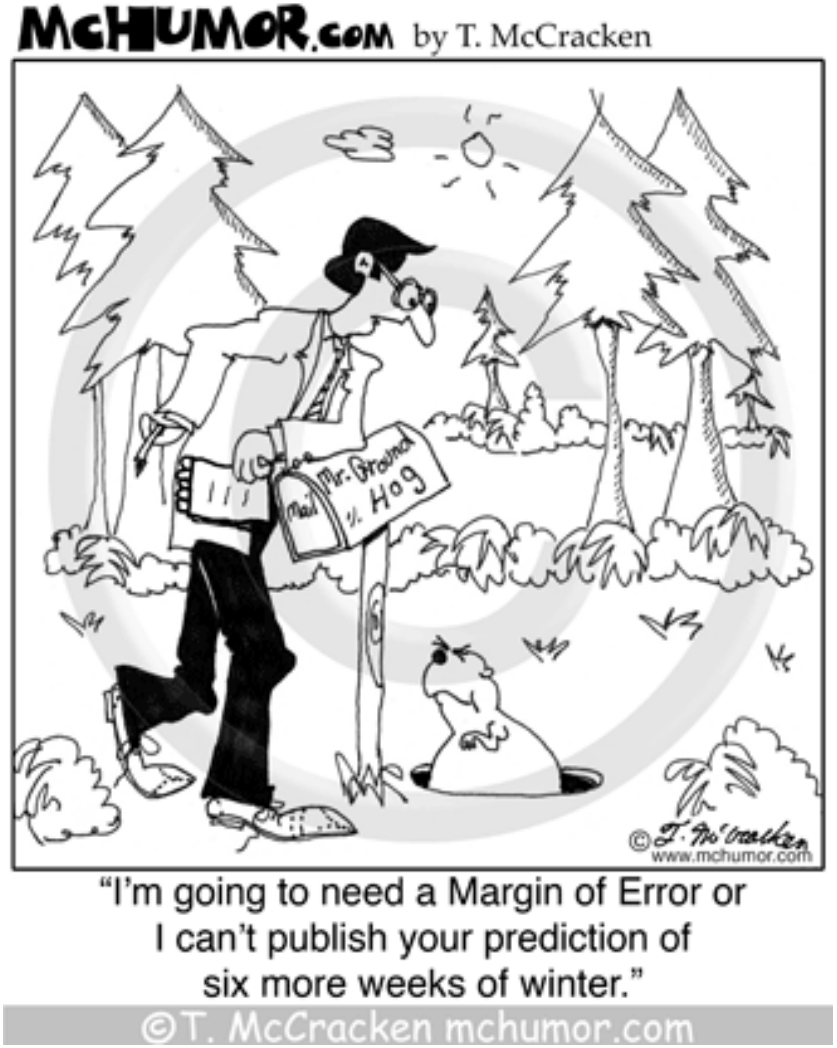
Measurement & Uncertainty

http://www.nd.edu/~dmcderm2/phys31210.html



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Physics 31210

Spring 2012

Today's Plan

1) Discuss the usual first day stuff, including the webpage:
http://www.nd.edu/~dmcderm2/phys31210.html
2) Design a simple experiment with a partner

3) Refine that experiment (how will we estimate uncertainty and compare with everyone in the class?)

4) Analyze the data:
-Draw error bars and look for overlap (qualitative analysis)
-Define Absolute and Relative Uncertainty
-Calculate Relative Uncertainty of our data
-Calculate the difference between our two measurements and its error (quantitative analysis)

5) *Briefly* define accuracy vs precision and statistics

6) Discuss the *optional* homework assignment

Is one of your hands longer than the other?

With a partner, design an experiment to answer the following question. **You will probably have some questions as you start your experiment.**

Go ahead and give it a try...

Supplies: Rulers, metersticks, and meter tapes.
You are welcome to use any supplies you find in the room and ask for additional supplies.

