PHYS 1443 – Section 002
Lecture #2

Wednesday, Aug. 29, 2007

Dr. Jaehoon Yu

- Brief history of physics
- Standards and units
- Uncertainties
- Dimensional Analysis
- Fundamentals
- One Dimensional Motion: Average Velocity; Acceleration; Motion under constant acceleration; Free Fall

Announcements

- Reading assignment #1: Read and follow through all sections in appendices A and B by Monday, Sept. 3
  - There will be a quiz on Wednesday, Sept. 5, on this reading assignment
- E-mail list: 15 of you subscribed to the list so far
  - Had a minor issue with the list but is resolved now
    - 5 point extra credit if done by Friday, Aug. 31
    - 3 point extra credit if done by Wednesday, Sept. 5
- 39 of you have registered for homework roster, of whom 18 submitted homework #1
  - Remember that you need to download and submit homework #1 for full credit!!
  - You need a UT e-ID and password to log-in and download homework
  - If you don't have them request e-id on the web http://www.utexas.edu/eid
- No class next Monday, Sept. 3, Labor day
  - Remember the homework #1 due at 7pm, though…

Why do Physics?

Exp. {
- To understand nature through experimental observations and measurements (Research)

Theory {
- 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

Models, Theories and Laws

- Models: An analogy or a mental image of a phenomena in terms of something we are familiar with
  - 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 ➔ The statement must be found experimentally valid
- Principles: Less general statements of how nature behaves
  - Has some level of arbitrariness

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)
  - Discovery of radioactivity
  - 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?

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 SI (*System Internationale*) was established in 1960
  - Length in meters (*m*)
  - Mass in kilo-grams (*kg*)
  - Time in seconds (*s*)

Definition of Base Units

SI Units	Definitions
1 *m (Length)* = *100 cm*	One meter is the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second.
1 *kg (Mass)* = *1000 g*	It is equal to the mass of the international prototype of the kilogram, made of platinum-iridium alloy kept in International Bureau of Weights and Measure in France.
1 *s (Time)*	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 (C^{133}) atom.

- *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*

Prefixes, expressions and their meanings

- deca (da): 10^{1}
- hecto (h): 10^{2}
- kilo (k): 10^{3}
- mega (M): 10^{6}
- giga (G): 10^{9}
- tera (T): 10^{12}
- peta (P): 10^{15}
- exa (E): 10^{18}
- zetta (Z): 10^{21}
- yotta (Y): 10^{24}

- deci (d): 10^{-1}
- centi (c): 10^{-2}
- milli (m): 10^{-3}
- micro (μ): 10^{-6}
- nano (n): 10^{-9}
- pico (p): 10^{-12}
- femto (f): 10^{-15}
- atto (a): 10^{-18}
- zepto (z): 10^{-21}
- yocto (y): 10^{-24}

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?

Unit 1 = Conversion factor X Unit 2

1 inch	2.54	cm
1 inch	0.0254	m
1 inch	2.54×10^{-5}	km
1 ft	30.3	cm
1 ft	0.303	M
1 ft	3.03×10^{-4}	km
1 hr	60	minutes
1 hr	3600	seconds
And many	More	Here….

Examples for Unit Conversions

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

What do we need to know?

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

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

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

- 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)?

