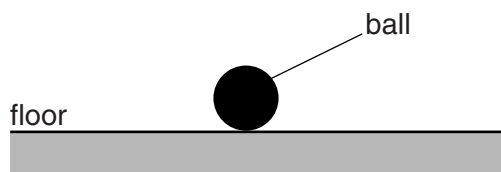


1. Question part 1/2 | 9702 May-June 2016 P2 V1 Q3

- 3** A ball of mass 150 g is at rest on a horizontal floor, as shown in Fig. 3.1.

**Fig. 3.1**

- (a) (i)** Calculate the magnitude of the normal contact force from the floor acting on the ball.

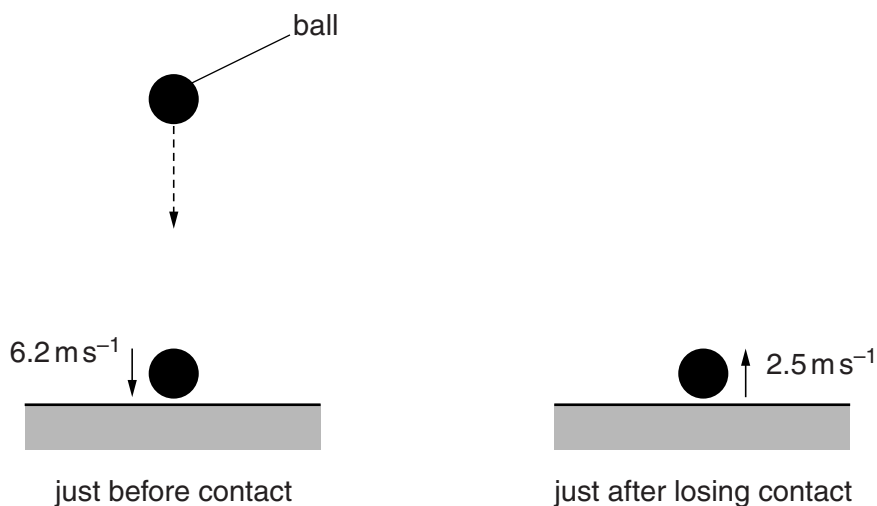
force = ... N [1]

- (ii)** Explain your working in **(i)**.

.....

 [1]

- (b)** The ball is now lifted above the floor and dropped so that it falls vertically, as illustrated in Fig. 3.2.

**Fig. 3.2**

Just before contact with the floor, the ball has velocity 6.2 ms^{-1} downwards. The ball bounces from the floor and its velocity just after losing contact with the floor is 2.5 ms^{-1} upwards. The ball is in contact with the floor for 0.12 s.

(i) State Newton’s second law of motion.

.....
.....[1]

(ii) Calculate the average resultant force on the ball when it is in contact with the floor.

magnitude of force = ... N
direction of force
[3]

(iii) State and explain whether linear momentum is conserved during the collision of the ball with the floor.

.....
.....
.....
.....[2]

[Total: 8]

5 (a) State the law of conservation of momentum.

.....

.....

..... [2]

(b) Two particles A and B collide elastically, as illustrated in Fig. 5.1.

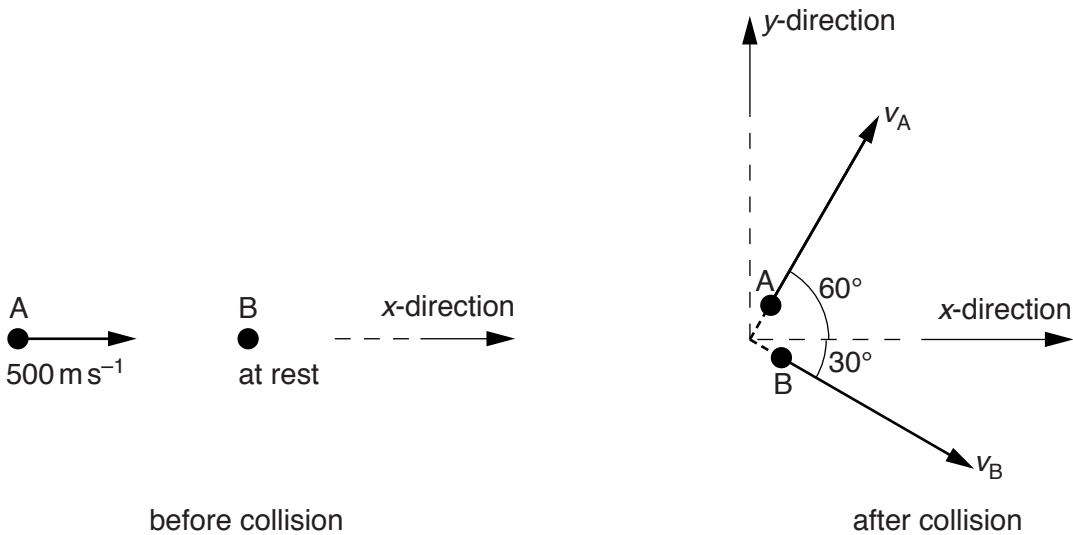


Fig. 5.1

The initial velocity of A is 500 ms^{-1} in the x -direction and B is at rest.

The velocity of A after the collision is v_A at 60° to the x -direction. The velocity of B after the collision is v_B at 30° to the x -direction.

The mass m of each particle is $1.67 \times 10^{-27} \text{ kg}$.

(i) Explain what is meant by the particles colliding *elastically*.

..... [1]

(ii) Calculate the total initial momentum of A and B.

momentum = ...Ns [1]

(iii) State an expression in terms of m , v_A and v_B for the total momentum of A and B after the collision

1. in the x-direction,

.....

2. in the y-direction.

.....

[2]

(iv) Calculate the magnitudes of the velocities v_A and v_B after the collision.

$v_A = \text{..... ms}^{-1}$

$v_B = \text{..... ms}^{-1}$

[3]

[Total: 9]

- 2 (a) State the *principle of conservation of momentum*.

.....
.....
.....[2]

- (b) Two blocks, A and B, are on a horizontal frictionless surface. The blocks are joined together by a spring, as shown in Fig. 2.1.

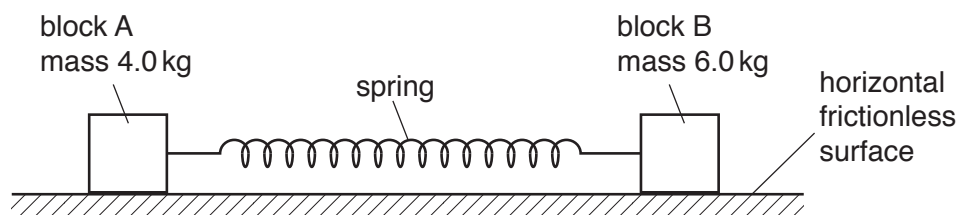


Fig. 2.1

Block A has mass 4.0 kg and block B has mass 6.0 kg.

The variation of the tension F with the extension x of the spring is shown in Fig. 2.2.

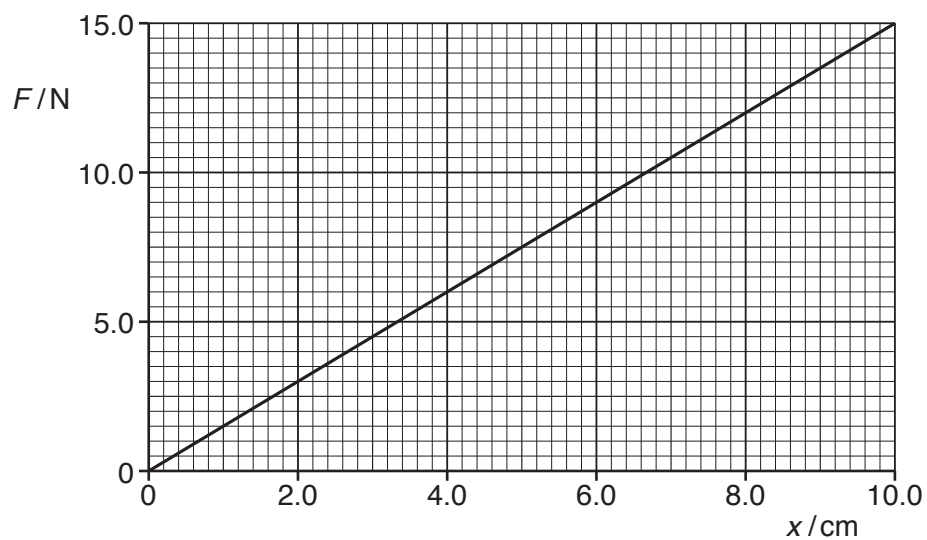


Fig. 2.2

The two blocks are held apart so that the spring has an extension of 8.0 cm.

- (i) Show that the elastic potential energy of the spring at an extension of 8.0 cm is 0.48 J.

[2]

- (ii) The blocks are released from rest at the same instant. When the extension of the spring becomes zero, block A has speed v_A and block B has speed v_B .

For the instant when the extension of the spring becomes zero,

1. use conservation of momentum to show that

$$\frac{\text{kinetic energy of block A}}{\text{kinetic energy of block B}} = 1.5$$

[3]

2. use the information in (b)(i) and (b)(ii)1 to determine the kinetic energy of block A. It may be assumed that the spring has negligible kinetic energy and that air resistance is negligible.

kinetic energy of block A = ... J [2]

3. Question part 3/4 | 9702 Feb-March 2017 P2 V2 Q2

(iii) The blocks are released at time $t = 0$.

On Fig. 2.3, sketch a graph to show how the momentum of block A varies with time t until the extension of the spring becomes zero.

Numerical values of momentum and time are not required.

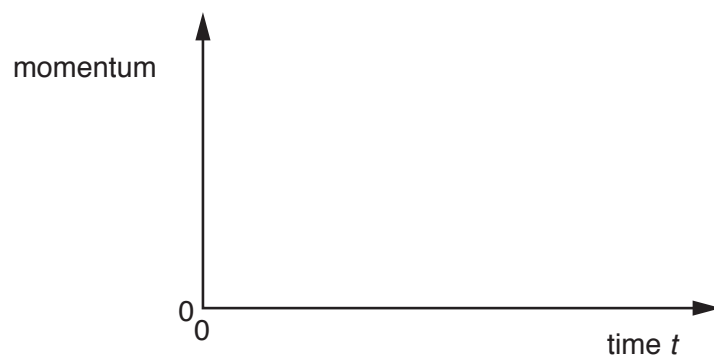


Fig. 2.3

[2]

[Total: 11]

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3 (a) Define *velocity*.

.....
[1]

(b) A car travels in a straight line up a slope, as shown in Fig. 3.1.

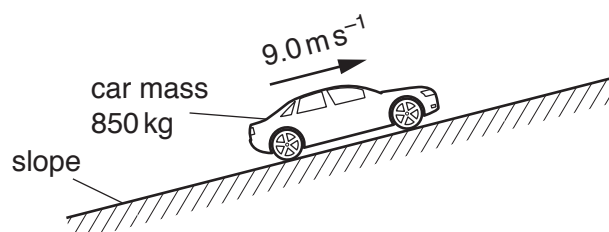


Fig. 3.1

The car has mass 850 kg and travels with a constant speed of 9.0 m s^{-1} . The car's engine exerts a force on the car of 2.0 kN up the slope.

A resistive force F_D , due to friction and air resistance, opposes the motion of the car.

The variation of F_D with the speed v of the car is shown in Fig. 3.2.

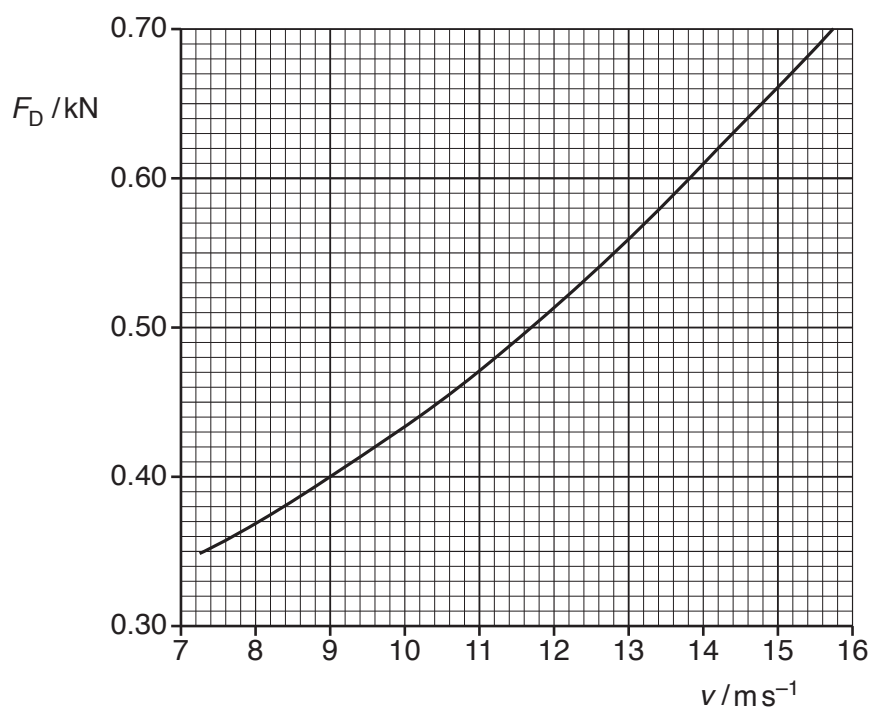


Fig. 3.2

(i) State and explain whether the car is in equilibrium as it moves up the slope.

.....

.....

.....[2]

(ii) Consider the forces that act along the slope. Use data from Fig. 3.2 to determine the component of the weight of the car that acts down the slope.

component of weight = ... N [2]

(iii) Show that the power output of the car is $1.8 \times 10^4 \text{ W}$.

[2]

(iv) The car now travels along horizontal ground. The output power of the car is maintained at $1.8 \times 10^4 \text{ W}$. The variation of the resistive force F_D acting on the car is given in Fig. 3.2.

Calculate the acceleration of the car when its speed is 15 m s^{-1} .

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

[Total: 10]

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

1.

.....

2.

.....

[2]

(b) A paraglider P of mass 95 kg is pulled by a wire attached to a boat, as shown in Fig. 2.1.

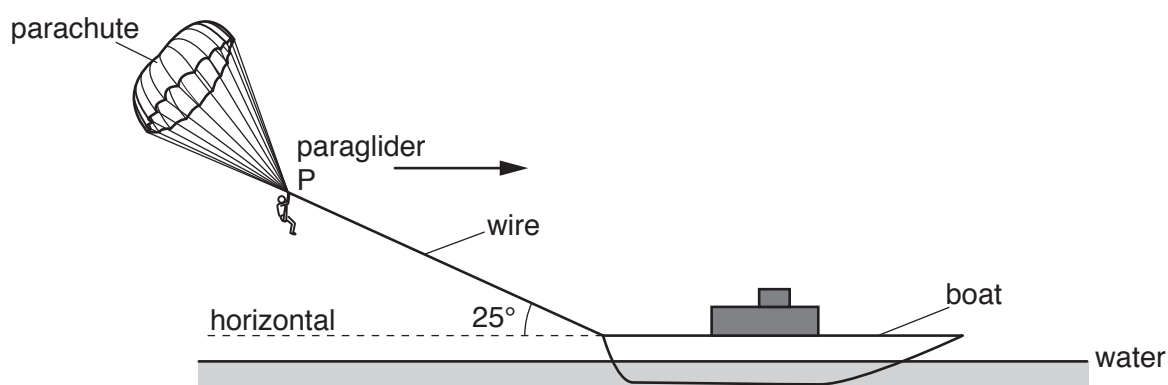


Fig. 2.1

The wire makes an angle of 25° with the horizontal water surface. P moves in a straight line parallel to the surface of the water.

The variation with time t of the velocity v of P is shown in Fig. 2.2.

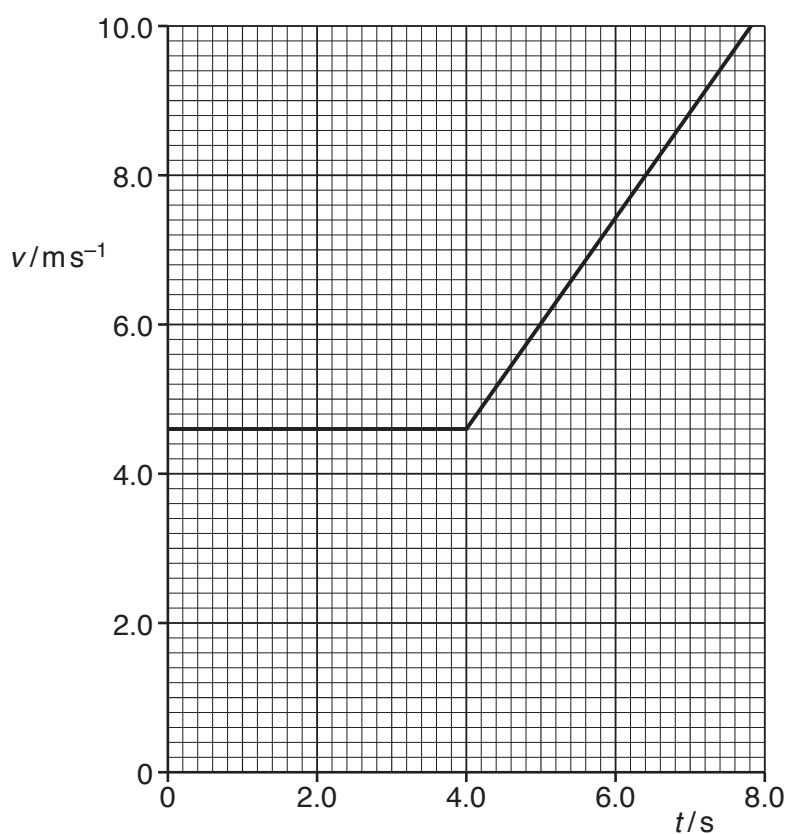


Fig. 2.2

- (i) Show that the acceleration of P is 1.4 m s^{-2} at time $t = 5.0 \text{ s}$.

