Transfer of Energy
Heat Flow

Discovery Question

What happens when two objects at different temperatures are left in contact with each other?

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Introduction

In this activity you will investigate how to alter heat flow.

Thinking About The Question

What happens when two objects at different temperatures are left in contact with each other?

We are constantly dealing with things at different temperatures. Sometimes we want the heat to flow faster (cooking) and sometimes we want to prevent its flow (sleeping bags). In your group, discuss other situations when you would want to alter heat flow. What are three such situations? How does energy flow change over time? Write your thoughts in Notes on your handheld computer.

Sometimes we prefer uniform temperatures (a non-drafty room) and sometimes we prefer contrast (hot syrup on ice cream). Can you think of other times when you want uniform or non-uniform temperatures? Which condition (uniform or non-uniform) is easier to keep for the longest period of time? Describe these situations in Notes on your handheld computer.

Materials

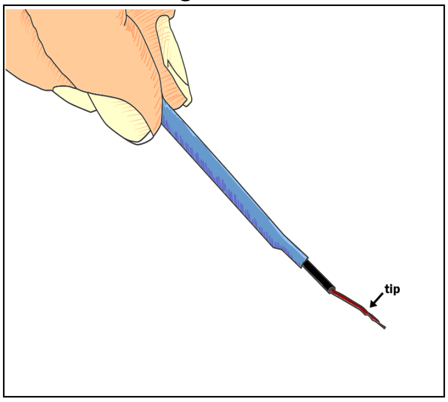
- CC Fast Response Temperature probe
- handheld computer
- CC LabBook software
- Styrofoam cup
- film canister (to measure water volume)
- small ball of clay (size of a large or shooter marble)
- paper towel (to dry off clay)
- water at two temperatures (warm tap water and ice water)

Safety

- No specific safety features needed for this activity.

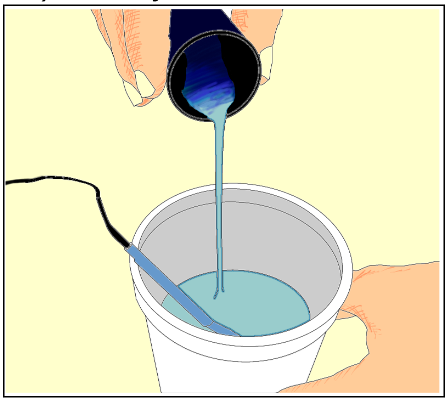
Trial I: Mixing the bath water just right

1. When you mix water at two temperatures (one is too hot and the other too cold) to make a bath that's just right for bathing, how much of each is needed? Connect the Temperature probe with your handheld. Refer to Technical Hints to see how to connect the Temperature probe. The sensitive part is just the very tip, where two wires are welded together.



2. What will happen when you touch the end of the probe and then let go? What happens when you put the probe in water? Record your thoughts in Notes on your handheld computer.
3. For heat to flow from one thing to another, they need have different temperatures. In this trial you need to have two samples of water at different temperatures. You can do this by selecting two of the following:
   a. water cooled with ice
   b. cold tap water
   c. room temperature water
   d. warm tap water
4. Start the software and observe the temperature versus time graph as you test your two choices of water. Stop the software. Be sure the two samples are at least 10 degrees Celsius different from each other. What are the two temperatures?
5. Before mixing the two samples of water together, predict the final temperature.
6. Make the temperature measurements one after another with the graph running. You will then have all of your data on one graph, and you can analyze it.
7. Restart the graph and retest the temperature of each sample of water.
8. Fill the film canister with one of the samples of water and pour it into the styrofoam cup. Quickly place the Temperature probe in the stryofoam cup. Fill the canister with the second sample and slowly add it to the Styrofoam cup. Observe the graph.
9. Stop when you think the temperature has come to a relatively stable

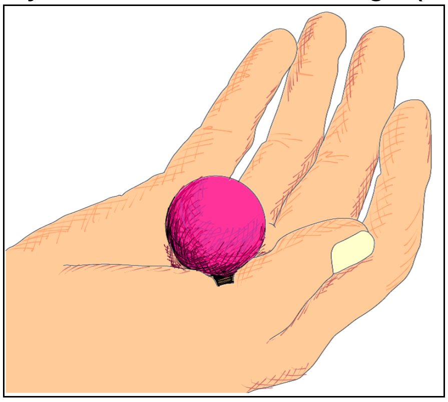
temperature (equilibrium). Save your data to the handheld.



