Lab 2

Position and Velocity

What You Need To Know:

Working With Slope In last week's lab you dealt with many graphing ideas. You will continue to use one of these ideas in this week's lab, specifically *slope*. However, instead of dealing with a lot of calculations we will be concentrating on getting a better feel for the *idea* of slope so you can apply it to the physics you will be learning today.

In graphing, there are always two axes that you deal with, a horizontal axis and a vertical axis. In grade school you were introduced to graphs that were probably *y vs. x* graphs in which the *y* values were placed on the vertical axis and the *x* values were placed on the horizontal axis. This does not always have to be the case. In this lab you will be dealing with *x vs. t* graphs which means that the *x* values will be placed on the *vertical* axis and the *t* values will be placed on the horizontal axis. The *x* values will represent an object's position and the *t* values will represent the time at which the object is at that position. **See Figure 1.**

FIGURE 1
x vs. t graph

You know that slope is defined by the change in your vertical value over a corresponding change in your horizontal value (i.e. the "rise" over the "run"). So, for the type of graphs you will be using today, the slope will equal …

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

Δx is the change in position [rise] (in meters, m)
Δt is the change in time [run] (in seconds, s)

Steep and Shallow One of the main things that you want to get a good feel for in this lab is when you have a large slope and when you have a small slope. From the equation above you can see that when your Δx is greater than your Δt then your slope is large. **See Figure 2.** You can see that when your line is *steep* you have a *large* slope. However, when your Δx is smaller than your Δt then your slope is small. **See Figure 3.** You can see that when your line is *shallow* you have a *small* slope.
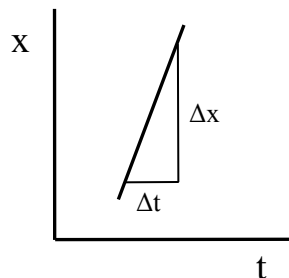
FIGURE 2
Large slope

FIGURE 3
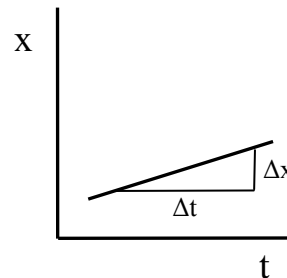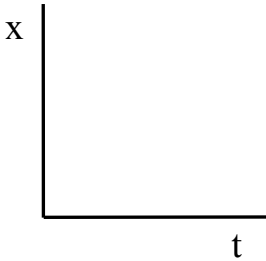Small slope

Positive and Negative   Another important idea is to determine if you have a positive or a negative slope. If your vertical value is increasing (going up) as your horizontal value is increasing (going right) then you have a positive slope. **See Figure 4.** If your vertical value is decreasing (going down) as your horizontal value is increasing (going right) then you have a negative slope. **See Figure 5.**
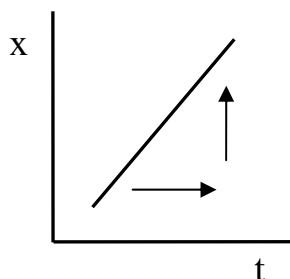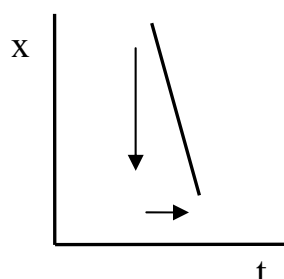
FIGURE 4
Positive slope

FIGURE 5
Negative slope

To tie all of this together you can use this analogy. Think of yourself as hiker who is hiking some hills. The lines on the graphs are a *side view* of the hill and you can *only* hike moving to the *right*. Let's say you were hiking the line in **Figure 3** (from the previous page). In moving to the right you would say that you were hiking *upwards* at a pretty *shallow incline*. Therefore, you would conclude that the line has both a *positive* and *small* slope. Now let's say you were hiking the line in **Figure 5**. In moving to the right you would say that you were hiking *downwards* at a pretty *steep incline*. You would conclude then that the line has a *negative* and *large* slope.
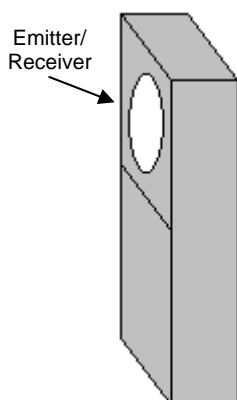
What You Need To Do:

The Equipment   For this lab you will be using a *motion sensor* (**See Figure 6**) attached to a computer. Open the file **POSITION AND VELOCITY**. The motion sensor will emit a pulse that travels out from the sensor until it hits an object. It then reflects off the object and comes back to the sensor and is received. Depending on how long it takes the pulse to return will determine the distance from the sensor to the object. Based on this information, the computer will make a graph of the object's position vs. time (i.e. an *x vs. t* graph).

