Motions and Forces
Air Cart

Discovery Question

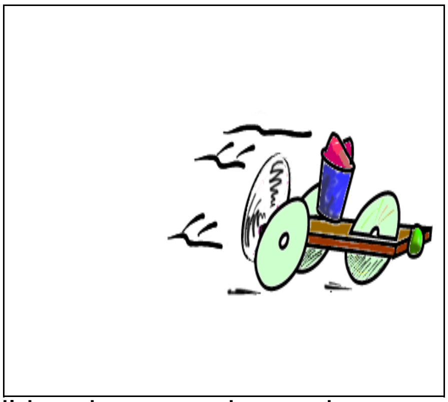
What happens to a vehicle when there's very little friction?

- Introduction
- Thinking About the Question
- Materials
- Safety
- Trial I: Building an air cart
- Trial II: Building a test ramp
- Trial III: Performing a coasting test
- Technical Hints
- Analysis
- Further Investigations

Discovery Question

What happens to a vehicle when there's very little friction?

Introduction



In this activity you will build and test an air cart that operates with very little friction.

Thinking About The Question

What happens to a vehicle when there's very little friction?

Have you ever wondered why cars stay on the road when they round a corner? Why is it more difficult to round those corners when the road is wet or covered with ice? Besides the banking of the road, the tires provide a frictional surface against the surface of the road. The ideal car provides friction when you need it (turning and braking) but has little when you don't want it (speeding along in a straight line).

It's not that easy to make a vehicle move with almost no friction. But that's the goal of this investigation. We want a cart that's almost friction free so that we can study the forces on moving objects without being confused by the forces due to friction. Suppose a frictionless cart is pushed across the floor. How far do you think the cart will go? What forces will affect the motion of a frictionless cart? Explain your predictions in Notes on your handheld computer.

Refer to Technical Hints to see how to use the CC LabBook software.

Materials

- CC SmartWheel
- cardboard for cart body (12cm x 40cm)
- cardboard for ramp (30cm x 100cm)
- 2 - junk CD-ROMs, with snap-in plastic hubs
- aluminum axle (15cm)
- drinking straw
- rubber bumper (popper)
- small paper drinking cup (150 ml)
- small DC motor with leads
- propeller
- 2 - new 1.5V AA batteries
- battery holder with leads
- clay (for added weight)
- accelerator acrobat
- wire for support of accelerator acrobat
- books to prop up ramp
- tape
- handheld computer
- CC LabBook software
- hot-melt (or cold-melt) glue gun and glue sticks
- utility knife
- metal straight edge ruler (metric)
- scissors

Safety

- If you are using a hot glue gun, caution should be taken until the glue cools and hardens. Burns may result.
- If you are using a utility knife to cut the cardboard, extreme care should be taken to prevent cuts. Use a sharp blade and get instruction in how to cut against a straightedge.
- If you choose to use the propeller, keep in mind that it turns rapidly when it is powered by the battery, so watch out for your fingers!

Trial I: Building an air cart

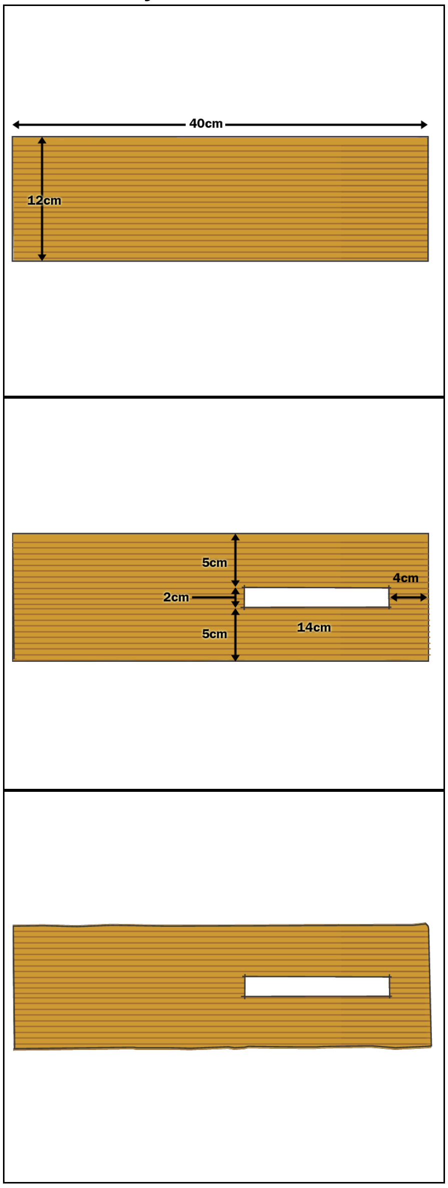
To build your air cart follow these easy steps!

1. Making the cardboard foundation

a. Carefully use the utility knife to cut out a 12cm x 40cm rectangle from cardboard for the air cart body. The corrugations in the cardboard should run the long way. Your teacher may provide this cardboard piece already cut.

b. Mark the slot for the SmartWheel probe. Be sure the slot is parallel to the cart length. The slot is 2cm wide and 14cm long, starting 4cm from one end of the cart.

c. Cut out the slot with a utility knife. Please be very careful!



