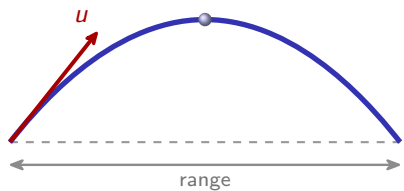
Kinematics

AS Physics ▪ Topic 2

A-Level Physics



What we will cover

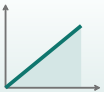
1 Describing motion

sheet 2.1.1: definitions



2 Motion graphs

sheet 2.1.2: gradient and area



3 Equations of motion

sheet 2.1.3: four equations

$v = u + at$

s u v a t

4 Free fall

sheet 2.1.4: g, and measuring it



5 Projectiles

sheet 2.1.5: two motions



6 Putting it together

problems, exam tips, recap



1 Describing motion

Sheet 2.1.1 – what you need to know

You must be able to:

- **define** distance, displacement, speed, velocity and acceleration
- tell **average speed** from **average velocity**; change $\mathrm{km\,h^{-1}}$ into $\mathrm{m\,s^{-1}}$
- add two displacements at right angles
- read a velocity from a displacement–time graph: a gradient, or a **tangent**

What the exam asks

"Define velocity." [1]

multiple choice: distance or displacement? which graph?

"Determine the velocity at time t." [2]

Practise on exercise sheet 2.1.1, then try the real exam questions on past-paper sheet 2.1.1.

From position to acceleration

In **kinematics** 运动学, each quantity is the **rate of change** of the one before it:

displacement
位移
vector ▪ m

$\div t$ →

velocity
速度
vector ▪ $\mathrm{m\,s^{-1}}$

$\div t$ →

acceleration
加速度
vector ▪ $\mathrm{m\,s^{-2}}$

Each is the rate of change *with time* of the one before it, and each has a **scalar** partner – **distance**, **speed**. **Learn the exact words**: the examiner gives marks for precise wording.



A speedometer reads speed, the rate of change of distance

Distance vs displacement

- **distance** – the whole path walked (a **scalar**)
- **displacement** 位移 – start to end in a straight line, *with direction* (a **vector**)

> Walk a full loop: distance is large, displacement is **zero**.



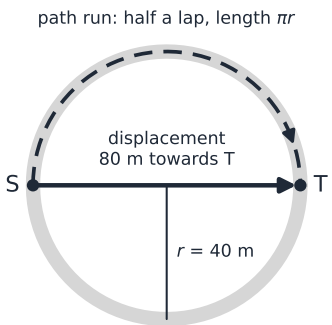
A train's distance along the track can far exceed its displacement

Definitions the examiner accepts

A definition is marked against **fixed wording**: learn these exactly, and give one answer only.

distance	距离	the total length of the path travelled (a scalar)
displacement	位移	the distance moved in a stated direction, from start to finish (a vector)
speed	速率	the rate of change of distance with time
velocity	速度	the rate of change of displacement with time
acceleration	加速度	the rate of change of velocity with time
uniform acceleration	匀加速	acceleration that is constant in magnitude and direction
acceleration of free fall	自由落体加速度	the acceleration of an object falling freely under gravity alone, with air resistance
		negligible 可忽略的

Average speed and average velocity



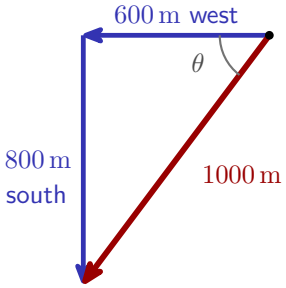
Half a lap of a track of radius $40\,\mathrm{m}$, from S to T, in $25\,\mathrm{s}$:

From S to T

distance $= \pi r = 126\,\mathrm{m}$
displacement $= 80\,\mathrm{m}$ towards T, the diameter
average speed $= 126/25 = 5.0\,\mathrm{m\,s^{-1}}$
average velocity $= 80/25 = 3.2\,\mathrm{m\,s^{-1}}$ towards T

After a **whole** lap the average velocity is **zero**.
The average speed is not.

Adding two displacements at right angles



A walker goes $600\,\mathrm{m}$ due west, then $800\,\mathrm{m}$ due south.

A displacement has a size and a direction

size: $\sqrt{600^2 + 800^2} = 1000\,\mathrm{m}$

direction: $\tan\theta = \dfrac{800}{600}$, so $\theta = 53°$ south of west

The **distance** walked is $1400\,\mathrm{m}$. The **displacement** is only $1000\,\mathrm{m}$.

Speeds in km h^{-1}: convert first

Speeds are sometimes given in km h^{-1}. **Convert to m s^{-1}** before you calculate:

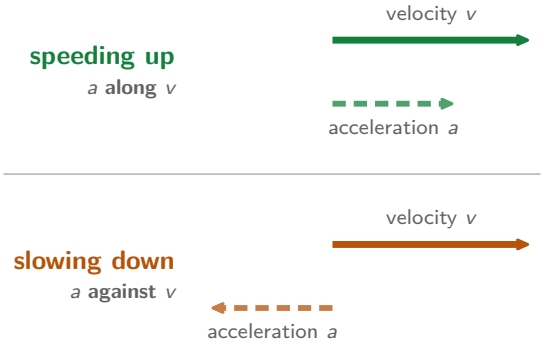
$$85 \text{ km h}^{-1} = \frac{85 \times 1000 \text{ m}}{3600 \text{ s}} = 23.6 \text{ m s}^{-1}$$

> $\times 1000$ turns kilometres into metres and $\div 3600$ turns hours into seconds – together, **divide by 3.6**.