[2]

- (ii) Calculate the total distance moved by P from time $t = 0$ to $t = 7.0 \text{ s}$.

distance = ...m [2]

- (iii) Calculate the change in kinetic energy of P from time $t = 0$ to $t = 7.0 \text{ s}$.

change in kinetic energy = ...J [2]

- (iv) The tension in the wire at time $t = 5.0 \text{ s}$ is 280 N .

Calculate, for the horizontal motion,

1. the vertical lift force F supporting P,

$F = \dots\dots\dots \text{ N}$ [3]

2. the force R due to air resistance acting on P in the horizontal direction.

$R = \dots\dots\dots \text{ N}$ [3]

[Total: 14]

4 (a) State Newton’s first law of motion.

.....

.....[1]

(b) An object A of mass 100 g is moving in a straight line with a velocity of 0.60 m s^{-1} to the right. An object B of mass 200 g is moving in the same straight line as object A with a velocity of 0.80 m s^{-1} to the left, as shown in Fig. 4.1.



Fig. 4.1

Objects A and B collide. Object A then moves with a velocity of 0.40 m s^{-1} to the left.

(i) Calculate the magnitude of the velocity of B after the collision.

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

(ii) The collision between A and B is inelastic.

Explain how the collision is inelastic and still obeys the law of conservation of energy.

.....

.....

.....[1]

[Total: 4]

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

.....
[1]

- (b) A constant resultant force F acts on an object A. The variation with time t of the velocity v for the motion of A is shown in Fig. 2.1.

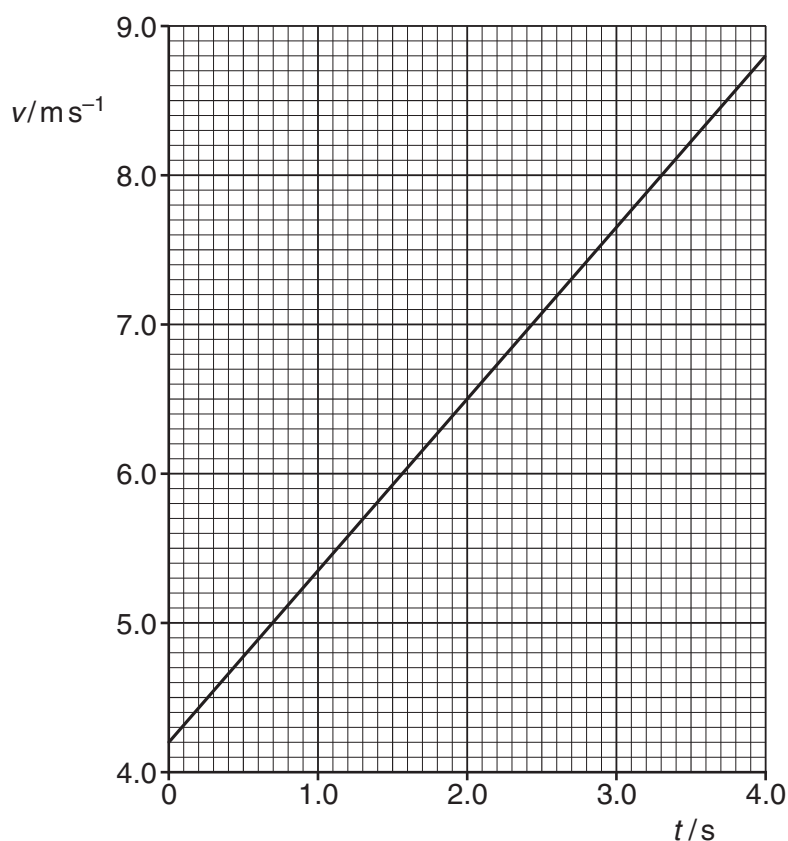


Fig. 2.1

The mass of A is 840 g.

Calculate, for the time $t = 0$ to $t = 4.0$ s,

- (i) the change in momentum of A,

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

- (ii) the force F .

$F =$ N [1]

- (c) The force F is removed at $t = 4.0\text{s}$. Object A continues at constant velocity before colliding with an object B, as illustrated in Fig. 2.2.



Fig. 2.2

Object B is initially at rest. The mass of B is 730 g.
The objects A and B join together and have a velocity of 4.7 m s^{-1} .

- (i) By calculation, show that the changes in momentum of A and of B during the collision are equal and opposite.

[2]

- (ii) Explain how the answers obtained in (i) support Newton’s third law.

.....
.....
.....
.....[2]

- (iii) By reference to the speeds of A and B, explain whether the collision is elastic.

.....
.....[1]

[Total: 9]

- 3 (a) State the principle of conservation of momentum.

.....

[2]

- (b) Ball A moves with speed v along a horizontal frictionless surface towards a stationary ball B, as shown in Fig. 3.1.

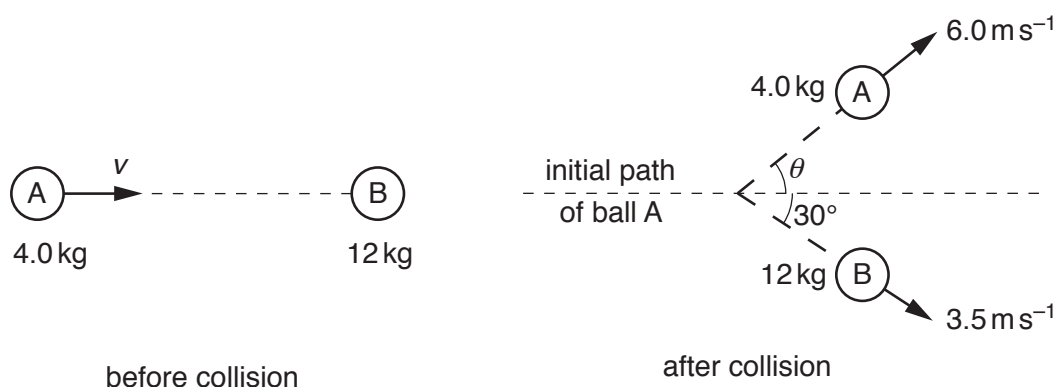


Fig. 3.1

Fig. 3.2 (not to scale)

Ball A has mass 4.0 kg and ball B has mass 12 kg.

The balls collide and then move apart as shown in Fig. 3.2.

Ball A has velocity 6.0 m s^{-1} at an angle of θ to the direction of its initial path.

Ball B has velocity 3.5 m s^{-1} at an angle of 30° to the direction of the initial path of ball A.

- (i) By considering the components of momentum at right-angles to the direction of the initial path of ball A, calculate θ .

$$\theta = \dots\dots\dots^\circ \text{ [3]}$$

(ii) Use your answer in (i) to show that the initial speed v of ball A is 12 m s^{-1} .
Explain your working.

[2]

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

.....
.....[3]

[Total: 10]

2 (a) State Newton's first law of motion.

.....
[1]

(b) A block of weight 15 N hangs by a wire from a remotely controlled aircraft, as shown in Fig. 2.1.

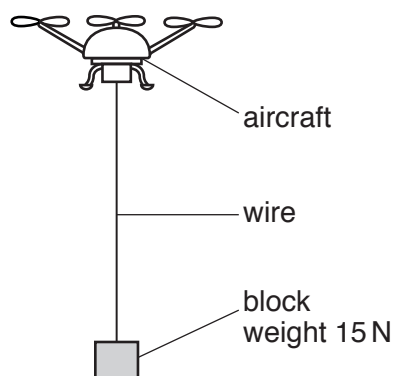


Fig. 2.1

The aircraft is used to move the block only in a vertical direction. The force on the block due to air resistance is negligible.

The variation with time t of the vertical velocity v of the block is shown in Fig. 2.2. The velocity is taken to be positive in the upward direction.

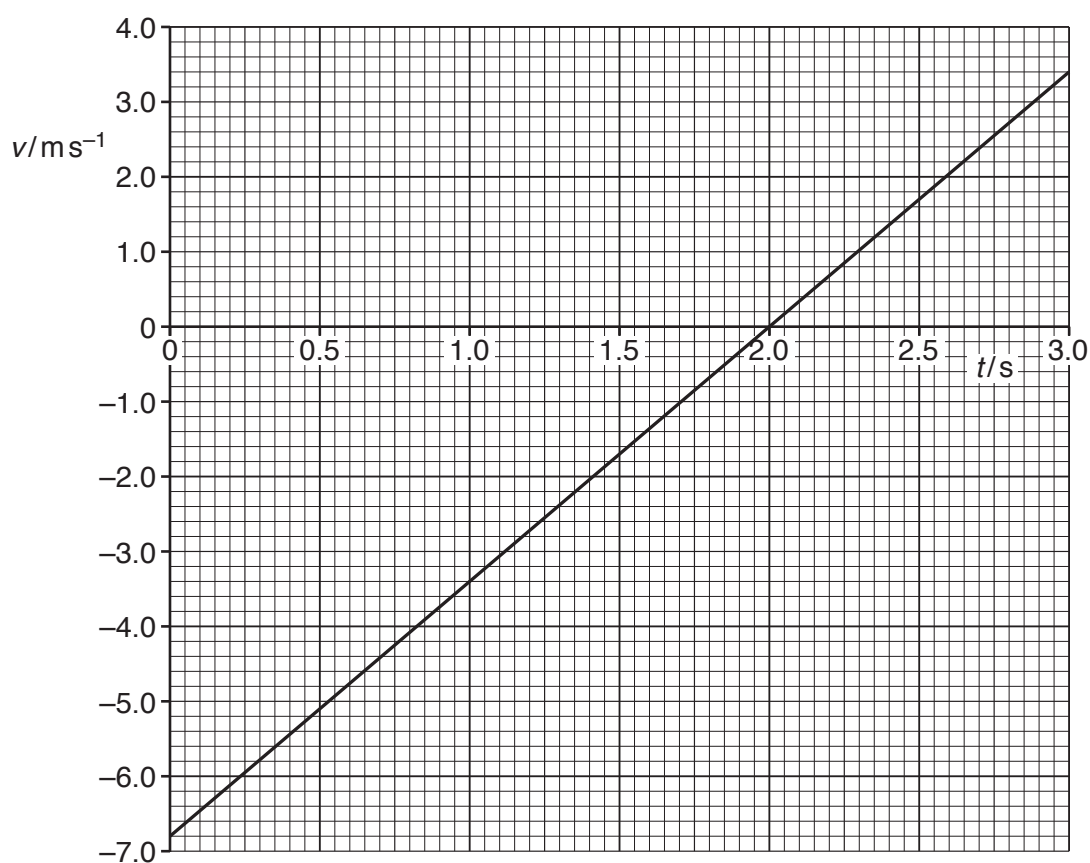


Fig. 2.2

9. Question part 2/4 | 9702 May-June 2018 P2 V1 Q2

(i) Determine, for the block,

1. the displacement from time $t = 0$ to $t = 3.0$ s,

magnitude of displacement = ... m

direction of displacement
[3]

2. the change in gravitational potential energy from time $t = 0$ to $t = 3.0$ s.

change in gravitational potential energy = ... J [2]

(ii) Calculate the magnitude of the acceleration of the block at time $t = 2.0$ s.

acceleration = ... ms^{-2} [2]

(iii) Use your answer in (b)(ii) to show that the tension T in the wire at time $t = 2.0$ s is 20 N.

[2]

- (iv) The wire has a cross-sectional area of $2.8 \times 10^{-5} \text{ m}^2$ and is made from metal of Young modulus $1.7 \times 10^{11} \text{ Pa}$. The wire obeys Hooke’s law.

Calculate the strain of the wire at time $t = 2.0 \text{ s}$.

strain = ... [3]

- (v) At some time after $t = 3.0 \text{ s}$ the tension in the wire has a constant value of 15 N .

State and explain whether it is possible to deduce that the block is moving vertically after $t = 3.0 \text{ s}$.

.....
.....
.....
.....[2]

[Total: 15]

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- 3 (a) State what is meant by the *mass* of a body.

.....
[1]

- (b) Two blocks travel directly towards each other along a horizontal, frictionless surface. The blocks collide, as illustrated in Fig. 3.1.

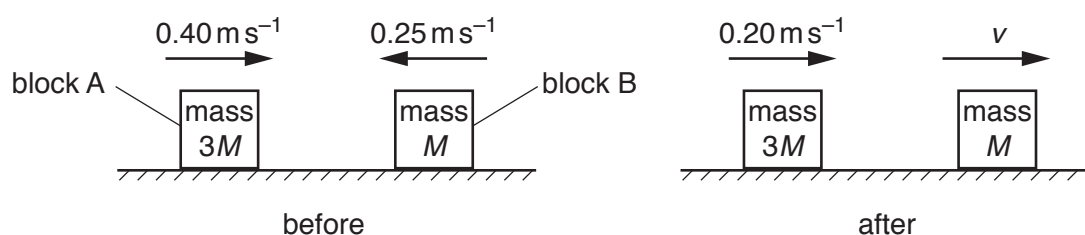


Fig. 3.1

Block A has mass $3M$ and block B has mass M .

Before the collision, block A moves to the right with speed 0.40 ms^{-1} and block B moves to the left with speed 0.25 ms^{-1} .

After the collision, block A moves to the right with speed 0.20 ms^{-1} and block B moves to the right with speed v .

- (i) Use Newton's third law to explain why, during the collision, the change in momentum of block A is equal and opposite to the change in momentum of block B.

.....

[2]

- (ii) Determine speed v .

$v = \dots\dots\dots \text{ms}^{-1}$ [3]

(iii) Calculate, for the blocks,

1. the relative speed of approach,

relative speed of approach = ... ms^{-1}

2. the relative speed of separation.

relative speed of separation = ... ms^{-1}
[2]

(iv) Use your answers in **(b)(iii)** to state and explain whether the collision is elastic or inelastic.

.....
.....[1]

[Total: 9]

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- 2 (a) State the principle of conservation of momentum.

.....

[2]

- (b) A stationary firework explodes into three different fragments that move in a horizontal plane, as illustrated in Fig. 2.1.

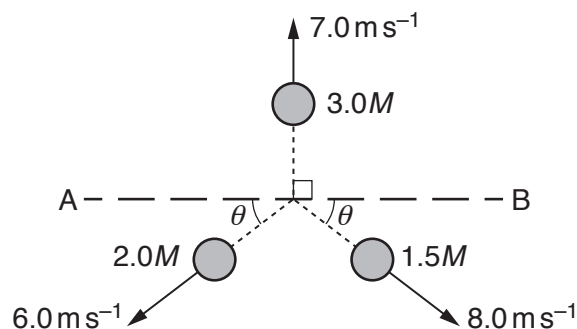


Fig. 2.1

The fragment of mass $3.0M$ has a velocity of 7.0 m s^{-1} perpendicular to line AB.
 The fragment of mass $2.0M$ has a velocity of 6.0 m s^{-1} at angle θ to line AB.
 The fragment of mass $1.5M$ has a velocity of 8.0 m s^{-1} at angle θ to line AB.

- (i) Use the principle of conservation of momentum to determine θ .

$\theta = \dots\dots\dots^\circ$ [3]

- (ii) Calculate the ratio

$$\frac{\text{kinetic energy of fragment of mass } 2.0M}{\text{kinetic energy of fragment of mass } 1.5M}.$$

ratio = ...[2]

[Total: 7]

- 2 A wooden block moves along a horizontal frictionless surface, as shown in Fig. 2.1.

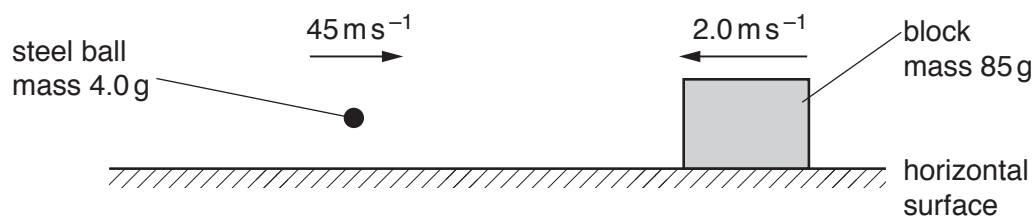


Fig. 2.1

The block has mass 85 g and moves to the left with a velocity of 2.0 ms^{-1} . A steel ball of mass 4.0 g is fired to the right. The steel ball, moving horizontally with a speed of 45 ms^{-1} , collides with the block and remains embedded in it. After the collision the block and steel ball both have speed v .

