Transfer of Energy
Heating with Electricity

Discovery Question

Can electricity be used to heat things?

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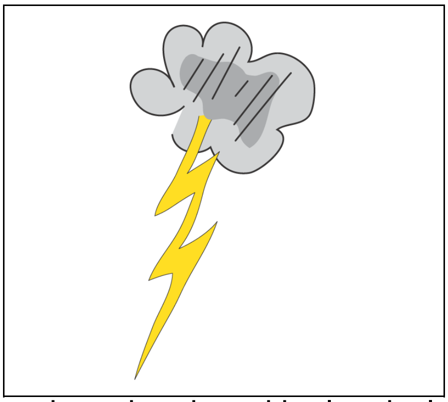
Discovery Question

Can electricity be used to heat things?

Introduction

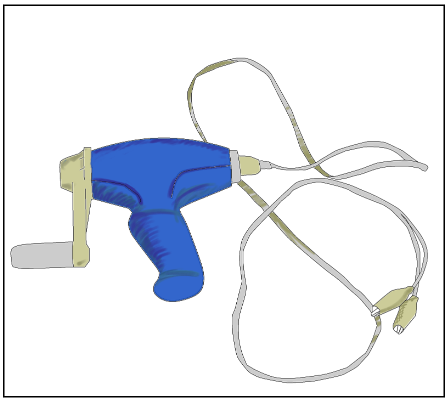


In this activity you will investigate heating with electrical devices.

Thinking About The Question

Can electricity be used to heat things?

When electricity flows through a wire, some of its energy goes into heating up the wire. Sometimes this is a problem. When electricity travels from a power station to the city, heat energy is wasted. But once the electricity arrives at your house for the purpose of heating a stove or a room, electrical heating is very efficient and flexible. What devices in your house use electricity for heating? Make a list in Notes on your handheld computer.



The Genecon is a little generator with the same basic design as the huge generators run by hydroelectric dams, coal-fired boilers, or nuclear power plants. In every case, some other form of energy (e.g., falling water, burning coal, decaying radioactive material) turns the "crank" of a generator and creates electrical power. In this case, you supply the power. Think of several ways that electric power is generated and the source of energy in each case. Make a list in Notes on your handheld computer.

Materials

- CC Fast Response Temperature probe
- CC VoltageCurrent Probe
- handheld computer
- CC LabBook software
- handheld generator (Genecon)
- heat cell with insulating cover
- mini light
- battery pack
- 2 - new 1.5V AA batteries
- clip leads

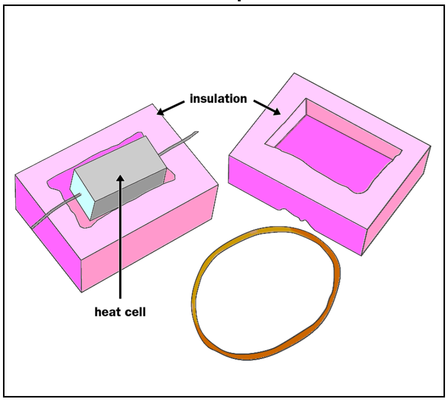
Safety

- Although the hand-held generator is sturdily constructed, excessive speed in rotating the handle can result in stripped gears.
- While lighting the mini light with your Genecon, keep in mind that the mini light will become hot to the touch. The mini light will also burn out if you crank the Genecon too fast.

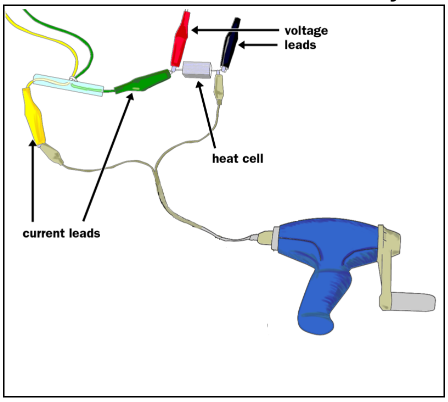
Trial I: Cranking with a Genecon

1. Connect the VoltageCurrent probe to your handheld computer. Refer to Technical Hints to see how to set up the VoltageCurrent probe.

2. Locate the parts for your small " heat cell" which consists of a resistor inside a block of aluminum. When you put electrical current through the resistor, it converts the electrical energy into heat and heats up the block of aluminum. The heat cell is placed in insulation to prevent heat loss to the environment.



3. Remove the heat cell from its insulation. Attach the two leads of the Genecon to wires extending from the heat cell. Also connect the voltage leads and the current leads of VoltageCurrent probe to the heat cell. Follow the diagram carefully. Don 't put the heat cell in the insulation yet.



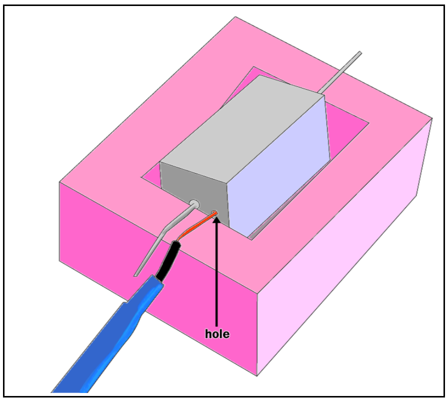
4. Start the software to record power. This measures the electrical power, in watts, that you are supplying to the heat cell with the Genecon.

