

# LAB 01-5: Video Analysis of Constant Force

## Objective

In this experiment, you will measure and graph the x-position and x-velocity of a cart as a function of time as the cart is accelerating. In addition, you will practice using video analysis software to analyze the motion of an object.

## Experiment—Constant Force on a Fan Cart

1. Go to our course web site, click the link to *Videos*, and download the file *01-5-two-carts.mov* by right-clicking on the link and choosing **Save As...** to save it to your desktop.
2. Open the *Logger Pro* software on your computer.
3. Use **Insert**→**Movie...** to import your video.

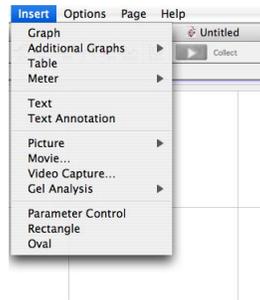


Figure 1: Insert movie menu

4. At this point, it's nice to lay out the video, data table, and graph so that you can clearly see everything. Go to **Page**→**Auto Arrange...** to organize the screen, as shown in Fig. ??.

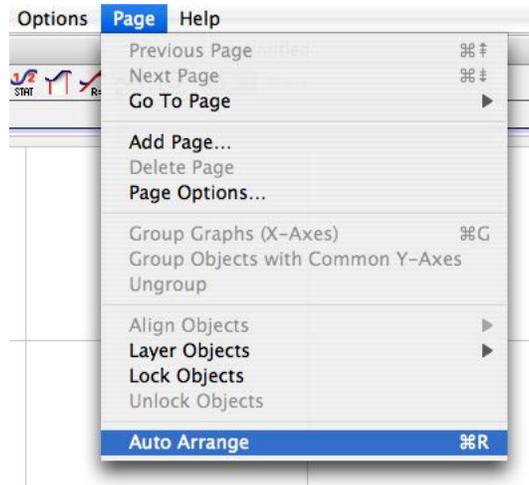


Figure 2: Auto arrange to clean up the panes in the window.

5. Improve your precision and reduce experimental error by expanding the video. To expand the video, click once on the video, grab the corner of the video window, and expand.

6. Note the video controls at the bottom of the video pane, shown in Fig. ???. Go ahead and play the video, step it forward, backward, etc. in order to learn how the video controls work.



Figure 3: Video controls used to play and step the video

7. Play the video and watch the motion of the two carts.

Describe in words the motion of the top cart.

Describe in words the motion of the bottom cart.

What can you say about the net force on the bottom cart?

What can you say about the net force on the top cart?

8. We will analyze the motion of the top cart.
9. Navigate to the first frame after the writing disappears from the video. This is the instant that you will begin making measurements of the position of cart.
10. You now need to define the origin of the coordinate system. Click the icon in the bottom right corner of the video pane (the icon with three red dots shown in Figure ??) in order to expand the sidebar used for video analysis.
11. In the sidebar of the video pane, click the icon in Fig. ?? to show the coordinate system (you can hover the mouse over each icon to see what they do).



Figure 4: Icon used to expand the sidebar of the video pane



Figure 5: Icon used to set the coordinate system

12. Click and drag on the video to place the origin of the coordinate system at the initial position of the cart (use the yellow dot painted on the side of the cart).

