1. Syllabus and Introduction

2. Chapter one
   • Uncertainties and Significant Figures
   • Standards and units
   • Estimates
   • Dimensional Analysis

Thanks to Dr. Yu for bringing this class into 21st Century!
Who am I?

- **Name:** Dr. Andrew Brandt (You can call me **Dr. Brandt**)
- **Office:** Rm 241C, Science Hall
- **Extension:** x2706, E-mail: *brandta@uta.edu*
- **Education:** B.S. Physics/Economics College of William and Mary 1985; Ph. D. 1992 UCLA

- **My Research Area: High Energy Physics (HEP)**
  - Collide particles (currently protons and anti-protons) at energies equivalent to 10,000 Trillion degrees
  - To understand
    - Fundamental constituents of matter
    - Interactions or forces between the constituents
    - Creation of Universe (**Big Bang** Theory)
  - A pure scientific research activity
    - Direct use of the fundamental laws not yet known, but use of discovery of electron was not immediately known either!
    - Indirect product of research contribute to every day lives; eg. WWW
Structure of Matter

10^{-2}\text{m} \quad 10^{-9}\text{m} \quad 10^{-10}\text{m} \quad 10^{-14}\text{m} \quad <10^{-18}\text{m}

Condensed matter/Nano-Science/Chemistry

Atomic Physics

Nuclear Physics

Baryon (Hadron)

Quark

Electron (Lepton)

protons, neutrons, mesons, etc. $\pi, \Omega, \Lambda$

top, bottom, charm, strange, up, down

$10^{-15}\text{m}$

$<10^{-19}\text{m}$

10^{-2}\text{m} \quad 10^{-9}\text{m}
The Standard Model

- Assumes the following fundamental structure:

- Discovered in 1995 by DØ and CDF
- Directly observed in 2000
Fermilab Tevatron Accelerator

- World’s Highest Energy proton-anti-proton collider
  \[ E_{cm} = 1.96 \text{ TeV} (=6.3 \times 10^{-7} \text{J/p} \rightarrow 1.3 \text{MJoule}) \]

http://www.fnal.gov/
What Does an Event Look Like in a Detector?

Highest $E_T$ dijet event at DØ

$E_T^1 = 475$ GeV, $\eta^1 = -0.69$

$E_T^1 = 472$ GeV, $\eta^2 = +0.69$
Forward Proton Detector Layout

- 9 momentum spectrometers comprised of 18 Roman Pots
- Scintillating fiber detectors (built at UTA) are moved close (~6 mm) to the beam to track scattered protons and anti-protons
- Reconstructed track is used to calculate momentum and scattering angle, covering new kinematic regions
- Allows combination of tracks with high momentum scattering in the central detector
Primary Web Page

Course Specification for 1443-501, Spring 2004

Class Schedule
5:30 - 6:50pm
Mondays & Wednesdays
Room 129, Science Hall

Instructor
Dr. Andrew Brandt

Office
Room 241C, Science Hall
Phone: (817) 272 - 2706
Secretary: (817) 272 - 2911

Office Hours
Mondays 4:30pm - 5:30pm, 7:00 - 7:30; Wednesdays 7:00 - 7:30;
or by appointment

Prerequisites
MATH 1426 or concurrent enrollment.
You must enroll in a relevant lab section, unless exempt

Textbook
Physics for Scientists and Engineers, 3rd Edition
Douglas C. Giancoli (ISBN # 0-13-021518-x)
Prentice Hall

http://www.hep.uta.edu/~brandta/sp2004/teaching.html
Grading

• Exams: 50%
  – Best of two midterms 25%
  – Comprehensive final 25%
  – Exams will be curved if necessary
  – Missing an exam is not permissible unless pre-approved
    • No makeup test
• Homework: 20% (no late homework)
• Pop-quizzes: 10% (no makeup quizzes)
• Lab score: 20%

NO Makeup Work!
Homework

• Solving problems is the only way to comprehend class material
• An electronic homework system has been setup for you
  – Details are in the syllabus and on web (class id 50143, pwd newton; everyone has their own password)
  – https://hw.utexas.edu/studentInstructions.html
• Each homework carries the same weight
• Home work will constitute 20% of the total ➔ A good way of keeping your grades high
• Allowed (encouraged) to work with others and get help from physics clinic as needed—always attempt homework first on your own, or you will likely pay for it on the tests
Attendance and Class Style

• Attendance:
  – is STRONGLY encouraged
  – pop quizzes will be given periodically

• Class style:
  – Lectures will be primarily on electronic media
    • The lecture notes will be posted AFTER each class
  – Will be mixed with traditional methods
  – Active participation through questions and discussions are STRONGLY encouraged
Why Do Physics?

