Symbols and Units

At A-Level, you're expected to use **standard scientific notation**. This means using **conventional symbols** and **units**, and writing very large and very small numbers in **standard form**.

The table below lists the different quantities you'll come across in this book, with their standard symbols and units:

Quantity	Symbol	Unit
Displacement (distance)	s	metre, m
Time	t	second, s
Velocity (speed)	v	metre per second, ms^{-1}
Acceleration	a	metre per second squared, ms^{-2}
Mass	m	kilogram, kg
Force	F	newton, N
Gravitational field strength	g	newton per kilogram, $N\,kg^{-1}$
Energy	E	joule, J
Work	W	joule, J
Power	P	watt, W
Frequency	f	hertz, Hz
Wavelength	λ	metre, m
Charge	Q	coulomb, C
Electric current	I	ampere, A
Potential difference	V	volt, V
Resistance	R	ohm, Ω

At A-Level, units like m/s are written ms^{-1}.
This is just **index notation**.
(If it doesn't make sense to you, look up 'rules of indices' in a maths book.)

Standard form lets us write **very big** or **very small** numbers in a more convenient way. It looks like this:

A must be between 1 and 10 → $A \times 10^n$ ← n is the number of places the decimal point moves

For example:
53 100 can be written as **5.31×10^4**, and **2.5×10^{-3}** is the same as **0.0025**.

You might also see large or small numbers given in units with these prefixes:

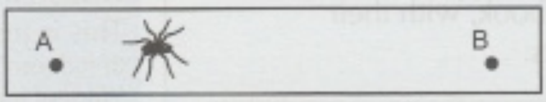
Multiple	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

Make sure you give your answers to questions to a sensible number of **significant figures**.
An easy way to do this is by always rounding your answers to the **same number** of significant figures as the given data value you've used in the calculation with the **least** significant figures.
Then **write** the number of significant figures you've rounded your answer to:
e.g. $2 \div 3.5 = 0.571... =$ **0.6 (to 1 s.f.)**
(2 is to 1 s.f., 3.5 is to 2 s.f., so the answer needs to be given to 1 s.f.)

Speed, Displacement and Velocity

Distance, Time and Speed are all Related

Points A and B are separated by a **distance** in **metres**. Now imagine a spider walking from A to B — you can measure the **time** it takes, in **seconds**, for it to travel this distance.



You can then work out the spider's **average speed** between A and B using this **equation**:

speed (in metres per second) = **distance travelled** (in metres) ÷ **time taken** (in seconds)

This is a very useful equation, but it does have a couple of **limitations**:

1) It only tells you the **average** speed. The spider could **vary** its speed from fast to slow and even go **backwards**. So long as it gets from A to B in the **same time** you get the **same answer**.
2) We assume that the spider takes the **shortest possible path** between the two points (a straight line), rather than **meandering** around.

Displacement is a Vector Quantity

To get from point A to point B you need to know what **direction** to travel in — just knowing the **distance** you need to travel **isn't enough**.

This information, **distance plus direction**, is known as the **displacement** from A to B and has the symbol **s**. It's a **vector** quantity — **all** vector quantities have both a **size** and a **direction**.

There is a Relationship Between Displacement and Velocity

Velocity is another **vector quantity** — velocity is the **speed** and **direction** of an object.

The **velocity** of an object is given by the following equation:

velocity (in metres per second) = **displacement** (in metres) ÷ **time taken** (in seconds)

Or, in symbols: $v = \frac{s}{t}$

This equation is very similar to the one relating **speed** and **distance**, except that it includes information about the **direction of motion**.

Displacement's in a relationship with velocity now, it's so over time...

1) An athlete runs a 1500 m race in a time of 210 seconds. What is his average speed?
2) The speed of light is 3.0×10^8 ms^{-1}. If it takes light from the Sun 8.3 minutes to reach us, what is the distance from the Earth to the Sun?
3) A snail crawls at a speed of 0.24 centimetres per second. How long does it take the snail to travel 1.5 metres?
4) How long does it take a train travelling with a velocity of 50 ms^{-1} north to travel 1 km?
5) If someone has a velocity of 7.50 ms^{-1} south, what is their displacement after 15.0 seconds?

Drawing Displacements and Velocities

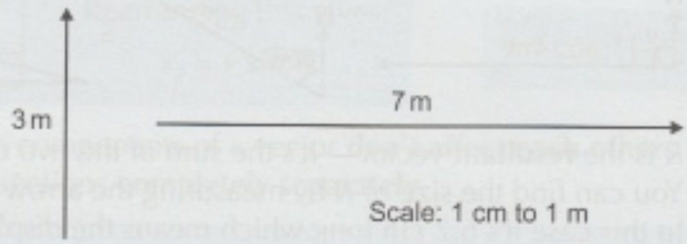
You can use **Scale Drawings** to **Represent Displacement**

The simplest way to draw a vector is to draw an **arrow**. So for a displacement vector the **length** of the arrow tells you the **distance**, and the way the arrow **points** shows you the **direction**.

You can do this even for very large displacements so long as you **scale down**. Whenever you do a scale drawing, make sure you **state the scale** you are using.