An average-speed camera times each car over a known distance

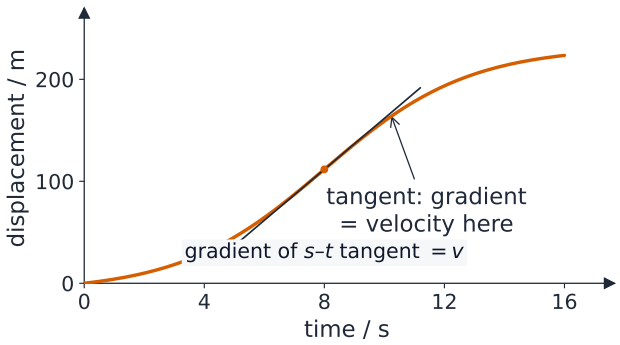
Deceleration is not a separate quantity



Deceleration 减速度 just means the **acceleration points the opposite way to the velocity**.

> It is **not** a separate quantity. In SUVAT, put it in as a **negative** a and let the signs do the work.

Displacement–time graphs

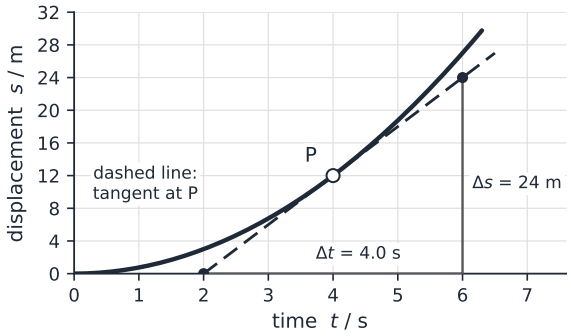


The **gradient** 斜率 of a displacement–time graph = **velocity**.

- flat line → **at rest**
- straight slope → **constant velocity**
- curve → **changing velocity**

For a curve, draw a **tangent** 切线 and find *its* gradient.

Velocity at one instant: draw a tangent



- draw the **tangent** at that time
- make a **large** triangle on it
- gradient = velocity at that instant

At P, $t = 4.0\,\mathrm{s}$

$$v = \frac{24 - 0}{6.0 - 2.0} = 6.0\,\mathrm{m\,s^{-1}}$$

This is the **instantaneous** 瞬时 velocity. The **average** velocity is the total displacement divided by the time.

2 Motion graphs

Sheet 2.1.2 – what you need to know

You must be able to:

- **acceleration** = gradient of a velocity–time graph, also at one instant on a curve
- **displacement** = area; area below the time axis is negative
- tell distance from displacement; estimate an area by **counting squares**
- sketch one motion graph from another

What the exam asks

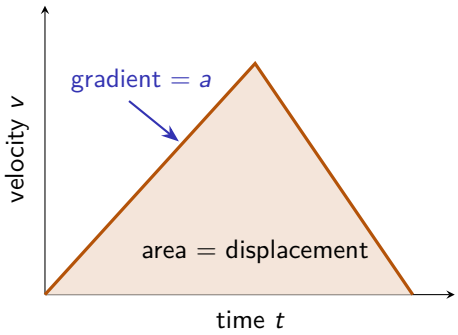
"Determine the acceleration at $t = 4.0\,\text{s}$." [2]

"Determine the displacement at $t = 12\,\text{s}$." [2]

"Sketch the variation with time of ..." [3]

Practise on exercise sheet 2.1.2, then try the real exam questions on past-paper sheet 2.1.2.

Velocity–time graphs



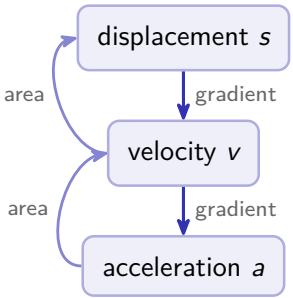
The **gradient** of a velocity–time graph = **acceleration**.

- flat line → **constant velocity**
- straight slope → **uniform acceleration**
- curve → **changing acceleration**

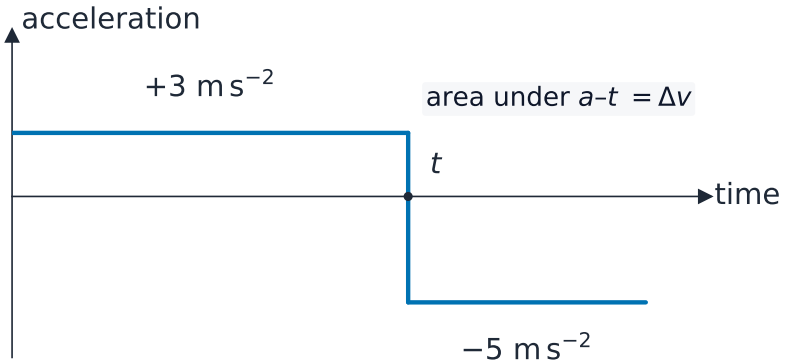
The **area** under the line = **displacement**. Area below the time axis is **negative**: the object moved backwards.

Gradient and area – at a glance

These are the **graphical methods** 图像法 the syllabus names. Two graphs carry most of the marks – displacement–time and velocity–time. Going **down** the chain you take a **gradient**; going **up** it you take an **area**.

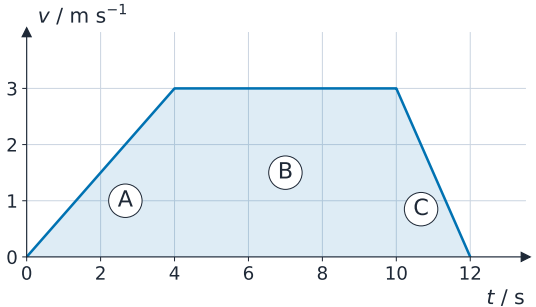


Gradient and area – at a glance, in detail



Each step is a **gradient** of the v–t graph; the **area** under a–t is Δv.

