Date_____Partners_____

Introduction to Motion

<u>Objectives</u>:

- To investigate how motion appears on a position versus time graph
- To investigate how motion appears on a velocity versus time graph and the relationship between the two graphs
- To investigate a simple example of non-constant velocity

<u>Overview</u>:

In this set of experiments you will examine ways that the motion of an object can be represented graphically. You will use a motion detector to plot position and velocity graphs of the motion of your own body and of a cart. The study of motion and its mathematical and graphical representation is known as *kinematics*.

A <u>sonar ranging device</u> such as our motion detector uses pulses of ultrasound (air pressure waves) that reflect from an object to determine the object's position relative to the detector. It detects the closest object directly in front of it including your arms or the track that the cart rides on. **The motion detector will not be able to measure anything closer than about ½ meter.**

Activity 1 –Position vs. Time Graphs

The purpose of this activity is to begin to learn how to relate graphs of position vs. time to the motions they represent. You will use a motion detector and your own motion.

As you walk, the graph on the computer screen displays how far away from the detector you are. It is common to refer to the distance of an object from some origin as the *position* of the object. Since the motion detector is at the origin of the coordinate system, the graphs you will make are *position vs. time* graphs.

1. First you will connect the motion sensor physically to the Pasco interface box. Notice that there are two kinds of channels, digital channels (1&2) and analog channels (A, B, & C). Plug the motion sensor into the digital channels 1 and 2. Turn on the interface box.

2. Now you will connect the motion sensor in the data acquisition software, Data Studio. Open the Data Studio program and select "Create Experiment". In the Experiment Setup window that pops up there will be an image of the Pasco interface box. Click on digital channel 1 and select the motion sensor from the list of possible sensors.

3. Finally you need a graph of the output of your motion sensor. From the display choices drag the graph icon over the motion sensor icon, this creates the graph of position vs. time you need.

4. A useful amount of data for this experiment is about 10s. You can change the scale of an axis by grabbing a number on the scale and pushing it away from or toward zero to zoom in and out respectively. Rescale the position axis so that it runs from 0 to 3m.

5. Mount the motion detector on a support rod near the computer at a height so that it is aimed at your midsection when you are standing in front of the detector. Make sure that you can move at least 2 meters away from the motion detector. NOTE: You will be moving backwards for part of this activity, so make sure there the area behind you is clear for at least 2 meters. Position the computer monitor so you can see the screen while you move away from the motion detector.

6. To see what happens, click the Start button and walk away from the motion detector. You can take multiple measurements each of which are stored as a separate run.

7. Use the detection equipment to make position vs. time graphs for the following motions. When motion has been recorded satisfactorily sketch the graph in the space below:

