PHYS 1443 – Section 002

Lecture #2

Wednesday, August 27, 2008

Dr. Jae-hoon Yu

• What do we want learn from this class?
• What is Physics?
• Brief history of physics
• Models, theories, laws and principles
• Uncertainties and significant figures
• Standards and units
• Estimates
• Dimensions and dimensional analysis
• Fundamentals in kinematics
Announcements

• Reminder for Reading assignment #1: Read and follow through all sections in appendices A and B by Wednesday, Sept. 3
  – There will be a quiz next Wednesday, Sept. 3, on this reading assignment

• Homework
  – 40 out of 68 registered so far... Excellent!!
    • But only 9 submitted the answers!!
    • Must try to download and submit the answer to obtain full credit!!
  – Trouble w/ UT e-ID?
    • Check out https://hw.utexas.edu/bur/commonProblems.html

• 17 out of 68 subscribed to e-mail list
  – 5 point extra credit if done by this Friday, Aug. 29
  – 3 point extra credit if done by next Wednesday, Sept. 3

• Want to keep up with LHC start up news?
  – First collision on Sept. 10, 2008, during the day in CERN time (7 hours ahead)
What do we want to learn in this class?

• Physics is everywhere around you.
• Understand the fundamental principles that surrounds you in everyday lives…
• Identify what laws of physics applies to what phenomena and use them appropriately
• Understand the impact of such physical laws
• Learn how to research and analyze what you observe.
• Learn how to express observations and measurements in mathematical language
• Learn how to express your research in systematic manner in writing
• I don’t want you to be scared of PHYSICS!!!

Most importantly, let us have a lot of FUN!!
Why do Physics?

Exp. { 
- To understand nature through experimental observations and measurements (Research)
- Establish limited number of fundamental laws, usually with mathematical expressions
- Predict the nature’s course

⇒ Theory and Experiment work hand-in-hand
⇒ Theory works generally under restricted conditions
⇒ Discrepancies between experimental measurements and theory are good for improvements
⇒ Improves our everyday lives, though some laws can take a while till we see them amongst us
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

• 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 do matters get mass?
  – How and why do matters interact with each other?
  – How is universe created?
Models, Theories and Laws

• **Models**: An analogy or a mental image of a phenomena in terms of something we are familiar with
  – Thinking light as waves, behaving just like water waves
  – Often provide insights for new experiments and ideas

• **Theories**: More systematically improved version of models
  – Can provide quantitative predictions that are testable and more precise

• **Laws**: Certain concise but general statements about how nature behaves
  – Energy conservation
  – The statement must be found experimentally valid to become a law

• **Principles**: Less general statements of how nature behaves
  – Has some level of arbitrariness
Uncertainties

• Physical measurements have limited precision, however good they are, due to:

  Stat.\{ – Number of measurements
  – Quality of instruments (meter stick vs micro-meter)

  Syst.\{ – 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, 34.2, 0.001, 34.100
      - 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 for simplicity:

  - 31400000=3.14x10^7
  - 0.00012=1.2x10^{-4}
Significant Figures

• Operational rules:

  – Addition or subtraction: Keep the **smallest number of decimal place** in the result, independent of the number of significant digits: $12.001 + 3.1 = \boxed{15.1}$

  – Multiplication or Division: Keep the **smallest significant figures** in the result: $12.001 \times 3.1 = \boxed{37}$, because the smallest significant figures is ?.

What does this mean? The worst precision determines the precision the overall operation!!
Needs for Standards and Units

• Three basic quantities for physical measurements
  – Length, Mass, and Time

• Need a language that everyone can understand each other
  – Consistency is crucial for physical measurements
  – The same quantity measured by one must be comprehendible and reproducible by others
  – Practical matters contribute

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

<table>
<thead>
<tr>
<th>SI Units</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m (Length) =</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>100 cm</td>
<td></td>
</tr>
<tr>
<td>1 kg (Mass) =</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>1000 g</td>
<td></td>
</tr>
<tr>
<td>1 s (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 ($^{133}\text{C}$) atom.</td>
</tr>
</tbody>
</table>

- There are prefixes that scale the units larger or smaller for convenience (see pg. 7)
- Units for other quantities, such as Kelvins for temperature, for easiness of use
Prefixes, expressions and their meanings

