Lab 3

Acceleration

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.

$$v_{ave.} = \frac{\Delta x}{\Delta t}$$

$v_{ave.}$ 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)

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 …

$$a_{ave.} = \frac{\Delta v}{\Delta t}$$

$a_{ave.}$ 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)

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.

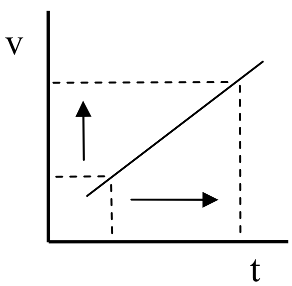

FIGURE 1 – Positive slope

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.

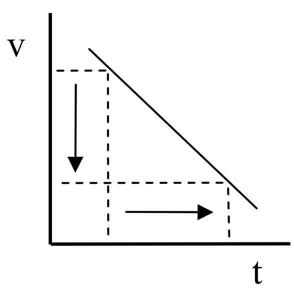

FIGURE 2 – Negative slope

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.

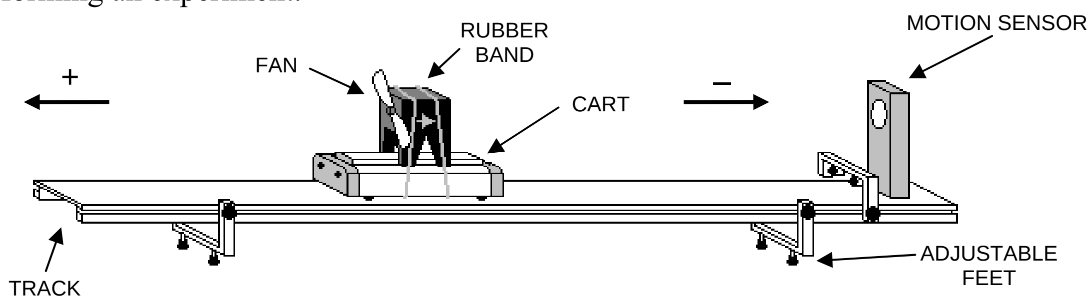

FIGURE 3 - Equipment Set-up (NOT DRAWN TO SCALE)

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 chart of all sign conventions.

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

FIGURE 4 -
Sign Conventions

Before you begin, you should level the track. With the fan off, place the cart on the track and let it go from rest. If the track is level the cart will not move. If the cart moves then adjust the feet underneath the track (**See Figure 3**) to level the track.

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.

Question 1 Below each graph write down what the acceleration would be. How do you know this?

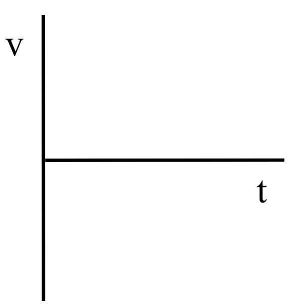

FIGURE 5 -
v vs. t graph

Part 2 – Changing Velocity Away From The Sensor Take your cart and place it 50 cm from the motion sensor. Make sure the arrow on the fan is pointing *away from* the sensor. Make a ***v vs. t*** graph like the one in **Figure 5**. Turn on the fan and release the cart. **NOTE: Make sure someone is always ready to catch the cart at the end of the track.** 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.

Now you are going to use the computer to make a graph of the cart's motion. Open the file **ACCELERATION**. You will see a ***v vs. t*** graph the same as in **Figure 5**. Set your cart up as you did before. Push "Collect" on the computer. 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. Sketch the graph on the computer screen next to the one you made right before using the computer.

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

Question 2 In examining the graph on the computer, is the velocity of the cart positive or negative? How can you tell from the graph?

Question 3 In examining the graph on the computer, do you have an increasing, decreasing, or constant velocity? How can you tell from the graph?

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. At the top-middle of the screen there is a button, "R=". 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.

Question 4 Based on the linear fit line, do you have a positive or negative acceleration? How can you tell from the graph?

Question 5 Based on the linear fit line, do you have an increasing, decreasing, or constant acceleration? How can you tell from the graph?

From the information in the little window, record the acceleration of the cart. Do two more trial runs and record those accelerations.

Question 6 What do you conclude about the acceleration offered by the fan? Is it changing or roughly constant?

Make a chart like **Figure 6**. (You will fill in the chart as you progress through the lab. Do *not* fill out the *entire* chart now.) The first row is for the motion you are currently doing (i.e. **Part 2**) in which your cart started close to the sensor and moved away. Put in a + or a – in the "v" and "a" columns for the first row. 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** on the previous page. Fill in the first row now.

Part	v	a	Motion of cart
2			
3			
4			
5			

FIGURE 6 – Motion Chart

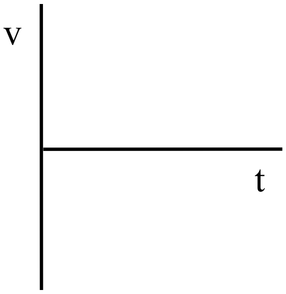

FIGURE 5 -
v vs. t graph

Part 3 – Changing Velocity Towards The Sensor Take your cart and place it about 140 cm from the motion sensor. Make sure the arrow on the fan is pointing *towards* the sensor. Make a ***v vs. t*** graph like the one in **Figure 5**. Turn on the fan and release the cart WITHOUT THE COMPUTER SOFTWARE RUNNING. **NOTE: Make sure someone is always ready to catch the cart at the end of the track before it hits the motion sensor.** Examine the motion of the cart and fill in your ***v vs. t*** graph based on your observations on the motion of the cart.

