LESSON 3.1.3

Risk, Reliability and Valid Experimental Design

A convincing investigation needs safe procedures, consistent measurements and a method that genuinely tests its aim.

SAFE

What could cause harm, and how will the procedure reduce that risk?

RELIABLE

Do repeated measurements agree, and can others obtain comparable results?

VALID

Does the method measure the intended quantity and isolate the intended effect?

LINK EACH HAZARD TO A SPECIFIC PRECAUTION

FALLING MASSES

A detached load may strike feet or hands.

Use a catch tray; keep clear; secure the support.

STRETCHED SPRING OR WIRE

Stored energy may release if the material fails.

Limit loads; keep faces away; use eye protection as required.

HEATED RESISTANCE WIRE

Current can heat the wire enough to burn skin.

Use low current; switch off; allow cooling before touching.

Hazard = source of harm. Risk considers how likely harm is and how serious it could be. Follow the laboratory risk assessment; precautions reduce risk, not necessarily to zero.

1 What do repeats tell you?

Consistency is evidence of precision, but it does not prove that the answer is correct.

REPEATABILITY

Use the same method and apparatus under the same conditions. Similar results support repeatability.

REPRODUCIBILITY

Compare results from another operator, apparatus or method. Agreement supports reproducibility.

WORKED EXAMPLE: EXTENSION AT ONE FIXED LOAD

Repeated extensions: 24.0 mm, 24.4 mm, 24.2 mm

$$\text{Mean} = \frac{24.0 + 24.4 + 24.2}{3} = 24.2 \text{ mm}$$

$$\text{Half-range} = \frac{24.4 - 24.0}{2} = 0.2 \text{ mm}$$

$$\text{Percentage uncertainty} = \frac{0.2}{24.2} \times 100\% \approx 0.8\%$$

Using half-range as a repeat-spread estimate gives (24.2 ± 0.2) mm. Consider instrument and method uncertainty too; half-range is not a guarantee of the true value.

RANDOM EFFECTS

Changing reading position or judging a moving pointer can cause scatter. Improve technique and average suitable repeats to reduce random effects.

SYSTEMATIC EFFECTS

A fixed zero offset can shift every reading together. Repeats alone cannot correct it; check calibration or compare with an independent method.

PRECISE DOES NOT AUTOMATICALLY MEAN ACCURATE

Precision describes agreement among readings. Accuracy concerns closeness to the true value. A tightly grouped set can still be biased.

2 Make the method test the aim

Example: investigate whether spring extension is proportional to the applied force.

MODEL: F = kx, within the limit of proportionality

F = applied force k = spring constant x = extension

1. Define the measured change

Vary the load and calculate F = mg, including the hanger. Measure extension x as loaded length minus the unloaded reference length.

2. Keep the comparison fair

Use the same spring, support, ruler and reference point. Wait for oscillations to stop, then read the pointer at eye level.

3. Use a useful, safe range

Pilot the loading range. Choose several well-spaced forces giving measurable extensions without permanent deformation.

4. Check unusual results

Repeat measurements at each load. Investigate an inconsistent reading and record what happened; do not delete it just to improve the line.

5. Analyse what was measured

Plot force F against extension x and use a best-fit line. Its gradient estimates k in the linear region. Do not force the line through zero.

A curved trend may show the proportional model no longer applies. An intercept may indicate an offset or missing load. Explain the evidence before claiming the model is supported.

Source alignment: Pearson IAL Physics (YPH11), Unit 3 planning and analysis.

Specification pp. 25-26 | Student Practical Guide, terminology p. 13

Lesson numbering follows the Jimlaoshi course sequence.