    a. Start at the ½-meter mark and walk <u>away</u> from the detector *steadily and slowly.*
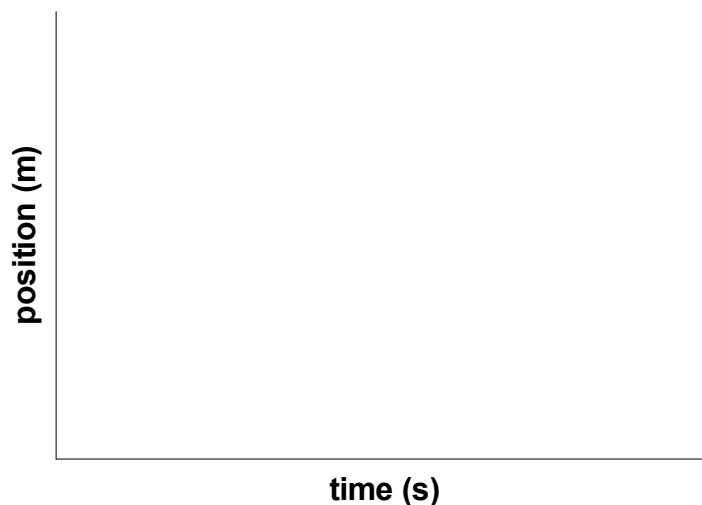
    b. Walk <u>toward</u> the detector *steadily and somewhat faster*.
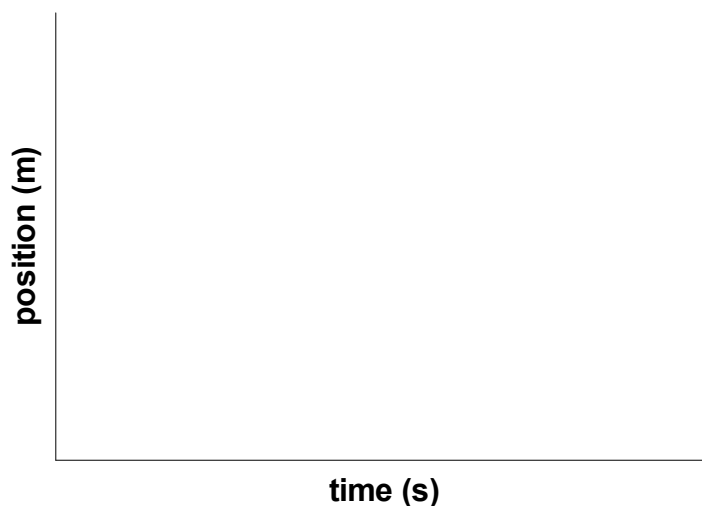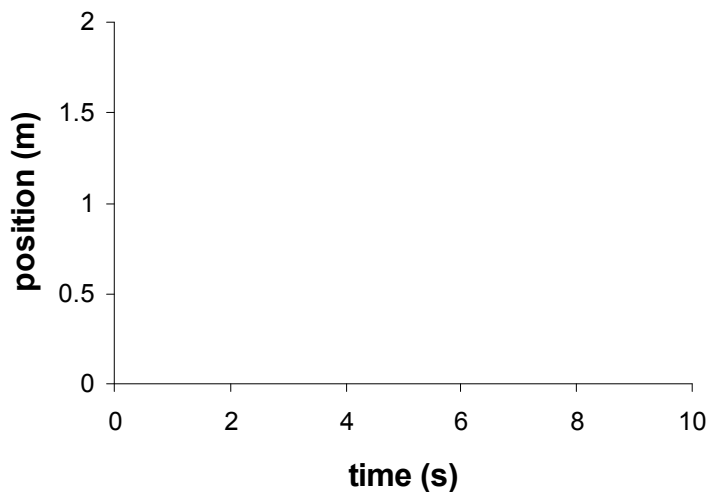
8. What feature of the graphs tells you which one is for the faster motion?



What feature of the graphs tells you which one is for motion toward the motion detector?

9. Predict the position vs. time graph produced when a person starts at the 1-meter mark, stands still for 1 second, walks away from the detector steadily and somewhat quickly for 3 seconds, stops for 3 seconds, and then walks toward the detector slowly.

Prediction

(Blank graph: y-axis labeled "position (m)" from 0 to 2 in increments of 0.5; x-axis labeled "time (s)" from 0 to 10 in increments of 2.)

Test your prediction. Move in the way described and graph your motion. When you are satisfied with your graph, sketch your group's final result.

Experimental Result
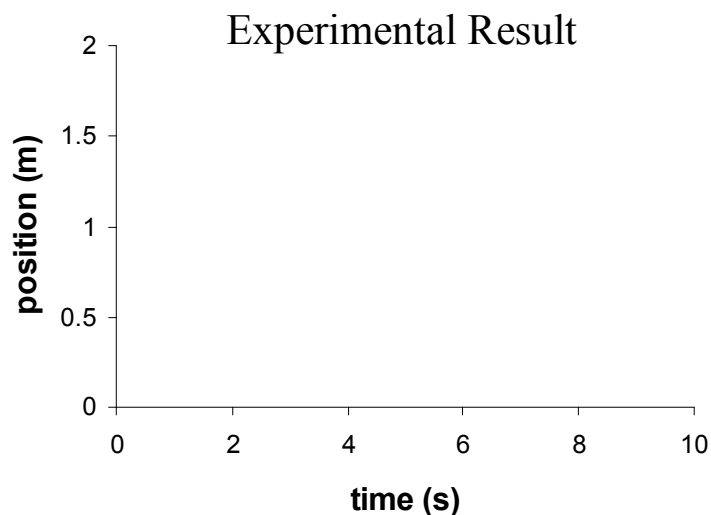
10. Now let's try to reproduce a position vs. time graph. **Open** the activity file "matching". Do not save the results of the previous section. You will see that there is a plotted position vs. time graph in this experiment window.

