Accelerated Motion

INTRODUCTION

How can we use mathematics to express the way an object moves when it is speeding up? The velocity of the object is constantly changing, rather than a steady value. In this exercise, you will apply curve fits to graphs of position *vs*. time and velocity *vs*. time for a fan cart. You will use the curve fits to determine the parameters of the motion.

OBJECTIVES

In this experiment, you will

- Use video analysis techniques to obtain position, velocity, and time data for a cart that is speeding up.
- Apply curve fits to your graphs to determine how to mathematically describe the motion.
- [Extension] Analyze an additional video to describe the acceleration of a different object.

MATERIALS

Vernier Video Analysis™ app in a web browser on a computer, Chromebook, or mobile device

PRE-LAB INVESTIGATION

1. Launch Vernier Video Analysis. Scroll through the list of sample videos and choose "Fan Cart." Play the movie once or twice to observe the motion of the cart.
2. Make a prediction of how the position *vs*. time graph and the velocity *vs*. time graph will look for the motion of the cart, and sketch your predictions.
3. If possible, share your predictions with classmates and discuss them.

PROCEDURE

1. Make the movie window large enough to easily view the motion of the fan cart. There are two ways to do this: 1) Click or tap the divider between the video and the other elements on the screen, and drag the divider to the right, or 2) use View, ⊞, to remove the graph and data table from view.
2. Use Step Forward, ↻, and Step Back, ↺, to advance the movie to the frame in which the fan cart is clearly no longer held in place.
3. You will be marking the position of a point on the fan cart for this activity. By default, each time you mark the object's location, the movie advances by just one frame. The fan carts starts moving very slowly, so your analysis will go more quickly if the movie advances more than one

frame at a time. To change the setting, click or tap Advanced Video Options, ⚙. Change the Advance Frame setting to 2, 5, or 10 frames, and then dismiss the window to save your changes.

4. Mark the location of the fan cart as it moves during the video:
    a. Click or tap Add, ADD.
    b. Decide where on the fan cart you will mark its location (e.g., the yellow spot, or the front right corner). **Important**: Be consistent in your marking. Always place the crosshairs in the same location on the fan cart.
    c. Position the crosshairs at the chosen location on the fan cart, and then click or tap to add the first point. **Note**: If you are using a phone or tablet, once you position the crosshairs you can click or tap anywhere in the video frame to mark the point.
    d. Continue this process until the fan cart reaches the end of the track. Should you wish to edit a point, click or tap Edit, EDIT. This allows you to move or delete a mismarked point by dragging it. **Note**: In order to be sure you are moving the correct dot, you can turn off the Trails setting to hide all the dots except the one in the frame you are viewing.

5. Set the scale in the video.
    a. Click or tap Scale, 1.0 SCALE. A scale bar and a set of axes will appear on the video.
    b. Drag the ends of the scale bar to match the ends of the meter stick in the video (see Figure 1).
    c. Verify that the length and units are set correctly (should be 1 m).

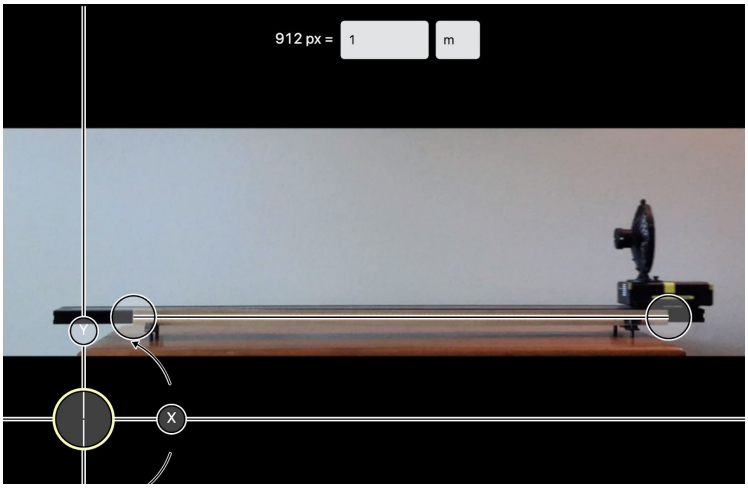

Figure 1

6. Adjust the origin by moving the axes so that the origin is over the first position marked on the video. This will make the starting horizontal position zero.

7. Use View, ⊞, to display two graphs, and hide the video and data table. Vernier Video Analysis defaults to display both the *x* and *y* positions of the object as a function of time. For a horizontally-moving object like the fan cart, you want to examine the graphs of the *x* component, only. To change which data are displayed, click or tap the vertical axis label. On one graph, display X Position *vs.* Time, and on the other graph, display X Velocity *vs*. Time.

ANALYSIS

1. Examine the graph of X Position *vs.* Time. What shape of graph do the dots make? Use Graph Tools,  , to add an appropriate curve fit to the graph. Record the curve fit equation.
2. Examine the graph of X Velocity *vs*. Time. What shape of graph do the dots make? Add an appropriate curve fit to this graph and record the curve fit equation.
3. You may have learned that the equations of motion for an object with constant acceleration are

   $$x = \tfrac{1}{2}at^2 + v_0t + x_0 \qquad \text{and} \qquad v = at + v_0$$

   Both of these equations contain the variable *a* for acceleration. Compare your two curve fit equations to these equations, and determine the value of *a* in each case.
4. What do your equations indicate is the starting velocity of the fan cart? Does this agree with observation?
5. What do your equations indicate is the starting position for the fan cart? Does this agree with observation?

EXTENSIONS

1. Move the origin of the axes on the video to a position *other* than the first marked point. Discuss the following:
   - How do the equations change?
   - What information from the equations does not change?
2. Find or create another video of an object undergoing constant acceleration. Determine the acceleration, starting velocity, and starting position for two frames of reference (two different positions of the origin of the axes).