Lab A1: *Investigating Motion with the Sonic Ranger*
(Windows 2000 Professional version)

Aug 11 2003

A1) *Setting up (some of this may already have been done, but just in case…)*

1) Plug in the cable from the Motion Detector into Digital/Sonic Port 1 on the Lab Pro Interface Box. The
2) Once the computer is turned on and the desktop screen appears, double click on the Logger Pro 3.1 icon.
   (Alternatively, you can click on the Start button in the lower left corner; then mouse-over Programs, Vernier Software, Logger Pro 3.1)
3) Close the Tip of the Day popup box. The screen should now show a data table and two graphs (one position vs time, the other velocity vs time). If not, you will have to troubleshoot a bit to find out what's wrong; some possibilities include: ac adaptor not plugged in; cable connections (to ac adaptor, to Motion Detector) not secure. Call us over for help if you can't fix the problem yourself.

A2) *Shutting down the equipment (please remember to do these at the end of the lab period)*

1) IMPORTANT: Remove the Motion Detector ***cable*** from the Lab Pro box, being careful to press on the plastic tab of the connector while pulling out the cable. The green light on the Motion Detector should then be off.
2) Put away any carts or inclined planes that you brought out.

B) Finding the Range of the Motion Detector *(please limit yourself to 8 minutes max in this part)*

1) Under Experiment, select Show Sensors (LabPro). Check that the following settings are present: DIG/SONIC1 should be highlighted; Motion Detector should be the sensor. If any of these settings are incorrect, call the instructor over, otherwise click Close. If a message pops up in regards to an inappropriate default calibration folder, call the instructor over.
2) Under Experiments, choose Data Collection. Change the Length of the experiment to 5 seconds and the Sampling Rate to 10 samples/second. Click Done.
3) Right-click on one of the graphs, and choose Delete. Under Insert, select Meter.
4) Right-click on the meter window you just created. Select Meter Options. Change the Column to Position. Click OK.
5) Click the button labeled Collect. The Position Meter will show the position (in meters) of the nearest solid object, relative to the sonic ranger.
6) Your job in this part is to experimentally determine the approximate minimum position and the maximum position that the sonic ranger measures correctly (allow for several centimeters of uncertainty). You'll need a meter stick to know the "accurate" positions. Record the results for the workable range of your Motion Detector in your lab journal. Check with the instructor to see if your answers are reasonable. In the remainder of the lab, REMEMBER THE LESSON OF THIS PART !

Skip the directions below, & go to the top of the next page; return here when you add/remove graphs in part C

General instructions for acquiring a graph using the motion detector

1) Decide which graphs to display. In general, you should always display the Position graph, and you may add the Velocity and Acceleration graphs ***ONLY IF*** you have predicted them first in your lab book.
2) ***To remove graphs***, right-click on the graph you want to remove, then select Delete.
3) ***To add graphs***, go to Insert and choose Graph. Left-click on the y-axis of the new graph and choose your dependent variable (position, velocity or acceleration).
4) To modify a graph that already exists, you must put the graph in front of any other graphs that overlap with it. To do that, right-click on a graph and choose Move to Front or Move to Back as needed.
5) Once you have created all the graphs you want to see, arrange your graphs so that they are all aligned vertically; resize them so they are all about the same size. The position graph should always be on top, followed by the velocity and acceleration graphs.

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C) Position, time, & velocity

1) Close the Position Meter window (by right-clicking on it and selecting Delete). Create a Position vs Time graph by following the instructions at the bottom of the previous page. No other graphs should be showing on your screen.

2) While standing still, aim the sonic ranger at a wall. Before asking the software to produce a graph of the wall's position vs. time, predict what you think that graph will look like (don't worry about putting numbers on your axes; you only need to predict the *shape* of the graph). Make a sketch of your predicted graph in your lab journal at the top of a new page; use the whole top half of the page for this prediction and reserve the bottom half for the velocity vs. time graph that will come later. Label your axes: position and time.

3) Once you've predicted the shape of the graph, aim the sonic ranger at the wall and click on the Collect button to get the software to plot the graph. Does your prediction agree with the plot? If so, note that in your lab book. Otherwise show the actual position-vs-time shape (on the same graph); distinguish "predicted" and "actual" with labels.

