# THE GREAT HEAT ESCAPE

## Overview:

Students observe a demonstration of the role of thermal conductivity in heat transfer, and design and conduct an experiment to compare the thermal conductivity of four substances. (NOTE: This lesson may require two class periods.)

## Objectives:

The student will:

- observe a demonstration of the role of thermal conductivity in heat transfer;
- design and conduct an experiment to compare the thermal conductivity of various substances; and
- compare the types of insulation used in traditional Athabascan homes to modern-day construction techniques.

## Targeted Alaska Grade Level Expectations:

*Science*

[7-8] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring and communicating.

[7-8] SA1.2 The student demonstrates an understanding of the processes of science by collaborating to design and conduct repeatable investigations, in order to record, analyze (i.e., range, mean, median, mode), interpret data, and present findings.

[7] SB1.1 The student demonstrates an understanding of the structure and properties of matter by using physical properties (i.e., density, boiling point, freezing point, conductivity, flammability) to differentiate among and/or separate materials (i.e., elements, compounds, and mixtures).

[8] SB1.1 The student demonstrates an understanding of the structure and properties of matter by using physical and chemical properties (i.e., density, boiling point, freezing point, conductivity, flammability) to differentiate among materials (i.e., elements, compounds, and mixtures).

[8] SD3.2 The student demonstrates understanding of cycles influenced by energy from the sun and by Earth's position and motion in our solar system by recognizing types of energy transfer (convection, conduction, and radiation) and how they affect weather.

## Vocabulary:

***catalyst* –** a substance that starts or speeds up a chemical reaction between other substances

***conduction* –** the flow of energy, such as heat or an electric charge, through a substance; in heat conduction the energy flows by direct contact of the substance's molecules with each other

***convection* –** the transfer of heat energy through liquids and gases by the movement of molecules; when molecules of liquid or gas come in contact with a source of heat, they move apart and away from the source of heat, and cooler molecules take their place; eventually, as the cooler molecules are heated, they move as well, and a convection current forms, transferring the heat

***energy* –** the capacity or power to do work; energy can exist in a variety of forms, such as electrical, mechanical, chemical, thermal, or nuclear

***energy transfer* –** any form of energy can be transformed into another form; different forms of energy include kinetic, potential, thermal, gravitational, sound, light, elastic and electromagnetic

***heat* –** a form of energy produced by the motion of molecules; the heat of a substance is the total energy produced by the motion of its molecules

***insulator* –** a material that blocks or slows down the passage of sound, heat, or electricity

***radiation* –** the emission or movement of energy through space or a medium, such as air

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***temperature*** – a measure of the average kinetic energy of atoms or molecules in a system; a numerical measure of hotness or coldness on a standard scale such as Fahrenheit, Celsius and Kelvin

***thermal*** – relating to heat

## Whole Picture:

Traditional Athabascan homes used materials readily available in the environment to create a warm and cozy winter home heated by a central fire pit and by body heat. Construction techniques used in dwellings, such as the sod house, showed an understanding of the insulating qualities of the building materials and of snow.

Modern home construction techniques seek to reduce the amount of heat transfer. In the winter, insulation keeps heat inside from escaping and keeps outside cold from entering. In summer it may be the opposite! In home insulation, the "R-value" indicates how well a material insulates. For example, one inch of high-density fiberglass has an R-value of five (R-5), an inch of polyurethane panel can obtain an R-value as high as eight (R-8), and one inch of brick has an R-value of one point eight (R-1.8). One inch of snow has an R-value of one (R-1).

Heat is transferred in three ways: conduction, convection and radiation.

Conduction is the flow of energy, such as heat, through a substance. Heat energy flows by direct contact of the materials. In other words, when things are touching, the heat passes from the hotter to the cooler. If you touch a hot surface, your fingers get burned because of the heat transfer.

Convection is the transfer of heat energy through liquids and gases (fluid) by the movement of molecules. Temperature difference is the catalyst that begins the convection process. There may be a difference in temperature within the fluid, between the fluid and its boundary, or from the application of an external heat source. The basic premise behind convection is that when material cools, it becomes more dense so it sinks, while heated matter becomes more buoyant and rises.

Convection plays a role in the movement of air in Earth's atmosphere. When air close to Earth's surface is heated by solar energy, it becomes less dense and rises. Cooler, more dense air sinks, rushing in to fill the space. The cooler air then heats, rises and the process continues. The American Meteorological Society defines convection as this: "Vertical air circulation in which cool air sinks and forces warm air to rise." The process is visible in a pot of water on a hot stovetop. The heated water expands (becoming lighter or more buoyant) and rises to the top. The cooler water sinks. The process repeats and a circulation cycle is visible. Fluid trapped in such a cycle is called a convection cell, a common weather phenomenon.

