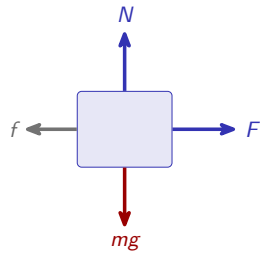


Force & Translational Dynamics

AP Physics C: Mechanics ■ Unit 2

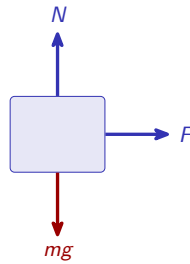
AP Physics C: Mechanics



Force & Translational Dynamics

What we will cover

- 1 Systems and center of mass
- 2 Free-body diagrams and Newton's laws
- 3 Gravitation
- 4 Friction
- 5 Spring forces
- 6 Resistive forces and terminal velocity
- 7 Circular motion



1 Center of mass

Systems and center of mass

A **system** 系统 moves as if all its mass sat at its **center of mass** 质心:

Discrete and continuous

$$x_{cm} = \frac{\sum m_i x_i}{\sum m_i} = \frac{1}{M} \int x dm$$

Only the **net external force** 净外力 accelerates the center of mass – internal forces cannot.

Worked example – a uniform rod

With $\lambda = M/L$, $dm = \lambda dx$:

$$x_{cm} = \frac{1}{M} \int_0^L x \lambda dx = \frac{L}{2}$$

The integral confirms it balances at the middle.

2 Newton's laws

Free-body diagrams and Newton's laws

Draw every force on a **free-body diagram** 受力图, resolve into components, add to the **net force** 合力.

The three laws

1st: inertia $\vec{F}_{net} = m\vec{a}$

3rd: equal-opposite pairs, different bodies



Rocket force

3 Gravity

Gravitation

Universal gravitation

$$F_g = \frac{Gm_1m_2}{r^2}, \quad g = \frac{GM}{r^2}$$

- **mass** 质量 is intrinsic; **weight** 重量 $= mg$
- a sphere pulls as if all mass sat at its centre
- g falls off as $1/r^2$ with **altitude** 海拔

Worked example

At one Earth radius up, r doubles:

$$g = \frac{9.8}{2^2} = 2.45 \text{ m/s}^2$$

The gentler pull is what lets satellites orbit high up.

4 Friction & springs

Friction and spring forces

Friction

$$f_s \leq \mu_s N, \quad f_k = \mu_k N$$

Depends on N and μ – not on the contact area.

Hooke's law

$$F_s = -kx$$

Combining springs: **parallel** adds ($k_{eq} = k_1 + k_2$, stiffer); **series** is softer ($\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2}$).

Two 100 N/m springs: parallel 200, series 50 N/m.

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Resistive forces

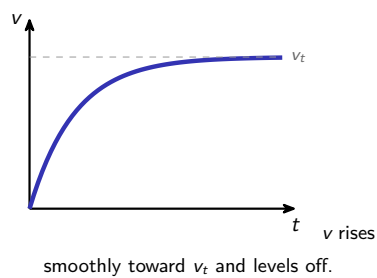
Resistive forces and terminal velocity

Drag grows with speed ($F = -bv$), so Newton's law becomes a **differential equation** 微分方程:

Falling with drag

$$m \frac{dv}{dt} = mg - bv$$

At **terminal velocity** 终极速度, $\frac{dv}{dt} = 0$, so $v_t = \frac{mg}{b}$.



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Circular motion

Force & Translational Dynamics
└ Circular motion

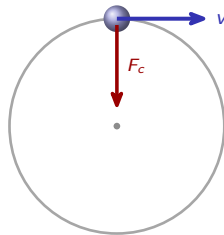
Circular motion

Uniform circular motion 匀速圆周运动:
steady speed, changing direction – so it
accelerates toward the centre:

Centripetal quantities

$$a_c = \frac{v^2}{r}, \quad F_c = \frac{mv^2}{r}$$

Non-uniform motion also has a **tangential** 切向
force that changes the speed.



A car needs F_c from
tyre friction – else it skids.

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Recap

Unit 2 – key takeaways

1 Center of mass

$$x_{cm} = \frac{1}{M} \int x dm; \text{ moved only by external force}$$

2 Newton

$$\vec{F}_{net} = m\vec{a}; \text{ third-law pairs act on different bodies}$$

3 Drag

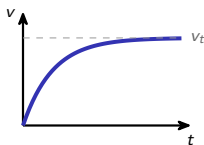
$$m dv/dt = mg - bv; \text{ terminal velocity } v_t = mg/b$$

4 Circular

$$a_c = v^2/r \text{ toward the centre; a role, not a new force}$$

Check yourself

- 1 What integral gives the center of mass of a continuous object?
- 2 At terminal velocity, what is the acceleration?
- 3 Two springs in parallel – stiffer or softer than one?
- 4 Rise altitude by one Earth radius – what happens to g ?



Answers 1. $\frac{1}{M} \int x dm$ 2. zero 3. stiffer 4. it drops to one quarter