The graph to match will look something like this:
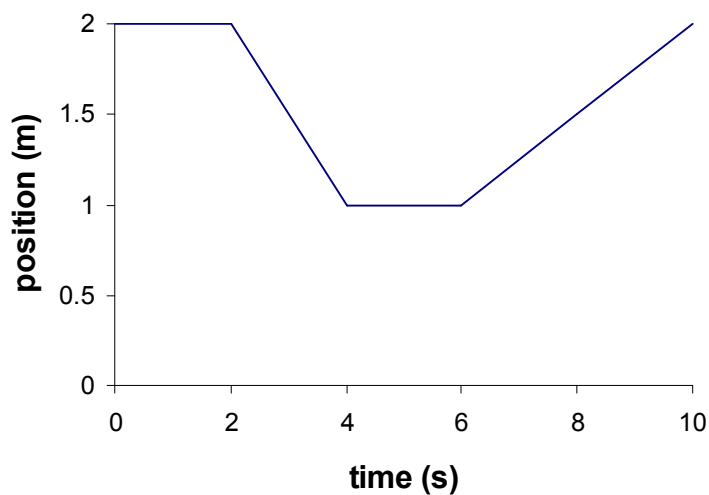
Record your motions as you move to match the graph on the computer screen. Each person in your group should make a few tries. Save your group's best run as "matchingYourNames".

What were the most difficult features of the graph to match? Speculate on why that feature was not actually possible to match perfectly.

Activity 2 – Velocity vs. Time Graphs and the Relationship to Position vs. Times Graphs

You have already plotted your position as a function of time. Another way to represent your motion during an interval of time is with a graph that describes how fast and in what direction you are moving. This is a *velocity vs. time* graph. *Velocity* is the rate of change of position with respect to time. It is a quantity that takes into account your speed (how fast you are moving) and also the direction you are moving. The sign of the velocity describes the direction of one-dimensional motion.

1. In the space below draw on the graph your group's prediction for what the velocity vs. time will look like for the run you saved as "matchingYourNames".

Prediction

velocity (m/s) vs. time (s)
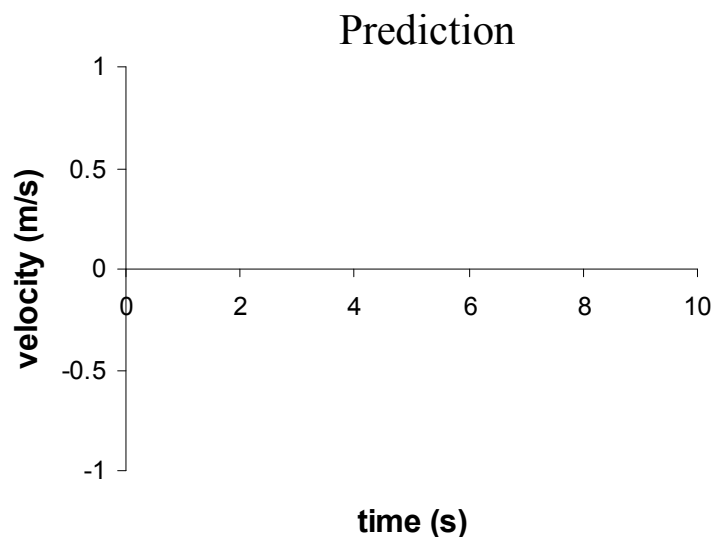
2. On the left side of the screen there are 3 types of data: position, velocity, and acceleration. Drag the velocity data from your final run onto the graph you already have, a new graph of velocity vs. time will appear below your position vs. time graph.

