Case File 14

Hot Air, Cold Body:
Using Newton's law of cooling to determine time of death

Use Newton's law of cooling to narrow down the number of suspects by determining when the victim was killed.

Memo to Detective Sergeant:

The elevator operator of the Ritz Palace Hotel died from a stab wound while on duty last Thursday evening. His body was discovered by a family on its way down to the pool. When we arrived at the scene, we canvassed the area but found nothing. The elevator is full of fingerprints of the hundreds of guests who ride it during the day. We have several suspects in mind, but we are having trouble pinning down the time of death. If we can determine that, we have a good shot at finding the killer.

Enclosed are a photograph of the crime scene and part of the paramedic report.

Paramedic report

Date: 10/5/05

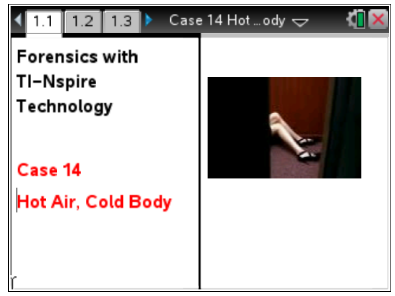
Time: 9:45 p.m.

Body temperature: 29.0°C

Notes: Elevator temperature was high; thermostat set at 27°C.

About the Lesson

- This lab introduces a practical use for Newton's law of cooling and the equation that describes it.
- Teaching time: one 45 minute class period



Science Objectives

- Determine the time of death of a person who has died within the last few hours.
- Create a temperature vs. time graph for cooling.
- Model the temperature data with an exponential function.
- Use the model to estimate time of death.

Activity Materials

- TI-Nspire™ technology
- *Case 14 Hot Air Cold Body.tns* file
- *Case 14 Hot Air Cold Body_Student.doc* student activity sheet
- Vernier Easy Link™ or TI-Nspire Lab Cradle
- Vernier EasyTemp® Probe
- One baked/boiled potato (“Body”), per group
- Aluminum foil (optional)

TI-Nspire™ Navigator™

- Send out *Case 14 Hot Air Cold Body.tns* file
- Monitor student progress using Class Capture.
- Use Live Presenter to spotlight student answers.

Teacher Notes and Teaching Tips

- The student activity sheet contains the complete instructions for data collection. The instructions are also included in the .tns file.
- You’ll need to practice the lab to find out what the cooling rates are like in your room.
- There will be approximately 20 minutes during the data collection where the students will not actively be doing anything. This may be a good time to review Newton's law of cooling or explain some background information. Students can also read the crime scene info and fill in data from that text in the Evidence Record

Resources

- This website from the University of Dundee (UK) includes interesting quotations on the difficulties in determining time of death, as well as a thorough exploration of the many changes that occur in the body after death.http://www.dundee.ac.uk/forensicmedicine/notes/timedeath.pdf

- This website contains a Java-based interactive time-of-death calculator. It also includes links to several other good forensic pathology sources http://www.pathguy.com/TimeDead.htm

Background

Body temperature readings for actual time-of-death estimates are usually taken rectally or intra-abdominally (in the liver). Ear, mouth, or armpit temperatures are generally considered inaccurate for these measurements. Depending on the level of your students, you may or may not wish to mention this or explore it further. In real life, the rate of cooling depends upon many things. The size of the body, how the body is dressed, the room temperature, where the corpse is located, and humidity all affect how fast a corpse cools. For this reason, investigators often use several different methods to estimate time of death. You should emphasize to your students that the model they are using is just that—*a model*.

Allow students to read the forensics scenario on the first page of the student activity sheet.

Procedure

Teacher Preparation (Prior to Lab)

1. Prior to class, bake or boil enough potatoes until cooked so that each group can have one. This will be the “Body”.

Cooking Tip: You want the skin to stay on, so the potato does not fall apart. If you boil them whole, without cutting them, the skin stays on pretty well. You can also wrap them in foil and boil them. A great method to consider for “cooking in the lab” is to wrap them in foil and put them into a crock pot or an electric roaster until they are done.

2. You will need to rewarm potatoes just before start of class so that students can observe and measure the “cooling constant” during class. You can rewarm in crockpot or roaster, or microwaves work fine, too. And even if all of the potatoes aren’t the same size or the same temperature, it really doesn’t matter. This variation is actually better for the students because then they have their own unique “body”.

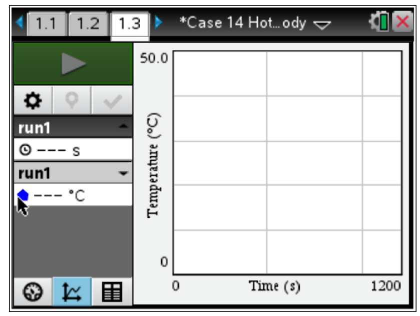
Part 1 – Collecting Data

Move to pages 1.2–1.5.

Students will obtain a "body" and follow the directions on pages 1.1-1.5 in the .tns file or on the student worksheet to model the cooling of the “body”.

