EXPLORATIONS

Activity 12

Murder in the First Degree — The Death of Mr. Spud

Objectives

- To model the process of cooling
- To use a cooling curve to simulate a forensic scenario to predict the time of death
- To use technology to find an exponential plot

Materials

- TI-83 Plus
- Small potato
- Pot with boiling water
- Celsius thermometer

Introduction

In a murder investigation, a forensic expert may be called in to determine the time of death. Such determinations may involve examining the contents of the victim's stomach or inspecting decomposing insects on the body. One interesting approach is to examine the temperature of the body. Human body temperature is approximately 37 degrees Celsius. Immediately after a person dies, the body temperature begins to drop. By determining how far the temperature has dropped, you may be able to arrive at an accurate measure of the time of death. This information could play an important role in either the prosecution or defense of an alleged criminal.

Problem

A potato is placed in boiling water. After removing the potato from the boiling water, it begins to cool, just as a human body cools after death. By examining the temperature of a potato, determine the time of death (removal from the boiling water).

Collecting the data

Forensic experts measure the temperature drop in corpses in order to establish *standard curves* under controlled conditions. When a person is found dead and foul play is suspected, the forensic expert measures the temperature of the body. The forensic pathologist can approximate the time of death by determining where the temperature is on the standard curve.

You will simulate the drop in a person's body temperature at the time of death. Your teacher placed a potato in a pot of boiling water and allowed it to stand for 15 minutes. Removal of the potato from the boiling water will simulate the death of a person. When the potato is removed from the pot, its temperature will drop toward the temperature of its surroundings, just as the temperature of a body drops following death. You will plot this data to establish a standard curve.

(Your teacher may choose to provide you with data for the standard curve.)

You will be given a potato whose time of death (removal from the boiling water) is unknown. This partially cooled potato will simulate a murder victim. Assume that the potato was murdered outdoors during the winter.

1. Use the sharp end of a pencil to puncture the potato. Turn the pencil around and use the blunt (eraser) end to penetrate to the center of the potato. Remove the pencil.
2. Insert a thermometer in the hole in the potato. Place the potato in ice water.
3. Observe the temperature rising. The temperature will peak and after a few minutes, it will begin to drop. Wait until the temperature drops 3 degrees from its peak. Record the temperature and enter the reading as time 0 in the table on the **Data Collection and Analysis** page.
4. Record the temperature every five minutes for 30 minutes.

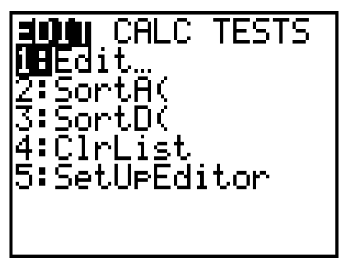
Setting up the TI-83 Plus

Before starting your data collection, make sure that the TI-83 Plus has the STAT PLOTS turned OFF, Y= functions turned OFF or cleared, the MODE and FORMAT set to their defaults, and the lists cleared. See the Appendix for a detailed description of the general setup steps.

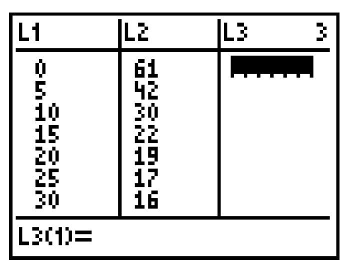
Entering the data in the TI-83 Plus

1. Press [STAT] and select **1:Edit** by pressing [ENTER].

   The list is displayed.



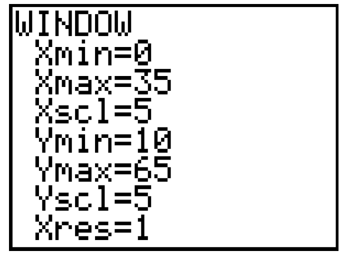
2. Enter the time in **L1**.
3. Move the cursor to **L2** and enter the temperature. (Make sure that the pairs of time and temperature match in each column.)



Setting up the window

1. Press [WINDOW] to set up the proper scale for the axes.

2. Set the **Xmin** value by identifying the minimum value in **L1**. Choose a number that is less than the minimum.



3. Set the **Xmax** value by identifying the maximum value in each list. Choose a number that is greater than the maximum. Set the **Xscl** to **5**.

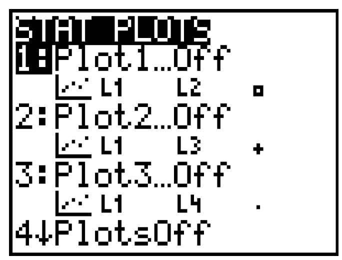
4. Set the **Ymin** value by identifying the minimum value in **L3**. Choose a number that is less than the minimum.

