Cambridge IGCSE · Physics 0625 · Notes

Motion

Read online at **pastopic.com/cambridge/physics-0625/notes/motion**

Last checked 29 September 2026

Read first: **Physical quantities and measurement techniques**

© 2026 Pastopic. Free for personal study. Please share the link, not the file.

What you need to know

By the end of this topic you should be able to:

1. **Define speed** as the distance travelled per unit time, and recall and use $v = \frac{s}{t}$.
2. **Define velocity** as speed in a given direction.
3. **Recall and use** average speed $= \frac{\text{total distance travelled}}{\text{total time taken}}$.
4. **Sketch, plot and interpret** distance–time and speed–time graphs.
5. **Say when an object is at rest, moving at constant speed, accelerating or decelerating**, from data or from the shape of a distance–time or speed–time graph.
6. **Calculate speed from the gradient** of a straight part of a distance–time graph.
7. **Calculate the distance travelled from the area under a speed–time graph**, for motion at constant speed or with constant acceleration.
8. **State that the acceleration of free fall,** g, near the Earth's surface is roughly constant and is about $9.8\ \mathrm{m/s^2}$.
9. **Extended only:** define acceleration as the change in velocity per unit time, and recall and use $a = \frac{\Delta v}{\Delta t}$.
10. **Extended only:** tell from data or from the shape of a speed–time graph when an object has a constant acceleration and when its acceleration is changing.
11. **Extended only:** calculate acceleration from the gradient of a speed–time graph.
12. **Extended only:** know that a deceleration is a negative acceleration, and use this in calculations.
13. **Extended only:** describe how objects fall in a uniform gravitational field, with and without air (or liquid) resistance, including terminal velocity.

Forces, $F = ma$, and kinetic and potential energy often appear in the same exam questions. They belong to the Forces and Energy topics.

Understand it

Speed

Speed tells you how much distance is covered in each unit of time:

$$\text{speed} = \frac{\text{distance}}{\text{time}}, \qquad v = \frac{s}{t}.$$

A runner who covers 400 m in 50 s has a speed of $400 \div 50 = 8.0$ m/s. Rearranged, the same equation gives $s = vt$ and $t = \frac{s}{v}$.

The SI unit is m/s. Road speeds are often in km/h: 1 km/h is 1000 m in 3600 s, so **divide km/h by 3.6 to get m/s** (72 km/h = 20 m/s) and multiply m/s by 3.6 to get km/h. Always put distance and time in matching units before dividing: minutes into seconds ($\times 60$), km into m ($\times 1000$).

Velocity

Velocity is speed in a given direction. "15 m/s" is a speed; "15 m/s due north" is a velocity. Speed is a scalar (size only); velocity is a vector (size and direction). A car going round a bend at a steady 15 m/s has a constant speed but a **changing velocity**, because its direction keeps changing. When a question asks for a velocity, give the direction too.

Average speed

Few journeys run at one steady speed, so we use

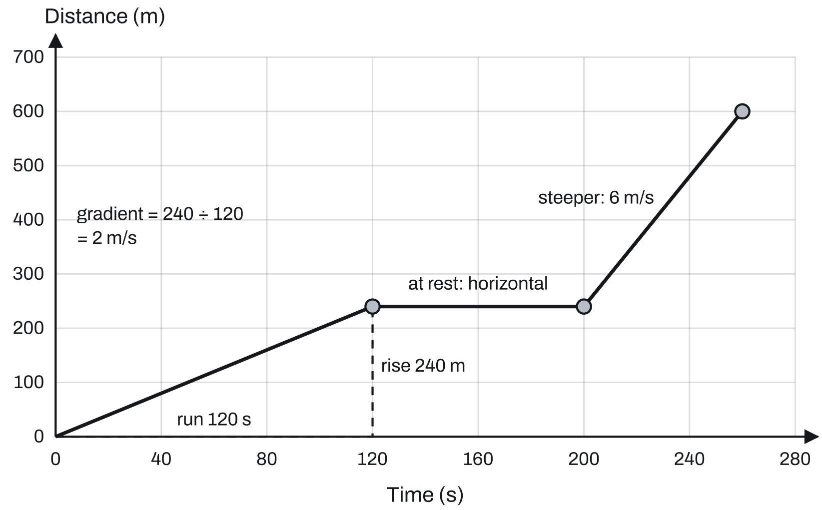
$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}.$$

Include the time spent stopped. A cyclist rides at 5 m/s for 20 s, then at 2 m/s for 30 s. The total distance is $5 \times 20 + 2 \times 30 = 160$ m in a total of 50 s, so the average speed is $160 \div 50 = 3.2$ m/s. It is **not** the mean of the two speeds, $(5 + 2) \div 2 = 3.5$ m/s, because more time was spent at the slower speed.

Distance–time graphs

A distance–time graph shows how far an object has gone (or how far it is from a starting point) at each moment.

