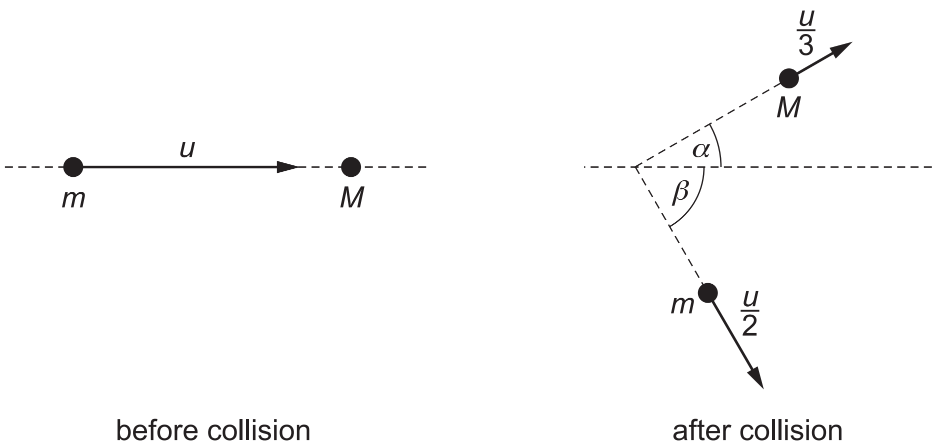
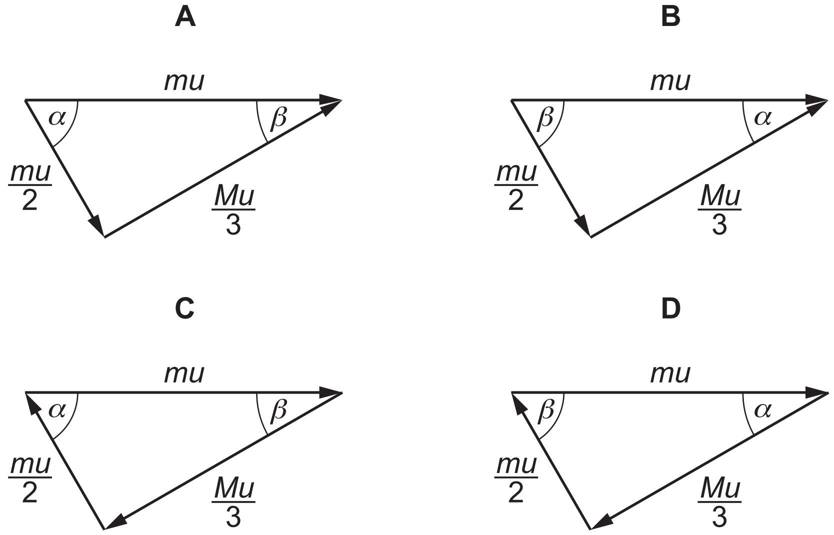
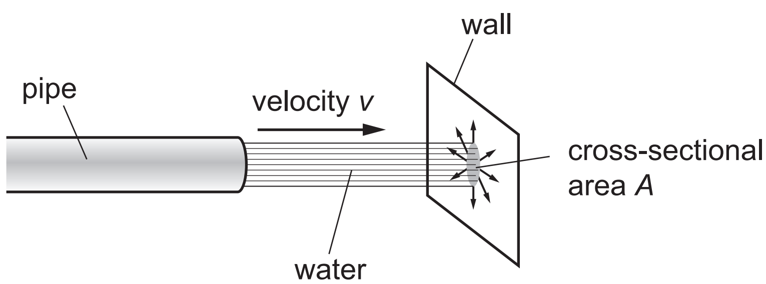
1 A particle of mass m, travelling with speed u, collides with a stationary particle of mass M. The velocities of the two particles before and after the collision are shown.



Which vector diagram correctly shows the momenta before and after the collision?



