Contents

Motion In a Straight Line

Motion On a Plane

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1.1 Describing Motion

Describe uniform straight line (rectilinear) motion and uniformly accelerated motion through qualitative descriptions.

Distance and displacement

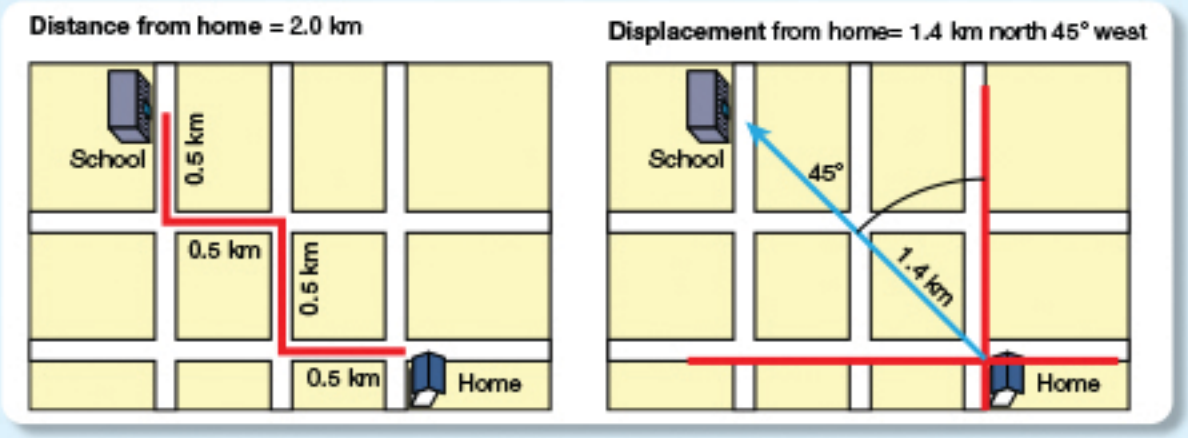
Distance

- Distance is a measure of how far an object has moved.
- Distance is measured in units like centimetres (cm), metres (m), and kilometres (km).
- Distance is a **scalar quantity** which means **no direction** is required.
- In equations, distance is given the symbols ***d***, or ***r*** (radius) or ***h*** (height) or similar.

Displacement

- **Displacement** is a measure of how far, and in what direction, an object is from its starting point.
- **Displacement** is also measured in centimetres, metres and kilometres.
- Displacement is a **vector quantity** which means a **direction must be given** whenever we state a displacement.
- In equations, displacement is given the symbol **s**.

Example



Stating the direction of displacement

- Displacement direction can be given as a **compass direction** or as a **bearing from north.**
- **A bearing is the angle of the displacement measured clockwise from north.**
- It is always expressed as a three number bearing.
- Due north will be bearing 000°.
- East will be bearing 045°.
- South will be expressed as bearing 180°.
- In the example above, the school from home is 90 + 90 + 90 + 45 = bearing 325°.
- Bearings are used in navigation and are preferred to compass directions because they are easier to compute and to communicate.

