

4.3 Conservation of Linear Momentum

Name: _____ Class: _____ Date: _____

Total: 15 marks

Objective

Build the skills to answer exam questions on **conservation of linear momentum**.

You must be able to:

- state that total **momentum** 动量 is conserved when no net external force acts
- apply $p_{\text{before}} = p_{\text{after}}$ to collisions and explosions
- solve for an unknown velocity after an interaction
- use signs for direction in one dimension

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.

■ Total momentum is conserved

If no net external force acts, the total momentum before equals the total after:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2.$$

■ A collision

A 2 kg cart at 3 m s^{-1} hits a stationary 1 kg cart and they stick. Total before = $2(3) + 1(0) = 6$. After, combined mass 3 kg at speed v :

$$6 = 3v \Rightarrow v = 2 \text{ m s}^{-1}.$$

■ An explosion

A stationary object splits. Total momentum stays zero, so the pieces fly apart with equal and opposite momenta.

2 Practice

Now apply the methods above.

2.1 State the condition for total momentum to be conserved. [1]

2.2 A 4 kg cart at 2 m s^{-1} collides and sticks to a stationary 4 kg cart. Find their common speed. [2]

2.3 A stationary object explodes into two pieces. State the total momentum afterward. [1]

2.4 Before a collision the total momentum is 30 kg m s^{-1} . State the total momentum after. [1]

3 Exam-style questions

3.1 Momentum is conserved in a collision provided [1]

- **A** kinetic energy is conserved
 - **B** no net external force acts
 - **C** the objects stick together
 - **D** the objects are identical
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3.2 A 3 kg ball at 4 m s^{-1} strikes a stationary 1 kg ball and they stick. Their speed after is [1]

- **A** 1 m s^{-1}
 - **B** 3 m s^{-1}
 - **C** 4 m s^{-1}
 - **D** 12 m s^{-1}
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3.3 A 60 kg skater at rest throws a 2 kg ball at 10 m s^{-1} .

(a) State the total momentum before the throw. [1]

(b) Find the skater's recoil speed. [2]

3.4 A 2 kg trolley at 5 m s^{-1} collides with a 3 kg trolley at rest; they couple together.

(a) Find the total momentum before. [1]

(b) Find the speed of the coupled trolleys. [2]

4 Go further

You are ready for more on this subtopic:

- work through the interactive **4.3 Conservation of Linear Momentum** lesson on the **Learn** page;
- read the **Linear Momentum** section of the AP Physics C: Mechanics handout on the **Know** page for the full explanation and worked diagrams.

Solutions

2.1 When no net external force acts on the system.

2.2 $4(2) = 8 = 8v \Rightarrow v = 1 \text{ m s}^{-1}$.

2.3 Zero (equal and opposite momenta).

2.4 30 kg m s^{-1} (conserved).

3.1 B —momentum is conserved when no net external force acts.

3.2 B $-3(4) = 12 = 4v \Rightarrow v = 3 \text{ m s}^{-1}$.

3.3 (a) Zero (both at rest). (b) $0 = 60v + 2(10) \Rightarrow v = -0.33 \text{ m s}^{-1}$, i.e. 0.33 m s^{-1} backward.

3.4 (a) $2(5) = 10 \text{ kg m s}^{-1}$. (b) $10 = 5v \Rightarrow v = 2 \text{ m s}^{-1}$.