- (a) Calculate v .

$$v = \dots \text{ ms}^{-1} \text{ [2]}$$

- (b) (i) For the block and ball, state

1. the relative speed of approach before collision,

$$\text{relative speed of approach} = \dots \text{ ms}^{-1}$$

2. the relative speed of separation after collision.

$$\text{relative speed of separation} = \dots \text{ ms}^{-1} \text{ [1]}$$

- (ii) Use your answers in (i) to state and explain whether the collision is elastic or inelastic.

.....
 [1]

- (c) Use Newton's third law to explain the relationship between the rate of change of momentum of the ball and the rate of change of momentum of the block during the collision.

.....

 [2]

[Total: 6]

- 3 (a) State the principle of conservation of momentum.

.....

[2]

- (b) The propulsion system of a toy car consists of a propeller attached to an electric motor, as illustrated in Fig. 3.1.

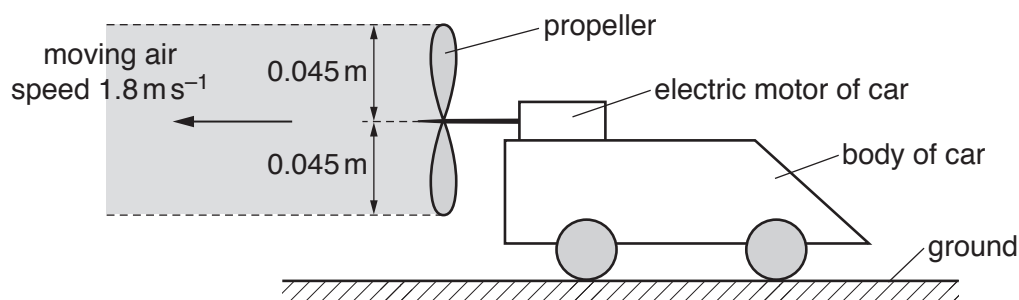


Fig. 3.1

The car is on horizontal ground and is initially held at rest by its brakes. When the motor is switched on, it rotates the propeller so that air is propelled horizontally to the left. The density of the air is 1.3 kg m^{-3} .

Assume that the air moves with a speed of 1.8 m s^{-1} in a uniform cylinder of radius 0.045 m . Also assume that the air to the right of the propeller is stationary.

- (i) Show that, in a time interval of 2.0 s , the mass of air propelled to the left is 0.030 kg .

[2]

(ii) Calculate

1. the increase in the momentum of the mass of air in **(b)(i)**,

increase in momentum = ... N s

2. the force exerted on this mass of air by the propeller.

force = ... N
[3]

(iii) Explain how Newton's third law applies to the movement of the air by the propeller.

.....
.....
.....[2]

(iv) The total mass of the car is 0.20 kg. The brakes of the car are released and the car begins to move with an initial acceleration of 0.075 ms^{-2} .

Determine the initial frictional force acting on the car.

frictional force = ... N [2]

[Total: 11]

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

.....
.....[1]

- (b) A toy rocket consists of a container of water and compressed air, as shown in Fig. 3.1.

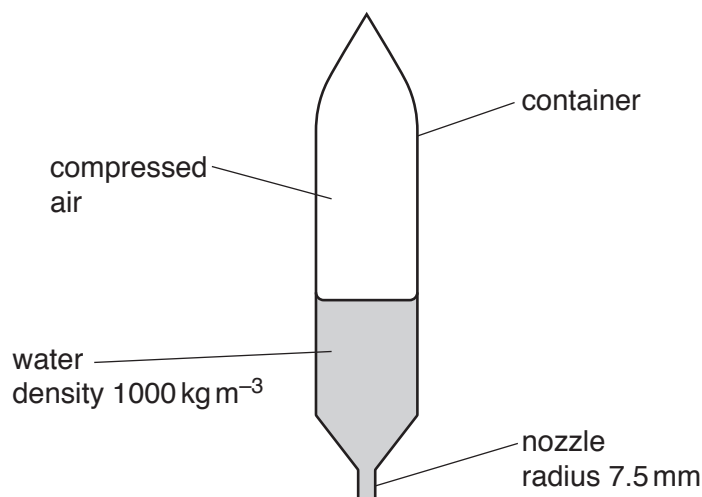


Fig. 3.1

Water is pushed vertically downwards through a nozzle by the compressed air. The rocket moves vertically upwards.

The nozzle has a circular cross-section of radius 7.5 mm. The density of the water is 1000 kg m^{-3} . Assume that the water leaving the nozzle has the shape of a cylinder of radius 7.5 mm and has a constant speed of 13 m s^{-1} relative to the rocket.

- (i) Show that the mass of water leaving the nozzle in the first 0.20 s after the rocket launch is 0.46 kg.

[2]

(ii) Calculate

1. the change in the momentum of the mass of water in **(b)(i)** due to leaving the nozzle,

change in momentum = ... N s

2. the force exerted on this mass of water by the rocket.

force = ... N
[3]

(iii) State and explain how Newton's third law applies to the movement of the rocket by the water.

.....
.....
.....[2]

(iv) The container has a mass of 0.40 kg. The initial mass of water before the rocket is launched is 0.70 kg. The mass of the compressed air in the rocket is negligible. Assume that the resistive force on the rocket due to its motion is negligible.

For the rocket at a time of 0.20 s after launching,

1. show that its total mass is 0.64 kg,

2. calculate its acceleration.

acceleration = ... ms^{-2}
[3]

[Total: 11]

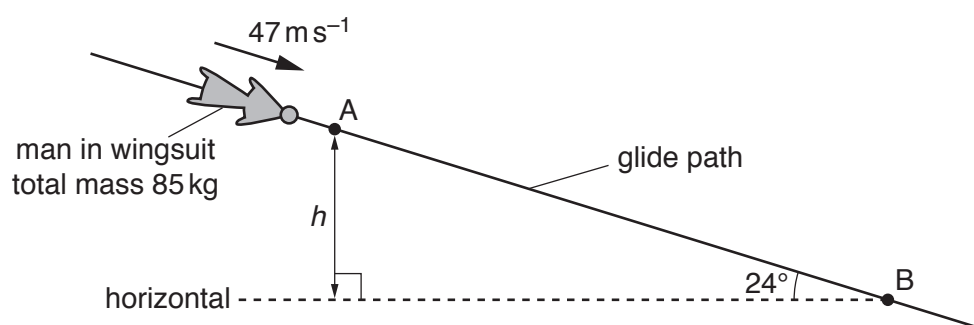
15. Question part 1/2 | 9702 Feb-March 2019 P2 V2 Q2

2 (a) Define:**(i)** *displacement*

.....
[1]

(ii) *acceleration*.

.....
[1]

(b) A man wearing a wingsuit glides through the air with a constant velocity of 47 ms^{-1} at an angle of 24° to the horizontal. The path of the man is shown in Fig. 2.1.**Fig. 2.1** (not to scale)

The total mass of the man and the wingsuit is 85 kg . The man takes a time of 2.8 minutes to glide from point A to point B.

(i) With reference to the motion of the man, state and explain whether he is in equilibrium.

.....

[2]

(ii) Show that the difference in height h between points A and B is 3200 m .

[1]

(iii) For the movement of the man from A to B, determine:

1. the decrease in gravitational potential energy

decrease in gravitational potential energy = ... J [2]

2. the magnitude of the force on the man due to air resistance.

force = ... N [2]

(iv) The pressure of the still air at A is 63 kPa and at B is 92 kPa. Assume the density of the air is constant between A and B.

Determine the density of the air between A and B.

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

[Total: 11]

16. Question part 1/2 | 9702 Feb-March 2019 P2 V2 Q3

- 3 Two balls, X and Y, move along a horizontal frictionless surface, as illustrated in Fig. 3.1.

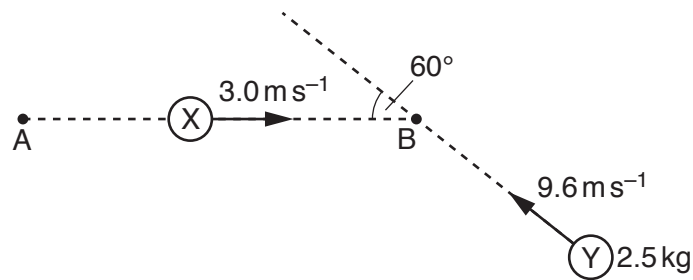


Fig. 3.1 (not to scale)

Ball X has an initial velocity of 3.0 ms^{-1} in a direction along line AB. Ball Y has a mass of 2.5 kg and an initial velocity of 9.6 ms^{-1} in a direction at an angle of 60° to line AB.

The two balls collide at point B. The balls stick together and then travel along the horizontal surface in a direction at right-angles to the line AB, as shown in Fig. 3.2.

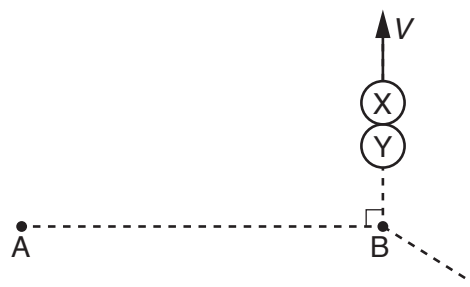


Fig. 3.2

- (a) By considering the components of momentum in the direction from A to B, show that ball X has a mass of 4.0 kg .

- (b)** Calculate the common speed V of the two balls after the collision.

$V = \dots\dots\dots \text{ms}^{-1}$ [2]

- (c)** Determine the difference between the initial kinetic energy of ball X and the initial kinetic energy of ball Y.

difference in kinetic energy = $\dots\dots\dots \text{J}$ [2]

[Total: 6]

17. Question part 1/2 | 9702 May-June 2019 P2 V1 Q2

- 2 A block X slides along a horizontal frictionless surface towards a stationary block Y, as illustrated in Fig. 2.1.

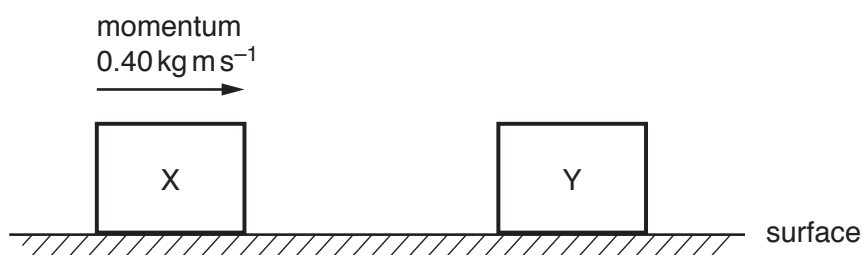


Fig. 2.1

There are no resistive forces acting on block X as it moves towards block Y. At time $t = 0$, block X has momentum 0.40 kg m s^{-1} . A short time later, the blocks collide and then separate.

The variation with time t of the momentum of block Y is shown in Fig. 2.2.

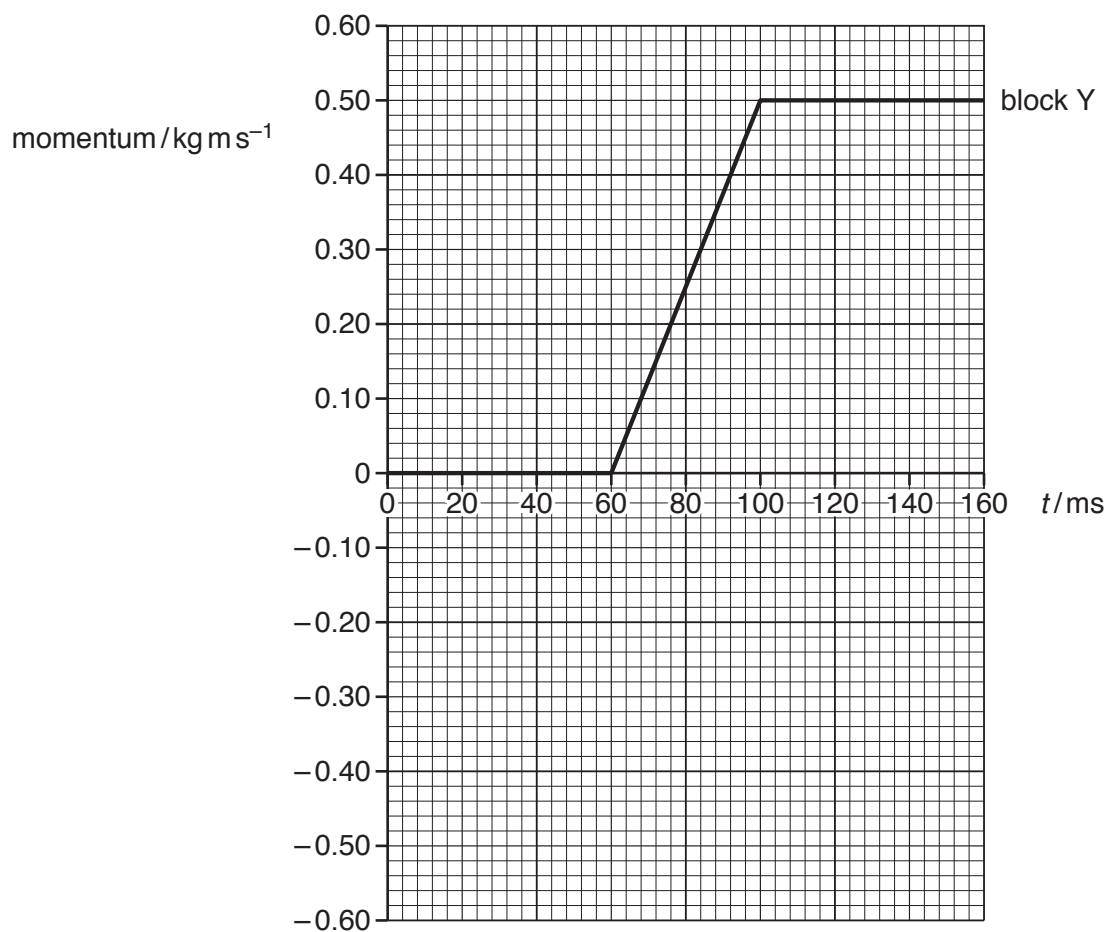


Fig. 2.2

(a) Define *linear momentum*.

.....[1]

(b) Use Fig. 2.2 to:

(i) determine the time interval over which the blocks are in contact with each other

time interval = ... ms [1]

(ii) describe, without calculation, the magnitude of the acceleration of block Y from:

1. time $t = 80$ ms to $t = 100$ ms

.....

2. time $t = 100$ ms to $t = 120$ ms.

.....
[2]

(c) Use Fig. 2.2 to determine the magnitude of the force exerted by block X on block Y.

force = ... N [2]

(d) On Fig. 2.2, sketch the variation of the momentum of block X with time t from $t = 0$ to $t = 160$ ms. [3]

[Total: 9]

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

.....
.....[1]

- (b) A car of mass 850 kg tows a trailer in a straight line along a horizontal road, as shown in Fig. 2.1.

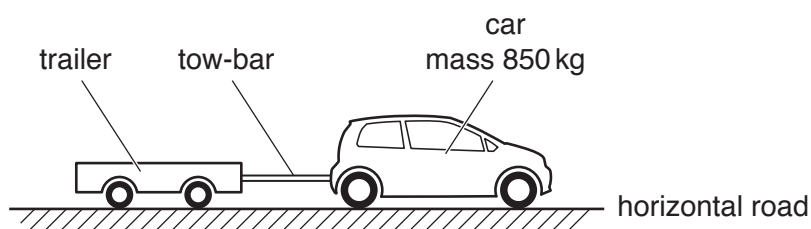


Fig. 2.1

The car and the trailer are connected by a horizontal tow-bar.

The variation with time t of the velocity v of the car for a part of its journey is shown in Fig. 2.2.

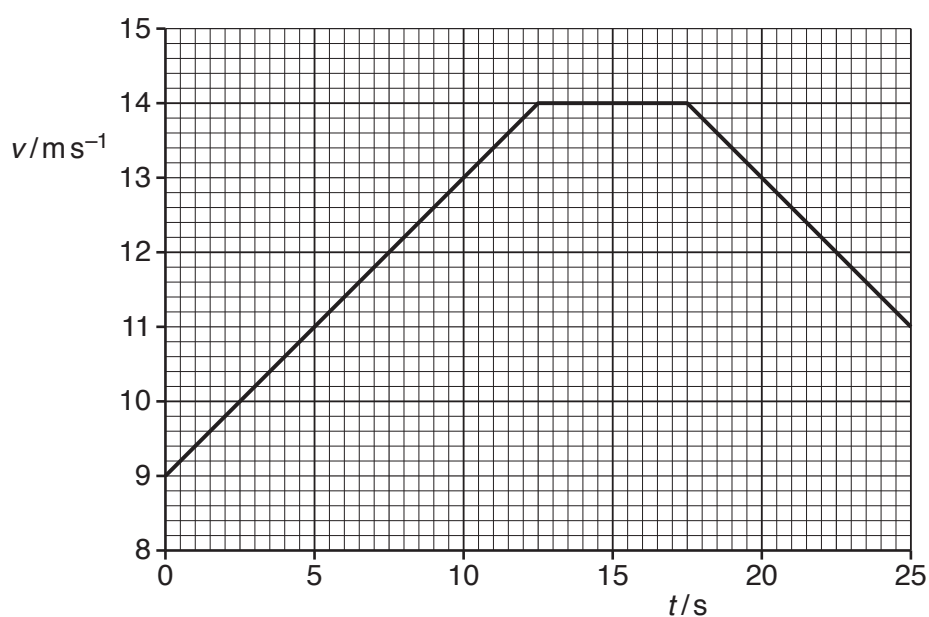


Fig. 2.2

- (i) Calculate the distance travelled by the car from time $t = 0$ to $t = 10$ s.

distance = ... m [2]

- (ii) At time $t = 10$ s, the resistive force acting on the car due to air resistance and friction is 510 N. The tension in the tow-bar is 440 N.

