3.3.2 Uncertainty, evaluation and statistics

Name: _____ Class: _____ Date: _____ **Total: 24 marks**

KEY WORDS random error • systematic error • anomalous result • error bars

Objective

Evaluate results the way WBI13 credits: random versus systematic error, percentage uncertainty, anomalies, realistic improvements, and named statistics (mean, SD, range, error bars) for variability and comparison. Original practice for the Unit 3 evaluation criteria.

1 Key knowledge and worked examples

■ Errors and what repeats can and cannot fix

Random error makes readings scatter either side of the true value; repeating and averaging reduces its effect on the mean. A **systematic error** shifts every reading the same way (a zero offset on the colorimeter, a mis-calibrated graticule); averaging does not remove it – zero the instrument on a blank, calibrate against a standard.

■ Uncertainty in arithmetic

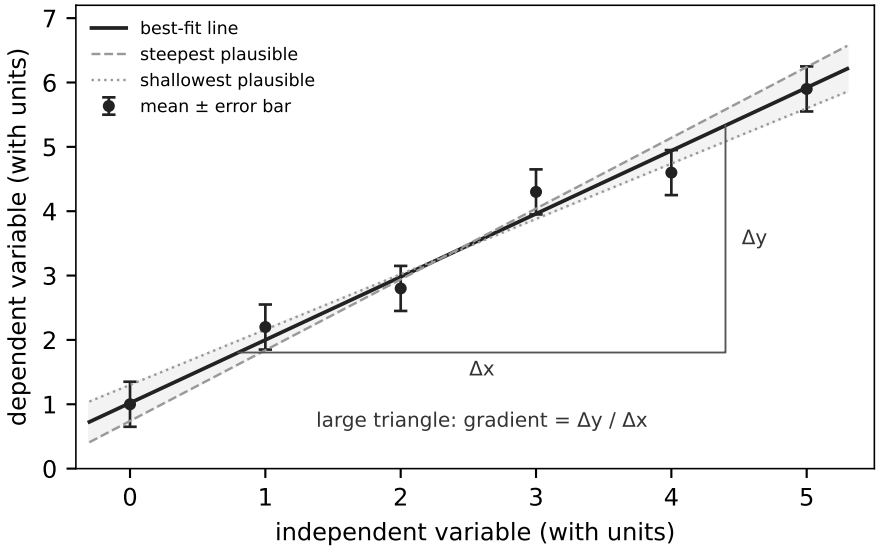
Percentage uncertainty of one reading = (absolute uncertainty ÷ value) × 100 %. For a product or quotient of independent measurements, add the percentage uncertainties; for a difference, add the absolute uncertainties first. Quote results to the significant figures the inputs support.

$$\frac{1.0\text{ mm}}{50.0\text{ mm}} \times 100\% = 2.0\%$$

■ Anomalies and improvements

An **anomalous result** is inconsistent with the other readings – a point far from the line of best fit. Check it by repeating that treatment; do not delete it silently. Improvements are named and realistic: a colorimeter replaces eye-judged colour (quantitative, removes judgement); zeroing removes an offset; more values within the range narrows interpolation; a thermostatted water bath holds temperature

better than a beaker.



■ **Statistics the scheme names**

For variability: standard deviation (SD), standard error, range, or error bars – name one and use it. Comparing organisms: repeat on *different* individuals under the same conditions, then report the mean with the spread. Overlapping error bars mean the difference is not secure.

2 Practice

2.1 State one thing repeat readings improve, and one kind of error they cannot remove, naming a fix for that kind. [3]

2.2 A length of 50.0 mm is measured with an absolute uncertainty of 1.0 mm, and a time of 20 s with 1 s. Calculate each percentage uncertainty and the maximum percentage uncertainty in a rate found by dividing length by time. [3]

2.3 Five replicate absorbance readings are 0.42, 0.44, 0.43, 0.41 and 0.62. Identify the anomaly and state what to do about it. [3]

2.4 A student compares pigment loss at two temperatures with three repeats each. State two statistics that would make the comparison convincing, and what overlap between them would mean. [3]

3 Exam-style questions

3.1 Describe how an investigation of starch content in one cassava root could be extended to determine the variability of starch concentration between different cassava roots, naming the conditions, the summary statistic and one measure of variability you would report. [3]

3.2 A gradient is determined from a best-fit line, with a steepest plausible gradient of 1.10 and a shallowest of 0.86 a.u. per hour. Explain how these lines were chosen, what they tell you about the gradient's uncertainty, and why the triangle used should span at least half the line. [4]

3.3 A membrane-permeability method reports "colour was judged by eye against a printed scale; one reading per treatment". Give three improvements, each with the weakness it removes, and state which one changes the method from semi-quantitative to quantitative. [5]