Building a Thermometer

Purpose

To build an instrument that can be used to measure water temperature

Overview

Students will construct a soda-bottle thermometer, which is similar to the thermometer used by GLOBE schools. Both are based on the principle that most substances expand and contract as their temperature changes. This experiment also demonstrates the principle of heat transfer.

Student Outcomes

Student will understand why and how a standard thermometer works.

Science Concepts

Physical Science

Substances expand and contract as they are heated and cooled.

Geography

The temperature variability of a location affects the characteristics of the physical geographic system.

Scientific Inquiry Abilities

Identify answerable questions.

Design and conduct scientific investigations.

Construct a scientific instrument.

Develop explanations and predictions using evidence.

Communicate results and explanations.

Time

Two class periods

1. To do experiment - one class period
2. To discuss principles of expansion, contraction, and heat transfer through conduction and convection – 15 to 30 minutes
3. To record class data onto board or overhead and make graphs – 30 minutes
4. To have each group present to the class their results, ideas for other variables to test, and any problems that they encountered – 30 minutes

Level

Intermediate

Materials and Tools

(per group of students)

Ice

Water

One liter plastic soda bottle

Clear or white plastic drinking straw

Modeling clay. A one-pound block of modeling clay should be enough for 25 to 30 thermometers

Two 2-liter plastic soda bottles – the tops of these bottles need to be cut off

Scissors or knife to cut the top off the 2-liter plastic bottles

Food coloring (yellow does not work as well as red, blue, and green)

A watch or clock with a second hand

A metric ruler

A marker, grease pencil, or pen to mark the side of the straw

Building a Thermometer Activity Sheet

Preparation

Assemble materials.

Review principles of heat transfer.

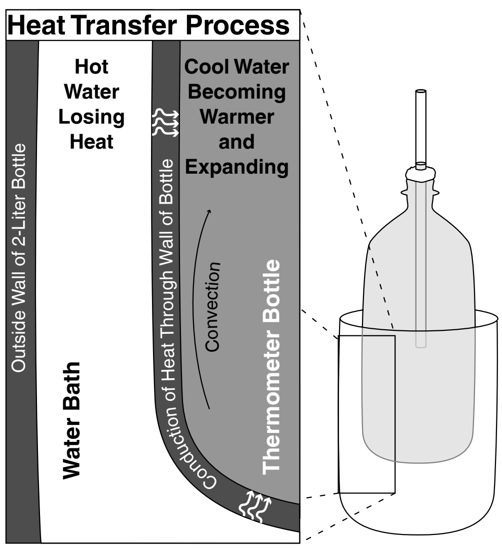
Prerequisites

Ability to make a graph

Background

Several scientific principles are at work in this activity. One is the principle of expansion and contraction. Most substances expand when heated and contract when cooled. Over the range of temperatures in this experiment, water too expands when heated and contracts when cooled. (As water approaches its freezing point, it again expands.)

Figure AT-TH-4



Substances expand when heated because their kinetic energy, or energy of movement, increases with temperature. The molecules move faster and spread farther apart, causing the material to expand. When the substance is cooled, molecular movement decreases and the substance contracts.

In the case of water, the coefficient of expansion is quite small, so the volume of the water increases by only a very small percentage. Nonetheless, because all of the increase in volume is channeled into the small-diameter straw, the expansion can be seen.

This experiment also illustrates heat transfer by conduction. Conduction occurs when energy is transferred from one molecule to the next by direct contact, such as when the metal handle of a pan becomes hot. Metals are good conductors of heat. Wood is a poor conductor. In this experiment, the warm water in the outer container transfers its heat by conduction through the plastic wall of the one-liter bottle to the water in the inner bottle.

Convection is the large-scale movement of a liquid or a gas which acts to redistribute heat throughout an entire volume. A common example of convection is water boiling in a pot. In this case, the water in contact with the bottom of the pot (where the heat source is) becomes heated and less dense than the water on top of it. This hot water rises, cooler water sinks and is then heated by contact with the bottom of the pot.

