OCR (B) Physics GCSE

Chapter 7: Ideas about Science

Notes

What needs to be considered when investigating a phenomenon scientifically?

Scientific explanations are based on data which must be carefully **collected** and **analysed**. There are many stages to scientific investigations.

Hypothesis and Predictions

Before any data can be collected and analysed, a **hypothesis** must be made. A hypothesis is a **possible explanation** for something which has been observed.

After the hypothesis is in place, a **prediction** is made to test whether the hypothesis is correct. The prediction is based on the hypothesis and is stated in such a way that it can be **easily tested**. The prediction will state how the effect of a **factor** will affect the outcome.

For example, suppose someone is investigating the effect of gravity on objects falling on Earth:

Hypothesis: *'Acceleration due to gravity is approximately constant on the Earth's surface. All objects with a negligible air resistance will fall at the same rate if dropped from the same height at the same time.'*
Prediction: *'If I drop a marble out of a window on the first floor, it will fall at the same rate as a cricket ball dropped out of the same window.'*

The prediction is tested by carrying out **experiments**.

Experiments

Experiments are carried out to directly test the **prediction**. Before planning the experiments, it is important to identify the different variables:

- ➔ **Independent variable** - the thing that you change in the experiment
- ➔ **Dependent variable** - the thing that you measure in the experiment
- ➔ **Control variables** - things which must be kept constant throughout the experiments

Control variables are important to ensuring a **fair test**. They must be kept the same throughout the experiments, otherwise they may affect the results of the experiment, making the experiment **invalid**.

For example, in the aforementioned experiment testing the effect of gravity, both objects, the marble and the cricket ball, were dropped from the same height. Since height may affect the time it will take for the objects to fall, this variable must be kept constant.

Generally, control variables are easy to control as it often just involves ensuring the **same masses/volumes** of samples are used. A **water bath** may be used to control the temperature of the surroundings of a reaction.

When planning an experiment, you must decide what **data** needs to be **collected** and what **measurements** will be taken. Depending on the type of investigation, this may include choosing a **sample size** or **range of values** which will be measured. When choosing a sample size or a range of values, it is important that it is big enough so that a reasonable correlation/conclusion can be taken from the results, but not too big that it will take an unnecessary amount of time for results to be collected and processed.

Once the type of data is chosen and the variables are outlined, the experiment method can be written. Within the method, **appropriate equipment** must be chosen which will make up an **apparatus list**. The equipment must be **suitable** for the job and must be chosen to ensure the data is as **precise**, **valid** and **accurate** as possible:

For example, if you need to measure 13 cm of rope use a ruler which can measure to a degree of accuracy of 1 cm - not 5 or 10 cm.

The method must be **clear**, **concise** and **repeatable** - it is important that other people can recreate the experiment and get the same results.

Along with the method, a **risk assessment** should be carried out to identify any hazards and risks.

Hazards and Risks

A **hazard** is something which could cause **harm**. A **risk** is the **chance** that the hazard will cause harm.

Experimental hazards can involve **radioactivity, light, electricity**, **fire** and **glass**. It is important to identify all possible hazards in an experiment, so that procedures can be put in place to **reduce the risk**.

Depending on the hazard, **reducing the risk** can be done by wearing protective equipment, turning off the power source when not in use, or minimising contact/exposure as well as endless other methods.

For example, if working with slotted masses, make sure to place a tray of sand underneath the apparatus. This will reduce the risk of any heavy masses landing on somebody's foot, potentially causing injury.

What processes are needed to draw conclusions from data?

After carrying out an experiment to investigate a hypothesis, there is a **process** of **collecting**, **presenting** and **analysing** the data.

Processing Data

Significant Figures

Experimental measurements must all be taken to the same number of **significant figures**. In any further calculations involving the results, the answers must be rounded to the **lowest number of significant figures** given.

Nomenclature and SI units

IUPAC chemical nomenclature is the worldwide system used for naming chemical compounds. It is important that chemicals are named in this way during an investigation, as this ensures the investigation can be read worldwide.

