Surfing

NSW PHYSICS 1&2

Module 1 Kinematics
Module 2 Dynamics

Brian Shadwick

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Science Press
Bag 7023 Marrickville NSW 1475 Australia
Tel: (02) 9516 1122 Fax: (02) 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

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Introduction

This book covers the Physics content specified in the NSW Physics Stage 6 Sllabus. Sample data has been included for suggested experiments to give you practice to reinforce practical work in class.

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

NSW PHYSICS 1&2

Module 1

KINEMATICS

CONTENT FOCUS

In this module you will:

- Investigate aspects of kinematics, by describing, measuring and analysing motion without considering the forces and the masses involved in that motion.
- Explore uniformly accelerated motion in terms of relationships between measurable scalar and vector quantities, including displacement, speed, velocity, acceleration and time.
- Describe linear motion and predicted motion both qualitatively and quantitatively using graphs and vectors, and the equations of motion.
- Understand that scientific knowledge can enable scientists to offer valid explanations and make reliable predictions, particularly in regard to the motion of an object.
- Engage with all the Working Scientifically skills for practical investigations involving the focus content to examine trends in data and to solve problems related to kinematics.

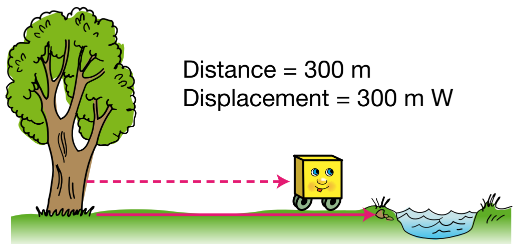
CONTENT FOCUS

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

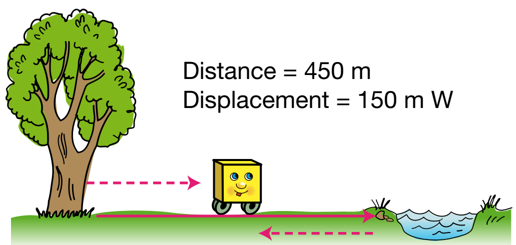
1 Distance and Displacement

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.

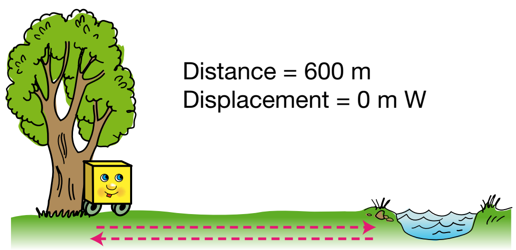
Displacement is a measure of how far, and in what direction, an object is from its starting point. Displacement is also measured in centimetres, metres and kilometres. Displacement is a **vector quantity** which means a *direction must be given* whenever we state a displacement.



Billy Box at the creek



Billy Box halfway back



Billy Box back at the tree

For example, Billy Box rolls from the shade of his favourite tree to a creek bed. The creek is 300 metres from the tree in a westerly direction. When he gets to the creek Billy will have rolled 300 metres west. We say the:

- Distance Billy rolled is 300 m.
- Displacement is 300 m west.

Note that the only difference between the distance travelled and the displacement is that the *direction* of displacement is (and *must be*) stated. However, when Billy Box is halfway back to the tree notice that the:

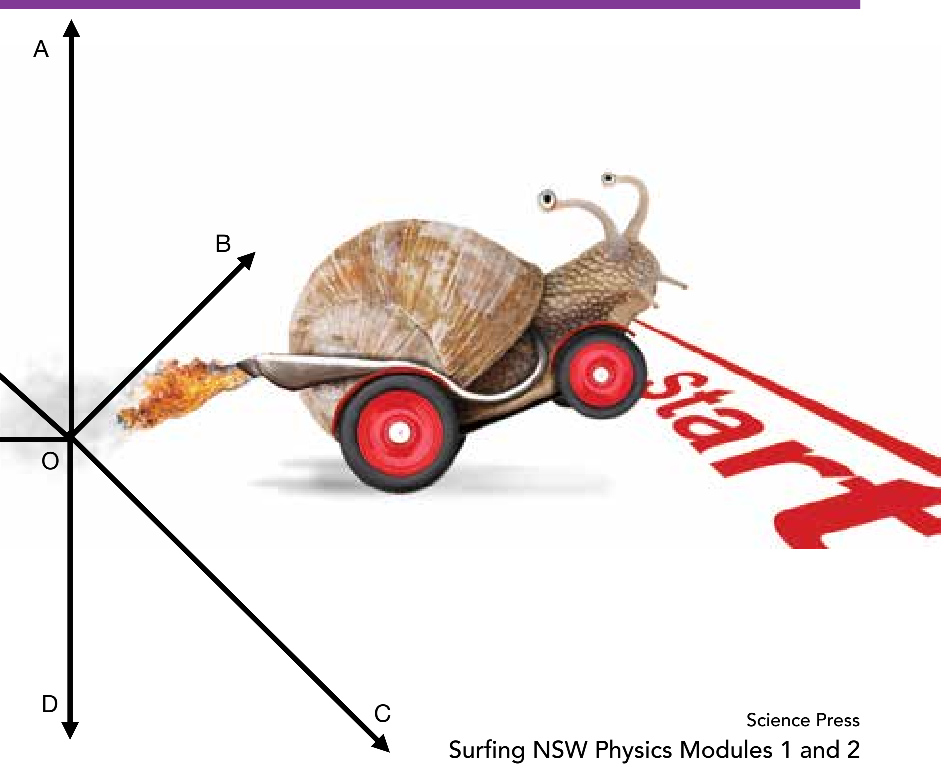
- Distance Billy rolled is 450 m.
- Displacement is 150 m west.

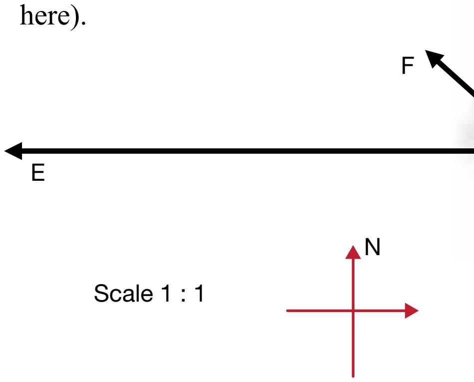
Notice the distance travelled and the displacement are quite different this time. When Billy Box is back at the tree the:

- Distance Billy rolled is 600 m.
- Displacement is zero.

