Cool It
Student Activity

Name ________________
Class ________________

How do drinks cool?

When you have a drink which is very hot, you have probably noticed that it quickly cools off to a temperature that you consider tolerable. Your drink then remains in a drinkable temperature range for quite a while until it eventually cools off too much as it approaches room temperature. When you think about how this drink cools, you are thinking about math and science. In this activity, you will explore how the temperature changes as a function of time. Because watching an entire cup of hot chocolate or coffee cool will take a long time, we will conduct our experiment by heating a temperature sensor and watching it cool. Begin by making a prediction of how the temperature will change as a function of time and sketching a graph of the prediction to the right. Begin your prediction graph at the instant the sensor is pulled from the water cup. Be sure to label your axes.

Write a sentence to explain why you think the graph will look like your prediction.

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Objectives:

- Understand how objects cool by recording temperature as a function of time for a sensor as it cools.
- Model the cooling data with the appropriate mathematical function.

Materials:

- Vernier EasyTemp® USB temperature sensor or Vernier Go! ® Temp USB temperature sensor with interface (Vernier EasyLink® USB sensor interface or TI-Nspire Lab Cradle)
- Cup of hot water with a temperature of 45º–55ºC or a hair drier to heat the temperature sensor.

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Data Collection:

1. Open a new document on the TI-Nspire™ handheld. Connect the temperature sensor directly or with the interface. You will use the default settings.
2. Place the temperature sensor in the cup of hot water and watch for the readings to become steady indicating that the sensor has reached the temperature of the water.
3. Remove the sensor from the cup of hot water, wipe it off so that evaporation is not a factor and let it sit on the edge of the table without touching anything to cool. Begin the data collection immediately by pressing the green arrow in the lower left corner of the screen (▷).
4. Once the data is collected, send the data file to each group member's handheld.

Analysis:

1. Compare your data with your prediction. If they are different, explain why you think data does not match your prediction exactly and sketch the graph of the collected data on the same set of axes, labeling each relationship.
2. Why is the room temperature important in this activity?
3. Click on the graph to select a data point. Move the tracing cursor to find the starting temperature and then use your graph or other methods to determine the temperature of the room in ºC. The room temperature should be lower than your lowest temperature recorded. Record them below

Starting Temperature (ºC)	
Room Temperature (ºC)	
Difference in Temperatures (ºC)	

4. You may recognize that the data appears to be exponential. You will model this data with an equation in the form $y = a \bullet b^x + c$. Use what you know about transformations and the data points in the table above to find values for *a* and *c*. Note that *a* is not the starting temperature. Explain why *a* is different value in the table. Record the values for *a* and *c* in the table to the right.

a	
c	

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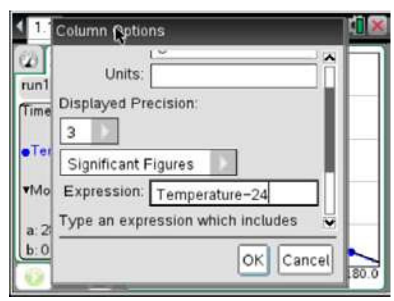
5. You will guess a value for *b*. Does the graph show exponential growth or decay? Based upon this, what are the possible values for *b*?

6. Select **MENU** > **Analyze** > **Model**. Type in the model $y = a \bullet b^x + c$ (be sure to enter the multiplication sign between *a* and *b*) and then enter the values for *a* and *c* along with your estimate for *b*. The spin increment will allow you to adjust the values in the increments you choose by the value entered. To obtain a good fit, you will need to adjust the value of *b* possibly *a* or *c*. Adjust the values using the up and down arrows in the details box to the left of the graph. You can also click the value of *b* and enter a specific value of your choice. Once the model fits the data, record the equation.

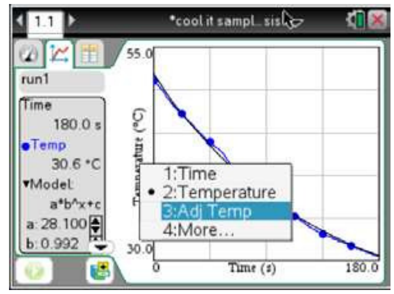
7. What is the physical representation of each parameter *a, b* and *c*?

8. An exponential regression can also be used to find the equation but the exponential regression is in the form $y = a \bullet b^x$ with no vertical shift value of *c* from above. How could the data be transformed so that the regression model can be used on the curve?

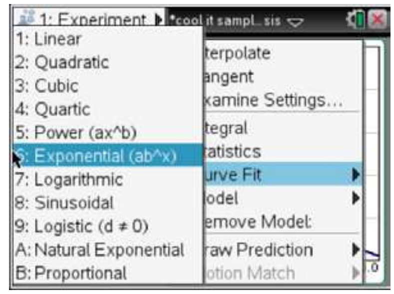
9. Since the temperature levels off at room temperature rather than zero, the exponential curve is shifted upward by room temperature. Subtracting room temperature from all of the temperature values will allow the data to be analyzed with an exponential regression. Select **Menu > Data > New Calculated Column**. Name the new column *Adj Temp*. The Expression must be typed in precisely with Temperature – Room Temperature value.



10. To see the graph of the Adjusted Temp as a function of time, click on the *Temperature* label along the dependent axis of the graph and change it to *Adj Temp*. Or you may select it from the Graph Menu.



11. Select **Menu > Analyze > Curve Fit > Exponential**. Record the value of the exponential regression.



12. Compare the exponential regression value with the value of the model you developed. Write an equation for the original data set using the exponential regression.

13. How would the graph change if the experiment were performed outside on a very cold day?

14. How would the graph change if the hot water had a higher initial temperature?

15. Write a short paragraph to summarize what you learned in this activity.

ERROR: undefined
OFFENDING COMMAND:

STACK: