Teacher Guide: Heat Transfer by Conduction

Learning Objectives

Students will …

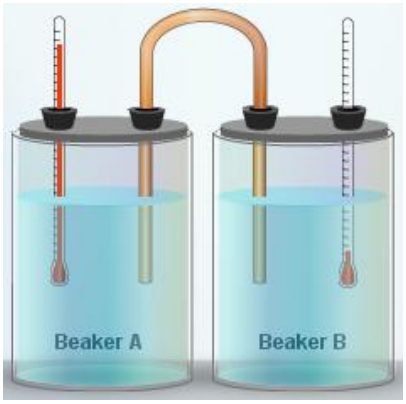
- Observe and measure the transfer of heat from one container to another via a thermal conductor.
- Interpret a graph of heat transfer.
- Find the relationship between the rate of temperature change and the temperature difference between the two containers.
- Compare the rate of heat transfer for different materials.
- Classify materials as thermal conductors or thermal insulators.

Vocabulary

conduction, convection, insulate, radiation, thermal conductor, thermal energy, thermal insulator

Lesson Overview

If you have ever grabbed the metal handle of a hot cast-iron frying pan, you have experienced how easily metal can conduct heat. Other materials, such as rubber or wood, resist the transfer of heat and therefore are good materials for pot handles.



The *Heat Transfer by Conduction* Gizmo™ allows students to measure the rate of heat transfer through a material that connects two beakers of water with different initial temperatures. Four different materials (aluminum, copper, steel, and glass) can be compared and classified.

The Student Exploration sheet contains two activities:

- Activity A – Students relate the rate of heat transfer to the temperature difference between the water in two beakers.
- Activity B – Students compare the rate of heat transfer through different materials.

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Too hot to handle!** (10 – 20 minutes)
   Obtain two frying pans or pots. One should have a metal handle and the other should have an insulated handle (such as a wood or rubber handle). Put some water in each pan (to prevent them from overheating) and place each pan over a hot plate or stove burner for several minutes. Test the handles for safety. If the handles are not too hot, allow your students to feel each handle. The metal handle will probably feel much hotter than the insulated handle because metal is a good conductor of heat.

   Afterwards, introduce the terms “conductor” and “insulator.” Ask your students which materials make the best conductors and which materials make the best insulators.

2. **Prior to using the Gizmo** (10 – 15 minutes)
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
    - What factors control the rate of temperature change in each beaker? [Two factors are demonstrated in the Gizmo: the temperature difference between the two beakers and the conductivity of the material that connects them. Other factors include the cross-sectional area and length of the connecting material.]
    - In the Gizmo, the beakers are perfectly insulated. What would happen if the beakers were not insulated?
    - Suppose the beaker on the left side of the Gizmo contained half as much water as the right beaker. How do you think this would alter the results of the experiment? [The temperature change of the left beaker would be twice as great as the temperature change of the right beaker.]
    - What type of material tends to be a good thermal conductor? [Metals tend to be good thermal conductors as well as good conductors of electricity.]

5. **Follow-up activities: Measuring heat transfer by conduction** (30 – 45 minutes)
A fun way to demonstrate conduction is to prepare a "conduction rod." To make a conduction rod, melt several drops of wax at regular intervals along a metal rod. Affix a marble to each melted drop of wax, and allow the wax to cool and harden. Use a Bunsen burner to heat one end of the rod. As heat travels along the rod, the wax will melt and the marbles will fall off one by one. See the **Selected Web Resources** on the next page of this document for details.

    The set-up shown in the *Heat Transfer by Conduction* Gizmo can be replicated in the laboratory. To minimize heat loss to the environment, use foam coffee cups or insulated mugs. Place a thermometer in each container. Fill one cup with hot water and the other with cold water, and connect the two cups with a U-shaped metal bar. Record the temperature of each cup or mug every 30 seconds, and create a graph of the results.

Scientific Background
The *thermal energy* of an object is a measure of how fast the particles that make up an object are moving. Molecules (or atoms) in a solid tend to vibrate, while molecules in a liquid or gas are in constant random motion, colliding frequently. The greater the thermal energy, the faster the particles are moving and the higher the temperature will be.

Thermal energy can be transferred by *radiation*, *conduction*, or *convection*. Radiation is the transfer of energy through space or matter in the form of electromagnetic waves. Types of electromagnetic radiation, from longest wavelength to shortest, include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays.

Convection is the transfer of thermal energy through the movement of molecules within a fluid. For example, if the water molecules at the bottom of a beaker are heated by a stove burner, the molecules will move faster and collide more violently with their neighbors. This causes the molecules to spread out, reducing their density and causing them to rise, thus transferring heat to the cooler water molecules at the top of the beaker. A *convection current* is a circulation pattern in which heated materials rise and cooler materials sink.

Conduction occurs when a hot substance comes into contact with a colder substance. The fast-moving particles in the hot substance collide with the slow-moving particles in the cold one. As a result of these collisions, the particles in the hot substance slow down and the particles in the cold substance speed up. This process continues until the temperatures of the substances are equal. Of the three processes, conduction is most relevant to solids because it involves no net motion of materials.

Materials that easily transfer thermal energy are *conductors*. Metals are good conductors due to the properties of the atoms that make up a metal. Metal atoms do not hold onto their outermost electrons very strongly. As a result, the electrons tend to move freely within the metal. These moving electrons are effective at conducting heat (or electricity). The most conductive metals are silver, copper, and gold. Most nonmetals do not conduct heat (or electricity) well because the electrons in nonmetals do not move around freely.

Earth Science Connection: The best thermal conductor

The best naturally-occurring thermal conductor is the diamond. Unlike metals, diamonds do not transmit heat through their free electrons. Instead, heat is transmitted through the strong covalent bonds that bind the carbon atoms in the diamond's crystalline structure. Because of this property, diamonds are used in several industrial processes, including the production of semiconductors. Gemologists often use a thermal probe to test the conductivity of a gem in order to determine if it is a genuine diamond.

Selected Web Resources

Conduction labs: http://www.angelfire.com/mb2/mbench/ch6/Assignments/conduction_lab.pdf, http://www.atmos.washington.edu/~durrand/demos/convection_conduction.htm
Conduction rod demonstrations: http://www.ucar.edu/learn/1_1_2_6t.htm, http://demo.physics.uiuc.edu/lectdemo/scripts/demo_descript.idc?DemoID=500
Heat transfer: http://hyperphysics.phy-astr.gsu.edu/HBASE/thermo/heatra.html, http://www.wisc-online.com/objects/ViewObject.aspx?ID=SCE304
Thermal conductivity: http://en.wikipedia.org/wiki/List_of_thermal_conductivities
Diamonds: http://en.wikipedia.org/wiki/Material_properties_of_diamond

Related Gizmos:
Conduction and Convection: http://www.explorelearning.com/gizmo/id?658
Calorimetry Lab: http://www.explorelearning.com/gizmo/id?460
Heat Absorption: http://www.explorelearning.com/gizmo/id?655
Radiation: http://www.explorelearning.com/gizmo/id?665