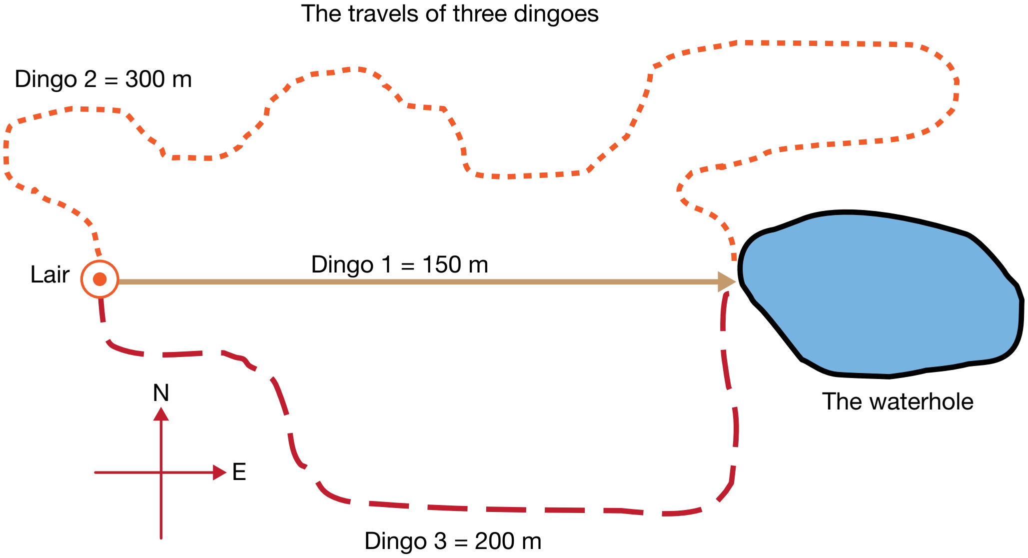
QUESTIONS

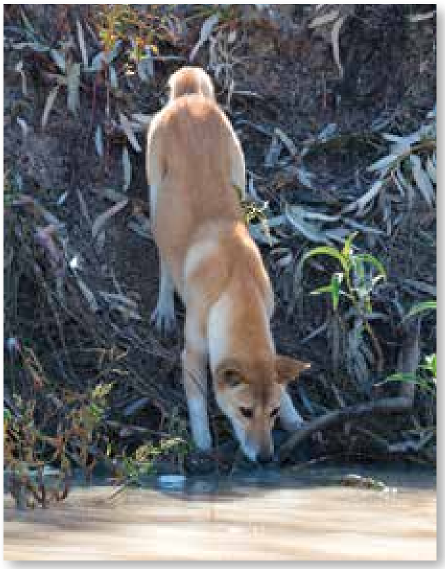
1. Six snails (A, B, C, D, E and F) start at O and crawl outwards from O as shown in the diagram.
   (a) Find the distance each snail has travelled.
   (b) Find the displacement of each snail (you will need a protractor here).





2. Three dingoes leave their lair in the morning. One heads straight for the waterhole which is 150 metres to the east. He stops here and rests. The other two dingoes travel by the pathways shown in the diagram. They also end up at the waterhole with the first dingo.





(a) Where did each dingo start?
(b) Where did each dingo end up?
(c) Where is the waterhole relative to the lair? (That is, how far and in what direction?)
(d) How far did dingo 1 travel?
(e) How far did dingo 2 travel?
(f) How far did dingo 3 travel?
(g) At the waterhole, how far is dingo 1 from the lair?
(h) At the waterhole, how far is dingo 2 from the lair?
(i) At the waterhole, how far is dingo 3 from the lair?
(j) What is the displacement of dingo 1 at the waterhole?
(k) What is the displacement of dingo 2 at the waterhole?
(l) What is the displacement of dingo 3 at the waterhole?

Now suppose the dingoes all walk *straight back* to the lair.
(m) What total distance has each now travelled?
(n) What is the displacement of each dingo now?

3. A parrot in a tree walks up and down a branch. The branch points straight out from the tree trunk towards the south. The parrot walks 50 cm towards the trunk, stops at A, turns around and then walks 80 cm back to B. It stops then walks 30 cm further along the branch to point C where it stops again. It turns around and heads back towards the tree trunk, walking another 70 cm before stopping again at D.
(a) Look briefly at questions (b), (c) and (d) and then draw up a table to fit your answers.
(b) What total distance has the parrot travelled from its starting point on the branch when it is at each point A, B, C and D?
(c) Using compass directions, what is the displacement of the parrot from its starting position at each point?
(d) What are these displacements using the +/– method of indication directions? (Remember to define which direction is + and –.)

2 Working Out Directions Another Way

Not all movement is conveniently in a main compass direction, or at one of the 45° angles from these (north-east or south-west and the like). We need to learn how to express directions that are not like these.

Let's look a bit more closely at how we work out directions.

An elephant walks from his favourite tree to a waterhole, a distance of 300 metres as shown in Figure 2.1.

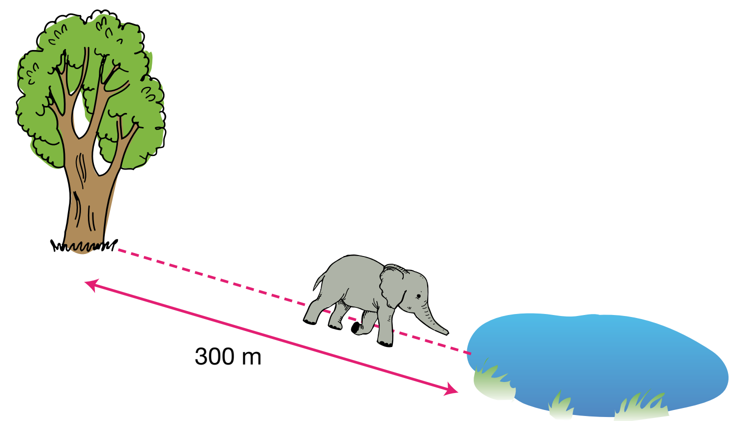


Figure 2.1

We need to draw a set of axes representing north, south, east and west, centred on the elephant's starting position (Figure 2.2).

We can now measure the angle *A* with a protractor. We can then say that the displacement of the elephant is 300 metres **east 25° south** (also Figure 2.2).

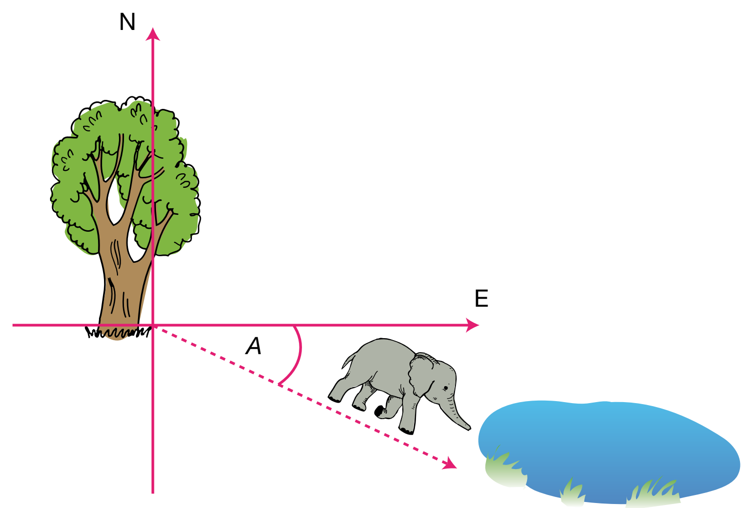


Figure 2.2

Or, we draw a set of axes representing north, south, east and west, centred on the elephant's starting position as before (Figure 2.3).

Measure angle *B* – notice that this represents the elephant's position relative to north – and state the displacement as 300 metres **bearing 115°** (Figure 2.3).