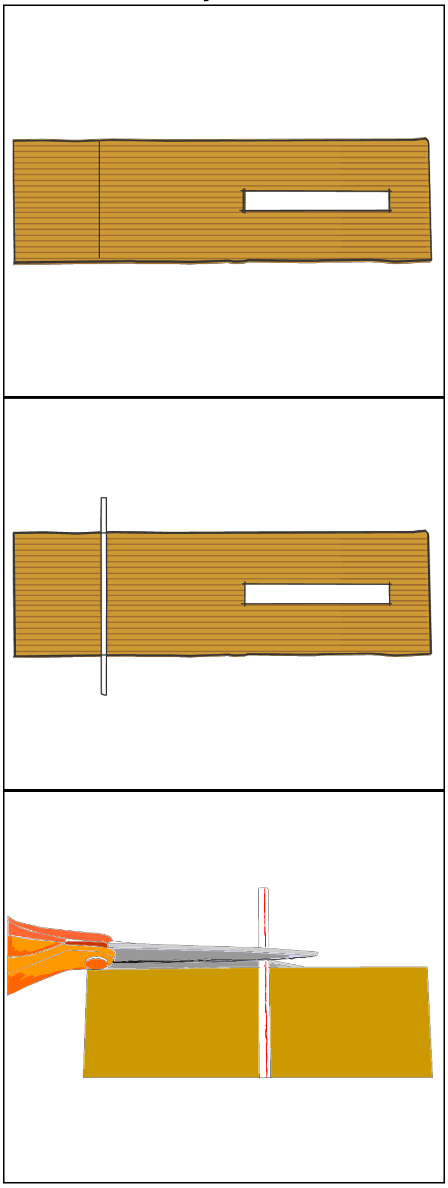
2. Installing the axles

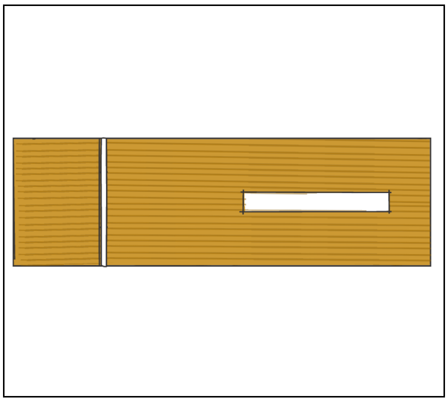
a. Mark the axle line. It is 8cm from the other end of the cart and perpendicular to the long side. You can use the corner of a piece of paper to make a perpendicular line.

b. Glue the straw to the axle line with hot-melt glue. Let it stick out on either side.

c. Cut off each end of the straw a bit longer than the cardboard.

d. The finished straw is now ready for the axle.





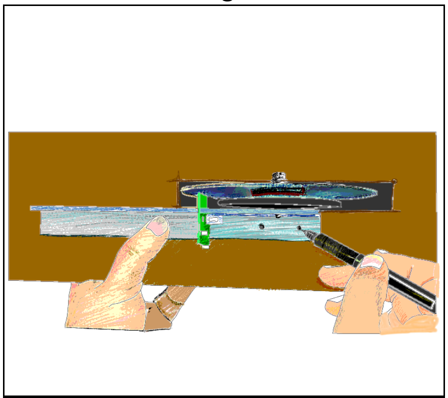
3. Attaching the SmartWheel to the Cart

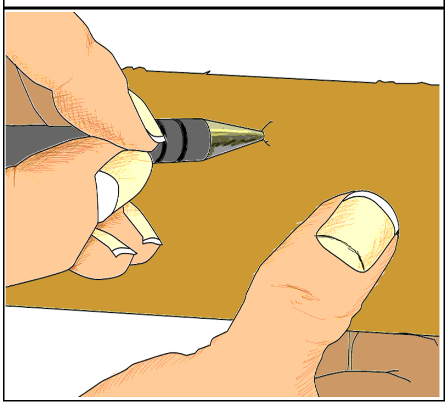
a. Center the SmartWheel in the slot so that it doesn't rub against the cardboard. Make it exactly parallel to the long edge of the cart. This will make the cart go straight. The aluminum arm goes against the same side of the cardboard as the straw. Mark two screw holes with a pencil or pen, one at each end.

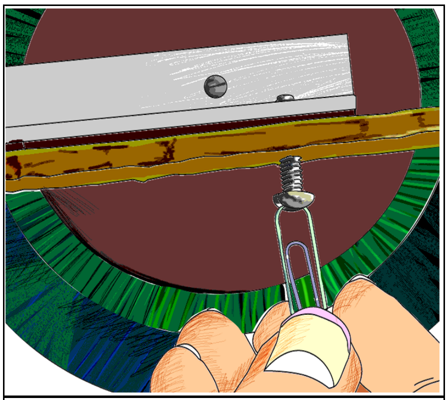
b. Make holes where the marks are, using a pencil or pen point. Enlarge the holes from both sides, until the screws fit snugly into them. The screws are provided with the SmartWheel.