Emitter/
Receiver

FIGURE 6
Motion Sensor

Since you will be using the motion sensor quite often during the semester it is important that you learn how to use it effectively. In this lab *you* will be the "object" that is moving back and forth in front of the sensor. If the pulse does not have a nice surface to reflect off of it will scatter and not go back to the sensor. You need, then, to hold a solid flat surface in front of you. A notebook will suffice. Also, when you hold up the notebook make sure you *aim* it at the sensor. Otherwise, the signal will bounce off to the side and the sensor will not read it.

The pulse "fans out" a bit when traveling from the sensor. If there are other objects close by like your lab partner or books stacked on the lab table, then they might reflect back the pulse and you will get spikes on your graph. Make sure that the area is clear before you begin.

Ok, so now you can try it out. *Put the sensor at the edge of your lab table* pointing at the wall. Get a flat surface to hold and stand somewhere in front of the sensor. Have your lab partner push the green COLLECT button on the computer screen. There will be a slight pause after pushing the button before the sensor starts emitting pulses. When it starts you can hear the pulses. Move back and forth in front of the sensor and observe what happens on the computer screen. Let each lab partner have a go. Practice at getting a nice, smooth graph. If you are getting spikes on your graph then reread the last couple of paragraphs. If that doesn't clear up your problem then grab your TA for assistance.

Notice that you will never be able to get a reading of "0" on the graph. "0" position would be right at the sensor. The sensor doesn't register objects that are closer than 40 cm from it. If an object is less than 40 cm from the sensor, then the graph will show an object right at 40 cm – no matter what small distance it is from the sensor. Try moving closer than 40 cm from the sensor and see what happens.

Part 1 - Velocity In this lab one lab partner will run the computer and the other will move in front of the sensor. Try to alternate these jobs. *Move the sensor about 40 cm from the edge of the lab table.* (It can't register you within that 40 cm distance anyway.)

A) Have one of you stand in front of the sensor at any distance from the table. Push COLLECT. Do not move for the entire time the sensor is active.

Notice on the computer screen that at all points in time (horizontal axis) you remain at the same position (vertical axis) relative to the sensor. Sketch the graph that you see on your computer screen in your lab report.

Question 1 Based on your graph, is your location positive or negative relative to the sensor? How do you know this? Is there any way you can get both positive and negative locations given how the system is set up right now?

Question 2 What is the slope of your line (shallow, steep, or zero)?

B) Stand close to the table. Once you push COLLECT and the sensor is pulsing move away from the sensor very slowly ("baby steps") and steadily. (Do not move any faster or slower as you walk.) Sketch the graph that you see on your screen in your lab report.

After doing a run on the computer, you might have some spikes at the beginning or end of your motion. You can just ignore these and focus only on the main part of your run in which you have a nice smooth line. **See Figure 7.**
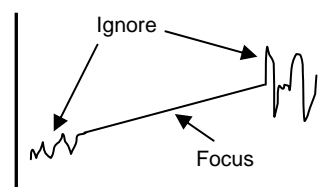

FIGURE 7

Question 3 What is the slope of your line (shallow, steep, or zero)?

C) Stand close to the table. Once you push COLLECT and the sensor is pulsing move away from the sensor rapidly and steadily. Sketch the relevant part of the graph that you see on your screen in your lab report.

Question 4 What is the slope of your line (shallow, steep, or zero)?

Question 5 Looking back at your answers to **Questions 2 - 4**, what do you conclude about the relationship between your different motions and the slopes of each of the corresponding graphs?

D) The first concept one learns about in physics is called *velocity*. An object's velocity is defined by taking an object's change in position and dividing it by its change in time.

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

v is the velocity (in meters per seconds, m/s)
Δx is the change in position (in meters, m)
Δt is the change in time (in seconds, s)

This operation is exactly the same as finding the slope of an *x vs. t* graph. So, *the slope of such a graph is equal to the velocity of an object*.

$$v = \frac{\Delta x}{\Delta t} = \frac{rise}{run} = slope$$

Go back to your three sketches that you made and next to each graph write down what kind of velocity you had. Write either *large velocity*, *small velocity*, or *zero velocity*.

E) In this lab you will be dealing with velocities that are either constant or *changing*. You can tell from your graphs if your velocity is constant or changing by looking to see if your slope is constant or changing. If your line is *straight* then it is *constant*. If your line is *curved* then your velocity is *changing*.

Go back to your three sketches that you made and next to each graph write down if you had a *constant velocity* or a *changing velocity*. **NOTE:** If you have a zero velocity then you don't have either kind since you are not moving.