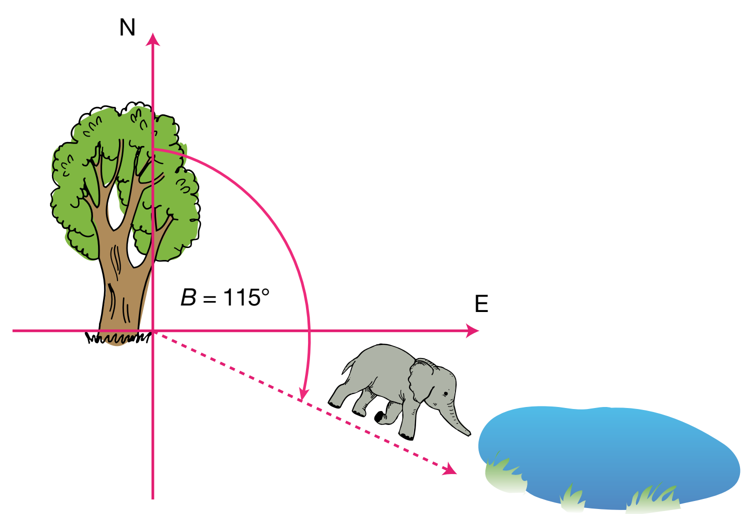


Figure 2.3

QUESTIONS

1. Expressing the directions as *bearings*, calculate the displacement of each of the snails in Figure 2.4. Each snail started at the origin. (Don't forget the scale!)

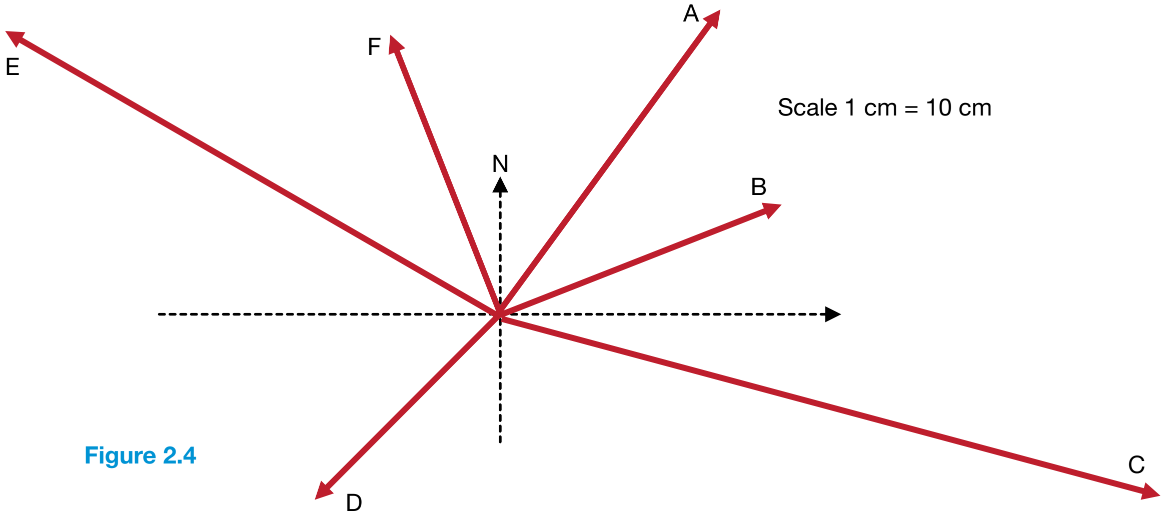


Figure 2.4

2. A car travels from S to T, 70 km apart, by the road shown in Figure 2.5. Draw up a table to show how far the car has travelled when it is at A, B, C, D and T, and what its displacement is at each position. Record the displacement direction in the two different ways shown above.

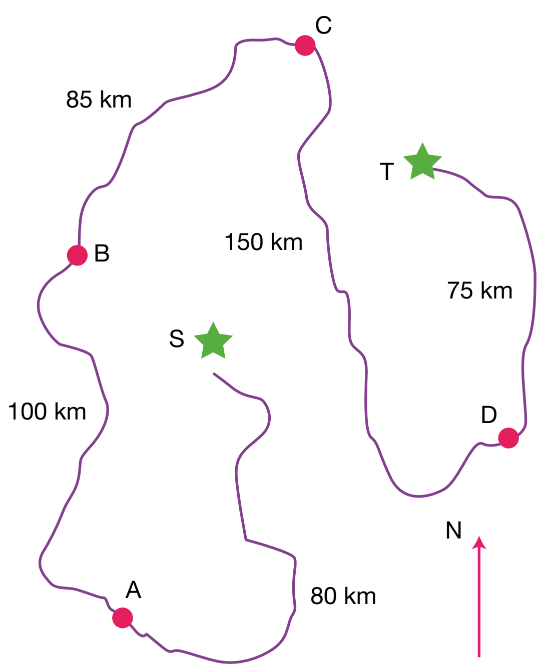


Figure 2.5

3. The map in Figure 2.6 has been drawn to scale where 1 cm = 10 km. Imagine that 10 different people start from J. Nine of them travel to each of the other marked places, and the tenth travels to the top of Little Ugly. What is the displacement of each person when each is at their destination?

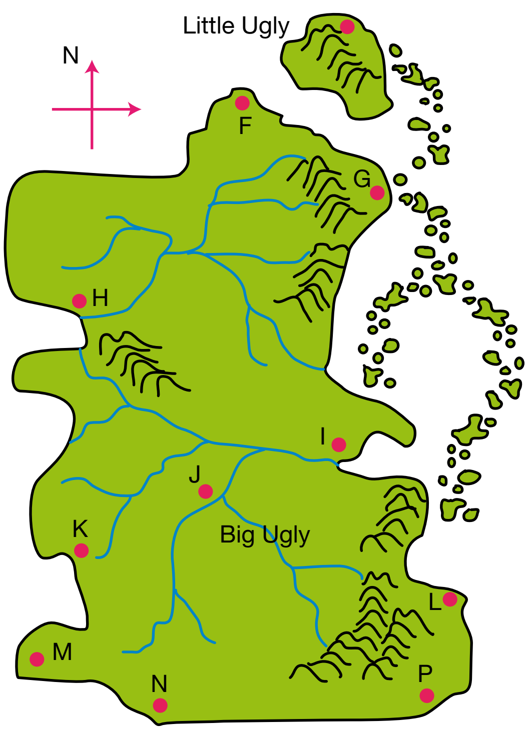


Figure 2.6

3 Speed

The following definitions describe 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, e.g. 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.

Imagine a car travels a distance of 80 km in 2 hours. Assuming the car travelled at the same speed (i.e. no traffic lights, hills, corners, or any other things which might cause it to slow down or speed up, or in other terms, **no acceleration**) in 1 hour the car would have travelled 40 km. Its **average speed** would be 40 km h^{-1}. It moves at an **average rate** of 40 km h^{-1}. Its **average rate of change of position** is 40 km h^{-1}. We can use the following equation to calculate the average speed of an object.

$$\text{Average speed} = \frac{\text{total distance travelled}}{\text{time taken}} = \frac{d}{t} = \frac{\text{initial speed} + \text{final speed}}{2}$$

Example: A car travels 200 metres in 15 seconds. Calculate its average speed.

Solution:

Data:

Distance = 200 m

Time = 15 s

Average speed = ? m s^{-1}

Calculation:

$$\text{Average speed} = \frac{\text{distance travelled}}{\text{time taken}} = \frac{200 \text{ metres}}{15 \text{ seconds}} = 13.33 \text{ m s}^{-1}$$

The average speed of the car is 13.33 m s^{-1}.

Of course, in real life, a car would not travel at the same speed all the time. Its speed would vary according to road, traffic, weather and other conditions. To talk sensibly about things moving we need different kinds of speeds to cover different situations. These are as follows.

