Worksheet

Dynamics

AS Level Dynamics 9702

PHYSICS WITH CYRUS

Cyrus Ishaq

ISL, BLL, BCCG, LGS, Roots IVY P5

+923008471504

Q1)

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

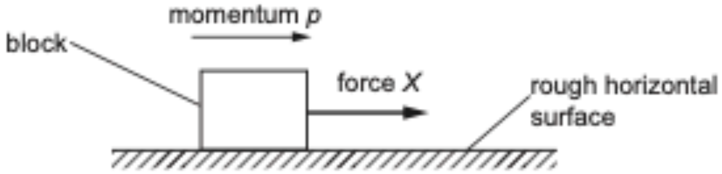


Fig. 3.1

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.

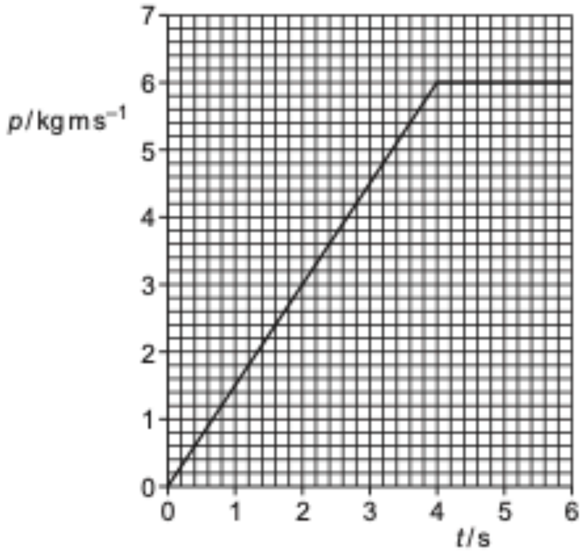


Fig. 3.2

(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 $t = 6.0\,s$.

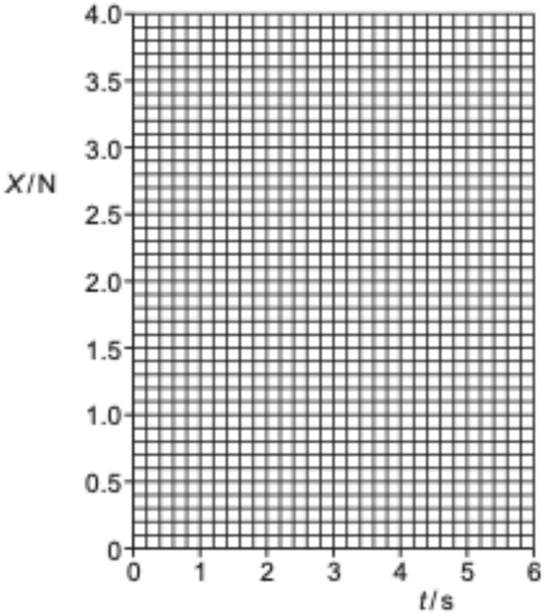


Fig. 3.3

[3]

[Total: 6]

Q2)

(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.

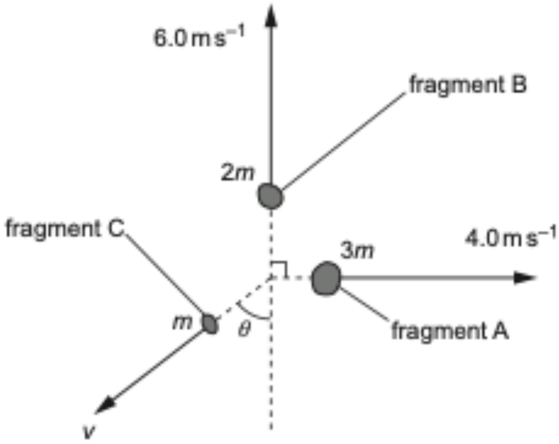


Fig. 3.1

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

Fragment B has a mass of $2m$ 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 = ... m s^{-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 = ... kg [3]

[Total: 11]

Q3)

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.

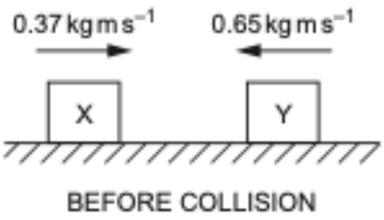


Fig. 4.1

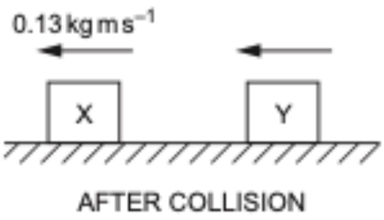


Fig. 4.2

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]

(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]

Q4)

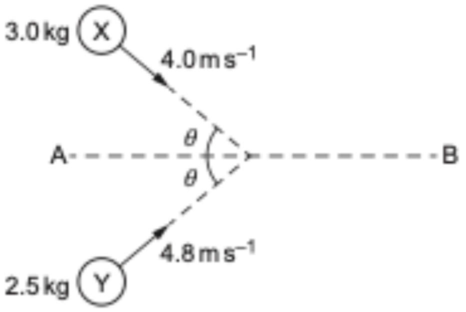
(a) State the principle of conservation of momentum.

....

....

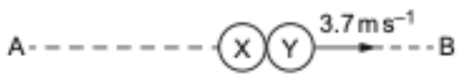
.... [2]

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

The balls collide and stick together. After colliding, the balls have a velocity of $3.7\,\text{m s}^{-1}$ 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]

Q5)

(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.

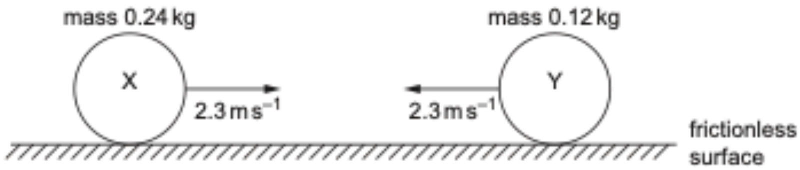


Fig. 2.1

Both balls have initial speed $2.3\,\text{m}\,\text{s}^{-1}$ 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.