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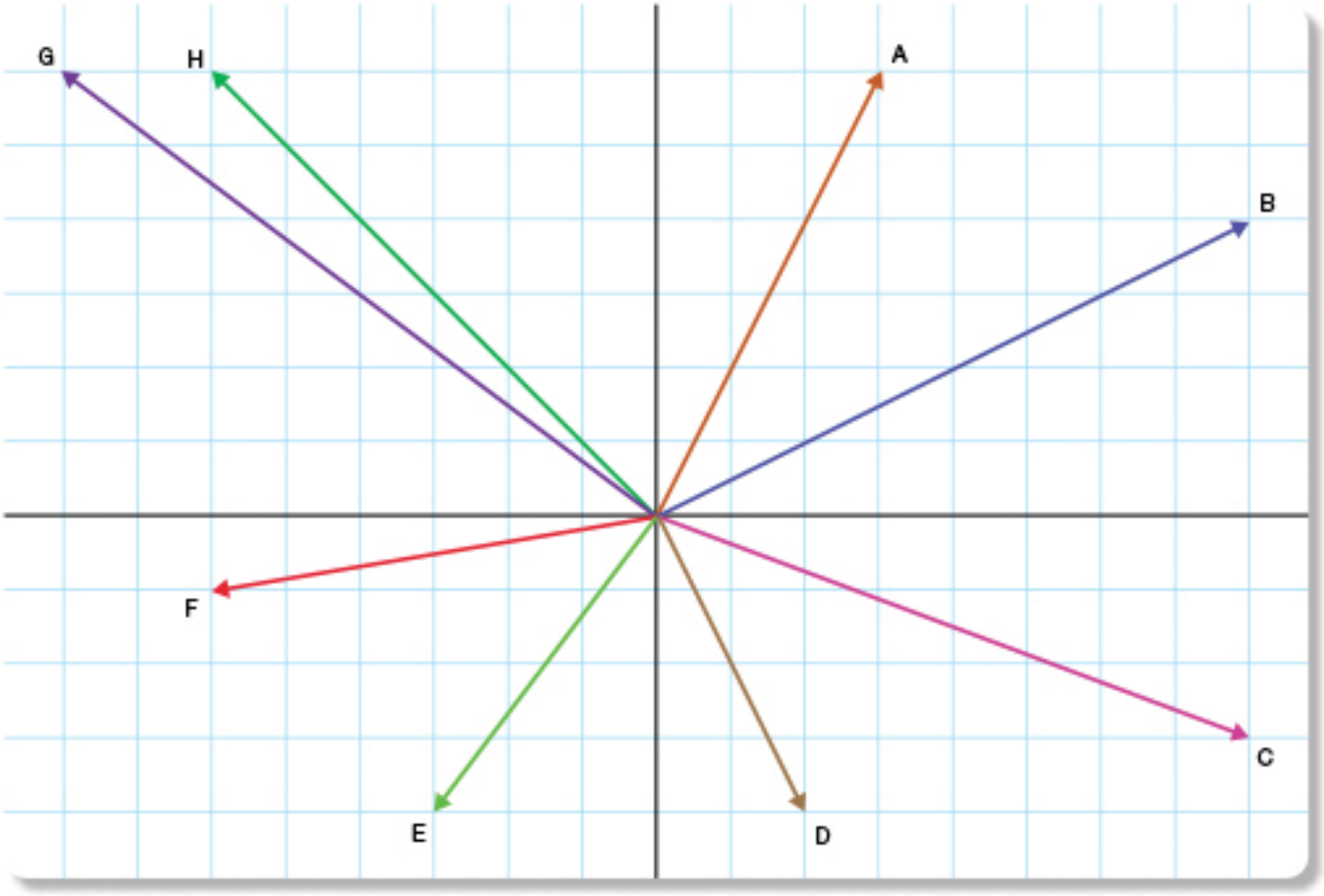
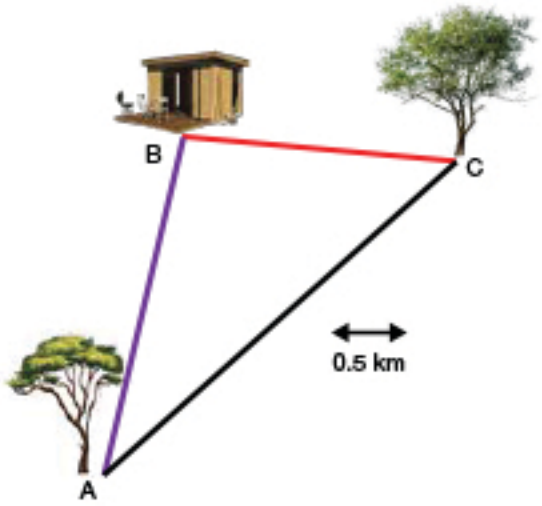
Sample Questions

1. The diagram shows the displacements of several points from a central point. Each square in the grid represents a 1.0 m × 1.0 m area. Find the displacements represented by the coloured arrows from O. Give your directions as bearings to the nearest degree.



2. Consider the diagram, and giving all directions where needed as bearings to the nearest degree:

(a) Find the distance between B and C.
(b) Find the distance between A and C.
(c) Find the distance between A and B.
(d) Find the displacement of B from A.
(e) Find the displacement of A from B.
(f) Find the displacement of C from A.
(g) Find the displacement of A from C.
(h) Find the displacement of B from C.
(i) Find the displacement of C from B.
(j) Consider your answer pairs to (d) and (e), then (f) and (g), then (h) and (i). What do these answers tell you about the directions on the displacements in each pair of answers?