For the car at time $t = 10$ s:

1. use Fig. 2.2 to calculate the acceleration

acceleration = ... ms^{-2} [2]

2. use your answer to calculate the resultant force acting on the car

resultant force = ... N [1]

3. show that a horizontal force of 1300 N is exerted on the car by its engine

[1]

4. determine the useful output power of the engine.

output power = ... W [2]

- (c) A short time later, the car in (b) is travelling at a constant speed and the tension in the tow-bar is 480 N.

The tow-bar is a solid metal rod that obeys Hooke's law. Some data for the tow-bar are listed below.

Young modulus of metal = 2.2×10^{11} Pa

original length of tow-bar = 0.48 m

cross-sectional area of tow-bar = 3.0×10^{-4} m²

Determine the extension of the tow-bar.

extension = ... m [3]

- (d) The driver of the car in (b) sees a pedestrian standing directly ahead in the distance. The driver operates the horn of the car from time $t = 15$ s to $t = 17$ s. The frequency of the sound heard by the pedestrian is 480 Hz. The speed of the sound in the air is 340 m s^{-1} .

Use Fig. 2.2 to calculate the frequency of the sound emitted by the horn.

frequency = ... Hz [2]

[Total: 14]

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- 3 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 3.1 is a side view of the aircraft when hovering.

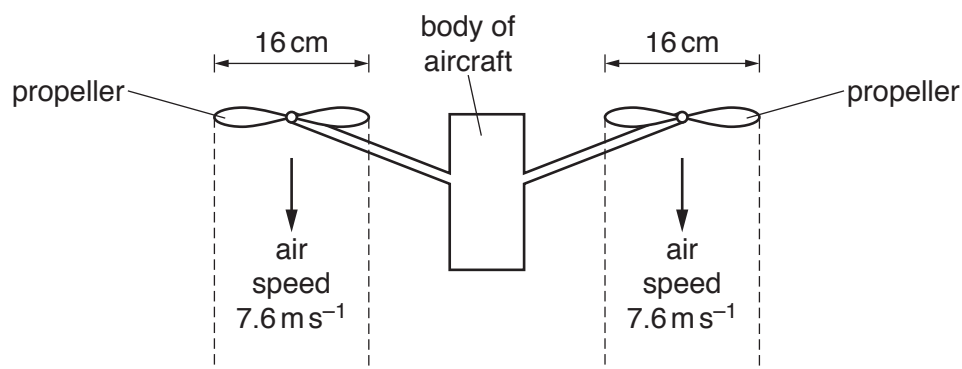


Fig. 3.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is 1.2 kg m^{-3} . Assume that the air from each propeller moves with a constant speed of 7.6 m s^{-1} in a uniform cylinder of diameter 16 cm. Also assume that the air above each propeller is stationary.

- (a) Show that, in a time interval of 3.0 s, the mass of air propelled downwards by **one** propeller is 0.55 kg.

[3]

- (b) Calculate:

- (i) the increase in momentum of the mass of air in (a)

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

- (ii) the downward force exerted on this mass of air by the propeller.

force = ... N [1]

(c) State:

- (i) the upward force acting on **one** propeller

force = ... N [1]

- (ii) the name of the law that explains the relationship between the force in **(b)(ii)** and the force in **(c)(i)**.

..... [1]

(d) Determine the mass of the aircraft.

mass = ... kg [1]

- (e) In order for the aircraft to hover at a very high altitude (height), the propellers must propel the air downwards with a greater speed than when the aircraft hovers at a low altitude. Suggest the reason for this.

.....
..... [1]

- (f) When the aircraft is hovering at a high altitude, an electric fault causes the propellers to stop rotating. The aircraft falls vertically downwards. When the aircraft reaches a constant speed of 22 m s^{-1} , it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is 340 m s^{-1} .

Determine the frequency of the sound heard by a person standing vertically below the falling aircraft.

frequency = ... Hz [2]

[Total: 11]

3 (a) State Newton’s third law of motion.

.....

.....

..... [2]

(b) A block X of mass m_X slides in a straight line along a horizontal frictionless surface, as shown in Fig. 3.1.

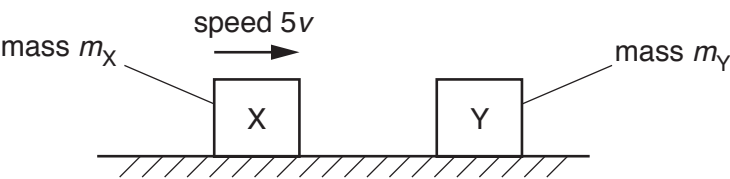


Fig. 3.1

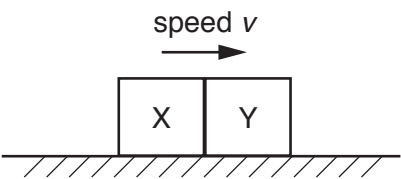


Fig. 3.2

The block X, moving with speed $5v$, collides head-on with a stationary block Y of mass m_Y . The two blocks stick together and then move with common speed v , as shown in Fig. 3.2.

(i) Use conservation of momentum to show that the ratio $\frac{m_Y}{m_X}$ is equal to 4.

[2]

(ii) Calculate the ratio

$$\frac{\text{total kinetic energy of X and Y after collision}}{\text{total kinetic energy of X and Y before collision}} .$$

ratio = ... [3]

(iii) State the value of the ratio in (ii) for a perfectly elastic collision.

ratio = ... [1]

(c) The variation with time t of the momentum of block X in (b) is shown in Fig. 3.3.

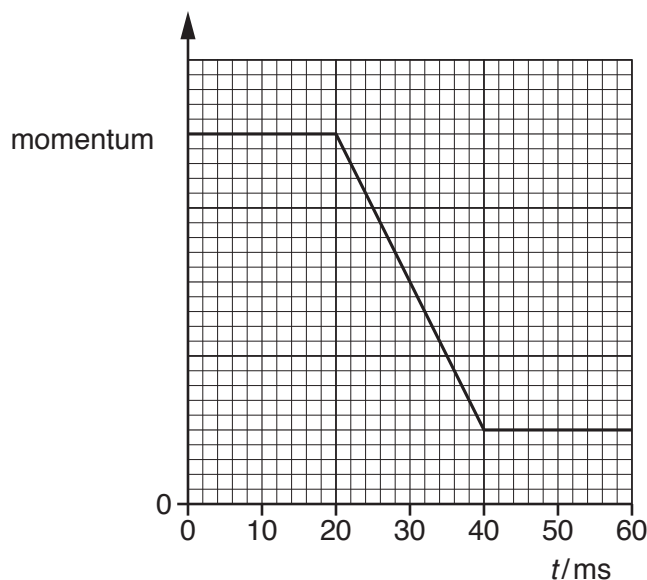


Fig. 3.3

Block X makes contact with block Y at time $t = 20$ ms.

(i) Describe, qualitatively, the magnitude and direction of the resultant force, if any, acting on block X in the time interval:

1. $t = 0$ to $t = 20$ ms

.....

2. $t = 20$ ms to $t = 40$ ms.

.....

.....

[3]

(ii) On Fig. 3.3, sketch the variation of the momentum of block Y with time t from $t = 0$ to $t = 60$ ms. [3]

[Total: 14]

21. Question part 1/3 | 9702 Oct-Nov 2019 P2 V3 Q4

- 4 A ball X moves along a horizontal frictionless surface and collides with another ball Y, as illustrated in Fig. 4.1.

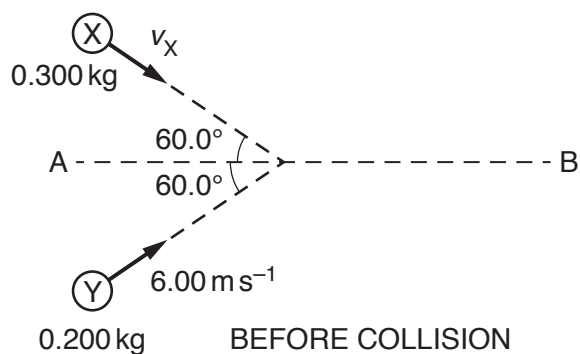


Fig. 4.1 (not to scale)

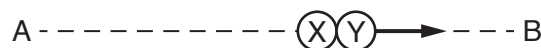


Fig. 4.2 (not to scale)

Ball X has mass 0.300 kg and initial velocity v_X at an angle of 60.0° to line AB.

Ball Y has mass 0.200 kg and initial velocity 6.00 m s^{-1} at an angle of 60.0° to line AB.

The balls stick together during the collision and then travel along line AB, as illustrated in Fig. 4.2.

- (a) (i) Calculate, to three significant figures, the component of the initial momentum of ball Y that is perpendicular to line AB.

component of momentum = ... kg m s^{-1} [2]

- (ii) By considering the component of the initial momentum of each ball perpendicular to line AB, calculate, to three significant figures, v_X .

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

- (iii) Show that the speed of the two balls after the collision is 2.4 m s^{-1} .

- (b) The two balls continue moving together along the horizontal frictionless surface towards a spring, as illustrated in Fig. 4.3.

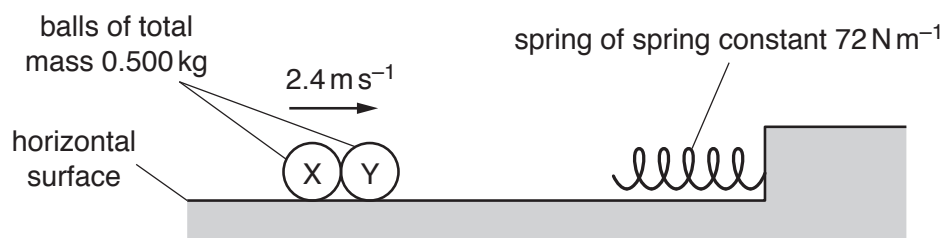


Fig. 4.3

The balls hit the spring and remain stuck together as they decelerate to rest. All the kinetic energy of the balls is converted into elastic potential energy of the spring. The energy E stored in the spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression. The spring obeys Hooke's law and has a spring constant of 72 N m^{-1} .

- (i) Determine the maximum compression of the spring caused by the two balls.

maximum compression = ...m [3]

(ii) On Fig. 4.4, sketch graphs to show the variation with compression x of the spring, from zero to maximum compression, of:

1. the magnitude of the deceleration a of the balls
2. the kinetic energy E_k of the balls.

Numerical values are not required.

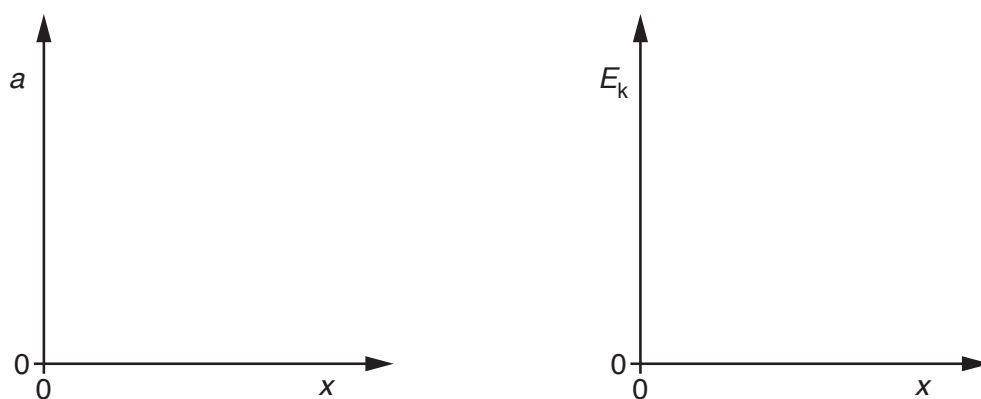


Fig. 4.4

[3]

[Total: 11]

2 (a) State Newton’s first law of motion.

.....
..... [1]

(b) A skier is pulled in a straight line along horizontal ground by a wire attached to a kite, as shown in Fig. 2.1.

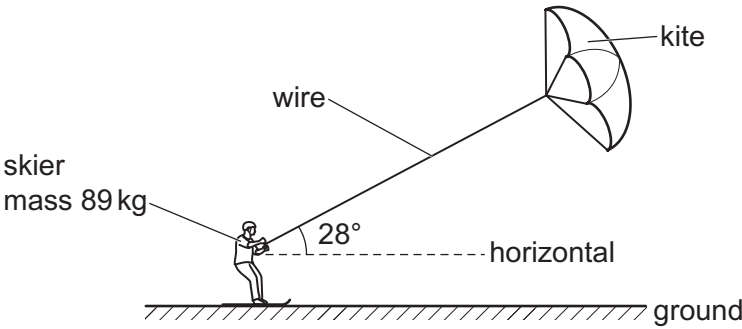


Fig. 2.1 (not to scale)

The mass of the skier is 89 kg. The wire is at an angle of 28° to the horizontal. The variation with time t of the velocity v of the skier is shown in Fig. 2.2.

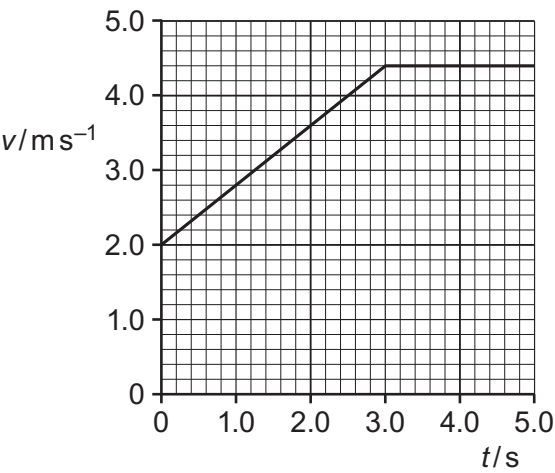


Fig. 2.2

(i) Use Fig. 2.2 to determine the distance moved by the skier from time $t = 0$ to $t = 5.0$ s.

distance = ... m [2]

- (ii) Use Fig. 2.2 to show that the acceleration a of the skier is 0.80 m s^{-2} at time $t = 2.0 \text{ s}$.

[2]

- (iii) The tension in the wire at time $t = 2.0 \text{ s}$ is 240 N .

Calculate:

1. the horizontal component of the tension force acting on the skier

horizontal component of force = ... N [1]

2. the total resistive force R acting on the skier in the horizontal direction.

$R = \dots\dots\dots$ N [2]

- (iv) The skier is now lifted upwards by a gust of wind. For a few seconds the skier moves horizontally through the air with the wire at an angle of 45° to the horizontal, as shown in Fig. 2.3.

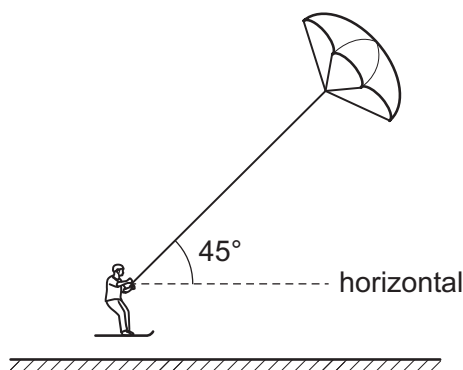


Fig. 2.3 (not to scale)

By considering the vertical components of the forces acting on the skier, determine the new tension in the wire when the skier is moving horizontally through the air.

tension = ... N [2]

[Total: 10]

- 3 (a) Define *force*.

.....
 [1]

- (b) A ball falls vertically downwards towards a horizontal floor and then rebounds along its original path, as illustrated in Fig. 3.1.

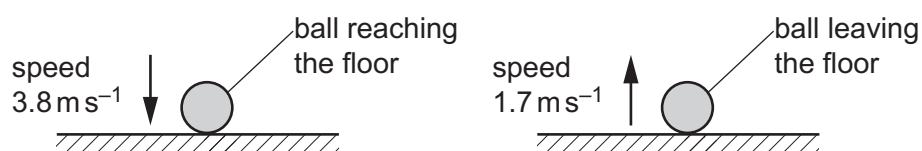


Fig. 3.1

The ball reaches the floor with speed 3.8 m s^{-1} . The ball is then in contact with the floor for a time of 0.081 s before leaving it with speed 1.7 m s^{-1} . The mass of the ball is 0.062 kg .

- (i) Calculate the loss of kinetic energy of the ball during the collision.

loss of kinetic energy = ... J [2]

- (ii) Determine the magnitude of the change in momentum of the ball during the collision.

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

- (iii) Show that the magnitude of the average resultant force acting on the ball during the collision is 4.2 N .

