

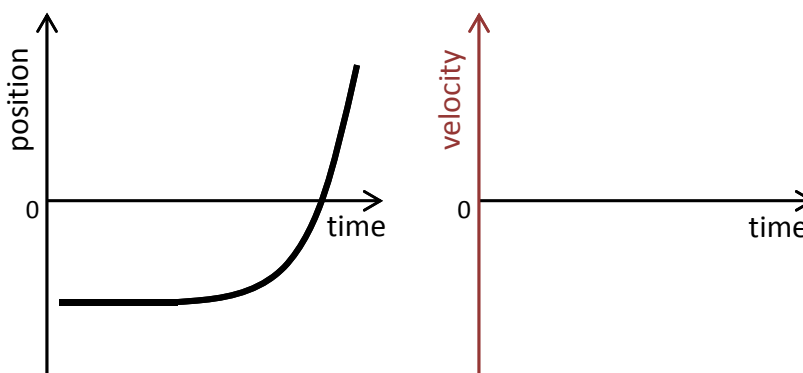
Name \_\_\_\_\_ Section \_\_\_\_\_ Date \_\_\_\_\_

**PRE-LAB PREPARATION SHEET FOR LAB 2:  
Position, Velocity, and Acceleration in one-dimensional motion**

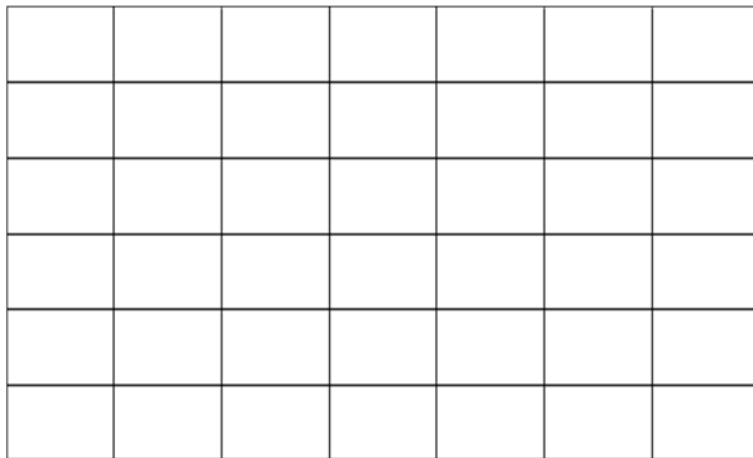
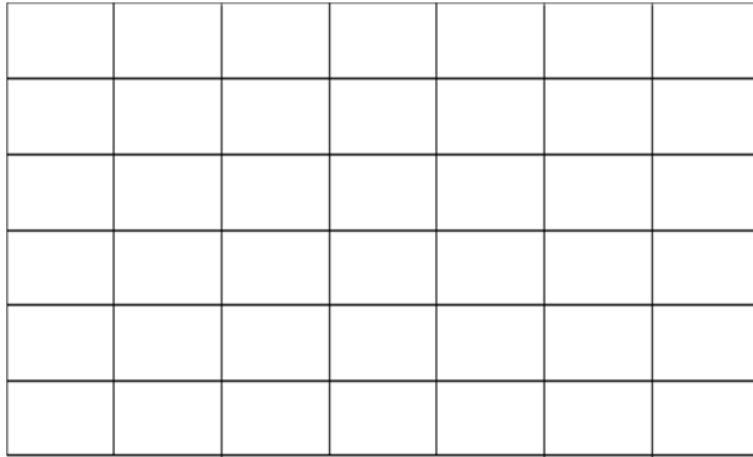
(DUE AT THE BEGINNING OF LAB)

Read over the lab and then answer the following questions

1. Given the following position curve, sketch the corresponding velocity curve.



2. Imagine kicking a box across the floor: it suddenly starts moving then slides for a short distance before coming to a stop. Make a sketch of the position and velocity curves for such motion.



Name \_\_\_\_\_ Date \_\_\_\_\_ Partners \_\_\_\_\_  
 TA \_\_\_\_\_ Section \_\_\_\_\_

## Lab 2: Position, Velocity, and Acceleration in one-dimensional motion

*"God does not care about our mathematical difficulties. He integrates empirically."  
 --Albert Einstein*

### Objectives:

- To understand graphical descriptions of the motion of an object.
- To understand the mathematical and graphical relationships among position, velocity and acceleration

### Equipment:

- 2.2-meter track w/ adjustable feet and end stop
- A block to raise one end of the cart
- Motion sensor
- Torpedo level
- PASCO dynamics cart and friction cart

### DISCUSSION

Velocity is the rate of change or time derivative of position.

