PHYS 1441 – Section 001 Lecture #2

Tuesday, June 9, 2015

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
  - 47/69 have registered as of early this morning
    - Only 25 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!
- Reading assignment #1: Read and follow through all sections in appendix A by tomorrow, Wednesday, June 10
- There will be a quiz tomorrow Wednesday, June 10, 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!
    - Cell phones or any types of computers cannot replace a calculator!
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the quiz
  - No derivations, word definitions or solutions of any problems !
  - 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 11

Highest Energy of 13 TeV Collisions

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 (it has been 55 yrs!)
  - **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	2.54×10^{-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 1.4 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) $$55\ \text{mi/h} = (55\ \text{mi})\left(\frac{1609\ \text{m}}{1\ \text{mi}}\right)\left(\frac{1}{1\ \text{h}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right) = 25\ \text{m/s}$$

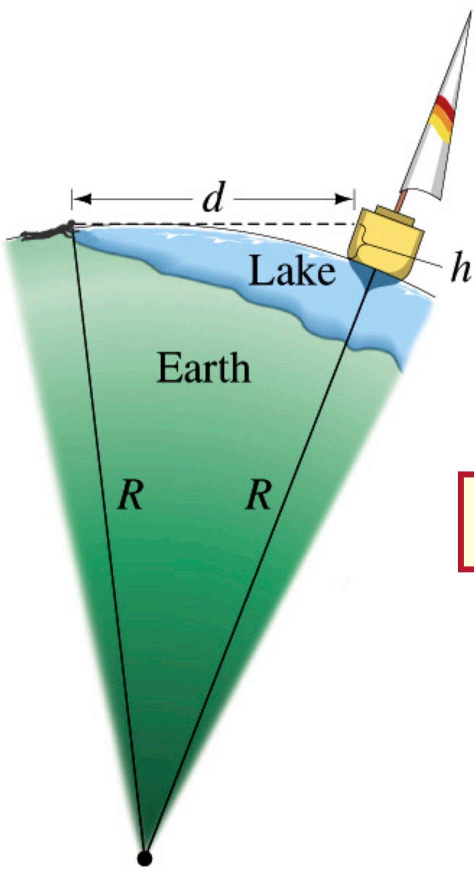
(b) $$55\ \text{mi/h} = (55\ \text{mi})\left(\frac{1.609\text{km}}{1\ \text{mi}}\right)\left(\frac{1}{1\ \text{h}}\right) = 88\ \text{km/hr}$$

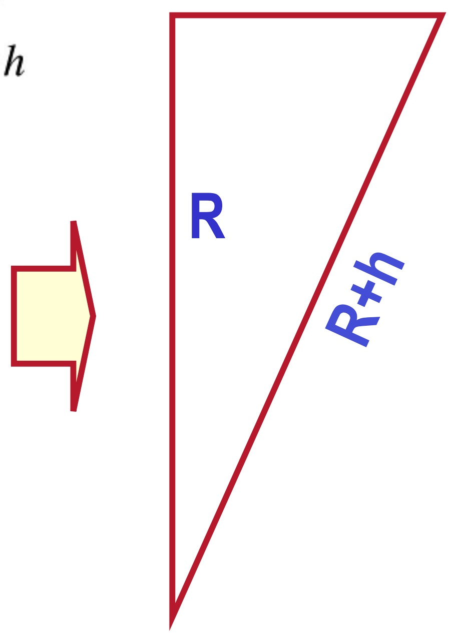
Estimates & Order-of-Magnitude Calculations

- 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

Back of the Chapter 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

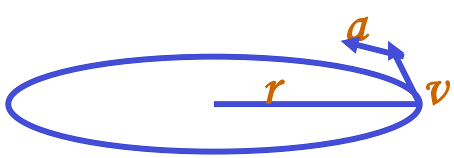
Dimension and Dimensional Analysis cnt'd

- 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?



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

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

Dimensionless constant

Length

Speed

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

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

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

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 the 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

Displacement, Velocity and Speed

One dimensional displacement is defined as:

$$\Delta x \equiv x_f - x_i$$

A vector quantity

Displacement is the difference between initial and final potions of the motion and is a vector quantity. How is this different than distance?

