3. Dynamics

3.3 Linear momentum and its conservation

Paper 1

Question Paper

1 Spheres X and Y form an isolated system. The mass of Y is greater than the mass of X.

Sphere Y is initially stationary.

Sphere X collides elastically with sphere Y.

The speed of sphere X before the collision is u.

Which statement **must** be correct?

A Sphere X rebounds with a speed that is greater than u, and sphere Y moves off with a speed that is less than u.

B Sphere X rebounds with a speed that is less than u, and sphere Y moves off with a speed that is also less than u.

C Sphere X rebounds with speed u, and sphere Y remains stationary.

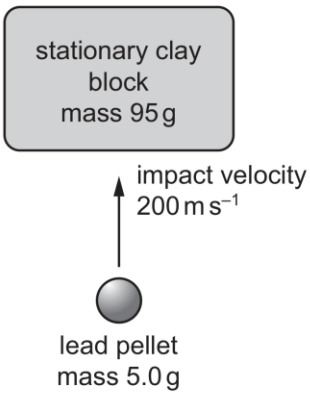
D Sphere X remains stationary, and sphere Y moves off with a speed that is less than u.

2 Two satellites in deep space collide inelastically.

What happens to the total kinetic energy and total momentum?

	total kinetic energy	total momentum
A	conserved	conserved
B	conserved	reduced
C	reduced	conserved
D	reduced	reduced

3 A lead pellet is shot vertically upwards into a clay block that is stationary at the moment of impact, but is able to rise freely after impact.



The mass of the pellet is 5.0 g and the mass of the clay block is 95 g.

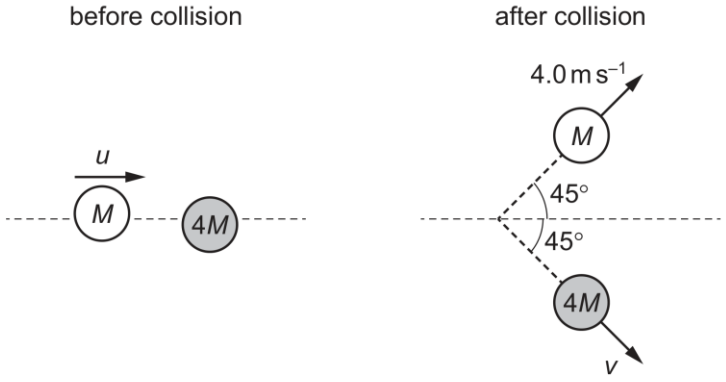
The pellet hits the block with an initial vertical velocity of 200 m s^{-1}. It embeds itself in the block and does not emerge.

How high above its initial position will the block rise?

A 5.1 m **B** 5.6 m **C** 10 m **D** 100 m

4 A disc of mass M is moving across a horizontal frictionless surface with constant velocity u. It collides with a stationary disc of mass $4M$.

The diagram shows the view from above of the motion of the two discs before and after the collision.



What is the initial velocity u of the disc of mass M?

A 1.1 m s^{-1} **B** 1.4 m s^{-1} **C** 3.5 m s^{-1} **D** 5.7 m s^{-1}

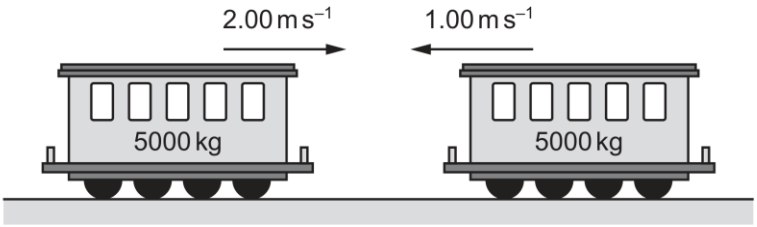
5 A moving object strikes a stationary object. The collision is inelastic. The objects move off together.

Assume that the two objects form an isolated system.

Which row shows the possible values of total momentum and total kinetic energy for the system before and after the collision?

	total momentum before collision / kg m s^{-1}	total momentum after collision / kg m s^{-1}	total kinetic energy before collision / J	total kinetic energy after collision / J
A	6	2	90	30
B	6	6	30	90
C	6	6	90	30
D	6	6	90	90

6 Two train carriages each of mass 5000 kg roll toward one another on a horizontal frictionless track. One is travelling at a speed of 2.00 m s^{-1} and the other at a speed of 1.00 m s^{-1}, as shown.



They collide and join together.

What is the kinetic energy lost during the collision?

