Kinematics

AP Physics 1 ▪ Unit 1

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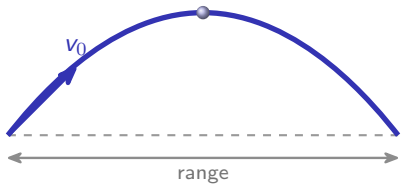
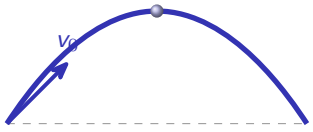


What we will cover

1. Scalars and vectors
2. Displacement, velocity, acceleration
3. Motion graphs and SUVAT
4. Reference frames
5. Projectile motion



1 Scalars and vectors

Scalars and vectors

- a **scalar** 标量 has only a **magnitude** 大小 – time, mass, speed
- a **vector** 矢量 has magnitude and **direction** 方向 – displacement, velocity, force

In 1-D, pick a **positive direction** 正方向: a − sign is a direction, not "less than nothing".

Speedometers measure magnitude of velocity

2 Displacement, velocity, acceleration

From position to acceleration

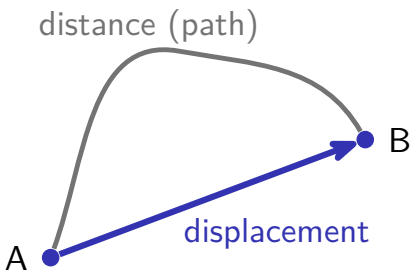
Each quantity is the rate of change of the one before it:

Each has a scalar partner – **distance**, **speed** – with size but no direction.

Distance vs displacement

- **distance** 距离 – the whole path travelled (a scalar)
- **displacement** 位移 $\Delta x = x_f - x_i$ – start to end, *with direction* (a vector)

One full lap of a track: distance is large, displacement is zero.



Velocity and acceleration, defined

Rates of change

$$v_{avg} = \frac{\Delta x}{\Delta t}, \qquad a_{avg} = \frac{\Delta v}{\Delta t}$$

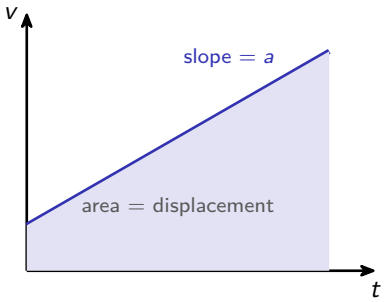
Instantaneous velocity 瞬时速度 = the slope of the tangent on an x–t graph.

An object slows down whenever a points opposite to v.

- speeding up, slowing down, *and* turning are all accelerations
- **speed** 速率 is the magnitude of velocity – no direction

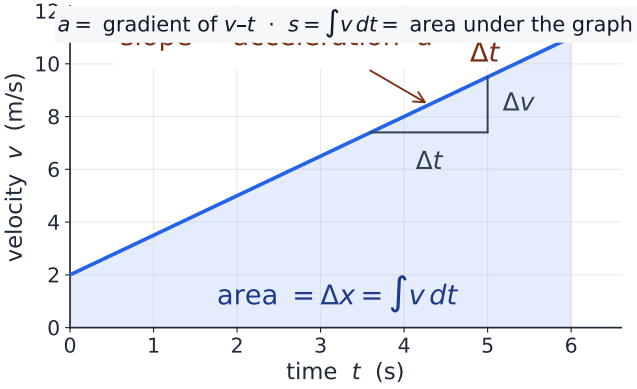
3 Motion graphs

Reading motion graphs



A high-speed train: kinematics describes displacement, velocity and acceleration over time

Reading motion graphs, continued



- On a **position–time** graph, the **slope** is velocity (steeper = faster; a curve = changing velocity).
- On a **velocity–time** graph, the slope is acceleration, and the **area** under the line is displacement.

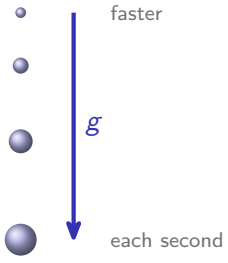
Constant acceleration and free fall

The kinematic equations

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \tfrac{1}{2} a t^2$$

Free fall 自由落体: gravity alone gives $a = g \approx 9.8\,\mathrm{m/s^2}$ downward – the same for every mass.