Part 2 - Velocity and Direction There is one more idea we need to look at relative to velocity and that is whether you have a positive or negative velocity.

A) Stand far from the table. Once you push COLLECT and the sensor is pulsing move *towards* the sensor very slowly and steadily. Sketch the graph that you see on your screen in your lab report.

There should be something different about your graph compared to the last ones. Based on what you learned in the **Introduction** of the lab, can you tell what the difference is? You now have a negative slope. This also means that you must have a negative velocity.

Question 6 Based on your observations for this run and the ones you did in **Part 1**, what does having a positive or negative velocity mean?

Some people think that having a negative velocity means that you are slowing down but you can see that this is not the case. A positive or a negative value in velocity *only* indicates the direction that you are moving in.

B) There are now three different comments you can make about an object's velocity. You can have a positive or a negative velocity, a constant or a changing velocity, and you can have a large, small, or zero velocity.

For the graph you just created write down what kind of velocity you have. (You should write down three different comments.) Also, go back to the graphs you made in **Part 1** and complete your comments for the velocities. (Three total comments.)

C) Stand far from the table. Once you push COLLECT and the sensor is pulsing move towards the sensor rapidly and steadily. Sketch the graph that you see on your screen in your lab report. Write down next to the graph what kind of velocity you have.

D) For the motion you just did in **C)** and *using information only from the graph*, explain how you knew what to write down for the three different comments about the velocity.

E) Explain the same thing again (as in **D)**) but *base your answers relative to your motion*. Some of yours answers will be really obvious but write them down anyway. For example, "I know that I had a small velocity because I was walking slowly."

Part 3 – Finding a Slope Once you have a graph of your motion it is possible to get a number value for your slope. This procedure is something that you will be doing a lot of during the semester. If you are confused about any of this then make sure you grab your TA for clarification.

A) To find the slope of your graph, first highlight the region which gives you the best slope reading. You only want to highlight the region that has a nice, smooth line like the region of focus in **Figure 7**. Using the last graph you made from **Part 2**, place your mouse on the left end of this region and click and hold. Drag the mouse to the right end of the region and unclick. At the top middle of the screen you should see a button "R=". If you click this button it will open a small window with several pieces of information, one of which is the slope of your highlighted region. Write down the slope value and explain how it agrees with any velocity comments you made earlier for this graph. Ask your TA for help if you are confused on this process.
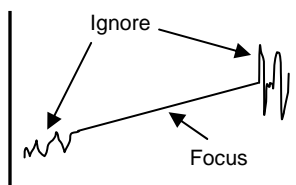

FIGURE 7

B) Close the small window. Do a run for moving away from the sensor very slowly and steadily. Using the same method you just used, find the slope of this line and explain how this agrees with your motion.

Part 4 – Velocity Graphs We've discussed how to *describe* the velocity of an object based on its position vs. time graph. Now we're going to talk about how to make a *velocity* vs. time graph based on a *position* vs. time graph.

Let's say you have an object whose position vs. time graph is like the one in **Figure 8a.** The slope of this line is zero which tells you that the velocity is zero. (The dashed lines signify the beginning and the end of the motion.) You
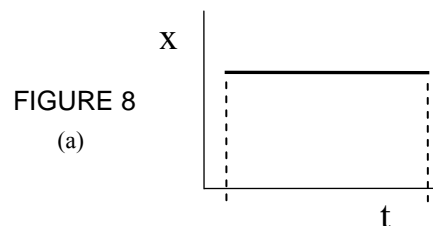

FIGURE 8

(a)

would then draw a velocity vs. time graph that shows zero velocity. **See Figure 8b.** NOTE: In other cases you have possibilities of positive or negative velocities, so the graphs are drawn with an option of a positive or a negative velocity (i.e. above or below the time axis).

For another example, let's say you have an object whose position vs. time graph is like the one in **Figure 9a.** The slope of this line is large, negative, and constant. In your velocity vs. time graph, **Figure 9b**, you would draw a line that has a high value (farther from the time axis), is negative (below the time axis, not above), and is a horizontal line (it has the same velocity value at any time, i.e. constant).
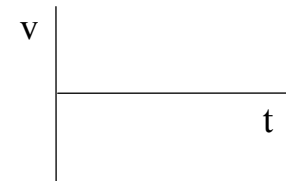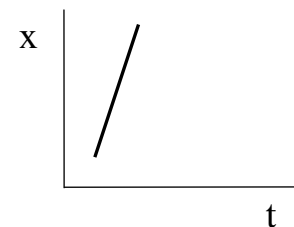
FIGURE 8 (b)