5. Try cranking at a fairly fast speed and observe the power on your graph. Can you crank at a steady fast rate? Now try to crank at a slower steady rate that produces half as much power.

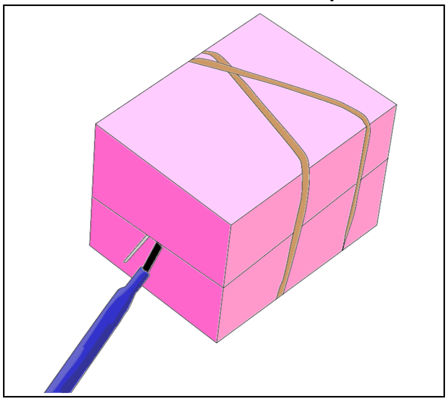
6. Practice until you can do two rates of cranking, slow and fast, where the faster rate produces twice as much power as the slower rate. Stop collecting data and disconnect the voltage and current leads. What is the power of each rate in watts?

7. Connect the Temperature probe to your handheld computer. Refer to Technical Hints to connect the Temperature probe. The sensitive part is just the very tip, where two wires are welded together.

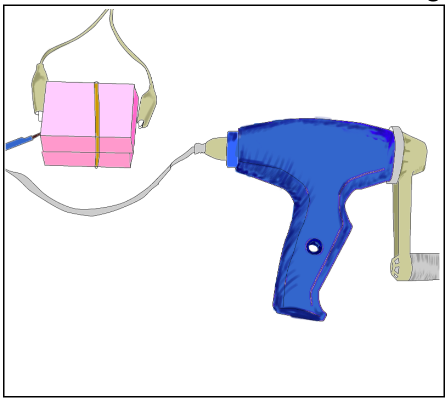
8. Put the tip of the Temperature probe into the small hole in one end of the heat cell.



9. Set the heat cell in the insulation and close up the box with a rubber band.



10. Attach the two Genecon leads to the wires extending from the heat cell.



11. Start the software for the Temperature probe. Start recording temperature.
12. Observe the temperature graph. After 10 seconds, crank the Genecon for 30 seconds at the fast rate. Then crank the Genecon for 30 seconds more at the slower rate. Then stop cranking and continue recording for another 60 seconds.
13. Stop recording the data. Save your data to the handheld.
14. Expand the graph so that you can see how much the temperature rose while you were cranking, and how much it fell after you stopped. Write down the following values on a piece of paper:
    a. starting temperature

b. the temperature after fast cranking

c. after slow cranking

d. the ending temperature

Record these values in Notes.

15. Calculate the following values on a piece of paper:

a. the temperature change during fast cranking

b. the temperature change during slow cranking

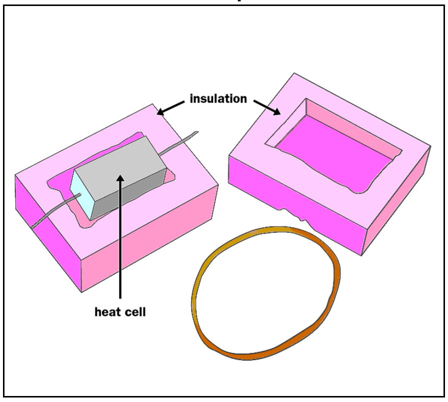
c. the temperature change while cooling

Record these values in Notes.

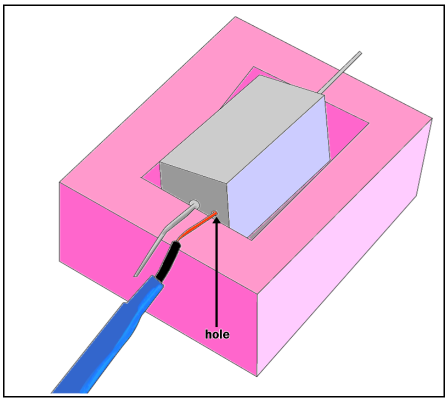
16. The heat cell is made so that it takes exactly 10 joules of energy to heat it one degree Celsius. How many joules did your 30 seconds of fast cranking produce? What about the 30 seconds of slow cranking? How many joules did the cell lose in 60 seconds as it cooled? Record your answers in Notes on your handheld computer.

Trial II: Heating with a battery

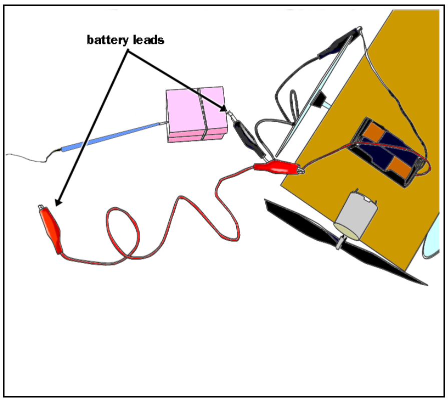
1. You may have found that it's a lot of work to generate even a little bit of heat! Now you will compare the heating you did with the Genecon to the heating a little battery can do. Connect the Temperature probe to your handheld computer. Refer to Technical Hints to connect the Temperature probe.
2. Locate the parts for your small " heat cell" which consists of a resistor inside a block of aluminum. When you put electrical current through the resistor, it converts the electrical energy into heat and heats up the block of aluminum. The heat cell is placed in insulation to prevent heat loss to the environment.