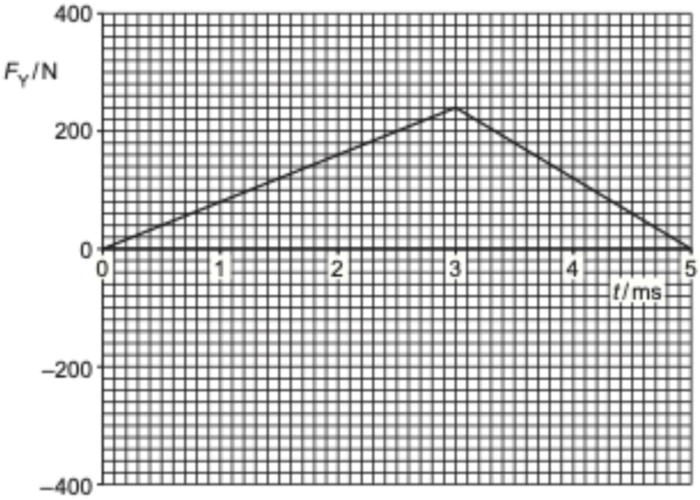


Fig. 2.2

(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)**.

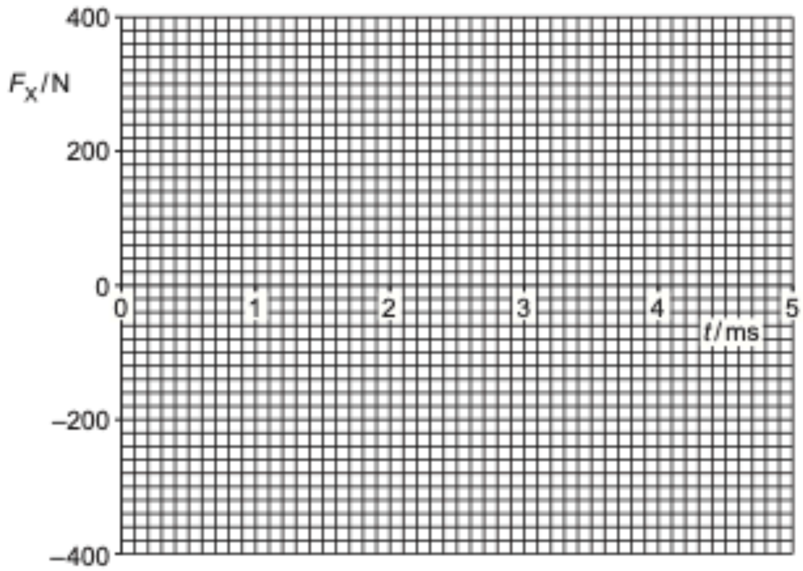


Fig. 2.3

[3]

[Total: 11]

Q6)

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

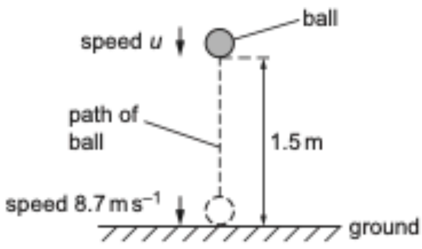


Fig. 2.1

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.

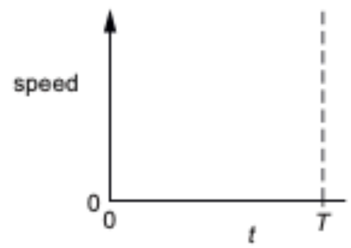


Fig. 2.2

[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]

Q7)

(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.

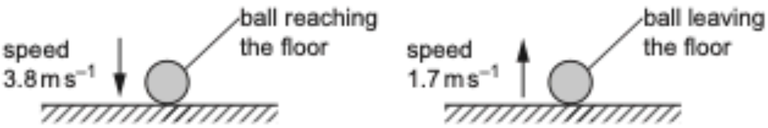


Fig. 3.1

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]

(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]

Q8)

(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.

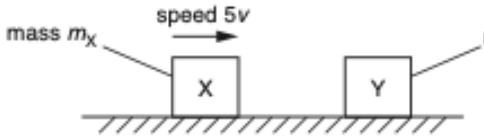


Fig. 3.1

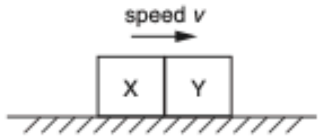


Fig. 3.2

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.

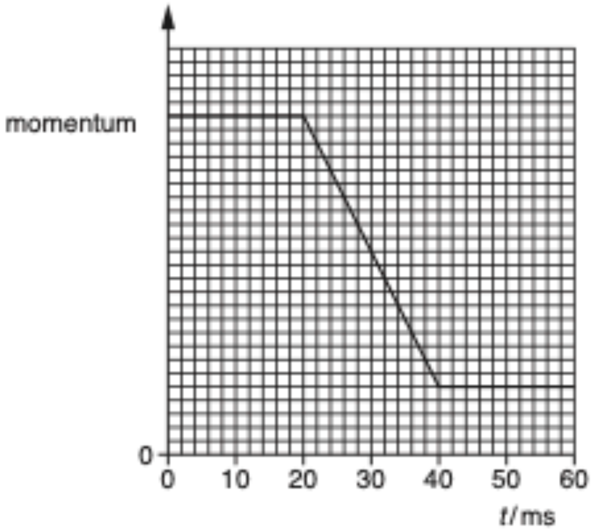


Fig. 3.3

Block X makes contact with block Y at time $t = 20\,\text{ms}$.

(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 $t = 20\,\text{ms}$

....

2. $t = 20\,\text{ms}$ to $t = 40\,\text{ms}$.

....

....
[3]

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

[Total: 14]

Q9)

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

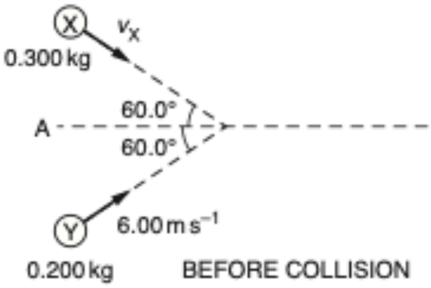


Fig. 4.1 (not to scale)

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

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

[2]

Q10)

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

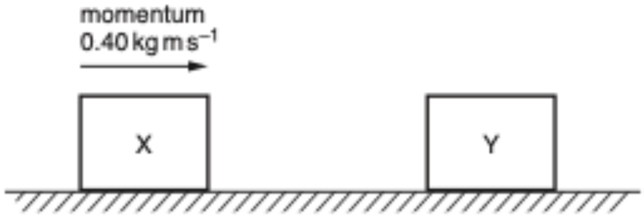


Fig. 2.1

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.