Worked example – a lift's velocity–time graph



Accelerations and distance

A: $a = (3.0 - 0)/4.0 = 0.75\,\mathrm{m\,s^{-2}}$

B: a flat line, so $a = 0$

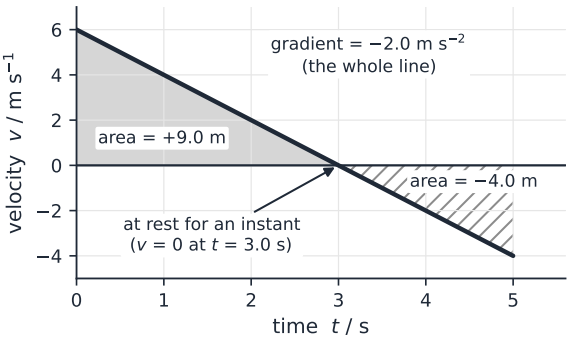
C: $a = (0 - 3.0)/2.0 = -1.5\,\mathrm{m\,s^{-2}}$

distance = area under the line:

$6.0 + 18 + 3.0 = 27\,\mathrm{m}$

Split the area into **triangles** ($\frac{1}{2} \times$ base $\times$ height) and **rectangles**. Under a curve, **count the squares** (half or more counts as one) and multiply by one square's value.

Area below the axis: displacement and distance



A trolley goes up a track and rolls back

gradient:

$$a = \frac{-4.0 - 6.0}{5.0} = -2.0\,\mathrm{m\,s^{-2}}$$

area above:

$$\tfrac{1}{2}(3.0)(6.0) = +9.0\,\mathrm{m}$$

area below:

$$\tfrac{1}{2}(2.0)(-4.0) = -4.0\,\mathrm{m}$$

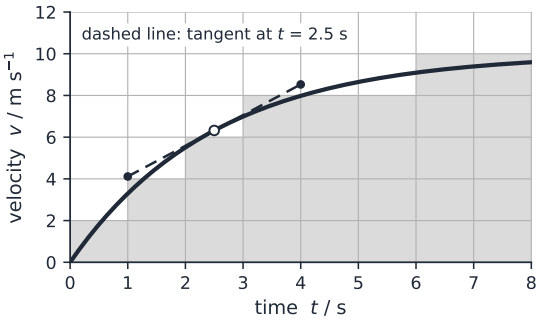
displacement $= 9.0 - 4.0 = 5.0\,\mathrm{m}$

distance $= 9.0 + 4.0 = 13\,\mathrm{m}$

Check: At $t = 3.0\,\mathrm{s}$ the velocity is zero, but the acceleration is **still** $-2.0\,\mathrm{m\,s^{-2}}$: the line is still sloping.

exercises.lol exercises.com.cn

A curved graph: a tangent and counting squares



Acceleration at $t = 2.5\,\mathrm{s}$

tangent through $(1.0,\ 4.1)$ and $(4.0,\ 8.5)$

$$a = \frac{8.5 - 4.1}{4.0 - 1.0} = 1.5\,\mathrm{m\,s^{-2}}$$

Displacement

one square $= 1\,\mathrm{s} \times 2\,\mathrm{m\,s^{-1}} = 2\,\mathrm{m}$

28 squares, so about $56\,\mathrm{m}$

Count every square that is **at least half** under the curve.

Sketching one graph from another

A train speeds up uniformly from rest to $12\,\mathrm{m\,s^{-1}}$ in $20\,\mathrm{s}$, keeps this speed for $30\,\mathrm{s}$, then brakes uniformly to rest in $15\,\mathrm{s}$.

From the velocity–time graph

$a_1 = \dfrac{12}{20} = 0.60\,\mathrm{m\,s^{-2}}$, then $a = 0$,

then $a_3 = \dfrac{-12}{15} = -0.80\,\mathrm{m\,s^{-2}}$

$s =$ area $= 120 + 360 + 90 = 570\,\mathrm{m}$

- *a*–*t*: three flat lines, one for each gradient of the *v*–*t* graph
- *s*–*t*: gets steeper, then a straight line, then flattens as the train stops

To **sketch** 画草图: label both axes, and give each part the right **shape** – straight or curved, steeper or flatter.

3 Equations of motion

Sheet 2.1.3 – what you need to know

You must be able to:

- **derive** the four equations from a velocity–time graph
- state when they apply: **constant acceleration** in a straight line
- choose the equation, and give every vector a sign
- solve **two stages**, **two objects**, and a quadratic with two answers

What the exam asks

"State two conditions for this equation to apply." [2]

"Calculate the acceleration." [2]

multiple choice: a train between two stations

Practise on exercise sheet 2.1.3, then try the real exam questions on past-paper sheet 2.1.3.

The four SUVAT equations

Straight line, **uniform acceleration** 匀加速: five symbols u, v, a, s, t – each equation drops one.

$v = u + at$ — no s

$s = ut + \frac{1}{2}at^2$ — no v

$s = \frac{1}{2}(u + v)t$ — no a

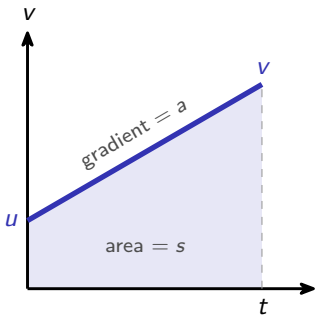
$v^2 = u^2 + 2as$ — no t

Pick the equation that holds your **three knowns** *and* your **unknown**. They hold only for **constant acceleration** in a straight line.

Where SUVAT comes from

Start from the **velocity–time graph** of the motion:

1. gradient: $a = \dfrac{v-u}{t}$, so $v = u + at$
2. **area** of a **trapezium** 梯形: $s = \frac{1}{2}(u+v)t$
3. put $v = u + at$ into 2:
   $s = \frac{1}{2}(u+u+at)t = ut + \frac{1}{2}at^2$
4. put $t = \dfrac{v-u}{a}$ into 2:
   $2as = (v+u)(v-u) = v^2 - u^2$



A **derive** question wants exactly these steps, each starting from a definition or an equation already shown, with **no numbers**.

