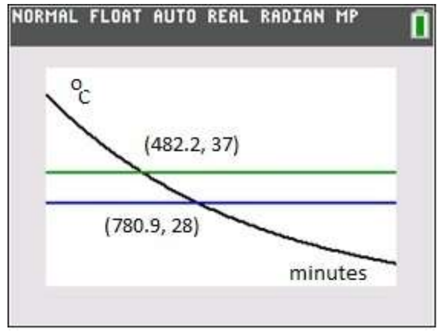
Murder in the First Degree

THE DEATH OF MR. SPUD



About the Lesson

In this activity, students will use a potato to simulate a human body cooling after death. Students can create a Standard Curve, find the exponential model, and estimate the time of death using graphical or algebraic methods.

As a result, students will:

- Use an exponential model to find the time (independent variable) that a certain temperature (dependent variable) occurs

Vocabulary

- exponential
- decay
- intersection

Teacher Preparation and Notes

- In this activity, students will use the exponential regression model that is provided on the TI-84 family of calculators: y = a*b^x to estimate a cooling curve.

Activity Materials

- Compatible TI Technologies:

  TI-84 Plus*
  TI-84 Plus Silver Edition*
  TI-84 Plus C Silver Edition
  TI-84 Plus CE

*** *with the latest operating system (2.55MP) featuring MathPrint™ functionality.*

- Small to medium-size potatoes (2 for each group)
- Vernier EasyTemp® probe (1 for each group)
- Crock Pot with a Keep Warm setting
- Ice and containers for ice water

Tech Tips:

- This activity includes screen captures taken from the TI-84 Plus CE. It is also appropriate for use with the rest of the TI-84 Plus family. Slight variations to these directions may be required if using other calculator models.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials
- Any required calculator files can be distributed to students via handheld-to-handheld transfer.

Lesson Files:

- Murder_First_Degree_Student.pdf
- Murder_First_Degree_Student.doc

Introduction

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.

Teacher Notes

- Cooling curves do not exactly follow the simple exponential regression that is built into the TI-84 family of calculators. Models that are more accurate are also more complex and therefore their use would not be appropriate in an introductory Algebra class. A more accurate model would be: $T_t = C + (T_0 - C)\ e^{-kt}$
    - 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.

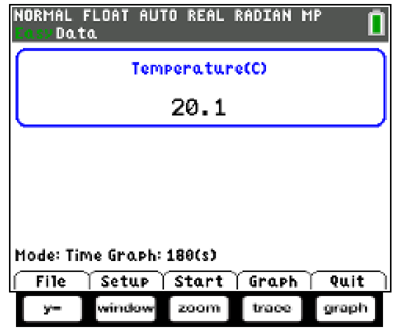
  The assumption is that the environmental temperature remains constant, which is often not the case.
- Use small to medium-size potatoes. Remember that different sized potatoes will give different standard curves. You will be preparing two sets of potatoes, if your students are making a standard curve first.
    - For the standard curve, put raw potatoes in a crock pot of hot water (on the Keep Warm setting this is about 70°C) for about 30 to 45 minutes prior to the activity. Getting the potatoes anywhere around 50 to 60°C is fine.
    - For the potatoes with an unknown time of death (Mr. Spud), these potatoes can have internal temperatures that vary from about 12°C to about 32°C, essentially any temperature below 37°C that will fit in the range of the Standard Curves being created by the students. One method is to put raw potatoes in the crock pot of hot water for 15 to about 30 minutes depending on how hot the water is. Measure the internal temperature of these "Mr. Spuds" before distributing to the students to make sure they are not too warm or to see if they need to be cooled down in the ice water.
- It is sometimes difficult for students 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.

Murder in the First Degree

THE DEATH OF MR. SPUD

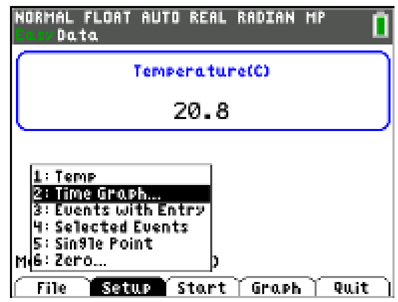
Using the Vernier EasyTemp® and Vernier EasyData® App

Connect the handheld with the EasyTemp sensor, and EasyData will immediately open, and the temperature probe will begin collecting temperature data. In the EasyData app, the tabs at the bottom indicate the menus that can be accessed by pressing the actual calculator keys directly below the tab.