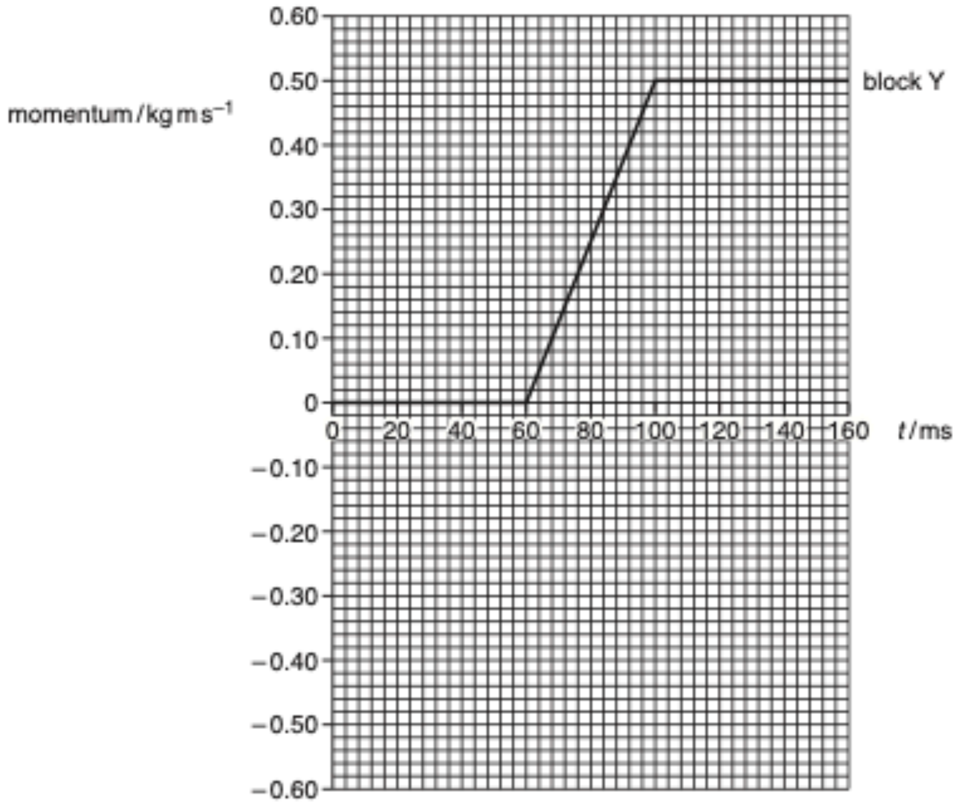


Fig. 2.2

(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 $t = 80\,\text{ms}$ to $t = 100\,\text{ms}$

....

2. time $t = 100\,\text{ms}$ to $t = 120\,\text{ms}$.

....

[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 $t = 160\,\text{ms}$. [3]

[Total: 9]

Q11)

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

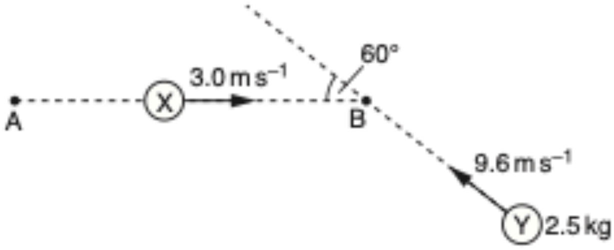


Fig. 3.1 (not to scale)

Ball X has an initial velocity of 3.0 m s^{-1} in a direction along line AB. Ball Y has a mass of 2.5 kg and an initial velocity of 9.6 m s^{-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.

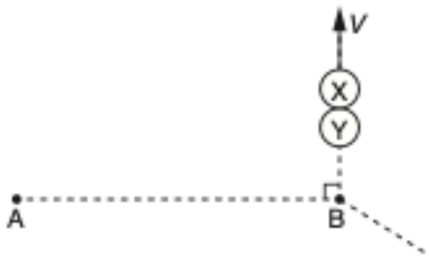


Fig. 3.2

(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.

[2]

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

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

[Total: 6]

Q12)

(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.

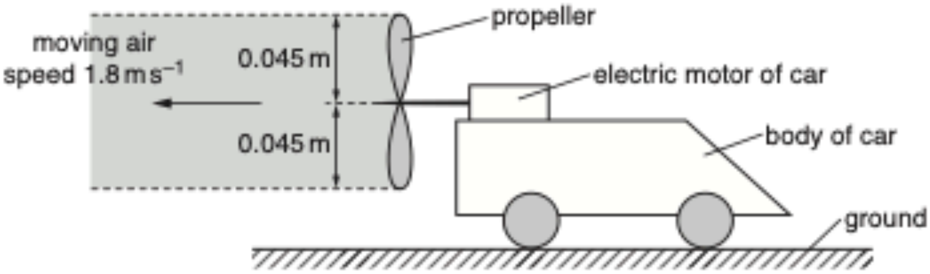


Fig. 3.1

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 $1.3\,\text{kg}\,\text{m}^{-3}$.

Assume that the air moves with a speed of $1.8\,\text{m}\,\text{s}^{-1}$ 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 $0.075\,\text{m}\,\text{s}^{-2}$.

Determine the initial frictional force acting on the car.

frictional force = ... N [2]

[Total: 11]

Q13)

(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.

