SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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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:

939

Evidence of Heat Transformations

March 1996
Adapted by: Brett Pyle

Earth's Internal Energy Sources: Radioactivity and Gravitational Potential Energy. (a) Students should consider evidence for heat produced in or coming from inside Earth. This includes the high temperatures of deep mines, volcanoes, geothermal vents, etc., (like videos taken from underwater robots). (*Earth and Space Sciences, A Framework for High School Science Education, p. 135.)*

Heat from within Earth and Heat from the Sun. (b) Students should study heat and heat transfer through a variety of heat transfer experiments. These heat experiments need to provide evidence to support the existence of the transfer methods—convection, conduction, and radiation. Providing simulations is helpful but (more importantly) what evidence do we have that heat travels in these ways? Such materials can also be considered form the point of view of that being reradiated. (*Earth and Space Sciences, A Framework for High School Science Education, p. 131.)*

Contents

This micro-unit was adapted by **Brett Pyle** (Grady Middle School, Houston, Texas)

939

Learning Sequence

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Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Conduct Yourself Accordingly **Activity 1** Lord Almighty, Feel My Temperature Rising! **Activity 2** Hot Connection **Activity 3** Current Events **Activity 4** Thank You, Fans! **Activity 5** Basking in the Glow **Activity 6** Don't Just Sit There Absorbing Everything I Tell You: Emit a Little! **Activity 7** Convection, Conduction, Radiation, 2 **Assessment 3** Convection, Conduction, Radiation, 3 **Assessment 4** Hot Sand **Assessment 9** Heat Transfer **Assessment 11** Convection Currents **Assessment 12** Conducting Heat **Assessment 13**	Convection **Assessment 1** Convection, Conduction, Radiation, 1 **Assessment 2** Convection, Conduction, Radiation, 3 **Assessment 4** Convection, Conduction, Radiation, 4 **Assessment 5** Convection, Conduction, Radiation, Adsorption **Assessment 7** Energy Efficiency **Assessment 8**	Convection **Assessment 1** Convection, Conduction, Radiation, 2 **Assessment 3** Greenhouse Effect **Assessment 10** Convection Currents **Assessment 12**	Convection, Conduction, Radiation, 5 **Assessment 6**

Suggested Sequence of Events

Event #1

Lab Activity

1. Conduct Yourself Accordingly (30 minutes)

Alternative or Additional Activities

2. Lord Almighty, Feel My Temperature Rising (45 minutes)
3. Hot Connection (1 hour)

Event #2

Lab Activity

4. Current Events (2 hours)

Alternative or additional activity

5. Thank You, Fans! (45 minutes)

Event #3

Lab Activity

6. Basking in the Glow (30 minutes)

Alternative or Additional Activity

7. Don't Just Sit There Absorbing Everything I Tell You: Emit a Little! (1.5 hours)

Event #4

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

Suggested readings:

Cowen, Ron, "The Once and Future Sun." *Science News*, March 26, 1994, pp. 204–205.

Lipkin, R., "A Refrigerator with the Coolest Sound." *Science News*, Feburary 26, 1994, p. 135.

Monastersky, Richard, "Scrambled Earth." *Science News*, April 9, 1994, pp. 235–237.

Assessment items are 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

Conduct Yourself Accordingly

What is the relationship between heat energy and conduction?

Overview:

Students will investigate the movement of heat energy by conduction. You may wish to have a pot holder or beaker for the students to drop hot objects on or in, so that lab tables are not damaged.

Materials:

Per lab group:
candle (or bunsen burner)
large paper clip
magic marker
ruler

Procedure:

Have the students light the candle or bunsen burner and place one finger about 6 cm to the side of the flame. Have them hold their finger there and note whether or not their finger gets hot. Then have them bend a paper clip so that it is straight. Have them mark the paper clip 6 cm from one end. They should then hold the clip at the mark and place the other end into the flame. Tell the students to remove it and drop it if it becomes uncomfortable. Discuss with the students any observations that they have. When discussing the movement of heat be sure to discuss if any matter moved in order to get the heat from the flame to their finger.

