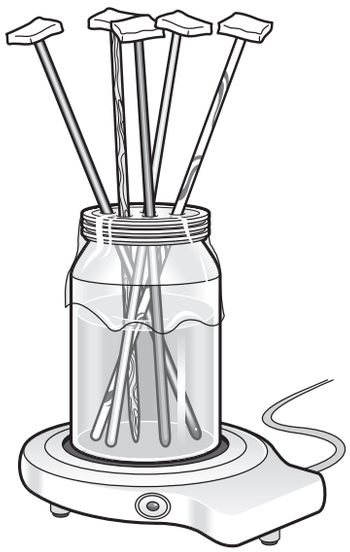
Lesson 6

Conductors: Testing the Transfer of Heat Energy



A QUICK LOOK

Big Idea

Warmer things lose heat, or transfer heat energy, to cooler things. Some materials conduct heat energy more easily than others.

Process Skills

- Comparing and contrasting
- Designing a fair test
- Identifying and controlling variables

Overview

Students continue exploring heat energy transfers, focusing on the concept of conduction. They compare how heat energy transfers from a warmer substance—in this case, water—to some cooler objects, and recognize that heat energy is conducted at different rates through different materials.

Key Notes

- If you don't think the students have an adequate understanding of how to design a fair test, consider teaching Skill Building Activity "Designing a Fair Test" on pages 224–233 prior to the lesson.
- For more information about the science content in this lesson, see the "Heat Transfer" section of the Teacher Background Information on page 247.

Lesson 6

Standards and Benchmarks

As the students observe a variety of materials to see which transfers heat most readily, they gain exposure to The Physical Setting Benchmark 4E (Energy Transformations), learning that: "Some materials conduct heat much better than others. Poor conductors can reduce heat loss."

They also strengthen their understanding of Physical Science Standard B (Transfer of Energy) as they discover that: "Heat moves in predictable ways, flowing from warmer objects to cooler ones."

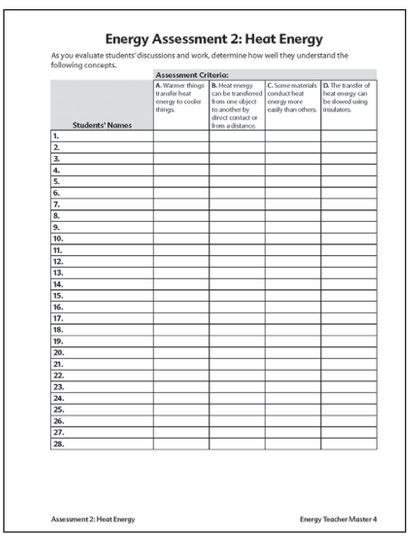
Lesson Goals

1. Recognize that a conductor is a material that allows heat energy to transfer through it.
2. Observe how some materials are better conductors than others.

Assessment Options

- Prior to this lesson, have students respond to the following question in their science notebook journal section: "Do you think heat is transferred through all materials at the same rate? Why or why not?" At the end of this lesson and at the end of Lesson 7, have the class respond to this question again so you can see how their understanding has grown.
- Assess the students' responses to the reflective questions on page 24 of their science notebooks. Do their answers show that they understand the fundamentals of heat energy conduction? Use criteria A through C on Assessment 2 to document the students' ideas. Check their understanding again during Lesson 7.

Notes



Energy Assessment 2: Heat Energy

As you evaluate students' discussions and work, determine how well they understand the following concepts.

Students' Names	Assessment Criteria: A. Warmer things transfer heat energy to cooler things.	B. Heat energy can be transferred from one object to another by direct contact or from a distance.	C. Some materials conduct heat energy more easily than others.	D. The transfer of heat energy can be slowed using insulators.
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Assessment 2: Heat Energy — Energy Teacher Master 4

