Lecture 2, Blackboard #1

(1)

## Classical Mechanics

- Motion of a particle
- Position vs. time
  - ⇒ Velocity *
  - ⇒ Acceleration
  - ↳ Translation / Rotation

## Ideal Particle

- Classical physics concept
- Point-like object — No size
  - ↳ Except Rotations
- Mass $\neq 0$
- Real Particles: size, charge, spin

## Newtonian Mechanics

3-Dimensional Space
Euclidean Geometry: $\Delta = 180°$ } Observations, Experiments.

**Time**

Absolute: Clock rates independant of position or velocity.

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Euclidean Geometry + Absolute Time } Classical/Newtonian Mechanics

**Principia Mathematica** (1687)

Laws of Motion + Gravity

## Measurements

Length: meters
Time: seconds } SI
Mass: kg

## Kinematics

- describes geometry of motion. How?

$$\text{position} \xrightarrow{\text{time}} \text{velocity} \xrightarrow{\text{time}} \text{acceleration}$$

- dynamics: Forces
  - Why?

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## Classical Mechanics

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## Newtonian Mechanics

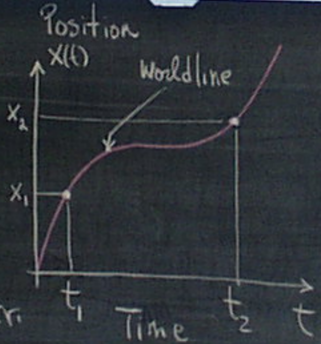
3-Dimensional Space
Euclidean Geometry : $\Delta = 180°$ } Observations / Experiments

### Time

Absolute: clock rates independent of position or velocity.

## Position: Moving Particle

Curve : 1-coordinate
Surface : 2-coordinates
Volume : 3-coordinates
Position vs Time : Complete Descr.



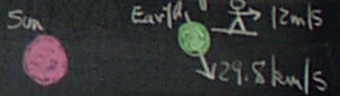

## Speed

Average Speed = $\dfrac{\text{distance travelled}}{\text{time taken}}$ $\dfrac{[L]}{[T]}$

$s = \dfrac{d}{t} > 0$ (Always) m/s, f/s

Speeds: Light $3 \times 10^{8}$ m/s
Sound 300
Person 12
Glacier $10^{-6}$ Continent: $10^{-8}$

Motion and Speed are relative.
Depend on Reference Frame




Lecture 2, Blackboard #2

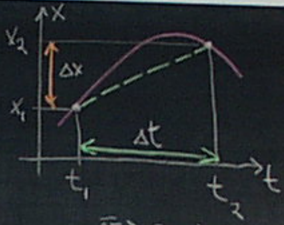
## Average Velocity

- 1-Dimension; St. line Motion
- If $x=f(t)$ changes $\Rightarrow$ particle moves.

$\Rightarrow$ $\boxed{\text{velocity}}$

Av Velocity $v_{av} = \bar{v} = \dfrac{\text{displacement}}{\text{change in time}} = \dfrac{x_2-x_1}{t_2-t_1} = \dfrac{\Delta x}{\Delta t}$

= Slope of line connecting $(x_1,t_1)$ and $(x_2,t_2)$




$\bar v > 0$ + x-axis

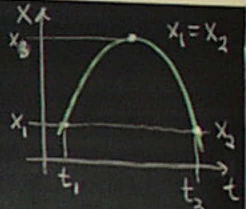
$\bar v < 0$ − x-axis

Average Speed: $\dfrac{\text{distance trav.}}{\text{time}}$

Average Velocity: $\dfrac{\text{displacement}}{\text{time}}$

$\bar S_{12} = \dfrac{2(x_3-x_1)}{t_2-t_1} \neq 0$

$\bar v_{12} = \dfrac{x_2-x_1}{t_2-t_1} \equiv 0$ !!!




## Instantaneous Velocity

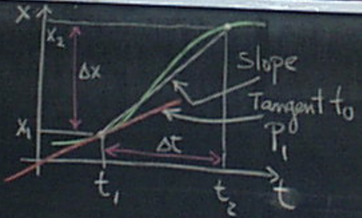
$\overline{P_1P_2}$ Slope $= \bar v_{av}(t_1 \to t_2)$

$\bar v = \dfrac{x_2-x_1}{t_2-t_1} = \dfrac{\Delta x}{\Delta t}$

What is velocity exactly at $P_1$?

Reduce $\Delta x$ and $\Delta t$

Inst. Velocity $\equiv$ Velocity limit as $\Delta T \to 0$!

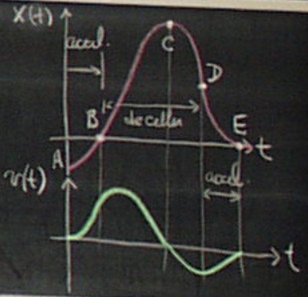



$v(t) = \lim\limits_{\Delta t \to 0} \dfrac{\Delta x}{\Delta t} = \dfrac{dx}{dt}$

velocity = time derivative of the position function

= first derivative w.r.t. t

Invariant to coord. system if no relative motion.




