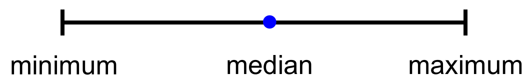
Determining the Uncertainty in a Measurement

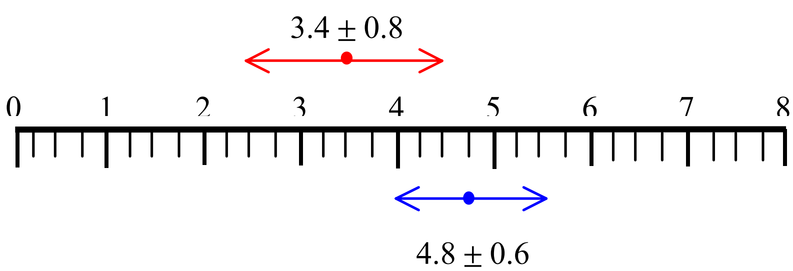
An absolute uncertainty:

- Gives a range of values

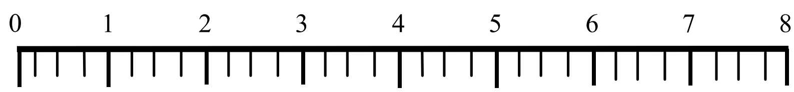


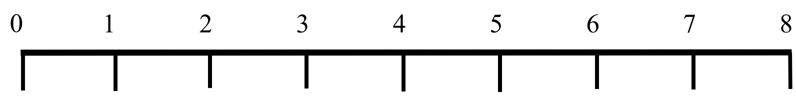
- Expresses a confidence level. Expect others doing same measurement with same equipment to get measurements inside this range about nearly all of the time.

- Two measurements agree if their range overlaps.



- Consists of two parts:
  a) *scale uncertainty*. Limitation due to precision of measuring instrument.





  The top scale is easier to read. We could read it to about ¼ of the smallest division. The best we could do with the bottom scale is about $^{1}/_{10}{}^{th}$ of the smallest division. As a result, the upper scale gives us a more precise (more significant figures) measurement.

  b) *technique uncertainty*. Limitation on how well one can use the measuring instrument.

  For instance, a block could have ends rougher than the smallest divisions of the ruler used or the block could be shaking. In either case we can make a reasonable estimate of how much uncertainty this introduces.

- In the lab, you must always explain your uncertainty estimates.

- Averaging repeated measurements allows you to estimate uncertainty. The spread in the data about the average of the measurements determines the uncertainty. However, the uncertainty will always be greater than the uncertainty in any particular measurement.

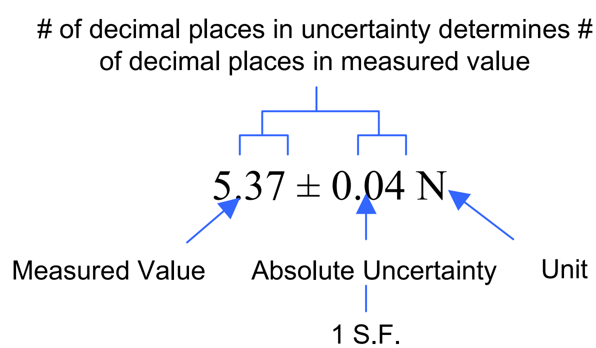
  Example: using stopwatch

	5.12 ± 0.01 s
	5.73 ± 0.01 s
	4.99 ± 0.01 s
	5.54 ± 0.01 s
	5.19 ± 0.01 s
	5.33 ± 0.01 s
Average:	5.32
Spread:	0.41
Standard Deviation:	0.27
Uncertainty:	0.11

Since the spread 0.41 is greater than the uncertainty in the individual measurements we can use the standard deviation σ to estimate the uncertainty. A full discussion of the meaning of the standard deviation is taught in Statistics. Here we take σ to be a measure of the spread of the data about the average. Statistics then says that the uncertainty in the average is given by $\sigma/\sqrt{N}$ where N is the number of measurements. Most scientific calculators let you calculate the standard deviation. In MS Excel, we use the function STDEV(*values*). We find the time to be t = 5.32 ± 0.11 s. Further measurements will allow us to improve the precision, but we will never do better than the accuracy of the stopwatch.

- Uncertainties usually have only one significant figure. However if that significant figure is a 1, keep two figures in the uncertainty.

- The position of the last figure in the uncertainty relative to the decimal place determines the last significant figure in the measurement.



- When using scientific notation record the measurement and the uncertainty to the same power of ten.