SI units are the standard units used all over the world. SI units must always be chosen when appropriate, as this ensures the data is easily **translatable**.

Quantity	SI Base Unit
Time	Second, s
Length	Metre, m
Energy	Joule, J
Mass	Kilogram, kg

Since data comes in a high range of sizes, various **prefixes** can be used to make the size of the numbers easier to process.

Prefix	**Mega (M)**	**Kilo (k)**	**Centi (c)**	**Milli (m)**	**Micro (μ)**	**Nano (n)**
Comparison to the base unit	1000000 times bigger	1000 times bigger	100 times smaller	1000 times smaller	1000000 times smaller	1000000000 times smaller

Interconverting units

You need to be able to **convert between units** as some equations or formulas will require measurements in specific units.

kg → x 1000 → g

g → ÷ 1000 → kg

m^3 → x 1000 → dm^3 → x 1000 → cm^3

cm^3 → ÷ 1000 → dm^3 → ÷ 1000 → m^3

g/cm^3 → x 1000 → g/dm^3

g/dm^3 → ÷ 1000 → g/cm^3

Errors

The experimental results will always vary slightly due to **random errors**. These types of errors may occur due to changes in environmental **conditions**, a worn out measuring **instrument** or a **person** taking an incorrect measurement.

If the results are wrong by the same amount every time then there is a **systematic error**.

An **anomalous result**, is a result which does not fit the **trend** of the other results. If there is a clear reason supporting the result as an anomaly (i.e. you work out what went wrong with that measurement), then it should **not be included** in the processing of the results.

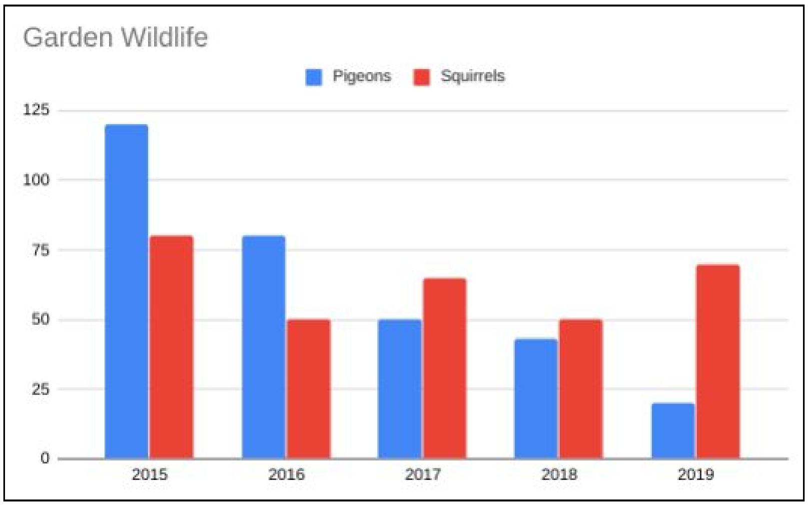
Presenting Data

Presentation of Data

Tables are commonly used to organise data. Tables must be drawn with a ruler and each column must have a **header**. The **units** must be included in the header - not in the main body of the table.

Conical Flask	Experiment 1 (cm^3)	Experiment 2 (cm^3)	Mean (cm^3)
A	50	32	41
B	45	29	37

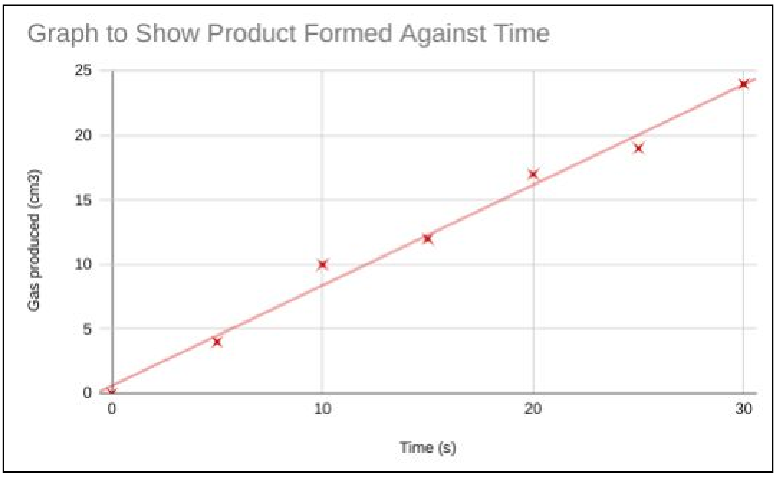
If the data collected is split into **categories**, it can be presented in a **bar chart**. A bar chart allows for easy **comparison** between various categories.



