MEC 496 **Senior Project II** **May 2022**

The Phoenix Mug

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Fulfillment Page

Phoenix Mug

A senior project submitted to the faculty of The College of New Jersey by:

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Abstract

The Phoenix Mug is a portable self-heating, self-brewing coffee mug. This addresses the inconvenience and inefficiency of waiting for the coffee to finish brewing before taking it on the road. Currently, there is no product on the market that can achieve this goal. Similar products cannot meet all the requirements set by The Phoenix Mug and are complicated to use, which is not practical for the average consumer.

The mug has functional brewing and heating mechanisms, a successful bluetooth phone application, and utilizes induction charging.

The overall process to brew the coffee is extremely user friendly. The first thing the user needs to do is fill the coffee with 8 ounces of water by filling the inner layer until the water reaches the fill line. Next, the user would fill the reusable coffee pod with about 2 tablespoons of coffee grounds. Once filled, the pod would be inserted into the cap and the cap firmly attached to the mug. Now, the brewing process would be ready to begin. The user would select the desired beverage type and temperature and press “Brew” on the phone application, which would trigger the hot ends to turn on and the pump cycle to begin. The perfect cup of coffee could be successfully brewed anytime, anywhere!

This project participated in the 2021-2022 Mayo Business Plan Competition.

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Introduction

The Phoenix Mug is a self-heating and self-brewing mug designed to act as a portable coffee machine. This product is different from those on the market, as it combines heating and brewing features into one portable mug. The mug works by having the user fill the inner layer with 8 ounces of water. Next, the user will fill the reusable coffee pod with approximately 2 tablespoons of coffee grounds and slide the pod into the cap and attach firmly to the mug's extender. The user will then pair the mug with their phone via Bluetooth, and use the Phoenix phone application to set the temperature and begin the brewing process. The mug is designed to be rechargeable through the use of induction pads. This allows for easy charging and plays a large role in maintaining the goal for the mug to be easy to use. The Phoenix Mug is also designed with many safety features in mind. The double-layer vacuum seal ensures that the surface of the mug is never hot enough to burn the user. Additionally, the electronic components of the mug are attached outside of the mug. This is to prevent overheating of the sensitive equipment. However, these components are protected to prevent the user from accidentally touching any high temperature electronics. Environmental concerns were also taken into account with the design of a reusable pod. This reusable pod can be cleaned and used again, as opposed to many of the single-use plastic pods on the market.

Since the start of this project, the Phoenix Team wanted to keep the average consumer in mind as they understood the misery of drinking cold and stale coffee after a long commute to work, paying for $5 coffees before class, and using complicated brewing devices on camping trips. By providing means for a simple-to-use and portable mug, the consumer is able to brew the perfect cup of coffee, anywhere, anytime regardless of situation. Overall, the Phoenix Mug creates a truly portable brewing and heating mechanism that currently does not exist on the market.

Team Management

For the Phoenix Mug's team, each member is a co-manager. This balanced structure allowed for each student to practice and strengthen their own leadership skills. By having no set leader, it encouraged each member to focus on deadlines, set meetings, and take charge when needed. Overall, the approach has been a great success. Each member has been able to step up when needed to act as leader. Using this balanced approach, many of the managerial tasks were split evenly. This included the budget, as it included parts from all of the subsystems. However, for the Gantt chart, the work was given to one singular person. This was to avoid confusion by having multiple members in the file and to ensure that one singular member had the sole responsibility to keep the schedule updated. The group constantly revisited and talked about the Gantt chart to make sure that they were on track.

Specifications

- Coffee temperature must reach 155ºF and be served at 120-145ºF
- Coffee should take less than 10 minutes to brew
- Inner layer must contain a minimum of 8 fluid ounces
- Coffee pod must hold two tablespoons of fine coarse coffee grounds
- Mug should fit into a car cup holder with the bottom diameter less than 3.25in
- Mug will operate using a Bluetooth phone application
- Application will control brewing temperature
- Mug will be portable
- Mug will be charged by induction

Chapter 1: Background

According to a survey on YouGovAmerica[3], the average American spends up to roughly 30 minutes getting ready for work/school in the morning. Additionally, around 26% to 33% of the allotted time is spent making coffee in preparation for the day ahead. The overall purpose of this device is to optimize the average time it takes to get ready for work/school in the morning by having the coffee brewed in a portable mug. By having a fully portable design, coffee can be brewed while in the car, which would save the user time and allow for them to drink fresh, hot coffee during their morning commute. Additionally, the mug can brew in class, at hiking camps, and anywhere else that the consumer wants hot and fresh coffee.

Some specifications to consider in the design would be the portability, the brewing temperature, the brewing time, the volume of coffee held, and the potential Bluetooth capabilities. In terms of portability, different mug sizes were taken into consideration to ensure the mug was large enough to house the electronic and heating components as well as the beverage, while also maintaining the ability to fit inside the standard car cup holder. To meet the standard brewing temperature in under 10 minutes, a complex heating system was required. One major requirement for the heating system was ensuring that the mug will be insulated so that the user will not burn themselves while the mug is brewing the coffee. Since the coffee and heating components would reach such high temperatures, ensuring user safety was a top priority. The subsystems were separated into four varying categories: structural, thermal, electrical and 3D printed component development. The structural subsystem mostly dealt with the overall shape and dimensions of the mug and inner layer to ensure the components are able to all fit in one whole assembly. The thermal subsystem dealt with the heat source and the connection to the

[3] https://today.yougov.com/topics/lifestyle/articles-reports/2012/07/10/morning-routine-30-spend-over-week-getting-ready-e

inner layer in order to provide the necessary heat transfer to boil the water. The electrical subsystem involves calculation, design, and integration of all electronic components and power sources. This subsystem also contains the Bluetooth and Arduino aspects of the project. Lastly, the 3D component subsystem involves the design of a custom cap, pod, extender, battery attachment and Arduino attachment.

The very first idea with the Phoenix mug initially involved the use of a hot plate at the bottom of the mug and using a plunger to compress the coffee brew into the liquid to brew it. This idea was scrapped due to the complexity of having the plunger take up half of the space of the inside of the mug. In the preliminary stages of designing the Phoenix Mug began with the overall structure of the mug having multiple layers to separate each of the different components.

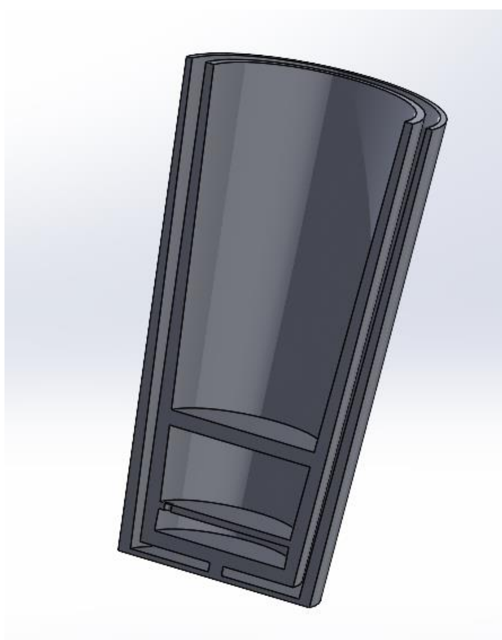


Figure 1: Sliced View of Preliminary Sketch

Initially, the mug was planned to heat up the liquid using thermal heating patches that would be placed within the inner walls while the battery was located in the bottom compartment along with the induction coils. The mug assembly was eventually refined to have just an inner capsule to place the liquid and that subassembly will be inserted into the body of a tumbler mug. This was chosen due to the difficulty to machine a mug with three separate layered compartments and it would be easier to access the inside with the current design as opposed to having the components sealed away.

Some other preliminary changes that were made include the heating sources. As mentioned before, the mug was originally going to be heated using thermal heating patches that would be placed along the second layer of the mug. After several calculations regarding the power output wattage and the temperature range of the heating patches reaching only 90℃. More thought needed to be put into the heating system to ensure that the water inside the basin is able to reach proper brewing temperatures. The group decided to pivot towards implementing the Denord thermal heating rods which will be scattered along the outside of the inner capsule. These rods have a maximum voltage rate at 120V and a maximum power output of 100 watts.

