# First day of school and kinematics

Eugenia Etkina

# Two goals of today's meeting:

1. How to start the school year in the ISLE approach?
2. Teaching kinematics through the ISLE approach.

Materials for this meeting are in the folder

https://drive.google.com/drive/folders/1rA2B68WaDKR-FQu9YFyNXygZoTp_IFzK?usp=sharing

## OALG 1.1.1 Observe, explain, and test your ideas

Watch the video at https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-1-1-1.

a. Come up with at least 3 explanations (crazy ideas) for why the person living in this house has 12 cameras.

b. Make a list of the explanations. How can you decide which one is correct? You can conduct additional experiments but you cannot talk to the person. Describe the experiments you plan to perform.

c. What outcomes of these experiments might convince you that certain explanations (or all of them) are not correct?

d. Read subsection "The process for devising and using new models" on pages 3-4 in the textbook and compare what you planned in parts b and c with what is described on these pages. Do you think there is a way to know with absolute certainty why the person living in the house has 12 cameras?

## OALG 1.1.2 Observe, explain and test your ideas

*Equipment: glass or transparent plastic cup, ice cold water, additional materials to test your ideas.*

Take a glass (or a transparent plastic cup) and pour ice cold water into it.

**a.** Carefully observe the glass for a few minutes. Describe what you observe in simple words. Take a photo of the glass to share with the class. If you do not have access to the materials, use the link https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-1-1-2a.

**b.** Think of different explanations (crazy ideas) for the observed patterns. Try to devise as many explanations as possible.

What did you observe?

State in simple words that a 5 year-old can understand.

Students: After cold water was poured into the glass, the glass got wet on the outside.

We can see water droplets on the outside.

Note: there is no fancy scientific language here. Anyone can be successful.

# Come up with a “wild idea” of where the water came from and to design an experiment to test the idea.

Wild idea: Water goes out from the top and settles on the outside.

Experiment: Take a glass filled with cold water and cover it.

Prediction based on the wild idea: It should not get wet.

Notice: the idea does not need to be correct, it just needs to be experimentally testable.

# Do it in class!

~~Goes out from the top and settles on the outside~~

Sips through the glass.

Experiment: Take an empty glass, put it into a cold place and then take out.

Prediction based on the idea under test: It should not get wet.

# Use your fridge!

~~Goes out from the top and settles on the outside~~

~~Sips through the glass~~

The material of the glass ”sweats” and the water comes from the material of the glass.

Experiment: Pour another cold liquid into the glass.

Prediction: There should still be water on the outside.

~~Goes out from the top and settles on the outside~~

~~Sips through the glass~~

The glass ”sweats” Failed to reject

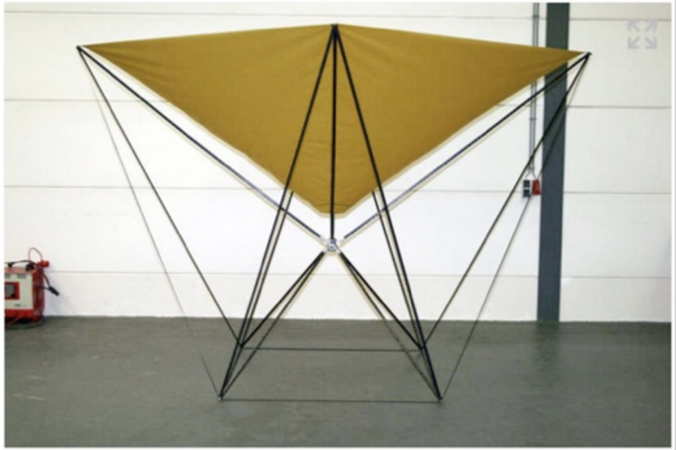
Water comes from the outside air.

Experiment: Use a scale.

Two different predictions! If “glass sweats”, *the mass should stay the same or decrease*. If the water comes from the outside air, *the mass should increase*.

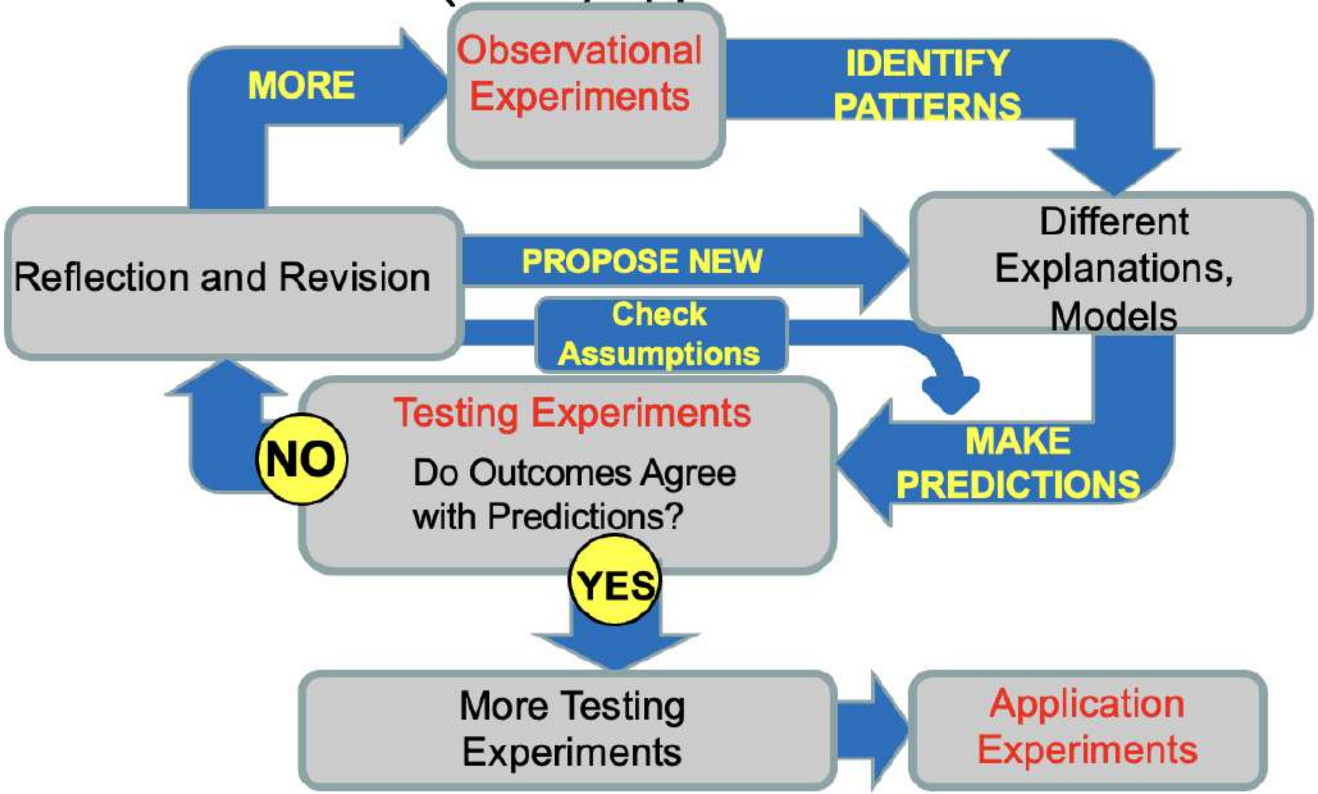
https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-OALG-1-1-2b

