AQA Physics A-level

Topic 1: Measurements and Their Errors

Key Points

SI Base Units

The **base units** are the set of seven units of measure from which all other SI units can be derived. The ones you need to know are:

- Mass: Kilogram (kg)
- Length: Metre (m)
- Time: Second (s)
- Current: Amps (A)
- Temperature: Kelvin (K)
- Amount of Substance: Mole (mol)

All other units can be expressed in terms of the base units. For example:

$$1\ J = 1\ kgm^2s^{-2}$$

$$1\ V = 1\ kgm^2s^{-3}A^{-1}$$

Unit Prefixes

Unit prefixes should be used when stating values to avoid the use of large amounts of noughts and standard form. You need to know the following prefixes:

T, tera: 10^{12}
G, giga: 10^{9}
M, mega: 10^{6}
k, kilo: 10^{3}
c, centi: 10^{-2}

m, milli: 10^{-3}
μ, micro: 10^{-6}
n, nano: 10^{-9}
p, pico: 10^{-12}
f, femto: 10^{-15}

You can convert between prefixes and standard form. For example:

$620\ nm = 620 \times 10^{-9}\ m = 6.20 \times 10^{-7}\ m$

Significant Figures

Your **Calculated quantities** should be given to the same number of significant figures as the value with the **least** number of significant figures used in the calculation.

In **tables**, data should be written to the same number of significant figures. However, when crossing multiples of 10, the same number of decimal places should be used to avoid changing the **accuracy**.

The number of decimal places of the **logarithm** of a value should be the same as the number of significant figures as the value. For example, ln(60) should be quoted as 4.09

Experimental Key Terms

Random error: Measurements vary due to unpredictable circumstances. They cannot be corrected and can only be mitigated by making more measurements and calculating a new mean.

Systematic error: Measurements differ from the true value by a consistent amount each time. They can be corrected by using a different technique to take measurements.

Precision: How close measurements are to each other and the mean.

Accuracy: How close a measurement is to the true value.

Repeatable: When the original experimenter repeats the investigation using the same method and equipment and obtains the same results.

Reproducible: When somebody else repeats the investigation or the investigation is performed using different equipment or techniques and the same results are obtained.

Resolution: The smallest change in a quantity being measured that gives a perceptible change in the reading.

Finding Uncertainties

The uncertainty of a result is the interval within which the true value can be expected to lie.

The **absolute uncertainty** of a reading is no smaller than plus or minus half of the smallest division. The absolute uncertainty of a measurement, where two judgements are required (e.g measuring a length using a ruler), is twice this. For multiple readings, the absolute uncertainty is half the range. Absolute uncertainties have the same units as the quantity.

The **fractional uncertainty** is the absolute uncertainty divided by the measured value (if multiple readings, divided by the mean). The **percentage uncertainty** is the fractional uncertainty multiplied by one hundred. Fractional and percentage uncertainties have no units.

Combining Uncertainties

When adding or subtracting data with uncertainties, add the **absolute uncertainties.**

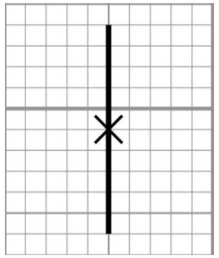
When multiplying or dividing data with uncertainties, add the **percentage uncertainties.**

When raising data with an uncertainty to a power, multiply the **percentage uncertainty** by that power.

When multiplying data with an uncertainty by a constant, multiply the **absolute uncertainty** by that constant but **not the percentage uncertainty.**

Uncertainties in Graphs

The uncertainty in a data point on a graph can be represented using error bars.



Two lines of best fit should be drawn on the graph. The ‘**best**’ line of best fit, which passes as close to the points as possible, and the ‘**worst**’ line of best fit, either the **steepest** possible or the **shallowest** possible line which fits within all the error bars. The **percentage uncertainty** in the gradient and y-intercept can be found from the equations below:

$$\text{Percentage Uncertainty} = \frac{|\text{Best Gradient - Worst Gradient}|}{\text{Best Gradient}} \times 100\ \%$$

$$\text{Percentage Uncertainty} = \frac{|\text{Best Y-Intercept - Worst Y-Intercept}|}{\text{Best Y-Intercept}} \times 100\ \%$$

Estimation of Physical Quantities

You can **estimate** the order of magnitude of physical quantities. Examples include:

Radius of proton: 10^{-15} m
Radius of atom: 10^{-10} m
Height of human: 10^{0} m
Radius of earth: 10^{7} m