Section 2.1.1 – Analysing Movement

Scalar & Vector Quantities

All physical measurements can be classified as either a vector or scalar quantities.

A **vector** measurement contains a **magnitude and direction.**
A **scalar** measurement contains a **magnitude** only.

Eg. A force of **5000** N **forwards**
A displacement of **200 m North**
An acceleration of **10 ms^2 downwards**

Each has a magnitude and direction
∴ a **vector**.

Eg. A mass of 9**00 kg**
A speed of **80 kmh^{-1}**
An energy of **3 kJ**

Each has a magnitude only
∴ a **scalar**.

Distance & Displacement

Distance is a scalar quantity. It measures the entire distance covered along a given journey. The international standard (**SI**) unit of measurement is the **metre.**

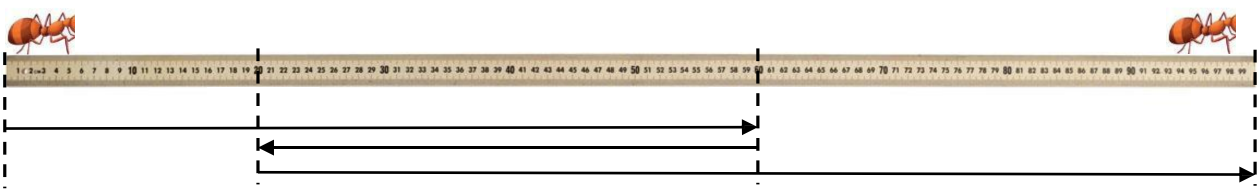
Displacement is a vector quantity. It measures the change in position – comparing the final position to that of the initial position (metres): "**as the crow fly**".

$$\boxed{\Delta s = s_{final} - s_{intital}}$$

where Δs represents the change in displacement (m)
s_{final} represents the final position (m)
$s_{intital}$ represents the initial position (m)

Example.1

Consider an ant walking upon a metre ruler. It starts at the 0 cm mark, it then travels to the 60 cm mark, returns to the 20 cm mark and finally moves forward to the 100cm mark.



Calculate the total distance travelled by the ant and its displacement.

<u>Distance travelled</u>
d = 60 cm (R) +40 cm (L) + 80 cm (R)
= 180 cm

<u>Displacement</u>
$\Delta s = s_{final} - s_{initial}$
$= 100\ cm\ (R) - 0cm$
$= 100\ cm\ (R)$

Example.2

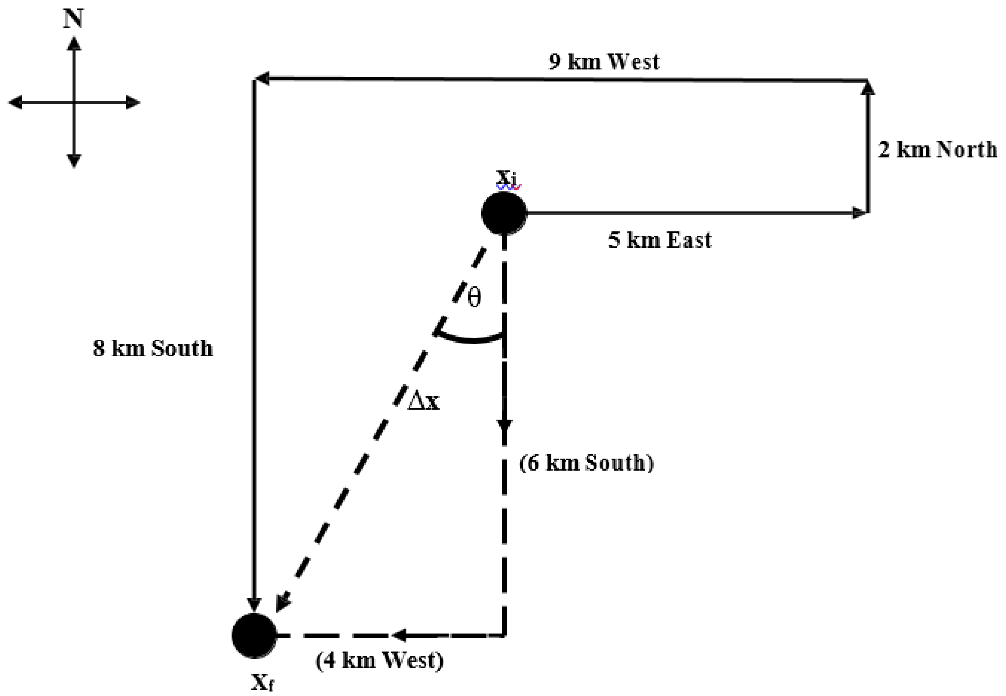
Consider the following journey of a postman during a particular delivery. In turn the postman travels.

