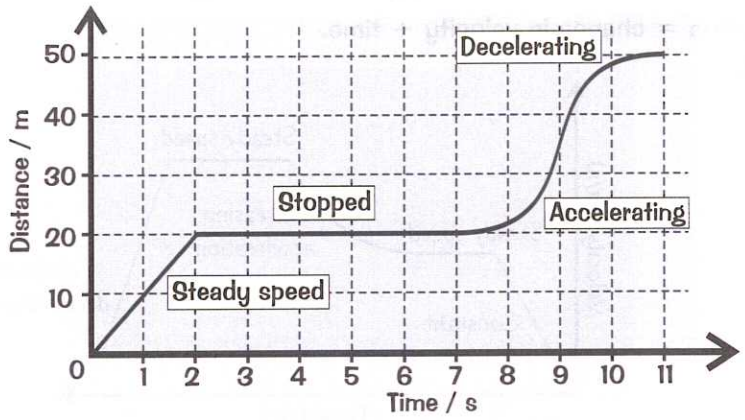
Distance/Time Graphs

A graph speaks a thousand words, so it's much better than writing 'An object starts from rest and moves at a steady speed of 10 m/s for 2 s until it has reaches a distance of 20 m, then remains stationary for 5 s before increasing its velocity with a constant acceleration for 2.5 s.'

Distance/Time Graphs Tell You How Far Something has Travelled



The different parts of a distance/time graph describe the motion of an object:

- The gradient (slope) at any point gives the speed of the object.
- Flat sections are where it's stopped.
- A steeper graph means it's going faster.
- Curves represent acceleration.
- A curve getting steeper means it's speeding up (increasing gradient).
- A levelling off curve means it's slowing down (decreasing gradient).

The Speed of an Object can be Found From a Distance/Time Graph

You can find the speed at any time on a distance/time graph:

1) If the graph is a straight line, the speed at any point along that line is equal to the gradient of the line.

For example, in the graph above, the speed at any time between 0 s and 2 s is:

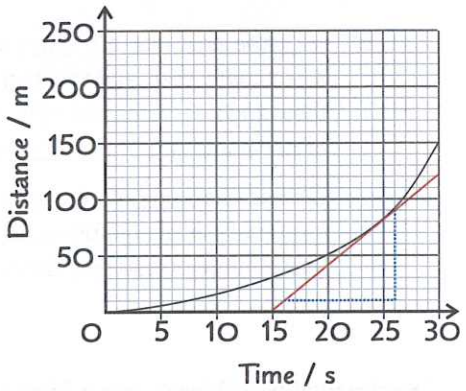
$$\text{Speed} = \text{gradient} = \frac{\text{change in the vertical}}{\text{change in the horizontal}} = \frac{20}{2} = 10 \text{ m/s}$$

A tangent is a line that is parallel to the curve at that point.

2) If the graph is curved, to find the speed at a certain time you need to draw a tangent to the curve at that point, and then find the gradient of the tangent.

3) You can also calculate the average speed of an object when it has non-uniform motion (i.e. it's accelerating) by dividing the total distance travelled by the time it takes to travel that distance.

EXAMPLE: The graph shows the distance/time graph for a cyclist on his bike.
Calculate:
a) the speed of the bike 25 s into the journey.
b) the average speed of the cyclist from 0 to 30 s.



a) Draw the tangent to the curve at 25 s (red line).
Then calculate the gradient of the tangent (blue lines).

$$\text{gradient} = \frac{\text{change in the vertical}}{\text{change in the horizontal}} = \frac{80}{10} = 8 \text{ m/s}$$

b) Use the formula from page 145 to find the average speed of the bike.

$$\text{average speed} = \text{distance} \div \text{time} = 150 \div 30 = 5 \text{ m/s}$$

Tangent — a man who's just come back from holiday...

For practice, try sketching distance/time graphs for different scenarios. Like walking home or running from a bear.