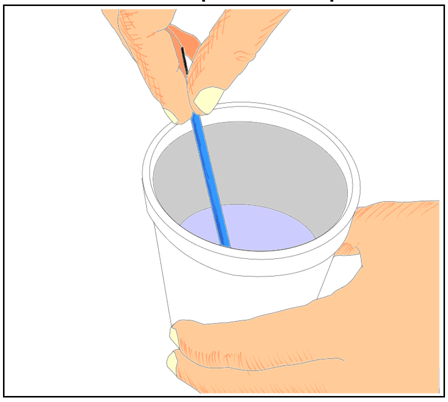
10. How many seconds did it take? How good was your prediction? Would this be a good temperature for your bath water? If not, how could you change the final temperature of the mixture? Record your reasoning in Notes on your handheld computer.

Trial II: Reaching equilibrium in temperature

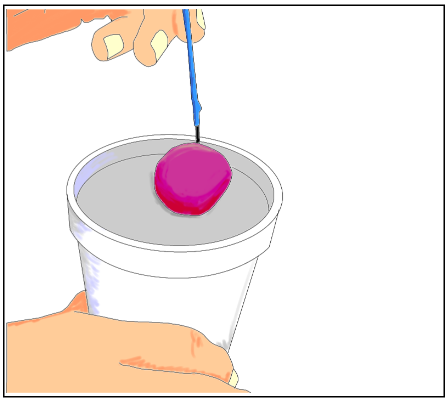
1. Make a small ball of clay, about the size of a large (shooter) marble.



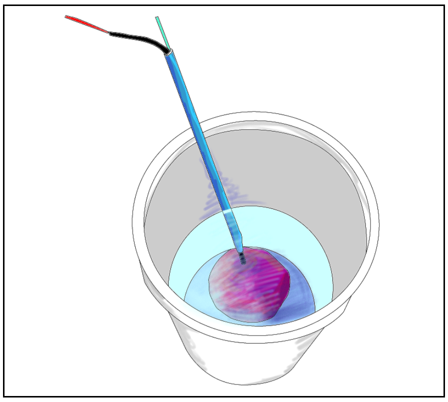
2. Connect the Temperature probe with your handheld. Refer to Technical Hints to see how to connect the Temperature probe. The sensitive part is just the very tip, where two wires are welded together.
3. Start the temperature graph and run through this series of measurements so that you get all of your data on one graph.
4. Measure the air temperature.
5. Use water from a non-room temperature source. It should be at least 10 degrees Celsius different from room temperature. Place two film canisters of the water into the styrofoam cup so that the clay will be fully immersed. Measure the water temperature with the Temperature probe.



6. Stick the probe into the center of the clay ball while the probe is still running.
7. With the probe in the clay ball, immerse it in the water. Watch the graph. Run it until you think it has come to relatively stable temperature (equilibrium).



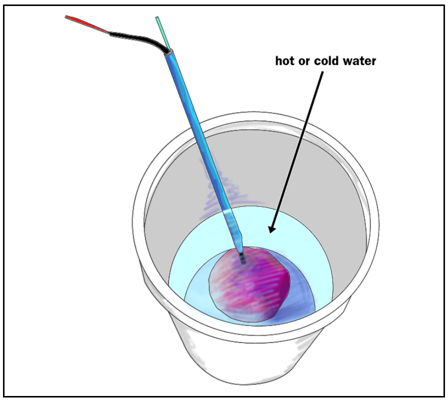
8. Pull the Temperature probe out of the clay ball and measure the temperature of the water. Save your data to the handheld.