Teacher Master 4, Assessment 2

Materials

Item	Quantity	Notes
ExploraGear		
Cup warmer	1	To heat water for exploration.
Rods, aluminum	4	To test heat conduction of aluminum.
Rods, bamboo	4	To test heat conduction of bamboo.
Rods, brass	4	To test heat conduction of brass.
Rods, copper	4	To test heat conduction of copper.
Rods, plastic	4	To test heat conduction of plastic.
Thermometer	1	To check water temperature.
Classroom Supplies		
Butter, chilled	1 stick (½ C)	For conduction exploration. Butter in stick form or small butter packets from restaurants work best. It will be cut into 6-mm (¼-in) thick slices.
Dental floss (optional)	1 piece	To cut butter slices.
Ice	1 plate	To keep butter chilled.
Glass canning jar, pint-size	1	To hold water and rods. Use a tall, heat-resistant jar with a wide mouth.
Plastic wrap	1 piece	To cover jar.
Scissors	1	To cut bamboo and plastic rods.
Stopwatch	1	To time how long it takes for butter to fall. A watch or clock with a second hand can be used instead.
Tray or foam plate	1	To hold butter.
Water	500 ml (2 C)	To heat on cup warmer for exploration.
Wax paper	1 piece	To line tray or foam plate.
Curriculum Items		
***Energy Science Notebook*, pages 22–24**		
***Energy Student Reference Book*, pages 57–68**		
Energy Assessment 2 "Heat Energy" (optional)		
Family Link Homework "Kitchen Conductors"		
Skill Building Activity "Designing a Fair Test," pages 224–233 (optional)		

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Preparation

- ❑ Fill the jar with approximately 500 ml (2 C) of water (use warm water if you have access to it). Place the jar on the cup warmer. Heat the water for **at least 1 hour prior** to the lesson. The water temperature should be around 44°C (111°F).

SAFETY NOTE: Do not use a microwave oven to heat the water. Water at 65°C (150°F) causes third-degree burns in two seconds; water at 60°C (140°F) causes third-degree burns in six seconds.

- ❑ You need to create one set of rods (aluminum, bamboo, brass, copper, and plastic) that are the same length. Use scissors to cut one bamboo rod and one plastic rod so they are the same length as the metal rods. Then mix them with the remaining rods. (During the introductory discussion, the students need to choose a set of rods that are all the same length from the batch of rods.)
- ❑ Use dental floss to cut the stick of butter into 6 mm (¼ in) slices. Lay the slices on a tray or foam plate lined with wax paper, and then freeze the slices overnight. Make sure the butter remains chilled until the lesson begins. Consider setting the tray or plate of butter slices on a bed of ice to keep the butter slices cool.
- ❑ Create a workspace in your classroom that all students can see easily. Include the following supplies:
  - Jar of water on cup warmer
  - Rods (aluminum, brass, bamboo, copper, and plastic)
  - A piece of plastic wrap
  - A stopwatch
  - Butter slices on a bed of ice
- ❑ (Optional) You may want to run through the exploration prior to the lesson so you have a clear understanding of the setup and expected results.
- ❑ Copy the **Family Link Homework "Kitchen Conductors"** for the students to take home.

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Using the Student Reference Book

To extend the students' understanding, have them read Chapter 6 of the student reference books after the lesson. This chapter may also help them as they work on the Family Link Homework "Kitchen Conductors." The history connection section on pages 64–67 is optional, and can be used for reading enrichment.

Vocabulary

conduction ..... The transfer of heat energy through a material.

conductor ..... A material that heat energy can transfer through.

fair test ..... An experiment that compares something by changing one variable while keeping all other variables the same.

good conductor .... A material that heat energy transfers through rapidly.

poor conductor ..... A material that heat energy transfers through slowly.

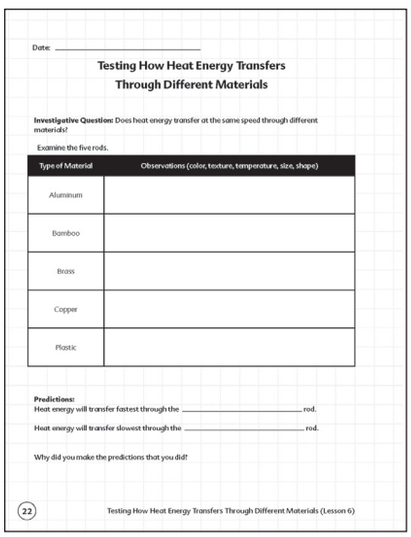
variable ..... Any factor in an experiment that can be changed.