Background:

The process of conduction involves the movement of heat energy through a material without the transfer of any matter. The heat energy on one end of an object will cause the kinetic energy of the molecules on that end to increase and move more rapidly. As these molecules “bump” into neighboring molecules, the energy is transferred down the object to the cooler end.

In general, objects that are made up of densely packed molecules conduct heat energy more readily while substances with loosely packed molecules (i.e., air and other gases) do not transfer this energy as well because there are fewer molecules to “bump” into.

Variations:

Students could try this experiment with a variety of materials to test which materials are better conductors of heat. Caution must be used when selecting materials to avoid objects that will catch on fire or melt. Other objects to try could include glass, aluminum foil, or wood dowel. If using dowel choose a fairly thick piece. It may catch fire but the students should observe that the end that they are holding will not get hot even at the point when the end in the flame catches fire.

Adapted from:
Jewett, John W., Jr., *Physics Begins with an M: Mysteries, Magic, and Myth,* Allyn and Bacon, Needham Heights, Mass., 1994.
Kardos, Thomas, *Physical Science Labs Kit,* The Center for Applied Research in Education, West Nyack, N.Y., 1991.

alternative activity for Event 1

Teacher Sheet

Science as Inquiry

Lord Almighty, Feel My Temperature Rising!

What are the effects of heat conduction?

Overview:

Students will investigate the effects of heat conduction. You may wish to have can for the students to drop hot objects on or in, so that lab tables are not damaged.

Materials:

Per lab group:
candle (or bunsen burner)
paper cup
water
metal strainer
paper scraps
insulated metal tongs

Procedure:

First have the students fill the paper cup halfway with water. Ask the students to predict what will happen when they place the cup over the flame. Then have them hold it with the tongs over an open flame and observe the results. Have the students continue to hold the cup over the flame until the water boils. Have them remove the cup once the water begins boiling. Next have the students put a few scraps of paper inside the metal strainer. Then have them predict what will happen when they place the strainer over the flame. Have them place the strainer over the flame and hold it there for several seconds and record their observations.

Background:

In both of the above cases the paper will not catch on fire. In the first case the heat from the flame is transferred to the water by conduction through the paper. The heat is then dissipated by the evaporation of the water. The paper will not reach a high enough temperature to burn until the water has all evaporated.

In the second case the metal of the strainer conducts heat away preventing the paper from reaching a high enough temperature to burn.

Regarding questions 4 and 5 on the student sheet. The nail is a much better conductor than the potato and so will conduct heat to the center of the potato helping the inside of the potato to heat up quicker and thus cook faster. Bridges will freeze first because the roadways overlie the ground which acts as a great conductor of heat from the warmer earth to the water on the surface of the road. The bridge has cold air under it, and so does not have the advantage of the warm Earth. For a complete discussion of additional considerations see Jewett, 1994, p. 194.

Variations:

You may wish to allow the students to let all of the water boil out of their cup to see that the cup will not ignite until the water is gone. The students should have a can to drop the cup into once it ignites as a safety precaution. You may also wish to have the students measure the time it takes for the paper to ignite in the strainer and compare that to the time it takes to ignite paper alone in the open flame.

Adapted from:
Jewett, John W., Jr., *Physics Begins with an M: Mysteries, Magic, and Myth*, Allyn and Bacon, Needham Heights, Mass., 1994.

Science as Inquiry

Hot Connection

How do we measure heat?

Overview:

Students will observe and measure the conduction of heat through an object.

