

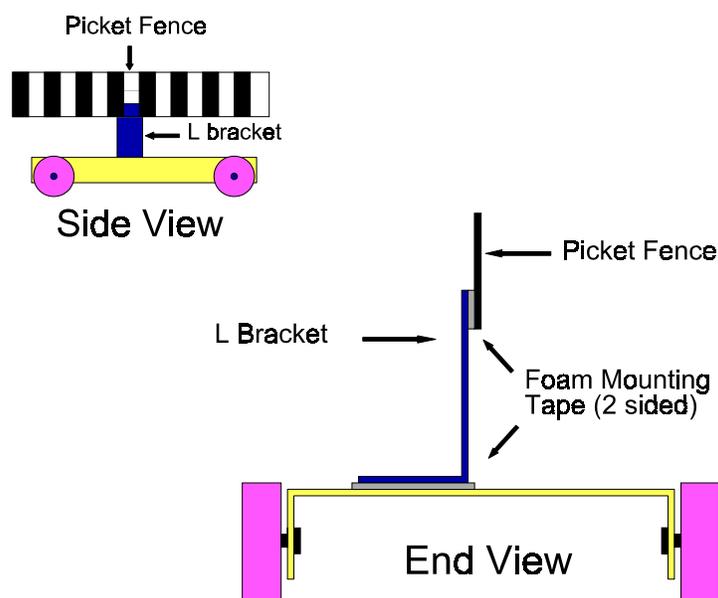
Core Lab: Measurement of Speed - Method 1

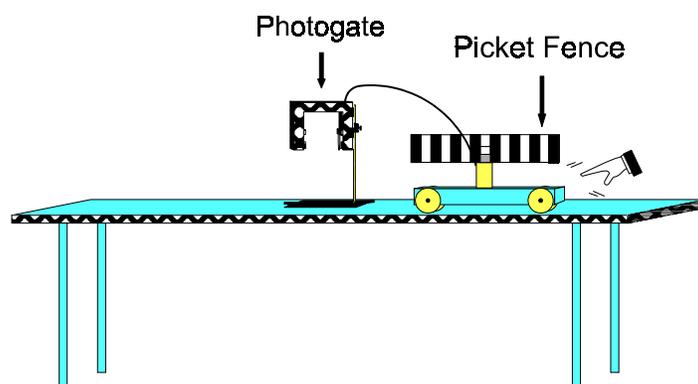
Unit 4: Motion

Purpose: To study the motion of a dynamics cart rolling on a level surface.

Apparatus: Vernier IBM Photogate Box, Pasco Photogate, picket fence, dynamics cart, computer, printer, foam tape, right angle bracket.

- Procedure:**
1. Set up your apparatus on a level table or lab bench.
 2. Connect the IBM photogate box to the gameport of the computer. Turn on the computer.
 3. Tape the picket fence to the right angle bracket and then tape the bracket to the dynamics cart. Refer to the diagram below. Make sure that the picket fence is parallel to the top and sides of the cart. Be accurate before you press the picket fence tightly to the tape as it is difficult to remove once pressure has been applied. (If you have a wooden dynamics cart that has aluminum plates on the ends, you may have to unscrew these plates to get the picket fence to fit properly).
 4. Check to see that the cart is free to move through the gate and that the infrared beam is broken by the picket fence. Refer to the diagram below. Push the cart back and forth through the photogate and watch the red LED on the top. **Make sure the photogate is high enough so that the bracket is not breaking the beam.**





5. Load the **precision timer** software by typing `cd PT` (enter) and then `PT` (enter).

NOTE: You will be working with **menus**. When you see the word **SELECT**, it usually means move to the menu item using the **cursor keys** and press **enter**.

6. Select **PHOTOGATE STATUS CHECK**. Place your hand in the photogate and verify that it is working.
7. Select **MOTION TIMER**.
8. Give the cart a shove. Make sure it moves through the photogate in a straight line. Press enter after the cart has gone through the gate.
9. When the cart goes all the way through the photogate, press the enter key. (Note that the screen refers to the **return** key; this is what the **enter** key is called on some computers.)

A **data table** will now be displayed. The **time** column displays the time for each of the 0.05 m (5 cm) intervals between the start of one black stripe and the start of the next black stripe on the picket fence. (The motion timer option starts the timer at the edge of each black stripe. There are 8 black stripes, so there are 7 time intervals...think about it!!!)

10. Press enter.
11. A **Data Analysis Options** screen will open. Select **F - File Options**.
12. A **File Options** screen will be displayed. Select **S - Save Data to File**.
13. You will be prompted for a filename so that you can save the data to the fixed disk in case you need to use it again. The filename can be up to 8 characters long but must not contain any spaces. A good filename to use here is **LAB2A**. Press enter when you have typed it in. ("A" is placed at the end of the filename because you will be doing 2 more runs with the cart. The second and third time you do this, you can name the files of data LAB2B and LAB2C. That way you end up with three files of data that clearly belong to LAB2.)