Is one of your hands longer than the other?

Things to consider

a) How will you ensure **accuracy** and estimate your **uncertainty?**

b) How will you **compare** your numbers with other groups?

c) How will you decide whether your hands are different?

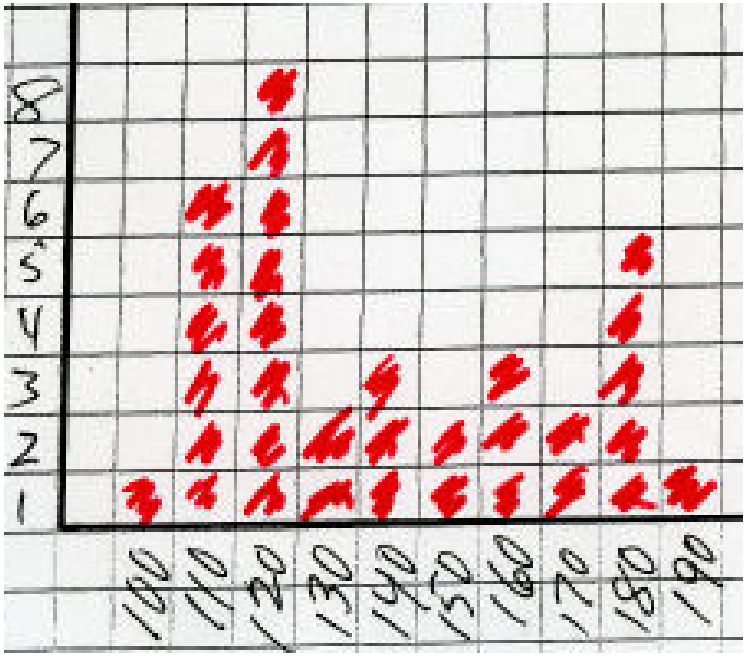
d) How will you **record and present** your data?

Supplies: Rulers, metersticks, and meter tapes.
You are welcome to use any supplies you find in the room and ask for additional supplies.

Is one of your hands longer than the other?

OK GO!

1. Enter your data in the spreadsheet up front
2. Add a data point to the histogram up front



How long are your hands?

$$L1 \pm \delta L1 \qquad L2 \pm \delta L2$$

This is the "little delta" in the Greek alphabet. It always means error.

Are they different lengths?

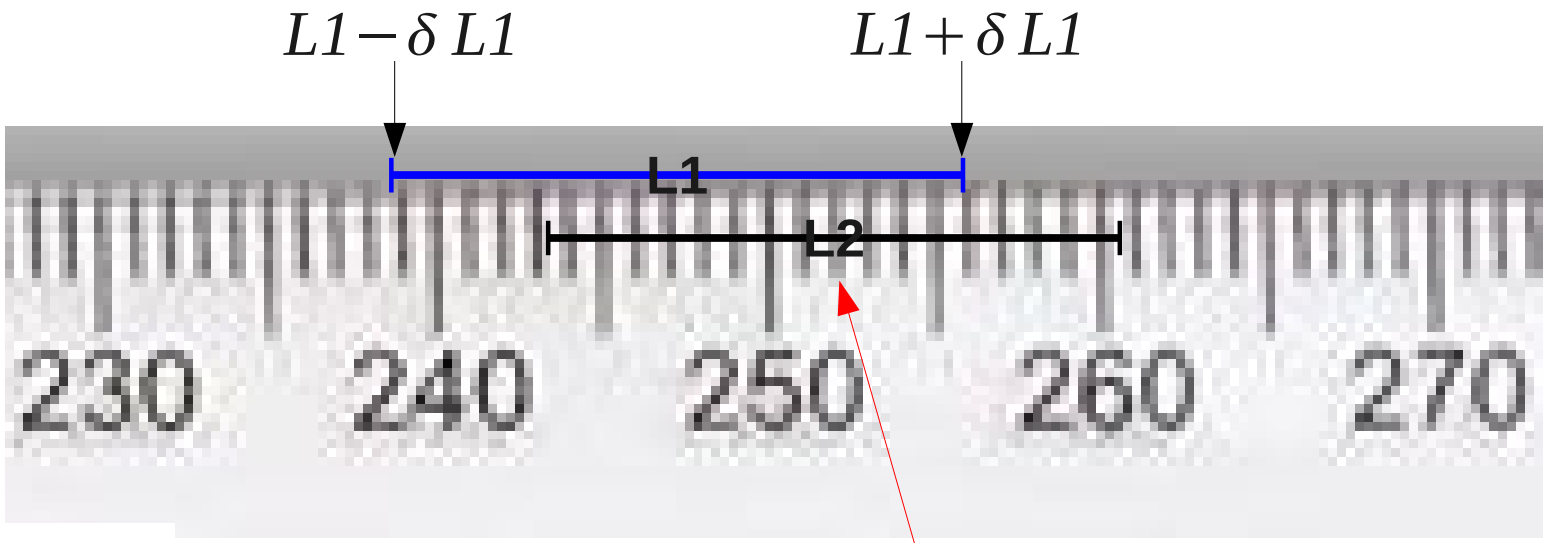
Example:

