Lesson 5: Expressing Error in Measurements

Causes of Error in Experiments

Anytime an experiment is conducted, a certain degree of uncertainty must be expected. There are basically three reasons you might have an error in a measurement.

1. **physical errors in the measuring device**
   Example 1: Your thermometer was dropped and has small air bubbles in it.

2. **improper or sloppy use of measuring device**
   Example 2: When you used your thermometer, you measured the values in Fahrenheit instead of Celsius.

3. **ambient conditions (temperature, pressure, etc.)**
   Example 3: Measuring the length of a piece of wood outdoors in the winter using a metal tape measure, you forget that metal contracts in the cold making the tape measure shorter.

Possible Error

While perform in an experiment and taking measurements, it would probably be a good idea to record how precise you think your measurement is. If two people are measuring distances, where one of them uses a beaten up metre stick and the other uses a laser distance finder, we would not be able to treat the two as if they were done with the same care.

The best way to do this is simply look at the smallest scale that the device can show. For example, lots of rulers will show millimetres as their smallest scale.

- The error you should record is ***half*** of the smallest division.
- Often this is stated as the "**possible error**" in the measurement.
- The idea is that you should be able to eyeball if it's a bit closer to one number or the next, or maybe about half ways in between.

Example 4: If you measure the length of a pencil using a regular ruler (they usually have 1 mm divisions) and find that looks like it's pretty much 102 mm long, you should write down…

102.0 ± 0.5 mm

The "plus-or-minus" (±) means "give-or-take" the possible error. The length of the pencil could be as little as 101.5 mm, or as much as 102.5 mm.

Calculating Errors

We often need to calculate the error we have made, like how far off our measured value in an experiment is when compared to an accepted value in a text book. In high school labs, don't be surprised if you obtain errors as high as 25% or higher. The important part is, can you ***explain*** your errors! Consider a lab a success if you are under about 10% error, and an amazing success if you are under 5%.

There are three common ways to calculate your error: **absolute error**, **percentage error**, and **percentage difference**.

Absolute Error

Absolute Error is when you subtract the accepted value from your measured value. It is not often used since it does not take into account the scale of your measurements.

Absolute Error = Measured Value - Accepted Value

- A positive answer means you are over the accepted value.
- A negative answer means you are under the accepted value

Percent Error

Percentage Error is the most common way of measuring an error. This is the correct method to use when you have an accepted value to compare your measured value from your experiment to.

$$Percent\ Error = \frac{(measured - accepted)}{accepted}$$

Example 5: You complete a lab to measure the acceleration due to gravity. During the lab you measured a value of 9.04 m/s^2, and the accepted value from your data sheet is 9.81 m/s^2. **Determine** the percent error.

$$Percent\ Error = \frac{(measured - accepted)}{accepted}$$

$$Percent\ Error = \frac{(9.04 - 9.81)}{9.81}$$

$$Percent\ Error = -0.078491 = -7.85\%$$

Warning!
The minus sign on the answer is perfectly fine! It just means that your measurement is ***under*** the accepted value. You have just as much chance to be under as over the accepted value.

Percent Difference

Percent Difference is useful if you have two measurements you've taken and you wish to see how different they are as a percentage. This is handy when you do **not** have an accepted value for comparison.

$$Percent\ Difference = \frac{difference}{average}$$

Example 6: You have measured the motion of a toy car using two different methods. The first method gave you a measurement of 8.4 m/s and the second method came out as 7.1 m/s. Determine the percent difference.

$$Percent\ Difference = \frac{difference}{average}$$

$$Percent\ Difference = \frac{(8.4 - 7.1)}{\left(\frac{8.4 + 7.1}{2}\right)}$$

$$Percent\ Difference = \frac{1.3}{7.75} = 0.167742 = 17\%$$

Warning!
Although it really doesn't matter which number you put first to calculate the difference, it is traditionally set up so that you will get a positive value on top.