TechLab: Canned Heat

an investigation of thermal absorption and emission

| PERIOD	1.		
	2.		
GROUP	3.		
	4.		

• Purpose •

In this activity, you will investigate the nature of heating and cooling by thermal absorption and emission. Specifically, you will be looking into the correlation (or lack thereof) between the surface characteristics of a container and its ability to absorb or emit thermal radiation.

• Focus Questions •

Do black cans absorb heat better than white ones? Do silver cans emit heat better than black ones? What color T-shirt should you wear on a hot day? What color should a coffee pot be? What kind of a surface should a high-flying plane with hot engines have? What color should you paint your house?

• Apparatus •

___ 3 radiation cans (1 black, 1 white, 1 silver)
___ computer (iBook) - Review Fundamentals of Computer Use
___ 3 temperature sensors - Review Temperature Sensor Use Instructions
___ interface device(s) for sensors - Review Fundamentals of Sensor Use.
___ port-multiplier as needed (USB 4-port hub)
___ adjustable lamp with heat lamp bulb (250W)
___ paper towel   ___ access to cold water   ___ access to hot water
___ water carrier (pitcher or equivalent)

temperature sensors

20 cm

adjustable lamp

heat lamp bulb

radiation cans

interface devices

port multiplier

computer
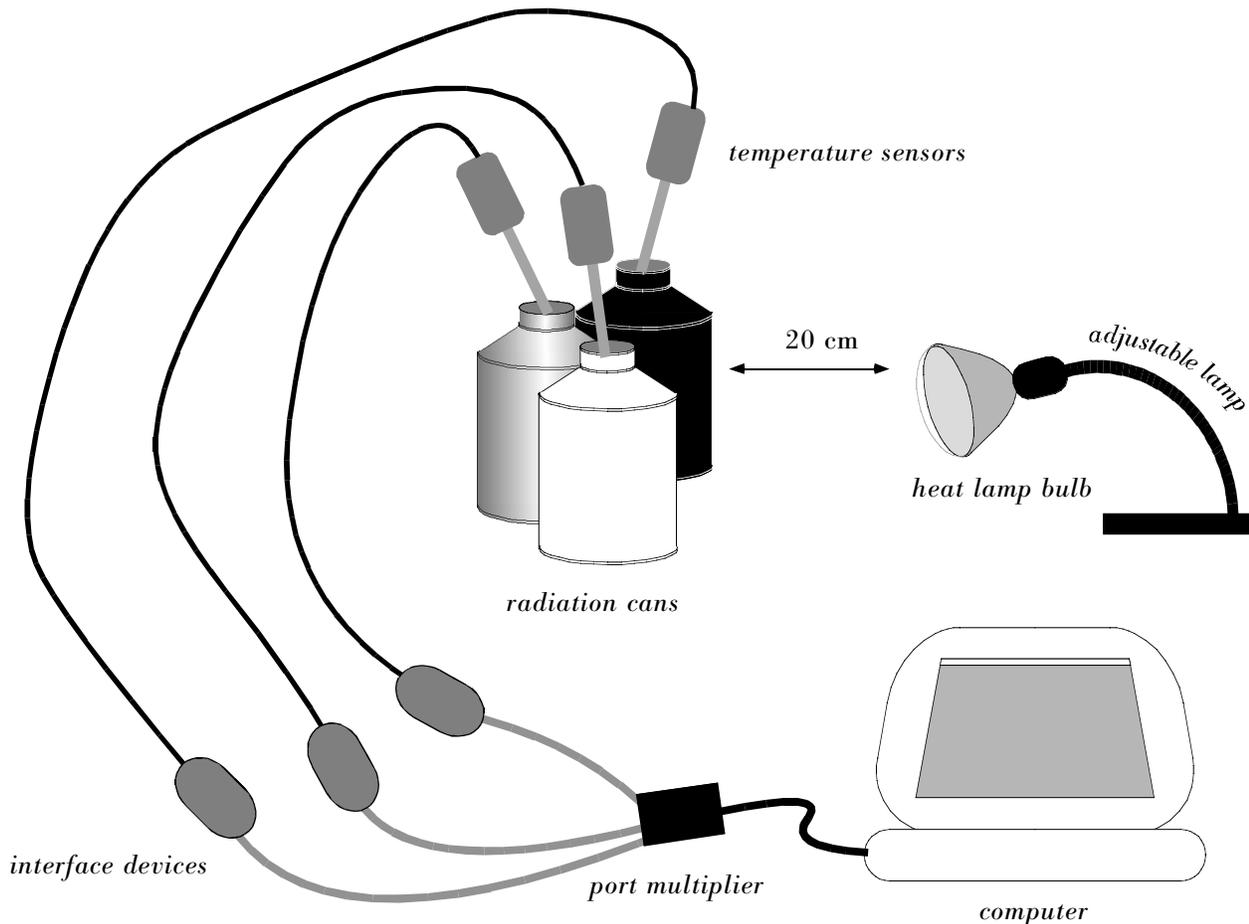
CAUTION: THE HEAT LAMP GETS VERY HOT! IT CAN MELT PLASTIC OR BURN YOU IF PROPER CARE IS NOT TAKEN.

