# **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. "075.0210" contains six 'sig-figs'. Zero at start does <u>not</u> count as significant.

#### What about whole numbers?

• For VCE Physics, whole numbers will have the same significant figures as the number of digits.

**E.g.** "400" has three sig-figs

"400.0" has four sig-figs

Why do we use sig-figs?

It lets us infer the claimed accuracy of the value!

**E.g.** 0.0675 is closer to 0.0675 than 0.0674 or 0.0676

**E.g.** 400 is closer to 400 than 399 or 401

#### **Operations:**

• Multiplication & Division: Retain as many significant digits as in the number with the fewest significant digits.

**E.g.** 326.95 x 10.2 ÷ 20.322 = 164, 
$$\frac{5 \text{ sig-figs}}{5 \text{ sig-figs}}$$
 3 sig-figs 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.

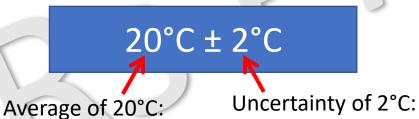
**E.g.** 
$$386.38 + 793.354 - 0.000397 = 1179.73$$
2 sig-figs 3 sig-figs 6 sig-figs 2 sig-figs

**ATARs Plus** 

## **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



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

Simple mean (possibly with *outliers ignored*)

An estimate of the spread of readings.

- 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.  $60\pm0.5$ ,  $62\pm0.5$ ,  $59\pm0.5$ ,  $60\pm0.5$ ,  $61\pm0.5$

$$Min = 59$$

$$Max = 62$$

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

**ATARs Plus** 

## **Uncertainty Error**

### **Propagation of Uncertainty**

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

### **Operations:**

- Addition & Subtraction: Absolute uncertainties are added.
  - E.g. Difference between  $62 \pm 2$  cm and  $52 \pm 2$  cm is  $10 \pm 4$  cm.

2 + 2 = 4 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.

ATARs Plus