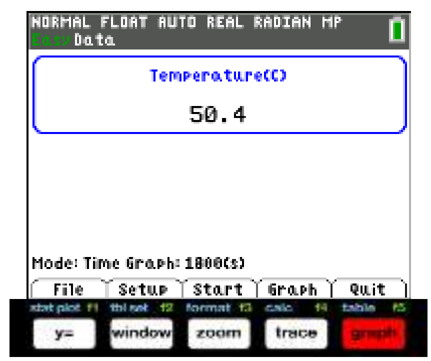
Making the Standard Curve:

1. Open the EasyData app, press WINDOW to select Setup. Choose [Time Graph]. Then press zoom to Edit the Time Settings.

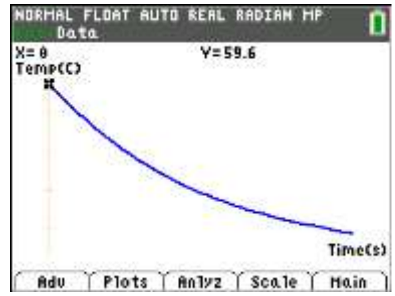


2. Follow the prompts to enter 30 as the Sample Interval and 60 as the number of Samples. The temperature will be collected for 30 minutes (1800 s).

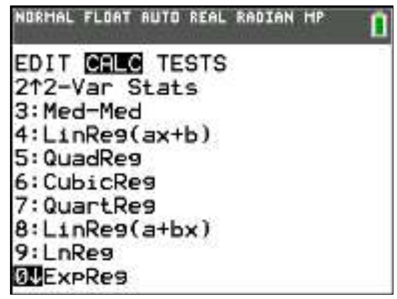
3. Distribute the *Standard Curve* potatoes. Instruct the students to insert the EasyTemp® temperature probe into the potato, place the potato into the ice water (without the water touching the temperature probe), and, when the temperature of the potato starts to go below 60°C, press zoom to select [Start]. If too much of the ice melts before the 30 minutes is done, have students put more ice in the water as the data collection proceeds.



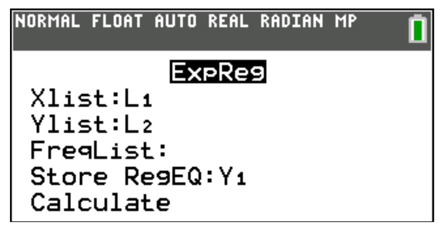
4. Their graph should look something the graph to the right. Instruct students to exit EasyData to do the exponential regression. To exit the app, press GRAPH twice.

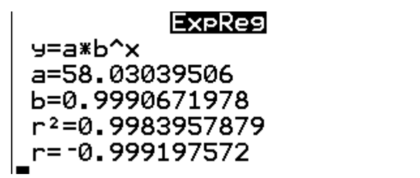


5. To do the regression, press stat and right arrow to the CALC menu. Then arrow down to the **ExpReg.**



6. Enter the settings shown. To access Y1, press vars, select [Y-VARS] > [Function] > [Y1] so that the regression equation is stored in Y1.



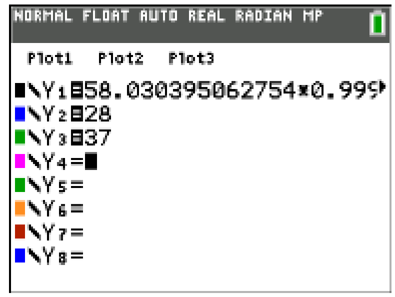


Teacher Tip: While the students are making their standard curve, the potatoes with an unknown time of death can be prepared. These potatoes can have internal temperatures that vary from about 12°C to about 32°C, essentially any temperature below 37°C that will fit in the range of the Standard Curves being created by the students. One method is to put raw potatoes in the crock pot of hot water for 15 to about 30 minutes depending on how hot the water is. Measure the internal temperature of these Mr. Spuds before distributing to the students to make sure they are not too warm or to see if they need to be cooled down in the ice water.

