OCR B Physics A-level

Module 1: Development of practical skills in physics

Notes

1.1.1 Planning

To plan an experiment you must:

1. Identify the apparatus required e.g. for measuring instantaneous velocity of a car down a ramp you'll need light gates, a car, ramp and a data logger.
2. Know the range (maximum and minimum readings possible) and resolution (the smallest change in the input that gives a change in reading) of all measuring instruments e.g. 0.1mm for vernier callipers and 0.01mm for micrometer screw gauges.
3. Calibrate instruments e.g. setting a mass balance to 0 when it is empty to avoid systematic error.
4. Measure the variables using appropriate instruments and techniques, e.g. temperature should be measured with a thermometer at eye level.
5. Identify control variables and keep them constant, e.g. when using Charles' law to determine absolute zero, pressure must be constant.
6. Know whether to take repeats, usually 3 repeats is sensible but if the results are very inconsistent (low precision) then more are necessary.
7. Identify, discuss or resolve health and safety issues e.g. reduce exposure times when using radioactive sources.
8. State a hypothesis, this is a prediction of what will happen and why, the hypothesis is tested during the experiment and the results are said to either support or contradict the hypothesis.
9. Apply the data to the situation to determine a conclusion and whether the data supports the hypothesis, identify sources of uncertainty and talk about how they could have been reduced.

1.1.2 Implementing

You must know the purpose of different measuring instruments and how to use them, for instance voltmeters are connected in parallel across components to measure the potential difference across them.

Measurements should be given to appropriate units, prefixes help make understanding data easier, e.g. writing 0.000005F as 5μF, prefixes and their meanings are below:

Name	Symbol	Multiplier
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}

Some examples:

6pF (picofarads) is **6×10^{-12} F**

9GΩ (gigaohms) is **9×10^{9} Ω**

10μm (micrometres) is **10×10^{-6} m**

Data presentation:

Data can be presented on graphs, charts or tables,

When data is displayed in a table the first column should be for the independent variable, the next n columns for n repeats of the dependent variable and the columns after that for processing the data e.g. calculations. The data in a column of a table should be to the same number of significant figures which is usually the same number as the resolution of the measuring instrument.

Quantitative data uses numbers whereas **qualitative** data is observed but not measured with a numerical value e.g. colour.

Charts and tables include bar and pie charts and scatter and line graphs, the way data is presented depends on what type of data it is:

Discrete - only certain values can be taken, e.g. number of objects. Display on scatter graphs and bar charts.
Continuous - can take any value on a scale e.g. current in a circuit. Display on line or scatter graph.
Categoric - values that can be sorted into categories e.g. types of material. Display on a pie or bar chart.
Ordered - data that can be put in ordered categories e.g. low, medium, high. Display on bar chart.

1.1.3 Analysis

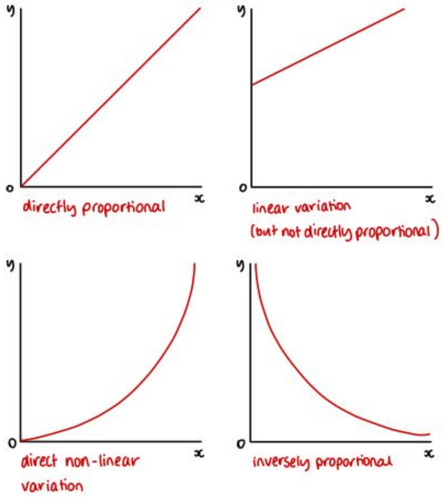
You must process, analyse and interpret results in the context of an experiment, for instance if (when voltage is constant) the current through a thermistor increases with temperature, using R=V/I we find that a thermistor's resistance decreases with temperature. Results can be interpreted quantitatively (with numbers e.g. 3A) or qualitatively (observations e.g. a light switching on). For repeat results a mean of the repeats should be found.

$$\text{Mean} = \frac{sum\ of\ results}{no.data\ points}$$

The mean value should be to the same number of significant figures as the data used to calculate it.

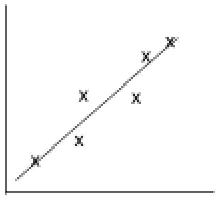
Graphs

Graphs are used to display data and show relationships between variables such as in the examples below:

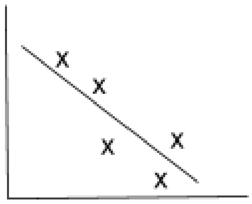


Scatter graphs are used to determine correlation, each point is plotted and a line of best fit drawn through them, an appropriate scale is one that is easy to read and allows the data to fill at least half of the page.

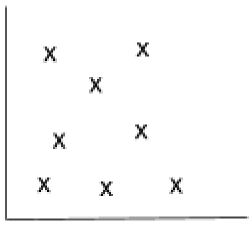
If two variables are positively correlated, it means that if one increases in value, so does the other.



Whereas negative correlation means the opposite - if one variable increases the other decreases.