Constant speed is the speed of an object which is travelling the same distance in every period of time.

Average speed is the constant speed at which an object would need to travel so as to travel the same distance in the same time.

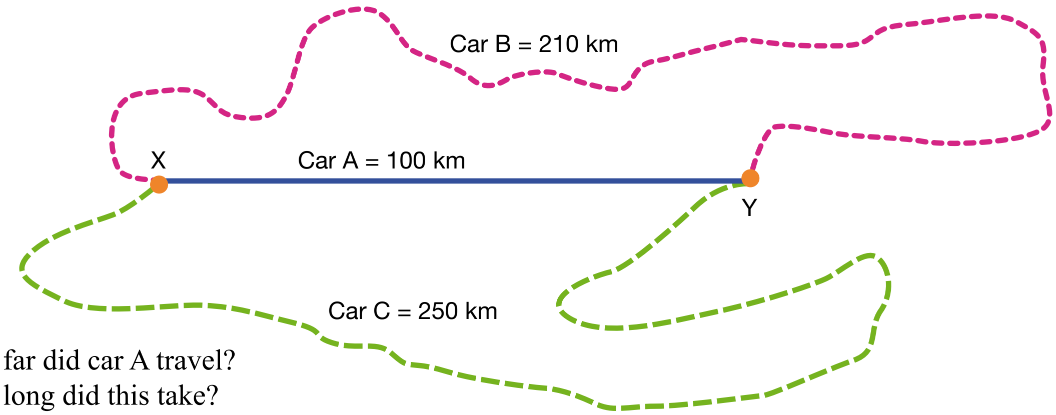
Instantaneous speed is the speed of an object in the instant of time we consider it. This will vary from instant to instant depending on, e.g. road and traffic conditions.

Initial speed is the speed of an object when we first consider it, i.e. the object's speed at the start of its journey.

Final speed is the speed of an object at the end of its journey or when we finish our consideration of its motion.

QUESTIONS

1. Consider three cars which started at town X and travelled to town Y by three different roads as shown in the diagram. Car A travelled from X to Y in 2 hours. Car B made its trip in 3 hours, while car C took 5 hours to go from X to Y.



(a) How far did car A travel?
(b) How long did this take?
(c) On average, how far did car A travel each hour?
(d) Calculate the average speed of car A.
(e) Calculate the average speed of car B.
(f) Calculate the average speed of car C.
(g) Explain why we are only talking about *average* speeds here.

2. A swimmer, travelling at a steady rate, swims the 50 metre pool in 30 seconds. Calculate her average speed.
3. A rocket travels 10 000 m in 6.5 seconds. Calculate its average speed.
4. Convert to m s^{-1}:
(a) 40 km h^{-1}
(b) 250 cm s^{-1}
(c) 60 km h^{-1}
(d) 100 km h^{-1}
5. Convert to km h^{-1}:
(a) 20 m s^{-1}
(b) 60 m s^{-1}
(c) 1000 cm s^{-1}
6. A racing car is attempting to break the 'standing kilometre' time record. When the starting light turns green, it accelerates at maximum rate and crosses the finish line at 180 km h^{-1} 40 s later (on a racing track of course).
(a) Identify the initial speed of the car.
(b) Identify its final speed.
(c) Calculate its average speed.
(d) Estimate its instantaneous speed 20 s after starting. Justify your answer.
(e) Predict the constant speed to cover the same distance in the same time.

7. Fill in the missing quantities in the table.

	Distance travelled	Time taken	Average speed
(a)	1500 m	30 s	
(b)	270 m	9 s	
(c)	243 m	27 s	
(d)	12.3 m	3.2 s	
(e)	640 m	16 s	
(f)	800 m		25 m s^{-1}
(g)	300 m		12 m s^{-1}
(h)	250 km		12.5 km h^{-1}
(i)	3.6 km		12 m s^{-1}
(j)	160 km		8 km h^{-1}
(k)		3.5 hr	16 km h^{-1}
(l)		150 s	5 m s^{-1}
(m)		2 min	10 m s^{-1}
(n)		25 s	0.5 m s^{-1}
(o)		0.3 s	90 m s^{-1}

4 Velocity

These definitions describe velocity.

Velocity is a measure of how fast, and in what direction, an object is going or has gone.

Velocity is the speed of an object with its direction of travel also given.

Velocity is a measure of the rate of change of displacement of an object.

Velocity is measured in the same units as speed. The direction of travel must also be given.

Velocity is a **vector quantity**, so direction *must* be given when stating it.

$$\text{Average velocity} = v_{av} = \frac{\text{total displacement}}{\text{total time taken}} = \frac{s}{t} = \frac{\text{initial velocity} + \text{final velocity}}{2}$$

Where s = displacement of the object in metres

t = time taken for displacement

v_{av} = average velocity in m s^{-1} (Again, this assumes acceleration is zero.)

Example: A car, travelling at constant velocity, travels 250 metres south in 20 seconds. Calculate its average velocity.

Solution:

Data:

Displacement = 250 m S

Time = 20 s

Average velocity = ? m s^{-1}

Calculation:

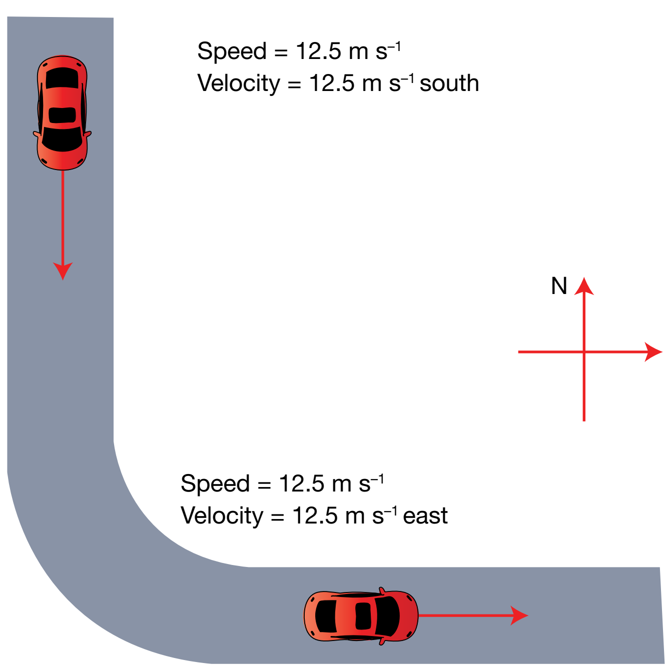
$$\text{Average velocity} = \frac{\text{displacement}}{\text{time taken}}$$

$$= \frac{\text{250 m south}}{\text{20 seconds}}$$

$= 12.5$ m s^{-1} south

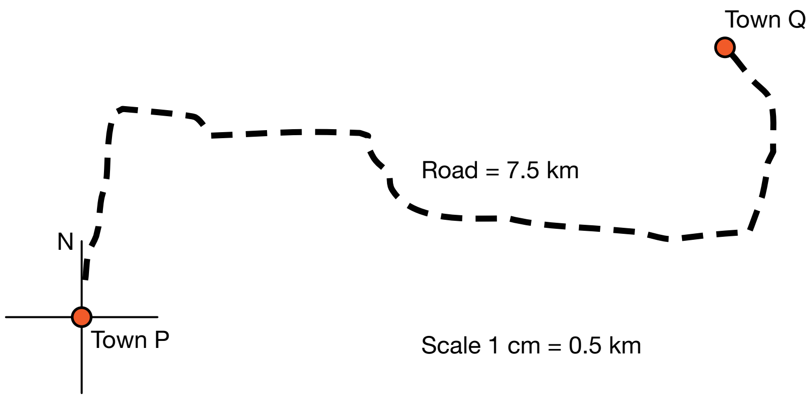
Of course, as with speed, a car would not travel at the same velocity all the time. Its speed (and therefore its velocity) would vary according to road, traffic, weather and other conditions. However, the **direction of travel** would change often also – most journeys involve turning corners. Because velocity includes direction, even if the speed stays the same, a direction change would indicate a velocity change.

