Motion, speed and acceleration

Teacher review edition. Ask your teacher if anything is unclear.

How can an object be moving quickly but have no acceleration?

What you will learn

- Calculate average speed and acceleration.
- Explain the difference between speed and velocity.
- Read distance–time and velocity–time graphs.

Distance and time

> **Distance**
> The total length of the path an object travels.

Distance is the total length of the path travelled. Time is how long the journey takes.

- Measure distance in metres (m) and time in seconds (s).
- For a trolley test, mark a clear start and finish.
- Start timing as the trolley passes the first mark and stop at the second.

Calculating average speed

> **Average speed**
> Total distance travelled divided by total time taken.

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

- Average speed = total distance travelled ÷ total time taken.
- A cyclist travels 150 m in 30 s: average speed = 150 ÷ 30 = 5 m/s.
- This is an average of 5 metres each second.
- An average covers the whole journey. The cyclist could speed up, slow down or stop briefly.

Speed and velocity

> **Velocity**
> Speed in a stated direction, such as 5 m/s east.

- “5 m/s” is a speed; “5 m/s east” is a velocity.

- Constant velocity means the speed and direction both stay the same.
- A car turning a corner changes velocity, even if its speed stays the same.

What is acceleration?

Acceleration
The change in velocity each second, measured in m/s².

Constant velocity
Motion at the same speed in the same direction. The acceleration is zero.

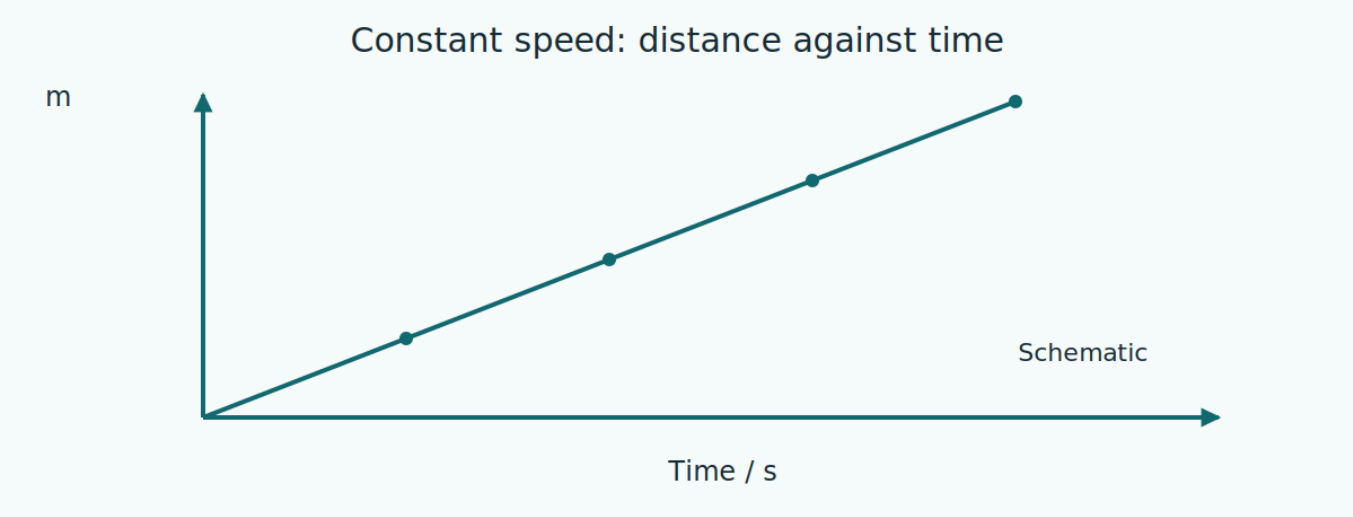
$$\text{acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}}$$

- Speeding up, slowing down and turning all change velocity.
- Constant velocity means zero acceleration.
- For straight-line motion: acceleration = (final velocity - initial velocity) ÷ time.
- The unit is m/s². An acceleration of 2 m/s² means velocity changes by 2 m/s each second.
- If the original direction is positive, slowing down gives a negative acceleration.

Reading a distance-time graph

Distance-time gradient
The slope of a distance-time graph. For total distance travelled, it gives the speed.

- Horizontal axis: time. Vertical axis: total distance travelled.
- Straight rising line: constant speed, with equal distances covered in equal times.
- Steeper line: greater speed.
- Horizontal line: no extra distance travelled, so the object is stopped.
- Line becoming steeper: the object is speeding up.



A straight rising line on a distance-time graph represents constant speed. Its gradient gives speed.

Reading a velocity-time graph

Check the axis labels: a velocity-time graph shows different information from a distance-time graph.

- Horizontal axis: time. Vertical axis: velocity.
- Horizontal line: constant velocity. A line at zero means the object is stopped.
- Gradient: acceleration.
- For motion in the positive direction, a straight rising line means velocity increases by the same amount each second.

Using the same units

Use matching units before calculating.

- Use metres and seconds for answers in m/s or m/s^2.
- To change km/h to m/s, divide by 3.6.
- Example: 72 km/h = 72 ÷ 3.6 = 20 m/s.
- The conversion uses 1 km = 1000 m and 1 hour = 3600 s.

Worked examples

A trolley speeds up from 2 m/s to 8 m/s in 3 s, without changing direction. Find its acceleration.

Work through it

1. Subtract the initial velocity from the final velocity: 8 − 2 = 6 m/s.
2. Divide this change by the time: 6 ÷ 3 = 2 m/s².
3. The trolley's velocity increases by an average of 2 m/s each second.

$$\text{acceleration} = \frac{8 - 2}{3} = 2 \text{ m/s}^2$$

Common mistakes

Common mistake: Using final velocity ÷ time for acceleration when the object was already moving.

Remember: First find the change: final velocity − initial velocity. Then divide by time.

Common mistake: Saying any rising graph means the object is speeding up.

Remember: Check the axes. A straight rising distance–time line shows constant speed.

Answering questions

- Convert speeds to the same unit before calculating a change in velocity.
- For graph questions, name the graph feature and explain it: "The line is horizontal, so the total distance stays constant."

Try an investigation

Mark out a distance on a clear trolley track. Measure the time a trolley takes to travel it, then calculate its average speed. Repeat the run and compare the results. A video or light gates can help with timing.

Plan, record and review

- Question and prediction: What are you testing, and what do you think will happen? Give a reason.
- Change, measure, keep the same: What will you deliberately change? What will you measure, and in what units? What stays the same to make it a fair test? For an observation, say what you will record consistently instead.
- Record and look for a pattern: Use a table with headings and units. Look for a pattern or a result that does not fit.
- Conclude from evidence: Answer your question using a result or observation. Say if the evidence is unclear.
- Improve the investigation: What would you repeat or change, and how would that make the evidence better?

Do practical work with your teacher and follow the laboratory safety instructions.