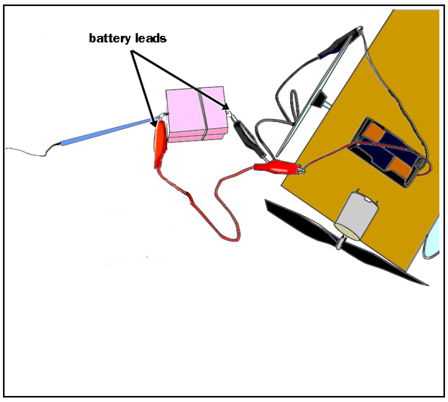
3. Insert the tip of the Temperature probe into the small hole in one end of the heat cell. Put on the insulation cover and close the box with a rubber band.



4. Use a 2-AA battery pack, which will supply somewhat less than 3 volts, to warm the heat cell. You can use the battery pack on the air cart for this. Attach one of the battery leads, but not the other, to the heat cell.



5. Start the software for the Temperature probe. Refer to Technical Hints to see how to use the software.
6. When the temperature graph reaches exactly 10 seconds, connect the second lead of the battery pack to the other end of the heat cell.



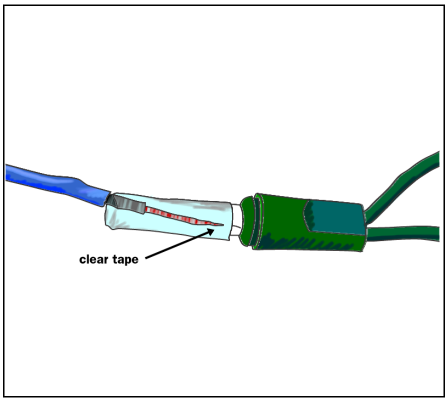
7. Heat the cell for 60 seconds, then disconnect one battery lead. Let the graph run another 60 seconds so that you can watch the cooling of the heat cell.
8. Stop recording the data. Save the data to your handheld computer.
9. Expand the graph so that you can see how much the temperature rose while the battery was attached and how much it decreased after you stopped. Place marks on the starting temperature, the maximum temperature, and the ending temperature. Write down the following values on a piece of paper.
   a. the starting temperature
   b. the maximum temperature
   c. the ending temperature

   Record these values in Notes.
10. Calculate the following values on a piece of paper:
    a. temperature change from start to maximum
    b. temperature change by cooling

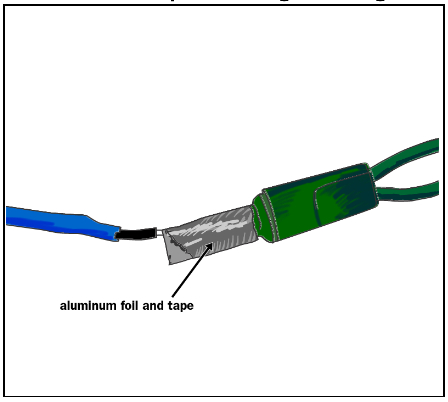
    Record these values in Notes.
11. Was each temperature rate over time steady?
12. The heat cell is made so that it takes exactly 10 joules of energy to heat it one degree Celsius. How many joules of heating did the battery produce in 60 seconds? How many joules did the cell lose in 60 seconds? Record your answers in Notes on your handheld computer.

Trial III: Heating with a light bulb

1. Let's find out how a mini light bulb compares to a heat cell as an electrical heating device. Connect the Temperature probe to your handheld computer. Refer to Technical Hints to connect the Temperature probe.
2. Divide the student research teams into two groups. Half the teams will surround the mini light with clear tape, and the other half will surround it with aluminum foil.

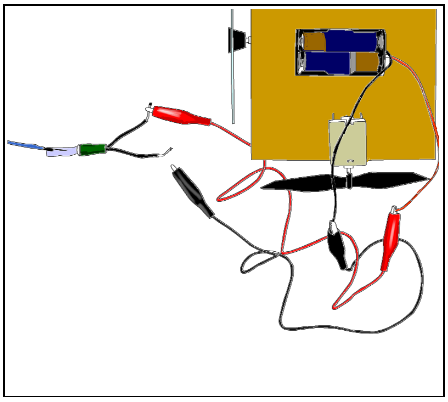


   a. Tape teams: Hold the tip of the Temperature probe against the mini light with a short piece of clear tape that goes right around the bulb.

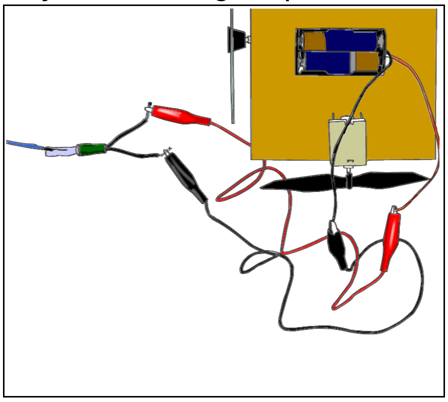


   b. Foil teams: Wrap the mini light with a small piece of aluminum foil that goes all the way around it. Hold the foil in place with a short piece of clear tape. Slide the tip of the Temperature probe in between the bulb and the aluminum foil.