4) You probably have some familiarity with the term velocity. What is the velocity of the wall (with respect to the sonic ranger) for the situation described in situation #2 above? What would the velocity-vs.-time graph for the wall look like? Make a prediction and sketch it in your lab book right below the position-vs.- time graph. Remember to label your axes with words.

5) We hope that you answered zero (or some equivalent) to the question about the velocity of the wall. Now go back to the computer and check your prediction. The instructions for adding a graph are on the 1st page. You should still keep the position graph but add the velocity graph below it.

6) Now look back at the position-vs.-time graph for the wall that you predicted and that the computer plotted. Is there anything ***zero*** about the position-vs.-time graph? Talk it over with your partner.

7) We trust that your answer to the previous question, without looking ahead, was something like "the slope of the line or graph is zero." Now, is it a coincidence that both the velocity and the slope of the line are zero? In your lab journal, write a general definition of the slope of a line. Do not use the symbols x and/or y in your answer, but you may use words like horizontal, vertical, rise, and/or run. This is the last we'll remind you to write ***only*** in your lab journal (NEVER on stray paper or lab handouts !!). In the future, we expect you to do this automatically.

8) If we now apply your definition of slope specifically to a position-vs.-time graph, we see that the slope of the graph is the *change in position* divided by the *change in time*. And this is exactly the definition of velocity.

9) Now let's try something that moves. One person will walk away from the sonic ranger at a fairly slow but constant rate. But before you ask the computer to record data, sketch a prediction of the position-vs.-time graph for the slow-walking person. Remember to start this new prediction at the top of a new lab book page. Again, label the axes (but do not worry about numbers other than the origin on your graph). Compare your prediction to your partner's.

10) Now collect data -- but first, remember to turn the velocity-vs.-time graph off (you haven't predicted it yet, right?) Record the computer-generated graph. Double-clicking on the face of the graph allows you to select various options for that graph, including all options you get by double-clicking on the axes or the scales. ***NOTE:*** If you occasionally get spikes (exceptionally high or low points) on the graph, this is due to the failure of the ranger to detect your reflected signal. It sometimes helps to hold a reflector in front of the ranger as you are walking. This could be a book or other hard, flat surface.

11) Did your prediction match reality? Check with the instructor if you're not sure. Estimate the slope of the position vs. time graph by reading two ordered pairs (time, position) of coordinates at the opposite ends of your line and calculating the slope. Avoid using points that seem to be noticeably off from the general trend. To obtain coordinates, under Analyze, select Examine; then drag the mouse around your graph. Show your work, and ***include units*** (m, s, m/s) ***every time*** you write a position, time, or velocity number.

12) Once you have calculated the slope of your position-vs-time graph: under Analyze, select Tangent. Then drag the mouse along your position-vs-time line. How do the Tangent values compare to the slope you calculated ?

13) Now for a new prediction. What would the <u>velocity</u>-vs.-time graph look like for the walk done above? Sketch your prediction immediately below the position graph (don't worry about numbers on axes). (Hint: Was the velocity of the walker constant? How could you tell from the position-vs.-time graph?)

14) After you have sketched your velocity-vs.-time graph prediction in your lab book, go back to the computer and add the velocity-vs.-time graph. Leave the position-vs.-time graph on. You might also set the minimum velocity equal to zero and the maximum velocity equal to 2 m/s. Was your velocity-vs.-time graph prediction correct?

15) The other partner will now try a faster walk away from the sonic ranger. Before this happens, however, make a prediction of the position-vs.-time graph ***on the same axes*** as your previous prediction for the slow walk. Label the first prediction slow and the second one fast. Also predict the velocity-vs.-time graph (don't worry about numbers here) for the fast walk and record it on the same velocity graph for the slow walk. Label both lines.

16) After predicting both position-vs.-time and velocity-vs.-time graphs for the fast walk, collect data for that walk, remembering to start at about the minimum working distance of the sonic ranger. Did your actual graph match predictions?

17) Summarize what you have learned so far about how velocity information shows up on an object's position-vs.-time graph.

D) Changing directions

1) Use a dynamics cart, loaded with a concrete-filled soda can, for these activities. Set the ranger on the floor, aimed at the cardboard reflector taped to the back of the cart. Change the software settings to give you ***only*** a position vs. time graph; set the maximum position to 3 meters.

