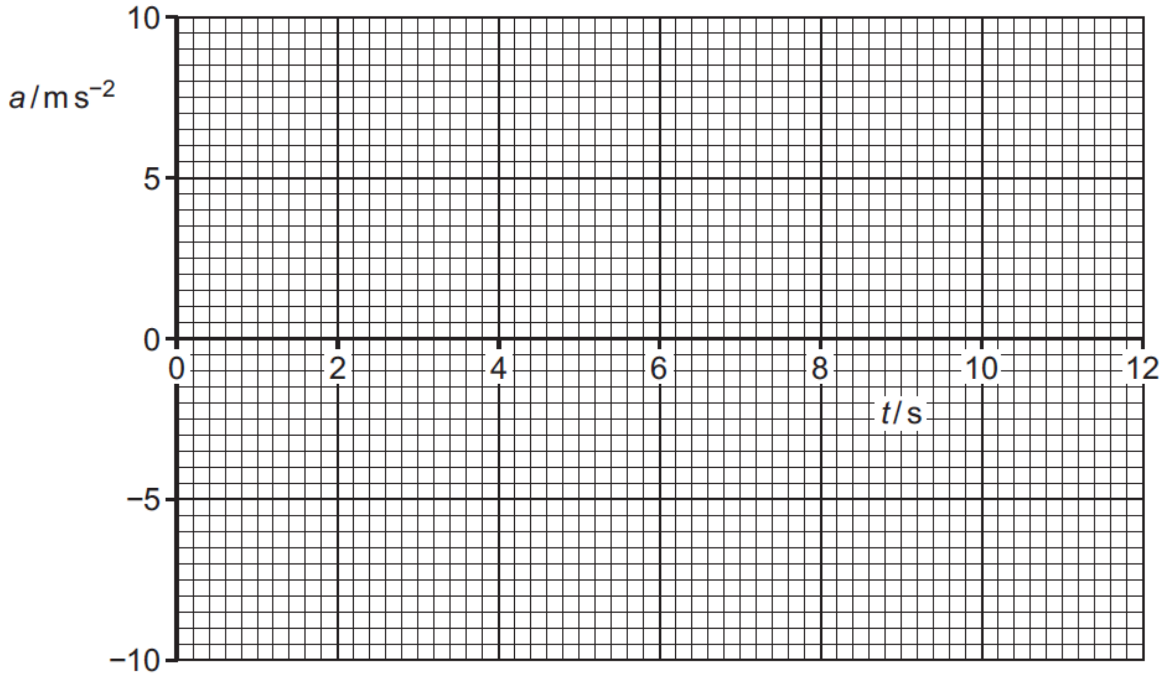


Fig. 2.2

[3]

[Total: 11]

Question 37

(a) Define momentum.

....

.... [1]

(b) A child stands on a scooter on horizontal ground. The combined mass of the child and the scooter is 16 kg.
The child starts from rest and pushes once on the ground with her foot which causes her to accelerate. The push lasts for a time of 1.1 s. The speed of the child and the scooter after the push is $0.60\,\text{m}\,\text{s}^{-1}$.

Determine the average resultant force acting horizontally on the child and the scooter during the push.

average force = ... N [2]

(c) Later, the child in **(b)** travels down a slope at a constant angle to the horizontal, as shown in Fig. 2.1.

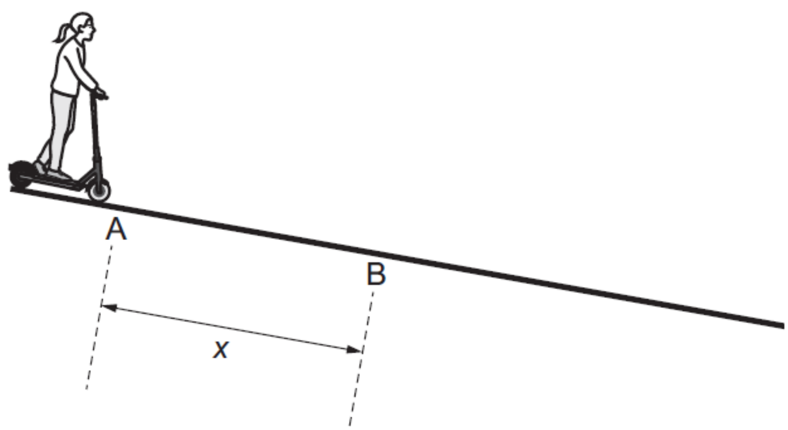


Fig. 2.1 (not to scale)

At point A her speed is $0.60\,\text{m}\,\text{s}^{-1}$. She has a constant acceleration of $0.85\,\text{m}\,\text{s}^{-2}$ parallel to the slope. After a time of 3.7 s, she reaches point B.

Calculate the distance x travelled by the child along the slope from A to B.

x = ... m [2]

(d) At point B, the child in **(c)** applies the brake with a constant force to maintain a constant velocity. Point C is 18 m from point B, as shown in Fig. 2.2.

