

Reading journeys from motion graphs

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: On a distance-time graph the gradient is the speed, and a flat line means the object is stationary. On a velocity-time graph the gradient is the acceleration and the area under the line is the distance travelled. Splitting shapes into rectangles and triangles lets you calculate these quantities.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** IGCSE 1.2

What does a distance-time graph show?

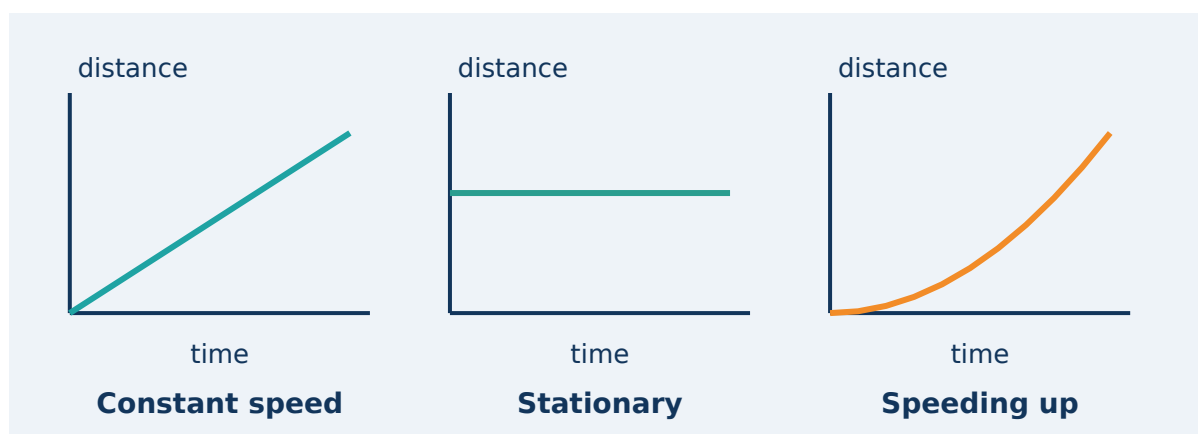
A motion graph turns a journey into a picture. On a **distance-time graph** the time is on the horizontal axis and the distance from the start is on the vertical axis. The shape of the line tells you how the object moved.

Definition

A motion graph plots how the distance from a starting point, or the velocity of an object, changes with time. Reading it means turning the shape of the line into a description of the journey.

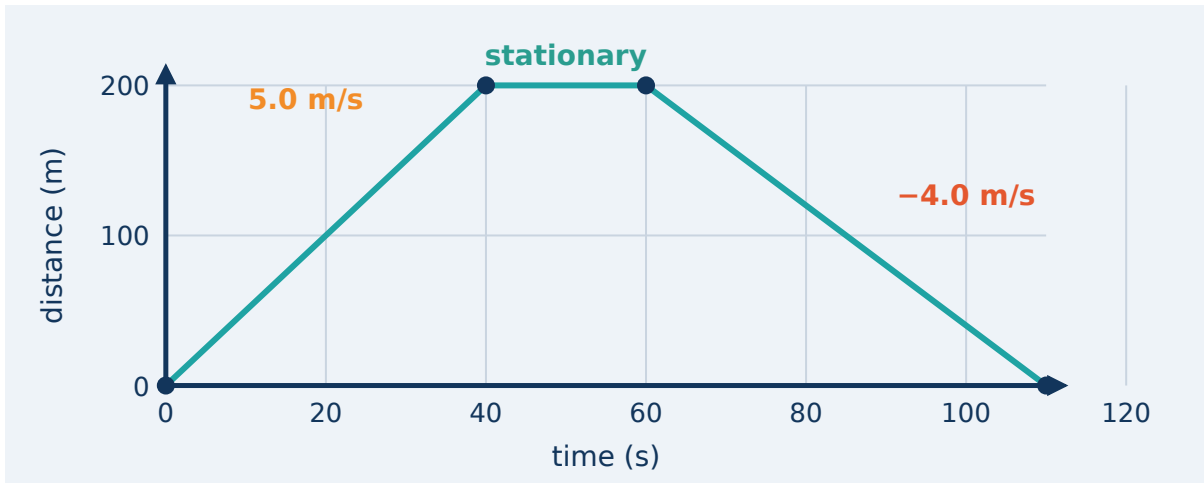
Key law

On a distance-time graph, the **gradient** (the slope) equals the speed. A steeper line means a faster object, a flat line means it is stationary, and a curve that gets steeper means it is speeding up.



The three basic shapes of a distance-time graph.