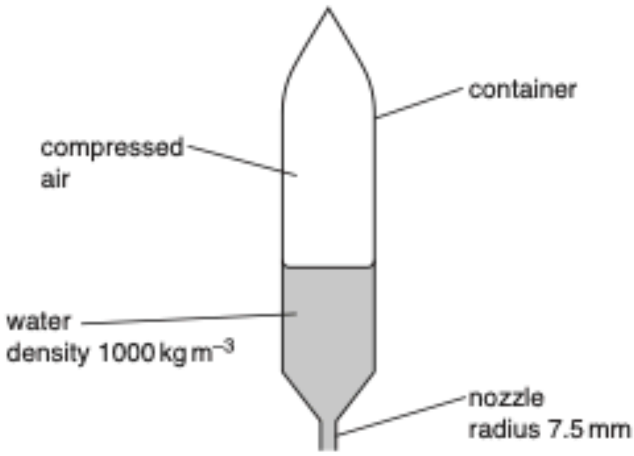


Fig. 3.1

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

[Total: 11]

Q14)

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

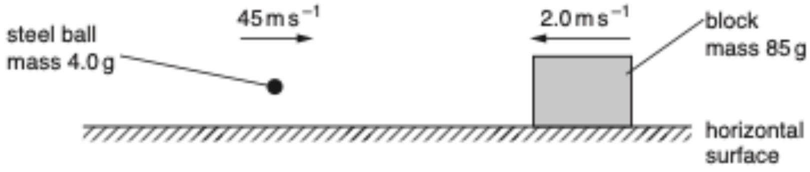


Fig. 2.1

The block has mass 85 g and moves to the left with a velocity of $2.0\,m\,s^{-1}$. A steel ball of mass 4.0 g is fired to the right. The steel ball, moving horizontally with a speed of $45\,m\,s^{-1}$, 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 = ... $m\,s^{-1}$ [2]

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

1. the relative speed of approach before collision,

relative speed of approach = ... $m\,s^{-1}$

2. the relative speed of separation after collision.

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

Q15)

(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.

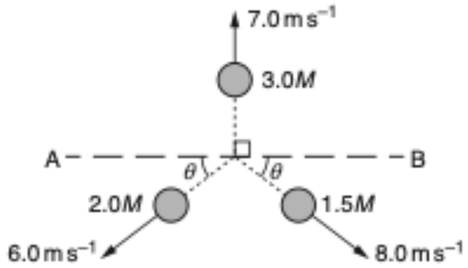


Fig. 2.1

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.

θ = ... ° [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]

Q16)

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

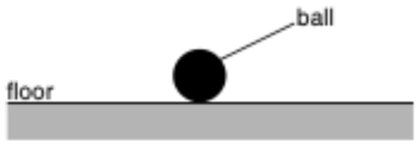


Fig. 3.1

(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.

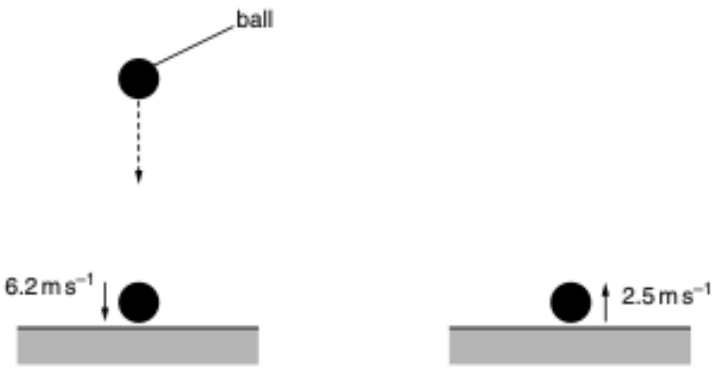


Fig. 3.2

Just before contact with the floor, the ball has velocity $6.2\,m\,s^{-1}$ downwards. The ball bounces from the floor and its velocity just after losing contact with the floor is $2.5\,m\,s^{-1}$ 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]

Q17)

(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.

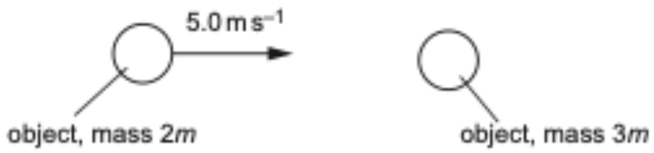


Fig. 3.1

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.

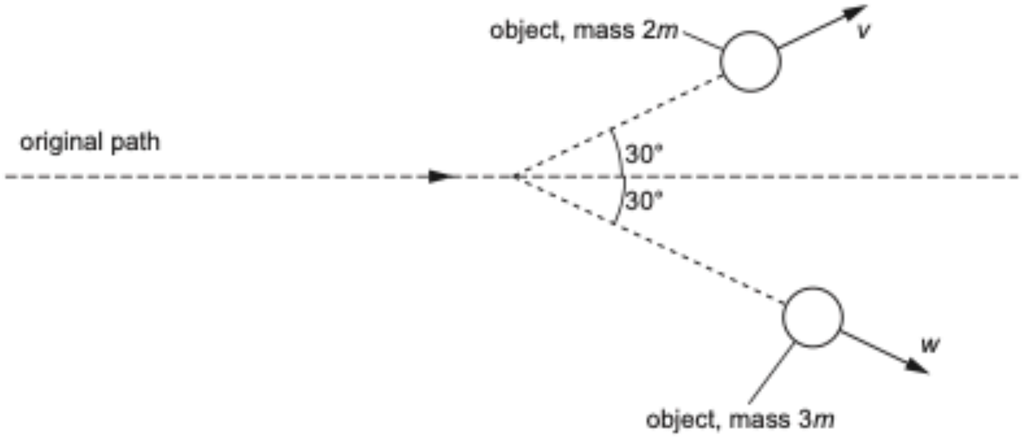


Fig. 3.2

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

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

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

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

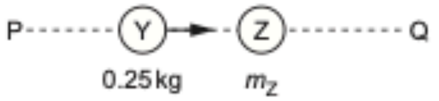
Calculate the magnitude of this force.

force = ... N [3]

[Total: 9]

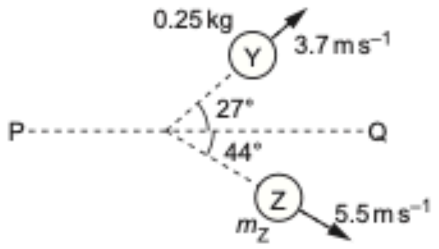
Q18)

(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.



