Physics 1140 Fall 2013
Introduction to Experimental Physics

Joanna Atkin

Lecture 1:

Introduction to Course

Significant Figures

Standard Notation

General information

- Lecture instructor: Joanna Atkin
  - *email:* joanna.atkin@colorado.edu

    Office: D1B17 (down the hall from the main physics office)

    Office hours: Tuesday 10 am - 12 pm or email me

- Course website:

  http://nano-optics.colorado.edu/index.php?id=57

  D2L: https://learn.colorado.edu

- Textbook: Taylor, *An Introduction to Error Analysis*
  - recommended.

Format of Physics 1140

- This is a 1 unit lab class
  - Coursework is "frontloaded." More work at beginning, but all work is done well before finals week

- Weekly 2 hr lab session
  - Lab work in G2B66 area
  - Expect to spend some time outside lab session to prepare for the lab (pre-lab) and completing your writeup
  - First week: Orientation for Mathematica
  - Then: 6 labs over 12 weeks

- 6 lectures, weekly
  - Mo or Tu 4-5pm
  - Homework due Wednesdays by 4 pm, in G2B66

Grading

- The course consists of two components:
  - 1. error analysis lectures, clicker questions, and HW (20% of the total grade).
  - 2. labs (70% of the total grade).
  - 3. midterm quiz (10% of the total grade)
- The labs have two parts to the grade:
  - A) The prelab questions (20% of total grade).
  - B) The lab report (50% of total grade).
- Your 6 labs are chosen from a total of 15 different labs
  - Lab 1 in week 2 must be Lab M1 on the **Simple Pendulum**
  - Lab 3 in week 6 must be Lab E1 on **Circuits**
  - the other 4 labs need to be chosen by you. Your TA will discuss more with you on this issue.

A few words about deadlines:

- Homework due Wednesday 4:00 pm
  - HW score is 20% of grade

- Prelabs due before you begin a lab.

- Lab report due 4:00 pm, three working days after second lab session for the lab.

- **All materials to be turned-in to G2B66 box for your TA.**

Lab books and lab report

- We supply your lab books
  - Raw data sheets will stay in the lab, signed by TA
- Guidelines for lab report
  - Rubric posted on website
  - Sample lab reports posted in the lab
  - Talk to your TA!

E-CLASS survey

- PER group is doing research on improving lab classes

http://ucsas.qualtrics.com/SE/?SID=SV_bIQR5h9iPvANQYB

- Optional: if you want to do it, please complete the survey by Friday.

- Extra credit!

Format of the lab

- In this lab, you will make simple measurements that you can relate, *quantitatively*, to the physics you learn in 1110/1120.
  - Measurements of length, force, mass, time for mechanics labs
  - Measurements of voltage, current for electromagnetism
  - Pressure, wavelength, etc...

- Data-taking teaches you the role of uncertainties and error in scientific research – how things work in reality
  - How to design and implement a good experiment
  - How to reduce uncertainties when possible, and otherwise to account for them

Experiments and uncertainty

- Scientific hypotheses are based on two fundamental assumptions:
  - Theories are tested by experiment.
  - Experiments are reproducible.

- In practice, there are always effects in the lab that cause our measurements to differ from expected values.

- We need a quantitative approach that statistically handles these differences and allows us to refute theories with experimental data.
  - Uncertainties!

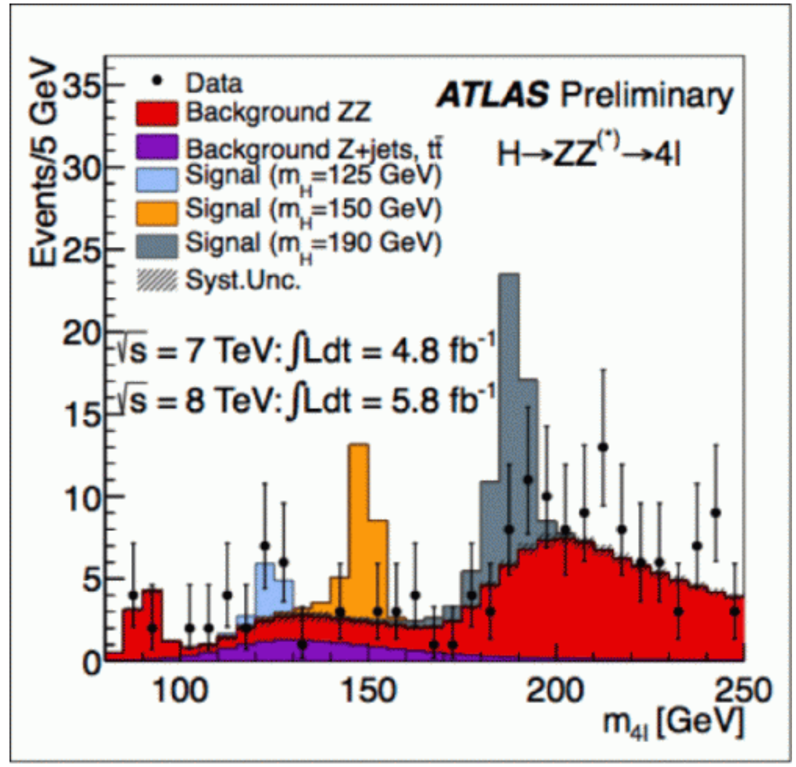
Why does this matter?