A 1250 J **B** 7500 J **C** 11 250 J **D** 12 500 J

7 An object of mass m, moving at speed u along a frictionless horizontal surface, collides head-on with a stationary object of mass $4m$.



before the collision

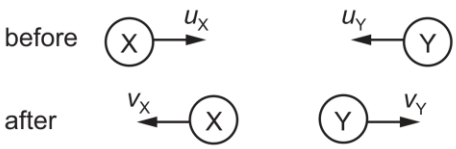
After the collision, the object of mass m rebounds along its initial path with $\frac{1}{4}$ of its kinetic energy before the collision.

What is the speed of the object of mass $4m$ after the collision?

A $\frac{u}{8}$ **B** $\frac{3u}{16}$ **C** $\frac{5u}{16}$ **D** $\frac{3u}{8}$

8 Two balls, X and Y, approach each other along the same straight line and collide. The collision is perfectly elastic.

Their initial speeds are u_X and u_Y respectively. After the collision they move apart with speeds v_X and v_Y respectively. Their directions are shown.



Which equation is correct?

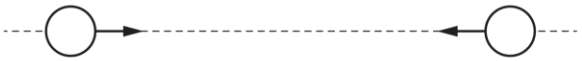
A $u_X + u_Y = v_X + v_Y$

B $u_X + u_Y = v_X - v_Y$

C $u_X - u_Y = v_X + v_Y$

D $u_X - u_Y = v_X - v_Y$

9 Two objects move towards each other along the same straight line.



After colliding, the two objects stick together and are stationary.

Which statement **must** be correct?

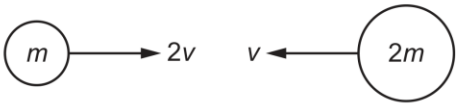
A The total kinetic energy of the two objects does not change during the collision.

B The total momentum of the two objects before the collision is zero.

C The two objects have equal mass.

D The two objects have the same speed before the collision.

10 Two balls, of masses m and $2m$, travelling in a vacuum with initial velocities $2v$ and v respectively, collide with each other head-on, as shown.



After the collision, the ball of mass m rebounds to the left with velocity v.

What is the loss of kinetic energy in the collision?

A $\frac{3}{4}mv^2$ **B** $\frac{3}{2}mv^2$ **C** $\frac{9}{4}mv^2$ **D** $\frac{9}{2}mv^2$

11 What is a statement of the principle of conservation of momentum?

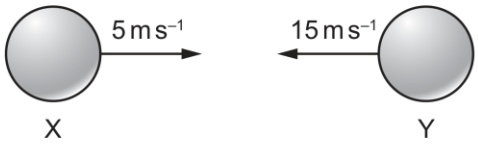
A A force is equal to the rate of change of momentum of the object upon which it acts.

B In a perfectly elastic collision, the relative momentum of the objects before impact is equal to their relative momentum after impact.

C The momentum of an object is the product of the mass of the object and its velocity.

D The total momentum of a system of interacting objects remains constant, providing no resultant external force acts on the system.

12 Two balls X and Y are moving towards each other with speeds of $5\,m\,s^{-1}$ and $15\,m\,s^{-1}$ respectively.



They make a perfectly elastic head-on collision and ball Y moves to the right with a speed of $7\,m\,s^{-1}$.

What is the speed and direction of ball X after the collision?

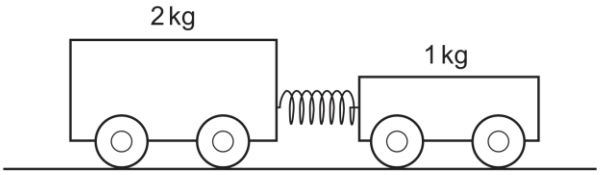
A $3\,m\,s^{-1}$ to the left

B $13\,m\,s^{-1}$ to the left

C $3\,m\,s^{-1}$ to the right

D $13\,m\,s^{-1}$ to the right

13 Two trolleys are held together on a horizontal surface with a compressed spring between them.

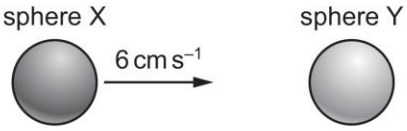


When they are released, the trolleys lose contact with the spring. The trolley of mass 2 kg moves to the left at a final speed of 2 m s^{-1}.

How much elastic potential energy was stored in the spring?

A 4 J **B** 6 J **C** 8 J **D** 12 J

14 Two solid spheres form an isolated system. Sphere X moves with speed 6 cm s^{-1} in a straight line directly towards a stationary sphere Y, as shown.