3. Attach one lead of the battery to the mini light, but not the other.



4. Start the software to record temperature.
5. Attach the second battery lead and light up the mini light.

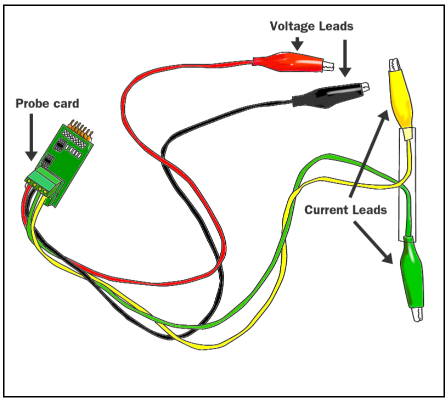


6. Monitor the temperature plot. Let it run for 30 seconds, then disconnect the second lead and let it run for another 30 seconds. Stop recording.
7. Stop recording the data. Save the data to your handheld computer.
8. Expand the graph so that you can see how much the temperature rose while the battery was attached and how much it decreased after you stopped. Write down the following values on a piece of paper:
   a. the starting temperature
   b. the maximum temperature
   c. the ending temperature

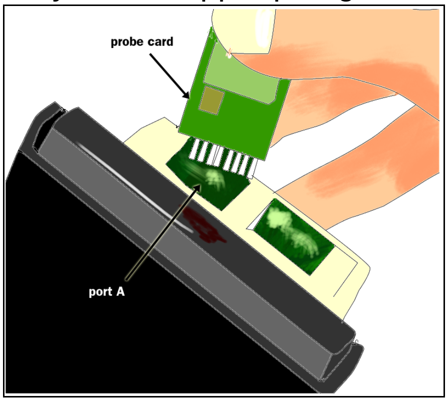
   Record these values in Notes.
9. How many degrees did the light heat up in 30s? How many degrees did it cool down in 30s? Record these values in Notes on your handheld computer.

Technical Hints

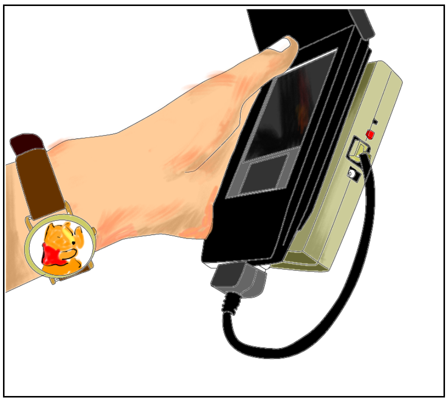
Connecting the VoltageCurrent probe



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



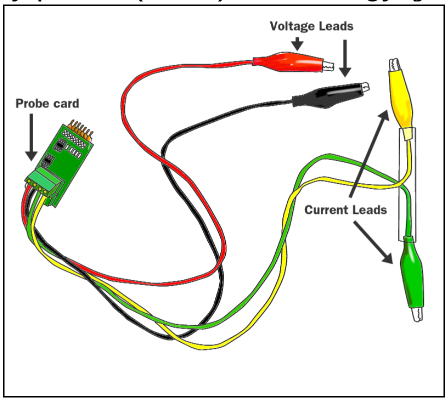
2. Attach the CCProbe Interface Box to your handheld with the Velcro square. Connect the CCProbe Interface Box to your handheld with the provided connector cable.



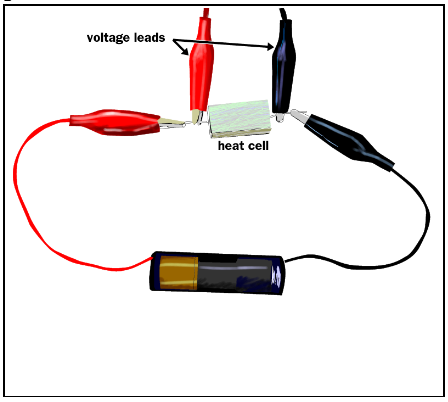
3. Tap on the the CCProbe icon to open the software. Open or create a VoltageCurrent probe data collector. Choose to read voltage, current, power, or energy.

Connecting the VoltageCurrent probe leads in a circuit

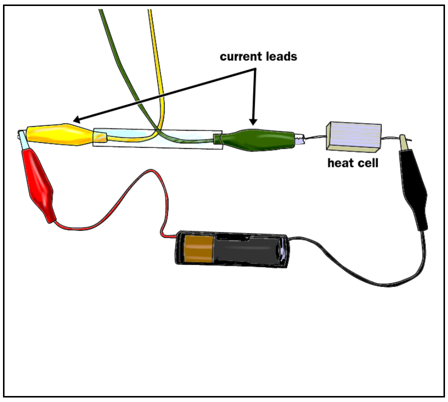
1. The Voltage/Current Probe measures either voltage or current. It can also measure both at the same time. The CCProbe software can use these readings to calculate and display power (watts) and energy (joules).