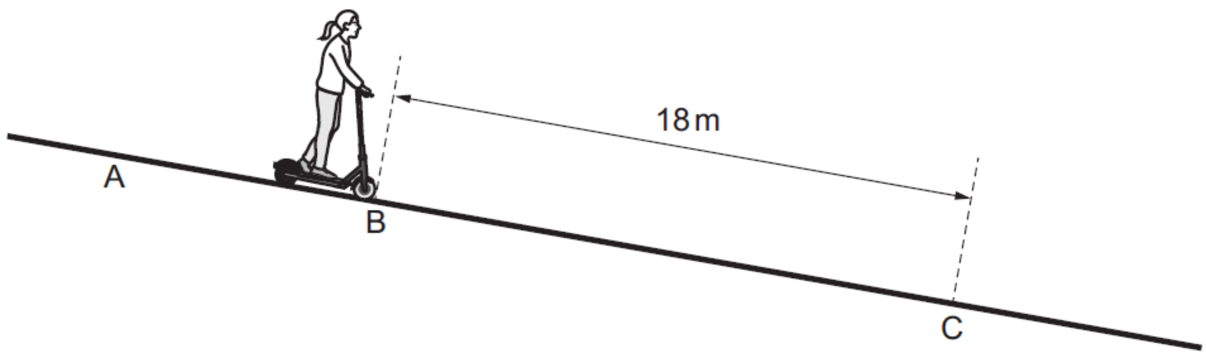


Fig. 2.2 (not to scale)

The work done by the braking force between B and C is 250 J.

(i) Determine the magnitude of the braking force.

force = ... N [2]

(ii) On Fig. 2.3, sketch the variation of the kinetic energy of the child and scooter with distance travelled from point A to point C.
Numerical values for kinetic energy are not required.

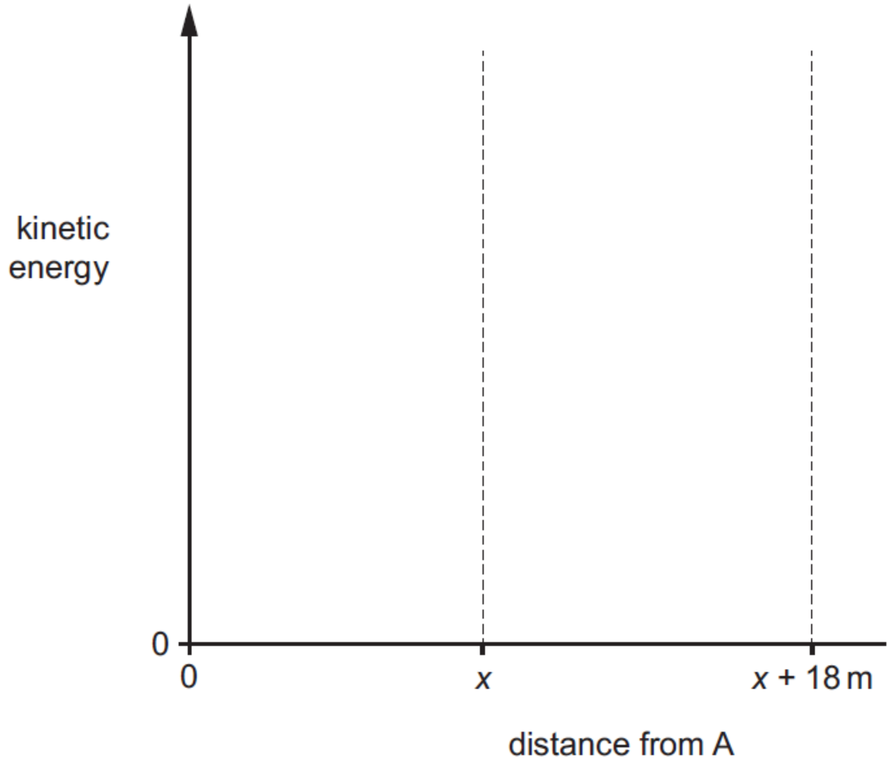


Fig. 2.3

[3]

[Total: 10]

Question 38

(a) Define acceleration.

....

.... [1]

(b) A small aircraft is flying horizontally at a speed of $42\,\mathrm{m\,s^{-1}}$ at a height of 63 m above horizontal ground, as shown in Fig. 1.1.

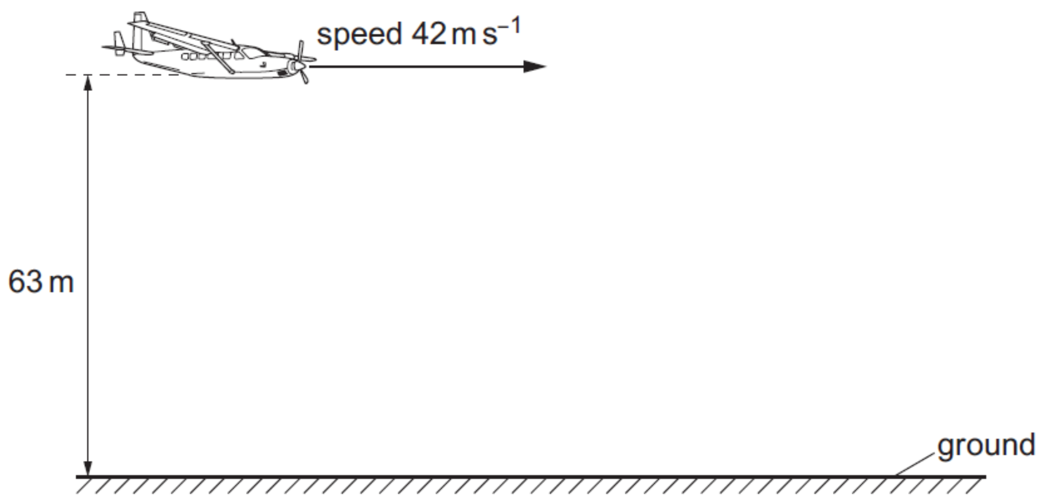


Fig. 1.1

The aircraft drops a small parcel. The parcel is released from the aircraft at the instant shown in Fig. 1.1. Air resistance is negligible.