Think of the explanation that you were not able to reject as a new piece of knowledge. Can you think of any application of this knowledge?



WatAir Dew Harvesting System Provides Safe Drinking Water

# The Investigative Science Learning Environment (ISLE) approach



# Overview of other important activities in Chapter 1

https://docs.google.com/document/d/1IjPreYBTrZ7A05YCvEsL7XJ2bwqCGv9O/edit

# Kinematics

***Students should be able to:***

1. "Read and write" with motion diagrams (students can interpret a given diagram and draw a diagram for a given scenario).
2. "Read and write" with motion graphs; reading in this context means being able to interpret a graph, to write a mathematical function for the motion on the graph, to find the slope of the graph and the area between the graph and the time axis; writing in this context means being given a function for any kinematics quantity and using it to draw all three graphs (position-vs-time, velocity –vs-time, and acceleration-vs-time).
3. "Read and write" with vectors.
4. Find consistency or inconsistency between different representations of motion.
5. Operate with average quantities and differentiate between the quantity and its change ( and  for example).
6. Compare and contrast displacement, velocity, and acceleration, and solve problems involving these quantities.
7. Compare and contrast position, displacement, distance, and path length, and solve problems involving these quantities.
8. Explain where the equations for position as a function of time for motion at constant velocity and at constant acceleration come from.
9. Explain the meaning of the term "reference frame" and analyze the same motion using different reference frames.

*Brief summary of student difficulties with kinematics*

Students have difficulties differentiating between velocity and acceleration, between velocity and displacement, and between position and displacement, understanding the difference between a physical quantity and the change in that quantity, interpreting graphs (including what quantity is represented on the graph, slopes and areas), interpreting signs of physical quantities (thinking that negative acceleration means slowing down), thinking that when velocity is zero acceleration must be zero.

