Motions and Forces
Tracker

Discovery Question

What does a graph of the motion of a low-friction cart look like?

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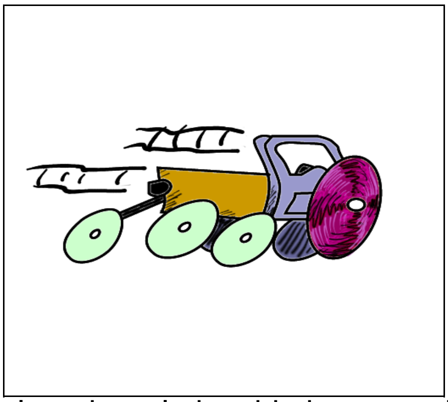
Discovery Question

What does a graph of the motion of a low-friction cart look like?

Introduction



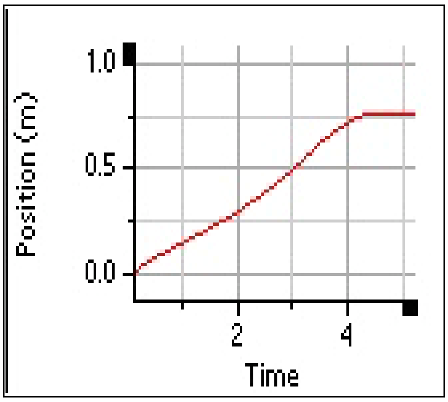
In this activity you will explore the relationship between the movement of a cart and the shapes of the resulting position and velocity graphs.

Thinking About The Question

What does a graph of the motion of a low-friction cart look like?

Think about how you would describe the motion of your cart to someone. What is the simplest way to describe its motion? Would you need to know its position, or velocity, or both? What tools would you need to measure its motion? Write your thoughts in Notes on your handheld computer.

The following position versus time graph of a cart was made with a SmartWheel. Discuss the motion shown with your group. Did the cart appear to change velocity at anytime?



Materials

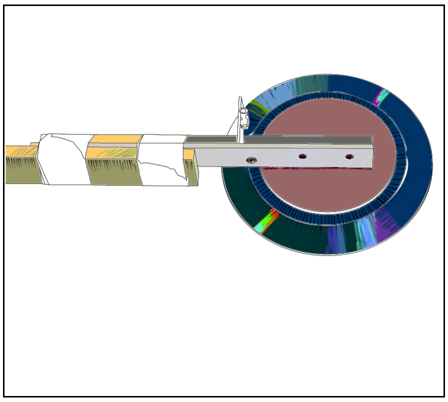
- CC SmartWheel probe removed from air cart
- meter stick
- masking tape
- CC SmartWheel probe installed on air cart
- CC LabBook software
- handheld computer
- constructed air cart (see Investigation: Air Cart)
- 2 - new 1.5V AA batteries
- string (for pulling cart)

Safety

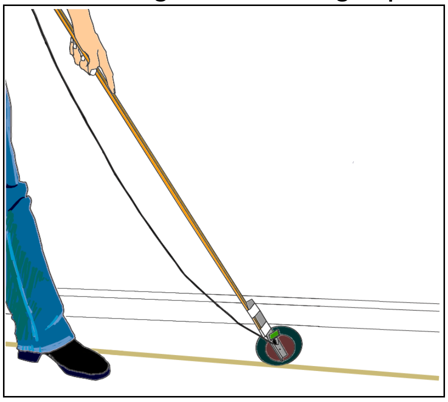
- No specific safety features needed for this investigation.

Trial I: Walking off distances

1. Remove the SmartWheel from your cart. Carefully save the two screws. Tape or screw the SmartWheel to the end of a meter stick so that you can walk along and roll it on the floor.



2. Place a piece of masking tape on the floor to make a straight line 2-3m long. You will use this line when navigating your SmartWheel.
3. Connect the SmartWheel to your handheld computer. Refer to Technical Hints to see how to connect the cables.
4. Start the software. Observe the position versus time graph as you roll the SmartWheel back and forth along the masking tape line on the floor.



