SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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SCOPE, SEQUENCE, and COORDINATION

> **National Science Education Standard—Earth and Space**
> **Energy in the Earth System**
> Earth systems have both internal and external sources of energy, both of which create heat. The sun is the major external source of energy.

Teacher Materials

Learning Sequence Item:

938

Heat, Temperature, and Transfer

March 1996
Adapted by: Linda W. Crow

Heat from Within Earth and Heat from the Sun. Students must be able to measure temperature and understand units of heat, initially in calories, since that unit is easily connected to the heating of water. For students to understand these concepts and relationships, they must experiment with both heat and heat transfer and the sun as a source of energy that produces heat *(Earth and Space Sciences, A Framework for High School Science Education, p. 131).*

Contents

This micro-unit was adapted by Linda W. Crow (University of Houston-Downtown)

938

Learning Sequence

Heat from Within Earth and Heat from the Sun. Students must be able to measure temperature and understand units of heat, initially in calories, since that unit is easily connected to the heating of water. For students to understand these concepts and relationships, they must experiment with both heat and heat transfer and the sun as a source of energy that produces heat. *(Earth and Space Sciences, A Framework for High School Science Education, p. 131.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Hot Sources **Activity 1**		Clues to Past Climate Found Down a Hole **Reading 1**	Matters of Heat and Fire **Assessment 1**
Solar Heating **Activity 2**		The Sun's Effect on Global Warming **Reading 2**	Pigs on Ice! **Assessment 2**
Radiometer Experiment **Activity 3**		Do Solar Variations Change Climate? **Reading 4**	
Measuring the Temperature of Three Liquids **Activity 4**			
The Divided Cup **Activity 5**			
Great Bolts of Fire! **Activity 6**			
Putting on the Heat **Activity 7**			
Radiating Cans **Activity 8**			

Suggested Sequence of Events

Event #1

Demonstration

1. Hot Sources (15 minutes)

Event #2

Demonstration

2. Solar Heating (10 minutes)

Alternative or Additional Demonstrations

3. Radiometer Experiment

Event #3

Lab Activity

4. Measuring the Temperature of Three Liquids (20 minutes)

Alternative or Additional Activity

5. The Divided Cup (30 minutes)

Event #4

Lab Activity

6. Great Bolts of Fire! (20 minutes)

Alternative or Additional Activity
Demonstration

7. Putting on the Heat (20 minutes with discussion)

Event #5

Lab Activity

8. Radiating Cans (20 minutes)

Event #6

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

The following readings are included in the student version of the unit:

Clues to Past Climate Found Down a Hole
The Sun's Effect on Global Warming
Do Solar Variations Change Climate?

Suggested readings:

Monastersky, Richard, "Dusting the Climate for Fingerprints," *Science News*, Vol. 147, No. 23, Science Service, Inc., pp. 362–363.

Assessment items can be found at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple-choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Hot Sources

Where does heat come from?

Demonstration

Overview:

This activity consists of a series of heat phenomena demonstrating sources and transformations.

Materials:

Per class:

coat hanger or wire
nail and hammer
plaster of paris, 1/4 cup
water
plastic reclosable bag
20-watt bulb with socket

Procedure:

This demonstration works best if students are involved in the actual process. It is composed of a series of different, quick activities selected to illustrate possible heat sources. Some can be done with the entire class while others may require that you select a volunteer/victim from the class. The focus of these activities is to demonstrate that heat can be produced from a variety of sources and by a variety of methods.

Rubbing Hands: Have students stand by their seats and rub their hands together several times. Ask them to describe the changes that they feel (heat energy from mechanical energy).

Bending Metal: Use a coat hanger or wire that can be moved back and forth several times. Select a student to feel the wire before and after the bending (heat energy from mechanical energy).

Plaster of Paris and Water: Select a student to hold a plastic reclosable bag that has 1/4 cup of plaster of paris in it. Slowly add water until it forms a thick syrup texture. Have the student close the bag and agitate the mixture in his/her hand (heat energy from chemical energy).

Sun: This demo requires some sunlight and access to an outside area. If possible move the entire class outside. Have them stand with one arm in the sun and the other in the shade. After a short period of time, ask them to describe what they felt on each arm (heat energy from light energy).

Bulb: This demo is a good alternative to demo #4. Have students place their hands close to a lighted bulb. Ask them to describe what they feel (heat energy from light energy).