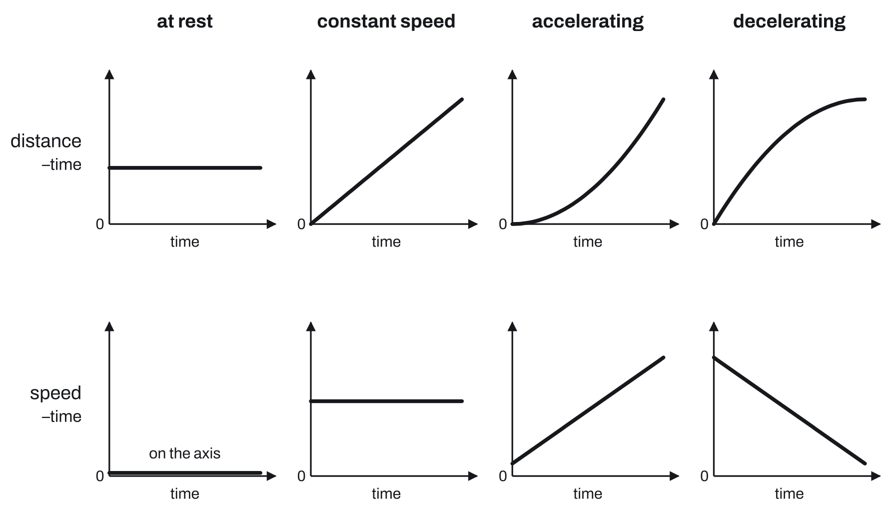
- **Gradient = speed.** The steeper the line, the faster the object.
- A **straight sloping line** means a constant speed.
- A **horizontal line** means the object is **at rest** (the distance is not changing).
- A **curve getting steeper** means the speed is increasing (accelerating); a **curve getting less steep** means it is slowing down (decelerating).



To find the speed from a straight section, pick two points far apart on it and work out $\frac{\text{rise}}{\text{run}} = \frac{\text{change in distance}}{\text{change in time}}$. In the graph, the first section gives $240 \div 120 = 2$ m/s, and the last gives $(600 - 240) \div (260 - 200) = 360 \div 60 = 6$ m/s. The walker is at rest for $200 - 120 = 80$ s. The average speed for the whole walk is $600 \div 260 = 2.31$ m/s.

Speed–time graphs

A speed–time graph shows how fast the object is going at each moment. **The same shapes mean different things** on the two kinds of graph, so always read the axis labels first.



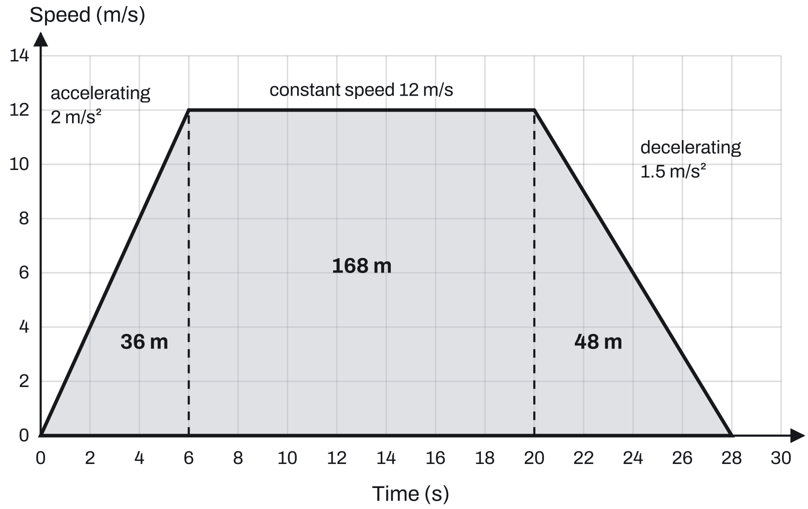
Distance–time: gradient = speed. Speed–time: gradient = acceleration, area = distance.

On a speed–time graph:

- a line **along the time axis** (speed zero) means at rest;
- a **horizontal line** above the axis means constant speed;
- a line **sloping up** means accelerating; a line **sloping down** means decelerating;
- the **steeper** the slope, the bigger the acceleration or deceleration;

- the **area under the graph is the distance travelled**.

The area rule works because distance = speed × time: under a horizontal line the area is a rectangle, speed × time. Under a straight sloping line from u to v, the average speed is $\frac{u+v}{2}$, so the distance is $\frac{u+v}{2} \times t$, which is exactly the area of the trapezium (or triangle, if it starts from rest).



Split the area into simple shapes:

- triangle: $\frac{1}{2} \times 6 \times 12 = 36$ m;
- rectangle: $(20 - 6) \times 12 = 14 \times 12 = 168$ m;
- triangle: $\frac{1}{2} \times (28 - 20) \times 12 = 48$ m.

Total distance $= 36 + 168 + 48 = 252$ m. (As one trapezium: $\frac{1}{2} \times (14 + 28) \times 12 = 252$ m.) The average speed is $252 \div 28 = 9$ m/s.

