Practical skills

Planning an experiment, taking and recording measurements, processing results with graphs and uncertainties, and drawing conclusions, as tested in Units 3 and 6.

Planning an experiment

Units 3 and 6 are written practical papers. You are asked to plan, describe or analyse an experiment, often one of the core practicals or one that uses the same ideas in a new setting.

What a good plan contains

1. **The aim** and the **variables**: the independent variable (what you change), the dependent variable (what you measure), and the control variables (what you keep the same).
2. **Apparatus**, with the right measuring instrument and its resolution (a metre rule to 1 mm, vernier callipers to 0.1 mm, a micrometer screw gauge to 0.01 mm).
3. **A method** a student could follow: how to set up, what to change and by how much, what to measure, and how many readings to take.
4. **How to control** the other variables so the test is fair.
5. **Repeat readings**, to spot anomalies and find a mean, where random error is likely.
6. **Safety**: the hazard, the risk, and the precaution (a clamp for a heavy mass, goggles for a spring that may break, a resistor to limit current).
7. **How the data will be used**: what graph to plot and what its gradient or intercept will give.

> **A plan must state what is measured and how, and what is done with it. "Measure the time" is not enough: say what is timed, with what, and over how many oscillations.**

Choosing and using instruments

- Time a **large number** of oscillations or events and divide, to reduce the effect of reaction time. Use a fiducial marker at the centre of an oscillation.
- Measure a **long** length where possible: the percentage uncertainty is smaller.
- Use a **zero check** on meters and micrometers, and correct for a zero error.
- Take a measurement across several positions for a diameter (a wire) and take the mean.

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Choosing the range

Take at least 6 sets of readings across as wide a range as is safe, evenly spread. Show the values you would use, such as lengths of 0.20 m to 1.00 m in steps of 0.20 m.

Implementation and measurements

Recording

Record raw data in a table with **headings and units** (for example T / s, l / m). Give every reading in a column to the **same number of decimal places**, matching the instrument's resolution. A mean may have one more significant figure than the readings.

Errors and uncertainty

- **Random errors** cause scatter in repeat readings. Repeats and averaging reduce them.
- **Systematic errors** shift every reading the same way (a zero error, a wrongly calibrated meter). Repeating does not remove them; a different method or a correction does.
- The **uncertainty** in a reading is at least half the smallest division, or the range of repeat readings divided by two.

Case	Uncertainty
Sum or difference	Add the **absolute** uncertainties
Product or quotient	Add the **percentage** uncertainties
Power x^n	Multiply the percentage uncertainty by n

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TRY IT

A length is measured as (25.0 ± 0.1) cm and a time as (1.50 ± 0.03) s. Find the percentage uncertainty in the product $l \times t$.

$\frac{0.1}{25.0} = 0.4\%$ and $\frac{0.03}{1.50} = 2\%$. The percentage uncertainty in the product is $0.4\% + 2\% = 2.4\%$.

Processing results

Graphs

Rearrange the equation into the straight-line form $y = mx + c$ so that the gradient and intercept give the quantity you want.

TRY IT

For a simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$, what should be plotted to find g?

Square it: $T^2 = \frac{4\pi^2}{g} l$. A graph of T^2 against l is a straight line through the origin with gradient $\frac{4\pi^2}{g}$, so $g = \frac{4\pi^2}{\text{gradient}}$.

When the relationship is a power law, $y = ax^n$, plot $\lg y$ against $\lg x$: the gradient is n and the intercept is $\lg a$. When it is exponential, $y = ae^{kx}$, plot $\ln y$ against x.

To draw a graph: label axes with quantity and unit, use more than half the grid in each direction, plot points to half a small square, and draw a best-fit line with roughly equal points either side (not joined dot to dot).

Gradient and its uncertainty

Take the gradient using a **large triangle** that uses more than half the line. For the uncertainty, draw the **steepest and shallowest** acceptable lines through the error bars and find the difference between their gradients, then halve it.

NOTE

Use points on the line, not data points, when finding a gradient, and show the coordinates used.

Anomalous results and conclusions

Identify an anomalous point and say what to do: repeat it, or exclude it with a reason. A conclusion states the relationship found (direct proportion, or y against x gives a straight line) and compares a result with an accepted value using percentage difference, relating it to the uncertainty.

Evaluating an experiment

Say what **limits** the accuracy and give a specific improvement:

- Reaction time in timing: use light gates, or time more oscillations.
- Parallax when reading a scale: view at eye level, use a set square.
- Heat loss: insulate the apparatus.
- Too few readings: take more over a wider range.

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- A zero error: check the zero and correct readings.

The core practicals

Be ready to describe, in outline, the method, the graph and the sources of error for the core practicals: acceleration of a freely-falling object; viscosity by the falling-ball method; the Young modulus; speed of sound with an oscilloscope; stretched-string resonance; wavelength by a diffraction grating; resistivity; e.m.f. and internal resistance; force and change of momentum; collisions; discharging a capacitor; a thermistor thermostat; specific latent heat; pressure and volume of a gas; absorption of gamma radiation; and resonance of an oscillating system.

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