OCR (B) Physics GCSE

P7: Ideas about Science

Summary Notes

IaS1: What needs to be considered when investigating a phenomenon scientifically?

Hypotheses:
- Formulating a hypothesis is a common starting point when investigating a phenomenon
- It is used to give an initial rough explanation for what has been observed

Predictions:
- A prediction takes the hypothesis and uses it to suggest what is expected to happen in an experimental scenario
- It often involves predicting how one variable will change as another one is altered
- An experimental procedure is required to test predictions and verify hypotheses

Hypothesis → Prediction → Experiment → Verify

Planning an Experiment:
After you have a hypothesis and prediction that you want to test, you can plan an appropriate experiment. This involves:

1. Identifying the **variables**
    a. Independent
    b. Dependent
    c. Control
2. Choosing appropriate **equipment and techniques** to carry out the experiment
3. Considering **hazards** and ways to reduce the risk involved (**risk assessment**)
4. Picking suitable **ranges** to experiment over
5. **Analysing** the experimental data

1. Variables
All experiments have independent, dependent and control variables. It is important to be able to identify what these are so that the experiment is **fair** and the data is recorded clearly.

- **Independent**: The variable that is **changed** throughout the experiment.
- **Dependent**: The variable that is **measured** for each change in the independent variable.
- **Control**: Any variable, other than the chosen independent variable, that may affect the outcome of the experiment and so must remain **constant** throughout.

Example: *In a free-fall experiment to find determine whether a heavier ball falls faster than a lighter ball:*

- Independent variable: the mass of the ball since this is what is changed

- Dependent variable: the time taken for the ball to fall

-Control variables: the height the ball is dropped from, the surface area of the ball, the gravitational field strength

2. Choosing Appropriate Experimental Apparatus

What apparatus should be used is based upon the **type** and **magnitude** of the measurement. It is also important that the equipment chosen is used properly to improve the **accuracy** of the measurements; equipment with adequate **resolution** should be chosen. The below table indicates what apparatus may be appropriate.

Measurements	**Instruments/Technique**	**Accuracy**
Length	Callipers, ruler, tape measure	Avoid **parallax error** by reading from the level of the scale
Area	Calculate after finding appropriate lengths	Measure lengths at several positions and find the average
Mass	Balance Newton meter (divide by g)	Avoid zero error through calibration of the balance
Time	Stopwatch	Subject to reaction times
Volume	Submerge in water and measure change in water level	Read from eye level to avoid **parallax error**
Temperature	Thermometer	Stir water first to uniformly distribute the heat

3. Identifying Hazards Involved with Data Collection

In certain experimental situations, there may be hazards involved when collecting data. A **risk assessment** should be produced before any experiment to identify any potential hazards as well as adopting procedures to **minimise the risk** involved.

Hazards are potential sources of danger (eg. open flames) and risks are their potential effects (eg. burns).

A risk assessment should:

- Identify any potential **hazards** involved
- State the **risks** associated with the hazards

- Explain how the risks are going to be **reduced and controlled** throughout the experiment

Example: *For the Force-Extension experiment, the risk assessment may look something like this:*

Hazard	***Risk***	***Precaution***
Spring	*When overloaded, the spring may break and has the potential to hit the experimenter's eye.*	*Add small increments of weights and stop when the spring starts to plastically deform. Wear safety glasses.*
Masses	*May fall onto the experimenter's foot and cause injury.*	*Avoid standing under the experimental set up and place a bucket below where the masses are hanging. Wear appropriate footwear.*
Clamp Stand	*May topple when masses are added and cause injury.*	*Use a counter balance or G-clamp to prevent the stand from toppling.*

4. Choosing Experimental Ranges

Before starting an experiment, an **appropriate sample size** and **range of values** to test over must be decided. If the range is too small, it may make it hard to make noticeable observations or demonstrate any patterns present. If the range is too large, the results may be too broad to draw conclusions from and the experiment may take more time than required; it could be a waste of time and resources.

