PHYS 1441 – Section 002
Lecture #3

Monday, Sept. 13, 2010

Dr. Jaehoon Yu

- Estimate and Order of Magnitude
- Dimensional Analysis
- Some Fundamentals
- One Dimensional Motion
  - Displacement
  - Speed and Velocity
  - Acceleration
  - Motion under constant acceleration

Today's homework is homework #2, due 10pm, Tuesday, Sept. 21!!

Announcements

- Homework registration
  - 75/80 registered
    - Of them only 63 submitted the first homework!
  - If you haven’t registered yet, please do so ASAP.
- E-mail subscription
  - 64/80 subscribed!
  - A test message will be sent out later today.
    - Would like you to confirm by replying ONLY to me!!
    - Please check the “TO” address before sending the reply.
- 1st term exam
  - Non-comprehensive
  - Time: 1 – 2:20pm, Wednesday, Sept. 22
  - Coverage: Appendices A.1 – A.8 and CH1.1 – what we finish coming Monday, Sept. 20

Reminder: Special Problems for Extra Credit

- Derive the quadratic equation for yx^2-zx+v=0 ➔ 5 points
- Derive the kinematic equation $v^2 = v_0{}^2 + 2a\left(x - x_0\right)$ 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 the upcoming lecture note!!!
- Due Monday, Sept. 27

How to study for this course?

- Keep up with the class for comprehensive understanding of materials
  - Come to the class and participate in the discussions and problems solving sessions
  - Follow through the lecture notes
  - Work out example problems in the book yourself without looking at the solution
  - Have many tons of fun in the class!!!!!
- Keep up with the homework to put the last nail on the coffin
  - One can always input the answers as you solve problems. Do not wait till you are done with all the problems.
  - Form a study group and discuss how to solve problems with your friends, then work the problems out yourselves!
- Prepare for upcoming classes
  - Read the textbook for the material to be covered in the next class
- The extra mile
  - Work out additional problems in the back of the book starting the easiest problems to harder ones

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….

Estimates & Order-of-Magnitude Calculations

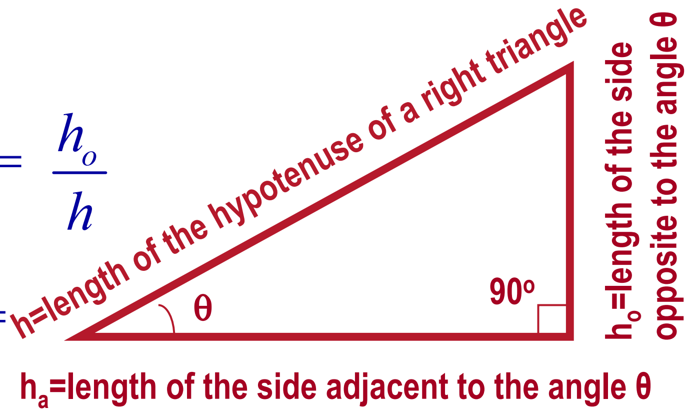
- Estimate = Approximation
  - Useful for rough calculations to determine the necessity of higher precision
  - Usually done under certain assumptions
  - Might require modification of assumptions, if higher precision is necessary
- Order of magnitude estimate: Estimates done to the precision of 10s 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

Trigonometry Reminders

- Definitions of sinθ, cosθ and tanθ

$$\sin\theta = \frac{\text{Length of the opposite side to }\theta}{\text{Length of the hypotenuse of the right triangle}} = \frac{h_o}{h}$$

$$\cos\theta = \frac{\text{Length of the adjacent side to }\theta}{\text{Length of the hypotenuse of the right triangle}} = \frac{h_a}{h}$$



$$\tan\theta = \frac{\text{Length of the opposite side to }\theta}{\text{Length of the adjacent side to }\theta} = \frac{h_o}{h_a}$$

