Past-paper walk-through

Linear momentum and its conservation ▪ 3.3

eXercise

Questions in this set

- 9702/11 N25 Q9 ▪ 1 mark
- 9702/11 N25 Q10 ▪ 1 mark
- 9702/12 N25 Q9 ▪ 1 mark
- 9702/12 N25 Q10 ▪ 1 mark
- 9702/12 N25 Q12 ▪ 1 mark
- 9702/14 N25 Q10 ▪ 1 mark
- 9702/14 N25 Q11 ▪ 1 mark
- 9702/11 J25 Q9 ▪ 1 mark
- 9702/12 J25 Q10 ▪ 1 mark
- 9702/14 J25 Q9 ▪ 1 mark

Questions in this set

- 9702/23 J25 Q4 ▪ 6 marks
- 9702/22 M25 Q7 ▪ 7 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 9

9702/11 N25 ▪ Q9 ▪ 1 mark

In which situation is total linear momentum **always** conserved? **[1]**

A in all collisions between two objects

B in collisions between two objects moving at equal and opposite velocity

C in collisions between two objects that form an isolated system

D in collisions between two objects with the same mass

Solution 9

- **A** in all collisions between two objects
- **B** in collisions between two objects moving at equal and opposite velocity
- **C** in collisions between two objects that form an isolated system ✓
- **D** in collisions between two objects with the same mass

Why

- Momentum is conserved whenever no external resultant force acts – that is what isolated means.
- It holds for elastic and inelastic collisions alike, so the type of collision is irrelevant.
- A is too broad: friction or another external force can act during a collision.

Question 10

9702/11 N25 ▪ Q10 ▪ 1 mark

An object of mass m moving with velocity $9.0\ \mathrm{m\,s^{-1}}$ has a head-on elastic collision with a stationary object of mass $2m$.

After the collision, both objects are moving. No external forces act on the system.

What is the velocity of the object of mass $2m$ after the collision? **[1]**

A $-6.0\ \mathrm{m\,s^{-1}}$

B $-3.0\ \mathrm{m\,s^{-1}}$

C $4.5\ \mathrm{m\,s^{-1}}$

D $6.0\ \mathrm{m\,s^{-1}}$

Solution 10

A -6.0 m s^{-1}

B -3.0 m s^{-1}

C 4.5 m s^{-1}

D 6.0 m s^{-1} ✓

Why

- For an elastic collision the relative speed of separation equals the approach speed, 9.0 m s^{-1}.
- Momentum gives $m(9.0) = mv_1' + 2mv_2'$.
- Solving the pair gives $v_2' = 6.0$ m s^{-1}, with the first object rebounding at -3.0 m s^{-1}.

Question 9

9702/12 N25 ▪ Q9 ▪ 1 mark

What is a statement of the principle of conservation of momentum? **[1]**

A In an elastic collision, momentum is constant.

B Momentum is the product of mass and velocity.

C The force acting on a body is proportional to its rate of change of momentum.

D The momentum of an isolated system is constant.

Solution 9

A In an elastic collision, momentum is constant.

B Momentum is the product of mass and velocity.

C The force acting on a body is proportional to its rate of change of momentum.

D The momentum of an isolated system is constant. ✓

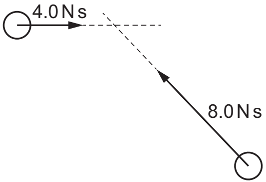
Why

- The principle states that the total momentum of an isolated system does not change.
- A is too narrow – momentum is conserved in inelastic collisions too.
- B is the definition of momentum and C is Newton's second law.

Question 10

9702/12 N25 ▪ Q10 ▪ 1 mark

10 The diagram shows the view from above of two balls moving along a horizontal frictionless surface before they collide. The momentum of each ball is also shown.



The balls stick together during the collision.

Which vector diagram represents the combined momentum of the balls after the collision?

A **B** **C** **D**

Question 10

Solution 10

Answer: **B**

Why

- Resolve: the 4.0 N s is $(+4.0, 0)$ and the 8.0 N s at 45° up-left is $(-5.7, +5.7)$.
- Adding gives $(-1.7, +5.7)$ N s – about 5.9 N s, mostly upwards and slightly to the left.
- Momentum is conserved, so the combined momentum after the collision is that same vector.