5 km East
2 km North
9 km West
8 km South

Task

1. Draw a scaled diagram of the journey (on graph paper)
2. Calculate the total distance travelled
3. Calculate the postman's displacement.

Solution



Distance travelled

distance = 5km + 2 km + 9 km + 8 km
= 24 km

Displacement

Δs is solved using Pythogoras' Theorem: $c^2 = a^2 + b^2$

$$\Delta s^2 = 6^2 + 4^2$$
$$\therefore \Delta s^2 = 36 + 16$$
$$\Delta s^2 = 52$$
$$\Delta s = \sqrt{52}$$
$$\Delta s = 7.2\ km$$

$$\tan(\theta) = \frac{Opp}{Adj}$$
$$\tan(\theta) = \frac{4}{6}$$
$$\therefore\ \theta = tan^{-1}\left(\frac{4}{6}\right) = 33.7^{\circ}$$

$$\therefore \underline{\boldsymbol{\Delta s = 7.2\ km, S\ 33.7^{\circ}\ W\ (or\ 213.7^{\circ}T)}}$$

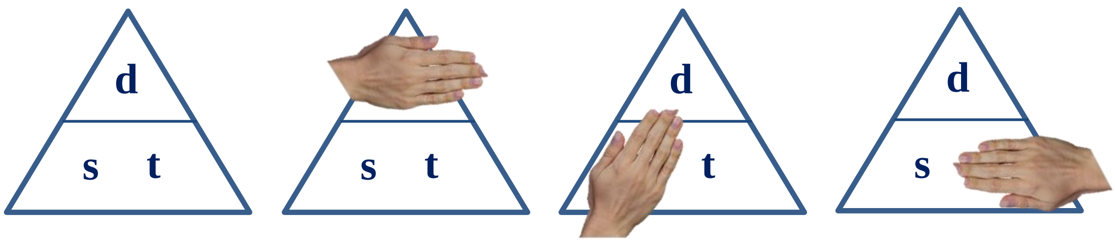
Speed & Velocity

An objects **speed** is a measure of the **rate** at which it travels over a **distance.**
SI unit of measurement is **metres per second (m/s) or (ms^{-1})**

$$\boxed{speed = \frac{distance}{time}}$$

Using the Triangle Technique

"Simply cover the quantity you wish to calculate and read the transposed equation."



Example.3

Consider the following land speed records for a vehicle over a distance of 1 km.

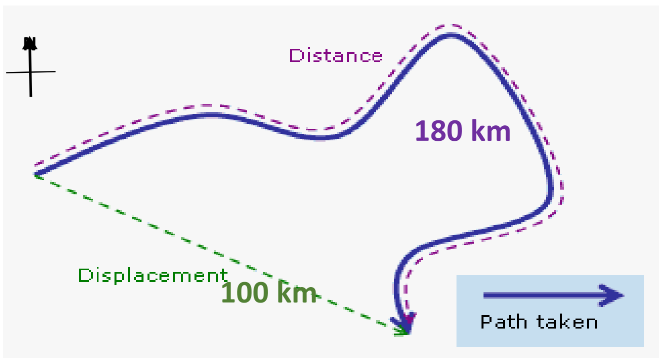
1899	$63\ kmh^{-1}$	1906	$205\ kmh^{-1}$	1927	$326\ kmh^{-1}$
1937	$502\ kmh^{-1}$	1965	$921\ kmh^{-1}$	1997	$1223\ kmh^{-1}$

Thrust supersonic car, is a British jet-propelled car developed by Richard Noble.

