Physics 2BL: Experiments in Mechanics and Electricity
Winter, 2011

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The Point of the Class

- Learn how scientists form models of nature -the process of doing science
- Learn to assess the accuracy of measurements
- Extend understanding of mechanics/electricity through hands-on exposure
- Learn how to report scientific results

Class components

- Labs – MHA 2722
- Lectures – York 2622
- Homework/Reading
- Website: http://physics.ucsd.edu/students/courses/winter2011/physics2bl

Introduction

- Basics of mechanics and measurements
- Perform 4 labs
  - Two sessions to complete each
  - Design and improve techniques
- Emphasize uncertainties
  - Estimate errors
  - Propagate errors

Labs

- 3 hours per weekly meeting
- Organized around different aspects of scientific methods (observation, forming and testing models, measuring relationships)
- Read lab description and do pre-lab homework **BEFORE** lab session
- Short quizzes at the start of the lab
- Record contact information for your TA

Lab Write-ups

- Begin with lab number & title, date and you and your partners name
- Start with Taylor homework and prelab questions
- State briefly the objective
- Record all data with units and uncertainties
- Brief description of procedure
- Make clear labeled diagrams of setups
- Use graphs to present data, label axes, plot error bars - Origin

Lab Write-up continued

- Include and justify functional fit of data
- Show calculations of final derived quantities, include uncertainty analysis
- State results and comment on the agreement with expectations (or not)
  - Be quantitative (within uncertainty, t-value)

Lectures

- Provide context for labs
- Error analysis
- Homework

Grading

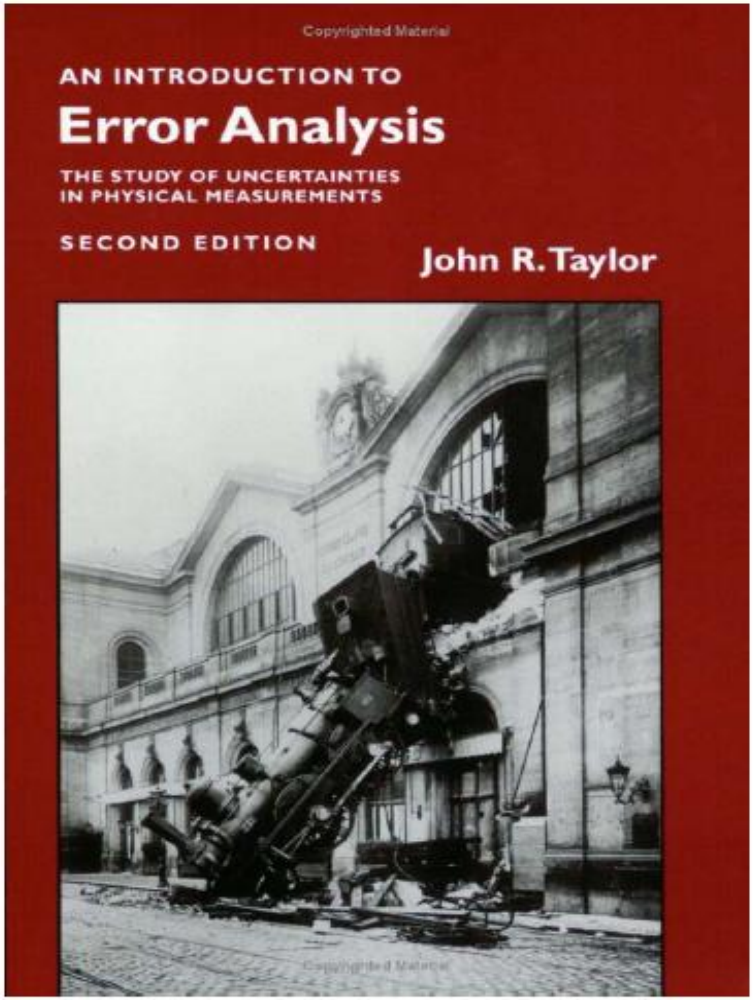
- Three components
  - 50 % for the labs and writeups
  - 20 % prelab quizzes/Homework
  - 30 % Final

Schedule

Meeting	Experiment
1 (Jan 4-6)	None (start Taylor)
2 (Jan 10-13)	1
3 (Jan 17-20)	1
4 (Jan 24-27)	2
5 (Jan 31 – Feb 3)	2
6 (Feb 7-10)	3
7 (Feb 14-17)	3
8 (Feb 21-24)	4
9 (Feb 28 – Mar 3)	4
10 (Mar 10-13)	Make-up

Readings - Text - Homework

- Yes
- Taylor, *An Introduction to Error Analysis,* 2nd ed.
- Weekly homework on website



How to do Well!