(i) On Fig. 1.1, draw a line to show the path of the parcel as it falls from the aircraft to the ground. [1]

(ii) Calculate the time taken from the instant of release to the instant the parcel reaches the ground.

time = ... s [2]

(iii) Calculate the vertical component of the velocity of the parcel immediately before it reaches the ground.

vertical component of velocity = ... $m\,s^{-1}$ [1]

(iv) Determine the speed at which the parcel reaches the ground.

speed = ... $m\,s^{-1}$ [2]

[Total: 7]

Question 39

(a) State the principle of conservation of momentum.

....

....

.... [2]

(b) A ball X has mass 240 g and moves in a straight line on a horizontal frictionless surface with an initial speed of $16\,m\,s^{-1}$. The ball collides with a stationary ball Y that has mass 480 g. After the collision, ball X is stationary, as shown in Fig. 2.1.

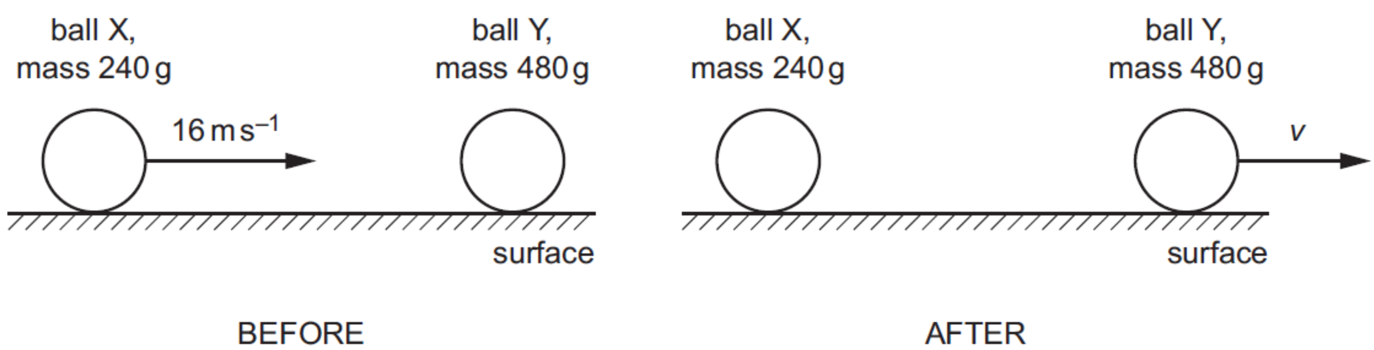


Fig. 2.1

(i) Show that the speed v of ball Y after the collision is $8.0\,m\,s^{-1}$.

[1]

(ii) Calculate the change in the total kinetic energy ΔE_K of the balls due to the collision.

ΔE_K = ... J [3]

(c) The collision in **(b)** lasts for a time of 2.0 ms. Assume that the contact force between the balls is constant during this time.

(i) Determine the magnitude and direction of the force exerted on ball X by ball Y during the collision.

magnitude = ... N

direction ....

[3]

(ii) Compare the magnitude and direction of the force exerted on ball Y by ball X during the collision with the answers in **(c)(i)**. No further calculations are required.

....

....

.... [2]

[Total: 11]

Question 40

(a) A truck R of mass 9400 kg moves with constant acceleration in a straight line down a slope, as illustrated in Fig. 3.1.

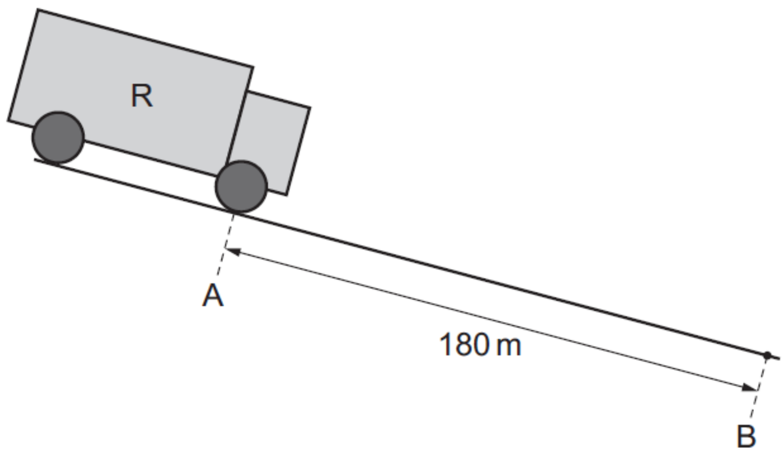


Fig. 3.1

At point A the speed of the truck is 13 $m\,s^{-1}$ and at point B the speed of the truck is 22 $m\,s^{-1}$. A and B are a distance of 180 m apart.

(i) Calculate the acceleration of the truck between A and B.

acceleration = ... $m\,s^{-2}$ [2]

(ii) Determine the gain in kinetic energy of the truck between A and B.

gain in kinetic energy = ... J [3]

(b) A short time after passing point B truck R moves in a straight line on horizontal ground. The driver of the truck applies the brakes. Fig. 3.2 shows the variation with time of the momentum of the truck.

