# PHYS 1441 – Section 001
# Lecture #2

*Tuesday, June 3, 2014*
*Dr. Jaehoon Yu*

- Chapter 1
  - Standards and units
  - Dimensional Analysis
- Chapter 2:
  - One Dimensional Motion
    - Instantaneous Velocity and Speed
    - Acceleration
    - Motion under constant acceleration

# Announcements

- Homework registration
  - 47/66 have registered as of early this morning
    - Only 20 have submitted answers!!
    - You must complete the process all the way to the submission to obtain the free full credit for homework #1!!
    - You need to get approval for enrollment from me so please take an action quickly!
  - Temporary issue with online submission has been resolved➔ Go ahead and submit online
- Reading assignment #1: Read and follow through all sections in appendix A by tomorrow, Wednesday, June 4
- There will be a quiz tomorrow Wednesday, June 4, on this reading assignment and what we have learned up to today!
  - Beginning of the class ➔ Do not be late
  - Bring your calculator but DO NOT input formula into it!
  - You can prepare a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the exam ➔ no solutions or derivations!
    - No additional formulae or values of constants will be provided!

# Special Project #1 for Extra Credit

- Find the solutions for $yx^2-zx+v=0$ ➔ 5 points
  - You cannot just plug into the quadratic equations!
  - You must show a complete algebraic process of obtaining the solutions!
- Derive the kinematic equation $v^2 = v_0^2 + 2a(x - x_0)$ from first principles and the known kinematic equations ➔ 10 points
- You must **show your OWN work in detail** to obtain the full credit
  - Must be in much more detail than in this lecture note!!!
  - Please do not copy from the lecture note or from your friends. You will all get 0!
- Due Thursday, June 5

# 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 fundamental quantities for physical measurements
  - Length, Mass, Time, Electric Current, Temperature, the Amount of substance and the 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 10)*
- *There are prefixes that scales the units larger or smaller for convenience (see T.1-4 pg. 10)*
- *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 | $2.54\times10^{-5}$ | km |
| 1 ft | 30.3 | cm |
| 1 ft | 0.303 | m |
| 1 ft | $3.03\times10^{-4}$ | km |
| 1 hr | 60 | minutes |
| 1 hr | 3600 | seconds |
| And many | More | Here…. |

# Examples 1.4 and 1.5 for Unit Conversions

- Ex 1.4: 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?

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

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

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

Ex 1.5: 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)?

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

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

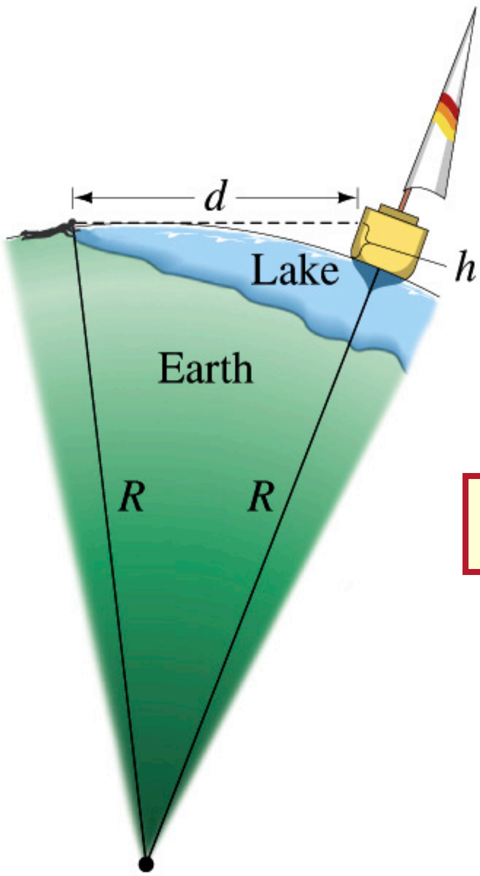
**(b)** $$55\ \text{mi/h} = (55\ \text{mi})\left(\frac{1.609\text{km}}{1\ \text{mi}}\right)\left(\frac{1}{1\ \text{h}}\right) = 88\ \text{km/hr}$$

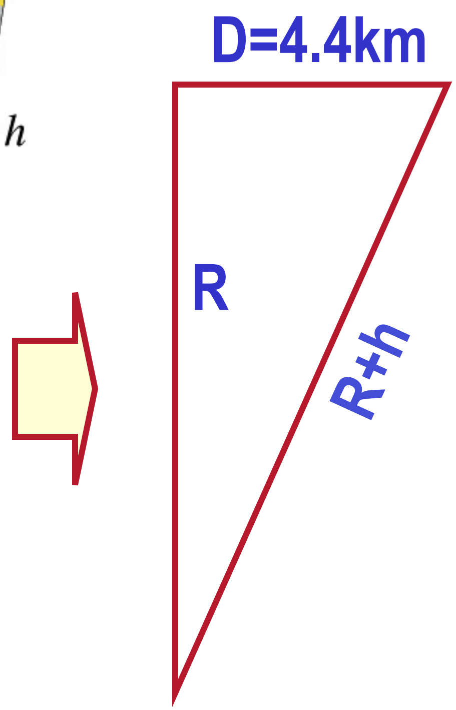
# Estimates & Order-of-Magnitude Calculations

- 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; $8\times10^7 \sim 10^8$
  - Similar terms: "Ball-park-figures", "guesstimates", etc

# Problem # 34

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**

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

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

$$= 6500km$$

**Real R=6380km**

# 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

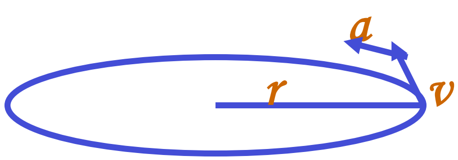
# Dimension and Dimensional Analysis cnt'd

- 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 $m$?




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

$$a = \underbrace{k}_{\text{Dimensionless constant}}\underbrace{r}_{\text{Length}}{}^{n}\,\underbrace{v}_{\text{Speed}}{}^{m}$$

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

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

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