Background:

The production of heat energy is usually indicated by an increase in temperature. Heat energy has been added if the temperature increases. Transformation of one type of energy to another can occur with all forms of energy. However, the total amount of energy remains constant as it changes form.

This demonstration sets the stage for associating the sun as the source of energy on Earth. A brief study of radiation, heat, and temperature is conducted. It will be revisited later!

Variations:

Demonstrate an endothermic reaction (sodium thiosulfate and water), and ask students to explain why they think the mixture gets cooler.

Adapted from:
"Heat," Operation Physics, American Institute of Physics, 1988.

Science as Inquiry

Solar Heating

How does solar heat reach the Earth?

Demonstration

Overview:

This simulation demonstrates the transfer of heat through a vacuum.

Materials:

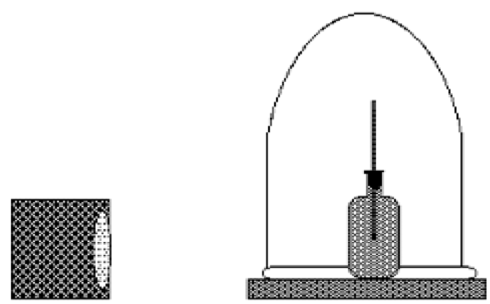
Per class:

bottle (pint size, clear and flat)
1-hole stopper (fits bottle)
thermometer
bell jar
vacuum pump
electric heater
water

Procedure:

This demonstration requires a little time to set up but very little time to execute. Fill the bottle with water and stopper it . Insert the thermometer and measure the initial temperature of the water. This can all be done before the class begins.

With students present, place the bottle (filled with water and stoppered) inside a bell jar on the vacuum stand. Make sure there is a good seal. Using the pump evacuate the bell jar. On the outside of the bell jar, place an electric heater so that it faces the jar. Turn it on and have students note the changes in temperature.



Bottle in Bell Jar with Heater

Background:

The focus here is to demonstrate that heat can be transferred through a vacuum. After the heater has been turned on, an increase in temperature should be noted. This demonstration attempts to simulate what is occurring when the sun produces solar energy and moves through space (a vacuum) to Earth. This is an example of the radiation of heat.

Variations:

A light bulb is composed of a glass bulb that has been at least partially evacuated. A hand held close to this bulb will begin to warm.

Adapted from:
"Heat," Operation Physics, American Institute of Physics, 1988.

an alternative activity for Event 2

Teacher Sheet

Science as Inquiry

Radiometer Experiment

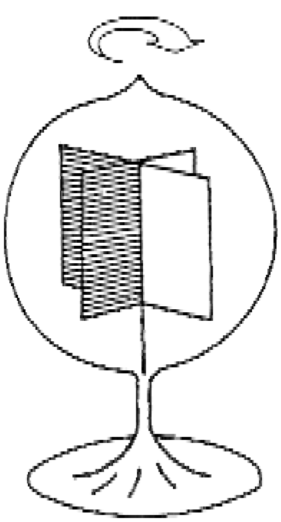
How does solar heat reach the Earth?

Overview:

A common radiometer is used to demonstrate radiation.

Materials:

Per class:
radiometer
light source (overhead projector turned on its side, sunlight, lamp)
black cloth (12-in square)



Procedure:

Have students place the radiometer in a bright light and observe what happens under different conditions of light. Ask them to explain in terms of heat, particles (or molecules), and pressure what they observe.

Background:

The vanes of a radiometer have a shiny mirrored side and a black side. The glass chamber that surrounds these vanes has been evacuated so that there are very few molecules remaining and very little pressure inside the chamber. This low pressure allows for a greater difference between energy transferred between the shiny side and the darker side of the vane. The effect of an increase in energy of the gas molecules compared to the number of molecules present is enhanced.

As the radiometer is exposed to bright light, gas particles on the black side of the vane gain energy upon collision with the vane. Thus they are made hotter. Since the gas particles bounce off at a greater velocity than before, this change in momentum imparts a reaction force to the vane, causing it to move away. The pressure, therefore, increases on the black side. The vanes begin to rotate with the black sides moving away from the bright light source. Note that this is opposite to the directions one would expect if it were radiation pressure. Radiation bouncing off the shiny side would impart twice the force to the shiny side than to the black side that absorbs radiation.

Variations:

Students could vary the experiment by moving the light source to see what effect this varying distance and position has on the outcome.

Adapted from:

Ehrlich, Robert, *Turning the World Inside Out*, Princeton: Princeton Univ. Press, 1990.