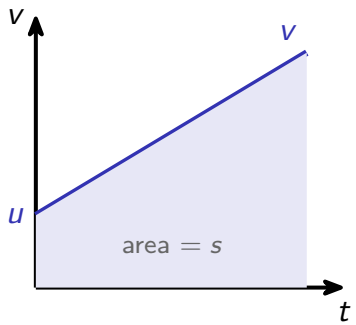
Worked example – find the acceleration

Car: $u = 8$, $v = 20\,\mathrm{m\,s^{-1}}$ **over** $s = 56\,\mathrm{m}$

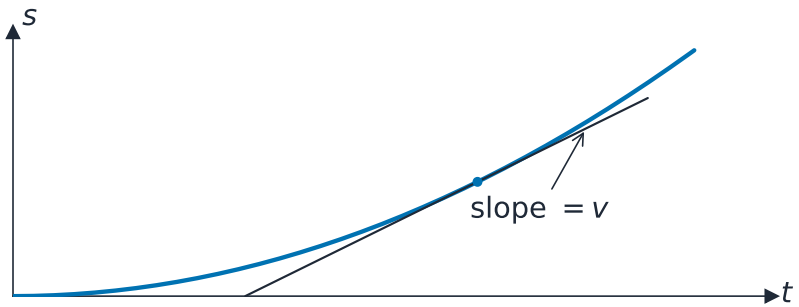
Knowns u, v, s; **want** a, so use $v^2 = u^2 + 2as$:

$$20^2 = 8^2 + 2a(56)$$

$$336 = 112\,a \;\Rightarrow\; a = 3.0\,\mathrm{m\,s^{-2}}.$$



The displacement–time graph is a parabola



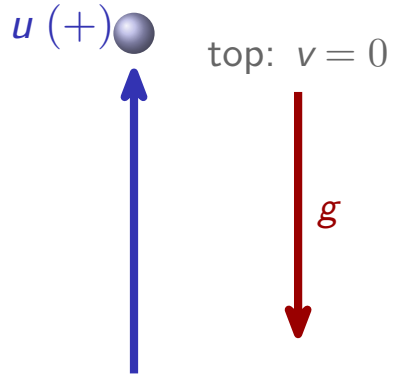
constant $a \Rightarrow s$–t is a parabola $\cdot$ gradient of tangent $= v$

With uniform acceleration the s–t graph is a **parabola** 抛物线: the gradient of the **tangent** at any point is the **velocity** at that instant.

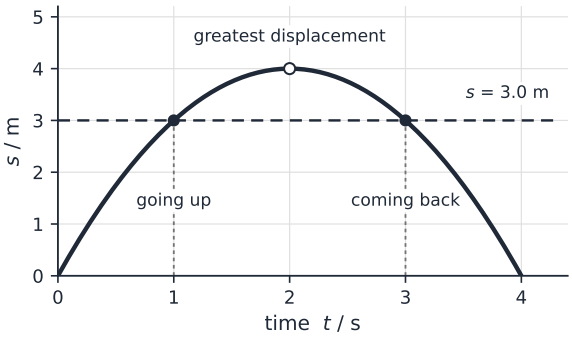
Choose a positive direction

Pick **one direction** as $+$ and **keep it**. Anything the other way gets a **minus sign**.

> Ball thrown up, "up" positive: $u > 0$, and $a = -g$ for the **whole flight**, on the way down too. **At the top** $v = 0$ but $s > 0$.



Signs, and two answers



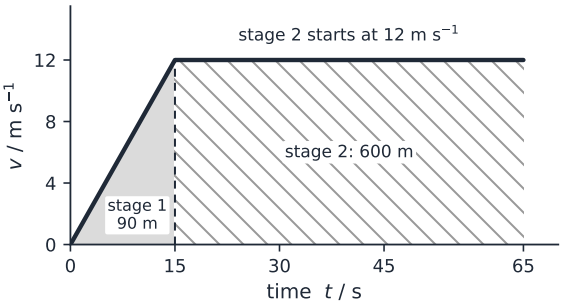
A ball rolls up a slope: $u = +4.0$, $a = -2.0$

stops: $v = u + at$, $0 = 4.0 - 2.0\,t$,
so $t = 2.0\,\mathrm{s}$

$3.0\,\mathrm{m}$ up the slope: $s = ut + \frac{1}{2}at^2$
$3.0 = 4.0\,t - 1.0\,t^2$
so $t = 1.0\,\mathrm{s}$ or $3.0\,\mathrm{s}$

Both answers are real: going up at $1.0\,\mathrm{s}$, coming back down at $3.0\,\mathrm{s}$. Reject an answer only when it makes no sense, such as a time before the start.

Two stages



A tram: $0.80\,\mathrm{m\,s^{-2}}$ for $15\,\mathrm{s}$, then steady for $50\,\mathrm{s}$

$v = u + at$:
$v = 0.80 \times 15 = 12\,\mathrm{m\,s^{-1}}$
$s = ut + \frac{1}{2}at^2$:
$s_1 = \frac{1}{2}(0.80)(15)^2 = 90\,\mathrm{m}$
steady speed, $s = vt$:
$s_2 = 12 \times 50 = 600\,\mathrm{m}$
total $= 690\,\mathrm{m}$

The **final velocity of stage 1** is the **initial velocity of stage 2**. A driver's **reaction time** 反应时间 is a stage too: the car keeps its speed.

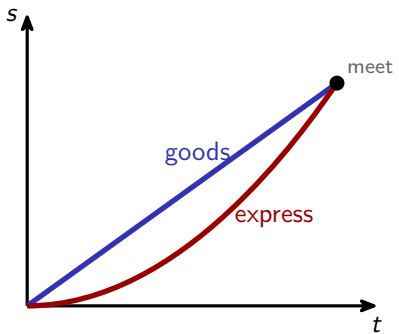
Two objects meeting

Same start time, **same positive direction**; set the **displacements equal** (or their difference to a given gap).