Drawing a bar chart:

1. Scale must be linear (divisions between values must be equal).
2. Label the axes and include the units.
3. Include a key to distinguish between the data.
4. Leave a gap between the various categories.

If the data is **continuous**, it can be plotted on a graph. **Continuous data** is data which can be measured and can have any value within a range.



Plotting a graph:

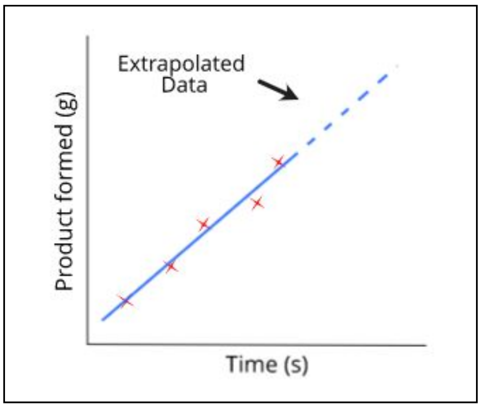
1. Draw a sensible scale on the axes.
2. The dependent variable goes on the vertical y axis.
3. The independent variable goes on the horizontal x axis.
4. Use a sharp pencil to plot data points, mark them as crosses.
5. Draw a line/curve of best fit through as many data points as possible. Ignore any anomalous results.

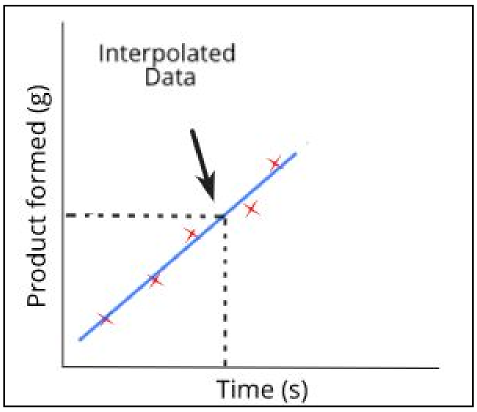
The **rate of reaction** can be calculated from the **gradient** of a graph if the amount of product formed/reactant used has been plotted against time.

Gradient = (change in y) ÷ (change in x)

Extrapolation and **interpolation** are also techniques which can be used to obtain values from graphs.

- **Extrapolation** involves continuing the trend on further to obtain **more data points** just **outside the range**.
- **Interpolation** involves constructing **new data points within the range** of known data points. This can be done by use of a line/curve of best fit.





Statistics

Statistics such as range and mean can be calculated when processing results. This will give values which can be **easily compared** across a range of experiments. **Anomalous results** should **not be included** in these calculations.

The **range** indicates how **spread** the data is:

Range = largest number - smallest number

The **mean** should always be calculated if **repeats** of an experiment have been carried out:

Mean = (Sum of all data value) ÷ (Total number of data values)

Experiment Improvements

It is important to **evaluate** the **success** of the experiment.

- Was the method **valid**?
- Was it a **fair** test? Were all the **control variables** controlled?
- Were there any **anomalous** results?
- Was there enough evidence for a **valid conclusion** to be reached?

From these questions, you should suggest any changes to the experiment which might increase the **quality** of the results obtained.

A possible suggestion for **improving accuracy** could be to take measurements of several cycles and divide by the number of instances at the end.

For example, when measuring the time it takes for one oscillation of a swinging pendulum, measure the time it takes for ten pendulum swings. Do this three times, take an average of the time for ten oscillations to take place and divide by ten to ascertain the period of the pendulum. Provided the experimental setup is sound, applying a method that involves repeat measurements will result in the attainment of a more reliable and accurate dataset.