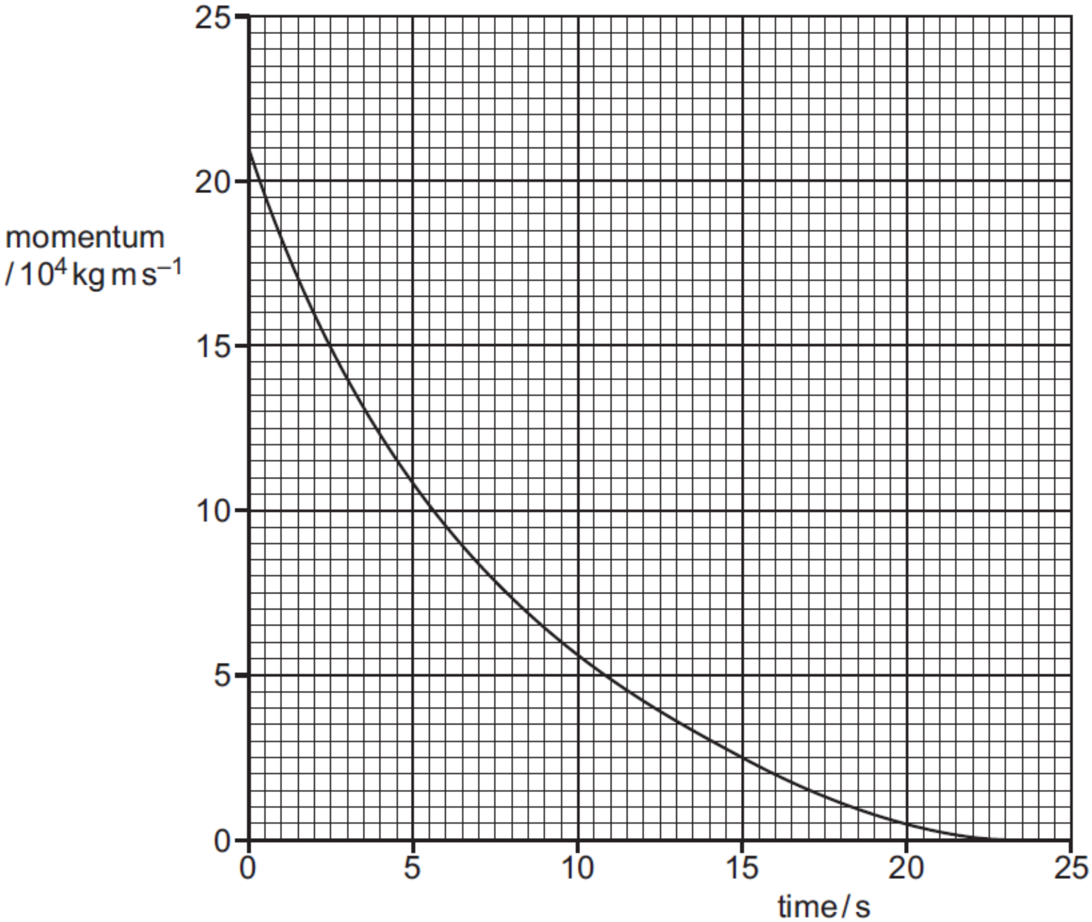


Fig. 3.2

(i) Define force.

....

.... [1]

(ii) Show that the average resultant force *F* acting on truck R between time $t = 0$ and $t = 15\,\text{s}$ is $-1.2 \times 10^4\,\text{N}$.

[1]

(iii) An identical truck S has the same initial momentum as truck R. Truck S experiences a constant force equal to the force *F* in **(b)(ii)**.

State and explain whether truck S will take more, less or the same amount of time to come to rest as truck R.

....

....

....

....

....

....

.... [3]

[Total: 10]

Question 41

(a) Define acceleration.

....

.... [1]

(b) In an experiment, two objects A and B are released from the side of a building, as shown in Fig. 1.1.