Teaching the Lesson

Engage

Introductory Discussion

1. Show the students the rods and let them know what material each rod is made of (aluminum, bamboo, brass, copper, and plastic).
2. Pass the rods around the classroom. Direct the students to feel and examine the rods closely and note their observations on page 22 of their science notebooks.
3. Tell the class that today they are going to use these rods to determine whether heat energy transfers at the same speed through different materials.
4. Define the term *variable* as any factor in an experiment that can be changed. Also review with the class that in a *fair test*, you only change one variable in an experiment and keep all other variables the same.



Date: _____

Testing How Heat Energy Transfers Through Different Materials

Investigative Question: Does heat energy transfer at the same speed through different materials?

Examine the five rods.

Type of Material	Observations (color, texture, temperature, size, shape)
Aluminum	
Bamboo	
Brass	
Copper	
Plastic	

Predictions:
Heat energy will transfer fastest through the _____ rod.
Heat energy will transfer slowest through the _____ rod.

Why did you make the predictions that you did?

22 Testing How Heat Energy Transfers Through Different Materials (Lesson 6)

***Science Notebook* page 22**

5. Challenge the students to identify the best set of rods to use to determine whether heat energy transfers at the same speed through different materials. Have the students consider the following questions as they determine which rods to compare:

   - If they want to determine whether heat energy transfers at the same speed through different materials, what variable should they change? (*They should change the type of material.*)
   - What are examples of variables that need to remain consistent among materials for the test to be fair? (*Length of rod, diameter of rod, liquid rods are placed into, etc.*)

6. Help the class reach a consensus on the best set of rods to compare. (*They should choose the aluminum, bamboo, brass, copper, and plastic rods that are the same length.*)

Explore

Testing Heat Energy Conductivity

This teacher-led exploration shows the relative conductivity of different materials. The students observe the time it takes for a slice of butter to slide from the top of each of the rods when the ends of the rods are placed in a container of hot water.

1. Point out the materials you set out in the exploration work space (jar of heated water on cup warmer, butter slices on a bed of ice, piece of plastic wrap, stopwatch, and the set of rods selected by the class).

Teacher Note: To confirm that the temperature of the water is warmer than the temperature of the rods, you might place a thermometer in the water and have a volunteer read the temperature and share it with the class. Then have the same volunteer feel the rods and relate to the class that the rods are cooler than the water.

2. Review with students the investigative question on page 22 of their science notebooks: "Does heat energy transfer at the same speed through different materials?" Then have them predict the material they think heat energy will transfer through the fastest and what material heat energy will transfer through the slowest.

Teacher Note: If the students are having difficultly with their predictions, have them think about items in their lives that are made of the same materials (a plastic container, an aluminum pan, a wooden pencil, etc.) and consider how easily heat energy might move through them.

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3. Explain to the students that, as a class, they will test their predictions by observing how quickly slices of butter slide from the rods when the rods are placed in a jar of hot water.

4. Engage the students in a conversation about the size and placement of the butter. Questions might include:

   - Does each slice of butter need to be the same size? (*Yes*)
   - Does it matter where on each rod the butter is placed? Why? (*Yes, the butter needs to be placed in the same location on each rod to ensure that the experiment is a fair test.*)

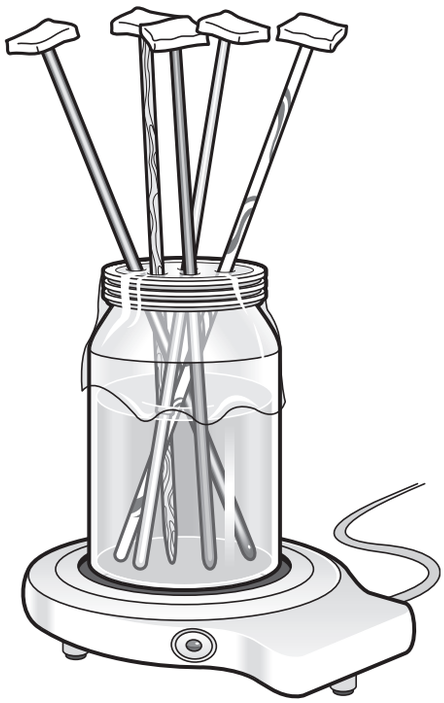
5. As you are performing the following steps to set up the experiment, discuss with the children why they think putting chilled butter on each rod will help them answer the investigative question. (*As the heat energy transfers from the water through the rods, it softens the butter and causes it to slide from the rods.*)