Following on from the scientific investigation, you could also suggest **further investigations** which could be carried out.

Drawing Conclusions

In order to reach a conclusion, you must **analyse the pattern** of the data. It is important that you **only conclude what the data shows** - you should not go any further. The results must justify the conclusion and the conclusion must state whether or not the data supports the **original hypothesis** made.

	Voltmeter reading	*Ammeter Reading*	*Resistance*
Component A	*16V*	*2A*	*8Ω*
Component B	*9V*	*3A*	*3Ω*

For example, from the data above, we can conclude that component A has a greater resistance than component B. Component A has a resistance 5Ω greater than component B.

How are scientific explanations developed?

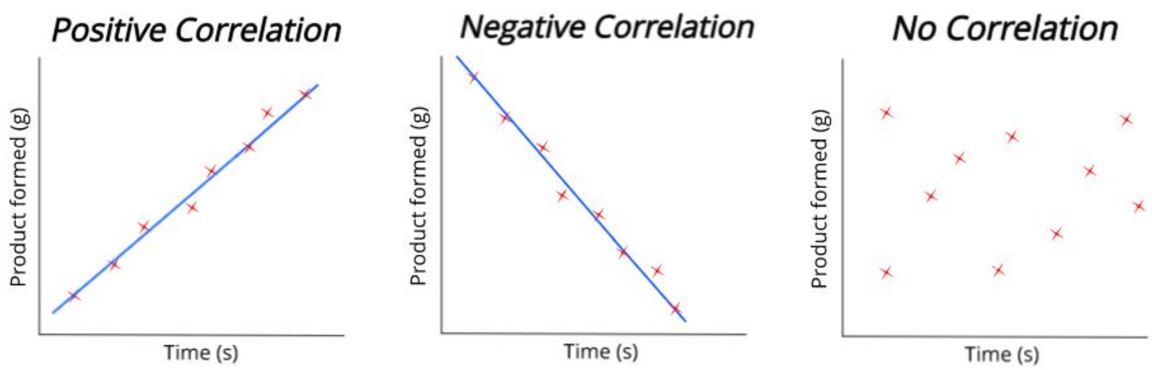
The identification of a **correlation** can lead to the identification of a **causation** which provides the basis of scientific explanations. The explanations are then developed and **modified** when **new evidence** is discovered. **'Peer review'** is also a process used to evaluate and develop scientific explanations.

Correlation and Causation

Correlation is not the same as **causation**.

A **correlation** describes the size and direction of a **relationship** between two or more variables. Importantly, a correlation between variables does not automatically mean that the change in one variable is the cause of the change in the other variable.

Correlations can be observed from **graphs** as follows:



Individual cases do not provide convincing evidence for or against a correlation as it is common for there to be some exceptions to a correlation.

For example, there has been shown to be a correlation between smoking and lung cancer, however there are some people who smoke but have not developed lung cancer. These individual cases are exceptions and do not disprove the correlation.

Causation, also known as **cause and effect**, indicates that one event is the **result** of the **occurrence** of the other event. Some correlations can be shown to be causations, if enough scientific evidence is provided to back up the theory.

For example, there is a correlation between carbon dioxide levels in the atmosphere and average global temperatures. This can be stated to be a causal link since the greenhouse effect explains how increasing levels of carbon dioxide in the atmosphere leads to increases in temperature on Earth.

An example of a correlation which is not a causal link is the correlation between sunglasses sales and hayfever. Clearly this is a correlation and not a causation as clearly sunglasses sales does not cause hay fever.

Modification of Scientific Theories

The biggest cause for the **modification** of scientific theories is the discovery of **new evidence.** The proposition of a scientific explanation involves **creative thinking**.

New evidence and data to support an explanation often relies on **technological developments**. This is why a theory often changes as the technology available becomes more advanced. An example of where technology developed scientific explanations is the **development** of the **big bang model**.

The development of telescopes allowed scientists to see that the universe was expanding at an accelerating rate.