Thrust SSC holds the World Land Speed Record, set on 15 October 1997, when it achieved a speed of 1,228 km/h (763 mph) and became the first car to officially break the sound barrier.

Example.4

Sally goes for an early Sunday morning drive. She travels along a windy road to eventually reach her destination some 2 hours later. Given that her distance travelled is 180 km, calculate her average speed.



speed = ?
distance = 180 km
time = 2 hrs

$$speed = \frac{distance}{time}$$

$$speed = \frac{180\ km}{2\ hr}$$

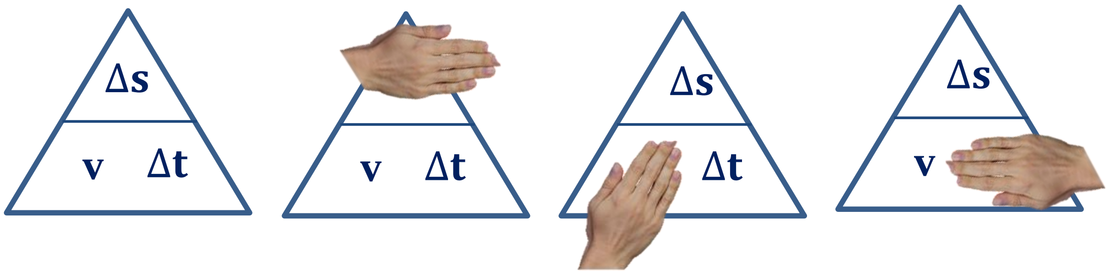
$$= 90\ kmh^{-1}$$

NB: km/hr is the same as kmh^{-1}

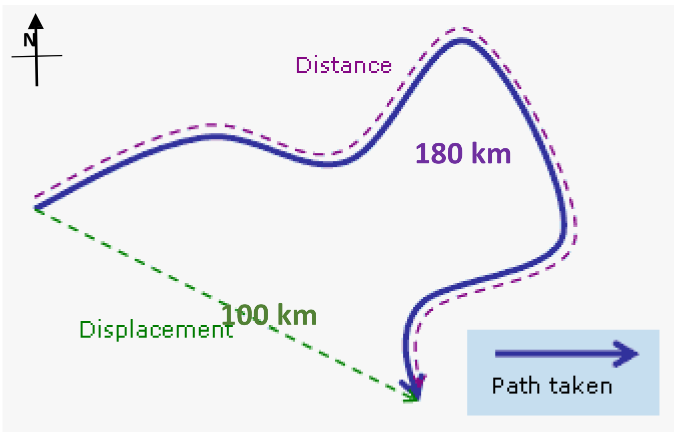
An objects **velocity** is a measure of the **rate** at which it travels over a given **displacement.**
SI unit of measurement is also **metres per second (m/s) or (ms^{-1})**.

$$\boxed{v_{avg} = \frac{\Delta s}{\Delta t} = \frac{s_2 - s_1}{t_2 - t_1}}$$

Where v_{avg} represents average velocity (ms^{-1})
Δs represents the change in displacement (m)
Δt represents the change in time (sec)



Example.5
Consider the previous example where Sally goes for an early Sunday morning drive. She travelsalong a windy road to eventually reach her destination some 2 hours later. Whilst her distance travelled is 180 km, her displacement (from start to finish) was only 100 km. Calculate her average velocity.



Avg. velocity (v)= ?
Δs = 100 km (approx. SE)
Δt = 2 hrs

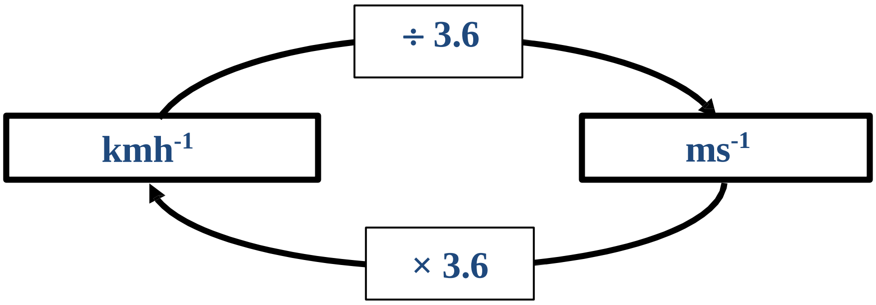
$$v_{avg} = \frac{\Delta s}{\Delta t}$$
$$v_{avg} = \frac{100\ km}{2\ hr}$$
$$= 50\ kmh^{-1}\ (approx. SE)$$

