# Statistical methods and when to use them

## Systematic uncertainties

Experimental uncertainties that cannot be measured by repetition of the measurements are known as *systematic uncertainties*. These are either due an imperfection of the measurement device (say, a slow stopwatch) or an inability to measure more precisely. The first case can be corrected by standardizing or calibrating the instrument to known behaviors but most of the time will be smaller than the precision of the instrument.

For the latter case, it depends on the style of the instrument. If it is an *analog* device, then the uncertainty due to its precision is given as half the increment of the markings. If the device is *digital*, then the uncertainty is the smallest digit since we cannot see indications between the final digit.

A measurement is then reported as [units].

## Mean and associated uncertainty (standard deviation of the mean)

When taking many points *of the same thing*, we can find the *random* uncertainty associated to conducting the experiment. We can take the mean and associated uncertainty to summarize all the trials conducted. We expect that the uncertainty decreases with an increased number of repeated measurements. You would then report the measurement as [units].

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## t-score

We can use the t-score to compare two values and if and only if we also know the associated uncertainties and , respectively.

The resulting t-score can then tell us if and are distinguishable or indistinguishable. See Table 1 for the exact scaling. One thing to note is that if your result is inconclusive, then we are obligated to take more data until you can make a conclusion. By definition, we cannot make a conclusion on something that is inconclusive.

**Table 1**: Results of the t-score and the conclusions that can be made. Also given is the appropriate follow up to the conclusion

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| --- | --- | --- |
| **t-score** | **Conclusion** | **Follow up** |
| |t| < 1 | Indistinguishable | Collect more data or decrease uncertainty to determine distinguishability |
| 1 < |t| < 3 | Inconclusive | Collect more data or decrease uncertainty to determine (in)distinguishability |
| |t| > 3 | Distinguishable | Re-evaluate or revise model |

## Last and most definitely least, Percent difference

Whenever we need to compare two values and *but we are not able to get the uncertainty in at least one of the values*, then we can use percent difference. This should be the last resort. Percent difference is typically calculated as

The difficulty with percent difference is that we don’t know what an (un)acceptable value should be. We need to make sure to set a standard or contextualize our results for percent differences.