Uncertainties in Measurements Wilfrid Laurier University

Terry Sturtevant

Wilfrid Laurier University

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Meaning of uncertainty Expressing uncertainty

Measurement Uncertainties

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Meaning of uncertainty Expressing uncertainty

Measurement Uncertainties

In labs, many numbers are approximate

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In labs, many numbers are approximate (in other words, they have *uncertainties*)

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Measurement Uncertainties

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Measurement Uncertainties

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The uncertainty reflects the range of possible *calculated* values based on the range of possible *data* values.

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Measurement Uncertainties

In labs, many numbers are approximate

(in other words, they have uncertainties)

When combined by addition, subtraction, multiplication, or division, the **results** have uncertainty

The uncertainty reflects the range of possible *calculated* values based on the range of possible *data* values.

It is the difference between the nominal value and the maximum or minimum value.

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Meaning of uncertainty Expressing uncertainty

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Meaning of uncertainty Expressing uncertainty

Meaning of uncertainty

 $x = 2 \pm 1$

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Meaning of uncertainty Expressing uncertainty

Meaning of uncertainty

$$x = 2 \pm 1$$

 $\rightarrow x$ can be as *small* as 1

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Meaning of uncertainty Expressing uncertainty

Meaning of uncertainty

 $x = 2 \pm 1$ $\rightarrow x$ can be as *small* as 1 since 2 - 1 = 1

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Meaning of uncertainty Expressing uncertainty

Meaning of uncertainty

 $\begin{aligned} x &= 2 \pm 1 \\ \rightarrow x \text{ can be as } small \text{ as } 1 \\ \text{since } 2 - 1 &= 1 \\ \rightarrow x \text{ can be as } big \text{ as } 3 \end{aligned}$

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Meaning of uncertainty Expressing uncertainty

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 $x = 2 \pm 1$ $\rightarrow x$ can be as *small* as 1 since 2 - 1 = 1 $\rightarrow x$ can be as *big* as 3 since 2 + 1 = 3

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Meaning of uncertainty Expressing uncertainty

Meaning of uncertainty

 $x = 2 \pm 1$ $\rightarrow x \text{ can be as small as 1}$ since 2 - 1 = 1 $\rightarrow x \text{ can be as big as 3}$ since 2 + 1 = 3 $y = 32.0 \pm 0.2$

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 $x = 2 \pm 1$ $\rightarrow x \text{ can be as small as 1}$ since 2 - 1 = 1 $\rightarrow x \text{ can be as big as 3}$ since 2 + 1 = 3 $y = 32.0 \pm 0.2$ $\rightarrow y \text{ can be as small as 31.8}$

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Meaning of uncertainty Expressing uncertainty

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 $x = 2 \pm 1$ $\rightarrow x$ can be as *small* as 1 since 2 - 1 = 1 $\rightarrow x$ can be as *big* as 3 since 2 + 1 = 3 $y = 32.0 \pm 0.2$ \rightarrow y can be as *small* as 31.8 since 32.0 - 0.2 = 31.8 \rightarrow y can be as *big* as 32.2 since 32.0 + 0.2 = 32.2

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Meaning of uncertainty Expressing uncertainty

Graphically,

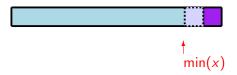


The nominal value of x is here. (i.e. the value without considering uncertainties)

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Graphically,

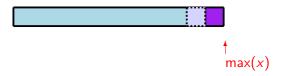


The minimum value of x is here. (i.e. the value with the uncertainty subtracted)

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Meaning of uncertainty Expressing uncertainty

Graphically,



The maximum value of x is here. (i.e. the value with the uncertainty added)

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Meaning of uncertainty Expressing uncertainty

Graphically,



 Δx

The uncertainty, Δx is here.

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Meaning of uncertainty Expressing uncertainty

Graphically,



 $\Delta x \Delta x$

The uncertainty, Δx is here and here.

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Meaning of uncertainty Expressing uncertainty

Expressing uncertainty

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Meaning of uncertainty Expressing uncertainty

Expressing uncertainty

Remember: Since uncertainties are an indication of the imprecise nature of a quantity, uncertainties are usually only expressed to one decimal place.

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Meaning of uncertainty Expressing uncertainty

Expressing uncertainty

Remember: Since uncertainties are an indication of the imprecise nature of a quantity, uncertainties are usually only expressed to one decimal place.

(In other words, it doesn't make sense to have an extremely *precise* measure of the *imprecision* in a value!)

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Purpose of Uncertainties

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Two measurements (or calculations) of the same quantity will rarely give *exactly* the same value.

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The purpose of uncertainties is ultimately to allow numbers to be compared.

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For instance suppose Alice measures a value for the acceleration due to gravity of $g_A = 10.1 \pm 0.3 m/s^2$ and Bob measures a value for the acceleration due to gravity of $g_B = 9.6 \pm 0.4 m/s^2$

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Are they different?

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Purpose of Uncertainties - continued

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Purpose of Uncertainties - continued

Since Alice's value has a minimum of $10.1-0.3m/s^2 = 9.8m/s^2$ and Bob's value has a maximum of $9.6+0.4m/s^2 = 10m/s^2$, we see they both include the range of values from $9.8 \rightarrow 10.0m/s^2$, so we say that they agree within their experimental uncertainties.

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Purpose of Uncertainties - continued

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Whenever two quantities with uncertainties have a range (or even a single value) in common, we say that they agree within their experimental uncertainties.

That means the difference can be *entirely* explained by the measurement uncertainties.

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Summary of Uncertainty Principles

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Summary of Uncertainty Principles

1. All measurements have uncertainties.

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- 1. All measurements have uncertainties.
- 2. Because of this, all calculated results have uncertainties.

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- 3. Uncertainties allow us to *compare* different quantities, by seeing if they *agree* within their uncertainties.

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When quantities *don't agree* within their uncertainties, that means the difference *can't be explained by the measurement uncertainties alone*.

In that case, we calculate the *percent difference* between the two values.

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