

OCR A Physics A-level

Module 2: Foundations of physics Notes



Physical quantities and units

Physical quantities

A physical quantity is a property of an object that can be measured, with a unit. Most quantities have a unit besides the magnitude/direction, and this unit is given using the **Systeme Internationale (SI) standard base units**. However, there are a few exceptions where the physical quantity is just a number without a unit.

The seven SI base units are:

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s ^a
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A
Luminous intensity	Candela	cd

The SI base units can be derived by finding a **formula for the quantity**, and substituting the units for each part of the formula. To check the **homogeneity** of an equation, we represent both sides of the equation in their SI base units, and show both sides are equal. For an equation to be correct, it must be homogeneous.

Prefixes are used as an easier way to **represent quantities of extreme magnitude**, as both very large and very small numbers are used in the study of physics. Prefixes are used as abbreviations for numbers which are multiplied by a power of ten.

The prefixes which must be learnt are:

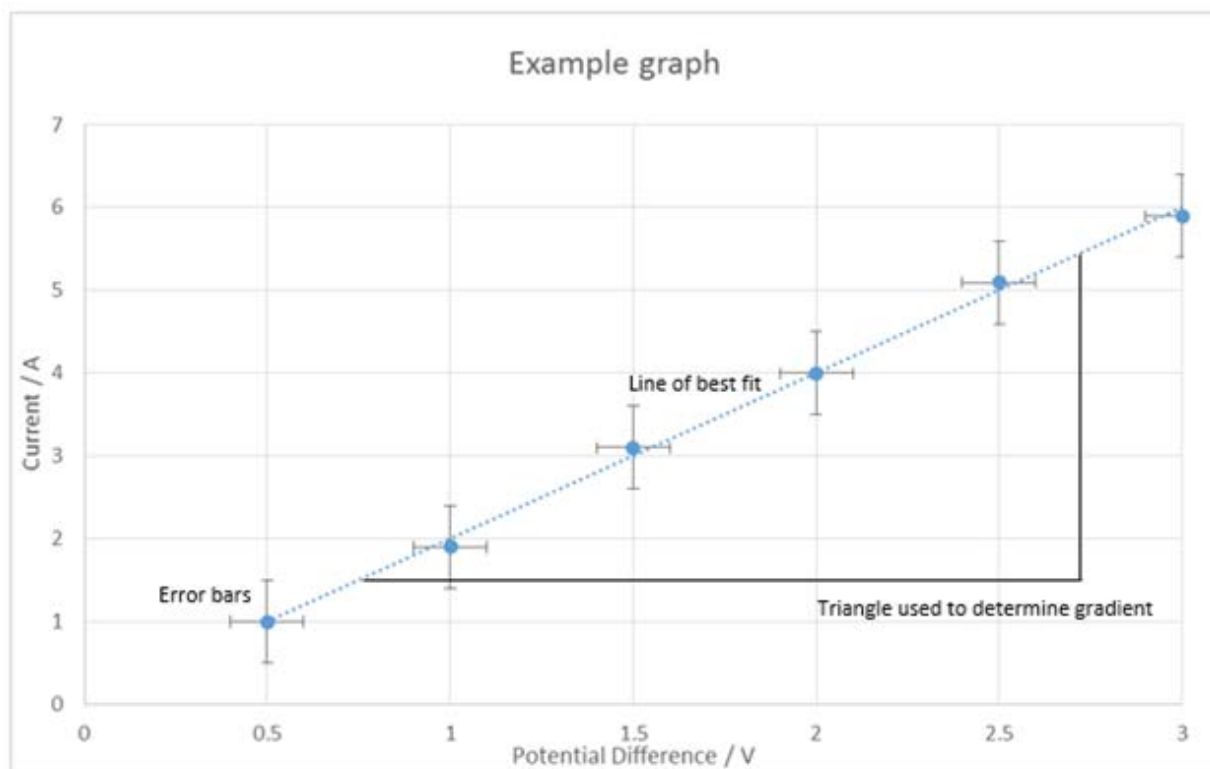
prefix	pico (p)	nano (n)	micro (μ)	milli (m)	centi (c)	deci (d)	kilo (k)	mega (M)	giga (G)	tera (T)
multiple of unit	1×10^{-12}	1×10^{-9}	1×10^{-6}	0.001 (1×10^{-3})	0.01 (1×10^{-2})	0.1 (1×10^{-1})	1000 (1×10^3)	1×10^6	1×10^9	1×10^{12}

Creating graphs and tables

When labelling table columns, the headings of the table show the quantity and unit, separated by a '/' (e.g Velocity / ms⁻²). All of the values in the table must be measured to the **same number of significant figures**. This is likely to be 2 or 3, depending on the resolution of the instrument used to measure the quantity. When labelling graph axes, the independent variable should be plotted on the x axis, and the dependant variable on the y axis. Each axis is then labelled with the quantity and the unit, again separated by a '/'. The graph must cover over 75% of the space provided, so a suitable scale must be used for each axis. When calculating the gradient, draw a straight line of best fit (or a tangent for curved graphs), and calculate using a triangle that covers at least 75% of the straight line. The points on the graph selected to draw the triangle should not be the original data points.



Graph demonstrating required conventions:



Making measurements and analysing data

Measurements and uncertainties

When carrying out experiments, no measurement can ever be perfect. Even if all sources of human error are removed, errors will still exist, and they are not mistakes. Scientifically, an error is the **difference between the result obtained, and the true value of the quantity**. A true value is the value that would be obtained in an **ideal measurement**. A measurement error is the difference between the measured value and the true value. Errors can be caused by measuring devices or the design of the experiment.

