# M1.11 Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined

### Tutorials

Learners may be tested on their ability to:

* calculate percentage error where there are uncertainties in measurement.

### Uncertainties

Any measurement we make tells us about a property of something. It might tell us how long something is, how heavy it is, how much coverage something has. The measurement gives a number to that property.

To make measurements we almost always need an instrument of some kind: a ruler, a thermometer, a quadrat, a top pan balance etc.

The measurement is recorded as both a number and a unit:

e.g. how hot is this flask of water?

37, degrees Celsius

When we make a measurement there is always some level of uncertainty. A well-made instrument should be trustworthy and give accurate, repeatable measurements. But for every measurement there is always a margin of doubt. We might describe this as accurate to within a given value of uncertainty. An example might be a measuring cylinder, which measures volumes of liquid to within 0.5 cm3. For example we might measure out 300 cm3 of liquid ±0.5 cm3, which means the true volume might be anywhere between 299.5 cm3 and 300.5 cm3.

For this instrument ±0.5 cm3 is the absolute uncertainty. It doesn’t matter how much liquid we measure; the measurement could always be out by this amount.

The relative uncertainty or **percentage error** is the ratio of absolute uncertainty to the original measurement, expressed as a percentage.

For example, when measuring 300 cm3 the relative uncertainty is $\frac{0.5}{300}\*100=0.17\%$

However, if I measured out only 50 cm3 the relative uncertainty is $\frac{0.5}{50}\*100=1\%$

So we can see that the amount of relative uncertainty is not fixed, it is dependent on the amount of absolute uncertainty afforded by the instrument, **and** the size of the measurement we are making.

When making more than one measurement, we must account for the absolute uncertainty for each new measurement.

If I measure out 65 cm3 of hydrochloric acid then there is an absolute uncertainty of 0.5 cm3, If I measure out and add 30 cm3 of sodium hydroxide solution, then there is also an absolute uncertainty of 0.5 cm3. Giving a total absolute uncertainty of 1 cm3. Therefore my combined volume is 95 cm3 ± 1 cm3.

My relative uncertainty for this measurement is $\frac{1}{95}\*100=1.05\%$

The same idea applies when we are looking at the change in a value, by subtracting the initial value from the final value.

For example we could use a top pan balance for simple potometry (measuring the water loss from a plant by change in mass).

For this example assume we are using a top pan balance with an absolute uncertainty of +/- 0.1 g

We take our initial mass measurement: 117.3 g

24 h later we take our final measurement: 110.0 g

To find the change in mass we subtract the initial value from the final value:

110.0 g – 117.3 g = - 7.3 g

The plant has changed mass by – 7.3 g (i.e. its mass has fallen by 7.3 g)

The **absolute** uncertainty associated with this figure is the sum of the absolute uncertainties of each measurement:

* 1. g + 0.1 g = 0.2 g

The **percentage error** or **relative uncertainty** is found, as in the previous examples, by dividing the absolute uncertainty by the measured value and expressing the result as a percentage:

$$\frac{0.2}{7.3}\*100=2.7\%$$

**Document updates**

 v1.0 April 2017 Original version.

 v1.1 June 2019 Changed how the word accuracy was used in order to be in line with the ‘Language of measurement’

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