Q1 Sketch a distance/time graph for an object that initially accelerates, then travels at a constant speed, then decelerates to a stop. [2 marks]

Velocity/Time Graphs

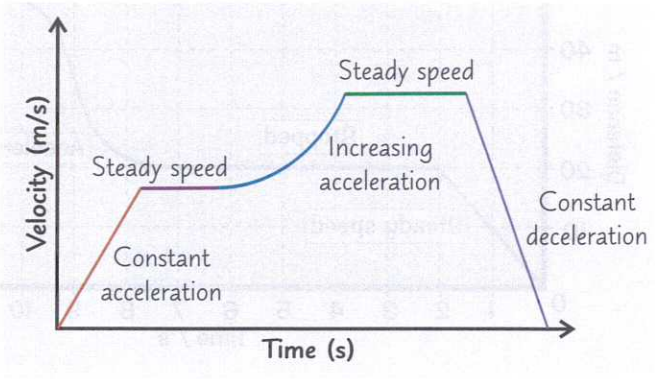
Huzzah, more graphs — velocity/time graphs this time. These look a lot like the distance/time graphs on page 147, so make sure you check the labels on the axes really carefully. You don't want to mix them up.

Velocity/Time Graphs can have a Positive or Negative Gradient

How an object's velocity changes over time can be plotted on a velocity/time (or *v*/*t*) graph.

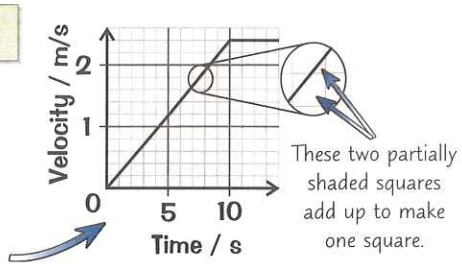
1) Gradient = acceleration, since acceleration = change in velocity ÷ time.
2) Flat sections represent a steady speed.
3) The steeper the graph, the greater the acceleration or deceleration.
4) Uphill sections (/) are acceleration.
5) Downhill sections (\) are deceleration.
6) A curve means changing acceleration.

If the graph is curved, you can use a tangent to the curve (p.147) at a point to find the acceleration at that point.



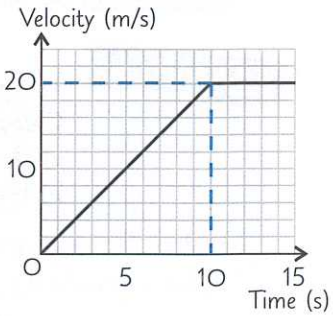
The Distance Travelled is the Area Under the Graph

1) The area under any section of the graph (or all of it) is equal to the distance travelled in that time interval.
2) For bits of the graph where the acceleration's constant, you can split the area into rectangles and triangles to work it out.
3) You can also find the area under the graph by counting the squares under the line and multiplying the number by the value of one square.



EXAMPLE: The velocity/time graph of a car's journey is plotted.

a) Calculate the acceleration of the car over the first 10 s.
b) How far does the car travel in the first 15 s of the journey?



a) This is just the gradient of the line:

$a = (v - u) \div t$
$= (20 - 0) \div 10 = 2\ m/s^2$

b) Split the area into a triangle and a rectangle, then add together their areas — remember the area of a triangle is ½ × base × height.

Area = (½ × 10 × 20) + (5 × 20)
= 200 m

Or find the value of one square, count the total number of squares under the line, and then multiply these two values together.

1 square = 2 m/s × 1 s = 2 m
Area = 100 squares
= 100 × 2 = 200 m

Understanding motion graphs — it can be a real uphill struggle...

Make sure you know the differences between distance/time and velocity/time graphs, and how to interpret them.

Q1 A stationary car starts accelerating increasingly for 10 s until it reaches a speed of 20 m/s. It travels at this speed for 20 s until the driver sees a hazard and brakes. He decelerates uniformly, coming to a stop 4 s after braking.
a) Draw the velocity/time graph for this journey. [3 marks]
b) Using the graph, calculate the deceleration of the car when it brakes. [2 marks]

