PHYSICS LAB EXPERIMENT - 2

DISPLACEMENT, VELOCITY, AND ACCELERATION IN ONE DIMENSION

OBJECTIVE: To give you a better understanding of how position versus time, velocity vs. time, and acceleration vs. time graphs connect to the observed motion of objects.

APPARATUS:

- A PocketLab and associated Bluetooth-enabled device.
- An air track with glider (or "cart").
- An air pump to power the track.
- A few wooden blocks

THEORY: *Displacement* is the difference in an object's initial and final positions. One way of representing this mathematically is

$$\Delta x = x_f - x_0$$

where Δx is the displacement of the object, x_f is the final position of the object, and x_0 is the initial position of the object, or the position of the object at time equal to zero. Displacement tells you the overall distance that an object has moved away from its initial position during the time period you're interested in. Note that the displacement of an object after a certain time is different from the distance an object has travelled in that time. Can you think of a situation where the displacement of an object would be zero, but the distance it travelled is not zero? The standard unit of measurement for both displacement and distance is a meter.

Clearly, the displacement of an object does not completely describe its motion. Often, one is interested how quickly this movement happens. In that case, the *velocity* of an object is useful. We can represent the average velocity ($\bar{v}$) during a period of time in the following way

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

where Δx is again displacement, and Δt is how much time passed between the object's movement from its initial position to final position. This tells us (on average) how quickly an object moved during a certain period of time.

Our last quantity of interest in this lab activity is *acceleration*, which is defined as the rate change of velocity, or

$$\bar{a} = \frac{\Delta v}{\Delta t}$$

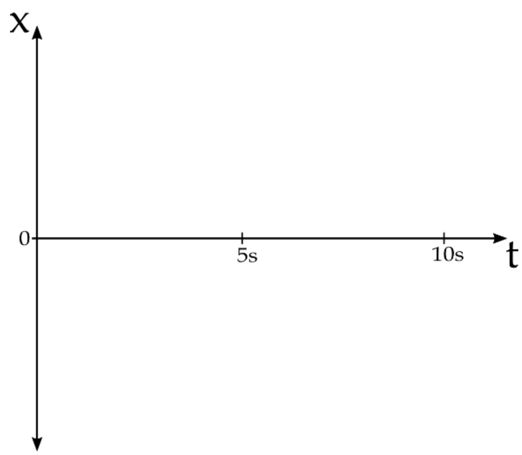
It is important to note a few things about acceleration. First is that it is almost completely independent of an object's velocity at a particular moment. One can have a huge acceleration while at the same time having a small velocity. Second is that we are dealing with the *change in* velocity, $\Delta v = v_f - v_0$, which is distinct from the average velocity of an object. Lastly, this definition is for the *average* acceleration during a period of time. For the instantaneous value of acceleration, we would want to take a derivative with respect to time of the function for velocity. This is equivalent to the *slope* of a velocity vs. time graph at a point in time.

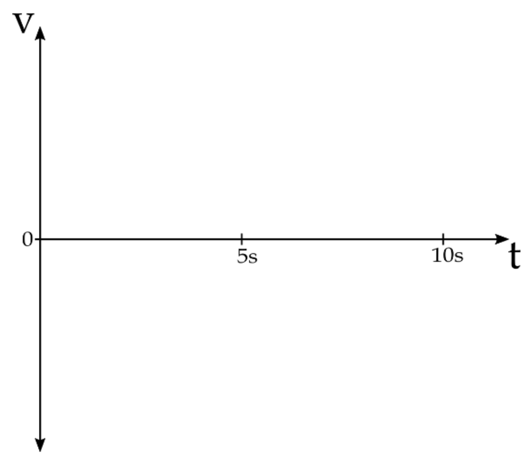
PROCEDURE:

1. Familiarize yourself with the operation of the air track, glider, and air pump. Then carefully level your track by adjusting the screw on the underside of one end.

