Time Scales

1s ~ Human heart beat

1ms ~ Human reaction times

1μs ~ Chemical Reactions

Velocities

1 m/s ~ Walking

4 m/s ~ Running

20 m/s ~ 5 miles / hour

"Mach-1" V_{sound} ~ 340 m/s

$V_{\text{air molecule}}$ ~ 340 m/s

$V_{\text{normal plane}} \sim \frac{1}{3} V_s \sim 100\,m/s$

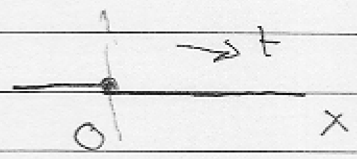
V_{bullet} ~ mach 2-3 ~ 600 m/s

$C \sim 3 \times 10^8\,m/s$

speed of Light

Displacement vs Distance

- Coordinate System measure position relative to an origin



(Table In Class)

- Displacement is the change in position over a time period

$$\Delta x = x_2 - x_1$$

Ex: 1 Professor moves to right two mete

$$\Delta x = 2m - 0$$

Ex: 2 Professor moves to left, starting from 3m to right and arrives at 1m to left of origin

$$\Delta x = x_2 - x_1$$

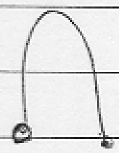
$$= (-1m) - (3m) = -4m$$

Obvious we moved four meters to left

* minus sign indicates leftward motion

Distance Travelled = 4m

Ex 3 : Tennis ball thrown up



Q1: Displacement = ?
Q2: Distance travelled = ?
Q3: Approximate Speed = ?

A1: 0
A2: ~2m
A3: ~2m/s

Average Velocity + Average Speed

$$\text{ave speed} = \frac{\text{distance travelled}}{\text{time elapsed}}$$

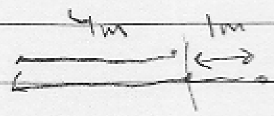
$$\bar{S} = \frac{d}{\Delta t} \quad \text{where } \Delta t = t_2 - t_1$$

$$\text{ave velocity} = \frac{\text{displacement}}{\text{time elapsed}}$$

$$\bar{V} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

Ex 1 : Prof Runs to Left for 1.5s, and reaches 4m to left of origin, having started 1m to right

ave velocity $= \frac{\Delta x}{\Delta t} = \frac{(-4m)-(1m)}{1.5s} = -2.66 \frac{m}{s}$



Ex2: Professor throws up ball. It rises 1.5m and falls back in 1.5s

estimate ave Spead : $\frac{\text{distance travelled}}{\text{time}} = \frac{3m}{1.5s} = 2m/$

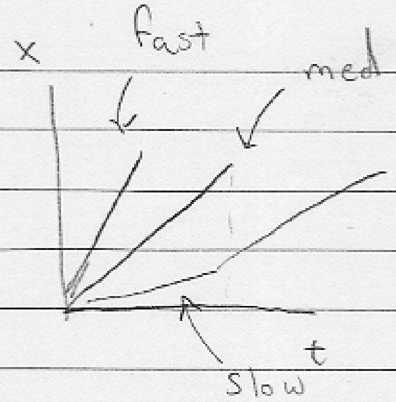
ave velocity : $\frac{\text{displacement}}{\text{time}} = \frac{0}{1.5s} = 0$

$\boxed{\text{Constant Velocity \& Position vs. Time}}$

Professor runs to the right @ constant velocity v. At each instant in time we can determine his position. Assume Proffessor starts at the origin.

$V = \frac{X(t)}{t}$

$X(t) = V t$ Equation of Motion



v = slope of x vs. t

Now often professor does not start at time zero or at the origin

$$V = \frac{\Delta x}{\Delta t}$$

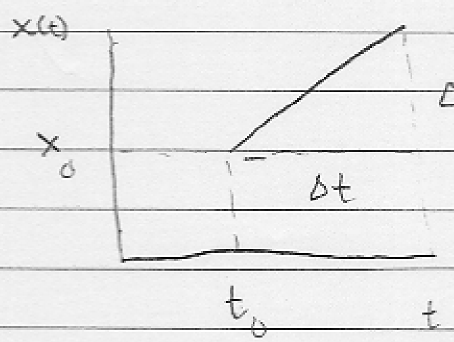
Assume Professor starts at position x_0 at time t_0

$$V = \frac{x - x_0}{t - t_0}$$

$$V(t - t_0) = x - x_0 \implies \boxed{x(t) = \underbrace{x_0}_{\text{starting pos}} + V(t - \underbrace{t_0}_{\text{Starting time}})}$$

equation of motion

Position vs. Time for constant velocity



$$V = \frac{\Delta x}{\Delta t} = \text{slople}$$

Example:

Professor runs to the right at 2m/s for 1.5s and then walks at 1m/s for four more seconds to left
speed

- Sketch the Professors Position vs. Time curve
- Write down the EOM for the professor
- What is the ave velocity? What is the average speed?

