The distance–time relationship

6.5.4.1.4 · Physics · revision notes

A distance–time graph shows how far an object is from a point as time goes on. You need to draw them from measurements, describe motion from their shape, find speed from the gradient and, on the Higher tier, find the speed of an accelerating object by drawing a tangent.

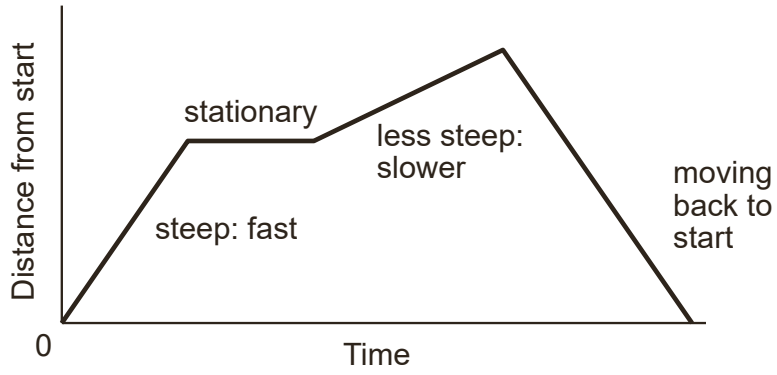
Key facts

- Distance–time graph: gradient = speed
- Straight sloping line = constant speed
- Curve getting steeper = accelerating; getting less steep = decelerating
- Grade 8+ only Speed at an instant = gradient of the tangent at that time
- Horizontal line = stationary
- Steeper line = greater speed
- Average speed = total distance ÷ total time

Notes

Reading a distance–time graph

- Distance is on the y-axis and time is on the x-axis.
- A **horizontal** line means the object is stationary: its distance is not changing.
- A **straight sloping** line means the object is moving at a constant speed. The steeper the line, the greater the speed.
- If distance is measured from a starting point, a line sloping back down towards the time axis means the object is moving back towards the start.



Reading a distance–time graph: the gradient is the speed.

Speed from the gradient

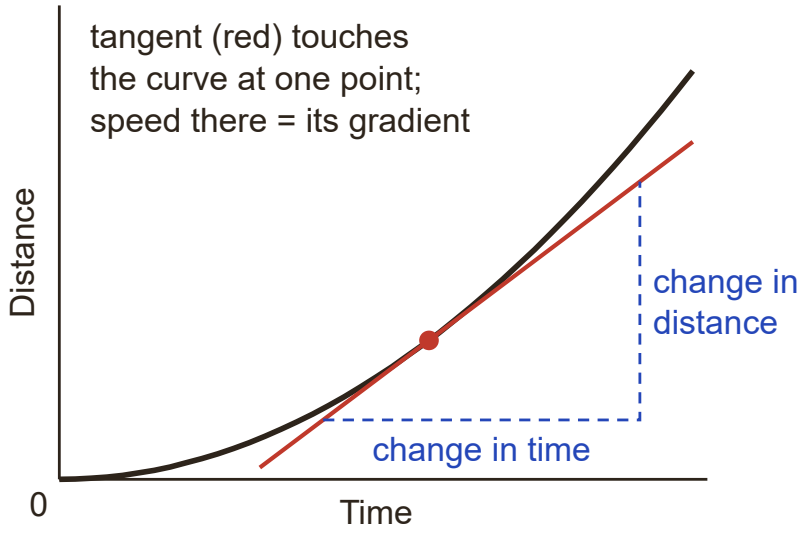
- Speed = gradient = change in distance ÷ change in time.
- Use two points far apart on a straight section and draw a large triangle.
- Example: from (2 s, 10 m) to (6 s, 34 m), speed = (34 − 10) ÷ (6 − 2) = 24 ÷ 4 = 6 m/s.
- Average speed = total distance travelled ÷ total time. If the graph shows distance from the start, add the lengths of all outward and return sections to find total distance.

Curved lines: changing speed

- A curve that gets **steeper** shows that the object is **accelerating**.
- A curve that gets **less steep** shows that the object is **decelerating**.

Speed at an instant Grade 8+ only

- If an object is accelerating, you can find its speed at a particular time by drawing a **tangent** to the curve at that time.
- A tangent is a straight line that just touches the curve at that point, with the same slope as the curve there.
- Draw the tangent long, then calculate its gradient using a large triangle. This gradient is the speed at that instant.



Speed at an instant = change in distance ÷ change in time, read from a large triangle on the tangent.

Drawing the graph

- Put time on the x-axis and distance on the y-axis. Label both axes with units.
- Choose scales that use more than half the grid, plot the points accurately, then draw a line of best fit (a straight line or a smooth curve).

How to answer each type of question

Describe the motion shown by a graph

2 to 3 marks | Grade 3

1. Describe each section in turn.
2. Use the words stationary, constant speed, accelerating or decelerating.
3. Compare sections: 'faster than', 'slower than'.

Example. A distance–time graph for a jogger has three sections. A: a steep straight line. B: a horizontal line. C: a straight line that is less steep than A.
Describe the motion of the jogger in each section.

Model answer.

A: constant speed	(1)
B: stationary	(1)
C: constant speed, slower than in A	(1)

Calculate speed from the gradient

2 marks | Grade 5

1. Read two points on the straight line, far apart.
2. Speed = change in distance ÷ change in time.
3. Give the unit (usually m/s).

Example. The distance–time graph for a cyclist is a straight line from 0 m at 0 s to 450 m at 90 s.
Calculate the speed of the cyclist.