Radiation is the emission or movement of energy through space or a medium, such as air. It is energy transmitted in a wave motion (like electromagnetic waves). The sun's energy (light and heat) reaches Earth through the process of radiation. It travels through space, then through Earth's atmosphere. When radiant energy reaches a surface it is either reflected or absorbed. Think of a greenhouse. The radiant energy enters through the glass and the heat energy is absorbed by things inside (soil, water, etc.) which "trap" the heat and slow it from leaving the greenhouse.

## Materials:

- Glass beaker
- Styrofoam™ cup
- 2 thermometers
- Hot water
- Bucket
- Snow or ice
- Small sheet of aluminum foil (one per group)
- Stopwatch
- Cotton balls (1 cup per group)
- Rice (1 cup per group)
- Play dough (2 ounces per group)

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- Cups, 3 ounces (four per group)
- Half-pint wide-mouth canning jars (four per group)
- Ice cubes (four per group)
- Aluminum dish, 9" x 9" or larger (one per group)
- STUDENT LAB: "Is it Hot or Not?"
- TEACHER INFORMATION SHEET: "Alternative Experiment"
- STUDENT INFORMATION SHEET: "Traditional Housing"
- STUDENT WORKSHEET: "Comparing Houses"

## Activity Preparation:

1. Prepare a bucket of ice or snow. Store in the freezer or outside if it is cold enough. If weather permits, this activity can be done outside using the snow on the ground instead.
2. Prepare a chart on the board or on chart paper. It should have three columns and 12 rows. One column will have the heading, "Time," the next "Styrofoam™ cup," and the last, "Glass beaker". The remaining rows will allow for the recording of temperature every 30 seconds over a five-minute period. See example at right:

| Time in minutes | Temperature: Styrofoam cup | Temperature: Glass beaker |
|---|---|---|
| 0:00 | | |
| 0:30 | | |
| 1:00 | | |
| 1:30 | | |
| 2:00 | | |
| 2:30 | | |
| 3:00 | | |
| 3:30 | | |
| 4:00 | | |
| 4:30 | | |
| 5:00 | | |

## Activity Procedure:

1. Hold up one glass beaker and one Styrofoam™ cup. Ask students what they think will happen to the temperature of hot water in the containers if they are placed in snow or ice. Ask students to predict which container will lose heat faster and write student predictions on the board. (NOTE: For the demonstration to be a "fair test" the beaker and the Styrofoam™ cup should be a similar size and shape so each has the same surface area touching the snow and ice. The amount of surface area has a big impact on conduction.)
2. Assign one student to be a timekeeper. Assign two other students to be temperature trackers, one for each container. Explain that when signaled, the timekeeper should begin the stopwatch and announce the time every 30 seconds for 5 minutes. The temperature trackers will note the temperature in their assigned container at each 30-second interval.
3. Pour 1 cup of hot water into a glass beaker and 1 cup into a Styrofoam™ cup. Place a thermometer inside each cup. Cover each with aluminum foil. (This will reduce the influence of cooling from evaporation and exposure to ambient air temperature.) Place the cup and beaker in the snow and signal the timekeeper to start the stopwatch and begin announcing the time for the temerature trackers. When five minutes are up, write the times and temperatures on the pre-prepared chart (see Activity Preparation) for all students to see.
4. Ask students to use the information on the chart to make a graph showing the water temperatures over time in both the Styrofoam™ cup and the glass beaker. Each graph must have the "X" and "Y" axes labeled and a key. Students should create a line graph. Give students five minutes to complete their graphs.