Question 12

9702/12 N25 ▪ Q12 ▪ 1 mark

Two different blocks, P and Q, slide towards each other on a horizontal frictionless surface. The blocks have an elastic collision.

The diagram shows the velocities of the two blocks immediately after the collision.

Which row gives possible velocities of the two blocks immediately before the collision?

	velocity of P	velocity of Q
A	10 cm s^{-1} to the right	60 cm s^{-1} to the left
B	50 cm s^{-1} to the right	zero
C	20 cm s^{-1} to the left	70 cm s^{-1} to the right
D	60 cm s^{-1} to the right	30 cm s^{-1} to the left

Question 12

[1]

- **A** velocity of P: 10 cm s^{-1} to the right; velocity of Q: 60 cm s^{-1} to the left
- **B** velocity of P: 50 cm s^{-1} to the right; velocity of Q: zero
- **C** velocity of P: 20 cm s^{-1} to the left; velocity of Q: 70 cm s^{-1} to the right
- **D** velocity of P: 60 cm s^{-1} to the right; velocity of Q: 30 cm s^{-1} to the left

Question 12

	velocity of P	velocity of Q
A	$10\,\text{cm}\,\text{s}^{-1}$ to the right	$60\,\text{cm}\,\text{s}^{-1}$ to the left
B	$50\,\text{cm}\,\text{s}^{-1}$ to the right	zero
C	$20\,\text{cm}\,\text{s}^{-1}$ to the left	$70\,\text{cm}\,\text{s}^{-1}$ to the right
D	$60\,\text{cm}\,\text{s}^{-1}$ to the right	$30\,\text{cm}\,\text{s}^{-1}$ to the left

Solution 12

- **A** velocity of P: 10 cm s^{-1} to the right; velocity of Q: 60 cm s^{-1} to the left
- **B** velocity of P: 50 cm s^{-1} to the right; velocity of Q: zero
- **C** velocity of P: 20 cm s^{-1} to the left; velocity of Q: 70 cm s^{-1} to the right
- **D** velocity of P: 60 cm s^{-1} to the right; velocity of Q: 30 cm s^{-1} to the left ✓

Why

- In an elastic collision the relative speed of separation equals the relative speed of approach.
- After the collision the blocks separate at $70 + 20 = 90$ cm s^{-1}.
- Only D approaches at $60 + 30 = 90$ cm s^{-1}; in C the blocks are already moving apart.

Question 10

9702/14 N25 ▪ Q10 ▪ 1 mark

An object of mass 2.0 kg is travelling at a speed of 3.0 m s^{-1} on a horizontal frictionless surface. This object collides head-on with a stationary object of mass 1.0 kg. The two objects stick together on impact.

How much kinetic energy is lost on impact? **[1]**

A zero

B 2.0 J

C 2.4 J

D 3.0 J

Solution 10

A zero

B 2.0 J

C 2.4 J

D 3.0 J ✓

Why

- They stick together, so momentum gives $v = (2.0 \times 3.0)/3.0 = 2.0$ m s^{-1}.
- Before: $\frac{1}{2}(2.0)(3.0)^2 = 9.0$ J. After: $\frac{1}{2}(3.0)(2.0)^2 = 6.0$ J.
- The kinetic energy lost is $9.0 - 6.0 = 3.0$ J.

Question 11

9702/14 N25 ▪ Q11 ▪ 1 mark

A moving object X collides with a stationary object Y.
The objects separate after the collision.
The collision is perfectly elastic and there are no external forces acting.
Which word equation is **not** correct? **[1]**

A during the collision, (force acting on object X) + (force acting on object Y) = zero

B (relative speed of approach of X and Y) + (relative speed of separation of X and Y) = zero

C (total kinetic energy before collision) = (total kinetic energy after collision)

D (total momentum before collision) = (total momentum after collision)

Solution 11

- **A** during the collision, (force acting on object X) + (force acting on object Y) = zero
- **B** (relative speed of approach of X and Y) + (relative speed of separation of X and Y) = zero ✓
- **C** (total kinetic energy before collision) = (total kinetic energy after collision)
- **D** (total momentum before collision) = (total momentum after collision)

Why

- For an elastic collision the relative speed of approach *equals* the relative speed of separation.
- Written as speeds both are positive, so their sum cannot be zero – their difference is.
- A, C and D are all correct statements about the collision.