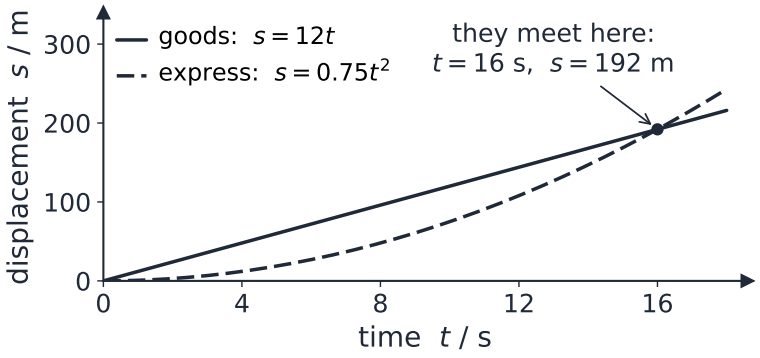
Goods train (constant u_G) and **express** (from rest, accel. a):

$$s_G = u_G t, \qquad s_E = \tfrac{1}{2} a t^2.$$

Level again when $s_G = s_E$: $\quad t = \dfrac{2u_G}{a}$.



Where the two graphs cross, the objects meet



Same s at the same t – that crossing point **is** the meeting: read t off the time axis.

4 Free fall

Sheet 2.1.4 – what you need to know

You must be able to:

- state the facts about g: the same for every mass, also at the top
- use **one sign convention** for a whole flight
- sketch the v–t graph of a thrown or a bouncing object
- explain the effect of air resistance; **describe** how to measure g

What the exam asks

"Show that the maximum height is ..." [2]

"Sketch the variation of v with t from 0 to T." [3]

"State what the gradient represents." [1]

Practise on exercise sheet 2.1.4, then try the real exam questions on past-paper sheet 2.1.4.

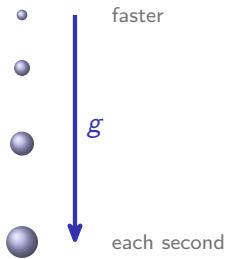
Free fall under gravity

Ignore **air resistance** 空气阻力: **free fall** 自由落体 in a **uniform gravitational field** 匀强重力场 has constant $g \approx 9.81\,\mathrm{m\,s^{-2}}$ downward.

Dropped from rest, falling a height h:

$$h = \tfrac{1}{2}gt^2, \quad v = gt, \quad v^2 = 2gh.$$

> **Same for every mass** – a feather and a hammer fall together in a vacuum and land at the **same speed**.



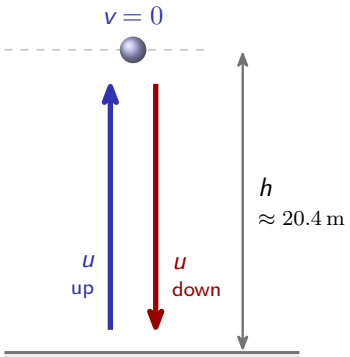
Worked example – greatest height

Thrown straight up at $u = 20\,\mathrm{m\,s^{-1}}$

At the top $v = 0$, so $h = \dfrac{u^2}{2g}$:

$$h = \frac{20^2}{2 \times 9.81} = \frac{400}{19.62} \approx 20.4\,\mathrm{m}.$$

Up and back is **symmetric** 对称: total time $= 2u/g$.



time up = time down = u/g

One sign convention for the whole flight

Choose one direction as positive, usually **up**, and keep it. Then $a = -9.81\,\mathrm{m\,s^{-2}}$ **all the time**.

In the question	**Write**
thrown upwards at $12\,\mathrm{m\,s^{-1}}$	$u = +12\,\mathrm{m\,s^{-1}}$
dropped, or released from rest	$u = 0$
released from something moving at velocity w	$u = w$, not zero
at the greatest height	$v = 0$
back at the level of the throw	$s = 0$
lands $1.5\,\mathrm{m}$ below the throw	$s = -1.5\,\mathrm{m}$

> At the top the velocity is zero, but the acceleration is **not**: it is still $9.81\,\mathrm{m\,s^{-2}}$ downwards.

Worked example – thrown up, lands below

$12\,\mathrm{m\,s^{-1}$ upwards from a hand $1.5\,\mathrm{m}$ above the ground

up positive: $u = +12$, $a = -9.81$, $s = -1.5$

$s = ut + \frac{1}{2}at^2$: $-1.5 = 12\,t - 4.905\,t^2$, so $t = 2.6\,\mathrm{s}$

$v^2 = u^2 + 2as$: $v^2 = 12^2 + 2(-9.81)(-1.5)$, so $v = -13\,\mathrm{m\,s^{-1}}$

The other root is negative, a time before the throw: reject it. The minus sign on v means **moving down**.

Released from something moving

A sandbag leaves a balloon rising at $4.0\,\mathrm{m\,s^{-1}}$, $30\,\mathrm{m}$ up.

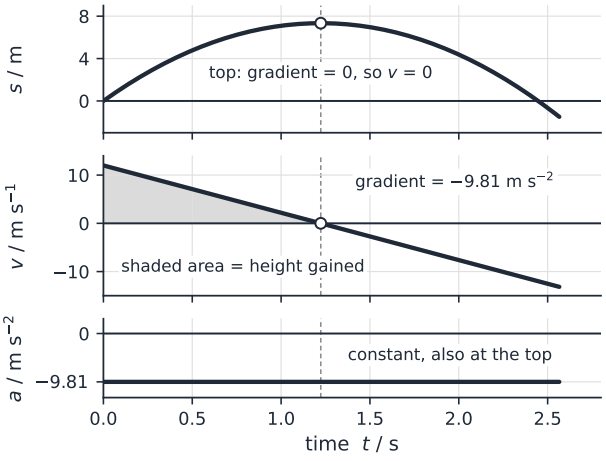
$u = +4.0\,\mathrm{m\,s^{-1}}$, not zero

$s = ut + \frac{1}{2}at^2$:

$-30 = 4.0\,t - 4.905\,t^2$

so $t = 2.9\,\mathrm{s}$ (with $u = 0$: $2.5\,\mathrm{s}$, wrong)