[1]

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23. Question part 2/2 | 9702 Oct-Nov 2020 P2 V1 Q3

(iv) Use the information in **(iii)** to calculate the magnitude of:

1. the average force of the floor on the ball during the collision

average force = ... N

2. the average force of the ball on the floor during the collision.

average force = ... N
[2]

[Total: 8]

24. Question part 1/2 | 9702 May-June 2021 P2 V1 Q3

- 3 A pendulum consists of a solid sphere suspended by a string from a fixed point P, as shown in Fig. 3.1.

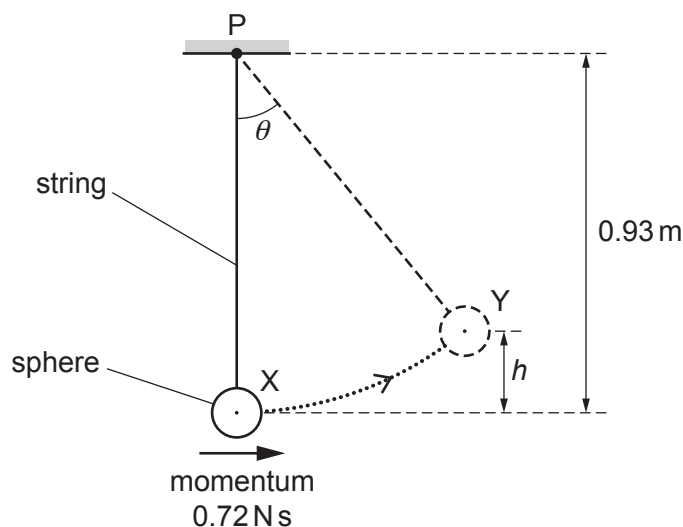


Fig. 3.1 (not to scale)

The sphere swings from side to side. At one instant the sphere is at its lowest position X, where it has kinetic energy 0.86 J and momentum 0.72 N s in a horizontal direction. A short time later the sphere is at position Y, where it is momentarily stationary at a maximum vertical height h above position X.

The string has a fixed length and negligible weight. Air resistance is also negligible.

- (a) On Fig. 3.1, draw a solid line to represent the displacement of the centre of the sphere at position Y from position X. [1]
- (b) Show that the mass of the sphere is 0.30 kg.

(c) Calculate height h .

$h = \dots\dots\dots$ m [2]

(d) The distance between point P and the centre of the sphere is 0.93 m. When the sphere is at position Y, the string is at an angle θ to the vertical.

Show that θ is 47° .

[1]

(e) For the sphere at position Y, calculate the moment of its weight about point P.

moment = $\dots\dots\dots$ Nm [2]

(f) State and explain whether the sphere is in equilibrium when it is stationary at position Y.

$\dots\dots\dots$
 $\dots\dots\dots$ [1]

[Total: 10]

2 (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.

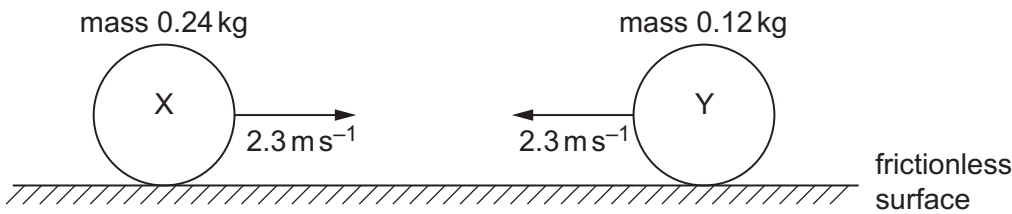


Fig. 2.1

Both balls have initial speed 2.3 ms^{-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.

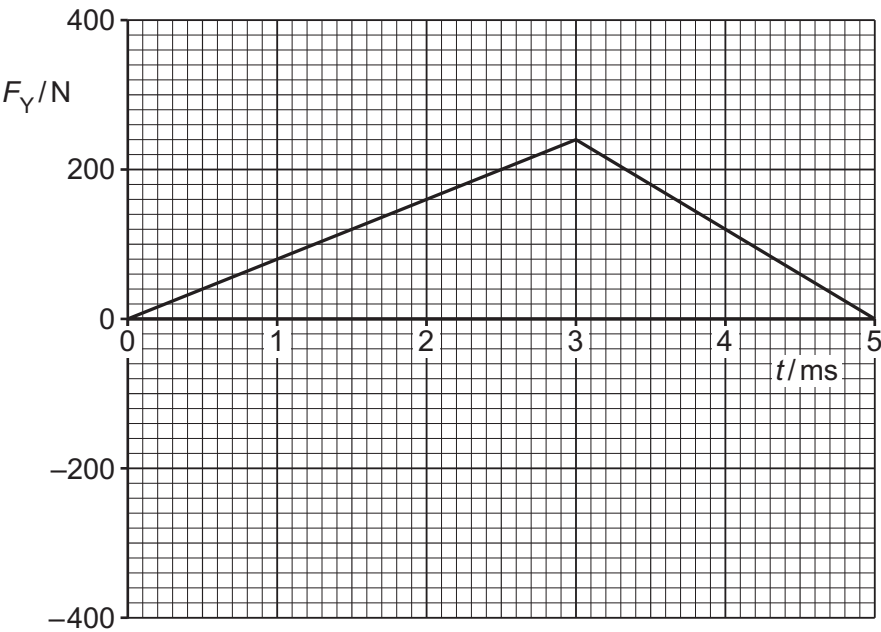


Fig. 2.2

(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 = ... ms^{-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).

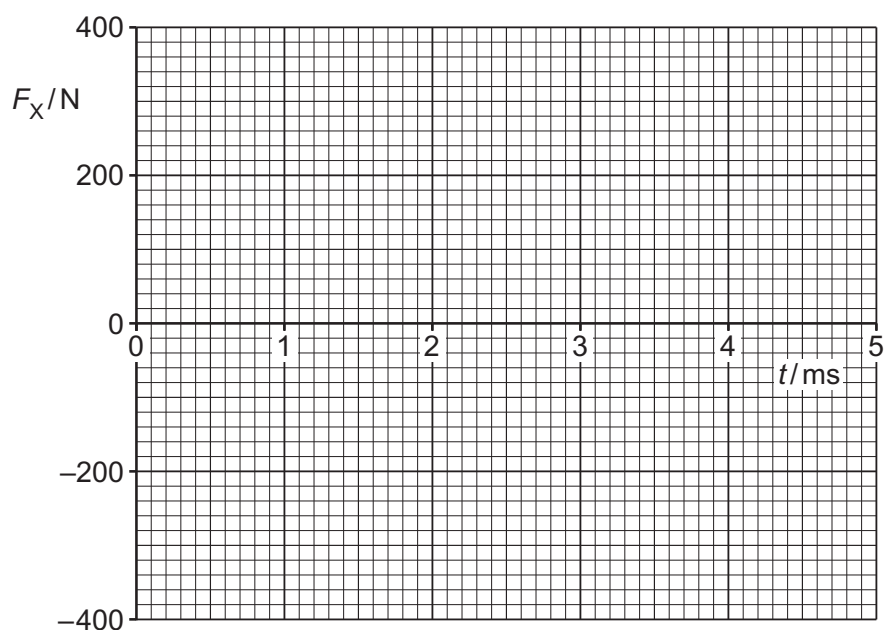


Fig. 2.3

[3]

[Total: 11]

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

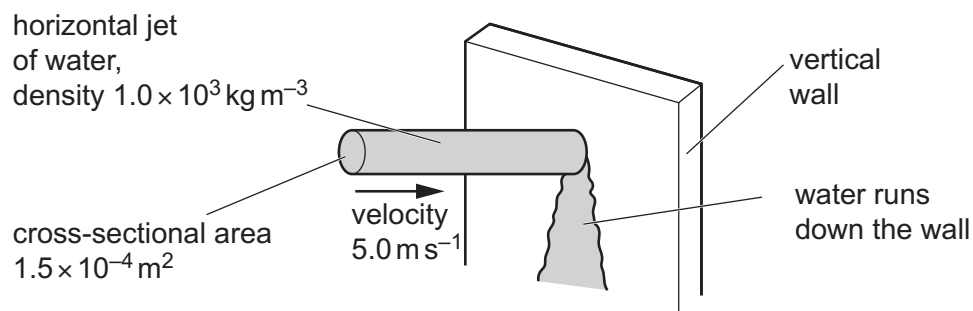


Fig. 3.1 (not to scale)

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

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]

4 (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.

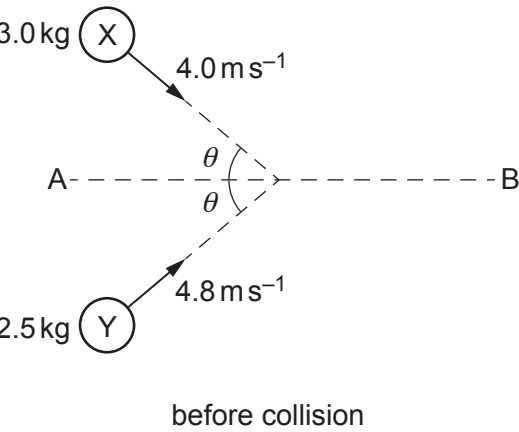


Fig. 4.1 (not to scale)

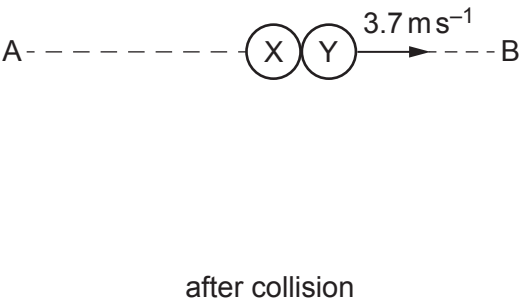


Fig. 4.2 (not to scale)

Ball X has a mass of 3.0 kg and a velocity of 4.0 ms⁻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 ms⁻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 ms⁻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 .

$\theta =$ ° [3]

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

.....
..... [2]

[Total: 7]

3 (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 = ... ms^{-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.

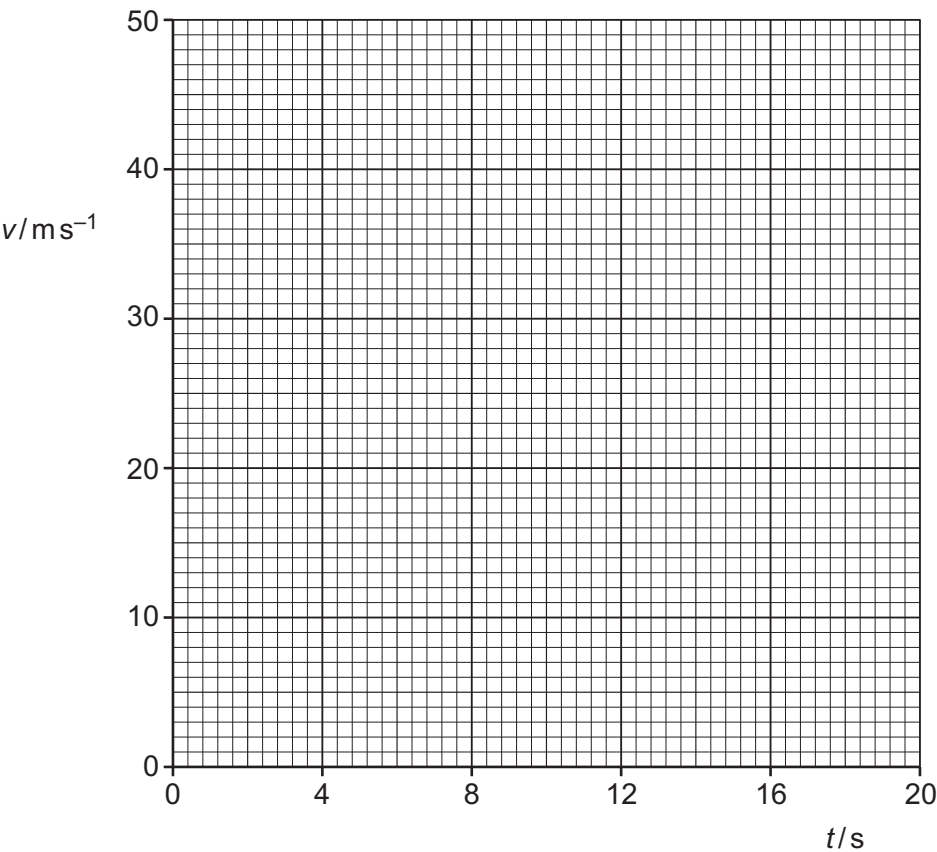


Fig. 3.1

[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 $t = 12\text{ s}$.
- (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 $t = 20\text{ s}$, 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]

29. Question part 1/2 | 9702 Oct-Nov 2022 P2 V2 Q4

- 4 A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

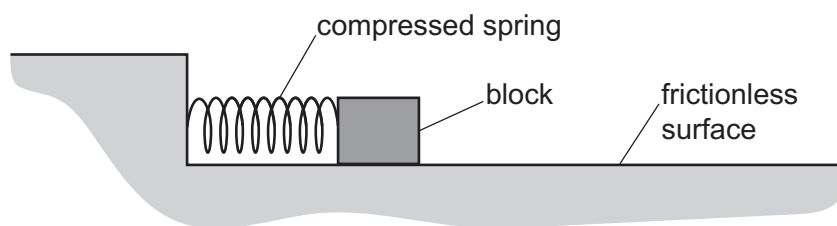


Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of 2.3 m s^{-1} , as shown in Fig. 4.2.

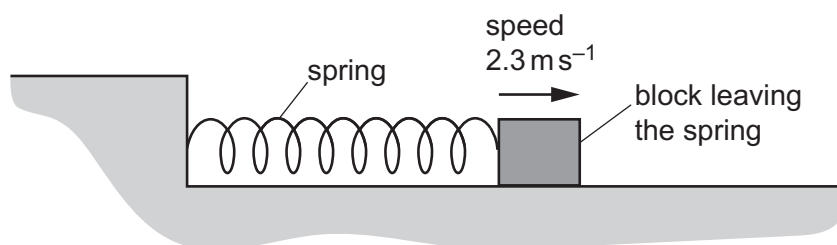


Fig. 4.2

The block has a mass of 250 g and the spring has a spring constant of 420 N m^{-1} .

Assume that the spring always obeys Hooke's law and that all the elastic potential energy of the spring is transferred to the kinetic energy of the block.

- (a) Calculate the kinetic energy of the block as it leaves the spring.

kinetic energy = ... J [2]

- (b) Calculate the compression of the spring immediately before the block is released.

compression = ... m [2]

- (c) After leaving the spring, the block moves along the surface until it hits a barrier at a speed of 2.3 m s^{-1} . The block then rebounds at a speed of 1.5 m s^{-1} and moves back along its original path. The block is in contact with the barrier for a time of 0.086 s .

Calculate:

- (i) the change in momentum of the block during the collision

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

- (ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

- (d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K .

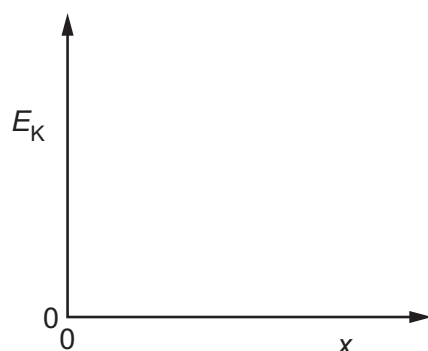


Fig. 4.3

[1]

[Total: 8]

3 (a) (i) Define force.

.....
..... [1]

(ii) State what is meant by work done.

.....
..... [1]

(b) A block of mass 0.40 kg slides in a straight line with a constant speed of 0.30 m s^{-1} along a horizontal surface, as shown in Fig. 3.1.



Fig. 3.1

Assume that there are no resistive forces opposing the motion of the block.

The block hits a spring and decelerates. The speed of the block becomes zero when the compression of the spring is 8.0 cm .

(i) Calculate the initial kinetic energy of the block.

kinetic energy = ... J [2]

- (ii) The variation of the compression x of the spring with the force F applied to the spring is shown in Fig. 3.2.

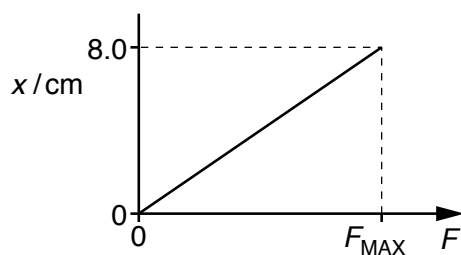


Fig. 3.2

Assume that the elastic potential energy of the spring when its compression is 8.0 cm is equal to the initial kinetic energy of the block.

Use your answer in **(b)(i)** to calculate the maximum force F_{MAX} exerted on the spring by the block.

$$F_{\text{MAX}} = \dots\dots\dots \text{ N [2]}$$

- (iii) Calculate the maximum deceleration of the block.

$$\text{deceleration} = \dots\dots\dots \text{ m s}^{-2} \text{ [2]}$$

- (iv) State and explain whether the block is in equilibrium:

- before it hits the spring

.....

- when its speed becomes zero.

.....

