Newton's Law of Cooling

Subject Area(s)	Measurement, physical science, physics
Associated Unit	None
Associated Lesson	None
Activity Title	Newton's Law of Cooling
Header	None

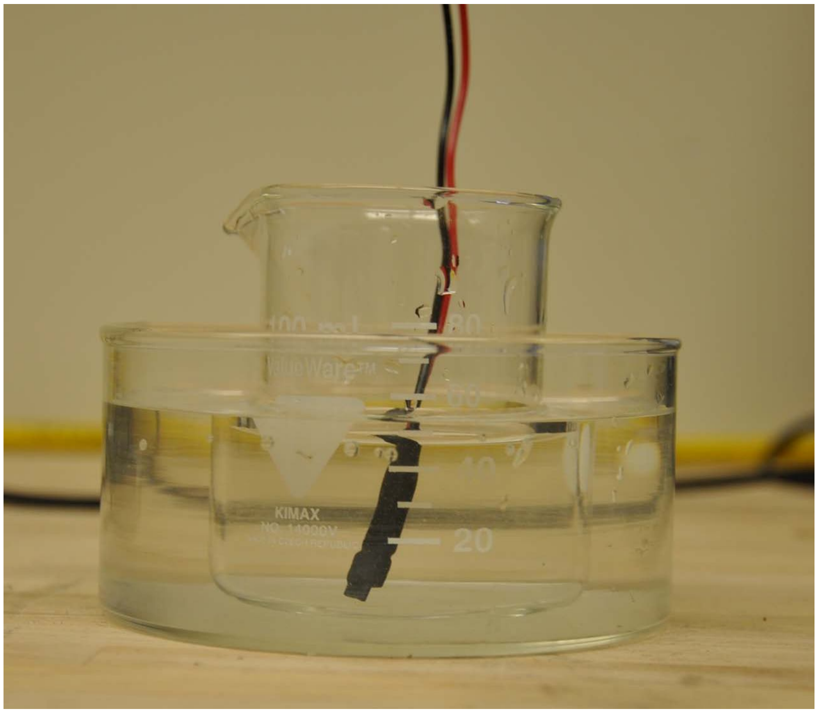

Figure 1
ADA Description: Close up of beaker in water bath with temperature probe
Caption: Figure 1: Temperature probe in beaker in water bath
Image file name: fig1.jpeg
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Grade Level	(6-8)
Activity Dependency	none
Time Required	50 minutes
Group Size	28
Expendable Cost per Group	$0

Summary

This activity demonstrates the exponential trend in the heating and cooling of a beaker of water. This task is accomplished by first appealing to the students' real-life experiences with heating, and by giving an example of an exponential curve. Next, the basic principles of heat transfer are discussed. Using this information, the students can make predictions about the heating and cooling curves of a beaker of water of different temperatures in the same ambient environment. By conducting the simple experiment of a beaker in a water bath, the temperature over time is recorded and different heating and cooling curves are created. These can then be recognized as having exponential trends, which verifies Newton's result.

Engineering Connection

Heat transfer is a broad topic used in many branches of engineering. Besides the explicit application in the field of fluid mechanics, the concept of heating and cooling is essential is the construction of every structure and machine with moving parts.

Engineering Category

(1) relates science concept to engineering

Keywords

cooling, exponential, heat, Newton, temperature, water

Educational Standards

State science: 4.4
State math: 3.4

Pre-Requisite Knowledge

Students should have a practical knowledge of temperature and the flow of heat from areas of high temperature to areas of low temperature. Students should be familiar with plotting points on the Cartesian plane, as well as the significance of independent and dependent axes.

Learning Objectives

After this activity, students should be able to:

- Record data displayed by a temperature probe
- Plot data points on a graph paper
- Identify a heating or cooling curve as having an exponential trend

Materials List

To share with the entire class:

- 100 mL beaker
- Known thermometer that accurately measures temperature around room temperature
- Large glass dish, at least 6 cm deep

- Basic Stamp 2 microcontroller on Parallax Board of Education
- 100 Ω resistor
- 0.22 µF capacitor
- Parallax AD592 temperature probe
- Laptop computer with PBasic software
- Hot water, tepid water, and ice
- Graph paper for every student

Introduction / Motivation

Heat transfer is a phenomena that influences almost every aspect of modern life, including transportation, technology, cooking, and hygiene. Mathematically, the distinct trend of a cooling or heating curve is an intuitive first foray into non-polynomial functions.