Preparation

This activity works well in teams of two or three students. Here are some job assignments and descriptions:

Student 1 Assembler – gathers materials and assembles the thermometer

Student 2 Timer/reporter – keeps track of 2-minute intervals when the experiment starts – makes marks on the straw showing how much the water has moved – measures the straw at the end of the experiment and tells the recorder the measurements – reports to the class the results of the experiment

Student 3 Recorder – records the measurements that the timer has made – also transfers the group's measurements onto the *Data Sheets.*

Make a copy of the *Building a Thermometer* Activity Sheet for each group of students.

The teacher should assemble materials before the class starts. If small groups are to be used, they should be assigned in advance. Students should bring in the 1-liter and 2-liter soda bottles. Allow a week or so to collect the necessary materials if students are supplying the bottles. Review the possible problems below before doing the experiment in class.

Be sure to understand the principles of heat transfer (conduction and convection) and the expansion and contraction of materials. Some examples of each in different situations would be helpful for a discussion. You may need to review how to measure in millimeters with the students.

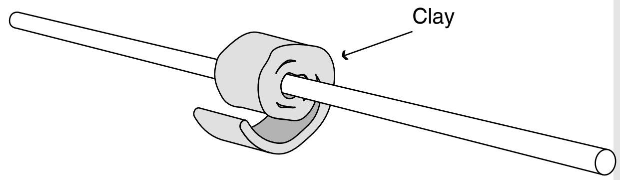
What To Do and How To Do It

This activity can be done as a demonstration but is probably more effective if students or groups of students make their own thermometers. These instructions also appear on the *Building a Thermometer* Activity Sheet in the *Appendix* which can be copied and distributed to students.

Building the Thermometer

1. Fill the 1-liter soda bottle to the very top of the lip with cold tap water.
2. Add four drops of food coloring. This makes the water line easier to see. Blue, green, or red work best.
3. Roll some modeling clay into a small ball about 25 mm in diameter. Then roll it out so that it forms a cylinder about the length and diameter of a pencil. Flatten the pencil-shaped clay into a thick ribbon. Wrap the ribbon around the mid-point of the straw. See Figure AT-TH-5.

Figure AT-TH-5



Team Data Sheet *measurements in millimeters*

2 minutes	
4 minutes	
6 minutes	
8 minutes	
10 minutes	

Class Data Sheet

	Group A	B	C	D	Average
2 minutes					
4 minutes					
6 minutes					
8 minutes					
10 minutes					

4. Place the straw into the bottle and use the clay to seal off the bottle. Be careful not to pinch the straw closed. You also do not want any holes or cracks in the clay that would allow water to escape. One half of the straw will be inside the bottle and one half will be outside the bottle. Press the clay plug into the neck of the bottle far enough to force the water level up into the straw so that it can be seen. See Figure AT-TH-6.

Experiment

1. Place the filled one-liter bottle (soda-bottle thermometer) into one two-liter plastic bottle container. Place a mark on the straw where you see the water line.
2. Fill the 2-liter container with hot tap water. Wait two minutes. Mark the straw at the water line. Repeat this marking every two minutes, for ten minutes. At the end of the ten minutes, use a ruler to measure the distance of each mark from the original water mark at the bottom of the straw. Record your measurements on the Team Data Sheet.
   Watch closely for any changes. Do you see any? Describe what you observe.
3. Put ice and cold water into the second two-liter container.
4. Place the thermometer bottle into the ice water. Record your observations.
5. What happens to the water level in the straw when the thermometer is placed in hot water? (Answer: It rises about 4 cm if there's a 25 degree C difference.)
   What happens to the water level when the thermometer is placed in cold water? (Answer: It falls.)
6. Explain why you think this is happening.
7. Using your answer to question 6, how does the maximum-minimum thermometer, used for the noon temperature measurements for GLOBE, work?
8. What are two other things (variables) that, if changed, might cause this experiment to work differently? (A few answers: the amount of water touching the soda-bottle thermometer, the temperature of the water, the size of the container, the diameter of the straw.)
9. Graph the measurements that you recorded on your team data sheet. The x-axis (horizontal) should be the time (in minutes) and the y-axis (vertical) should be your measurements from the original line before the hot water is added (in millimeters). Be sure to give your graph a title and to label the axes of the graph so that someone else could understand it.
10. Make a class data sheet on a chalkboard or on a sheet of poster paper. Record your data on the *Class Data Sheet*. Combine your data with that of your classmates to find the average movement of water for each two-minute time period.
11. Add the average figures for the movement of water to your graph. Be sure to label this new line. How is the graph of your measurements different from the graph of the class average?