5. With your team member, take turns practicing making the following motions until you have all four motions on the same graph, one after the other.
   a. walking forward at a constant velocity
   b. walking forward, then backward, at constant velocity
   c. walking forward slowly, then quickly, then stopping
   d. gradually speeding up, then gradually slowing down
6. Save your data to the handheld computer.
7. Draw and describe the graph for each set of movements in Notes on your handheld computer.
   a. walking forward at a constant velocity

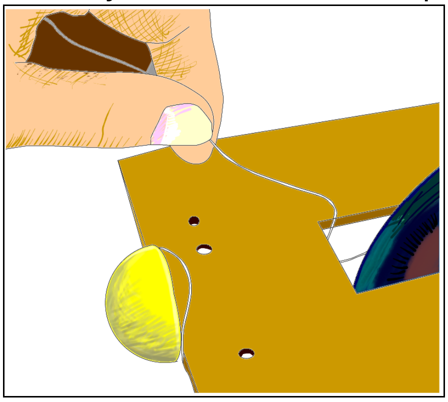
b. walking forward, then backward, at constant velocity

c. walking forward slowly, then quickly, then stopping

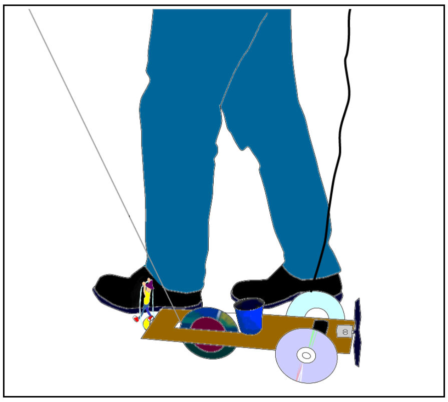
d. gradually speeding up, then gradually slowing down

Trial II: Rolling cart

1. Reattach the SmartWheel to your cart. Refer to Technical Hints to see how to attach the SmartWheel to the air cart.
2. Connect the SmartWheel to your handheld computer. Refer to Technical Hints to see how to connect the cables.
3. Attach a string to the front of your cart. It can be looped around the bumper.



4. Practice pulling the cart while draping the connecting cable above the cart so that it doesn't pull the cart one way or the other. One person will need to walk alongside the cart while carrying the handheld computer and keeping the wire from obstructing the movement of the cart as it moves in a straight line.



5. Predict the resulting graphs for each of the following motions in Notes on your handheld computer.
    a. pulling the cart forward at a constant velocity
    b. pulling the cart at a slow constant velocity, then a faster constant velocity, then coasting
    c. gradually speeding up the cart, then coasting
    d. pulling the cart, then letting it bounce off a wall

6. Start the software and observe the position versus time graph as you make the following motions on the same graph. Practice until you have all four motions on the same graph, one after the other. Observe how the acrobat responded during each motion.

a. pulling the cart forward at a constant velocity

b. pulling the cart at a slow constant velocity, then a faster constant velocity, then coasting

c. gradually speeding up the cart, then coasting

d. pulling the cart, then letting it bounce off a wall

7. Save your data to the handheld computer.

8. Draw and describe a graph for each set of movements in Notes on your handheld computer.

   a. pulling the cart forward at a constant velocity

   b. pulling the cart at a slow constant velocity, then a faster constant velocity, then coasting

   c. gradually speeding up the cart, then coasting

   d. pulling the cart, then letting it bounce off a wall

9. Discuss the following questions with your group. What do the graphs show you about the motion of the cart? How did the acrobat respond during the constant motion and the changing motion? Write your ideas in Notes on your handheld computer.

Trial III: Rolling to a stop

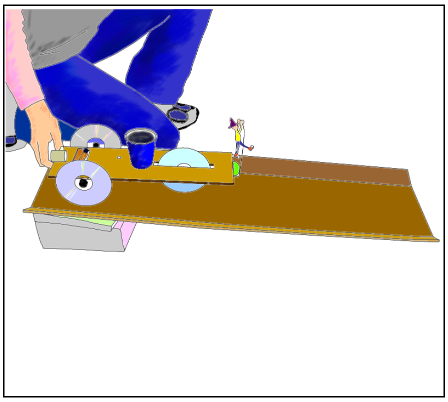
1. Using the ramp to initiate motion of the cart, design a method to slow down the cart and bring it to a stop in exactly 5 seconds as it rolls across a rug or another rough surface. Share your method with other members of your group. What is your method? Explain your design in Notes on your handheld computer.