Converting units of speed

$$100\ kmh^{-1} = \frac{100{,}000\ m}{60 \times 60\ sec}$$

$$= \frac{100{,}000\ m}{3600\ sec}$$

$$= 27.\dot{7}\ ms^{-1}$$



Example.6

Betty drives trucks for Linfox transport from Melbourne to Brisbane three times a week.

Her one way journey covers a distance of 1861 km and takes her a total of 17.5 hours. Calculate her average speed in kmh^{-1} and convert to m/s.

speed = ?
distance = 1861 km
time = 17.5 hrs

$$speed = \frac{distane}{time}$$

$$= \frac{1861\ km}{17.5\ hr}$$

$$= 106.3\ kmh^{-1}$$

Conversion from kmh^{-1} into ms^{-1}

$$Speed\ (ms^{-1}) = \frac{Speed\ (kmh^{-1})}{3.6}$$

$$= \frac{106.3}{3.6}$$

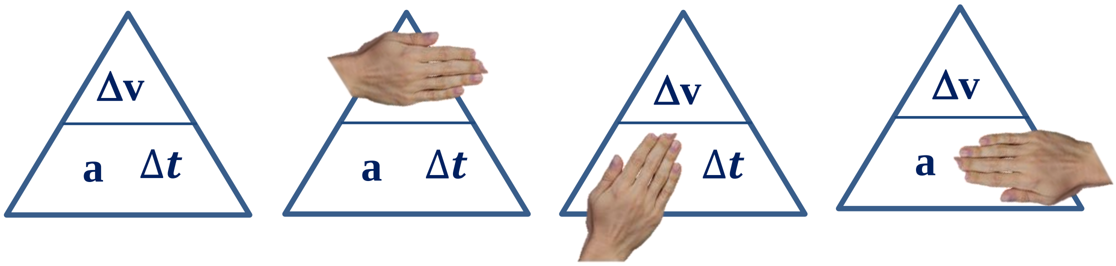
$$= 29.5\ ms^{-1}$$

Acceleration

An objects **acceleration** is a measure of the **rate** at which it **changes its velocity**.
An object that is **increasing its velocity** is said to be **accelerating**.
An object that is **decreasing its velocity** is said to be **decelerating**.
SI unit of measurement for acceleration is **metres per second per second (m/s/s) or (ms^{-2})**

$$\boxed{a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}}$$

Where a_{avg} represents average acceleration (ms^{-2})
Δv represents the change of velocity (ms^{-1})
Δt represents the change in time (sec)



Example.7

On the weekend Alex is involved with street racing. His sports car can accelerate from rest to 100 kmh^{-1} in 2.8 seconds. Calculate his cars rate of acceleration.

a_{avg} = ?

$$\begin{aligned}\Delta v &= v_{final} - v_{initial}\\ &= 100\ kmh^{-1} - 0\ kmh^{-1}\\ &= 100\ kmh^{-1}\\ &= \frac{100\ kmh^{-1}}{3.6}\\ &= 27.8\ ms^{-1}\end{aligned}$$

$\Delta t = 2.8\ sec$

$$\begin{aligned}a_{avg} &= \frac{\Delta v}{\Delta t}\\ &= \frac{27.8}{2.8}\\ &= 9.9\ ms^{-2}\end{aligned}$$

Example.8

Whilst travelling at 100 kmh^{-1}, Alex enters a school zone with a 40 kmh^{-1} speed limit. He breaks suddenly reducing his speed to the required limit of 40 kmh^{-1} in 0.75 second. Calculate his cars rate of deceleration.

a_{avg} = ?

$$\begin{aligned}\Delta v &= v_{final} - v_{initial}\\ &= 40\ kmh^{-1} - 100\ kmh^{-1}\\ &= -60\ kmh^{-1}\\ &= \frac{-60}{3.6}\\ &= -16.7\ ms^{-1}\end{aligned}$$