FIGURE 9 (a) (b)
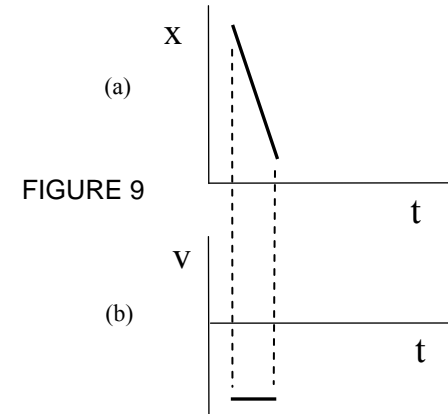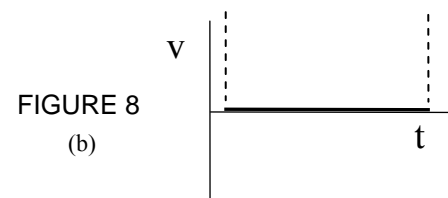
A) Copy the next three sets of graphs into your lab report and complete the velocity vs. time graphs. Also, next to each set of graphs, describe in words what kind of velocity the object has.
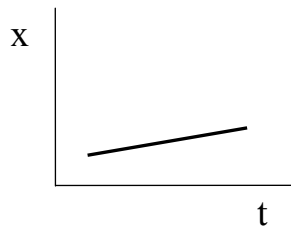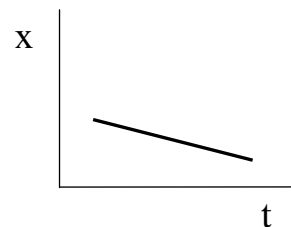
(I)   (II)   (III)

Part 5 – Graph Matching Close out of **Position and Velocity** and open up **GRAPH MATCHING**. You should see a position vs. time graph with a light blue line on it that represents several different motions. *Move the sensor about 70 cm from the edge of table*.

A) For each of the different types of motion over each increment of time write out what you would have to do in front of the motion sensor to match the blue line. Also state what kind of velocity you have for each motion. For example …

   ➤ From 0 to 1 second I would stand at rest a distance of 1 meter away
      from the motion sensor. I would have a velocity of zero.

B) Now try to match the graph by actually doing what you wrote out in **A)**. Take no more than ten minutes to do this.

Part 6 – Changing Velocity So far, everything you have done has been either zero velocity or constant velocity. Now you are going to be doing a changing velocity. Close out of **Graph Matching** and open back up **POSITION AND VELOCITY**.

A) Start close to the sensor, push COLLECT, and move away from it at a steadily increasing rate. HINT: Start out with very small "baby-steps" and then increase your stride. You should get a graph that looks similar to the one in **Figure 10**. Sketch your graph in your lab report.

B) Highlight the first 0.5 seconds of your graph in which you have a smooth curve. Push "R=" and record your velocity. Do the same for the last 0.5 seconds.

x

t

FIGURE 10

Question 7 What happened to your velocity from the beginning of your motion to the end of your motion? Describe your velocity fully. (i.e. constant, increasing, or decreasing; positive or negative)

C) Make a velocity vs. time graph of your motion. NOTE: No matter what your *x vs. t* graph looks like you will never have a curved line in your *v vs. t* graph. It will always be either a horizontal straight line or angled straight line.

D) Start far from the sensor, push COLLECT, and walk towards it at a steadily increasing rate. Sketch your graph. Describe your velocity. Make a *v vs. t* graph for your motion.

E) Copy the next two sets of graphs into your lab report. Do the following for each set …

- For each *x vs. t* graph describe how you would move in front of the sensor in order to achieve the graph.

- Based on each *x vs. t* graph, state what kind of velocity the object has.
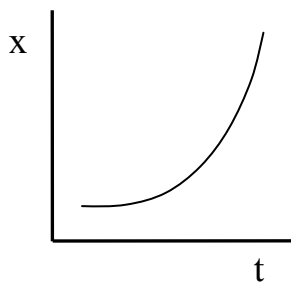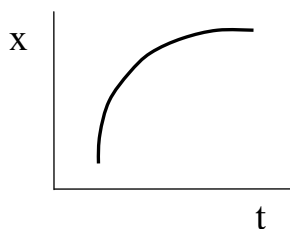
- Complete the *v vs. t* graph.

(I)   (II)

Part 7 – A Few Questions Just to test what you have learned, answer the following questions …

Question 8 Given a *position* vs. time graph for a motion, how can you tell whether your velocity is constant?

Question 9 Given a *velocity* vs. time graph for a motion, how can you tell whether the velocity is constant?

Question 10 Given a *position* vs. time graph for a motion, how can you tell the direction of motion?

Question 11 Given a *velocity* vs. time graph for a motion, how can you tell the direction of motion?

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 graphs that you are asked to draw.