

A-Level Physics – Practical Skills and Uncertainties

A-Level Physics (Edexcel/AQA/OCR) · Total marks: 41 · Answers on the last page

Practice questions on measurement uncertainties, combining uncertainties, and graphical analysis (including log plots and evaluation of experiments), matching the required practical and 'working scientifically' content of A-Level Physics. A calculator is required throughout.

Section A – Measurement and Uncertainty

1. A student measures the length of a spring as $L = 2.5$ cm, with an absolute uncertainty of ± 0.1 cm. Calculate the percentage uncertainty in this measurement. [2]
2. Explain the difference between a random error and a systematic error, giving an example of each that could occur when using a stopwatch to measure the period of a pendulum. [4]
3. A student times one oscillation of a pendulum five times, obtaining: 2.01 s, 2.05 s, 1.98 s, 2.03 s, 2.00 s.
 - (a) Calculate the mean time.
 - (b) Estimate the absolute uncertainty in the mean using half the range of the readings. [3]
4. State two ways in which a student could reduce the percentage uncertainty in a measurement of the diameter of a thin wire made using a micrometer screw gauge. [2]

Section B – Combining Uncertainties (Calculator required)

5. A cylinder has radius $r = (1.20 \pm 0.02)$ cm and height $h = (5.00 \pm 0.05)$ cm.
 - (a) Calculate the percentage uncertainty in r and in h .
 - (b) Calculate the volume $V = \pi r^2 h$ and its percentage uncertainty.
 - (c) Express the volume with its absolute uncertainty, to an appropriate number of significant figures. [6]
6. The potential difference across a resistor is $V = (5.0 \pm 0.1)$ V and the current through it is $I = (0.40 \pm 0.02)$ A. Using $R = V/I$, calculate the resistance R and its absolute uncertainty. [4]
7. Explain why, when a quantity is calculated as a product or quotient of several measured quantities, it is the percentage (or fractional) uncertainties that are added, rather than the absolute uncertainties. [2]
8. A quantity z is calculated using $z = \frac{2x^3}{y}$, where $x = (3.0 \pm 0.1)$ and $y = (6.0 \pm 0.3)$. Calculate the percentage uncertainty in z , and hence find z together with its absolute uncertainty. [5]

Section C – Graphical Analysis and Evaluation (Calculator required)

9. The period T of a simple pendulum of length L is given by $T = 2\pi\sqrt{\frac{L}{g}}$. A student plots a graph of T^2 (on the y -axis) against L (on the x -axis) and obtains a straight line through the origin with gradient $4.05 \text{ s}^2 \text{ m}^{-1}$. Calculate the value of g determined from this graph. [3]

10. Explain why plotting a graph of T^2 against L , rather than T against L , is a better method for determining g from pendulum data. [3]
11. A student plots $\ln T$ against $\ln L$ for pendulums of different lengths, and obtains a straight line of gradient 0.50 and y -intercept 0.90. Given that $T = kL^n$, find the values of n and k . [4]
12. A student concludes that "the results confirm the pendulum equation" simply because a straight line of best fit could be drawn through the plotted data points. Evaluate this conclusion, and suggest one specific improvement to the experimental procedure that would increase confidence in the value of g obtained. [3]

Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- Percentage uncertainty = $\frac{0.1}{2.5} \times 100 = 4.0\%$.
- A random error causes unpredictable variation in readings above and below the true value (e.g. the experimenter's variable reaction time when starting/stopping the stopwatch), and can be reduced by repeating readings and averaging. A systematic error consistently shifts all readings in the same direction (e.g. the stopwatch itself running slightly slow, or a consistent delay in starting the watch every time), and is not reduced by averaging repeated readings.
- (a) Mean = $2.014 \text{ s} \approx 2.01 \text{ s}$.
(b) Uncertainty = $\frac{2.05 - 1.98}{2} = 0.035 \text{ s} \approx \pm 0.04 \text{ s}$.
- Take repeat readings at different points along and around the wire and calculate a mean (reducing random error); or measure the diameter of several turns of wire wound tightly together and divide by the number of turns, which increases the size of the quantity measured relative to the fixed instrument resolution, reducing the percentage uncertainty.
- (a) Percentage uncertainty in $r = \frac{0.02}{1.20} \times 100 = 1.7\%$; in $h = \frac{0.05}{5.00} \times 100 = 1.0\%$.
(b) $V = \pi(1.20)^2(5.00) = 22.6 \text{ cm}^3$. Percentage uncertainty = $2(1.7) + 1.0 = 4.3\%$.
(c) Absolute uncertainty = $22.6 \times 0.043 \approx 1 \text{ cm}^3$, so $V = (23 \pm 1) \text{ cm}^3$.
- $R = \frac{5.0}{0.40} = 12.5 \Omega$. Percentage uncertainty = $\frac{0.1}{5.0} \times 100 + \frac{0.02}{0.40} \times 100 = 2.0\% + 5.0\% = 7.0\%$.
Absolute uncertainty = $12.5 \times 0.07 = 0.9 \Omega$, so $R = (12.5 \pm 0.9) \Omega$.
- Absolute uncertainties in quantities with different units (or different sizes) cannot be directly added or compared, but percentage uncertainties are dimensionless and represent the relative size of the uncertainty compared with the quantity itself; adding them accounts correctly for how each measured quantity's relative uncertainty contributes to the overall relative uncertainty in the calculated result.
- Percentage uncertainty in x^3 is $3 \times \frac{0.1}{3.0} \times 100 = 10.0\%$; in y is $\frac{0.3}{6.0} \times 100 = 5.0\%$. Total percentage uncertainty in $z = 10.0 + 5.0 = 15\%$. $z = \frac{2(3.0)^3}{6.0} = 9.0$. Absolute uncertainty = $9.0 \times 0.15 = 1.4$, so $z = (9.0 \pm 1.4)$.
- $T^2 = \frac{4\pi^2}{g}L$, so gradient = $\frac{4\pi^2}{g} \Rightarrow g = \frac{4\pi^2}{4.05} = 9.75 \text{ m s}^{-2}$.
- T^2 against L gives a straight line through the origin (since $T^2 = \frac{4\pi^2}{g}L$), whereas T against L gives a curve. A straight-line graph allows a gradient to be found accurately using a line of best fit, whereas finding g reliably from a curve is much more difficult and less precise.
- Taking logs: $\ln T = n \ln L + \ln k$, so $n = \text{gradient} = 0.50$, and $\ln k = 0.90 \Rightarrow k = e^{0.90} = 2.46$.
- A line of best fit alone does not confirm the equation; the student should also check that the line passes through the origin (as predicted) and compare the gradient-derived value of g with the accepted value (9.81 m s^{-2}), calculating a percentage difference. Improvement: time a larger number of oscillations (e.g. 20) rather than one and divide by that number to reduce the percentage uncertainty in the period due to reaction time.

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