1919: First test of Einstein's General Relativity

© Royal Observatory Greenwich

1.60 ± 0.31 arcseconds
1.98 ± 0.12 arcseconds

2012: Experimental evidence for the Higgs Boson

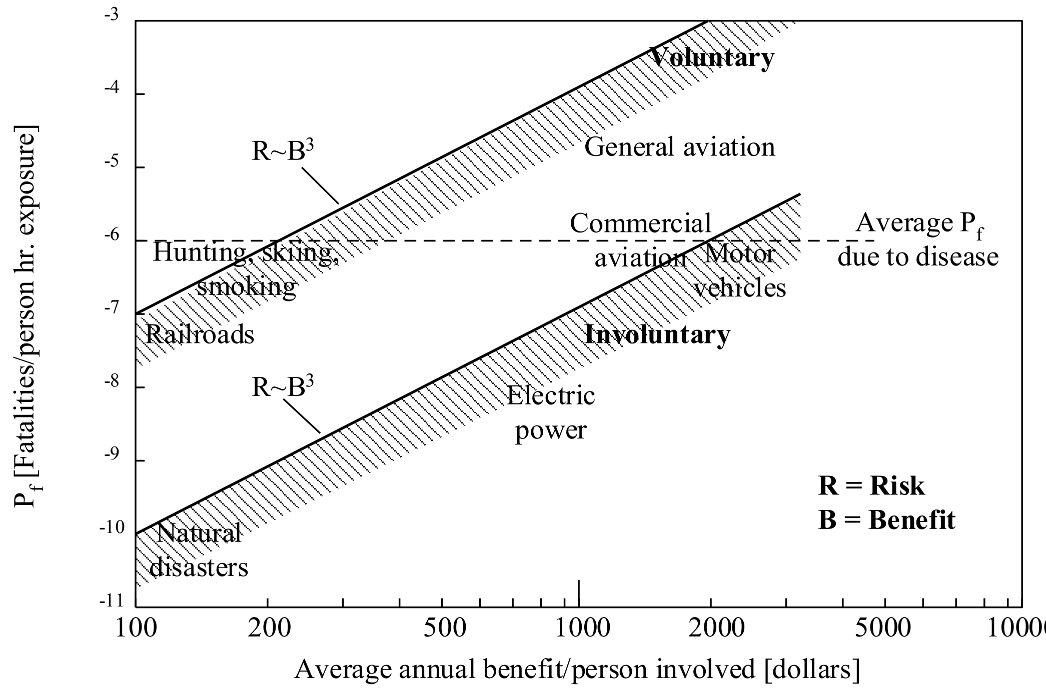


© CERN 2012

Statistically significant number of particles at
125.3 ± 0.4 (stat) ± 0.5 (sys) GeV/c^2
126.0 ± 0.4 (stat) ± 0.4 (sys) GeV/c^2

Why does this matter?

http://ta.twi.tudelft.nl/users/vuik/wi211/
disasters.html#sleipner



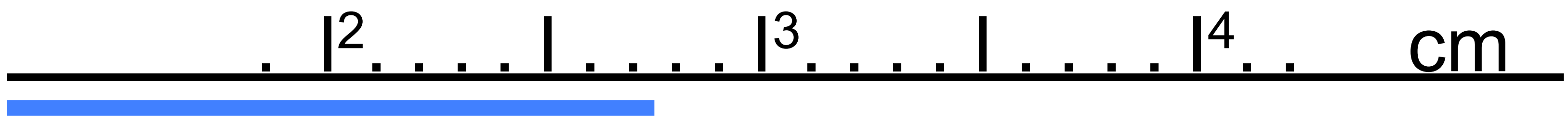
Starr, C., *Science* **165**, 1232 (1969)

Design
Building
Epidemiology
Risk assessment
....

