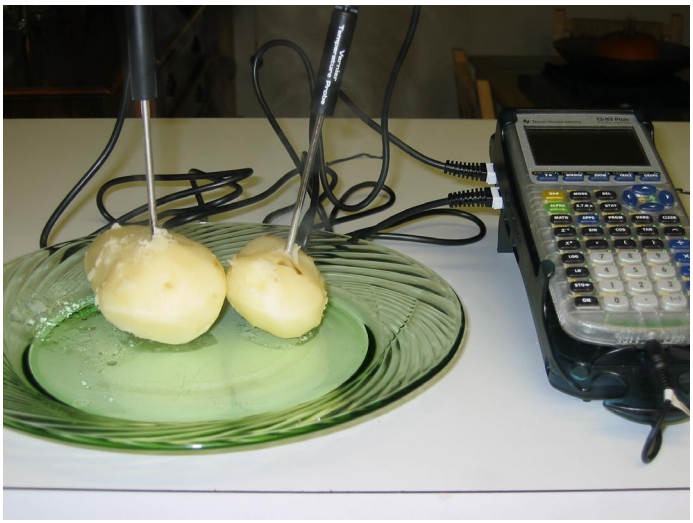
How Quickly Does Your Potato Cool?

Have you ever sat down to a nice, hot Thanksgiving dinner only to find that the potatoes have gotten cold while things were readied? Does the size of the potatoes affect how long they stay hot? In this investigation, you will compare the rate of cooling of small and large potatoes after they are removed from boiling water.

Peel one large and one small potato and place them in boiling water on the stove. Allow them to cook in the boiling water for 30 minutes. Meanwhile, connect two Temperature Probes to Channel 1 and 2 of the interface and start the data collection program. If two Temperature Probes are not automatically identified, set up Channel 1 and Channel 2 for two Temperature Probes. Set the data collection rate to 1 sample/minute and the experiment length to 45 minutes. Record room temperature displayed in the live readouts on the graph or main screen of your program.



Carefully remove the potatoes from the water. **Caution:** *The potatoes will be very hot!* Place a Temperature Probe into each of the potatoes so that the tip of the probe is close to the center of the potato. Start data collection and allow the potatoes to cool for 45 minutes.

Once data collection is finished, a graph of the temperatures of the cooling potatoes will be displayed. Examine the graph.

1. Which potato cooled at a faster rate?

2. What is the relationship between the surface area of the potato and the rate at which it cools?

OPTIONAL: Determine the cooling rate of each of the potatoes mathematically. Examine the graph to determine the change in temperature during the first minute. Express the rate in ^{o}C/min. Repeat the process to determine the cooling rate during minute 5, minute 10, minute 15, minute 20, minute 25, minute 30, minute 35, and minute 40. Record the data in a table. Repeat for the other potato.

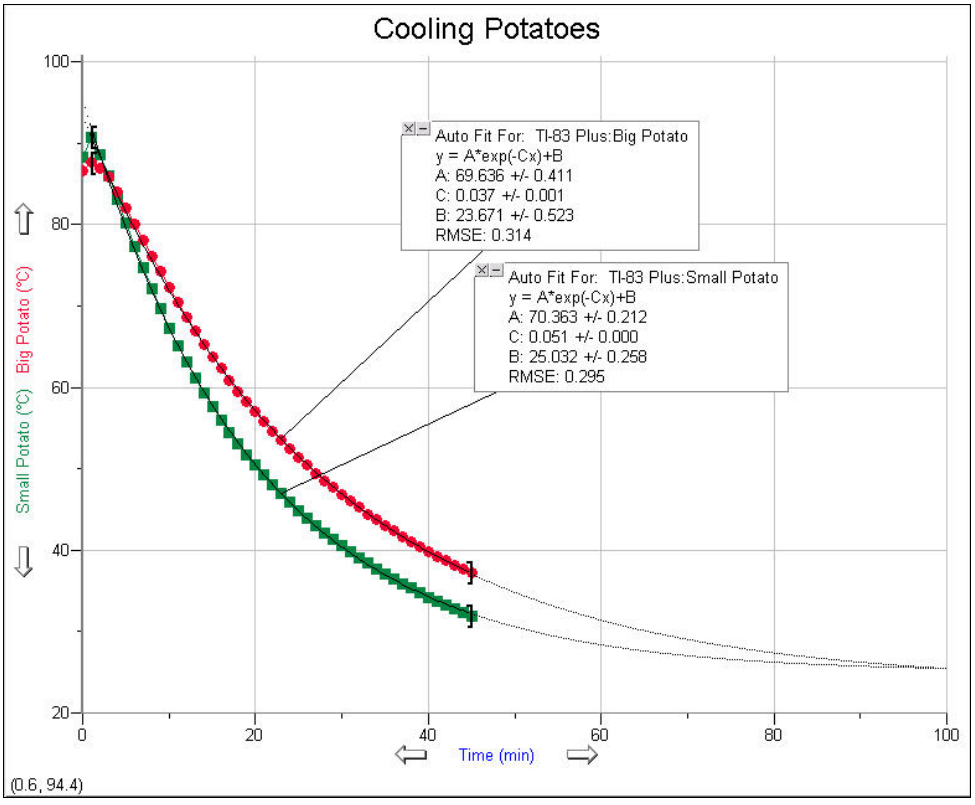
3. Which potato had a faster cooling rate in minute 5?

4. What happened to the cooling rates of both potatoes as time progressed?

5. What is the relationship between temperature and cooling rate?

CALCULUS EXTENSION: Use the curve fit feature of your data collection program to fit a natural exponent function to your data. Match the variables *x*, *y*, *A*, *B*, *and C* in the fitted equation to terms in the solution to Newton's law of cooling, which is an expression of the potato temperature as a function of time:
$T(t) = T_0 e^{-kt} + T_{room}$.
Take the derivative of this expression with respect to time, giving you another expression for the rate of change of potato temperature as a function of time. When is the cooling rate (for either potato) the highest? How does the rate of change of potato temperature (that is, the instantaneous cooling rate) change as a function of time? From your derivative expression, which potato has the larger cooling rate at the starting time? How about at any time?

Sample Results:



These data were recorded using a LabPro interface and a TI-83 Plus Silver Edition calculator. The data were transferred over to Logger *Pro* 3 for analysis.

Small Potato			
Time	Temperature (begin) ^{o}C	Temperature (End) ^{o}C	Rate of Cooling ^{o}C/min
1-2 min	90.7	86.6	–4.1
5-6 min	80.2	77.3	–2.9
10-11 min	67.3	65.1	–2.2
15-16 min	57.6	56.0	–1.6
20-21 min	50.4	49.2	–1.2
25-26 min	44.9	43.9	–1.0
30-31 min	40.5	39.8	–0.7
35-36 min	37.1	36.5	–0.6
40-41 min	34.2	33.7	–0.5

Big Potato			
Time	Temperature (begin) ^{o}C	Temperature (End) ^{o}C	Rate of Cooling ^{o}C/min
1-2 min	87.6	86.9	–0.7
5-6 min	82.1	80.1	–2.0
10-11 min	72.3	70.5	–1.8
15-16 min	63.8	62.3	–1.5
20-21 min	57.0	55.8	–1.2
25-26 min	51.4	50.4	–1.0
30-31 min	46.8	46.0	–0.8
35-36 min	43.0	42.3	–0.7
40-41 min	39.9	39.3	–0.6