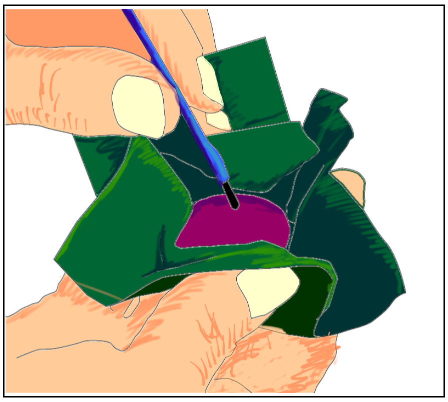
9. What is the final temperature of the combination of water and clay? How many degrees did the clay change? How many degrees did the water change? How did you decide when equilibrium was reached? How many seconds did it take? Record your answers in Notes on your handheld computer.

Trial III: Using insulation to prevent heat flow

1. Connect the Temperature probe with your handheld. Refer to Technical Hints to see how to connect the Temperature probe. The sensitive part is just the very tip, where two wires are welded together.
2. Make a small ball of clay, about the size of a large (shooter) marble.
3. Design an insulation to keep the clay at this temperature. You can use any available materials. Record why you think your design is good in Notes on your handheld computer.
4. Start the temperature graph and run through the complete series of measurements so that you obtain all of your data on one graph.
5. Measure the air temperature. Place the Temperature probe into the center of the clay ball.
6. Place the clay ball and Temperature probe in the Stryfoam cup that contains water. Any amount of water will do that's NOT at room temperature. Let it come to a relatively stable temperature (equilibrium). It can be either colder or warmer than room temperature.



7. Leaving the temperature probe in the clay, pull the clay out of the water and quickly dry it off. Quickly wrap the clay and temperature probe in your insulation system.

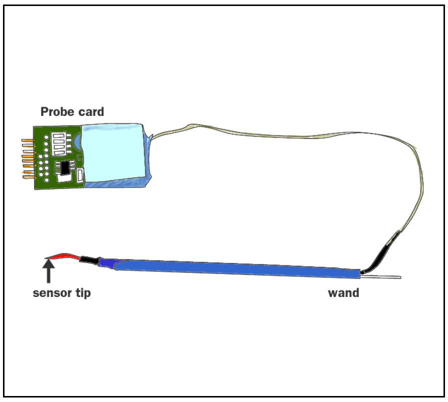


8. Monitor the temperature of the clay until it's near to equilibrium. Save your data to the handheld. How long does it take to reach equilibrium? Is the time greater or less than you thought it would be? Record your observations in Notes

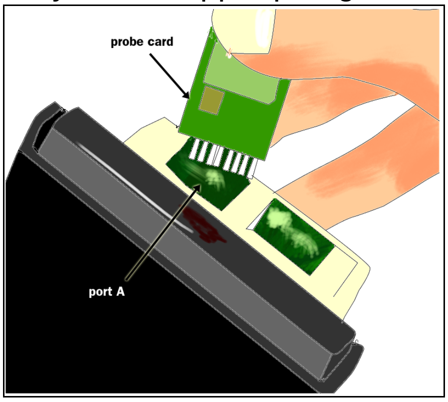
on your handheld computer.

Technical Hints

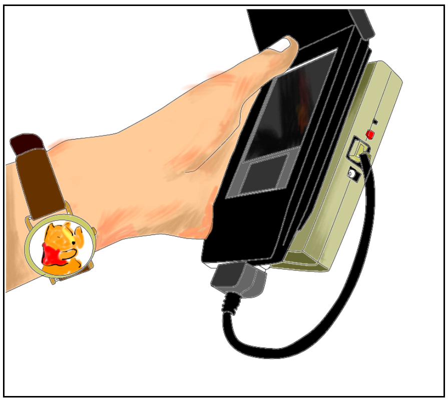
Connecting the Temperature probe



1. Connect the flexible cable from the Temperature probe to the Temperature probe card. Plug the Temperature probe 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 Temperature probe data collector.