MANAGEMENT NOTE: Consider having one or two student volunteers assist you. One student might hold the rods once the butter is placed on them (before they are put into the jar). A second volunteer might start the stopwatch once the rods are placed into the jar.

   a. Cover the top of the jar with plastic wrap. With a pencil or pen, carefully poke five holes through the plastic wrap. Place the holes close to the edge of the jar.

   b. Press a piece of butter on top of each rod.

c. Place the rods in the jar through the holes in the plastic wrap, making sure the rods do not come in contact with each other in the water.



d. Start the stopwatch immediately (or use a clock with a second hand). Tell students the beginning time to record in the data table on page 23 of their science notebooks.

e. Note the time on the stopwatch (or clock) when a slice of butter slides down a rod and touches the rim of the jar. Tell students the ending time for each type of rod so they can record the data in their science notebooks. Let a volunteer feel each rod and report to the class whether the rod feels warm or cool to the touch.

TEACHER NOTES: The butter on the copper and aluminum rods should fall quickly. It will take longer for the butter on the brass, bamboo, and plastic rods to fall. The butter may fall from the brass rod within ten minutes; however it will not fall from the bamboo and plastic rods within the ten minute timeframe.

6. End the exploration after ten minutes. Remind students to respond to the reflective questions on page 24 of their science notebooks.

NOTES

Date: _____

Testing How Heat Energy Transfers Through Different Materials

Date:

Material	Beginning Time	Time When the Butter Slid Down	Elapsed Time (or 10+ minutes)	How the Rods Felt When Touched (Cool, Warm, Hot)
Example 1	12:02 P.M.	12:10 P.M.	8 minutes	Warm
Example 2	12:02 P.M.		10+ minutes	Cool
Aluminum				
Bamboo				
Brass				
Copper				
Plastic				

1. Use the space below to calculate the time that elapsed (passed) before the butter fell off or slid down each rod.

2. What can you conclude about the transfer of heat through different materials?

Testing How Heat Energy Transfers Through Different Materials (Lesson 6) 23

***Science Notebook* page 23**

Date: _____

Testing How Heat Energy Transfers Through Different Materials

Reflective Questions:
Think about the materials you tested in class and how quickly heat energy transferred through each of them.

1. How did your results compare with your predictions?

2. Which material or combination of materials would you use to make a baking pan to bake a batch of cookies in the oven? Why?

3. Which material or combination of materials would you use to make a mug for hot chocolate? Why? (Remember that you want to keep your hands cool but the hot chocolate hot!)

24 Testing How Heat Energy Transfers Through Different Materials (Lesson 6)

***Science Notebook* page 24**

NOTES

Big Idea

Warmer things lose heat, or transfer heat energy, to cooler things. Some materials conduct heat energy more easily than others.

Reflect and Discuss

Synthesizing

1. Review how heat energy moved from the warmer water to the cooler rods.
   - How did heat energy transfer in the setups? (*It transferred from the warmer water to the cooler rods.*)
   - Did heat energy transfer from the rods to the butter? (*Yes, but only appreciably for the rods that the butter slid from.*)
   - How do the observations the students made relate to their findings in the previous science lesson? (*In Lesson 5 they discovered that heat energy transferred from warm water to cold water. In this lesson, the heat energy transferred from warm water through different materials, although it transferred through each rod at a different rate.*)
   - How did their results compare to their predictions?
2. Introduce the terms conduction and conductor. Stress the difference in the terms: *Conduction* is the transfer of heat energy through a material. A *conductor* is a material that heat energy can transfer through.
3. Discuss with the class how there are both *good conductors* and *poor conductors* of heat energy.
   - Which of the tested materials were good conductors? (*The copper and aluminum rods were good conductors.*)
   - Which materials were poor conductors? (*The brass, plastic, and bamboo rods were poor conductors.*)
   - Do they think water is a good or poor conductor of heat energy? (*Water is a good conductor.*)
4. Have the students think of times when people want heat energy to be conducted through things and times when they don't:
   - What are some objects people want heat energy to conduct through easily? (*Examples include pots and pans for cooking, the water in your bathtub, etc.*)
   - What are some objects people don't want heat energy to conduct through easily? (*Examples include house insulation, oven mitts, winter coats, mittens, etc.*)

