MEASUREMENTS

SI base units

In the SI system of units, there are **seven** base quantities and their units. These 7 quantities are assumed to be mutually independent.

Base Quantities	SI Base Units	
	Name	Symbol
Length	metre	m
Mass	kilogram	kg
Time	seconds	s
Current	ampere	A
Amount of substance	mole	mol
Luminous Intensity	candela	cd

Prefixes (Order of magnitudes)

Can be added to SI base units and derived units to make larger or smaller units. (e.g. 1 ms = 10^{-3} s, 1 km = 10^{3} m)

Name	Symbol	Factor
pico	p	$\times 10^{-12}$
nano	n	$\times 10^{-9}$
micro	μ	$\times 10^{-6}$
milli	m	$\times 10^{-3}$
centi	c	$\times 10^{-2}$
deci	d	$\times 10^{-1}$
kilo	k	$\times 10^{3}$
mega	M	$\times 10^{6}$
giga	G	$\times 10^{9}$
tera	T	$\times 10^{12}$

Homegeneity of Physical Equations

- Each term in an homogeneous equation has the same units.
- For any two quantities to be **equated, added or subtracted**, they must have the same dimension (or units).
- Homogeneous equation may not be correct (e.g. missing terms / coefficients) but a non-homogeneous equation must be wrong.

Derived Quantities

Derived quantities are physical quantities expressed in terms of one or more base quantities.

General rules for determining the units of derived quantities:

1) For addition / subtraction of two or more quantities, each quantity must have the SAME unit.
2) For multiplication / division, rules of algebraic multiplication and division apply.
3) Exponents (powers/indexes) are unitless.

Systematic Error & Random Error

Systematic errors have the same magnitude and sign when measurements are repeated.

Causes: Instrument errors (e.g. zero errors), Environmental conditions, Poor experimental techniques (e.g. parallax error).

Systematic error can be eliminated if the source of the error is known.

Random errors have different magnitudes and signs (i.e. varying both magnitude and direction) when measurements are repeated.

Causes: Variations in environmental conditions, Irregularity of the quantity being measured, Limitation of equipment.

Random error cannot be completely eliminated but can be minimised by finding the average of repeated measurements.

Precision & Accuracy

Precision refers to how close the repeated measured values are to each other, without regard to the true value of the quantity. Repeated measurements which are very close to one another are precise measurements. Thus an experiment which has small random errors (i.e. small spread of readings) is said to have high precision.

Accuracy refers to how close a measured value is to the true value of a quantity. An experiment which has small systematic errors is said to have high accuracy. The average value is close to the true value.

Errors / Uncertainties

When making any measurement, there is always some ***uncertainty / error***.

Experimental uncertainty or error = Measured value – True value

Absolute error / uncertainty – e.g. error / uncertainty in measuring length, $\Delta\ell$

Fractional error / uncertainty – e.g. $\frac{\Delta\ell}{\ell}$ **Percentage error / uncertainty** – e.g. $\frac{\Delta\ell}{\ell}\times 100\%$

General rules for recording measurement with its uncertainty (i.e. $\ell \pm \Delta\ell$):

- Round off errors / uncertainties / absolute uncertainties to 1 s.f. (i.e. $\Delta\ell$ rounded to 1 s.f.)
- Write the measured value to the same decimal place as its error / uncertainty / absolute uncertainty. (i.e. ℓ rounded to same d.p. as $\Delta\ell$)

Consequential Uncertainties (Formula method)

Method 1 - Numerical Substitution

1. Find the "best" value
2. Find the "maximum" value
3. Uncertainty = max value – best value

Alternatively,

1. Find the "minimum" value
2. Find the "maximum" value
3. Uncertainty =

Method 2 - Formula Method

Addition/Subtraction

If $Y = nA \pm mB$

then $\Delta Y = n\Delta A + m\Delta B$

Multiplication/Division

If $X = nA^{\alpha}.mB^{\beta}$ or $X = \frac{nA^{\alpha}}{mB^{\beta}}$, where α, β, *m* and *n* are numbers,

then $\frac{\Delta X}{X} = \alpha\frac{\Delta A}{A} + \beta\frac{\Delta B}{B}$

These rules can also "stack up", e.g.:

if $Z = \frac{nA^{\alpha}B}{mC^{\beta}D}$, where α, β, *m* and *n* are numbers,

then $\frac{\Delta Z}{Z} = \alpha\frac{\Delta A}{A} + \frac{\Delta B}{B} + \beta\frac{\Delta C}{C} + \frac{\Delta D}{D}$

Important: To determine the error of a quantity, always express the quantity as the subject of the equation first.

Scalars & Vectors

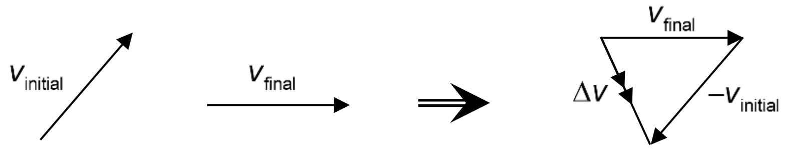
A **scalar quantity** is one with magnitude only.

A **vector quantity** is one that has a magnitude and direction (e.g. displacement, velocity, acceleration, momentum, etc).

Vector addition

- Use to determine the resultant of two vectors.
- Use parallelogram or vector triangle.

Change of a vector (e.g. Δv) refers to final vector – initial vector. (e.g. $\Delta v = v_{final} - v_{initial}$)



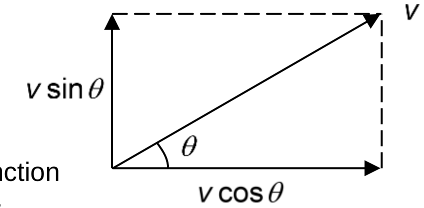
Relative velocity refers to the velocity of one object relative to another moving object.

Suppose body 1 has velocity $\vec{v}_1$ and body 2 has velocity $\vec{v}_2$. Relative velocity of 1 with respect to 2 is represented as $\vec{v}_{12} = \vec{v}_1 - \vec{v}_2$.

Resolution of Vector into two perpendicular components:

Remember:

- The component on the side ***adjacent*** to the angle – **cosine** function
- The component on the side ***opposite*** to the angle – **sine** function



Note: 2 perpendicular vectors are independent of each other.

To determine the **vector sum** of 3 or more vectors:

1. Identify two perpendicular axes to determine components of each vector.
2. Determine the components of each vector.
3. Determine the vector sum of each component for all vectors.
4. Find the resultant of the two net perpendicular components using Pythagoras theorem.