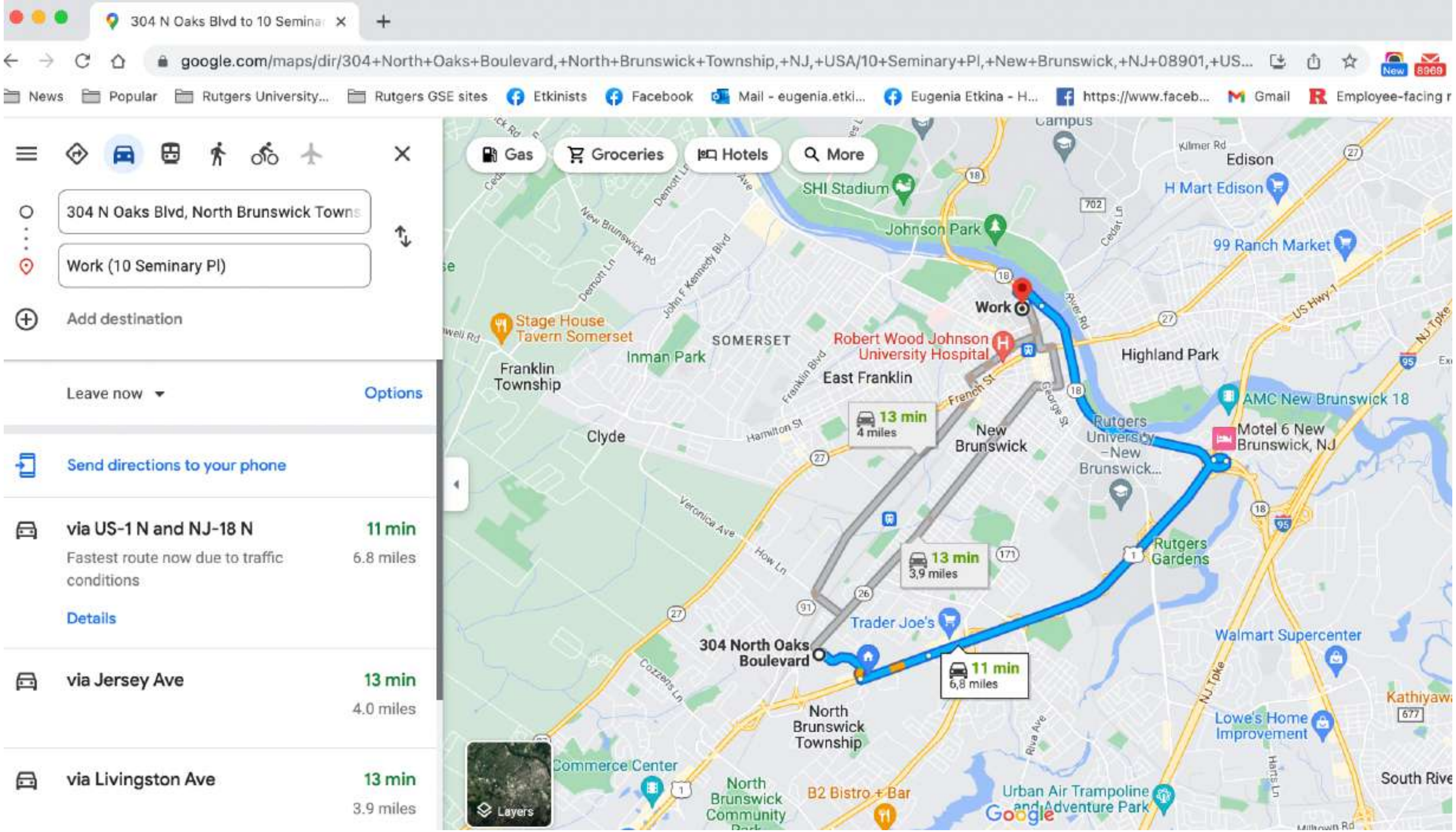
# Need to know

## Kinematics: Motion in One Dimension

When you drive, you are supposed to follow the three-second tailgating rule. When the car in front of you passes a sign at the side of the road, your car should be far enough behind it that it takes you 3 s to reach the same sign. In this chapter, we will learn the physics behind the three-second rule.

- What is a safe following distance between your car and the car in front of you?
- Can you be moving and not moving at the same time?
- Why do physicists say that an object thrown upward is falling?

# Need to know


304 N Oaks Blvd to 10 Semina
google.com/maps/dir/304+North+Oaks+Boulevard,+North+Brunswick+Township,+NJ,+USA/10+Seminary+Pl,+New+Brunswick,+NJ+08901,+US...
304 N Oaks Blvd, North Brunswick Towns
Work (10 Seminary Pl)
Add destination
Leave now
Options
Send directions to your phone
via US-1 N and NJ-18 N
11 min
Fastest route now due to traffic conditions
6.8 miles
Details
via Jersey Ave
13 min
4.0 miles
via Livingston Ave
13 min
3.9 miles
Gas
Groceries
Hotels
More
Work
304 North Oaks Boulevard
13 min
4 miles
13 min
3.9 miles
11 min
6.8 miles
New Brunswick
Highland Park
Edison
Franklin Township
North Brunswick Township
Robert Wood Johnson University Hospital
Rutgers University–New Brunswick...
Layers

# Need to know

https://www.youtube.com/watch?v=vvbN-cWe0A0

# What is the purpose of this first activity?

## 2.1.1 Describe

***Class:*** *Equipment per group:* none.

Each member of your group plays a role in the story described below. Assign roles and discuss the answers to the questions. Then get up and enact the story for the rest of the class.

Story: A person sits in the passenger seat of a car that is traveling along a street. Describe the person’s motion as seen by each of the following observers:

**a.** another person sitting in the backseat of the car;

**b.** a pedestrian standing on the sidewalk as the car passes; and

**c.** the driver of a second car moving in the same direction and passing the first car.

# Concrete representations of motion

## 2.2.1 Observe

***PIVOTAL* Lab or class:** *Equipment per group:* metronome (download a metronome app.) or any device to keep track of time in seconds, low-speed battery-operated car, sugar packets (or any other marking device), meter stick (or any other length-measuring device), whiteboard and markers.

This activity requires collaboration and coordination of all group members. Set a metronome to about one beat per second. Person 1 turns on a battery-operated toy car and releases it to roll across the floor. Person 2 places sugar packets on the floor at the points where the car is located at every blip of the metronome (instead of sugar packets you can use anything else that will allow you to mark the floor where the car was every second, be creative!). Do not try to put the sugar packets where the car was just released. After about 5 to 7 blips, stop the car and draw a sketch showing the locations of the sugar packets as dots. Discuss with the group members how you can use the dots to describe the motion of the car. After you come to a consensus, draw your representations on the board and share it with the class. [If you do not have a toy car, you can use a hard ball such as a billiard ball or bowling ball that you roll on a smooth floor.]

# Variation for on-line learning

## OALG 2.2.1 Observe

Watch the four experiments in video OET 2.1 on page 15 in the textbook [https://mediaplayer.pearsoncmg.com/assets/_frames.true/secs-experiment-video-1]. Use the data from the video to sketch the position of the bean bags by representing them as dots.

a. What patterns did you notice in the placement of the dots?

b. How can you use the distances between the dots to describe the motion of the bowling ball?

# Team 1

a. What patterns did you notice in the placement of the dots?

b. How can you use the distances between the dots to describe the motion of the bowling ball?

# Team 2

a. What patterns did you notice in the placement of the dots?

b. How can you use the distances between the dots to describe the motion of the bowling ball?

# Team 3

a. What patterns did you notice in the placement of the dots?

The top dots were

b. How can you use the distances between the dots to describe the motion of the bowling ball?