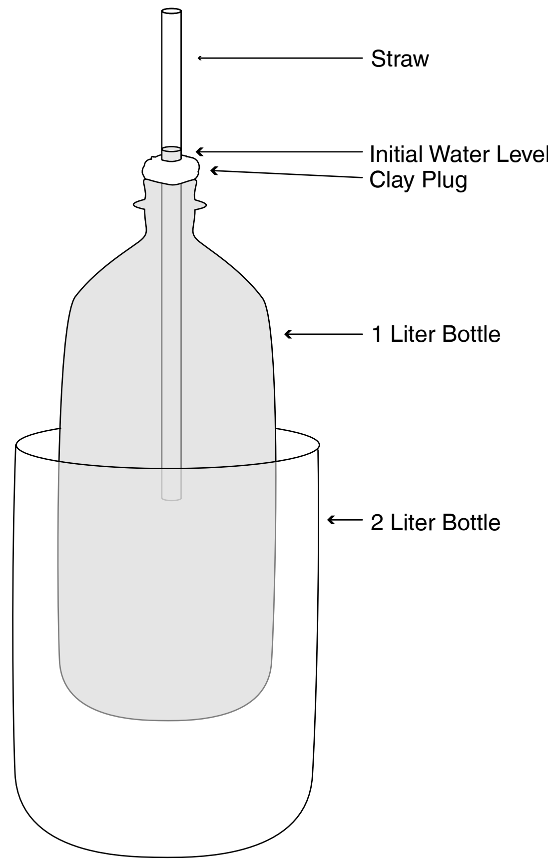


Figure AT-TH-6

12. Explain the graph. What story does your graph tell? Can you draw any conclusions?
13. Why might it be important to have more than one trial when you are drawing conclusions?

Possible Problems with the Experiment

- The seal with the modeling clay has cracks in it, allowing the water to escape
- If the 1-liter water bottle is not filled to the top, it takes a longer time for the water to move up the straw. Indeed, the water may not move up the straw at all.
- There is not enough of a temperature difference between the water in the 1-liter bottle and the water in the 2-liter bottle. A 25 degree Celsius or larger difference is optimum. If there is a smaller difference, you will not get very large movements on the straw. Hot tap water and cold tap water should have enough of a difference for the experiment to work.
- Students will forget to mark the beginning level in the straw. Be sure that they understand that the mark should be made immediately after placing the 1-liter bottle into the 2-liter bottle, before adding the hot water.
- If you have trouble getting or keeping ice in the classroom, you can omit this part of the experiment or show it as a demonstration.

Adaptations for Younger and Older Students

For younger students: Younger students can make the thermometer apparatus and observe the movement of the water in the straw, but not mark the water level at two-minute intervals. The teacher should cut the two-liter plastic container ahead of time.

For older students: Other variables could be tested, such as different size straws, larger or smaller containers for the hot water, or different size containers for the thermometers. The students could design their own experiment, conduct it, and present their findings to the class. They could calibrate their thermometer with a standard thermometer.

Further Investigations

1. Use a standard thermometer to measure the temperature of the water in the inside of the soda-bottle thermometer and compare it to the temperature of the water outside the thermometer. Does the amount of water movement in the straw change when there are different temperatures? Perform an experiment, keep records, and present your findings to the class.
2. Does the size of the containers affect the way the thermometer works? Design an experiment that tests this concept, do the experiment, and make a chart showing your results.
3. Go to the library and research what materials are used to make different thermometers. Be sure to find out the different principles on which they operate. Present your findings to the class.
4. Call the local weather offices or television or radio stations and see what type of thermometers are used there. Take a trip to visit the weather station. Take pictures and make a poster to share with your class.
5. Make thermometers using different diameters of straws and see if there are any differences. What do you think might have caused any differences you see? Would this have an effect on the construction of real thermometers?
6. Find out how scientists record the temperature at different depths of the ocean. On a map of the oceans, show the average water temperature. Make a chart to share with the class.