2. What will the position versus time graph look like? Sketch the graph in Notes on your handheld computer.

3. Connect the SmartWheel to your handheld computer. Refer to Technical Hints to see how to connect the cables.

4. Now try your method out. Start the software and observe the position versus time graph as you roll the cart down the ramp. Be sure to drape the wire to the SmartWheel so that the cart rolls freely. Observe how the acrobat responded during the motion.

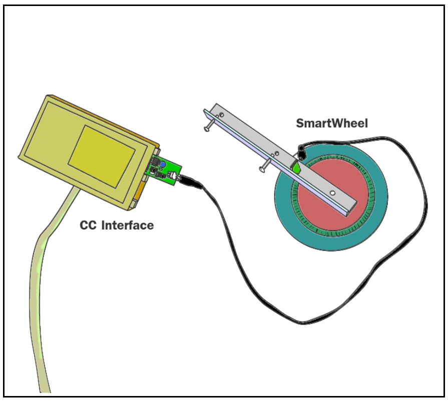
5. Save your data to the handheld.



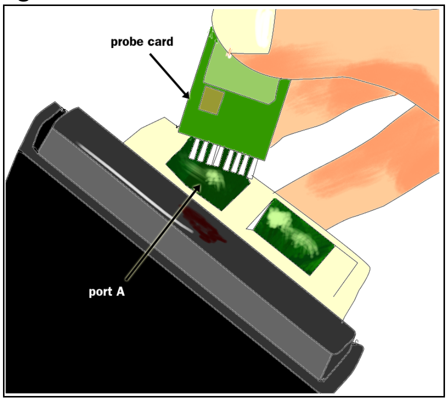
6. Look at your position versus time graph. How do you know that your cart slowed down? Did it slow down at the same rate for the entire 5 seconds? If not, when and why did the rate change? Explain your reasoning in Notes on your handheld computer.

Technical Hints

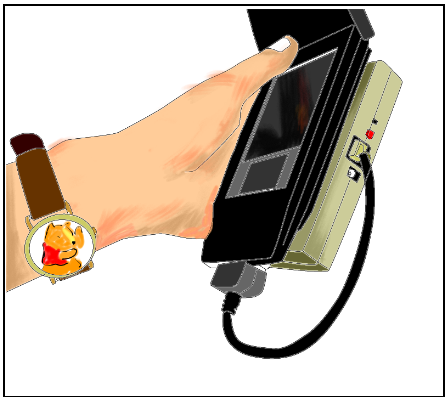
Connecting the SmartWheel



1. Connect the flexible cable from the SmartWheel to the SmartWheel card. Plug the SmartWheel card into Port A of the Interface Box. Be careful not to bend any of the copper prongs, or it won't work.