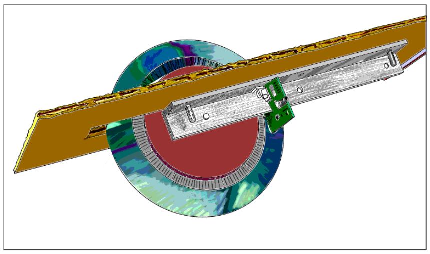
c. Put the screws first through the cardboard from the other side, and then screw them into the arm of the SmartWheel. Tighten them until the heads squeeze the cardboard a little bit. A paper clip will work as a screwdriver.

d. Now the SmartWheel is in place. It can be taken on and off. You will need to do this for the Tracker Investigation.







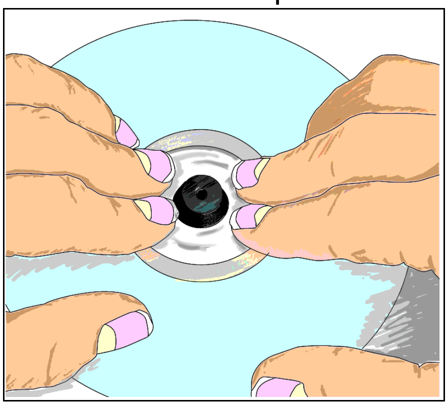


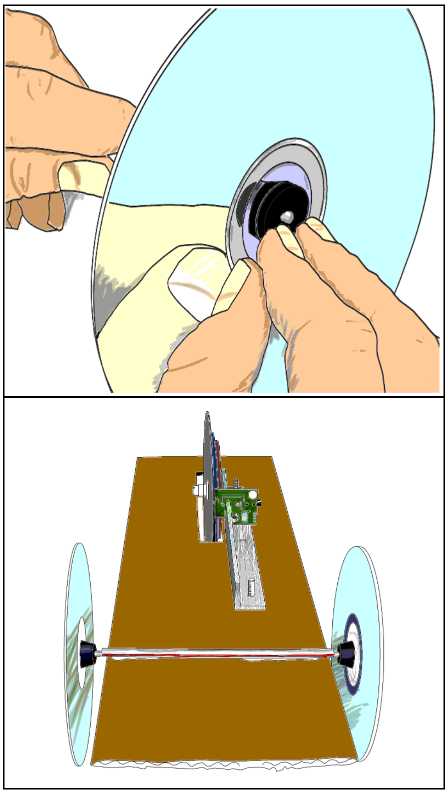
4. Attaching the CD ROM wheels to the cart

a. Snap each CD ROM wheel onto a black hub, if this isn't already done. Put the hub on a table with the tapered end pointing up, and push the CD wheel down, snapping it into place.

b. Push the aluminum axle into the black hub on one CD ROM wheel. The long tapered end of the black hub should face toward the cart.

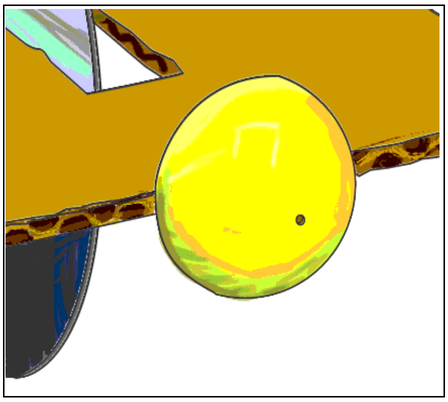
c. Slide the axle through the straw and then slide on the other CD ROM wheel. The picture shows the cart upside down.





5. Glueing on the bumper

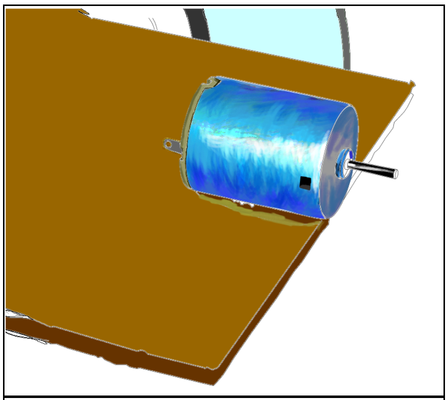
Glue the bumper in the center on the front end that contains the SmartWheel end.

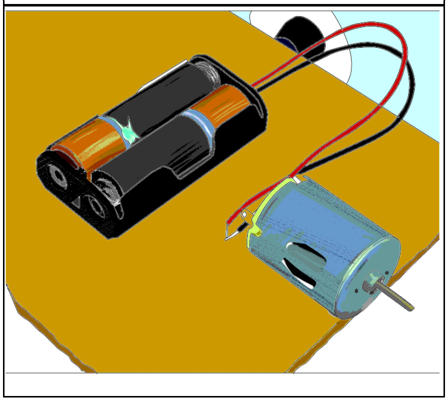


6. Attaching the motor

a. Glue the motor on the back end, in the center, with its body sticking out a little bit beyond the cardboard. Use plenty of glue.