- To understand nature through experimental observations and measurements (Research)
- Establish limited number of fundamental laws, usually with mathematical expressions
- Explain and predict nature

Theory and Experiment work hand-in-hand
Discrepancies between experimental measurements and theory are good for improvement of theory
Modern society is based on technology derived from detailed understanding of physics
What do you want from this class?

I want an “A”  I just want to pass!

\textit{I want you to:}

- Understand the fundamental principles that surround you
- Identify what law of physics applies to what phenomena
- Learn how to do research and analyze what you observe
- Learn how to express observations and measurements in mathematical language
- Learn how to solve problems

\textit{I don’t want you to be scared of PHYSICS!!!}
Brief History of Physics

• **AD 18th century:**
  – Newton’s Classical Mechanics: A theory of mechanics based on observations and measurements

• **AD 19th Century:**
  – Electricity, Magnetism, and Thermodynamics

• **Late AD 19th and early 20th century (Modern Physics Era):**
  – Einstein’s theory of relativity: Generalized theory of space, time, and energy (mechanics)
  – Quantum Mechanics: Theory of atomic phenomena (small distance scales)

• Physics has come very far, very fast, and is still progressing, yet we’ve got a long way to go
  – What is matter made of?
  – How does matter get mass?
  – How and why do particles interact with each other?
  – How is universe created?
Uncertainties

- Physical measurements have limited precision, no matter how good they are, due to:
  - Number of measurements
  - Quality of instruments (meter stick vs micrometer)
  - Experience of the person doing measurements
  - Etc.

In many cases, uncertainties are more important and difficult to estimate than the central (or mean) values.
Significant Figures

Significant figures denote the precision of the measured values

- Significant figures: non-zero numbers or zeros that are not place-holders

  - 34 has two significant digits; 34.2 has 3; 0.001 has one because the 0’s before 1 are place holders, 34.100 has 5, because the 0’s after 1 indicates that the numbers in these digits are indeed 0’s.

- When there are many 0’s, use scientific notation:
  - $31400000 = 3.14 \times 10^7$
  - $0.00012 = 1.2 \times 10^{-4}$
Significant Figures

• Operational rules:
  – Addition or subtraction: Keep the **smallest number of decimal places** in the result, independent of the number of significant digits: $34.001 + 120.1 = 154.1$
  – Multiplication or Division: Keep the **number of significant figures of the operand with the least S.F.** in the result: $34.001 \times 120.1 = 4083$, because the smallest number of significant figures is 4.
Needs for Standards and Units

• Basic quantities for physical measurements
  – Length, Mass, and Time

• Need a language so that everyone can understand each other. (How far is it to Chicago? 1000)
  – Consistency is crucial for physical measurements
  – The same quantity measured by one must be comprehensible and reproducible by others

• A system of units called \textbf{SI} (\textit{System International}) established in 1960
  – Length in meters \((m)\)
  – Mass in kilo-grams \((kg)\)
  – Time in seconds \((s)\)
## Definition of Base Units

<table>
<thead>
<tr>
<th>SI Units</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1 \ m \ (\text{Length}) = 100 \ cm$</td>
<td>One meter is the length of the path traveled by light in vacuum during a time interval of $\frac{1}{299,792,458}$ of a second.</td>
</tr>
<tr>
<td>$1 \ kg \ (\text{Mass}) = 1000 \ g$</td>
<td>It is equal to the mass of the international prototype of the kilogram, made of platinum-iridium in International Bureau of Weights and Measure in France.</td>
</tr>
<tr>
<td>$1 \ s \ (\text{Time})$</td>
<td>One second is the duration of $9,192,631,770$ periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the Cesium 133 ($\text{C}^{133}$) atom.</td>
</tr>
</tbody>
</table>

- There are prefixes that scales the units larger or smaller for convenience (see pg. 7)
- Units for other quantities, such as Kelvins for temperature, for easiness of use
International Standard Institutes