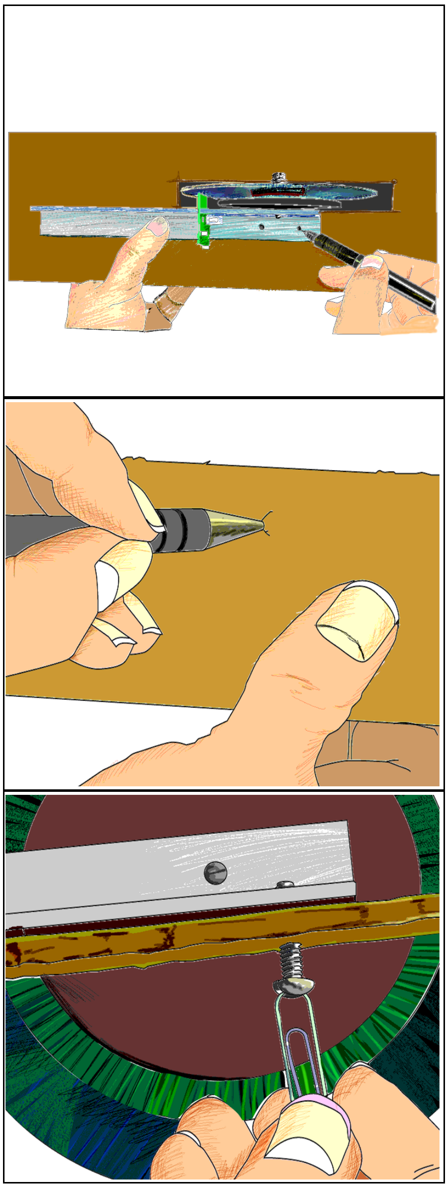
2. Attach the CCProbe Interface Box to your handheld with the Velcro square. Connect the CCProbe Interface Box to your handheld with the provided connector cable.

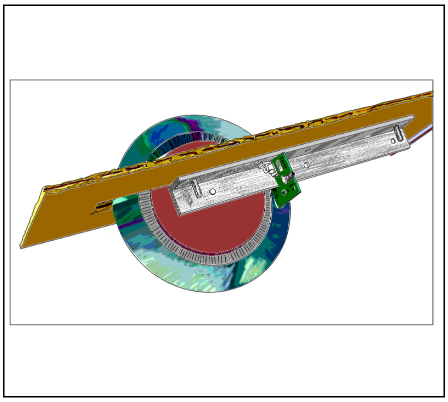


3. Tap on the CCProbe icon to open the software. Open or create a SmartWheel data collector. Choose either the linear position or the linear velocity mode.

Attaching the SmartWheel to the air cart

1. Center the SmartWheel in the slot so that it doesn't rub against the cardboard. Make it exactly parallel to the long edge of the cart. This will make the cart go straight. The aluminum arm goes against the underside of the cardboard, the same as the straw. Mark two screw holes with a pencil or pen, one at each end.
2. Make holes where the marks are, using a pencil or pen point. Enlarge the holes from both sides, until the screws fit snugly into them. The screws are provided with the SmartWheel.
3. Put the screws first through the cardboard from the other side, and then screw them into the arm of the SmartWheel. Tighten them until the heads squeeze the cardboard a little bit. A paper clip will work as a screwdriver.
4. The SmartWheel is now ready to use.





Using the CC LabBook software

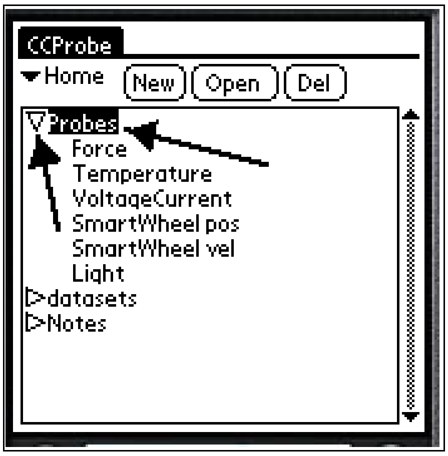
To use CC LabBook just follow these easy steps!

1. Opening the software

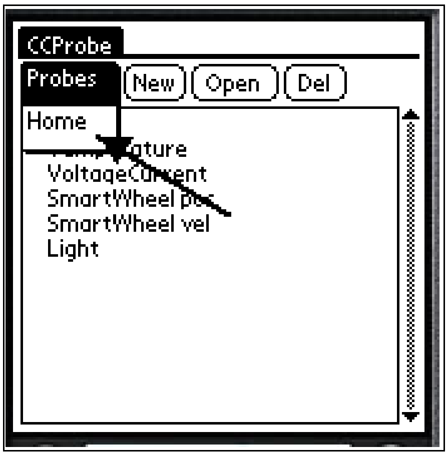
a. To open the software, tap the CCProbe icon.

b. The first screen you see is the LabBook.