Acceleration

Extended only: acceleration is the change in velocity per unit time:

$$a = \frac{\Delta v}{\Delta t} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}.$$

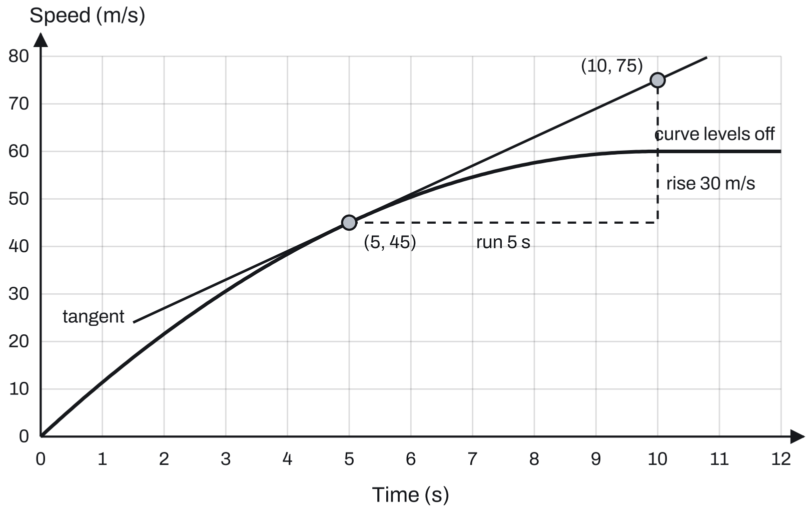
Its unit is m/s² (metres per second, per second). An acceleration of 2 m/s² means the velocity grows by 2 m/s every second. In the graph above, the speed rises by 12 m/s in 6 s, so $a = 12 \div 6 = 2$ m/s². **The gradient of a speed–time graph is the acceleration.**

Extended only: a **deceleration is a negative acceleration**: the velocity is decreasing. In the last section, the speed goes from 12 m/s to 0 in 8 s: $a = \dfrac{0 - 12}{8} = -1.5$ m/s², a deceleration of 1.5 m/s². "Deceleration of 1.5 m/s²" and "acceleration of -1.5 m/s²" say the same thing. A deceleration is **not** "an acceleration that is getting smaller": that is a different idea, shown next.

Constant and changing acceleration

Extended only: a **straight** sloping line on a speed–time graph means **constant** acceleration: the gradient is the same everywhere. A **curved** line means the acceleration is **changing**: if the curve gets less steep, the acceleration is decreasing; if it gets steeper, the acceleration is increasing. From data, constant acceleration means the speed goes up by the **same amount** in each equal time interval.

To find the acceleration at one moment on a curve, draw a **tangent**: a ruled line that just touches the curve at that point and follows its direction. Then find the tangent's gradient using a large triangle.



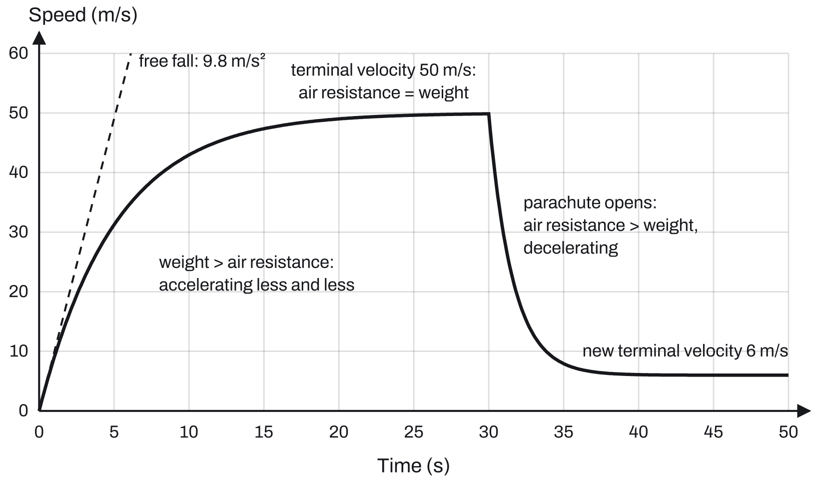
Here the tangent at 5 s passes through $(5, 45)$ and $(10, 75)$, so the acceleration at 5 s is $\dfrac{75-45}{10-5} = \dfrac{30}{5} = 6$ m/s². The curve then levels off: by 10 s the gradient, and so the acceleration, is zero.

Falling objects

Near the Earth's surface, every object falling **without air resistance** has the same acceleration, the **acceleration of free fall**, $g \approx 9.8\ \mathrm{m/s}^2$. It is roughly constant all the way down and **does not depend on the mass**: a heavy stone and a light one dropped together land together. Its speed–time graph is a straight line through the origin with gradient 9.8.