• Procedure •

1. HEATING UP: INVESTIGATING ABSORPTION

a. Predictions. Which of your cans will absorb heat from a lamp the best? In other words, if all cans are filled with cold water and then placed under a heat lamp, which can of water will undergo the quickest increase in temperature? Or will each undergo the same change?

b. IMPORTANT: Computers and water don't mix! Use a thoughtful arrangement of apparatus to keep water away from the computer during the activity. Your group is responsible for keeping water away from the computer during this lab.

Two lab tables pushed together with a small gap between them.

c. Turn the computer on. While it is starting up, connect the temperature probes to the interface devices (USB Links). Connect interfaces to the port multiplier (USB Hub).

d. When the computer has completed its start-up process, connect the port multiplier (or the interfaces) to the computer. After a few seconds, the computer will ask you what to do now that you've connected the sensors. Select the "Launch DataStudio" option. The software will configure itself for taking temperature data.

e. Save the activity. Go to the file menu and select "Save Activity As." This will open a "Save" dialogue box. Navigate to the apprpriate folder on the computer's hard drive (if you're not already there). Give the activity a title using the following protocol: N Conceptname PG where N is the unit number (e.g. 1.01-2.12), Conceptname is a brief word description of the activity, P is the period, and G is the group. For example, "1.07 Can Heat 2G" would be a document saved by a 2nd period student in group G working on a unit 1.07 lab having to do with heating a can. Click "Save."

Ask your instructor for the correct filepath.

f. Fill the cans with cold water. All cans should be filled to capacity. It is best to fill a larger container (milk carton or pitcher) at a faucet and fill the cans from water in the larger container. If filling from a faucet, fill all cans from the same faucet; all cans should start at the same temperature as nearly as possible.

g. Wipe up spilled water and water on and around the cans.

h. With the lamp still off, arrange the heat lamp so that its light will strike all cans with equal intensity. (Do not set them in a straight line!)
   • **Aim low:** the light should hit the **body** of the can more than the top of the can. If the lamp is aimed too high, its thermal radiation could melt the sensors.
   • The cans must not touch each other.
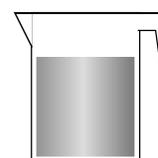   • **The cans must be at least 20 cm away from the heat lamp bulb.**

i. Place one temperature sensor in each can. Wipe up any spillage.

j. Allow one minute for the sensors to equilibrate to the temperature of the water. **Use the temperature sensors as stirrers to keep the water agitated during the data sampling.** A gentle swirling motion is recommended.

k. Click the on-screen "Start" button to initiate data sampling. Move the cursor (arrow) away from the on-screen "Stop" button to prevent accidental termination of the sampling session. **Keep the water agitated as long as data sampling continues! Do not stop data sampling until instructed to do so (at the end of step "m").**

l. Do not stop the data sampling already in progress. Turn on the heat lamp and continue data sampling for 10–15 minutes. **Keep the water agitated!** While the graphing is in progress, maximize the graph window by clicking the maximize button in the title bar. Get a better view of the temperature graphs by clicking the Scale to Fit Tool. The Scale to Fit Tool is the first tool (that is, farthest to the left) in the graph window's toolbar. Clicking it should magnify the data to fit the entire window.

