Goals for Today

- Introduce relativity
- Understand speed, velocity, and acceleration
- Text lol activity

Relativity 101

- All motion is relative!
  - This means when we describe motion, we are moving relative to something
  - The train is leaving the station, or is the station leaving the train?

What does it even mean to be motionless?

- You might be "motionless" in your seat right now, but…
  - The Earth rotates at **1500 km/hr**
  - …and revolves around the Sun at **107,000 km/hr**
  - …which revolves around a the supermassive black hole at the center of the Milky Way Galaxy at **792,000 km/hr**
  - …which is moving outward from Big Bang location at **2.1 million km/hr!**
  - Could the universe itself be moving?

Please please please do NOT try this…

- If you're sitting on an Amtrak train going ~100 mph, and you throw a 10 mph slow-pitch softball to your classmate sitting a few rows up, how fast would the softball be going relative to the Earth?
  - It's effectively going **110 mph!**

How Aroldis Chapman Threw The Fastest Pitch Ever

08/28/2016 09:04 pm ET | **Updated** May 23, 2017

BY SD DIRK ON FLICKR (ORIGINALLY POSTED TO FLICKR AS "AROLDIS CHAPMAN") [CC BY 2.0], VIA WIKIMEDIA COMMONS

Aroldis Chapman Delivers a Fastball for the Cincinnati Reds in 2010

← 105 mph!

It’s all relative

- You would be very lost if I told you ”Disneyland is 40 km away, meet me there” unless I specify it is 40 km away *from where*
- And also, *in what direction?*

Review from yesterday

- What is the difference between distance and displacement?
- What is a scalar? What is a vector?
- Fill in the blank – “if we multiply numbers in scientific notation, we _____ the exponents, while if we divide numbers we _____ the exponents.”