For example, a ball dropped from rest falls freely for 1.5 s. Its speed is then $9.8 \times 1.5 = 14.7$ m/s, and the distance fallen is the area of the triangle, $\frac{1}{2} \times 1.5 \times 14.7 = 11$ m (2 s.f.).

Extended only: with **air resistance** (or liquid resistance, for a ball falling through oil) the story changes, because air resistance grows as the speed grows.



1. **At the start** the speed is zero, so there is no air resistance. The only force is the weight, and the acceleration is g.
2. **As the speed increases**, air resistance increases. The weight stays the same, so the **resultant (downward) force decreases** and the **acceleration decreases**. The graph gets less and less steep.
3. **Eventually** air resistance equals the weight. The resultant force is zero, the acceleration is zero, and the object falls at a **constant speed** called its **terminal velocity**.

Extended only: when a skydiver opens a parachute, the air resistance suddenly becomes **greater than the weight**. The resultant force is upwards, so she decelerates. As she slows, the air resistance falls, the deceleration gets smaller, and when air resistance equals weight again she moves at a new, **lower** terminal velocity. The parachute can never bring her speed to zero, because air resistance needs movement: at a lower speed it would be less than her weight and she would speed up again.

Key facts and formulas

The 0625 exams have no formula sheet, so learn everything here.

Formula	Status
Speed: $v = \frac{s}{t}$, so $s = vt$ and $t = \frac{s}{v}$	Learn it
Average speed $= \dfrac{\text{total distance travelled}}{\text{total time taken}}$	Learn it
Distance–time graph: gradient $=$ speed	Learn it
Speed–time graph: area under the graph $=$ distance travelled	Learn it
Distance at a steady change from u to v: $s = \dfrac{u+v}{2} \times t$ (the trapezium area)	Learn it
Acceleration of free fall: $g \approx 9.8\ \mathrm{m/s^2}$	Learn it
Extended only: acceleration $a = \dfrac{\Delta v}{\Delta t}$, in m/s²	Learn it
Extended only: speed–time graph: gradient $=$ acceleration	Learn it

Formula	Status
Extended only: deceleration $=$ negative acceleration	Learn it

Useful conversions: $1\ \mathrm{km/h} = \frac{1}{3.6}\ \mathrm{m/s}$; $1\ \mathrm{min} = 60\ \mathrm{s}$; $1\ \mathrm{h} = 3600\ \mathrm{s}$; $1\ \mathrm{km} = 1000\ \mathrm{m}$.

Graph	Gradient means	Area means	Horizontal line means
Distance–time	speed	nothing useful	at rest
Speed–time	acceleration	distance travelled	constant speed

How to do it

In the Paper 1 to 4 questions we have tagged for this topic (145 different questions, 2021–2025; 24 more appear on two papers), the types came up this often. 53 of the 145 questions mix two or more types, so the counts add up to more than 145.

Question type	Questions
Distance from the area under a speed–time graph	48
Reading and describing a speed–time graph	46
Falling objects, free fall and terminal velocity	31
Speed and average speed	28
Acceleration and deceleration	27
Distance–time graphs	22
Definitions: speed, velocity, acceleration	17
Drawing or sketching a motion graph	6

1. Distance from the area under a speed–time graph (48 questions)

1. **Mark the time interval** the question asks about, for example "between 20 s and 35 s", not the whole graph.
2. **Split the area** under the line in that interval into rectangles and triangles (or use one trapezium).
3. **Read the values carefully** from the axes: check what one small square is worth, and the units (m/s, cm/s, or minutes on the time axis).
4. **Work out each area** (rectangle: base × height; triangle: $\frac{1}{2}\times$ base × height) and add them.
5. Give the unit: m/s × s gives m.

For example, a speed rising steadily from 4 m/s to 10 m/s in 5 s covers $\frac{1}{2} \times (4 + 10) \times 5 = 35$ m.

Variations you will meet:

- **"Which quantity is the area under a speed–time graph?"** The distance travelled.
- **"Show that the distance is ..."**: write the area calculation with the numbers, then the answer to one more significant figure than the one given (for example 2.46 m for "show that it is about 2.5 m").
- **Comparing distances** (multiple choice): the section or the object with the larger area went further, even if its speed was lower at the end.
- **Height of a fall** from the speed–time graph of a falling object: the height is the area.
- **Time in minutes** on the axis: change it to seconds first when the speed is in m/s.
- **Velocity–time graphs with a negative part**: area above the axis is movement one way, area below is movement back. Equal areas mean the object is back where it started.

2. Reading and describing a speed–time graph (46 questions)

1. **Read a speed**: go up from the time to the line, then across to the speed axis. Draw these lines on the graph if asked "show how you obtained".
2. **Describe the motion** of a section using exact phrases:
   - line up from the axis: **accelerating** (speed increasing); add "constant acceleration" if it is straight;
   - horizontal: **constant speed** (give the value, for example "constant speed of 12 m/s");
   - line down: **decelerating** (speed decreasing);
   - on the time axis: **at rest** (stationary).
3. **Compare sections**: a steeper line means a greater acceleration or deceleration.