Model answer.

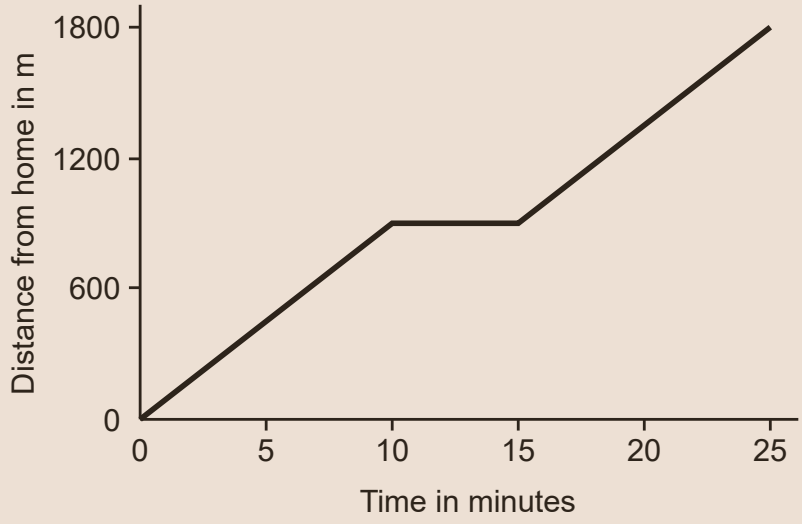
speed = 450 ÷ 90	(1)
speed = 5.0 m/s	(1)

Calculate an average speed from a graph

3 marks **Grade 6**

1. Read the total distance and the total time from the graph.
2. Convert the units if needed.
3. Average speed = total distance ÷ total time.

Example. The distance–time graph shows a walk. The walker walks away from home along a straight path and stops for a 5-minute rest.



Calculate the average speed of the walker over the 25 minutes, in m/s.

Model answer.

from the graph: 1800 m in 25 min; t = 25 × 60 = 1500 s (1)

average speed = 1800 ÷ 1500 (1)

= 1.2 m/s (1)

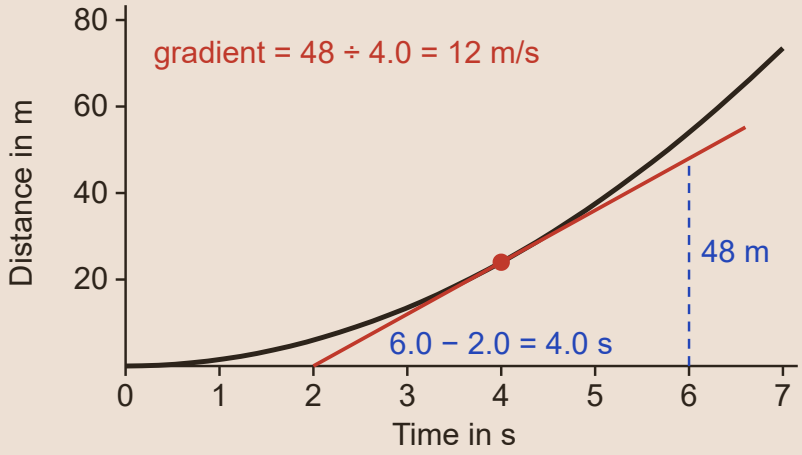
Draw a tangent to find the speed at an instant

3 to 4 marks | Grade 8

1. Draw a straight line that just touches the curve at the time given.
2. Choose two points far apart on the tangent.
3. Gradient of the tangent = speed at that time.

Example. A car accelerates from rest and its distance–time graph is a curve. A student draws a tangent to the curve at t = 4.0 s. The tangent passes through (2.0 s, 0 m) and (6.0 s, 48 m). Determine the speed of the car at t = 4.0 s.

Model answer.



tangent drawn touching the curve at 4.0 s (1)

gradient = (48 − 0) ÷ (6.0 − 2.0) (1)

speed = 12 m/s (1)

Don’t lose marks

- Mixing up distance–time and velocity–time graphs: on a distance–time graph a horizontal line means stationary.
- On a curve, dividing the distance by the time at one point (which gives an average speed) instead of drawing a tangent.
- Using a time axis in minutes but giving the gradient in m/s without converting.
- Drawing a 'tangent' that cuts through the curve instead of just touching it.

More tips

Memory tricks

- Flat = stopped. Steep = fast.
- Gradient = rise ÷ run = distance ÷ time = speed.
- Use a big triangle for gradients: it reduces reading errors.
- Tangent tip: tilt your ruler until the gaps between the ruler and the curve look the same on both sides of the point.

Exam technique

- Draw your gradient triangle on the graph and write down the values you read.
- When describing motion, use the key words stationary, constant speed, accelerating and decelerating, and compare sections.
- Check the axis units: time may be in minutes or hours, and distance in km.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Describe motion from a distance–time graph**
A horizontal line means stationary; a straight sloping line means constant speed.

Grade 4 — **Plot a distance–time graph from data**
Time on the x-axis, distance on the y-axis, labelled axes with units and sensible scales.

Grade 4 — **Recognise acceleration and deceleration on a distance–time graph**
A curve getting steeper shows acceleration; a curve getting less steep shows deceleration.

Grade 5 — **Calculate speed from the gradient**
Speed = change in distance ÷ change in time for a straight section.

Grade 6 — **Calculate average speed from a graph**
Read the total distance and total time, then divide.

Grade 8 — **Find speed at an instant using a tangent**
Draw a tangent to the curve at that time and calculate its gradient.

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