

# Experimental programme

International Baccalaureate · IB Diploma · Physics · HL

## Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

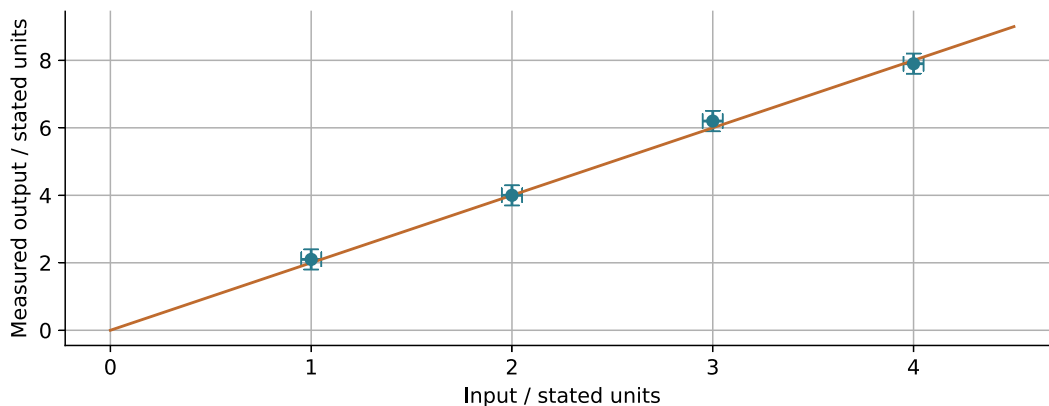
## Uncertainty, gradients and model testing

### ■ What would explain this observation?

- A line passing near every data point is useful, but its gradient can still be uncertain. A graph is evidence for a model within the measurement range.

### ■ Build the model

- Random variation makes repeated readings differ.
- **Systematic error** shifts results consistently.
- Absolute **uncertainty** has the measured unit; relative or percentage uncertainty compares uncertainty with the measured value.
- uncertainty: A quantified limitation on a measured result.
- systematic error: A consistent measurement bias.



*Every point lies within its uncertainty of the line of best fit*

### ■ Choose evidence that can test it

- For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation.
- For a difference, add absolute uncertainties.
- A nonzero intercept can reveal an offset or an incomplete model.

**In the lab:** Show units on axes and choose a sensible scale. Plot uncertainty bars where justified, draw a best-fit line rather than joining every point, and estimate steepest and shallowest plausible gradients when the course method calls for them.

### ■ Work from known quantities

- Known: length = 50.0 mm with uncertainty 1.0 mm.
- Percentage uncertainty =  $\text{absolute uncertainty} / \text{value} \times 100 = 1.0 / 50.0 \times 100 = 2.0\%$ .
- For a quotient of two independently measured quantities with maximum percentage uncertainties 2% and 3%, the summed maximum estimate is 5%.

**Your turn:** A 40 cm reading has an absolute uncertainty of 1 cm. Find percentage uncertainty.

### ■ Check the conclusion and its limits

- Repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error.
- Do not quote more decimal places than your measurement can support.

**Not true:** Repeating a measurement always removes a calibration offset. Repeating and averaging reduces RANDOM scatter in the mean. A calibration offset shifts every reading identically, so repeats land on the same wrong value; only recalibration removes it.

### Key:

- Random variation makes repeated readings differ.
- For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation.
- Watch for: repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error.

### ■ Write from a percentage uncertainty of 5 percent

- An 80 cm reading has an absolute uncertainty of 4 cm.
- Find the percentage uncertainty. Repeating the reading does not remove a calibration offset.

■ **Write from a product uncertainty**

- Two measured factors carry 3% and 4% maximum uncertainties.
- The product carries  $3 + 4 = 7\%$  – percentage uncertainties ADD for products and quotients.

■ **Write from a repetition gain**

- A measurement is repeated four times and averaged.
- The mean's random uncertainty falls to about half a single reading's – but repetition never touches a SYSTEMATIC error: a zero error repeats too.