# CIE Physics IGCSE

## General practical skills

### Analysing results and assessing validity

# Analysing Data

## Precision

In the context of science experiments, **precision** refers to **how close together repeat readings are**; the closer the readings, the more precise they are. The precision of your readings can be increased by using instruments with a **higher resolution**, meaning more decimal places. For example, a digital thermometer is preferable over an analogue one as it gives readings to **more decimal places**.

## Accuracy and Errors

The **accuracy** of scientific results refers to **how close the readings are to the true value**. To increase accuracy, experiments should be **repeated several times.** The accuracy of results can be affected by different types of errors: systematic and random.

**Systematic errors** are due to a **fault with the equipment** and these are **not random**; for example, not **calibrating instruments** properly or not taking into account **zero error** (when an instrument gives a **false reading when the measured quantity is zero**, e.g. the needle on an ammeter does not return to zero when no current flows.) These errors can be resolved by carrying out the **same experiment using different sets of equipment**.

**Random errors** are due to **unpredictable changes** in the experiment and they cause data to differ from the true amount by a different value each time. These can be the result of not taking readings the same way each time. For example: **parallax error** due to taking readings from a different position (not eye-level) each time. These errors cannot be completely resolved since they are unpredictable, but can be reduced by **increasing the amount of data** – having lots of readings makes it easier to identify potential **anomalies** within the data.

It is important to remember that **precision and accuracy are not related** – it is possible for repeat readings to be very close together (precise) but nowhere near the true value (inaccurate).

Also consider how reliable your results are; in other words, if you could repeat the experiment using the same method and equipment, would you obtain the same result? It is good practice to repeat an experiment at least twice with the aim of obtaining **concordant** results, which will also help discount any **anomalies**.

## Presenting Data

The results from an experiment should be presented in a **graph** (for **continuous data**) or a **bar chart** (for data with **specific categories**), with the **independent variable on the x-axis** and the **dependent variable on the y-axis**. When plotting your graph, make sure to choose an **appropriate scale** for each of the axes so that the plotted results make up **more than half of the space on the graph** (to do this, you may need a break in the axes, represented by a zig-zag line). Ensure both axes are **labelled** with the quantity and unit in the same way as the table headings.

For a graph, a line (or curve) of best fit should be drawn, and there should be an **equal number of points on either side of the line** if possible. This should be done with a **sharp pencil** so the line is thin and easy to read from. If the independent variable is **directly proportional** to the dependent variable, the line of best fit will be a **straight line through the origin**.

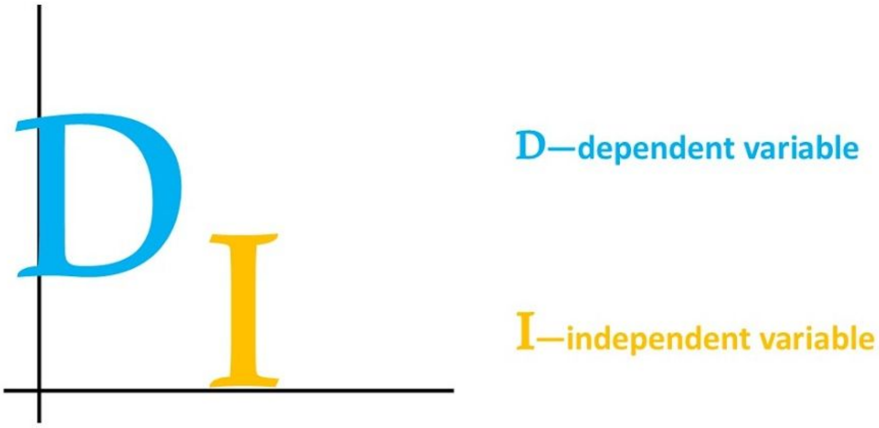
To determine the **gradient** of a line of best fit, you should start by finding two points on the line where it is easy to read the x and y values. Then use the formula $gradient = \frac{change\ in\ y}{change\ in\ x}$ and substitute the values from the graph into it.

### Drawing graphs

You will not only need to be able to **read and interpret** graphs given to you in the exam, you may also be expected to **draw** a graph from a set of data given. Here are some important tips for drawing graphs:

- Always use a **sharpened pencil** and **ruler** to draw the axis and line of best fit.
- **Label** the **axis** with its variable and its **units.**
- Draw your graph a **sensible size.**
  - Use up at least half of the graph paper given.
- Use a sensible **scale.**
- The **dependent variable** goes on the **vertical y axis.**
- The **independent variable** goes on the **horizontal x axis.**
- Determine the **ranges** of the axis so you can include all the data points collected.
- Give the graph an appropriate **title .**
- Indicate any **anomalies** but identify them as anomalous.
  - Ignore these when drawing your line of best fit.
- Draw a **line of best fit** if possible.
  - The 'line' could be **straight or curved.** If the line of best fit is not a straight line, a freehand continuous curve must be drawn.
  - **Never** just connect the points like a dot-to-dot.
  - Bring a long, **clear** ruler to the exam so you can see the data points when drawing a straight line of best fit.