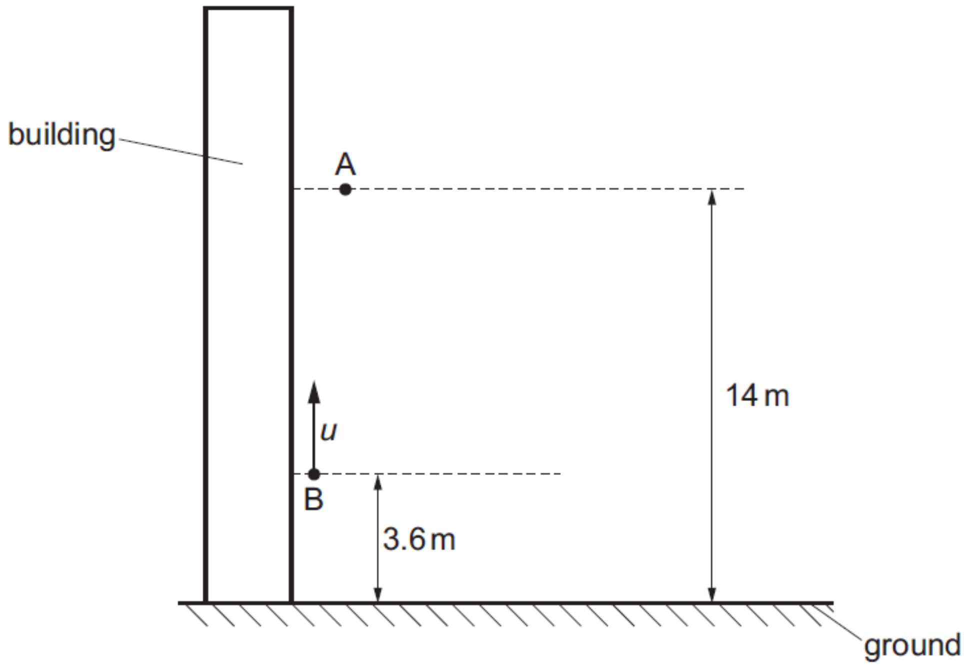


Fig. 1.1 (not to scale)

Object A is released from rest at a height of 14 m above the horizontal ground.
Object B is released with an initial upwards vertical velocity *u* at a height of 3.6 m above the ground.
Both objects take the same time to reach the ground and they do not collide with each other.
Air resistance is negligible.

(i) Calculate the time taken for object A to reach the ground.

time = ... s [2]

(ii) Use your answer in **(b)(i)** to calculate u.

u = ... $m\,s^{-1}$ [2]

(c) In a second experiment, object B is released from the same height and given the same initial speed as in **(b)** but at a release angle θ to the vertical, as shown in Fig. 1.2.

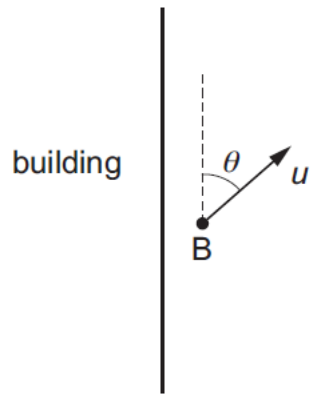


Fig. 1.2

(i) State and explain whether the time taken for object B to reach the ground is less than, the same as or greater than the time in **(b)(i)**.

....

....

.... [2]

(ii) By considering energy, state and explain the effect of the change in release angle on the speed at which B reaches the ground.

....

....

.... [2]

[Total: 9]

Question 42

A small ball is dropped from rest from height h_1 above the ground and falls vertically downwards. The ball collides with the ground and bounces back vertically upwards, reaching a maximum height h_2. Fig. 4.1 shows the ball just before and just after hitting the ground.

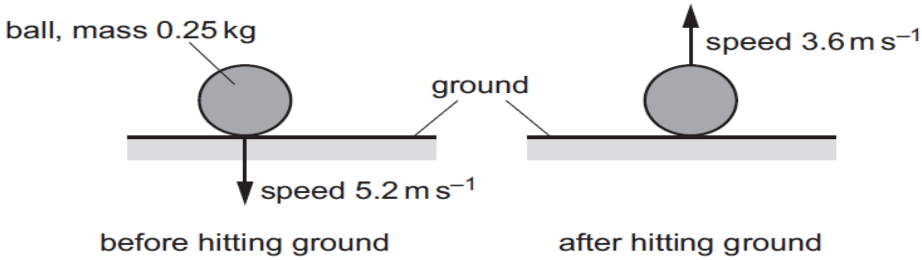


Fig. 4.1

The ball has mass 0.25 kg and is in contact with the ground for a time of 0.18 s.
Just before the ball hits the ground, it has speed 5.2 m s^{-1}. Just after it leaves the ground, it has speed 3.6 m s^{-1}.
Air resistance acting on the ball is negligible.

The ball has mass 0.25 kg and is in contact with the ground for a time of 0.18 s.
Just before the ball hits the ground, it has speed 5.2 m s^{-1}. Just after it leaves the ground, it has speed 3.6 m s^{-1}.
Air resistance acting on the ball is negligible.

(a) State and explain whether the collision is elastic or inelastic.

....

....

.... [1]

(b) **(i)** Calculate the change in momentum of the ball during the collision with the ground.

change in momentum = ... $kg\,m\,s^{-1}$ [2]

(ii) Determine the average force on the ball during the collision with the ground.

force = ... N [2]

(c) Calculate the ratio $\frac{h_2}{h_1}$.

ratio = ... [3]

[Total: 8]

Question 43

An object of constant mass moves in a straight line. The variation with time t of the momentum p of the object is shown in Fig. 2.1.

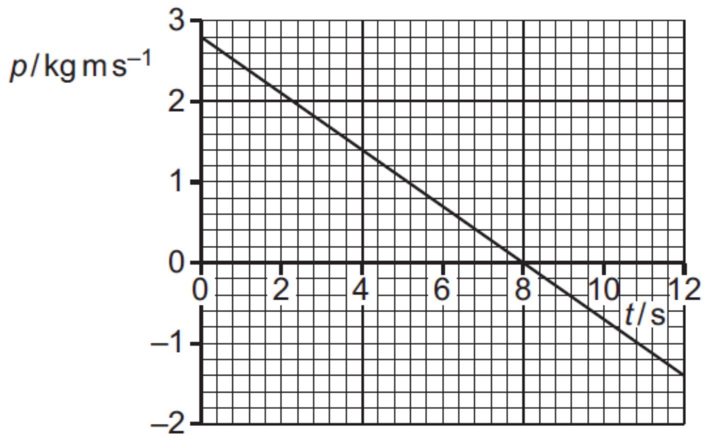


Fig. 2.1

(a) Define momentum.