Using the CC LabBook software

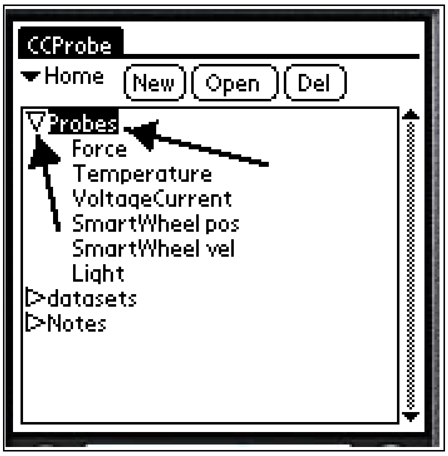
To use CC LabBook just follow these easy steps!

1. Opening the software

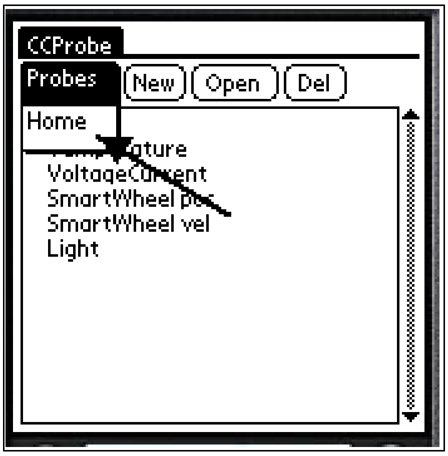
a. To open the software, tap the CCProbe icon.

b. The first screen you see is the LabBook.

2. Opening folders and subfolders



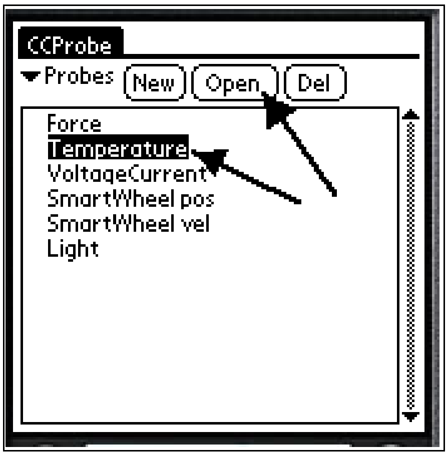
a. The LabBook lists all of the folders, data collectors, notes, saved datasets, and other objects in the LabBook. To open folders and subfolders, tap the triangles or double-tap the folder name.



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

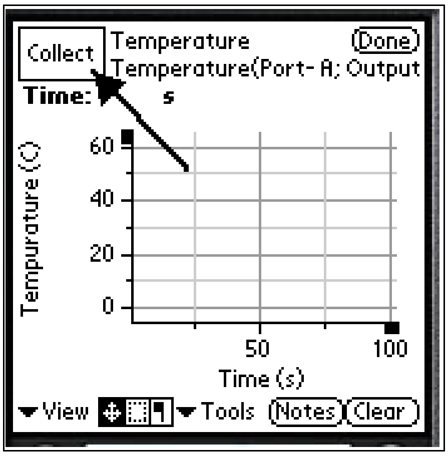
3. Opening a data collector

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.

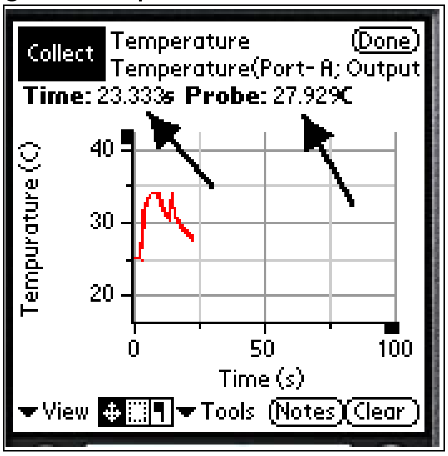


b. To open an existing data collector, highlight its name, then tap it twice or tap Open. It may take a few seconds for the graph to appear.