Materials:

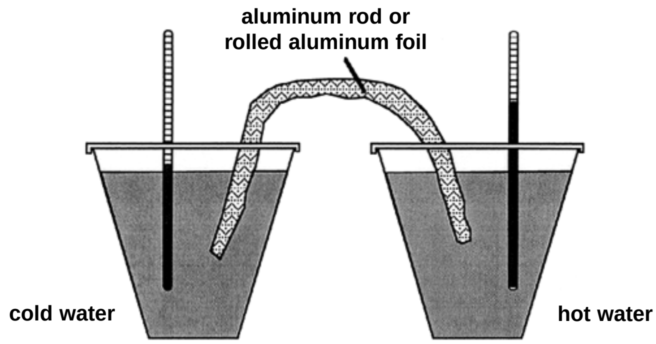
Per class:

2 styrofoam cups with lids
2 thermometers
aluminum bar (or tightly rolled aluminum foil)
boiling water
cold water

Procedure:

Have the students put two holes in the top of each cup lid, one for the thermometer and one for the aluminum rod to fit through. They should the place boiling water in one cup and cold water in the other cup and place the thermometers in the cups. Let the cups sit until the thermometers stop moving and record the temperature in each cup. This will be used as the starting temperature for each cup. Then have the students place the aluminum rod into each cup through the holes in the lid so that each end is submerged in water.

The students should record the temperature of the water in each cup of water every minute for 15 minutes.



Background:

A solid aluminum rod would probably work best for this experiment. These rods will have to be bent into a “U” shape so use a fairly thin diameter rod. Rolled aluminum foil will also work but it must be rolled tightly. After completing the measurements the students should graph the results.

Variations:

You could have the students test various materials in place of the aluminum. Plastic would make for a good comparison and plastic rods could be easily bent after being warmed over a flame.

Adapted from:
Discoveries in Earth Science, United Publishing Company.

Science as Inquiry

Current Events

What is the relationship between heat energy and convection?

Overview:

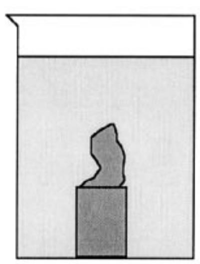
Students will observe how heat is transferred by convection.

Materials:

Per lab group:
1000-mL beaker
food coloring
ice cube dyed with food coloring
hot water
Option a.
small vial with cork)
Option b.
small flask (125 mL)
two-hole stopper
2 pieces of glass tubing

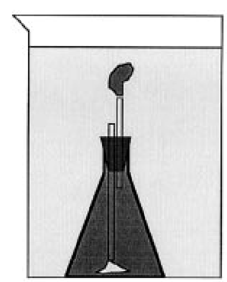
Procedure:

There are a number of variations of this experiment. They all involve setting up a convection cell in a beaker by mixing hot and cold water. Dye or food coloring is used to observe the water movement.



As the lid is removed, colored water will begin to rise.

Option a. The students should fill up their beaker with 700 mL of cold water. The students should the place powdered dye or food coloring into the small vial and fill it with hot water. The students should place the cork on the vial and place it on the bottom of the beaker full of cold water. The students should the slowly and carefully remove the cork and remove their hand slowly from the water, disturbing the water as little as possible. The students then observe the movement of the colored water over time.



Flask of hot colored water in a beaker of cold water. Note relative position of glass tubes.

Option b. The students should fill the beaker with 700 mL of cold water. Place the dye in the flask and fill with hot water. Place the stopper in the flask and place the flask in the beaker. Make sure the top of both glass tubes is below the water level in the beaker. The students should observe the movement of the colored water in the beaker.

After the students have completed either option a or option b, have them fill their beaker with hot water and ask them to predict what will happen if they put a colored ice cube into the water. After they have made their predictions have them carry out the experiment.

Background:

During convection, the temperature of a fluid rises and the fluid then moves from one place to another taking the energy with it. In natural systems this movement is caused by a density difference between the heated fluid and the cooler fluid around it. The heated fluid will rise. By the same method if the fluid is cooled relative to the surrounding fluid it will sink. This movement causes the fluids to mix and distribute the heat energy.

Open fireplaces do not effectively heat an entire home. In reality they often cause most of the house to become colder. The heated air in the chimney rises and so pulls air from inside the house into the chimney as a convection cell is set up. The air which replaces the air in the house being pulled into the chimney usually comes through cracks around doors and windows. This is cold outside air. Thus the warm inside air is being pulled up the chimney and replaced by cold outside air coming through cracks in the house. To reduce this effect, place a glass cover over the fireplace and have ventilation holes in the fireplace lead to the outside so that the air to feed the fire comes from outside, not from inside your house. The glass doors will allow the radiant heat to pass through while stopping the convection cell to be set up within your house.

