26 Heat Transfer
Cooling Curves

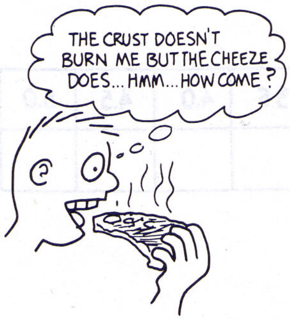
Purpose

To compare the rates of cooling of objects of different colors and surface reflectances.

Required Equipment and Supplies

4 empty soup cans of the same size (one covered with aluminum foil, one painted black, one white, and one any other color)
100-watt light bulb and receptacle
4 thermometers (Celsius) *or*
  Apple II Series computer
  interface box
  temperature probes
  LabTools software
  printer
large test tube
one-hole rubber stopper, with thermometer or temperature probe mounted in it, to fit test tube
600-mL beaker
graduated cylinder
Styrofoam cups with covers
hot water
crushed ice and water mixture
variety of different size, color, and shaped containers made of various materials
meterstick
block of Styrofoam
Data Plotter graphing program (optional)

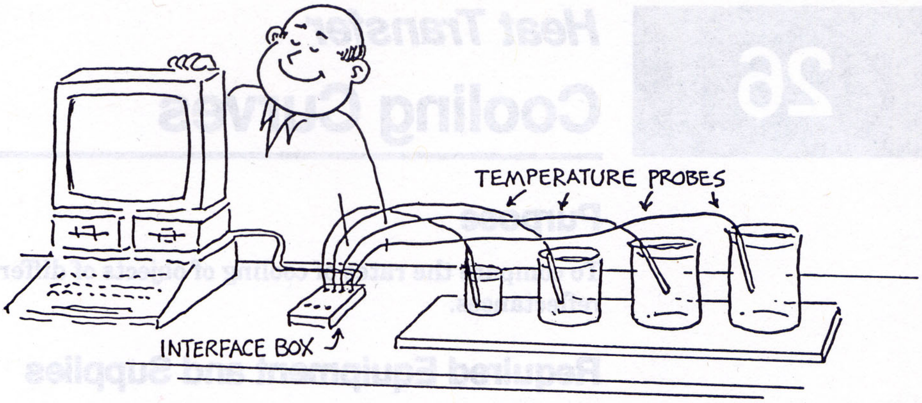
Discussion



When you are confronted with a plate of food too hot to eat, you may have noticed that some things cool faster than others. Mashed potatoes can be comfortably eaten when boiled onions are still too hot. And blueberries in a blueberry muffin are still hot when the rest of the muffin has cooled enough to eat. Different materials cool at different rates. Explore and see.

Procedure

Step 1. Place the four cans 20 cm from an unshielded light bulb. Place a thermometer in each can, and turn on the light. Record the temperature of each can after 1 minute, 2 minutes, and 3 minutes in Data Table 26.1. If a computer is available, use the "Thermometer" program on *LabTools*. Calibrate your probes according to the instructions on the disk. Have a data disk ready to save your data. Monitor the temperature rise of each can. Save your data on a data disk and make a printout to include with your report.



Data Table 26.1

CAN	TEMPERATURE (°C)		
	1 MIN	2 MIN	3 MIN
1			
2			
3			
4			

1. For which can was the temperature rise the fastest?

2. For which can was the temperature rise the slowest?

3. After several minutes the temperature of all the cans levels off and remains constant. Is the can no longer absorbing radiant energy from the bulb?

4. For a can at constant temperature, what is the relationship between the amount of radiant energy being absorbed by the can and the amount of radiant energy being radiated and convected away from the can?

Step 2. Place 25 mL of hot (about 90° C) water in a test tube. Insert the thermometer mounted in the rubber stopper. Place the test tube in a beaker filled with crushed ice and water. Monitor and record the temperatures every 30 seconds for the next 5 minutes in Data Table 26.2. If you have a computer, use the "Thermometer" program and a temperature probe. Set the time interval to 30 seconds, and the computer will automatically plot and record the temperature. If not, make a graph of temperature vs. time.

Data Table 26.2

TIME (MIN)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
TEMP. (°C)											

5. Describe your graph.

Step 3. Fill a Styrofoam cup with hot water and place it on a block of Styrofoam (or equivalent insulator). Monitor the temperature drop with either a thermometer or temperature probe. Record your results in Data Table 26.3. Make a graph of temperature vs. time.

Data Table 26.3

TIME (MIN)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
TEMP. (°C)											

Step 4. Repeat Step 3, but cover the cup with a plastic lid. Poke a hole (if it doesn't already have one), and insert the probe in the water to monitor the temperature. Record your results in Data Table 26.4 and make a graph of temperature vs. time.

Data Table 26.4

TIME (MIN)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
TEMP. (°C)											

6. How do the cooling curves compare?

7. What cooling process is primarily responsible for the *difference* in the cooling rates?

Going Further

Step 5. Place 200 mL of hot water in a variety of containers. You may want to wrap them with various materials. List the containers used.

Predict which container will cool the fastest and which container will cool the most slowly.

Predicted fastest: ____________________

Predicted slowest: ____________________

Step 6. Monitor the cooling with either temperature probes or thermometers. Record which cooled the fastest and which the most slowly.

Observed fastest: ____________________

Observed slowest: ____________________

8. What factors determine the rate of cooling, based on your data from Step 6?

Going Even Further

Step 7. **Plot your data in Step 6 using *Data Plotter*. Make your graph a straight line. Hint: Use the "log of the x-y values" option on "Graph Set-Up".**

9. Describe the graph which results in a straight line. What mathematical relationship exists between the temperature drop and time?