Unit? **m**

The average velocity is defined as: $$v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t} \equiv \frac{\text{Displacement}}{\text{Elapsed Time}}$$

Unit? **m/s**

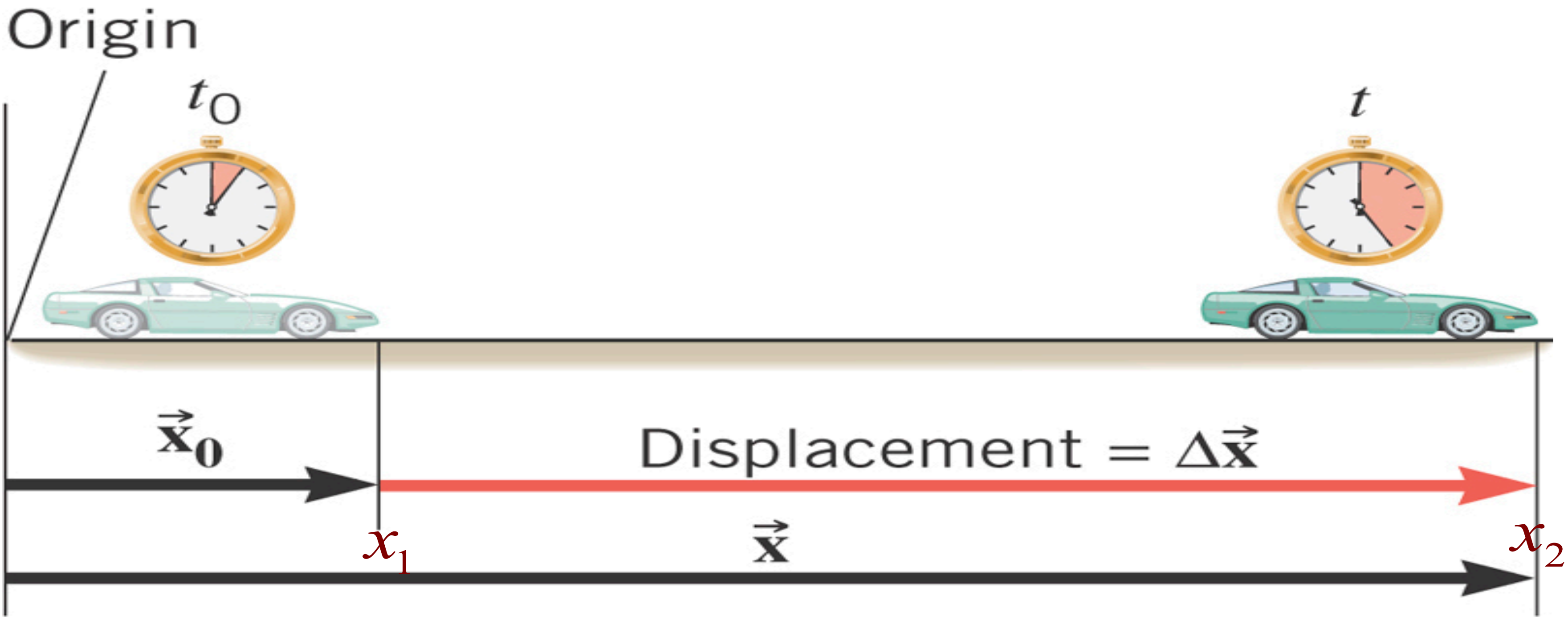
A vector quantity

Displacement per unit time in the period throughout the motion

The average speed is defined as: $$v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Elapsed Time}}$$

Unit? **m/s**

A scalar quantity



What is the displacement? $\Delta x = x_2 - x_1$

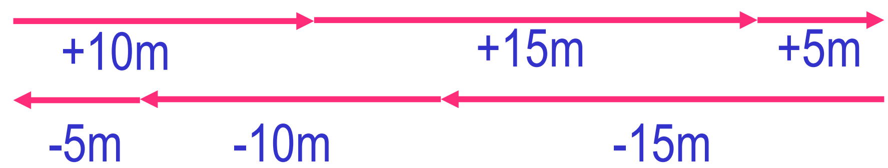
How much is the elapsed time? $\Delta t = t - t_0$

Difference between Speed and Velocity

- Let's take a simple one dimensional translation that has many steps:

Let's call this line as X-axis

Let's have a couple of motions in a total time interval of 20 sec.



Total Displacement: $\Delta x \equiv x_f - x_i = x_i - x_i = 0(m)$

Average Velocity: $v_x \equiv \dfrac{x_f - x_i}{t_f - t_i} = \dfrac{\Delta x}{\Delta t} = \dfrac{0}{20} = 0(m/s)$

Total Distance Traveled: $D = 10 + 15 + 5 + 15 + 10 + 5 = 60(m)$

Average Speed: $v \equiv \dfrac{\text{Total Distance Traveled}}{\text{Total Time Interval}} = \dfrac{60}{20} = 3(m/s)$