Variations:

You may wish to discuss with your students the freezing of lakes and ponds in the winter and how this is affected by convection. Remember that the other important part of this phenomenon is that solid water (ice) is less dense than liquid water. Ponds and lakes then will freeze from the top down and will only freeze when all of the water in the lake or pond is lowered to the freezing point. As water is cooled at the surface it sinks and warmer water is forced to the top. Once a layer of ice forms on the surface it insulates the water below and unless it is extremely cold for a long period of time the pond will not freeze solid (lucky for the fish!).

Adapted from:
Robinson, Paul, and Paul G. Hewitt, *Conceptual Physics: The High School Physics Program*, Laboratory Manual, Addison-Wesley Publishing Co., Menlo Park, Calif., 1992.
Jewett, John W., Jr., *Physics Begins with an M: Mysteries, Magic, and Myth*, Allyn and Bacon, Needham Heights, Mass., 1994.
Discoveries in Earth Science, United Publishing Company.

alternative activity for Event 2

Teacher Sheet

Science as Inquiry

Thank You, Fans!

What is the relationship between convection currents and air?

Overview:

Students will observe the effects of convection currents in air.

Materials:

Per lab group:

overhead projector
paper clip
string (about 20 cm)
candle, bunsen burner, or boiling water
paper spiral (see student section)
scissors
thermometer

Procedure:

The students should cut the spirals out provided at the back of this lab. They should then tape the string to the middle of the spiral and tie the other end to the paper clip. Ready the heat source (the candle, bunsen burner, or beaker of boiling water) and hold the paper spiral so that it is about 20 cm above the heat source. Have the students record their observations and then have the students measure the temperature of the surrounding room air and compare it to the temperature of the air where the spiral is hanging.

Background:

Have the students be careful not to get the spiral to close to the heat source if they are using an open flame. You may want to discuss with them why the heated air is moving in the direction that it is.

Regarding question 4 on the student sheet. In the summer, your ceiling fan should be running so that it is pulling air up from the ground (if it is reversible). This pulls the cooler air off of the floor and up to the ceiling where it is pushed out to the edges of the ceiling. Here it sinks back to the ground and a convection cell is set up. This helps to eliminate air temperature differences in a room. Since most of our body is not on the floor when we are sitting, standing, and even sleeping, it helps to get the cooler air into the upper part of the room. In the winter when you have the heat on it is best to reverse the ceiling fan so that it is blowing air downward. This pushes the hot air to the ground where it is moved out to the edges of the room and then rises again setting up a convection cell. Both of these methods are designed to even out the temperature between the top and bottom of a room making it feel cooler in the summer and warmer in the winter.

Variations:

You could also demonstrate the movement of heated air by holding a stick of incense over your heat source. You have the added bonus of having a sweet smelling room at the end of the lab.

Adapted from:
Kardos, Thomas, *Physical Science Labs Kit,* The Center for Applied Research in Education, West Nyack, N. Y., 1991.

Science as Inquiry

Basking in the Glow

What is the relationship between heat and radiation?

Overview:

Students will observe heat transfer by radiation.

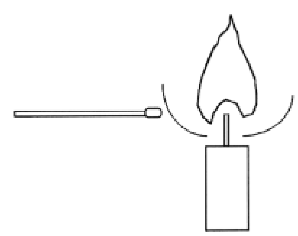
Materials:

Per lab group:

candle
toothpick
wax shavings

Procedure:

Have the students place some wax shavings on the end of the toothpick and press them so that they form a small blob on the end. Then the students should bring the wax end of the toothpick close to the flame until the wax just begins to melt. They should pull back the toothpick and let the wax solidify and repeat this process around the sides and bottom of the flame. The students should make a drawing of the distance at which the wax melted all around the flame.