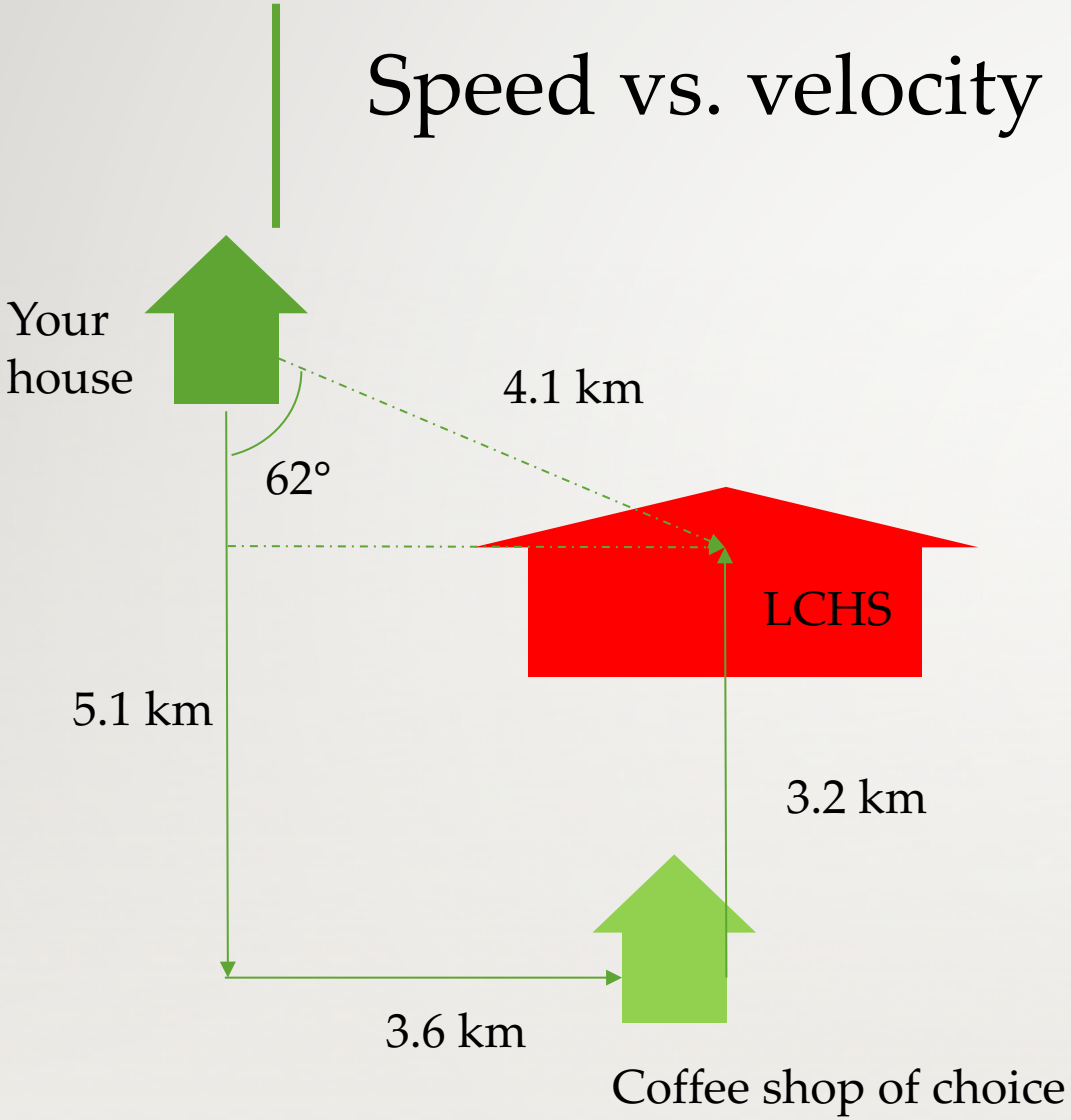
Speed vs. velocity

- Both refer to how fast something is moving
- Both measure the **rate of change of position**
- **Average speed**
  - **Distance traveled divided by the time it takes to travel that distance.**
  - $average\ speed = \frac{distance}{time}$

Speed vs. velocity

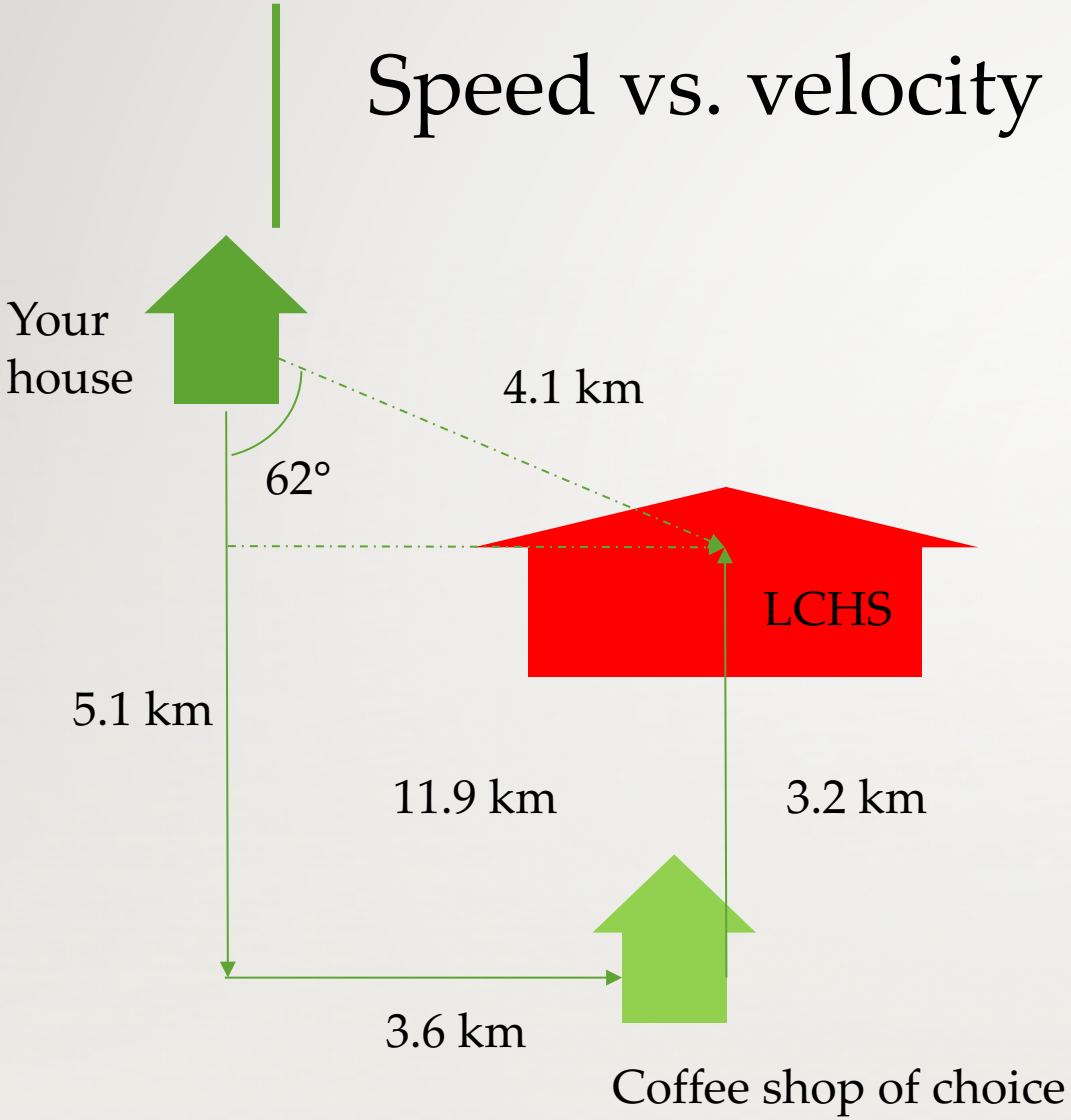
- Velocity refers to both the *magnitude* of how fast an object is moving and the *direction* in which it is moving.
- **Average velocity**
  - **Displacement traveled divided by time**
  - $average\ velocity = \frac{displacement}{time}$

