Section 1: Displacement and distance

Notes and Examples

These notes contain subsections on

- **Displacement and distance: definitions**
- **Velocity and speed: definitions**

Displacement and distance: definitions

Displacement is the shortest route between two points. A distance and direction are needed. It is a vector quantity.

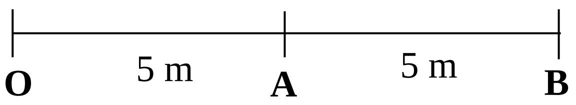
Position describes the location of something relative to a fixed point. This fixed point is usually referred to as the origin. Like displacement, a distance and direction are needed. It is a vector quantity.

The **distance** between two points involves no direction. It is just the physical distance between the chosen points. It is a scalar quantity.

The **distance travelled** between two points does not have to be the same as the distance between two points, described above. If you take a route which is not direct, them the distance travelled will be greater than the direct distance between the two points. Distance travelled is a scalar quantity.

To highlight the differences in the concepts of displacement, position, distance and distance travelled, look at Example 1 below.

Example 1



An object starts from A and travels to the right to B, then back through A to O and then back through A to stop at B.
Write down
(i) The final displacement of the object
(ii) The final position of the object
(iii) The distance between its starting and finishing points
(iv) The total distance travelled by the object

Solution
(i) The final displacement from its initial position at A is 5 m to the right.
(ii) Its final position is 10 m right of O.
(iii) The distance between its starting and finishing points (A and B) is 5 m.
(iv) The total distance travelled is 25 m: 5 m from A to B, 10 m from B to O and another 10 m from O to B.

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Velocity and speed: Definitions

Speed is a scalar quantity; it just has a particular size, e.g. 5 ms^{-1}. No direction is given or implied. Speeds are always positive.

Velocity is a vector quantity. It must have a size and a direction, e.g. 6 ms^{-1} upwards.

Velocities can be either positive or negative.

Average speed $= \dfrac{\text{total distance travelled}}{\text{total time taken}}$

Average velocity $= \dfrac{\text{total displacement}}{\text{total time taken}}$

From these formulae it is possible to see why average velocity can be negative if the resultant displacement is negative, whereas the total distance travelled will always be positive.

You can also find velocities as gradients of distance- time graphs (see p8).

Displacement-time graphs

A displacement-time graph can be very useful in solving problems. Note the following points:

- The gradient of a displacement-time graph is given by
  $$\frac{\text{change in displacement}}{\text{time}}$$
  which is equal to the velocity.
- A straight line on a displacement-time graph indicates that the velocity is constant. If the gradient is positive then the velocity is positive and if the gradient is negative then the velocity is negative.
- A horizontal line on a displacement-time graph indicates that the displacement is not changing: i.e. the object is stationary.
- Parts of a displacement-time graph below the time axis indicate that the displacement is negative: i.e. the object has moved to the negative side of the origin.
- The average velocity for a journey is given by
  $$\frac{\text{total displacement}}{\text{time}}$$
  The average speed for a journey is given by

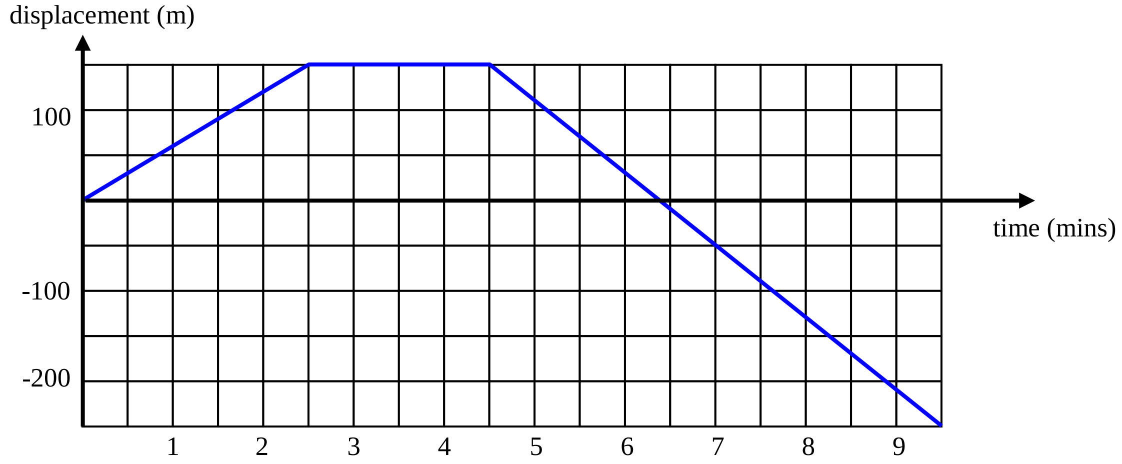
$\frac{\text{total distance travelled}}{\text{time}}$

Notice that these may be different, if a journey involves moving in both directions.

Example 2 illustrates the use of a displacement-time graph. Notice the distinction between distance and displacement, and between speed and velocity.

Example 2

Omar gets off a bus, walks to the shop to buy some milk, and then walks home. The displacement-time graph below models Omar's journey.