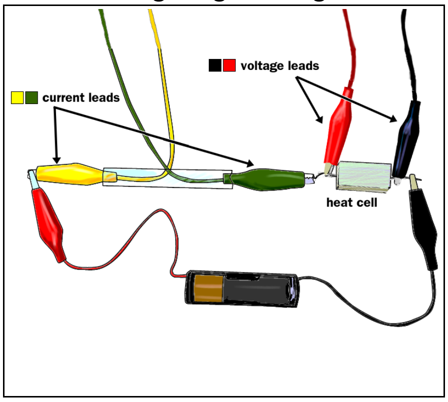
2. Voltage difference is measured in volts (V). The red clip lead goes to the positive (+) place, and the black clip lead goes to the negative (-) place. Here is how to measure voltage between two ends of a heat cell attached to a battery:



3. To measure the current in a wire, you have to break the wire and force the current to go through your current probe. The convention is that current is positive when it flows from a positive to a negative voltage, that is, from red to black. For the current through the probe to be positive, it should flow into the yellow clip lead and out of the green clip lead. Here is how to measure current going through a heat cell attached to a battery. Current is measured in amperes (A).

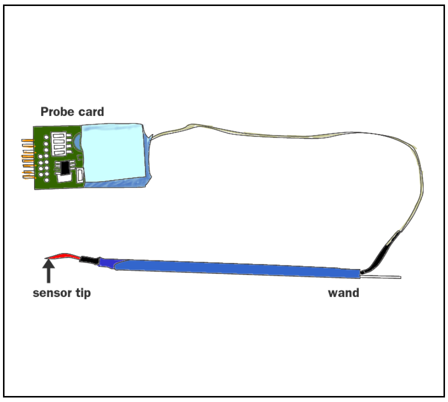


4. Electrical power, the rate of using energy, is voltage difference times current. It can be pictured as the number of electrons flowing per second, multiplied by the energy each one loses. Power is measured in watts (W).
5. Electrical energy is the power accumulated over time. It can be pictured as the total number of electrons that flow, multiplied by the energy that each one gains (or loses). Energy is measured in joules (J).
6. To measure the power or energy, you must measure both voltage and current. Here is how to measure current going through a heat cell attached to a battery.

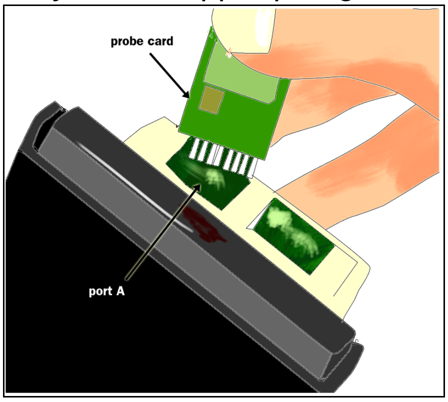


7. The CCProbeware will calculate and display the power or energy from these measurements.

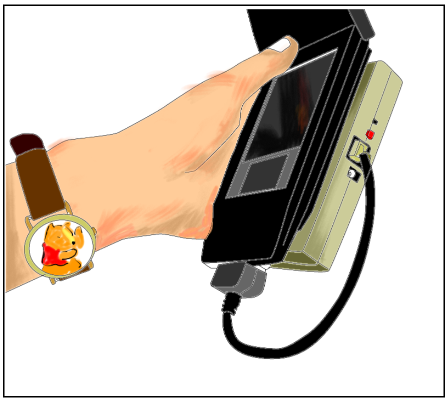
Connecting the Temperature probe



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

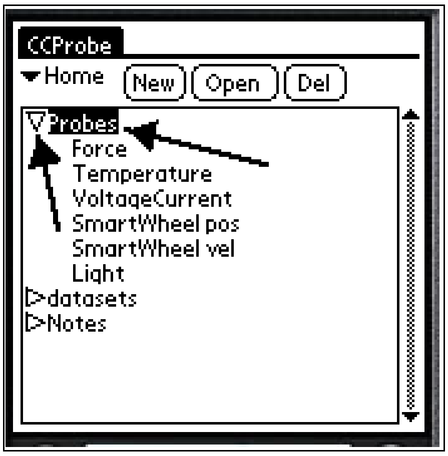
To use CC LabBook just follow these easy steps!

1. Opening the software

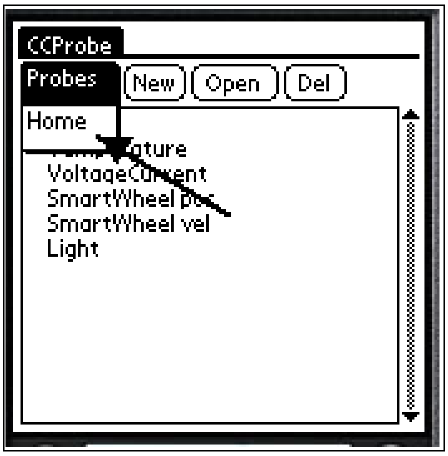
a. To open the software, tap the CCProbe icon.

b. The first screen you see is the LabBook.