- Show up to all lectures and labs
- Read **before** the lectures the recommended reading
- Before each lab:
  - Review lecture slides
  - Read experiment guidelines
  - Answer all pre-lab questions within.
- Do the homework/practice problems
- Ask questions!

The Four Experiments

- **Determine the average density of the earth**

Weigh the Earth, Measure its volume

– Measure simple things like lengths and times

– Learn to estimate and propagate errors

- **Non-Destructive measurements of densities, inner structure of objects**

– Absolute measurements *vs.* Measurements of variability

– Measure moments of inertia

– Use repeated measurements to reduce random errors

- **Construct and tune a shock absorber**

– Adjust performance of a mechanical system

– Demonstrate critical damping of your shock absorber

- **Measure coulomb force and calibrate a voltmeter.**

– Reduce systematic errors in a precise measurement.

Uncertainties/Errors

Errors

Mistakes – systematic

Uncertainties - not mistakes!

inevitable and intrinsic part of any experiment

Doing Science: Tools for Building Knowledge

- Science is a process that studies the world by:
  - Focussing - specific topic (***making a choice***)
  - Observing (***making a measurement***)
  - Refining Intuitions (***making sense***)
  - Extending (***seeking implications***)
  - Demanding consistency (***making it fit***)
  - Community evaluation and critique

Making a choice

- Choosing a channel on cat television
- Relates to the questions we are asking

choice - measure - make sense - seek implications - make it fit

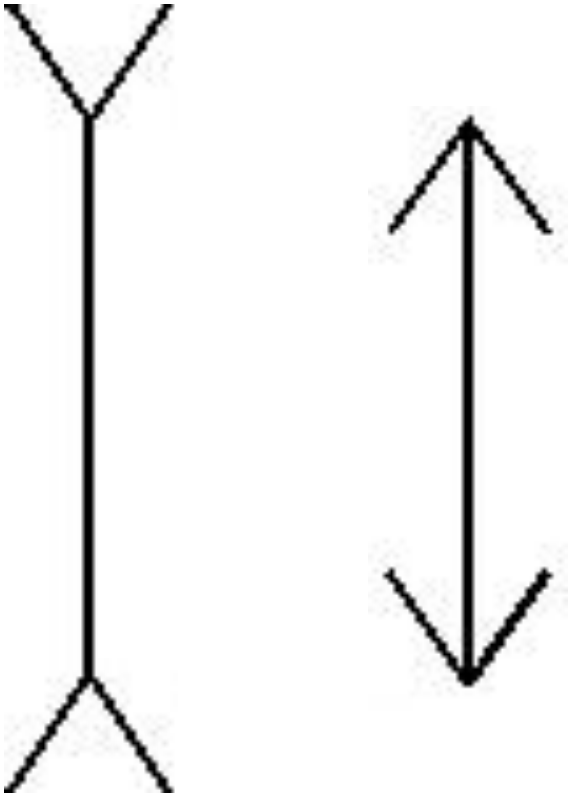
Making a Measurement (and sense)

- How do we see the world around us?
- How do we know we see things the same? (reliable)
- How do we know that we see things correctly? (valid)
- Our own VR:
  - We gather info through our senses
  - Our brains interpret these stimula
  - But don't necessarily get them right