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

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

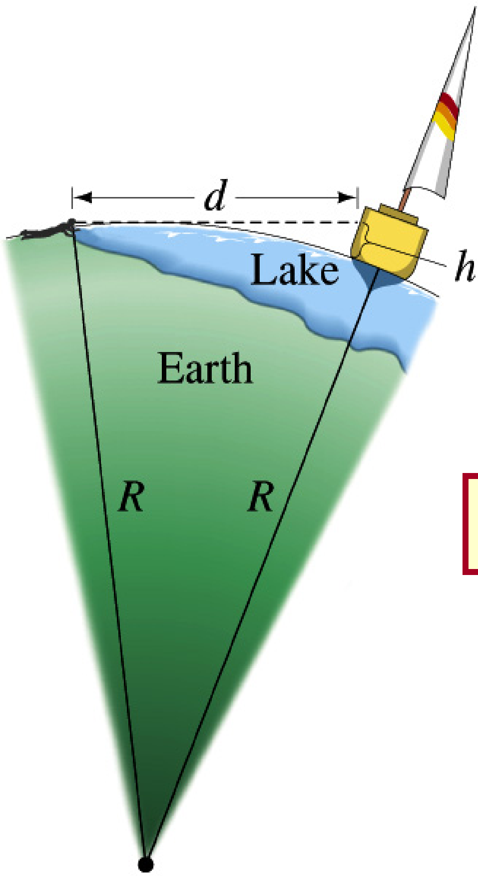
(b) $$65\ \text{mi/h} = (65\ \text{mi})\left(\frac{1.609\ \text{km}}{1\ \text{mi}}\right)\left(\frac{1}{1\ \text{h}}\right) = 104\ \text{km/h}$$

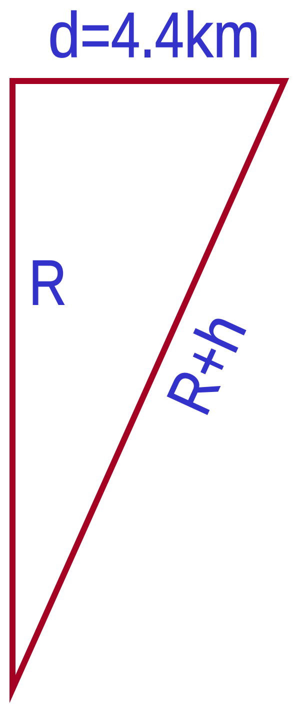
Estimates & Order-of-Magnitude Calculations

- 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; $8x10^7 \sim 10^8$
  - Similar terms: "Ball-park-figures", "guesstimates", etc

Example for estimates (ex1.8)

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





Pythagorian theorem

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

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

Solving for R

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

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

$$= 6500km$$

Uncertainties

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

Stat.{ – Number of measurements

Syst.{
- Quality of instruments (meter stick vs micro-meter)
- 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 value
  - Significant figures: non-zero numbers or zeros that are not place-holders
    - How many significant figures? 34, 34.2, 0.001, 34.001
      - 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 place** in the result, independent of the number of significant digits: 12.001+ 3.1= 15.1
  - Multiplication or Division: Keep the **smallest significant figures** in the result: 12.001 x 3.1 = 37 , because the smallest significant figures is ?.

Dimension and Dimensional Analysis

- An extremely useful concept in solving physical problems
- Good to write physical laws in mathematical expressions
- 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 two algebraic operations; multiplication or division

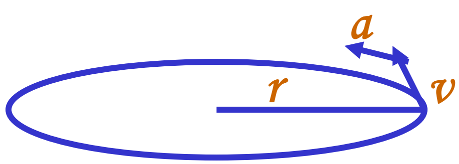
Dimension and Dimensional Analysis

- One can use dimensions only to check the validity of one's expression: Dimensional analysis
  - Eg: Speed $[v] = [L]/[T]=[L][T^{-1}]$
    - *Distance (L) traveled by a car running at the speed V in time T*
    - $L = V*T = [L/T]*[T]=[L]$
- 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 $[v] = [at]$ is dimensionally correct
  - Speed: $[v]$ =L/T
  - Acceleration: $[a]$ =L/T^2
  - Thus, $[at]$ = (L/T^2)xT=LT$^{(-2+1)}$ =LT^{-1} =L/T= $[v]$

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



$$a = kr^n v^m$$

Dimensionless constant — Length — Speed

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

$$-m = -2 \Rightarrow \boldsymbol{m = 2}$$

$$n + m = n + 2 \equiv 1 \Rightarrow \boldsymbol{n = -1}$$

$$a = kr^{-1}v^2 = \frac{v^2}{r}$$