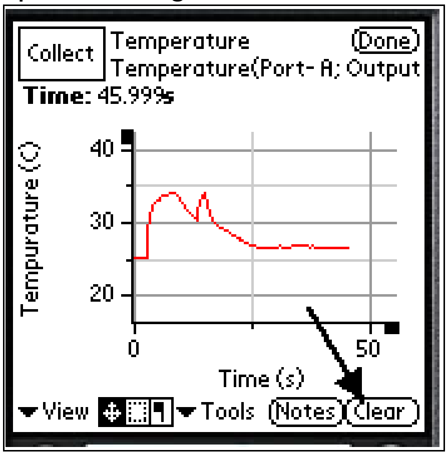
4. Collecting and clearing data



a. To start collecting data, tap Collect.



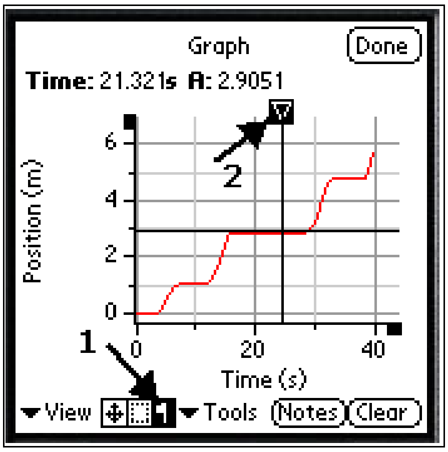
b. As data is collected, the current values appear at the top of the graph. To stop collecting, tap Collect again.



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

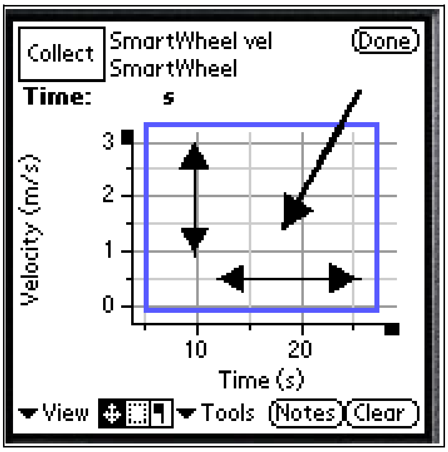
Force probe, 200/sec = about 15 seconds

SmartWheel = about 40 seconds

All others 3/sec = several minutes

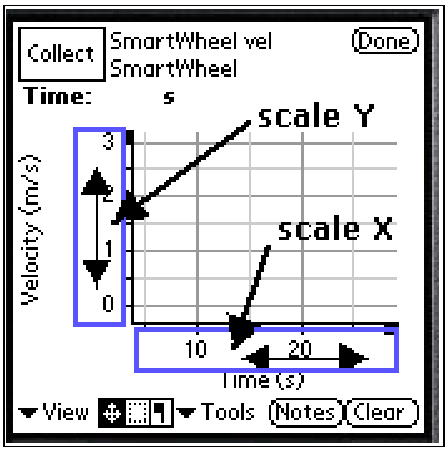
7. Scrolling around the graph

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

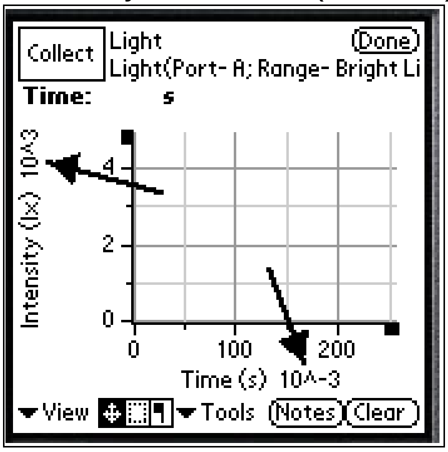


8. Changing the scale of an axis

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.

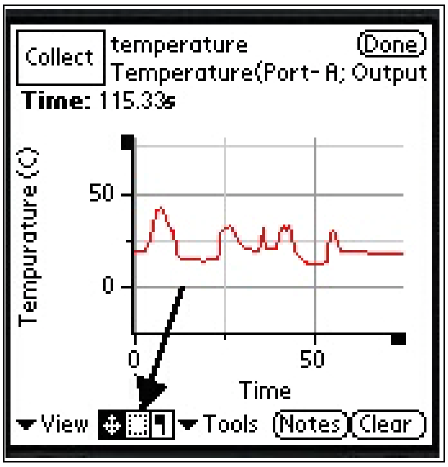


b. If you stretch or shrink the scale a great deal, it will switch by a factor of 1000, shown as 10^3 (for large numbers) or 10^-3 (for small numbers). For example, in the following screen, time is in milliseconds (1/1000 of a second) and light intensity is in kilolux (1000 lux).

