

Linear Momentum

AP Physics 1 ■ Unit 4

AP Physics 1



Linear Momentum

What we will cover

- 1 Linear momentum
- 2 Impulse and its theorem
- 3 Conservation of momentum
- 4 Elastic and inelastic collisions



1 Linear momentum

Linear momentum

Mass in motion

$$\vec{p} = m\vec{v}$$

A **vector** 矢量 – points the way the velocity does. Total momentum = the **vector sum**.

Momentum grows with **both** mass and speed – a slow truck and a fast bullet can match.

$$2 \text{ kg} \longrightarrow 3 \text{ m/s}$$

$$\text{same } p = 6 \text{ kg m/s}$$

$$6 \text{ kg} \longrightarrow 1 \text{ m/s}$$

2 Impulse

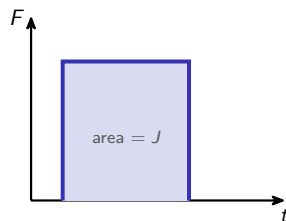
Impulse

Force over time

$$\vec{J} = \vec{F}_{\text{net}} \Delta t = \Delta \vec{p}$$

The **impulse-momentum theorem** 冲量动量定理. Impulse = area under an F - t graph.

For a fixed Δp , a longer **contact time** 接触时间 means a **smaller** force.



Airbag 安全气囊: $10\times$ the time $\Rightarrow \frac{1}{10}$ the force.

3 Conservation

Linear Momentum
↳ Conservation

Conservation of momentum

With **zero net external force**, a system is **isolated** 孤立的 and its total momentum stays constant.

- internal forces cancel (Newton's third law)
- only external forces change total p

Holds for **collisions** 碰撞 and **explosions** 爆炸 alike.



Momentum is conserved in collisions

4 Collisions

Elastic and inelastic collisions

Momentum is conserved in **every** collision; kinetic energy is not.

- **elastic** 弹性碰撞 – KE conserved
- **inelastic** 非弹性碰撞 – some $KE \rightarrow$ heat, sound
- **perfectly inelastic** 完全非弹性碰撞 – they stick

Worked example (stick together)

2 kg at 3 m/s hits a 4 kg at rest:

$$2(3) = (2+4)v_f \Rightarrow v_f = 1 \text{ m/s}$$

KE : $9 \text{ J} \rightarrow 3 \text{ J}$; the missing 6 J became heat.

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Recap

Unit 4 – key takeaways

1 Momentum

$\vec{p} = m\vec{v}$, a vector; add momenta as vectors

2 Impulse

$\vec{J} = \vec{F}\Delta t = \Delta\vec{p}$; longer time, smaller force

3 Conservation

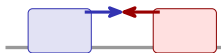
zero net external force keeps total momentum constant

4 Collisions

momentum always conserved; KE only if elastic

Check yourself

- 1 Why does an airbag reduce the force on you?
- 2 Two skaters push off from rest – total momentum?
- 3 In a collision, is momentum always conserved?
- 4 Which collision conserves kinetic energy?



Answers 1. longer contact time 2. zero 3. yes 4. elastic