choose - measure - make sense - seek implications - make it fit

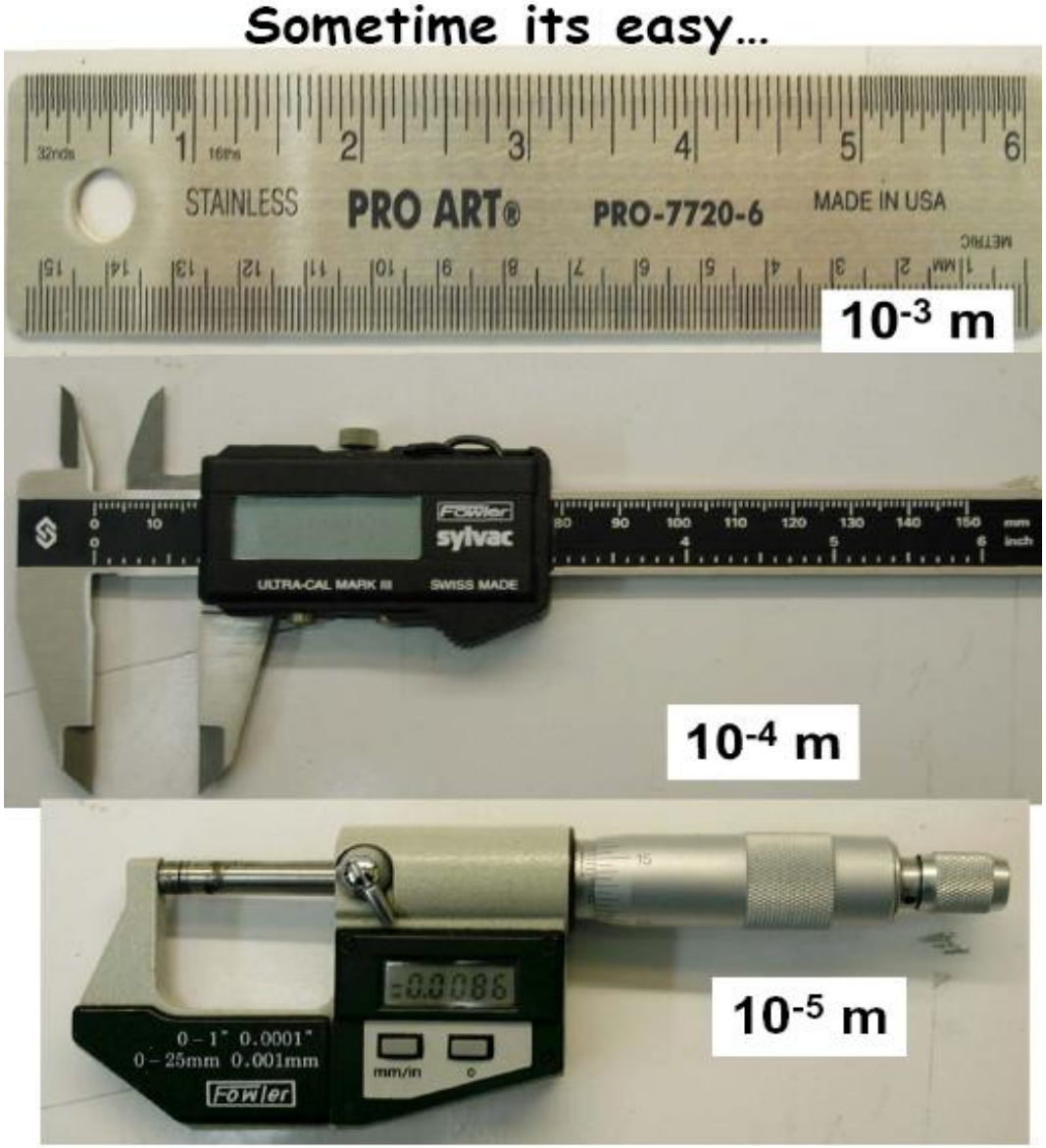
Making a Measurement

- Do these line segments look the same?
- Are they?



choose - measure - make sense - seek implications - make it fit

Uncertainties in devices

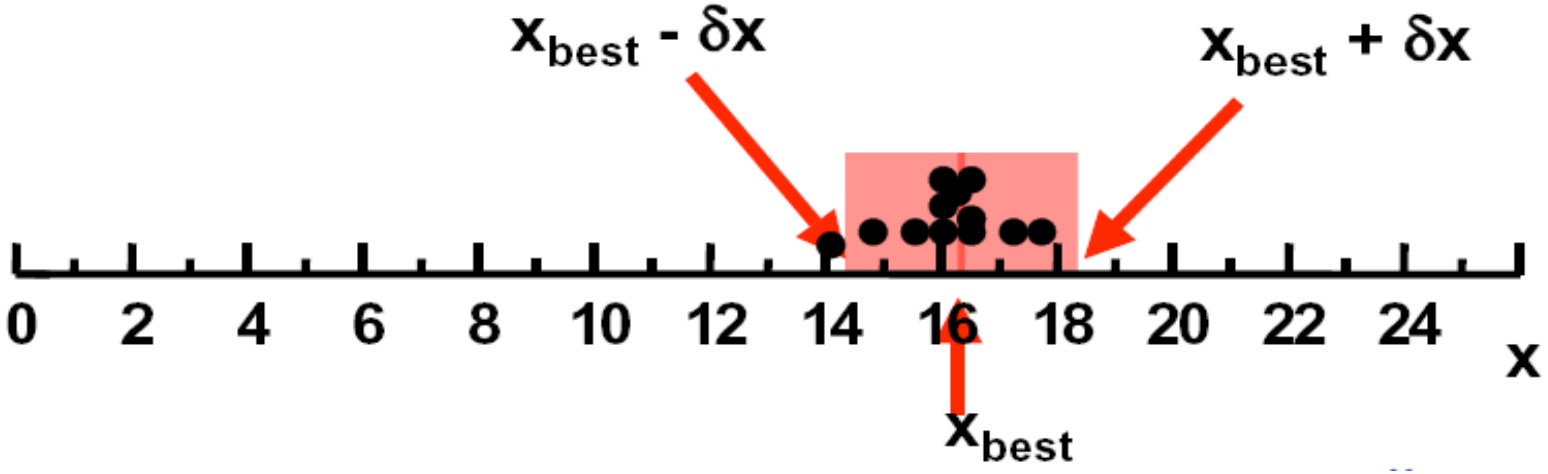


Determine range of values from multiple measurements

Statistically - Take a few measurements of some variable x

1. Find the most likely value - "best"
2. Estimate the spread - uncertainty

$$x = x_{best} \pm \delta x$$



Making Sense

- What is this?
- Hint: it's an animal
- Hint: it's not oriented correctly

choose - measure - make sense - seek implications - make it fit

Hmmmm….