$$L1 = 17.8 \pm .2\ cm$$
$$L2 = 17.7 \pm .2\ cm$$

How long are your hands?

$$L1 \pm \delta L1 \qquad L2 \pm \delta L2$$

Qualitative Comparison: Do they overlap within error?



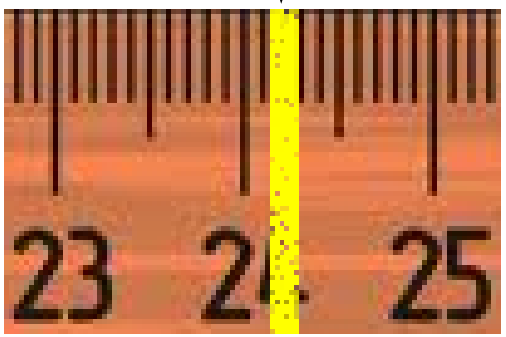
These are “error bars.”

Absolute Uncertainty

Value	Absolute Error	Relative Error
L	δL	
24.2 cm	0.5 cm	

$L = 24.2 \pm 0.5$ cm

Absolute Error has the same units as the value. It represents a range of correct values.



Relative Uncertainty

Value	Absolute Error	Relative Error
L	δL	$\delta L / L$
24.2 cm	0.5 cm	

$$Relative\ Uncertainty = \frac{Absolute\ Uncertainty}{Measured\ Value}$$

Relative Error/Uncertainty is a comparison between the absolute error δL = 0.5 cm and value L = 24.2 cm.

Relative Uncertainty

Value	Absolute Error	Relative Error
L	δL	$\delta L / L$
24.2 cm	0.5 cm	0.2 %

$$Relative\ Uncertainty = \frac{\delta L}{L}$$

$$\delta L / L = 0.5 / 24.2 = 0.00207 = 0.2\,\%$$

Convert this pure decimal number to a percent

Round to a reasonable value (usually just keep one digit)

$$Relative\ Uncertainty = \frac{Absolute\ Uncertainty}{Measured\ Value}$$

1) Calculate the relative uncertainty in your measurements of each hand.

2) Imagine you are given a machine that measures hands with relative uncertainty 5%. Calculate the absolute uncertainties of L1 and L2 (using your actual data).

HINT: First convert 5% to a pure decimal and then do a little algebra to the formula above.

3) Which value is more precise, yours or the 5% (i.e. which has a smaller relative error)? Based on this, which is a better measurement technique.

(Quantitative)

Are your hands really different?

