

Physical Quantities & Units

AS Physics ■ Topic 1

A-Level Physics

the length of an object



1.5 m

Physical Quantities & Units

What we will cover

- 1 Physical quantities
- 2 SI units & prefixes
- 3 Errors & uncertainties
- 4 Scalars & vectors
- 5 Recap & self-check



1 Physical quantities

Physical Quantities & Units

Physical quantities

A number *and* a unit

A **physical quantity** 物理量 has two parts:

- a **magnitude** 大小 – the number
- a **unit** 单位 – what the number means

The number alone tells you **nothing**.

1.5 m
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magnitude unit

"1.5" ❌

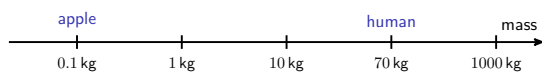
"1.5 m" ✅

Physical Quantities & Units

Physical quantities

Estimate the everyday

A good estimate has the right **order of magnitude** 数量级.



body weight $\approx 700 \text{ N}$

sound $\approx 340 \text{ m s}^{-1}$

light $\approx 3.0 \times 10^8 \text{ m s}^{-1}$

$g \approx 9.81 \text{ m s}^{-2}$

2 SI units

SI base quantities

The SI system has **seven base quantities** 基本量; these **five** are used here:

kg mass	m length	s time	A current	K temperature
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Combine them with $\times$ and $\div$ to get **every other unit** – N, J, W, Pa, ...

Build any derived unit

Each **derived unit** 导出单位 is just base units, from its defining equation:

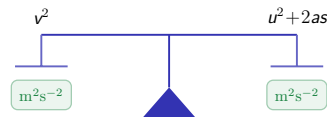
N force kg m s^{-2}	J energy $\text{kg m}^2 \text{s}^{-2}$	W power $\text{kg m}^2 \text{s}^{-3}$	Pa pressure $\text{kg m}^{-1} \text{s}^{-2}$
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e.g. **force** = $m \times a \Rightarrow \text{kg m s}^{-2} = \text{N}$.

Do the units balance?

Homogeneous 量纲一致 = both sides have the **same base units**. Test $v^2 = u^2 + 2as$:

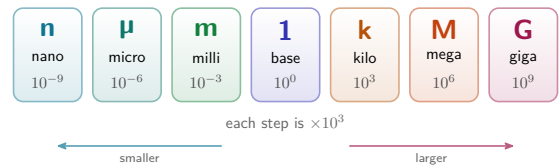
- LHS = $\text{m}^2 \text{s}^{-2}$
- $u^2 = \text{m}^2 \text{s}^{-2}$; $2as = \text{m}^2 \text{s}^{-2}$



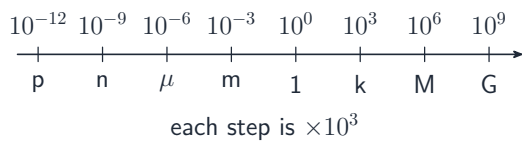
Matching units don't **prove** an equation right – but **mismatched** units prove it wrong.

Prefixes – powers of ten

A **prefix** 词头 scales a unit by a power of ten.



Prefixes on the page



Each step is a factor of 1000, so converting is a shift of three places — never a new calculation.

Worked example – converting prefixes

$$0.25 \text{ kN mm}^{-2} \rightarrow \text{N m}^{-2}$$

Replace each prefix – and **square** the mm:

$$0.25 \frac{10^3}{(10^{-3})^2} = 2.5 \times 10^8 \text{ N m}^{-2}.$$

$$0.25 \text{ kN mm}^{-2}$$

replace prefixes
 $\times 10^3 / 10^{-6}$

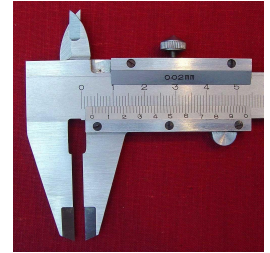
$$2.5 \times 10^8 \text{ N m}^{-2}$$

3 Errors and uncertainties

Every measurement is uncertain

Every measurement carries some **uncertainty** 不确定度. A good experimenter:

- knows where it comes from
- estimates it fairly
- carries it to the answer



Calipers measure with a small uncertainty

The micrometer – to 0.01 mm

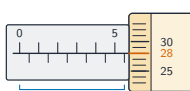


(a) zero check



reads 0.00 mm

(b) a measurement

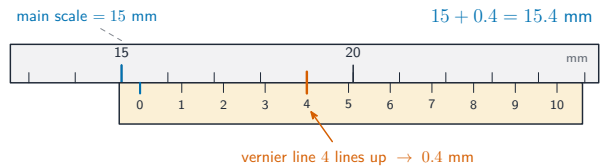


5.5 mm
 $5.5 + 0.28 = 5.78$ mm

Reading = sleeve (main scale) + thimble scale.

A micrometer 千分尺 reads to 0.01 mm: sleeve + thimble.

The vernier caliper – to 0.1 mm



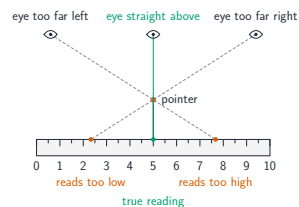
Whole mm from the main scale
+ tenths from the lined-up vernier mark.