[2]

30. Question part 3/4 | 9702 Specimen 2022 P2 Q3

- (v) The block is now replaced by another block of the same mass. Frictional forces affect the motion of this block so that it has a speed of 0.25 m s^{-1} when it makes contact with the spring.

A short time later, the block has a speed of 0.15 m s^{-1} as it loses contact with the spring and moves back along its original path.

Calculate the magnitude of the change in momentum of the block.

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

[Total: 12]

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31. Question part 1/2 | 9702 Feb-March 2023 P2 V2 Q4

- 4 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.

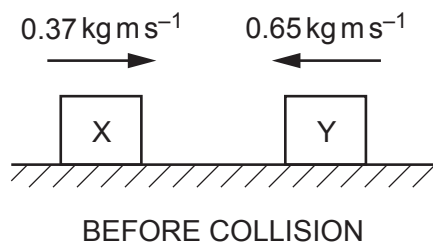


Fig. 4.1

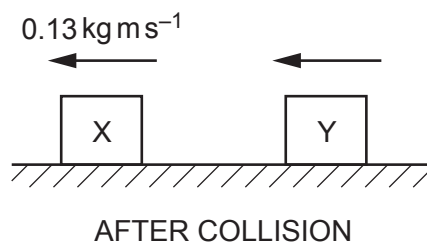


Fig. 4.2

Block X initially moves to the right with a momentum of 0.37 kg m s^{-1} . Block Y initially moves to the left with a momentum of 0.65 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 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 = ... kg m s^{-1} [1]

31. Question part 2/2 | 9702 Feb-March 2023 P2 V2 Q4

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

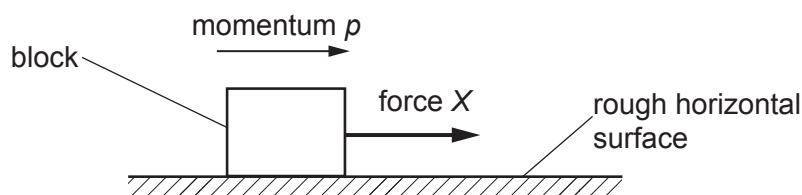
Calculate the time that the blocks are in contact with each other.

time = ... s [2]

[Total: 6]

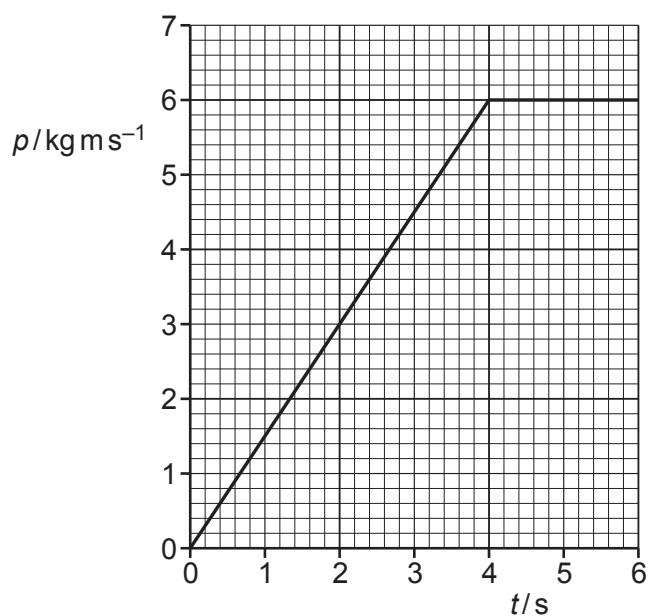
32. Question part 1/3 | 9702 May-June 2023 P2 V1 Q3

- 3 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 $t = 2.0\text{ s}$, 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 $t = 6.0\text{ s}$.

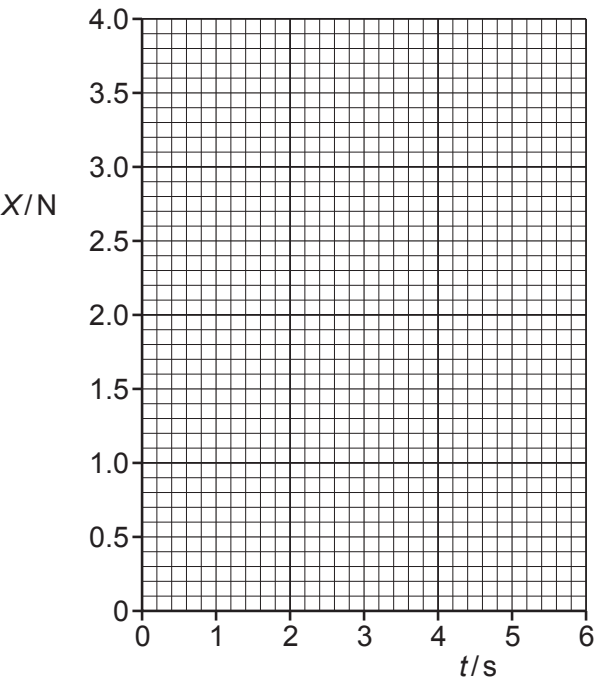


Fig. 3.3

[3]

[Total: 6]

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33. Question part 1/2 | 9702 May-June 2023 P2 V2 Q3

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

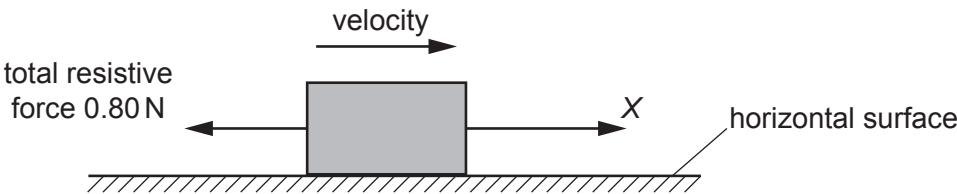


Fig. 3.1

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.

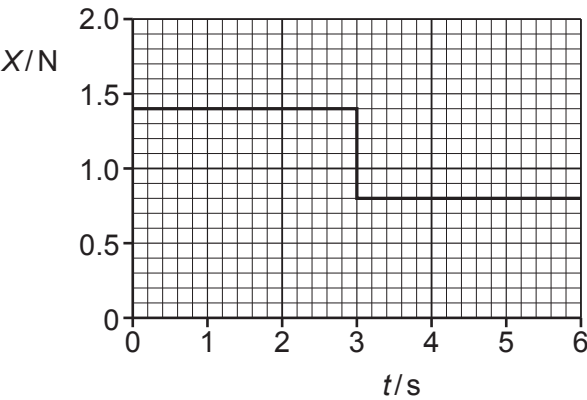


Fig. 3.2

- (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 $t = 3.0\text{ s}$ and time $t = 6.0\text{ s}$.

.....

.....

.....

..... [2]

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

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 $t = 6.0\text{ s}$.
Numerical values of momentum are not required.

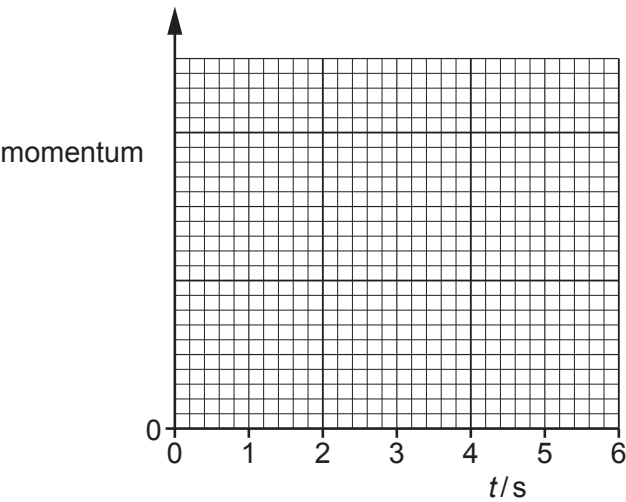


Fig. 3.3

[2]

[Total: 10]

34. Question part 1/2 | 9702 May-June 2023 P2 V3 Q3

- 3 (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.

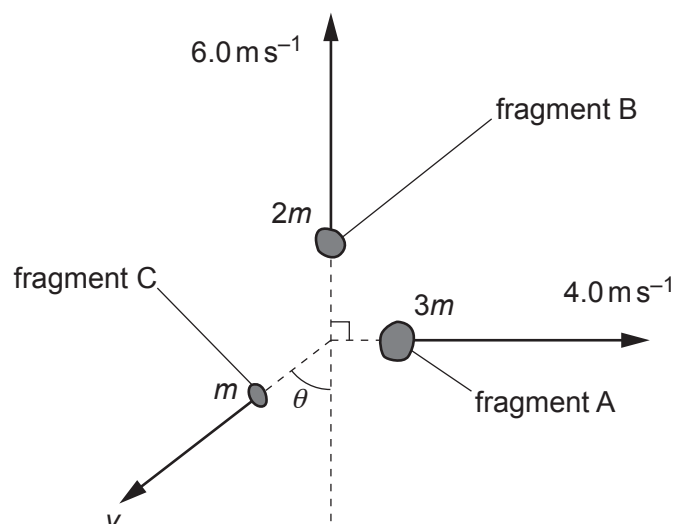


Fig. 3.1

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

Fragment B has a mass of $2m$ and moves away from the explosion at a speed of 6.0 m 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

$\theta = \dots\dots\dots^\circ$ [3]

(ii) the speed v .

$v = \dots\dots\dots \text{ms}^{-1}$ [2]

- (c) The firework in (b) contains a chemical that has mass 5.0 g and has chemical energy per unit mass 700 J 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]

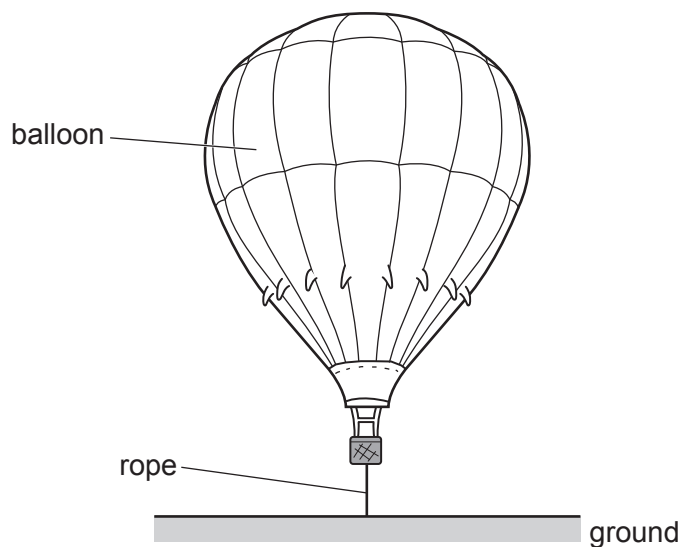
(ii) Calculate the mass m .

$m = \dots\dots\dots \text{kg}$ [3]

[Total: 11]

35. Question part 1/2 | 9702 Oct-Nov 2023 P2 V1 Q2

- 2 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 $3.39 \times 10^4 \text{ N}$. The tension T in the rope is $4.00 \times 10^2 \text{ N}$.
Upthrust U acts on the balloon.
The density of the surrounding air is 1.23 kg 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 = ... ms^{-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 ms^{-1} when it hits the ground.

Explain why the actual speed of the ball will be much lower than 100 ms^{-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 $6.0 \times 10^{-5} \text{ m}$.

[1]

- (ii) Calculate the elastic potential energy E_p of the rope.

$E_p = \dots\dots\dots \text{ J}$ [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]

- 3 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/ ms^{-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.

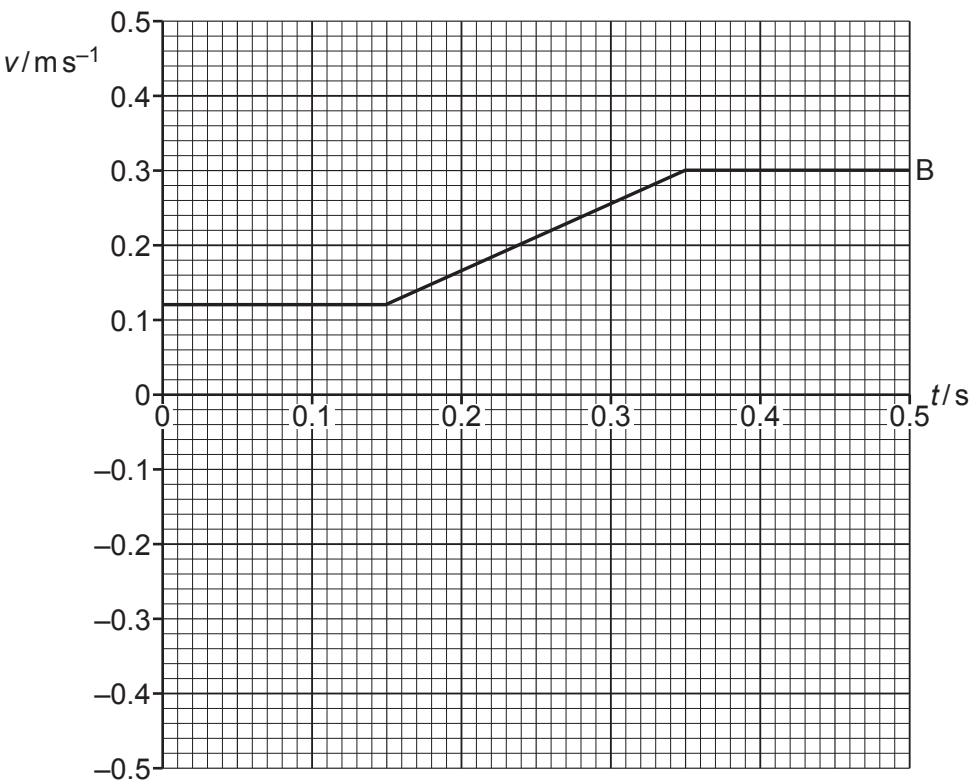


Fig. 3.2

(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 = ... ms^{-2} [2]

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

magnitude = ... ms^{-1}
direction [3]

(c) On Fig. 3.2, sketch the variation of the velocity of trolley A with time t from $t = 0$ to $t = 0.50\text{ s}$. [3]

[Total: 9]

37. Question part 1/2 | 9702 Oct-Nov 2023 P2 V2 Q2

- 2 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.

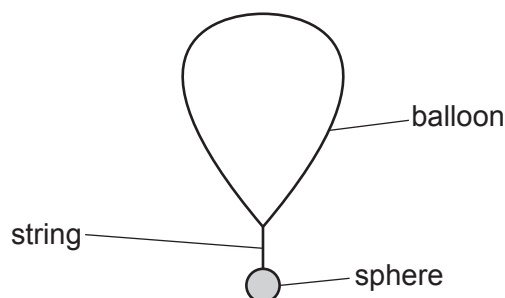


Fig. 2.1 (not to scale)

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 = ... ms^{-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]

37. Question part 2/2 | 9702 Oct-Nov 2023 P2 V2 Q2

(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 m s^{-2} .

resistive force = ... N [2]

[Total: 8]

- 4 (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.

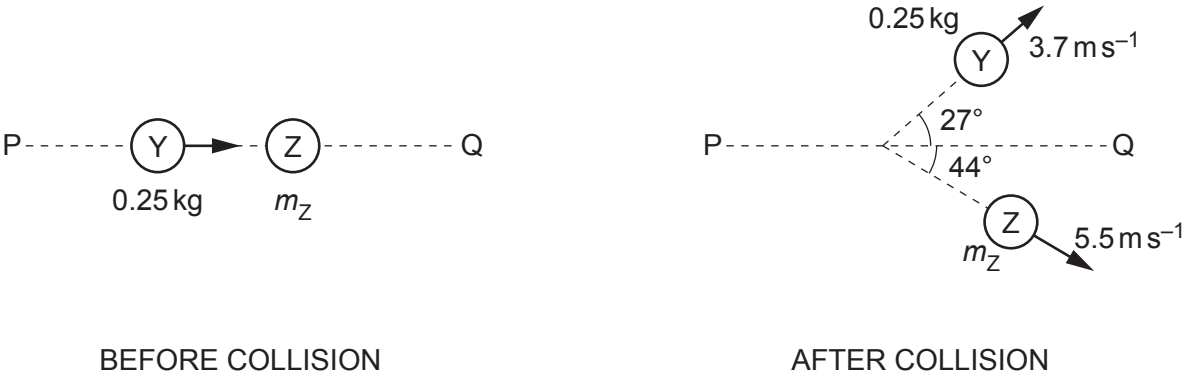


Fig. 4.1 (not to scale)

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 ms^{-1} at an angle of 27° to line PQ and ball Z has a final velocity of 5.5 ms^{-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 .

$m_Z = \text{..... kg}$ [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 m s^{-1} and block B has a speed of 6 m s^{-1} . After the collision, block B moves back along its original path with a speed of 2 m s^{-1} .

Calculate the speed of block A after the collision.

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

[Total: 6]

3 (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.

