Activity
2

Investigating Motion

Investigating Constant Velocity with a Motion Detector

The study of how things move and why they move is an important part of an introductory physics course. The use of technology greatly aids the collection and analysis of data. In this activity you will have the opportunity to learn how to use a Motion Detector to examine aspects of the motion of an object.

The motion detector works by emitting and detecting ultrasound. It generates a series of ultrasound pulses, and then detects the echoes returning from an object. The time between the emitting of a pulse and the reception of its echo is used to calculate the position of the object using the speed of sound. Position and time data are then used in software to determine the velocity of the object.

OBJECTIVES

In this activity, you will

- Practice using the motion detector in a variety of experiments.
- Use a variety of analysis tools on graphs of position-time and velocity-time data.
- Interpret the equations resulting from the analysis of these graphs.

MATERIALS

Vernier data-collection interface	Motion Detector and bracket
Logger *Pro* or LabQuest App	Vernier Dynamics Track

PROCEDURE

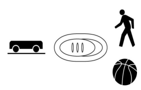
1. Connect the Motion Detector to the interface and start the data-collection program. Two graphs: position *vs.* time and velocity *vs.* time will appear in the graph window. For now, you need only consider the position *vs.* time graph.

   - In Logger *Pro*, delete the velocity graph, then choose Auto Arrange from the Page menu.
   - In LabQuest App, tap the Graph tab, then choose Show Graph and select Graph 1.

   Later, during the analysis of data, you will add the velocity *vs.* time graph back to your view.

2. Attach the motion detector to the bracket that will allow you to position it near one end of the track.

3. If your motion detector has a switch, set it to the Track setting.



4. Place the cart approximately 20 cm[1] in front of the motion detector. The live readout on the display in Logger *Pro* or LabQuest App will tell you the position of the cart. Note the position of the back end of the cart on the scale on the track.

5. Position the end stop on the track so that when the cart runs into it, the cart will have moved a known distance (~70–85 cm) from its initial position[2] (see Figure 1).

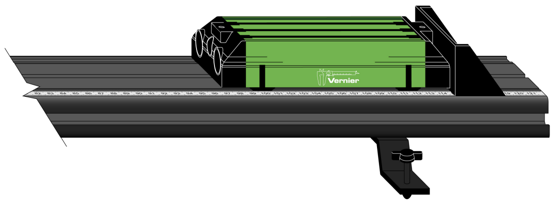


Figure 1

6. Return the cart to its original position near the motion detector. Start data collection, then, once you hear the motion detector clicking, give the cart a gentle push. Data collection stops automatically after 5 seconds.

7. The motion detector sends out its signal in a cone, and it detects the first echo from the nearest object in the cone. This object may or may not be the object of interest. Examine the position *vs*. time graph. If there are jagged dips in the graph once the cart began moving, it could be that your hand or some other object was picked up by the motion detector. If this is the case, repeat Step 6, but be sure that your hand or other stray objects do not interfere with the signal returned by the cart. If you have a smooth graph, store this run.
   - In Logger *Pro*, choose Store Latest Run from the Experiment menu.
   - In LabQuest App, tap the filing cabinet icon.

8. Repeat Step 6, but this time, launch the cart somewhat faster than you did the first time. If you have a smooth graph, store this run. Note differences in the appearance of the position-time graph for the two runs. You will examine this in greater detail in the Evaluation of Data section.

Zeroing the motion detector

9. In the analysis of position-time (x-t) data it is convenient to consider the initial position as zero. This can be done with the motion detector. Place the cart at the starting position you used in the previous run, then zero the detector.
   - In Logger *Pro*, choose Zero from the Experiment menu.
   - In LabQuest App, tap the position reading in the Meter tab and choose Zero.

10. Repeat Step 6, then store this run as before. Compare the x-t graph for this run to that obtained in your previous runs.

[1] If you are using an older motion detector without a switch, the cart needs to be at least 45 cm from the detector.
[2] This distance will be less if you are using an older motion detector.

Reversing the detector

11. Now, position the cart at the far end of the track. Start data collection, then give the cart a gentle push toward the motion detector. Be sure to catch the cart before it runs into the detector. If your *x-t* graph is smooth, store this run.

12. The default setting for the motion detector is to designate the direction of motion *away* from the detector as positive. In this run, the object was moving in the opposite direction; note that the *x-t* graph has a positive vertical intercept and a negative slope. It is sometimes useful to consider the direction of motion as positive. You can set the motion detector to treat motion *toward* the detector as positive.

    - In Logger *Pro*, choose Set Up Sensors from the Experiment menu, then select your interface (LabQuest, Lab Pro, etc.). Click the icon representing the motion detector and choose Reverse Direction in the pop-up dialogue box, then close the box.
    - In LabQuest App, tap the position reading in the meter tab and choose Reverse Direction.

13. Now, position the cart at the far end of the track. Zero the motion detector as you did in Step 9, then give the cart a gentle push toward the detector. Be sure to catch the cart before it runs into the detector. If your *x-t* graph is smooth, store this run. Compare the appearance of your *x-t* graph to that obtained in the previous run. You need not store this run; however, you should save this experiment file.

EVALUATION OF DATA

1. Examine the position *vs*. time graph for your first run.

    - In Logger *Pro*, the color of the entries in the data table matches the trace of the line in the graph. You can choose to view only one run by clicking the vertical axis label, choosing More, then selecting Position for the run of interest and de-selecting the other runs.
    - In LabQuest App, you can choose to view any of your four runs by tapping on the number for that run.

2. Determine the rate of change of position of the cart while it was moving at nearly constant speed. To do this, select the portion of the graph in which the plot appears linear by dragging your cursor (or stylus) across this region. Then perform a linear fit on that portion of the graph.

    - In Logger *Pro*, choose Linear Fit from the Analyze menu. You can adjust the segment over which the linear fit was performed by dragging the bounds, marked by **[** and **]** symbols.

    - In LabQuest App, choose Curve Fit from the Analyze menu, check the box marked position, then, in the Choose Fit drop down menu, choose Linear. If you decide you wish to adjust the region over which you have performed the linear fit, repeat the process.

3. What information about the motion of the cart is provided by the slope of the graph? How do the units confirm your answer?

4. Now choose to view the position *vs*. time graph for your second run. Explain how you can tell, by looking at the graph alone, how the speed of the cart compares to that in the first run. Now, repeat Step 2 and compare the value of the slope of the linear region to that obtained for your first run.

5. Now choose to view the position *vs*. time graph for the run in which you first launched the cart *toward* the motion detector (Run 4). What is the significance of the sign of the slope of the linear portion of this graph?

6. Now return to your first run. Choose Velocity as the vertical axis label. How does the plot of velocity *vs*. time correspond to the motion that you observed? Can you account for the fact that the plot may not be entirely horizontal?

7. Select an interval during which the velocity was nearly constant by dragging your cursor (or stylus) across this region. Choose Statistics from the Analyze menu. **Note:** Either application will display a number of statistical measures relating to velocity over this interval. From the information provided determine the percent decrease in the velocity over this interval.

8. In addition to slope, the area under a curve often has physical meaning. To determine the area, select the portion of the graph corresponding to when the cart was moving, then choose Integral from the Analyze menu.

9. What are the units of the area under the curve? What information about the motion of the cart does the area provide?