Lines show approximate spot where was will melt around the flame.

Background:

In this lab the students must observe a heat transfer that cannot be due to conduction or convection. After they have mapped the line around the sides and below the candle flame where the wax melts, ask them how the heat traveled to a point below the flame to melt the wax. It cannot be due to convection since heated air will travel upwards. It cannot be due to convection since we have demonstrated in an earlier lab that air is actually an insulator. This leaves us with a third alternative, radiation.

Electromagnetic radiation carries energy which is absorbed by materials and can result in a rise in temperature. This radiation does not need a medium to travel through, it can pass through a vacuum. The most common form of electromagnetic radiation is light and the absorption of heat from this type of radiation can be observed by standing in the sun or sitting by a fire.

Variations:

Another way to demonstrate heat transfer by radiation is to use a radiometer. The inside of a radiometer is almost completely evacuated. Therefore the energy that makes the spinner spin could not be passed to the blades of the spinner by convection or conduction. You might also try placing a radiometer inside a vacuum pump that is located by a sunny window for even more dramatic evidence.

Adapted from:
Marson, Ron, *Heat*, TOPS Learning Systems, 1990.

alternative activity for Event 3

Teacher Sheet

Science as Inquiry

Don't Just Sit There Absorbing Everything I Say: Emit a Little!

What properties affect the absorption or emission of radiation?

Overview:

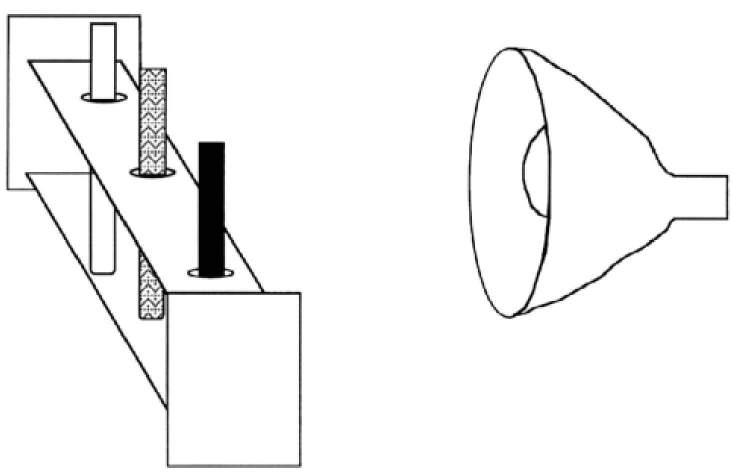
Students will investigate the properties of materials that affect how they absorb and emit radiation.

Materials:

Per lab group:
3 test tubes
test tube rack
3 thermometers
one 200-watt light with reflector
aluminum foil
black paper
white paper
water

Procedure:

Have students wrap the test tubes tightly with the given materials and tape them securely. They will have one tube wrapped in black paper, one wrapped in white paper, and one wrapped in foil (shiny side out). Now have them fill each test tube with room temperature water and place the test tube in a rack. Place the 200 watt light approximately 20 cm from the rack and point it directly at the test tubes. The students should record an initial temperature in each test tube and then turn on the light. Temperature readings should be taken in each test tube every minute for ten minutes. At the end of ten minutes have



the students switch off the light and turn the light away from the test tubes. Now the students should record the temperature in each tube every minute for another ten minutes. When they have completed this they should construct a line graph of the data comparing temperature changes over time.

Background:

In this activity the students will determine what effect the color and shininess of an object has on its ability to absorb and emit radiation. Darker objects appear dark because they absorb most of the light that strike them. This also means that they will heat up more because of all of the energy they are absorbing.

Variations:

You could add other colored papers to the testing lineup and have students record the results for various light and dark colors.

Adapted from:
Marson, Ron, *Heat*, TOPS Learning Systems, 1990.
Discoveries in Earth Science, United Publishing Company.