Variations you will meet:

- **Match letters to descriptions**, or name the section with the largest acceleration: the steepest upward line.
- **Maximum speed**: the highest point on the graph.
- **Two graphs on one set of axes**: the steeper one has the greater acceleration; say "steeper gradient" as the reason.
- **Extended only: constant or changing acceleration.** A straight line is constant acceleration; a curve is changing acceleration. A curve that flattens out means the acceleration is decreasing; a curve getting steeper means it is increasing.
- **Data in a table** instead of a graph: equal rises in speed in equal times mean constant acceleration; the same speed each time means constant speed.
- **No resultant force**: a horizontal section (constant speed) shows the forces are balanced.

3. Falling objects, free fall and terminal velocity (31 questions)

Without air resistance (Core and Extended):

1. The acceleration is constant, about 9.8 m/s^2, for every mass. The speed increases steadily; the speed–time graph is a straight line; an acceleration–time graph is a horizontal line.

2. Objects dropped together from the same height land together. From a greater height the object falls for longer and reaches a higher speed, so its **average** speed is greater.

With air resistance (Extended):

1. **Start**: only weight acts, so it accelerates at g.
2. **Speed increases** → air resistance increases → resultant force decreases → acceleration decreases.
3. **Air resistance = weight** → resultant force zero → acceleration zero → constant speed, the **terminal velocity**.

Write these as a chain of short statements, one idea per statement: each link usually earns a mark.

Variations you will meet:

- **Which row is correct?** At terminal velocity the velocity is constant and the acceleration is zero; before that the velocity increases and the acceleration is positive but decreasing. The weight stays constant throughout; the air resistance increases.
- **Initial and final accelerations**: g at the start, zero at the end.
- **The parachute opens**: air resistance becomes greater than weight, so the skydiver decelerates to a lower terminal velocity. Label points on a speed–time graph: acceleration zero on a horizontal part, negative on a downward part, decreasing where the upward curve flattens.
- **A ball falling through oil**: the same story with liquid resistance; the ball and the oil also warm up slightly, because of friction.
- **A ball thrown upwards** with air resistance: its speed falls faster going up than it rises coming down, and it lands slower than it was thrown.
- **The speed after falling** from rest for a time t: $v = 9.8 \times t$; the distance is the area of the triangle.
- **A ball thrown straight up, no air resistance** (Extended): it decelerates at 9.8 m/s² all the way up and is momentarily at rest at the top. Time to the top $= u \div 9.8$, where u is the launch speed. The height is the area of the triangle under the speed–time graph, $\frac{1}{2} \times t \times u$. For a ball thrown up at 19.6 m/s: $t = 19.6 \div 9.8 = 2.0$ s and height $= \frac{1}{2} \times 2.0 \times 19.6 = 19.6$ m.
- **A drop through a known height** (Extended): the speed is $v = 9.8t$ and the height is the triangle area, $\frac{1}{2} \times t \times 9.8t = 4.9t^2$. Find the t that makes this equal the height (solve, or try values), then $v = 9.8t$. For a 20 m drop: $4.9t^2 = 20$ gives $t = 2.02$ s, so $v = 9.8 \times 2.02 = 19.8$ m/s. Checking a trial value: $t = 2.0$ s gives $4.9 \times 2.0^2 = 19.6$ m, just under 20 m.

4. Speed and average speed (28 questions)

1. **Write the equation in words**: average speed $=$ total distance $\div$ total time.
2. **Convert units** so they match: minutes to seconds, km to m, or leave as km and h if the answer is in km/h.
3. **Substitute and calculate**, with a unit.

For example, a car travels at 36 km/h. In m/s that is $36 \div 3.6 = 10$ m/s.

Variations you will meet:

- **Two stages at different speeds**: find each distance (speed × time) and each time, then total distance ÷ total time. Never average the two speeds.
- **"Which quantity does the driver calculate?"** Total distance ÷ total time on a winding road is the **average speed**, not the velocity (the direction keeps changing).
- **Distance or time from a speed**: $s = vt$, $t = s \div v$. A train 90 m long passing a person at 30 m/s takes $90 \div 30 = 3.0$ s: the distance is the train's own length.
- **Time on a stop-watch** such as 2 minutes 15 seconds: change to seconds first (135 s).
- **Which runner was fastest?** Compare distance ÷ time for each, or the time for the same distance (the shortest time is fastest).
- **What must be measured?** The total distance (with a tape measure or trundle wheel) and the total time (with a stop-watch).

5. Acceleration and deceleration (27 questions)

1. **Find the change in speed**: final $-$ initial.
2. **Divide by the time taken**: $a = \dfrac{\Delta v}{\Delta t}$, unit m/s².
3. **On a graph**, this is the gradient of the speed–time line. For a curve, draw a tangent at the time asked, make a large triangle on it, and divide rise by run.
4. **For a deceleration**, the change in speed is negative; give the size and call it a deceleration (or give a negative acceleration).

