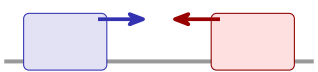
Linear Momentum

AP Physics 1 ▪ Unit 4

AP Physics 1



What we will cover

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

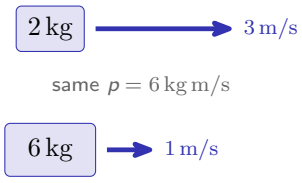
Linear momentum

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.



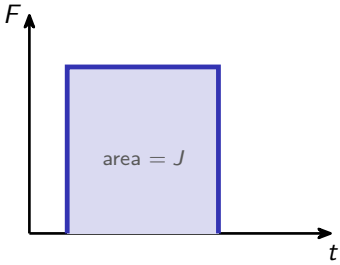
Impulse

Force over time

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

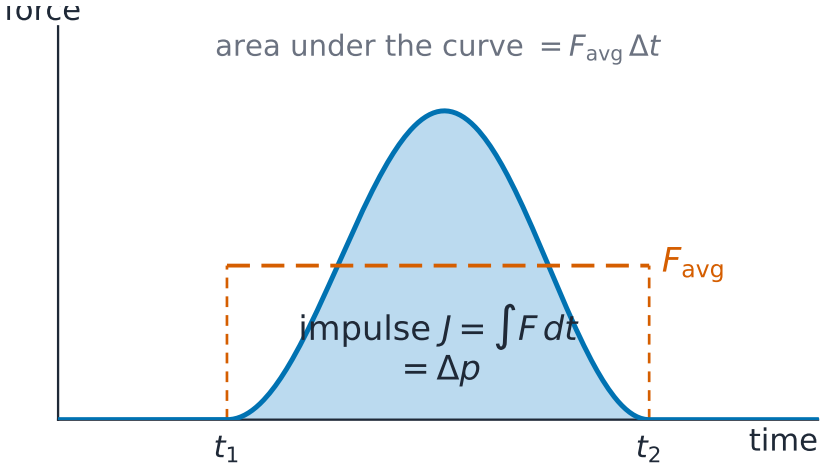
The **impulse-momentum theorem** 冲量动量定理. Impulse = area under an F–t graph.

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.

Impulse

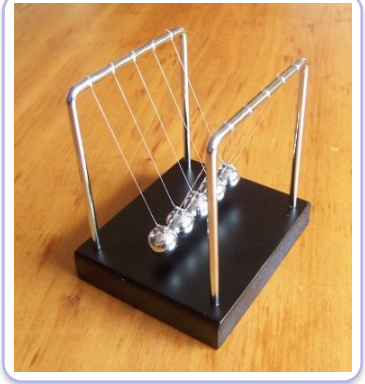

force
area under the curve $= F_{\text{avg}}\,\Delta t$
F_{avg}
impulse $J = \int F\,dt$
$= \Delta p$
t_1
t_2
time

Conservation of momentum

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

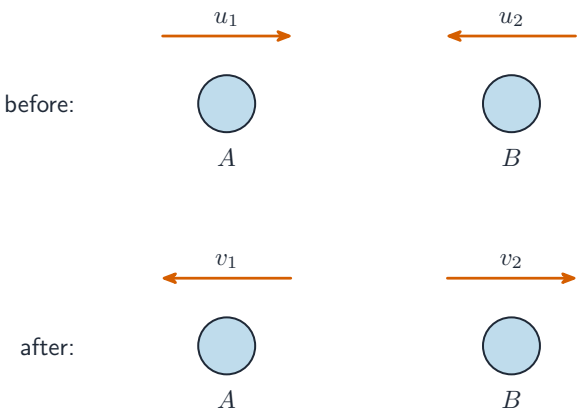
- internal forces cancel (Newton's third law)
- only external forces change total p

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



Momentum is conserved in collisions

Conservation of momentum



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 $KE \to$ heat, sound
- **perfectly inelastic** 完全非弹性碰撞 – they stick

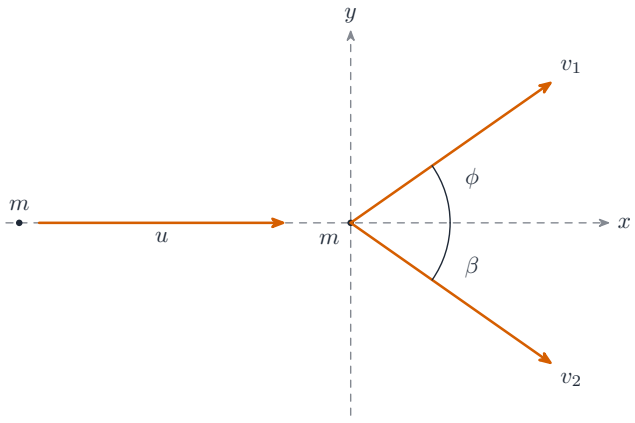
Worked example (stick together)

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

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

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

Elastic and inelastic collisions



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

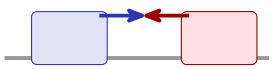
zero net external force keeps total momentum constant

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