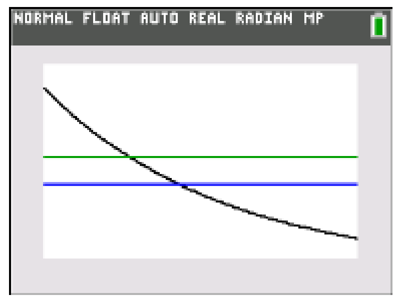
Collecting the Data

Mr. Spud is found dead by the side of the road near his house on a cold morning at about 7:00 am. The temperatures that night were between 4oC and 8oC. At this time, it appears that the death was not a result of natural causes. You arrive at the scene at 7:30 am, and the Medical Examiner wants you to determine time of death.

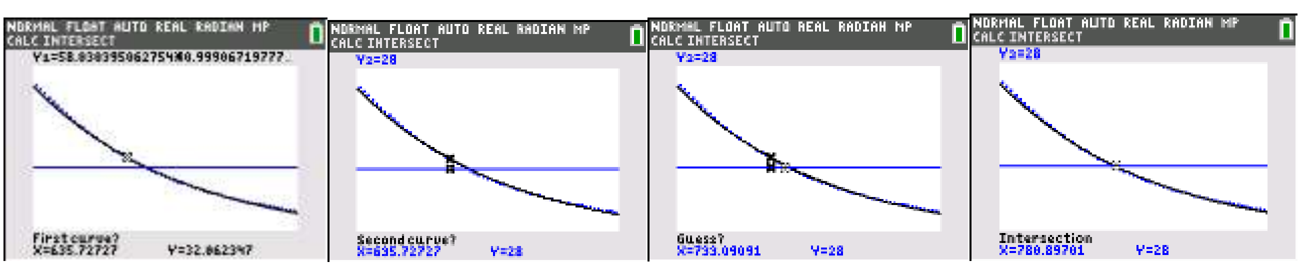
1. After students determine the internal temperature of their potato, they need to enter Mr. Spud's body temperature into Y2 and enter normal body temperature (37°C) into Y3. They will also record the information on their student activity sheet.



2. Student graphs should look similar to the graph on the right.



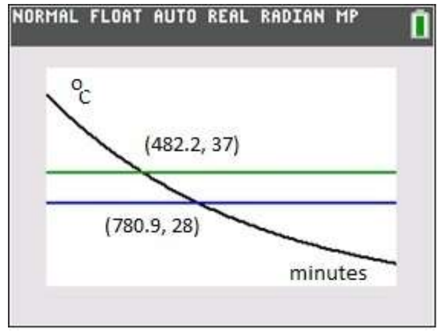
3. Students need to find both intersections by using the [2nd][CALC] menu and selecting [intersection]. They will press [enter] three times to indicate the First Curve? Second Curve? Guess? As long as they are near the intersection point, the calculator will display the coordinates. See the screens below:



11. In the sample data,
Time of Mr. Spud's body temperature = 780.9 min.

Standard Curve time for 37°C = 482.2 minutes

I estimate Mr. Spud's time of death to be about 298.7 minutes prior to 7:30 am. That is about 5 hours before 7:30 am or about 2:30 am.



12. If having the students make their own standard curve is not possible for your class schedule, then the following sample could be used to get the exponential regression equation, $y = 58.03(0\ 99907)^x$

Time (min)	0	4	8	12	16	20	24	28	30
Temperature (°C)	59.6	47.2	36.9	29.1	23.1	18.6	15.1	12.4	11.2

Analyzing the Data

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

   Answer: 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?

   Answer: The plot approaches the environmental temperature.

3. Explain why the plot is not linear.

   Answer: 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 will vary, but one difference is the fact that the environmental temperature does not stay the same following death

Going Further

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.

Graphing the data and finding the exponential model, students can put the model into Y1 and 100 into Y2 and find the intersection.

Number of time intervals	0	1	2	3	4	5	6
Time (years)	0	5600	11200	16800	22400	28000	33600
C-14 (Grams)	1000	500	250	125	62.5	31.25	15.625

Answer: The intersection of $y = 1000(0.5)^x$ is (3.32, 100). So 3.32 time periods of 5600 years is 18,592 years or about 18,600 years ago that the animal died.