Picking a suitable range may involve carrying out a **preliminary experiment** to determine what changes occur for different ranges of values.

IaS2: What processes are needed to draw conclusions from data?

After carrying out an experiment, it is important to analyse the data properly so that the correct conclusions can be made.

Processing data effectively involves:
1. Identifying what **type of data** you have
2. Recording the data following standard scientific **conventions**
3. Identifying any **anomalous results**
4. Recognising any **errors** that may have occurred in the experiment
5. Choosing a **suitable format** to present the data

1. Types of Data

Different experiments will produce different types of data. It is important to identify what type of data you are dealing with so that you can choose an appropriate format to present and analyse the data.

Data can be described using different terms:

- **Categorical data** is data that represents a characteristic rather than having a numerical significance. This is also known as **qualitative** data.
- **Numerical data** is data that has a numerical significance. This is also known as **quantitative** data
- **Discrete Data:** Discrete data only has a **finite number** of distinct values. Data cannot be split down further and cannot exist between the distinct groupings.
- **Continuous Data:** Continuous data can take an **infinite number** of values within a given range. Values can be added between other values and there are no distinct groupings.

2. Recording Data

When recording data, it is important to follow standard conventions when it comes to the number of **significant figures**, **units** and **prefixes** used.

- **SI Units**
  - ➢ When taking measurements and carrying out calculations and analysis, it is good scientific practice to be consistent with the units that you use. It is standard practice to use the following SI units:

Quantity	Unit	Unit symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	degrees Celsius	°C
Pressure	Pascal	Pa
Energy	Joule	J
Current	Ampere (or Amp)	A

- **Prefixes**
  - ➢ To avoid having to use several zeros in the figures you record, the following unit prefixes can be used:

Prefix name	Prefix symbol	Power
Tera	T	$\times 10^{12}$
Giga	G	$\times 10^{9}$
Mega	M	$\times 10^{6}$
Kilo	k	$\times 10^{3}$
Centi	c	$\times 10^{-2}$
Milli	m	$\times 10^{-3}$

Micro	μ	$\times 10^{-6}$
Nano	n	$\times 10^{-9}$

- **Significant Figures**
  - Data should always be given to the **lowest number** of significant figures of the apparatus used to measure it.
  - Stating data to a greater number of significant figures than can be certain is bad scientific practice.
  - It is also important to **state the number of significant figures** being presented.

Example: *In the Force-Extension practical, the extension is measured using a ruler and so can only be measured to an accuracy of +/- 1mm. This means that data values should be quoted to 1mm accuracy.*

3. Anomalous Results

An anomalous result is one that **doesn't match the pattern** of the data and disagrees with the values suggested by repeat readings. They can be caused by random experimental error or may be the result of incorrect readings or the following of an incorrect method.

Repeat Readings

When carrying out an experiment, repeat readings can be used to identify anomalous results. If anomalous results are suspected, reasons as to why they arose should be considered, and then if it is appropriate to do so, the anomalous results can be discarded before carrying out further analysis. **Averages** for the result readings can then be calculated to **reduce the uncertainty** in the results.

4. Statistical Analysis and Errors

When carrying out an experiment it is important to check your results for any indication of errors. It is also beneficial at this stage to analyse the experimental method used to see whether the results are accurate and reproducible. Key terminology that should be considered include:

- **Accuracy:** How close a value is to the **true** value.
- **Precision:** How close a value is to the **mean** value.
  - Precise results will be close to each other, so not a large range of values
- **Repeatability:** If repeatable, the **same person** can repeat the experiment using the **same method and equipment** and obtain the same results.
- **Reproducibility:** If reproducible, the experiment can be carried out by a **different person** and with a **different method** and still obtain the same results.

