HOW IS HEAT TRANSFERRED?

UNIT 1: Energy & Heat
Lesson 1 — Grades 4 -5
INSTRUCTIONS

Overview

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

Objectives

On successful completion of this lesson, students will be able to:

- investigate how heat flows from one object to another by conducting an experiment with different insulating and conducting materials;
- explain the effectiveness of different insulating and conducting materials with respect to heat flow by reporting on recorded results; and
- use scientific processes and inquiry to dirctly support concepts on energy, heat, light, and sound.

Alaska Standards

Alaska Science Standards / Grade Level Expectations

[4, 5] 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.

[4, 5] SA1.2 The student demonstrates an understanding of the processes of science by using quantitative and qualitative observations: observing, measuring, and collecting data from explorations and using this information to classify, predict, and communicate.

[4, 5] SA 2.1 The student will demonstrate an understanding of the attitudes and approaches to scientific inquiry by supporting their ideas with observations and peer review.

[4, 5] SB2.1 The student demonstrates an understanding of how energy can be transformed, transferred, and conserved by investigating the effectiveness of different insulating and conducting materials with respect to heat flow and demonstrates an ability to record the results.

[4, 5] SG2.1 The student demonstrates an understanding of the bases of advancement of scientific knowledge by recognizing the need for repeated measurements

Alaska Cultural Standards

[A] Culturally-knowledgeable students are well grounded in the cultural heritage and traditions of their community.

[D] Culturally-knowledgeable students are able to engage effectively in learning activities that are based on traditional ways of knowing and learning.

Bering Strait School District Scope & Sequence

4th Grade Sequence #1: Energy, Heat, Light, & Sound

5th Grade Sequence #2: Energy, Heat, Light, & Sound

Materials

- Glass beaker (approximately the same size and shape as the Styrofoam™ cup)
- Styrofoam™ cup (approximately the same size and shape as the glass beaker)
- 2 thermometers
- Hot water
- Bucket or tub
- Snow or ice
- 2 small sheets of aluminum foil
- Stopwatch
- Cotton balls (1 cup per group)
- Rice (1 cup per group)
- Play dough (2 ounces per group)
- 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: "The Great Heat Escape"
- Student Information Sheet: "Traditional Housing"
- Student Worksheet: "Comparing Houses"

Additional Resources

Harcourt School Publishers Science IV: Ch. 14, Lesson 2

Harcourt School Publishers Science V: Ch. 15, Lessons 2, 3

Activity Preparation

1. Prepare a tub of ice. Store it 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. Optional: Practice the experiment on your own the day before. Prepare the graph so you can help students as needed.

3. Prepare a chart on the board or on chart paper, following the example below. It should have three columns and 12 rows.

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		

Whole Picture

Traditional Alaska Native architecture used materials readily available in the environment to create winter and summer homes. Construction techniques used in dwellings showed an understanding of the insulating qualities of the building materials and of snow. Typically, winter homes were semi-subterranean and sod-covered, with an entrance tunnel that was lower than the main chamber's floor. Temperatures inside could range from mildly warm to extremely hot, depending on the hearth/cooking lamp and how many people were inside. All homes had some means of ventilating stale air and heat. Usually, this was through a gut or skin skylight in the ceiling.

In the summer months, most groups relocated to an above-ground summer dwelling. Unlike winter homes with their tunnel entrances, summer dwellings were usually a tent-like construction, made from a framework of poles (either bone or wood) and covered with seal or caribou skin. Some groups maintained their semi-subterranean dwellings, but had an above-ground summer entrance. Summer shelters were used primarily for sleeping, as all cooking took place outdoors.

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, by direct contact from one source to another. 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. For example, when ironing, heat from the iron moves directly onto the clothing.

Convection is the transfer of heat energy in liquids and gases by the movement of molecules. As a gas or liquid is heated the heat causes the molecules to move up, carrying heat to the area above the source. Cooler, denser molecules sink, replacing the warm ones, and the process continues, forming a current.

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.

Vocabulary

conduction	the transfer of thermal energy from one object directly into another; the movement of heat between two materials that are touching
convection	the transfer of heat in liquids and gases by the movement of molecules; as a gas or liquid is heated the heat causes the molecules to move up, carrying heat to the area above the source
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 by waves that move through space or a medium, such as air

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, or Kelvin

Activity Procedure - Demonstration

1. Hold up one glass beaker and one Styrofoam™ cup. (**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.)
    a. Ask students what they think will happen to the temperature of hot water in the containers if they are placed in snow or ice.
    b. Ask students to predict which container will lose heat faster and write student predictions on the board.
2. Ask for five student volunteers
    a. Assign one student to be a timekeeper.
        i. Explain that when signaled, the timekeeper should begin the stopwatch and announce the time every 30 seconds for 5 minutes.
    b. Assign two other students to be temperature trackers, one for each container.
        i. They will read the thermometer in their assigned container at each 30-second interval, and relay the information to the scribe.
    c. Assign the remaining two students to be the scribes.
        i. Each will partner with one of the temperature trackers; they are responsible for writing the temperatures on the chart for everyone to see.
3. Pour 1 cup of hot water into the glass beaker and 1 cup into the Styrofoam™ cup.
    a. Place a thermometer inside each cup.
    b. Cover each with aluminum foil. (This will reduce the influence of cooling from evaporation and exposure to ambient air temperature.)
    c. Place the cup and beaker in the tub of ice, and signal the timekeeper to start the stopwatch.
4. When five minutes have passed, assist students in using the information on the chart to make a line graph showing the water temperatures over time in both the Styrofoam™ cup and the glass beaker.
    a. Each graph must include labeling of the "X" and "Y"axes, as well as a key.
    b. Allow students five minutes to complete their graphs. Assist students as necessary.
5. Discuss the results of the activity. Ask the following questions:

   a. Which container kept the water hot for the longest period of time?
   b. Did the results surprise you? Why? Why not?
   c. How might the 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.
   a. It is transferred by conduction, convection, and radiation. Review the definitions.
   b. 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.)
   c. Make sure students understand that the water is cooled because heat is being transferred from the hot water, to 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.
   a. Discuss why the water in the glass beaker lost heat faster than the Styrofoam™ cup.
   b. Explain that the Styrofoam™ cup has a lower thermal conductivity than the glass beaker.
      i. Thermal conductivity is a measure of the rate at which heat travels through a substance and is a physical property of matter.
      ii. A material with a high thermal conductivity, like glass, transfers heat quickly.
      iii. A material with a low thermal conductivity, like Styrofoam™ transfers heat slowly.
      iv. 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.
   a. When is thermal conductivity important? (*Insulation for walls, roofs, jackets, coats, coffee mugs, thermoses, etc.)*

Activity Procedure: Student Lab

1. Show students the materials list for the Student Lab "The Great Heat Escape" (air, cotton balls, play dough, rice).
   a. Ask, "Which do you think has the highest thermal conductivity?" (Do not give the answer, allow students to suggest hypotheses and test them through the experiment.)
   b. Explain that students will conduct an experiment to determine which material has the highest thermal conductivity.

2. Divide students into small groups and distribute the Student Lab "The Great Heat Escape".
3. Assist students throughout the process of writing a hypothesis.
4. Allow students time to perform their experiments and complete their worksheets. Assist as needed.
5. Discuss how student results differed and why. (Differing amount of insulation, etc.)
    a. (**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.)
6. Ask the following critical thinking questions:
    a. Based on the results of this experiment, what can be inferred about insulating a home? (*It is good to use materials with low thermal conductivity)*
    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 do Bunny Boots (extreme cold vapor-barrier boots) keep feet warm? *(These boots have an area of dead air space and a layered sole.)*
7. Hand out STUDENT INFORMATION SHEET: "Traditional Housing" and the STUDENT WORKSHEET: "Comparing Houses"
    a. Read the information with the class.
    b. Instruct students to complete the worksheet. Assist as needed.

