# Newton's Law of Cooling

Chemistry
High
Exponential Regressions

**Introduction**: As soon as a cup of hot coffee is poured, it begins to cool. The cooling process is rapid at first, then levels off. After a long period of time, the temperature of the coffee eventually stabilizes at the same temperature of the room. Temperature variations and the rate at which objects cool were summarized by Isaac Newton. He stated that the rate at which a warm body cools is approximately proportional to the difference between the temperature of the warm object and the temperature of its environment. State mathematically….

$$\frac{\Delta T}{\Delta t} = -k\,(T - C)$$

Where D T represents the objects temperature change for a very small interval of time, D t. T is the temperature of the body at some instant, C is the temperature of the environment, and k is proportionality constant. This equation can be solved using advanced techniques to….

$$T - C = (T - T_o)\, e^{-kt}$$

$T_o$ is the body's temperature when time is zero.

In this experiment, you will investigate temperature variations for a cooling object and attempt to verify Newton's Law of Cooling.

**Objectives**: Students will be able to…

1. Collect data by following an experimental procedure.
2. Input data in a graphing calculator.
3. Compare results.
4. Draw conclusions.
5. Make predictions.
6. Discuss the relationships in thermodynamic systems.

**Related Key Words**:

| | | | |
|---|---|---|---|
| heat flow | conduction | radiation | convection |
| cooling | temperature | kinetic energy | thermodynamics |

**Materials**:

CASIO CFX-9850G Color Graphing Calculator
EA-100 with temperature probe and data link cable
Large beaker (400, 600, or 800 mL)
Distilled water
Bunsen burner and ring stand or hotplate
Ice
Laboratory thermometer

**Purpose:** This experiment allows student to investigate the temperature variations of a cooling object.

**STEP 1—** Connect the EA-100 and the graphing calculator together with the data link cable. Make sure to press the cable ends firmly.

**STEP 2--** Connect the temperature probe to channel 1 (CH1) on the top edge of the EA-100 data collector.

**STEP 3—** Turn on the EA-100 unit and the calculator. The EA-100 is now ready to receive commands from the calculator, or have parameters inputted manually. If using calculator to set up the EA-100, go into the program and access the TEMPROBE program. If setting the EA-100 manually, data is collected at a rate of one data point every second for 100 data points, and absolute time measurements.

Filename:TEMPROBE

```
Cls·
{1,0}→List 6·
Send(List 6)·
{1,1,1}→List 6·
Send(List 6).
{3,1,100,1}→List 6·
Send(List 6) »
Receive(List 1)·
Receive(List 2)·
S-Gph1 DrawOn,Scatter,List 1,List 2,1,Square,Green ·
S-Gph2 DrawOff·
S-Gph3 DrawOff·
DrawStat·
Text 2,10,"TEMP"·
Text 55,100,"TIME"
```

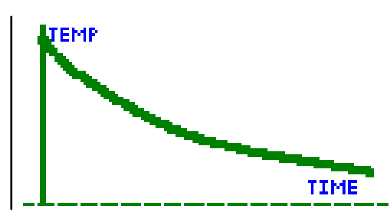
(ENTER is the [EXE] key represented by the dot at the end of each line below)

**STEP 4—** Using the laboratory thermometer, record the room temperature.

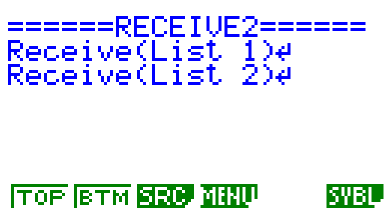
**STEP 5—** Fill a beaker with water. Bring the water to a boil and place the temperature probe of the EA-100 in the water for several seconds.

**STEP 6—** Be sure the EA-100 is on, remove the probe and, if using the TEMPROBE program, hit [EXE], the calculator will display "DONE" followed by " – Disp – ". This is to tell you to hit the [TRIGGER} key to begin the sampling process. When the EA-100 indicator reads "DONE", hit the [EXE] key on the calculator to complete the program. When the program is complete, you will have a graph of the data displayed on your screen.