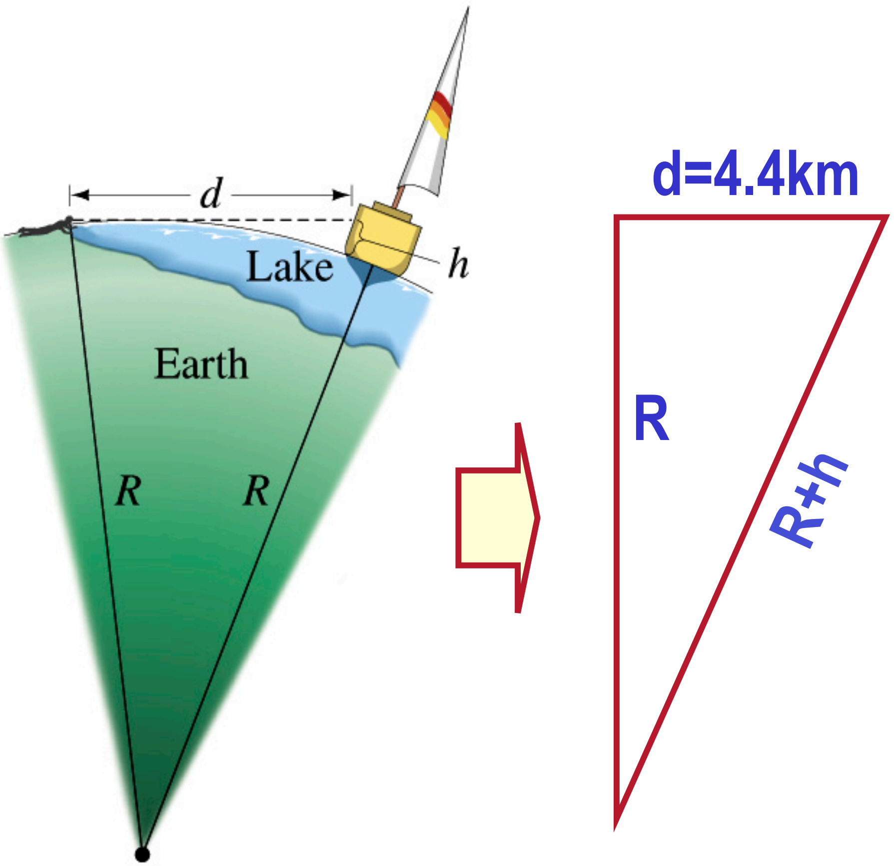
$$\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{\frac{h_o}{\cancel{h}}}{\frac{h_a}{\cancel{h}}} = \frac{h_o}{h_a}$$

Pythagorian theorem: For right triangles

$$h^2 = h_o^2 + h_a^2 \Rightarrow h = \sqrt{h_o^2 + h_a^2}$$

Example for estimates using trig..

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

- A very 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
- These symbols can be treated as variables in algebra
  - Can multiply or divide them out

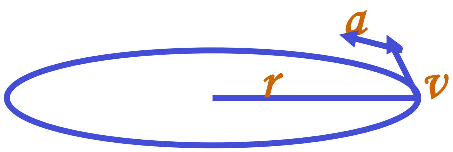
Dimension and Dimensional Analysis

- One can use dimensions only to check the validity of one's expression: Dimensional analysis
  - Eg: Speed $[v] = [\mathcal{L}]/[\mathcal{T}]=[\mathcal{L}][\mathcal{T}^{-1}]$
    - *Distance* ($\mathcal{L}$) *traveled by a car running at the speed* $\mathcal{V}$ *in time* $\mathcal{T}$
    - $\mathcal{L} = \mathcal{V}*\mathcal{T} = [\mathcal{L}/\mathcal{T}]*[\mathcal{T}]=[\mathcal{L}]$
- More general expression of dimensional analysis is using exponents: eg. $[v]=[\mathcal{L}^n\mathcal{T}^m] =[\mathcal{L}][\mathcal{T}^{-1}]$ *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

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

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

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

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

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
- Space 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 straight 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**