Distance/Time Graphs

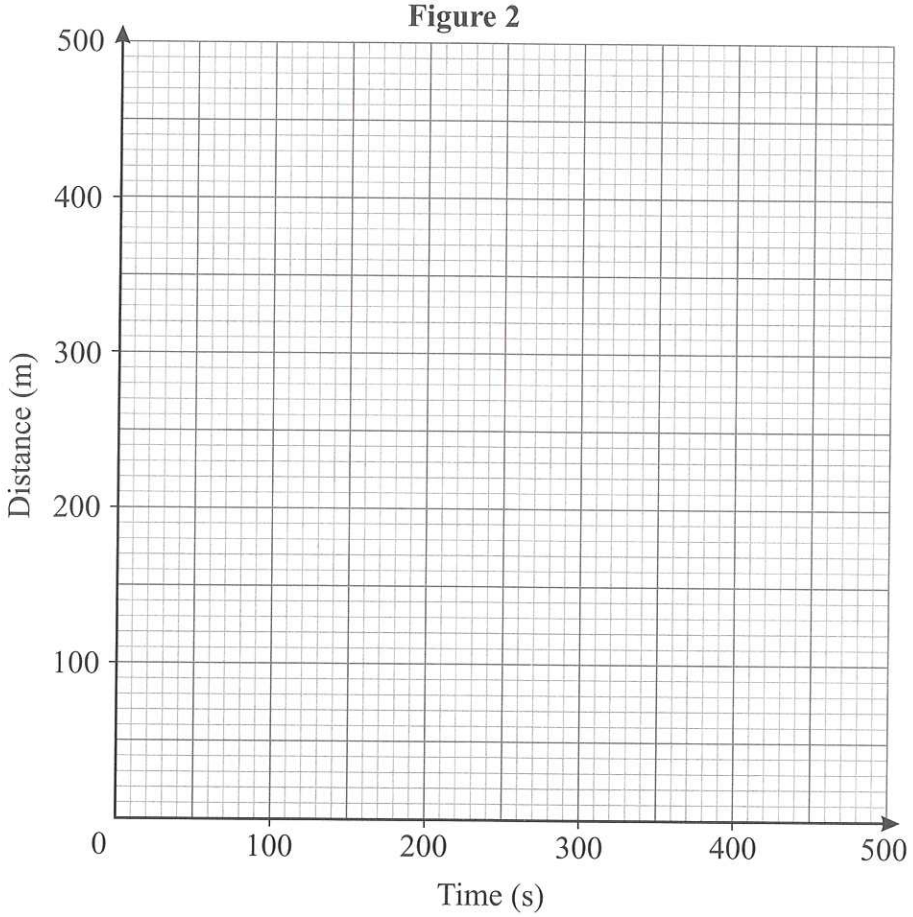
1 A boat is being rowed along a straight canal. Some students time how long after setting off the boat passes marker posts spaced 100 metres apart. **Figure 1** shows their results.

Grade 6–7

Figure 1

Distance (m)	0	100	200	300	400	500
Time (s)	0	85	165	250	335	420

Figure 2



a) Draw the distance/time graph for the results in **Figure 1** on the axes shown in **Figure 2**.

[3]

b) Using **Figure 2**, determine how far the boat travelled in 300 s.

Distance = ... m

[1]

c) Determine the time taken for the boat to travel 250 m, using **Figure 2**.

Time = ... s

[1]

d) The students take the timings using a stopwatch. Suggest **one** way the students can make their measurements are as accurate as possible.

.....

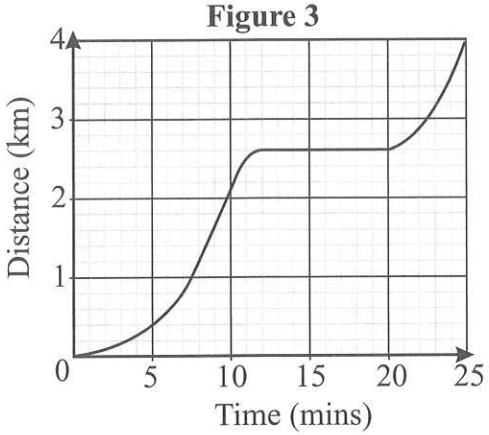
.....

[1]

[Total 6 marks]

2 **Figure 3** shows the distance/time graph for a cyclist's bike ride. Grade 6-7

Figure 3



a) Determine how long the cyclist rode for before stopping for a rest.

.....

[1]

b) Describe the cyclist's motion in the first five minutes of her journey.