2. Opening folders and subfolders



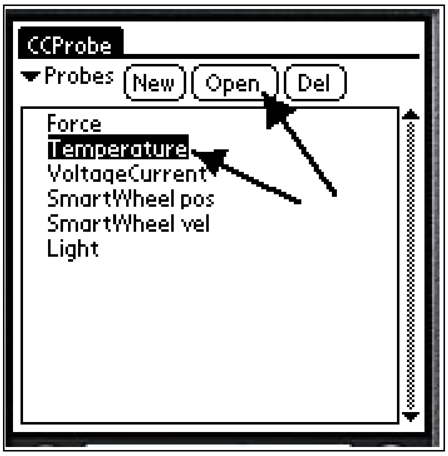
a. The LabBook lists all of the folders, data collectors, notes, saved datasets, and other objects in the LabBook. To open folders and subfolders, tap the triangles or double-tap the folder name.



b. Click Home (upper left) to go back to the top level folder.

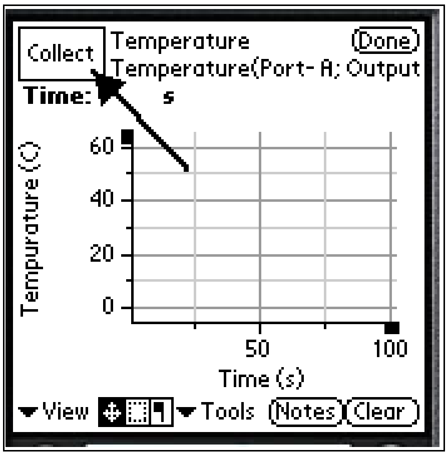
3. Opening a data collector

a. To take data with a CC probe, you must open or create a data collector. In these investigations, the data collectors have already been created.

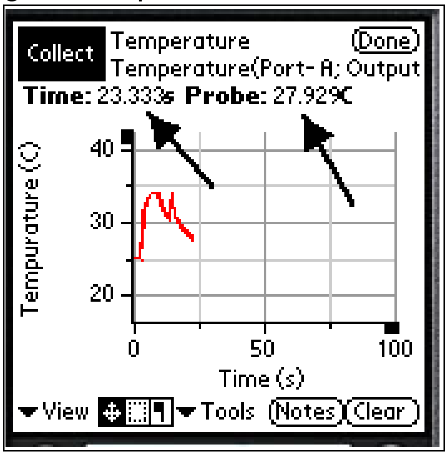


b. To open an existing data collector, highlight its name, then tap it twice or tap Open. It may take a few seconds for the graph to appear.

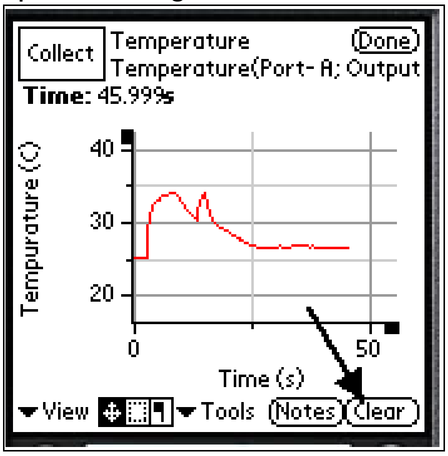
4. Collecting and clearing data



a. To start collecting data, tap Collect.



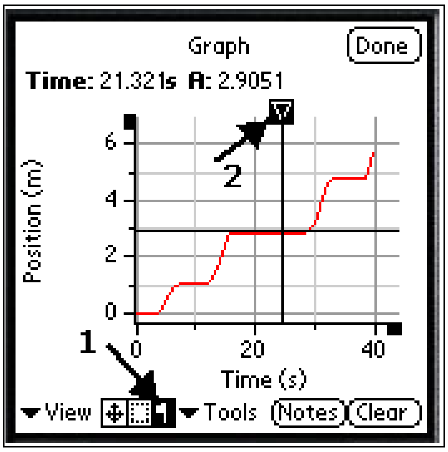
b. As data is collected, the current values appear at the top of the graph. To stop collecting, tap Collect again.



c. You can clear the data with Clear, and then continue collecting data with Collect.