14. When the file is saved, press enter.
15. Select **X - Return to Data Analysis Menu**.
16. You will now make two graphs, one a distance vs time and the other a speed vs time. Select **G - Graph Data**.
17. Select **D - Displacement vs Time**. (For this lab, displacement means the same as distance.)
18. **EITHER:** You will now be prompted to "**Enter the distance between timings (in metres)**". Note the number, **.05**, already on the screen. This is called a default. Press enter to accept it. Remember the distance between black stripes is indeed 0.05 m (5 cm). **OR** you will see a screen that simply asks you to select **picket fence**.

A **Graphing Options** screen is now displayed. This menu controls the graph display. The options are turned **on** and **off** by pressing the **space bar**. When you first enter this screen, if the **point protectors** are not turned "on", do so by pressing the space bar.

19. Move to **G - Grid on Graph** and press the spacebar.
20. In the same way, move to, and turn on **R - Regression line, S - Statistics and T - Specify Graph Title**.
21. Check to see if you have the correct options turned **on**, then press enter.
22. The default title, **Displacement vs Time**, may appear on the screen. If so, use the **← Back Space** key to delete this title and type **Distance vs Time**. Press the enter key to continue.
23. Press enter to accept **A - Automatic Scaling, Axis Starts at 0**.
24. Again press enter to accept **A - Automatic Scaling, Axis Starts at 0**

The graph should now be displayed. Here is a brief explanation of what you should be seeing. The little triangular boxes represent the actual data points. The line, called a **regression line** or **line of best fit** represents an average through the points. If you don't have very much friction in your setup, this line will probably go very close to most of your actual data points. Near the top of the screen you will find some statistics. The **m** is the **slope** of the regression or best fit line. The **b** is the **y - intercept**. Remember, for a straight line, the equation is $y = mx + b$. Don't concern yourself with the rest of the stats.

25. When you have finished viewing the graph, press enter.

Make sure your printer is properly connected to the computer, turned on and has paper.

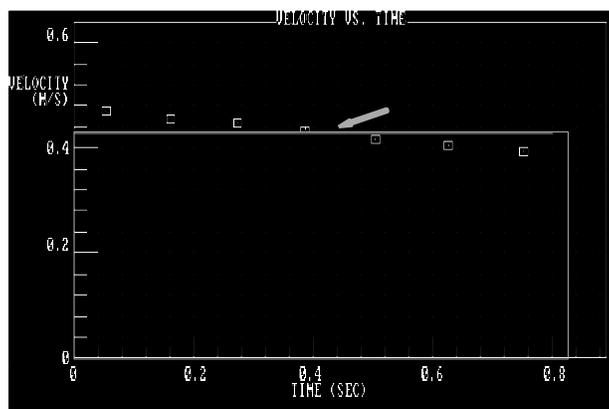
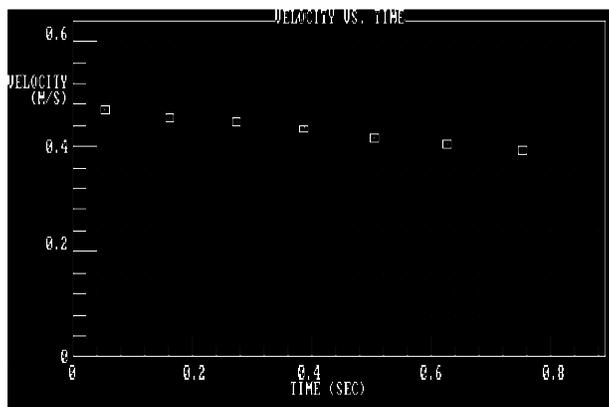
26. Select **O - Print Graph**.

27. Press enter to print the graph
28. When the graph is printed, select **P - Print Table of Values**.
29. When the your data table prints, select **A - Alter Type of Graph**.
30. Select **Velocity vs Time** (For this lab, we will use only the speed component of velocity.)
31. We won't need the statistics on this graph; move to **S - Statistics** and turn it to off by pressing the space bar.
32. Press enter to accept the menu of options.
33. The default title, **Velocity vs Time** will appear on the screen. Use the **← Back Space** key to delete this title and type **Speed vs Time**. Press the enter key to continue.
34. Press enter **twice** more to accept automatic scaling on both axes.
35. When finished viewing the graph, press enter.
36. Select **O - Print Graph**.
37. When the graph has printed, select **X - Return to Data Analysis Menu**.
38. Select **X - Return to Main Menu**.

Go back to the  symbol on page 8 and repeat this procedure **twice** more. Each time, try to push the cart through the photogate at a different speed.