3. Sketch below your actual graph of the motion, using smooth lines to "average out" the bumpiness.

Experimental Result
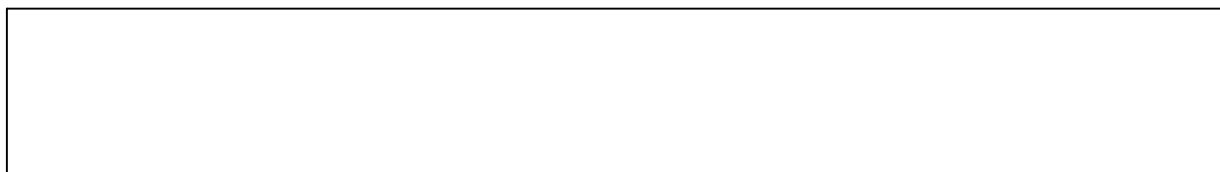
velocity (m/s) vs. time (s)
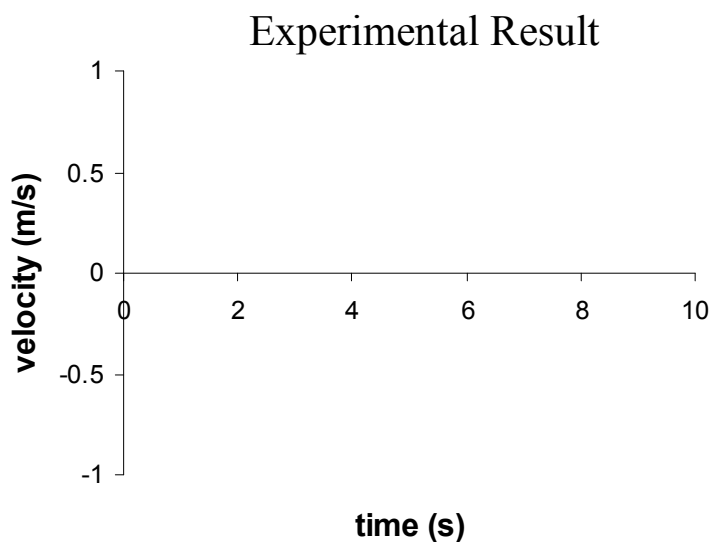
Explain carefully the magnitude and sign of the velocity for the various parts of the graph. (How is the graph different when walking quickly or walking slowly, when walking toward the detector or walking away?)

4. We want to calculate the slope of the best straight-line segment of your position vs. time graph. At the top of your graph there is a button with an "xy" in it. Click on that button. You will now have a cross-hair cursor. When you move it to anywhere in the graph area, the coordinates of that location are displayed next to the labels on the axes.

    Record the coordinates of two widely separated points on the best straight-line segment of your position vs. time graph and calculate the slope of the line. (Click anywhere to remove the cross-hair cursor.)

5. We will use the velocity vs. time graph to obtain the average velocity for that same time interval.

    Click on the Σ button that is also at the top of your graph. This displays various statistics in the legend of each graph. You can change which statistics are displayed in the pull down menu next to the Σ button. By default all of the data for a given run will be included in the average. To restrict the average to a subset of the data click on the run of interest and highlight the data points of interest.

    How does the value of the mean velocity compare to the slope of the position vs. time graph?

Activity 3 – Non-Constant Velocity

In this activity, you will look more closely at the relationships among position, velocity, and acceleration (rate that the velocity changes). The object in motion will be a cart that will ride on a tilted low friction track.

1. Place the motion detector at the higher end of the track. Place the cart on the track at the low end of the track with the wood plate facing the motion detector.

2. We now need a fresh start. In the Experiment menu select "Delete ALL Data Runs" and close the graph window. Drag the graph icon from the Displays window over the motion sensor icon. You should once again have a blank position vs. time graph. Rescale this graph so that the position axis runs from 0 to 3m.

3. You want to collect position vs. time data for the car going up the track, coming to a stop at the highest point of its motion, and then coming down the track. The car should not get closer than 0.5 m to the detector when it stops but you want to get as close as possible to that. One technique is to release the car from the top, let it bounce at the bottom and then start collecting data on the way back up. You want to remember to stop collecting data before the car gets back to the bottom of the track.

4. Collect data using the Start button. Repeat until you get a smooth and complete graph of the motion.

5. For your best run, sketch below a graph of position vs. time.

Experimental Result
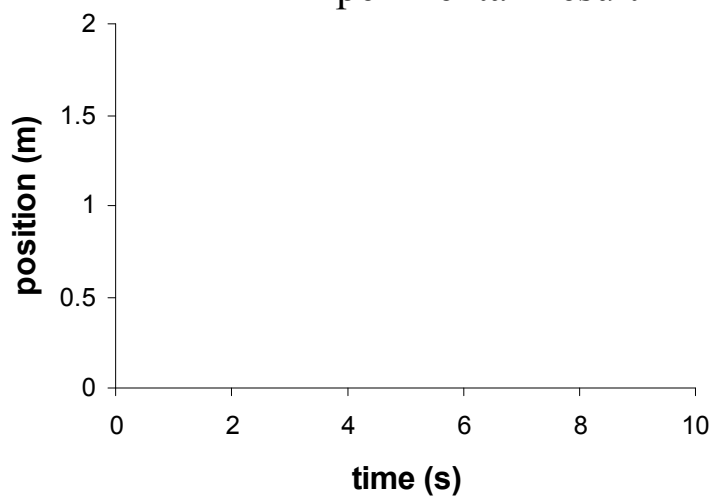
6. In the space below draw your group's prediction for what the velocity vs. time will look like for this motion.