Suppose the car in the example above turned a corner and started travelling towards the east. Its speed would still be the same, 12.5 m s^{-1}, but its velocity would change to 12.5 m s^{-1} east. These differences are shown in the diagram.



QUESTIONS

1. A car travelled 200 km north in 4 hours. Calculate its average speed and velocity.
2. A ball rolled 6.0 m from X to Y. This took 3 s. Calculate its average speed and velocity.
3. A cyclist left P and rode to Q, 7.5 km away as shown in the diagram. Because of bends, the road was 3.0 km longer than the actual distance between P and Q. The journey took 30 minutes.



   (a) Calculate the cyclist's average speed for the trip.
   (b) Calculate his average velocity.
4. PQRS is a rectangular field where PQ is 3.0 km and QR is 4.0 km. R is south of S and west of Q. A rider travels around the field, starting at P and travels PQRSPQR. This takes 7 hours.
   (a) Calculate the total distance the rider travels.
   (b) Calculate the average speed of the rider.
   (c) Calculate the displacement of the rider when she is at each corner of the field.
   (d) Calculate the rider's displacement at the end of the ride.
   (e) Calculate the average velocity of the rider for the whole trip.
   (f) Calculate the average velocity of the rider as she moves along PQ.
5. Complete the table.

	Displacement	Time taken	Average speed	Average velocity
(a)	2000 m south	40 s		
(b)	250 m east	12.5 s		
(c)	120 m west	4 s		
(d)	5.6 m NW	1.4 s		
(e)	525 m bearing 063°	2.5 s		
(f)	800 m bearing 142°		40 m s^{-1}	
(g)	300 m bearing 237°		15 m s^{-1}	
(h)	80 km bearing 010°		5 km h^{-1}	
(i)	2.6 km NW		20 m s^{-1}	
(j)	150 km N		25 km h^{-1}	
(k)		1.5 hr		20 km h^{-1} W
(l)		15 s		2.5 m s^{-1} SE
(m)		12 min		6 m s^{-1} NE
(n)		35 s		0.6 m s^{-1} S
(o)		0.5 s		40 m s^{-1} bearing 042°

5 Acceleration

When an object speeds up we say that it **accelerates** or has an acceleration **in the direction of the motion**, or that it has a **positive acceleration**. When an object slows down, it also accelerates, but more correctly we say that it has a **negative acceleration** or that it has an acceleration **against the motion**, or that it **decelerates**. A moving object also accelerates when it changes direction whether its speed changes or stays the same because a change in direction *is* a change in velocity.

Acceleration is a measure of the rate at which velocity changes.

Acceleration may be positive (speeds up) or negative (slows down).

Acceleration tells us how much the velocity changes each second.

Acceleration is usually measured in metres per second per second ($m\ s^{-2}$).

Acceleration also occurs when the direction of travel changes.

Acceleration is a vector quantity and the direction *must* be stated.

Example: Consider a car which is moving at $10\ m\ s^{-1}$ east and which accelerates to $50\ m\ s^{-1}$ east over a period of 5 seconds. Find its acceleration.

Solution: Its speed changes from $10\ m\ s^{-1}$ east to $50\ m\ s^{-1}$ east, a change of $40\ m\ s^{-1}$ east. This change takes 5 seconds. So, on average, the change in speed is $8\ m\ s^{-1}$ each second. We say that the acceleration of the car is $8\ m\ s^{-2}$ east. Notice that this answer can be found using the equation:

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time for change to occur}} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time taken}} = \frac{50-10}{5} = 8\ m\ s^{-2}$$

To make things a bit simpler we use symbols for each of these quantities and usually express the above equation as follows.

$$a = \frac{v-u}{t}$$

Where a = acceleration in $m\ s^{-2}$

u = initial velocity in $m\ s^{-1}$

v = final velocity in $m\ s^{-1}$

t = time taken for change in seconds

Notice that this equation can be rearranged to give: $v = u + at$

Note also that if acceleration is constant (including zero), the average velocity of an object is given by: $v_{av} = \frac{u+v}{2}$

QUESTIONS

1. A car, at rest, accelerates at $3\ m\ s^{-2}$ N for 12 s. Calculate its velocity after 4, 8 and 12 s.
2. A rock falls from rest. Its speed when it hits the ground 3 s later is $29.4\ m\ s^{-1}$. Calculate its acceleration.
3. A car moving at $32\ m\ s^{-1}$ W hits a wall and stops in 0.02 s. Calculate the acceleration stopping the car.
4. After 4 s of accelerating at $2.5\ m\ s^{-2}$, a car moves at $50\ m\ s^{-1}$. Calculate its initial velocity if the acceleration was:
   (a) Positive (in direction of motion).
   (b) Negative (opposing motion).
5. A rocket accelerates at $40\ m\ s^{-2}$ until its speed is $1800\ m\ s^{-1}$. How long does this take?
6. A car accelerates at $4.5\ m\ s^{-2}$ S for 6 s. After this time it is moving at $36\ m\ s^{-1}$ S. Calculate its initial velocity.
7. A car accelerates at $2.5\ m\ s^{-2}$ E for 16 s. After this time the car is moving at $10\ m\ s^{-1}$ W. Calculate its initial velocity.

6 SI Units and Powers Of Ten

SI units are units of measurement which form the International System of Units. These are units for the measurement of quantities which have been agreed on internationally and used so that communications of quantities between nations is easier. It is the modern form of the metric system. When using SI units, note the following.

- No full stops are used after units.
- All units are lower case unless they are named in honour of a person (e.g. amperes = A). The only exception is L for litre to avoid confusion with some typeface number 1's or i's.
- If a combination of units is used, e.g. metres per second, then there are three acceptable formats:
  (i) m/s (Use a slash between the m and the s.)
  (ii) m.s^{-1} (A full stop between the m and the s^{-1}.)
  (iii) m s^{-1} (A space between the m and the s^{-1}. This is the preferred format to use.)

For large measurements, it is more sensible to use units which better suit that measurement. For example, we would not measure the distance to the next galaxy in metres. Light years, or parsecs are much more sensible units. While they are not SI, there is international agreement on their use.

Common SI units

The table shows the common SI units and their symbols you will meet in this course.

Quantity	SI unit (name and symbol)	Quantity	SI unit (name and symbol)
Mass	kilogram (kg)	Electric potential difference	volt (V)
Length	metre (m)	Electrical resistance	ohm (Ω)
Time	second (s)	Electric current	ampere (A)
Displacement	metre (m)	Speed	metres per second (m s^{-1})
Force	newton (N)	Velocity	metres per second (m s^{-1})
Energy	joule (J)	Acceleration	metres per second per second (m s^{-2})
Power	watt (W)	Temperature	kelvin (K)
Momentum	kilogram metre per second (kg m s^{-1} or newton second (N s)	Volume	litre (L)

Powers of ten

The table shows the prefixes and symbols used for numbers expressed as scientific numbers.