2. Attach the PocketLab to the glider so that its rangefinder pointed parallel to the track.

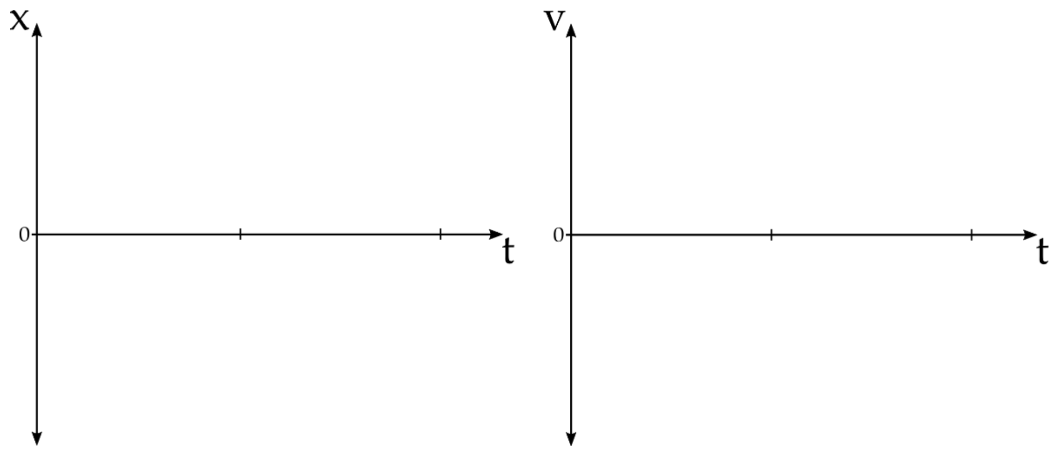
3. **PREDICTION 1:**
   Consider a glider that is given a slight push away from the end of the track at which the rangefinder is pointed. Then at t = 5 seconds, the cart hits the end of the track and turns around. You can assume that this collision changes the glider's direction, but not its speed (i.e. the magnitude of its velocity). Plot the velocity of the glider as a function of time and the position as a function of time for the glider during the entire 10 second period. Take the cart's initial position as x = 0, and its initial speed as 1 m/s.





4. **EXPERIMENT 1:**
   Now try to experimentally approximate the situation described in PREDICTION 1. You will need to place a book or large flat surface at the end of the track for the rangefinder to detect. Monitor the "rangefinder" and "rangefinder velocity" sensors (use the "2-graph" option to monitor both at once) on your PocketLab to see graphs similar to the ones above, and give the glider a push such that it bounces (gently) back from the end of the air track. Repeat this experiment a few times until you are satisfied with the quality and repeatability of your tests, and then record a trial and *save the data for your report*.

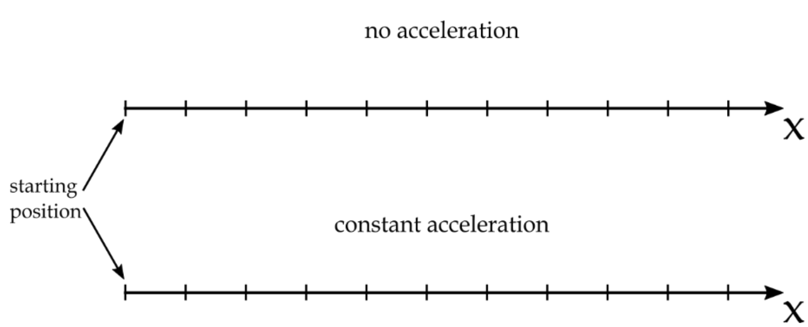
5. **PREDICTION 2:**
   Now think about a glider that is given an initial push so that it is initially moving up an inclined track. Sketch what you would expect its position and velocity vs. time graphs to look like. Again, take the glider's initial position to be zero.



6. **EXPERIMENT 2:**
   Now try to experimentally approximate the situation described in PREDICTION 2. Use a wooden block to give the track a small incline, and give the glider a quick but gentle push *up* the incline. Use your PocketLab to monitor the glider's rangefinder, rangefinder velocity, and scalar acceleration. You can do this using the "3-graph" option in the sensor menu. Repeat this experiment a few times until you are satisfied with the quality and repeatability of your tests, and then record a trial or two that shows the glider's position, velocity, and acceleration as it moves up the track and then back down. *Save this data for your report*.

QUESTIONS:

1. On the position axes below, draw predictions for a glider's position at one second intervals as it moves with no acceleration (top axis) and constant acceleration (bottom axis).



2. Look at your velocity vs. time graph in Prediction 1. Where on the graph did your glider change direction, and how did you determine this?

3. Compare Prediction 1 to the data you collected in Experiment 1. What differences do you see, and why do you think those differences occurred?

4. Compare Prediction 2 to the data you collected in Experiment 2. What differences do you see, and why do you think those differences occurred?

5. Answer the following questions based on your experimental data from Experiment 2.
   a) During the time the glider was moving up the track, what was the sign of its acceleration?

      What was the sign of its velocity?

   b) During the time the glider was moving down the track, what was the sign of its acceleration?

      What was the sign of its velocity?

   c) What was the glider's acceleration when it was changing direction at its highest point on the track?

6. Do any of your answers from question 5 seem to be incorrect based on what you understand about the theory behind the motion of the glider? Whether they seem correct or incorrect, please briefly explain your conclusions.

7. Finally, use a computer program (i.e. Microsoft Excel or the like) and the data you saved from the PocketLab to make:
   a. Graphs of the position and velocity data from Experiment 1 (level track).
   b. Graphs of position, velocity, and acceleration vs. time for Experiment 2 (sloped track).

   Make sure to include an appropriate descriptive title for each plot, and to label each axis with its corresponding variable and units. *Also*, label relevant events on the plots, i.e. "glider was pushed here", "glider bounced off the end of the track", etc.