Errors:
You should be aware of the following types of errors and where possible, take steps to prevent them from occurring:

- **Measurement error:** Difference between the **measured and true values**
- **Random error:** Differences caused by **unpredictable** and uncontrollable factors. They cannot be corrected for and so instead, repeat readings and averages should be used.
- **Systematic error:** Readings differ from the true value by the **same amount** each time. It may be necessary to take new measurements through another method.
- **Zero error:** A form of **systematic** error where the zero value isn't correctly calibrated. This can often be avoided by ensuring the measuring instruments being used are zeroed before use.

5. Presenting Data

Tables:
Using tables is a good way to clearly record data when carrying out an experiment. However when using tables, certain conventions should be followed:

- Each column should have a **clear heading**
- Each heading should be followed by a forward slash and the **units** being used
- The **independent variable** should be in the left-hand column
- All data should be recorded to the **same number of significant figures**, which should be determined by the apparatus used to take the measurements

Example:

Length/m **± 1 mm** (independent)	**Current/A** **± 0.01 A**	**Potential Difference/V** **± 0.01 V**	**Resistance/Ω** No ± available since R was obtained through R = V/I
0.000	0.00	0.00	0.0
0.100	0.10	0.12	1.2
0.200	0.11	0.23	2.3

Graphs:
Using graphs to display data can help demonstrate the **trends and patterns** that are present. The type of graph depends on the type of data:

Data Type	**Appropriate Graph**
Discrete	Bar chart, column chart, pie chart, histogram
Continuous	Line graphs

When graphing data, the following conventions should be followed:
- Axes should be clearly **labelled** with what is being measured, as well as the **unit** it is being measured in
- Data points should be marked using a **cross**
- The **independent** variable should be on the **x-axis**
- The scales used should spread across as much of the space as possible whilst covering the **full data range**

Lines of Best Fit:
Once data points are plotted, a line of best fit can be drawn to demonstrate a **trend** and estimate other values. When drawing a line of best fit:

- Consider any known **underlying principles**, as well as using the data points, to determine whether a straight line or a curve is more appropriate
- Consider whether the **origin** (0,0) is a data point
- If drawing a straight line, it is important to ensure that there is roughly an equal number of data points **above** the line as there is **below** it

◦ However, don't force a line through the middle if it is not a good fit for the data

Using Graphs:
Once a graph has been drawn, it can be used to **estimate values** of one variable for a given value of the other. However when doing this, it must be identified whether the given value is:

- Interpolation: estimating **within** the range of the experiment and data
- Extrapolation: estimating **outside** of the experimented range of values

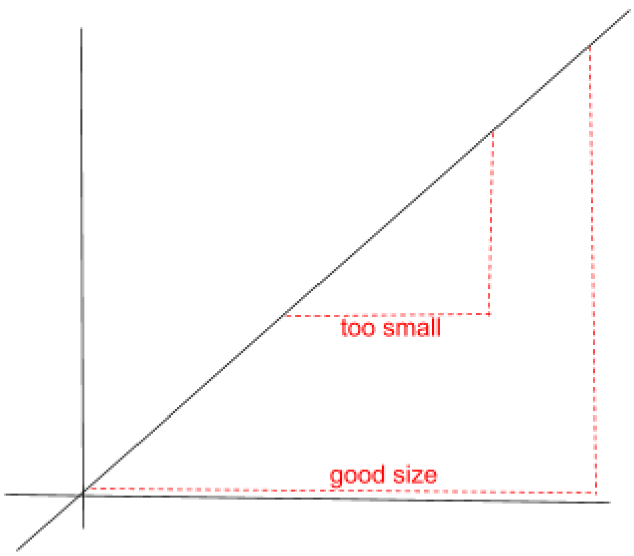
If the given value is extrapolation, the estimate given by the graph may not be valid since it is unknown whether the **pattern** shown by the graph continues outside the range of the data. Therefore estimates are **only valid** within the **interpolation** region.