5. Discuss the results of the activity. Ask the following questions:
   a. Which container kept the water hot for a longer period of time?
   b. Did the results surprise you?
   c. What difference in the materials of each container might have contributed to the loss of heat?
   d. If you wanted to keep your hot chocolate warm for as long as possible, which container would you choose?
6. Remind students that heat can also be called thermal energy. It is transferred by conduction, convection, and radiation. Review the definitions. Ask students which type of energy transfer occurred in the demonstration (conduction). (NOTE: Radiation and convection also occur, but only the transfer of heat to the surrounding medium is considered in this demonstration.) Make sure students understand that the water is cooled because heat is being transferred from the hot water through the container to the ice or snow around the cups, not because the ice or snow transfers cold.
7. Refer students back to the chart and to their graphs. Discuss why the water in the glass beaker lost heat faster than the Styrofoam™ cup. Explain that the Styrofoam™ cup has a lower thermal conductivity than the glass beaker. Thermal conductivity is a measure of the rate at which heat travels through a substance and is a physical property of matter. A material with a high thermal conductivity, like glass, transfers heat quickly. A material with a low thermal conductivity, like Styrofoam™, transfers heat slowly. Things that have a low thermal conductivity are also called insulators, because they insulate or slow down the loss or gain of heat.
8. Ask students why they might want to know the thermal conductivity of a substance. When is thermal conductivity important? (Insulating walls, roofs; in jackets, coats; coffee mugs, thermoses, etc.)
9. Show students the materials list for the STUDENT LAB: "Is it Hot or Not?" (air, cotton balls, play dough, rice). Ask, "Which do you think has the highest thermal conductivity?" Explain that students will conduct an experiment to determine which material has the highest thermal conductivity. Divide students into small groups and distribute the STUDENT LAB: "Is it Hot or Not?"
10. Assist students throughout the process of writing a hypothesis and designing their experiment as needed. Check student experimental procedures for practicality and experimental validity before providing them with the necessary materials. Student experiments should have a control group and a single variable. (NOTE: If students are unable to design an appropriate experiment, or if time or materials are unavailable, use the procedure in the TEACHER INFORMATION SHEET: "Alternative Experiment.")
11. Allow students time to perform their experiments and complete their worksheets.
12. Ask each group to share their experiment with the class, including their hypothesis, process, data and conclusion. Discuss how student results differed and why. (Differing experimental procedure, etc.) (NOTE: While the thermal conductivity of air is very low, heat is transported effectively through the process of convection. This may happen in the experiment, but should not substantially influence the results. It is, however, important to a more in-depth understanding of density and heat transfer. In low-density materials with high air volumes and large empty spaces, heat can be transferred quickly through convection, as opposed to more slowly through conduction.)
13. Ask the following critical thinking questions:
   a. Based on the results of this experiment, what can be inferred about insulating a home?
   b. How does a thermos keep things cold? (*Remember, a thermos is often made of metal and glass, which seems counter intuitive. The reason it works is the vacuum between those materials. The heat cannot be transferred because there are no molecules present in the vacuum.*)
   c. How about bunny boots (extreme cold vapor-barrier boots) developed by the United States armed forces? (*These boots have an area of dead air space and a layered sole.*)
14. Hand out STUDENT INFORMATION SHEET: "Traditional Housing." Read the information with the class. Ask students to complete STUDENT WORKSHEET: "Comparing Houses."

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## Extension Ideas:

1. If you have access to different kinds of furs, such as caribou, moose, rabbit, etc., do a similar test as in the lesson. Wrap the fur around jars of hot water and do a "before and after" temperature measurement to see which fur is the best insulator.
2. Test man-made materials, such as socks or mittens, to see which is the best insulator.

## Answers to STUDENT LAB: "Is it Hot or Not?"

1. Styrofoam™ cup.
2. 2-14 Answers will vary

## Answers to STUDENT WORKSHEET: "Comparing Houses"

1. Modern
2. Traditional
3. Traditional
4. Modern
5. Traditional
6. Answers will vary

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## Testable Question

Which material has the highest thermal conductivity: air, cotton balls, rice, or play dough?

## Observations

1. In the classroom demonstration, which material had the higher thermal conductivity: glass beaker or Styrofoam? ______________________________
2. Based on the classroom demonstration and your own personal experience, which material do you believe has the highest thermal conductivity? Explain your reasoning.

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

## Background Information

Thermal conductivity is the measure of how much heat is transferred through a substance. The higher the thermal conductivity, the faster heat is transferred through the substance. Air has a very low thermal conductivity. In the case of snow, the more dense it is, the higher its thermal conductivity.

## Hypothesis

3. Use the background information in this worksheet to write a hypothesis about which material has the highest thermal conductivity: air, cotton balls, rice, or play dough.

If ______________________________________________________________

then ______________________________________________________________

because ______________________________________________________________ .

## Experiment

**Materials:**

4. List the materials required for the experiment:

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

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**Procedure:**

5. Write the procedure for the experiment, step by step. If more steps are needed, continue on the back of this sheet, or attach a separate sheet of paper.

STEP 1 ____________________________________________________________

STEP 2 ____________________________________________________________

____________________________________________________________

STEP 3 ____________________________________________________________

____________________________________________________________

STEP 4 ____________________________________________________________

____________________________________________________________

STEP 5 ____________________________________________________________

____________________________________________________________

STEP 6 ____________________________________________________________

____________________________________________________________

STEP 7 ____________________________________________________________

____________________________________________________________

STEP 8 ____________________________________________________________

____________________________________________________________

STEP 9 ____________________________________________________________

____________________________________________________________

STEP 10 ____________________________________________________________

____________________________________________________________

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**Data:**

6. Use the grid below to chart experimental data.

**Analysis:**

7. Use the grid below to graph the data.

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8. What patterns do you see in the data? ______________________________

9. How would you explain the patterns in the data? ______________________________

**Conclusion:**

10. Was your hypothesis proved or disproved? ______________________________

11. What data proved or disproved your hypothesis? ______________________________

**Questions:**

12. If your hypothesis was disproved, how would you revise your hypothesis? Explain your reasoning.

13. If you were to repeat the experiment, how would you change the procedure? Why?

14. What new questions do you have?

## Materials

- 3-ounce cups (4)
- Half-pint wide-mouth canning jars (4)
- Cotton balls (1 cup)
- Play dough (2 ounces)
- Rice (1 cup)
- Ice cubes (4)
- Hot water, not boiling
- Aluminum or glass baking dish (9" x 9" or bigger)

## Procedure

STEP 1. Place cotton balls in one of the canning jars to the cover the bottom. Fill the bottom of the other two jars with play dough and rice. Leave one cup empty; this is the control, filled with air.