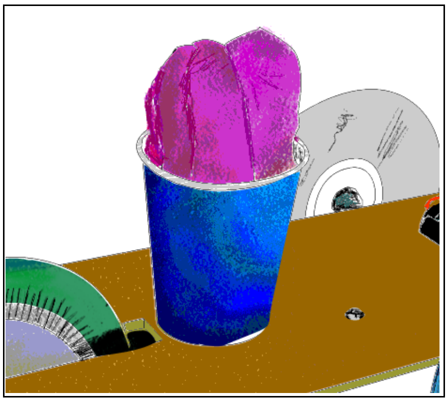
b. Place the batteries in the battery holder. Make sure the batteries are loaded in opposite directions in the holder. Glue it down in the center next to the motor. Leave a little bit of space between the battery holder and the motor.





7. Glueing on the clay holder

Glue down the paper cup in the center right behind the SmartWheel slot. Make a lump of clay so that you can add weight to the cart.



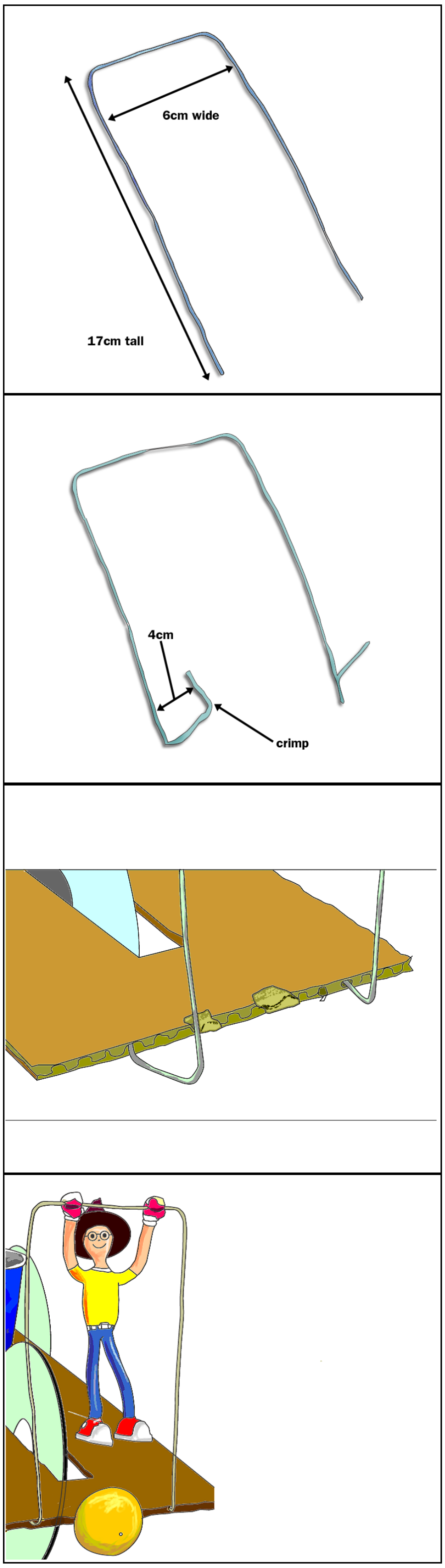
8. Attaching the acrobat and holder

a. To make the swinging bar for the acrobat, first bend the wire into a "U" about 6cm wide and 17cm long.

b. Bend up the ends of the "U" and crimp them a little bit. Each crimped end should be about 4cm. long.

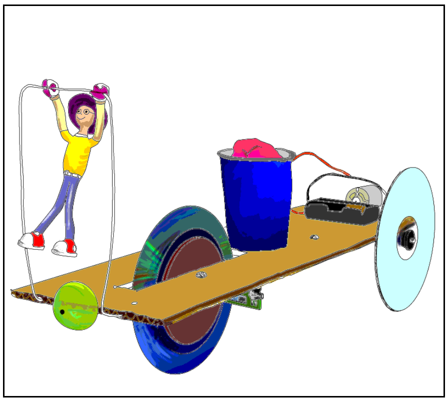
c. Slide the crimped ends into the corrugated cardboard. If the ends of the wire are crimped, they will fit snugly into the end of the corrugated cardboard and stay firm during collisions. The acrobat needs to be removed when you mount the Force probe on the cart.

d. Put bits of clay into the acrobat's hands so that it has a good grip. Hang the acrobat on the wire.