5. Set the **Ymax** value by identifying the maximum value in **L3**. Choose a number which is greater than the maximum. Set the **Yscl** to **5**.

Graphing the data: Setting up a scatter plot

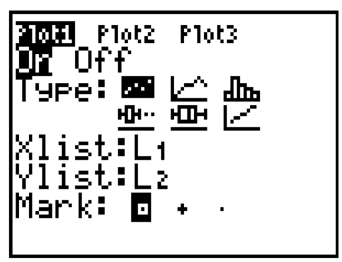
In order to analyze the data, you will need to set up a scatter plot and model the data by graphing a line of best fit (exponential regression). You will then use the exponential regression as the standard curve to predict the time of death of a murdered potato.

1. Press [2nd] [STAT PLOT] and select **1:Plot1** by pressing [ENTER].

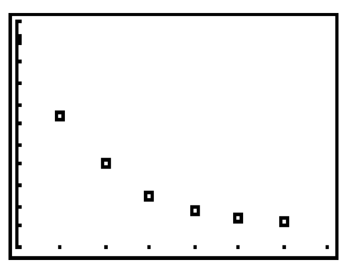


2. Set up the plot as shown by pressing [ENTER] [▼] [ENTER] [▼] [2nd] [L1] [ENTER] [2nd] [L2] [ENTER] [ENTER].

   Note: *Press [▼] [▼] if **L1** and **L2** are already displayed.*



3. Press [GRAPH] to see the plot.

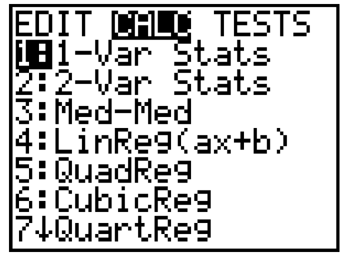


It is necessary to determine an appropriate regression model for this data. Does the plot appear to be linear? If not, how does the slope change?

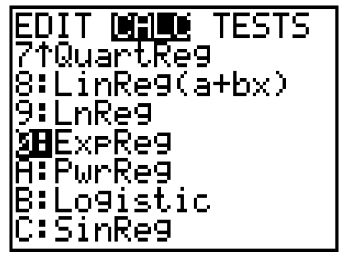
Analyzing the data

Finding an exponential regression

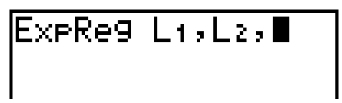
1. Press [STAT] and move the cursor to the **CALC** menu.



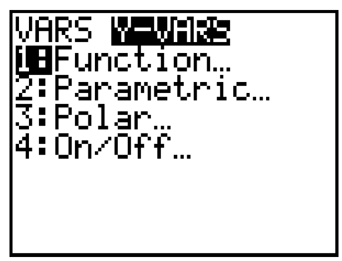
2. Press the up arrow [▲] or the down arrow [▼] to select **0:ExpReg** and press [ENTER].



3. Press [2nd] [L1] [,] [2nd] [L2] [,].

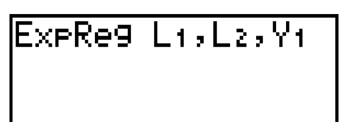


4. Press [VARS] and move the cursor to the **Y-VARS** menu.

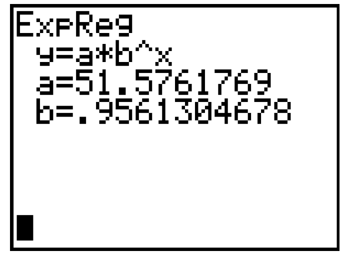


5. Select **1:Function** by pressing [ENTER].

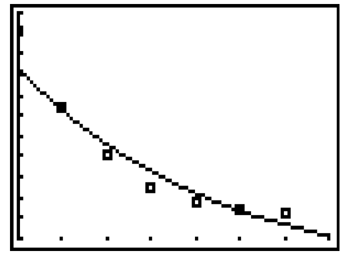
6. Select **1:Y1** by pressing [ENTER].



7. Press [ENTER] to calculate the exponential regression and paste the function in **Y1**.



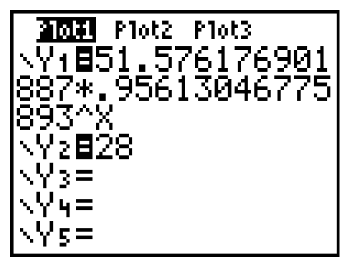
8. Press [GRAPH] to see the exponential regression.



