1 Measurements

Base SI Units

Base Quantities (Symbol)	Unit (Symbol)
Mass (m)	Kilogram (kg)
Length (*l*)	Metre (m)
Time (t)	Second (s)
Temperature (T)	Kelvin (K)
Electric current (I)	Ampere (A)
Amount of substance (n)	Mole (mol)
Luminous intensity*	Candela (Cd)

* not in syllabus

All units can be derived from the 7 base units shown on the right, and thus are called derived units. Some examples of derived units are force (measured in Newtons), and work done (measured in Joules).

An equation is **homogenous** if each of the terms in the equation can be expressed using the same base units, but need not be physically correct.

Prefixes

Prefixes can be added to SI units to make larger or smaller units.

Prefix (Abbreviation)	Factor
Tera (T)	10^{12}
Giga (G)	10^{9}
Mega (M)	10^{6}
Kilo (k)	10^{3}
Deci (d)	10^{-1}
Centi (c)	10^{-2}
Milli (m)	10^{-3}
Micro (μ)	10^{-6}
Nano (n)	10^{-9}
Pico (p)	10^{-12}

Scalars and Vectors

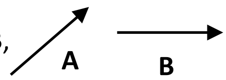
Scalar quantity: Defined by a single magnitude. Examples include mass, distance and speed.

Vector quantity: Defined by both magnitude and direction. It is represented by an arrow having the appropriate length and direction. Examples include weight, displacement and velocity.

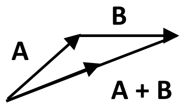
Addition of vectors

a. Tail to head method
b. Parallelogram method

Eg. To add two vectors **A** and **B**,



We translate one vector (say **B**) such that the tail of one is touching the head of the other.

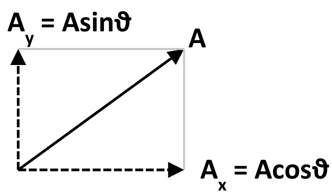


The resultant (net) vector **A + B** is then the unpaired tail to the unpaired head as shown.

To add more than 2 vectors, the method can be repeated for the third vector, so on and so forth.

Decomposition of vectors

It is often useful to decompose a vector into its horizontal and perpendicular components as we can then analyse the two components separately.

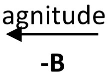


In this example, vector **A** can be decomposed into a vertical component $\mathbf{A_y}$ and horizontal component $\mathbf{A_x}$, where **A** = $\mathbf{A_x}$ + $\mathbf{A_y}$. $\mathbf{A_x}$ and $\mathbf{A_y}$ can be calculated if ϑ is given.

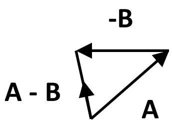
Scalars and Vectors

Subtraction of vectors

Using the previous vectors, suppose we want to subtract **B** from **A**, i.e. **A** – **B**.

To do so, the easiest way is to see it as **A** + (**-B**), where **–B** is the vector with the same magnitude as **B** but is in the opposite direction, i.e. 

Using the same method for addition,
A – **B** = **A** + (-**B**) is thus



Errors and Uncertainties

An error is **systematic** if repeated measurements taken under the same conditions result in measurements that are consistently above or below the true values. Some examples of systematic errors:

Error Source	**Examples**
Instrumental error	- Zero error - Incorrect calibration - End error
Poor experimental technique	- Length of pendulum incorrectly measured from end of thread to surface of bob instead of centre of bob
External factors	- Background radiation - Heat loss to surroundings

An error is **random** if repeated measurements taken under the same conditions result in measurements that are scattered about a mean value. Some examples of random errors:

Error Source	**Examples**
Limitations of observer	- Human reaction time - Error of judgement
Environmental conditions	- Fluctuations in conditions e.g. temp, pressure, etc.
Intrinsic irregularity	Small fluctuations in diameter of a wire

Errors and Uncertainties

Accuracy vs Precision

Accuracy is the degree of conformity of the experimental result with the correct value. If an experiment has **small systematic errors**, it is said to have **high** accuracy.

Precision is the degree of numerical agreement among measurements of the same quantity. If an experiment has **small random errors**, it is said to have **high** precision.

Uncertainties

Uncertainties in a reading can occur due to 1) random errors, or 2) precision of the instrument used.

Uncertainties are expressed in the form of **A ± ΔA**, and must be to **1 significant figure**. The calculated value A must be to the **same decimal place** as the uncertainty of the value.

Uncertainties **always add up**.

Percentage uncertainty = Fractional uncertainty $(\frac{\Delta A}{A})$ x 100%

Combining Uncertainties

Equation	**Uncertainty**
$Y = mA \pm nB$	$\Delta Y = m\Delta A + n\Delta B$
$Y = kAB$ / $Y = m\frac{A}{B}$	$\frac{\Delta Y}{Y} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$
$Y = kA^nB^m$	$\frac{\Delta Y}{Y} = n\frac{\Delta A}{A} + m\frac{\Delta B}{B}$
$Y = k\frac{A^nB^m}{C^p}$	$\frac{\Delta Y}{Y} = n\frac{\Delta A}{A} + m\frac{\Delta B}{B} + p\frac{\Delta C}{C}$