41.1 Uncertainty, gradients and model testing

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

KEY WORDS systematic error • uncertainty

Objective

Uncertainty, gradients and model testing. Original classroom practice for IB HL; not an official IB paper.

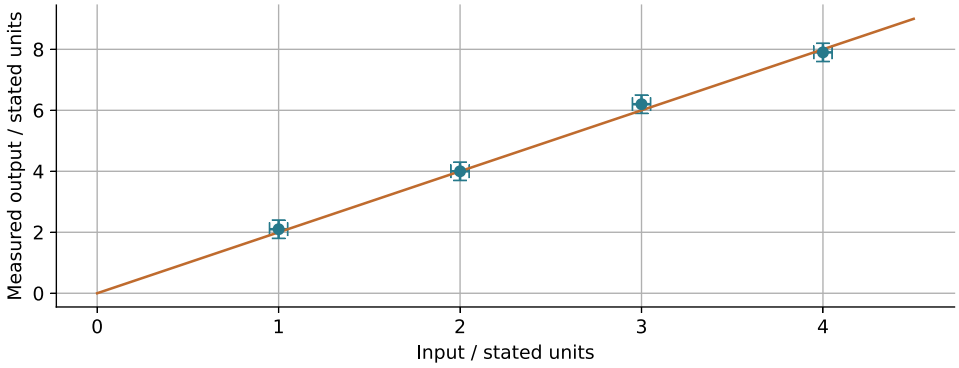
1 Key knowledge and worked examples

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.



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 = absolute uncertainty/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- Do not quote more decimal places than your measurement can support.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 an uncertainty of 15 percent

- A 40 mm reading has an absolute uncertainty of 6 mm.
- Find the percentage uncertainty. For a quotient, add the percentage uncertainties.

2 Practice

2.1 Which is most likely a systematic error? Choose one answer.

- **A** A balance reads 0.20 g when empty
- **B** Repeated values fluctuate either side of the mean
- **C** Random differences in reaction time [1]

2.2 A 40 cm reading has an absolute uncertainty of 1 cm. Find percentage uncertainty. Show the relation, substitution and units. [2]

2.3 Decide whether this claim is true and justify: Repeating a measurement always removes a calibration offset. [2]

2.4 A quantified limitation on a measured result: write the technical term. [1]

3 Exam-style questions

3.1 Lengths are(50 ± 1) mm and(20 ± 1) mm. Estimate the quotient and its maximum percentage uncertainty; distinguish this convention from independent standard-uncertainty propagation. [4]

Solutions

2.1 A A balance reading 0.20 g when empty shifts EVERY reading the same way - that is a systematic zero error. Fluctuations either side of the mean and variable reaction times scatter randomly and shrink with repeats; an offset does not.

2.2 percentage uncertainty=1/40×100=2.5%.

2.3 False. 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.

2.4 uncertainty. uncertainty means A quantified limitation on a measured result.

3.1 Quotient 2.5. Maximum estimate 2%+5%=7%, absolute 0.175≈0.18. Independent standard uncertainties instead combine in quadrature, about 5.39%; declare which convention the data support.