Student Assessment

Students should be able to answer the questions in the experiment on the student activity sheet. They should also be able to explain how a thermometer works in class or on a quiz.

Building a Thermometer Activity Sheet

Purpose

To help you understand how and why a liquid-in-glass thermometer works.

Overview

The soft drink bottle thermometer that you construct in this activity is similar to the thermometer you use in the GLOBE Instrument Shelter. However, there are differences. Both use liquids, but the liquids are different. Do you know what liquid is in the standard GLOBE thermometer? Also, the thermometer you will make has no degree markings. But the principles of operation are the same for both types of thermometers.

The thermometer you use for measurements and the instruments you will build are both based on the principle that substances expand and contract as their temperature changes.

This lab also demonstrates the principle of heat transfer. When a warm object is placed against a cold object heat is transferred from the warm object to the cold object by conduction. For example, in the winter if you place your bare hand on the fender of an automobile, your hand transfers heat to the metal by conduction.

Usually when you work in a job, you are part of a team. In this activity you will also be part of a team. Here are your job descriptions:

Student 1 – assembler - gathers materials and assembles the thermometer

Student 2 – timer/reporter - uses clock or watch to keep track of 2-minute intervals when the experiment starts - makes marks on the straw showing how much the water has moved - measures the straw at the end of the experiment and tells recorder the measurements - reports to the class the results of the experiment

Student 3 – recorder - records the measurements that the timer has made - also transfers the group's measurements onto the class chart

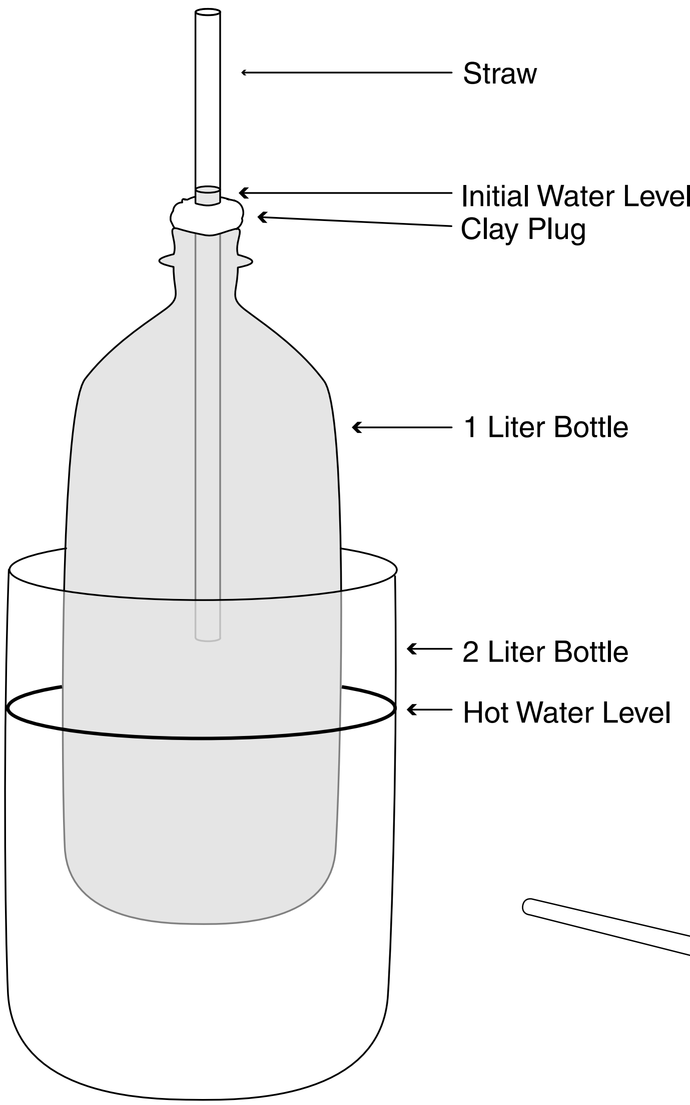
Materials and Tools

(per group of students)