2. Opening folders and subfolders



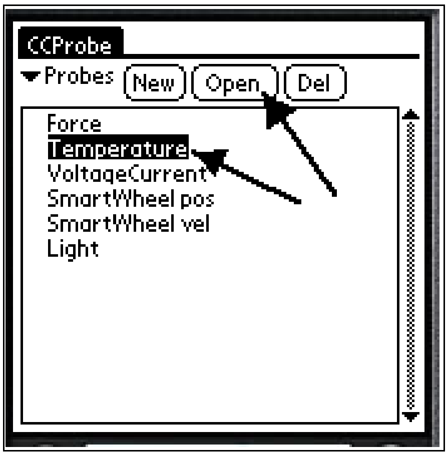
a. The LabBook lists all of the folders, data collectors, notes, saved datasets, and other objects in the LabBook. To open folders and subfolders, tap the triangles or double-tap the folder name.



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

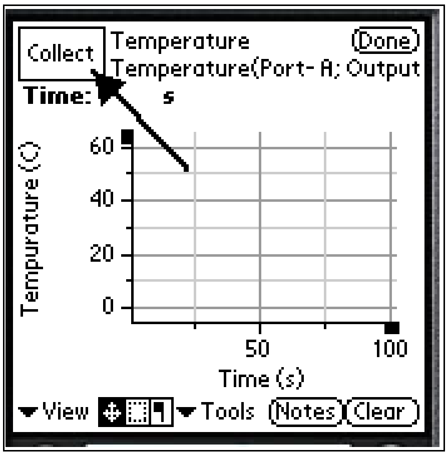
3. Opening a data collector

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.

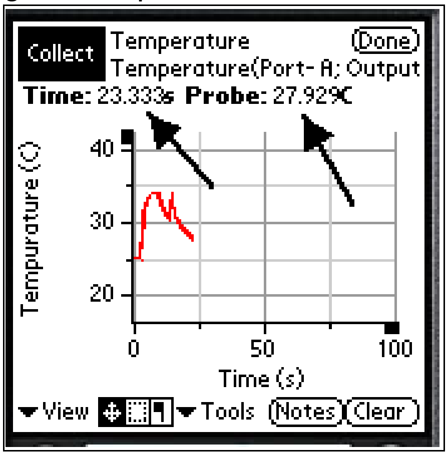


b. To open an existing data collector, highlight its name, then tap it twice or tap Open. It may take a few seconds for the graph to appear.

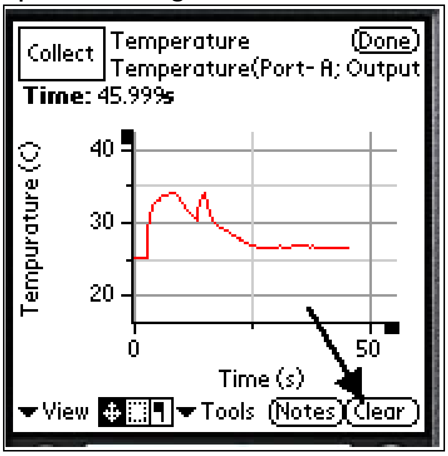
4. Collecting and clearing data



a. To start collecting data, tap Collect.



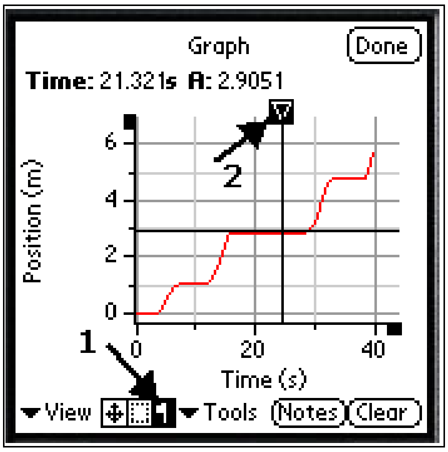
b. As data is collected, the current values appear at the top of the graph. To stop collecting, tap Collect again.