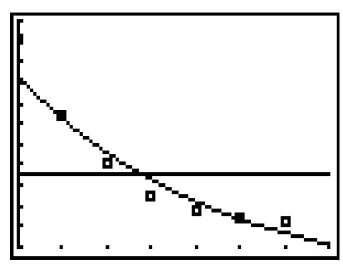
Determining the time of death

You can determine the time of death based on the temperature of the potato.

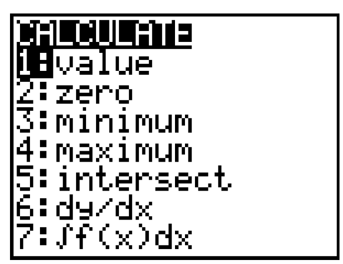
1. Your teacher will give you a potato. Insert the thermometer in the potato as you did earlier, first using the sharp end of a pencil to create a small hole and then using the eraser end to widen the hole.
2. Determine the temperature of the potato by leaving the thermometer in the potato until the temperature stabilizes. Record the temperature on the **Data Collection and Analysis** page.
3. Press [Y=] and move the cursor to **Y2**. Enter the temperature of the potato (use 28°C).



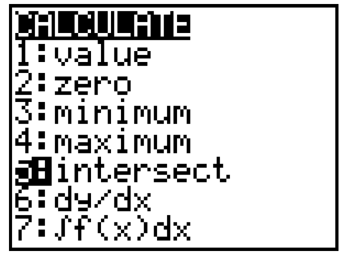
4. Press [GRAPH] to see the intersection of the two lines. The *x* value of the point where the two functions intersect is the time (in minutes) when the potato was murdered!



5. Press [2nd] [CALC].

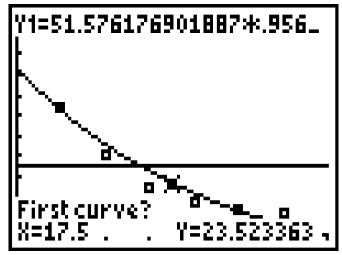


6. Select **5:intersect**.

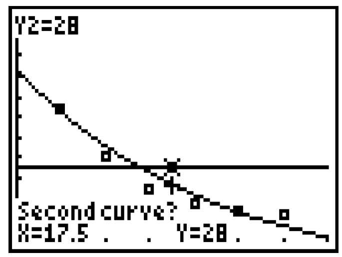


7. Press [ENTER] to find the coordinates of the point of intersection of the two lines.

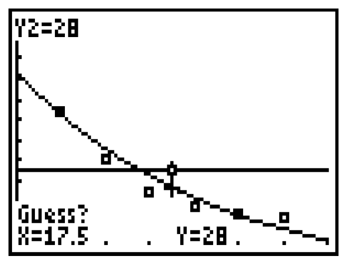
8. The calculator will prompt you for the *First curve*. Make sure the cursor is flashing on the regression line and then press [ENTER].



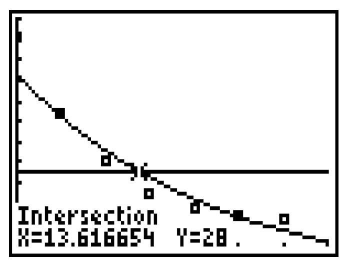
9. The calculator will prompt you for the *Second curve*. Make sure the cursor is flashing on the second line and then press [ENTER].



10. The calculator will prompt you to *Guess*. Try to estimate the coordinates of the point of intersection.



11. Press [ENTER] to find the exact point of intersection.



Record the point of intersection on the **Data Collection and Analysis** page.

Answer questions 1 through 5 on the **Data Collection and Analysis** page.

Data Collection and Analysis

Name ______________________

Date ______________________

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Collecting the data

Time (minutes)	0	5	10	15	20	25	30
Temperature (°C)							

Temperature of the potato: ______________________

Time of death of the potato: ______________________

Analyzing the data

1. Describe the shape of the time versus temperature plot.

____

____

2. What temperature does the plot appear to be approaching? What does that temperature correspond to in the situation being studied?

____

3. Explain why the plot is not linear. (**Hint:** if the plot were linear, it would mean that the temperature is dropping at a constant rate. Why would such a drop not be expected?)

____

____

4. In what way(s) is this simulation not consistent with a real forensic study of the drop in body temperature following death?

____

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5. Which model — exponential or linear — would be the better model to describe the following situations? Explain your answer in each case.

a. A car slowing down by 1/3 of the speed it was going the previous second.