....

.... [1]

(b) Calculate the change in momentum of the object from time $t = 0$ to $t = 12$ s.

change in momentum = ... kg m s^{-1} [1]

(c) Calculate the magnitude of the resultant force acting on the object.

force = ... N [2]

(d) Describe the variation of the speed of the object from time $t = 0$ to $t = 8.0\,s$.

....

.... [1]

(e) By reference to Fig. 2.1, explain why the resultant force acting on the object during the first 8.0 s of its motion cannot be due to air resistance.

....

....

....

.... [2]

(f) At time $t = 0$ the displacement d of the object is zero.

On Fig. 2.2, sketch the variation of d with time t from $t = 0$ to $t = 12\,s$.

Numerical values of d are not required.

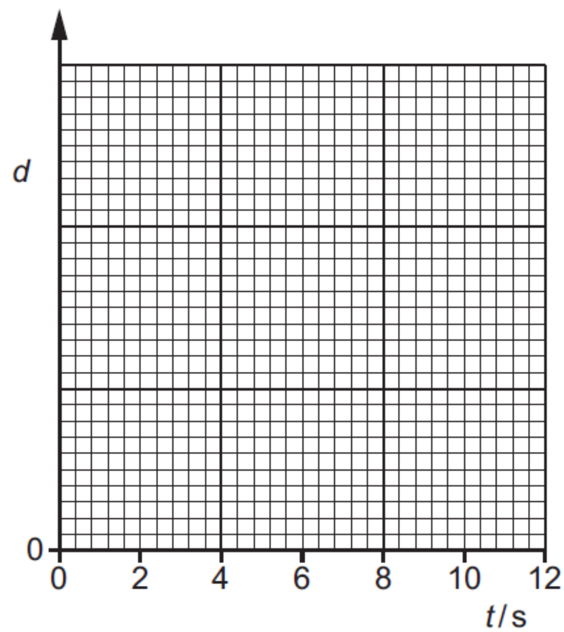


Fig. 2.2

[3]

[Total: 10]

Question 44

(a) Define acceleration.

....

.... [1]

(b) A rocket is launched vertically from the surface of the Earth.

Fig. 1.1 shows the variation of the velocity of the rocket with time for the first 20 s after its launch.

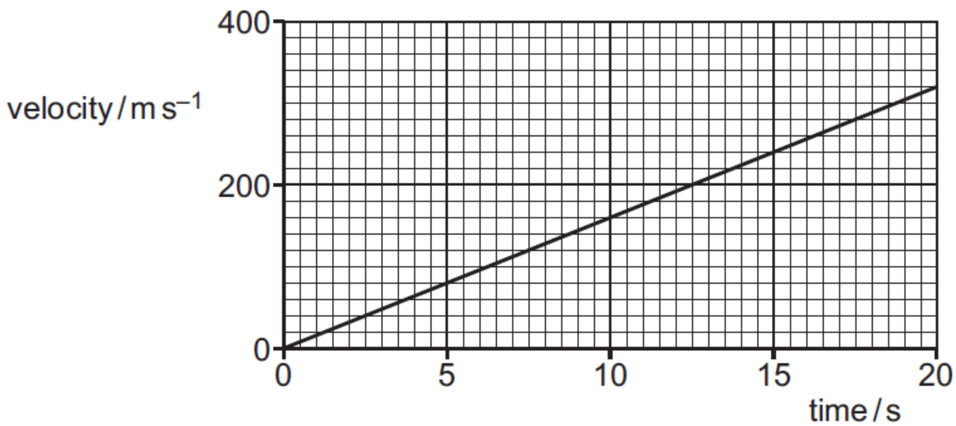


Fig. 1.1

(i) Determine the acceleration of the rocket.

acceleration = ... m s^{-2} [1]

(ii) Show that the height of the rocket above the surface of the Earth at a time of 20 s after launch is 3.2 km.

[2]

(c) The mass of the rocket in **(b)** is 2.9×10^{6} kg. Assume that this mass remains constant.

For this rocket, from launch to its height at a time of 20 s after launch:

(i) calculate the gain in gravitational potential energy ΔE_P

ΔE_P = ... J [2]

(ii) calculate the gain in kinetic energy ΔE_K

ΔE_K = ... J [2]

(iii) determine the average power output of the rocket engines. Assume that resistive forces are negligible.

power = ... W [2]

[Total: 10]

Question 45

A spacecraft in deep space uses jets of hot gas from its thrusters to change its velocity. Fig. 2.1 shows a side view of the spacecraft and some of its thrusters.