The spheres have a perfectly elastic collision. After the collision, sphere X moves with speed 2 cm s^{-1} in the same direction as before the collision.

What is the speed of sphere Y?

A 2 cm s^{-1} **B** 4 cm s^{-1} **C** 6 cm s^{-1} **D** 8 cm s^{-1}

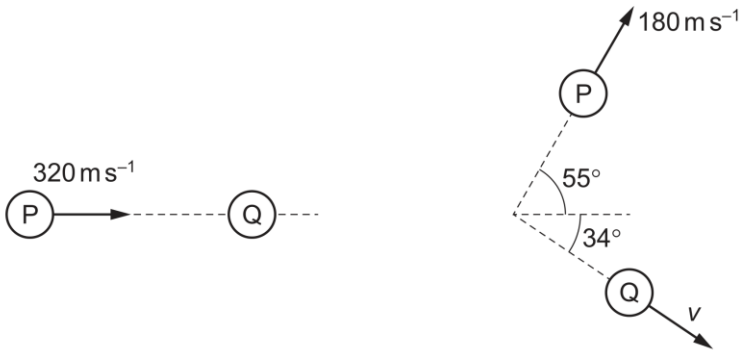
15 Which quantities are conserved in an inelastic collision?

	kinetic energy	total energy	linear momentum
A	conserved	not conserved	conserved
B	conserved	not conserved	not conserved
C	not conserved	conserved	conserved
D	not conserved	conserved	not conserved

16 A nitrogen molecule P travelling at a speed of $320\,m\,s^{-1}$ in a vacuum collides with a stationary nitrogen molecule Q.

After the collision, P travels at a velocity of $180\,m\,s^{-1}$ at an angle of 55° to its original path.

Q travels in a direction at an angle of 34° to the initial path of P.



before collision after collision

Assume that there are no external forces acting on the molecules.

What is the magnitude v of the velocity of Q after the collision?

A $120\,m\,s^{-1}$ **B** $140\,m\,s^{-1}$ **C** $180\,m\,s^{-1}$ **D** $260\,m\,s^{-1}$

17 The table shows four different collisions between two blocks, each of mass 0.50 kg.

Which collision is perfectly elastic?

	before collision	after collision
A	$4.0\,m\,s^{-1} \rightarrow$ 0.50 kg $0.0\,m\,s^{-1}$ 0.50 kg	$2.0\,m\,s^{-1} \rightarrow$ 0.50 kg + 0.50 kg
B	$2.0\,m\,s^{-1} \rightarrow$ 0.50 kg $\leftarrow 2.0\,m\,s^{-1}$ 0.50 kg	$0.0\,m\,s^{-1}$ 0.50 kg + 0.50 kg
C	$2.0\,m\,s^{-1} \rightarrow$ 0.50 kg $\leftarrow 1.0\,m\,s^{-1}$ 0.50 kg	$\leftarrow 2.0\,m\,s^{-1}$ 0.50 kg $3.0\,m\,s^{-1} \rightarrow$ 0.50 kg
D	$4.0\,m\,s^{-1} \rightarrow$ 0.50 kg $1.0\,m\,s^{-1} \rightarrow$ 0.50 kg	$1.0\,m\,s^{-1} \rightarrow$ 0.50 kg $4.0\,m\,s^{-1} \rightarrow$ 0.50 kg

18 A mass m_1 travelling with speed u_1 collides with a mass m_2 travelling with speed u_2 in the same direction. After the collision, mass m_1 has speed v_1 and mass m_2 has speed v_2 in the same direction. The collision is perfectly elastic.



before the collision after the collision

Which equation is **not** correct?

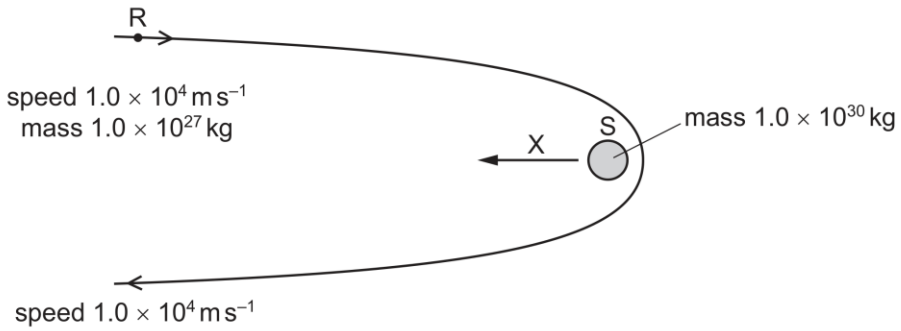
A $m_1u_1^2 - m_1v_1^2 = m_2v_2^2 - m_2u_2^2$

B $v_2 + u_2 = v_1 + u_1$

C $m_1(u_1 - v_1) = m_2(v_2 - u_2)$

D $m_1(u_1 - v_1)^2 = m_2(u_2 - v_2)^2$

19 A rock R of mass 1.0×10^{27} kg is a large distance from a star S and is travelling at a speed of 1.0×10^{4} m s^{-1}. The star has mass 1.0×10^{30} kg. The rock travels around the star on the path shown so that it reverses its direction of motion and, when finally again a large distance from the star, has the same speed as initially.