BEFORE COLLISION

Fig. 4.1 (not to scale)



AFTER COLLISION

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 = ... Ns [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 $4\,m\,s^{-1}$ 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]

Q19)

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

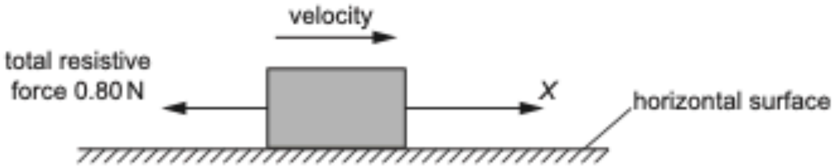


Fig. 3.1

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.

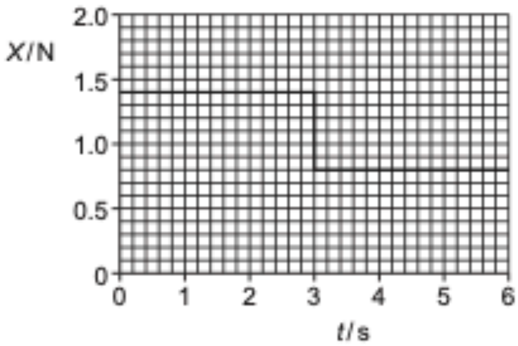


Fig. 3.2

(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 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.

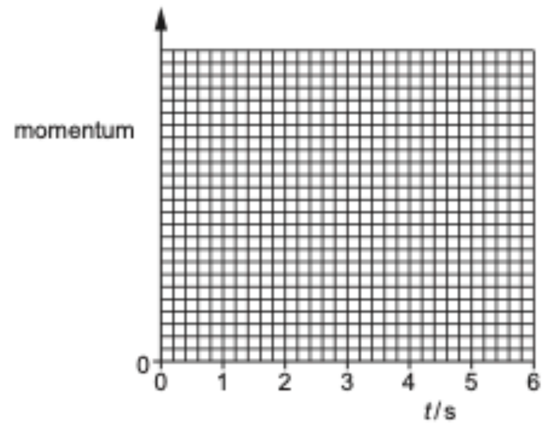


Fig. 3.3

[2]

[Total: 10]

Q20)

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.

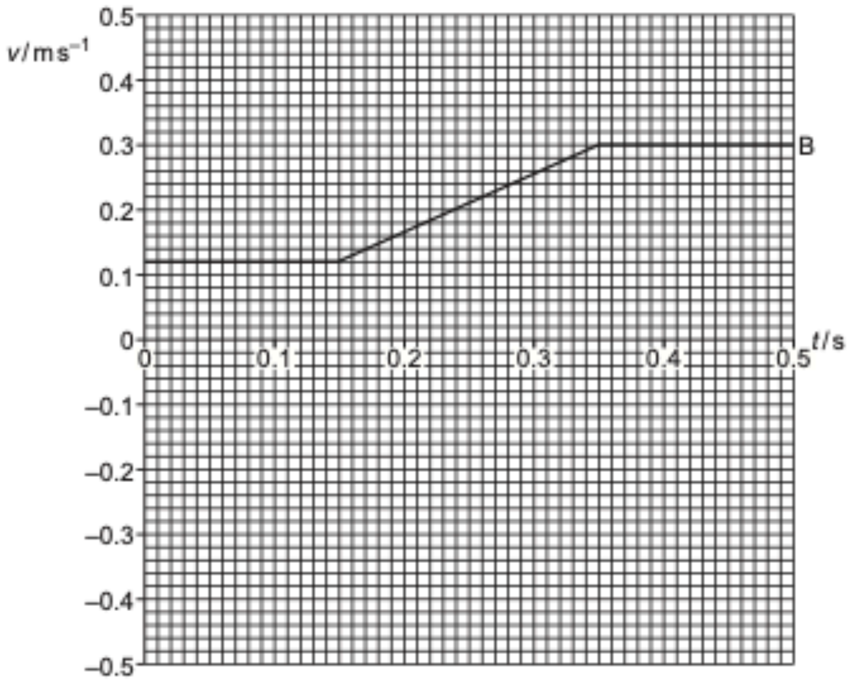


Fig. 3.2

(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]

Mark Scheme

Ans1)

Question	Answer	Marks
3(a)	(resultant) force (on an object) is proportional to / equal to the rate of change of momentum	B1
3(b)(i)	resultant force = e.g. 6.0 / 4.0 = 1.5 N	A1
3(b)(ii)	force X = 1.5 + 2.0 = 3.5 N	A1
3(c)	from t = 0 to t = 4.0 s: horizontal line at any non-zero value of X	B1
	from t = 0 to t = 4.0 s: horizontal line at X = 3.5 N	B1
	from t = 4.0 s to t = 6.0 s: horizontal line at X = 2.0 N	B1

Ans2)

Question	Answer	Marks
3(a)	sum / total momentum before = sum / total momentum after **or** sum / total momentum (of a system of objects) is constant	M1
	if no (resultant) external force / for an isolated system	A1
3(b)(i)	$3m \times 4 = m \times v \sin\theta$ ($v \sin\theta = 12$)	C1
	$2m \times 6 = m \times v \cos\theta$ ($v \cos\theta = 12$)	C1
	therefore $\sin\theta = \cos\theta$ **or** $\tan\theta = 1$ $\theta = 45°$	A1
3(b)(ii)	$mv \times \cos 45° = 12m$ **or** $mv \times \sin 45° = 12m$ **or** $(mv)^2 = (3m \times 4)^2 + (2m \times 6)^2$	C1
	v = 17 m s^{-1}	A1
3(c)(i)	(chemical energy) = 0.0050 × 700 = 3.5 (J) **or** (chemical energy) = 5.0 × 0.700 = 3.5 (J)	A1

Question	Answer	Marks
3(c)(ii)	$E = \frac{1}{2}mv^2$	C1
	total $E = (0.5 \times 3m \times 4^2) + (0.5 \times 2m \times 6^2) + (0.5 \times m \times 17^2)$	C1
	$3.5 = 204m$ $m = 0.017$ kg	A1

Ans3)