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

Question 7 In examining the graph on the computer, is the velocity of the cart positive or negative? How can you tell from the graph?

Question 8 In examining the graph on the computer, do you have an increasing, decreasing, or constant velocity? How can you tell from the graph?

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 “R=” for your linear fit.

Question 9 Based on the linear fit line, do you have a positive or negative acceleration? How can you tell from the graph?

Question 10 Based on the linear fit line, do you have an increasing, decreasing, or constant acceleration? How can you tell from the graph?

Go back to your motion chart that you made like **Figure 6**. For the row **Part 3**, fill in the columns for “v”, “a”, and “Motion”. 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. Take the cart and place it at 50 cm away from the sensor with the arrow pointing *towards* the sensor. Turn on the fan. Give the cart a push *away from* the sensor and catch the cart when it stops at its “peak”.

Based on what you observed, fill in the row corresponding to **Part 4** in your motion chart. (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.) 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 Take the cart and place it 140 cm away from the sensor with the arrow pointing *away from* the sensor. Turn on the fan. Give the cart a push *towards* the sensor and catch the cart when it stops at its “peak”. Based on what you observed, fill in the final row in your motion chart.

Before answering the next question, ask your TA to come over and check to make sure that your motion chart is correct.

Question 11 Upon examining your completed motion chart, 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 Have your instructor do a demonstration run of an object in free-fall and then bring the strip of white paper with the freefall data back to your table.

Remove the cart and motion sensor from the track. Using some tape from the front of the lab room, attach the strip of paper with the free-fall data to the track with the first dot on the strip in line with a convenient point on the track. You will be using the ruler on the track so don't cover it with the strip but attach it close for easier reading. If you have some kind of card in your wallet then you can use that to line up the dots with the rulings on the track. Next, in your lab report, make a data chart like the one in **Figure 7**.

n	t_n	Δt	y_n	Δy	v
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					

FIGURE 7 - Freefall data

In the chart, "n" is the dot number (i.e. the 2nd dot is n = 2), "t_n" is the time for the nth dot, "y_n" is the location of the nth dot. Don't worry about the rest of the chart for now.

Start taking data from your *second* dot on the strip and put the measurements in the "y_n" column in your chart. NOTE: We are going to define our system with the direction *"downwards" as positive*. So, all of 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.**

The spark machine was set so that the time between each spark (or dot) was 1/30 of a second. Fill the "t_n" column with your times in *decimal* form. (Keep three significant figures.). DO NOT fill out the rest of the chart now. You will be instructed on how to fill out the rest of the chart after **Question 12**. Please remove and return the strip.

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

Question 12 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.

You are now going to fill in the rest of the chart from **Figure 7**. 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. Do all of the calculations for Δt and Δy and place these values in the chart. Now, calculate v using $v = \Delta y/\Delta t$.

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. Compare the graph you plotted and the one you sketched in **Question 12**. Were the graphs the same? If not, then what error did you make in your reasoning?

Using your plotted graph, calculate the acceleration of the object. Again, make sure you use all that you learned from the Graphical Analysis lab. Using a percent error, compare your calculated value for the acceleration and its true value.

Question 13 What were the signs (+ or –) for your velocity and acceleration of the object according to our defined system?

Question 14 What kind of motion did the object have ("speeding up" or "slowing down")? Does this agree with what you learned from the **Figure 6** Motion Chart?

Part 7 – Back And Forth Motion Re-open the **ACCELERATION** file. Take the cart and place it 170 cm away from the sensor with the arrow pointing *away from* the sensor. Turn on the fan, push COLLECT on the computer, and give the cart a push *towards* the sensor. Let the cart move towards the sensor and then back to its starting point. 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.

Question 15 What does the graph tell you about the cart's acceleration at all times?

Make a chart in your lab report like the one in **Figure 8**. Fill in the chart 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.

FIGURE 8 - Motion chart

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

Question 16 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 **Question 15**?

Before moving on to the next part, ask your TA to come over and check to make sure that your motion chart is correct.

Part 8 – Throwing a Bag 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.

Make a chart in your lab report like the one in **Figure 9**. Fill in the chart 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.

FIGURE 9 - Motion chart

Duration	v	a	Motion of ball
Moving up into the air			
At the peak			
Moving back down			

Question 17 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.)

Compare the charts in **Figures 8** and **9**. They should be exactly the same. If they aren't then you made a mistake at some point.

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 of 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. ☺

What You Need To Turn In:

On a separate sheet of paper from this lab manual answer all of the questions, including all of the charts that you are asked to draw. Also, turn in the graph paper with your plot from **Part 6**.