2) In this part you will give the cart a push away from the ranger. Try it first without the sonic ranger recording data (just turn the ranger face down on the floor temporarily). Then predict the position-vs.-time graph (again, in your lab book, at the top of a new page). Does the cart slow down as it moves across the floor? If so, how will that show up on the graph? Once you've predicted, obtain the graph.

3) Based on the cart's position vs. time graph, predict (in the space immediately below the position-vs-time graph) what the velocity vs. time graph of the same motion will look like. (Hint: As the slope of the position-vs.-time graph changes, how does the velocity-vs.-time graph change?)

4) Turn on the velocity vs. time graph and check your prediction from (D3). Sketch the actual graph you obtain (if different from your predicted graph). Was your prediction correct?

5) When you compare the actual velocity-vs.-time graph to your prediction, you may find that the former has more irregularities than you might expect. This is due to the fact that the velocities are not measured directly by the ranger but instead are calculated by dividing the differences in position between successive data points by the corresponding time differences. Since the differences are quite small, substantial error is introduced into the calculated result. These errors show up as bumps and valleys in the graph. You should be looking for overall trends in the graph.

6) Next you'll look at a collision. If you push the cart so that the plunger end strikes a wall, the cart will push back off and return. Set up the ranger facing the wall and about 2 meters away. Put the cart about a half-meter from the ranger, ready to be pushed toward the wall. But wait! That's right, make your predictions of the position-vs.-time and velocity-vs.-time graphs. (If you don't think you can do both together, do the position one first, verify, and then predict the second.) You can, however, try the experiment without having the sonic ranger recording, if that will help you visualize the position and velocity graphs. Once you've predicted, push the cart and record results.

7) When the cart turned around at the wall, how did the position vs. time graph change? Be sure to be specific in discussing the slope of the line.

8) How did the velocity vs. time graph change? Again, be specific.

9) Something to note at this point is that changes of velocity are caused by the application of forces. What caused the moving cart to slow down? frictional forces! When the cart changes direction, for example, bouncing off the wall, that is due to the push of the wall on the cart. (It may seem strange to think of a solid, immovable wall as exerting a push. Later we'll see that walls, floors, and other “immovable” objects do indeed exert such forces.)

10) Something else to note is that there are two ways that velocity can change. One way is when the object speeds up or slows down. The other is when the object changes direction. You probably noticed that the velocity of the cart changed more quickly when it bounced off the wall than when it was slowing due to friction. This rate of change of velocity, termed acceleration, is investigated in the next section.

E) Velocity, time, & acceleration

1) In this part, you'll look more closely at acceleration. Use the same cart as before, but allow it to roll down an inclined ramp. You'll find a variety of boards in the lab to serve as ramps. Start with an incline angle of just a few degrees. **Continue to make predictions before performing each of the experiments**.

2) Here, you'll start the cart at the top of the ramp. Position the sonic ranger aimed down the ramp so that the cart will move away from the ranger while rolling down the ramp. Obtain position-vs.-time and velocity-vs.-time graphs and record them. You may need to change scales if the maximum values are too small/large.

3) Describe in words each of the graphs you just obtained. Use words like constant, increasing, decreasing, slope, positive, negative, zero.

4) How do you think you could determine the acceleration of the cart? (Hint: Think about how you found velocity from a position-vs.-time graph. How can you find acceleration from a velocity-vs.-time graph?)

5) We hope that you realized that the slope of the line on the velocity-vs.-time graph is the acceleration. You can calculate a value for it by reading two (time, velocity) coordinate pairs from the graph and using the slope formula. Do that now, and be sure to carry units throughout the calculation. Note that the units of acceleration are m/s per s or m/s^2 for short. Once again, avoid using points that seem to not follow the overall trend. Since we are interested mainly in the cart’s motion while it was rolling down the ramp, choose points that correspond to that time interval.

6) Add a graph of acceleration vs. time below the velocity-vs.-time graph. You may see a lot of bumps in this graph, because the process of calculating accelerations from the velocity-time data introduces error in addition to those introduced in calculating velocities from the position-time data. Do any time intervals on the graph have constant acceleration?

Conclusion/Summary (see end of Lab Guide in your lab book!)