Experimental Skills

Variables

Many experiments involve changing one quantity and measuring the effect on another quantity.

- The quantity being deliberately changed is called the 'independent variable'.
- The quantity that changes as a result is called the 'dependent variable'.
- All other factors are held constant, if possible, throughout an experiment.

Graphs

When a graph is plotted:

- The independent variable (or a quantity calculated from it) is plotted horizontally (x axis*)*
- The dependent variable (or a quantity calculated from it) is plotted vertically (y axis)

Every graph should include a title and labelled axes with appropriate scales and units.

Relationships between variables in an experiment can be shown by a line (or curve) of best fit.

- The plotted points should be scattered evenly above and below the line of best fit
- The line of best fit does not necessarily pass through the origin of the graph.

If a straight line of best fit passes through the origin of the graph and is a good representation of the data, the plotted quantities are directly proportional to each other.

Random and Systematic Errors

Every measurement is affected by random and/or systematic errors.
Random errors cause each measurement to differ from its true value by a random amount, leading to scatter in the measured values. Increasing the number of measurements minimises the effects of random errors.
Systematic errors are present when measured values differ consistently from the true value, leading to a shift in the intercept(s) of the line of best fit.
Systematic errors can be identified and results verified by repeating an experiment, using an alternative source of equipment and materials.

Precision and Accuracy

The accuracy of an measured value is how close it is to the true value. Systematic errors decrease the accuracy of measurements.

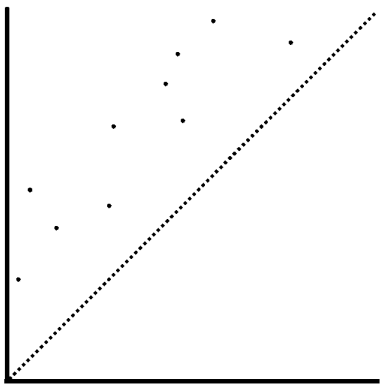
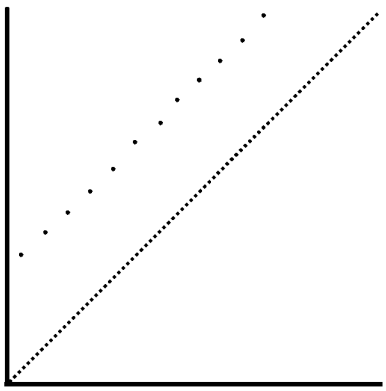
Measurements are more precise when there is less scatter in the results. Precision depends on how well random errors are minimised.

The resolution of a measuring instrument is the smallest increment measurable.

- Using equipment with better resolution will allow for more precise results.
- Usually the range of possible random error is plus or minus (±) half the smallest measurement on the equipment.
- The number of significant figures used to record measurements should be appropriate to the resolution.

The calibration of a measuring instrument is how close its values match the true values. Poorly calibrated equipment is a possible source of systematic error.

In the graphs below, the dotted line shows the true values.

<table>
<tr>
<td> 
Low precision (significant random error)
Low accuracy (significant systematic error)</td>
<td> 
High precision (little random error)
Low accuracy (significant systematic error)</td>
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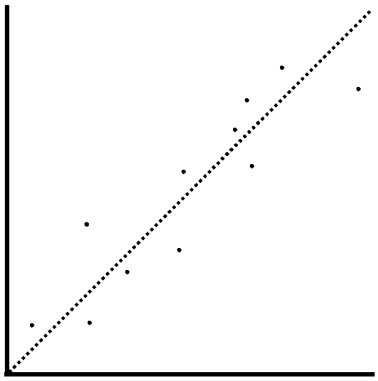
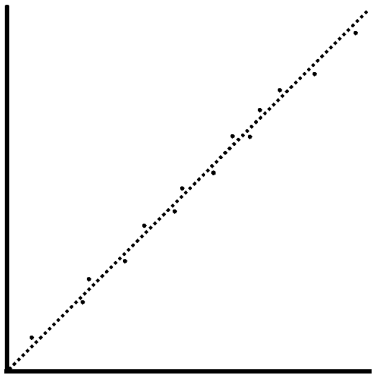
<td> 
Low precision (significant random error)
High accuracy (little systematic error)</td>
<td> 
High precision (little random error)
High accuracy (little systematic error)</td>
</tr>
</table>

Analysis of data to formulate a conclusion

- Use the line of best fit on the graph to determine the mathematical relationship
- Discuss any Physics relevant to the formulas
- Restate the hypothesis and conclude whether the results support it or not

Evaluation of procedure and suggestion for improvements

- Mention any evidence of error in the data (e.g. scatter or non-zero intercept)
- Identify at least four possible sources of error
    - Include sources of both random and systematic error
- For each source, discuss the effect it would have on the data
- Describe at least three possible improvements to the procedure
    - Explain how each would improve the data collected
    - One improvement for each source of error listed is often a good approach here
- Things that should be mentioned somewhere:
    - How the effect of random errors can be minimised (or was minimised, if relevant)
    - How systematic error could be detected