STEP 2. Place a 3-ounce cup inside each of the jars.

STEP 3. Fill the space in-between the cup and the jar with rice, play dough, and/or cotton balls. You may need to remove the cup to fill the sides and then replace the cup. [Illustration]

STEP 4. Place the jars inside the baking dish so that they are evenly spaced. Fill the dish with hot water.

STEP 5. Place an ice cube in each 3-ounce cup. Check cups and make observations every 5 minutes for 30 minutes.

# TRADITIONAL HOUSING


Archives, University of Alaska Fairbanks

Traditionally among Athabascans, housing was built to suit the season and tasks of the people.

During the spring and summer, many families traveled to fish camps like this one along the Tanana River (*right*).

Summer camps consisted of tents or other semi-permanent dwellings.

Winter camps, however, were set up during the coldest months of the year and interiors had to be warm.

Winter camp was made up of several households, and although the exact house plan and building materials varied from area to area, the winter houses of many Athabascan groups were similar. They were semi-subterranean structures made of a wood frame covered by birch or spruce bark, which was then covered by moss, and topped with soil. All that was visible of the houses from ground level were mounds of snow with smoke curling out of the centers. The semi-subterranean house plan used by most Alaskan Native groups in winter is excellent for retaining heat, because there is little surface area through which heat can escape and cold winds cannot penetrate the structure. In addition, the many layers of insulation used on Interior Athabascan winter houses kept the inside quite warm.

## Chief Robert Charlie Talks About Building a Sod House

"Let us go back to the ancestral times of Athabascan People when there was no such building material as is available nowadays. To build a sod house, say a 15' by 15' round structure, you must first gather your materials. Athabascans always carried hand-made tools with them when moving in small groups, for cutting and digging. In this case tools were made of bones or obsidian."

"Laying the foundation is digging dirt two or three feet deep for a 15' x 15' family-sized house. The wall frame is spruce or willow 10 feet long and three inches in diameter at the trunk. The poles would be four to six inches apart all the way around. The house is built like a tepee, seven to eight feet high with a hole in the upper center so the smoke can go out. Around the frame they wrap birch bark or dried and oiled caribou hide. Once the hide is up they would put soil and moss on the outer part of the walls. They put extra soil around the skirt of the sod house. The door would be of bear hide with full fur."

"Once the sod house is completed, there is no draft coming in and it makes it very comfortable. The fire in the center makes for a bright light and is used for cooking."

**NAME: ______________________________**

## COMPARING HOUSES

Think about the traditional housing described in STUDENT INFORMATION SHEET: "Traditional Housing" and compare it to modern construction techniques used in homes.

Label each sentence "Traditional" or "Modern."

1. ________________________ homes use materials like fiberglass and foam to insulate walls and roofs.

2. ________________________ homes use materials commonly found in the environment, such as moss, to insulate walls.

3. ________________________ homes ventilate using a hole in the center of the roof to let the smoke escape.

4. ________________________ homes have a heating system, such as a furnace or wood-burning stove.

5. ________________________ homes have a fire pit for heat. Having lots of people in the home also provides heat.

### Critical Thinking

6. Why is it important to know the thermal conductivity (how much heat will transfer through) of materials used in building a home?

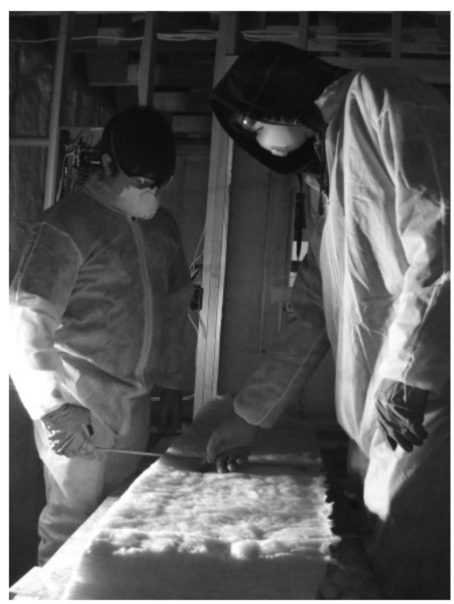
_______________________________________________________

_______________________________________________________

_______________________________________________________

_______________________________________________________

_______________________________________________________



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