

Unit 3: Practical Skills in Physics I

WPH13 · Issue 3 · planning, measurement and processing · sheets 3.1–3.3

Which measurement would you trust?

- A result needs a method, a unit and an uncertainty.
- WPH13 tests practical skills from Units 1–2.
- Use sheets 3.1–3.3 alongside real laboratory work.

Name the variable and how it is controlled

Lamp-angle investigation	Measure / control
Independent: lamp angle	Change angle; measure from the stated reference direction.
Dependent: cell power	Measure the electrical quantities needed for output power.
Controls	Keep lamp–cell distance, lamp output, cell and load fixed. Shield changing background light.

Use the evidence

A power change may otherwise come from distance, light or load.

A method another student could follow

Name the apparatus and suitable range/resolution; draw the arrangement and define measurement positions.



Specify the independent settings and the actual start/end events or contacts for each measurement.

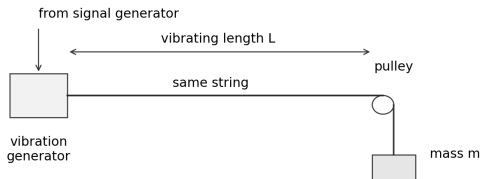


Keep important causes steady; repeat under comparable conditions and record raw readings with units.



State the processing route, uncertainty sources and specific improvements; link each realistic hazard to a protective action.

Turn the model into a test



- 1 **Model** $f = \frac{1}{2L} \sqrt{T/\mu}$
- 2 **Linearise** $f^2 = T/(4L^2\mu)$
- 3 **Plot** f^2 vertically against T horizontally

Zero check and calibration are different

Zero check

Close the micrometer jaws correctly or empty the balance. Check the correct zero condition.

If closed jaws read $+0.03$ mm, subtract 0.03 mm from subsequent readings. Repetition alone cannot remove the offset.

Calibration

Compare instrument readings with known reference values across the measuring range.

A correct zero does not establish a correct scale elsewhere. Investigate disagreement with the references, rather than simply averaging it away.

Your turn: a changing cell is not random scatter

- Repeated voltage readings steadily decrease under a large load.
- Explain why the mean alone is inadequate.
- Suggest two changes that restore comparable conditions.

Restore conditions before averaging

Repeated terminal voltages steadily fall under a large load: this is a trend, not merely unpredictable scatter.



Large current can change cell temperature or charge state. The readings may no longer represent the same conditions.



Reduce current and open the switch between readings. Allow stabilisation or restore the cell's starting conditions.



Repeat under comparable conditions; inspect the sequence before reporting a mean. Averaging alone cannot repair drift.

Clustered values can all be wrong

Precise but inaccurate

A micrometer with a positive zero offset can give closely clustered repeat diameters.

The cluster demonstrates precision. The fixed offset shifts the values away from the correct diameter, reducing accuracy.

Improve the appropriate problem

Correct the known offset or its cause to address systematic error.

Repeat and average stable measurements to reduce random variation. Repeats cannot establish that the scale is correctly calibrated.

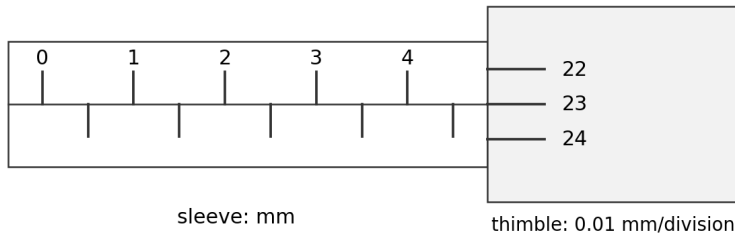
Two different checks on consistency

Consistency check	Evidence and interpretation
Repeatability	Same operator, method and apparatus over a short time: similar results under comparable conditions.
Reproducibility	Different operators, apparatus or methods: similar results across independent measurement arrangements.
If groups disagree	Compare zero checks, calibration, measurement definitions and controls; do not silently discard one group.

Use the evidence

Closely clustered repeats alone do not establish accuracy or independent agreement.