Which statement is correct?

A The change in the momentum of S is in the direction of arrow X.

B The change in the velocity of S is approximately 20 m s^{-1}.

C The magnitude of the change of momentum of R is 10^{3} times greater than the magnitude of the change of momentum of S.

D The momentum of R does not change.

20 The diagram shows the masses and velocities of two trolleys that are about to collide.



After the impact they move off together.

What is the kinetic energy lost in the collision?

A 4 J **B** 6 J **C** 12 J **D** 14 J

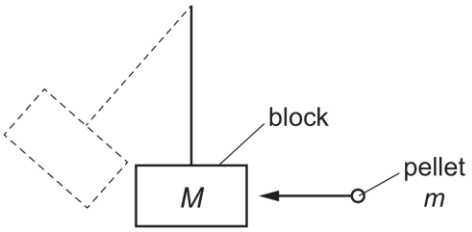
21 Two balls, one of mass $2m$ and one of mass m, collide.

The diagrams show the initial and final velocities of the balls.

Which collision is **not** elastic?

	before collision	after collision
A	$2m$ $4.0\,\text{m s}^{-1}$ → m $1.0\,\text{m s}^{-1}$ →	$2m$ $2.0\,\text{m s}^{-1}$ → m $5.0\,\text{m s}^{-1}$ →
B	$2m$ $6.0\,\text{m s}^{-1}$ → m $3.0\,\text{m s}^{-1}$ →	$2m$ $4.0\,\text{m s}^{-1}$ → m $7.0\,\text{m s}^{-1}$ →
C	$2m$ $8.0\,\text{m s}^{-1}$ → m $2.0\,\text{m s}^{-1}$ →	$2m$ $5.0\,\text{m s}^{-1}$ → m $8.0\,\text{m s}^{-1}$ →
D	$2m$ $10.0\,\text{m s}^{-1}$ → m $4.0\,\text{m s}^{-1}$ →	$2m$ $6.0\,\text{m s}^{-1}$ → m $12.0\,\text{m s}^{-1}$ →

22 The diagram shows a 'ballistic pendulum'.

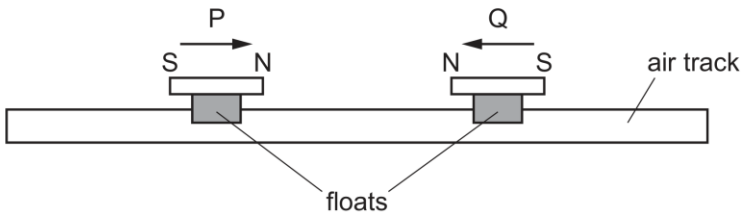


A pellet of mass m travelling at a speed u hits a stationary block of mass M. The pellet becomes embedded in the block and causes the block to move at a speed v immediately after the impact.

When a pellet of mass $2m$, travelling at a speed $2u$, hits a block of mass $2M$, what is the speed of the block immediately after the impact? (Neglect the small increase in the mass of the block as the pellet's mass is added during the collision.)

A v **B** $v\sqrt{2}$ **C** $2v$ **D** $4v$

23 Two bar magnets P and Q are mounted on floats which can slide without friction along an air track.



The two magnets slide towards each other along the air track and interact, without making contact.

The relative speed of approach of the magnets is equal to their relative speed of separation.

Which statement about P and Q must be correct?

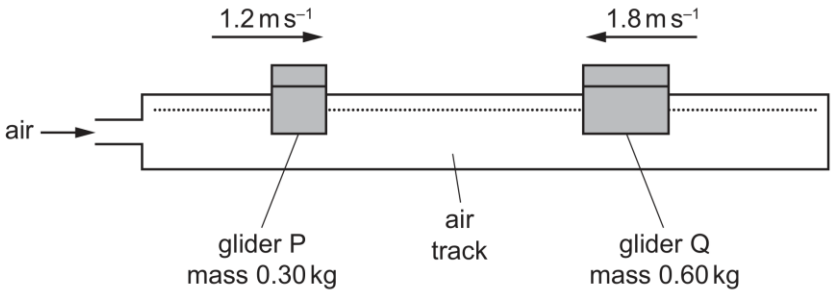
A During the interaction between P and Q some of the total kinetic energy is lost.

