

Linear Momentum

AP Physics C: Mechanics ■ Unit 4

AP Physics C: Mechanics



Linear Momentum

What we will cover

- 1 Linear momentum
- 2 Impulse and $\vec{F} = d\vec{p}$
- 3 Conservation of momentum
- 4 Elastic and inelastic collisions



1 Momentum

Linear Momentum
└─ Momentum

Linear momentum

Mass in motion

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

A **vector** 矢量. A **system** 粒子系统's total
= $M\vec{v}_{cm}$.

Momentum grows with **both** mass and speed – a heavy slow object can match a light fast one.



Newton's cradle

2 Impulse

Linear Momentum
└─ Impulse

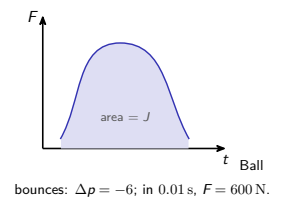
Impulse and Newton's law

Impulse – and the deepest form of $F = ma$

$$\vec{J} = \int \vec{F} dt = \Delta\vec{p}$$

$$\vec{F}_{net} = \frac{d\vec{p}}{dt}$$

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



3 Conservation

Linear Momentum
└ Conservation

Conservation of momentum

With **zero net external force**, a system is **isolated** 孤立系统 and total momentum is conserved. **Internal forces** 内力 cancel in third-law pairs.

Worked example – recoil

Astronaut 60 kg throws a 2 kg wrench at 10 m/s:

$$0 = 2(10) + 60v \Rightarrow v = -0.33 \text{ m/s}$$



4 Collisions

Linear Momentum
└ Collisions

Elastic and inelastic collisions

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

- **elastic** 弹性碰撞 – KE conserved (add it as a 2nd equation)
- **inelastic** 非弹性碰撞 – some KE lost
- **perfectly inelastic** 完全非弹性碰撞 – they stick

Worked example (stick)

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

$$2(3) = 6v_f \Rightarrow v_f = 1 \text{ m/s}$$

KE: 9 → 3 J; the lost 6 J became heat.

5 Recap

Linear Momentum
└ Recap

Unit 4 – key takeaways

1 Momentum

$$\vec{p} = m\vec{v}, \text{ a vector; system total} \\ = M\vec{v}_{cm}$$

2 Impulse

$$\vec{J} = \int \vec{F} dt = \Delta\vec{p}; \vec{F} = d\vec{p}/dt$$

3 Conservation

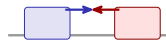
zero external force keeps total momentum constant

4 Collisions

momentum always conserved; KE only if elastic

Check yourself

- 1 Write Newton's second law in terms of momentum.
- 2 What is the area under a force-time graph?
- 3 An astronaut throws a tool – which way does she drift?
- 4 Which collision also conserves kinetic energy?



Answers 1. $\vec{F} = d\vec{p}/dt$ 2. the impulse 3. opposite the throw 4. elastic