Teacher Sheet

Science as Inquiry

Measuring the Temperature of Three Liquids

How does heat compare to temperature?

Overview:

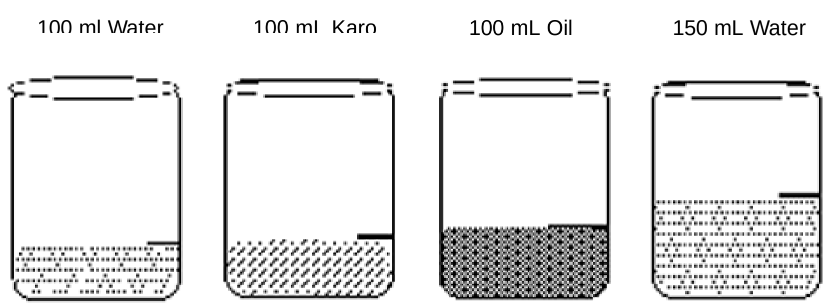
A variety of liquids and varying volumes are used to examine heat and temperature. One word of caution, the oil is messy. Some caution should be used when heating the oil. It might be wise to let only a few groups heat the oil or do that portion as a demonstration.

Materials:

Per lab group:
250-mL beakers, 4
Celsius thermometer
hot plate
water, 250 mL
Karo Syrup, 100 mL
cooking oil, 100 mL
hot pad (hot hands or beaker tongs)
ring stand with ring, clamp
safety goggles

Procedure:

Have students place 150 mL of water in a 250-mL beaker. They should then place the beaker on the hot plate and turn the hot plate to high. Have them heat the beaker of water for 5 minutes. While this beaker of water is heating, they should place 100 mL of water in another 250-mL beaker. Using a thermometer they then take the starting temperature of this water.



After the five minutes of heating, students remove the beaker (containing 150 mL of water) and determine its temperature. They then place the second beaker (100 mL of water) on the hot plate and insert the thermometer, holding it in place by a clamp on a ring stand. Have them record the temperature every 30 seconds for 5 minutes.

In the two remaining beakers students place 100 mL of Karo syrup and cooking oil respectively and repeat the procedure, recording temperatures every 30 seconds for five minutes. These beakers could be set up and heated all at the same time. Multiple ring stands could be used to hold the thermometers in place.

Have students graph the time versus temperature for each liquid.

Background:

Although in everyday language we sometimes confuse heat and temperature, they have very distinct meanings in science. The heat content of a substance depends on its quantity, temperature, and the material of which the substance is made. Temperature does not indicate the heat contained by that body. It is more a measure of the hotness of that body.

Water will heat up slower than the oil and Karo syrup. On the graph, the oil and Karo syrup lines will be steeper, indicating that they heat faster than water. The beaker containing the greater amount of water will not have as high a temperature as the beaker containing the smaller volume of water.

Variations:

Repeat the same experiment using different liquids.

Adapted from:

"Heat," Operation Physics, American Institute of Physics, 1988.

Science as Inquiry

The Divided Cup

How does a hot object affect a cold object?

Overview:

Students often will not believe that hot and cold water will eventually be the same temperature. This activity provides proof.

Materials:

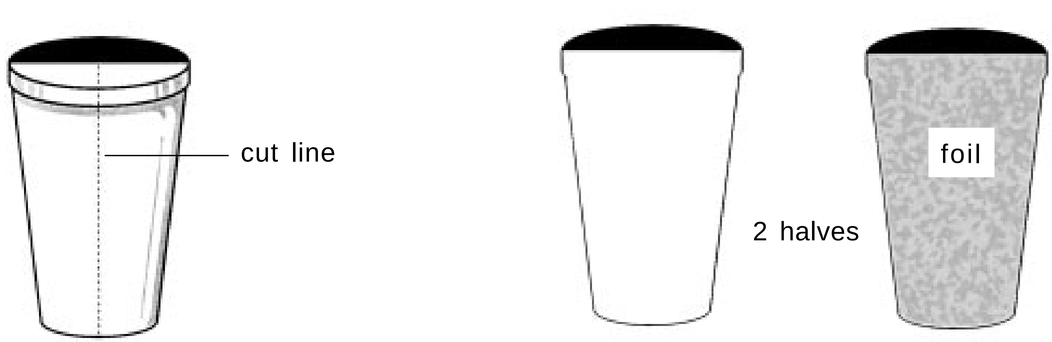
Per lab group:

thermometers, 2
water, hot and cool
containers (metal, preferably aluminum), small, 2
aluminum foil
Styrofoam cups with lids (larger size), 2
copper foil or thin copper plates
epoxy glue
silicone sealant