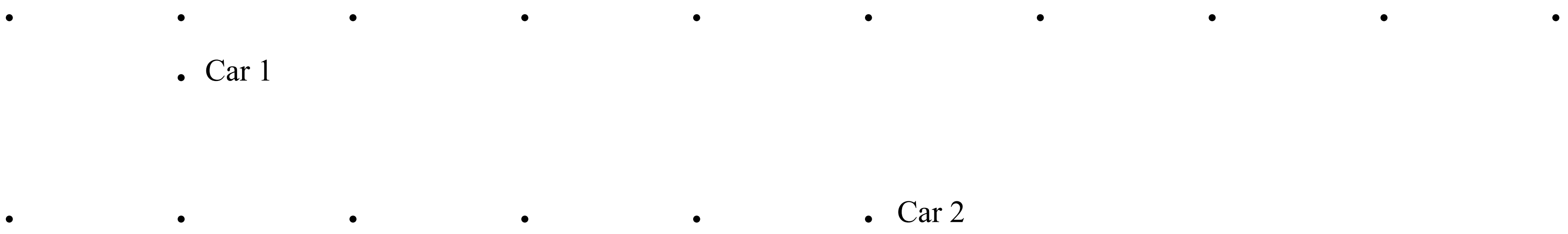
# Team 4

a. What patterns did you notice in the placement of the dots?

b. How can you use the distances between the dots to describe the motion of the bowling ball?

OALG 2.2.2 Represent and reason

You have two battery-operated toy cars that you can release simultaneously on a smooth floor and a metronome set to 1-second intervals. You and a friend each walk next to one of the cars, and at every “blip” of the metronome, you place a sugar packet at your car’s location. The dots in the figure below represent the locations of the sugar packets for the two cars. The cars start simultaneously at the dot on the left and move to the right.




**a.** Were the cars ever next to each other? If so, where?

**b.** If there were a passenger in car 1, how would the passenger describe the motion of car 2?

**c.** If there were a passenger in car 2, how would the passenger describe the motion of car 1?

# Team 1

a. Were the cars ever next to each other? **If so, where?** **Cars were together at the beginni**

**b.** If there were a passenger in car 1, how would the passenger describe the motion of car 2?

**Moving forwards**

**c.** If there were a passenger in car 2, how would the passenger describe the motion of car 1?

**Moving backwards**

# Team 2

a. Were the cars ever next to each other? If so, where?

- Yes, at the beginning

**b.** If there were a passenger in car 1, how would the passenger describe the motion of car 2?

- Car 1 sees car 2 going forward (to the right)

**c.** If there were a passenger in car 2, how would the passenger describe the motion of car 1?

- Car 2 sees car 1 going backward (to the left)

# Team 3

a. Were the cars ever next to each other? If so, where?

At the start t = 0

**b.** If there were a passenger in car 1, how would the passenger describe the motion of car 2?

Pulling ahead

**c.** If there were a passenger in car 2, how would the passenger describe the motion of car 1?

Falling behind

# Team 4

a. Were the cars ever next to each other? If so, where?

Only at starting moment, starting place

**b.** If there were a passenger in car 1, how would the passenger describe the motion of car 2?

Going forward

**c.** If there were a passenger in car 2, how would the passenger describe the motion of car 1?

Going backward

## OALG 2.2.3 Observe

*Equipment:* a ball, sugar packets, a distance measuring device.

For this activity you will need any ball that you can find in the house. A basketball, a tennis ball – any rolling object (even a mechanical toy car will work). Using your computer or your phone, find a metronome that beeps every second. You will also need sugar packets or any objects that you can place on the floor to mark the position of the ball. Place the ball (or a toy car) at rest on the floor. Push the ball abruptly and, as it rolls, place the sugar packets to mark its location every second. Make sure that the ball rolls in a straight line. Take a picture of the sugar packets and paste it into the document you are working on.  Use it to draw a corresponding dot diagram representing the packets. Describe the relative distances between the packets. How does the distance between the packets correspond to the observed motion of the ball?

# OALG 2.2.4 Explain Please do not type on this slide

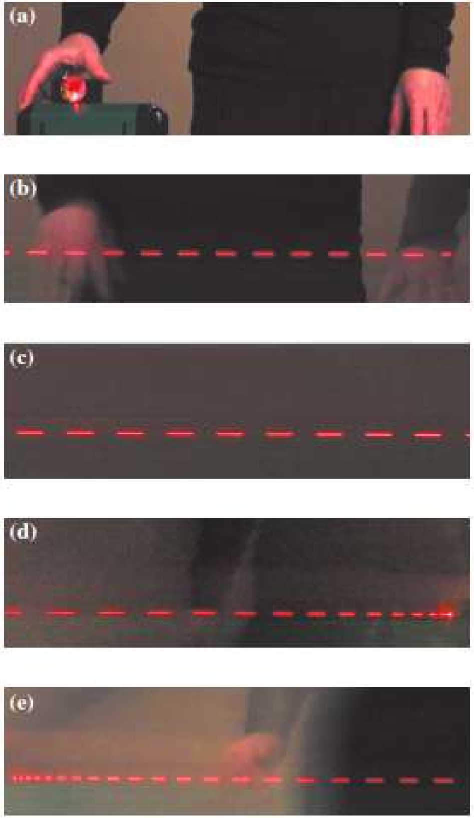
Examine Figure below. Explain the changes in the light traces of the LED in each experiment (do not forget to state your assumption about the direction of motion). In particular:

**a.** What can the length of the light trace tell you about the motion of the cart?

**b.** If each subsequent light trace gets shorter, what does that tell you about the motion of the cart?

**c.** If each subsequent light trace gets longer, what does that tell you about the motion of the cart?

**FIGURE 2.2** Long-exposure photographs of a moving cart with a blinking LED.



# Team 1

a) The length of the lines is relative to how fast the car goes

a) If each line is shorter, car is slowing

\

a) If each line is longer, car is going faster

# Team 2

a. The length of the light trace shows how far the cart moved while the light was on.
b. If the trace gets shorter, the cart is going slower (less distance for light on)
c. If the trace gets longer, the cart is going faster (farther distance for light on)

# Team 3

Length of trace is same for constant speed

Longer trace is faster (LED image blurs when faster) (c is faster than b)

So when getting longer … speeding up (e) assuming motion is from left to right

When getting shorter … slowing down (d) assuming motion is from left to right

# Team 4

a. What can the length of the light trace tell you about the motion of the cart?