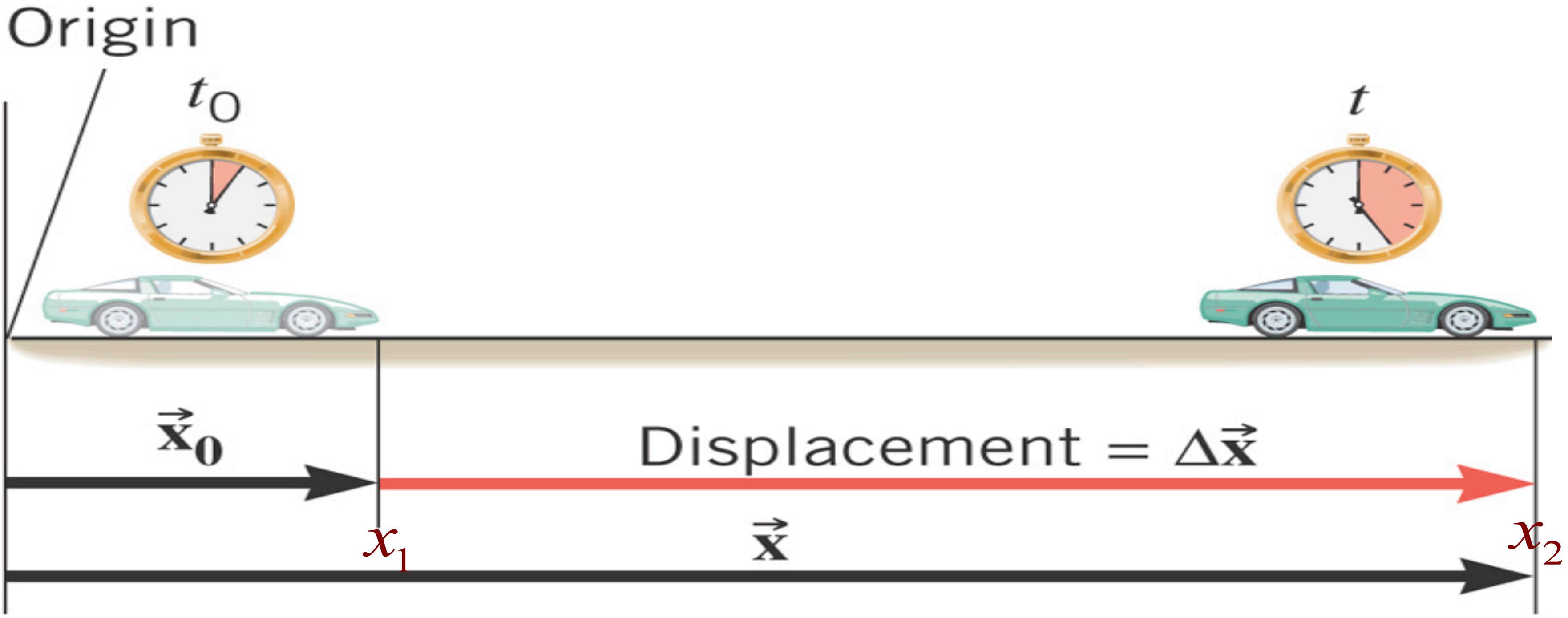
A vector quantity

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? $\Delta t = t - t_0$

Displacement, Velocity and Speed

One dimensional displacement is defined as:

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

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

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

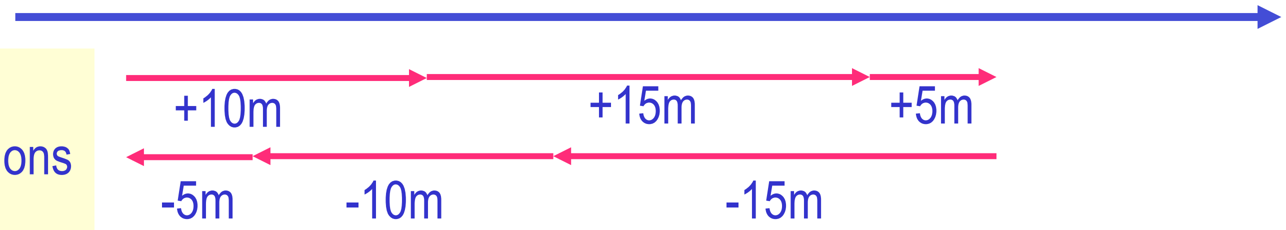
Can someone tell me what the difference between speed and velocity is?

Difference between Speed and Velocity

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

Let's call this line 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: $v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t} = \frac{0}{20} = 0(m/s)$

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

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