2 Water flows out of a pipe and hits a wall.



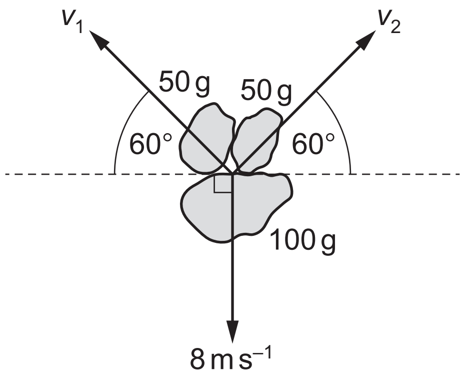
When the jet of water hits the wall, it has horizontal velocity v and cross-sectional area A.

The density of the water is ρ. The water does not rebound from the wall.

What is the force exerted on the wall by the water?

A $\frac{\rho v}{A}$ **B** $\frac{\rho v^2}{A}$ **C** $\rho A v$ **D** $\rho A v^2$

3 A stationary firework explodes into three pieces. The masses and the velocities of the three pieces immediately after the explosion are shown.

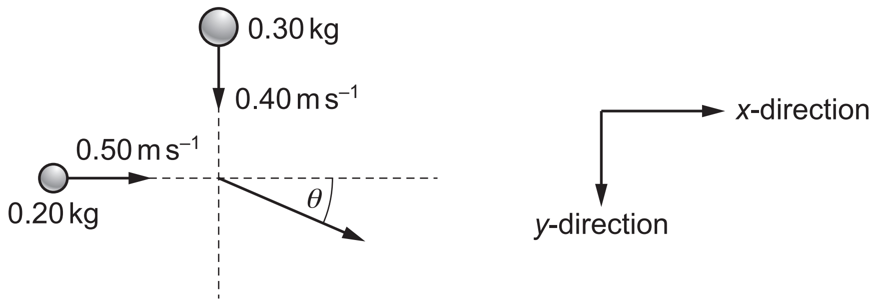


What are speed v_1 and speed v_2?

	v_1 / m s^{-1}	v_2 / m s^{-1}
A	4.0	4.0
B	9.2	9.2
C	14	14
D	16	16

4 A ball of mass 0.20 kg, travelling in the x-direction at a speed of 0.50 m s^{-1}, collides with a ball of mass 0.30 kg travelling in the y-direction at a speed of 0.40 m s^{-1}.

The two balls stick together after the collision, travelling at an angle θ to the x-direction.



What is the value of θ?

A 39° **B** 40° **C** 50° **D** 51°

1 Two balls, X and Y, move along a horizontal frictionless surface, as illustrated in Fig. 1.1.

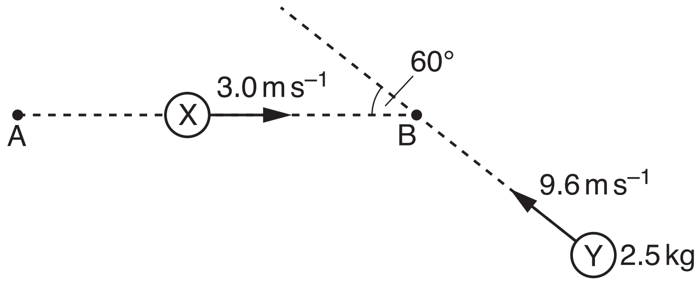


Fig. 1.1 (not to scale)

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. 1.2.

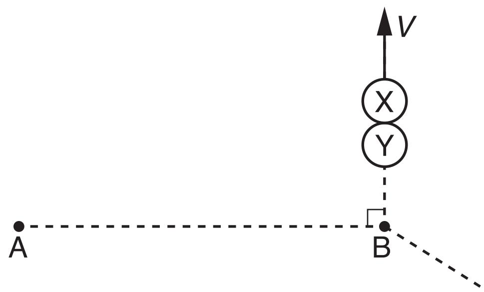


Fig. 1.2

(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]

2 **(a)** State the law of conservation of momentum.

....

....

.... [2]

(b) Two particles A and B collide elastically, as illustrated in Fig. 2.1.