- Questions:**
1. What is the **value** of the **slope** for each of the three **Distance vs Time** graphs? (If you wish, calculate the slope of the regression or best-fit line and compare to the one given in the statistics.)
 2. What are the **units** for the **slope**? (Remember $m = \Delta y / \Delta x$. In this case, **distance** is on the y-axis and **time** is on the x - axis.)
 3. What measurement does the **slope** of a **Distance - Time** graph represent?
 4. Calculate the area under the **velocity - time** graphs and compare the areas to the distance moved by the picket fence through the photogate (0.35 m). This can be done more easily if you draw a **horizontal** line of best fit through the data points, which results in a rectangle whose area is simply **length x width**. The following examples will help in this calculation.

NOTE: Sometimes in this or other lab activities when you have a graph on the monitor, you may see a faint "garbage" graph on the bottom of the screen. It will also appear on your print-out. Just ignore it. It's a bug in the program.



(You could ask your teacher for the disk that fixes the problem.)

Consult your table of data to determine how far to extend the rectangle. AS IN THE GRAPH ABOVE, THE LAST "TIME" IN YOUR TABLE WILL BE JUST A BIT BEYOND THE LAST POINT IN YOUR GRAPH.

NOTE: The line of best fit is a little "lower" in the second graph to show the rectangle. When you do a line of best fit, try to get as many points above the line as below, providing the slope of the points is uniform.

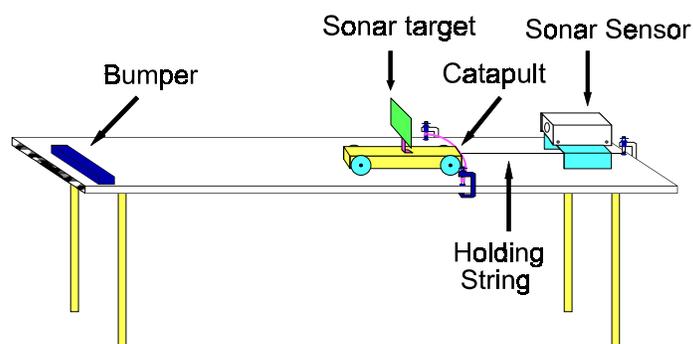
Core Lab: Measurement of Speed - Method 2

Unit 4: Motion

Purpose: To study the motion of a dynamics cart rolling on a level surface.

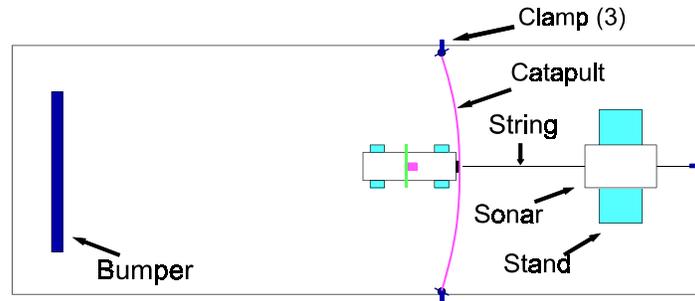
Apparatus: Vernier MPLI, motion sensor (sonar), dynamics cart, computer, printer, foam tape, right angle bracket, sonar target (see procedure), C-clamps (3) or similar.

Procedure: 1. Set up your apparatus on a level table or lab bench as shown in the diagram:



2. Connect the motion sensor (sonar) to port A of the MPLI box. Connect the MPLI box to the computer. There are two identical ports at the back of the computer--the ones with the little "claws." If the program doesn't work, try the other port.
3. Construct a sonar target from a piece of cardboard; a square 10 cm on a side works fine. Tape the target to the right angle bracket and then tape the bracket to the dynamics cart. Refer to the diagram. Make sure that the target is "square" with the cart. Be accurate before you press the target tightly to the tape as it is difficult to remove once pressure has been applied.
4. Place the motion sensor (sonar) on some kind of platform so that the gold sensor is aligned with the centre of the target and pointing squarely down the table. The sensor should be about 40 cm from the target as this is the minimum distance over which measurements can be made.

The cart has to be shoved or 'launched' down the table with a constant speed. A simple way to do this is to make a catapult from a piece of rubber lab tubing, elastic or rubber bands. You can use clamps to secure the catapult to the table. A string is tied to the cart which is pulled back against the catapult. The string is tied to another clamp and burned or cut through to launch the cart. Refer to the next diagram. (If you don't have the apparatus to do this, you can devise another method, or shove the cart being careful to move your arm quickly away from the sonar beam.)



5. Load the **Motion Plotter** software by typing `cd MP` (enter) and then `MP` (enter). If the `MP` program is not loaded on your hard drive, refer to Appendix A (pp. 107-108). However, you will have to make these changes on pp. 107-108: everywhere you see `PT`, type `MP`; everywhere you see "Precision Timer", think "Motion Plotter", and in #4 on p. 107 change the word "green" to "pink"!
6. When the graphic loads, press enter to see the main menu.
7. Select **O - Other Options**.
8. **Channel A** should already be selected after **Motion Detector Input**. If not, select **Channel A** by using the space bar.
9. Move to **F - Force Transducer Input** and press the **spacebar** until the current setup reads **none**.
10. Move to **R - Sample Rate** and press enter.
11. Change the sample rate to **40** and press enter.
12. Select **X - Return to Main Menu**.