1. Calculate the difference between the lengths.

$$\Delta L = L1 - L2$$

2. Calculate "the error in the difference." This is called "adding absolute errors in quadrature." This is the rule any time you add or subtract two numbers with uncertainty.

$$\delta(\Delta L) = \sqrt{(\delta L1)^2 + (\delta L2)^2}$$

"little delta"

The "big delta" in Greek always means the difference between two numbers.

(Quantitative)

Are your hands really different?

1. Calculate the difference between the lengths.

$$\Delta L = L1 - L2$$

$$\Delta L = 17.8 - 17.7 = .1\,cm$$

2. Calculate "the error in the difference." This is called "adding absolute errors in quadrature." This is the rule any time you add or subtract two numbers with uncertainty.

$$\delta(\Delta L) = \sqrt{(\delta L1)^2 + (\delta L2)^2}$$

$$\delta(\Delta L) = \sqrt{(.2)^2 + (.2)^2}$$

$$\delta(\Delta L) = .282843\ cm$$

$$\delta(\Delta L) = 0.3\text{cm}$$

Round so that your error isn't more precise than your original estimates of uncertainty.

(Quantitative)

Are your hands really different?

1. Calculate the difference between the lengths.

$$\Delta L = L1 - L2$$

$$\Delta L = 17.8 - 17.7 = .1\,cm$$

2. Calculate "the error in the difference."

$$\delta(\Delta L) = \sqrt{(\delta L1)^2 + (\delta L2)^2}$$

$$\delta(\Delta L) = 0.3\text{cm}$$

3. Present your "Best Answer."

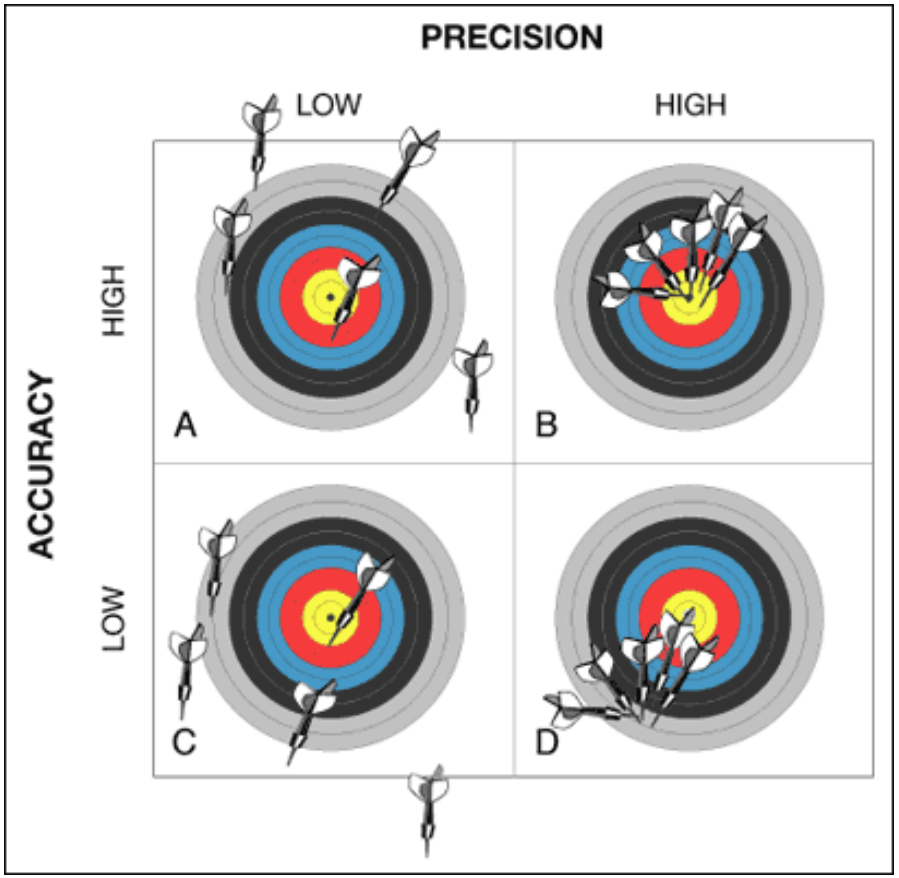
$$\Delta L \pm \delta(\Delta L)$$

