Lab 3: Acceleration

Experiment for Physics Introductory Mechanics 211 Lab at CSU Fullerton.

What You Need To Know:

The Physics

In the previous lab you learned that the velocity of an object can be determined by finding the slope of the object's position vs. time graph.

$$\boldsymbol{v_{avg}} = \frac{\boldsymbol{\Delta x}}{\boldsymbol{\Delta t}}$$

v_{avg}	is the average velocity (in meters per seconds, m/s)
Δx	is the change in position [rise] (in meters, m)
Δt	is the change in time [run] (in seconds, s)

Equation 1 – Average velocity

The next concept in motion, *acceleration*, can be found in a similar fashion. An object is accelerating when it is changing its velocity. The equation for average acceleration is …

$$\boldsymbol{a_{avg}} = \frac{\boldsymbol{\Delta v}}{\boldsymbol{\Delta t}}$$

a_{avg}	is the average acceleration (in, m/s^2)
Δv	is the change in velocity [rise] (in, m/s)
Δt	is the change in time [run] (in seconds, s)

Equation 2 – Average acceleration

This equation tells you that in looking at a velocity vs. time graph you will be able to determine the acceleration of an object. Therefore, in this lab, you can use all of the concepts you learned in the previous lab on determining slopes. However, in this case, you will be using a ***v vs. t*** graph instead of an ***x vs. t*** graph.

Let's review some of those ideas. The first thing you learned in last week's lab was that in *moving away* from the sensor you are moving in the *positive* direction thus you have a *positive* velocity. The opposite is also true. In moving *towards* the sensor you have a *negative* velocity.

You learned that if your vertical value on the graph is increasing while moving to the right along the horizontal axis, then you have a positive slope. **See Figure 1.** The opposite is also true. If your vertical value decreases while moving to the right along the horizontal axis then you have a negative slope. **See Figure 2.** You also learned that if your plotted line is straight then you will have a constant slope and therefore a constant velocity. You will still be using these ideas for this lab.

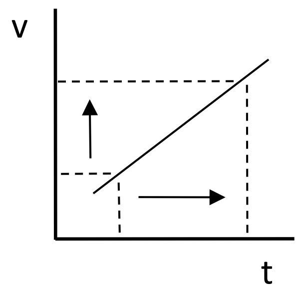


Figure 1 – Positive Slope

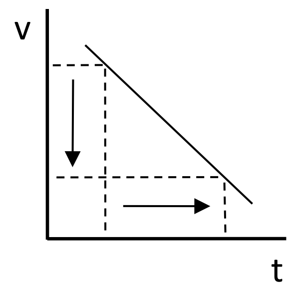


Figure 2 – Negative Slope

Common Acceleration Ideas

One idea that is often incorrectly believed is that when an object's velocity at a particular time is zero then the acceleration of the object is also zero. This is not always the case. Acceleration is the CHANGE in velocity over a period of time ($a = \Delta v/\Delta t$) not just velocity over time (not $a = v/t$). For example, when you throw a ball up in the air it stops briefly at the peak before it comes back down. We would say that $v = 0$. However the acceleration is not zero because the velocity is still changing as the ball stops for an instant of time. You will be doing an experiment in this lab to show this idea.

What You Need To Do:

The Equipment

For this lab you will be using a track, a cart with an acceleration fan, and a motion sensor. **See Figure 3.** Attach the fan to the cart using two rubber bands as shown below. Place the cart with the fan on the track and make sure it is in working order. Since the batteries drain quickly, only turn on the fan when performing an experiment.