For example, a car slowing from 18 m/s to rest in 4.0 s has $a = \dfrac{0 - 18}{4.0} = -4.5$ m/s², a deceleration of 4.5 m/s².

Variations you will meet:

- **Find the final speed or the time**: rearrange, $\Delta v = a \times t$ and $t = \dfrac{\Delta v}{a}$. Starting at 12 m/s and accelerating at 3.0 m/s² for 4.0 s gives $12 + 3.0 \times 4.0 = 24$ m/s.
- **Speed at the start of a steady deceleration**: a car that stops in 6.0 s at 2.5 m/s² was going $2.5 \times 6.0 = 15$ m/s, and its average speed while braking is $(15 + 0) \div 2 = 7.5$ m/s.
- **Greatest acceleration and deceleration** from a graph: the steepest upward and downward lines; work out each gradient.
- **Tangent at a point**: the tangent must touch, not cross, the curve at exactly that time. Use two points on the tangent that are far apart.
- **Units in km/h**: change to m/s first (divide by 3.6), for example 108 km/h = 30 m/s.
- **Next step with $F = ma$**: many questions go on to find the resultant force. That is in the Forces topic; the acceleration you find here goes straight into it.

6. Distance–time graphs (22 questions)

1. **Read the axes**: a distance from a starting point against time.

2. **Speed of a straight section** $= \dfrac{\text{change in distance}}{\text{change in time}}$, the gradient.
3. **Describe each section**: sloping straight line, constant speed; horizontal, at rest; steeper, faster.

For example, a line rising 1500 m in 300 s shows a constant speed of $1500 \div 300 = 5$ m/s.

Variations you will meet:

- **How long was it stopped?** The length of the horizontal section on the time axis.
- **Which section is fastest?** The steepest one; give "steepest gradient" as the reason.
- **Going back home**: the line slopes **down** towards zero distance; the speed is still change in distance ÷ change in time (ignore the minus sign).
- **Curves**: getting steeper means accelerating; getting less steep means decelerating.
- **Matching a speed–time graph to a distance–time graph**: constant speed becomes a straight slope; steady acceleration from rest becomes a curve getting steeper; at rest becomes a horizontal line.
- **"Which graph could show a train at rest?"** A horizontal line is at rest on a distance–time graph but moving at constant speed on a speed–time graph: check the axis.
- **Positions at equal time intervals** (dots or photos): equal gaps mean constant speed; growing gaps mean accelerating; shrinking gaps mean decelerating.

7. Definitions: speed, velocity, acceleration (17 questions)

Learn these in your own words, each with its key phrase:

- **Speed**: distance travelled **per unit time**.
- **Velocity**: speed **in a given direction** (velocity is a vector, speed is a scalar).
- **Acceleration** (Extended): **change in velocity per unit time**, or the rate of change of velocity.
- **Deceleration** (Extended): a **negative acceleration**, or a decrease in velocity per unit time.

Variations you will meet:

- **"State the difference between velocity and speed"**: velocity has a direction; speed doesn't.
- **"Determine the velocity"** of a cyclist moving north at 15 m/s: 15 m/s **north**, both parts.
- **"Describe what happens to the velocity"** of a car going round a bend at constant speed: its direction changes, so the velocity changes.

8. Drawing or sketching a motion graph (6 questions)

1. **Label the axes** if they are not labelled, with units.
2. **Plot the given points** accurately, then join them with **ruled straight lines** for constant speed or constant acceleration.
3. For a sketch, show the **shape** correctly: straight where the acceleration is constant, curved where it changes, horizontal where the speed is constant.

Variations you will meet:

- **Add a section to a graph**: for a van slowing steadily from 16 m/s to 4 m/s in 6 s from $t = 30$ s, draw a straight line from $(30, 16)$ to $(36, 4)$.
- **A constant speed drawn on a speed–time graph**: a horizontal line at that speed for the stated time.
- **Sketch a speed–time graph from a description**: speeding up as a rising line, then the other parts in order, keeping the times right.
- **Extended only: sketch an acceleration–time graph** from a speed–time curve: where the speed–time graph gets less steep, the acceleration line falls.
- **Distance–time from a description**: constant speed is a straight line; steady acceleration from rest is a curve getting steeper, joining smoothly onto the straight part.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A student cycles to school. She rides 1200 m in 240 s, waits at traffic lights for 60 s, then rides the last 900 m in 150 s.