Unit prefix	Symbol	Meaning	Unit prefix	Symbol	Meaning
deca	da	10^{1}	deci	d	10^{-1}
hecta	h	10^{2}	centi	c	10^{-2}
kilo	k	10^{3}	mille	m	10^{-3}
mega	M	10^{6}	micro	μ	10^{-6}
giga	G	10^{9}	nano	n	10^{-9}
tera	T	10^{12}	pico	p	10^{-12}
peta	P	10^{15}	femto	f	10^{-15}
exa	E	10^{18}	atto	a	10^{-18}
zeta	Z	10^{21}	zepto	z	10^{-21}
yotta	Y	10^{24}	yocto	y	10^{-24}

CONTENT FOCUS

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.

7 Displacement-Time Graphs 1

Distance-time and displacement-time graphs can be used to summarise the way an object moves. From them we can do the following.

- 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.

For example, consider the following graph.

The graph tells us (amongst other things) that:

- The object travelled 16 m in 4 seconds.
- From the gradient of the graph we get:

$$\text{Gradient} = \frac{\text{rise}}{\text{run}} = \frac{\text{distance}}{\text{time taken}}$$

$$= \text{average speed} = \frac{16}{4} = 4 \text{ m s}^{-1}$$

- As the gradient is constant, speed is constant.
- Because no direction has been given, we cannot state the velocity of this object.

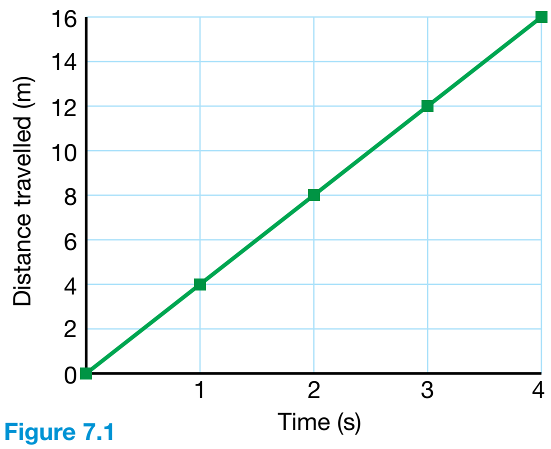


Figure 7.1

QUESTIONS

1. With reference to the graph in Figure 7.1:
   (a) How far had the object travelled after 2.5 s?
   (b) When was the object 12 m from its starting position?
   (c) What was the speed of the object at time 2.0 s?
   (d) What was the speed of the object at time 3.5 s?
   (e) Account for the similarity in your answers to (c) and (d).

Now consider the following graph.

The graph tells us (amongst other things) that:

- The object was at a displacement of 30 m north at time zero and stayed there for 2 s.
- At $t = 2$ s, the object moved towards zero displacement and got there at $t = 8$ s.
- The total distance travelled by the object was 30 metres.

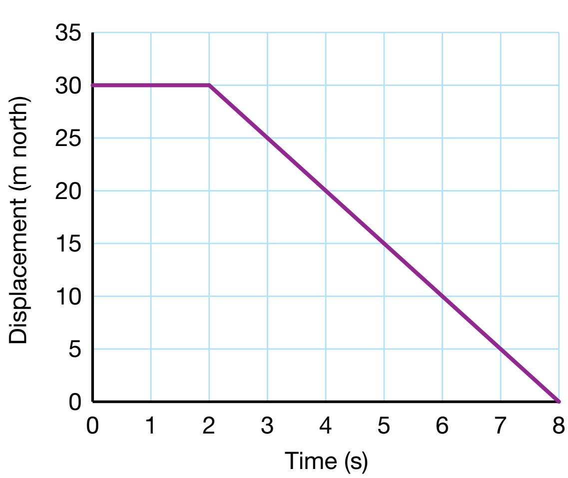


Figure 7.2

- The displacement of the object was 30 m south of its original position.
- While it was actually moving, it moved 30 m in 6 s.
- Its average speed while moving was therefore 5 m s^{-1} (gradient).
- Its average velocity was 5 m s^{-1} south (gradient has a negative slope).
- Its average speed for the whole period covered was 3.75 m s^{-1} (total distance divided by *total* time), i.e.

$$\text{Average speed} = \frac{\text{total distance travelled}}{\text{total time taken}} = \frac{30}{8} = 3.75 \text{ m s}^{-1}$$

- Its average velocity was 3.75 m s^{-1} south (displacement divided by *total* time), i.e.

$$\text{Average velocity} = \frac{\text{displacement}}{\text{time}} = \frac{30 \text{ m S}}{8} = 3.75 \text{ m s}^{-1} \text{ south}$$

MORE QUESTIONS

2. With reference to the graph in Figure 7.2:
(a) How far had the object travelled after 2.5 s?
(b) What is the displacement of the object after 4 s?
(c) When was the object 20 m from its starting position?
(d) What was the velocity of the object at time 1.5 s?
(e) What was the velocity of the object at time 3.5 s?
(f) At time 7 s the object has moved 25 m south of the position it started from. Can we therefore say that its displacement at time 7.0 s is 25 m south? Explain your answer.

3. Figure 7.3 shows how the displacement of an object varied over time.

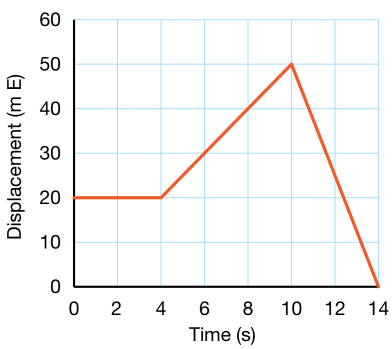


Figure 7.3

(a) Determine the displacement of the object at time = 2, 4, 6, 8, 10, 12 and 14 s.
(b) When was its speed constant?
(c) Calculate the speed of the object between:
$t = 0$ and $t = 2$ s
$t = 4$ and $t = 10$ s
$t = 10$ and $t = 14$ s
(d) Calculate its velocity during these three time intervals.
(e) Calculate the average speed of the object for the whole journey.
(f) Calculate the average velocity for the whole trip.

4. Figure 7.4 shows the displacement-time relationship for an object over 12 seconds.

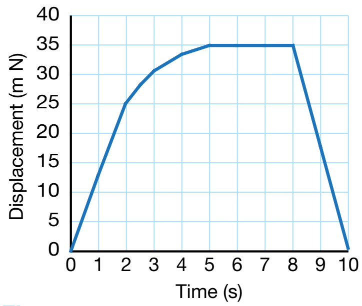


Figure 7.4

(a) Describe the velocity of the object between time 5 and 8 seconds.
(b) Describe the velocity of the object between time 8 and 10 seconds.
(c) Find its average speed for the journey.
(d) Find its average velocity for the journey.
(e) Without drawing it, describe how a distance travelled-time graph for this object would be different to the displacement-time graph.