You can test now to see if the Motion sensor (sonar) is working. Select **L - Display Distance in Large Digits**. You should get a readout of the distance to the target in metres. If you move the cart down the table, the display should give continuously the range to the target. This is a good test of the alignment of the sonar with the target. When you are certain the sonar is working, press enter to return to the main menu.

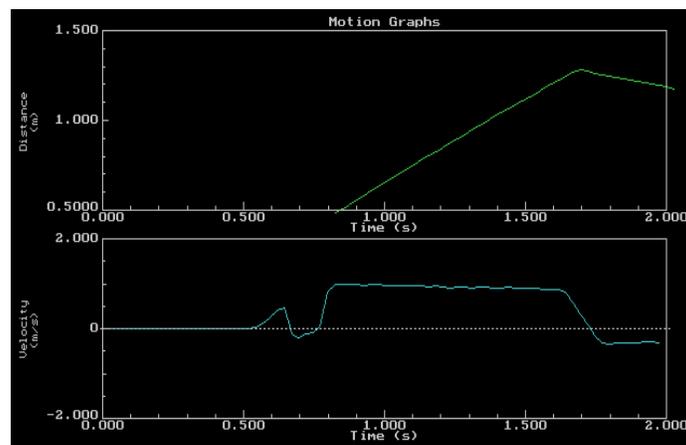
13. Select **M - Monitor/Graph in Real Time**.
14. A Graph Style Option menu will be displayed. You can turn the options ON/OFF by moving to the particular option and pressing the **spacebar**. The options you should have on are: **G - Background Grid of Dots**, **L - Line Connecting Points**, and **M - Store Data in Memory** (this should be on already). When finished selecting options, press enter.

A graph setup screen will appear. Find **distance** and **velocity** and use the space bar to turn these **on**. Find **acceleration** and **force** and turn them **off**. (Note: **acceleration** may be called **Bottom Graph** on some screens).

15. Just below **distance** find **Minimum** and press enter. Type **.5** and press enter. Move to **Maximum** and press enter. Type **1.5** and press enter.
16. Move to **I - Time of Run** and press enter. Use the cursor keys to move to the second-last digit on the right. Type **02** to change to time of 2 seconds. (It should read **00:02**.) Press enter when finished.
17. Move to **G - Start Graph** and press enter

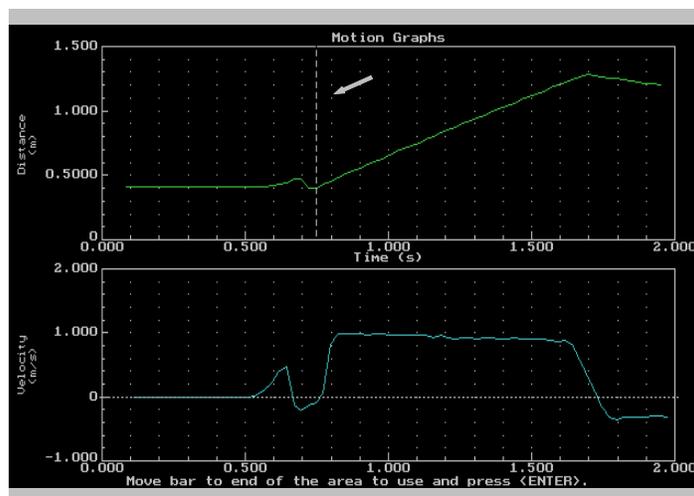
You might want to ask someone for help with the launching of the cart!! If you are using the method shown in the diagram, you will need a match, lighter or razor blade.

18. Press enter. **Immediately burn through/cut the holding string.** Your screen should look something like the next diagram.

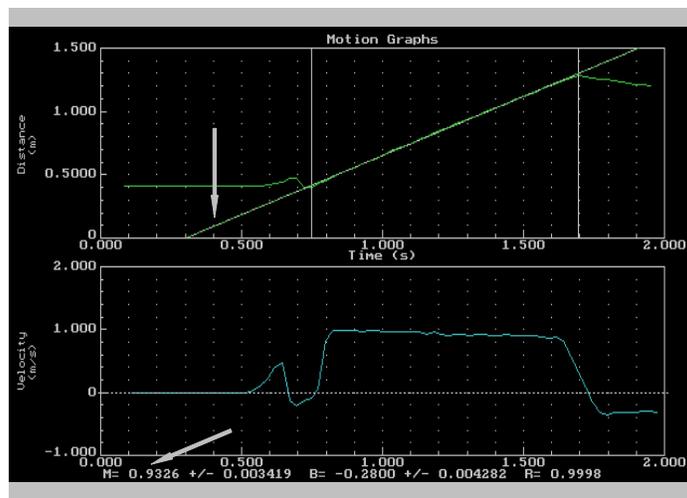


19. If your screen is a lot different, you may have waited too long to launch the cart, or your sonar was not aligned with the target. Reset the apparatus and try again. Press enter.
20. Select **X - Return to Main Menu**.
21. Select **P - Plot Graph**.
22. A Graph Style Option menu will be displayed. You can turn the options ON/OFF by moving to the particular option and pressing the **spacebar**. The options you should have on are: **G - Background Grid of Dots** and **L - Line Connecting Points**. When finished selecting options press enter.
23. Press enter **3 times** to select **Automatic Scaling - Variable Origin**.