The graphs of a vertical throw

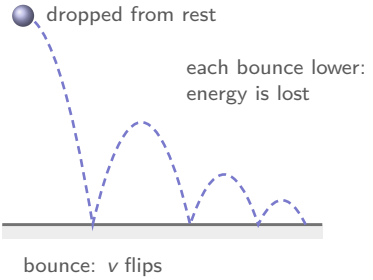


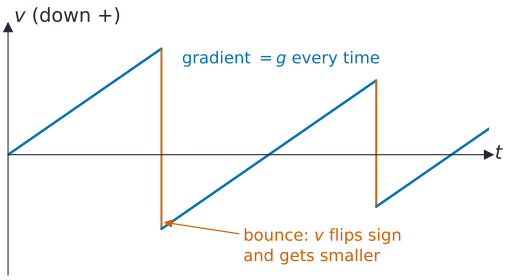
- v–t is **one straight line**, never a V shape: gradient $-9.81\,\mathrm{m\,s^{-2}}$ all the way
- it crosses the time axis **at the top**, where $v = 0$
- area above the axis = height gained; area below = height lost

"State what the gradient represents": the **acceleration** of free fall.

Bouncing ball

Dropped from rest and bouncing – take **down as positive**:



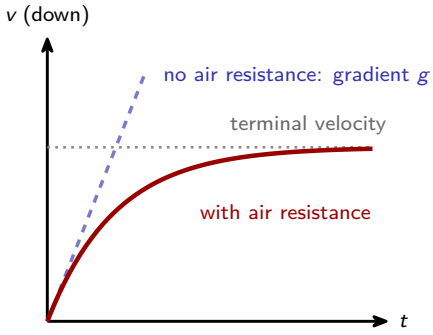


Every line has **gradient** g; at a bounce v **flips sign** and shrinks as **energy** 能量 is lost. Where a line **crosses the time axis** the ball is at its highest point, and that flight's triangle **area** is the bounce height. Add up the times and distances across the bounces.

Falling with air resistance

The equations above assume the **weight** is the only force. When air resistance is **not** negligible:

- **force**: the resultant force is *less* than the weight
- **acceleration**: less than g, and *decreasing*, as air resistance grows with speed
- **motion**: the v–t line curves; its gradient falls to zero at **terminal velocity** 收尾速度 (topic 3)



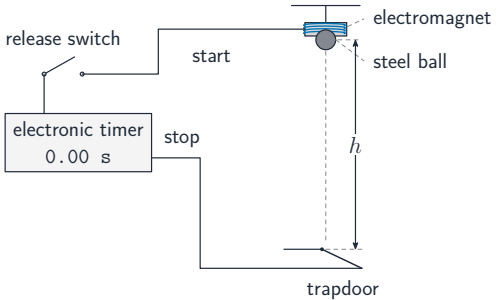
"State and explain": the **force** first, then its effect on the **acceleration**, then on the **motion**.

Experiment – measuring g

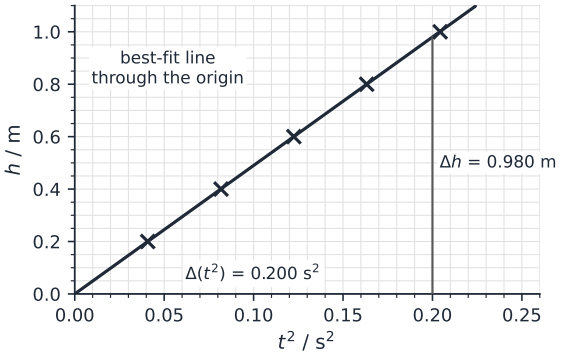
Drop from rest; measure h and t:

$$g = \frac{2h}{t^2}$$

- plot h against t^2: **gradient** $= g/2$, so g is twice the gradient
- repeat ⇒ less **random error** 随机误差
- **light gates** 光电门 or an **electronic timer**: no reaction-time error



Measuring g – from the graph to the answer



- from rest $h = \frac{1}{2}gt^2$: plot h against t^2
- gradient $= \dfrac{0.980}{0.200} = 4.90\,\mathrm{m\,s^{-2}}$
  $g = 2 \times 4.90 = 9.80\,\mathrm{m\,s^{-2}}$
- **uncertainty** 不确定度: add the percentages, and count the time **twice**

Systematic error 系统误差: if the ball leaves after the timer starts, every t is too long. The line **misses the origin**, and g from one reading is too small.

exercises.lol exercises.com.cn

5 Projectiles

Sheet 2.1.5 – what you need to know

You must be able to:

- explain why the horizontal velocity of a projectile is **constant**
- **resolve** the launch velocity into components
- solve a horizontal launch, an angled launch, and a launch at a wall or a target
- give a velocity as a size and an angle; sketch v_H and v_V

What the exam asks

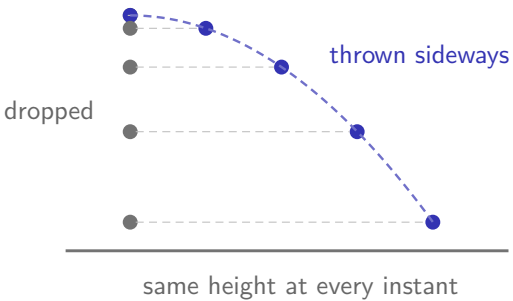
"Show that the time to reach the wall is ..." [2]

"Determine the magnitude and the angle of the velocity." [3]

"Explain why the horizontal component is constant." [1]

Practise on exercise sheet 2.1.5, then try the real exam questions on past-paper sheet 2.1.5.

Two independent motions



A **projectile** 抛体 has two motions that **do not affect each other**:

- **horizontal** 水平: constant velocity
- **vertical** 竖直: free fall at g

Solve each as its own SUVAT problem – linked only by the **time** t.

