**Motion: Acceleration**

How do we change velocity? How can we describe changes in velocity?

**Day 3**
- Get your clickers ready!
- Motion
  - Position, velocity
  - Acceleration

**Reminders:**
- HW 1 due tonight
- Helproom today, this and Monday

Next up: finish acceleration, move on to force

**Reading Quiz (Sections 1.1, 1.2)**
1. Which carries more information about motion?
   - a. speed
   - b. velocity
   - c. Neither, they are the same

2. Acceleration:

3. ...

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**Summary**

**Last time:**
- Scalars: Distance and Speed
- Vectors: Position and velocity
  - Speed = Distance covered / Time taken

Velocity: \( v = \frac{\Delta x}{\Delta t} \)

Graphs: \( x \) vs \( t \) and \( v \) vs \( t \)

**Today:**
- Graphs: relationship between position and velocity graphs
- Acceleration
- Equations of motion
  - Constant velocity
  - Constant acceleration
- Changing units

**Speed and velocity question**

1. You are driving 60 miles per hour north.
2. You are driving 60 miles per hour.
   
   a. both give your speed, can’t tell your velocity.
   b. 2. gives speed, 1. gives velocity.
   c. both are giving your velocity.
   d. 2 gives velocity, 1. gives your speed.

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**Tricky speed and velocity question**

I start in Boulder and drive 20 miles west to Nederland in 40 mins. When I get to Ned I go round the roundabout and head straight back to Boulder. Its downhill so I only take 20 mins for the return trip.

What is my average **speed** for whole trip?

a. 0 mph
b. 30 mph
c. 40 mph
d. 60 mph
e. Something else

Hint: Average Speed = Total distance covered / Total time taken

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What is my average **velocity** for whole trip?

a. 0 mph
b. 30 mph
c. 40 mph
d. 60 mph
e. Something else

Hint: Average \( \bar{v} = \frac{\Delta \vec{x}}{\Delta t} \)
Position and velocity graphs

Person #1 moves away from the origin as shown.

Sketch position vs. time and velocity vs. time graphs for person #2 moving away from origin (motion detector) twice the velocity of person #1.

Relationship between position vs time graph and velocity vs time graph

Velocity is the slope of position-time graph.

What does velocity graph look like?

What does it look like between 0 and 1s?

Relationship between position vs time graph and velocity vs time graph

Velocity is the slope of position-time graph.

What about velocity between 1s and 3s?

a) Negative, decreasing magnitude
b) Negative, increasing magnitude
c) Negative, constant magnitude
d) Positive, constant magnitude
e) Can’t tell from info given

Equations of motion

Several ways to describe motion so far:

1. Words
2. Arrows (vectors) and numbers (scalars)
3. Graphs
4. Equations

Velocity \( v = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} \)

Rearrange:

\( x_f = x_i + v(t_f - t_i) \)

Now let \( t_i = 0s \) and so \( x_i = x_0 \)

\( x_f = x_0 + vt \)

The subscript \( f \) is now unnecessary so we can write:

\( x = x_0 + vt \)
Motion at constant velocity

\[ x(t) = x_0 + vt \]

Your position at time \( t \) depends on:
- Where you started,
- How fast and in what direction you’re going,
- How long you’ve been going

Practice question

\[ x(t) = x_0 + vt \]

I start 1m to the right of the origin at \( t=0 \). I walk to the right for 3s at 2m/s. What is my position at 3s? (Define positions to the right of the origin as positive)

- a. 1m
- b. 4m
- c. -5m
- d. 3m
- e. 7m

Break to discuss units

If you drive 60 miles/hour, that’s a speed. It’s also 1 mile/minute. It’s also 1/60 mile/s.

“Physics” units: meters/second (m/s)

There are 1600 meters in a mile. If you drive 60 miles/hour, how fast is this in m/s?

- a) 60 m/s
- b) 160 m/s
- c) 27 m/s
- d) 270 m/s
- e) 1600 m/s

How did you get that?

- We want to change the units but keep the answer (speed) the same
- Remember 2 things:
  - Multiply any answer by 1 and it doesn’t change
    - \( 1600 \text{m} = 1 \text{mile} \rightarrow 1600 \text{m} \times \frac{1}{1 \text{mile}} = 1 \)
  - \( 60 \text{mi} \times \frac{1600 \text{m}}{1 \text{mi}} \times \frac{1 \text{hr}}{60 \text{min}} \times \frac{1 \text{min}}{60 \text{s}} \)

\[ \text{Speed} = \frac{60 \times 1600}{60 \times 60} \text{m/s} = 27 \text{m/s} \]

You will convert between different units of distance, time, mass, energy etc etc throughout the course. This method always works!
Walking man moves according to the position-time graph, below. At which time is Walking Man slowing down (speed getting smaller)?

a) A only  
b) B only  
c) C only  
d) A and C  
e) A, B, and C  

Answer a: slope is getting smaller with time.

Equations when velocity is changing
What if velocity is changing? ... Accelerating

Acceleration (a) is a VECTOR

\[ a = \frac{\text{Change in velocity} (\Delta v)}{\text{Time taken} (\Delta t)} \]

Units = m/s = m/s²

Graph shows the velocity of a car as a function of time. What is its acceleration?

a. -0.25 m/s²  
b. +0.25 m/s²  
c. -0.5 m/s²  
d. +0.5 m/s²  
e. 0 m/s²

Motion at constant acceleration

\[ v(t) = v_0 + at \]

Your velocity at time t depends on:
- Your velocity when you started,
- How fast and in what direction you are accelerating,
- How long you’ve been going.
What about position at constant acceleration?

So far:  
\[ x = x_0 + vt \quad (a = 0) \quad (1) \]
\[ v = v_0 + at \quad (a = \text{constant}) \quad (2) \]

From (1):  
\[ x = x_0 + v_{\text{average}} t \quad (\text{if } a \neq 0) \quad (3) \]

\[ v_{\text{average}} = v_0 + \frac{1}{2} (\text{change in velocity}) \]
\[ \Rightarrow v_{\text{average}} = v_0 + \frac{1}{2} at \quad (4) \]

Substitute (4) into (3)

\[ x = x_0 + (v_0 + \frac{1}{2} at)t \]
\[ x = x_0 + v_0 t + \frac{1}{2} at^2 \]

Position at constant acceleration

\[ x(t) = x_0 + v_0 t + \frac{1}{2} at^2 \]

A car accelerates at a steady rate from stationary along a straight road. Sketch position, velocity and acceleration as a function of time.

Hint:
\[ a \text{ is slope of } v \text{ vs } t \]
\[ v \text{ is slope of } x \text{ vs } t \]