To find a gradient, pick two points far apart on the line and use $\text{gradient} = (\text{change in distance}) \div (\text{change in time})$. Wide triangles reduce reading errors.



Aarav's ride: three sections with three different gradients.

Worked example 1

Use the ride above to find Aarav's speed in the first section and on the way back.

First section: gradient = $200\text{ m} \div 40\text{ s} = 5.0\text{ m/s}$. Return: the distance falls by 200 m in $110 - 60 = 50\text{ s}$, so the velocity is $-200 \div 50 = -4.0\text{ m/s}$ and the speed is **4.0 m/s**.

What does a velocity-time graph show?

On a **velocity-time graph** the vertical axis shows velocity. Now the gradient and the area both carry meaning.

Key law

On a velocity-time graph, the **gradient equals the acceleration** and the **area under the line equals the distance travelled** (the displacement, if velocity can be negative).



A motorbike taxi: speeding up, cruising, then slowing to a stop. The shaded area is the distance.

Feature	On a distance-time graph	On a velocity-time graph
Sloping straight line	constant speed	constant acceleration
Horizontal line	stationary	constant velocity (not stopped)

Feature	On a distance-time graph	On a velocity-time graph
Gradient	speed	acceleration
Area under the line	no meaning	distance travelled
Line getting steeper	speeding up	increasing acceleration

Worked example 2

Use the taxi graph. Calculate the acceleration in the first 4.0 s.

$$a = \text{gradient} = (8.0 - 0) \div (4.0 - 0) = 8.0 \div 4.0 = \mathbf{2.0 \text{ m/s}^2}.$$

Worked example 3

Calculate the total distance of the taxi journey and its average speed.

$$\text{Area} = \text{triangle } (\frac{1}{2} \times 4 \times 8 = 16 \text{ m}) + \text{rectangle } (6 \times 8 = 48 \text{ m}) + \text{triangle } (\frac{1}{2} \times 2 \times 8 = 8 \text{ m}) = \mathbf{72 \text{ m}}. \text{ Total time} = 12 \text{ s, so average speed} = 72 \div 12 = \mathbf{6.0 \text{ m/s}}.$$

How do you describe a whole journey from its graph?

Work through the graph one section at a time, from left to right. For each section give the gradient, say whether the object is stationary, moving at constant speed or speeding up, and note the direction. In the ride above, Aarav pedals away at 5.0 m/s, waits for 20 s, and then returns more slowly at 4.0 m/s. Always write the numbers and units, not only words such as fast or slow.

You can also work the other way and sketch a graph from a story. Draw one straight section for each stage, give a steeper line to a faster stage, and make a horizontal section wherever the object waits.

How do you find areas under a velocity-time graph?

Split the shape into rectangles and triangles. A rectangle has area width $\times$ height, and a triangle has area $\frac{1}{2} \times \text{base} \times \text{height}$. Because the horizontal axis is in seconds and the vertical axis in m/s, the area comes out in metres. For a curve, count squares and treat part squares as halves.

Common mistake

A horizontal line on a velocity-time graph does not mean the object has stopped. It means the velocity is constant. An object is at rest only when the line lies on the time axis at zero velocity.

Lina's tip

Before reading numbers, say out loud what the two axes are. Then ask: do I need the gradient or the area? Gradient answers "how fast" or "how quickly", and area answers "how far".

Key points to remember

- Distance-time graph: gradient = speed; flat line = stationary.
- Velocity-time graph: gradient = acceleration (m/s^2).
- Area under a velocity-time graph = distance travelled (m).
- Triangle area = $\frac{1}{2} \times \text{base} \times \text{height}$; rectangle area = width $\times$ height.
- A flat velocity-time line means constant velocity, not rest.

Reading journeys from motion graphs: frequently asked questions

What does the gradient of a distance-time graph represent?

It represents the speed of the object. A steeper line means a higher speed, and a horizontal line means the object is not moving.

How do you find distance from a velocity-time graph?

Find the area between the line and the time axis. Split the shape into rectangles and triangles, calculate each area and add them. The result is in metres.

What does a horizontal line on a velocity-time graph mean?

It means constant velocity, so the acceleration is zero. The object is moving at a steady speed unless the line is at zero, which means it is at rest.

How can a graph show a negative acceleration?

On a velocity-time graph a negative gradient means velocity is decreasing. If the line falls from a positive value to zero, the object is slowing down.

What does a curved distance-time graph tell you?

A changing gradient means a changing speed. A curve that gets steeper shows the object is speeding up, and a curve that flattens shows it is slowing down.