5. Reading graph values

a. To read values of a graph once it has been collected, tap on the Mark flag and tap where you want to read the value.



b. A little triangle will appear, connected to crossed lines. The mark can be moved around with the cursor, and the x and y values of the graph will show at the top.

6. Recognizing collection limits

Currently there is a limit to how much data can be collected at once, about 4000 data points. The collecting will stop when this amount is reached, so plan your experiments with this in mind. In terms of time, the limits are as follows:

Force probe, 400/sec = about 7 seconds

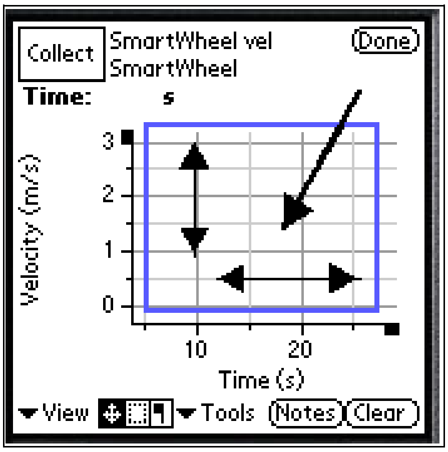
Force probe, 200/sec = about 15 seconds

SmartWheel = about 40 seconds

All others 3/sec = several minutes

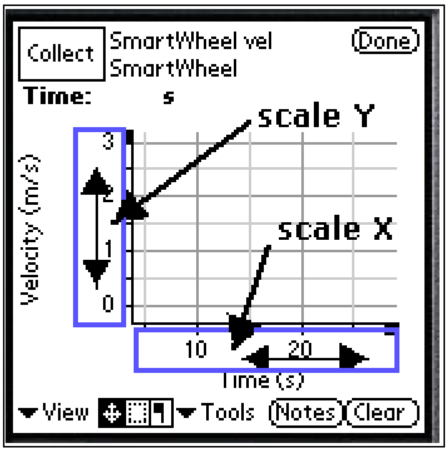
7. Scrolling around the graph

To scroll around the graph, tap and drag within the graph area itself. There may be a slight delay before the graph responds.

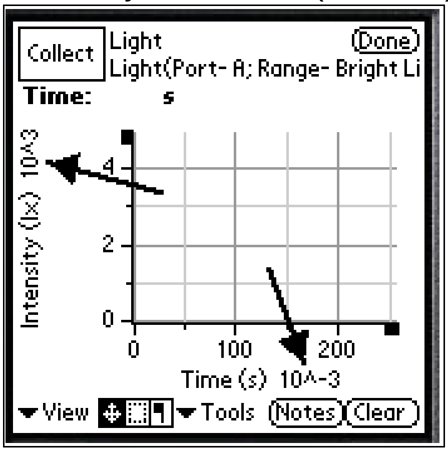


8. Changing the scale of an axis

a. To change the scale of an axis, tap and drag on the region along the axis. Drag away from zero to expand the scale and toward zero to shrink the scale. There may be a slight delay before the graph responds.

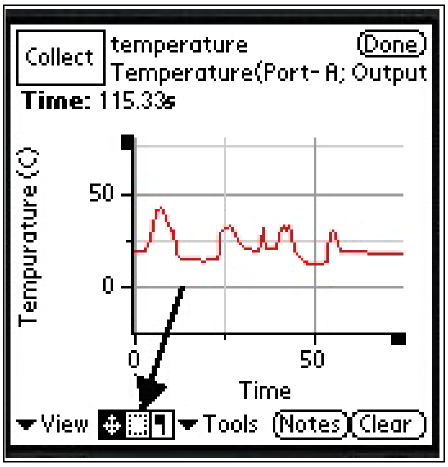


b. If you stretch or shrink the scale a great deal, it will switch by a factor of 1000, shown as 10^3 (for large numbers) or 10^-3 (for small numbers). For example, in the following screen, time is in milliseconds (1/1000 of a second) and light intensity is in kilolux (1000 lux).