Question 9

9702/11 J25 ▪ Q9 ▪ 1 mark

What is always conserved in elastic collisions? **[1]**

A total kinetic energy: yes, total velocity: yes

B total kinetic energy: yes, total velocity: no

C total kinetic energy: no, total velocity: yes

D total kinetic energy: no, total velocity: no

Question 9

	total kinetic energy	total velocity
A	yes	yes
B	yes	no
C	no	yes
D	no	no

Solution 9

- **A** total kinetic energy: yes, total velocity: yes
- **B** total kinetic energy: yes, total velocity: no ✓
- **C** total kinetic energy: no, total velocity: yes
- **D** total kinetic energy: no, total velocity: no

Why

- An elastic collision is defined by the total kinetic energy being conserved.
- "Total velocity" is not a conserved quantity at all – momentum is.
- So the row reads yes for kinetic energy and no for velocity.

Question 10

9702/12 J25 ▪ Q10 ▪ 1 mark

Which statement does **not** describe an elastic collision between two objects? **[1]**

A The relative speed of approach of the two objects equals the relative speed of separation.

B The total kinetic energy of the objects is conserved.

C The total kinetic energy of the objects is reduced.

D The total linear momentum of the objects is conserved.

Solution 10

A The relative speed of approach of the two objects equals the relative speed of separation.

B The total kinetic energy of the objects is conserved.

C The total kinetic energy of the objects is reduced. ✓

D The total linear momentum of the objects is conserved.

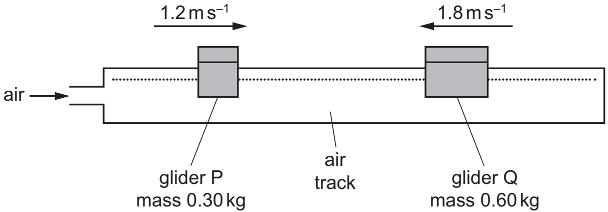
Why

- In an elastic collision the total kinetic energy is unchanged, not reduced.
- A reduction in kinetic energy is exactly what makes a collision inelastic.
- A, B and D are all true of an elastic collision.

Question 9

9702/14 J25 ▪ Q9 ▪ 1 mark

9 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 $1.2\,\mathrm{m\,s^{-1}}$. Glider Q has mass 0.60 kg and is moving with a constant speed of $1.8\,\mathrm{m\,s^{-1}}$.



The gliders have a perfectly elastic collision.

Question 9

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

Solution 9

Answer: **C**

Why

- Momentum: $0.30(1.2) - 0.60(1.8) = -0.72$ kg m s^{-1}, taking P's direction as positive.
- Elastic, so the relative speed of separation equals the approach speed, $1.2 + 1.8 = 3.0$ m s^{-1}.
- Solving the two together gives P at 2.8 m s^{-1} and Q at 0.2 m s^{-1}.

Question 4

9702/23 J25 ▪ Q4 ▪ 6 marks

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 m s—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 m s—1 in the same direction as A, as shown in Fig. 4.1.

object A, mass 4.0 kg object B, mass 2.0 kg surface 6.0 m s–1 3.0 m s–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 = m s—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.

Question 4

percentage = % [2]

, ,

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

(b)(i) Object A of mass 4.0 kg travels at 6.0 m s ^{1} to the right on a horizontal frictionless surface, towards object B of mass 2.0 kg moving at 3.0 m s ^{1} in the same direction. The two objects collide and move off together. Calculate their common velocity. **[2]**

(b)(ii) Calculate the percentage of the total kinetic energy that is transferred to other forms during the collision. **[2]**

Solution 4

(a)

Mark scheme

- sum / total momentum (of a system of bodies) is constant
- or
- sum / total momentum before = sum / total momentum after
- for an isolated system / no (resultant) external force

Solution 4

(b)(i) Worked steps

Momentum is conserved, and after the collision the two move as one 6.0 kg object.

