**Measurement uncertainty and error**

A large amount of control is needed when conducting an experiment to ensure the relationship between variables is accurately measured. Being aware of controlled variables are therefore really important. Controlled variables that are not controlled well will reduce accuracy and precision. This ability to reproduce experimental results is a key part of science. If experimental results are not reproducible, the experiment may not be providing useful/accurate information. Sources of error and uncertainty must also be considered. The uncertainty of an experimental result can be calculated by considering *systematic* and *random* errors.

**Systematic Errors**

Systematic errors are consistent or proportional differences between the *observed* and *true* values of a measurement. For example, a mass balance consistently reports masses as 0.05g higher than they actually are.

Systematic errors affect the *accuracy* of the measurement.

**Random Errors**

Random errors are statistical fluctuations between the *observed* and *true* values of a measurement based on the precision accuracy of the instrument. Random errors can be reduced by calculating an average over multiple trials.

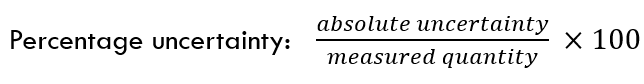
Random errors affect the *precision* of the measurement.

**Determining Uncertainties on Equipment**

Most equipment will have an uncertainty assigned to it – record at the time of measurement.

If there is no uncertainty written assigned to a piece of equipment – Use *half the smallest measurement* as the uncertainty. This is common practice, and applies to all **analogue** equipment.

**Calculating Percentage Uncertainties**

****

**Calculating Uncertainties in Processed Data**

Adding/subtracting two measurements: add/subtract the *absolute uncertainties*

* + - E.g.

Multiplying/dividing two measurements: add the *relative uncertainties*

* + - *E.g.*

Multiplying by a constant: multiply the *absolute uncertainty*, but leave the *relative uncertainty* the same

* + - *E.g. (*

*E.g.*

**Calculating Percentage Error**

**Significant Figures**

1. Do not count 0 after a decimal point, but before integers.   
   *0.00234 has 3 significant figures.*
2. Count 0 after integers as significant, even if in a decimal or in scientific notation.   
   *0.100 has 3 significant figures.*
3. 0s are significant if surrounded by integers on both sides   
   *24040 has 5 significant figures.*
4. Match number of significant figures to other measurements or figures, so that you are consistent.   
   *E.g. if mass = 0.21g, there are 2 significant figures, so your uncertainty should also have 2 significant figures.*
5. Report any calculations to the lowest number of significant figures used in the calculations.

**Scientific Notation**

Scientific notation is a short hand way of writing numbers that are really big or really small.  A number is written in scientific notation when a number between 1 and 10 is multiplied by a power of 10.

*Decimal notation 🡪 Scientific Notation*

To convert a number from decimal notation to scientific notation, ‘move’ the decimal place and count the number of spaces. If the decimal place is moved to the left, the exponent should be a positive number. If the decimal place is moved to the right, the exponent should be a negative number.

*For example, 0.00005 can be written as . 7 300 000 can be written as .*

*Scientific Notation 🡪 Decimal Notation*

To convert a number from scientific notation to decimal notation, ‘move’ the decimal place by the number of spaces dictated by the exponent. If the exponent is positive, move the decimal place to the right. If the exponent is positive, move the decimal place to the left.

*In the following example, the exponent is -9. The decimal place is ‘moved’ 9 spaces to the left to convert from scientific notation to decimal notation.*