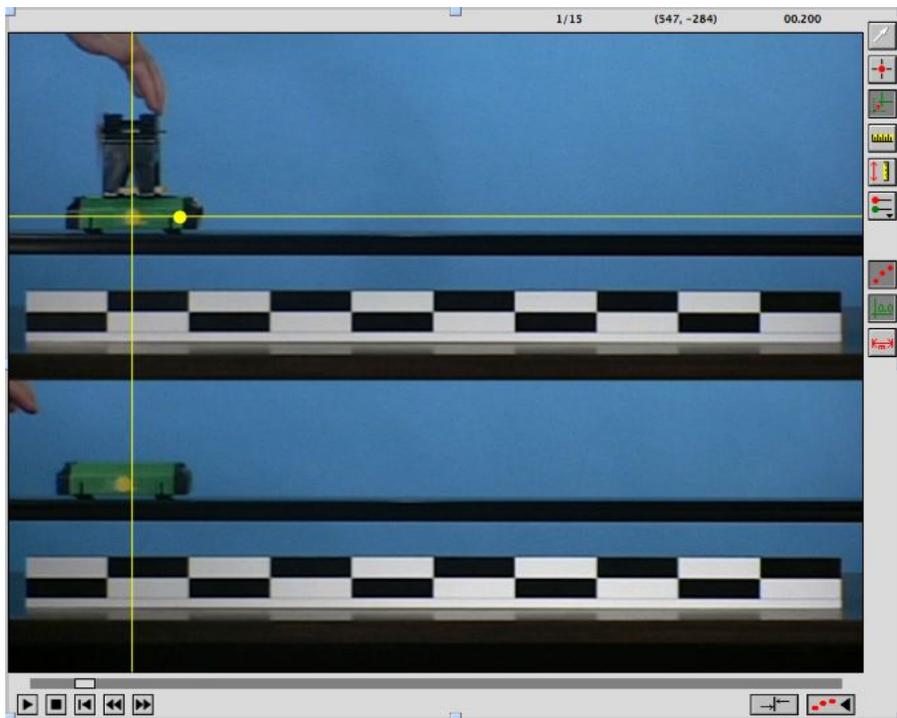


Figure 6: Click and drag to set the origin of the coordinate system

13. Now, you must calibrate distances measured in the video. In the sidebar, click on the icon shown in Figure ?? to set the scale for the video.



Figure 7: Icon used to set the scale.

14. Click and drag to draw a green line from the left end to the right end of the white and black checkered meterstick. In the resulting dialog box (shown in Figure ??), enter the length of the meterstick, 1.0 m.

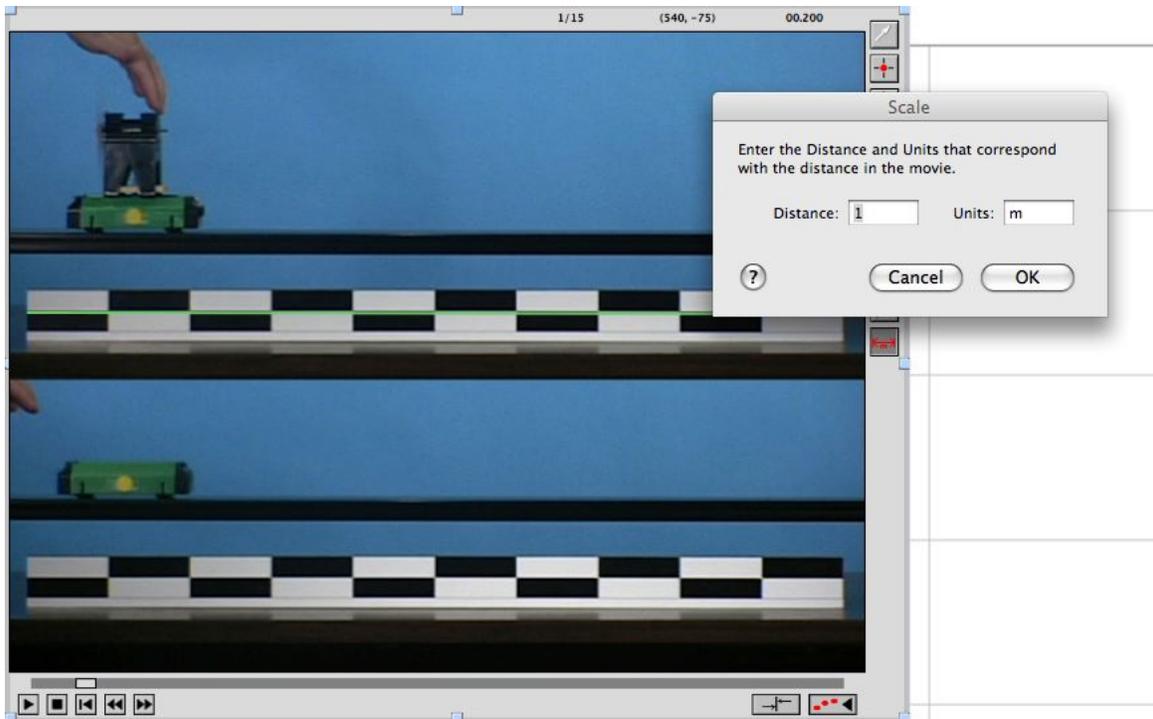


Figure 8: Enter the length of the meterstick.

