PHYS 1443
Lecture #2

Wednesday, Aug. 25, 2004
Venkat

1. Dimensional Analysis
2. Fundamentals
3. One Dimensional Motion
   - Displacement
   - Velocity and Speed
   - Acceleration
   - Motion under constant acceleration

Announcements

- Homework #2 is due 1pm, Wednesday, September 1st 2004
- Reading assignment is
  - Appendix A
  - Appendix B
- Quiz on September 1st will cover both appendices

Uncertainties

- Physical measurements have limited precision, however good it is, 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 values
  - Significant figures: non-zero numbers or zeros that are not place-holders
    - 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:
      - $31400000=3.14\times10^{7}$
      - $0.00012=1.2\times10^{-4}$

Significant Figures

- Operational rules:
  - Addition or subtraction: Keep the <u>smallest number of decimal place</u> in the result, independent of the number of significant digits: 12.001+ 3.1= ???
  - Multiplication or Division: Keep the <u>smallest significant figures</u> in the result: 12.001 x 3.1 = ???, 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 algebraic operations, addition, subtraction, multiplication or division

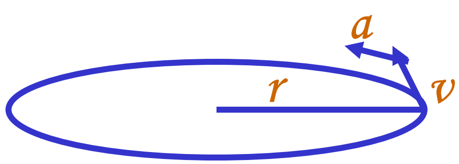
Dimension and Dimensional Analysis

- 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 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:

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

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

Average velocity is defined as:

$$v_x \equiv \frac{x_f - x_i}{t_f - t_i} = \frac{\Delta x}{\Delta t}$$

Displacement per unit time in the period throughout the motion

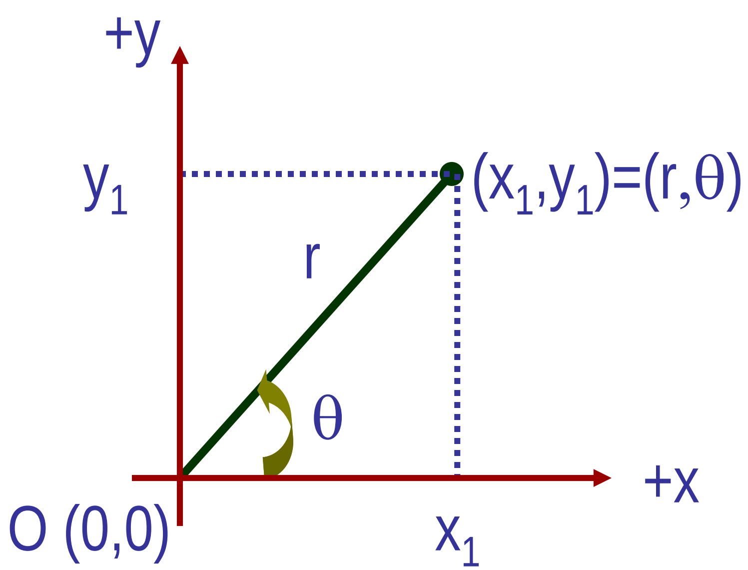
Average speed is defined as:

$$v \equiv \frac{\text{Total Distance Traveled}}{\text{Total Time Spent}}$$

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

Coordinate Systems

- Makes it easy to express locations or positions
- Two commonly used systems, depending on convenience
  - Cartesian (Rectangular) Coordinate System
    - Coordinates are expressed in (x,y)
  - Polar Coordinate System
    - Coordinates are expressed in (r,θ)
- Vectors become a lot easier to express and compute



How are Cartesian and Polar coordinates related?

$$x_1 = r\cos\theta \qquad r = \sqrt{\left(x_1^{\,2} + y_1^{\,2}\right)}$$

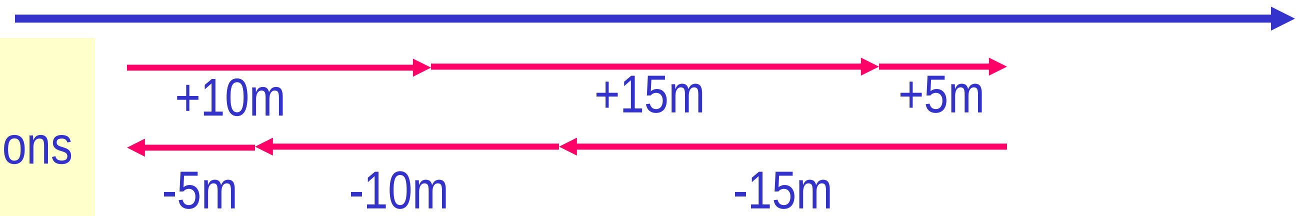
$$y_1 = r\sin\theta \qquad \tan\theta = \frac{y_1}{x_1}$$

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: $\Delta x \equiv x_f - x_i = x_i - x_i = 0$

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

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

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