Science and Technology/Science in Personal and Social Perspectives

Convection

Item:

A thermos bottle is designed to keep hot liquids hot. Construction usually involves a double-walled container with a vacuum inside, a silver-coated wall, and felt pads to keep this vessel separate from the outer container. The vacuum in the chamber is present to reduce heat loss mostly by:

A. Conduction.
B. Convection.
C. Radiation.
D. All three transfer mechanisms.

Justification:

An operating electric light bulb (incandescent) has a very hot filament at its center. If you could measure it, you would find that the filament temperature is higher than that required to melt glass! Explain why the outer glass of the light bulb doesn't melt.

Answer.

A and B (mostly A). Molecular collisions are necessary for heat flow. If all the molecules are removed, then neither conduction nor convection can occur. The vacuum chamber is also made of low conductivity material (glass, plastic, or stainless steel) so that conduction by the walls is minimized.

In the light bulb, obviously heat transfer (technically, heat is only transferred energy, but that's the way most people say it!) is kept to a minimum by having a vacuum or low pressure gas. In high intensity lamps, the envelope is made of quartz, which is higher melting; the gas pressure is higher because this has been found to make filaments last longer (tungsten evaporates more slowly, especially with iodine vapor present, which "recycles" the tungsten), and the envelope is much hotter, as anyone who has ever touched one will attest!

Science and Technology

Convection, Conduction, Radiation, 1

Item:

People who like to fly in gliders seek out desert areas on warm days when they wish to have long flights. This is primarily because:

A. Gliders can absorb heat to provide them with power.
B. The desert reflects light that supports the glider.
C. Hot warm air rises to provide lift for the glider.
D. Desert areas have fewer towns and more potential landing areas for safety.

Justification:

By drawing a diagram showing air motions and forces on a glider, demonstrate that you know how a glider can fly higher even when it has not engine power.

Answer.

C. The land heats up to a high temperature from absorption of sunlight, and so emits large amounts of infrared radiation, which heats the air close to the ground. The hot air is less dense than the colder air above it, so it rises, taking the glider with it. Direct sunlight doesn’t heat the air so much, since air is fairly transparent to visible radiation, but not to infrared.

Science as Inquiry/Science in Personal and Social Perspectives

Convection, Conduction, Radiation, 2

Item:

While watching TV weather forecasts, a student notices that the inner city daytime temperatures are almost always slightly higher than the suburb temperatures. This is so mostly because:

A. The larger number of people in the city produces more heat.
B. The darker buildings absorb more solar radiation during the daytime.
C. The grass lawn in the suburbs radiate more heat back into space.
D. Convection currents cannot operate in the congested city streets.

Justification:

In some city parks, a large outdoor chessboard has been built by using alternating black and white concrete squares. A youngster running around on the chessboard on a sunny day notices that it seems warmer when he is standing on some squares than on the others. Which do you think would be warmer, black or white? Why?

Answer.

B. Substances are darker colored if they absorb more visible radiation. They also emit more infrared radiation because of the darker color. So not only do dark objects heat up more when exposed to sunlight, but they warm up the air in the vicinity more, because infrared radiation is more absorbed in air (by carbon, dioxide, water vapor, etc.), than is visible light. The net effect is warmer air temperatures over darker areas.

Science and Technology

Convection, Conduction, Radiation, 3

Item:

A thermos bottle is designed to keep hot liquids hot. Construction usually involves a double-walled container with a vacuum inside, a silver-coated wall, and felt pads to keep this vessel separate from the outer container. The silvered surface is included in order to reduce heat loss by:

A. Conduction.
B. Convection.
C. Radiation.
D. All three loss mechanisms.

Justification:

Light bulbs called *spotlights* are designed to fit in confined spaces, and to produce an intense beam of light. They always have a shiny back surface. Explain what this does.

Answer.

C. Silvered surfaces reflect electromagnetic radiation. For warm liquids, this will be infrared radiation, for the lamp, it is visible light (and infrared). The silvered-surface helps to keep the back of the light bulb cooler as well as to focus the light beam.

