ICE WARS (2 Hours)

Addresses NGSS
Level of Difficulty: 4
Grade Range: 3-5

OVERVIEW

In this activity, students will create their own insulating "ice chambers" and then test them against the models made by their classmates.

Topic: Heat transfer

Real World Science Topics:

- An exploration of how to use the design process
- An exploration of the factors that affect the rate of heat transfer

Objective

Students will gain an understanding of the engineering design process by designing containers that slow down the process of heat transfer.

Materials Needed for Each Team of Two to Four Students:

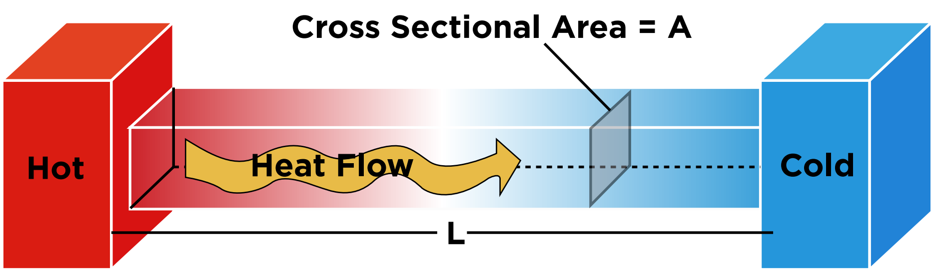
ice cubes
paper cup
stopwatch
clear tape or duct tape
string
scissors
triple beam balance
small graduated test tube (or other small liquid measuring unit, like measuring spoons)
various insulating materials such as pieces of polystyrene foam (such as Styrofoam™), cotton balls, different types of fabric, such as cotton, polyester, or wool, newspaper, plastic wrap, cardboard, and aluminum foil

NGSS Three-Dimensions

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions	**PS3.B: Conversation of Energy and Energy Transfer**	**Energy and Matter**
• Use tools and materials provided to design a device that solves a specific problem.	• Energy can also be transferred from place to place by electric currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.	• Energy can be transferred in various ways and between objects.

STEPS FOR *ICE WARS*

1. **Warm-up Activity:** Open the class by telling the students that they are going to use ice to learn about heat. Have each student touch a piece of ice. Then, show them the diagram below showing the process of **heat transfer** by conduction. Ask students to use the diagram to explain why they experienced the sensation of "cold" when they touched the ice. Guide students by explaining that heat is energy that flows from an object at a higher temperature to an object at a lower temperature. This process of heat transfer continues until both objects are at the same temperature. When an object feels cold, heat is being transferred from your body to the object. When an object feels hot, heat is being transferred from the object to your body. Ask students what happens to the rate of heat transfer when they put on a coat on a cold day. Explain that the coat is an insulator—a material that slows down the rate of heat transfer from the body to the environment. During this activity, students will use the design process to create an insulating "ice chamber."



Heat always flows from an object at a higher temperature to an object at a lower temperature until both objects are at the same temperature. At this point, the two objects are said to be in a state of *thermal equilibrium.*

2. Distribute the *Ice Wars* handout and materials to each group of two to four students.

3. This activity is largely student-directed. Tell the students that the goal of the project is to build an ice chamber that will provide the best insulation that a homemade ice chamber can. Before students begin their design process, it is important that you lead a discussion with the class to determine the conditions of the experiment. The entire class will need to agree upon these experimental conditions. Also, they must be held constant across each trial so that the results of each experiment are reliable. Such experimental conditions should include the size and number of ice cubes to be used in each trial and how long each trial will last (the time the ice chamber remains in the cup). When students decide on the size of the ice cube, they will need to think of a way to measure the size (by weighing it, for example). Students will also need to agree on the method by which the winning ice chamber is determined. For example, they may decide to measure either the difference in the weight of the ice or the amount of liquid water in the cup after 10 minutes has elapsed. Alternatively, they could measure the time it takes for a certain amount of liquid water to collect in each cup or for the ice cube to melt entirely. **Tell students that the only restriction on the ice chamber is that the insulation cannot contain more than three materials.**

STEPS FOR *ICE WARS*

4. Have each group construct an ice chamber by wrapping materials around the outside of the cup. Teams should build the first ice chamber and then test it to measure how well it performs. Students should understand that the ice cube will need to be put inside the cup, so they should not close off the cup before the cube is inserted. Note: Students will need to make sure that the ice cubes used by each team are the same size so that the contest is fair. Students may decide to measure the mass of each ice cube to make sure that the cubes are equal. If a cube is too heavy, students may allow it to melt (by holding it in their hands); however, the cube should then be returned to the freezer and allowed to solidify before being tested. Students should record the results of each trial on the handout. You should record the results for all teams on the board. Have the class identify the winning design and the second-place design.

5. Students should regroup and conduct a second round of designing and building. Tell students that they should try to design an ice chamber that insulates even better than the winning design from the first round. For the second round, stipulate that each team must change at least one material from the first-round ice chamber, and that at least one material must be different from the winning design from the first round. As in the previous round, you should record the results for all teams on the board. Have the class identify the winning design and the second-place design.