Gradients:
If the mathematical relationship between variables is known, the gradient of the graph may be useful to calculate the **third variable**. To find the gradient of a straight line graph you must use the equation:

Gradient = Change in X / Change in Y

Take care to pay attention to whether the change is positive or negative for each axis.

You should draw on the values that you use to form a **gradient triangle**. You should use the **widest range** (biggest triangle) possible to improve the accuracy of your value.



IaS3: How are scientific ideas developed?

Correlations and Causation:

1. Correlation:
Correlation is a link between variables. The correlation can be described in a number of ways:

- **Positive**: As one variable **increases**, so does the other
- **Negative**: As one variable **decreases**, so does the other
- **Linear**: The rate of change of both variables is constant and so forms a **straight-line** graph
- **Non-Linear**: The rates of change of each variable isn't constant and so forms a **curved** graph
- **Directly Proportional**: The graph is a **straight line** which passes through the **origin** (0, 0)

2. Causation
If two variables are correlated, it **doesn't** necessarily mean that a change in one variable directly causes a change in the other. There may be another variable that hasn't been considered and which may in fact explain the correlation. **Correlation does not necessarily mean causation!**

Development of Scientific Ideas:

1. Changes over Time:
As more experiments are carried out over time, the evidence to support or disagree with a principle will grow. As more data is collected, hypotheses may be changed, or may be proven to such a point that the principle in question becomes **widely accepted**.

2. Scientific Theory:
A scientific theory is an explanation which can be applied to different situations and remain valid. It is backed up by **sufficient scientific evidence** and is widely accepted by the scientific community. Existing scientific theories are often starting points when considering new scientific phenomena.

3. Peer Review:
Peer review is a process which scientific theory must go through before being accepted as valid. The process involves:

- Confirming that the experiment is **repeatable**
- Confirming that the results are **reproducible**
- Reviewing the **conclusions** that have been drawn from experimental work

In general, a scientific theory that meet these criteria will remain in place until evidence that **contradicts** it is found.

4. Scientific Models:

Scientific models outline a set of **fundamental rules** that a given system is expected to follow, and can be used to make predictions about events that take place. There are several different types of models used:

- **Mathematical** models: Identifying patterns and forming equations
- **Computational** models: Larger scale and more complex models that often involve large amounts of mathematical processing
- **Representational** model: Using physical analogies or 3D models to visualise principles
- **Descriptive** models: Using words and diagrams to explain a phenomenon

Scientific models mean that phenomena can be investigated **without the ethical and practical implications** often associated with scientific experimentation. The usefulness of models is **limited** by the extent to which the given model mirrors real life. It is rare to find a model that perfectly matches reality.

IaS4: How do science and technology impact society?

It is important to consider the negative impacts and risks involved with scientific work, as well as the positive impacts. It is important to think about the risks involved as well as an ethical implications that the work may have.

1. Perceived and Calculated Risk

Less common and unknown things often come with a **greater perceived risk**. For example humans generally assume that there is a greater risk associated with flying somewhere than cycling somewhere, although evidence doesn't necessarily support this. Risk can be estimated by **examining large samples** and then scaling it up. Doing this however assumes that the scale doesn't affect the risk.

Calculating risk involves taking into account the consequences and likelihood of a dangerous event occurring. For example, stubbing your toe has small consequences, but a high likelihood, whereas nuclear disasters have devastating consequences but a very low likelihood.

2. Ethical Implications:

Certain scientific experimentation carry significant ethical implications. These implications span a range of different factors including:

- **Social Factors:** Scientific and technological work can have associated social implications.
- **Environmental Factors:** Certain scientific work will have an environmental impact. The **gain to society** must be compared to any negative environmental effects as a result of the work.
- **Economic Factors:** All scientific experimentation has an **associated cost**. The value of the work being carried out may be perceived to be different to different people and areas of society. Before any scientific work is carried out, it must be decided whether the benefit to society is worth the associated cost, or whether the resources would be better used elsewhere.