

Lab: Specific Heat

Summary

Students relate thermal energy to heat capacity by comparing the heat capacities of different materials and graphing the change in temperature over time for a specific material. Students explore the idea of insulators and conductors in an attempt to apply their knowledge in real world applications, such as those that engineers would.

Engineering Connection

Engineers must understand the heat capacity of insulators and conductors if they wish to stay competitive in “green” enterprises. Engineers who design passive solar heating systems take advantage of the natural heat capacity characteristics of materials. In areas of cooler climates engineers chose building materials with a low heat capacity such as slate roofs in an attempt to heat the home during the day. In areas of warmer climates tile roofs are popular for their ability to store the sun's heat energy for an extended time and release it slowly after the sun sets, to prevent rapid temperature fluctuations. Engineers also consider heat capacity and thermal energy when they design food containers and household appliances. Just think about your aluminum soda can versus glass bottles!

Grade Level: 9-12

Group Size: 4

Time Required: 90 minutes

Activity Dependency ⓘ:None

Expendable Cost Per Group ⓘ: US\$ 5

The cost is less if thermometers are available for each group.

NYS Science Standards:

STANDARD 1	Analysis, Inquiry, and Design
STANDARD 4	Performance indicator 2.2

Keywords: conductor, energy, energy storage, heat, specific heat capacity, insulator, thermal energy, thermometer, thermocouple

Learning Objectives

After this activity, students should be able to:

- Define heat capacity.
- Explain how heat capacity determines a material's ability to store thermal energy.
- Measure the temperature of a material over time.
- Describe the difference between materials with high-heat capacity and low-heat capacity.

[Type text]

- Understand that materials with high-heat capacities store thermal energy better than materials with low-heat capacities.
- Determine which material has the highest heat capacity and, thus, stores thermal energy well.
- Explain why engineers need to know about the heat capacity of materials when designing equipment, structures and products

Materials List

Each group needs:

- 1 thermometer (or TCI¹)
- 1 Stopwatch per group
- 3 tin cans (preferably 1 pint or so in size)
- One tin filled 1/2 way or so with water
- One tin filled 1/2 way or so with sand
- One tin filled 1/2 way or so with metal filings
- Lab worksheet, one per student

Introduction/Motivation

Jumping into a pool on a hot summer day is refreshing because the water is cooler than the air around you and the ground under your feet. You may wonder why the water is cooler since the water, air, and ground are being heated by the same source—the sun. One reason is that it takes more heat to raise the temperature of some substances than others. The amount of heat required to raise the temperature of 1 g of a substance by 1 degree Celsius is called the specific heat capacity, or specific heat, of that substance. Water, for instance, has a specific heat of 4.18 J/g°C. This value is high compared to the specific heats for other materials, such as concrete or metals. In this experiment, you will compare the specific heat of water and some of the elements in the surface of the earth.

Vocabulary/Definitions

<i>Heat:</i>	A form of energy associated with the motion of atoms or molecules, and capable of being transmitted through solid and fluid media by conduction, through fluid media by convection, and through empty space by radiation.
<i>Specific heat capacity:</i>	The amount of heat required to raise the temperature of one mole or one gram of a substance by one degree Celsius without a change of phase (from solid to liquid, or liquid to gas, etc.).
<i>Thermal energy:</i>	The energy an object has due to the motion of its particles. Also called heat energy.
<i>Insulator</i>	A material that retards the transfer of heat or electricity

¹ The TCI or Temperature Control Instrument is a design by Ayoub and Cohen. This device which uses a thermocouple and requires the use of a laptop with BasicStamp in order to run the program attached to the lesson plan.

[Type text]

<i>Thermocouple</i>	a device that consists of the junction of two dissimilar metallic conductors, as copper and iron, in which an electromotive force is induced when the conductors are maintained at different temperatures, the force being related to the temperature difference: used to determine the temperature of a third substance by connecting it to the junction of the metals and measuring the electromotive force produced.
<i>Thermometer:</i>	An instrument for measuring temperature, especially one having a graduated glass tube with a bulb containing a liquid (typically mercury or colored alcohol) that expands and rises in the tube as the temperature increases.

Procedure

Before the Activity

- Calculate the quantity of each material that you will need in order to provide each student group with ~4/5 cup (200 ml) of one of the materials.
- Gather materials and make copies of the Lab sheet
- Set up stations for each test material: containers filled with the various materials, the thermometers or thermocouples, ceramic plate and stop watches
- If necessary, set up the laptops with program (ultimate) uploaded

With the Students

- Divide the class into student teams of four to five students each.
- Have the students complete the “DO NOW”
- Ask the students to fill out their hypothesis
- Have students do a materials check
- Explain the instructions
- Go through the assignment sheet
- Allow students time to work
- Collect materials

Attachment

- Lab Sheet
- BasicStamp program

Troubleshooting Tips

Be sure to have the BasicStamp program already up and running if you are using the TCI for temperature instrumentation. Also check to make sure the thermocouple wires are not touching anywhere other than the end of the wiring.

Assessment

Pre-Activity Assessment

Prediction: Have the students predict which material will have the best thermal energy storage (or, hold in heat the longest) and record their predictions on the worksheets.

[Type text]

Activity Embedded Assessment

Worksheet: Have students follow along with the activity and record measurements on the lab Sheet. After students have completed their worksheet, have them compare answers with their peers. Review their answers to gauge their mastery of the subject.

Graphing: Have students graph the time vs. temperature results of their particular material on their worksheet.

Post-Activity Assessment

Closing Discussion: Go around the room and elicit students to identify what materials they believe to be good conductors, and insulators. Identify properties of the materials that make the material that way. Remember to acknowledge not all conductors of electricity are good conductors of heat i.e. gold.

Prediction Analysis: Have students compare their initial predictions with their test results, as recorded on the worksheets. Ask the students to explain their understanding of which materials have a high-heat capacity and which have a low-heat capacity.

Engineering Analysis: Have students compare their graphs to other teams' graphs and determine which material had the highest heat capacity (stored heat the longest). Which of the materials that the class measured would an engineer choose for insulating a home in the winter? (Answer: The ones with high thermal storage.) Which of the materials would an engineer use to design a good food storage container for soup? (Answer: One with a high thermal energy storage capacity.) Which of the materials would an engineer use for the design of a product that you want to heat up quickly? (Answer: Something with a low thermal storage capacity.)

Activity Extensions

If time, direct students to identify items around the room they would consider an insulator or a conductor based on the experiment.

References

Teach Engineering, "How Hot is Hot?" August 5, 2009 Online. Available.
http://teachengineering.org/view_activity.php?

This work is supported by the Research Experience for Teachers Site Program of National Science Foundation under grant EEC-0807286: Science and Mechatronics Aided Research for Teachers (SMART). The authors are thankful to Professor Maged Iskander and Saumil Parikh for their helpful comments and suggestions. This work was conducted in summer 2009 in the Soil Mechanics and Civil Engineering Lab at the Polytechnic Institute of New York University and authors fondly acknowledge the hospitality and support of the lab personnel.