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 ruler, you forget that metal contracts in the cold making the ruler 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" ($\pm$) 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

At times, there may be an accepted value for a measurement (verified in laboratories with very high standards).

- Some of these numbers are on the back of your data sheet. They are usually given with three sig digs.

It is often useful to compare your measurement to this accepted value in order to evaluate how accurate you were. 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…

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, and often the most easy to understand.

Percentage Error = Absolute Error / Accepted Value

Example 5: You measured a pencil to be 102mm long, and an independent lab with high tech equipment measured it as 104mm. **Determine** the **percentage error**.

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.

Percentage Error = $\frac{(102-104)}{(104)}=-0.0192$

Which means you got a -1.92% error.

Percent Difference

Percentage 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.

Percentage Difference = (difference in measurements) / (average of measurements)

Don't confuse this with percentage error. Here we have two measurements you've made, but no "accepted value."

Example 6: You measure the length of a desk twice and get the numbers 1.15m and 1.13m. Determine the percent difference between your values.

Percentage Difference = $\frac{(1.15-1.13)}{\left(\frac{(1.15+1.13)}{2}\right)} = 0.0175$

A **percent difference** of 1.75%.

In high school labs, don't be surprised if you obtain errors as high as 25%. The important part is, can you ***explain*** your errors!

- When you try to explain your error, always look back to the three reasons given at the start of this lesson... maybe you can reason out how those sort of conditions caused error in your lab.