Question	Answer	Marks
4(a)	$E = \frac{1}{2}mv^2$	C1
	$p = mv$	C1
	$m = 0.37^2 / (2 \times 0.30)$ **or** $0.37 / 1.6$ **or** $(0.30 \times 2) / 1.6^2$ $= 0.23$ kg	A1
4(b)	$0.37 - 0.65 = -0.13 - p$ $p = 0.15$ kg m s^{-1}	A1
4(c)	$7.7 = (0.13 + 0.37) / (\Delta)t$ **or** $7.7 = (0.65 - 0.15) / (\Delta)t$	C1
	time = 0.065 s	A1

Ans4)

Question	Answer	Marks
4(a)	<u>sum</u>/<u>total</u> momentum before = <u>sum</u>/<u>total</u> momentum after **or** <u>sum</u>/<u>total</u> momentum (of a system of objects) is constant	M1
	<u>if no (resultant) external force/for a closed system</u>	A1
4(b)(i)	$(3.0 \times 4.0 \times \cos\theta)$ **or** $(2.5 \times 4.8 \times \cos\theta)$ **or** (5.5×3.7)	C1
	$(3.0 \times 4.0 \times \cos\theta) + (2.5 \times 4.8 \times \cos\theta) = (5.5 \times 3.7)$	C1
	$\theta = 32°$	A1
4(b)(ii)	(initial $E_K = \frac{1}{2} \times 3.0 \times 4.0^2 + \frac{1}{2} \times 2.5 \times 4.8^2 =$) 53 (J) **or** (final $E_K = \frac{1}{2} \times 5.5 \times 3.7^2 =$) 38 (J)	C1
	values of initial E_K and final E_K both correct **and** inelastic stated	A1

Ans5)

Question	Answer	Marks
2(a)	mass × velocity	B1
2(b)(i)	kinetic energy $= \frac{1}{2}mv^2$	C1
	$= \frac{1}{2} \times 0.24 \times 2.3^2$	C1
	= 0.63 J	A1
2(b)(ii)	change in momentum $= \frac{1}{2} \times 240 \times 5.0 \times 10^{-3}$	C1
	= 0.60 N s	A1
2(b)(iii)	(change in velocity of Y) = 0.60 / 0.12 (= 5.0 m s^{-1})	C1
	final velocity of Y = 5.0 – 2.3 = 2.7 m s^{-1}	A1
	or	
	(final momentum of Y) = 0.60 – 0.12 × 2.3 (= 0.324 N s)	**(C1)**
	final velocity of Y = 0.324 / 0.12 = 2.7 m s^{-1}	**(A1)**
2(c)	sloping straight line from (0, 0) to t = 3.0 ms **and** another straight line continuous with the first from t = 3.0 ms to (5.0, 0)	B1
	lines showing maximum force of magnitude 240 N	B1
	lines wholly in the negative F region of the graph	B1

Ans6)

Question	Answer	Marks
2(a)	$v^2 = u^2 + 2as$ $u^2 = 8.7^2 - (2 \times 9.81 \times 1.5)$	C1
	$u = 6.8\ \text{m s}^{-1}$	A1
2(b)	(magnitude of) force on ball (by ground) equal to force on ground (by ball)	B1
	(direction of) force on ball (by ground) opposite to force on ground (by ball)	B1
2(c)(i)	(p =) 0.059×8.7 **or** 0.059×5.4	C1
	change in momentum = 0.059 (8.7 + 5.4) = 0.83 N s	A1
2(c)(ii)	resultant force = 0.83 / 0.091 **or** 0.059 [(8.7 + 5.4) / 0.091] = 9.1 N	A1
2(c)(iii)	(W =) 0.059×9.81	C1
	(W =) 0.58 (N) force = 9.1 + 0.58 = 9.7 N	A1
2(d)	straight line with a positive gradient and starting from a non-zero value of speed at $t = 0$ and ending when $t = T$	B1
2(e)	air resistance increases	B1
	resultant force/acceleration decreases so gradient (of curve) decreases	B1

Ans7)

Question	Answer	Marks
3(a)	(force =) rate of change of momentum	B1
3(b)(i)	$E = ½mv^2$ **or** $½ \times 0.062 \times 3.8^2$ **or** $½ \times 0.062 \times 1.7^2$	C1
	loss of KE = $½ \times 0.062 \times (3.8^2 - 1.7^2)$ = 0.36 J	A1
3(b)(ii)	$p = mv$ **or** 0.062×3.8 **or** 0.062×1.7	C1
	change in momentum = $0.062 \times (1.7 + 3.8)$ = 0.34 N s	A1
3(b)(iii)	(average resultant force =) 0.34 / 0.081 = 4.2 (N) **or** (average resultant force =) $0.062 \times (1.7 + 3.8) / 0.081$ = 4.2 (N)	A1
3(b)(iv)	**1.** average force = $4.2 + (0.062 \times 9.81)$ = 4.8 N	A1
	2. average force = 4.8 N	A1

Ans8)

Question	Answer	Marks
3(a)	force on body A (by body B) is equal (in magnitude) to force on body B (by body A)	B1
	force on body A (by body B) is opposite (in direction) to force on body B (by body A)	B1
3(b)(i)	$m_X \times 5v$ **or** $(m_X + m_Y) \times v$	C1
	$m_X \times 5v = (m_X + m_Y) \times v$ (so) $m_Y / m_X = 4$	A1
3(b)(ii)	$(E =) \frac{1}{2}mv^2$	C1
	ratio $= [\frac{1}{2} \times (m_X + m_Y) \times v^2] / [\frac{1}{2} \times m_X \times (5v)^2]$	C1
	$= 0.2$	A1
3(b)(iii)	ratio = 1	A1
3(c)(i)	**1.** (magnitude of resultant force is) zero	B1
	2. (magnitude of resultant force is) constant	B1
	(direction of resultant force is) opposite to the momentum	B1
3(c)(ii)	horizontal line from (0 ms, 0 squares) ending at (20 ms, 0 squares)	B1
	straight line from (20 ms, 0 squares) ending at (40 ms, 4.0 squares [= 4.0 cm vertically])	B1
	horizontal line from (40 ms, 4.0 squares) ending at (60 ms, 4.0 squares)	B1

Ans9)