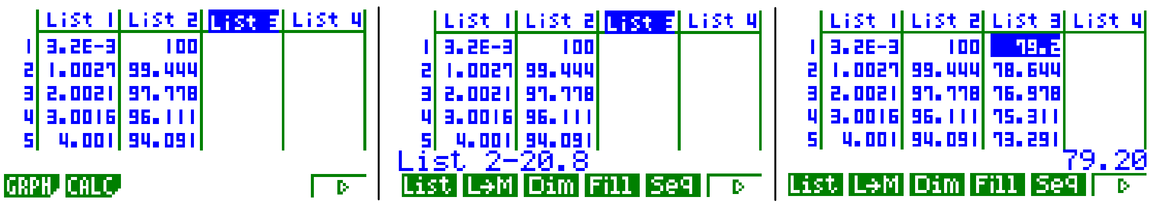



If you are using the EA-100 without the program, hit the [TRIGGER] button. After the data has been collected, run the "RECEIVE2" program. This program will send the data from the EA-100 to your calculator.

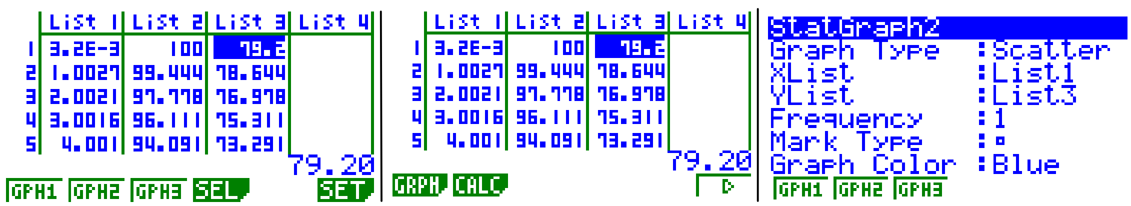


**STEP 7—** In either method, with or without the program, you will now have data stored in the STAT menu of the calculator. Newton's Law of Cooling states that the quantity Y = T – C varies exponentially with time. To create this model accurately, we must subtract the room temperature from the collected temperature values. Access the STAT menu from the MAIN MENU.

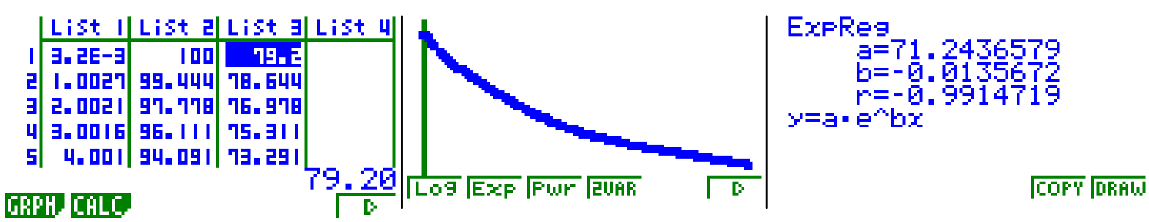
**STEP 8—** You will have data similar to that below. (Note: The data pictured below is insignificant to the experiment you are performing.) Use the arrow keys to highlight List 3. Now subtract the room temperature from the collected temperature. List 1 is the time values, List 2 is the collected temperatures. Press the [OPTN] key to bring up a new soft menu. Press [F1] for LIST, then [F1] again for List. The word List will appear at the bottom of the screen. Type 2, then minus (-), then the room temperature (in this case 20.8). Finally, press [EXE] to complete the calculation.




**STEP 9—** StatGraph1 will set up to graph the collected temperatures versus time. From the SET option under the GRPH [F1] soft menu option, set up Statgraph2 as indicated below.




Step 10 -- Perform an exponential regression on the adjusted data by graphing StatGraph2. Press [F6] for more options followed by [F2] for Exp. Your calculator will display the equation with the calculated variables. Select [F5] if you wish to copy the equation to the GRAPH menu of the calculator, or select [F6] to draw the regression curve.




Questions and Problems:

Level 1: Answer the following questions in complete, well-structured sentences.

1. Explain how the results might be different if the room was hotter or colder than the value you have.
2. What is the value of your correlation coefficient? What does this tell you about your data and the regression model you chose?
3. Predict how your curve might be different if you started the data collection at some other temperature other than 100 degrees Celsius.
4. What did you do with the probe as you let it cool? How might the results be effected if the probe is set down on the counter top? Held in you hand? Left near the hotplate?
5. Do the experiment again, but this time start with the probe in an ice bath and allow it warm up. Explain the results.