Science and Technology

Convection, Conduction, Radiation, 4

Item:

A thermos bottle is designed to keep hot liquids hot. Construction usually involves a double-walled container with a vacuum inside, a silver-coated wall, and felt pads to keep this vessel separate from the out container. The felt support pads are included to reduce heat losses by:

A. Conduction.
B. Convection.
C. Radiation.
D. All three loss mechanisms.

Justification:

Inexpensive ice chests are usually just a box made of foam. Explain how this prevents ice from melting when placed inside the ice chest on a warm day.

Answer:

A. Felt has a low conductivity and the contact points are small, anyway. The air space also has a low conductivity. Heat is transferred in conduction by molecular collisions or motions. When these are small, because of low density or poor molecular packing, then the insulation is good. The ice chest works the same way.

History and Nature of Science

Convection, Conduction, Radiation, 5

Item:

Before refrigerators were common, people preserved food and cooled drinks by using an ice-box. A large block of ice was delivered daily and placed in the box in the kitchen. Grandmother liked to spend time in the kitchen in the summer, because the room was cooler than other rooms in the house. When grandmother acquired her first refrigerator, she noticed that the kitchen no longer was cool in the summer time. In fact, she thought it felt warmer than other rooms in the house. Of course, grandmother's house had no air conditioning. Was grandmother right about the effect of replacing the ice box with the refrigerator? Please explain why or why not.

Answer:

Science and Technology

Convection, Conduction, Radiation, Adsorption

Item:

On a sunny day, it feels warmer when you walk across a parking lot or black-topped school yard than when you walk across a grassy area or dirt lot. Explain this in terms of heat transfer.

Answer:

Science and Technology

Energy Efficiency

Item:

The efficiency of any mechanical device is determined by taking the useful energy output and dividing it by the energy input to making the device run. A typical train has an efficiency of 36%, a car has an efficiency of 15%, an electric power station has an efficiency of 35%, and the human muscle has an efficiency of 40%.

Based on the information, human muscle power is the most efficient. Explain why inventors have felt the need to invent—and we use—the other kinds of devices, if human muscle power is the most efficient way to use energy.

Historically, human muscle power was used to make major accomplishments, such as building pyramids in South America, or Egypt. What important features had to be present to make this work?

Answer:

What is “input” for human muscle power? Is it food, or merely energy fed directly to the muscle fibers? If the latter, when the whole chain is included, the picture is not so rosy. The same is true for other devices—the energy to extract oil is not included in the efficiency of a train, for example.

The second point concerns the ability to harness large quantities of energy for extensive work. Human muscle can only marshall relatively small quantities at a time, so it is limited in what can be accomplished. Having lots of people-coordinated muscle power was done to build obelisks and pyramids. This required extensive arrangements to feed the workers (Egyptian records show this) and obedience to coordinate motion (so all pulled in the same direction at one time) to move large heavy objects.

Science as Inquiry

Hot Sand

Item:

If you were to spend your summer days at different beaches throughout the world, your feet would notice that different sands seemed to have different temperatures. Is this because different types of sand transmit differently to your feet; the sun's radiation is different at different beaches; different colored sands;or the sand is wet or dry? Does sand really have different temperatures when all other factors are controlled?

Design and carry out an experiment to find out if different colored sands heated under controlled conditions have different temperatures.

Materials. Samples of different colored-sands; pan and thermometer for each sample of sand; light source to simulate the sun (or the sun).

Write a report, presenting your conclusions and answering the following:

A. What variables did you have to be careful to control—and how did you do it?

B. Why did the changes you observe occur in temperature? (Use the terms *radiation, conduction,* and *convection* when appropriate.)

C. Predict what would happen if you removed the light source and watched what happened to the sand temperatures. Which will cool fastest, which will cool the slowest, or will they be the same?

D. If time permits, carry out the latter experiment and compare to your predictions. How would you explain any differences? (Use the terms *radiation, conduction,* and *convection* when appropriate.)