Another preliminary design consideration was the usage of a charging system. Since the mug is battery powered the group wanted to implement a charging system similar to Samsung smart phones where the mug will be placed on a platform allowing for induction charging to repower the batteries.

Chapter 2: Cap and Pod Design

During the conceptual creation of the Cap and Pod design, it was noted that both pieces needed to be custom designed. To begin designing the cap, it was necessary to identify key features that the cap needed to have. Firstly, a proper ventilation system needed to be designed in, as there would be a large buildup of steam and heat inside the mug, and it was important to have an outlet for the pressure. Additionally, in order to prevent heat loss, the cap needed a mechanism to keep the hole for drinking closed when not in use. Multiple solutions could have been used, as other products on the market already have solved this issue. These style caps include: a sliding mechanism, which allows a cover to slide over the hole and slide back when in use; and a flip mechanism, that would flip and snap on the hole to form a tight seal. Based on a decision matrix highlighted in Appendix E, the flip style was the better option as it provided a sturdier option for keeping the hole shut. As shown in **Figure 2**, the flip mechanism includes a hole in order to utilize a 4037 alloy steel dowel pin with a diameter of 1/16'' and length of 1''.

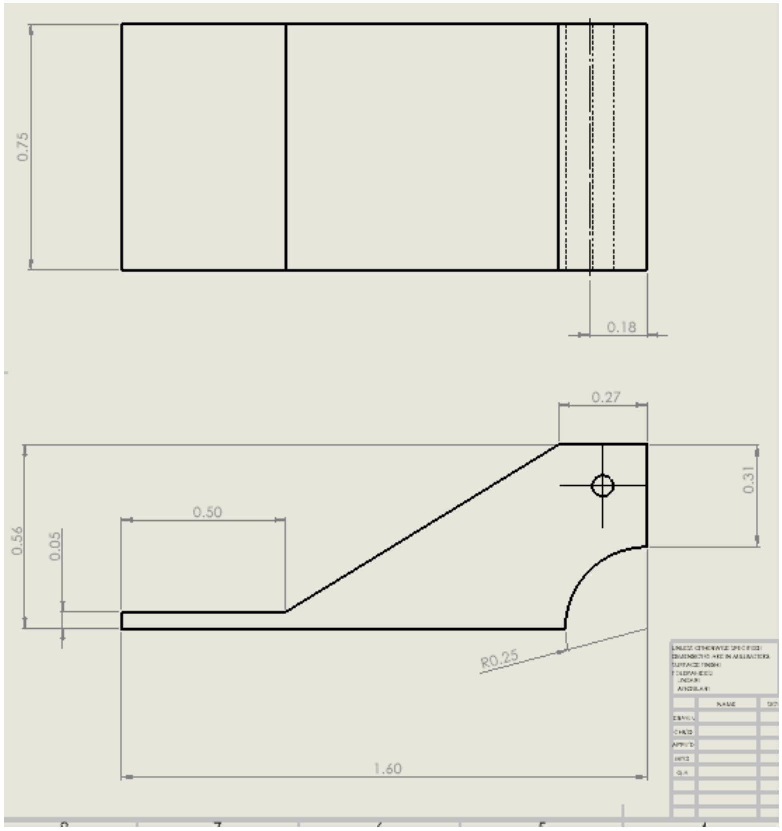


Figure 2: Flip Mechanism

Another feature of the cap was the forming a tight seal with the mug. To achieve this, an O-ring was used. Since the diameter of the 40-ounce tumbler is 4.5 inches, the O ring would need to be 4.129 inches to take into account tolerance. As shown in **Figure 3**, the O-ring selected archives the given dimensions.

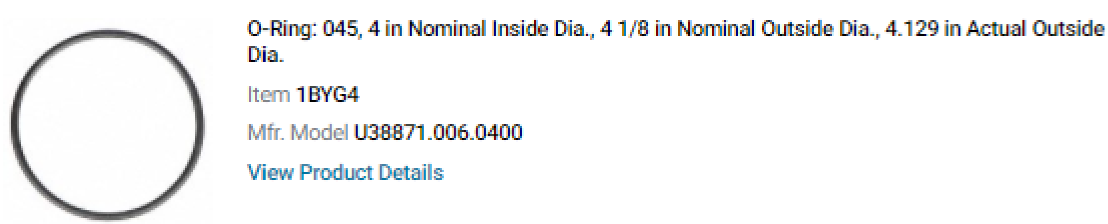


Figure 3: 0.07in Width O-Ring

Another key aspect of the cap design was the compatibility with the pod design. The pod needed to be easily removed and attached to the cap. A simple twisting locking mechanism was designed so that the cap would slide into the cap and twist to be locked in place.

The pod design changed drastically from initial design to final design. Initially, the pod was going to be single-use. Similar to other products, the pod was going to be spring loaded and require the use of a sharp object or force to puncture the plastic material. Additionally, the design was complicated further with the use of sensors, and there was a challenge involved regarding how the pump would feed water into the pod. The team soon realized that a redesign was needed. The final design needed to be user friendly, simple, support the pump, and have better environmental effects. The first thing the students needed to tackle was a way to attach the pod to the mug. Since a spring loaded mechanism was far too complicated, a simple locking mechanism connecting the pod directly to the cap was designed. The pod would easily twist into the cap, allowing for easy access for the user to remove and fill the pod. Next, the students needed to figure out how the pump would connect to the pod. The students designed the pump to come in from the side of the inner layer. The water would then hit the pod from the side, where a hole would be cut for easier access. Then the water would soak into the grounds and drip through the pod's mesh material and into the mug. The concentration of the coffee could be adjusted and the pump would cycle more to increase it. A food-safe mesh material was chosen to keep the grounds from going into the water. To improve the environmental impact of the mug, the students designed the pod to be reusable. Through this, plastic waste will be avoided which would benefit the environment. The final design of the pod can be seen in **Figure 4**.

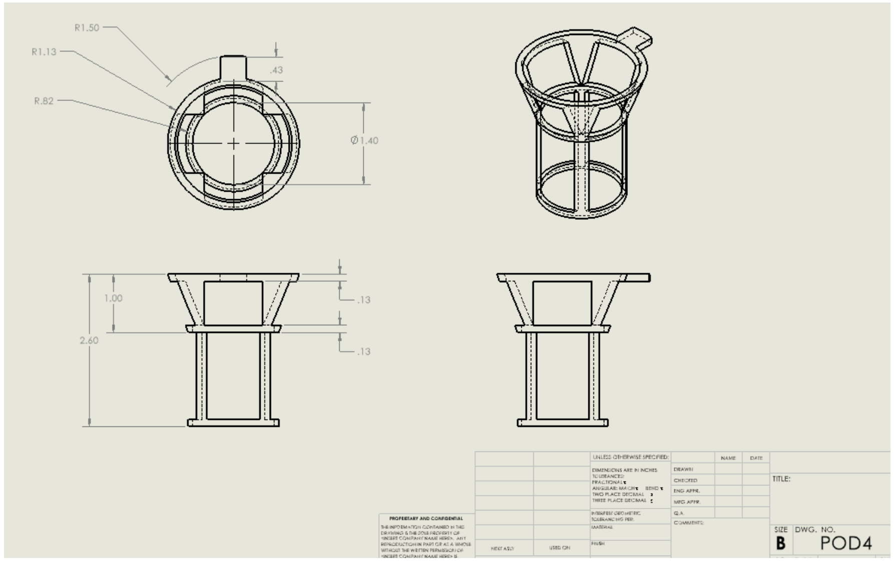


Figure 4: Final Pod Design

Another consideration regarding the cap and pod design was the material. The original plan was to 3D print the cap and pod. However, upon further research, the market for current food-safe 3D printing filaments is underdeveloped as those who claim their products are food-safe don't have FDA approval and only partially guarantee such claims for only the first use. Especially in the case of the Phoenix Mug where the filament will constantly be exposed to temperatures above 130°F, the filament will start to be heat treated which will remove any food-safe seal that might be applied to the filament. However, due to time constraints, the 3D printed designs would be incorporated into the prototype. This would not be a part of the final design. More research will be needed to determine the material and manufacturing of the final product. Images of the 3D printed models of the cap and pod can be seen in **Figure 5**.

