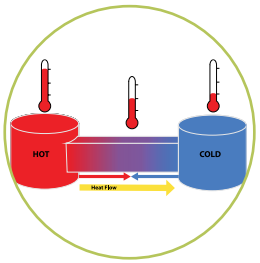
Developing a Computational Model for Heat Exchange

A Carolina Essentials™ Activity

Student Worksheet



Overview

Heat energy, or thermal kinetic energy, results from the motion of particles. When you take the temperature of a substance, you are measuring the average kinetic energy of the particles colliding with the thermometer. Generally, the more kinetic energy particles have, the warmer we perceive it to be. Thermal energy, like all other forms of energy, can be transferred and obeys the law of conservation of energy. In this activity, you will investigate the transfer of energy between two cups of water at different temperatures via an aluminum bar. You will then use the data to construct a mathematical model of thermal kinetic energy transfer.

Phenomenon

You come into class and your chair seat is warm, warmer than the classroom itself. What do you need to know to explain this phenomenon?

SAFETY REQUIREMENTS

MATERIALS

Heat Transfer Kit

2 beakers, 600 mL (optional—for stabilizing the cups)

Graduated cylinder, 100 mL

Warm water (50–70° C)

Cold water (5–15° C)

High/low temperature gloves

Essential Question

How can energy flow into and out of a system be modeled mathematically?

Activity Objectives

1. Collect data to evaluate the transfer of thermal energy between cups with different temperatures of water.
2. Determine the mathematical relationship between energy transfer, mass, and change in temperature.

Safety Procedures and Precautions

Wear eye protection and handle the beakers containing warm and cool water with gloves.

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Activity Procedures

1. For stability, place the foam cups in beakers, if provided.
2. Label the cups “A” and “B.”
3. Add 75 mL of warm water to cup A and cover it quickly. Record the mass of water. (Remember that 1 mL of water weighs approximately 1 g.)
4. Add 75 mL of cold water to cup B and cover it quickly. Record the mass of water.
5. Insert the aluminum bar into both cups. Make certain the bar is submerged in the water in both cups.
6. Insert the thermometers into the water in both cups and record the initial temperatures for both.
7. Wait until the temperature of the water in both cups is the same, and record the final temperature for both cups.
8. Repeat the process with more warm water in cup A than cold water in cup B. Record the mass, initial temperature, and final temperature for both cups.
9. Repeat the process a third time, with more cold water in cup B than warm water in cup A. Record the mass, initial temperature, and final temperature for both cups.
10. Place your data on the class data table.

Data and Observations

Energy Transfer Data

Trial	**Cup A** Mass of Water (g)	**Cup A** Initial Temperature (°C)	**Cup A** Final Temperature (°C)	**Cup B** Mass of Water (g)	**Cup B** Initial Temperature (°C)	**Cup B** Final Temperature (°C)

Record all calculations in a table.

1. Using the **class data table**, calculate the change in temperature **(ΔT)** for cups A and B. **ΔT** is calculated $T_{final} - T_{initial}$. One cup will have a $-\Delta\mathbf{T}$.
2. Using class data and the **ΔT** calculations from above, calculate the ratio of $\Delta\mathbf{T_A} : \Delta\mathbf{T_B}$ for every trial. Record the ratio as a decimal number rounded to the tenths place.
3. Using class data, calculate the ratio of $Mass_A$: $Mass_B$ for every trial. Round to the tenths place.
4. Graph the ratio of masses to the ratio of temperature change.
5. Draw the line of best fit and calculate the slope of the line.
6. The line should go through 0,0. Determine the equation for the line. Remember that you graphed **ratios**.
7. Rewrite and interpret the equation of the line so data from cup A is on one side of the equal sign and data from cup B is on the other side. Remember that you graphed ratios. This is the mathematical model.

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Analysis and Discussion

1. How is temperature related to kinetic energy?

2. Use your data to explain how the aluminum bar transfers energy between cups.

3. Use your data to explain how the equation in item 7 above relates to the law of conservation of energy.

4. How would the mathematical model change if the substances in cups A and B were not the same?

5. Use the law of conservation of energy and heat transfer to explain the warm seat from the phenomenon.

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