Two graphs now should be displayed (refer to the next diagram). The top graph is **distance vs time**. Note the "sloping portion" which I have marked on the diagram. The bottom graph is **Velocity (speed) vs Time**. Note the "rectangular portion" which is also marked.

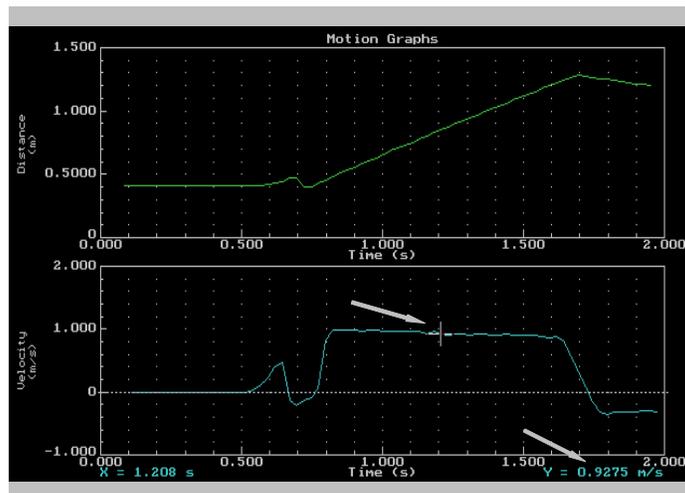


24. Press enter to display the Graph Follow-up Options menu. Select **Regression Line**. The graphs will be re-displayed with a dotted line on the left of the top graph.
25. Using the right cursor key, move the dotted line to the beginning of the sloping portion and press enter.
26. Move the dotted line to the last point on the sloping portion and again press enter. A straight **line of best fit** will now superimpose on the graph. A number of statistics will also appear at the bottom of the screen. (Refer to next diagram.)

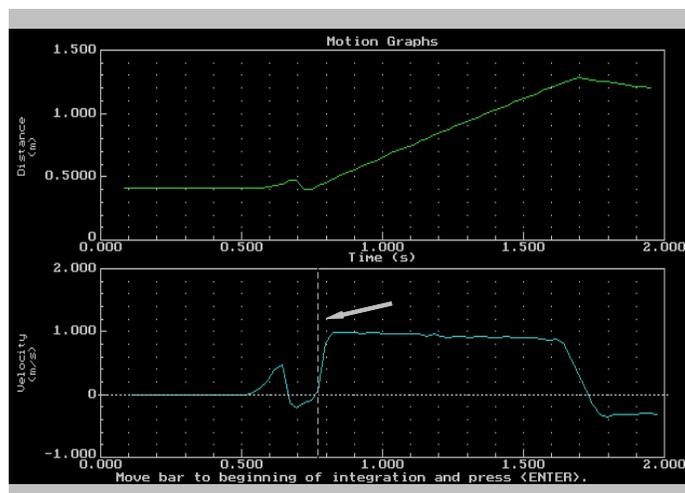


27. Read the value of the slope from the statistics ($M = \text{xxxx}$). Record the slope in the **Analysis** section (Slope 1.)
28. Press enter to re-display the graph menu.
29. Select **E - Examine Data**.
30. A **cross-hair** will appear on the top graph. Using the cursor keys, move the

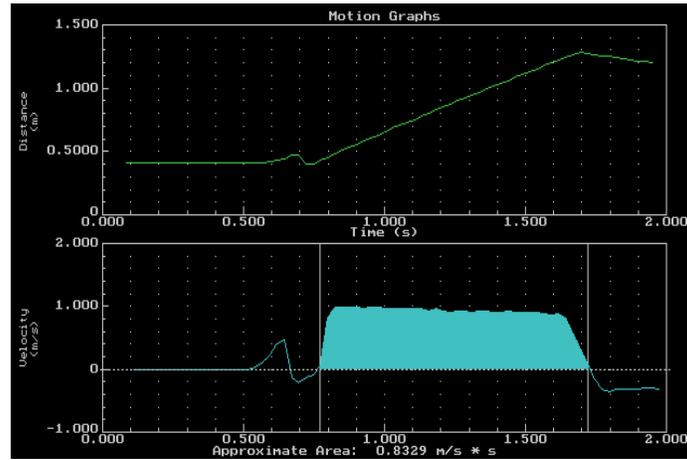
cross-hair down and over to the middle of the "rectangle" on the velocity - time graph (refer to the next diagram.)