Procedure:

You will need to prepare "divided cups." A larger-size Styrofoam cup should be used. The copper foil can usually be obtained through glass art supply shops. Copper plates can be bought at most hardware stores, but they must be thin. The amount of copper needed is determined by the amount needed to bisect the cup. To make a "divided cup," carefully cut the cup in half lengthwise. Then use one-half of it to draw a pattern on the copper foil or plate. Cut this pattern out and glue (epoxy glue) the copper foil to one side of the cup. Then glue the remaining cup half to it. Finally, seal the glued edges with silicone sealant. Each group needs one of these cups. You may need a few extra cups for backups.

Using the divided cup, students fill one side with hot water and the other side with an equal amount of cool water. A lid is placed on the top and two thermometers are stuck through the lid into each side.



Students then record temperatures (every 2 minutes) over a 10-minute period. A table of time and temperature can be used.

The second divided cup now can be set up and the procedure repeated, recording temperatures every 2 minutes over a 10-minute period, except this time have the students use half as much cool water as hot water. Students should then repeat the procedure a third time, this time using only half as much hot water as cool water. Have students construct a heating and cooling curve using their tables of time and temperature. Over time, the water (both hot and cold) will be the same temperature.

Background:

Heat energy is always transferred from areas of greater temperature to areas of lower temperature. Without intervention, a state of thermal balance or equilibrium will be achieved. The hotter substance loses an amount of heat, and the colder substance gains that same amount of heat. (Some heat may be lost if the system of interaction is not completely closed.)

Variations:

Repeat the experiment using different liquids.

Adapted from:
Crow, Linda W., Hot Stuff, Baylor College of Medicine, 1992.

Science as Inquiry

Great Bolts of Fire!

How is temperature different from heat?

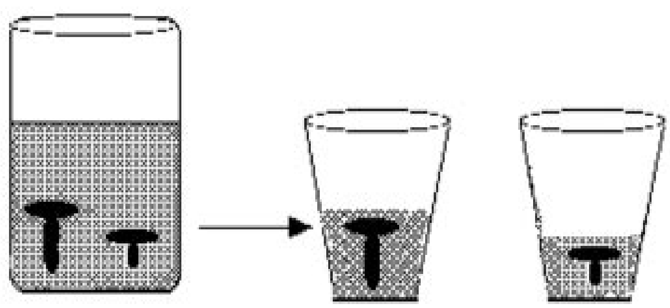
Overview:

In this activity students study thermal equilibrium using metal bolts of different sizes.

Materials:

Per lab group:
beaker
tongs
water
hot plate
bolts (different lengths), 2
graduated cylinder
Styrofoam cups, 2
thermometer

Procedure:



Be sure that the length of the bolts is less than the diameter of the cups. Have students place the two bolts into a beaker of water and heat it until it boils. They should continue to boil this combination of "bolted" water for several minutes.

After a few minutes, have students place equal amounts of tap water in the two Styrofoam cups (be sure that just enough water is used to cover the bolts). Using the thermometer they should measure the starting temperature of this tap water.

Removing the bolts from the boiling water, students then place each into a cup of tap water and measure the temperature of the water every one minute for 3 minutes.

Background:

Prior to this experiment students will need to have some understanding of thermal equilibrium. If two bodies of different temperatures come in contact with one another, there is a transfer of energy until they reach the same temperature or achieve thermal equilibrium.

When objects of different masses (identical materials) are heated in water for the same amount of time at the boiling point, they achieve the same temperature and are also at the temperature of the boiling water (100 °Celsius). If these same objects of different masses were placed in a small amount of water (at room temperature), the temperature of this water would increase. However, the temperature of the water that contained the larger mass would increase more. More heat energy is transferred by the larger object even though both objects were at the same temperature after boiling.

Temperature and heat are not the same. Temperature is a measure of how hot or cold something is. If objects are composed of the same material, then heat energy transfer is dependent upon two things—temperature and the quantity of material.

Variations:

Repeat the experiment using more than two sizes of bolts.

Adapted from:

"Heat," Operation Physics, American Institute of Physics, 1988.

an alternative activity for Event 4

Teacher Sheet

Science as Inquiry

Putting on the Heat

What is the relationship between mass of water and temperature change when heat is applied?

