Lab 2: Final Report
Marco Armendariz-Gonzalez, David Candia, Miranda Stern

Vaccine in a Box

Introduction

The purpose of this lab was to design a system that would insulate an unknown number of water vials, and to get them into a specific temperature range after a set amount of time. Our section in particular was given the parameters of 8 vials of water to be brought within 45-50 degrees Fahrenheit after 2 hours. As restrictions, the box and its contents had to be made out of recyclable materials and we could only use different amounts of water and ice to control the temperature of the vials.

Box Design

In the early stages of our brainstorming in regard to our box design, we decided that the main modes of heat transfer from the environment to the vials would be convection from the surrounding air and conduction from the ground to the bottom side of the box. It should be noted that this decision was made based on assumptions. Some groups wrapped their box in metal foil to reduce the radiative heat transfer from the surroundings. We further decided that regardless of our methods to control the temperature of the vials, we would want the environment to interact with the box as little as possible. We collected material from the recycling room in Towne such as hard cardboard, paper towels, various textbooks, and a single beanie. The vials, water, and ice would be stored in a smaller compartment made out of hard composite cardboard. This component was raised off of the base of the box by two textbooks. The open top of the component was sealed with a beanie and another textbook. All of this was then surrounded by crumpled and shredded cardboard and paper towels. Once the box was closed, we used packing tape to seal the edges to limit the amount of air that could be exchanged.

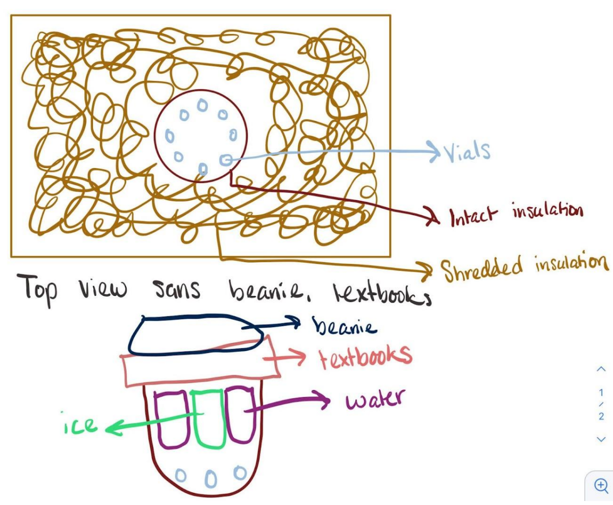


Fig. 2: Diagram of Experimental Setup

Model

Our model was made in Matlab. It used ode45 to solve the three differential equations governing the temperatures of the ice, the water, and the vials. These differential equations are derived from Newton's Law of Cooling. Our model assumed that convection was the main mode of heat transfer between the pack of ice, pack of water, and water vials. Additionally, based on the layout of our box and the relative masses of the water, ice, and vials, we assumed that the temperature of the water depended on the ambient temperature of the room, the temperature of the vials, and the temperature of the ice. The temperature of the vials depended on the temperature of the water and the temperature of the ice. The temperature of the ice depended on the temperature of the water. Our model allowed us to input the total time, range of target temperature, and the number of vials. Our model allowed us to change the mass of the water and mass of the ice until we find a combination that has the final temperature of the vial in the target temperature range. Our code and an image of the graph of the three temperatures can be found in the appendix.

Experimental Results

In order to determine the R value of our system and gain a better understanding of how long the phase change of the ice takes before it heats up, we ran experiments on the different components of our box.

We isolated the time it takes for the ice to melt in our insulated box. This allowed us to adjust our model to better recognize the temperature experienced by the water and vials. We also used this to control how long our model would assume the temperature of the system to be at freezing. The results of these tests can be seen below.

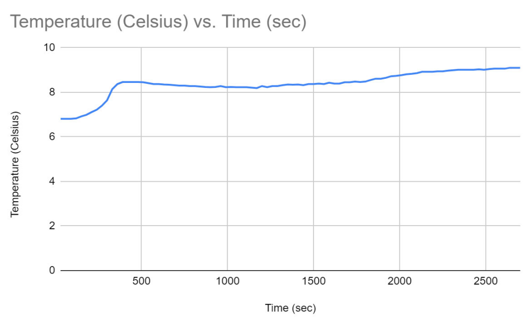


Fig. 2: Melting of 10 Ice Cubes in Box

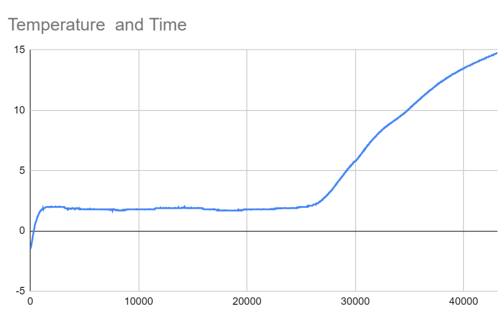
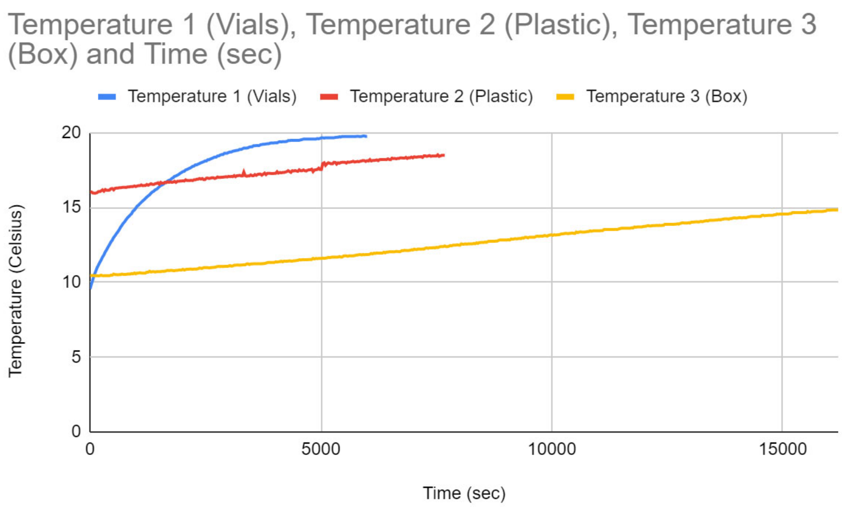


Fig. 3: Melting of 0.96kg Ice in Box

We also ran experiments to determine the R values of the plastic vials, plastic bags that held the water and ice, and the box itself once filled with our chosen insulation materials as specified in previous sections. We had hoped to do more experiments with the elements combined to better isolate the total R value, but we struggled to use the Arduino shield, and our computer tests with these setups were incomplete due to error in communication between the serial monitor and the thermistor. As a result, we ran individualized simultaneous simulations and used this data for our model.



Comparison of R Values for Different Components

<u>Final Performance</u>

Our model was having issues accounting for a larger rate of heat transfer with different amounts of ice. The rate of heat transfer was only taking into account the difference in temperature without considering that a larger volume of ice would be able to cool water at a greater rate. Knowing this, we decided to use more cold water than ice, since our model performed well in this manner. We decided to use a large amount of cold water and a small amount of ice in order to err on the cold side of the range. Using our model to guide our plan, we decided on using 2kg of water (cooled to 35F) and .1kg of ice. Our insulation setup performed well in a sense that at the end of the 2 hours, our vials were measured to be 45 degrees Fahrenheit, successfully within the given range of 45-50. This matched very well with our modeled prediction.

Fig. 5: Close up of Vials in Box