Prediction
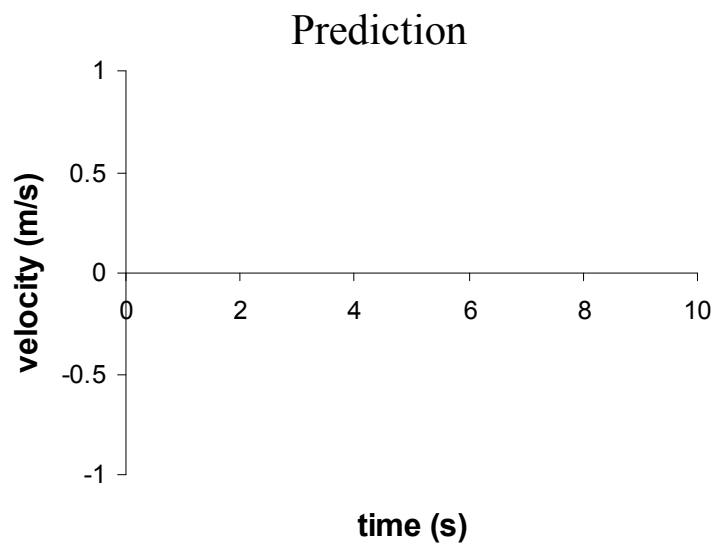
7. Add the velocity vs. time graph below the position vs. time graph. Do this by dragging "velocity" from the Data window into the graph window. Sketch the resulting graph in the space below. Again, you can rescale the vertical axis by dragging a number on that axis in the proper direction.

Experimental Result
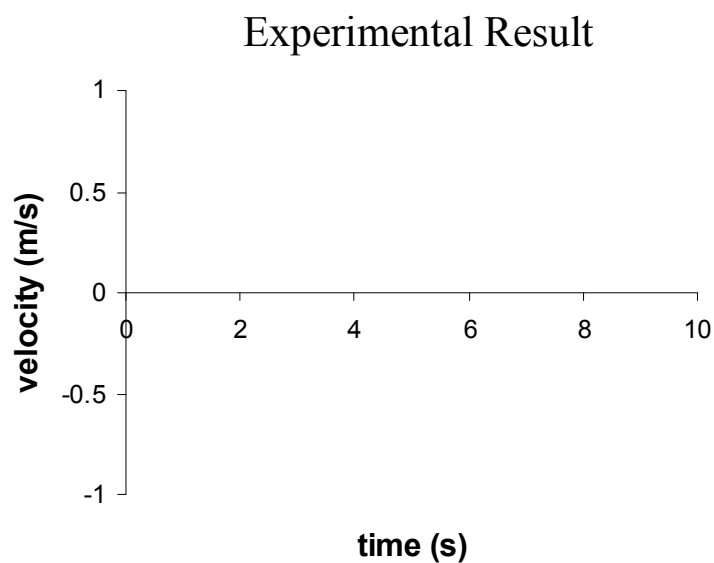
8. Now let's look at the slope of the velocity vs. time graph.

What are the <u>units</u> of the slope of this graph?

Use the "xy" cursor and two widely spaced points on the straightest portion of the velocity vs. time graph to calculate the slope. (When through, click to turn the cross hair cursor off.)

What physical quantity is represented by this slope?

9. We can also calculate a best-fit line to a segment of the data using Data Studio. Use the cursor to select a good straight-line segment of your velocity vs. time graph. Click on the fit button at the top of the graph window and select "Linear Fit". A linear equation of the form y=mx+b will be shown with best-fit values for the constants m and b.

What actual physical quantities are represented by *y* and *x* in this fit equation?

Explain why the technique for finding the slope in step 9 is superior to that in step 8.

10. Add an acceleration vs. time graph below the velocity vs. time graph. You may need to make the graph window larger to get three good graphs (i.e. ones that have numbers on the axes.)

Is the graph of the acceleration what you expected? Explain.

How does the average value of the acceleration from this graph compare to the value of the slope of the velocity vs. time graph?

11. Considering all three graphs: The velocity of the cart was zero at one time.

Where was the cart in its actual motion on the track at that time? What was happening in the position vs. time graph at that time? Was the acceleration zero at that time?

When the velocity changed direction, did the acceleration change direction?

Print out your graphs from activity 3 and include them with this packet.