- Indicates how fast the cart's moving

b. If each subsequent light trace gets shorter, what does that tell you about the motion of the cart?

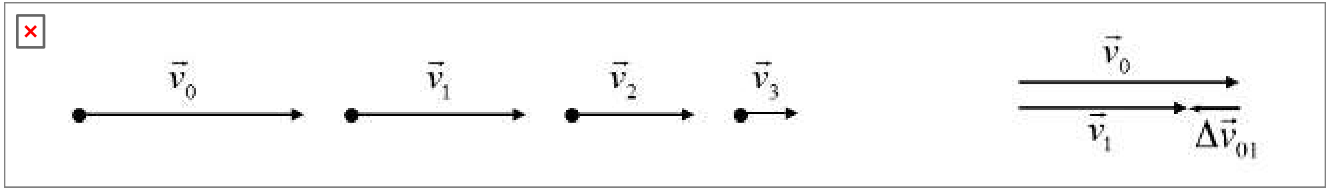
- the cart was getting slower

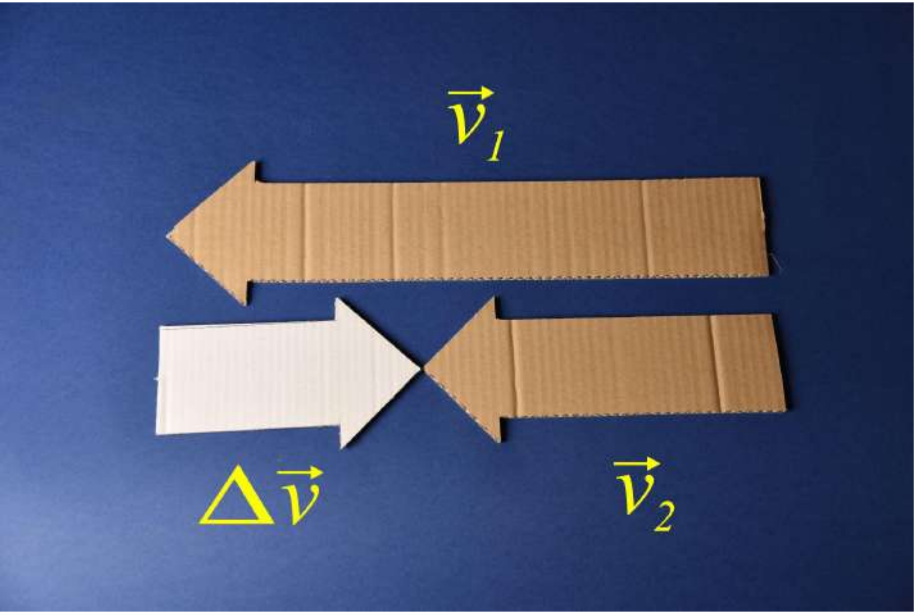
c. If each subsequent light trace gets longer, what does that tell you about the motion of the cart?

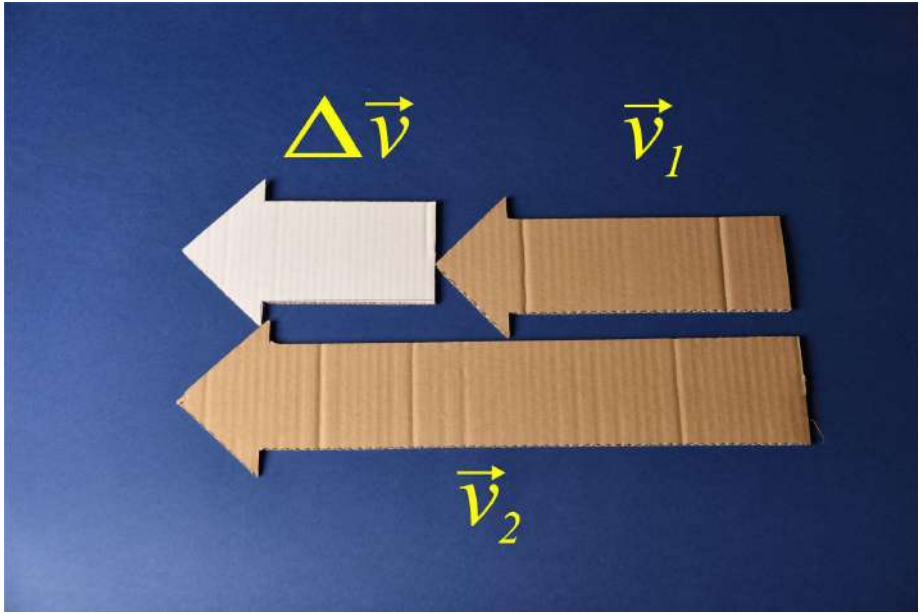
- Cart was getting faster

# OALG 2.2.5 Represent and reason

The illustration below relates to the experiment you performed with the ball in Activity 2.2.3. The dots represent the locations of the ball measured each second. The arrows represent the direction of motion and how fast the ball was moving (we call them *velocity arrows*). Consider velocity arrows 0 and 1. Move them side by side with their tails at the same horizontal position. Decide what change arrow  you would have to add to arrow 0 to make it the same length as arrow 1. Repeat for arrow 1—what change arrow is needed to change it into arrow 2, and what change arrow is needed to change arrow 2 into arrow 3? We call these *velocity change arrows*.




