Linear Momentum

AP Physics C: Mechanics ▪ Unit 4

AP Physics C: Mechanics

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

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.

Newtons cradle

2 Impulse

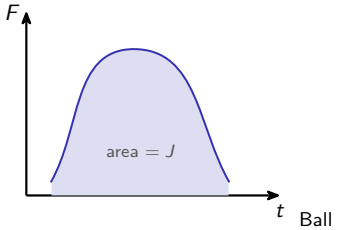
Impulse and Newton's law

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.



Ball bounces: $\Delta p = -6$; in $0.01\,\mathrm{s}$, $F = 600\,\mathrm{N}$.

3 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 $60\,\mathrm{kg}$ throws a $2\,\mathrm{kg}$ wrench at $10\,\mathrm{m/s}$:

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

Conserved separately along each axis in 2-D.

4 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)

$2\,\mathrm{kg}$ at $3\,\mathrm{m/s}$ hits a $4\,\mathrm{kg}$ at rest:

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

KE: $9 \to 3\,\mathrm{J}$; the lost $6\,\mathrm{J}$ became heat.

5 Recap

Unit 4 – key takeaways

1 Momentum

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

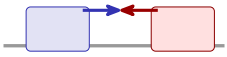
zero external force keeps total momentum constant

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