Uncertainty Error

Significant Figures

- Commonly referred to as ‘Sig-figs’
- General rules:
  - Non-zero digits are always significant!
  - Leading zeros are never significant!
  - Following zeros and zeros between non-zero digits are always significant!
    - **E.g.** “$\underbrace{0}_{\text{Not significant}}\underbrace{75.0210}_{\text{Significant}}$” contains six ‘sig-figs’. Zero at start does not count as significant.

Why do we use sig-figs?

It lets us infer the claimed accuracy of the value!

- **E.g.** 400 is closer to 400 than 399 or 401
- **E.g.** 0.0675 is closer to 0.0675 than 0.0674 or 0.0676

What about whole numbers?

- For ***VCE Physics***, whole numbers will have the same significant figures as the number of digits.
  - **E.g.** “$\underbrace{400}_{\text{Significant}}$” has three sig-figs “$\underbrace{400.0}_{\text{Significant}}$” has four sig-figs

Operations:

- **Multiplication & Division**: Retain as many significant digits as in the number with the fewest significant digits.
  - **E.g.** $\underbrace{326.95}_{\text{5 sig-figs}} \text{ x } \underbrace{10.2}_{\text{3 sig-figs}} \div \underbrace{20.322}_{\text{5 sig-figs}} = \underbrace{164}_{\text{3 sig-figs}}$
- **Addition & Subtraction**: Retain as many digits to the right of the decimal as in the number with the fewest significant digits to the right of the decimal.
  - **E.g.** $386.\underbrace{38}_{\text{2 sig-figs}} + 793.\underbrace{354}_{\text{3 sig-figs}} - 0.\underbrace{000397}_{\text{6 sig-figs}} = 1179.\underbrace{73}_{\text{2 sig-figs}}$

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Uncertainty Error

Determining Uncertainty

- Error always exists when a measurement is made – Categories of errors include:
  - Personal errors – Mistakes or miscalculations
  - Systematic errors – Accuracy of measurement errors, readings differ from true value by a consistent amount
  - Random errors – Precision errors, unpredictable
  - Outliers – Readings a long way off other results
- **E.g.** *Temperature of 20°C±2°C, has an uncertainty of 2°C*

20°C ± 2°C

Average of 20°C:

Simple mean (possibly with ***outliers ignored***)

Uncertainty of 2°C:

An estimate of the spread of readings.

True value expected to lie within range. *I.e. 18-22°C*

- If there are multiple readings, the <u>average</u> should have the <u>same number of decimal places</u> as the <u>uncertainty</u>.
- **E.g.** 60±0.5, 62±0.5, 59±0.5, 60 ±0.5, 61 ±0.5 →

Ave = 60.4 (60 rounded)   Min = 59   Max = 62

The larger difference between the average and min / max is = 62-60=2cm

∴ 60±2cm

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Propagation of Uncertainty

- Various ways to represent uncertainty, for *VCE Physics*, uncertainty should be represented as:
  - Absolute uncertainties*:*
    - **E.g.** $h = 60\text{cm}, \Delta h = \underbrace{2\text{cm}}$
  - Proportional uncertainties:
    - **E.g.** $\Delta h/h = 2\text{ cm} / 60\text{ cm} = \underbrace{0.033}$ *or* $\underbrace{3\%}$ *(to 1 significant figure)*

Operations:

- **Addition & Subtraction**: Absolute uncertainties are added.
  - **E.g.** Difference between 62 ± $\underbrace{2}$ cm and 52 ± $\underbrace{2}$ cm is 10 ± $\underbrace{4}_{2 + 2 = 4\text{ cm}}$ cm.
- **Multiplication & Division**: Proportional uncertainties are added.
  Note: *This is more advanced and beyond the expectations of VCE Physics*
- For other mathematical treatment of variables, substitute the lowest and highest data points to determine the range.
  - **E.g.** *The uncertainty in the gradient of a linear trend line could be found by comparing the gradients of the steepest and the least steep trend lines that could be fitted to the data.*

Source: https://www.vcaa.vic.edu.au/curriculum/vce/vce-study-designs/Physics/advice-for-teachers/Pages/MeasurementinScienceQuantitativeAnalysisofUncertainty.aspx