$\vec{v}_1$
$\Delta\vec{v}$
$\vec{v}_2$


$\Delta\vec{v}$
$\vec{v}_1$
$\vec{v}_2$

# How do we connect conceptual understanding to mathematics?

The next few activities will be from the Online Active Learning Guide Chapter 2 posted in the folder for today's meeting. The link to the file is

https://docs.google.com/document/d/1vdHREK0kJBwGAn7dHCc5KOAD7N36hFbo/edit

We will start with Activities 2.5.1 and 2.6.1. They have a lot of steps, so if you need additional slides, just add a new slide after your team's slide. It is important that you see the connection between these two activities.

# Team 1 2.5.1 and 2.6.1

**a.** Write everything you can about the bike rides and indicate any pattern in the data. What was happening at the clock reading of zero?

**b.** Draw motion diagrams for both bikes.

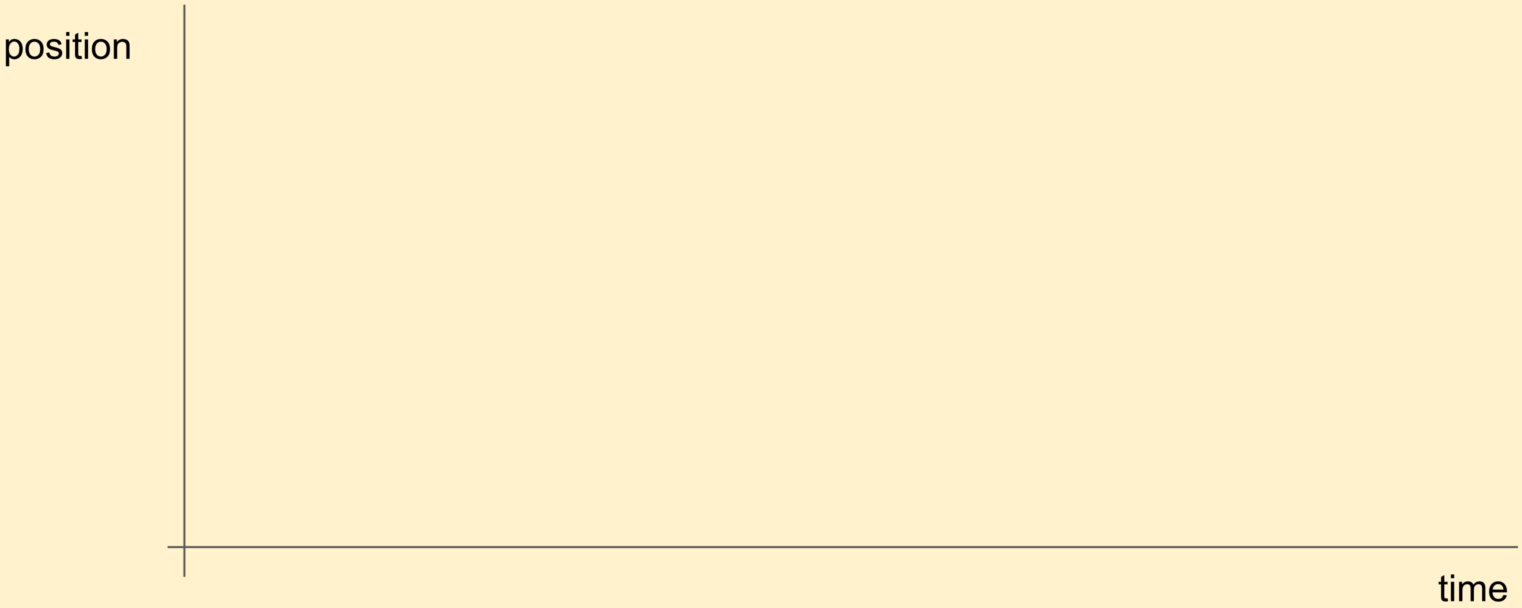
**c.** Construct position-versus-clock-reading graphs for both bike trips using the same coordinate axes in which $x$ is a dependent variable and $t$ is an independent variable. Compare and contrast the graphs – how do the graph lines represent the differences in the bikes' motions? If you are having trouble, read and interrogate section 2.5 in the textbook.

**d.** How do the motion diagrams in part b. correspond to the graphs in part c? How do you need to position the motion diagrams with respect to the graph axes so that it helps you visualize the motions?