(i) What assumptions have been made in drawing this graph?
(ii) What is Omar's final displacement?
(iii) What is the total distance Omar has walked?
(iv) In which part of the journey was Omar walking fastest?
(v) How far is the bus stop from Omar's home?
(vi) How far is the shop from the bus stop?
(vii) What is Omar's average speed for the whole journey?
(viii) What is Omar's average velocity for the whole journey?
(ix) What is Omar's average speed when he is actually walking?
(x) Draw a speed-time graph for Omar's journey.
(xi) Draw a velocity-time graph for Omar's journey.

Solution

(i) The assumptions are that he walked at constant speed during both parts of the journey.

(ii) Omar's final displacement is -250 m.

Note that this is negative because the direction of the shop has been chosen to be positive.

(iii) The total distance walked is 150 + 400 = 550 m.

(iv) Omar was walking fastest on the way home from the shop.

The last part of the graph is steeper than the first part.

(v) The bus stop is 250 m from Omar's house.

(vi) The shop is 150 m from the bus stop.

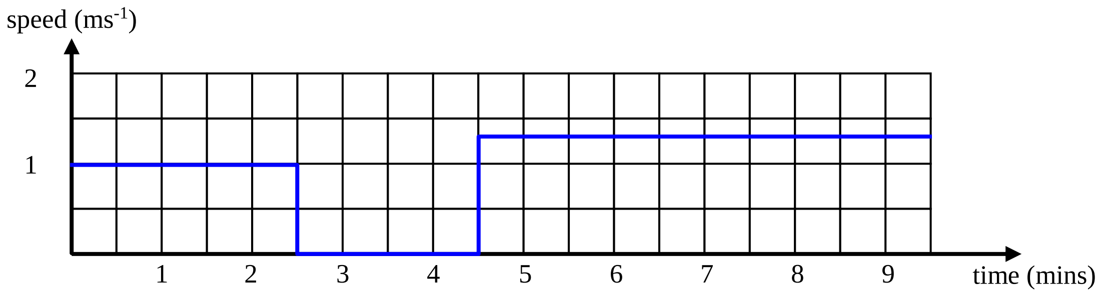
(vii) Total distance travelled = 550 m.
Total time taken = $9.5 \times 60 = 570$ seconds.
Average speed $= \frac{550}{570} = 0.965\,\text{ms}^{-1}$ (3 s.f.)

(viii) Total displacement = -250
Total time taken = $9.5 \times 60 = 570$ seconds.
Average velocity $= -\frac{250}{570} = -0.439\,\text{ms}^{-1}$ (3 s.f.)

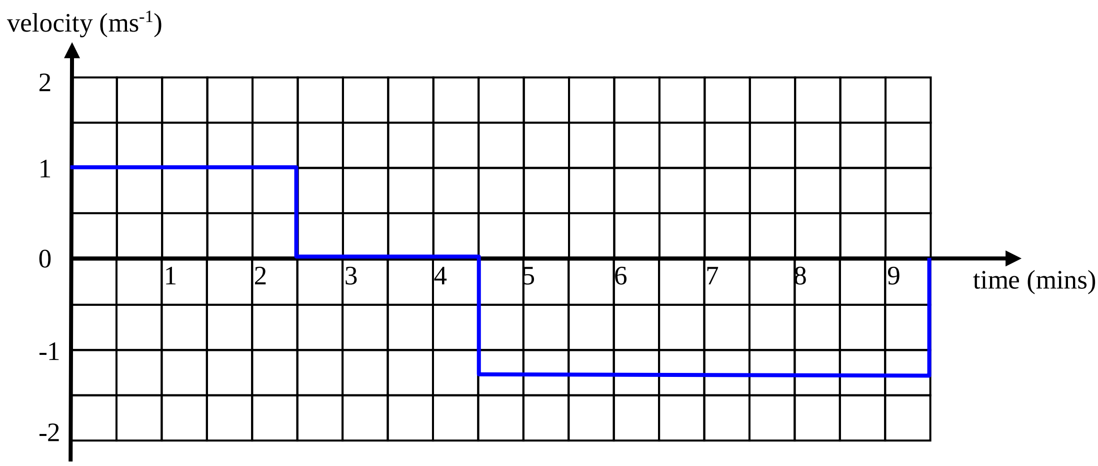
(ix) Total distance travelled = 550 m.
Total time taken when walking = $7.5 \times 60 = 450$ seconds.
Average speed $= \frac{550}{450} = 1.222\,\text{ms}^{-1}$ (3 s.f.)

(x) Speed during journey to shop $= \frac{150}{2.5 \times 60} = 1\ \text{ms}^{-1}$.

Speed during journey from shop to home = $= \frac{400}{5 \times 60} = 1.33\,\text{ms}^{-1}$ (3 s.f.)



(xi) Velocity during journey to shop = 1 ms^{-1}.
Velocity during journey from shop to home = -1.33 ms^{-1} (3 s.f.)



Notice in Example 2 that if you want to know how fast Omar walks, then the average speed and velocity calculations are not very helpful as they include the time he spent at the shop. The calculation of average speed when he was walking in part (vii) gives you the best idea of Omar's walking speed.