During the first period:

$$x(t) = \cancel{x_0} + v(t - \cancel{t_0}) = vt = (2m/s)\,t$$

During the second period:

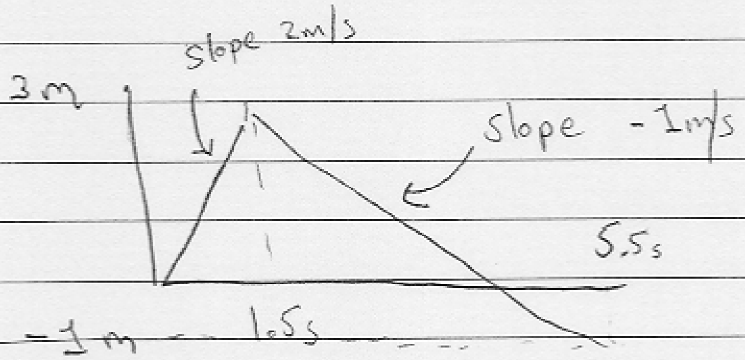
$$x(t) = x_0 + v(t - t_0)$$

x_0 is the place where professer is at $1.5s = t_0$, since he was

$$x_0 = (2m/s)(1.5s) = 3m$$

$$x(t) = 3m - 1m/s\,(t - 1.5s)$$

So Graph

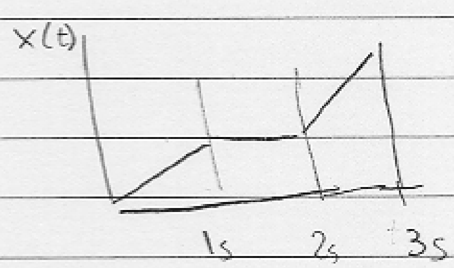


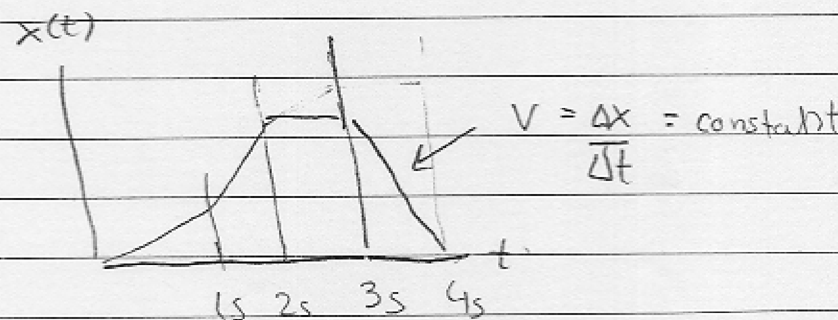
ave velocity = $\frac{x_f - x_i}{t_f - t_i} = \frac{(-1m) - 0}{5.5s} = -0.18$ m/s

ave spead = $\frac{3m + 4m}{5.5s} = 1.27$ m/s

Instantaneous Velocity

More examples:



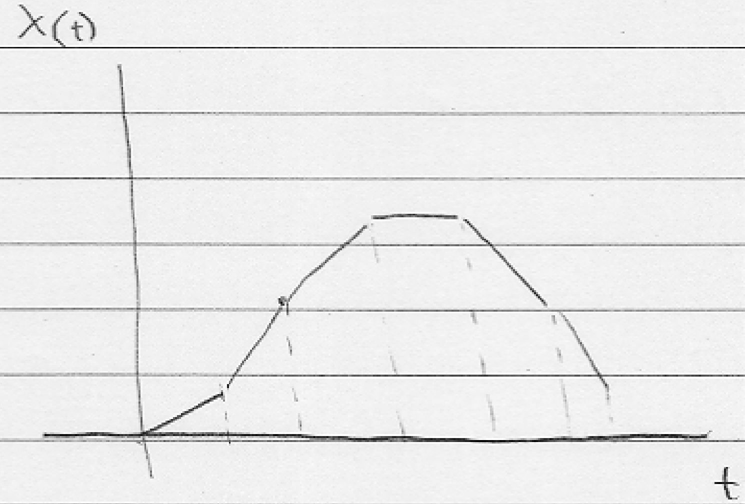


three steps

four steps

- Discussed What graphs mean

Now as we increase the number of Steps more and more



- Position becomes a continuous curve : x(t)
- The velocity in each step (V(t)) is the slope

$$V = \frac{\Delta x}{\Delta t} \rightarrow \boxed{\frac{dx}{dt} = \text{derivative of pos vs. time} \\ = V(t)}$$

the velocity in each step or "instantaneous velocity"

The differential form

Acceleration

→ Things change velocity all the time

$$\text{ave accel} = \frac{\text{Change in } v}{\text{elapsed time}}$$

$$\bar{a} = \frac{v_2 - v_1}{t_2 - t_1}$$

$$\bar{a} = \frac{\Delta v}{\Delta t}$$

Typical Accelerations,

(1) Acceleration due to gravity $= 1g = 9.8 m/s^2$

(2) Sports Car $0 \to 60$ mph in 6 secs

$$a = \frac{60 \text{ mph}}{6s} \sim \frac{30 m/s}{6s} \sim \frac{5m}{s^2} \qquad a \sim \frac{1}{2} g$$

Units meters per sec per second $\frac{m}{s^2} = \frac{m/s}{s}$

(3) Fighter Plane $\sim$ several g

(4) a_{blackout} $\sim 4g$