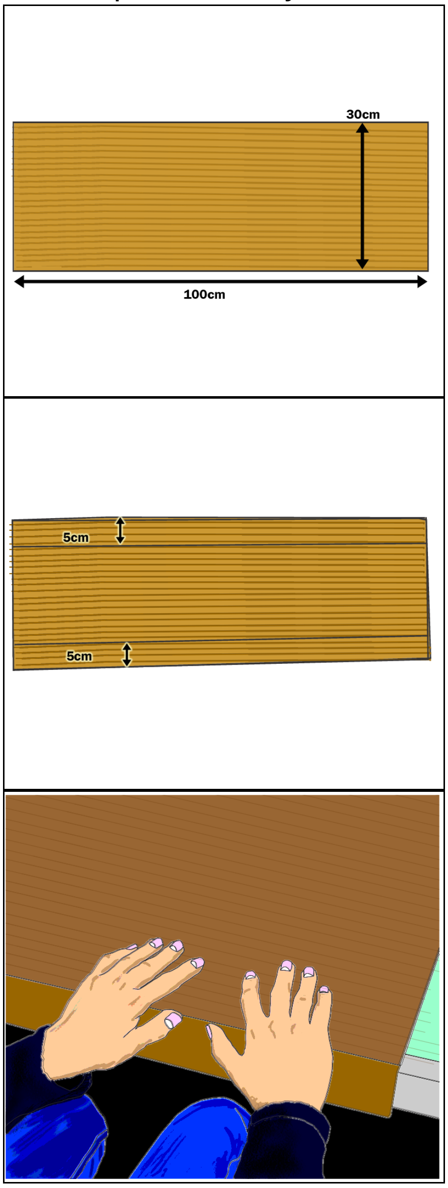
9. Decorating your cart

Decorate your cart to your liking...



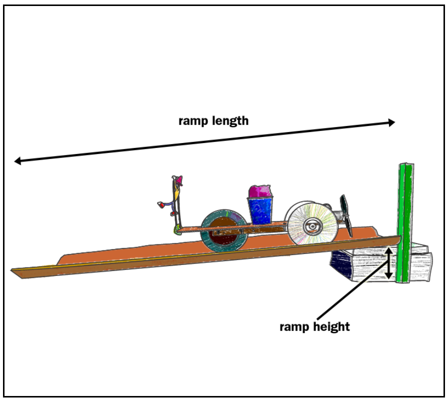
Trial II: Building a test ramp

1. You will need to build a ramp to provide your cart an equal start, again and again.
   a. Cut a piece of cardboard about 1m long and at least 30cm wide.
   b. Mark two lines 5cm from each side of the cardboard.
   c. Along the two lines, fold the cardboard into a "U" to make the edges stiff and keep the cart from running off the edge.
   d. Then the cardboard ramp rests easily on a flat surface.



2. To use the ramp, you will need to prop one end up with books. One simple way to measure the slope of the ramp is to give the ratio of the height of one end to the length. Thus, if the ramp end is raised 10cm and it is 1 meter long, its slope is about 1:10, or 10 percent. Don't raise it much more than this. The cart will go too fast!

   HINT: How should you measure how far "up" the cart is when you release it? The distance along the ramp from its bottom edge to the rear wheels of the cart is a good measure.

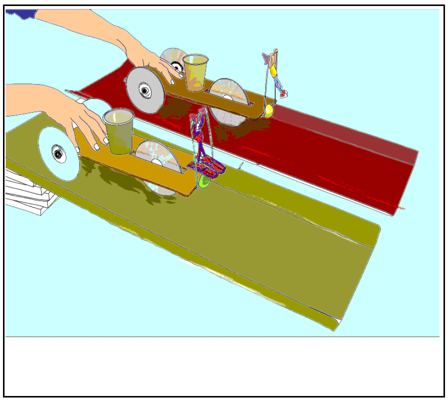


3. Experiment with different slopes and distances up the ramp. How do slope and distance affect how far the cart will roll? What arrangement is the best for testing the friction of the cart? Write your thoughts in Notes on your handheld computer.

Trial III: Performing a coasting test

1. Propose a way to test the relative friction of the carts, without using the motor and fan. You can use the ramp, however. HINT: Decide on a distance, a way to start together, and a way to compare your cart with at least three other carts. Should they all race together on separate ramps, or race one by one and compare them? Do they get more than one run? Do you think this is a fair test of the friction of the cart?

2. Race your air cart with at least three other carts by rolling them down the ramp. Observe the motion of the acrobat during the race. What is your measure of friction? Which one has the least friction?



Technical Hints

Using the CC LabBook software

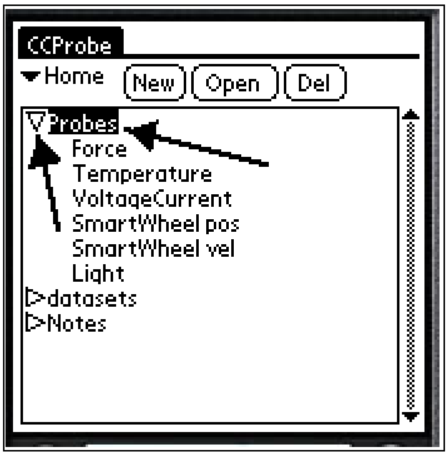
To use CC LabBook just follow these easy steps!

1. Opening the software

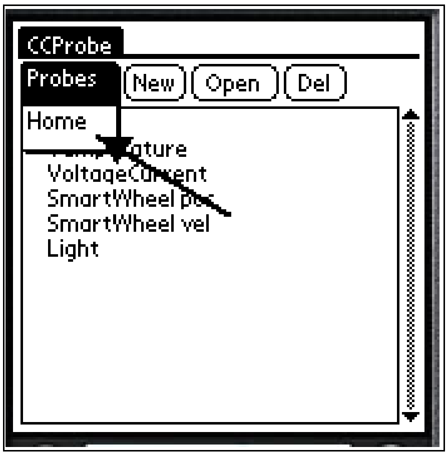
a. To open the software, tap the CCProbe icon.

b. The first screen you see is the LabBook.