(a) Calculate her speed in the first part of the journey. **[3]**

(b) State what the distance–time graph looks like while she waits at the lights. **[1]**

(c) Calculate her average speed for the whole journey. **[3]**

(d) State which part of the journey would have the steepest line on a distance–time graph. Give a reason. **[2]**

(a) speed $= \dfrac{\text{distance}}{\text{time}}$ **C1** $= \dfrac{1200}{240}$ **C1** $= 5.0$ m/s **A1**

(b) A horizontal line (the distance does not change while she is at rest). **B1**

(c) Total distance $= 1200 + 900 = 2100$ m; total time $= 240 + 60 + 150 = 450$ s, including the wait. **C1**

Average speed $= \dfrac{2100}{450}$ **C1** $= 4.67 \approx 4.7$ m/s **A1**

(d) The last part **B1**: its speed is $900 \div 150 = 6.0$ m/s, the highest, and the gradient of a distance–time graph is the speed. **B1**

Example 2

A tram starts from rest. Its speed increases steadily to 15 m/s in 10 s. It then travels at 15 m/s for 40 s, and then slows steadily to rest in 12 s.

(a) Sketch the speed–time graph for the journey, with values on the axes. **[2]**

(b) Calculate the total distance travelled. **[4]**

(c) Calculate the average speed of the tram. **[2]**

(d) **Extended only.** Calculate the acceleration at the start and the deceleration at the end. **[3]**

(a) Straight line from $(0, 0)$ to $(10, 15)$; horizontal line at 15 m/s to $(50, 15)$; straight line down to $(62, 0)$. **B1** for the shape, **B1** for the values.

(b) Distance $=$ area under the graph. **C1**

- speeding up: $\frac{1}{2} \times 10 \times 15 = 75$ m
- steady: $40 \times 15 = 600$ m
- slowing: $\frac{1}{2} \times 12 \times 15 = 90$ m **C1** for the correct shapes and values

Total $= 75 + 600 + 90$ **C1** $= 765$ m **A1**. (As one trapezium: $\frac{1}{2} \times (40 + 62) \times 15 = 765$ m.)

(c) Total time $= 10 + 40 + 12 = 62$ s. Average speed $= 765 \div 62$ **C1** $= 12.3$ m/s **A1**

(d) Acceleration $= \dfrac{\Delta v}{\Delta t} = \dfrac{15 - 0}{10}$ **C1** $= 1.5$ m/s² **A1**

Deceleration $= \dfrac{15}{12} = 1.25$ m/s² (an acceleration of -1.25 m/s²). **B1**

Example 3

This question is **Extended only**.

A car travels at 25 m/s. The driver sees a hazard, and 0.70 s later applies the brakes. The car then decelerates uniformly at 5.0 m/s² until it stops.

(a) Calculate the distance travelled in the 0.70 s before the brakes are applied. **[2]**

(b) Calculate the time taken to stop once the brakes are applied. **[2]**

(c) Calculate the braking distance, and the total stopping distance. **[3]**

(a) Constant speed, so $s = v \times t$ **C1** $= 25 \times 0.70 = 17.5$ m **A1**

(b) $t = \dfrac{\Delta v}{a}$ **C1** $= \dfrac{25}{5.0} = 5.0$ s **A1**

(c) The speed falls steadily from 25 m/s to 0, so the distance is the triangle under the speed–time graph (or average speed × time): $\frac{1}{2} \times 5.0 \times 25$ **C1** $= 62.5$ m **A1**

Stopping distance $= 17.5 + 62.5 = 80$ m **B1**

Example 4

This question is **Extended only**. It refers to the skydiver's speed–time graph in "Understand it".

(a) State the acceleration of the skydiver at the moment she leaves the aircraft, and explain why. **[2]**

(b) Explain, in terms of forces, why her speed stops increasing. **[3]**

(c) She falls at her terminal velocity of 50 m/s for 12 s before opening the parachute. Calculate the distance she falls in this time. **[2]**

(d) Describe and explain her motion after the parachute opens. **[3]**

(a) 9.8 m/s^2 **B1**: at zero speed there is no air resistance, so the only force is her weight. **B1**

(b) As her speed increases, the air resistance increases **B1**, so the resultant downward force (weight $-$ air resistance) decreases and so does her acceleration **B1**. When the air resistance equals her weight, the resultant force is zero and she falls at constant speed (terminal velocity). **B1**

(c) Constant speed, so distance $= 50 \times 12$ **C1** $= 600$ m **A1**

(d) The air resistance becomes greater than her weight, so there is a resultant upward force and she decelerates **B1**. As she slows, the air resistance decreases, so the deceleration decreases **B1**, until air resistance equals weight again and she falls at a new, lower, constant terminal velocity. **B1**

Common mistakes

- **Using the whole graph, or the wrong interval.** Examiners see areas worked out under the entire graph when the question asked for one section. Mark the start and end times on the graph before you calculate.
- **Distance = speed × time on a sloping section.** On a speed–time graph where the speed is changing, you must use the area (or the **average** speed × time). Multiplying the final speed by the time gives double the answer for a triangle.
- **Mixing up the two kinds of graph.** A horizontal line means at rest on a distance–time graph but constant speed on a speed–time graph. The speed is the gradient of a distance–time graph, not the area under it. Read the axis labels every time.
- **Averaging speeds.** Average speed is total distance ÷ total time. Adding two speeds and halving them is wrong unless the two times are equal.
- **Forgetting to convert units.** Minutes to seconds, km/h to m/s, and hours written as 1 h 20 min $= 1.33$ h, not 1.20 h.
- **"Deceleration means the acceleration is decreasing."** It doesn't: deceleration means the **speed** is decreasing (a negative acceleration). Say which one you mean.
- **Vague descriptions.** "It goes up" or "it moves" earns nothing. Say "accelerating", "constant speed", "decelerating" or "at rest", and use "constant acceleration" for a straight sloping line.