Question	Answer	Marks
4(a)(i)	$p = mv$	C1
	$= 0.2(00) \times 6.(00) \times \sin 60(.0)°$ **or** $0.2(00) \times 6.(00) \times \cos 30(.0)°$ $= 1.04\ \text{kg m s}^{-1}$	A1
4(a)(ii)	$0.300 \times v_x \times \sin 60.0° = 1.04$ $v_x = 4.00\ \text{m s}^{-1}$	A1
4(a)(iii)	$0.30 \times 4.0 \times \cos 60°$ **or** $0.20 \times 6.0 \times \cos 60°$ **or** $(0.30 + 0.20)v$ **or** $0.50v$	C1
	$0.30 \times 4.0 \times \cos 60° + 0.20 \times 6.0 \times \cos 60° = (0.30 + 0.20)v$ **or** $0.50v$ so $v = 2.4\ \text{m s}^{-1}$	A1

Ans10)

Question	Answer	Marks
2(a)	(momentum =) mass × velocity	B1
2(b)(i)	time = 40 ms	A1
2(b)(ii)	**1.** (the magnitude of the acceleration is) constant	B1
	2. (the magnitude of the acceleration is) zero	B1
2(c)	$F = \Delta p / (\Delta)t$ **or** F = gradient	C1
	e.g. $F = 0.50 / 40 \times 10^{-3}$ $= 13$ N	A1
2(d)	horizontal line from (0, 0.40) to (60, 0.40)	B1
	straight line from (60, 0.40) to (100, –0.10)	B1
	horizontal line from (100, –0.10) to (160, –0.10)	B1

Ans11)

Question	Answer	Marks
3(a)	$(m \times 3.0)$ or $(2.5 \times 9.6 \times \cos 60°)$	C1
	$(m \times 3.0) - (2.5 \times 9.6 \times \cos 60°) = 0$ so $m = 4.0$ (kg)	A1
Question	**Answer**	**Marks**
3(b)	$2.5 \times 9.6 \times \sin 60° = (4.0 + 2.5) \times V$	C1
	$V = 3.2$ m s^{-1}	A1
	or use of momentum vector triangle: $(4.0 \times 3.0)^2 + [(4.0 + 2.5) \times V]^2 = (2.5 \times 9.6)^2$	(C1)
	$V = 3.2$ m s^{-1}	(A1)
3(c)	$E = ½mv^2$ difference in $E_K = ½ \times 2.5 \times (9.6)^2 - ½ \times 4.0 \times (3.0)^2$	C1
	$= 97$ J	A1

Ans12)

Question	Answer	Marks
3(a)	sum/total momentum (of a system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	M1
	for an isolated system **or** no (resultant) external force	A1
3(b)(i)	$m = \rho V$	C1
	$= 1.3 \times \pi \times 0.045^2 \times 1.8 \times 2.0 = 0.030$ (kg)	A1
3(b)(ii)	**1.** $(\Delta)p = (\Delta)mv$	C1
	$= 0.030 \times 1.8$ $= 0.054$ N s	A1
	2. $F = 0.054/2.0$ **or** $0.030 \times 1.8/2.0$ $= 0.027$ N	A1
3(b)(iii)	force on air (by propeller) equal to force on propeller (by air)	M1
	and opposite (in direction)	A1
3(b)(iv)	resultant force $= 0.20 \times 0.075$ (= 0.015 N) frictional force $= 0.027 - 0.015$	C1
	$= 0.012$ N	A1

Ans13)

Question	Answer	Marks
3(a)	(resultant) force proportional/equal to rate of change of momentum	B1
3(b)(i)	$\rho = m / V$	C1
	$V = \pi \times (7.5 \times 10^{-3})^2 \times 13 \times 0.2$ ($= 4.59 \times 10^{-4}$ m^3) $m = \pi \times (7.5 \times 10^{-3})^2 \times 13 \times 0.2 \times 1000 = 0.46$ kg	A1
3(b)(ii)	**1.** $(\Delta)p = (\Delta m)v$	C1
	$(\Delta)p = 0.46 \times 13$ $= 6.0$ N s	A1
	2. $F = 6.0/0.20$ $= 30$ N	A1
3(b)(iii)	force on water (by rocket/nozzle) equal to force on rocket/nozzle (by water)	M1
	in the opposite direction	A1
3(b)(iv)	**1.** mass $= 0.40 + 0.70 - 0.46 = 0.64$ kg	A1
	2. acceleration $= [30 - (0.64 \times 9.81)]/0.64$ **or** $30/0.64 - 9.81$	C1
	$= 37$ m s^{-2}	A1

Ans14)

Question	Answer	Marks
2(a)	(p =) mv **or** 4.0×45 **or** 2.0×85 **or** $89v$	C1
	$(4.0 \times 45) - (2.0 \times 85) = 89\,v$ $v = 0.11\,\text{m s}^{-1}$	A1
2(b)(i)	**1.** speed of approach = $47\,\text{m s}^{-1}$ **and** **2.** speed of separation = 0	A1
2(b)(ii)	speed of separation less than/not equal to speed of approach **and** so inelastic collision	A1
2(c)	force is equal to rate of change of momentum	B1
	force on ball (by block) equal and opposite to force on block (by ball) so rates of change of momentum are equal and opposite	B1
	or	
	force on ball (by block) equal and opposite to force on block (by ball)	(B1)
	force is equal to rate of change of momentum so rates of change of momentum are equal and opposite	(B1)

Ans15)

Question	Answer	Marks
2(a)	sum/total momentum (of a system of bodies) is constant **or** sum/total momentum before = sum/total momentum after	**M1**
	for an isolated system **or** no (resultant) external force	**A1**
2(b)(i)	(p =) mv **or** (3.0M × 7.0) **or** (2.0M × 6.0) **or** (1.5M × 8.0)	**C1**
	3.0M × 7.0 = 2.0M × 6.0 sinθ + 1.5M × 8.0 sinθ	**C1**
	θ = 61°	**A1**
	or (vector triangle method)	
	momentum vector triangle drawn	**(C1)**
	θ = 61° (*2 marks for* ±1°, *1 mark for* ±2°)	**(A2)**
	or (use of cosine rule)	
	p = mv **or** (3.0M × 7.0) **or** (2.0M × 6.0) **or** (1.5M × 8.0)	**(C1)**
	$(21M)^2 = (12M)^2 + (12M)^2 - (2 \times 12M \times 12M \times \cos 2\theta)$	**(C1)**
	θ = 61°	**(A1)**
2(b)(ii)	(E =) $\frac{1}{2}mv^2$	**C1**
	ratio = $(\frac{1}{2} \times 2.0M \times 6.0^2) / (\frac{1}{2} \times 1.5M \times 8.0^2)$ = 0.75	**A1**