$$\Delta L = 0.1 \pm 0.3\,cm$$

Accuracy and Precision

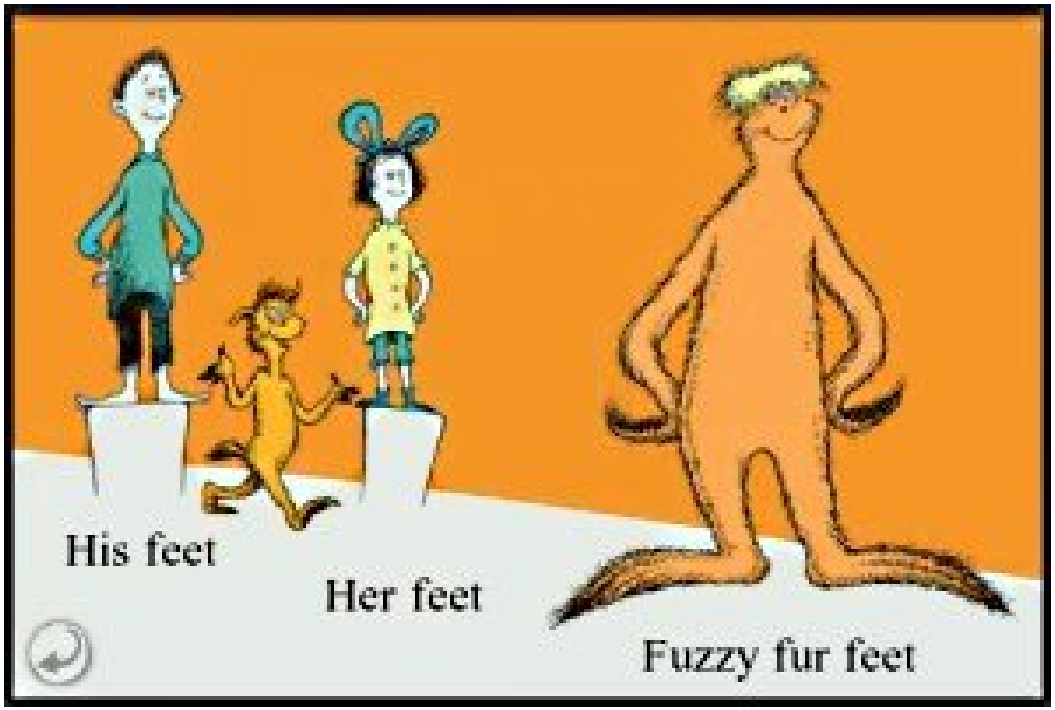
Accuracy:
Is your measured value correct? More specifically does it agree with expected values?

Precision:
Is your relative uncertainty small? Do all of the data points *from a single set of measurements* fit in a small range of values?



Statistics

A mathematical way to describe how things like the foot-lengths naturally vary from person to person. This is a much different kind of uncertainty than the “reading error” associated with measuring devices.



Accuracy: Is your number correct?

Uncertainty: What is the range of possible right answers?

Compare your hands (qualitative): Do their lengths overlap within error?

Compare with others: collect/graph data – it would help tremendously if we all use the same units of measurement.

Accepted value: the textbook answer. Does it fit within your error bars?

Record and present: Graph? Chart? Units? Uncertainty?

Statistics: A mathematical way to describe how things like the length of hands naturally vary from person to person.

Optional Homework

Write up this experiment as you would a normal lab report using the Lab Guidelines handout. Make sure the work is one page or less (preferably less). Your TA will grade this as though it were a normal assignment and return it to you before Lab 1 is due.

"I think there was a typo in the lab instructions."