The buildup of **new evidence** can lead to a **hypothesis to be modified** and sometimes even becoming an accepted explanation or theory.

A **scientific theory** is a **general explanation** which can be applied to a large number of situations or examples whereas a **scientific explanation** is the **application** of a scientific theory to a particular situation.

Peer Review

The **'peer review'** process of developing a scientific explanation involves new scientific claims being **evaluated** by **other scientists**. It is important that new scientific findings are checked by the scientific community before being generally accepted as a scientist's personal background, experience or interests may **influence their judgements**.

Once a scientific explanation is accepted, it usually survives and remains in place (even if new evidence disagrees with it) until a better explanation is available.

Models and their Limitations

Models are used to help **explain ideas** and to **quickly test** explanations, without ethical or practical limitations.

A model represents the **main features** of a system and can be used to predict possible outcomes.

There are a wide range of different types of models.

- **Representational models** use physical analogies or spatial representations to help visualise explanations and mechanisms.

Examples include the particle model and the representations of atoms, ions and molecules. Descriptive models are used to explain specific phenomena.

- **Mathematical models** predict behaviour by using data patterns of past events and already known scientific relationships. Computers are often used to carry out the complex calculations.

Due to the simplifications, there are **limitations** to models. For example, the limitations of the **particle model** includes the facts that in the model there are no forces between the spheres, and that atoms, molecules and ions are not solid spheres.

How do science and technology impact society?

As well as advancing scientific explanations, science and technology have a significant effect on society.

Benefits of Science

Science and technology can benefit people's lives, and can improve their **quality of life**.

There are many **examples** which demonstrate the benefits of science:

- **Seat belts, airbags and crumple zones** use the ideas of impulse to improve the effectiveness of car safety.
- **Radioactive tracers** allow diagnostic techniques to be improved by using the ideas of nuclear physics.
- **Electric motors** allow for the improvement of transport and point us towards a more sustainable future.
- **Nuclear energy** provides an effective alternate path to burning fossil fuels for energy.
- **Ionising radiation** can be carefully used to our advantage for a range of cancer treatments.

Risks

Some applications of science can pose a risk to people's **quality of life** or to the **environment**. Scientists work to **reduce** the negative impacts of the applications. This can involve using **sustainable** resources, and carrying out processes to prevent pollutants entering the atmosphere, such as **flue gas scrubbing** and **carbon capture**.

Nothing is completely risk free, and everything carries a certain level of risk of **accident** or **harm**. The **size** of a risk can be estimated by analysing data. For example, you could estimate the risk of cycling accidents by recording how many people in a group of 100,000 cyclists have an accident over the period of a year.

People are generally **happier to accept** a risk if it is associated with something they **choose** to do, rather than something which is **imposed**. People will also more easily accept a risk with **short term effects**.

Higher Tier Only

People often have an idea of a perceived risk, which regularly differs from the calculated risk. A perceived risk is often an overestimate of the risk as people tend to overestimate the risk of unfamiliar things. For example, cycling is relatively high risk and flying is pretty safe, but many people would believe that flying is more high risk than cycling since it is unfamiliar. Also, people overestimate the risk of things whose effect is invisible or long-term, like ionising radiation.

Ethical Issues

Some scientific explanations can have **ethical implications**.

An example of an ethical issue is the **use of ionising radiation**, to treat disease. Most people would agree that the **benefits outweigh the risks**, however some people are concerned about the handling of radioactive waste and the impact it has on the environment.

Another example of an ethical issue is the use of **nanotechnology**. Nanotechnology has many useful medical applications, however it is still a relatively new science, and so the potential effects of nanoparticles on the body, as well as on the environment, are largely unknown. This leads to **disagreements** between people on the **increasing use** of nanotechnology.

It is generally argued that the **right decision** is the decision which leads to the **best outcome** for the **greatest number** of people.

Communicating Science

Scientists must communicate their work in a way which can be **understood** by a **range** of audiences - including the **public**, other **scientists**, and **politicians**. This allows **decisions** to be easily made based on information given about risks, benefits, costs and ethical issues.