Systematic vs random errors

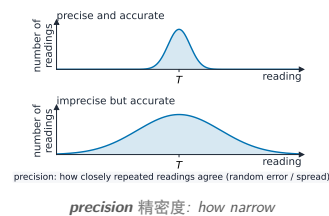
systematic error 系统误差 – same shift every time (**zero error** 零点误差, **calibration** 校准, **parallax** 视差).



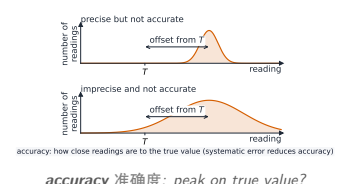
random error 随机误差 – scatters with no pattern; the mean of many repeats cancels it.



Precision vs accuracy



precision 精密度: how narrow



accuracy 准确度: peak on true value?

Combining uncertainties

Value $x \pm \Delta x$; **percentage uncertainty** 百分比不确定度 $= \frac{\Delta x}{x} \times 100\%$.

- **add / subtract** $\Rightarrow$ add **absolute uncertainty** 绝对不确定度
- **multiply / divide** $\Rightarrow$ add the %
- **power** $a^n \Rightarrow$ multiply % by $|n|$

$$y = \frac{ab}{c}$$

$$\frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$$

Worked example – uncertainty in a volume



$$d = (5.26 \pm 0.02) \text{ cm}$$

$$V = \frac{\pi}{6} d^3 = 76.2 \text{ cm}^3$$

1

% uncertainty in d

$$\frac{0.02}{5.26} \times 100\% = 0.38\%$$

2

$V \propto d^3$: triple it

$$3 \times 0.38\% = 1.14\%$$

3

back to absolute

$$1.14\% \times 76.2 = \Delta V = 0.9 \text{ cm}^3$$

$$V = (76.2 \pm 0.9) \text{ cm}^3$$

Significant figures

Match the **significant figures** 有效数字 to the least precise measurement – usually 2 or 3.

- too many $\Rightarrow$ looks too exact
- too few $\Rightarrow$ loses information

76.2 34...

drop extra

$$76.2 \text{ cm}^3 \text{ (3 s.f.)}$$

4

Scalars and vectors

Size only, or size *and* direction?

Scalar 标量

5 kg

magnitude only

mass · time · energy
speed · distance · density

Vector 矢量



magnitude + direction

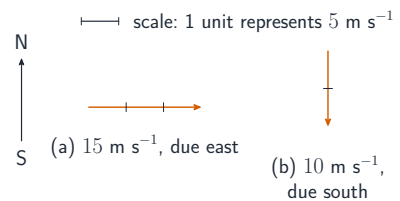
displacement 位移 · velocity
force · momentum 动量

Quick test – can you ask “in which direction?” If yes, it is a **vector**.

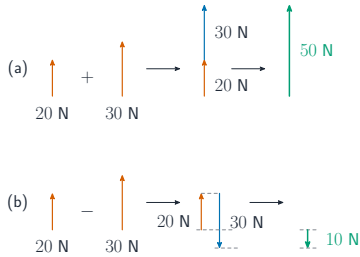
Drawing vectors to scale

A vector is an arrow:

- **direction** of arrow = direction
- **length** (to scale) = magnitude

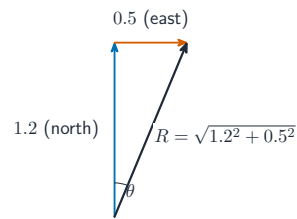


Adding tip to tail



- add **coplanar** 共面 vectors **tip to tail**
- the **resultant** 合矢量 runs first tail $\rightarrow$ last tip
- to subtract $\vec{X} - \vec{Y}$, add the reverse of $\vec{Y}$

Vectors at right angles



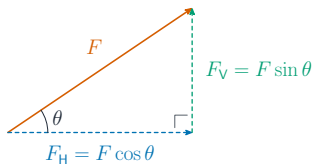
For **perpendicular** 垂直 vectors:

$$|\vec{R}| = \sqrt{X^2 + Y^2}, \quad \tan \theta = \frac{Y}{X}.$$

Swimmer

1.2 m s⁻¹ north, current 0.5 m s⁻¹ east:
 $|\vec{R}| = 1.3 \text{ m s}^{-1}$, $\theta \approx 23^\circ$ E of N.

Resolving into components



Split into perpendicular **components** 分量:

$$v_H = v \cos \theta, \quad v_V = v \sin \theta.$$

On an **inclined plane** 斜面:

$$W_{\parallel} = W \sin \theta, \quad W_{\perp} = W \cos \theta.$$

5 Recap

Topic 1 – key takeaways

1 Magnitude + unit

every quantity is a number *and* a unit

2 Derived units

built from 5 base units; check homogeneity

3 Precision vs accuracy

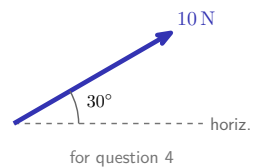
spread of repeats vs the true value

4 Vectors

add tip-to-tail; resolve into components

Check yourself

- 1 SI base units of the **pascal**?
- 2 Close, but far from true – precise or accurate?
- 3 $y = ab^2$ – how do the % combine?
- 4 10 N at 30° – horizontal component?



Answers 1. kg m⁻¹s⁻² 2. precise, not accurate 3. $\frac{\Delta y}{y} = \frac{\Delta a}{a} + 2\frac{\Delta b}{b}$ 4. 8.7 N