A-LEVEL PHYSICS • EXERCISE SHEET

3.3 Linear momentum and its conservation

Name: ______________ Class: __________ Date: ____________ **Total: 14 marks**

Objective

Build the skills to answer exam questions on **conservation of momentum** 动量守恒—collisions, explosions, and elastic vs inelastic interactions.

You must be able to:

- state and apply **conservation of momentum** (using signed velocities)
- distinguish **elastic** and **inelastic** collisions
- use the elastic test: relative speed of **approach** = relative speed of **separation**

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

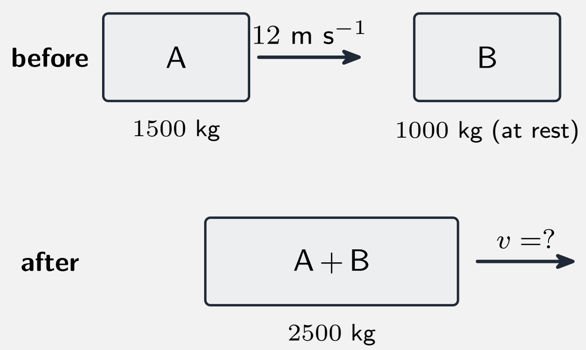
■ The principle

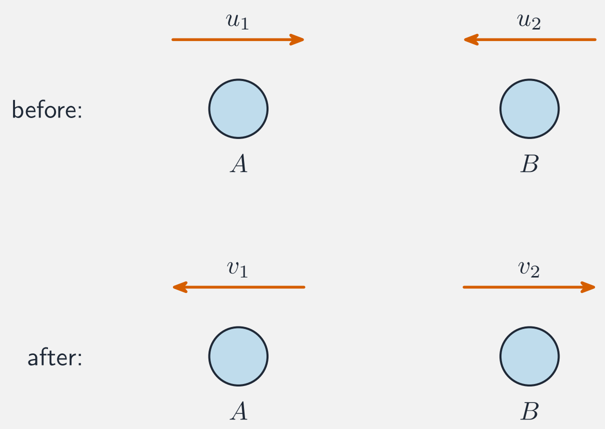
With **no resultant external force**, total momentum is **constant**. Always write momenta with **signs** (positive in one direction).

Explosion/recoil. A 2.0 kg and a 3.0 kg trolley spring apart from rest. Total momentum stays zero:

$$0 = (2.0)(6.0) + (3.0)(-v) \Rightarrow v = 4.0 \text{ m s}^{-1} \text{ (opposite way).}$$

■ Inelastic collision (objects stick)





Momentum is conserved in a head-on collision

Momentum conserved, $v_1 = v_2 = v$:

$$1500(12) + 1000(0) = (2500)\, v \Rightarrow v = \frac{18\,000}{2500} = 7.2 \text{ m s}^{-1}.$$

Elastic vs inelastic

- **Every** collision conserves **momentum**.
- An **elastic** collision **also** conserves **kinetic energy**; test: $u_1 - u_2 = -(v_1 - v_2)$ (relative speed of approach = of separation).
- An **inelastic** collision loses KE (to heat/sound/deformation); if they stick, it is perfectly inelastic.

2 Practice

Now apply the methods above.

2.1 State the **principle of conservation of momentum**. [1]

2.2 State what is conserved in (a) an **elastic** and (b) an **inelastic** collision. [2]

2.3 Two trolleys, 2.0 kg and 3.0 kg, are pushed apart from rest by a spring. The 2.0 kg trolley moves off at 6.0 m s^{-1}. Find the speed of the 3.0 kg trolley. [2]

2.4 State the test (using relative speeds) for an **elastic** collision. [1]

3 Exam-style questions

3.1 In an **inelastic** collision, which quantity is conserved? [1]

- **A** kinetic energy only
- **B** momentum only
- **C** both momentum and kinetic energy
- **D** neither

3.2 A 1500 kg car moving at 12 m s^{-1} hits a stationary 1000 kg car and they lock together. Calculate their **common velocity** just after the collision. [3]

3.3 A 0.50 kg ball moving at 4.0 m s^{-1} collides **elastically** and head-on with a stationary 0.50 kg ball. State the velocity of **each** ball after the collision. [2]

3.4 Explain why the **kinetic energy** can decrease in a collision while the **momentum** does not. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **3.3 Linear momentum and its conservation** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/23 J25 —Q4 (conservation of momentum)
- 9702/11 N25 —Q9 (elastic and inelastic collisions)
- 9702/22 M25 —Q7 (collision calculation)
- 9702/12 N25 —Q10 (momentum and collisions)

Solutions

2.1 With **no resultant external force**, the **total momentum** of a system stays **constant**.

2.2 (a) Elastic —**momentum and kinetic energy**; (b) inelastic —**momentum only** (KE decreases).

2.3 $0 = (2.0)(6.0) + (3.0)(-v) \Rightarrow v = 12/3.0 = 4.0\ \mathrm{m\ s^{-1}}$.

2.4 The **relative speed of approach** equals the **relative speed of separation**.

3.1 **B** —momentum only.

3.2 $1500(12) + 1000(0) = (1500 + 1000)v$; $18\,000 = 2500v$; $v = 7.2\ \mathrm{m\ s^{-1}}$.

3.3 Equal masses, elastic, target at rest: the first ball **stops** ($0\ \mathrm{m\ s^{-1}}$) and the second moves off at $4.0\ \mathrm{m\ s^{-1}}$.

3.4 In a collision the equal-and-opposite forces conserve total momentum; but kinetic energy can be transferred to **thermal/sound/deformation** energy, so total KE can decrease.