4E – PROJECT: DESIGN AN INSULATOR

OVERVIEW

Students will use a variety of materials to design an insulated container with the goal of keeping a heated solution from losing less than 2 °C over 2 minutes.

TIME REQUIRED

3 – 5 60-minute class periods.

MATERIALS

- Device with SPARKvue software
- Temperature sensor
- Beakers, 250-mL (3)
- Beaker tongs
- Heater stirrer
- Aluminum foil, 4-in x 4-in square
- Scissors
- Ruler

Building materials:

- Polystyrene foam
- Aluminum foil
- Cardboard
- Cotton balls
- Bubble wrap
- Rubber band
- Tape

BACKGROUND

Insulators are materials that do not readily allow energy to pass through from one material to the next. Insulators can slow down the flow of energy in the form of heat, sound or electricity. Examples of insulators are the glass fiber materials found between the walls of your home which helps to keep heat from the inside of the house from escaping or heat from the outside surrounding of the house from entering. Insulating material is also used to surround and cover electrical wires to prevent them from conducting electricity from wire to wire in unintended directions or to prevent hot wires from touching each other. Insulators are also used to keep hot drinks hot and cold drinks cold.

SAFETY

Follow these important safety precautions in addition to your regular classroom procedures.

- Wear safety goggles at all times.
- Use beaker tongs when handling hot water.

PERFORMANCE CRITERIA

You work with a team of engineers at an insulation design company. A local coffee shop has asked your team to use the materials provided to create an insulated container that is low cost and has high thermal efficiency. The company would like to maximize its profits by using the least amount of material while designing an insulator that minimizes the amount of heat lost. Your team's job is to design an insulator with the least amount of material that will keep a heated solution from losing less than 2 °C over 2 minutes.

CONSTRAINTS

Your team must design an insulator that loses less than 2 °C in 2 minutes or more and that has a materials cost of $5 or less.

RESEARCH

Using available resources (i.e. text, notes and/or internet), research the performance of insulators and their everyday uses. You will use this research to help create and complete the design of your cup.

Cost Considerations: You will need to select and measure out the specific materials you would like to use for your design. Keep track of what you are using, the quantity used and the cost of the materials. If you have brought in any alternative materials, you will need to research their price and suggest a price to your teacher based on comparable materials in the table below.

Material	Cost
Polystyrene foam	\$0.12 per in^2
Aluminum foil	\$0.10 per in^2
Cardboard	\$0.08 per in^2
Bubble wrap	\$0.08 per in^2
Cotton ball	\$0.40 each
Rubber band	\$0.50 each
Tape	\$0.10 per in

Record your results on your answer sheet.

PROCEDURE

1. Open SPARKvue.
2. Open the 04E Design an Insulator lab file in SPARKvue.
3. Use the Bluetooth icon to connect the Temperature sensor.
4. Label the beakers: A, B, and C.
5. Set the temperature sensor inside beaker A. Set the beaker aside.
6. Add about 120 mL of tap water to beaker B and set it to boil on the hot plate. While you wait for the water to boil, observe the building materials to get ideas of what to use and how much to request. Do not take any building materials until your design is approved in the next phase of the project.
7. Once the water in beaker B has come to a boil, use beaker tongs to help you pour about 50 mL of boiling water in beaker A. Immediately put beaker B back on the hot plate so it can return to a boil.
8. Start collecting data. SPARKvue will automatically record the water temperature every 15 seconds for 2 minutes. Answer the following question on your answer sheet while you collect data: Does the uncovered beaker represent an open system or a closed system? Explain your reasoning.
9. After data collection has stopped, remove the temperature sensor and place it in beaker C.
10. Review your data. Calculate the change in temperature and record it in the Analysis section on your answer sheet.
11. When the water in beaker B comes to a boil, pour 50 mL of boiling water into beaker C and cover the top of the beaker with foil. Keep the sensor inside the beaker.
12. Start collecting data. Allow data collection to continue for 2 minutes. Answer the following question on your answer sheet while you wait: Is the covered beaker an open system or a closed system? Explain your reasoning.
13. When data collection stops, record the change in temperature on your answer sheet.

ANALYSIS

Complete the analysis on your answer sheet.

INITIAL DESIGN

1. Use the information from your research, your data from the Analysis section, and observations of available materials to help you brainstorm ideas for a new beaker insulator design that will keep the amount of heat lost by boiled water below 2 °C over 2 minutes. Your goal is to minimize cost and maximize thermal efficiency. You cannot use more than $5 worth of materials. Your team must work together to create the design. Everyone's ideas should be discussed.