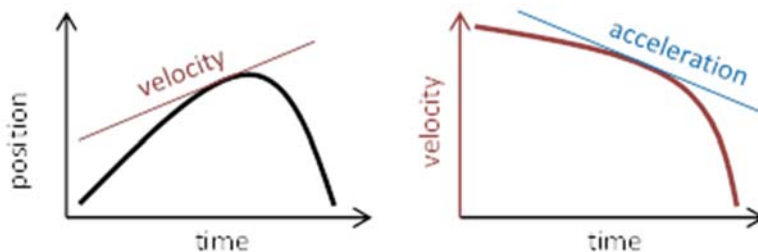
$$\vec{v} = \frac{d\vec{x}}{dt} \quad (2.1)$$

On a Cartesian plot of position vs. time, the slope of the curve at any point will be the instantaneous velocity.

Likewise, acceleration is the rate of change or time derivative of velocity (the 2<sup>nd</sup> derivative of position).

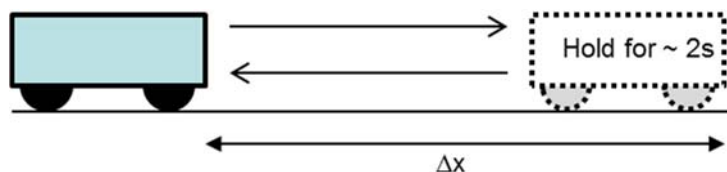
$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{x}}{dt^2} \quad (2.2)$$

On a Cartesian plot of velocity vs. time, the slope of the curve at any point will be the instantaneous acceleration.

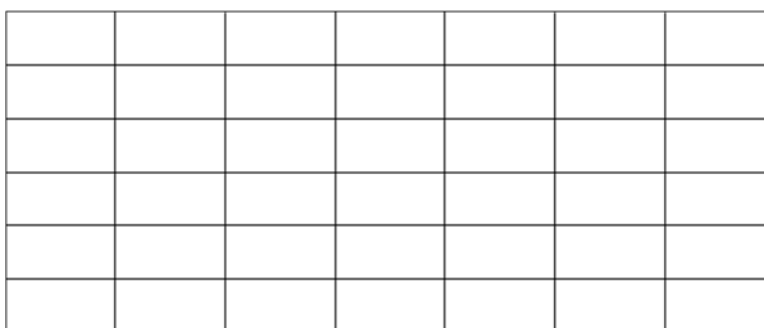




Thus, the shape of any one curve (position, velocity, or acceleration) can determine the shape of the other two.

### Exercise 1: Back and Forth



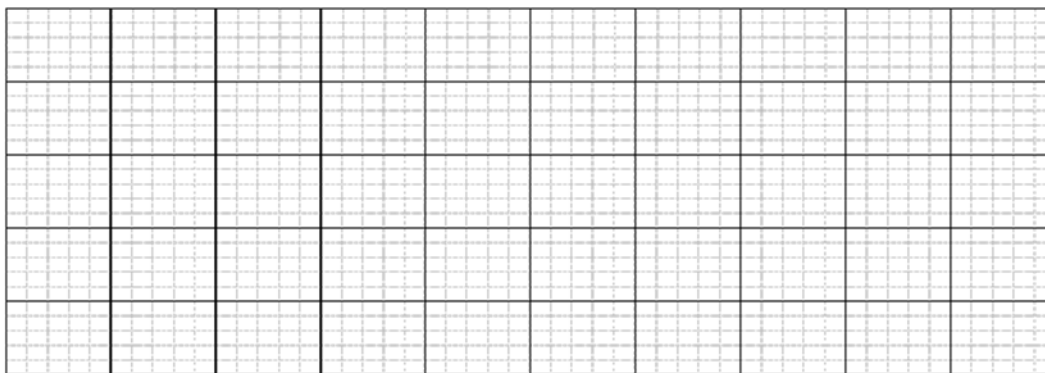
- a. Place the friction cart on the track. (That is the one with the friction pad on the bottom. Without letting go of the cart, quickly push it toward the detector by about a foot, then stop it for 1 or 2 seconds. Then quickly but smoothly return the cart to the starting point. Note the distance it travels, and sketch the position vs. time curve for the block on the plot below.




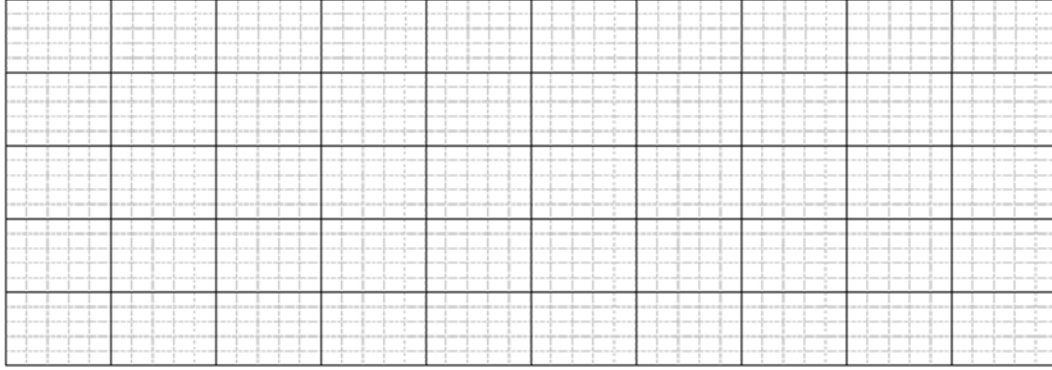
- b. Now, open the Labfile directory found on your computer's desktop. Navigate to A Labs/Lab2 and select the program Position. The PASCO DataStudio program should open and present you with a blank position vs. time graph.
- c. Click the **Start** button (upper left side of the screen), and repeat the experiment above. Click **Stop** to cease recording data. Note how the PASCO plot compares to yours.  
**Note:** The cart may bounce or stutter in its motion. If you don't get a smooth curve, delete the data<sup>1</sup> and repeat the run with more Zen<sup>2</sup>.
- d. By clicking the scaling icon  (top left corner of the Graph window) you can better fill the screen with the newly acquired data.
- e. Select the slope icon . A solid black line will appear on the screen. By dragging this line to points along the plot, you can measure the slope of the curve at those points. Using this tool, find the steepest part of the curve (that is, the largest velocity). Then, sketch the velocity curve for the block in the graph below. Add appropriate numbers to the x and y axes.


<sup>1</sup> To delete data: Top bar, Experiment, Delete ALL Data Runs

<sup>2</sup> "This time, let go your conscious self and act on instinct." Obi-Wan Kenobi




- f. How does the shape of the position curve determine the sign of the velocity curve?
- g. Now, let's see how well you drew it! Double-click on the new graph icon  (left side of the screen, lower half) and select **Velocity** for the y-axis. Note the shape and position of the curve and see how well it matches your sketch. Also note how it aligns with the position curve.
- h. Use the slope tool to find the changing slope along the velocity curve. With this information, sketch the acceleration curve for the block. Again, appropriately mark the axes.



- i. Let's see what PASCO says about the acceleration. Again, create a new graph  and select **Acceleration** for the y-axis. Compare it to your acceleration curve and PASCO's velocity curve.
- j. How does the shape of the position curve determine the sign of the acceleration curve?
  
- k. Print out the three PASCO plots. On these plots, annotate the times when the push began, when the push ended, when it was slowing, and when it stopped. Notice how these times correspond to features on the three curves.

**Exercise 2: Skidding to a Stop**


Delete your previous runs. (Top bar, Experiment, Delete ALL Data Runs). With a left click of the mouse, you can remove the slope tools.

- a. Move the cart to end of the track opposite the detector.
- b. Start recording data, then give the cart a quick, firm push so that it slides a few feet before coming to rest. Stop the data acquisition.
- c. By clicking the scaling icon , you can better fill the screen with the newly acquired data. Again, if the data is not reasonably smooth, delete the data and repeat the experiment with more Zen.
- d. Print out the curves and annotate on the graphs with the times when the push began, when the push ended, and when the cart was sliding on its own.

You should notice that as the cart is slowing down, the acceleration curve is nearly a constant flat line.

- e. Given constant acceleration, what mathematical expression describes the velocity?
  
  
  
  
  
  
  
  
  
  
- f. What mathematical expression describes the position?


You can verify that these expressions work by numerically fitting the data.

- g. With a click and drag of the mouse, highlight the region of the velocity curve where the cart is slowing down. Then, select the fitting tool  and choose the appropriate expression to describe the data. Record the results of the fit below. (Note the uncertainty provided by the fit.)





**Exercise 3: Up and Down**

- a. Place a block under one of the track stands to form a ramp. The detector must be on the raised end.
- b. Place a low friction cart on the track and give it a push so that it rolls a few feet up the incline and then rolls back. After a few practice runs, run the detector and acquire motion data.
- c. With a click and drag of the mouse, highlight that section of the data where the cart is freely rolling along the track. Then use the scaling tool  to zoom-in on that section of the data.
- d. Print out these plots and annotate the graphs with the following information.  
When and where does the velocity of the cart go to zero?  
When and where does the acceleration of the cart go to zero?
- e. Find the average acceleration going up the slope and down the slope. Record the results below.
  
- f. How does the acceleration up the slope compare with the acceleration down the slope? What might account for the difference?