Figure 5: Cap and Pod Printed Assembly

From fall to spring semester, the design of the cap and pod was modified. In order to attach the inner layer to the outer mug, an extender was added. This design is discussed further in Chapter 3. By adding this extender, the pod needed to be much longer than the original design. Additionally, the cap was slightly edited to better fit the extender.

Chapter 3: Extender Design

In the spring semester, the students realized that their original design for attaching the inner layer would not work. Originally, the students were going to attach the inner layer to the side of the mug using epoxy. However, they worried that this would not be strong enough and that this was at risk of failing. Additionally, the hot ends were longer than the inner layer, which meant there was a risk of the hot ends not fitting inside of the mug. To combat both issues, an extender was created. This extender allowed for more room for the hot ends to fit, while also securely attaching the inner layer. Additionally, before the design of the extender, there was no way to have any electronics outside of the mug without damaging the vacuum seal of the purchased tumbler. The extender allowed for holes to be cut to allow for the passage of wires. This ended up being critical as the design of the PCB board was not achieved. With the extender, the students were able to use their backup plan of an Arduino Mega that would be placed outside of the mug. The design of the extender can be seen in **Figure 6** and **Figure 7**.

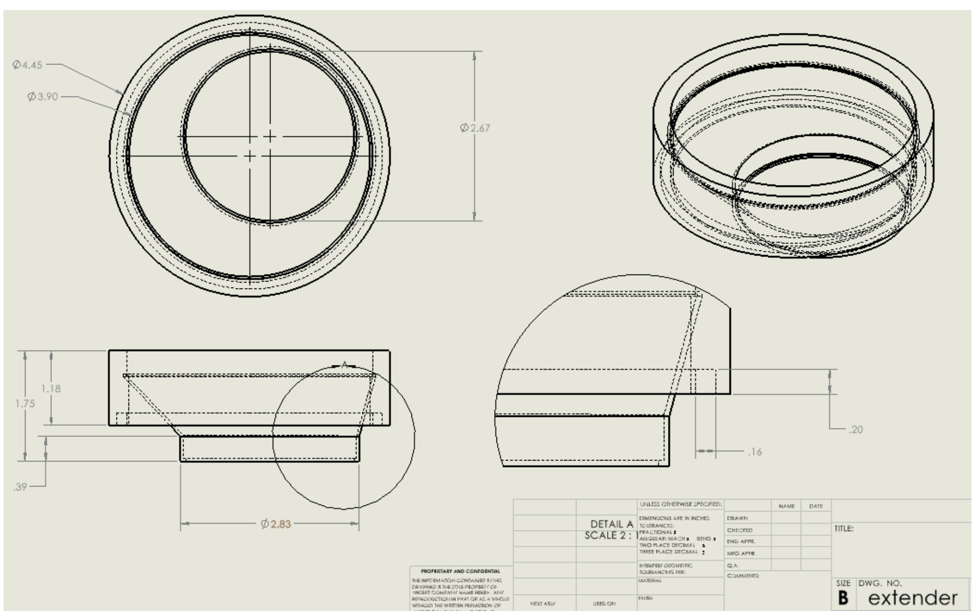


Figure 6: Extender Drawing

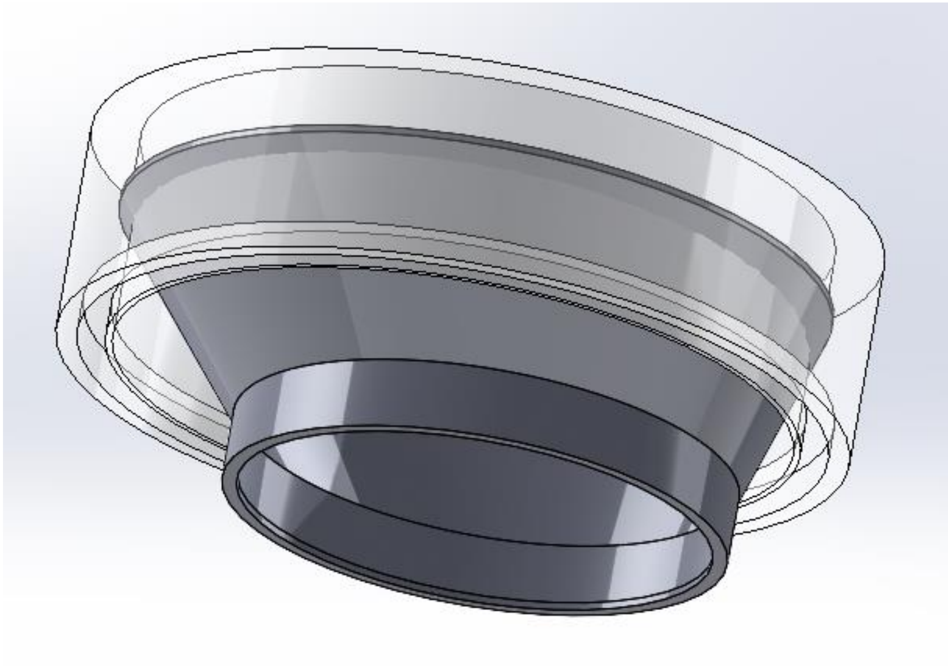


Figure 7: Extender Design

For the prototype, 3D printing was determined to be the best method. This would allow for fast results with no cost impact to the limited budget. The students did face challenges when printing this piece. This was due to the precision needed to attach the inner layer and to fit the outer layer. Due to shrinkage, the 3D printed pieces ended up not fitting properly. However, through adjustments, the final component was achieved. The final printed extender can be seen in Figure 8.

Figure 8: 3D Printed Extender

Chapter 4: Inner Layer Design

The purpose of the inner capsule is to contain the liquid for the mug. This layer is critical as it keeps the liquid separate from the heating elements and other electronics. This layer is an open topped cylinder with a hole on the bottom and one side. The purpose of these holes are to attach a tube so that water can get pumped from the bottom to the side of the mug. The hole on the side of the layer has a dimensions of .5 inches and will accept one side of a 0.43-inch diameter silicone tube. The hole was designed to be smaller than this due to the fact that the tube was very flexible and could easily be compressed. By making the hole dimension smaller, it ensured a tight fit for the tubing. The dimensions for this capsule are 4.00 inches tall with an outer diameter of 3.0 inches. The inner layer was designed to hold 8 ounces of water, taking into consideration the displacement of the pod. There was a fill line added at 8 ounces, to ensure that the correct amount of water was filled by the user. The material used for this layer was originally going to be high-temperature aluminized low-carbon steel with a thickness of 0.047". However, after further discussion with manufacturing, stainless steel with a thickness of 0.047" was used. **Figure 9**, demonstrates the final inner layer design.