The method for every projectile question

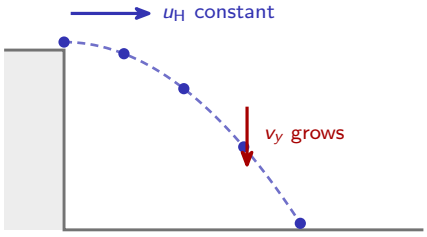
1. **Resolve** the launch velocity: $u\cos\theta$, $u\sin\theta$
2. Find the **time** from the direction you know enough about
3. Use that time in the **other** direction
4. **Combine** v_{H} and v_{V}: a size and an angle

Falls to the ground: the **vertical** motion gives the time. A wall or a target at a known distance: the **horizontal** motion gives the time.

Horizontal throw

- **horizontal**: $x = u_\mathrm{H}\, t$ (constant)
- **vertical**: $y = \frac{1}{2} g t^2$ and $v_\mathrm{V} = gt$ (from rest)
- graphs: v_H is **flat**; v_V is a **straight line** from 0, gradient g

Time to land depends **only on the height** – not on u_H.

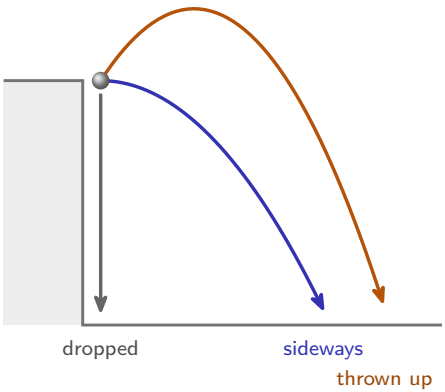


Cliff $h = 20\,\mathrm{m}$, $u_\mathrm{H} = 15\,\mathrm{m\,s^{-1}}$

$t = \sqrt{2h/g} \approx 2.0\,\mathrm{s}$

range $= u_\mathrm{H} t \approx 30\,\mathrm{m}$

Comparing throws from the same height



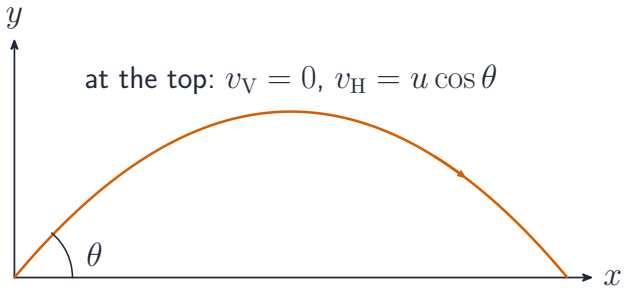
- **dropped** and **thrown sideways** at the same moment: they **land together**, because their vertical motions are identical
- thrown with an **upward component**: it **lands later** – it must rise and come back to the start height first
- the same launch speed in *any* direction gives the **same landing speed**: kinetic energy gained = potential energy lost (topic 5)

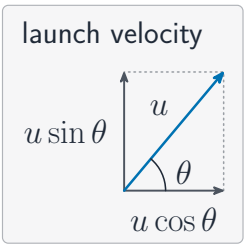
Launched at an angle

Resolve the launch speed u into **components** 分量:

- $u_{\mathrm{H}} = u\cos\theta$ – **stays constant**
- $u_{\mathrm{V}} = u\sin\theta$ – **falls to** 0 at the top

Time to the top: $t = \dfrac{u\sin\theta}{g}$.

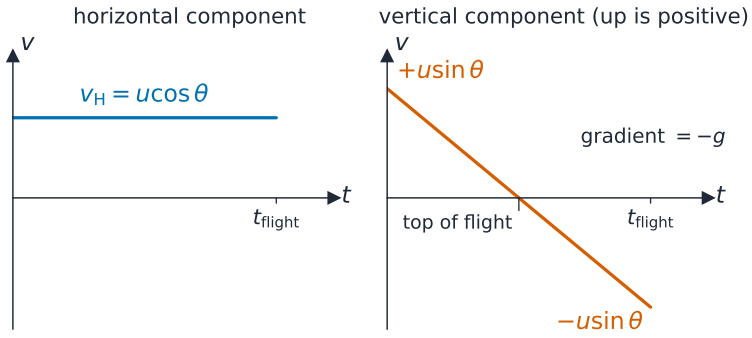




Sketching the velocity graphs

Examiners often ask you to sketch both components against time. Take **upwards as positive**:

- v_{H}: a **flat line** at $u\cos\theta$ for the whole flight
- v_{V}: a **straight line** of gradient $-g$, from $+u\sin\theta$ through **zero at the top** to $-u\sin\theta$ on landing



Label each line, mark where it starts and stops, and put the zero crossing exactly at t_{up}.

Worked example – a "show that" question

$18\,\mathrm{m\,s^{-1}}$ at $60°$: show that it is highest at $t = 1.6\,\mathrm{s}$

$u_V = 18\sin 60° = 15.6\,\mathrm{m\,s^{-1}}$

At the top $v_V = 0$. Use $v = u + at$ with $a = -9.81\,\mathrm{m\,s^{-2}}$:

$$0 = 15.6 - 9.81\,t$$

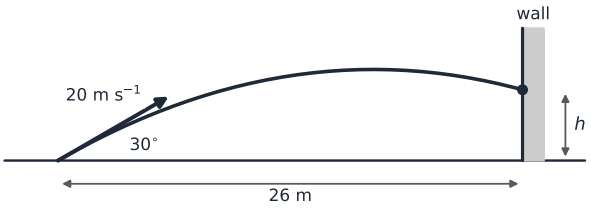
$$t = \frac{15.6}{9.81} = 1.59\,\mathrm{s} \approx 1.6\,\mathrm{s}$$

The answer is given, so the marks are for the **method**:

- state the **equation**
- substitute **every value**, with its unit
- give **one more significant figure** than the value quoted

> Reaching the quoted value proves nothing on its own.

Worked example – reaching a wall



The distance to the wall is horizontal, so the **horizontal** motion gives the time.

