Time Scales

1s ~ Human heart beat

1ms ~ Human reaction times

1μs ~ Chemical Reactions

Velocities

1m/s ~ Walking

4m/s ~ Running

20 m/s ~ 5 miles/hour

"Mach-1" $v_{\text{sound}}$ ~ 340 m/s

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

$v_{\text{normal plane}}$ $\sim \frac{1}{3}v_{5}$ ~ 100 m/s

$v_{\text{bullet}}$ ~ mach 2-3 ~ 600 m/s

$c$ ~ $3 \times 10^8$ m/s

Speed of Light
Displacement vs Distance

- Coordinate System - measure position relative to an origin
  \[ x \rightarrow t \]
  \[ 0 \]
  (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 meters
  \[ \Delta x = 2 \text{m} - 0 \]

Ex: 2 Professor moves to left, starting from 3m to right and arrives at 1m to left of origin
  \[ \Delta x = x_2 - x_1 \]
  \[ = (-1 \text{m}) - (3 \text{m}) = -4 \text{m} \]

\[ \rightarrow \text{Obvious we moved four meters to left} \]

* 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

\[ \text{Average speed} = \frac{\text{distance travelled}}{\text{time elapsed}} \]

\[ \overline{S} = \frac{d}{\Delta t} \text{ where } \Delta t = t_2 - t_1 \]

Average velocity = \[
\overline{V} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}
\]
Ex 1: Prof runs to left for 1.5s, and reaches 4m to left of origin, having started 1m to right

\[
\text{ave velocity} = \frac{\Delta x}{\Delta t} = \frac{(-4m) - (1m)}{1.5s} = -2.67 m/s
\]

Ex 2: Professor throws up ball. It rises 1.5m and falls back in 1.5s.

estimate ave speed : distance travelled = 3m - 2m = 1m

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

[Constant Velocity & Position vs. Time]

Professor runs to the right. At each instant in time we can determine his position. Assume Professor starts at the origin. \( V = x(t) \)

\[
x(t) = V \cdot t \quad \text{Equation of Motion}
\]
Now often professor does not start at time zero or at the origin. Assume professor starts at position \( x_0 \) at time \( t_0 \).

\[
V = \frac{\Delta x}{\Delta t}
\]

\[
V = \frac{x-x_0}{t-t_0}
\]

\[
V(t-t_0) = x-x_0 \Rightarrow \quad x(t) = x_0 + V(t-t_0)
\]

Position vs. Time for constant velocity

\[
V = \frac{\Delta x}{\Delta t} = \text{Slope}
\]
Example:

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

- Sketch the Professor’s Position Vs. Time curve.
- Write down the EOM for the professor.
- What is the average velocity? What is the average speed?

During the first period:

\[ x(t) = x_0 + V(t - t_0) = Vt = (2 \text{ m/s}) t \]

During the second period:

\[ x(t) = x_0 + V(t - t_0) \]

\( x_0 \) is the place where professor is at \( t = t_0 \), since he was.

\[ x_0 = (2 \text{ m/s}) (1.5 s) = 3 \text{ m} \]

\[ x(t) = 3 \text{ m} - 1 \text{ m/s} (t - 1.5 s) \]
So Graph

\[ \text{slope } 2 \text{ m/s} \]

\[ 3 \text{ m} \] \quad \text{slope } -1 \text{ m/s} \]

\[ -1 \text{ m} \quad 5.5 \text{ s} \]

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

ave speed = \( \frac{3 \text{ m} + 4 \text{ m}}{5.5 \text{ s}} = 1.27 \text{ m/s} \)

Instantaneous Velocity

More examples: \( x(t) \)

\[ x(0) \quad 1 \text{ s} \quad 2 \text{ s} \quad 3 \text{ s} \]

\[ 1 \text{ s} \quad 2 \text{ s} \quad 3 \text{ s} \quad 4 \text{ s} \]

three steps \quad few steps

- Discussed what graphs mean
Now as we increase the number of steps more and more

\[ x(t) \]

- Position becomes a continuous curve: \( x(t) \)

- The velocity in each step is the slope

\[ v = \frac{\Delta x}{\Delta t} \]

\[ \frac{dx}{dt} = \text{derivative of pos vs. time} \]

\[ = v(t) \]

The differential form

The velocity in each step or "instantaneous velocity"
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 = \(1g = 9.8 \text{ m/s}^2\)

2. Sports car 0 \(\rightarrow\) 60 mph in 6 sec

\[
a = \frac{60 \text{ mph}}{6 \text{ s}} \approx \frac{30 \text{ m/s}}{6 \text{ s}} = \frac{5 \text{ m}}{8 \text{ s}^2} \approx \frac{1 \text{ g}}{2}
\]

Units: meters per sec per second \(\frac{\text{m}}{\text{s}^2}\)
3. Fighter Plane ~ several g
4. a blackout ~ 4 g