Demonstration

Overview:

How does increasing water mass affect temperature change when heat is applied? What if you change the initial temperature of the water? Does it take equal amounts of heat to raise the temperature of 1 gram of water 1 °Celsius from 40° to 41° and from 60° to 61°? This demonstration examines heat transfer.

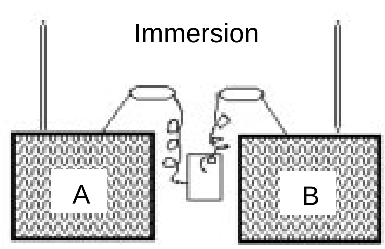
Materials:

electric immersion heaters, 2
Styrofoam tanks (small coolers), 2, labeled A and B
thermometers, 2
water

Procedure:

This demonstration involves heating different volumes of water and comparing changes in temperatures. In each trial, tank A contains 2000 grams (mL) of water and the heating of the two tanks continues until tank A's is temperature has risen 10 °C. In this manner all tanks receive the same amount of heat. Remember to change the water each time in Tank A.

A faster demonstration can be done by showing one trial of this procedure and then just examining the data for all the trials. Repeat this procedure for the following masses of water: 500 g, 1,000 g, 1,500 g, 2,000 g, 2,500 g, and 3,000 g. Have students collect the temperature change in relationship to the mass of water.



Mass of Water	Temperature Change	Mass × Temperature Change
3000	6.5	1.95 × 103
2500	8.4	2.10 × 103
2000	10.0	2.00×10^3
1500	13.1	1.97×10^3
1000	19.9	1.99×10^3

Some sample data may be helpful to you:

Background:

In this experiment, increasing the mass of the water decreased the rise in temperature. However, in each case the product of the mass times the temperature change is approximately the same. If the initial temperatures of the different masses of water were different and the experiment was repeated, the results would not be different.

In each situation, the amount of heat put into the water was the same and the product of the mass times the temperature change is the same. This product is the measure of the heat transferred. Calorie is the name given to this unit of heat (quantity heat needed to raise one gram of water 1°C).

Variations:

Repeat the experiment using the same mass of water with different initial temperatures with the same amount of heat. Or repeat the experiment using other liquids than water (such as oil).

Adapted from:
IPS Group, Introductory Physical Science, Prentice-Hall, New Jersey, 1967.

Science as Inquiry

Radiating Cans

How fast do cans radiate heat?

Overview:

Does the color of the earth affect heat radiation? This activity looks at this problem.

Materials:

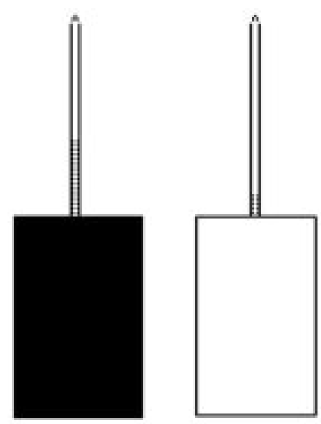
Per lap group:

metal cans, same size (1 qt. or larger) with tops intact, 2
flat, black spray paint
thermometers, 2
1-hole stoppers, 2
heater
clay

Procedure:

Before class begins, paint half of the metal can with the flat black paint. In the center of each can (painted and shiny) make a large hole for the stopper. Insert a thermometer in each stopper and place it in the can. Seal any other holes with clay.

Have students place these cans at an equal distance from a small space heater. They should measure the temperature every minute for 10 minutes.



Space heater

Background:

The surface of the material affects how much radiation is absorbed. Dark surfaces of the earth such a soil produce a similar effect as the black can. Dull surfaces absorb a maximum whereas shiny surfaces reflect the most radiation. The temperature of the blackened can rises more than the shiny cans. These observations should be applied to a discussion of how different surfaces are affected by sunlight. Water heats up slowly whereas land heats up quickly.

Variations:

None suggested.

Adapted from:
Brandewein, Paul, Sourcebook for the Physical Sciences, 1974.

History and Nature of Science

Matters of Heat and Fire

Item:

Lavoisier proposed the name "calorique" (caloric in English) to refer to heat (chaleur), fire (feu) and "matter of heat and fire." He listed calorique in the same table as oxygen, nitrogen, and carbon, as simple substances that could not be further decomposed.

The term "calorie" has been used until recently as the unit for quantities of heat. How does a calorie differ from caloric? Why is it not listed in a table of elements today? Explain what was discovered that changed the view about caloric.