Making measurements and calculating values

- Exact numbers
  - Counted; i.e. I have 4 apples
  - Unit conversions; i.e. 1 meter = 100 cm
- Measured numbers
  - When a measuring tool is used to determine a quantity such as your height or weight, the numbers you obtain are called *measured numbers*.
  - Measured numbers generally will have an uncertainty associated with them
- Derived Quantities
  - Quantities obtained by processing data are called *derived quantities*

Simple measurement: Reading a Meter stick



First digit (known) = 2: 2.?? cm

Second digit (known) = 0.7 2.7? cm

Third digit (estimated) between 0.04 - 0.06

Length reported = 2.75 cm

or 2.76 cm

or 2.74 cm

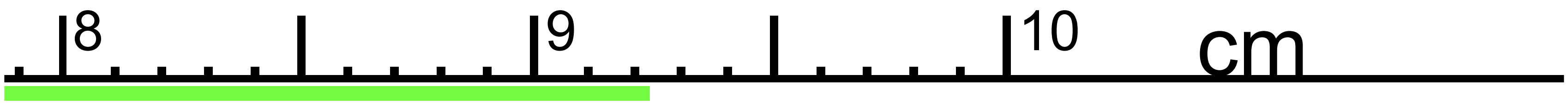
"standard format"
value ± uncertainty [units]

or 2.75±0.01 cm

Known + Estimated Digits

- In general, when making a measurement, we record all the digits that we are certain of and then estimate ***one more digit***.
  - Known digits 2 and 7 are 100% certain
  - The third digit 5 is estimated (uncertain)
- Uncertainty determines how many digits are significant.
  - for the reported length, all three digits (2.75 cm) are significant including the estimated one

Clicker Question 1



What is the length of the line?

A) 9.2 cm

B) 9.22 cm

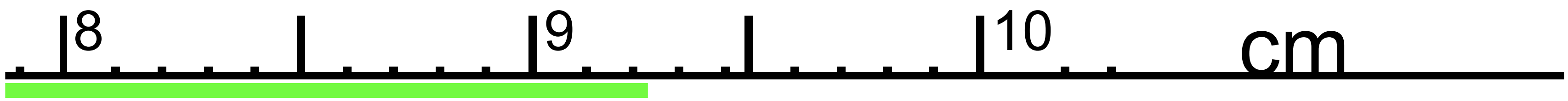
C) 9.23 cm

D) 9 cm

E) 9.26 cm

How does your answer compare with your neighbor's answer?

Solution



Estimate to the hundredth place (0.01 cm)

B) 9.22 cm

C) 9.23 cm

The estimated digit may be slightly different. Both readings are acceptable.

Significant figures

- So number of digits reported gives you an idea of the confidence in the measurement

Rules for significant figures:

1. All non-zero digits (1,2,3,4,5,6,7,8,9) are significant.
2. All zeros between non-zero digits are significant.
3. Zeros that set the decimal point are usually not significant.
4. Trailing zeros which don’t set the decimal point are significant.

Examples of significant figures

- $g = 9.80665\ ms^{-2}$ 6 sig. figs.
  - Rule 1, 2
- $L = 0.0925\ m$ 3 sig. figs.
  - Rule 3
- $X = 9.30$ 3 sig. figs.
  - Rule 4

Clicker question 2

- How many sig. figs. are there in the value 4.500?

A) 1

B) 2

C) 3

D) 4

E) ambiguous

Clicker question 3

- How many sig. figs. are there in the value 4200?

A) 1

B) 2

C) 3

D) 4

E) ambiguous

4200 ± 10	3 sig. figs.
4.2×10^3	2 sig. figs.
4.200×10^3	4 sig. figs.

Math with sig. figs.

- Round to the same number of sig. figs. as the least precise value

  3.14159 x 4.75 = 14.9

  2.718 + 1.1 = 3.8

- For intermediate results, you should keep one or two extra sig. figs. to avoid rounding errors.

Standard format

- Uncertainty defines how many digits in the reported value are significant
  - usually one sig. fig. in uncertainty
  - precision (decimal place) of value and uncertainty must match

$$D = 6.119 \pm 0.005$$

Exception for uncertainty starting with “1”:

$$D = 6.1193 \pm 0.0014$$

Clicker question 4

- Which of the following is NOT in standard format?

A) 3810 ± 40 Hz

B) 125.35 ± 0.8 cm

C) (5.13 ± 0.03) x 10^4 counts/s

D) 101 ± 4 Dalmations

E) 4.518 ± 0.006 kg

Summary

- Standard format: 2.75 ± 0.01 cm
  - Measured value ± uncertainty
  - Number of significant figures
  - Units!
- No lecture next week
- Week 09/09: More on uncertainties, propagating uncertainties, discrepancies
- This week's lab is familiarizing you with Mathematica