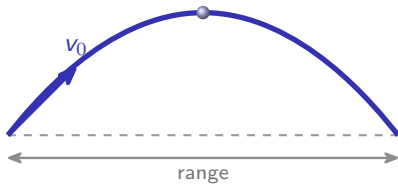


Kinematics

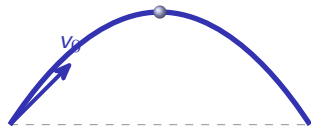
AP Physics 1 ■ Unit 1

AP Physics 1



What we will cover

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





Scalars and vectors

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

In 1-D, pick a **positive direction** : a
– sign is a **direction**, not “less than nothing”.



Speedometers measure magnitude of velocity



From position to acceleration

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

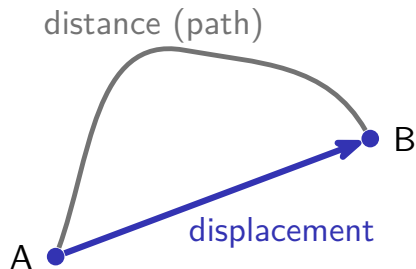


Each has a **scalar** partner – **distance**, **speed** – with size but no direction.

Distance vs displacement

- **distance** – the whole path travelled (a **scalar**)
- **displacement** $\Delta x = x_f - x_i$ – 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

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

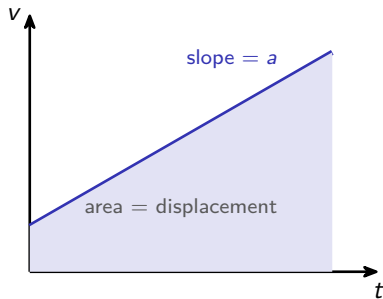
Instantaneous velocity = the slope of the tangent on an $x-t$ graph.

An object **slows down** whenever a points **opposite** to v .

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

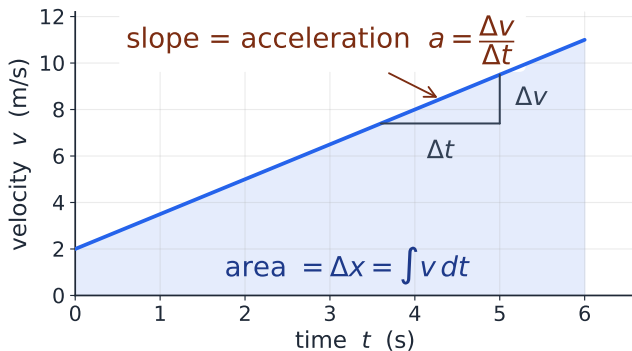


Reading motion graphs



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

Reading motion graphs, continued



$$a = \text{gradient of } v-t \quad \cdot \quad s = \int v dt = \text{area under the graph}$$

- 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.

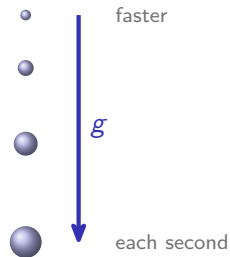
Constant acceleration and free fall

The kinematic equations

$$v = v_0 + at$$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

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





Reference frames and relative motion

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

Add velocities as vectors

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

you, on the train

→ +1.5

→ +30

train

+31.5 m/s relative to the ground

Reference frames, and free fall

kinematics

describes *how* objects move, without asking why

a scalar

size only – distance, speed, time

a vector

size **and direction** – displacement, velocity, acceleration

average velocity

$\Delta x / \Delta t$ over an interval; instantaneous velocity is the value at one moment

free fall

at the highest point the velocity is momentarily **zero**, while $a = -g = -9.8 \text{ m/s}^2$ **throughout**

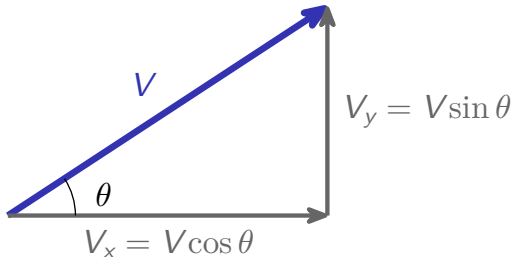
an inertial reference frame

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.