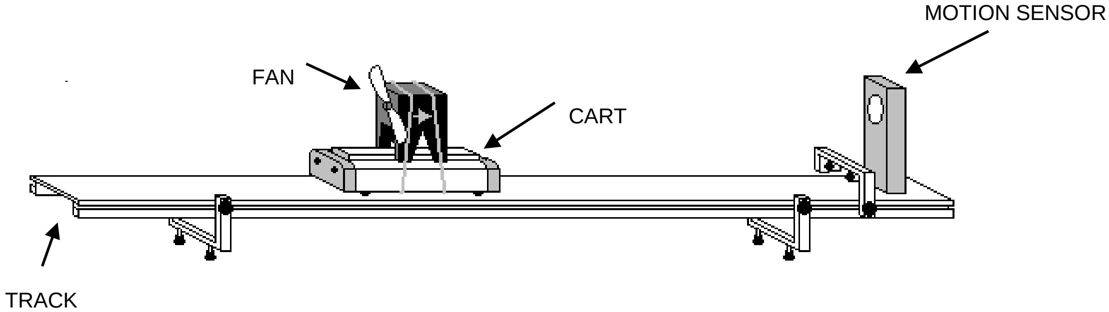


Figure 3 - Equipment

There are colored arrow stickers on both sides of the fan that point in the direction of the acceleration caused by the fan. If the arrow is pointing *away from* the sensor then the acceleration of the cart is *positive*. If the arrow is pointing *towards* the sensor then the acceleration is *negative*. See **Figure 4** for a table of all sign conventions.

Description	Velocity
Cart moving away from sensor	+
Cart moving towards sensor	–
Description	**Acceleration**
Arrow pointing away from sensor	+

Figure 4 – Sign Conventions

Before you begin place the cart stationary on the track. If the cart begins rolling one way or the other then ask your instructor to check that your track is level.

Part 1 – Constant Velocity

You should already know, based on last week's lab, what a graph of constant velocity looks like in a ***v vs. t*** graph. Begin your lab report by making two ***v vs. t*** graphs: one of a positive constant velocity and one of a negative constant velocity.

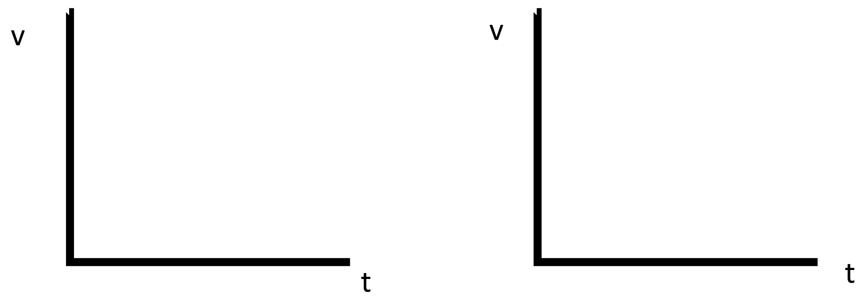


Figure 5 – Part 1 Sketches

Question 1:

Below each graph write down what the acceleration would be. How do you know this?

Part 2 – Changing Velocity Away from the Sensor

Start by using the fan moving the cart away from the sensor and see what happens.

A) Take your cart and place it 50 cm from the motion sensor.

B) Make sure the arrow on the fan is pointing *away from* the sensor.

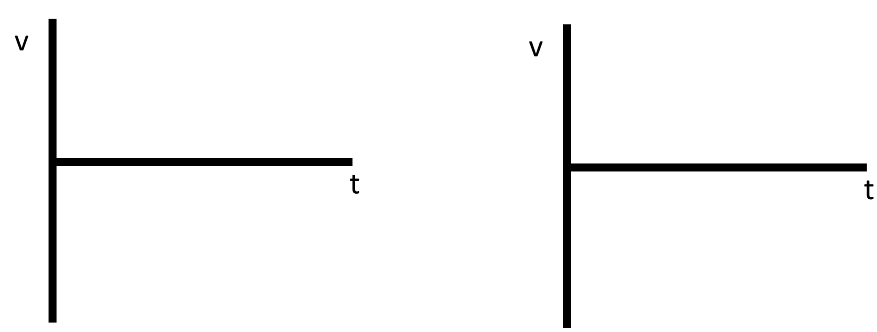
C) Prepare to release the cart…

   a. **Make sure someone is always ready to catch the cart at the end of the track. Do not release the cart if one partner is not ready to catch it.**

   b. Turn on the fan and release the cart.

   c. Examine the motion of the cart and fill in your ***v vs. t*** graph based on your observations for what you think the motion of the cart is.

Figure 6 – Part 2 Sketches



Now you are going to use the computer to make a graph of the cart's motion.

D) Open the file **ACCELERATION**. You will see a ***v vs. t*** graph the same as in **Figure 5**.

E) Set your cart up as you did before.

F) Push "Collect" on the computer.

G) Once the motion sensor starts clicking, release the cart. If you are not getting a good signal on your screen it is probably because the motion sensor is not pointed directly down the line of the track. Re-aim the sensor and try again.

H) Sketch the graph on the computer screen next to the one you made right before using the computer.