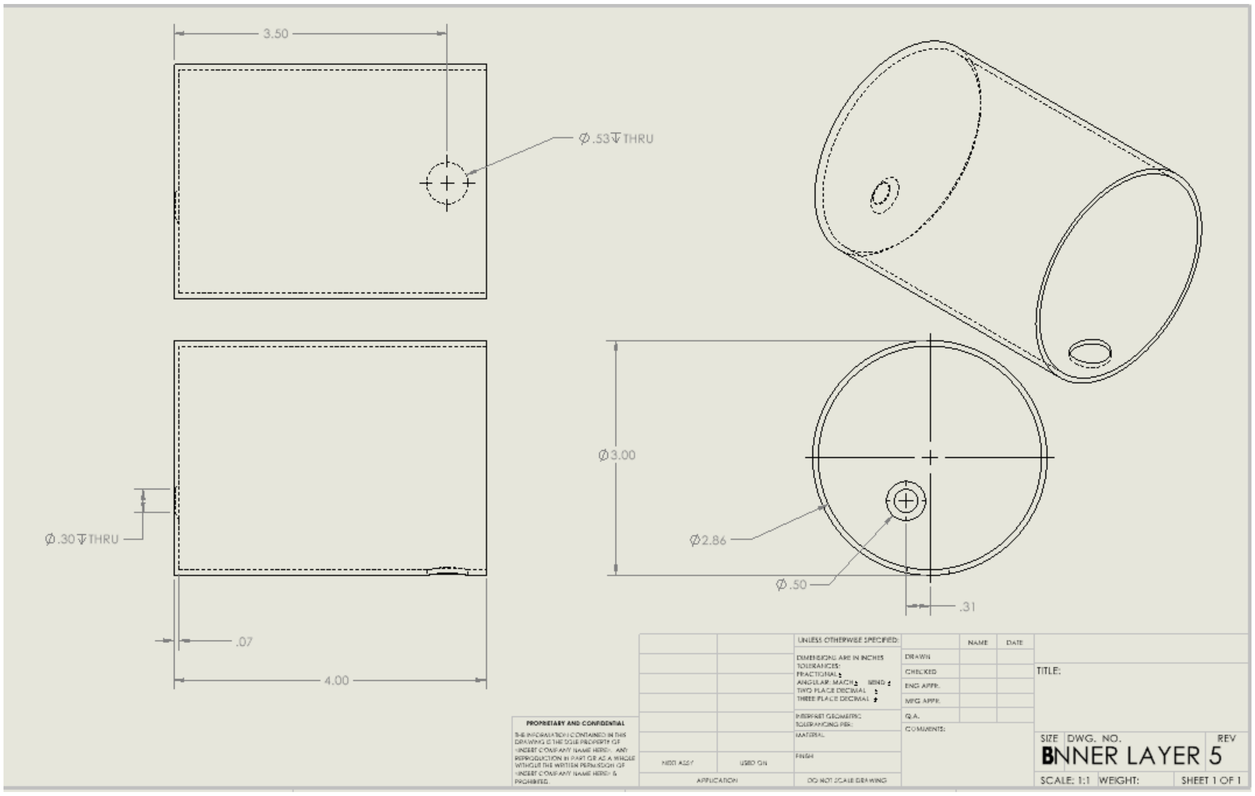


Figure 9: Inner Layer Design

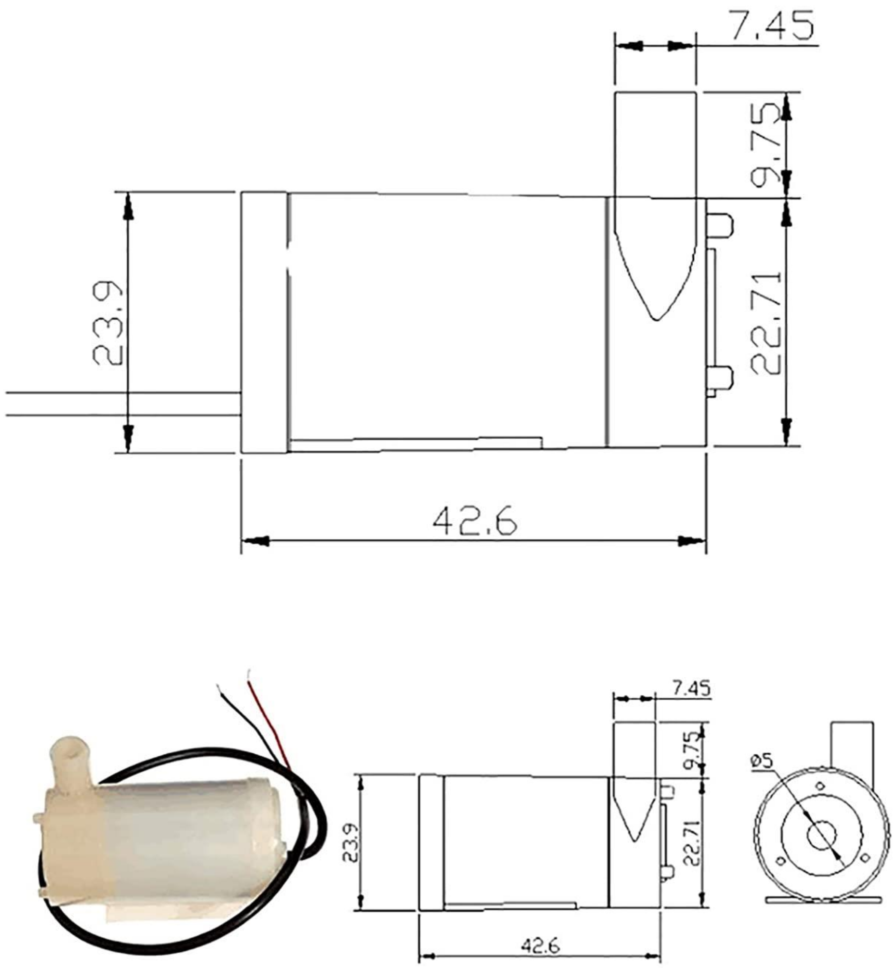
The inner layer was manufactured at The College of New Jersey's machine shop. To manufacture the inner layer, the sheet metal was cut to the correct length by calculating the circumference of the circle. Once cut, the metal was then rolled. The sheet metal roller had a minimum diameter of 2 inches, since the part needed a diameter of 3 inches it could be used. Once the part was rolled, the bottom circle was created through the use of a waterjet. At first, the circle cut was too small due to warping that occurred. This issue was fixed and a second circle was cut that fit properly this time. Then, the bottom could be connected to the side cylinder through welding. To smooth out the welds, a belt grinder was used. Once this was all welded together and smoothed out, the holes could be cut. The bottom hole was cut first through the use of the milling machine. The side hole was verified first with the creation of the pod before it was cut on a milling machine. The final machined inner layer can be seen in **Figure 10** and **Figure 11**.

Figure 10: Inner Layer

Figure 11: Inner Layer with Pump Attached

The hole running through the side of the capsule is where the silicone tubing will be fed through. When the cap and pod system is on the mug assembly. The tube fed through the hole of the inner capsule will aim the water at the coffee pod.

The hole on the bottom is where the pump will be connected. The pump that will be used for this project is a Gikfun submersible mini water pump. This pump shown in **Figure 12** has a voltage range of 2.5V to 6V and an overall water discharge capacity of 100L/h.



Model	Voltage Scope (DC)	Current (A)	Power (W)	Max Water Head (M)	Max Flow Rate (L/H)	Starting Voltage	waterproofing grade
JT-DC3W-3	3V	0.12	0.36	0.35	80	1	IP68
JT-DC3W-4.5	4.5V	0.18	0.91	0.55	100	1	IP68

Figure 12: Submersible Mini Water Pump Design Specs

The diameter of the inlet of the pump and the hole on the bottom of the inner capsule has a diameter of 0.3 inches. Due to the pump's larger discharge rate, the water flow exit velocity will be sufficient in reaching the pod to make contact with the coffee grounds.

Chapter 5: Heating Mechanism

One of the major components of the Phoenix Mug is the heating mechanism. One of the deliverables for the project is to brew and heat the coffee, which is largely dependent on the heating mechanism. Water is a challenging item to heat up, as it requires a lot of energy to be put into it before the temperature starts to increase. This was one of the first obstacles the team had to overcome. The heating system worked closely with the electronic system, as the input power determined the wattage of the heating system. A big factor in the heating system is the size constraint. The mug needed to fit the inner layer, and the electronics system which includes the hot ends, batteries, Bluetooth system, pump and sensors.

The main goal of the heating system is to bring the temperature of the water to the 155ºF brewing temperature and allow for the coffee to be served at 140ºF. Additionally, the team wanted to limit brewing time. This led to an optimization problem as the goal was for the consumer to enjoy the largest amount of coffee while limiting the amount of time it took to brew. From this problem, calculations shown in **Table 1** were formed which compares the volume of liquid with the time it takes to brew and the amount of watts required in each scenario.