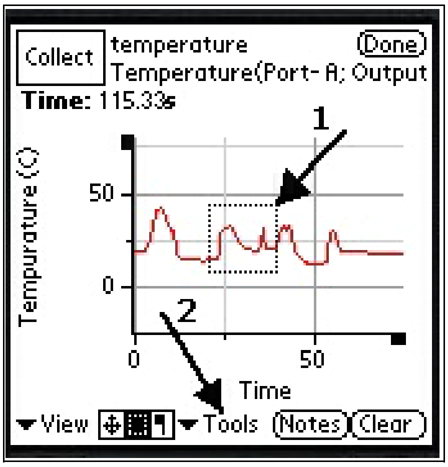


9. Zooming in on the graph

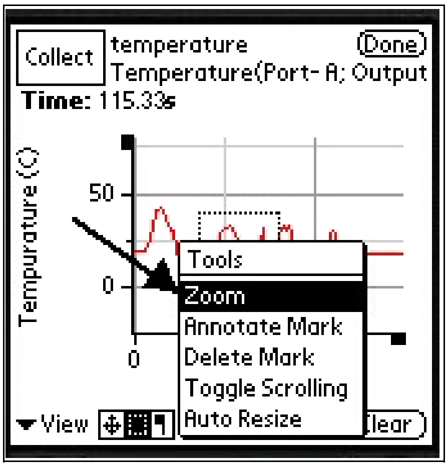
a. To zoom in on part of a graph, tap on the area selector at the bottom of the screen.



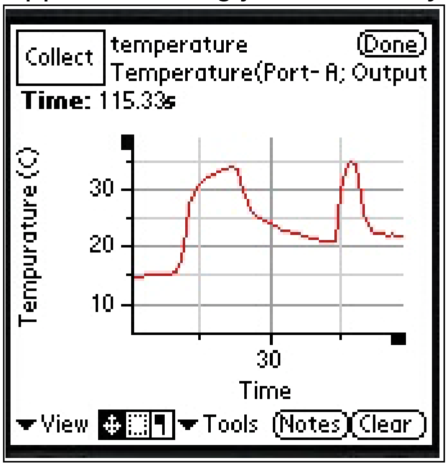
b. Drag the outline around the area of the graph you want to zoom in on, then tap Tools.



c. Click Zoom in the Tools list.

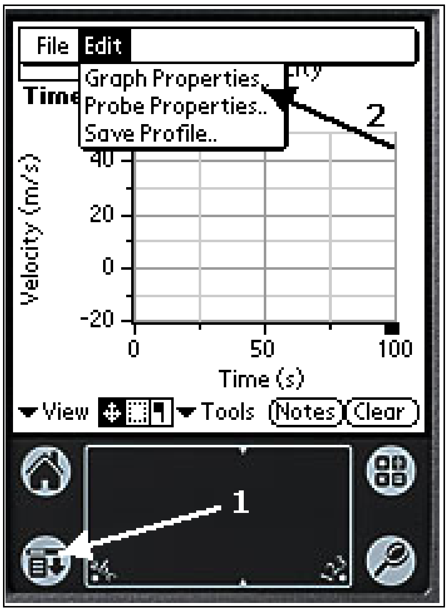


d. The graph will reappear showing just the area you selected.