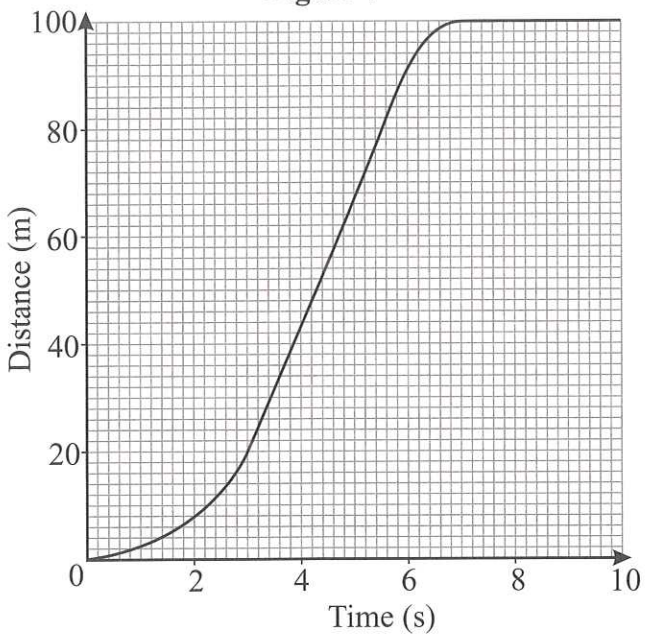
.....

[1]

[Total 2 marks]

3 **Figure 4** shows the distance/time graph for a car's journey. Grade 7-9

Figure 4



a) Use **Figure 4** to find the speed of the car 5 s into its journey.

Speed = ... m/s

[3]

b) Use **Figure 4** to find the speed of the car 2 s into its journey.

Speed = ... m/s

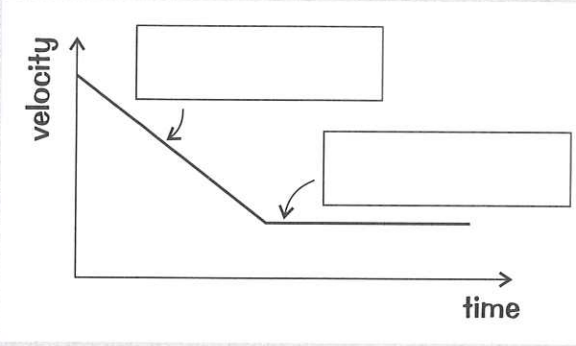
[3]

[Total 6 marks]

Velocity/Time Graphs

Warm-Up

Use two of the phrases from the list below to correctly label the velocity/time graph.



decreasing deceleration
steady speed
decreasing acceleration
constant acceleration
constant deceleration

1 Velocity/time graphs can be used to show the motion of an object. Grade 4-6

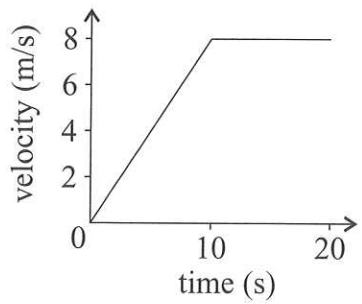
Which quantity is represented by the area under a velocity/time graph?

- ☐ **A** speed
- ☐ **B** acceleration
- ☐ **C** distance
- ☐ **D** deceleration

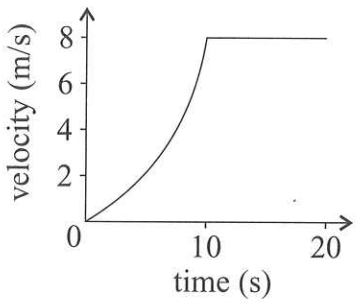
[Total 1 mark]

2 A bear runs with a constant acceleration for 10 s before running at a constant velocity of 8 m/s for a further 10 s. Which of the following velocity/time graphs shows this? Grade 6-7