<table>
<thead>
<tr>
<th>Larger</th>
<th>Smaller</th>
</tr>
</thead>
<tbody>
<tr>
<td>deca (da): 10^1</td>
<td>deci (d): 10^{-1}</td>
</tr>
<tr>
<td>hecto (h): 10^2</td>
<td>centi (c): 10^{-2}</td>
</tr>
<tr>
<td>kilo (k): 10^3</td>
<td>milli (m): 10^{-3}</td>
</tr>
<tr>
<td>mega (M): 10^6</td>
<td>micro (µ): 10^{-6}</td>
</tr>
<tr>
<td>giga (G): 10^9</td>
<td>nano (n): 10^{-9}</td>
</tr>
<tr>
<td>tera (T): 10^{12}</td>
<td>pico (p): 10^{-12}</td>
</tr>
<tr>
<td>peta (P): 10^{15}</td>
<td>femto (f): 10^{-15}</td>
</tr>
<tr>
<td>exa (E): 10^{18}</td>
<td>atto (a): 10^{-18}</td>
</tr>
<tr>
<td>zetta (Z): 10^{21}</td>
<td>zepto (z): 10^{-21}</td>
</tr>
<tr>
<td>yotta (Y): 10^{24}</td>
<td>yocto (y): 10^{-24}</td>
</tr>
</tbody>
</table>
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/
How do we convert quantities from one unit to another?

\[
\text{Unit 1} = \text{Conversion factor} \times \text{Unit 2}
\]

<table>
<thead>
<tr>
<th>Unit 1</th>
<th>Conversion factor</th>
<th>Unit 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td>2.54</td>
<td>cm</td>
</tr>
<tr>
<td>1 inch</td>
<td>0.0254</td>
<td>m</td>
</tr>
<tr>
<td>1 inch</td>
<td>2.54 \times 10^{-5}</td>
<td>km</td>
</tr>
<tr>
<td>1 ft</td>
<td>30.3</td>
<td>cm</td>
</tr>
<tr>
<td>1 ft</td>
<td>0.303</td>
<td>m</td>
</tr>
<tr>
<td>1 ft</td>
<td>3.03 \times 10^{-4}</td>
<td>km</td>
</tr>
<tr>
<td>1 hr</td>
<td>60</td>
<td>minutes</td>
</tr>
<tr>
<td>1 hr</td>
<td>3600</td>
<td>seconds</td>
</tr>
</tbody>
</table>

And many More Here…
Examples 1.3 and 1.4 for Unit Conversions

- Ex 1.3: An apartment has a floor area of 880 square feet \( (\text{ft}^2) \). Express this in square meters \( (\text{m}^2) \).

What do we need to know?

\[
880 \text{ ft}^2 = 880 \text{ ft}^2 \times \left( \frac{12\text{ in}}{1\text{ ft}} \right)^2 \left( \frac{0.0254 \text{ m}}{1 \text{ in}} \right)^2
\]

\[
= 880 \text{ ft}^2 \times \left( \frac{0.0929 \text{ m}^2}{1 \text{ ft}^2} \right)
\]

\[
= 880 \times 0.0929 \text{ m}^2 \approx 82 \text{ m}^2
\]

Ex 1.4: Where the posted speed limit is 55 miles per hour (\( \text{mi/h} \) or \( \text{mph} \)), what is this speed (a) in meters per second (\( \text{m/s} \)) and (b) kilometers per hour (\( \text{km/h} \))?

1 \( \text{mi} \) = \( (5280 \text{ ft}) \left( \frac{12 \text{ in}}{1 \text{ ft}} \right) \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right) \left( \frac{1 \text{ m}}{100 \text{ cm}} \right) \) = 1609 \( \text{m} \) = 1.609 \( \text{km} \)

(a) \( 55 \text{ mi/h} = (55 \text{ mi}) \left( \frac{1609 \text{ m}}{1 \text{ mi}} \right) \left( \frac{1}{1 \text{ h}} \right) \left( \frac{1 \text{ h}}{3600 \text{ s}} \right) = 25 \text{ m/s} \)

(b) \( 55 \text{ mi/h} = (55 \text{ mi}) \left( \frac{1.609 \text{ km}}{1 \text{ mi}} \right) \left( \frac{1}{1 \text{ h}} \right) = 88 \text{ km/hr} \)
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; $8 \times 10^7 \sim 10^8$
  – Similar terms: “Ball-park-figures”, “guesstimates”, etc
Example 1.8

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

\begin{align*}
( R + h )^2 & \approx d^2 + R^2 \\
R^2 + 2hR + h^2 & \approx d^2 + R^2 \\
\text{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}
\end{align*}