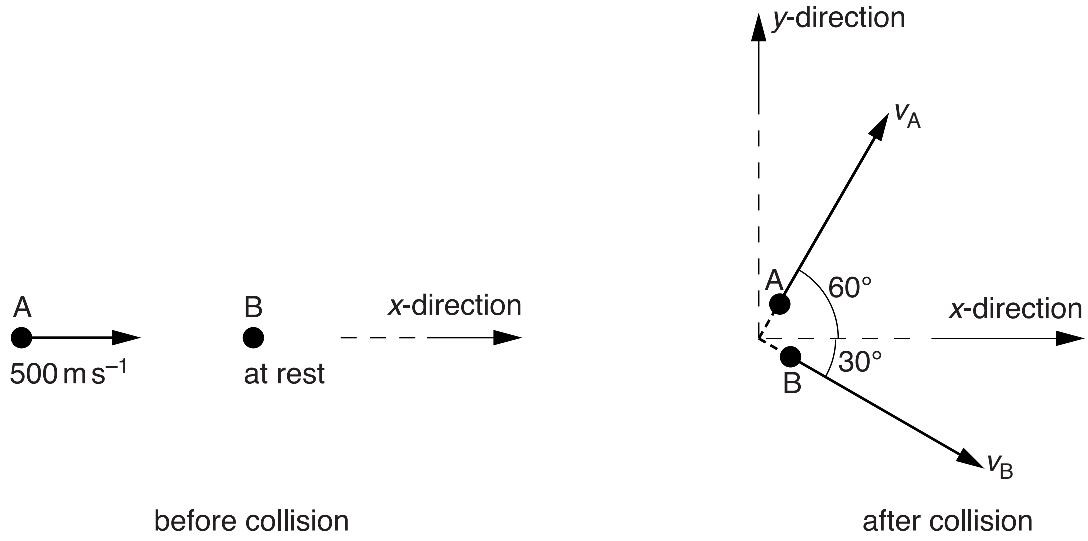


Fig. 2.1

The initial velocity of A is $500\,\text{m s}^{-1}$ 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 1.67×10^{-27} kg.

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

.... [1]

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

momentum = ... N s [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 = ... $m\,s^{-1}$

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

[Total: 9]

3 **(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. 3.1.

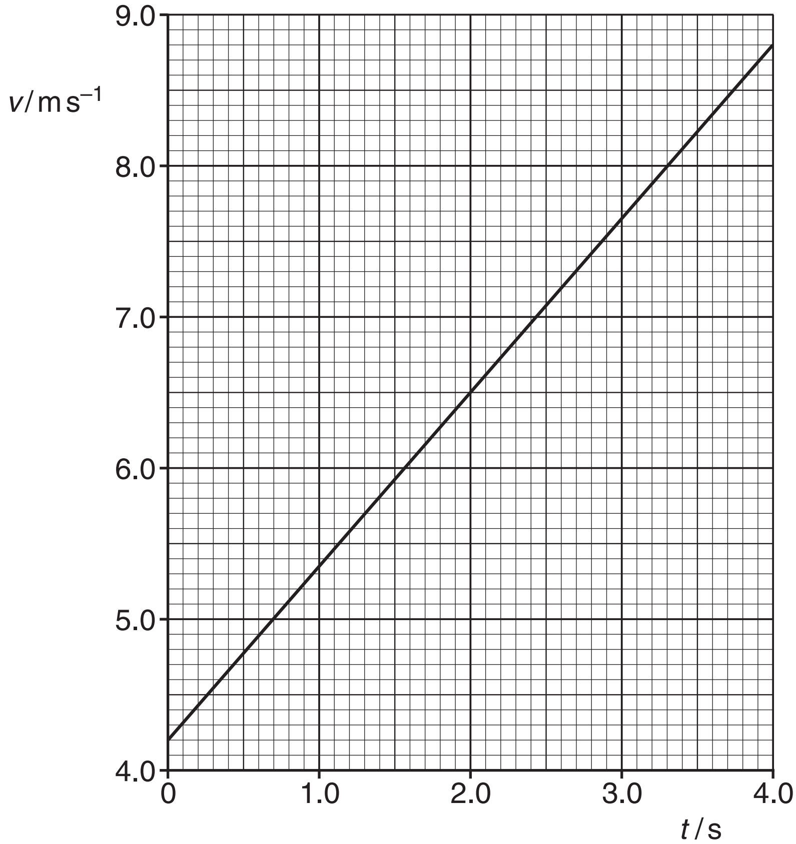


Fig. 3.1

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 $t = 4.0\,s$. Object A continues at constant velocity before colliding with an object B, as illustrated in Fig. 3.2.