Checkpoint 1:

Compare the two graphs. Are the graphs the same? If not, then what error did you make in your reasoning?

Checkpoint 2:

In examining the graph on the computer, is the velocity of the cart positive or negative? How can you tell from the graph?

Checkpoint 3:

In examining the graph on the computer, do you have an increasing, decreasing, or constant velocity? How can you tell from the graph?

Now find the slope of that graph

I) On the computer screen, highlight the area of your graph that corresponds to the main motion of the cart until just before you stopped it.

J) At the top-middle of the screen there is a button, "Linear Fit". This will give you a linear fit to your highlighted region. A little window will also pop up to tell you the slope of the line and the y-intercept. Also, note that there is a faint black line that will overlay your graph.

Checkpoint 4:

Based on the linear fit line, do you have a positive or negative acceleration? How can you tell from the graph?

Checkpoint 5:

Based on the linear fit line, do you have an increasing, decreasing, or constant acceleration? How can you tell from the graph?

K) From the information in the little window, record the acceleration of the cart.

L) Do two more trial runs and record those accelerations so that you have three acceleration values to use in your answer to the following question.

Question 2:

What do you conclude about the acceleration offered by the fan? Is it changing or roughly constant? Support your answer.

M) Fill in the Part 2 row of Table 1… (You will fill in the table as you progress through the lab. Do *not* fill out the *entire* table now.)

a. Put in a + or a – in the "v" and "a" columns for the first row based on your observations from ealrier.

b. In the fourth column, write down the motion of the cart; was it "speeding up" or "slowing down"? Keep in mind the sign conventions that were given to you in **Figure 4.**

Table 1 – Data Parts 2-5

Part	v	a	Motion of cart
2			
3			
4			
5			

Part 3 – Changing Velocity Towards The Sensor

Now we'll repeat Part 2 but with the fan facing towards the sensor instead.

A) Take your cart and place it about 140 cm from the motion sensor.

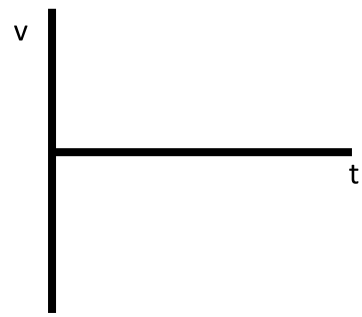
B) Make sure the arrow on the fan is pointing towards the sensor.

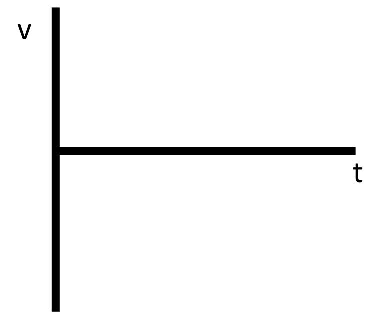
NOTE: Always make sure someone is always ready to catch the cart at the end of the track before it hits the motion sensor.

C) Turn on the fan and release the cart WITHOUT THE COMPUTER SOFTWARE RUNNING.

D) Examine the motion of the cart and fill in your ***v vs. t*** graph based on your observations on the motion of the cart.

Figure 7 – Part 3 Sketches





E) Repeat the above procedure *with* the computer tracking the cart. Sketch the graph on the computer screen next to the one that you just made.

Checkpoint 6:

Compare the two graphs. Are the graphs the same? If not, then what error did you make in your reasoning?

Checkpoint 7:

In examining the graph on the computer, is the velocity of the cart positive or negative? How can you tell from the graph?

Checkpoint 8:

In examining the graph on the computer, do you have an increasing, decreasing, or constant velocity? How can you tell from the graph?

F) On the computer screen, highlight the area of your graph that matches the motion from when you released the cart until just before you stopped it. Click on "Linear fit" for your linear fit.

Checkpoint 9:

Based on the linear fit line, do you have a positive or negative acceleration? How can you tell from the graph?

Checkpoint 10:

Based on the linear fit line, do you have an increasing, decreasing, or constant acceleration? How can you tell from the graph?

G) Fill in the row **Part 3 in Table 1**, fill in the columns for "v", "a", and "Motion".

Checkpoint 11:

It is often believed that when an object has a negative acceleration that the object will slow down. Is this the case for **Part 3**?

Part 4 – Opposite Velocity and Acceleration

NOTE: You do not need the computer software for this part.