Ans16)

(a)	**(i)**	force (= mg = 0.15 × 9.81) = 1.5 (1.47) N	A1	[1]
	(ii)	resultant force (on ball) is zero so normal contact force = weight *or* the forces are in opposite directions so normal contact force = weight *or* normal contact force up = weight down	A1	[1]
(b)	**(i)**	(resultant) force proportional/equal to rate of change of momentum	B1	[1]
	(ii)	change in momentum = 0.15 × (6.2 + 2.5) (= 1.305 N s)	C1	
		magnitude of force = 1.305 / 0.12 = 11 (10.9) N	A1	
		or		
		(average) acceleration = (6.2 + 2.5) / 0.12 (= 72.5 m s^{-2})	(C1)	
		magnitude of force = 0.15 × 72.5 = 11 (10.9) N	(A1)	
		(direction of force is) upwards/up	B1	[3]
	(iii)	there is a change/gain in momentum of the floor	M1	
		this is equal (and opposite) to the change/loss in momentum of the ball so momentum is conserved	A1	[2]
		or		
		change of (total) momentum of ball and floor is zero so momentum is conserved	(M1) (A1)	
		or		
		(total) momentum of ball and floor before is equal to the (total) momentum of ball and floor after so momentum is conserved	(M1) (A1)	

Ans17)

Question	Answer	Marks
3(a)	<u>sum / total</u> momentum before (a collision) = <u>sum / total</u> momentum after (a collision) **or** <u>sum / total</u> momentum (of a system) is constant	**M1**
	if no (resultant) external force (acts) / for an isolated system	**A1**
3(b)	along direction of motion: $10m = 2mv \cos 30° + 3mw \cos 30°$	**C1**
	perpendicular to direction of motion: $2mv \cos 60° = 3mw \cos 60°$ ($v = 3w / 2$)	**C1**
	$v = 2.9\ \text{m s}^{-1}$	**A1**
	$w = 1.9\ \text{m s}^{-1}$	**A1**
3(c)	$E_K = ½ \times m \times v^2$ ($= ½ \times 4.2 \times 6.0^2$) (= 76 J)	**C1**
	force = work done / distance	**C1**
	force = 76 / 0.050 = 1500 N	**A1**
3(c)	**or**	
	$a = (–)u^2 / 2s$ $= (–)6.0^2 / (2 \times 0.050)$ ($= (–)360\ \text{m s}^{-2}$)	**(C1)**
	$F = ma$	**(C1)**
	$F = 4.2 \times 360$ = 1500 N	**(A1)**
	or	
	$a = (–)u^2 / 2s$ $= (–)6.0^2 / (2 \times 0.050)$ ($= (–)360\ \text{m s}^{-2}$)	**(C1)**
	$t = –u / a$ $= –6.0 / –360$ (= 0.017 s) $F = \Delta p / t$	**(C1)**
	$F = (0 – 4.2 \times 6) / 0.017$ = 1500 N	**(A1)**

Ans18)

Question	Answer	Marks
4(a)(i)	component of momentum $= 0.25 \times 3.7 \times \sin 27°$	C1
	$= 0.42$ N s	A1
4(a)(ii)	$m_{(Z)} \times 5.5 \times \sin 44° = 0.42$ **or** $m_{(Z)} \times 5.5 \times \sin 44° = 0.25 \times 3.7 \times \sin 27°$ $m_Z = 0.11$ kg	A1
4(a)(iii)	magnitudes: equal	B1
	directions: opposite	B1
4(b)	$4 + 6 = 2 + v$ $v = 8$ m s^{-1}	A1

Ans19)

Question	Answer	Marks
3(a)(i)	rate of change of momentum	B1
3(a)(ii)	change in momentum $= (1.4 - 0.80) \times 3.0$	C1
	$= 1.8$ kg m s^{-1}	A1
3(b)(i)	resultant force (on block) is zero	B1
	(so) velocity is constant	B1
3(b)(ii)	$P = Fv$ **or** $P = Fs / t$	C1
	$v = 2.0 / 0.80$ (= 2.5 m s^{-1})	C1
	distance = 2.5×3.0 = 7.5 m	A1
	or	
	$P = W / t$ **or** $P = Fs / t$	(C1)
	$W = 2.0 \times 3.0$ (= 6.0 J)	(C1)
	distance = $6.0 / 0.80$ = 7.5 m	(A1)
3(c)	0 to 3.0 s: upward sloping straight line from the origin.	B1
	3.0 to 6.0 s: horizontal line at non-zero value of momentum with no 'step change' in momentum at 3.0 s	B1

Ans20)

Question	Answer	Mark
3(a)	displacement	**A1**
3(b)(i)	a = gradient **or** $a = \Delta v / (\Delta)t$ **or** $a = (v - u) / t$	**C1**
	e.g. $a = (0.30 - 0.12) / (0.35 - 0.15)$ $a = 0.90\ \text{m s}^{-2}$	**A1**
3(b)(ii)	$(0.25 \times 0.48) + (0.75 \times 0.12) = (0.25\ v) + (0.75 \times 0.30)$ **or** $(0.48 - 0.12) = (0.30 - v)$ **or** $(\frac{1}{2} \times 0.25 \times 0.48^2) + (\frac{1}{2} \times 0.75 \times 0.12^2) = (\frac{1}{2} \times 0.25 \times v^2) + (\frac{1}{2} \times 0.75 \times 0.30^2)$	**C1**
	$v = (-)0.060\ \text{m s}^{-1}$	**A1**
	direction: to the left / from the right / opposite to (its) initial velocity / opposite to (initial / final) velocity of B	**B1**
3(c)	sketch: horizontal line from (0, 0.48) to (0.15, 0.48)	**B1**
	horizontal line from (0.35, –0.06) to (0.5, –0.06)	**B1**
	straight line between (0.15, 0.48) and (0.35, –0.06)	**B1**