PHYS 1443 – Section 002
Lecture #2

Monday, January 24, 2011

Dr. Jaehoon Yu

- Why do 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

Today's homework is homework #2, due 10pm, Tuesday, Feb. 1!!

Announcements

- Reminder for Reading assignment #1: Read and follow through all sections in appendices A and B by Wednesday
  – There will be a quiz this Wednesday, Jan. 26, on this reading assignment
- Homework
  – 46 out of 58 registered so far... Excellent!!
    - 17 are yet to submit 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
  – Need to resubmit homework #1.. Sorry…
- 39 out of 58 subscribed to e-mail list
  – 5 point extra credit if done by today
  – 3 point extra credit if done by Wednesday, Jan. 26

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, even 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

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

- Denote the precision of the measured values
  - The number 80 implies precision of +/- 1, between 79 and 81
    - If you are sure to +/-0.1, the number should be written 80.0
  - 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 to position "."
      - 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:
      - $31400000=3.14\times10^{7}$
      - $0.00012=1.2\times10^{-4}$

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 number of significant digits** in the result: 12.001 x 3.1 = $\boxed{37}$, because the smallest significant figures is ?.

What does this mean? **The worst precision determines the precision the overall operation!!**

In English? **Can't get any better than the worst measurement!**

Needs for Standards and Units

- Seven basic quantities for physical measurements
  - Length, Mass, Time, Electric Current, Temperature, the Amount of substance and Luminous intensity
- 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 Three Relevant Base Units

SI Units	Definitions
1 *m (Length)* = *100 cm*	One meter is the length of the path traveled by light in vacuum during the 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 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 total of seven base quantities (see table 1-5 on page 7)*
- *There are prefixes that scales the units larger or smaller for convenience (see pg. 7)*
- *Units for other quantities, such as Newtons for force and Joule for energy, for ease of use*

Prefixes, expressions and their meanings

Larger

- 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}

Smaller

- 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 1.3 and 1.4 for Unit Conversions

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

What do we need to know?

$$880\ \mathrm{ft}^2 = 880\ \mathrm{ft}^2 \times \left(\frac{12\mathrm{in}}{1\mathrm{ft}}\right)^2 \left(\frac{0.0254\ \mathrm{m}}{1\ \mathrm{in}}\right)^2$$

$$= 880\ \cancel{\mathrm{ft}^2} \times \left(\frac{0.0929\ \mathrm{m}^2}{1\ \cancel{\mathrm{ft}^2}}\right)$$

$$= 880\ \times 0.0929\ \mathrm{m}^2\ \approx 82\mathrm{m}^2$$

Ex 1.4: Where the posted speed limit is 55 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)?

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

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

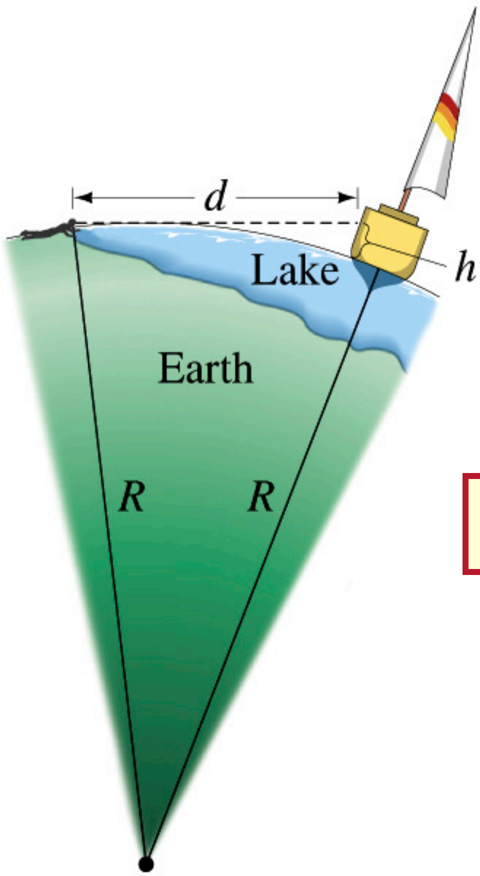
(b) $$55\ \mathrm{mi/h} = (55\ \mathrm{mi})\left(\frac{1.609\mathrm{km}}{1\ \mathrm{mi}}\right)\left(\frac{1}{1\ \mathrm{h}}\right) = 88\ \mathrm{km/hr}$$

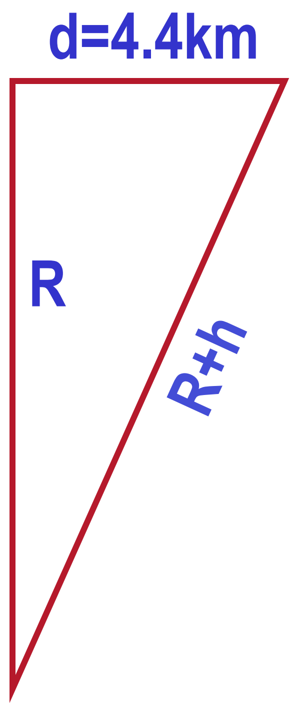
Estimates & Order-of-Magnitude Calculations

- 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; $8\times10^7 \sim 10^8$
  - 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=4.4km 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

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

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

$$= 6500km$$

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 treated as algebraic quantities: Can perform two algebraic operations; multiplication or division

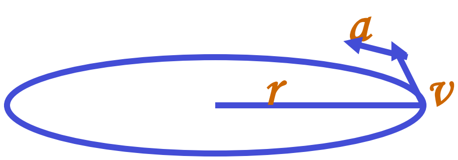
Dimension and Dimensional Analysis

- 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

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

$$-m = -2 \Rightarrow m = 2$$

$$n + m = n + 2 = 1 \Rightarrow n = -1$$

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

Some Fundamentals

- Kinematics: Description of Motion without understanding the cause of the motion
- Dynamics: Description of motion accompanied with understanding the cause of the motion
- Vector and Scalar quantities:
  - Scalar: Physical quantities that require magnitude but no direction
    - Speed, length, mass, height, volume, area, magnitude of a vector quantity, etc
  - Vector: Physical quantities that require both magnitude and direction
    - Velocity, Acceleration, Force, Momentum
    - It does not make sense to say "I ran with velocity of 10miles/hour."
- Objects can be treated as point-like if their sizes are smaller than the scale in the problem
  - Earth can be treated as a point like object (or a particle)in celestial problems
    - Simplification of the problem (The first step in setting up to solve a problem…)
  - Any other examples?

Some More Fundamentals

- Motions:Can be described as long as the position is known at any given time (or position is expressed as a function of time)
  - Translation: Linear motion along a line
  - Rotation: Circular or elliptical motion
  - Vibration: Oscillation
- Dimensions
  - 0 dimension: A point
  - 1 dimension: Linear drag of a point, resulting in a line ➔ Motion in one-dimension is a motion on a line
  - 2 dimension: Linear drag of a line resulting in a surface
  - 3 dimension: Perpendicular Linear drag of a surface, resulting in a stereo object