15. You are ready to add markers to the video to mark the position of the cart. First, let's not show the coordinate system and scale. It's too distracting. So, click each of the two icons in the lower right corner of the video pane, shown in Fig. ???. These icons are used to hide or show the coordinate system and scale.



Figure 9: Use these icons to show or hide the coordinate system and scale.

16. To add markers, first click on the icon with the red dot and cross hairs, shown in Fig. ???. You will now be in an editing mode to add points.



Figure 10: Icon toggle the editing mode for marking positions in the video.

17. In this case, we will mark the painted yellow dot on the cart. Click once on the cart. You should notice that a marker appears at the position of the cart where you clicked and that the video advances one frame.
18. Continue marking the position of the cart in successive frames. After marking the cart as it moves from the left end to the right end of the track, your video should look like the picture shown in Fig.

??.

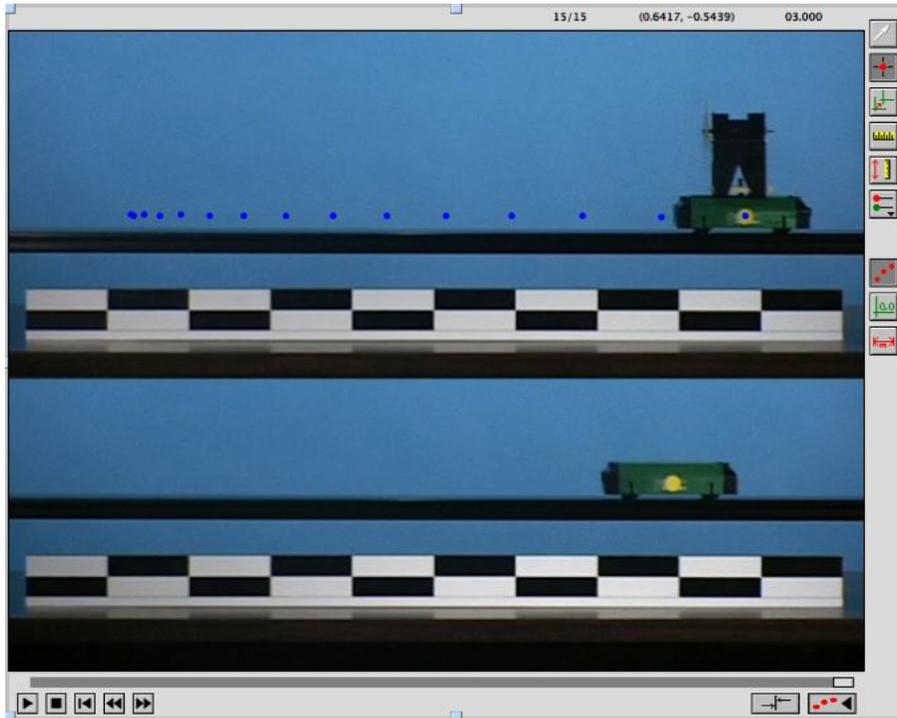


Figure 11: Marks showing the cart's position in successive frames of video

19. Logger Pro will calculate data for  $t$ ,  $x$ ,  $x$ -velocity, and  $y$ -velocity. In this situation, we are only interested in the  $x$  vs.  $t$  graph and the  $x$ -velocity vs.  $t$  graph.

## Analysis

1. Click the graph to bring it to the front. Go to **Page**→**Auto Arrange** to automatically arrange the windows so that the video and data windows are out of the way.
2. By default, it will show both  $x$  vs.  $t$  and  $y$  vs.  $t$  on the same graph.
3. Let's change what is being plotted. First, click the label on the vertical axis. By default, both  $X$  and  $Y$  are shown. When you click this label, you will have a menu that you can select what is being plotted. Select  $X$  for now.

What function describes this graph of  $x$  vs.  $t$ ? (i.e. linear, quadratic, square root, sinusoidal, etc.)

4. Go to **Analyze**→**Curve Fit**. In the resulting window, select the quadratic function and check the box that says Time Offset as shown in Figure ?? . Click the **Try Fit** button and Click **OK**.