2. Calculate the cost of your design and record results on your answer sheet. Sketch the design on your answer sheet and go to your teacher to get design approval.

3. Upon approval of your design, collect only the amount of materials stated in your approved design. You are not allowed to modify your design until you have finished testing it. Build and test the new beaker insulator and determine the temperature change of boiled water over 2 minutes as before. Record the temperature change on your answer sheet.

RE-DESIGN

1. Record your work for the following on your answer sheet: Alter the design and recalculate cost in order to minimize cost and heat loss. Sketch a new design, calculate cost, get approval for your new design, build it and test it as before. Record the temperature change.

SUMMARY

Your team will present the initial and final insulator designs and overall findings to your supervisor (the class). You may use a traditional presentation board, PowerPoint presentation and/or another multimedia presentation device such as Animoto, PowToons and/or iMovie. This is your sales pitch; your team is competing with other teams to earn a contract to build the insulators for your company. Review the grading rubric on the next page to increase your chances of a successful sales pitch.

Present the insulator and graphs of all the data you collected during your sales pitch. Use these materials to justify the most cost-efficient and thermally efficient design for your insulator. Speak in an objective and scientific tone. Discuss points your audience will be interested in. For example, what are the specific reasons why the materials you chose make good insulators?

Include the cost of materials and estimate the actual cost of production to create your insulated cup. The cost of production includes pay for individuals that build the insulator, transportation costs to distribute the insulator to stores, etc. Recommend a profitable sales price for your insulator with at least 50% profit. Remember, your company is interested in a design that works and can be made at a low cost while being sold at a reasonable price.

Your supervisor is a very busy person, so keep your presentation short and to the point. It must be less than 3 minutes long. Everyone on the team must speak an equal amount of time during the presentation.

EXTENSION

For an additional challenge, you may be asked to explore the following options:

1. Test very cold water to determine the rate of temperature change using the beaker. The designed insulator should be able to reduce the overall temperature change for both the hot and cold water.

2. Test the hot water over a 10-15 minute time frame in order to minimize the heat lost in the design relative to the amount of heat lost in the glass beaker.

3. Limit the design to no more than 100 g above the mass of the glass beaker used. You will need to mass the beaker alone and again with the insulated material used.

4. Limit the design to an overall materials cost of no more than $2.

5. Use recyclable, green material proposing an eco-friendly design that can be recycled upon disposal.

GRADING RUBRIC

Criterion	*Criterion Not Met (0 pts.)*	*Needs Improvement (1 pt.)*	*Satisfactory (2 pts.)*	*Excellent (3 pts.)*
Temperature Change	Temperature changes not measured	Temperature lost is **greater than** 2 °C in 2 minutes.	Temperature lost is **equal to** 2 °C in 2 minutes	Temperature lost is **less than** 2 °C in 2 minutes.
Data Collection & Analysis	Data from the design and re-designed experiments are not included.	Insufficient data collected to prove the effectiveness of the design. Data may be incomplete or erroneous. Data may be disorganized and difficult to interpret.	Control data with the beaker alone indicates the overall amount of heat lost in 2 minutes. Data for the design indicates the overall heat lost has been reduced relative to the controlled experiment. Data is interpreted correctly but may not include a graph to compare runs.	Control data with the beaker alone indicates the overall amount of heat lost in 2 minutes. Data for the design indicates the overall heat lost has been limited to under 2 °C in 2 min. Students have included a graph comparing **multiple** data runs.
Design	The design is incomplete or missing.	Design is not reasonable to build.	Design is reasonably easy to build.	Design is attractive to consumers and reasonable to build using available supplies.
Build Cost	The build cost is missing.	The cost to build exceeds the sales price proposed.	The cost is less than the sales price but the profit margin is less than 50%.	The cost is less than the sales price proposed with a 50% profit margin.
Visual Presentation	The visual presentation was not included.	The visual presentation is missing key information required.	Visual presentation addresses all required components and is simple.	Visual presentation summarizes all required components and is interesting.
Oral Presentation	The oral presentation was not completed.	The salesperson was unable to explain the design, data and/or cost.	The sales group could address the design, data and/or cost but did not add in any additional, possibly pertinent information for consideration.	The sales group could address the design, data and/or cost adding some limited information that was pertinent to the sales pitch.