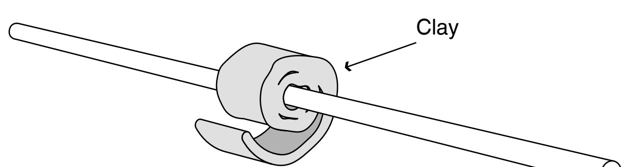
Ice
Water
One liter plastic soda bottle
Clear or white plastic drinking straw
Modeling clay (a ball about 25 mm in diameter)
Scissors or knife to cut the top off the two liter plastic bottle
2 two-liter plastic soda bottles - the top of the bottle needs to be cut off so that it is used as a container to hold water and the 1 liter plastic soda bottle
Food coloring (yellow doesn't work as well as red, blue, and green)
Watch or clock with second hand
Metric ruler
Marker, grease pencil, or pen to make marks on the side of the straw

Building the Thermometer

1. Fill the one liter soft drink bottle to the very top of the lip with cold tap water.
2. Add four drops of food coloring – this helps make the water line easier to see. Blue, green, or red work best.



3. Roll some modeling clay into a small ball about 25 mm in diameter. Then roll it out so that it forms a cylinder about the length and diameter of a pencil. Flatten the pencil-shaped clay into a thick ribbon. Wrap the ribbon around the midpoint of the straw.
4. Place the straw into the bottle and use the clay to seal off the bottle. In doing this, be careful not to pinch the straw closed. You also do not want any holes or cracks in the clay that would allow water to escape. One half of the straw will be inside the bottle and one half will be outside the bottle. Press the clay plug into the neck of the bottle far enough to force the water level up into the straw so that it can be seen.



Experiment

1. Place the filled one liter bottle (the soft drink bottle thermometer) into the empty two liter plastic bottle container. Place a mark on the straw where you see the water line.
2. Fill the two liter container with hot tap water. Wait two minutes. Mark the straw at the water line. Repeat this marking every two minutes, for ten minutes. At the end of ten minutes use a ruler to measure the distance of each mark from the original water mark at the bottom of the straw. Record your measurements in millimeters under “hot water” in the table below.

Team Data Sheet

Time	*Hot Water*	*Cold Water*
2 minutes		
4 minutes		
6 minutes		
8 minutes		
10 minutes		

Watch closely for any changes. Do you see any? Describe what you observe.

____

____

3. Put ice and cold water into the second two-liter container.
4. Place the thermometer bottle into the ice water. Record your observations in millimeters under "cold water" in the table above.

5. What happens to the water level in the straw when the thermometer is placed in hot water?

____

____

____

What happens to the water level in the straw when the thermometer is placed in cold water?

____

____

____

6. Explain why you think these changes happen.

____

____

____

7. Using your answers to question 6, how does the maximum-minimum thermometer used for the GLOBE measurements work?

8. What are two other things (variables) that, if changed, might cause this experiment to work differently?

9. Graph the measurements that you recorded in your team data sheet at step number 2. The x-axis (horizontal) should be the time (in minutes) and the y-axis (vertical) should be your measurements (in millimeters) from the original line before the hot water was added. Be sure to give your graph a title and to label the axes of the graph so that someone else could understand it.

10. Record your data on the *Class Data Sheet* on the board or as your teacher instructs. Combine your data with that of your classmates to find the average movement of water for each two-minute time period.

11. Add the average figures for the movement of water to your own graph. Be sure to label this new line. How is the graph of your measurements different from the graph of the class average?

12. Explain the graph. What story does your graph tell? Can you draw any conclusions?

13. Why might it be important to have more than one trial when you are drawing conclusions?