A) Take the cart and place it at 50 cm away from the sensor with the arrow pointing *towards* the sensor.

B) Turn on the fan and give the cart a push *away from* the sensor and catch the cart when it stops at its “peak”.

C) Based on what you observed, fill in the row corresponding to **Part 4** in Table 1. (Do not take into account the acceleration of the cart due to your hand pushing on the cart. Only take into account the acceleration due to the fan.)

Checkpoint 12:

Was the cart’s velocity +/– ? How can you tell? Was the cart’s acceleration +/– ? How can you tell? What kind of motion did the cart have?

Part 5 – Opposite Velocity and Acceleration Again

A) Take the cart and place it 140 cm away from the sensor with the arrow pointing *away from* the sensor.

B) Turn on the fan. Give the cart a push *towards* the sensor and catch the cart when it stops at its “peak”.

C) Based on what you observed, fill in the final row in your Table 1.

D) Before answering the next question, ask your instructor to come over and check to make sure that your Table 1 is correct.

Question 3:

Upon examining your completed Table 1, write down an overall statement that you can make about the relationship between velocity of an object, acceleration of an object, and its motion.

Part 6 – Freefall

There is one setup for freefall at the front of the room. Your instructor may choose to have you come up one at a time to do it or do one demo for the class and pass out/collect already done freefall strips.

A) Either way start by getting the strip of white paper with the freefall data and taking it back to your table. The paper will need to be at least a meter long to get 6 spots

The thicker muddled spot is n=1, at t=0, you’ll ignore that spot and start with n=2, the first clear double dot mark beyond it.

B) Attach the strip of paper with the free-fall data to the track:

a. Remove the cart and motion sensor from the track.

b. Using some blue tape place with the first dot on the strip in line with a convenient point on the track. (Such as 10cm, 20cm)

c. You will be using the ruler on the track so don't cover it with the strip but attach it close for easier reading.

Table 2 – Freefall Data

n	t_n	Δt	y_n	Δy	v
2					
3					
4					
5					
6					

In Table 2, "n" is the dot number (i.e. the 2^{nd} dot is n = 2), "t_n" is the time for the n^{th} dot, "y_n" is the location of the n^{th} dot (read directly off the tape) Don't worry about the rest of the table for now.

C) Reading directly off the tape measure on the track fill in the y_n column using dots 2 through 11.

Caution: Be sure there are no missing dots on the freefall tape when you're counting, if it looks like a spot is blank take another data point.

NOTE: We are going to define our system with the direction "downwards" as positive. So, all your "y_n" data will be positive. Take data on ten dots so that you will fill the column.

DO NOT MAKE MARKS ON THE STRIP.

D) Fill the "t_n" column with your times in *decimal* form.

a. The spark machine was set so that the time between each spark (or dot) was $1/10^{th}$ of a second. (Keep three significant figures.). DO NOT fill out the rest of the table now. You will be instructed on how to fill out the rest of the table as you continue.

E) Please carefully remove and return the strip to your instructor.

F) Close out of **Acceleration**, open **GRAPHICAL ANALYSIS or Excel**. Make a plot of ***y vs. t***. Once you have plotted your data, make a rough sketch of the graph in your lab report.

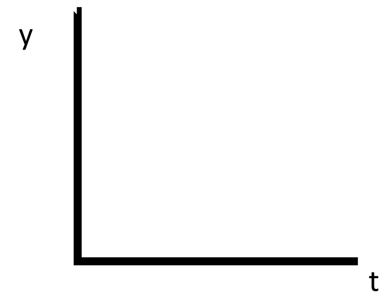


Figure 8 – Part 6 Sketch

Question 4:

Based on what you learned in last week's lab and the graph you just made, what kind of velocity is this graph showing? (i.e. pos./neg. and inc/dec/constant?) Make a sketch of what you think the ***v vs. t*** graph will look like.

G) You are now going to fill in the rest of the table from **Table 2**.

a. In order to calculate Δt and Δy you will use **every other data point**. For example, in order to calculate the first un-shaded box for the Δt column (i.e. the **n = 3** row) you will use t_4 and t_2, for the **n = 4** row, you will use t_5 and t_3, etc.

b. Do all of the calculations for Δt and Δy and place these values in the table.

c. Now, calculate v using $v = \Delta y/\Delta t$.