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

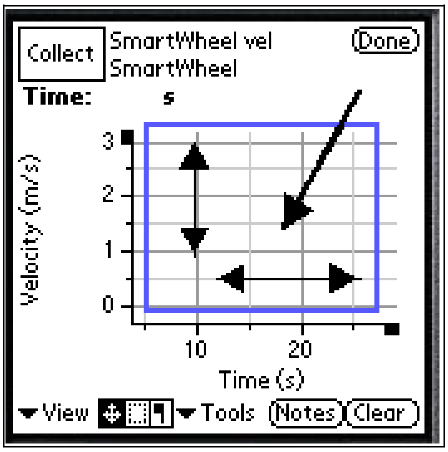
Force probe, 200/sec = about 15 seconds

SmartWheel = about 40 seconds

All others 3/sec = several minutes

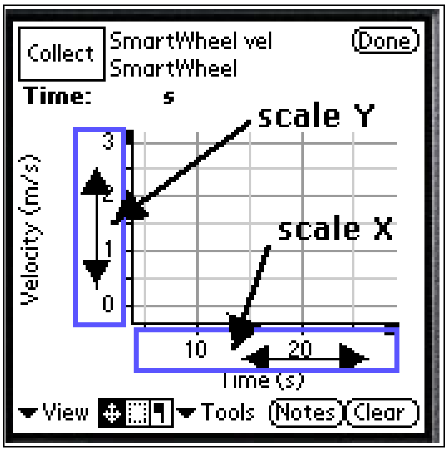
7. Scrolling around the graph

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

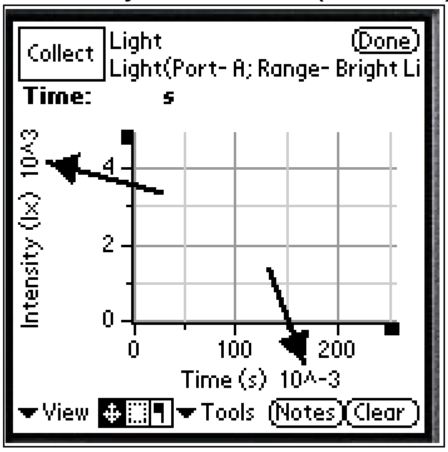


8. Changing the scale of an axis

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.

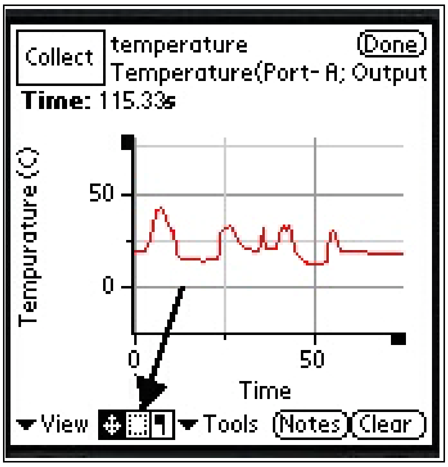


b. If you stretch or shrink the scale a great deal, it will switch by a factor of 1000, shown as 10^3 (for large numbers) or 10^-3 (for small numbers). For example, in the following screen, time is in milliseconds (1/1000 of a second) and light intensity is in kilolux (1000 lux).

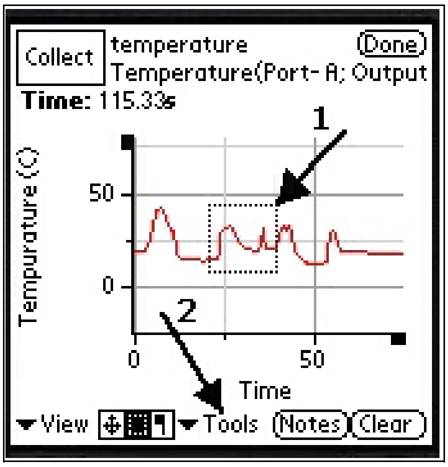


9. Zooming in on the graph

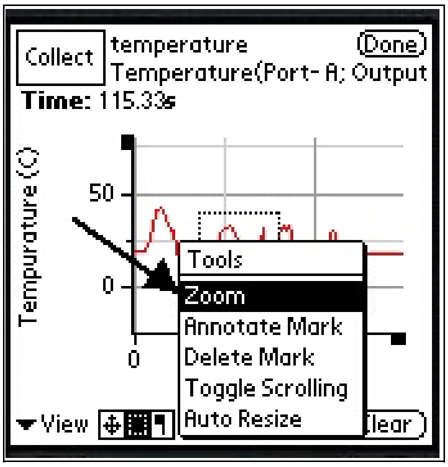
a. To zoom in on part of a graph, tap on the area selector at the bottom of the screen.



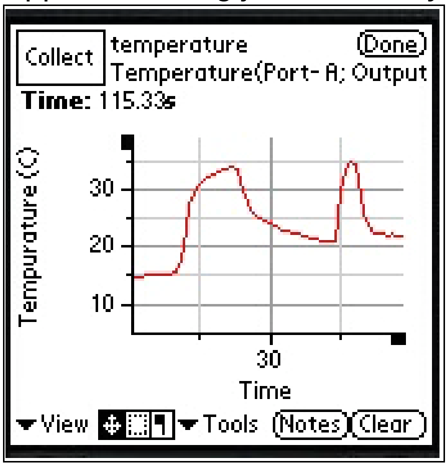
b. Drag the outline around the area of the graph you want to zoom in on, then tap Tools.



c. Click Zoom in the Tools list.

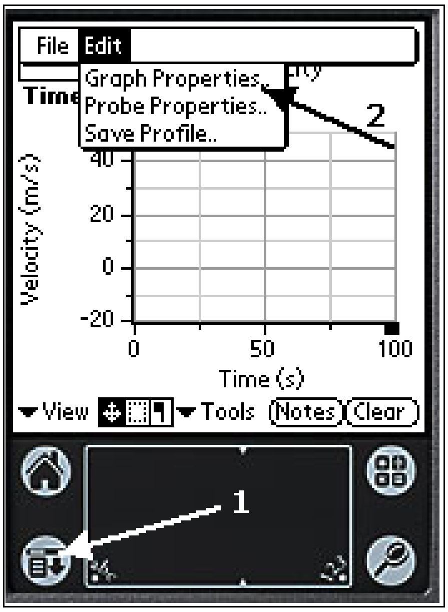


d. The graph will reappear showing just the area you selected.