Lecture 2, Blackboard #3

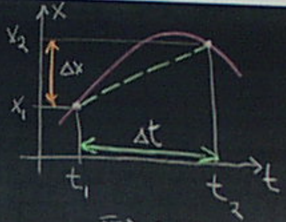
## Average Velocity

- 1-Dimension; St. line Motion
- If $x = f(t)$ changes $\Rightarrow$ particle moves.

$\Rightarrow$ $\boxed{\text{velocity}}$

Av. Velocity $v_{av} = \bar{v} = \frac{\text{displacement}}{\text{change in time}} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$

= Slope of line connecting $(x_1 t_1)$ and $(x_2 t_2)$




$\bar{v} > 0$ + x-axes

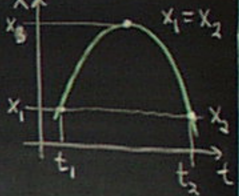
$\bar{v} < 0$ − x-axis

Average Speed: $\frac{\text{distance trav.}}{\text{time}}$

Average Velocity: $\frac{\text{displacement}}{\text{time}}$

$\bar{S}_{12} = \frac{2(x_3 - x_1)}{t_2 - t_1} \neq 0$

$\bar{v}_{12} = \frac{x_2 - x_1}{t_2 - t_1} \equiv 0$ !!!




## Example: Particle Moving along a st. line

$x(t) = 2.1t^2 + 2.80$ (m) t in s

What are $\bar{v}$ and $v(t)$ at $t = 3, 5$ s?

$t_1 = 3$ $\quad x_1 = 2.1(3)^2 + 2.8 = 21.7$ m

$t_1 = 5$ $\quad x_1 = 2.1(5)^2 + 2.8 = 55.3$ m

$v_{av}: \bar{v} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{55.3 - 21.7}{5 - 3} = 16.8$ m/s

$x = 2.1t^2 + 2.80$ ①

$x + \Delta x = 2.1(t + \Delta t)^2 + 2.80$ ②

$x + \Delta x = 2.1t^2 + 4.2t(\Delta t) + 2.1(\Delta t)^2 + 2.80$ ③

$\Delta x = 4.2t(\Delta t) + 2.1(\Delta t)^2$

$\bar{v} = \frac{\Delta x}{\Delta t} = 4.2t + \cancel{2.1(\Delta t)}$

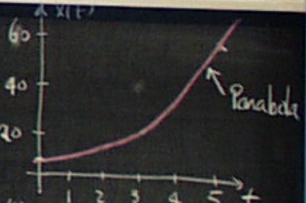
$v(t) = \lim_{\Delta t \to 0} = 4.2t \equiv \frac{dx}{dt}$

Calculus

$v(5) = 21.0$ m/s

$v(3) = 12.6$ m/s

$\Big]$ 16.8




## Constant Velocity Motion: Special Case

Slope of $x(t)$ = constant

$\bar{v} = \frac{\Delta x}{\Delta t} = \text{Const} = v_0$ $\quad$ $v(t) = \frac{dx}{dt} = \text{Const} = v_0$

Average = Instantaneous.

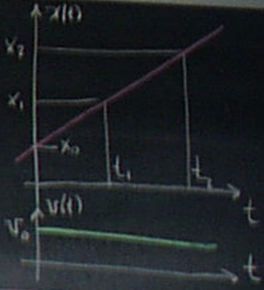
$\bar{v} = v(t) = v_0$

Suppose $x(t) = x_0$ at $t = 0$

$\bar{v} = v_0 = \frac{x(t) - 0}{t - 0}$

$$\boxed{x(t) = x_0 + v_0 t}$$

Eq. of St. line
1-D Motion for
Const. $v(t) = v_0$

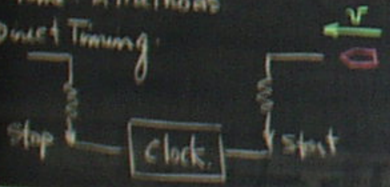



## Speed of a Bullet

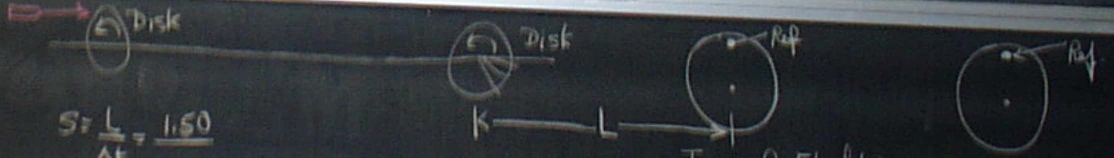
Distance: $L = 1.50\,\text{m} \pm .01$

Time: 2 Methods

Direct Timing:




$S = \frac{L}{\Delta t} = \frac{1.50}{\phantom{x}}$




Time-of-Flight:

$\Delta t = \frac{\Delta\theta}{360} \times$

$S = \frac{L}{\Delta t} = \frac{1.50}{\phantom{x}}$