Random errors can occur when any measurement is being made, and are measurement errors where the measurements **vary unpredictably**. They can be caused by **external factors** affecting the environment, which it may not be possible to control, and also by **difficulty in reading a measuring device** and deciding the value it shows. Random errors can't be corrected, but their effect can **be mitigated** by **conducting repeats** of the experiment and reporting the mean value calculated.

Systematic errors are measurement errors in which the measurement differs from the true value by a **consistent amount** each time. This could be caused by the way in which measurements are taken, or by a faulty measuring device. It is **possible to correct** for systematic errors.



The **accuracy** of a measurement is how close the measurement is to the true value. The closer the value, the more accurate the measurement is. The **precision** of a measurement is how close repeated measurements are to each other. The closer they are, the more precise the measurement is.

When any measurement is taken, it will have an **uncertainty**, which is the interval in which the true value of the measurement should lie. If there are a range of values taken, for example when the experiment has been repeated several times, then outliers should be discarded and the absolute uncertainty is $\pm(\text{range of measurements}/2)$. If there is only one measurement, then the resolution of the measuring equipment can be used instead. The percentage uncertainty is calculated by using the formula $\frac{\text{Absolute Uncertainty}}{\text{Actual Value}} \times 100$.

When quantities are combined in an equation, the rules used to calculate the **overall uncertainty** in the value vary according to how the quantities have been combined.

- When quantities have been added or subtracted, add the absolute uncertainties for each value.
- When the quantities have been multiplied or divided by each other, add the percentage uncertainty for each value
- When a quantity is raised to a power n , multiply the percentage uncertainty for this value by n .

Graphical treatment of errors and uncertainties

When producing a graph of results for an experiment, **anomalous data should be ignored**. Each data point is marked with an x, and **error bars** are used to show the absolute uncertainty for each value, in both the x and y axis directions. When the line of best fit is drawn, it must **pass within all of the error bars**, and have a balanced number of data points on each side.

The uncertainty in the gradient is calculated by drawing a **line of worst fit**. This is the least acceptable line passing through all of the error bars (usually the shallowest or most steep line possible). Then the formula $\frac{\text{Grad of Best line} - \text{Grad of Worst line}}{\text{Grad of Best line}} \times 100$ is used to provide the percentage uncertainty. The numerator of the fraction is the absolute uncertainty.

Nature of quantities

Scalars and vectors

Scalar quantities have **magnitude but not direction**, for example energy, mass, or time, and such quantities with the same unit can be added and subtracted as usual. A **vector** quantity has **both magnitude and direction**, such as velocity or acceleration, and these quantities have different rules for addition and subtraction.

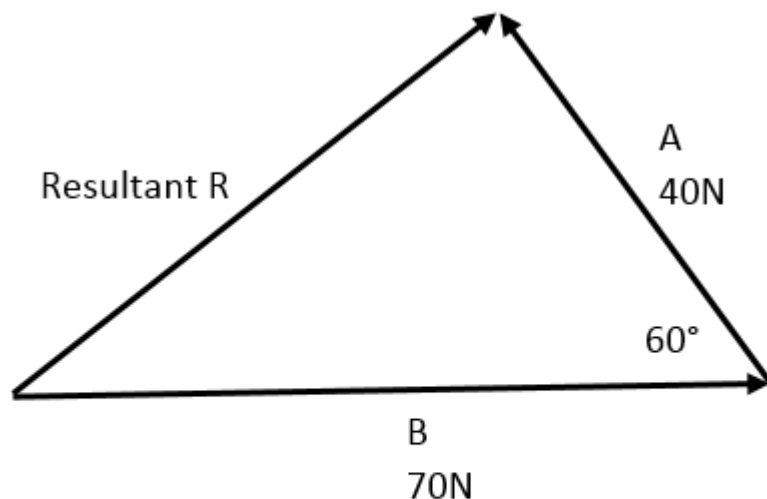
Vector addition

Vectors in one dimension have **arrowheads to indicate direction**, and their length is usually scaled to represent magnitude. If two vectors are **parallel**, their **magnitudes can be added** to find the resultant magnitude. If they are parallel, but opposite in direction, then they can still be added and subtracted as usual, as one direction is taken as negative.



When vectors are at angles to each other, a **vector triangle** is used to add them. The vectors are drawn with arrows labelled with direction and scaled in proportion to magnitude, on the correct angles. The first vector is drawn, and then the second vector is drawn with its tail end at the arrow end of the first vector. The **resultant vector** is then found by drawing a line from the tail end of the first vector to the arrow end of the second vector. To calculate the magnitude of the resultant, if the vectors are at right angles then Pythagoras' theorem can be used, and for other angles the sine and cosine rules can be used. When subtracting vectors, the same rules apply, but the direction of one of the vectors is reversed.

Using a vector triangle:



$$\text{Cosine rule: } a^2 = b^2 + c^2 - 2bc \cos A$$

$$\text{So } R^2 = 40^2 + 70^2 - 2 \times 40 \times 70 \times \cos 60$$

$$R = 50\text{N}$$

When the resultant vector has been found, it can be resolved into its horizontal and vertical components. For a vector of magnitude F , at an angle of i degrees above the x axis, the component in the x direction, F_x , is $F \cos i$, and the component in the y direction, F_y , is $F \sin i$.