Table 1: Time vs Volume Optimization

Size: 1 oz		Size: 2 oz		Size: 3 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	118.5377644	1	237.0755287	1	355.6132931
2	59.26888218	2	118.5377644	2	177.8066465
3	39.51258812	3	79.02517623	3	118.5377644
4	29.63444109	4	59.26888218	4	88.90332326
Size: 4 oz		Size: 5 oz		Size: 6 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	474.1510574	1	592.6888218	1	711.2265861
2	237.0755287	2	296.3444109	2	355.6132931
3	158.0503525	3	197.5629406	3	237.0755287
4	118.5377644	4	148.1722054	4	177.8066465
Size: 7 oz		Size: 8 oz		Size: 9 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	829.7643505	1	948.3021148	1	1066.839879
2	414.8821752	2	474.1510574	2	533.4199396
3	276.5881168	3	316.1007049	3	355.6132931
4	207.4410876	4	237.0755287	4	266.7099698
Size: 10 oz		Size: 11 oz		Size: 12 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	1185.377644	1	1303.915408	1	1422.453172
2	592.6888218	2	651.9577039	2	711.2265861
3	395.1258812	3	434.6384693	3	474.1510574
4	296.3444109	4	325.978852	4	355.6132931

After consideration, the team decided on working with 8 ounces of water at 3 minutes. In order to achieve such a feature, the group needed to find a way to supply 316.1 Watts of energy into the water.

At first, the original design utilized Polyimide heating pads as shown in **Figure 13**

Figure 13: Polyimide Heating Pads

However, to the specified power requirements that needed to be met, to heat the water in a timely manner the surface area required for the pads exceeded the size of the inner mug. This required a new heating mechanism to be explored.

The next viable solution was ceramic heating rods as shown in **Figure 14**.

Figure 14: 100 W Heating Rods

These heating rods were small enough to fit into the mug with ease. Additionally, they were also very inexpensive, which helped solidify the selection. Upon further research, it was concluded that four of these rods can support a load of 400 Watts which was more than sufficient to supply a load requirement of 316.1 Watts. During the testing process, it was concluded that the battery's heat dissipation would gradually increase causing a safety hazard from the interior of the mug. Due to the change to have the batteries on the exterior of the mug via the battery pack, a greater quantity of batteries can be used while also allowing for the batteries to have consistent sizing and voltage. In terms of wattage, the new battery pack can output 108 Watts. The optimization calculations had to be re-evaluated to optimize the number of hot ends used, as shown in **Table 2**. In doing so, the time to brew increased to 9 minutes, given ideal conditions.

Table 2: Updated Time vs Volume Optimization

Time (Minutes)	Watts Needed
1	948.3021148
2	474.1510574
3	316.1007049
4	237.0755287
5	189.660423
6	158.0503525
7	135.4717307
8	118.5377644
9	105.3669016
10	94.83021148
11	86.20928316
12	79.02517623

After re-evaluating the amount of wattage with reference to the time to heat up the inner capsule, it was determined that the mug's batteries will no longer need to supply power to 4 thermal heating rods but instead will only need to supply power to two.

In order to effectively use the thermal heating rods in the system, the thermal rods will have to be placed at the same end as the pump and hose mechanism. The thermal heating rods will have to be surrounded by insulation to ensure that heat is only transferred through the stainless steel. By using the ceramic insulation as well as the thermal tape, the thermal heating rods were fastened to the exterior of the inner capsule.

Chapter 6: Bluetooth Mechanism and Phone Application

The Bluetooth system was integral to the development of the project as it enabled communication between the user and the mug. The Bluetooth chip utilized HC-06 protocols and piggy-backed off of the com-ports of the Arduino for communication. **Figure 15**, is the image of the circuit used to enable Bluetooth communication.

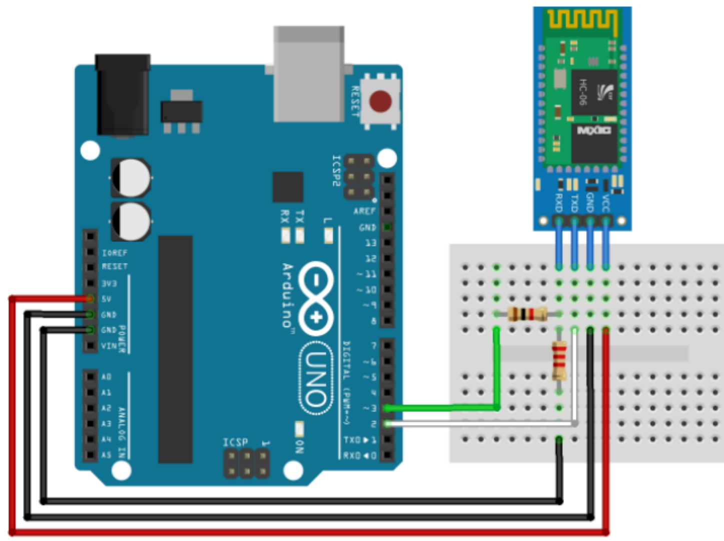


Figure 15: HC-06 Circuit

The phone application was written using MIT app inventor and had the basic functionality to communicate to the mug what beverage was selected and the brewing temperature that it should warm the water to. The information being sent back to the phone is the current water temperature as well as if the drink is finished brewing. **Figure 16** demonstrates the MIT app inventor code. Additionally, **Figure 17** is a picture of the UI for the application. Lastly **Figure 18** is the code for the Bluetooth module.