2. Opening folders and subfolders



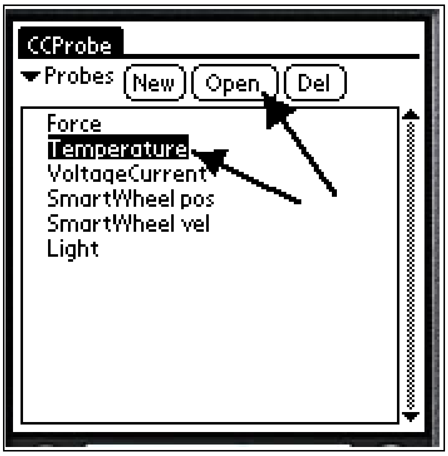
a. The LabBook lists all of the folders, data collectors, notes, saved datasets, and other objects in the LabBook. To open folders and subfolders, tap the triangles or double-tap the folder name.



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

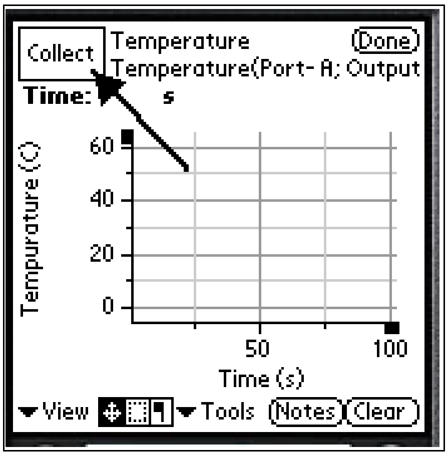
3. Opening a data collector

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.

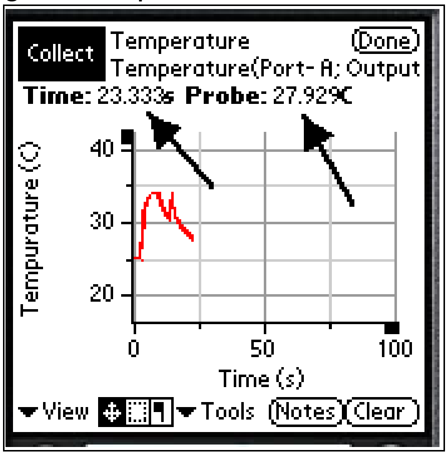


b. To open an existing data collector, highlight its name, then tap it twice or tap Open. It may take a few seconds for the graph to appear.

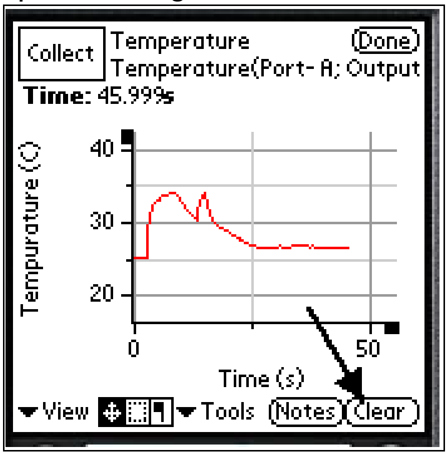
4. Collecting and clearing data



a. To start collecting data, tap Collect.



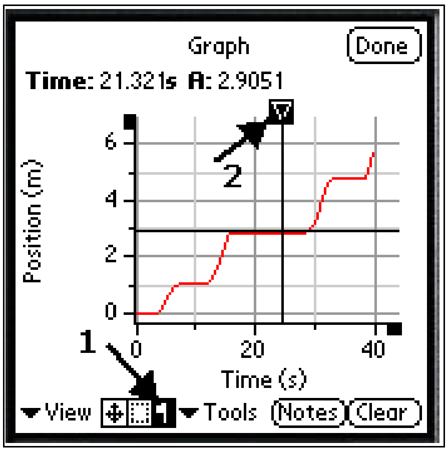
b. As data is collected, the current values appear at the top of the graph. To stop collecting, tap Collect again.