EXAMPLE: Draw arrows to scale to represent a displacement of 3 metres upwards and a displacement of 7 metres to the right.

A displacement of 3 metres upwards could be represented by an arrow of length 3 centimetres. Using this same scale (1 cm to 1 m) a displacement of 7 metres to the right would be an arrow of length 7 centimetres.

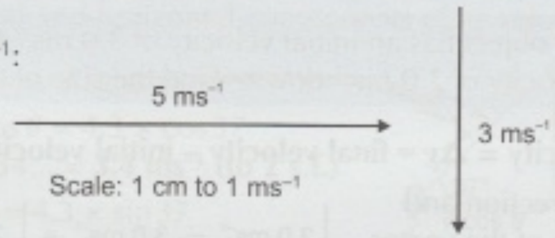


You can also **Represent Velocities** with **Arrows**

Velocity is a **vector**, so you can **draw arrows** to show velocities too. This time, the **longer** the **arrow**, the **greater** the **speed** of the object. A typical scale might be 1 cm to 1 ms^{-1}.

EXAMPLE: Draw arrows to scale to represent velocities of 5 metres per second to the right and 3 metres per second downwards.

Draw the velocities like this with a scale of 1 cm to 1 ms^{-1}:



Drawing displacements — not about leaving your sketchbook at home...

1) Draw arrows representing the following displacements to the given scale:
   a) 12 m to the right (1 cm to 2 m)
   b) 110 miles at a bearing of 270° (1 cm to 20 miles)
2) Draw an arrow to represent each velocity to the given scale. Take north to be up the page.
   a) 60 ms^{-1} to the south-east (1 cm to 15 ms^{-1})
   b) 120 miles per hour to the west (1 cm to 30 miles per hour)

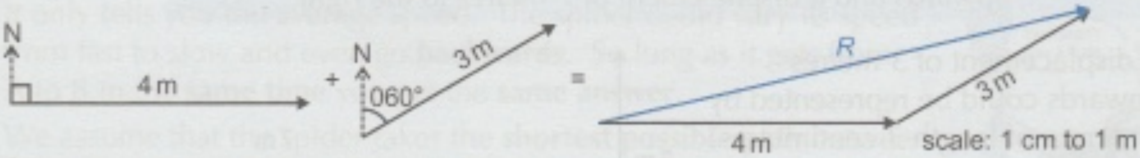
Combining Displacements and Velocities

You can use **Arrows** to **Add** or **Subtract Two Vectors**...

To **add** two velocity or displacement vectors, you **can't** simply add together the two distances as this doesn't account for the **different directions** of the vectors. What you do is:

1) **Draw** arrows representing the two vectors.
2) **Place** the arrows **one after the other** "tip-to-tail".
3) Draw a **third** arrow from start to finish. This is your **resultant vector**.

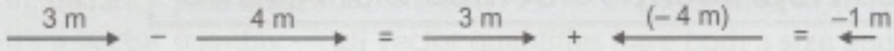
EXAMPLE: Add a displacement of 4 metres on a bearing of 090° to a displacement of 3 metres on a bearing of 060°. Use a scale of 1 cm to 1 m.



R is the **resultant** vector— it's the sum of the two displacements.
You can find the size of R by measuring the arrow and scaling up.
In this case it's 6.7 cm long which means the displacement is **6.7 m.**

To **subtract** vectors you need to **flip the direction** of the vector you are subtracting.
This **changes the sign** of the vector.
Adding the flipped vector is the **same** as **subtracting** the vector.

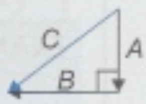
For example:



...Or Use **Pythagoras** if the Vectors make a **Right Angle Triangle**

If two vectors, A and B, are at right angles to each other, you can also use Pythagoras' theorem to find the resultant.

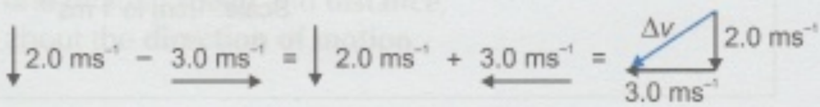
$A^2 + B^2 = C^2$



EXAMPLE: An object has an initial velocity of 3.0 ms^{-1} to the right, and a final velocity of 2.0 ms^{-1} down. Find the size of the change in velocity.

Change in velocity = Δv = final velocity – initial velocity.

First, flip the direction and change the sign of the vector that is being subtracted.



$A^2 + B^2 = C^2$, so $C = \sqrt{A^2 + B^2} = \sqrt{2.0^2 + 3.0^2} = 3.605... =$ **3.6 ms^{-1} (to 2 s.f.)**

(This answer is rounded to 2 s.f. to match the data in the question — see page 1.)

Subtracting velocity vectors is easy — subtracting velociraptors, less so...

1) Find the size of the resultant of the following displacements by drawing the arrows "tip-to-tail".
   a) 5.0 m right and 4.0 m up.
   b) 15.0 miles south and 15.0 miles on a bearing of 045°.
2) Initial velocity = 1.0 ms^{-1} west and final velocity = 3.0 ms^{-1} north. Find the size of Δv.