Read the scale that is actually shown



- Add the visible sleeve and aligned thimble reading.
- Include a visible half-millimetre sleeve mark.
- Check the stated resolution and zero condition.

Correct the indicated diameter

- 1 Read scale** Sleeve 4.5 mm, thimble division 23, resolution 0.01 mm. Include the visible half-millimetre mark.
- 2 Indicated** $d_i = d_s + 23r = 4.5 \text{ mm} + 23(0.01 \text{ mm}) = 4.73 \text{ mm}$.
- 3 Correct offset** $d_c = d_i - d_0 = 4.73 \text{ mm} - 0.02 \text{ mm} = 4.71 \text{ mm}$.
- 4 Interpret** Subtract a positive zero offset. Repeating the uncorrected reading cannot remove it.

Measure the quantity the model needs

One light gate

Measure the interrupting length l and blocking time t . Passage speed is $v = l/t$.

This measures speed during passage. It does not give acceleration without additional measurements or a justified motion model.

A timed video

Define the same start/end events and count frame intervals N . With known frame rate, $t = N/f_{\text{frame}}$.

Frame interval limits timing resolution. Blurred images and unclear event positions may still dominate uncertainty.

Record only the digits the instrument resolves

Reading	Time / s
1	5.12
2	5.24
3	5.18
4	5.20

Use the evidence

These raw times share 0.01 s resolution. Keep units in the heading; investigate and record any anomaly decision.

Resolution is a starting uncertainty estimate

Resolution estimate

For one reading, this specification uses half the instrument resolution as a basic absolute uncertainty.

A 0.1 g display gives a starting estimate of 0.05 g. Larger method limitations can dominate.

Observed method variation

Reaction time, alignment or a poorly defined endpoint may exceed the scale estimate.

Percentage uncertainty is absolute uncertainty divided by measured size, multiplied by 100%. State which source the estimate represents.

A balance reading with units

- 1 **Known / reason** Balance reading 135.0 g; display resolution 0.1 g. Use the specified half-resolution estimate.
- 2 **Absolute uncertainty** $\Delta m = \text{resolution}/2 = (0.1 \text{ g})/2 = 0.05 \text{ g}$.
- 3 **Percentage** $u_m = (\Delta m/m)100\% = (0.05 \text{ g}/135.0 \text{ g})100\% = 0.037\%$.
- 4 **Limit** This estimates resolution contribution; it does not prove that calibration or the measurement method is perfect.

Your turn: use the repeat spread

- Times: 5.12, 5.24, 5.18, 5.20 s.
- Find mean, half range and percentage uncertainty.
- Would half the display resolution describe this spread?

The observed spread is larger than resolution

- 1 Known / reason** Repeated times: 5.12, 5.24, 5.18, 5.20 s. Use mean and half range for the observed spread.
- 2 Mean** $\bar{t} = \sum t/N = (5.12 + 5.24 + 5.18 + 5.20) \text{ s}/4 = 5.185 \text{ s}.$
- 3 Half range** $\Delta t = (t_{\max} - t_{\min})/2 = (5.24 - 5.12) \text{ s}/2 = 0.06 \text{ s}.$
- 4 Percentage** $u_t = (\Delta t/\bar{t})100\% = (0.06/5.185)100\% = 1.2\%.$
- 5 Report / compare** About $(5.19 \pm 0.06) \text{ s}.$ Half display resolution is only 0.005 s; it misses the much larger observed spread.

Stay within the stated Unit 3 demand

A known error

An instrument reads a known positive offset at zero. Subtract that offset from the indicated reading.

The correction changes the central value. Repeating does not remove the same known error.

An uncertainty interval

An uncertainty estimates the plausible spread around a measurement; it is not automatically a mistake.

Unit 3 does not require compounding percentage uncertainties. Use a supplied uncertainty in a calculated quantity directly.

Choose a graph that answers the investigation

Put the required quantities on the correct axes with units and regular scales; use a substantial part of the grid.



Plot small crosses accurately. Use a thin best-fit straight line or smooth curve appropriate to the model.