# Team 2 2.5.1 and 2.6.1

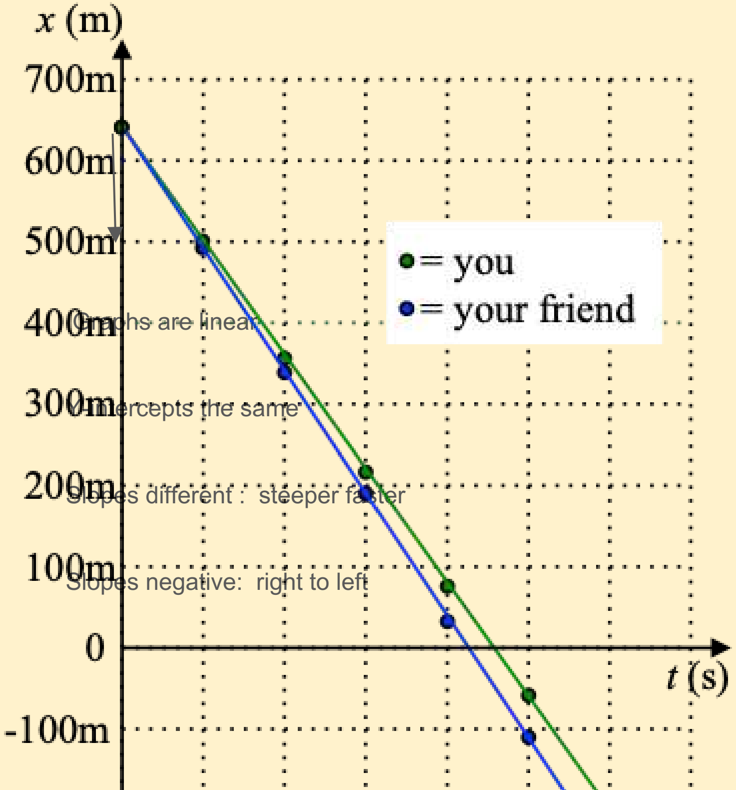
- Person 1 changed position by 140 m every 20 s from start to finish
- Person 2 by 150 every 20 s from start to finish
- Both persons’ positions are decreasing
- What does the negative position mean?
  - Interpretation of “opposite direction”
- Planning is definitely needed
- “Why do we do math in science class?”
  - Math is the tool, not the actual physics
- Some students “know” the answer without actually knowing the correct reasoning or physics

# Team 2 2.5.1 and 2.6.1



# Team 3 2.5.1 and 2.6.1

We are both going from right to left. The friend is faster then me.

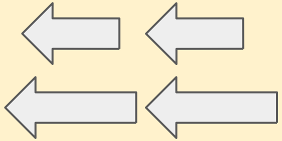



Graphs are linear

Y intercepts the same

Slopes different : steeper faster

Slopes negative: right to left



Since change of position is negative

Over the 20 second time interval

# Team 4 2.5.1 and 2.6.1

**a.** Write everything you can about the bike rides and indicate any pattern in the data. What was happening at the clock reading of zero?

Both are at the same spot at $t = 0$, both bikes head to the left, our position changed by 140 m every 20 s while our friend's position changed by 150 m every 20 s

**b.** Draw motion diagrams for both bikes.

Constant spacing for both, but ours would be spaced a little closer

**c.** Construct position-versus-clock-reading graphs for both bike trips using the same coordinate axes in which $x$ is a dependent variable and $t$ is an independent variable. Compare and contrast the graphs – how do the graph lines represent the differences in the bikes' motions? If you are having trouble, read and interrogate section 2.5 in the textbook.

**d.** How do the motion diagrams in part b. correspond to the graphs in part c? How do you need to position the motion diagrams with respect to the graph axes so that it helps you visualize the motions?

You can tilt the motion diagrams, with both coinciding at $t=0$, to get the lines on the graph

# Team 4 continued (2.6.1)

**a.** Examine the graphs you drew in Activity 2.5.1c. Write two functions *x* (*t*) for the graphs. Consider your labeling system: how can you distinguish the function for your bike from the function for your friend's bike?

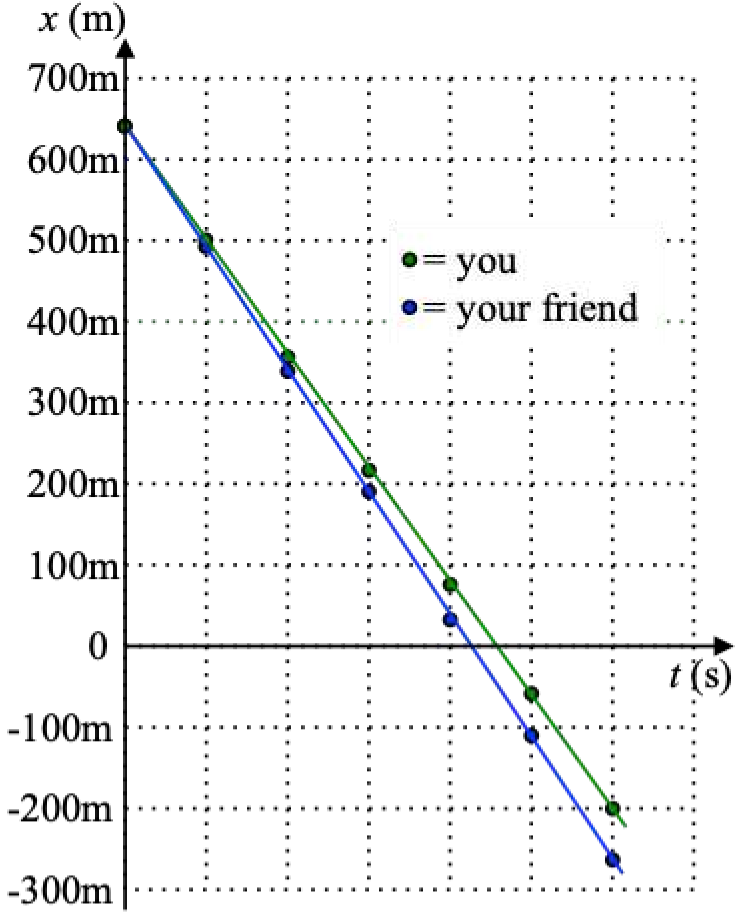
x(t) = 640-140/20*t

y(t) = 640-150/20*t

**b.** What are the physical meanings of the slope of each function and the intercepts? What common name can you use for the slope? Explain the meanings of positive or negative values for these physical quantities. If you are having trouble, read and interrogate Section 2.6 in the textbook. Especially pay attention to the sub-section "*Equation of motion for constant velocity linear motion.*"

The slope is the velocity, the intercept is the position at time 0.