Extension Activities

- 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.
- Test man-made materials, such as mittens made from nylon and polyester, to see which is the best insulator.
- For homework, have students talk to cultural knowledge bearers to learn about methods for retaining heat. Instruct students to ask their parents, aunties, and grandparents about local stories and terms related to warmth. These might include stories about traditional men's community houses and sweat lodges, information about how clothing was traditionally constructed to provide for the greatest warmth, or language terms relating to heat and warmth. Ask students to share what they learn during the next class period.

Answers to Student Lab: "The Great Heat Escape"

Observations

1. Styrofoam cup™
2. Answers will vary (students should provide an explanation)

Hypothesis

3. Answers will vary, though all student hypotheses should include a statement about what they think will happen and why

Data

1. All student graphs should look the same, based on the data collected during the demonstration.
2. Graphs should be similar but will vary based on student data.

Analysis

3. Answers will vary based on grids above.
4. Answers will vary.

Conclusion

5. Answers will vary.

Questions

6. Answers will vary.
7. Answers will vary.

Answers to Student Worksheet: "Comparing Houses"

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

References

Lee, Molly, and Reinhardt, Gregory A. (2003). Eskimo Architecture: Dwelling and Structure in the Early Historic Period. Fairbanks: University of Alaska Press.

HOW IS HEAT TRANSFERRED?

Student Lab: "The Great Heat Escape"

Name: ____

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 (air, cotton balls, rice, or play dough)? 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.

   I think____

   because____

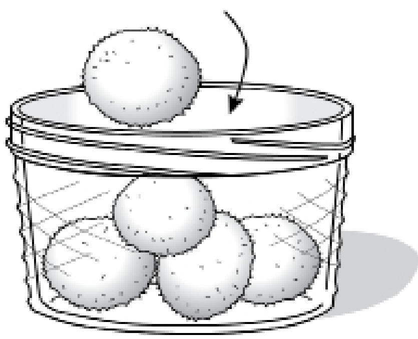
   ____

Materials

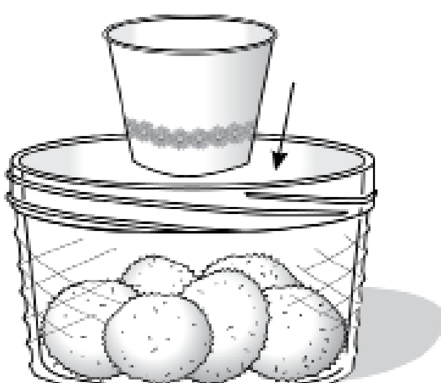
- 3-ounce cups (4)
- Half-pint wide-mouth canning jars (4)
- Cotton balls (1 cup)
- Play dough (2 ounces)
- Rice (1 cup)
- Ice cubes (4)
- Hot water, not boiling
- Aluminum or glass baking dish (9" x 9" or bigger)

Procedure

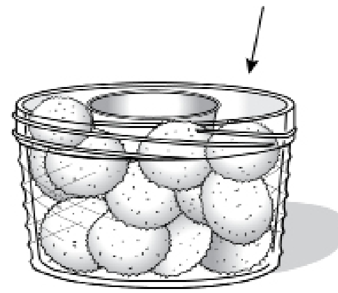
1. Place cotton balls in one of the canning jars to cover the bottom. Fill the bottom of the other two jars with play dough and rice. Leave one cup empty; this is the control, filled with air.



2. Place a 3-ounce cup inside each of the jars, on top of the insulator (cotton balls, rice, playdough).

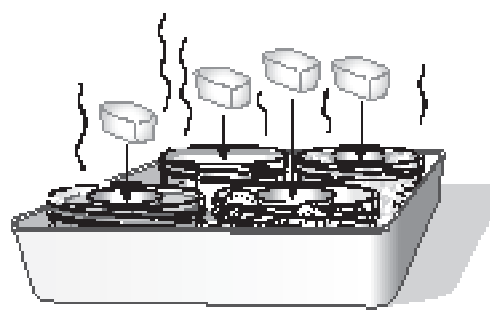


3. Fill the space between the cup and the jar with rice, play dough, or cotton balls. You may need to remove the cup to fill the sides and then replace the cup.