____

____

b. A car slowing down by 5 mph each second.

____

____

Extensions

In this activity, you determined the time of death by the drop in temperature. A similar problem that has a similar solution (conceptually) is to date the time of death when an organism died *thousands* of years ago. To solve this problem, scientists use a technique called *radioactive dating*. It is based on the decay of a substance called carbon–14 (C-14).

Most carbon in a living organism is called carbon-12 (C-12) and it does not decay. There is a small amount of C-14 in all living tissue. Once the organism dies, however, it no longer incorporates this substance in its body. The C-14 begins to decay. By examining how much C-14 is present (the ratio of C-12: C-14), you can determine the time since death. Carbon-14 has a half-life of about 5,600 years (actual half-life is 5,780 years). Instead of examining the drop in temperature of a corpse, radioactive dating is based on the decay of C-14 over thousands of years.

Consider the problem of dating an animal's remains. Assume that by analyzing the amount of carbon in its remains, you believe that it originally had 1000 grams of C-14, but now has only 100 grams.

♦ Determine the amount of C-14 that remains after each 5,600-year interval, starting with 1000 grams of the substance.

Time (years)	5600	11200	16800	22400	28000	33600	39200
C-14 (Grams)	1000						

Amount of C-14 in Recovered Organism: 100 Grams

Years Since Organism Died: ______________________ yrs

Teacher Notes

Activity 12

Murder in the First Degree — The Death of Mr. Spud

Objectives

- To model the process of cooling
- To use a cooling curve to simulate a forensic scenario to predict the time of death
- To use technology to find an exponential plot

Materials

- TI-83 Plus
- Small potato
- Pot with boiling water
- Celsius thermometer

Preparation

- The temperature of a corpse drops after death, assuming the environmental temperature is lower than the body temperature. When the body begins to putrefy the temperature goes up a bit. If the body temperature has already reached that of the environment, other techniques must be used to pinpoint the time of death.
- Cooling curves do not exactly follow the simple exponential regression that is built into the TI-83 Plus. Models that are more accurate are more complex and their use would not be appropriate in an introductory Algebra class. A more accurate model would be:

  $T_t = C + (T_o - C) e^{-kt}$ where T_t is the temperature of the body at time t, T_0 is the initial temperature of the body, C is the environmental temperature, and k is the cooling rate constant. The assumption is that the environmental temperature remains constant, which is often not the case.

- It is sometimes difficult to know how far to insert the thermometer in the potato. The students may hold the thermometer next to the potato to see how far to insert it. You could mark the thermometer with a strip of masking tape to identify the point where the thermometer was inserted.
- Use small to medium size potatoes. Different size potatoes give different standard curves.

- It is understood that you may not want to spend class time collecting data for the standard curve unless this activity is being coordinated with a science and math teacher. You may want to provide the data for the standard curve (see number 6, sample data below). Give the students potatoes that were removed from the boiling water at different time intervals. The students have to use their standard curves to find the time of death of their potatoes.
- In the **Extensions** section, it may be easier for some students to use manipulatives to better visualize radioactive decay. Here are a few suggestions:

  a. Use small candies such as M&M's® to simulate radioactive decay. Students are told to spill about 50 M&M's from a cup and remove all of the samples with the letters facing up. Ask the students to count the number of remaining M&M's. Repeat the procedure, counting the number of M&M's left after each spill.

  b. Use coins to simulate radioactive decay.

Answers to Data Collection and Analysis

Collecting the data

- Sample data.

Time (minutes)	0	5	10	15	20	25	30
Temperature. (ºC)	61	42	30	22	19	17	16

Analyzing the data

1. Describe the shape of the time versus temperature plot.

The temperature drops sharply at first and then levels off.

2. What temperature does the plot appear to be approaching? What does that temperature correspond to in the situation being studied?

The plot approaches the environmental temperature.

3. Explain why the plot is not linear. (**Hint:** if the plot were linear, it would mean that the temperature is dropping at a constant rate. Why would such a drop not be expected?)

A linear plot would mean that the rate at which the temperature drops is constant. The closer the potato gets to the environmental temperature, however, the less quickly it drops.

4. In what way(s) is this simulation not consistent with a real forensic study of the drop in body temperature following death?

Answers may vary, but one difference is the fact that the environmental temperature does not stay the same following death.

5. Which model — exponential or linear — would be the better model to describe the following situations? Explain your answer in each case.

a. A car slowing down by 1/3 of the speed it was going the previous second.

Exponential

b. A car slowing down by 5 mph each second.

Linear