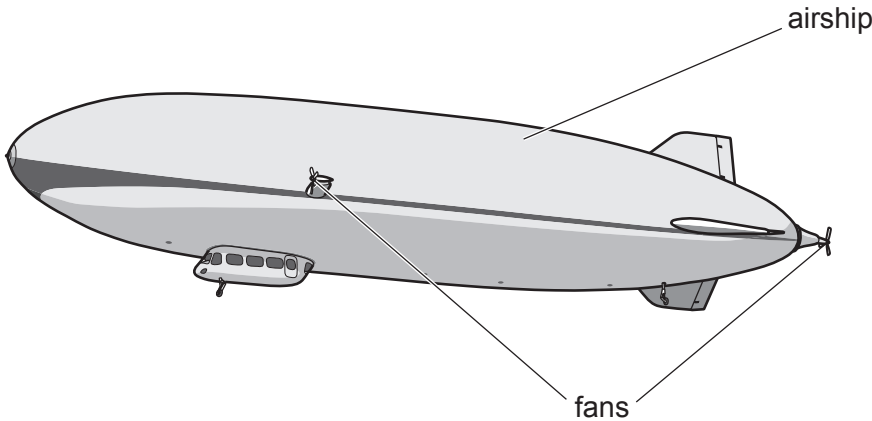


Fig. 3.1

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 $3.0 \times 10^3 \text{ N}$ 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

$$\Delta p = \dots\dots\dots \text{ kg ms}^{-1} \text{ [2]}$$

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

$$\text{speed} = \dots\dots\dots \text{ ms}^{-1} \text{ [2]}$$

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

$$\text{kinetic energy} = \dots\dots\dots \text{ J [2]}$$

[Total: 11]

2 (a) Define acceleration.

.....
..... [1]

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

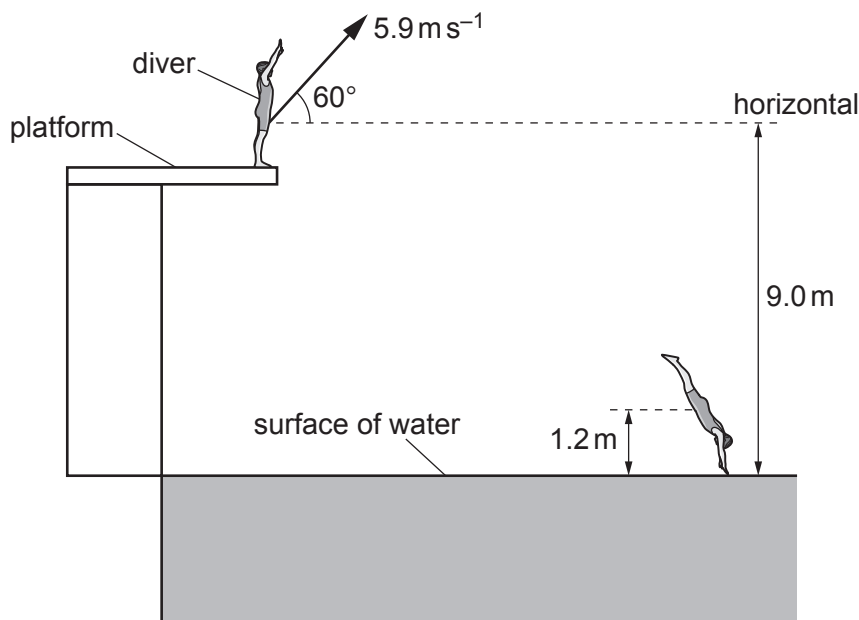


Fig. 2.1 (not to scale)

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 m 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 = ... ms⁻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 $7.5 \times 10^{-2} \text{ m}^3$. The density of the water is $1.0 \times 10^3 \text{ kg m}^{-3}$.

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 = ... ms^{-2}

direction

[4]

41. Question part 1/2 | 9702 May-June 2024 P2 V1 Q1

1 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.

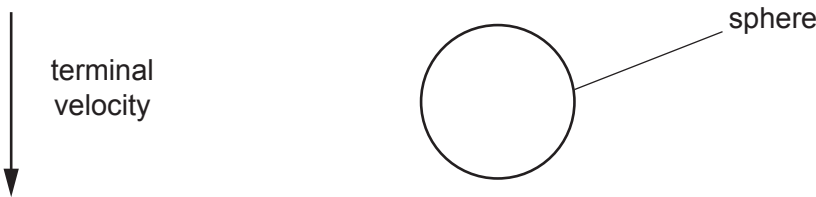


Fig. 1.1

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.

$F_D = \dots\dots\dots$ N [2]

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Topical questions | 51 questions

41. Question part 2/2 | 9702 May-June 2024 P2 V1 Q1

- (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]

- 3 (a) State the principle of conservation of momentum.

.....
.....
..... [2]

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

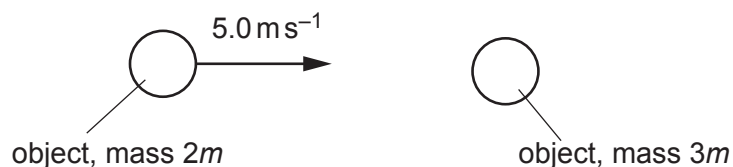


Fig. 3.1

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.

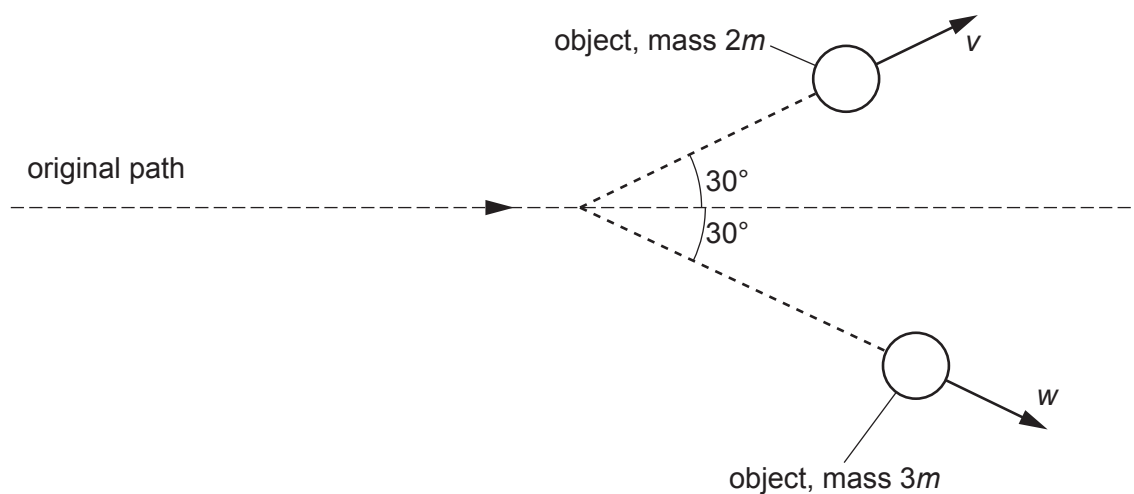


Fig. 3.2

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

$$v = \dots\dots\dots \text{ms}^{-1}$$

$$w = \dots\dots\dots \text{ms}^{-1}$$

[4]

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

Calculate the magnitude of this force.

$$\text{force} = \dots\dots\dots \text{N} \quad [3]$$

[Total: 9]

43. Question part 1/2 | 9702 May-June 2024 P2 V2 Q2

- 2 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.

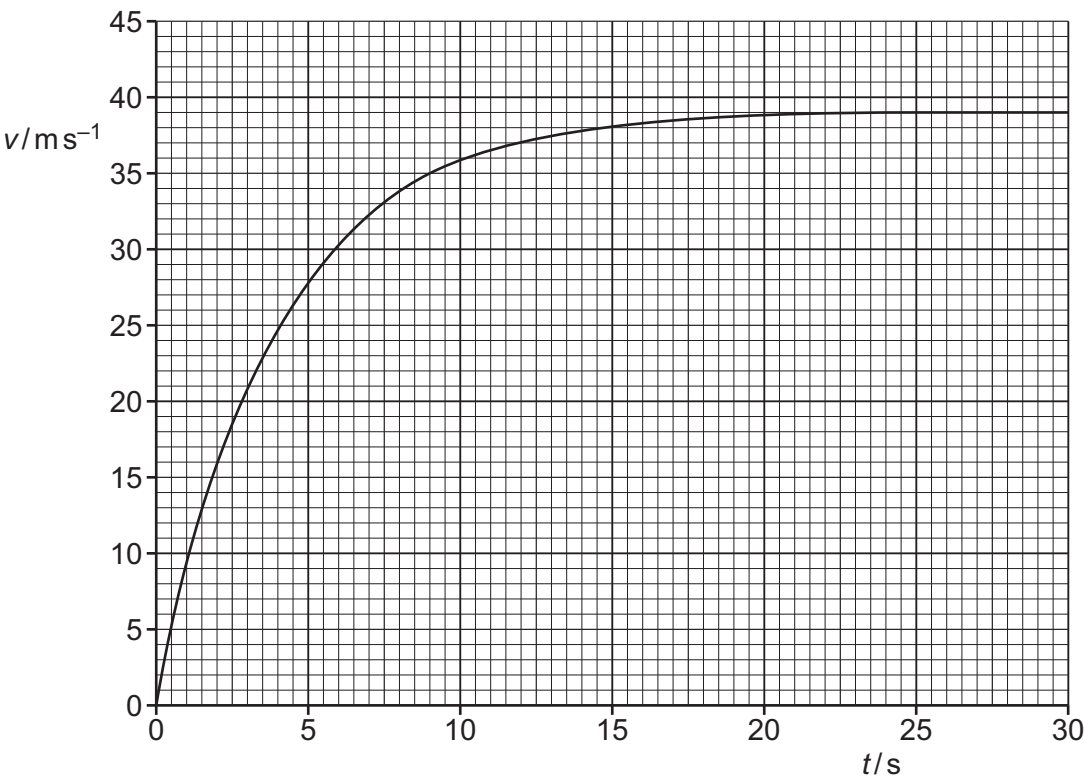


Fig. 2.1

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

terminal velocity = ... ms^{-1} [1]

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

acceleration = ... ms^{-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 = ...ms⁻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 ms⁻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 = ... N s [2]

[Total: 10]

2 (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.

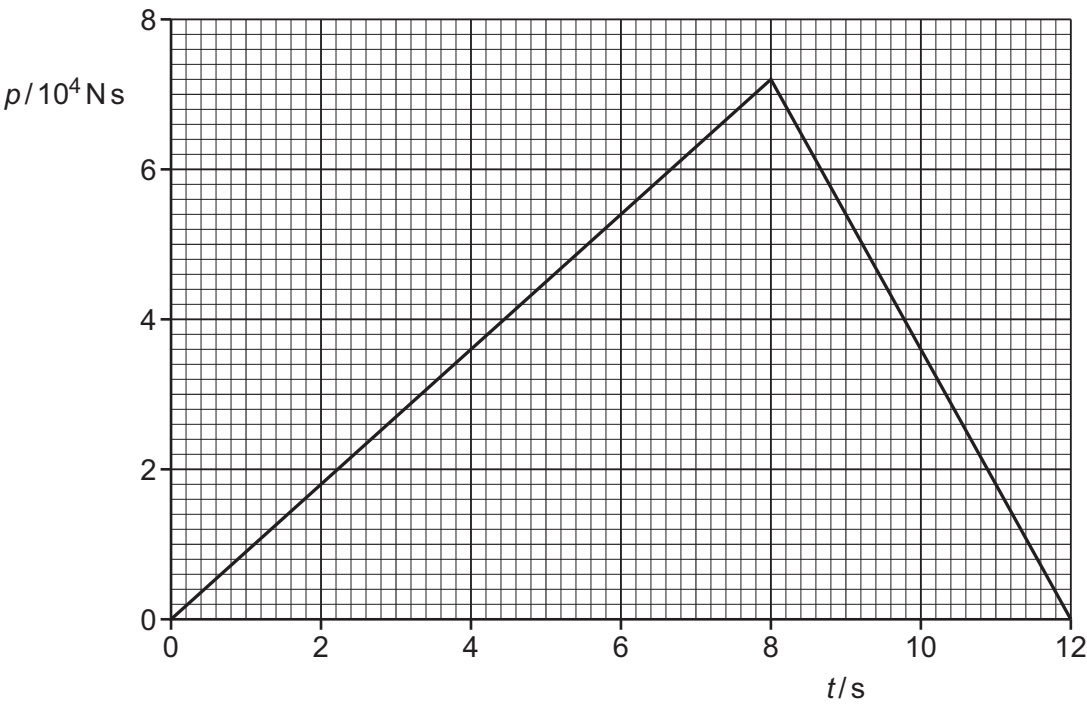


Fig. 2.1

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

maximum speed = ... ms^{-1} [1]

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

maximum kinetic energy = ... J [2]

44. Question part 2/2 | 9702 Oct-Nov 2024 P2 V1 Q2



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

[2]

(iv) Determine the distance travelled by the car between times $t = 0$ and $t = 12.0\text{ s}$.

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 $t = 12.0\text{ s}$.

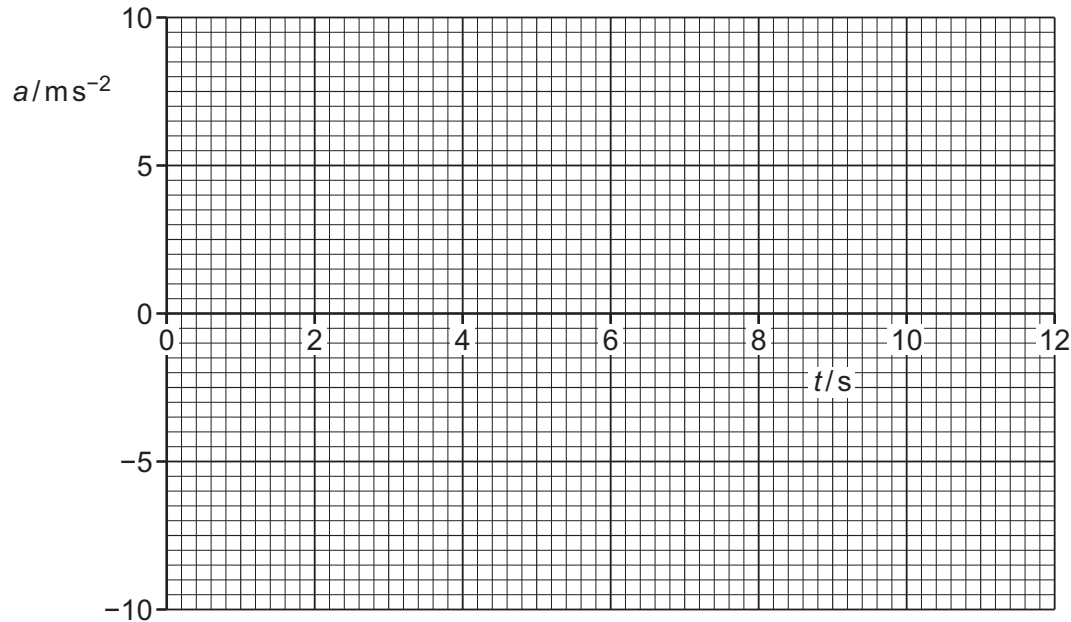


Fig. 2.2

[3]

[Total: 11]

45. Question part 1/2 | 9702 Oct-Nov 2024 P2 V2 Q2

2 (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 ms^{-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.

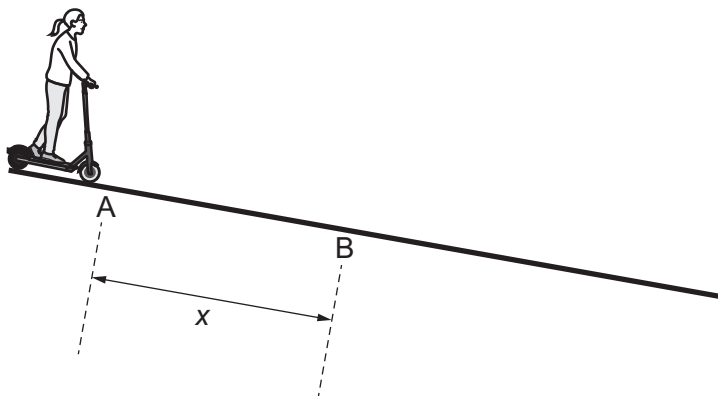


Fig. 2.1 (not to scale)

At point A her speed is 0.60 ms^{-1} . She has a constant acceleration of 0.85 ms^{-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]

45. Question part 2/2 | 9702 Oct-Nov 2024 P2 V2 Q2



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

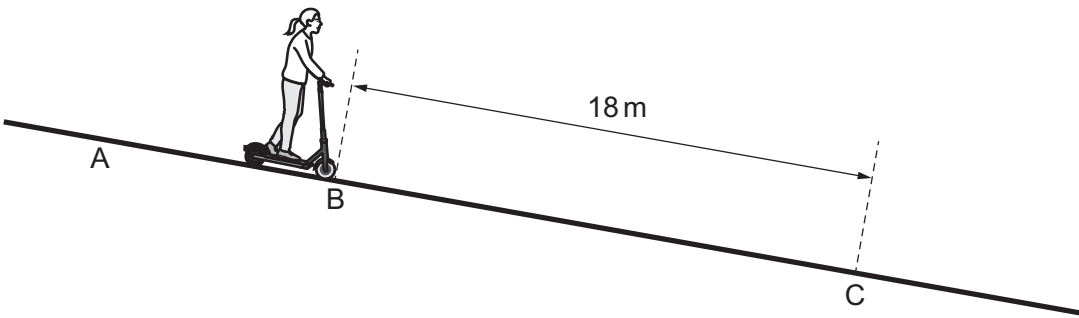


Fig. 2.2 (not to scale)

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.