- **Thinking the speed still increases at terminal velocity.** At terminal velocity the speed is constant and the acceleration is zero; the forces are balanced. More candidates in one year chose "still increasing" than the right answer.
- **Saying the weight changes as it falls.** The weight stays the same; it is the **air resistance** that increases with speed.
- **No tangent.** When a question says "draw a tangent", the working mark needs the tangent drawn on the graph; a chord between two points on the curve is not a tangent.
- **Speed instead of velocity.** "Determine the velocity" needs a direction as well as the number.

How to get the marks

- **Write the equation, then substitute, then answer.** Calculations are marked with a C1 for the equation (in symbols or words), another for the numbers substituted, and A1 for the answer. A correct method with a slip still scores.
- **Units.** Give m/s for speed, m/s^2 for acceleration, m for distance, unless the answer line already shows the unit. Some questions ask you to "include the unit" and give a mark for it.
- **Significant figures.** 2 or 3 significant figures is usual. Keep the full value in your calculator until the end.
- **"Show that"**: give every step, and a final value to more significant figures than the one printed.
- **"Describe the motion"**: one clear phrase per section, with the speed value if it is constant ("constant speed of 12 m/s").
- **"State and explain which …"**: name the answer (car X), then give the graph evidence ("its line is steeper").
- **"Explain in terms of forces"** (Extended): name both forces (weight and air resistance), say which is bigger, say what happens to the resultant force, and link it to the acceleration. Short linked statements, in order.
- **Reading a graph**: read to half a small square; when asked, draw lines on the graph to show where you read the value.
- **Tangents**: a long, ruled line touching at the right time; the gradient uses two points on the tangent, far apart.
- **Multiple choice**: work the answer out first. The wrong options are the results of the usual slips: area of the whole graph, the mean of two speeds, forgetting to convert minutes.

Quick check

1. A cheetah runs 150 m in 6.0 s. Calculate its average speed.
2. A bus travels at a constant 54 km/h. Convert this to m/s, and find how far the bus travels in 2 minutes.
3. A trolley's speed increases steadily from 0.4 m/s to 1.6 m/s in 3.0 s. Calculate the distance it travels in this time. **Extended only:** calculate its acceleration.
4. A walker covers 3.0 km in 40 minutes, rests for 20 minutes, then walks 2.0 km in 20 minutes. Calculate her average speed in km/h.

5. **Extended only.** Ignore air resistance. (a) A stone is dropped from rest from a high bridge and falls freely for 2.5 s. Calculate its speed after 2.5 s and the distance it falls in that time. (b) A ball is thrown vertically upwards at 12 m/s. Calculate the time it takes to reach its highest point, and its maximum height.

Answers

1. $v = \dfrac{s}{t} = \dfrac{150}{6.0} = 25$ m/s.
2. $54 \div 3.6 = 15$ m/s. In 2 minutes $= 120$ s: $s = 15 \times 120 = 1800$ m.
3. Area of the trapezium: $\frac{1}{2} \times (0.4 + 1.6) \times 3.0 = 3.0$ m. Acceleration $= \dfrac{1.6 - 0.4}{3.0} = 0.4$ m/s².
4. Total distance $= 5.0$ km; total time $= 40 + 20 + 20 = 80$ min $= \frac{80}{60}$ h. Average speed $= 5.0 \div \frac{80}{60} = 3.75$ km/h (the rest counts in the total time). In m/s: $5000 \div 4800 = 1.04$ m/s.
5. (a) $v = 9.8 \times 2.5 = 24.5$ m/s. Distance = area of the triangle $= \frac{1}{2} \times 2.5 \times 24.5 = 30.6$ m, about 31 m. (b) The ball decelerates at 9.8 m/s² until its speed is zero: $t = 12 \div 9.8 = 1.22$ s. Height = area of the triangle $= \frac{1}{2} \times 1.22 \times 12 = 7.35$ m, about 7.3 m (using the unrounded time).

Past questions to try

- **0625/33/O/N/24 Q1**: describing a speed–time graph, the area, then average speed from a stop-watch time.
- **0625/32/O/N/24 Q1**: reading a distance–time graph of a walk with stops.
- **0625/42/O/N/21 Q1**: changing acceleration, a tangent, and the area under the graph (Extended).
- **0625/41/M/J/24 Q1**: a ball falling through oil, its acceleration and a tangent (Extended).