Fig. 3.2

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]

4 **(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. 4.1.

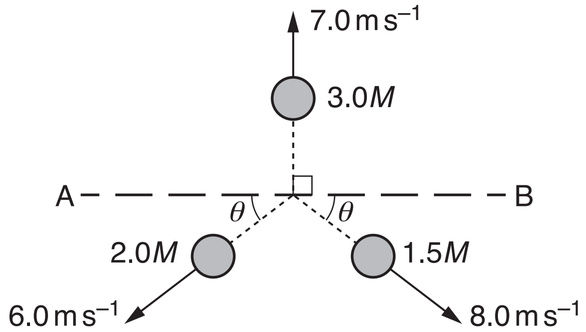


Fig. 4.1

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]

5 **(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. 5.1.

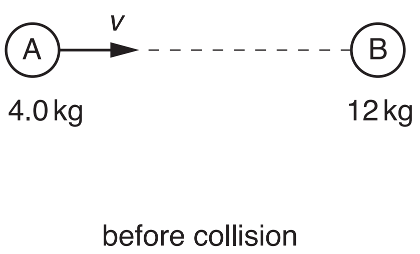


Fig. 5.1

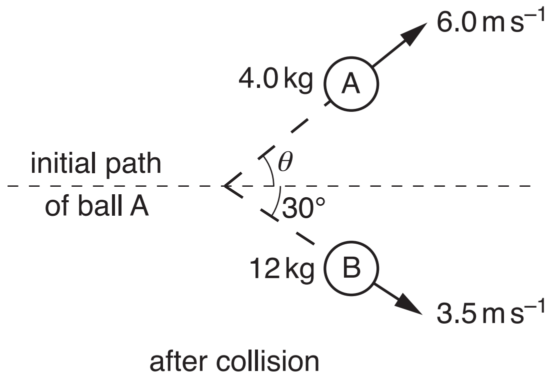


Fig. 5.2 (not to scale)

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. 5.2.
Ball A has velocity $6.0\,\mathrm{m\,s^{-1}}$ at an angle of θ to the direction of its initial path.
Ball B has velocity $3.5\,\mathrm{m\,s^{-1}}$ 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.

θ = ... ° [3]

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

[2]

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

....

....[3]

[Total: 10]

6 A small remote-controlled model aircraft has two propellers, each of diameter 16 cm. Fig. 6.1 is a side view of the aircraft when hovering.

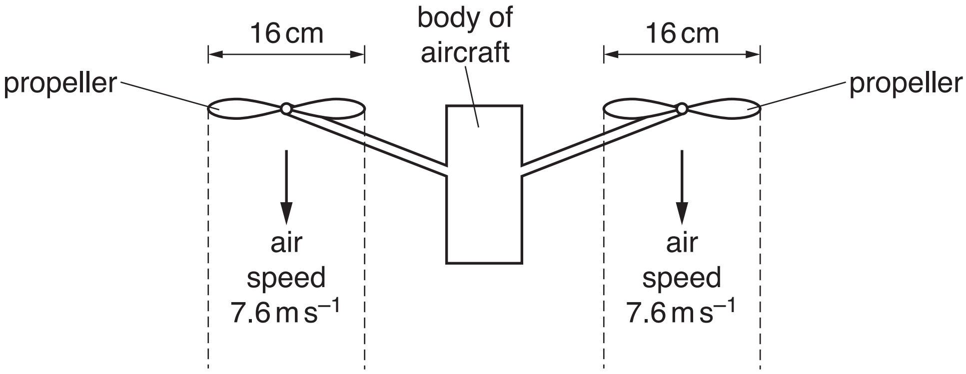


Fig. 6.1

Air is propelled vertically downwards by each propeller so that the aircraft hovers at a fixed position. The density of the air is $1.2\,\text{kg}\,\text{m}^{-3}$. Assume that the air from each propeller moves with a constant speed of $7.6\,\text{m}\,\text{s}^{-1}$ 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 $22\,\text{m}\,\text{s}^{-1}$, it emits sound of frequency 3.0 kHz from an alarm. The speed of the sound in the air is $340\,\text{m}\,\text{s}^{-1}$.