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

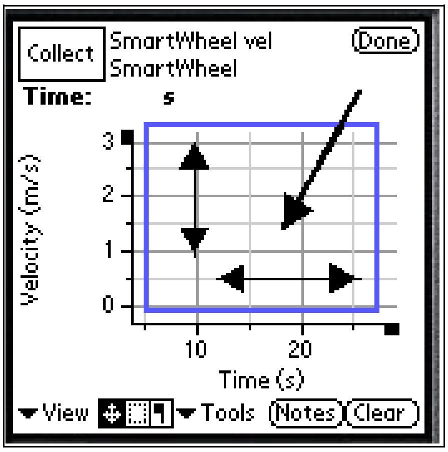
Force probe, 200/sec = about 15 seconds

SmartWheel = about 40 seconds

All others 3/sec = several minutes

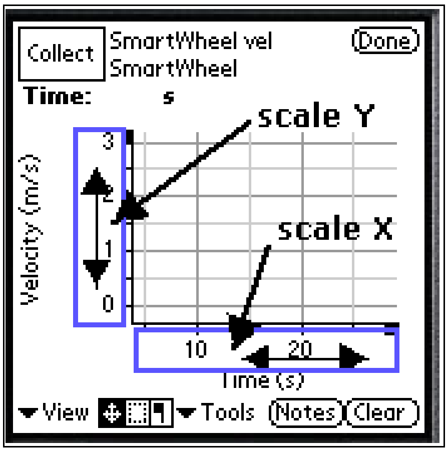
7. Scrolling around the graph

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

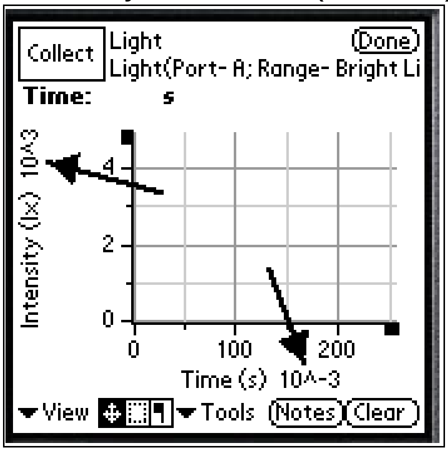


8. Changing the scale of an axis

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.

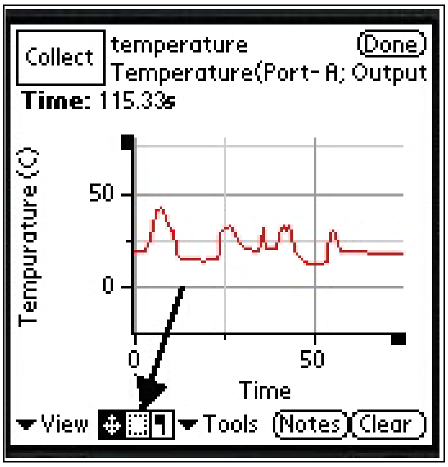


b. If you stretch or shrink the scale a great deal, it will switch by a factor of 1000, shown as 10^3 (for large numbers) or 10^-3 (for small numbers). For example, in the following screen, time is in milliseconds (1/1000 of a second) and light intensity is in kilolux (1000 lux).

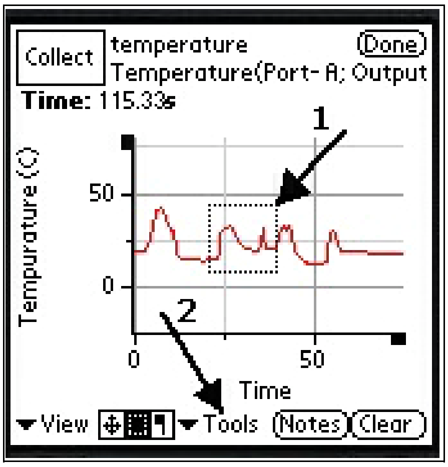


9. Zooming in on the graph

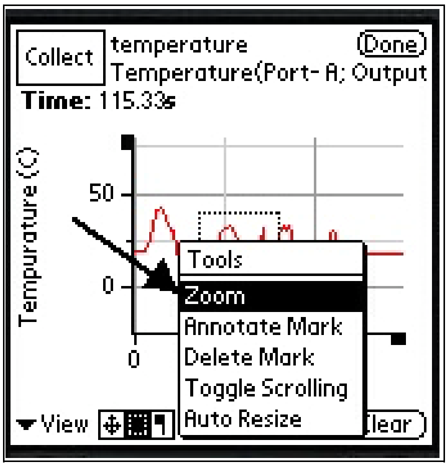
a. To zoom in on part of a graph, tap on the area selector at the bottom of the screen.



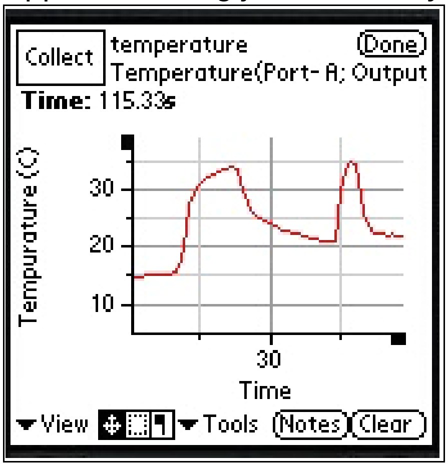
b. Drag the outline around the area of the graph you want to zoom in on, then tap Tools.



c. Click Zoom in the Tools list.