Speed vs. velocity



- In our example from yesterday, say you completed your trek in 15 minutes (not including time stopped at your CSOC)
- What was your average speed *in m/s*?
- $\frac{(11.9km)}{15\ \text{min}} = 0.79\ km/\ \text{min} \quad * \frac{1000m}{km} * \frac{1min}{60\ s} = 13m/s$
- This is ~30 mph, reasonable in residential zones

Speed vs. velocity



- In our example, say you completed your trek in 15 minutes (not including time stopped at your CSOC)
- What was your average speed *in m/s*?
  - $13\ m/s$
- What about your average velocity *in m/s*?
- $\frac{4.1km}{15\ \text{min}} = 0.27\frac{\text{km}}{\text{min}} * \frac{1000\text{m}}{\text{km}} * 1\frac{\text{min}}{60\text{s}} = \mathbf{4.5\ m/s}$
- Why is the average velocity < average speed?

Your first kinematic equation

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

Could also be written as

$$v = (x_f - x_i)/(t_f - t_i)$$

Example #1

- It takes about 1 hr to fly from Los Angeles to San Francisco (~560 km). What is the velocity of the plane in m/s?
  - *Ans:* 160 m/s

Example #2

- Samus, from the video game series *Metroid*, is capable of traveling at supersonic speeds (~410 m/s). How long would it take her to travel from downtown San Francisco to downtown Los Angeles? (~560 km)?
  - 1.4×10^3 seconds (this is ~22 min!)

Example #3

- Samus, from the video game series *Metroid*, is capable of traveling at supersonic speeds (~410 m/s). How far could she travel in 1 day?
  - 3.5×10^7m – this is almost the circumference of the earth

Instantaneous vs. average velocity

- As you drive toward downtown LA, your car's speedometer reads 40 mph.
- If downtown LA is 10 miles away, how long will it take you to get there?
- What is the difference between that answer and how long it actually takes you to get there?
- It would probably take us much longer than 15 minutes…

Acceleration

- Going in a straight line at the same speed – **constant velocity**
- But if we change our speed or our direction then we have a **changing velocity**.
- Changing our **speed** or **direction** is **Acceleration**

Acceleration

- Rate of change of velocity
- How quickly velocity changes

- $\boldsymbol{a} = \dfrac{\Delta \boldsymbol{v}}{\Delta \boldsymbol{t}}$

$$\boldsymbol{a} = (v_f - v_i)/(t_f - t_i)$$

Conceptual question – in partners

- Why is acceleration considered a change in either speed or direction instead of just a change in speed?
- Remember – velocity has both a magnitude and a direction!

Example #1

- The California Screamin' ride at California Adventure accelerates from 0 to 89 km/hr in 4.0 seconds at launch. What is its acceleration in m/s^2?
  - *Ans = 6.2 m/s^2*

Example #2

- You're driving down the 2 Freeway at 26 m/s when you see traffic up ahead, so you brake to 12 m/s in 7.0 seconds. What is your acceleration?
  - *Ans* = *-2.0* m/s^2
- What does the negative sign mean?

Let’s ask a question

- How far could your car go in the time it takes to text “lol”?

Let's do an experiment!

- In groups of 4, measure the amount of time it takes each person in the group to text "lol" and hit "send"
  - Each person will text, and while you are texting, the other 3 group members will be timing the text with their stopwatches.
  - Average the 3 times to get the time for "name 1", then average all four of you to get your "group average".