Answer:

Heat was thought to be a substance that moved from one compound or object to another. After many trials, it was concluded that only energy flowed, not matter, when hot objects were placed near cold objects and they ended up at the same temperature. Now we understand heat to be related to the kinetic energy (translational motion) of particles and not to the particles themselves. Thus a calorie is the energy that causes a specific change in the motion of molecules in 1 gram of water that we see exemplified by a 1° rise in temperature of the water. Thus motion and particles/molecules had to be understood before the true nature of heat and the calorie could be established.

History and Nature of Science

Pigs on Ice!

Item:

Lavoisier and Laplace, in about 1783, devised an "ice calorimeter" to measure the amount of caloric evolved in chemical changes. They placed a guinea pig in this device and found that 13 ounces of ice were melted in 10 hours, though the guinea pig's body temperature had not changed. They measured the amount of carbon dioxide produced by the guinea pig in this time. When they burned enough carbon to make the same amount of carbon dioxide, they melted very nearly the same amount of ice.

The conclusions they made from this experiment were:

A. Guinea pigs must use carbon as food.
B. Living things always have constant body temperature.
C. Ice is always melted at a constant rate.
D. The processes of combustion and respiration must be closely related.

Justification:

Explain how an "ice calorimeter" must work (even if you have never heard of one!) to allow consistent measurement of quantities of heat (calories or joules).

Consumables

Item	Quantity (per lab group)	Activity
1-hole stopper	2	8
1-hole stopper (fits pint size bottle)	1 (per class)	2
20-watt bulb with socket	—	1
aluminum foil	—	5
black cloth, 2-inch square	1	3*
bolts, different lengths	2	6
clay	—	8
coat hanger or wire	— (per class)	1
copper foil or thin copper plates	—	5*
epoxy glue	—	5*
Karo syrup	100 mL	4
nail	1 (demo)	1
oil, cooking	100 mL	4
paint, flat black spray	—	8
plaster of Paris	1/4 cup (per class)	1
plastic bag, reclosable	1 (per class)	1
silicone sealant	—	5
styrofoam cups with lids, large	2	5, 6
water	—	1, 2, 6, 7*
water	250 mL	4
water, hot and cool	—	5*

Nonconsumables

Item	Quantity (per lab group)	Activity
beaker	1	6
beaker, 250-mL	4	4
bell jar	1 (per class)	2
bottle, pint size, clear, flat	1 (per class)	2
electric heater	1 (per class)	2
electric immersion heaters	2 (per class)	7*
graduated cylinder	1	6
hammer	1 (per class)	1
heater	1	8
hot pad (hot hands or beaker tongs)	1	4
hot plate	1	4, 6
light source (sunlight, lamp, projector on its side)	1	3*
metal cans, same size, 1 qt. or larger with tops intact	2	8
metal containers (pref. aluminum), small	2	5*

(continued)

radiometer	1	3*
ring stand with ring, clamp	1	4
safety goggles	1 pr	4
styrofoam tanks (coolers) labeled A and B	2 (per class)	7*
thermometer	1 (per class)	2
thermometer	1	6
thermometer	2	5*, 8
thermometer	2 (per class)	7*
thermometer, Celsius	1	4
tongs	1 pr	6
vacuum pump	1 (per class)	2

*indicates alternative or additional activity

Key to activities:
1. Hot Sources
2. Solar Heating
3. Radiometer Experiment
4. Measuring the Temperature of Three Liquids
5. The Divided Cup
6. Great Bolts of Fire!
7. Putting on the Heat
8. Radiating Cans

Activities

Brandewein, Paul, *Sourcebook for the Physical Sciences*, 1974.
Crow, Linda W., *Hot Stuff*, Baylor College of Medicine, 1992.
Ehrlich, Robert, *Turning the World Inside Out*, Princeton: Princeton Univ. Press, 1990.
“Heat,” *Operation Physics*, American Institute of Physics, 1988.
IPS Group, *Introductory Physical Science*, Prentice-Hall, New Jersey, 1967.

Readings

Reid, George C., “Do Solar Variations Change Climate?” *Earth in Space*, Vol. 5, No. 4, American Geophysical Union, 1992, p. 10.
Lean, Judith, and David Rind, “The Sun’s Effect on Global Warming,” *Earth in Space*, Vol. 6, No. 5, American Geophysical Union, 1993, pp. 11–12.
Lewis, Trevor, and Kelin Want, “ Clues to Past Found Down a Hole,” *Earth in Space*, Vol. 5, No. 2, American Geophysical Union, October 1992, pp. 10–12.