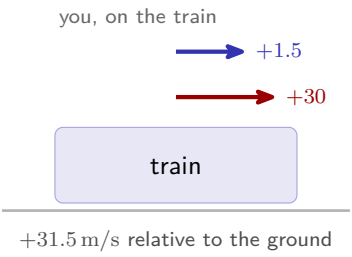
4 Reference frames

Reference frames and relative motion

A **reference frame** 参考系 is what you treat as fixed while measuring. Motion is **relative** 相对 to it.

Add velocities as vectors

$$v_{A/C} = v_{A/B} + v_{B/C}$$



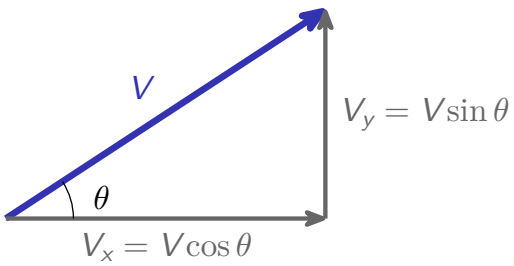
Reference frames, and free fall

kinematics 运动学	describes *how* objects move, without asking why
a scalar	size only – distance, speed, time
a vector	size and direction – displacement, velocity, acceleration
average velocity 平均速度	$\Delta x/\Delta t$ over an interval; instantaneous velocity is the value at one moment
free fall 自由落体	at the highest point the velocity is momentarily zero, while $a = -g = -9.8\ \mathrm{m/s^2}$ throughout
an inertial reference frame 惯性参考系	one that is not accelerating – in it, a free object obeys Newton's first law

Zero velocity does not mean zero acceleration. The top of a throw is the standard case, and it is asked almost every year.

5 Projectiles

Resolving a vector into components



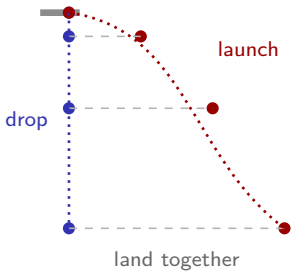
Break each vector into its **components** 分量 on the x- and y-axes.

Back to magnitude and angle

$$V = \sqrt{V_x^2 + V_y^2}, \quad \theta = \tan^{-1}\frac{V_y}{V_x}$$

The x and y motions are independent – they share only the time t.

Projectile motion



A **projectile** 抛体 has gravity as its only force. Its **trajectory** 轨迹 is a parabola:

- **horizontal**: no force, v_x constant
- **vertical**: free fall at g

A dropped ball and a launched ball fall together – horizontal speed does not change the fall.

Worked example – a ball off a table

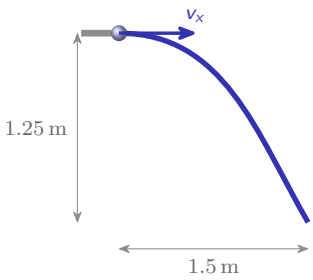
Table $h = 1.25\,\text{m}$, $v_x = 3.0\,\text{m/s}$

Vertical (fall from rest): $h = \frac{1}{2}gt^2$

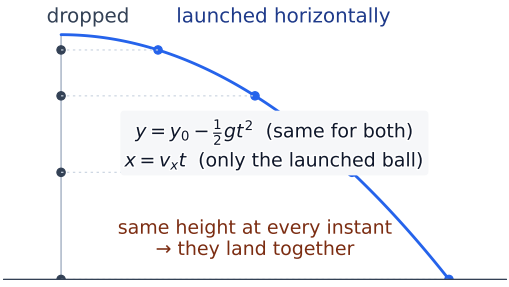
$$1.25 = \tfrac{1}{2}(9.8)\,t^2 \;\Rightarrow\; t = 0.50\,\text{s}$$