31. The bottom right of the graph will display $Y = \text{xxxx}$. Since this is a speed - time graph, the Y - Axis is a measurement of speed. Record this number in the **Analysis** section as **Speed 1**.
32. Press enter to re-display the graph menu.
33. Select **I - Integrate**.
34. The graphs will now re-display with a dotted line on the left of the top graph. Move this line to the bottom graph and place it at the point where the "rectangle" moves up from the X - Axis. Press enter (refer to the next diagram.)



35. Move the line to the point where the "rectangle" moves down to, and intercepts, the X - Axis. Press enter (refer to the next diagram).



36. The "rectangle" will be shaded in blue. The "area" of the rectangle is shown at the bottom of the screen. Record this in the **Analysis** section as **Area 1**.
37. Press enter to re-display the graph menu.
38. Select **O - Print Graph**.
39. Make sure that the setup is set for a **large** graph, **high quality** and **Epson compatible** printer. Read the instructions at the bottom of the screen if you need to change options.
40. When ready select **P - Start Printing**.
41. Make sure the printer is turned on, has paper and is on a new page. Press enter.
42. When the printer stops, select **X - Return to Main Menu**.
43. Select **F - File Options**.
44. Select **S - Save Data to Disk**.
45. Enter a file name. For example, type **TRIAL1** and press enter. The next time you do this use **TRIAL2** and so on.
46. Select **X - Return to Main Menu**.

Set up the cart again. This time make it go faster. If you are using the catapult, haul back further on the holding string. Do 2 more trials, increasing the speed each time.

47. Go back to the  and start trial 2.

Results: Slope 1 _____ Speed 1 _____ Area 1 _____
Slope 2 _____ Speed 2 _____ Area 2 _____
Slope 3 _____ Speed 3 _____ Area 3 _____

- Questions:**
1. What are the **units** for the **slope**? (Remember $m = \Delta y / \Delta x$. In this case, **distance** is on the y-axis and **time** is on the x - axis.
 2. How does the **slope** of the **Distance - Time** graph change as the cart moves faster?
 3. What measurement does the **slope** of a **Distance - Time** graph represent?
 4. What are the units for the **area** (of the "rectangle") under the **Velocity (speed) - Time graph**?
 5. What does the **area** of the "rectangle" represent? How can the printed graphs be used to support your answer?

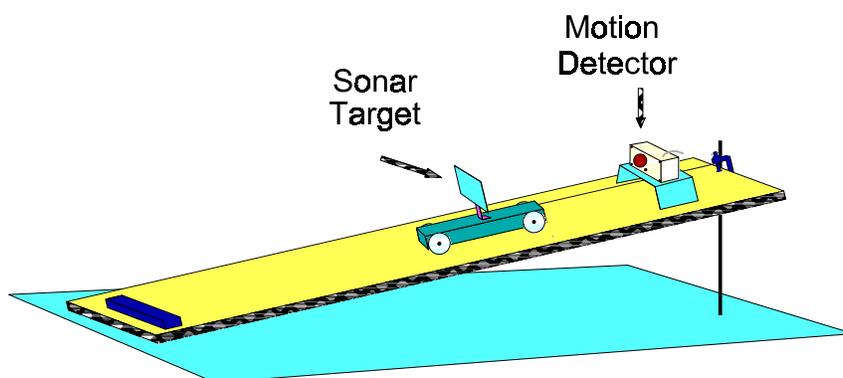
Core Lab: Measurement of Speed - Method 3

Unit 4: Motion

Purpose: To study the motion of a dynamics cart rolling on a inclined surface.

Apparatus: Vernier MPLI, motion sensor (sonar), dynamics cart, computer, printer, foam tape, right angle bracket, sonar target (see procedure), C-clamps (3) or similar.

Procedure: 1. Set up your apparatus on a level table or lab bench as shown in the diagram:



2. Connect the motion sensor (sonar) to port A of the MPLI box. Connect the MPLI box to the computer. If you can't remember how to do this, refer to Appendix B.
3. Construct a sonar target from a piece of cardboard; a square 10 cm on a side works fine. Tape the target to the right angle bracket and then tape the bracket to the dynamics cart. Refer to the diagram. Make sure that the target is "square" with the cart. Be accurate before you press the target tightly to the tape as it is difficult to remove once pressure has been applied.
4. Place the motion sensor (sonar) on some kind of platform so that the gold sensor is aligned with the centre of the target and pointing squarely down the table. The sensor should be about 40 cm from the target as this is the minimum distance over which measurements can be made.

Note: One method of release is to tie a string to a clamp and to the cart (see diagram). When you are ready, the string can be cut or burned through. In this way you will not get in the way of the ultrasonic beam from the motion detector.