Ongoing Learning

Science Center

Put the rods from the exploration in the Science Center. Have the students place them on a windowsill on a sunny day or on a heating vent for an hour and then feel each rod. Do the results match those in the exploration? Have the students record their observations in the journal section of their science notebooks.

Family Link

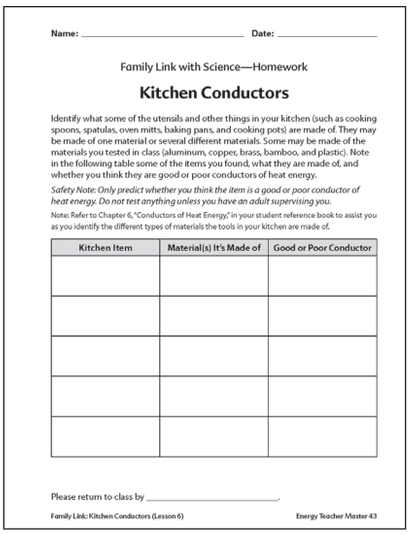
Give students the Family Link Homework "Kitchen Conductors," which invites them to examine the utensils and other tools in their kitchen to see what they are made of and compare their conductive qualities to the rods they tested in class.

Maintenance

Be sure to review the Family Link once all of the students have returned it. In particular, discuss similarities and differences in the items they found and encourage them to speculate about whether each one is a good or poor conductor of heat energy.

Notes

Materials: One of each of the types of rods (aluminum, brass, copper, plastic, and bamboo)



Name: _____ Date: _____

Family Link with Science—Homework

Kitchen Conductors

Identify what some of the utensils and other things in your kitchen (such as cooking spoons, spatulas, oven mitts, baking pans, and cooking pots) are made of. They may be made of one material or several different materials. Some may be made of the materials you tested in class (aluminum, copper, brass, bamboo, and plastic). Note in the following table some of the items you found, what they are made of, and whether you think they are good or poor conductors of heat energy.

Safety Note: Only predict whether you think the item is a good or poor conductor of heat energy. Do not test anything unless you have an adult supervising you.

Note: Refer to Chapter 6, "Conductors of Heat Energy," in your student reference book to assist you as you identify the different types of materials the tools in your kitchen are made of.

Kitchen Item	Material(s) It's Made of	Good or Poor Conductor

Please return to class by _____.

Family Link: Kitchen Conductors (Lesson 6) Energy Teacher Master 43

Teacher Master 43, Family Link

NOTES

Extending the Lesson

Further Science Explorations

Observing the Path of Heat Conduction

Put several pats of butter on an aluminum or copper rod at varying distances from one end of the rod. Place the rod in a jar of water that has been heated on the cup warmer. Have the students note the direction the heat energy conducts along the rod by observing the order in which the pats of butter slide down the rod.

Feeling for Conduction

Put out various materials (bamboo, metal, glass, plastic, wool, etc.) and let the students feel them. If available, use liquid crystal thermometer strips so the students see that the materials are all the same temperature. Have the students offer ideas on why the metal feels colder than the other materials. (*The heat from their hands traveled through the metal, making them lose some of their body heat so their hands felt cold.*) Use this experience to reinforce their awareness that heat moves easily through most metals.