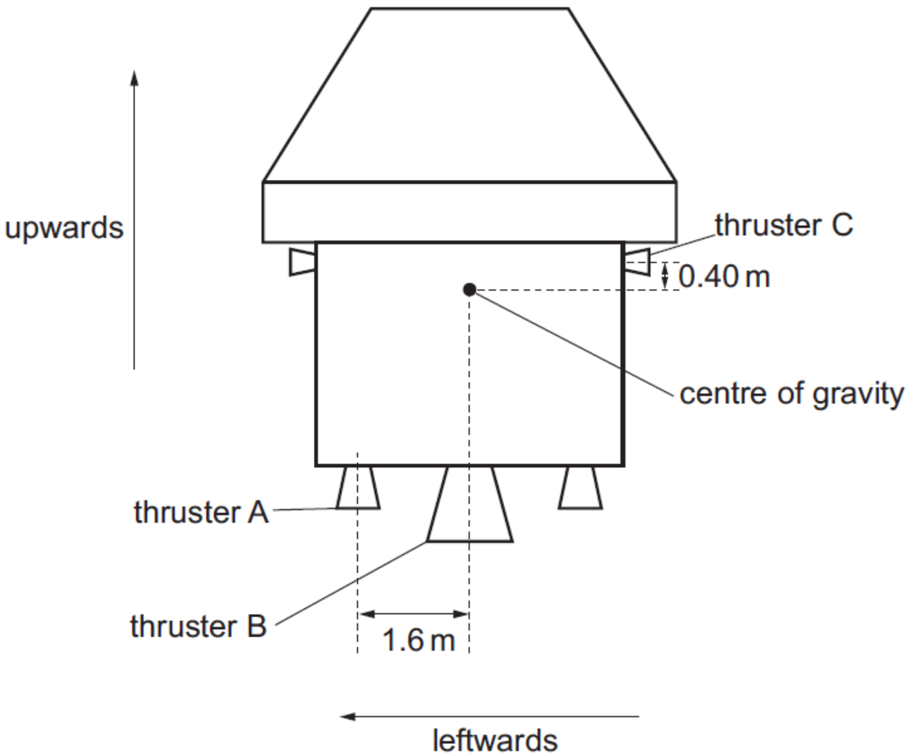


Fig. 2.1 (not to scale)

Thruster A is a distance of 1.6 m leftwards from the centre of gravity of the spacecraft. Thruster C is a distance of 0.40 m upwards from the centre of gravity of the spacecraft.

Thrusters A and B can produce forces on the spacecraft in the upwards direction only.
Thruster C can produce a force on the spacecraft in the leftwards direction only.
All the thrusters shown produce forces entirely in the same plane as the centre of gravity.

(a) **(i)** Thruster A is activated, producing a force of 60 N upwards on the spacecraft. Thruster C is also activated, producing a force of 220 N in the leftwards direction on the spacecraft.

Calculate the resultant moment due to these forces about the centre of gravity.

resultant moment = ... N m [2]

(ii) State and explain whether the forces from A and C are a couple.

....

....

.... [1]

(b) Thrusters A and C are now switched off and the spacecraft is stationary. Thruster B is activated at time t_1, producing a constant force on the spacecraft until the fuel runs out at time t_2. As the fuel is used, the total mass of the spacecraft decreases.

On Fig. 2.2, sketch the variation of speed of the spacecraft with time from t_1 to t_2.

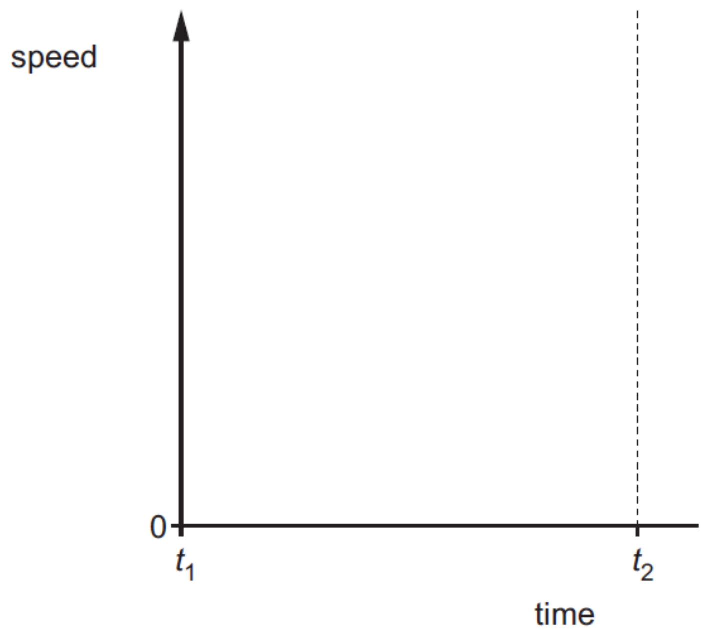


Fig. 2.2

[2]

(c) The spacecraft now splits apart into a carrier and a payload as shown in Fig. 2.3.

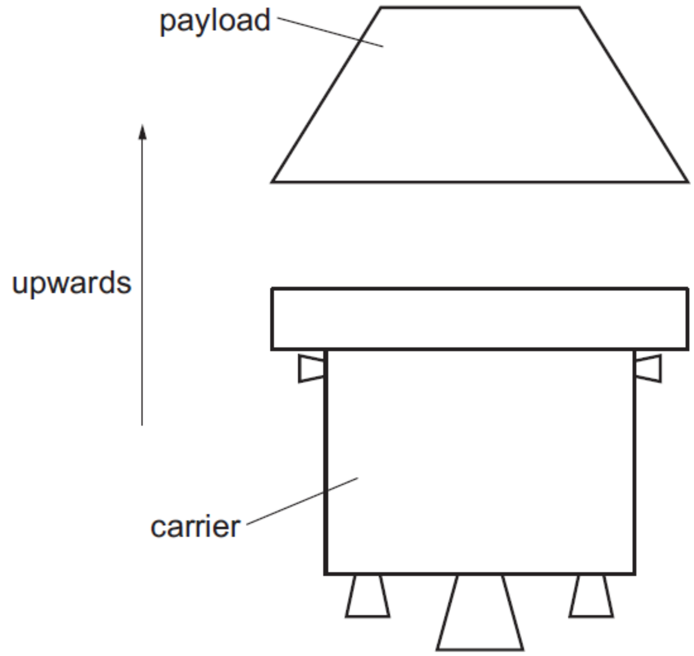


Fig. 2.3

During the split, an average force of 5500 N acts on the payload for a time of 0.36 s. The velocity of the payload increases by 8.5 m s^{-1} in the upwards direction.

