TCI
Temperature Control Instrument
Mechatronics Department
Civil Engineering Department

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Lesson Plan

Medium: Smartboard lesson/Labsheet
Aim: What is specific heat?
Subject: Earth Science
Topic: Climate
Subtopic: Properties of water
Time: 1 Double period lab (90 minutes)

Student materials:

- Enough worksheets for each student to record data individually
- 1 or more ESRTs (Earth Science Reference Tables) per group

Station Materials:

- 1 TCI (temperature control instrument)
- 1 Stopwatch per group
- 3 tin cans (preferably 1 pint or so in size)
- Filled 1/2 way or so with water
- Filled 1/2 way or so with sand
- Filled 1/2 way or so with metal filings

Station Set-up:

Laptop with BasicStamp already installed, open and running the "TCI" program. Connected to the computer would be the TCI with the thermocouple submerged in the test material. Place heat strip on a ceramic plate. Have students place the tin can they are sampling on top of the heat strip. The tin can should not touch the table directly while hot or being heated. 24 Volt AC adapters should not be plugged in until it is time for use.

Lesson:

Slide 1:

Do Now:

"A watched pot never boils." Based on that expression what can you tell me about water?
(Expected answers: It takes a very long time to heat up.)

Why is the expression not, "A watched piece of metal does not get hot?"
(Expected answer: Metals tend to heat up much more quickly that water does.)

Slide 2: **Problem**

How long does it take various materials to heat up?

Slide 3: **Hypothesis**

There are 3 sample materials in front of you; water, sand and metal filings. Write your hypothesis as to which material will heat up the quickest.

What about the slowest. ____

Which material do you believe will cool down the fastest, and the slowest? ________

Explain the reasoning for your answers.

Slide 4: **Material Check**

Does your station look like the diagram below?

Raise your hand if you are missing any of the equipment.

Slide 5: **Procedure**

Working in your groups (of 4-5) you are going to be asked to measure the rate of heating and cooling of the materials in front of you. Using the data chart record the temperature every minute for 5 minutes. Then record the cooling rate of each material every minute for 5 minutes.

Place the sample being tested on top of your heating strip. The heating strip should have already been placed on top of the ceramic plate.

IT SHOULD NEVER LEAVE THE TOP OF THE CERAMIC PLATE!

Slide 6: **Instructions**

Run the TCI program from basicstamp. Identify your thermocouple as type 1 to start. After program is already running and specimen is in place, plug in the AC adapter for the heating strip.

Disconnect the power for heat strip after each 5 minute test interval.

You may want to have roles for each group member;

- Recorder or heating
- Materials manager
- Programmer/ Time keeper

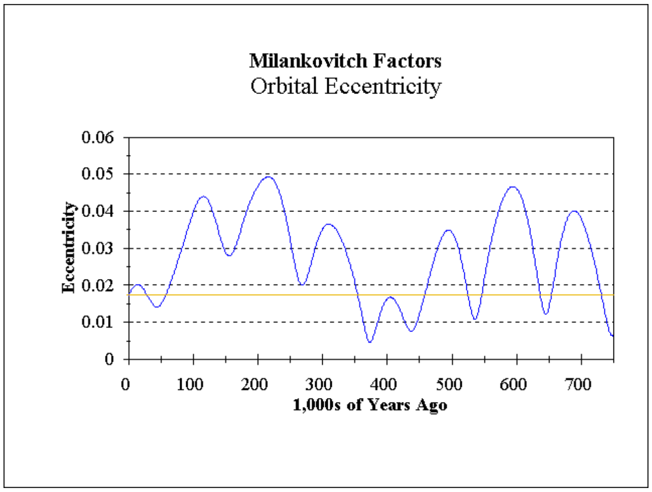
- Recorder of cooling
- (If 5th member) Facilitator

[Not on slide]- Mention to students how the equipment works. Students should not plug in the 24 Voltage AC adapters until the program is already running and the materials are in place for testing. Plugging in the heating coil too early or leaving it plugged in too long can cause injury.