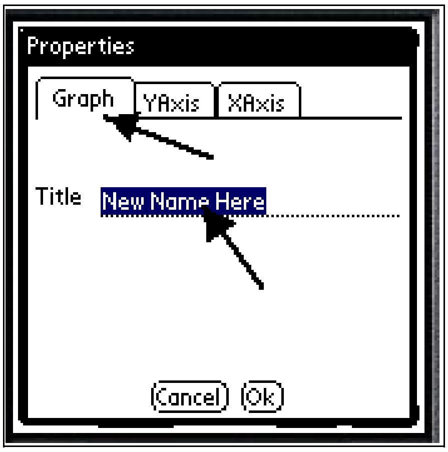


10. Changing graph properties

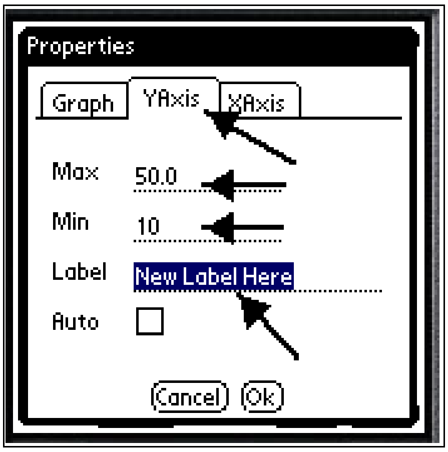
a. To change graph properties, tap the Palm menu icon at the bottom left corner, then the Edit menu item. Tap Graph Properties.



b. To change the title, go to the Graph tab. Write the new title, and then tap OK.



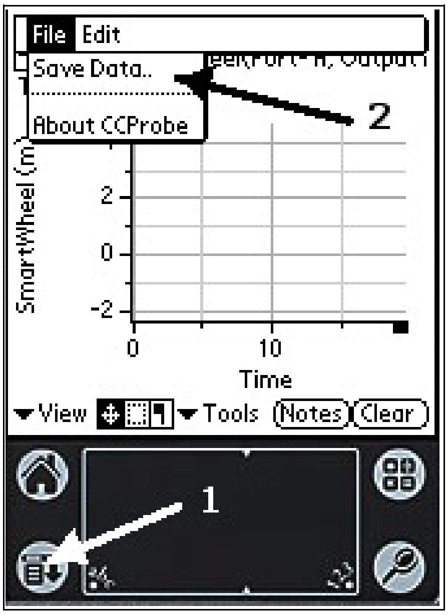
c. To change the range and the label of an axis, tap on the YAxis or XAxis tab. Write in the Max, the Min, and the Label, and then tap OK.



d. Another method of changing the range and the label of an axis is to tap on the ends of axes to open graph properties.

11. Saving data

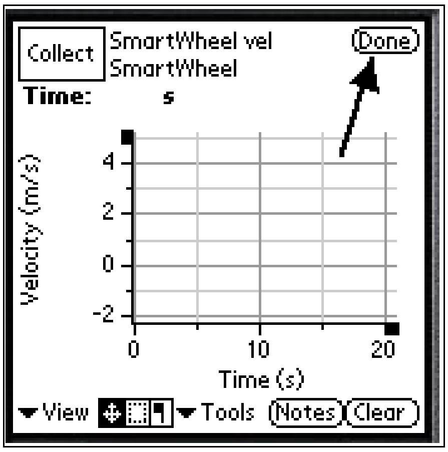
a. To save your data, tap the Palm menu icon at the bottom left corner. Then tap Save Data in the File menu. The menu will disappear when the data is saved. This may take several seconds.



b. When prompted, give your data set a name. It will be saved in your LabBook.

12. Closing the data collector

To close the data collector and go back to the LabBook screen, tap Done. Your data will NOT automatically be saved.



Analysis

1. What does the steepness of the position versus time graph tell you about the velocity of the cart? How can you tell from the graph whether the cart is going forward or backward?

2. What is the shape of the distance versus time graphs of a cart as it moves at:
   a. constant velocity?
   b. decreasing velocity?
   c. increasing velocity?

3. How did the acrobat move during Trial II and Trial III? What happened to either make it move or keep it still during each motion of the cart?

4. How would you calculate velocity from the position versus time graph? Do you think that if you knew the position of the cart at every moment, you could know its velocity as well?

Further Investigations

- Draw a position graph of a motion that you would like your cart to do. Try to replicate the graph by moving your cart with the SmartWheel attached and the software set to read position.
- Draw a velocity graph of a motion that you would like your cart to move. Try to replicate the graph by moving your cart with the SmartWheel attached and the software set to read velocity.
- Try pushing the cart up the ramp and then letting it roll back down the ramp. Predict what you think the position and speed graphs will look like and then test your prediction.
- Try keeping your cart moving at a constant velocity for 30 seconds. Describe how this could be done and test your method out. Examine the resulting position versus time graph.

