

## PME1.3: ERRORS IN MEASUREMENT

Every measurement in science is an approximation. For various reasons, one can never be absolutely certain about the exact value of any measurement.

### Mistakes

Mistakes include such things as:

- (i) Writing down the wrong value, e.g. the scale reads “72” but you write down “27” by mistake.
- (ii) Using the wrong pipette, e.g. adding 1 ml instead of 10 ml.
- (iii) Misusing the calculator, e.g. pressing the “÷” button instead of the “x”.

In the scientific sense, the term mistake does not mean the same as error of uncertainty of measurement.

### Errors of measurement

There is a limit to the accuracy of any measure, depending on the equipment used and the skill of the person making the measurement.

Some of the more common sources of errors in measurements are:

- (a) Difficulty in reading scales
- (b) Parallax error
- (c) Instrument design and choice
- (d) Instrument calibration
- (e) Instrument zero-ing
- (f) Deterioration
- (g) Outside influences.

### Absolute Error

If a value is measured several times, then the mean (average) can be calculated and an estimate of the accuracy can be given. The estimate of accuracy is called the absolute error.

#### Example

The length of an A4 page is measured a number of times and the result was found to be  $297 \pm 0.5\text{mm}$ . This indicates that your best estimate (the mean of your measurements) of the value is 297mm but it could lie somewhere between 296.5mm and 297.5mm. The absolute error is estimated at 0.5mm.

### Fractional Error

$$\text{Fractional Error} = \frac{\text{Absolute Error}}{\text{Measured Value}} = \frac{\Delta l}{l}$$

So for the previous example of the A4 page, the fractional error would be:

$$\text{Fractional Error} = \frac{\Delta l}{l} = \frac{0.5}{297} = 0.0017$$

Therefore the length of an A4 (measured with a millimetre ruler) is  $297 \pm 0.0017\text{mm}$ .

### Percentage Error

Fractional error is often converted into a percentage of the measured value.

$$\text{Percentage Error} = \text{Fractional Error} \times 100\%$$

So the length of our A4 page could also be expressed as  $297 \text{ mm} \pm 0.17 \%$ . ( $0.0017 \times 100$ )

### Exercise

Complete the following table. Give fractional error answers to 3 decimal places

<b>Measurements taken and result calculated</b>	<b>Absolute Error</b>	<b>Fractional Error</b>	<b>% Error</b>
(a) $7.3 \pm 0.2\text{g}$			
(b) $105 \pm 5\text{cm}$			
(c) $0.032 \pm 0.003\text{m}$			
(d) $6.2 \pm 0.3\text{kg}$			
(e) $0.050 \pm 0.005\text{mm}$			
(f) $73.5 \pm 0.05\text{s}$			

### Answers

(a)	0.2g	0.027	2.7%
(b)	5cm	0.048	4.8%
(c)	0.003m	0.094	9.4%
(d)	0.3kg	0.048	4.8%
(e)	0.005mm	0.100	10%
(f)	0.05s	$6.8 \times 10^{-4}$	0.07%