## Uncertainty in Measurement



The length of the board is 'measured' (really estimated) using meter sticks with different degrees of precision. The first meter stick has very little precision compated to the last meter stick. As the precision of the tool increases (A to D), the amout of information about the length of the board also increases. Let's look at each sample.

## SAMPLE A

The meter stic in SAMPLE A has no marks. From the picture, we see that the board is more than half a meter, but by how much? We can guess only to the first decimal (tenths place) of the board, maybe 0.6 or 0.7 meters depending on the person doing the measuring. The value of the tents place is uncertain. Uncertainty is often added to a measurement as a 'plus or minus' ( $\pm$ ) value. In this case, the board might be recorded as $0.6 \pm 0.1 \mathrm{~m}$ or $0.7 \pm 0.1 \mathrm{~m}$.

## SAMPLE B

The graduated marks on this ruler are every 0.1 m . This is the same as 10 centimeter (cm). There are 100 cm in 1 meter. Now when we look at the board, we see that the edge of the board is between 60 and 70 cm or 0.6 m and 0.7 m as previously indicated. However, when we look at the tool, we see the edge is closer to the $60-\mathrm{cm}$ mark than the $70-\mathrm{cm}$ mark, but by how much? Again, it is time to guess. The length seems closer to 64 cm ; another evaluator might read the length as 65 cm . Either 64 cm or 65 cm are reasonable values to write for the length. Notice that we express the
value of the measurement with the "certain" value plus a "guess". We would write the length of the board as either $64 \mathrm{~cm} \pm 1 \mathrm{~cm}$ or $65 \mathrm{~cm} \pm 1 \mathrm{~cm}$.

## SAMPLE C

In SAMPLE C, a magnifying glass is placed on the board, highlighting the 1 cm mark as the last certain value. Now, we can read the measurement to more precision (the 0.1 cm mark, or the 1 mm mark will be our guess). In the magnified section, the board ends between $64-\mathrm{cm}$ and $65-\mathrm{cm}$, but the end of the board is closer to the $64-\mathrm{cm}$ mark than the $65-\mathrm{cm}$ mark. We can estimate one more digit for the value of the length of the board. The board is less than 64.5 cm , maybe $64.2-\mathrm{cm}$ or 64.3 cm long. It is clearly not $64.4-\mathrm{cm}$ because the edge is not close enough to the (imaginary) halfway point. We could write this several ways, all of them valid estimates for the length of the board:
$64.2 \pm 0.1-\mathrm{cm}, 64.3 \mathrm{~cm} \pm 0.1 \mathrm{~cm}$ (other metric prefixes such as decimeter etc: $6.42-\mathrm{dm} \pm 0.01-\mathrm{dm}$, $0.642-\mathrm{m} \pm 0.001-\mathrm{m})$.

## SAMPLE D

Again, a magnified section is added to the meter stick to highlight the smallest graduation and make an 'estimated' guess. Looking carefully at the meter stick, we might be able to read the meter stick to the millimeter mark, and with care, maybe to the 0.1 mm (our guess). Usually, you can estimate between the smallest graduation marks on the tool. I can clearly read this the 0.2 cm ( 64.2 cm but the guess $(0.01-\mathrm{cm})$ is harder to read. IT'S A GUESS! $64.25 \mathrm{~cm} \pm 0.01 \mathrm{~cm}$.

Tools are imperfect. They age and wear. Marks are hard to read; temperature can be a factor. Metal rulers can expand or contract changing the overall measurements from one day to the next. Consider your tool!


What is the length of this piece of granite? ${ }^{12}$


What is the uncertainty of the measurement in the graduated cylinder? ${ }^{34}$

[^0]

Which is a better measuring device for the bolt, the top or the bottom ruler? Why? ${ }^{56}$


What is the best answer, 98.5 or 98.51 ? why? ${ }^{78}$

[^1]
[^0]:    ${ }^{1}$ http://www.wou.edu/chemistry/files/2017/01/sig_fig_ruler.png
    ${ }^{2} 1.36 \pm 0.01 \mathrm{~cm}$ units, assuming cm
    ${ }^{3}$ https://s3-us-west-2.amazonaws.com/courses-images/wpcontent/uploads/sites/1107/2016/11/07220537/CNX_Chem_01_05_Measure1.jpg ${ }^{4} \pm 0.1 \mathrm{~mL}$

[^1]:    ${ }^{5}$ https://blog.duncanaviation.aero/hs-ff/hub/10680/file-13074324-gif/images/tape-measure.gif ${ }^{6}$ the top one. It has more marks giving the tool more precision.
    7 https://i.ytimg.com/vi/uzoILIG_17w/maxresdefault.jpg
    ${ }^{8}$ The best answer is 98.5 ; the precision of the tool is $\pm 0.1$ units.