The data sampling may appear to "stall" from time to time during the trial. Don't worry, it'll catch up. As long as the digital time reading at the top center of the screen has green digits (not red digits), data sampling is occurring. This is true even if the digits themselves are not advancing. If you think there is a problem, ask the teacher for help, but do not stop the sampling.

m. When the data sampling interval has concluded, turn off the heat lamp **but do not stop the data sampling.** Instead, disconnect the temperature sensors in alphabetical order. (Pull their individual USB link plugs from the several ports—or hub—they are connected to; do not remove the sensors from the water, do not disconnect the USB hub from the computer, and do not disconnect the probe from its box.) First, disconnect the temperature sensor in the **b**lack can. Observe the on-screen graph and note which line stopped. Next, disconnect the **s**ilver. The only graph continuing to plot is the **w**hite. Now stop the data sampling by clicking the on-screen "Stop" button.

n. Use the Note Tool to label the graph for the black can, silver can, and white can. The Note Tool is among the tools in the graph window, its icon is the letter "A." Select the Note Tool, then click somewhere in the graph window. A dialog box will appear. Type the information you wish to display and click "OK." Use the handles on the corners of the text box to resize it. Drag the text box to an appropriate location. Drag the tip of the pointer to an appropriate location. None of the boxes should cover any of the data, and none of the pointer lines should cross a plotted line. For that matter, the legend should not cover any data, either. If it does, move it so that it does not.

o. Rename the run titles. In the Data section of the Summary window (column to the far left on the screen), you see the names of the sensors (Temperature, Temperature2, and Temperature3). Beneath the name of each sensor is the title of each trial made with that sensor (Run #1). Now that you know the identity of each plot, rename the titles of each run. That is, click once on the title "Run #1" under the sensor named "Temperature." Wait a moment, then click it once again. "Run #1" becomes editable text. Type the appropriate color of the can. When asked if DataStudio should rename all data from this run, click "No." Now, repeat for Run #1 of Temperature2 and Temperature3.

p. Determine the minimum and maximum temperatures for the water in the three cans. Click the Statistics Tool, whose icon is the capital letter sigma ( ).

Black Can   Minimum Temperature_____   Maximum Temperature_____

Silver Can   Minimum Temperature_____   Maximum Temperature_____

White Can   Minimum Temperature_____   Maximum Temperature_____

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q. Save the activity again (File: Save).

r. Prepare to print the graph. Make sure the graph window is selected (active) by clicking once anywhere in the graph. Go to the File menu and select "Page Setup." Choose the wide orientation (landscape). Once the wide orientation is selected, click "OK." Save the file again.

s. Obtain a PhyzBlessing. Once you have secured a PhyzBlessing, go to the File menu and select "Print...." Enter the number of copies you need so that each member of the group gets one. Then click "OK."

t. Determine the change in temperature for each can. Which can underwent the greatest change in temperature? Draw a box around it.

Black:_____   Silver:_____   White:_____

u. How do your observations compare to your predictions?

2. COOLING DOWN: INVESTIGATING EMISSION
If you have been using the heat lamp, you can put it away now.
   a. Predictions. Which of your cans will emit or radiate its internal energy fastest and which will radiate slowest? If the cans are filled with hot water and allowed to sit and cool, which can of water will undergo the quickest drop in temperature and which will undergo the slowest drop in temperature?

b. Set up. The computer should be configured as before (with the temperature sensors plugged in). If DataStudio is already open, go to the File menu and select "New Activity."

c. Save the new activity. Go to the file menu and select "Save Activity As." (See the instructions for saving in the previous activity if you're not sure how to proceed.) Use a file name that is slightly different than the one you used for the previous activity.