Time, then height

$u_H = 20\cos 30° = 17.3\,\mathrm{m\,s^{-1}}$

$x = u_H t$:

$t = 26/17.3 = 1.50\,\mathrm{s}$

$u_V = 20\sin 30° = 10.0\,\mathrm{m\,s^{-1}}$

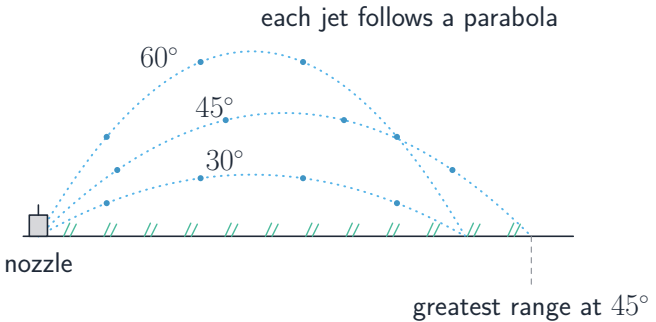
$y = u_V t + \frac{1}{2}at^2$:

$h = 15.0 - \frac{1}{2}(9.81)(1.50)^2 = 4.0\,\mathrm{m}$

At the wall $v = u + at$ gives $v_V = -4.7\,\mathrm{m\,s^{-1}}$: already **coming down**.

Every projectile traces a parabola

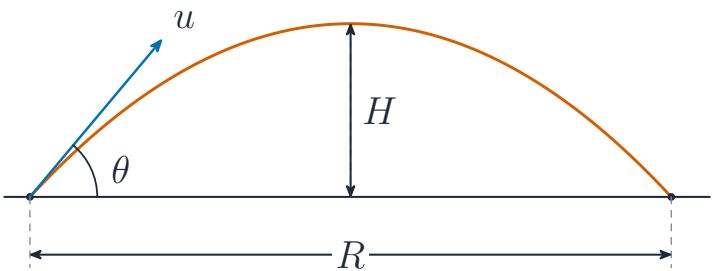
Constant horizontal velocity with constant vertical acceleration gives a **parabola** – the same curve for a sprinkler, a ball or a shell.



Range and maximum height

From level ground, back to the same height:

- **total flight time** $= 2\,t_{\text{up}}$
- **range** 射程 $R = u_{\text{H}} \times$ flight time
- greatest range at $\theta = 45°$



What changes the flight – and what does not

- **Why is the horizontal velocity constant?** No horizontal force acts on the projectile, so it has **no horizontal acceleration**.
- **A greater mass** changes nothing: the acceleration of free fall is the same for every mass, so the time, the height and the range stay the same.
- **Displacement or distance?** The displacement is the straight line from launch to landing, $\sqrt{x^2 + y^2}$. It is **shorter** than the distance along the curved path.

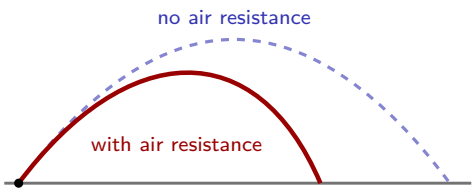
> These are one-mark and two-mark "state and explain" parts. Give the **reason**, not only the result.

Projectiles with air resistance

With air resistance, a projectile:

- has a **shorter range**
- reaches a **lower maximum height**
- is **not symmetrical**: it comes down more steeply than it went up

> The acceleration keeps changing, so **SUVAT does not apply** – only the graph methods work.



6 Putting it together

Solving any kinematics problem

1. **Draw** a diagram; mark + direction
2. **List** the SUVAT symbols & signs
3. **Pick** the equation with your 4 symbols
4. **Projectiles:** split H & V, linked by t

5. **check** the units and the size of your answer

Exam tips

- Use the **SUVAT** equations only for **constant acceleration**; list s, u, v, a, t and pick the equation missing your unknown.
- Choose one direction as **positive** and keep signs consistent (usually $g = -9.81$ m s^{-2}).
- On a **velocity-time graph**, gradient = acceleration and area = displacement.
- For projectiles, treat **horizontal (constant velocity) and vertical ($a = g$) motion separately**, linked by the same time.

Common mistakes

✗ The mistake	✓ What is right
"The heavier ball lands first."	Without air resistance both fall with the **same acceleration** and land at the **same speed**.
Taking the gradient of a v–t graph when the question wants the area (or the reverse).	**Gradient** = acceleration; **area** = displacement.
Drawing a curve on a v–t graph for constant acceleration.	Constant acceleration is a **straight line**; at a bounce only the sign of v changes.
$g = +9.81\,\mathrm{m\,s^{-2}}$ for a ball thrown up, with up positive.	$a = -9.81\,\mathrm{m\,s^{-2}}$ for the **whole flight** – on the way down too.
Using SUVAT while the acceleration changes.	With air resistance or a curved graph, **only the graph methods** work.

7 Recap

Topic 2 – key takeaways

1 Vectors

displacement, velocity, acceleration have **direction**

2 Graphs

gradient & **area** read off velocity and displacement

3 SUVAT

four equations for **uniform acceleration**

4 Projectiles

split into **independent** H and V motions

Check yourself

1. What does the **area** under a v–t graph give?
2. A stone dropped from rest falls for $3\,\mathrm{s}$ – how far?
3. Two balls, one dropped, one thrown sideways – which lands first?
4. Best launch angle for maximum range?

Try all four first – the answers appear on the next slide.

Check yourself

1. What does the **area** under a v–t graph give?
   $\Rightarrow$ **displacement**

2. A stone dropped from rest falls for $3\,\mathrm{s}$ – how far?
   $\Rightarrow h = \frac{1}{2}gt^2 = \frac{1}{2} \times 9.81 \times 3^2 \approx$ **44 m**

3. Two balls, one dropped, one thrown sideways – which lands first?
   $\Rightarrow$ **same time** – their vertical motions are identical

4. Best launch angle for maximum range?
   $\Rightarrow 45^\circ$ – level ground, no air resistance