No correlation means there's no relationship between the variables

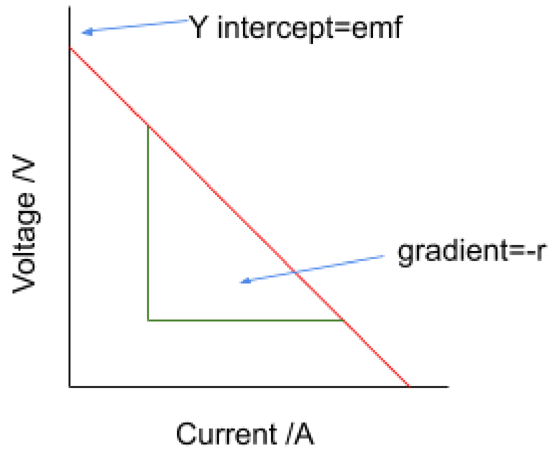


Straight line graphs allow determination of unknown variables as they are always in the form of

$y = mx + c$

where 'm' is the gradient, 'c' is the y intercept and 'x' and 'y' represent the x and y coordinates at a point on the graph.

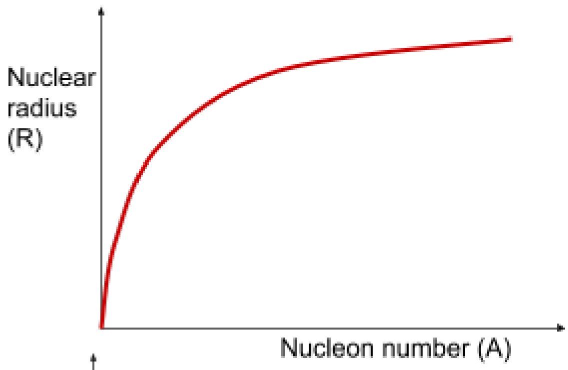
For example, when determining the internal resistance of a component, plot a graph of voltage against current:



As V= -Ir + ε, this is in the form of y = mx+c with m = -r and c = ε. To determine the gradient, draw a large triangle on the graph and divide the difference in y by the difference in x. The gradient will be negative if y decreases as x increases.

For logarithmic graphs read the scale carefully. A straight line on a logarithmic graph where one of the variables is e indicates an exponential relationship. Logarithmic graphs can be used to determine unknown relationships between variables such as in the example below:

The graph to the right shows no clear trend between nuclear radius and nucleon number, however if you plot a log graph you will be able to find the relationship between them:



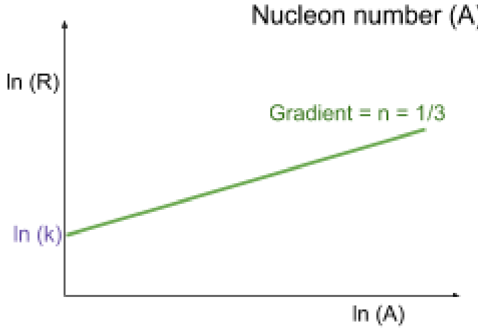
$R = kA^n$ Where k is a constant

$ln\ R = ln(kA^n)$

$ln\ R = ln(k) + n\ ln(A)$

Using the log laws: ln(AB) = ln(A) + ln(B) and $\ln(A^n) = n \ln(A)$

If you plot a graph of ln (R) against ln (A), the gradient will give you the relationship between them, and measuring the y-intercept will give you the value of ln (k).



If you carry out this investigation you will find that n is 1/3, and k is approximately 1.4 fm, the constant k is renamed R_0 and the following equation can be formed:

$$R = R_0 A^{\frac{1}{3}}$$

1.1.4 Evaluation

The scientific community evaluate results and draw conclusions through a process known as peer-review in which other scientists repeat an experiment and evaluate its reproducibility, they publish their results online and in journals and compare them. A conclusion is only valid if supported by evidence.

When evaluating results consider whether all the variables were controlled, whether anomalous results are present and whether uncertainty could have been reduced e.g. by using higher resolution equipment. There are always potential limitations of experimental methods such as the constant presence of random errors. These random errors cannot be completely removed but the effect of them can be reduced by taking as many repeats as possible and using the average of the repeats.

Anomalous results are those that do not fit with the general trend in data, they can be identified by a line graph. If the line doesn't go through the error bars for a data point then the point is anomalous and should be excluded from calculations.

Precision	Precise measurements are consistent, they fluctuate slightly about a mean value - this doesn't indicate the value is accurate
Accuracy	A measurement close to the true value is accurate

The **uncertainty** of a measurement is the bounds in which the accurate value can be expected to lie e.g. 20°C ± 2°C , the true value could be within 18-22°C

Absolute Uncertainty: uncertainty given as a fixed quantity e.g. 7 ± 0.6 V

Fractional Uncertainty: uncertainty as a fraction of the measurement e.g. $7 \pm \frac{3}{35}$ V

Percentage Uncertainty: uncertainty as a percentage of the measurement e.g. $7 \pm 8.6\%$ V

To reduce percentage and fractional uncertainty measure larger quantities e.g. a longer rope.

In order to reduce the uncertainty of results for an experiment some changes may need to be made to the method:

- A set square can be used to determine whether a spring is vertical, 2 objects are at right angles to each other or check 2 lines are parallel.
- Electronic data loggers are more accurate, quick and reliable than manual logging as they can take multiple readings per second and present the data as a graph or table in real-time.
- Cameras can be used to take photos in experiments that happen too quickly to read a scale, use a camera to take a photo burst as the experiment happens and then read the scale from the photos afterwards, if the time each photo is taken is known then properties such as velocity can be calculated.