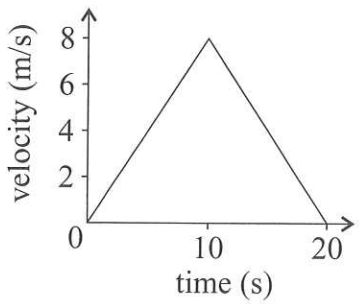
☐ **A**



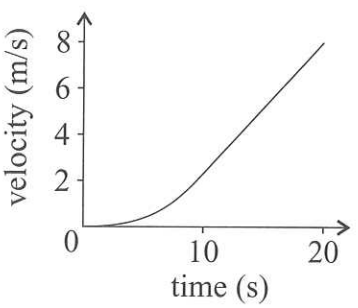
☐ **B**



☐ **C**



☐ **D**

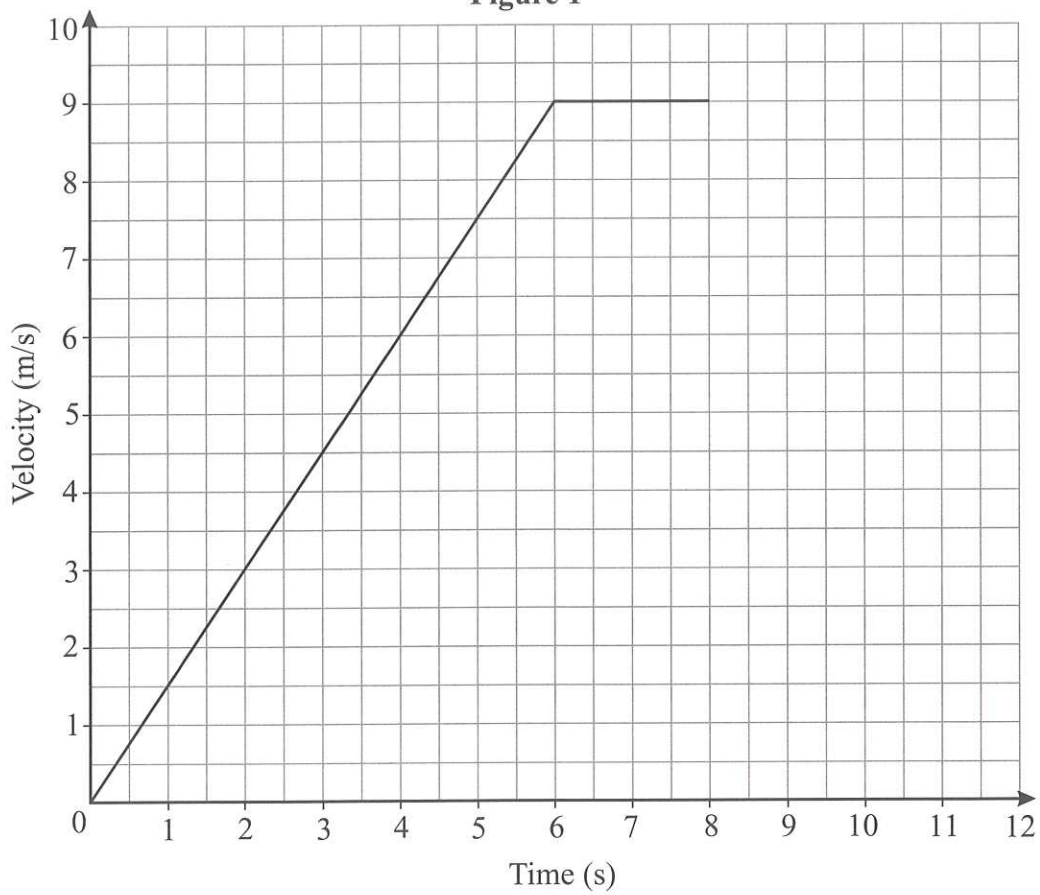


[Total 1 mark]

3 **Figure 1** shows an incomplete velocity/time graph for a rollercoaster ride.

Grade 7–9

Figure 1



a) After 8 seconds, the rollercoaster decelerates at an increasing rate.
It comes to rest 4 seconds after it begins decelerating.
Complete the velocity/time graph in **Figure 1** to show this.

[2]

b) Calculate the acceleration of the rollercoaster during the first 6 seconds of the ride.

Acceleration = ... m/s^2
[2]

c) Calculate the distance travelled by the rollercoaster between 0 and 8 s.

Distance = ... m
[3]

d) Estimate the distance travelled by the rollercoaster between 8 and 12 seconds, to the nearest metre.

Distance = ... m
[3]

[Total 10 marks]