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Speed

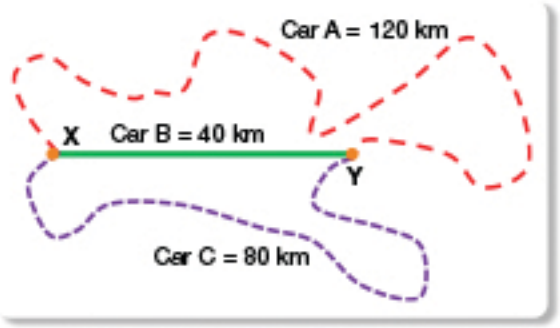
- **Speed** is a measure of how fast an object is moving.
- **Speed** is a measure of the rate at which an object moves.
- **Speed** is a measure of the rate of change of position of an object.
- **Speed** is measured in units like metres per second (m s^{-1}), or kilometres per hour (km h^{-1}), or centimetres per 100 years.
- **Speed** is a scalar quantity so no direction is required when stating it.
- **Speed** can be found using the equation:

$$\text{Average speed} = \frac{\text{total distance travelled}}{\text{time taken}} = \frac{d}{t}$$

- **Constant speed:** The speed an object which is travelling the same distance in every period of time.
- **Average speed:** The constant speed at which an object would need to travel so as to travel the same distance in the same time.
- **Instantaneous speed:** The speed of an object in the instant of time we consider it. This will vary from instant to instant depending on, e.g. road and traffic conditions.
- **Initial speed:** The speed of an object when we first consider it, e.g. the object's speed at the start of its journey.
- **Final speed:** The speed of an object at the end of its journey or when we finish our consideration of its motion.

Sample Questions

1. Consider three cars which started at town X and travelled to town Y by three different roads as shown. Car A travelled from X to Y in 3 hours. Car B made its trip in 1 hour, while car C took 1.5 hours to go from X to Y.
   (a) Calculate the average speed of car A.
   (b) Calculate the average speed of car B.
   (c) Calculate the average speed of car C.
   (d) Explain why we are only talking about *average* speeds here.



2. A sprinter runs the 800 metre race in exactly 2.0 minutes. Calculate her average speed in m s^{-1}.
3. A satellite travels 12 000 m in 1.53 seconds. Calculate its orbital speed.
4. A racing car attempts to break the 'standing kilometre' time record. When the starting light turns green, it accelerates at maximum rate and crosses the finish line 18 s later.
   (a) Identify the initial speed of the car.
   (b) Calculate its average speed.
   (c) For an object with uniform acceleration, the final speed is twice the average speed. Use this idea to find the final speed of the car.
5. What is your average speed, in km h^{-1} and m s^{-1} if you travel 20 km in 1 hour and 15 minutes?
6. Sally runs at 5.6 km h^{-1}. If she ran for a period of 2.5 hours, how far has she travelled?
7. If you were travelling at 30 km h^{-1}, how long would it take to travel a distance of 70 km?

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1.2/3 Motion-Time Graphs

Use mathematical modelling and graphs to analyse and derive relationships between time, distance, displacement, speed, velocity and acceleration in rectilinear motion. Describe ways in which the motion of objects changes and describe and analyse these graphically for velocity and displacement.

Displacement-time graphs 1

Displacement-time graphs

- Read directly from the graph to find the distance travelled or the displacement of an object at particular times, or vice versa.
- Calculate the **speed** or **velocity** of the object from the **gradient** of the graph.
- Notice that because distance is a scalar quantity, direction is not required on the *y*-axis of a distance travelled-time graph.
- Notice that because displacement is a vector quantity, direction is required on the *y*-axis of a displacement-time graph.

Example

The graph tells us (amongst other things) that:

(a) The object travelled 16 m in 4 *s*.

(b) The displacement of the object travelled after 2 s is 8 m east.

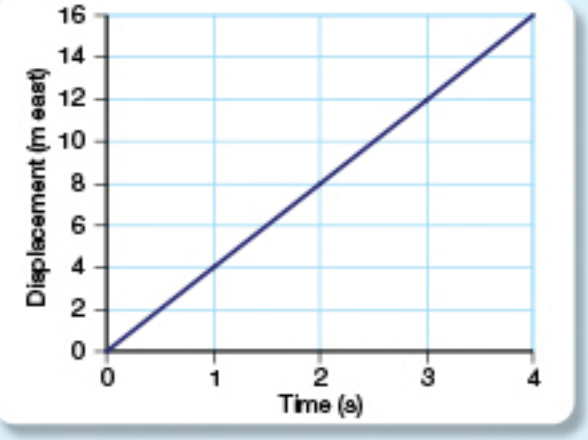
(c) At 2.5 s the object had travelled 10 m east.

(d) From the gradient of the graph we get:

$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{16}{4}$$

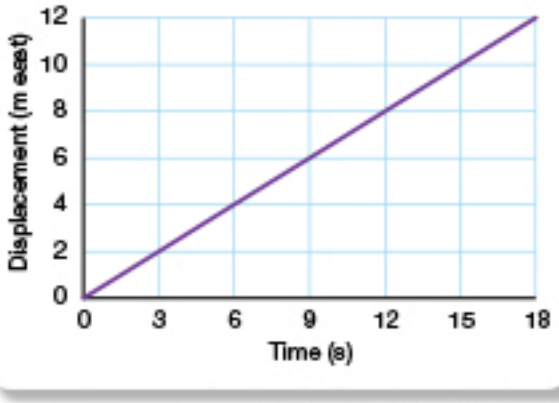
= average velocity = 4 m s^{-1} east

(e) As the gradient is constant, velocity is constant.