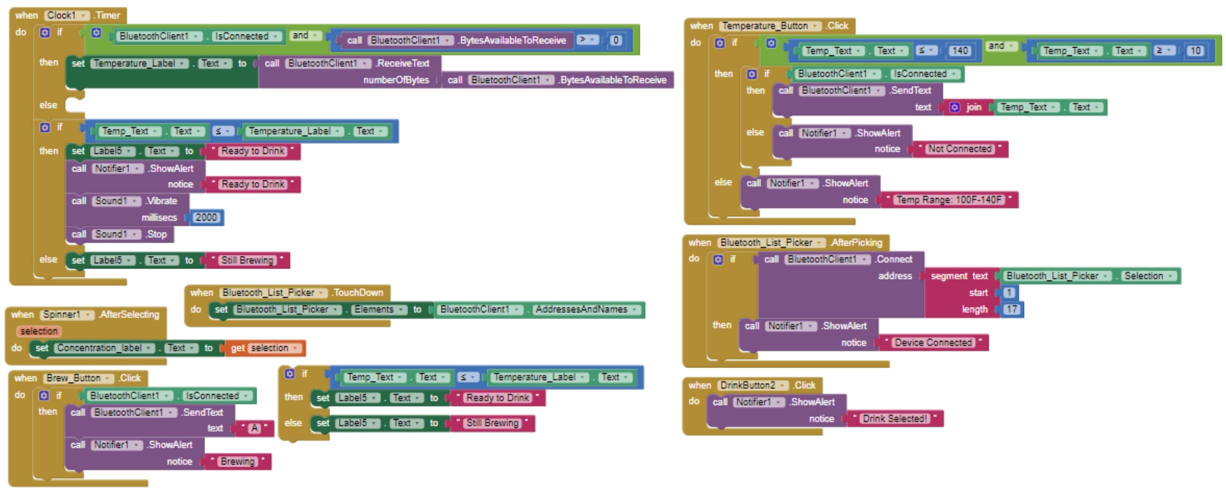


Figure 16: MIT app inventor code

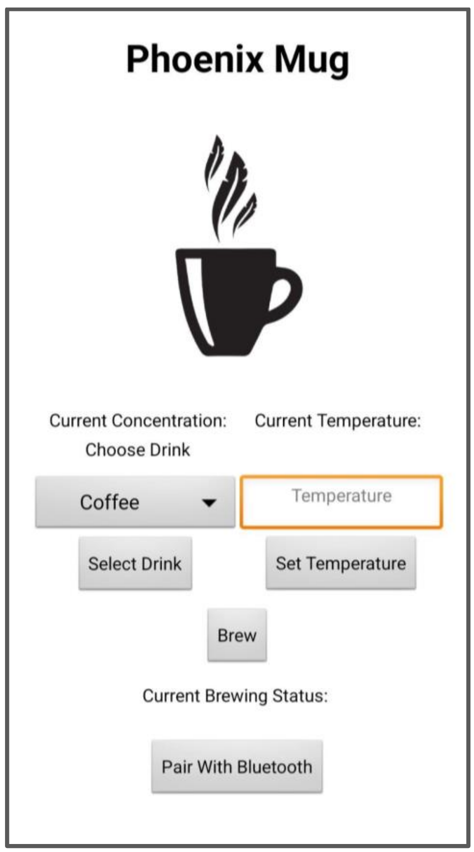


Figure 17: Application UI

```
#include <SoftwareSerial.h>
SoftwareSerial BTserial(2, 3); // RX | TX
// Connect the HC-06 TX to the Arduino RX on pin 2.
// Connect the HC-06 RX to the Arduino TX on pin 3 through a voltage divider.
// Connect a LED in serial with ~220 Ohm resistor to Pin 12 and ground.

#define LEDPin 12
char recievedChar;

void setup()
{
Serial.begin(9600);
Serial.println("Enter AT commands:");

// HC-06 default serial speed is 9600
BTserial.begin(9600);

pinMode(LEDPin,OUTPUT);
}

void loop()
{

// Keep reading from HC-06 and send to Arduino Serial Monitor
if (BTserial.available())
{ recievedChar = BTserial.read();
Serial.write(recievedChar);
//if(recievedChar == ‘o’){
//digitalWrite(LEDPin, HIGH);
//BTserial.write("LED is On \r\n");
//}
//else if(recievedChar == ‘f’){
//digitalWrite(LEDPin, LOW);
////BTserial.write("LED is Off \r\n");
//
//}
//else{Serial.write("Wrong Command");}

}

// Keep reading from Arduino Serial Monitor and send to HC-06
if (Serial.available())
{
BTserial.write(Serial.read());
}

}
```

Figure 18: Arduino code for bluetooth

Chapter 7: Electronic System - Temperature Measurements

For measuring the temperature of the water, 100K ohm NTC 3950 Thermistors were used as show in **Figure 19**. An Arduino Mega 2560 (**Figure 20**) was used to measure and output the data.

Figure 19: 100K ohm NTC 2950 Thermistor

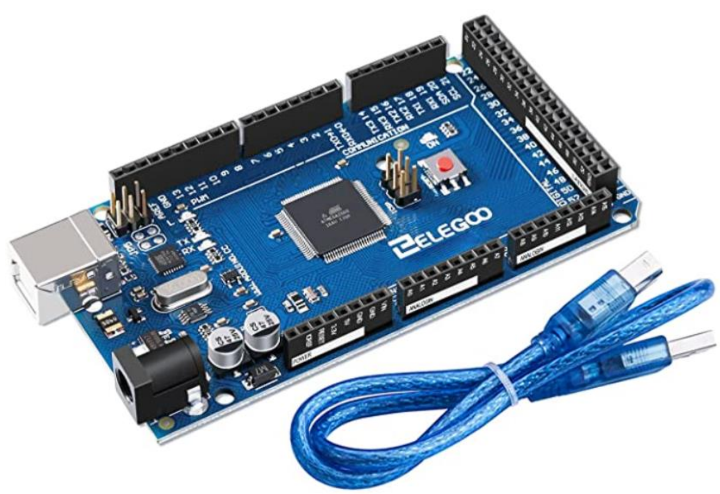


Figure 20: Arduino Mega 2560

Wiring is important when it comes to analyzing the correct signal. **Figure 21** represents the wiring diagram that was used on this portion of the project.

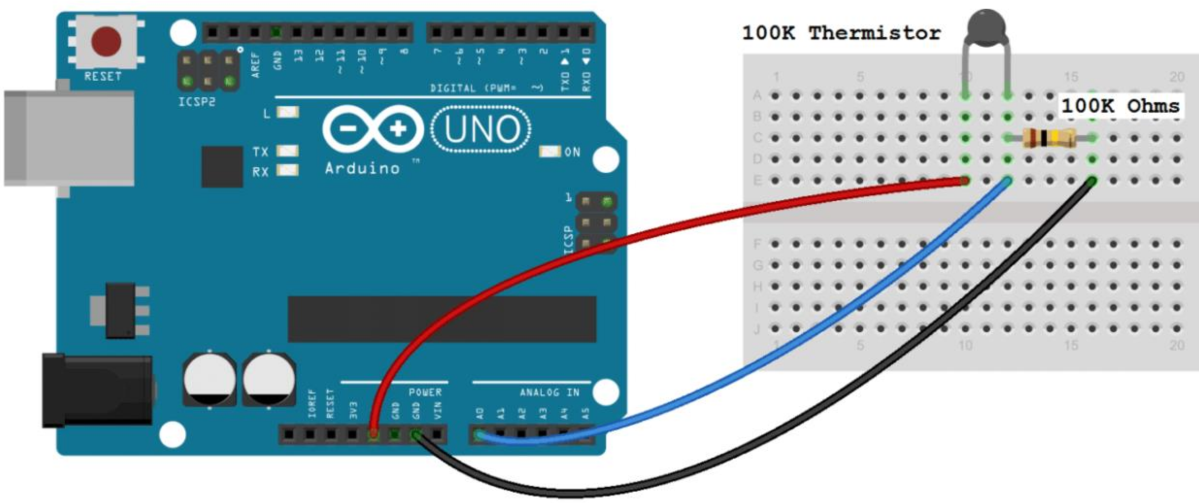


Figure 21: Wiring Diagram for Temperature Measurement

In order to read the data from the thermistor, code must be written to the Arduino so that it can interpret the voltage differences and turn it into a readable temperature format. The Arduino IDE was used for processing and uploading data into the Arduino. **Figure 22** demonstrates the code used to push data on the serial monitor.

```
//Thermometer with thermistor

/*thermistor parameters:
   RT0: 10 000 Ω
   B: 3977 K +- 0.75%
   T0:  25 C
   +- 5%
*/

//These values are in the datasheet
#define RT0 10000   // Ω
#define B 3977      // K
int row_excel = 3; // number of lines




//---------------------------------------


#define VCC 5    //Supply voltage
#define R 10000  //R=10KΩ
#define PTrans 2
#define LED 3

//Variables
float RT, VR, ln, TX, T0, VRT;
int test = TX; //test variable to be passed to Excel
float n;

```

```

void setup() {
  Serial.begin(9600);
  pinMode(PTrans, OUTPUT);
  pinMode(LED, OUTPUT);
  T0 = 25 + 273.15;                 //Temperature T0 from datasheet, conversion from Celsius to kelvin
  n = 0;
}

void loop() {
 n = n + .5;
VRT = analogRead(A0);              //Acquisition analog value of VRT
  VRT = (5.00 / 1023.00) * VRT;      //Conversion to voltage
  VR = VCC - VRT;
  RT = VRT / (VR / R);               //Resistance of RT

  ln = log(RT / RT0);
  TX = (1 / ((ln / B) + (1 / T0))); //Temperature from thermistor

  TX = TX - 273.15;                 //Conversion to Celsius
 if(TX >= 60){
  digitalWrite(PTrans, LOW);
  digitalWrite(LED, LOW);
  Serial.print("TEMP IS NICE AND WARM");
  Serial.print("\t");
  Serial.println(TX);

}
 else{
  digitalWrite(PTrans, HIGH);
  digitalWrite(LED, HIGH);
    row_excel++; // row number + 1
   // excel record current date and time


  Serial.print("Time:");
  Serial.print("\t");
  Serial.print(n);
  Serial.print("C\t\t");
  Serial.print("Temperature:");
  Serial.print("\t");
  Serial.print(TX);
  Serial.print("C\t\t");
  Serial.print(TX + 273.15);        //Conversion to Kelvin
  Serial.print("K\t\t");
  Serial.print((TX * 1.8) + 32);    //Conversion to Fahrenheit
  Serial.println("F");
 }
 delay(500);

 }

```

Figure 22: Arduino Code for Temperature Measurement

This code was written so that it can take information in 0.5 second increments. However, because Arduino serial monitor does not have a copy/paste function, the team had to resort to another method to collect the data. Ultimately, the program called PUTTY, was used to fix this issue. Because this program had another interface which allowed for the conversion of the serial monitor into a .txt form when the experiment was over, the data could be easily collected and analyzed.

The experiment included using 108 Watts of energy to heat up a measured 8 ounces of water in the Rtic mug. **Figure 23** demonstrates that it will take 10.2 minutes to heat up water from room temperature (73 degrees Fahrenheit) to 155 degrees Fahrenheit.

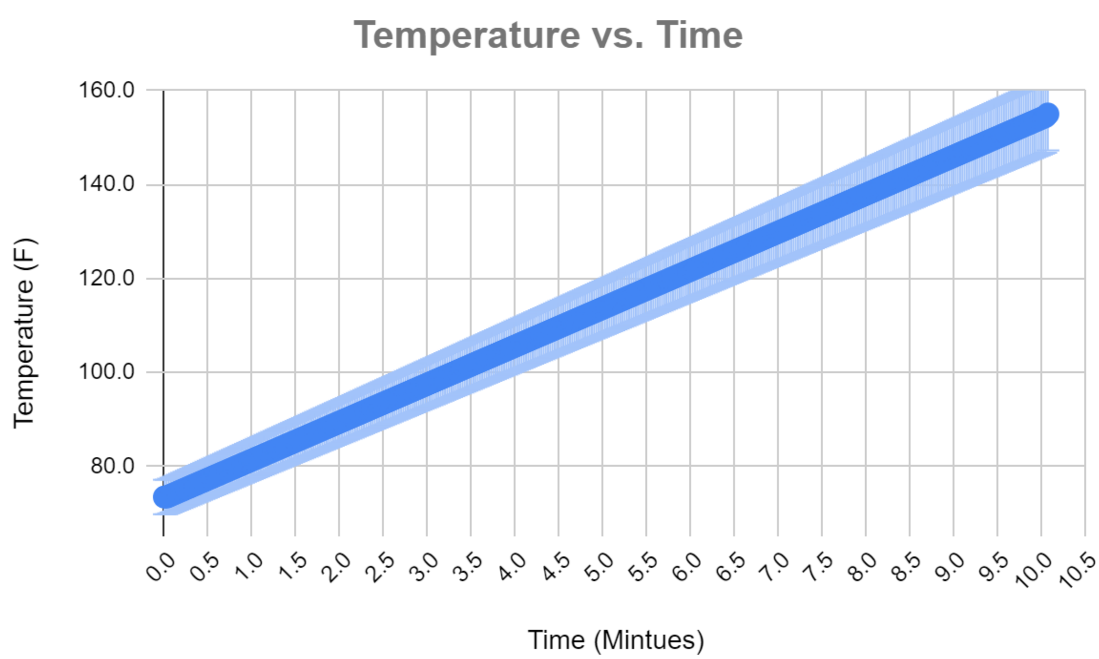


Figure 23: 108W 8 Ounce Temperature Gain vs. Time

Additionally, other experiments were tested to measure the heat loss of the system over a period of 6 hours. To start this experiment, 8 ounces of 138 degree Fahrenheit water was left in the mug with the cap on. **Figure 24** measures the degradation of temperature in respect to time.

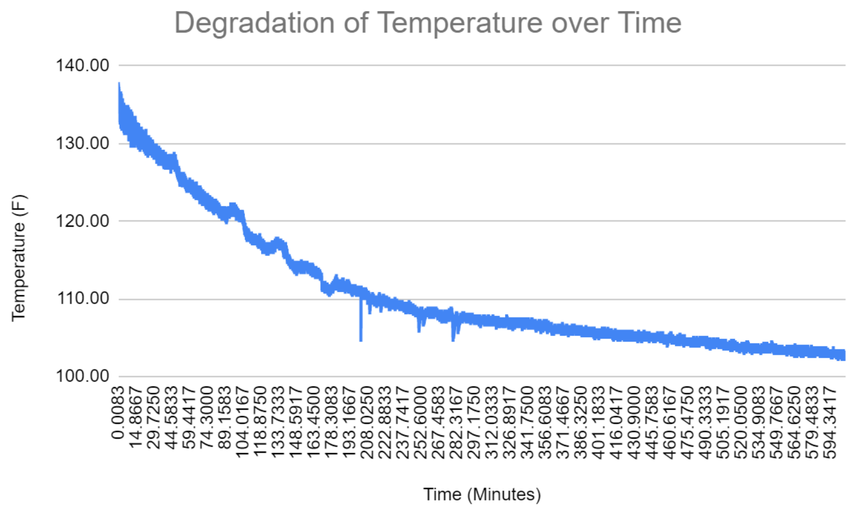


Figure 24: Degradation of Temperature over Time

From this data, it was determined that it took 6 hours for the temperature to decrease by 40 degrees Fahrenheit. The results for this experiment, are better than expected, as according to ScienceFocus.com[4], the average time it takes to drink a cup of coffee is 10-15 minutes.

The group plans on using a second thermistor to accurately measure the temperature of the ambient air in the electronics. By doing so, the internal temperature can be regulated as a safeguard so that the ambient temperature does not go above the temperatures for the batteries.

[4] https://www.sciencefocus.com/the-human-body/how-long-does-caffeine-take-to-kick-in/

Chapter 8: Battery Attachment

Originally, the team intended on containing everything within the mug. However, during the bench testing phase, the students realized that there were some major issues with this plan. The batteries became extremely hot (~145 F) during normal use. This required the students to make a tough decision and remove the batteries from inside the mug. Once this was done, the students were able to go from 4 to 8 batteries, which improved the time it would take to brew and the temperature reached. However, by having the batteries outside of the mug, the design was no longer portable. Additionally, having the hot batteries exposed would be a safety risk as well. To remedy this, the students designed a handle attachment that would store the batteries. This handle would be 3D printed and would contain a hole where the batteries would rest. To ensure that the plastic would not melt, the students wrapped the inside of the hole with thermal tape. The handle was attached to the exterior of the mug using epoxy. Overall, this attachment design allowed for the design to remain portable and increased the number of batteries that could be utilized. The design can be seen in **Figure 25** and **Figure 26**. The final printed component can be seen in **Figure 27**.