Vocabulary / Definitions

Word	Definition
Ambient	Present on all sides; surrounding
Temperature	How hot or cold something is
Heat	Energy transferred from one body to another because of a temperature difference

Procedure

Before the Activity

- Build the circuit on the Board of Education diagramed in the schematic in Fig. 2 and pictured on the prototyping board in Fig. 3.

Image 2 (left justified)

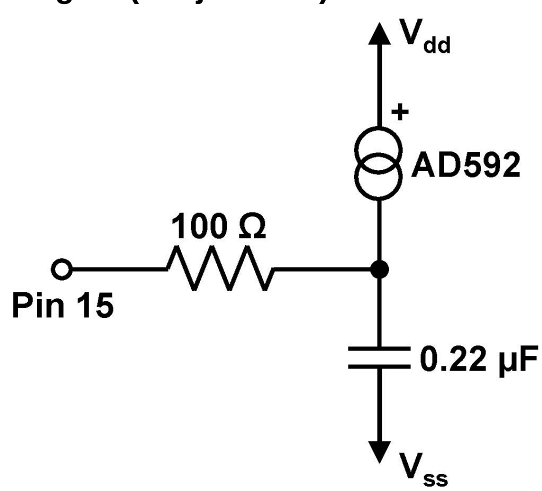

Figure 2
ADA Description: Schematic of temperature probe circuit
Caption: Figure 2: Circuit schematic
Image file name: fig2.jpeg
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Image 3 (left justified)

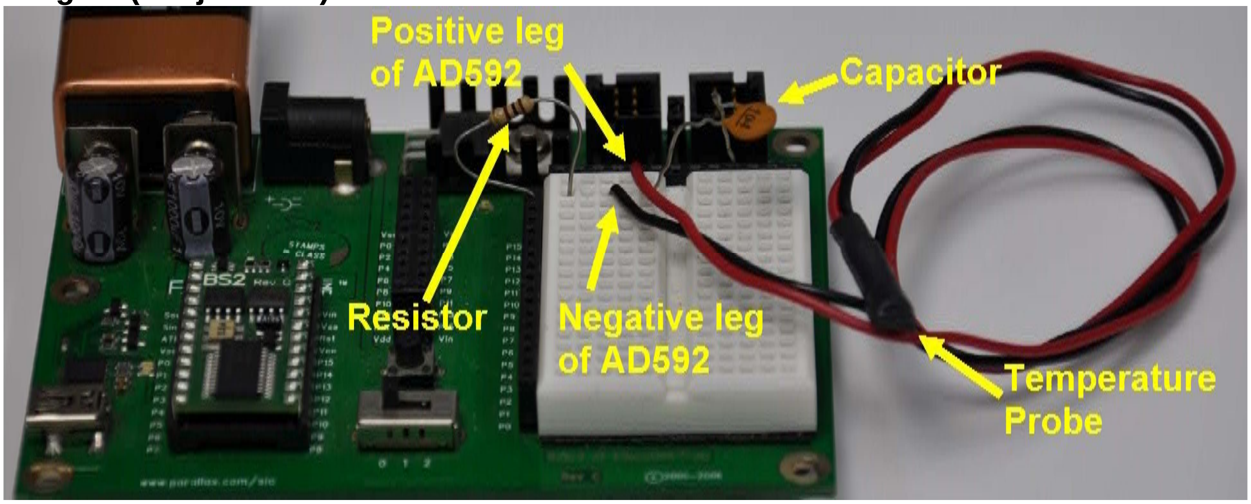

Figure 3
ADA Description: Parallax Board of Education with built temperature probe circuit
Caption: Figure 3: Circuit
Image file name: fig3.jpeg

- Implement the attached PBasic code thermometer.bs2 to read temperature probe.
- Use known thermometer to calibrate temperature probe using the constant “Kal” in thermometer.bs2.
- Have about 3 L of water, one room temperature (~20 ºC), one “hot” (~60 ºC), and one “cold” (~10 ºC).
- Have ice on hand.
- Prepare setup from Figure 4 with ice bath, temperature probe and Basic Stamp connected to laptop.