**c.** Compare and contrast how we write linear functions in mathematics to how you just wrote the position-versus-time functions for these motions. What is the same between them? What is different?


x (m)
700m
600m
500m
400m
300m
200m
100m
0
-100m
-200m
-300m
t (s)
= you
= your friend

How did the students invent the concept of velocity? What is the connection between physics and mathematics?

# Kinesthetic activities for physical quantities, units, and relations

The first two rows of Table 2.7 show position and time data for the falling ball:

**TABLE 2.7 Position and time data for a falling ball**

| | | | | | | |
|---|---|---|---|---|---|---|
| $t$ (s) | 0.000 | 0.100 | 0.200 | 0.300 | 0.400 | 0.500 |
| $y$ (m) | 0.000 | 0.049 | 0.196 | 0.441 | 0.784 | 1.225 |
| $t^*$ (s) | 0.050 | 0.150 | 0.250 | 0.350 | 0.450 | |
| $v_{av}$ (m/s) | 0.49 | 1.47 | 2.45 | 3.43 | 4.41 | |

From the table you can see that the distance that the ball travels during each successive time interval increases; Figure 2.22 shows the position of the ball every 0.100 s. If the distance that the ball travels during each successive interval increases, the velocity must increase, too. To determine the average velocity during each time interval, we calculate the displacement of the ball between consecutive times and then divide by the time interval. For example, the average velocity between 0.100 s and 0.200 s is $(0.196\text{ m} - 0.049\text{ m})/(0.200\text{ s} - 0.100\text{ s}) = 1.47\text{ m/s}$; it is positive because we pointed the axis down. We can think of this average velocity as the instantaneous velocity that the ball had in the middle of the time interval—in this case, the 0.150 clock reading. We can now put these calculated velocities $v_{av}$ and the associated clock readings $t^*$ in the middle of each time interval in the two bottom rows of the table. These data now allow us to plot a velocity-versus-time graph (Figure 2.23). Notice that the best-fit curve for these data is a straight line. This occurs when the *velocity of the object increases or decreases at a constant rate*, that is, by the same amount during the same time interval. In our case, the velocity increases by 9.8 m/s every second in the downward direction.

FIGURE 2.22 The position of a falling ball every 0.100 s.

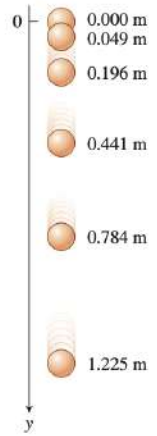
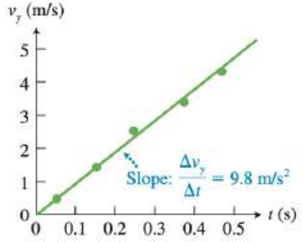



FIGURE 2.23 A velocity-versus-time graph for a falling ball.



# Activities for the invention of the concept of acceleration

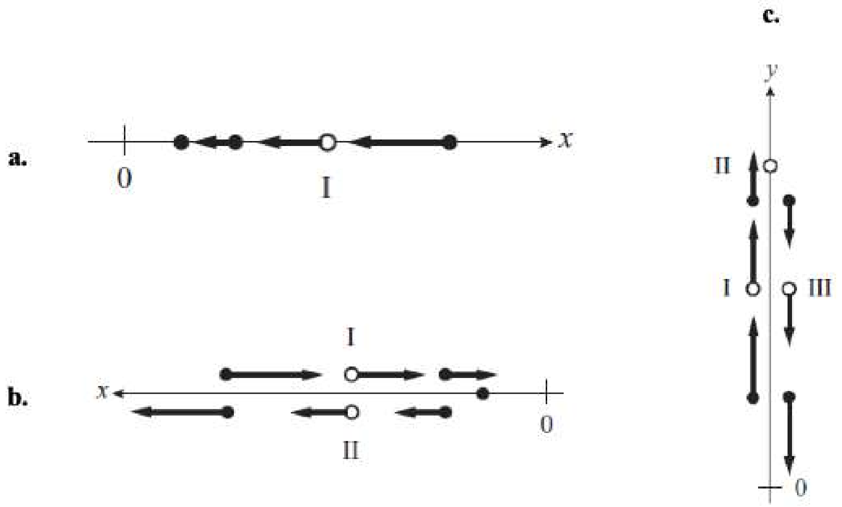
Read activity 2.7.1 (do not do it). How is it similar to 2.6.1? How is it different?

https://docs.google.com/document/d/15_k0tnj8mdkse-pJsKMdlzBWexGZsJnm/edit

How do we connect the the concept of acceleration invented in 2.7.1 with the delta v arrow on the motion diagram? (use whiteboard)

## OALG 2.7.2 Represent and reason

The motion diagrams in the illustrations below represent the motion of different objects. The arrows are velocity arrows.




A different coordinate axis is provided for each of the three motion diagrams. An open circle indicates a location of interest (there are three locations: I, II, and III). Add a single velocity change arrow for each diagram. Then, determine the signs of the position, velocity component, velocity change component, and acceleration component at the position(s) of the open dots for each diagram. Note: what assumptions about motion do you need to make in order to use only *one* velocity change arrow for part b. and one for part c?

# What did you learn today?

I relearned the importance of engaging in the ISLE approach and how I use language as the teacher to model expectations to the students.

How the “need to know” is not just an intro, but is referred to all the way along to motivate the whole thing.