During the split, an average force of 5500 N acts on the payload for a time of 0.36 s. The velocity of the payload increases by 8.5 m s^{-1} in the upwards direction.

The combined mass of the carrier and payload is 2.5×10^3 kg.

(i) State the principle of conservation of momentum.

....

....

.... [2]

(ii) Show that the mass of the payload is 230 kg.

[2]

(iii) Calculate the magnitude of the change in velocity of the carrier.

change in velocity = ... $m\,s^{-1}$ [3]

[Total: 12]

Question 46

A child kicks a ball so that it leaves horizontal ground with a velocity of $28\,\text{m}\,\text{s}^{-1}$ at an angle of 34° to the horizontal, as shown in Fig. 1.1.

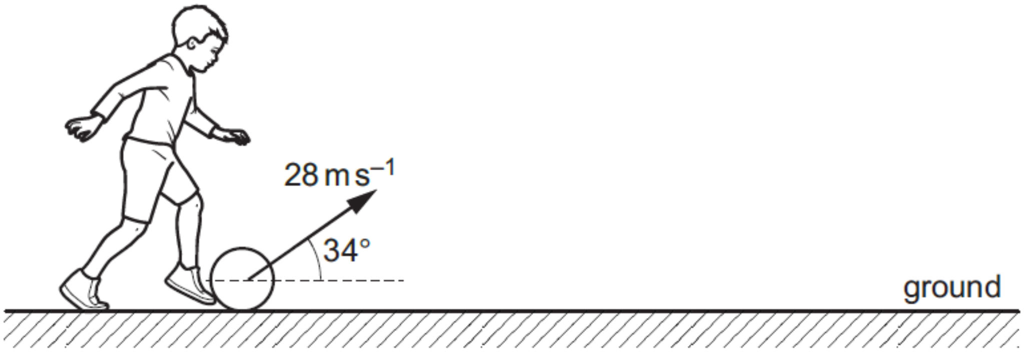


Fig. 1.1

Air resistance is negligible. The ball leaves the ground at time $t = 0$.

(a) (i) Calculate the horizontal component v_H and the vertical component v_V of the velocity of the ball immediately after it has left the ground.

v_H = ... $\text{m}\,\text{s}^{-1}$

v_V = ... $\text{m}\,\text{s}^{-1}$
[2]

(ii) Show that the ball reaches its maximum height at time $t = 1.6\,\text{s}$.

[1]

(iii) On Fig. 1.2, sketch the variation of v_H with time t between $t = 0$ and $t = 3.2$ s. Label your line H.

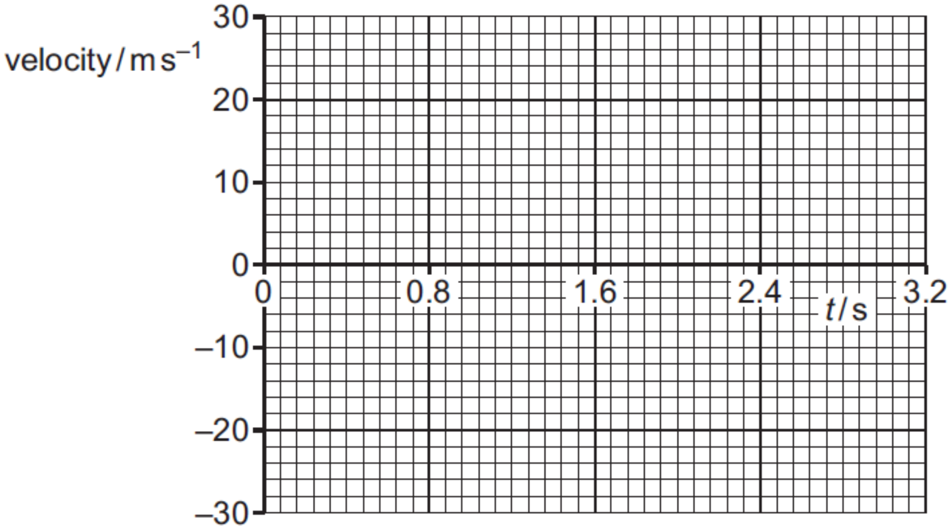


Fig. 1.2

[1]

(iv) On Fig. 1.2, sketch the variation of v_V with time t between $t = 0$ and $t = 3.2$ s. Assume that velocity in the upward direction is positive. Label your line V. [3]

(b) The total change in momentum of the ball between leaving the ground at $t = 0$ and landing on the ground at $t = 3.2$ s is 13 kg m s^{-1}.

(i) Define momentum.

....

.... [1]

(ii) Calculate the force that acts on the ball while it is in the air.

force = ... N [2]

(iii) Determine the mass of the ball.

mass = ... kg [1]

[Total: 11]

End of Question Paper • Waseem Ahmad, A Level Physics Teacher • examspath.com