5. Figure 7.5 shows how the displacement of an object changes over time.

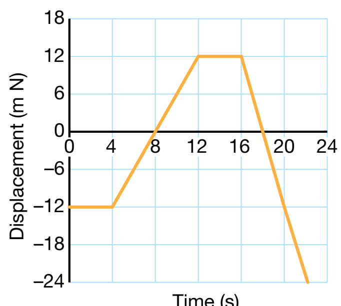


Figure 7.5

(a) How far does the object travel in the first 8 s of its journey?
(b) What is its average speed during the first 8 s?
(c) What is its average velocity during the first 18 s?
(d) Identify the instantaneous velocity of the object at $t = 9$ s.
(e) Identify the instantaneous velocity of the object at $t = 17$ s.
(f) What is its displacement after 22 s?
(g) Calculate the object's average speed and velocity for the 22 s.

Answers

Module 1 Kinematics

1 Distance and Displacement

1. A = 5.5 cm, 5.5 cm north
   B = 3.5 cm, 3.5 cm north-east
   C = 6.0 cm, 6.0 cm south-east
   D = 4.0 cm, 4.0 cm south
   E = 7.0 cm, 7.0 cm west
   F = 2.0 cm, 2.0 cm north-west
2. (a) At the lair.
   (b) At the waterhole.
   (c) 150 m east
   (d) 150 m
   (e) 300 m
   (f) 200 m
   (g) 150 m
   (h) 150 m
   (i) 150 m
   (j) 150 m east
   (k) 150 m east
   (l) 150 m east
   (m) 1 = 300 m, 2 = 450 m, 3 = 350 m
   (n) Zero
3.

Parrot at	Total distance travelled	Displacement using north/south convention	Displacement using +/– convention (+ = north)
A	50 cm	50 cm N	+50 cm
B	130 cm	30 cm S	–30 cm
C	160 cm	60 cm S	–60 cm
D	210 cm	10 cm N	+10 cm

2 Working Out Directions Another Way

1. A = 50 cm bearing 035°
   B = 40 cm bearing 069°
   C = 90 cm bearing 106°
   D = 35 cm bearing 225°
   E = 75 cm bearing 300°
   F = 40 cm bearing 340°
2. Distances:
   Scale: 1 cm = 20 km using ST distance.
   At A = 80 km
   At B = 180 km
   At C = 265 km
   At D = 415 km
   At E = 490 km
   Displacements:
   At A = 70 km bearing 195°
   At B = 40 km bearing 300°
   At C = 76 km bearing 016°
   At D = 70 km bearing 108°
   At T = 70 km bearing 050°
3. F = 61 km bearing 006°
   G = 53.5 km bearing 030°
   H = 34 km bearing 325°
   I = 21 km bearing 070°
   K = 21 km bearing 244°
   L = 40 km bearing 112°
   M = 37 km bearing 225°
   N = 33.5 km bearing 193°
   P = 46.5 km bearing 132°
   Hint: Little Ugly = 75 km bearing 016°

3 Speed

1. (a) 100 km
   (b) 2 hours
   (c) 50 km
   (d) Average speed = $\frac{\text{distance}}{\text{time}} = \frac{100}{2} = 50 \text{ km h}^{-1}$
   (e) Average speed = $\frac{210}{3} = 70 \text{ km h}^{-1}$
   (f) Average speed = $\frac{250}{5} = 50 \text{ km h}^{-1}$
   (g) Data does not take into account hills, stoplights, corners – cars rarely travel at constant speeds.
2. Average speed = $\frac{50}{30} = 1.67 \text{ m s}^{-1}$
3. Average speed = $\frac{10\,000}{6.5} = 1538.5 \text{ m s}^{-1}$
4. (a) $40 \text{ km h}^{-1} = \frac{40 \times 1000 \text{ metres}}{1 \times 60 \times 60 \text{ sec}} = \frac{40\,000}{3600} = 11.1 \text{ m s}^{-1}$
   (b) $250 \text{ cm s}^{-1} = \frac{250}{100} = 2.5 \text{ m s}^{-1}$
   (c) $60 \text{ km h}^{-1} = \frac{60 \times 1000}{3600} = 16.67 \text{ m s}^{-1}$
   (d) $100 \text{ km h}^{-1} = \frac{100 \times 1000}{3600} = 27.8 \text{ m s}^{-1}$
5. (a) $20 \text{ m s}^{-1} = \frac{3600 \times 20}{1000} = 72 \text{ km h}^{-1}$
   (b) $60 \text{ m s}^{-1} = \frac{3600 \times 60}{1000} = 216 \text{ km h}^{-1}$
   (c) $1000 \text{ cm s}^{-1} = \frac{3600 \times 1000}{100\,000} = 36 \text{ km h}^{-1}$
6. (a) Zero
   (b) 180 km h^{-1} (50 m s^{-1})
   (c) Average speed = $\frac{0 + 180}{2} = 90 \text{ km h}^{-1}$ (25 m s^{-1})
   (d) Instantaneous speed = 90 km h^{-1} (25 m s^{-1}) as 420 s is half the time taken.
   (e) Constant speed = $\frac{3600 \times 1}{40} = 90 \text{ km h}^{-1}$ (25 m s^{-1})
7. (a) Average speed = $\frac{1500}{30} = 50 \text{ m s}^{-1}$
   (b) Average speed = $\frac{270}{9} = 30 \text{ m s}^{-1}$
   (c) Average speed = $\frac{243}{27} = 9 \text{ m s}^{-1}$
   (d) Average speed = $\frac{12.3}{3.2} = 3.8 \text{ m s}^{-1}$
   (e) Average speed = $\frac{640}{16} = 40 \text{ m s}^{-1}$
   (f) Time = $\frac{\text{distance}}{\text{average speed}} = \frac{800}{25} = 32 \text{ s}$
   (g) Time = $\frac{300}{12} = 25 \text{ s}$
   (h) Time = $\frac{250}{12.5} = 20$ hours
   (i) Time = $\frac{3.6 \times 1000}{12} = 300 \text{ s}$
   (j) Time = $\frac{160}{8} = 20$ hours
   (k) Distance = average speed × time = 16 × 3.5 = 56 km
   (l) Distance = 5 × 150 = 750 km
   (m) Distance = 10 × (2 × 60) = 1200 m
   (n) Distance = 0.5 × 25 = 12.5 m
   (o) Distance = 90 × 0.3 = 27 m

4 Velocity

1. Average speed = $\frac{200}{4} = 50 \text{ km h}^{-1}$, $v_{av} = 50 \text{ km h}^{-1}$ north
2. Average speed = $\frac{6.0}{3} = 2 \text{ m s}^{-1}$, $v_{av} = 2 \text{ m s}^{-1}$ from X to Y
3. Average speed = $\frac{7.5}{0.5} = 15 \text{ km h}^{-1}$, $v_{av} = \frac{4.5}{0.5} = 9 \text{ km h}^{-1}$ bearing 067°