d. Be prepared to move quickly. Fill the cans with hot water. THE WATER MAY BE SCALDING HOT: HANDLE IT WITH CARE! Leave your cans at your lab station and use a larger container to transport hot water to the cans. Fill the cans to capacity and **space them at least 30 cm apart.** Don't worry about spills yet.

e. Click the on-screen "Start" button to initiate data sampling. **After sampling has begun,** place the sensors in the cans in alphabetical order. Black can first; then wait a few moments. Then silver, then white. By examining the plots, you can identify which graph corresponds to which can.

f. **Use the sensors to agitate the water during data sampling.** Clean up any spilled water. Continue recording data for 10-15 minutes. The longer you can record data, the better the results will be. Keep the water agitated.

g. When the data sampling interval has concluded, stop the data sampling by clicking the on-screen "Stop" button.

h. Use the Note Tool to label the graph for the black can, silver can, and white can.

i. Rename the run titles. In the Data section of the Summary window (column

to the far left on the screen), you see the names of the sensors (Temperature, Temperature2, and Temperature3). Beneath the name of each sensor is the title of each trial made with that sensor (Run #1). Now that you know the identity of each plot, rename the titles of each run. That is, click once on the title "Run #1" under the sensor named "Temperature." Wait a moment, then click it once again. "Run #1" becomes editable text. Type the appropriate color of the can. When asked if DataStudio should rename all data from this run, click "No." Now, repeat for Run #1 of Temperature2 and Temperature3.

j. Determine the extent to which each can cooled down. Click the Statistics Tool ( ) to view the minimum and maximum temperatures recorded during the trial. Unfortunately, the minimum temperatures displayed correspond to the early moments in the trial when the probes were still measuring the air temperature in the room. To get around this problem, we will select sections of each data set to analyze.

In the Legend box (showing the Minimum and Maximum temperatures), click to select the Black can. Then, move the cursor near to the end of the black can plot. Make sure the cursor is to the right and below the end of the plot. Click down and drag up and to the left to create a selection rectangle enveloping the cooling portion of the graph only. That is, go left until you reach the peak of the plot. Then release the mouse or trackpad key. The statistics displayed in the Legend box now reflect the values in the selected range of the graph only.

Black Can   Peak Temp. (Max)_____   Final Temp. (Min)_____   Change_____

Silver Can   Peak Temp. (Max)_____   Final Temp. (Min)_____   Change_____

White Can   Peak Temp. (Max)_____   Final Temp. (Min)_____   Change_____

k. How do your observations compare to your predictions?

l. Save the activity (File: Save).

m. Clean up the graph. Remove the statistics by clicking the statistics tool button ( ) again. De-select the highlighted portions of each graph to remove the yellow highlighting. You must do this one data set at a time.

n. Prepare to print the graph. Make sure the graph window is selected (active) by clicking once anywhere in the graph. Go to the File menu and select "Page Setup." Choose the wide orientation (landscape). Once the wide orientation is selected, click "OK." Save the file again.

o. Obtain a PhyzBlessing. Once you have secured a PhyzBlessing, go to the File menu and select "Print...." Enter the number of copies you need so that each member of the group gets one. Then click "OK."

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• Post-Lab Questions •

1. Rank—in order of best absorber to worst absorber—the three cans.

2. What color T-shirt should you wear on a hot day: black or white? Defend your answer with evidence from the lab.

3. Which can, black or silver, was the poorer emitter of radiation?

4. What color **should** a coffee pot be, black, silver, or white? Defend your answer with evidence from the lab.

5. Is it a good idea to wrap hot food in aluminum foil? Aluminum foil is more expensive than paper and a much better conductor of heat.

6. What color surface should a high-flying jet with hot engines have: silver or black? (Low flying jets rely on conduction with the surrounding air to cool the engines; high flying jets move through thinner regions of the atmosphere where conduction is less effective.) Defend your answer with evidence from the lab.

7. What color should you paint your house? Is the best color in the summer also the best color in winter? (In the summer, you don't want your house to absorb heat from the warmer surroundings; in the winter, you don't want your house to radiate heat to the cold surroundings.) Defend your answer with evidence from the lab.

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