5. Load the **Motion Plotter** software by typing `cd MP` (enter) and then `MP` (enter). There are two identical ports at the back of the computer--the ones with the little "claws." If the program doesn't work, try the other port.

If the **MP** program is not loaded on your hard drive, refer to Appendix A (p. 142) . However, you will have to make these changes on pp. 141-142: everywhere you see **PT**, type **MP**; everywhere you see "Precision Timer", think "Motion Plotter", and change the word "green" to "pink"!

6. When the graphic loads, press enter to see the main menu.
7. Select **O - Other Options**.
8. Move to **F - Force Transducer Input** and press the **spacebar** until the current setup reads **none**.
9. Move to **R - Sample Rate** and press enter.
10. Change the sample rate to **40** and press enter.
11. Select **X - Return to Main Menu**.

You can test now to see if the motion sensor (sonar) is working. Select **L - Display Distance in Large Digits**. You should get a readout of the distance to the target in metres. If you move the cart down the table, the display should give the range to the target. This is a good test of the alignment of the sonar with the target. When you are certain the sonar is working, press enter to return to the main menu.

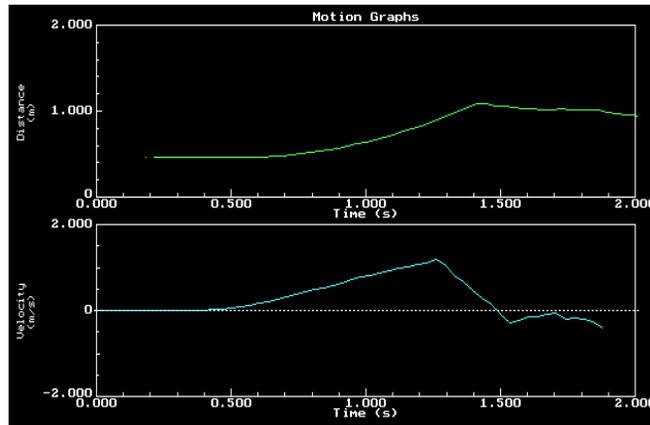
12. Select **M - Monitor/Graph in Real Time**.
13. A Graph Style Option menu will be displayed. You can turn the options ON/OFF by moving to the particular option and pressing the **spacebar**. The options you should have on are: **G - Background Grid of Dots**, **L - Line Connecting Points**, and **M - Store Data in Memory** (this should be on already). When finished selecting options, press enter.

A graph setup screen will appear.

14. Move to **M - Minimum** and press enter. Type **.5** and press enter.
15. Move to **N - Maximum** and press enter. Type **1.5** and press enter.
16. Move to **A - Acceleration** and press enter (turn it off).
17. Move to **I - Time of Run** and press enter. Use the cursor keys to move to the second-last digit on the right. Type **02** to change to time of 2 seconds. (It should read **00:02**.) Press enter when finished.
18. Move to **G - Start Graph** and press enter

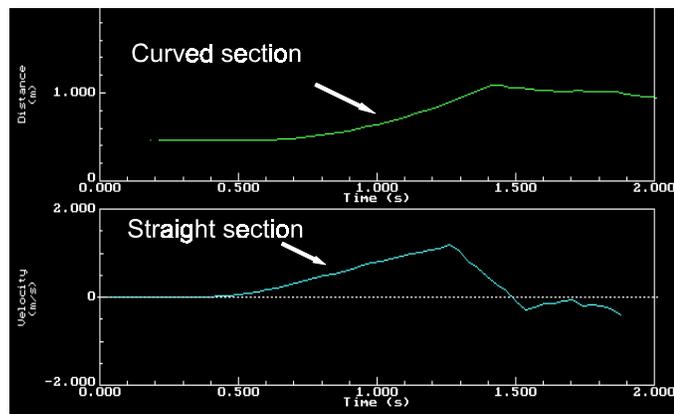
You might want to ask someone for help with the launching of the cart!! If you are using the method shown in the diagram, you will need a match, lighter or razor blade.

19. Burn through/cut the holding string. As soon as the cart starts moving, press enter to activate the motion detector. Your screen should look something like the next diagram.



20. If your screen is a lot different, you may have waited too long to release the cart, or your sonar was not aligned with the target. Reset the apparatus and try again.
21. Press enter.
22. Select **X** - Return to Main Menu.
23. Select **P** - Plot Graph.
24. A Graph Style Option menu will be displayed. You can turn the options ON/OFF by moving to the particular option and pressing the **spacebar**. The only option you should have on is **L** - Line Connecting Points. When finished selecting options press enter.
25. Press enter **3** times to select **Automatic Scaling - Variable Origin**.

