# DEALING WITH UNCERTAINTIES

## IB PHYSICS EXPECTATIONS

- Describe and give examples of *random* and *systematic* errors.
- Distinguish between *precision* and *accuracy*.
- Explain how the effect of random error may be reduced.
- Calculate quantities and results of calculations to the appropriate number of significant figures.
- State uncertainties as absolute, fractional and percentage uncertainties.
- Determine the uncertainties in the results of calculations.
- Identify uncertainties as *error bars* in graphs (one axis only).
- State random uncertainties as an uncertainty range (±) and represent it graphically as an *error bar* in a graph.
- Determine the uncertainties in the slope and intercepts of a straight-line graph.

## SUMMARY OF BASIC RULES

*Repeated Measurements*

For a number of repeated values, we find the average or mean.
The uncertainty in the mean is plus or minus one-half of the range between the maximum value and the minimum value.

$$\bar{x} \pm \Delta\bar{x} = \frac{x_1 + x_2 + \ldots x_n}{n} \pm \frac{x_{\text{Max}} - x_{\text{Min}}}{2}$$

*Sum* $$(A \pm \Delta A) + (B \pm \Delta B) = (A + B) \pm (\Delta A + \Delta B)$$

*Difference* $$(A \pm \Delta A) - (B \pm \Delta B) = (A - B) \pm (\Delta A + \Delta B)$$

*Product* $$\left(A \pm \Delta A\right) \times \left(B \pm \Delta B\right) = \left(A \times B\right) \pm \left[\left(\frac{\Delta A}{A}100\%\right) + \left(\frac{\Delta B}{B}100\%\right)\right]$$

*Quotient* $$\frac{A \pm \Delta A}{B \pm \Delta B} = \frac{A}{B} \pm \left[\left(\frac{\Delta A}{A}100\%\right) + \left(\frac{\Delta B}{B}100\%\right)\right]$$

*$n^{th}$ Power* $$\left(A \pm \Delta A\right)^n = A^n \pm n\left(\frac{\Delta A}{A}100\%\right) = A^n \pm n\,\Delta A\%$$

*$n^{th}$ Root* For $\sqrt[n]{A \pm \Delta A}$, we find $\sqrt[n]{A} \pm \frac{1}{n}\left(\frac{\Delta A}{A}100\%\right) = \sqrt[n]{A} \pm \frac{\Delta A\%}{n}$

*Gradients in Graphs*

The gradient of the best straight-line of a graph = $m_{\text{Best}}$ and the minimum and the maximum gradients based on the uncertainty range of the first and last data points are $m_{\text{Max}}$ and $m_{\text{Min}}$.

$$m_{\text{Best}} \pm \Delta m = m_{\text{Best}} \pm \left(\frac{m_{\text{Max}} - m_{\text{Min}}}{2}\right)$$

*Stating Uncertainties*

Experimental uncertainties should be rounded off to one significant figure. The least significant figure in a stated answer should be of the same order of magnitude (in the same decimal position) as the single digit uncertainty value.

$$g \pm \Delta g = \left(9.81734 \pm 0.0217\right)\text{m s}^{-2} \quad \rightarrow \quad \therefore g \pm \Delta g = \left(9.82 \pm 0.02\right)\text{m s}^{-2}$$