Sample Questions

1. With reference to the graph:
   (a) How far did the object travel in 7.5 s?
   (b) When was the object 10 m from its starting position?
   (c) What was its velocity at time 2.0 s?
   (d) What was the velocity of the object at time 3.5 s?
   (e) Account for the similarity in your answers to (c) and (d).



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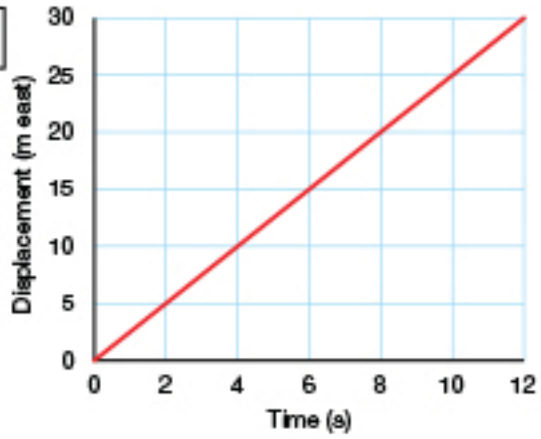
2. For each of the graphs on this page find:

(a) The initial displacement of the object.
(b) The final displacement of the object.
(c) The displacement for the journey.
(d) The total distance each object travelled.
(e) The average velocity for the whole journey.
(f) The average speed for the whole journey.
(g) The instantaneous velocity at time 8 *s*.
(h) The displacement of the object at time 6 s.
(i) The displacement of the object at time 12 *s*.
(j) The speed of the object at time 12 s.
(k) The velocity of the object at time 12 *s*.

A



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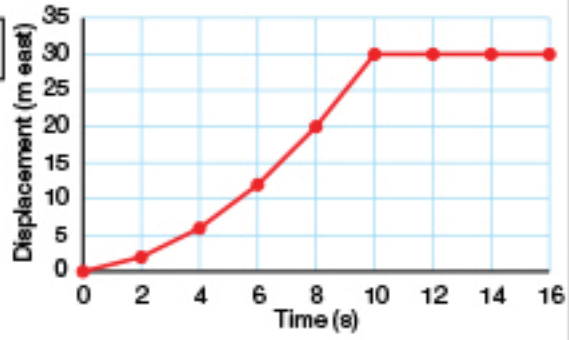

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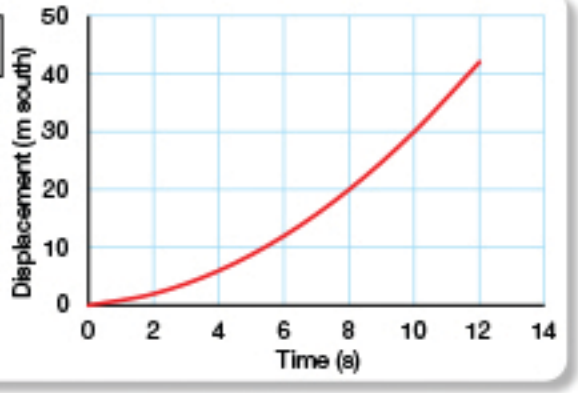

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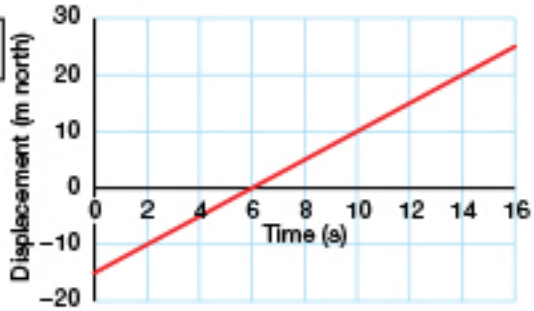
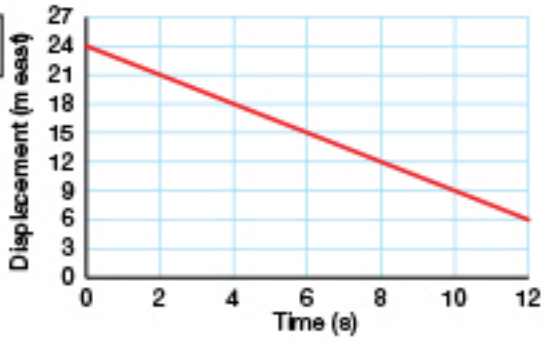


E



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