Image 4 (left justified)

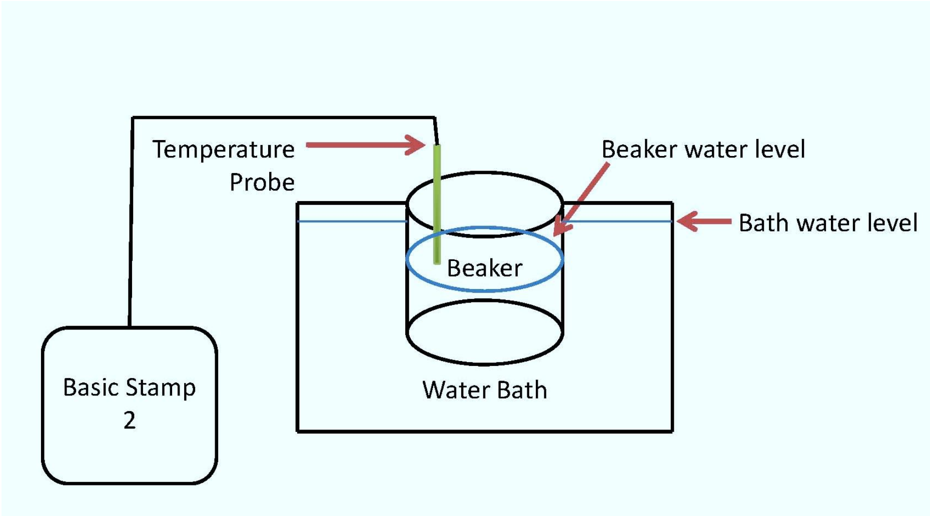

Figure 4
ADA Description: Schematic of beaker in water bath with temperature probe connected to the Basic Stamp 2 microcontroller
Caption: Figure 4: Experimental setup
Image file name: fig4.jpeg

With the Students

1. Discuss the students' intuition regarding cooling trends, based on personal experience. For example, if you placed a room-temperature can of soda in the refrigerator and waited for it to cool, how would you expect the temperature to change? What kind of trend do you think the temperature would have over time?
2. Present Newton's Law of Cooling.
   a. The rate of cooling of a body is proportional to the temperature difference between the body and the ambient environment.
   b. Draw a graph, explaining that as the temperature of the soda reaches the temperature of the fridge, it has less to cool, so the "slope" of the graph is less steep.
3. Distribute a copy of the attached worksheet and a sheet of graph paper to each student and prepare demonstration.
4. Prepare ice bath, and control volume of tepid water in the 100 mL beaker. See Fig 5.
5. Turn on the Basic Stamp and run thermometer.bs2 program. Have a designated student read the temperature displayed in the debug window aloud at 15 second intervals, either from the computer screen, or from a display if a projector is available.
6. Begin the demonstration by measuring the temperature of the tepid water with the probe. With the probe still in the water, place the beaker in the ice bath. Have the designated student announce temperature at 15 second intervals, while students record data on worksheet.
7. After 5 minutes, stop program, and have students plot temperature over time on graph paper.

8. Discuss the results. Does the trend match the curve predicted by Newton's Law of Cooling?
9. Have students predict the response of tepid water in a hot water bath, shown in Fig 6. Repeat steps 5 through 7 with a hot water and record results. Do the results match the prediction?

Image 5 (left justified)