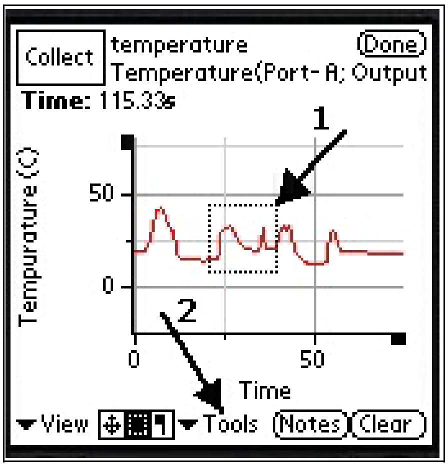


9. Zooming in on the graph

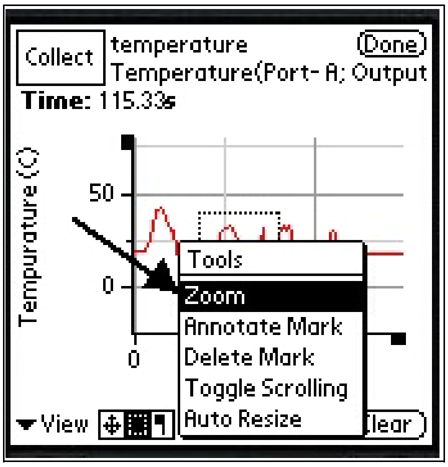
a. To zoom in on part of a graph, tap on the area selector at the bottom of the screen.



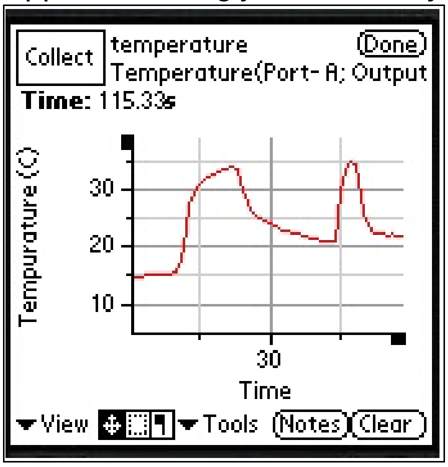
b. Drag the outline around the area of the graph you want to zoom in on, then tap Tools.



c. Click Zoom in the Tools list.

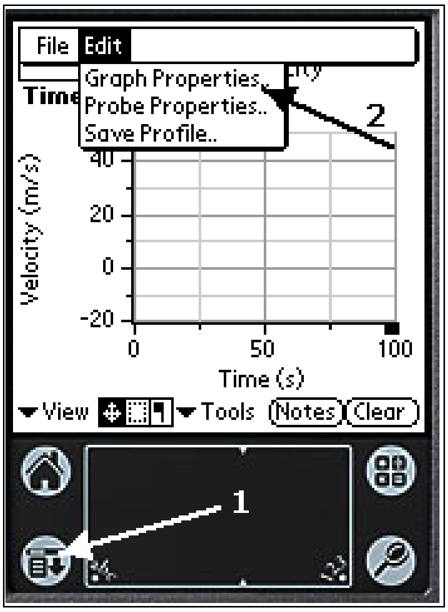


d. The graph will reappear showing just the area you selected.