Horizontal (v_x constant):

$$x = v_x t = 3.0 \times 0.50 = 1.5\,\text{m}$$

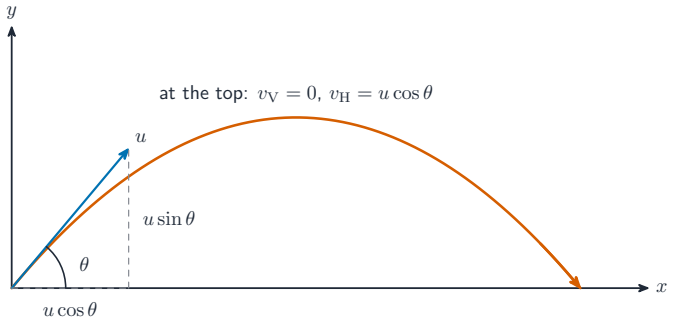


Vectors and Motion in Two Dimensions



A dropped ball and a horizontally launched ball fall together – the vertical motions are identical

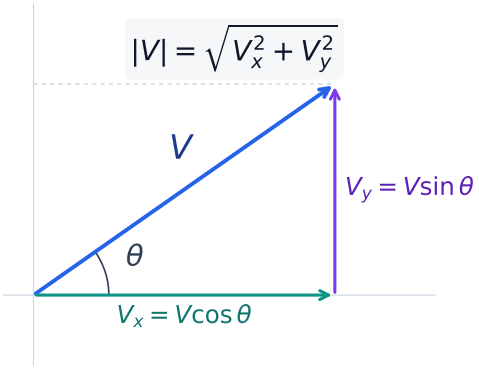
A projectile launched at an angle: the – one



A projectile launched at an angle: the horizontal and vertical motions are independent

A projectile launched at an angle: the horizontal and vertical motions are independent

A projectile launched at an angle: the – two



A velocity vector resolved into its horizontal and vertical components

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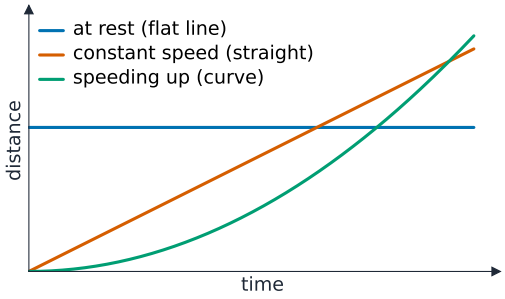
Representing Motion



Reading a distance-time graph: flat means at rest, a straight slope means constant speed

Displacement, Velocity, and Acceleration

A high-speed train: kinematics describes displacement, velocity and acceleration over time

Exam tips

- Choose the right **kinematic equation** by listing the three quantities you know plus the one you want, so only one unknown remains; the SUVAT equations apply **only** while acceleration is constant.
- Fix a **positive direction** first – every displacement, velocity, and acceleration then carries a sign; a negative velocity means "moving the other way", not "slow".
- Treat a projectile as **two independent 1-D problems** sharing only the time t: constant velocity horizontally, $a = -g$ vertically. At the top $v_y = 0$ but v_x is unchanged.
- On a **velocity–time graph** the gradient is the acceleration and the **area** is the displacement (area below the axis is negative).
- Distinguish **distance** (scalar, total path) from **displacement** (vector, start-to-end), and **speed** from **velocity**.

6 Recap

Unit 1 – key takeaways

1 Vectors

displacement, velocity, acceleration have direction; use signs in 1-D

2 Graphs

x–t slope $= v$; v–t slope $= a$, area = displacement

3 Kinematics

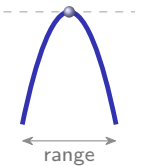
$v = v_0 + at$; $x = x_0 + v_0 t + \frac{1}{2} a t^2$; free fall at g

4 Projectiles

independent x and y motions, joined only by time

Check yourself

1. One full lap of a track – what is the displacement?
2. On a v–t graph, what does the area give?
3. Two balls, one dropped, one launched sideways – which lands first?
4. a points opposite to v: speeding up or slowing down?



Answers **1.** zero **2.** displacement **3.** same time (equal heights) **4.** slowing down