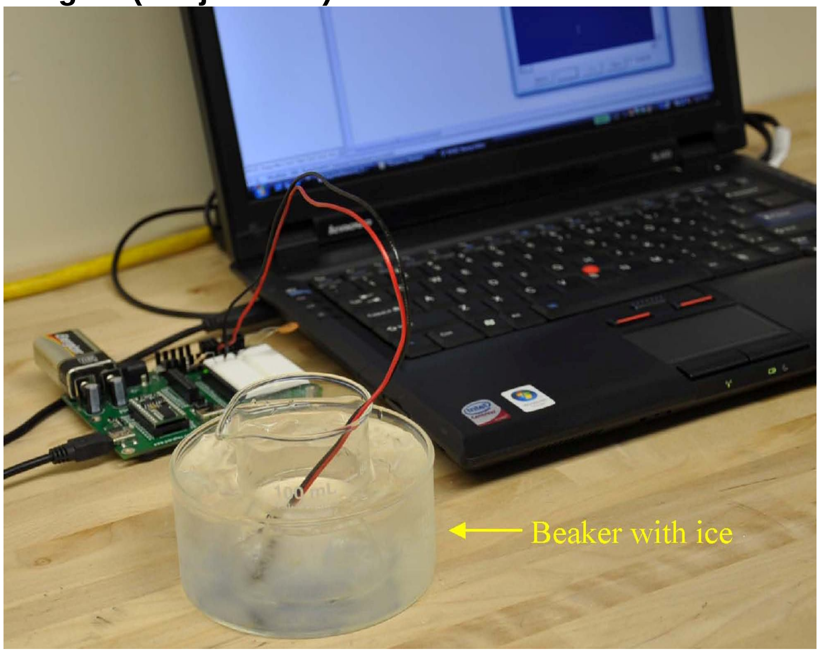

Figure 5
ADA Description: Beaker in ice water bath with temperature probe connected to the Basic Stamp 2 microcontroller and laptop
Caption: Figure 5: Experimental setup with ice water bath
Image file name: fig5.jpeg

Image 6 (left justified)

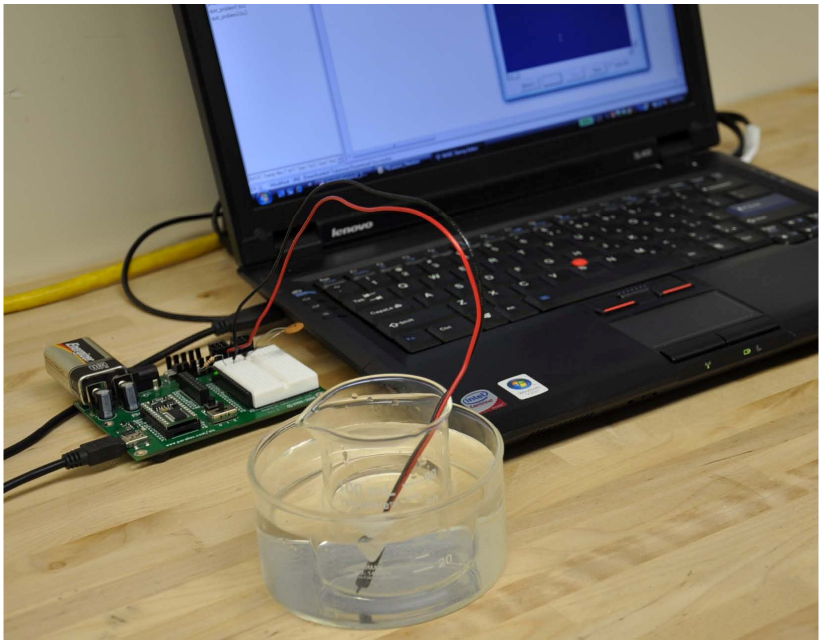

Figure 6
ADA Description: Beaker in hot water bath with temperature probe connected to the Basic Stamp 2 microcontroller and laptop
Caption: Figure 6: Experimental setup with hot water bath
Image file name: fig6.jpeg

Attachments
Thermometer.bs2

Safety Issues
- Water in proximity to electronics always requires caution.

Troubleshooting Tips
Temperature probes tend to drift. This can lead to difficulty calibrating the probe.

Investigating Questions

Assessment

Pre-Activity Assessment
Title: Cool experiences
Where do students encounter heating and cooling in their daily lives? Consider the refrigerator. If you placed a room-temperature can of soda in the refrigerator and waited for it to cool, how would you expect the temperature to change? What happens to its temperature over time?

Activity Embedded Assessment
Title: Attached worksheet

Post-Activity Assessment
Title: Hot experiences
Using the results from the ice bath demonstration, students should predict the response of tepid water in a hot water bath.

Activity Extensions

Activity Scaling

- For lower grades, students can discuss Newton's Law of Cooling and participate in the demonstration using an analog (mercury or other) thermometer.
- For upper grades, students can build the circuit that controls the temperature probes, as well as program the Basic Stamp using the PBasic software. Also, acknowledge that functions with the trend of a cooling curve are called "exponential"

Additional Multimedia Support

References

Giancoli, Douglas C. Physics, principles with applications Prentice Hall: Englewood Cliffs, New Jersey. 1985.

Other

Redirect URL http://gk12.poly.edu/amps-cbri

Owner AMPS GK-12 Program, Polytechnic Institute of New York University

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