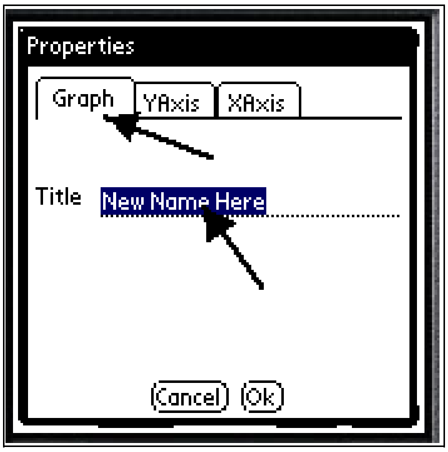


10. Changing graph properties

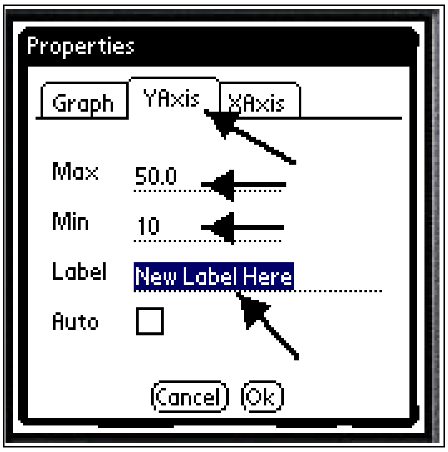
a. To change graph properties, tap the Palm menu icon at the bottom left corner, then the Edit menu item. Tap Graph Properties.



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



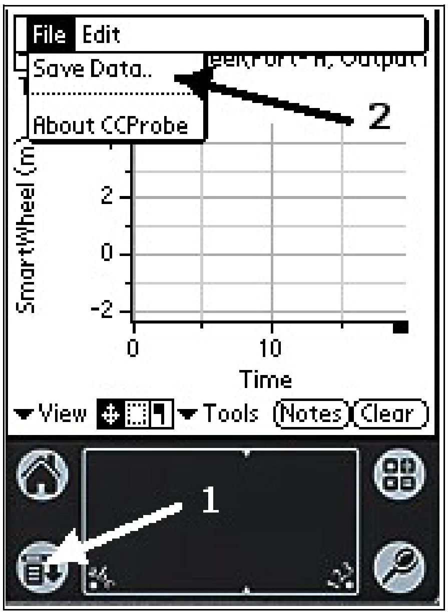
c. To change the range and the label of an axis, tap on the YAxis or XAxis tab. Write in the Max, the Min, and the Label, and then tap OK.



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

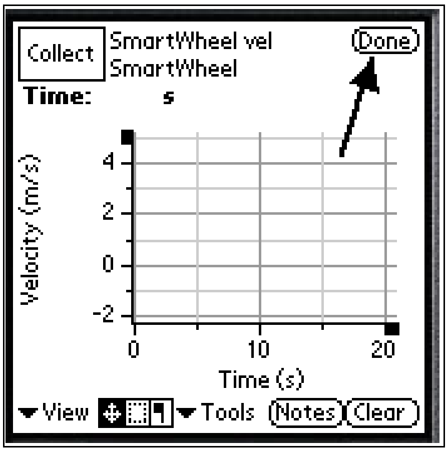
a. To save your data, tap the Palm menu icon at the bottom left corner. Then tap Save Data in the File menu. The menu will disappear when the data is saved. This may take several seconds.



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. While mixing water at two temperatures, did the result match your prediction? If they differed, why? Derive a formula for the final temperature when you mix equal amounts of different temperatures of water.

2. Which exchanged heat faster, the water mixed together or the clay in the water? Why?

3. Draw the resulting graph of the clay temperature as it approaches the temperature of the water. Why do you think it has that shape?

4. Do you think the shape of the clay makes a difference in the results? Give examples of other shapes besides a ball that you could use and how they would behave differently.

5. How did your method of insulation compare to methods used by others? Explain why the differences occurred.

Further Investigations

- Mix two parts of one temperature with one part at another temperature. Pedict what the final temperature will be, then do it. How good was your prediction this time? Derive a formula for the final temperature when mixing two different amounts of water (of different temperatures) together?
- Do you think equal volumes of clay and water have equal heat content? Devise an experiment to find out.
- Devise a way to test different insulation materials and how well they prevent heat from flowing from one object to another. For example, look at different kinds of hot beverage containers and how long they keep things hot.