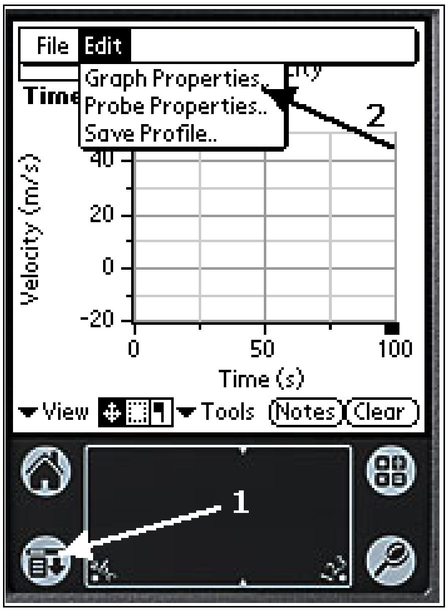


d. The graph will reappear showing just the area you selected.

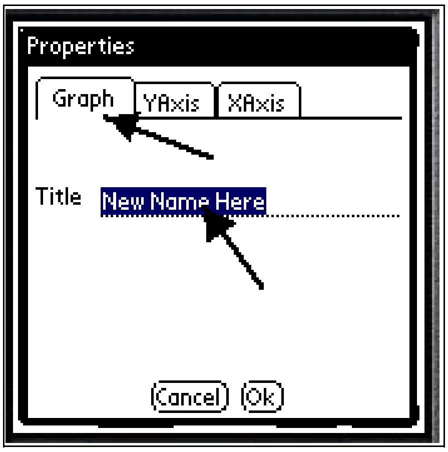


10. Changing graph properties

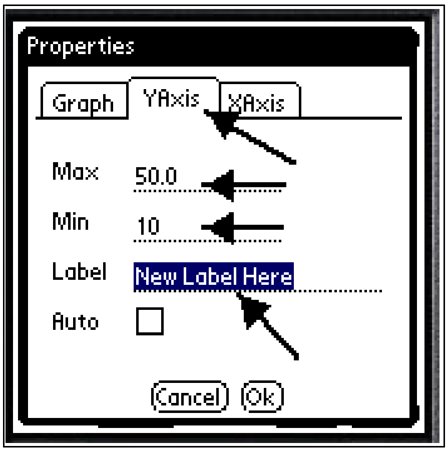
a. To change graph properties, tap the Palm menu icon at the bottom left corner, then the Edit menu item. Tap Graph Properties.



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



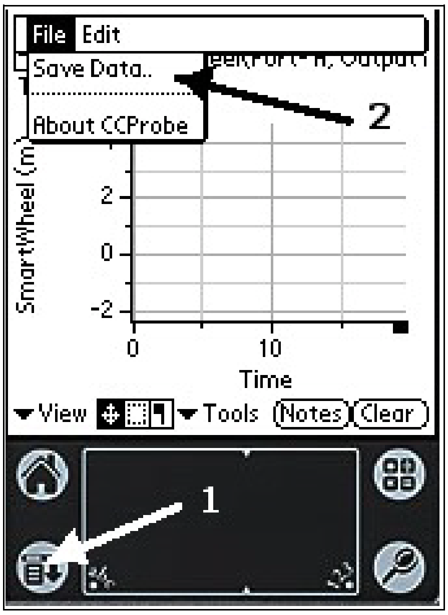
c. To change the range and the label of an axis, tap on the YAxis or XAxis tab. Write in the Max, the Min, and the Label, and then tap OK.



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

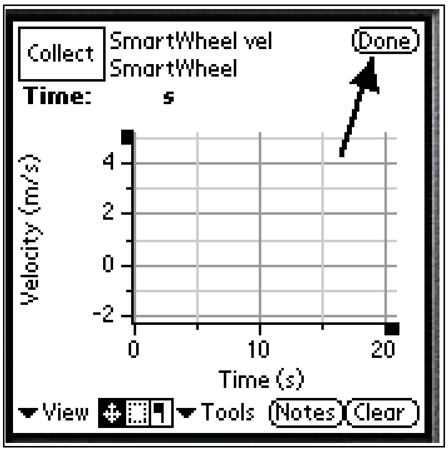
a. To save your data, tap the Palm menu icon at the bottom left corner. Then tap Save Data in the File menu. The menu will disappear when the data is saved. This may take several seconds.



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. Rank your cart and at least two others in order of how they did on the friction test. What differences in the carts might account for the results?

2. When your cart is moving, it has energy of motion. What factors do you think affect its energy? When your cart slows down and stops, where does the energy go? When your cart slows down and stops, where does the energy go?

3. What happened to the motion of the acrobat when the cart slowed down? What about when the cart hit something?

4. What are the sources of friction for these carts? Do you think air resistance plays a role? How could you find out?

5. How does a vehicle behave when there is very little friction? Does it take a lot of force to get it going? To keep it going?

Further Investigations

- What slows the cart down? Investigate ways to reduce the friction of your cart. Your cart should use the SmartWheel, but anything else about it can be changed. Provide reasons for your design choices. Which changes will have the greatest decrease in friction?
- Decide on a way to compare the friction of different carts. Why is this a fair test? Compare various carts and see if you can understand what the differences are that make them have more or less friction. Do they test the same every time?
- Play the sabotage game. Investigate ways to increase the friction of your (or your opponent's) cart.