A helpful way to remember which axis the independent and dependent variables go on is to imagine the letters 'I' and 'D' sat on their respective axis as shown:

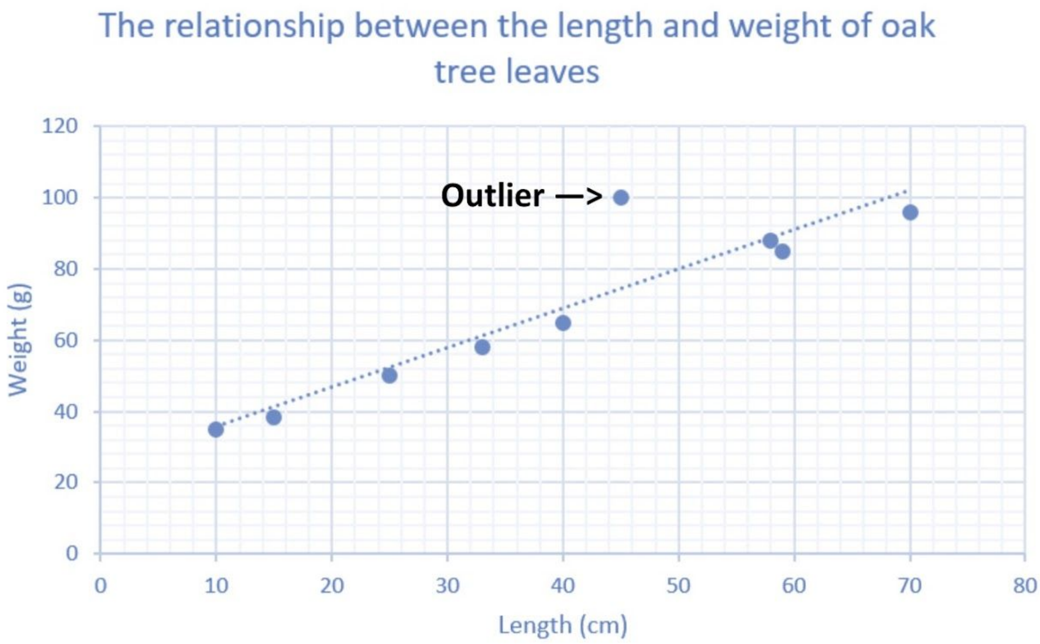



**Shown below is an example graph drawn for the following table of results:**

Notice that the **units** of measurements are only included in the title of each column. Each measurement of the same type must be given to the same **degree of accuracy** - e.g. in the table below, each weight value is given to three significant figures.

| Length (cm) | Weight (g) |
|---|---|
| 10 | 35.0 |
| 15 | 38.5 |
| 25 | 50.0 |
| 33 | 58.0 |
| 40 | 65.0 |
| 45 | 100 |
| 58 | 88.0 |
| 59 | 85.0 |
| 70 | 96.0 |

The **graph** to represent this data:




### Anomalies

Data points can be considered **anomalies** if they do not fit the trend of the data, which happens as a **result of random errors** during the experiment. Anomalies should always be **removed from the data set** before calculating or concluding anything.

### Drawing conclusions

When drawing conclusions from an experiment it is important to **reference the data.** In the exam this includes **giving examples of data** collected to illustrate a **trend or pattern** and **averages** such as the **mean and ranges**. You are expected to use a **calculator** when necessary, such as when calculating these averages. An **explanation** of the trends and observations from your experiment should accompany the data you've included in your conclusion. These explanations should draw upon **scientific knowledge** from your entire course.

### An example conclusion

The data collected shows that as the length of oak leaves increases, the weight of them also increases linearly. For instance, a leaf which measured 10 cm weighed only 35.0 g whereas a leaf which measured 59 cm weighed 85.0 g. The explanation for this is that longer leaves have a larger surface area and, therefore, a greater mass. If I were to repeat this experiment I would measure longer leaves to investigate whether the trend remains the same and if it remains linear for lengths past 80 cm.

### This conclusion includes:

- The **pattern/trend**
- **Data points** to illustrate the trend
- A **scientific explanation** for the trend
- A short **evaluation**

### Exam questions

As well as drawing graphs you will need to be able to **interpret and read graphs** given to you in the exam. Possible skills you could be tested on include:

- **Reading data points** off a graph
- **Drawing** an appropriate **line of best fit**
    - Remember it may not be straight!
- Suggesting the **type of graph** you would use for a given set of data
    - General rule of thumb - if **quantitative** use a **scatter graph**, if **qualitative** use a **bar chart.**
- Identifying **patterns** and **trends**
- **Drawing conclusions** from the graph which must include **referencing data points**
- **Comparing** 2 similar graphs
    - For instance, comparing 2 graphs which have the same dependent and independent variables but a different subject of study (e.g. for the example above, comparing that graph to another graph which shows the lengths and weights for a different species of leaf).

## Validity

**Validity** is the extent to which your results are able to answer the question you originally asked. Before analysing results, reread the introduction to remind yourself of the **aims** of the experiment, as well as any **theories** underlying the research area. This will help you think about whether your results answer your question.

Some things that may **reduce** the validity of your experiment include;

- **Resolution** of equipment; if your equipment is not very precise, you may not have the correct amount of substance.
- Size of **increments**; with equipment such as pipettes, only a fixed increment size is available, limiting the accuracy of your measurements.
- **Confounding** variables; these are any variables other than your independent variable(s) that affect your dependent variable. It is important to try and control for confounds, however this is not always possible e.g. temperature of the room.
- Error types; **random** errors do not have any identifiable cause and therefore cannot be corrected. Instead you must make new measurements. **Systematic** errors result in measured values that differ by the same amount every time. The cause can be identified and thereby the error eliminated. **Experimenter** errors occur through human error e.g. the researcher might misread a measurement, or write something down incorrectly.