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

frequency = ... Hz [2]

[Total: 11]

7 **(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. 7.1.

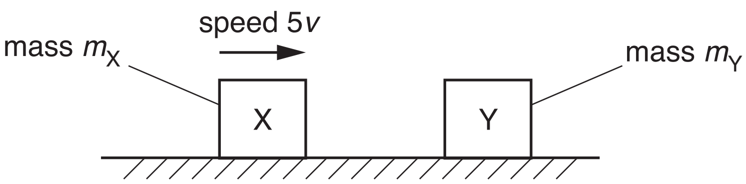


Fig. 7.1

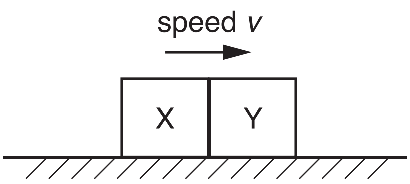


Fig. 7.2

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. 7.2.

(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. 7.3.

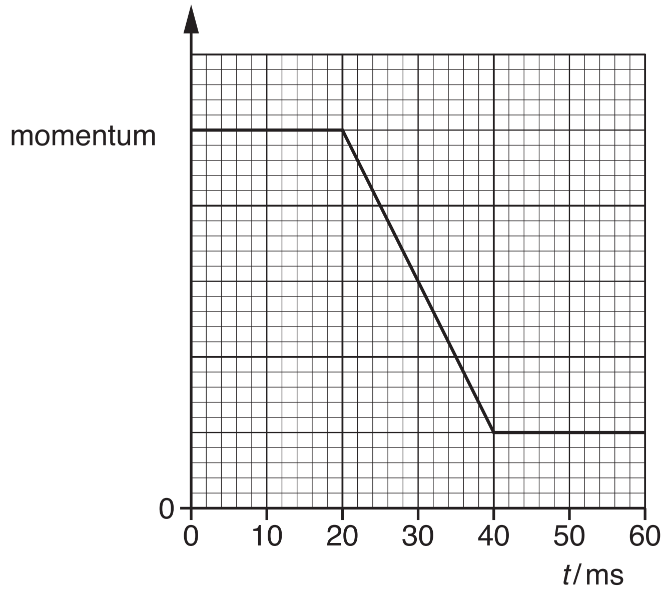


Fig. 7.3

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. 7.3, sketch the variation of the momentum of block Y with time t from $t = 0$ to $t = 60\,\text{ms}$. [3]

[Total: 14]

8 A ball X moves along a horizontal frictionless surface and collides with another ball Y, as illustrated in Fig. 8.1.

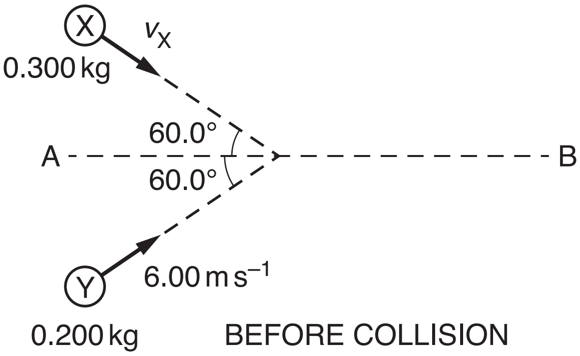


Fig. 8.1 (not to scale)

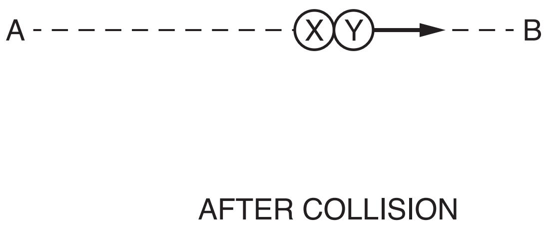


Fig. 8.2 (not to scale)

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. 8.2.

(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]