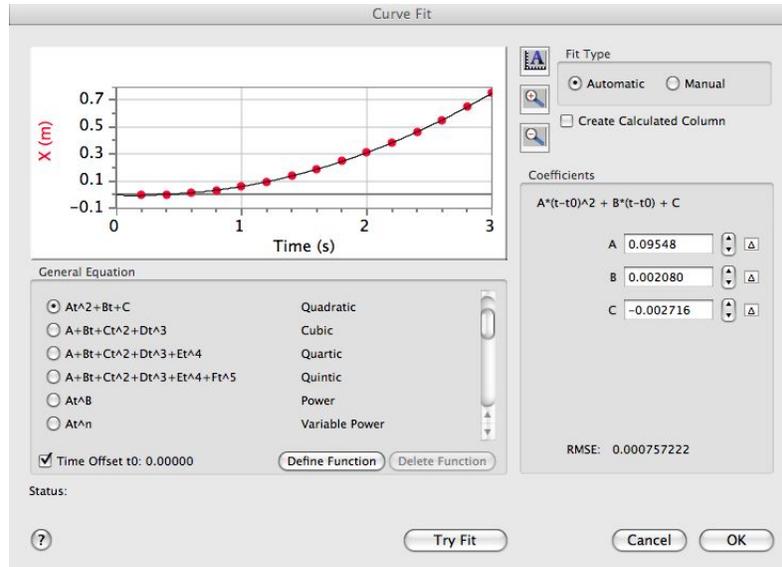


Figure 12: Select the quadratic fit.

Neatly sketch the graph, including axes and labels, below.

Record the function and the values of the constants for your curve fit. Write the function for  $x(t)$ , with the appropriate constants (also called fit parameters).

What do you expect the  $x$ -velocity vs. time graph to look like? Sketch your prediction below.

5. Change the vertical axis to X Velocity.
6. Using your mouse, highlight the data by drawing a window around the data points as shown below. Do not include the first two points and the last two points.

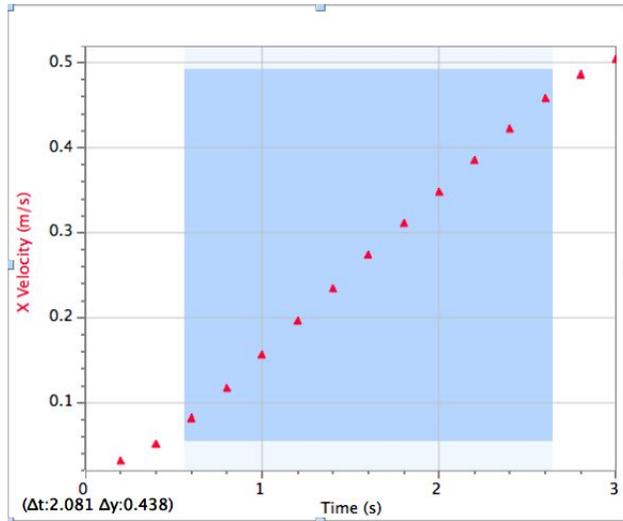


Figure 13: Highlight the x-velocity data.

What function describes this graph of  $v_x$  vs.  $t$ ? (i.e. linear, quadratic, square root, sinusoidal, etc.)

7. Go to **Analyze**→**Curve Fit**. In the resulting window, select the linear function and check the box that says Time Offset. Click the **Try Fit** button and Click **OK**.

Neatly sketch the graph of  $v_x$  vs.  $t$ , including axes and labels, below.

Record the function and the values of the constants for your curve fit. Write the function for  $v_x(t)$ , with the appropriate constants (also called fit parameters).

## Application

1.

What does the slope of the  $v_x$  vs.  $t$  graph represent?

2.

Take the derivative of the function for  $x(t)$ . What do you get?

3.

How does  $\frac{dx}{dt}$  compare to the function  $v_x(t)$ ?

4.

How is the slope of the  $v_x$  vs.  $t$  graph related to the coefficient  $A$  on the quadratic term of the  $x$  vs.  $t$  graph?

5. From the  $x$  vs.  $t$  graph, what is the x-displacement of the cart from  $t = 1$  s to  $t = 2$  s? Explain how you obtained your answer.
6. From the  $v_x$  vs.  $t$  graph, what is the x-displacement of the cart from  $t = 1$  s to  $t = 2$  s? Explain how you obtained your answer. Note: there is a wonderful tool for calculating the area under a curve. Highlight the data from  $t = 1$  s to  $t = 2$  s and click on the icon shown in Figure ??.



Figure 14: The icon used to calculate the area under a curve.

7. Compare your answers for the displacement from  $t = 1$  s to  $t = 2$  s in the previous two questions. Do they agree?