Δt = 0.75 sec

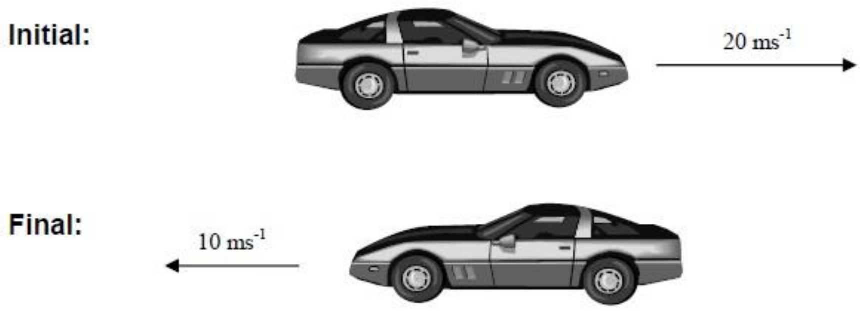
$$\begin{aligned}a_{avg} &= \frac{\Delta v}{\Delta t}\\ &= \frac{-16.67}{0.75} = -22.2\ ms^{-2}\\ &= -22.2\ ms^{-2}\end{aligned}$$

$\therefore$ Alex's rate of deceleration is 22.2 ms^{-2}

Exam Style Questions

Questions 1 - 3 refer to the following information

A car is travelling at 20 ms^{-1} East. After 20 seconds the car is observed to be now travelling at 10 ms^{-1} West.



Question.1
The car travels through a 40 kmh^{-1} school zone while doing 20 ms^{-1} East.
Is the car breaking the speed limit?

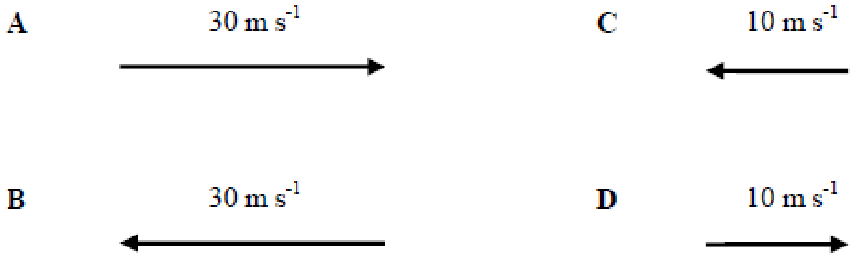
Circle your choice: **Breaking Speed limit** **Not breaking speed limit.**

Support your choice by with an appropriate calculation.

20 ms^{-1} = 20 x 3.6
= 72 kmh^{-1}

72 kmh^{-1} > 40 kmh^{-1} speed limit
∴ speeding

Question 2.
Which of the following vectors (A – D) best represents the change in velocity (Δv) of the car?

