A LEVEL MATHS 9709 · PAPER 4 MECHANICS · 4.3 · ~4 MIN READ

Momentum

Momentum as mass × velocity, the principle of conservation of momentum for direct collisions in one dimension, particles that coalesce, and deciding whether further collisions happen.

Momentum | Conservation of momentum | Direct collisions | Coalescing particles | Signs & directions | Loss of kinetic energy | Further collisions

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Paper tag = **where it is examined** FORMULA LIST (MF19) given in the exam M1 A1 B1 how marks are awarded highlight = comes up again and again Test yourself at the end

IN 30 SECONDS

- **Momentum = mv,** in N s or kg m s^{-1}. It is a vector, so direction matters: pick a positive direction.
- **Conservation:** in a collision, total momentum before = total momentum after (no external forces along the line of motion).
- **Coalescing** particles stick together and move with one common velocity.
- **Further collisions** happen if a particle behind is moving faster (in the same direction) than the one in front.

BY THE END YOU CAN

- Use momentum as mass × velocity, taking account of direction.
- Use conservation of momentum for direct impacts in one dimension, including coalescing particles.
- Decide whether further collisions take place.

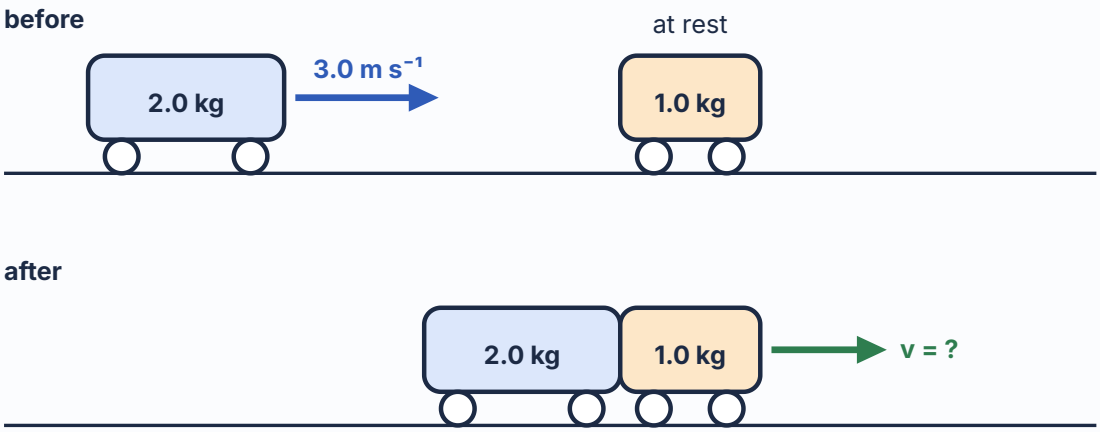
1 Conservation of momentum

Before = after

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

velocities with signs; one positive direction for all

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p before = p after: 2.0 × 3.0 = 3.0v, so v = 2.0 m s⁻¹

Before and after: the total momentum is unchanged, even though kinetic energy usually isn't.

- **Draw before-and-after diagrams** with arrows and masses. Mark unknown velocities in the positive direction; a negative answer means it moves the other way.

WORKED EXAMPLE

A (3 kg) moves at 4 m s⁻¹ towards B (2 kg), which moves at 1 m s⁻¹ towards A. They coalesce. Find their common velocity.

1. positive in A's direction: 3 × 4 + 2 × (−1) = 5v M1 A1
2. **v = 2 m s⁻¹ in A's original direction** A1

WORKED EXAMPLE

P (0.5 kg) moving at 6 m s⁻¹ hits Q (0.3 kg) at rest. After the collision P moves at 2 m s⁻¹ in the same direction. Find Q's speed and the loss of kinetic energy.

1. 0.5 × 6 = 0.5 × 2 + 0.3v ⇒ **v = 20/3 ≈ 6.67 m s⁻¹** M1 A1
2. KE before = ½ × 0.5 × 36 = 9 J; after = 1 + ½ × 0.3 × (20/3)² = 7.67 J M1
3. **loss = 1.33 J** A1

COMMON MISTAKE

Signs dropped: a particle moving left must enter as −u. The 2024 Paper 4 report: most errors in momentum were sign errors.

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2 Further collisions

Chains of impacts

- **Compare velocities after each impact.** If the one behind moves faster in the same direction, they collide again.

WORKED EXAMPLE

P (2 kg) moving at 5 m s^{-1} hits Q (1 kg) at rest; afterwards P moves at 2 m s^{-1} in the same direction. Q then hits R (3 kg) at rest, and Q and R coalesce. Will P collide with the combined particle?

1. first impact: $10 = 4 + v_Q \Rightarrow v_Q = 6$ m s^{-1} M1 A1
2. second impact: $1 \times 6 = 4v \Rightarrow v = 1.5$ m s^{-1} M1 A1
3. **P moves at 2 > 1.5 in the same direction, so yes, P catches up and collides again** A1

COMMON MISTAKE

Assuming kinetic energy is conserved. Momentum is conserved in every collision; kinetic energy usually isn't.

LINKING QUESTION

Changes in kinetic energy link to Energy, work and power; momentum, impulse and elastic collisions in Physics are in Dynamics.

Test yourself — cover the answers first

QUICK CHECK

1. Find the momentum of a 0.2 kg ball moving at 15 m s^{-1}.
2. Two particles coalesce. How many velocities are there after?
3. A 2 kg particle at 3 m s^{-1} hits a 1 kg particle at rest and they coalesce. Find v.
4. Is kinetic energy conserved when particles coalesce?
5. A velocity comes out negative. What does it mean?

EXAM-STYLE

6. A truck of mass 4000 kg moving at 3 m s^{-1} couples to a stationary truck of mass m kg; they move off at 2 m s^{-1}. Find m.
7. A (4 kg, 5 m s^{-1}) and B (2 kg, −4 m s^{-1}) collide; A's velocity after is −1 m s^{-1}. Find B's velocity.
8. For the collision above, find the loss of kinetic energy.

Show answers

1. 3 N s
2. one common velocity
3. 2 m s^{-1}
4. no, some is lost
5. it moves in the opposite direction to the one chosen as positive
6. $12000 = 2(4000 + m) \Rightarrow m = 2000$
7. $20 - 8 = -4 + 2v \Rightarrow v = 8$ m s^{-1}
8. before $50 + 16 = 66$ J; after $2 + 64 = 66$ J; no loss (perfectly elastic)

Stuck on a question?

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