Resolving a vector into components



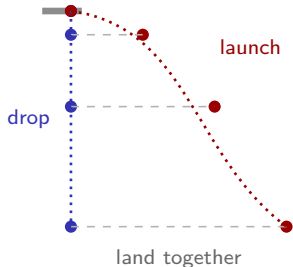
Break each vector into its **components** on the x- and y-axes.

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** has gravity as its only force. Its **trajectory** 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

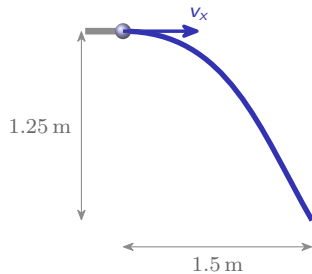
Table $h = 1.25 \text{ m}$, $v_x = 3.0 \text{ m/s}$

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

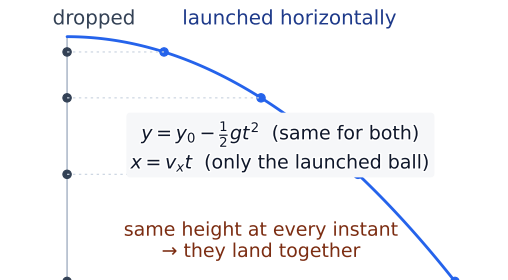
$$1.25 = \frac{1}{2}(9.8) t^2 \Rightarrow t = 0.50 \text{ s}$$

Horizontal (v_x constant):

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

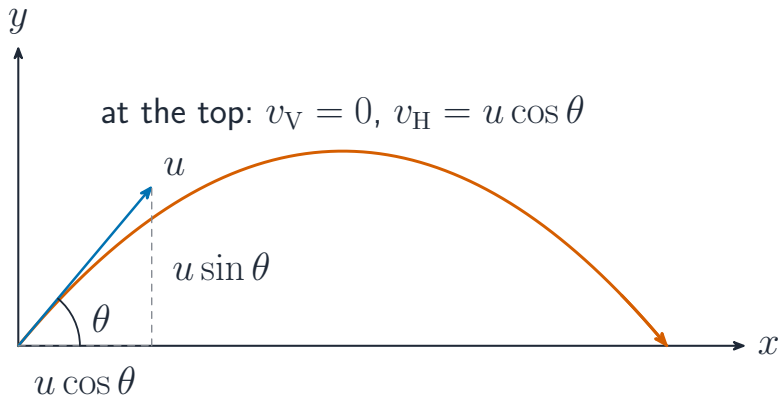


Vectors and Motion in Two Dimensions



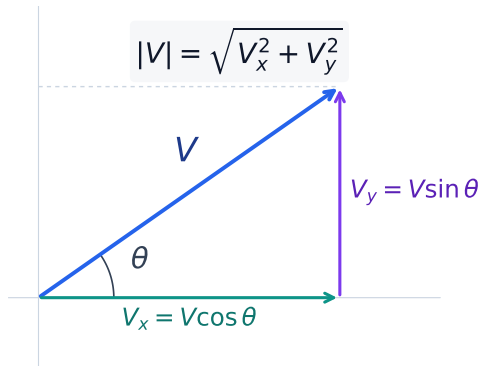
A dropped ball and a horizontally launched ball fall together – the vertical motions are identical

A projectile launched at an angle: the – one



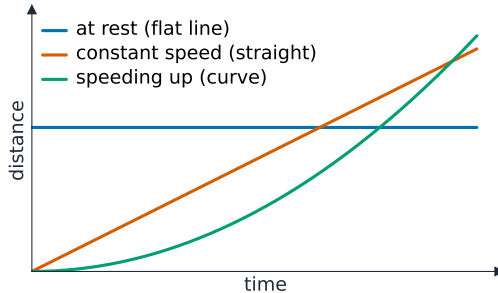
A projectile launched at an angle: the horizontal and vertical motions are independent

A projectile launched at an angle: the – two



A velocity vector resolved into its horizontal and vertical components

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**.



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

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

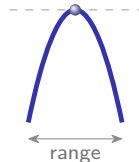
4

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