As they are measuring the room temperature, be sure they hold the Temperature Probe in the air away from heat sources and sunlight. Make sure the tip of the probe is not touching anything warmer or cooler than room temperature (such as their hands). Students will need to record this data (room temperature) on the “From the Model” section of the Evidence Record. Students will be asked to determine and record initial and final temperature of the “body”, and calculate duration of the temperature measurement (elapsed time). When data collection is complete, students will trace the temperature vs. time graph or select **menu→ analyze→ statistics** to view the max, min, mean, etc. Remind students to insert the temperature probe into the middle of the “body”, and not let the tip poke through the outside of the potato.

You may also want to have students do fit a logistics model to the data they collect on page 1.3, **Menu→ Analyze→ Curve fit→ Logistics**. Ask students if they think the graph is linear. If the graph were extended up to the left and down to the right, it would level off in both directions--resembling an "S". In this activity, students will use the solver method to determine time of death, but a graph like this may also be used to make predictions.



Part 2 – Modeling the Data with an Exponential Function

Move to pages 3.1–3.4.

7. Students will now use their collected data from the “body” to ultimately determine time of death at the crime scene.

We can use Newton’s law of cooling: Newton’s law of cooling is an exponential relationship that states:

$$T = T_0^{\,e-kt} + T_{room}$$

where T is temperature of the object at any time t, T_0 represents the temperature difference between the initial temperature of the object and the room temperature, k is a constant that represents the cooling rate, and T_{room} is the room temperature.

8. Students will use the equation and spreadsheet on page 2.2, to determine ***k***. You may want to explain and/or show that the cooling equation has been rearranged from the above format to solve for the unknown variable ***k***. Students will input their data from the Evidence Record into the spreadsheet on the right side of the page. When the zeroes are replaced, the “no solution” message on the left side, will render the answer. You may have to remind students to not be confused by the notations used in the spreadsheet: *there is a “m” after each variable, to indicate this is the data from your model. m= model.* This is done so that there will not be a variable conflict when the students enter data from the crime scene into the spreadsheet on page 2.3.

   The ***k*** value (cooling constant) will be calculated and displayed on the left side (under the equation), once all the data has been entered into the spreadsheet. Students record this value as ***k*** (cooling constant) in the "From the Model" section of the Evidence Record

9. Students will now move to page 2.3 and enter the data from the Crime Scene in the spreadsheet. You may want to have a discussion with students reminding them "What we know?" and "What we don't know?" Remind students that the ***k*** (cooling constant) they determined above using their data will now be applied to the Crime Scene to determine the elapsed time, and ultimately the Time of Death.

Modifications

You can ask more-advanced students to investigate other methods of determining time of death (e.g., forensic entomology). However, be aware that many resources and methods may involve rather gruesome pictures, descriptions, or diagrams. You can also introduce and discuss some of the major sources of error in estimating time of death from body temperature

Evidence Record

SAMPLE DATA

From the Model ("Potato/Body")	
Ambient (room) temperature for model(ºC)	24.9
Initial temperature of model (ºC)	140.8
Final temperature of model (ºC)	97.8
Time of maximum model temperature (s)	0
Time of minimum model temperature (s)	1800
Duration of model temperature measurement (s)	1800
Cooling constant, k	0.00258

From the Evidence Report at Crime Scene	
Ambient (room) temperature in the elevator (ºC)	27
Time body temperature was measured	9:45
Temperature of body (ºC)	29
Cooling time, t (s)	6248
Cooling time, t (min)	104
Actual Time of Death	8:01 pm

Case Analysis

Move to pages 3.1–3.7.

Have students answer the following questions on the handheld, on their activity sheet, or both.

Q1. The term T_{room} represents the room temperature. How closely did the room temperature at the crime scene match the room temperature in your experiment with the "Potato/Body"?

Answer: The temperature from the elevator was 27 ºC . The room temperature in the "potato/body" experiment was 24.9 ºC. They were within a couple degrees.

Q2. What was T_0 for the crime scene. How closely does this match the data you collected in your experiment with the "Potato/Body"?

Answer: In the "potato/body" experiment, the beginning temperature difference of object vs room temp was 43 ºC (140ºC – 97 ºC). The initial difference from the crime scene was 10ºC. There was a 33 degree difference. This range will vary obviously vary depending on how hot the temperature of the potatoes were.

Q3. Use the elapsed cooling time to estimate the time of death in the case

Answer: The elapsed cooling time as about 104 minutes. That would put the time of death to be about 8:00 PM.

Q4. The experiment performed to model the cooling of a victim is much simpler than the actual cooling at a crime scene. What other facts would affect the cooling rate of a victim?

Answer: Factors in real life that would affect the cooling process include the type clothing on the victim, factors that affect the beginning temperature of the victim, e.g. was the victim suffering from a fever, and the type and nature of other materials that the body was in contact with, e.g. cold ground.

Q5. What would happen to the time-of-death estimate if the victim had a fever when he or she died? What if the person died of hypothermia?

Answer: We assumed the initial body temperature was normal at 37 ºC. If the initial temperature was higher or lower than that, the estimated time of death could incorrectly be reported as sooner or later, depending whether the body temp was higher or lower than normal.

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This is a great activity to monitor student progress as the data collection is being completed, data tables organized, and data graphed. It is a good idea to begin student presentation.