Answer:

Students should recognize the need to control for mass of sand [or volume and shape (piles vs. flat spread—thickness) and does density make a difference?] as well as for radiation per unit area. They need to describe exactly how they knew it was controlled—not just that they did so.

It should be possible to get colored sands from an aquarium store, or to dye some with non-water soluble dyes (if wet sand is to be tried).

For non-beach students, substitutes might include comparing a black-top surface to a pale cement surface, or different colored bricks or paving, or different colored roofing materials (from a builder's supply store). Placing thermometers becomes a little more challenging, and may be another variable if not in good contact.

Science in Personal and Social Perspectives

Greenhouse Effect

Item:

The greenhouse effect is what makes greenhouses so hot on sunny days, and keeps the Earth's surface temperature high enough to support life. The greenhouse effect is explained by:

A. The large number of plants growing in greenhouses and on the Earth.

B. The light energy coming in is able to penetrate the glass surface (or atmosphere) but the heat given off is trapped and cannot escape.

C. Freon from air conditioners and spray cans depleting the ozone layer.

D. The sun is very strong and there is not enough air circulation to let the heat escape.

Justification:

What phenomenon is making the Earth's greenhouse effect more pronounced in today's society?

Answer:

B. The light energy coming in is able to penetrate the glass surface (or atmosphere) but the heat given off is trapped and cannot escape.

The level of thinking is knowledge and the science is ". . . Some materials are transparent to some forms of radiation. . . ." The error with "A" is that although plants usually grow in greenhouses, their growth is not responsible for this effect. The error with "C" is that freon and the ozone layer is a separate concern relating to our atmosphere. The error with "D" is that it is too simplistic an answer and does not apply to the Earth. None of the incorrect answers can be correctly justified.

Science as Inquiry

Heat Transfer, Etc.

Item:

Concept: heat transfer, radiation, absorption, reflection.

Materials. 3 thermometers; 3 pieces aluminum foil (10 × 10 cm square, paint one white, one black and leave one unpainted); timing device; sunlight (or lamp with 100-watt bulb); 1–2 sheets graph paper; 3 pencils (different colors)

Completely cover the bulb of each thermometer with a different piece of foil. Record the temperature of each thermometer. Place in sunlight (or under the lamp). After one minute, read and record the temperature of all three thermometers. Repeat this for a total of 15 minutes. Make a line graph of the three sets of temperature readings.

What was the initial temperature of the three thermometers? What was the final temperature of the three thermometers? How do the three slopes of the graph compare? What do you think caused your results to be the way they turned out? Explain in therms of heat transfer.

Justification:

Answer:

Science as Inquiry/Science in Personal and Social Perspectives

Convection Currents

Item:

Determine how convection currents work.

Materials. 400-mL beaker; red vegetable dye; hot plate; 2 thermometers; safety goggles; eye dropper.

Put on safety goggles. Fill beaker about 3/4 full. Very carefully drop one or two drops of red dye in the water, near the edge of the beaker. Turn the hot plate on to low. Put one thermometer in the water, down to the bottom of the beaker. Place the second thermometer so that only the tip is in the water, at the top of the beaker. Continue to observe the beaker until after the water begins to boil. Keep a record of the temperature of the water, both on the bottom and on the top. Note what the dye is doing.

What does the movement of the dye in the beaker suggest about what is happening inside the beaker? How is the water at the top of the beaker warmed? What is this process called? Describe it. How could you use what you have learned here to explain what is happening in the ocean?

Justification:

Answer:

Science as Inquiry

Conducting Heat

Item:

Show the conduction of heat.

Materials. Ring stand and crossbar; burner; 4 strings—all waxed at one end and weighted on the other.

On the crossbar of the ring stand, heat the waxed ends of the stings and fasten about 1 inch apart, near the end. Hold the heated, waxed-end of the string to the crossbar until it cools off and sets. Near where the crossbar crosses the perpendicular end of the ring stand, heat the bar until the string falls off.

Describe the process that was taking place to cause the strings to fall off. Why did the strings fall in the order they did?

Justification:

Answer: