**Bioshipping Package Design**

**Introduction**The integrity of many items, such as perishable foods, pharmaceuticals, and biogenic samples,  
depends on maintaining them at controlled temperatures. This is especially challenging when  
we need to ship these items over great distances. Typically, packaging used to ship items  
below room temperature is constructed from or includes some type of insulating material along  
with ice, dry ice, or gel packs.

TriCore Reference Laboratories (TriCore), a medical research laboratory based in Albuquerque,  
New Mexico, is facing a particular challenge in which they wish to receive biogenic samples  
from some of their clients who reside in rural New Mexico. Samples are collected at the point  
of care by doctors, and the samples then come to the centralized laboratory for analysis.

TriCore sees an average of 13,500 samples come through their laboratory daily, and they  
estimate that 25-30% of those originate from rural areas. TriCore hopes that offering this  
service will allow more people, especially those in rural areas, to receive the medical tests they  
require by making the process of biogenic sample submission much more convenient while  
keeping patient costs low.  
Project Constraints

TriCore Reference Laboratories has approached your engineering firm to aid in the design of  
the thermal shipping package. To keep costs low for their customers, TriCore proposes to  
cover the cost of shipping to and from patients’ homes. The internal space of the box need  
only be as large as 9” x 6 ½” x 5 ½” in order to contain the sample vial and instant cold pack.  
The rest of the internal space may be taken up by materials as part of your design. TriCore  
would like the entire box to remain within FedEx's One Rate shipping dimensions of 11 ¼” x 8  
¾” x 7 ¾”.

Insulation must be incorporated into the design of the shipping container in order to maintain  
the low temperatures required by the biogenic samples. The total cost of insulating material  
should not exceed $2 per box. For the range of samples to be sent using this service, it has  
been determined that the temperature should reach no higher than 50°F and drop no lower  
than 38°F within a 24-hour period. This range of temperatures must be maintained assuming  
that the package will spend a majority of its time in the back of a delivery truck where the  
ambient temperature can reach as high as 100°F.

**Student Learning Outcomes**Students will be able to:  
• apply basic heat transfer and thermodynamics principles to a real world challenge  
• manage time effectively and be accountable to their teammates  
• evaluate different material properties and determine their usefulness as insulators  
• apply math, physics, and chemistry to design a consumer product  
• design a product within the constraints imposed by the client

**Project Roles**  
All members contribute to all aspects of design process and completion of deliverables. Each  
team member will serve in the role of designer during your design process and spokesperson  
during the final pitch. Each aspect of the teamwork will have a designated leader:

|  |  |
| --- | --- |
| Job title | Job Description |
| Project Manager | Responsible for submitting team deliverables, keeping the team on track and managing group progress. Everyone will pitch in with the design and aid in the brainstorming, but at some point you will need to decide on an idea, and the project manager has final say. This reflects the real world, and sometimes ideas may be selected that are not your own. Compromise to make a better product! |
| Lead Research Scientist | Leads the team in conducting research. This person should organize documents and information gathered by the team and can assign specific research tasks to members of the team. This person should be organized and analytic. |
| Lead Market & Financial Analyst | Oversees market research on existing products. Confirms accuracy of numbers and accounts for how the team spends time. When you are working as a professional engineer, you will be responsible for justifying the time spent to your client. This person needs to be good at attention to detail and have strong ethics. |
| Lead Requirements Engineer | Responsible for keeping stakeholder requirements and customer needs in focus. This person should be able to empathize with customer experience and consider different points of view, while also considering material constraints. |

**Project Timeline and Deliverables**You will be expected to meet the following criteria to receive full credit for this challenge.

|  |  |
| --- | --- |
|  |  |
| Deliverable | Points |
| Pre-lab: How can you keep your sample cool? • Design a chiller • Plan your lab procedure | 10 |
| Lab worksheet (completed as a group) | 50 |
| Short Technical Report (completed as a group) A 3-4 page technical report summarizing in a concise manner: • Describe your design process • Describe the material(s) you chose, with prices, thermal properties, and discuss the advantages and disadvantages of your material(s) • Explain how your design met the requirements • Calculations regarding thermal performance • Design schematic • Report should include tables/figures presenting data | 65 |
| TOTAL | 125 |

Background Information For Evaporation Cooling Lab

**Evaporation of Water is More Effective Than Melting of Ice**• Heat of fusion 80 cal/g while heat of evaporation is 540 cal/g for water  
• Evaporation is endothermic, i.e. heat must be added to cause evaporation  
• That heat can come from the surroundings, unless you take it away from the water itself – i.e. evaporative cooling  
• Evaporation involves transfer of mass (water) away from the surface

**Water Evaporation Occurs when the Partial Pressure is less than the vapor pressure**• Definition: P\* = vapor pressure  
• Partial pressure of water = PH2O = yH2O x Ptotal (Raoult’s Law)  
• If P\*>PH2O, evaporation occurs  
• If P\*=PH2O, we have equilibrium  
• If P\*<PH2O, we have condensation

**Can you change the boiling point of water?**• 100 C is the boiling point of water at sea level  
• What is the boiling point in Albuquerque?  
• How about Santa Fe?  
• How about the top of Sandia peak?

**Convection is necessary for evaporative cooling**  
• Dipping a can of soda in water does not allow for evaporative cooling – why?  
• The can achieves a temperature close to that of the water, but putting a can into ice water is even better, and will make it cold sooner. And, sloshing the ice water around the can will speed up the cooling.  
• For evaporative cooling, we must carry the water vapor away – hence use a fan  
• The purpose of using a fabric is to provide a source of water to evaporate – what is the ideal fabric?

**How can we enhance the rate of evaporative cooling?**• Low humidity  
• Enhance Convection  
• Minimize conductive resistance to heat transfer – a very thick fabric might cause a resistance to heat  
transfer  
• What would you do if the relative humidity was very high? Brainstorm with your team

*How could you apply this idea in the design of your bioshipping container?  
What other ideas do you have, in terms of insulation, phase change materials, and other approaches to  
design this container?*

Pre-lab: How can you keep your sample cool?

(Completed as a team)

**Team number:**

**Team Member Names:**

# Introduction & Statement of problem

To help you investigate potential insulation materials for your design, you will have the opportunity to test an approach to chilling in the laboratory. Prior to the lab, your task is to plan a laboratory procedure to collect useful data.

Design a chiller for a soda can that makes use of evaporative cooling. You will perform experiments to determine the efficacy of your design. You will then complete the design and present it in your lab report. For the lab, you will be provided with a thermocouple to record temperature. This can be taped to the can when you start the experiment. You will record the temperature as a function of time. Your goal is to achieve the lowest temperature, in the shortest possible time.

You can choose:

* the medium used to facilitate evaporation
* the method of delivering water for evaporation

Your design will be based on how a swamp cooler—the cooling method used in the majority of homes in New Mexico—works.

**Bonus:** Come up with a design that could be used on your next camping or hiking trip so you can get a cool can of soda on a hot day, when trekking up the La Luz trail, for example.

Some considerations for planning your approach.

1. Why water must evaporate for cooling to happen?
2. To cool your can of soda, you need water on the outside surface of the can. How will you get water on the surface of your can?
3. You may choose to create some sort of sleeve or other covering to hold the water. For instance, you will be given possible fabrics in class, and you can cut and take a piece home. Over the coming week you can create a covering to bring next week to test in the lab. Brainstorm some ideas for what you think will work well. You are free to choose something other than the fabric.

As you plan this lab, be thinking about how this scenario is similar to and different from designing insulation for transporting medical samples at a stable temperature.

# Design diagram

Provide a detailed sketch of your design. Label all components. The diagram should make clear how the water is delivered to your design.

Explain why you selected the materials you choose.

# Lab Procedure Plan

Your task is to come up with an experimental procedure to test how well your design cools down a soda can. You will compare your results to the results of your peers. Write out your procedure like a recipe in a cookbook, with instructions **clear enough that someone else could follow them.**

In this lab, we will not try to modify the relative humidity of the air, but in your design you could consider this aspect.

Worksheet for Evaporative Cooling Laboratory

Date 2017 03 31

Group #

Group member names:

**Record the following quantities at the start and at the end of the lab session**

|  |  |  |
| --- | --- | --- |
| *(in Celsius)* | **Start of lab** | **End of lab** |
| Ambient pressure in the lab |  |  |
| Dry bulb temperature (the ambient temperature in the lab) |  |  |
| Wet bulb temperature |  |  |
| Relative humidity (RH) (read from charts) |  |  |
| Dew Point (read from charts, or calculated from the RH) |  |  |
| Dew Point in Albuquerque  <http://www.accuweather.com/en/us/albuquerque-nm/87102/current-weather/349680> |  |  |

# Procedure

At the start of the experiment, affix the thermocouple to the can. Start recording temperature at 1 minute intervals. After a few minutes, when temperature reaches steady state (i.e. no change with time), introduce the water using the approach you want to test. Continue recording temperature till a new steady state is reached.

Draw and label your lab setup. Make sure to describe how you deliver water to the soda can, and whether you used fan, no fan, or lab air.

**Record your data, making note of when steady state is reached**

|  |  |
| --- | --- |
| **Time (min)** | **Temperature (C)** |
| 0 |  |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |
| 6 |  |
| 7 |  |
| 8 |  |
| 9 |  |
| 10 |  |
| **Time (min)** | **Temperature (C)** |
| 11 |  |
| 12 |  |
| 13 |  |
| 14 |  |
| 15 |  |
| 16 |  |
| 17 |  |
| 18 |  |
| 19 |  |
| 20 |  |
| 21 |  |

After you finish, submit your data here: **https://tinyurl.com/CBE101EvapLab**

# Calculations

After the lab is complete, you can determine the following quantities. You will have a little time in class next week, but try to answer everything before class.

How close did the can approach the dew point of air in the room?

How close did it approach the wet bulb temperature?

What was the total heat transferred from the can? Heat transferred = mCpT since the can is composed of a metal shell and liquid in it you have to take the sum of the heat transferred to the can and to the contents.

What was the heat flux – i.e. Joules/s (Hint it will vary during the course of the experiment, so find the maximum heat flux. Ask the TAs for help if you are not sure how to estimate the derivative).

# Bonus questions

What would you change in your design to achieve faster cooling?

How would you design a cooler to use on a camping trip?

The class data will be posted on Learn. How did your design compare to other designs? Use a graph to show this.

Bioshipping Short Technical Report

*Completed as a group*

Short technical reports are commonly written for the client to provide backing for your design. These can be difficult to write well, because engineers must be very selective about what goes in the report. They must have a very clear understanding of the most important things that need to be communicated.

Your report should be **3 to 4 typed, one and a half spaced pages,** including figures and tables, but excluding reference list and cover sheet. Use a standard font and size, such as Times 12 or Arial 10. Margins should be 1 inch. Writing should be concise, but substantive. Avoid fluff and filler.

Cover Sheet: (single page, does not count in page limit): Includes title, date, and team number. Also include your names, roles and work completed by each member.

|  |  |
| --- | --- |
| **Team member name** | **Work completed** |
| **Project Manager:** |  |
| **Lead Research Scientist:** |  |
| **Lead Market & Financial Analyst:** |  |
| **Lead Requirements Engineer:** |  |

Introduction: One paragraph that concisely describes the client, the problem your design solution addresses, and the design requirements (needs and constraints).

Procedure: (~1 page) Brief summary of your decision-making process, major design choices made, research conducted and analysis (calculations) used to reach decisions. A limited number of well-prepared graphs, tables or figures are appropriate in this section. Figures and tables need to adhere to margin limits. They should have a descriptive caption (1-3 sentences) and labels/units that allows them to be understood on their own.

Results: (1 to 1 ½ pages) This section describes your final design, and should include a design schematic with descriptive labels and dimensions. Discuss the advantages and disadvantages of the material(s) your chose, including their cost and material properties, specifically their density in kg/m3, heat capacity in J/K, thermal conductivity in J/(s\*m\*K). A limited number of well-prepared graphs, tables or figures are appropriate in this section. Figures and tables need to adhere to margin limits. They should have a descriptive caption (1-3 sentences) and labels/units that allows them to be understood on their own.

Conclusions and Recommendations: (½ to 1 page) Explain how well your design meets the needs while not violating constraints. Consider your design in contrast to existing solutions. What makes your design more efficient, in terms of cost or ability to meet the identified needs? What next steps should be taken to improve the performance of your design? What did you learned from the design process?

References: (does not count in page limit): At the end of your report, list the references in numerical order. All references must be complete, and should be cited in the report, using numbers in square brackets.