H) Using the graph paper provided, make a plot ***v vs. t***. Make sure you use all that you learned from the Graphical Analysis lab to graph properly. Use as much of the graph paper as possible.

Checkpoint 13:

Compare the graph you plotted and the one you sketched in **Question 4**. Were the graphs the same? If not, then what error did you make in your reasoning?

I) Using your plotted graph, calculate the acceleration of the object. Again, make sure you use all that you learned from the Graphical Analysis lab.

J) Using a percent difference, compare your calculated value for the acceleration and its theoretical value.

Checkpoint 14:

What were the signs (+ or –) for your velocity and acceleration of the object according to our defined system?

Checkpoint 15:

What kind of motion did the object have ("speeding up" or "slowing down")? Does this agree with what you learned from **Table 6**?

Part 7 – Back And Forth Motion

A) Re-open the **ACCELERATION** file.

B) Take the cart and place it 170 cm away from the sensor with the arrow pointing *away from* the sensor.

C) Turn on the fan, push COLLECT on the computer, and give the cart a push *towards* the sensor.

D) Let the cart move towards the sensor and then back to its starting point.

E) Repeat this until the cart turns around at just about 50 cm from the sensor AND you have a smooth graph while the cart is freely moving. Make a sketch of this graph in your lab report.

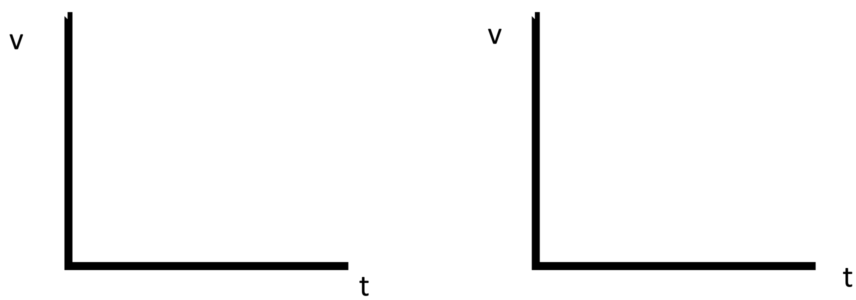


Figure 9 – Part 7 Sketches

Checkpoint 16:

What does the graph tell you about the cart's acceleration at all times?

F) Fill in Table 3 with +, – , or 0 for the "v" and "a" columns and then the type of motion in the motion column. Again, keep in mind you are not to take into account the acceleration of the cart due to your hand pushing it. Take into account only the acceleration due to the fan.

Table 3 – Part 7 Data

Duration	v	a	Motion of cart
Moving towards the sensor			
At the peak			
Moving away from the sensor			

Question 5:

Does your "a" column have the same value for all three rows? If so, explain why. If not, explain why. (Think about what the fan is doing during the entire motion.) Does your answer agree with your answer from **Checkpoint 16**?

Before moving on to the next part, ask your Instructor to come over and check to make sure that your table 3 is correct.

Part 8 – Throwing a Bag

A) Take the bean bag at your table and throw it straight up into the air and catch it at the same level that you threw it. Think about what kind of motion it has on its way up, at the peak, and back down.

B) Fill in Table 4 with +, – , or 0 for the "v" and "a" columns and then the type of motion in the motion column. ***NOTE: Recall from before that we are defining "downwards" as positive.***

Table 4 – Part 8 Data

Duration	v	a	Motion of cart
Moving towards the sensor			
At the peak			
Moving away from the sensor			

Question 6:

Does your “a” column have the same value for all three rows? If so, explain why. If not, explain why. (Think about what gravity is doing during the entire motion.)

C) Compare Tables 3 and 4. They should be the same. If they aren’t then you made a mistake at some point. Check with your instructor on what to do.

A common misunderstanding that’s made is that when an object reaches its peak its acceleration is zero. This is not the case. Gravity does not “turn off” just because the ball stops. It is “on” all the time, just like the fan on the cart was on all of the time, even though the cart stopped briefly at its “peak”.

Another misunderstanding is that the sign of the acceleration is changing from when the ball moves up to when the ball moves back down. This is not the case either. Gravity always pulls down regardless of how the ball is moving. Did the fan on the cart change directions while the cart was moving “up” and then “down”? No, it did not. Gravity is not “paying attention” to what you or any object is doing. That would be very egocentric. Get over yourself. ☺

Conclusion

Follow the lab report guide to write a conclusion on this lab.

Conclusion