6. **Wrap-up Activity:** Review the results of the two contests with the students. Ask the class to analyze the winning designs for similarities and differences. Which materials were used? How did the designs differ? Was there a difference in the craftsmanship of the designs? Ask the students to describe how they changed their second design and to explain why they made the changes they did. Have students identify the least effective ice chamber design in the second contest. How was this different from the most effective design? Draw a Venn diagram on the board that compares and contrasts the most and least effective designs from the second contest. Ask students if they can conclude which materials and designs made the best insulators. They should state that the best insulators were usually the thickest or most dense materials. The best designs should be those in which the insulating materials covered the most surface area on the cup. Students should recognize that the best insulators prevented external heat in the room from entering the cup (and thus lowering the temperature inside the cup).

Ice Wars Extension Activity

To extend this activity, students can use a procedure similar to the one in the main activity, except this time they can change some of the variables or introduce some additional limiting factors. Additional variables might include increasing the amount of ice used or increasing the amount of time allowed for each trial. Limiting factors might include setting a maximum weight for the materials used or setting a cost limit for materials used by assigning fictional monetary values for specified quantities of each material.

ICE WARS
BACKGROUND INFORMATION

What is heat?

Heat is the energy that is transferred between objects at different temperatures. Like other forms of energy, heat is measured in units called joules. One joule is equal to one Newton-meter (N-m), or one kilogram-meter per second squared ($kg\text{-}m/s^2$). According to the second law of thermodynamics, heat always flows in one direction—from the hotter object to the cooler object. The process by which heat flows from one object to another is known as heat transfer. Heat transfer can occur in three different ways—by radiation, by convection, or by conduction. In this activity, students will be concerned mainly with heat transfer by conduction.

How is temperature different from heat?

A common misconception is that heat and temperature are the same. However, unlike heat, temperature is not a form of energy. Instead, temperature is a measurement of the average kinetic energy of the molecules that make up an object. To further illustrate the difference between heat and temperature, consider two objects that are made of the same material and have the same temperature, but have different masses. While the temperatures of the objects are identical, the object with the larger mass contains more heat energy.

There are three different scales for measuring temperature: the Celsius scale, the Fahrenheit scale, and the Kelvin scale. Both the Celsius and Fahrenheit scales use units called degrees and are based on the melting and boiling points of water. The Kelvin temperature scale is based on the thermodynamic properties of substances and uses units known as Kelvins. On the Kelvin scale, a temperature of zero is theoretically the lowest temperature possible (known as "absolute zero"). At zero K, an object cannot transfer any heat to its surroundings.

What is thermal conductivity?

Thermal conductivity, or the rate at which heat is transferred through an object, depends on the physical characteristics of the object. Thermal conductors are materials that allow heat to be transferred quickly, while thermal insulators are materials that slow down the process of heat transfer. However, even the best insulators cannot stop the transfer of heat—they can only slow it down. Because heat is a form of energy, it cannot be "contained" within an object for any amount of time. When an object is said to "contain" a given amount of heat, this actually refers to the amount of heat within the object at a given instant.

Engineers take advantage of the thermal conductivities of different materials when designing containers and other devices for practical use. For example, most gases are good insulators if they are contained in one area. For this reason, some containers are made with materials that incorporate tiny air pockets, which enhance their ability to insulate.

ICE WARS
BACKGROUND INFORMATION

How does the transfer of heat affect changes in state?

When a substance changes state, or phase, the amount of heat it contains changes although the temperature remains constant. For example, when ice melts there is no difference between the temperature of the solid water and the liquid water. However, heat must be absorbed by the ice for it to change from solid to liquid. Similarly, when water freezes to form ice, it must release heat to its surroundings to change its phase. The amount of heat that is released or absorbed by a substance as it changes phase is called latent heat.

Key Vocabulary
heat: the energy that is transferred from an object at a higher temperature to an object at a lower temperature
temperature: a measure of the kinetic energy of the particles that make up a substance
insulator: a material that is resists the transfer of heat between two substances
thermal equilibrium: describes two systems that are at the same temperature; when this occurs, no heat will flow between the two systems
thermodynamics: the study of heat and energy in a system

STUDENT HANDOUT FOR *ICE WARS*

Experimental design:

How many ice cubes will you use for each trial? ____________________

How large will each ice cube be? ______________________________

How will you measure the size of each ice cube? _________________________

How will you determine how well the ice chamber works?

Follow the directions below to build an insulating ice chamber.

1. Discuss with your teammates which materials you think would be good insulators.

List them here: ____

Why do you think they will be good insulators?

2. Think up a design for your ice chamber. You can attach up to three materials to the outside of the cup. Sketch your design below:

STUDENT HANDOUT FOR *ICE WARS*

3. Build your design and test it. Record your results in the table below:

Trial 1			
Properties of ice (such as number of cubes, mass, temperature, etc)	Ice chamber design and materials used	Duration of test	Results

4. Observe which team's ice chamber was most successful. What materials were used for this ice chamber? What was the design of this chamber?