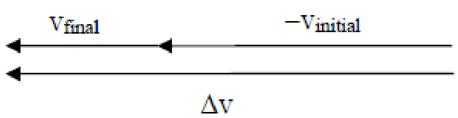


B

NB: Take west as positive and east as negative

$V_{initial}$ = -20 ms^{-1}
V_{final} = 10 ms^{-1}

$\Delta v = v_{final} - v_{initial}$
= 10 – (-20)
= 30 ms^{-1}
= 30 ms^{-1} West



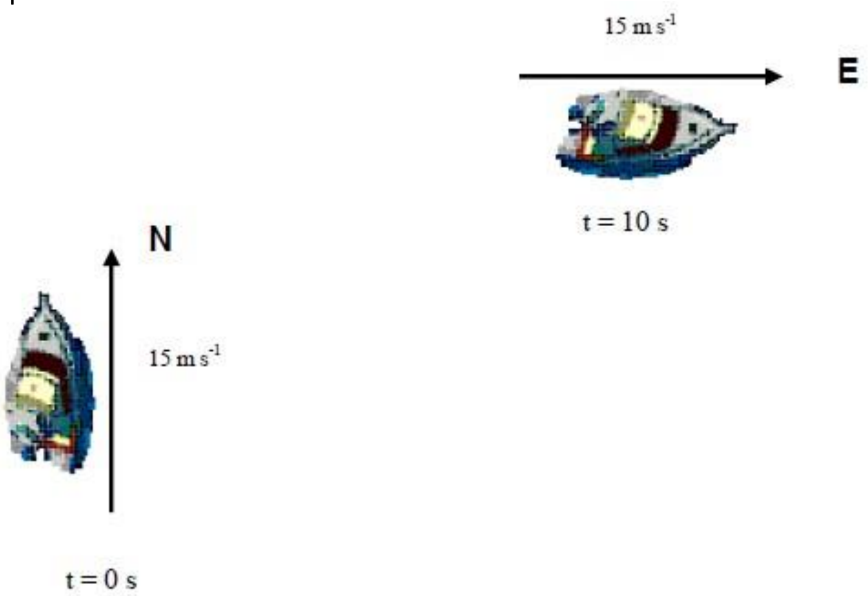
Question 3.
What is the magnitude of the average acceleration of the car in ms^{-2}, as it changes direction during these 20 seconds?

Δv = 30 ms^{-1}
Δt = 20 sec
a_{avg} =?

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{30}{20} = 1.5\, ms^{-2}\ West$$

Questions 4 to 6 refer to the following information

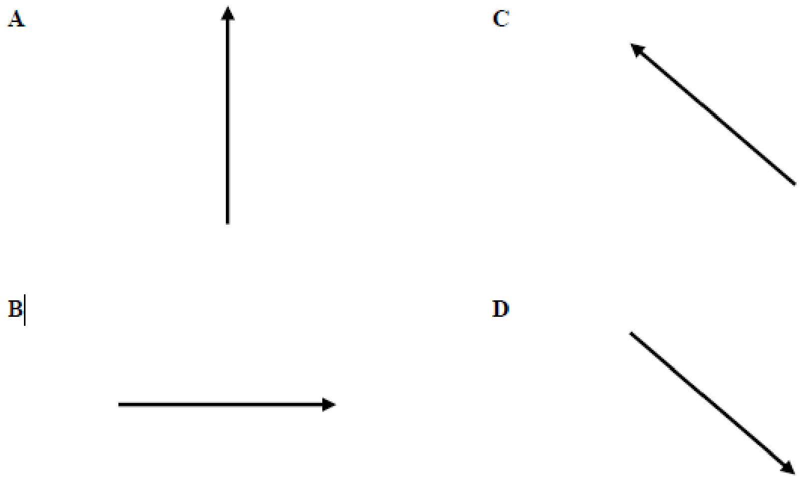
A motorboat, shown in plan view from above, is observed to be travelling at 15 ms^{-1} due North. It makes a right hand turn and is then seen travelling at the same speed due East. The turn takes 10 $seconds$ to complete.



Question 4.
What is 15 ms^{-1} in kmh^{-1}?

15 ms^{-1} = 15 x 3.6
= 54 kmh^{-1}

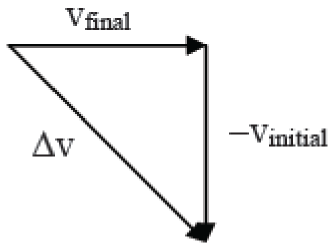
Question 5
Which of the following vectors (**A - D**) best represents the change in velocity (Δv) of the motorboat during the right hand turn shown in the plan view on the previous page?



$\boxed{\textbf{D}}$

$\Delta v = v_{final} - v_{initial}$
$\Delta v = v_{final} + (-v_{initial})$

As a vector this looks like:



Question 6.
What is the magnitude of the average acceleration of the boat in ms^{-2}, as it makes the turn?

$a_{avg} = ?$
$\Delta v = v_{final} + (-v_{initial})$ [Use Pythagoras' theorem]
$= \sqrt{15^2 + 15^2}$
$= \sqrt{225 + 225}$
$= \sqrt{450}$
$= 21.21\ ms^{-1}$
$\Delta t = 10$ sec

$a_{avg} = \dfrac{\Delta v}{\Delta t}$
$= \dfrac{21.21}{10}$
$= 2.12\ ms^{-2}$