

Measurements and their errors

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SI base units

SI (international system) base units:
Set of units of measure. They are defined as a fundamental set from which all other SI units can be derived.

Switching between units

Some units are equivalent. We switch between them by multiplying or dividing by the conversion factor.
For example:

$$1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$$

$$1 \text{ atm} = 1005 \text{ N m}^{-2}$$

$$1 \text{ kWh} = 3.60 \times 10^6 \text{ J}$$

$$1 \text{ ly} = 9.46 \times 10^{15} \text{ m}$$

Orders of magnitude and prefixes

Order of magnitude:

defines the size of a quantity as a power of ten

SI prefix:

is a symbol that precedes a unit of measure to indicate its order of magnitude

Prefixes and their orders of magnitude

Prefix	Prefix symbol	Order of magnitude
tera	T	$\times 10^{12}$
giga	G	$\times 10^9$
mega	M	$\times 10^6$
kilo	k	$\times 10^3$
centi	c	$\times 10^{-2}$
milli	m	$\times 10^{-3}$
micro	μ	$\times 10^{-6}$
nano	n	$\times 10^{-9}$
pico	p	$\times 10^{-12}$
femto	f	$\times 10^{-15}$

Quantities and their SI base units

Physical quantity	Base unit
Amount of substance	mole
Temperature	kelvin
Length	metre
Time	second
Mass	kilogram
Current	ampere

Estimation

Estimation:
a method of determining the value of a quantity without any given variables using educated guessing of the variables, usually to the power of ten

Table of estimates

Physical quantity	Estimated value
Mass of average man	60–80 kg
Speed of sound	300 m/s
Height of average man	1.6–1.8 m
Mass of a car	1000 kg
Density of water	1000 kg m ⁻³
Pressure of atmosphere	100 000 Pa



You will be expected to estimate quantities like those in the table. You will use them within equations to make educated estimates of the values of other physical quantities.

Exam Tip!

Numbers in standard form are expressed as a number between 1 and 10, multiplied by an order of 10, in the form $x \times 10^n$
So, 94 700 would be written as 9.47×10^4

Errors and uncertainties



Uncertainty:

The degree to which we can say a measurement is accurate. A measurement of 15.5 cm on a ruler would have an uncertainty of ± 0.1 cm.

Accuracy:

A measurement is accurate if its value is in close proximity to the accepted (true) value.

Precision:

A measurement is precise if its value is in close proximity to the other repeated measurements of the same quantity.

Repeatability:

A measurement is said to be repeatable if the experiment can be repeated to obtain the same results under the same conditions.

Reproducibility:

An experiment is reproducible if it can be reproduced by the same experimenter or another independent experimenter.

Definitions of errors

Systematic error:

an error that causes the measurements to differ from the true value by the same amount

Random error:

an error caused by unpredictable circumstances and resulting in measurements that differ from the true value by varying amounts

Combining uncertainties

To combine errors:

Adding or subtracting variables
 $x = a + b$
 $x = a - b$

Add the absolute uncertainties
 $\epsilon_x = \epsilon_a + \epsilon_b$

Multiplying or dividing variables
 $x = \frac{ab}{c}$
 $x = \frac{a}{b}$

Add the percentage uncertainties
 $\sigma_x = \sigma_a + \sigma_b$
 $(\sigma_x = \frac{\epsilon_x}{x} \times 100 \%)$

How to reduce potential errors

Systematic error:

- Repeating experiment using a comparable apparatus to identify the source of error
- Accurate calibration of equipment
- Confirming experimental method against literature and sources

Random error:

- Taking averages over multiple measurements, not including anomalous results
- Repeating the experiment and averaging over all the measurements

Percentage uncertainties:

$$\frac{\Delta x}{x} \times 100\%$$