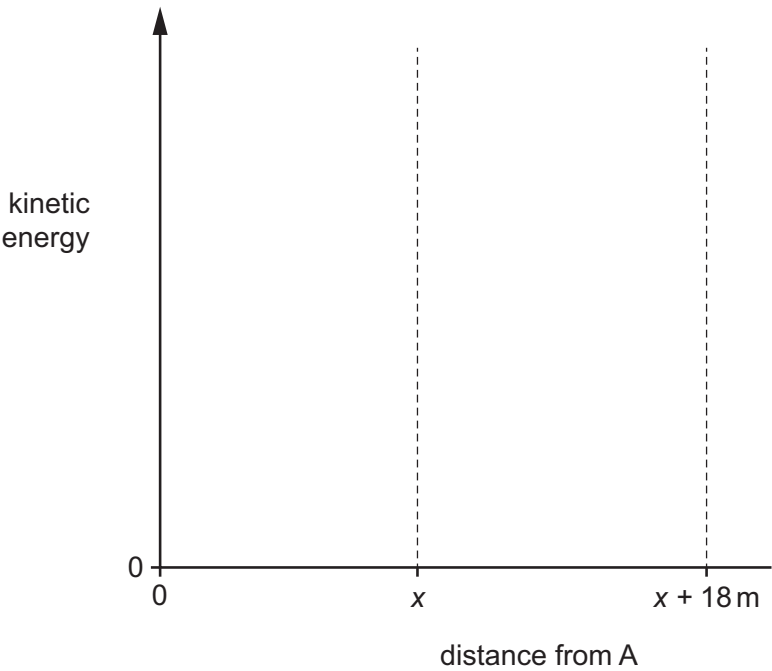


Fig. 2.3

[3]

[Total: 10]

2 (a) State the principle of conservation of momentum.

.....

.....

..... [2]

(b) A ball X has mass 240g 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 480g. After the collision, ball X is stationary, as shown in Fig. 2.1.

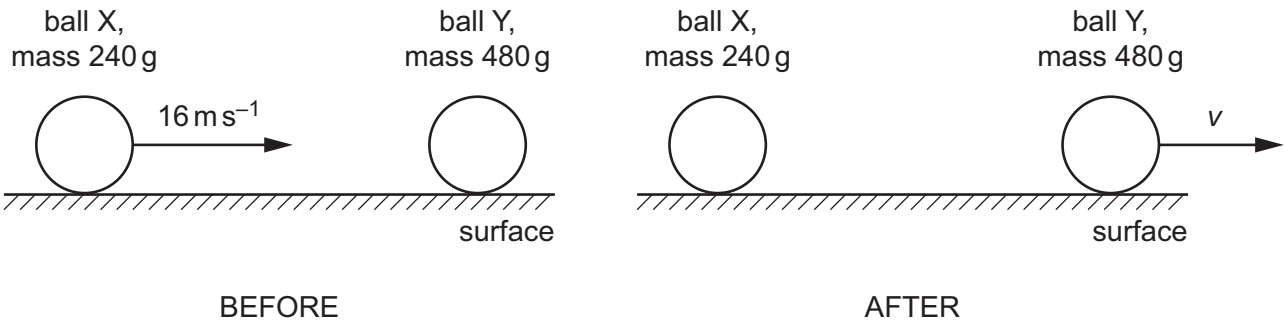


Fig. 2.1

(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.

$\Delta E_K = \dots\dots\dots \text{ J [3]}$

46. Question part 2/2 | 9702 Oct-Nov 2024 P2 V3 Q2



- (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

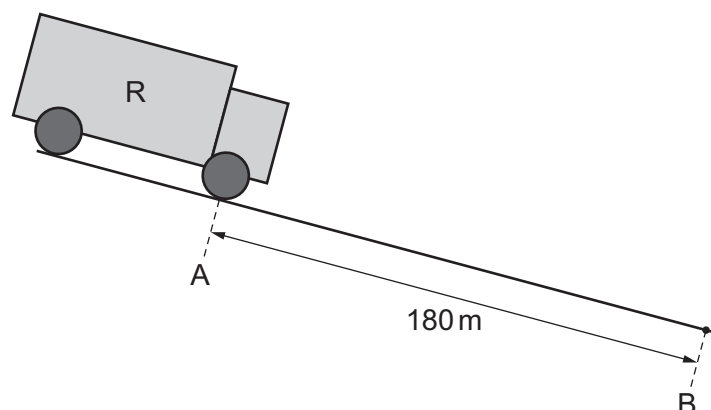
direction [3]

- (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]

47. Question part 1/3 | 9702 Feb-March 2025 P2 V2 Q3

- 3 (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]

47. Question part 2/3 | 9702 Feb-March 2025 P2 V2 Q3



(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.

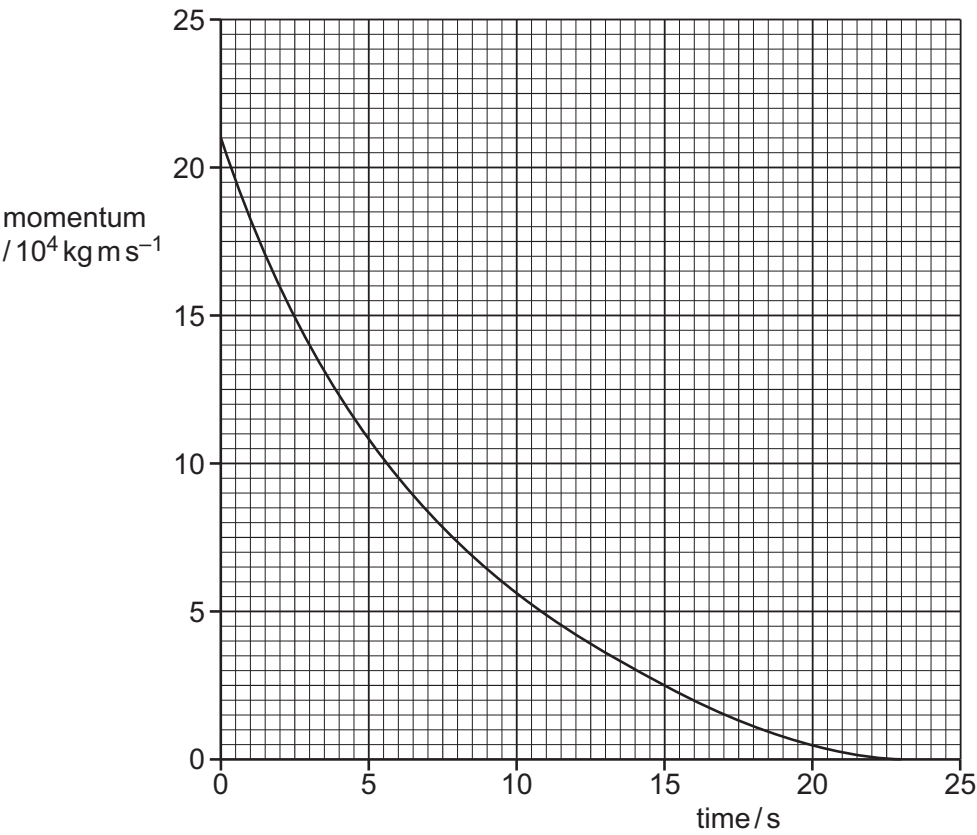


Fig. 3.2

(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 $-1.2 \times 10^4 \text{ N}$.

47. Question part 3/3 | 9702 Feb-March 2025 P2 V2 Q3



(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]

48. Question part 1/2 | 9702 May-June 2025 P2 V2 Q4

- 4 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.

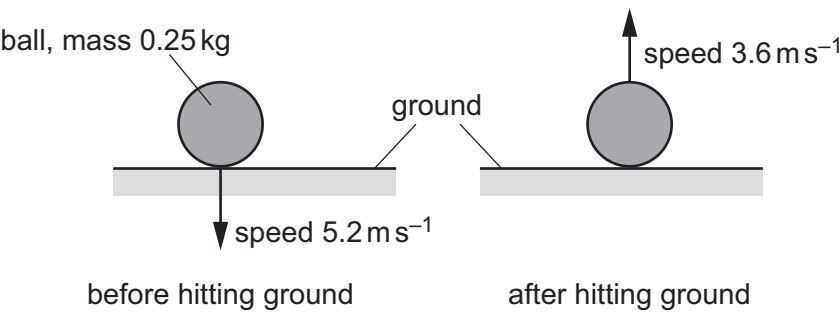


Fig. 4.1

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.

- (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]

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

ratio = ... [3]

[Total: 8]

49. Question | 9702 May-June 2025 P2 V3 Q4

4 (a) State the principle of conservation of momentum.

.....

.....

..... [2]

(b) An object A of mass 4.0 kg travels at a velocity of 6.0 ms⁻¹ to the right on a horizontal frictionless surface. It moves towards a second object B of mass 2.0 kg that is moving at a velocity of 3.0 ms⁻¹ in the same direction as A, as shown in Fig. 4.1.

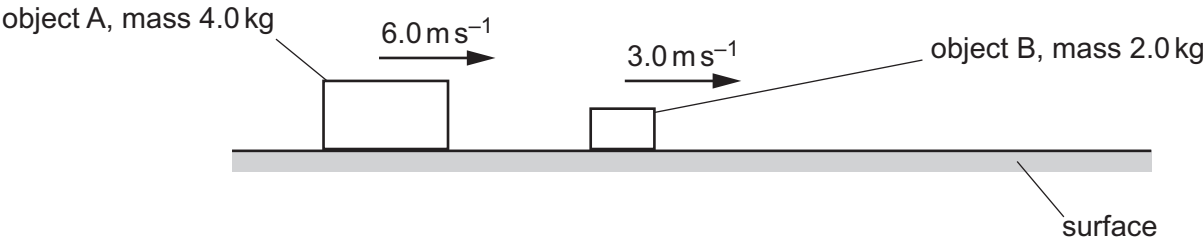


Fig. 4.1

Object A collides with object B. The two objects join and move off together with velocity v .

Calculate:

(i) velocity v

$v = \text{..... ms}^{-1}$ [2]

(ii) the percentage of the total initial kinetic energy of the two objects that is transferred to other forms of energy during the collision.

percentage = ...% [2]

[Total: 6]

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- 2 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.

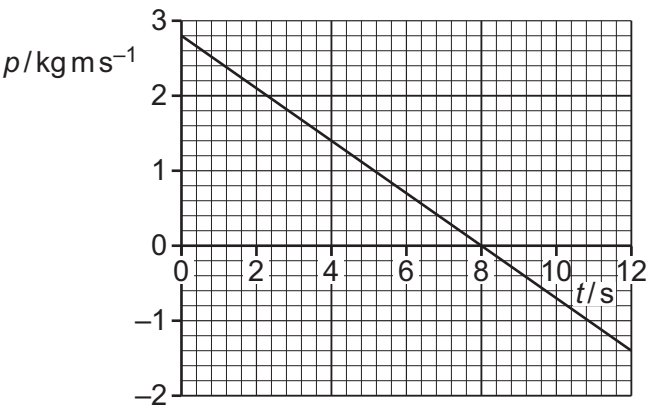


Fig. 2.1

- (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 ms⁻¹ [1]

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

force = ... N [2]

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

.....
..... [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 $t = 12\text{ s}$.

Numerical values of d are not required.

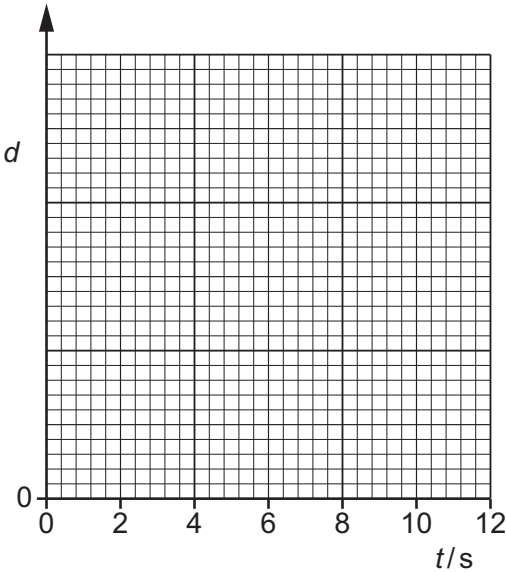


Fig. 2.2

[3]

[Total: 10]

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- 2 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.

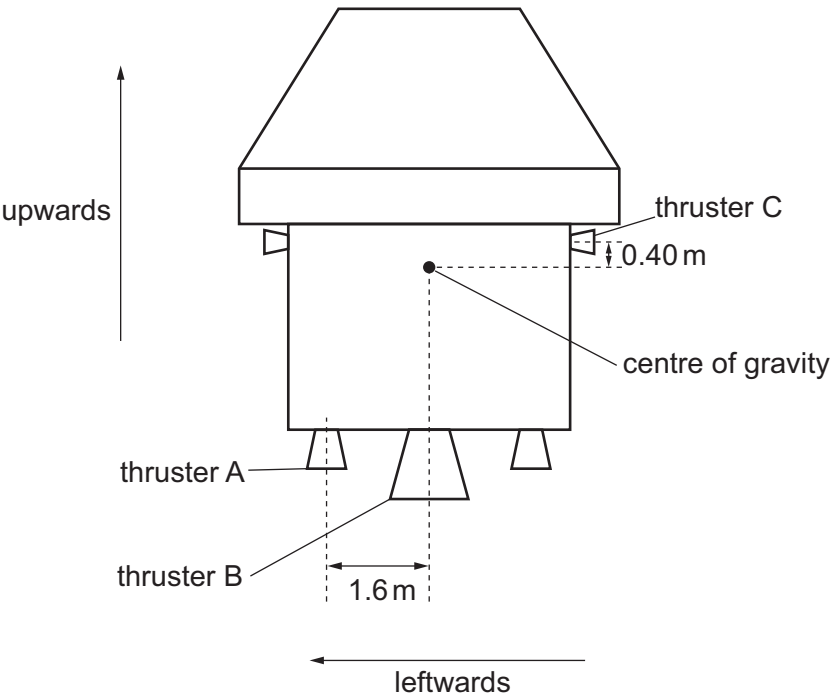


Fig. 2.1 (not to scale)

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 = ...Nm [2]

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

.....
.....
..... [1]

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- (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 .

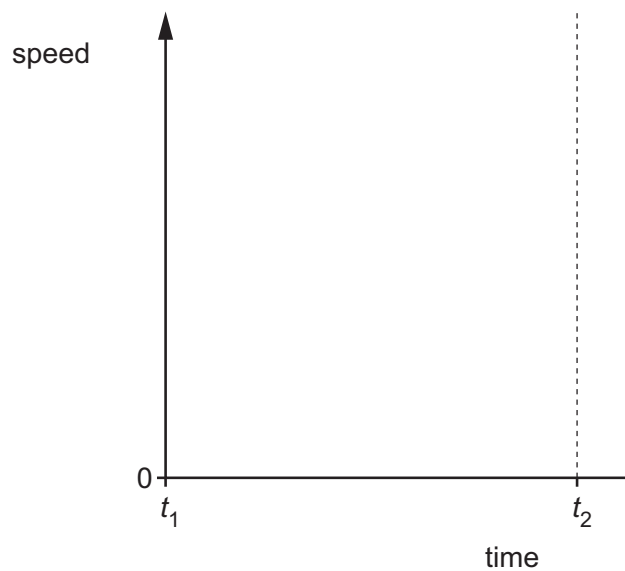


Fig. 2.2

[2]

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

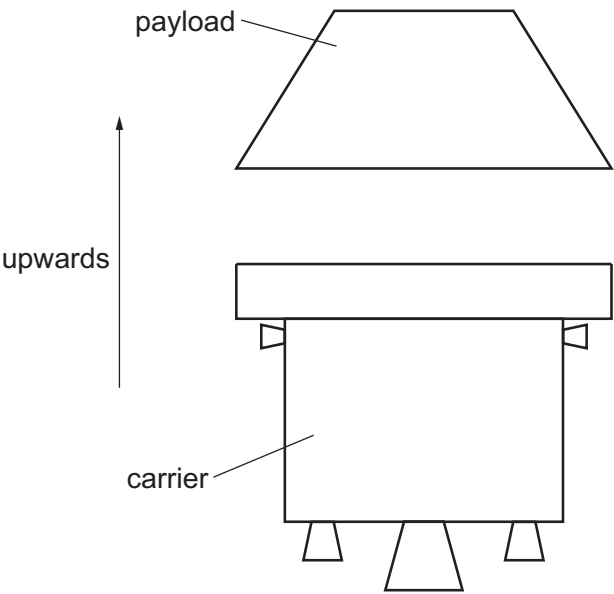


Fig. 2.3

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 ms^{-1} in the upwards direction.

The combined mass of the carrier and payload is $2.5 \times 10^3\text{ kg}$.

(i) State the principle of conservation of momentum.

.....

.....

..... [2]

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

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

change in velocity = ... ms^{-1} [3]

[Total: 12]