• International Bureau of Weights and Measure
  http://www.bipm.fr/
  – Base unit definitions: http://www.bipm.fr/enus/3_SI/base_units.html
  – Unit Conversions: http://www.bipm.fr/enus/3_SI/

• US National Institute of Standards and Technology (NIST) http://www.nist.gov/
Examples 1.3 & 1.4

• Ex 1.3: A silicon chip has an area of 1.25 in$^2$. Express this in cm$^2$.

\[
1.25 \text{ in}^2 = 1.25 \text{ in}^2 \times \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right)^2
\]

\[
= 1.25 \times \left( \frac{6.45 \text{ cm}^2}{1 \text{ in}^2} \right)
\]

\[
= 1.25 \times 6.45 \text{ cm}^2 = 8.06 \text{ cm}^2
\]

• Ex 1.4: Where the posted speed limit is 65 miles per hour (mi/h or mph), what is this speed (a) in meters per second (m/s) and (b) kilometers per hour (km/h)?

(a) \[
65 \text{ mi/h} = (65 \text{ mi}) \left( \frac{1609 \text{ m}}{1 \text{ mi}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) = 29.1 \text{ m/s}
\]

(b) \[
65 \text{ mi/h} = (65 \text{ mi}) \left( \frac{1.609 \text{ km}}{1 \text{ mi}} \right) \left( \frac{1 \text{ h}}{1 \text{ h}} \right) = 104 \text{ km/h}
\]
Estimates & Order-of-Magnitude Calculations

• Estimate = Approximation
  – Useful for rough calculations to determine the necessity of higher precision
  – Usually done under certain assumptions
  – Might require modification of assumptions, if higher precision is necessary

• Order of magnitude estimate: Estimates done to the precision of 10s or exponents of 10s;
  – Three orders of magnitude: $10^3 = 1,000$
  – Round up for Order of magnitude estimate; $8 \times 10^7 \approx 10^8$
  – Similar terms: “Ball-park-figures”, “guesstimates”, etc
Examples 1.8

Estimate radius of the Earth using triangulation as shown in the picture when $d=4.4\text{km}$ and $h=1.5\text{m}$.

**Pythagorean theorem**

$$(R + h)^2 \approx d^2 + R^2$$

$$R^2 + 2hR + h^2 \approx d^2 + R^2$$

Solving for $R$

$$R \approx \frac{d^2 - h^2}{2h}$$

$$= \frac{(4400\text{m})^2 - (1.5\text{m})^2}{2 \times 1.5\text{m}}$$

$$= 6500\text{km}$$
Dimension and Dimensional Analysis

- An extremely useful concept in solving physical problems
- No matter what units are used the base quantities are the same
  - **Length** (distance) is length whether meter or inch is used to express the size: Usually denoted as \([L]\)
  - The same is true for **Mass** ([M]) and **Time** ([T])
  - One can say “Dimension of Length, Mass or Time”
  - Dimensions are used as algebraic quantities: Can perform algebraic operations, addition, subtraction, multiplication or division
Dimension and Dimensional Analysis

- One can use dimensions only to check the validity of one’s expression: Dimensional analysis
  - Eg: Speed \[ [v] = \frac{[L]}{[T]} = [L][T^{-1}] \]
  - Distance (\(L\)) traveled by a car running at the speed \(V\) in time \(T\)
    \[ L = V \times T = \left(\frac{L}{T}\right) \times [T] = [L] \]
  - More general expression of dimensional analysis is using exponents: eg. \[ [v] = [L^nT^m] = [L][T^{-1}] \]
    where \(n = 1\) and \(m = -1\)
Examples

• Show that the expression \([\nu] = [at]\) is dimensionally correct
  
  - Speed: \([\nu] = L/T\)
  - Acceleration: \([a] = L/T^2\)
  - Thus, \([at] = (L/T^2) \times T = LT^{(-2+1)} = LT^{-1} = L/T = [\nu]\)

• Suppose the acceleration \(a\) of a circularly moving particle with speed \(\nu\) and radius \(r\) is proportional to \(r^n\) and \(\nu^m\). What are \(n\) and \(m\)?

\[
L^1 T^{-2} = (L)^n \left(\frac{L}{T}\right)^m = L^{n+m} T^{-m}
\]

\[-m = -2 \implies m = 2\]

\[n + m = n + 2 = 1 \implies n = -1\]

\[
a = kr^{-1}\nu^2 = \frac{\nu^2}{r}
\]