UNIT 5·1 Describing motion

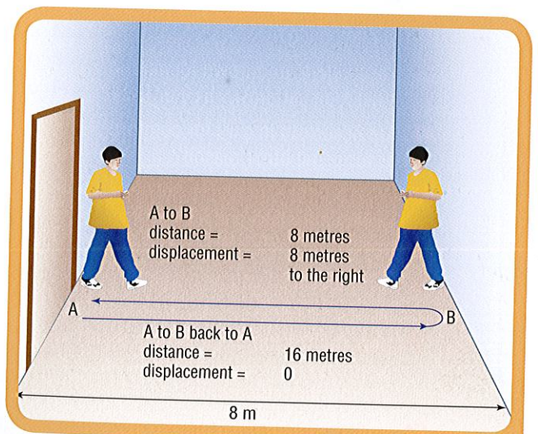
context

You are in motion all the time. Even when you are asleep, you are travelling at a speed of about 1300 km/h. How can this be? It's because the Earth is rotating on its axis and revolving around the Sun, carrying you with it. It's a journey that you take for granted, but what about other movements like running for the school bus in the morning? Let's now look at how scientists describe motion.

Distance and displacement

How would you describe your journey to school this morning? Apart from 'boring', you might mention the distance travelled and the time it took. Scientists use two terms, distance and displacement, when describing a journey.

- **Distance** can be measured in any length units, but is usually converted into metres (m) for calculations. Likewise, **time** is usually converted into seconds (s).
- **Displacement** is distance with a difference. Displacement is how far you end up from where you started, and in which direction (up, left, north, towards the window). It is distance with direction. You travel a considerable distance each day, but your overall displacement is likely to be zero. You will end up in the same bed that you crawled out of this morning.



The difference between distance and displacement *Fig 5.1.1*

Physics facts

Distance and displacement

Symbol in formulas: *s* (distance has no direction, displacement has direction)
Unit: metres
Unit abbreviation: m

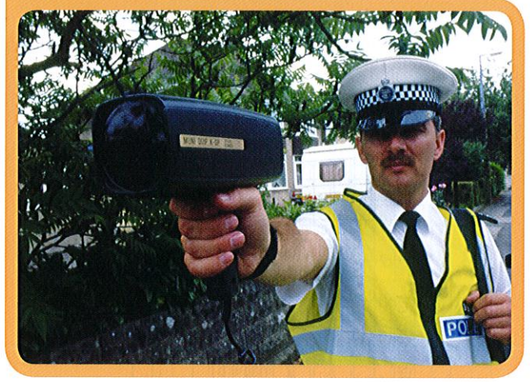
Speed and velocity

Speed

In a car, **speed** is measured continuously by the speedometer in kilometres per hour (km/h or km h^{-1}). This is its **instantaneous speed** or its speed at any moment in its travels. Speed is the *rate* at which distance is covered.

Fig 5.1.2 A cloud of ice crystals forms as an aircraft reaches an instantaneous speed of 1200 km/h.

Fig 5.1.3 Police radar guns measure instantaneous speed.



We do not always have a speedo or radar gun with us to measure instantaneous speed. Some simple measurements, however, allow us to calculate average speed:

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

or $v = \frac{s}{t}$

Science Focus

That's slow!

The speed limit for cars in France was 13 km/h in 1893. Originally all cars in Great Britain had to have a man walking in front of them with a red flag to alert horseriders! In 1896 the speed limit was raised to 20 km/h, and in 1904 to 33 km/h. The first Australian speeding ticket was given to a Tasmanian, George Innes, who was recklessly driving a car through Sydney at 13 km/h—tourists!

Physics facts

Speed and velocity

Symbol in formulas:
v (speed has no direction, velocity has direction)
Unit: metres per second
Unit abbreviation: m/s or m s^{-1}

Time

Symbol in formulas: *t*
Unit: seconds
Unit abbreviation: s

If your school bus took half an hour to travel 10 kilometres to school, its average speed would be:

$$v = \frac{10}{0.5} = 20 \text{ km/h}$$

This seems slow, but is an average of all the instantaneous speeds the bus did on its journey. The bus went faster than 20 km/h, but also stopped at traffic lights and bus stops. It also had to reduce its speed through school zones and shopping areas.

How to convert speed units

km/h $\xrightarrow{\div 3.6}$ m/s
m/s $\xrightarrow{\times 3.6}$ km/h

Averages are useful but tell little about what is actually happening. If the distance or time chosen for the average is small, however, average and instantaneous speeds become closer to each other. A runner might be timed at completing the 100 metre sprint in 12 seconds, but it would be better to measure the times taken to run past markers spaced at, say, 10 metres. The average speed of each section would show any changes that happened along the way. Spacings of one metre would be even better.

Science Focus

That's fast!

Measurements are only as accurate as the device that measures them, and faulty equipment will never give accurate measurements. This was particularly true when a driver in Belgium was fined after a radar gun measured his speed at 3500 km/h!

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Velocity

A weather report of 60 km/h wind gusts is useless to pilots, sailors, surfers and people fishing unless they also know the wind's direction. **Velocity** is speed in a given direction. Wind movement is an example of velocity.

$$\text{Average velocity} = \frac{\text{displacement}}{\text{time}}$$

The ticker-timer

A **ticker-timer** is an instrument that breaks movement into a series of small intervals. It gives us a way of accurately measuring distances travelled and times taken, and provides the data from which speeds can be calculated. A small electric hammer strikes a piece of carbon paper at the same frequency as the AC power supply, 50 times a second or 50 Hz. Motion is then recorded as dots on a strip of paper that passes under the hammer. Fifty dots are produced every second, so a space between dots takes only one-fiftieth of a second or 0.02 seconds to produce.

Science Focus

Don't even think about stopping!

In about 700 BC, King Sanherib of Assyria built a road from his capital, Nineveh, to nearby temples. It was so wide that it would have been equivalent to a modern freeway of eighteen lanes! The king was justifiably proud of his road and didn't want it spoiled by chariots parked along it. Death was the penalty for doing so, with offenders being impaled on spikes!