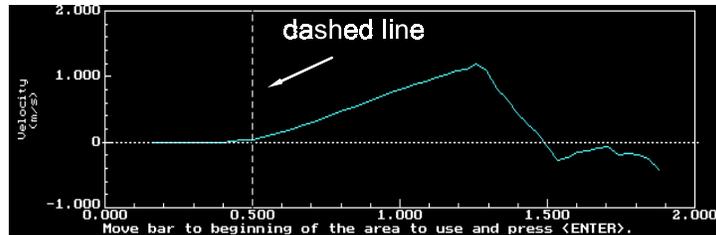
Two graphs now should be displayed (refer to the next diagram). The top graph is **distance vs time**. Note the "curved section" which is indicated by arrows on the diagram. The bottom graph is **velocity vs time**. Note the "straight section".



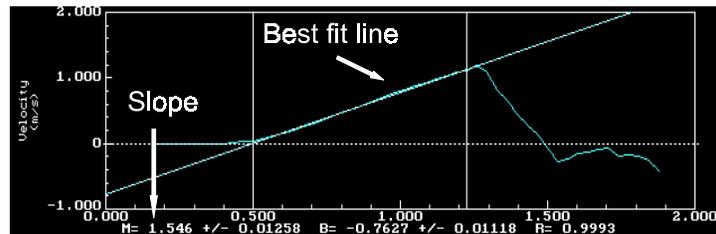
26. Press enter to display the **Graph Follow-up Options** menu. Select **Regression**

Line. The graphs will be re-displayed with a dashed line on the left of the top graph.

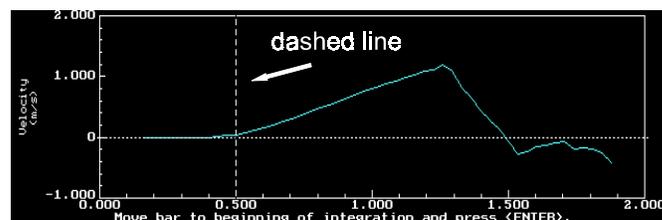
27. Using the down cursor key, move the dashed line to the second graph. Using the right cursor key, move the dashed line to the beginning of the "straight section" and press enter. See the next diagram. Only the lower, velocity graph is shown here.



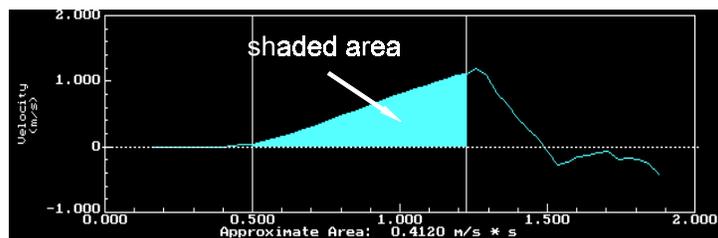
28. Move the dashed line to the last point on the "straight section" and again press enter. A straight line of best fit will now superimpose on the graph. A number of statistics will also appear at the bottom of the screen. See the next diagram.



29. Read the value of the slope from the statistics ($M = \text{xxxx}$). Record the value of the slope in the **Analysis** section as **Slope 1**.
30. Press enter to re-display the graph menu.
31. Select **I - Integrate**. The graphs will be re-displayed with a dashed line on the left of the top graph.
32. Using the down cursor key, move the dashed line to the second graph. Using the right cursor key, move the dashed line to the beginning of the "straight section" and press enter. See the next diagram. Only the lower, velocity graph is shown here.



33. Move the dashed line to the last point on the "straight section" and again press enter. The area under the graph (a triangle will be shaded in blue and the value of that area displayed below the graph. See the next diagram.



34. Read the value of the area from the bottom of the graph. Record the value of the area in the **Analysis** section as **Area 1**.
35. Press enter to re-display the graph menu.
36. Select **O - Print Graph**.
37. Make sure that the setup is set for a **large graph**, **high quality** and **Epson compatible** printer. Read the instructions at the bottom of the screen if you need to change options.
38. When ready select **P - Start Printing**.
39. Make sure the printer is turned on, has paper and is on a new page. Press enter.
40. When the printer stops, select **X - Return to Main Menu**.
41. Select **F - File Options**.
42. Select **S - Save Data to Disk**.
43. Enter a file name. For example, type **L1M2RUN1** and press enter. The next time you do this use **L1M2RUN2** and so on.
44. Select **X - Return to Main Menu**.

Set up the cart again. This time make it go faster or slower by raising or lowering the inclined plane. Do 2 more trials.
45. Go back to the  symbol and start trial 2 or 3.

Results: Slope 1 _____ Area 1 _____
Slope 2 _____ Area 2 _____
Slope 3 _____ Area 3 _____

- Questions:**
1. What are the **units** for the **slope** of the velocity - time graph?
(Remember: $m = \Delta y / \Delta x$. In this case, **velocity** is on the y-axis and **time** is on the x - axis.)
 2. How does the **slope** of the velocity - time graph change as the cart moves faster?
 3. What measurement does the **slope** of a velocity - time graph represent?
 4. What are the units for the **area** (of the "rectangle") under the velocity - time graph?
 5. What does the **area** of the "rectangle" represent? How can the printed graphs be used to support your answer?