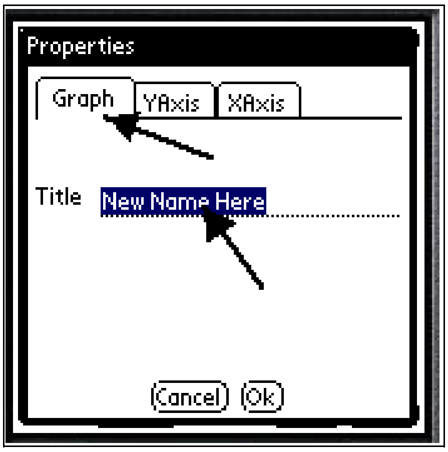


10. Changing graph properties

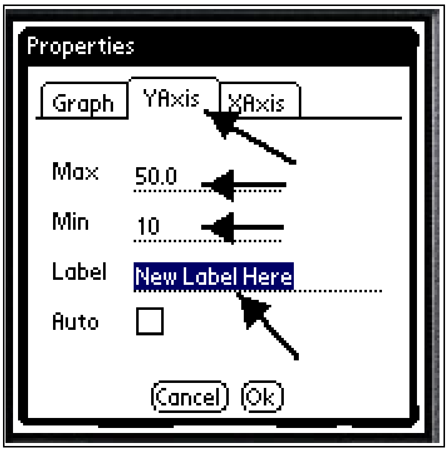
a. To change graph properties, tap the Palm menu icon at the bottom left corner, then the Edit menu item. Tap Graph Properties.



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



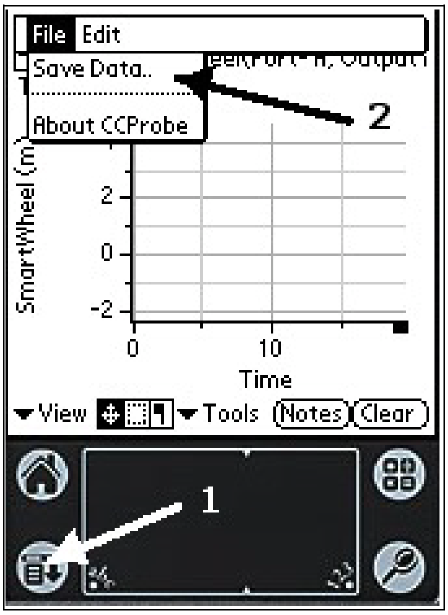
c. To change the range and the label of an axis, tap on the YAxis or XAxis tab. Write in the Max, the Min, and the Label, and then tap OK.



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

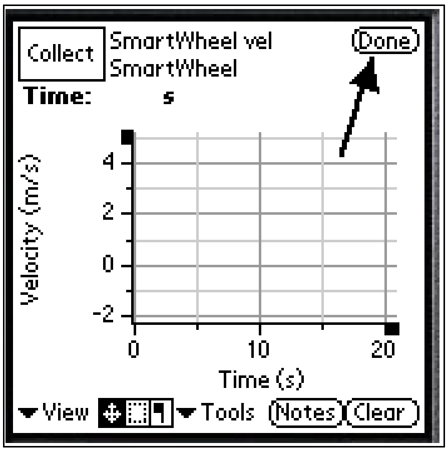
a. To save your data, tap the Palm menu icon at the bottom left corner. Then tap Save Data in the File menu. The menu will disappear when the data is saved. This may take several seconds.



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. Discuss the shape of the temperature graph when you supplied electrical energy to the heat cell with the Genecon. Draw the graph. Does it start to heat right away? What does the slope of the line tell you? Is it the same for fast and slow cranking?

2. Compare the rate of heating by the Genecon and the batteries. Which heats faster? How can you tell? Are you surprised by the cranking speed it takes to equal what a small battery can do?

3. Is the amount of cooling significant over the period of 60 seconds?

4. Is the shape of the graph for cooling the same as the shape for heating? How long would it take for the heat cell to cool down to room temperature?

5. Could the energy in the battery be called "potential" energy? What form do you think it is in?

6. Why did the light bulb heat up so much more rapidly than the heat cell?

7. Compare the tape teams' data with the foil teams' data. Did the bulb heat up faster with the clear tape or the aluminum foil? How does the electricity turn into heat? What difference does the covering make?

Further Investigations

- Heat the cell, out of its box, until it reaches about 45 degrees Celsius. Monitor how fast the heat cell cools down. Try the same thing with the heat cell in the insulation block and with other insulation systems of your own invention.
- As you heat the cell with the battery, monitor the electrical energy input with the Voltage/Current probe as well as the temperature with the FastResponseTemperture probe. Then compare the electrical energy that is supplied by the battery with the heat energy that is measured in the heat cell. Do you think they should be the same? The electrical energy is displayed directly on the energy graph. The heat energy is:

  Energy in joules = 10 x (temperature change in degrees Celsius)

- As you heat the cell with the battery, monitor the voltage of the battery. It should drop slowly. What do you think is happening? Where is the battery energy coming from? Do you think the battery could heat the cell forever?
- Put the heat cell in other things, like water or clay, and heat them. Explore the idea of heat capacity. How much heat energy is needed to heat up different materials?