B During the interaction between P and Q some of the total momentum is lost.

C The momentum of Q after the interaction is equal to the momentum of P before the interaction.

D The values of (kinetic energy of P + kinetic energy of Q) before and after the interaction are equal.

24 Two gliders are travelling towards each other on a horizontal air track. Glider P has mass 0.30 kg and is moving with a constant speed of $1.2\,m\,s^{-1}$. Glider Q has mass 0.60 kg and is moving with a constant speed of $1.8\,m\,s^{-1}$.

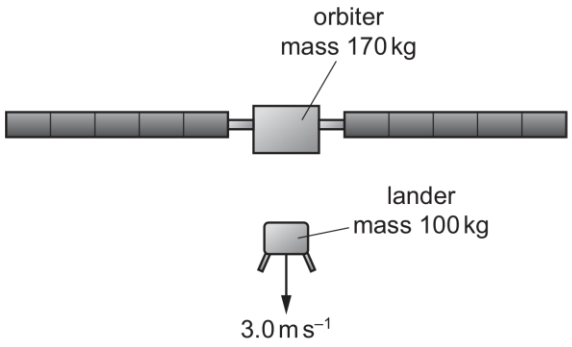


The gliders have a perfectly elastic collision.

What are the speeds of the two gliders after the collision?

	speed of P / $m\,s^{-1}$	speed of Q / $m\,s^{-1}$
A	1.2	0.6
B	2.0	1.4
C	2.8	0.2
D	3.6	0.6

25 The space probe Rosetta was designed to investigate a comet. The probe consisted of an orbiter and a lander. The orbiter had a mass of 170 kg and the lander had a mass of 100 kg. When the two parts separated, the lander was pushed towards the surface of the comet so that its change in velocity towards the comet was $3.0\,m\,s^{-1}$.



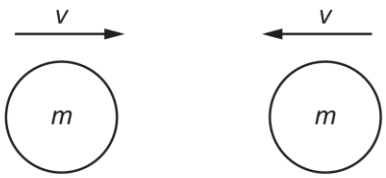
Assume that the orbiter and lander were an isolated system.

The orbiter moved away from the comet during the separation.

What was the change in the speed of the orbiter?

A $1.8\,m\,s^{-1}$ **B** $2.3\,m\,s^{-1}$ **C** $3.0\,m\,s^{-1}$ **D** $5.1\,m\,s^{-1}$

26 Two similar spheres, each of mass *m* and travelling with speed *v*, are moving towards each other.



The spheres have a head-on elastic collision.

Which statement is correct?

A The spheres stick together on impact.

B The total kinetic energy after impact is mv^2.

C The total kinetic energy before impact is zero.

D The total momentum before impact is $2mv$.

27 An elastic collision occurs between two bodies X and Y. The mass of body X is m and the mass of body Y is $4m$. Body X travels at speed v before the collision and speed $\frac{3v}{5}$ in the opposite direction after the collision. Body Y is stationary before the collision.



What is the kinetic energy of body Y after the collision?

A $\frac{8}{10}mv^2$ **B** $\frac{34}{50}mv^2$ **C** $\frac{16}{50}mv^2$ **D** $\frac{1}{5}mv^2$

28 Two bodies travelling along the same straight line collide in a perfectly elastic collision.

Which statement **must** be correct?

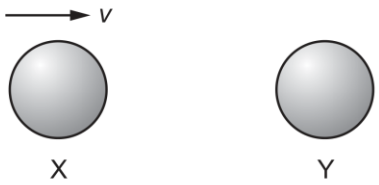
A The initial speed of one body will be the same as the final speed of the other body.

B The relative speed of approach between the two bodies equals their relative speed of separation.

C The total momentum is conserved but the total kinetic energy will be reduced.

D One of the bodies will be stationary at one instant.

29 The diagram shows two identical spheres X and Y.



Initially, X moves with speed v directly towards Y. Y is stationary. The spheres collide elastically.

What happens?

	X	Y
A	moves with speed $\frac{1}{2}v$ to the right	moves with speed $\frac{1}{2}v$ to the right
B	moves with speed v to the left	remains stationary
C	moves with speed $\frac{1}{2}v$ to the left	moves with speed $\frac{1}{2}v$ to the right
D	stops	moves with speed v to the right