TEACHER INFORMATION

Activity
17

Chill Out: How Hot Objects Cool

1. There are currently 3 different combinations of equipment that will work for collecting temperature data. The most common method, which works for both the TI-83 Plus and TI-84 Plus families of calculators, is to use a Temperature Probe attached to a CBL 2 or LabPro.

   The TI-84 Plus calculator has a USB port located at the top right corner. Using the USB port, either an EasyTemp or an EasyLink with a Temperature Probe can be connected to collect temperature data. For more information on EasyTemp and EasyLink refer to Page *ix* in the front section of this book.

2. When connecting an EasyTemp or an EasyLink to a TI-84 Plus calculator using USB, the EasyData application automatically launches when the calculator is turned on and at the home screen.

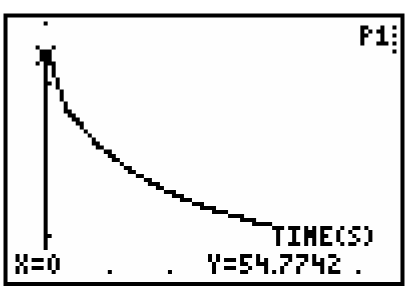
3. As a short-cut you can have students warm the probe by rubbing the tip with their hands. The magnitude of the temperature change will be much smaller, but the analysis is the same.

4. Data collection must be started *after* the probe has started to cool. Don't worry about catching the first few seconds of cooling.

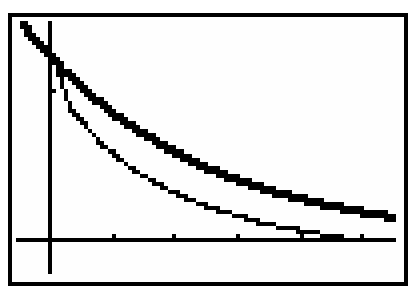
5. The L2 list must not contain zero or negative values, or the exponential fit will fail. If the student is careless in subtracting the final value, rounded down, from the original list values, then non-positive values could result. Negative values in L2 are the most likely cause of errors in this activity.

6. Ideally the student would subtract room temperature from the list L2. However, if the room temperature measurement is done too quickly with a warmed probe, then the room temperature value will be high, and the L2 list would then contain negative numbers. To make the activity fail-safe from such an error, we have the student subtract the minimum value of the series, as determined by a trace. Some teachers may wish to modify the activity to use a careful room-temperature measurement and subtraction.

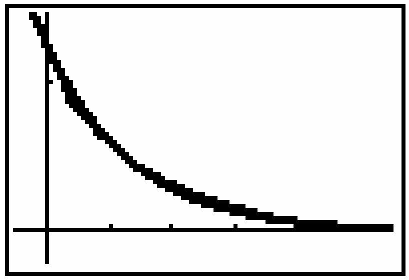
SAMPLE RESULTS



Uncorrected temperature *vs*. time data



Data and model with first guess for *k* (0.01)



Data and regression line

DATA TABLE

Minimum Temperature (°C)	24

$y = Te^{-kx}$	**T**	30
	k	0.02
$y = ab^x$	**a**	38.03
	b	0.977

ANSWERS QUESTIONS

1. Yes, the data are consistent with a decreasing exponential, as the graph is always decreasing, but it never crosses the horizontal axis.
2. Model equation is $y = 30e^{-0.02x}$.
3. The regression line fits the data well. Both the regression and the model are exponential functions, so they can have the same shape.
4. The bases of the exponential functions are different, leading to different multiplicative terms in the exponent. Comparing the exponential terms, we have $b^x = e^{-kx}$, or $-\ln(b) = k$.
5. When $t = 0$, we have $e^0 = 1$.
6. When t is large, $e^{-\text{large}}$ approaches zero, so the temperature difference approaches zero.
7. A decreasing k would correspond to a longer time to cool. To make the probe take longer to cool, wrap it in insulation.
8. $1 = 30e^{-0.02t}$, or $t = 170$ seconds, using the model.
9. No, it takes more than half as long. Using the model expression, we see that the time to 1 C temperature difference is ln(starting temp difference)/0.02. If the starting temp difference is 15 C, then it takes 135 seconds to reach a 1 C difference.