5. Discuss how your original design performed and come up with some ideas on how it might be improved.

STUDENT HANDOUT FOR *ICE WARS*

6. When you build the next ice chamber, you must change at least one of the materials from the original design. Also, you cannot copy the winning design from the first round. At least one material must be different from the first round's winning design. List the materials that you will use for the second design:

____

Sketch the design below:

7. Build the new ice chamber. Test the chamber and record your results in the table below:

Trial 2			
Properties of ice (such as number of cubes, mass, temperature, etc)	Ice chamber design and materials used	Duration of test	Results

8. Did the second ice chamber insulate the ice better than the first chamber? Can you explain why this might have happened?

9. Which materials were the most effective insulators?

STUDENT HANDOUT FOR *ICE WARS*

10. Which design was the most effective insulator?

11. What do you think makes a good insulator?

TEACHER HANDOUT FOR *ICE WARS*

Experimental design:

How many ice cubes will you use for each trial? ____Possible answer: 1___________________

How large will each ice cube be? _____ Possible answer: 5 grams_____________________________

How will you measure the size of each ice cube? _____ Possible answer: use a triple beam balance

How will you determine how well the ice chamber works?

Possible answer: After 10 minutes, pour the water in each ice chamber into a graduated cylinder and measure it. The one with the least amount of water is the best ice chamber.

Follow the directions below to build an insulating ice chamber.

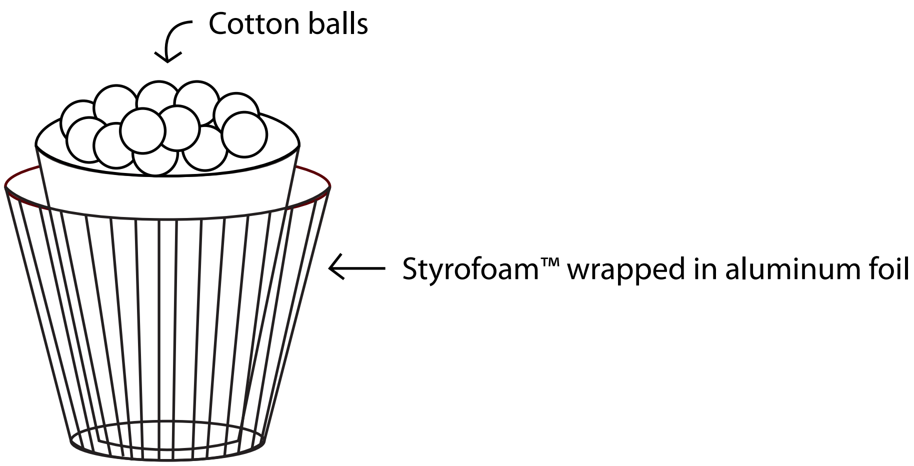
1. Discuss with your teammates which materials you think would be good insulators.

List them here: Possible answer: cotton balls, aluminum foil, Styrofoam™

Why do you think they will be good insulators?

Possible answer: Because cotton and Styrofoam™ are thick.

2. Think up a design for your ice chamber. You can attach up to three materials to the outside of the cup. Sketch your design below:



TEACHER HANDOUT FOR *ICE WARS*

3. Build your design and test it. Record your results in the table below:

Possible answers:

Trial 1			
Properties of ice (such as number of cubes, mass, temperature, etc)	Ice chamber design and materials used	Duration of test	Results
1 cube, 5.1 grams, 32º C	• Styrofoam™ is wrapped around the cup • Aluminum foil is wrapped around the Styrofoam™ • Cotton balls are stuffed into the top of the cup	10 minutes	5 mL of water melted in the ice chamber

4. Observe which team's ice chamber was most successful. What materials were used for this ice chamber? What was the design of this chamber?

Answers will vary.

5. Discuss how your original design performed and come up with some ideas on how it might be improved.

Answers will vary.

6. When you build the next ice chamber, you must change at least one of the materials from the original design. Also, you cannot copy the winning design from the first round. At least one material must be different from the first round's winning design. List the materials that you will use for the second design:

Possible Answers: Styrofoam™, cotton balls, cotton fabric

Sketch the design below:

Designs will vary.

TEACHER HANDOUT FOR *ICE WARS*

7. Build the new ice chamber. Test the chamber and record your results in the table below:

Possible answers:

Trial 1			
Properties of ice (such as number of cubes, mass, temperature, etc)	Ice chamber design and materials used	Duration of test	Results
1 cube, 5.2 grams, 32º C	• Styrofoam™ is wrapped around the entire cup • Cotton balls are glued to the outside of the Styrofoam™ • The entire chamber is then wrapped with cotton fabric	10 minutes	3 mL of water melted

8. Did the second ice chamber insulate the ice better than the first chamber? How can you tell?

Possible answer: Yes, the second chamber insulated the ice better because less ice melted during the second trial.

9. Which materials were the most effective insulators?

Answers will vary.

10. Which design was the most effective insulator?

Answers will vary.

11. What do you think makes something a good insulator in this experiment?

The best insulators prevented the heat in the room from getting into the cup. Materials that were thicker or denser worked best.