4. (a) $d = 3 + 4 + 3 + 4 + 3 + 4 = 21$ km
(b) Average speed $= \frac{21}{7} = 3$ km h^{-1}
(c) P = 0, Q = 3 km S, R = 5 km bearing 127° S = 4 km E
(d) $s = 5$ km bearing 127°
(e) $v_{av} = \frac{5}{7} = 0.71$ km h^{-1} bearing 127°
(f) $v_{av} = 3$ km h^{-1} bearing 180°
5. (a) Average speed $= \frac{2000}{40} = 50$ m s^{-1}, $v_{av} = 50$ m s^{-1} S
(b) Average speed $= \frac{250}{12.5} = 20$ m s^{-1}, $v_{av} = 20$ m s^{-1} E
(c) Average speed $= \frac{120}{4} = 30$ m s^{-1}, $v_{av} = 30$ m s^{-1} W
(d) Average speed $= \frac{5.6}{1.4} = 4$ m s^{-1}, $v_{av} = 4$ m s^{-1} NW
(e) Average speed $= \frac{525}{2.5} = 210$ m s^{-1}, $v_{av} = 210$ m s^{-1} bearing 063°
(f) Time $= \frac{800}{40} = 20$ s, $v_{av} = 40$ m s^{-1} bearing 142°
(g) Time $= \frac{300}{15} = 20$ s, $v_{av} = 15$ m s^{-1} bearing 237°
(h) Time $= \frac{80}{5} = 16$ hours, $v_{av} = 5$ km h^{-1} bearing 010°
(i) Time $= \frac{2.6 \times 1000}{20} = 130$ s, $v_{av} = 20$ m s^{-1} NW
(j) Time $= \frac{150}{25} = 6$ hours, $v_{av} = 25$ km h^{-1} N
(k) $s = 20 \times 1.5 = 30$ km W, average speed = 20 km h^{-1}
(l) $s = 2.5 \times 15 = 37.5$ m SE, average speed = 2.5 m s^{-1}
(m) $s = 6 \times (12 \times 60) = 4320$ m NE, average speed = 6 m s^{-1}
(n) $s = 0.6 \times 35 = 21$ m S, average speed = 0.6 m s^{-1}
(o) $s = 40 \times 0.5 = 20$ m bearing 042°, average speed = 40 m s^{-1}

5 Acceleration

1. $v = ?$; $u = 0$; $a = 3$ m s^{-2} N; $t = 4, 8, 12$ s
$v = u + at = 0 + 3 \times 4 = 12$ m s^{-1} N
$v = 0 + 3 \times 8 = 24$ m s^{-1} N
$v = 0 + 3 \times 12 = 36$ m s^{-1} N
2. $v = 29.4$ m s^{-1} down; $u = 0$; $a = ?$ m s^{-2}; $t = 3$ s
$a = \frac{v-u}{t} = \frac{29.4-0}{3} = 9.8$ m s^{-2} down
3. $v = 0$; $u = 32$ m s^{-1} W; $a = ?$ m s^{-2}; $t = 0.02$ s
$a = \frac{v-u}{t} = \frac{0-32}{0.02} = -1600$; i.e. 1600 m s^{-2} against motion
4. (a) $v = 50$ m s^{-1}; $u = ?$ m s^{-1} W; $a = +2.5$ m s^{-2}; $t = 4$ s
$v = u + at$; $u = v - at = 50 - 2.5 \times 4 = 40$ m s^{-1}
(b) $v = 50$ m s^{-1}; $u = ?$ m s^{-1} W; $a = -2.5$ m s^{-2}; $t = 4$ s
$v = u + at$; $u = v - at = 50 - (-2.5 \times 4) = 60$ m s^{-1}
5. $v = 1800$ m s^{-1}; $u = 0$ m s^{-1} W; $a = 4.5$ m s^{-2}; $t = ?$ s
$t = \frac{v-u}{a} = \frac{1800-0}{40} = 45$ s
6. $v = 36$ m s^{-1}S; $u = ?$ m s^{-1} W; $a = 4.5$ m s^{-2}; $t = 6$ s
$u = v - at = 36 - (4.5 \times 6) = 9$ m s^{-1} S
7. $v = -10$ m s^{-1} W; $u = ?$ m s^{-1} W; $a = +2.5$ m s^{-2} E; $t = 16$ s (E is positive)
$u = v - at = -10 - (2.5 \times 16) = -50$; i.e. 50 m s^{-1} W

6 SI Units and Powers Of Ten

No questions.

7 Displacement-Time Graphs 1

1. (a) 10 m
(b) At time 3.0 s
(c) Gradient = 4 m s^{-1}
(d) Gradient = 4 m s^{-1}
(e) The speed at any instant is the gradient of the graph, and since this is constant, then the object is travelling at constant speed. Its speed at any instant of time will be the same.
2. (a) 2.5 m
(b) 20 m N
(c) At time = 6.0 s (read the question carefully).
(d) Zero – it is stationary.
(e) Gradient = –5 m s^{-1}, i.e. south.
(f) No, because in this case, the zero displacement position is defined by the y-axis of the graph. Certainly the object has moved 25 m south, but its displacement is not 5 m N.
3. (a) 20 m E, 20 m E, 30 m E, 40 m E, 50 m E, 25 m E, 0
(b) From $t = 0$ to 4 s, 4 to 10 s, and 10 to 14 s (different values; straight lines).
(c) 0, speed $= \frac{\text{rise}}{\text{run}} = \frac{50-20}{10-4} = 5$ m s^{-1}, speed $= \frac{-50}{14-10}$ $= 12.5$ m s^{-1}
(d) 0, 5 m s^{-1} east, –12.5 m s^{-1} or 12.5 m s^{-1} west
(e) Average speed $= \frac{30+50}{14} = 5.7$ m s^{-1}
(f) $v_{av} = \frac{20}{14} = 1.43$ m s^{-1} west
4. (a) It was constant at zero.
(b) It was constant at $v_{av} = \frac{-35}{10-8}$ $= -17.5$ m s^{-1} or 17.5 m s^{-1} south.
(c) Average speed $= \frac{2 \times 35}{10} = 7.0$ m s^{-1}
(d) Zero (displacement for the journey is zero).
(e) The last section (between time 8 and 10 s) would rise up to a distance of 70 rather than falling to the zero displacement axis.
5. (a) 12 m
(b) Average speed $= \frac{12}{8} = 1.5$ m s^{-1} north.
(c) $v_{av} = \frac{12}{18} = 0.67$ m s^{-1} north
(d) Gradient $= \frac{\text{rise}}{\text{run}} = \frac{24}{8} = 3$ m s^{-1} north.
(e) Gradient $= \frac{-24-12}{22-16} = \frac{-36}{6} = -6$ m s^{-1} or 6 m s^{-1} south.
(f) $s = -12$ m or 12 m S
(g) Average speed $= \frac{24+36}{22} = 2.73$ m s^{-1}, average velocity $= \frac{12\text{ S}}{22} = 0.55$ m s^{-1} S

8 Displacement-Time Graphs 2

1. A Object is stationary at a displacement of 10 m N for 10 s.
B Gradient $= \frac{-5}{20} = -0.25$ m s^{-1}. Object starts at a displacement of 5 m S and travels with a constant velocity of 0.25 m s^{-1} S for 20 s ending at the zero displacement position.
C Gradient $= \frac{5}{5} = 1.0$ m s^{-1}. Object starts at the zero displacement position and travels with a constant velocity of 1.0 m s^{-1} east for 5 s ending at a displacement of 5 m E.
D Gradient $= \frac{8}{2} = 4$ m s^{-1}. Object starts at a displacement of zero and travels with a constant velocity of 4.0 m s^{-1} S for 2 s reaching a displacement of 8 m S. It then stops and remains there for 3 more seconds. Its average velocity for the journey was 1.6 m s^{-1} S.
2. (a) A Zero
B Zero
C 6 m N
D 20 m W
(b) A About 8.8 m W
B 12 m N
C 8 m S
D 15 m E
(c) A About 8.8.m
B 12 m
C 14 m
D 35 m
(d) A About 8.8.m W
B 12 m N
C 14 m S
D 35 m E