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

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



Data

1. Use the grid below to create a line graph using the demonstration data.

2. Use the grid below to create a graph using your own experiment data.

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Analysis

3. What patterns do you see in the data?_______________________________________

____

____

4. What do these patterns mean? (How would you explain the patterns?) ___________

____

____

Conclusion

5. Was your hypothesis proved or disproved? Explain.___________________________

____

Questions

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

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____

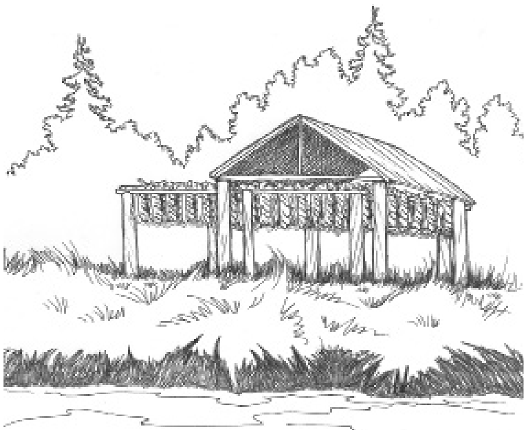
____

7. What new questions do you have?____

____

Student Information Sheet: Traditional Houses

Among Alaska Natives, housing was traditionally 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 a river.



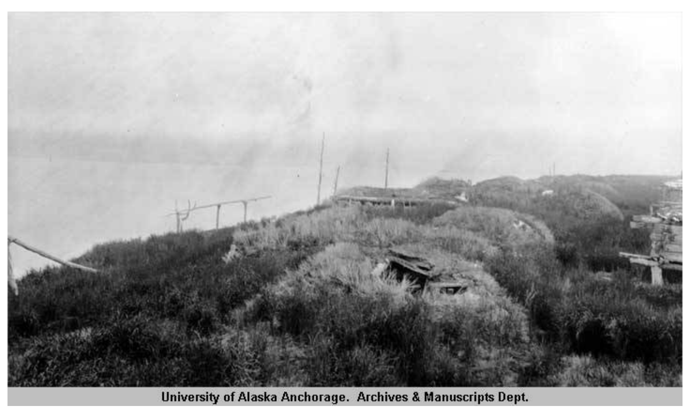
Summer fish camp along a river

Summer camps consisted of tents or other semi-permanent dwellings. These were constructed using bone or wood poles, and walrus, caribou, or other skin walls.

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 groups were similar.

Winter houses were semi-subterranean structures made of a wood frame covered by moss, and topped with soil. All that was visible of the houses from ground level were earthen mounds with smoke curling out of the centers. In the winter, these mounds looked like snow drifts! To enter the houses, people crawled through a long, low tunnel below the level of the main room. This meant a person entered through the floor!



Sod house in Old Savonoski, 1918

In the image to the right, the mounds of grass are sod-covered houses. The one in the foreground has a collapsed ceiling.

Most houses were heated by a central fire pit in the center of the room. Others were heated only by the small oil lamps that also provided artificial light. A small skylight in the center of the roof, usually covered by a gut "window" could be opened to provide ventilation and let smoke out. "Body heat" provided by people's own bodies, also helped to keep the rooms warm. The more people there were, the warmer it was!

The semi-subterranean winter house plan used by most Alaska Native groups was excellent for retaining heat, because there was little surface area through which heat could escape and cold winds could not penetrate the structure.

Image Sources

Illustration of summer fish camp by Putt Clark, 2013

Sayre, Jasper Dean. (1918). "Old Savonoski." National Geographic Society Katmai expeditions photo graphs, Archives and Special Collections, Consortium Library, University of Alaska Anchorage. UAA-hmc-0186-volume4-3678.

Student Worksheet: "Comparing Houses"

Name: ____

Think about the traditional housing described in the Student Information Sheet "Traditional Housing" and compare it to modern construction techniques used in homes.

Complete each sentence by writing either "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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____