- Momentum before $= (4.0 \times 6.0) + (2.0 \times 3.0) = 24 + 6 = 30$ kg m s^{-1}
- Momentum after $= (4.0 + 2.0)v = 6.0v$
- $v = \dfrac{30}{6.0} = 5.0$ m s^{-1}, to the right.

Solution 4

Check it is sensible: 5.0 lies between 3.0 and 6.0, which it must.

Mark scheme

- p = mv or 4.0×6.0 or 2.0×3.0
- $(4.0 \times 6.0) + (2.0 \times 3.0) = 6.0 \times v$
- so v = 5.0 m s—1
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- May/June 2025

Solution 4

(b)(ii) Worked steps

Kinetic energy is **not** conserved here, so work it out before and after and compare.

- Before: $\frac{1}{2}(4.0)(6.0)^2 + \frac{1}{2}(2.0)(3.0)^2 = 72 + 9 = 81$ J
- After: $\frac{1}{2}(6.0)(5.0)^2 = 75$ J
- Lost $= 81 - 75 = 6$ J
- Percentage $= \dfrac{6}{81} \times 100 = 7\%$

The collision is inelastic — as any collision in which the objects stick together must be.

Mark scheme

- KE before

Solution 4

- $= (0.5 \times 4.0 \times 6.0^2) + (0.5 \times 2.0 \times 3.0^2)$
- $= 81$ J
- KE after
- $= (0.5 \times 6.0 \times 5.0^2)$
- $= 75$ J
- (C1)
- percentage transferred
- $= [(81 - 75) / 81] \times 100$
- $= 7\%$

Question 7

9702/22 M25 ▪ Q7 ▪ 7 marks

7 An isolated stationary nucleus Q decays into nucleus R and an α-particle. The α-particle has speed 1.5 $\times$ 107 m s–1.

(a) Complete the equation for this decay 88 Q

222 R + 4 2 α

[1]

(b) By considering momentum, calculate the speed of nucleus R after the decay.

speed = m s–1 [3]

(c) State three quantities that are conserved during the decay. 1 2 3 [3]

, ,

(a) Complete the equation for this decay: ${}_{88}\mathrm{Q} \rightarrow {}^{222}\mathrm{R} + {}^{4}_{2}\alpha$ **[1]**

(b) By considering momentum, calculate the speed of nucleus R after the decay. **[3]**

(c) State three quantities that are conserved during the decay. **[3]**

Solution 7

(a)

Worked steps

Both nucleon number and proton number balance across the arrow.

- Nucleon number: $A_{\mathsf{Q}} = 222 + 4 = 226$
- Proton number: $88 = Z_{\mathsf{R}} + 2$, so $Z_{\mathsf{R}} = 86$
- The equation is ${}^{226}_{88}\mathsf{Q} \rightarrow {}^{222}_{86}\,\mathsf{R} + {}^{4}_{2}\,\alpha$

Mark scheme

- nucleon number of Q = 226 and proton number of R = 86

Solution 7

(b) Worked steps

Q is **stationary**, so the total momentum before is zero — the two products must carry equal and opposite momentum.

- $m_R v_R = m_\alpha v_\alpha$
- Masses in atomic mass units cancel their unit: $222 v_R = 4 \times 1.5 \times 10^7$
- $v_R = \dfrac{6.0 \times 10^7}{222}$
- $v_R = 2.7 \times 10^5$ m s^{-1}, in the opposite direction to the α-particle.

Solution 7

You never need the mass in kilograms: only the **ratio** of the masses matters, which is why nucleon numbers do the job.

Mark scheme

- 4(u) $\times$ 1.5 $\times$ 107 or 222(u) $\times$ v
- v $=$ 4(u) $\times$ 1.5 $\times$ 107 / 222(u)
- $=$ 2.7 $\times$ 105 m s–1
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- February/March 2025

Solution 7

(c) Mark scheme

- Any three from:
- ▪
- momentum
- ▪
- charge
- ▪
- nucleon number
- ▪

Solution 7

- neutron number
- ■
- proton number