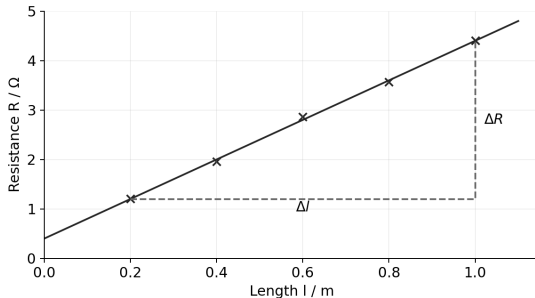


Balance scatter rather than joining each noisy point. Neither axis always has to start at zero.



Compare the fitted intercept with zero before claiming direct proportionality; a straight line alone is insufficient.

Read distant points on the fitted line



- The large triangle reduces relative coordinate-reading uncertainty.
- Use fitted-line points, not adjacent noisy measurements.

Match the graph to the physical equation

- 1 Model / known** $R = (\rho/A)l + R_0$. Fitted points: (0.20 m, 1.20 Ω) and (1.00 m, 4.40 Ω).
- 2 Gradient** $m = \Delta R / \Delta l = (4.40 - 1.20) \Omega / [(1.00 - 0.20) \text{ m}] = 4.00 \Omega \text{ m}^{-1}$.
- 3 Intercept** $R_0 = R - ml = 1.20 \Omega - (4.00 \Omega \text{ m}^{-1})(0.20 \text{ m}) = 0.40 \Omega$.
- 4 Resistivity** For $A = 1.0 \times 10^{-7} \text{ m}^2$,
 $\rho = mA = (4.00 \Omega \text{ m}^{-1})(1.0 \times 10^{-7} \text{ m}^2) = 4.0 \times 10^{-7} \Omega \text{ m}$.
- 5 Interpret** The intercept may represent lead/contact resistance. One measured R/l includes the offset and is not the fitted gradient.

Axis scale factors change the numerical gradient

- 1 Read the axes** Vertical: f/MHz ; horizontal: $\sin \theta$, which is dimensionless. The read gradient has MHz units.
- 2 Convert** Before using SI quantities, multiply the numerical MHz gradient by 10^6 Hz/MHz .
- 3 Match the model** If supplied $f = (v/\lambda) \sin \theta$, compare with $y = mx$: $m = v/\lambda$, not v .
- 4 Rearrange / interpret** $v = \lambda m$. Metres times hertz gives metres per second. Use degree mode for angles measured in degrees.

Locate a maximum and name the limitation

Specific limitation	Targeted improvement
Maximum lies between sparse settings	Survey broadly, then add finer settings around the peak. Repeating one existing setting cannot locate an unmeasured peak.
Changing background light	Use shielding or a dark enclosure in the lamp experiment.
Unclear horizontal position	Use a set square to transfer the measured position onto the ruler.
Resonance tuning uncertainty	Approach resonance from both higher and lower frequencies, then repeat.

Your turn: what does agreement establish?

Your turn

A density is 8.90 g cm^{-3} with 0.9% uncertainty. Compare with 8.94 g cm^{-3} . Give a justified conclusion and one limit of the evidence.

Attempt the complete task before advancing. Show the method and interpret the result.

Turn a percentage into a comparison interval

- 1 Known / reason** Measured density 8.90 g cm^{-3} with 0.9% uncertainty; proposed value 8.94 g cm^{-3} . Compare a full interval.
- 2 Absolute uncertainty**
$$\Delta\rho = (u/100)\rho = (0.9/100)(8.90 \text{ g cm}^{-3}) = 0.080 \text{ g cm}^{-3}.$$
- 3 Interval** $\rho \pm \Delta\rho$ gives approximately 8.82 to 8.98 g cm^{-3} .
- 4 Conclusion** 8.94 g cm^{-3} lies inside: the result is consistent with that value. It does not uniquely identify the composition.

Check yourself

- Explain why repeats cannot remove a zero offset.
- Describe a valid graph and a large gradient triangle.
- State a conclusion that uncertainty can support.