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Uncertainty: quantifying error in our measurements

Remember I asked you to estimate the length of this line using your naked eye? Remember that our estimate was ~20cm?

To account for the possibility it could be 17.5489cm or anywhere between 10cm and 20cm, it would be more appropriate to state our estimate as 15±5cm. The "±" sign suggests that we are uncertain about our estimate within 5cm up or down of 15cm. Another way to word this could be we are NOT confident that our estimate IS exactly 15cm, but we are confident that it is somewhere between 10cm and 20cm.

The smaller our uncertainty, the __more__ confident we are with our measurement. __More__ confidence means that our measuring instrument is __more__ precise.

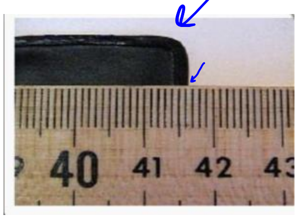
When making a single reading (no repeated trials),

For stable readings:

1) Estimate the last digit that is __one decimal__ smaller than the smallest increment of your measuring device.
2) Write the uncertainty as ± __half__ of the smallest increment of your measuring device.

Below are a few examples:

Ex 1.



cm

Figure 1. http://www.mrpalermo.com/uploads/9/8/9/6/9896107/__________7032975_orig.jpg

41.65 ± 0.05cm

same place value

41.64 ± 0.05 cm

For unstable readings:

1) Wait until the reading stabilizes for a good while and write this value down.
2) When the reading fluctuated, note the range of it's fluctuation and write your uncertainty as the difference between your stable value and the furthest fluctuated reading.

Ex. 2

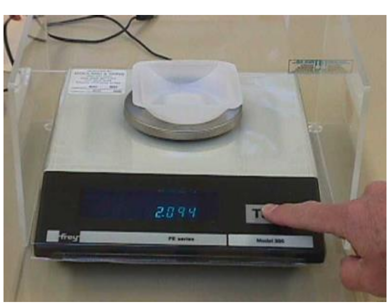


Figure 2. http://dl.clackamas.edu/ch104/lesson1images/mvc-021s.jpg

g

1s 2.094g
2s 2.093g
3s 2.094g
4s 2.097g
5s 2.094g

stabilized

2.094g ± 0.003g

2.097g − 2.094g = 0.003g

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If you think the uncertainty for your reading is higher or lower than expected, make sure you **justify** why you chose your uncertainty.

To decrease random error (more on this later), it is better to conduct repeated experiments.

With more than one piece of data, we must calculate our uncertainty differently. A fast a dirty way is to take half the range of your data:

Uncertainty = $\frac{max - min}{2}$

From repeated experiments, you can get an average of all your results then write your final result as

average ± uncertainty ($y \pm \Delta y$, Δ = delta, δ)

There are 2 important rules when we write our uncertainties:

1) Your uncertainty must be rounded up to 1 sig fig. (±15 → ±20, ±11)
2) Your average must be rounded up to the same place value as your uncertainty.

Ex.

Time for a 1000g mass to oscillate 10 times

	Trial 1	Trial 2	Trial 3	Trial 4
Time (s)	9.330	9.550	9.390	9.250

Do not round → Average = $\frac{9.330s + 9.550s + 9.390s + 9.250s}{4} = 9.38s$

Uncertainty = $\frac{max - min}{2} = \frac{9.550 - 9.250}{2} = 0.15s$

for 10 oscillations: 9.38 ± 0.15s → 9.4 ± 0.2s

Ex.

Time for a 80.00cm length pendulum to oscillate 10 times

	Trial 1	Trial 2	Trial 3	Trial 4
Time (s)	17.95	18.09	17.90	17.99

Average = $\frac{17.95 + 18.09 + 17.90 + 17.99}{4} = 17.9825s$

Uncertainty = $\frac{18.09 - 17.90}{2} = 0.095s$

17.9825 ± 0.095s

18.0s ± 0.1s (units)

Conceptually, you can never be more precise than your uncertainty. This is the reason why your uncertainty and average are rounded this way.