- Does this help?

choose - measure - make sense - seek implications - make it fit

How about this?

- First this…

choose - measure - make sense - seek implications - make it fit

Now this

- Context matters…
- Here we are REFINING INTUITION and making sense, which depends upon context

choose - measure - make sense - seek implications - make it fit

Making sense of physics

- Does this look like dots
- Or deep relations of electric forces

$$\vec{F}_0 = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{q_0 q_i}{\left|\vec{r}_i - \vec{r}_0\right|^3}(\vec{r}_i - \vec{r}_0)$$

choose - measure - make sense - seek implications - make it fit

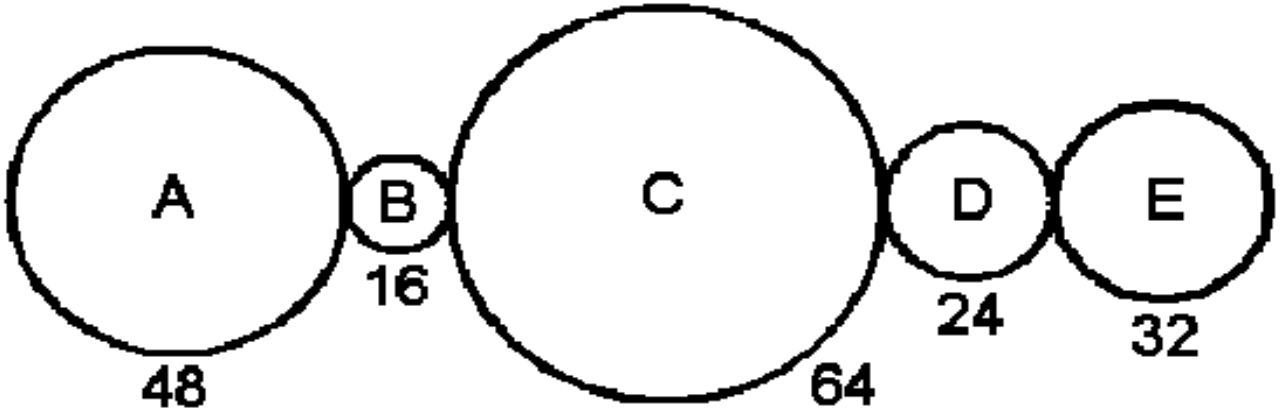
Seeking Implications

- Elaboration -- when we assume one thing it is bound to have implications beyond the exact case we are considering.
- Figuring out what something implies is a good way to examine the thing itself
- And develop MODELS which are applicable beyond our immediate case

choose - measure - make sense - seek implications - make it fit

Elaboration

- The drawing shows a chain of five gear-wheels, identified as **A** to **E**, each one meshing properly with its immediate neighbour(s). The number under each one show how many teeth that particular gear-wheel has.



- When **A** is turned clockwise ten full turns, **in which direction does E turn, and how many times?**

choose - measure - make sense - seek implications - make it fit

Seeking consistency / Making it Fit

- Science seeks consistency in patterns
- Want our principles to be as broad as possible
- Breadth depends upon the state of what we know
- Physics has been around for quite some time and hence, developed a high degree of consistency.

choose - measure - make sense - seek implications - make it fit

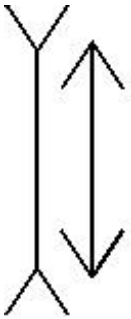
The puzzle analogy

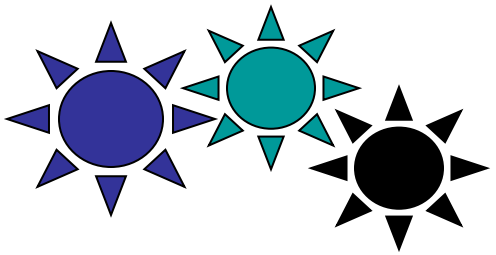
- Seek consistency
- Patterns fit
- Lack of consistency leads to frustration
- The same is true in physics

choose - measure - make sense - seek implications - make it fit

Next steps… summary cues

- Making a choice
- Making a measurement
- Making sense
- Elaboration
- Coherence





Homework

Read Taylor chapters 1 - 3

Prelab problems

Taylor problems 2.1, 3.10, 3.28, 3.36