Slide 7: Graph your results!

Make sure to include title, labeled axis, and connect data points with a solid line.

Example:



Slide 8: conclusion

Answer the questions at the end of the lab.

Slide 9: Wrap-Up

Turn in all group members labs together with individual name and group number noted.

Return all materials to original position. Turn off heating strip and program.

Name: __________________
Class: ____________________
Group: __________________

Lab: Specific Heat

Purpose

To determine the differences between the specific heats of water and some other earth materials

Background

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 using a simple calorimeter.

Skills Focus

Measuring, observing, drawing conclusions, applying concepts

Roles

Identify who is doing each of the following roles;

Recorder or heating ____

Materials manager ____

Programmer/ Time keeper ____

Recorder of cooling ____

(5th) Facilitator ____

Instructions

Part I

Pick your first can (sand) and place it on the heat strip, which should be placed on your ceramic plate. Run the TCI program from BasicStamp on your laptop. When asked type in 1 into your debug command box to identify your thermocouple type in order to start. After the program is already running and specimen is in place, place the thermocouple wire into the material. (Be sure to have the wire completely covered and not touching the sides of the container. Now you may plug in the AC adapter for the heating strip. Repeat until all samples are done.

Disconnect the power for heat strip after each 5 minute heating interval.

Sand	**Heating**						
	0 min	1 min	2 min	3 min	4 min	5 min	Rate of Change (use ESRT)
Remember to plug in the heat strip.	______*C	______*C	______*C	______*C	______*C	______*C	______*C/min
	Cooling						
	6 min	7 min	8 min	9 min	10 min	Rate of Change (use ESRT)	Average temperature / 10 minutes
Remember to unplug the Heat Strip!	_______*C	_______*C	_______*C	_______*C	_______*C	______*C/min	_______*C/min

Water	**Heating**						
	0 min	1 min	2 min	3 min	4 min	5 min	Rate of Change (use ESRT)
Remember to plug in the heat strip.	______*C	______*C	______*C	______*C	______*C	______*C	______*C/min
	Cooling						
	6 min	7 min	8 min	9 min	10 min	Rate of Change (use ESRT)	Average temperature / 10 minutes
Remember to unplug the Heat Strip!	_______*C	_______*C	_______*C	_______*C	_______*C	______*C/min	_______*C/min

Metal Filings	**Heating**						
	0 min	1 min	2 min	3 min	4 min	5 min	Rate of Change (use ESRT)
Remember to plug in the heat strip.	______*C	______*C	______*C	______*C	______*C	______*C	______*C/min
	Cooling						
	6 min	7 min	8 min	9 min	10 min	Rate of Change (use ESRT)	Average temperature / 10 minutes
Remember to unplug the Heat Strip!	_______*C	_______*C	_______*C	_______*C	_______*C		_______*C/min

						_______*C/min	

Part II

Make a multiline graph for each of the materials based on your data above. Make sure to include title, labeled axis, and connect data points with a solid line.

Key

Sand	
Water	
Metal	

Part III

1. What raised in temperature the fastest? ______________________________________

2. Did the material that took the longest to heat also the material that took the longest to cool?

    i. _____________________________________

3. In your own words explain why it took so long for the water to raise in temperature.

4. Looking back at the background on page one of this hand out would you classify the following materials as having a higher or lower specific heat than water.

Sand - ________________________________

Metal Filings - _________________________

5. Does water hold a lot of heat energy or a little? Explain your answer.

6. What material had the greatest rate of change? How does this relate to specific heat?

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.

- 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 TCI[1])
- 1 Stopwatch per group
- 3 tin cans (preferably 1 pint or so in size)
- On 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/gºC. 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

Heat:	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.
Specific heat capacity:	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.).
Thermal energy:	The energy an object has due to the motion of its particles. Also called heat energy.
Insulator	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.

Thermocouple	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.
Thermometer:	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.

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 student s 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?

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