Exploring Radiation

Introduce students to the transfer of heat energy over a distance, also known as *radiation*. Place a pat of butter on a small paper plate. Hold the plate about 10 cm (4 in) below a clamp lamp with an illuminated 25W incandescent light bulb and observe what happens. (*The butter melts.*) Discuss how heat energy was transferred through the air from the lamp to make the butter melt.

Mathematics Extension

Students can create a bar graph of the data they collected during the exploration to see even more clearly how the different materials compare as conductors.

Social Studies Extension

Have the students review the energy timeline in their student reference books on pages 129–146. Which milestones are related to heat energy? Some milestones might include the harnessing of fire, and the invention of the match, refrigerator, toaster, and microwave oven.

Planning Ahead

For Lesson 7

- You will need at least 9 wide-mouth plastic bottles (16–20 oz) with tops for Lesson 7. The mouths of the bottles have to be wide enough for the thermometers to fit into them. You might consider purchasing two six-packs of a sport-drink or juice so that you have bottles of the same size, shape, and type. The bottles should also fit easily into a gallon-size resealable plastic bag.
- Prior to Session 1 and Session 3, you will need to prepare enough ice to fill a large container, such as a large, plastic, underbed storage box. Make sure you acquire enough ice beforehand.

Science Notebook page 22

Date: _____

Testing How Heat Energy Transfers Through Different Materials

Investigative Question: Does heat energy transfer at the same speed through different materials?

Examine the five rods.

Type of Material	Observations (color, texture, temperature, size, shape)
Aluminum	
Bamboo	
Brass	
Copper	
Plastic	

Predictions:
Heat energy will transfer fastest through the _____ rod.

Heat energy will transfer slowest through the _____ rod.

Why did you make the predictions that you did?

Science Notebook page 23

Date: _____

Testing How Heat Energy Transfers Through Different Materials

Data:

Material	Beginning Time	Time When the Butter Slid Down	Elapsed Time (or 10+ minutes)	How the Rods Felt When Touched (Cool, Warm, Hot)
Example 1	12:02 P.M.	12:10 P.M.	8 minutes	Warm
Example 2	12:02 P.M.		10+ minutes	Cool
Aluminum				
Bamboo				
Brass				
Copper				
Plastic				

1. Use the space below to calculate the time that elapsed (passed) before the butter fell off or slid down each rod.

2. What can you conclude about the transfer of heat through different materials?

Science Notebook page 24

Date: _____

Testing How Heat Energy Transfers Through Different Materials

Reflective Questions:
Think about the materials you tested in class and how quickly heat energy transferred through each of them.

1. How did your results compare with your predictions?

2. Which material or combination of materials would you use to make a baking pan to bake a batch of cookies in the oven? Why?

3. Which material or combination of materials would you use to make a mug for hot chocolate? Why? (Remember that you want to keep your hands cool but the hot chocolate hot!)

Teacher Master 4, Assessment 2

Energy Assessment 2: Heat Energy

As you evaluate students' discussions and work, determine how well they understand the following concepts.

	Assessment Criteria:			
Students' Names	**A.** Warmer things transfer heat energy to cooler things.	**B.** Heat energy can be transferred from one object to another by direct contact or from a distance.	**C.** Some materials conduct heat energy more easily than others.	**D.** The transfer of heat energy can be slowed using insulators.
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Teacher Master 43, Family Link

Name: _____ Date: _____

Family Link with Science—Homework

Kitchen Conductors

Identify what some of the utensils and other things in your kitchen (such as cooking spoons, spatulas, oven mitts, baking pans, and cooking pots) are made of. They may be made of one material or several different materials. Some may be made of the materials you tested in class (aluminum, copper, brass, bamboo, and plastic). Note in the following table some of the items you found, what they are made of, and whether you think they are good or poor conductors of heat energy.

Safety Note: Only predict whether you think the item is a good or poor conductor of heat energy. Do not test anything unless you have an adult supervising you.

Note: Refer to Chapter 6, "Conductors of Heat Energy," in your student reference book to assist you as you identify the different types of materials the tools in your kitchen are made of.

Kitchen Item	Material(s) It's Made of	Good or Poor Conductor

Please return to class by _____.

Family Link: Kitchen Conductors (Lesson 6) Energy Teacher Master 43