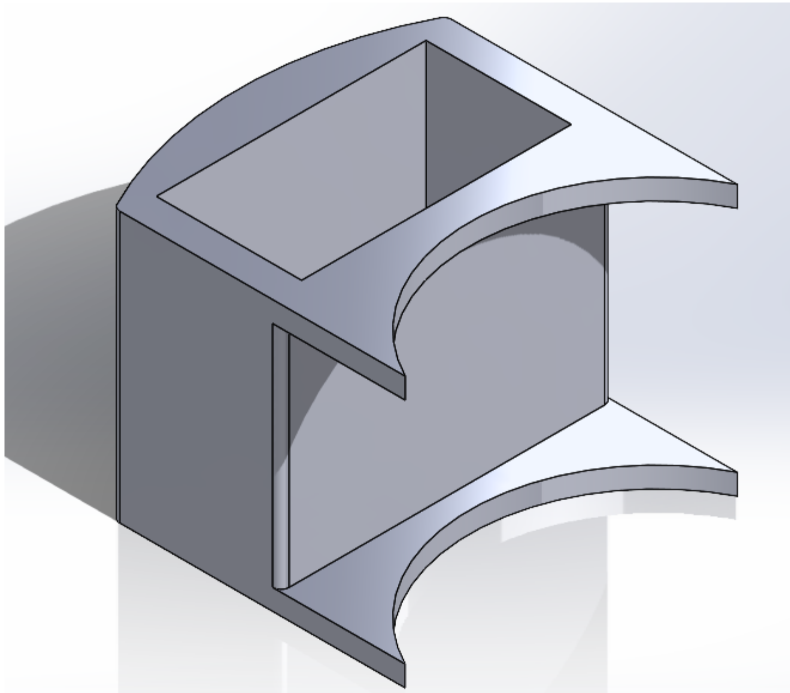


Figure 25: Battery Attachment Design

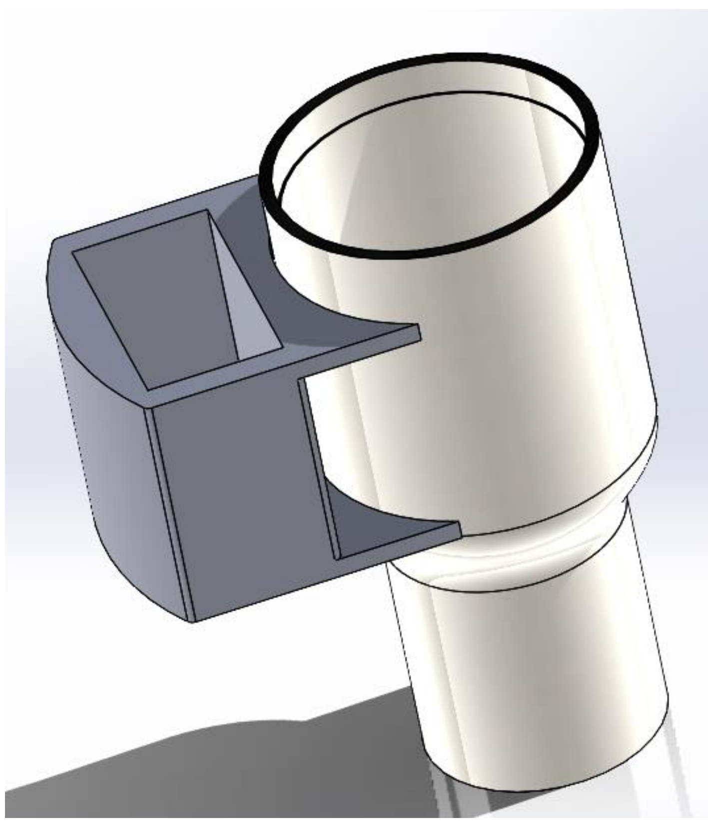


Figure 26: Battery Attachment Assembly

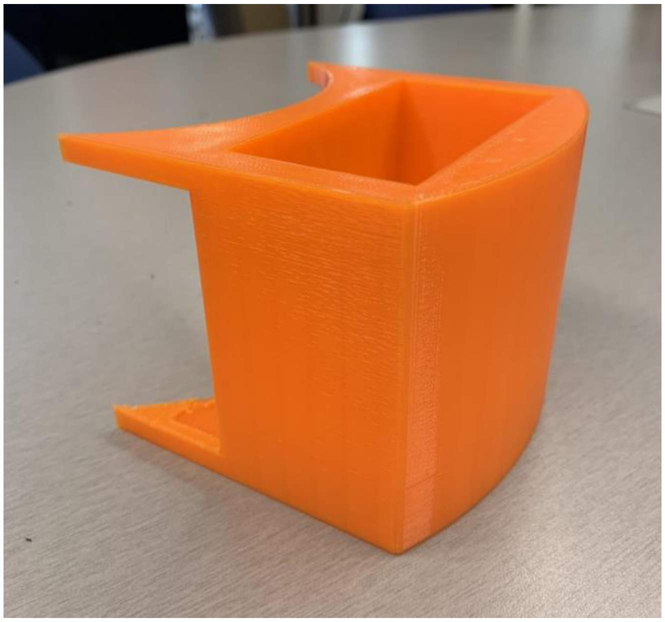


Figure 27: Final Battery Attachment Component

Chapter 9: Arduino Attachment

Once it was determined that the electronics could be outside of the mug, additional design changes were required. The students decided that since size would no longer be a constraint, the use of a PCB was no longer required or necessary. Instead, an Arduino and breadboard could be utilized. To remain portable, the Arduino and breadboard needed a way to attach to the mug. Originally, the students planned on attaching these components to the side of the battery attachment. However, they noticed that this caused a weight imbalance, as the batteries were very heavy. To fix the weight imbalance, the students designed an Arduino attachment, which was similar in appearance to the battery attachment. This design was also printed in high density PLA 3-D printing filament to ensure that the Arduino attachment provides a sufficient counter moment to stabilize the balance of the entire mug assembly. The design was very beneficial in keeping the mug portable, while solving the issue of the imbalance. Velcro strips were used as a way to mount the electronics to the Arduino attachment. The design and final component can be seen in **Figure 28** and **Figure 29**.

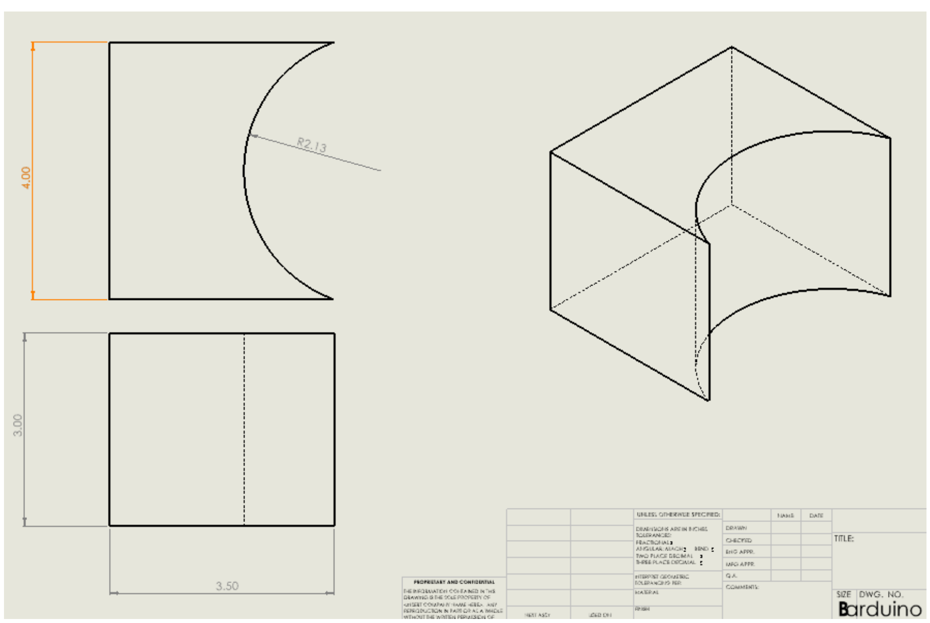


Figure 28: Arduino Attachment Design

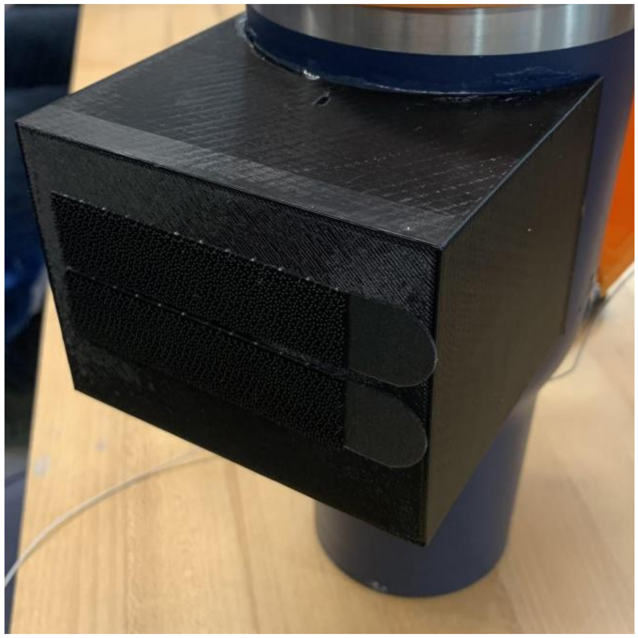


Figure 29: Arduino Attachment

Chapter 10: Cost Estimate

A major component of the project is creating and staying within a proposed budget. Throughout the design, the budget was edited and reworked to ensure accuracy. Additionally, the budget was closely monitored and managed to ensure that the students did not exceed the approved budget. During the early stages of the project, a preliminary budget was created. This budget was a rough estimate mainly used to determine if the students would need to request additional funds. This budget was not accurate as it was too early in the design stage to determine all of the components properly. This preliminary budget can be seen in **Table 3**.

Table 3: Preliminary Budget

Purchasable Parts	QTY.	Price ($)		
MECHANICAL				
YETI Rambler MagSlider Lid -30	3	9.99		
Polished Multipurpose 304 Stainless Steel Sheet, Brushed #3, 0.075" Thick, 24" x 24"	4	106.06		
Gikfun DC 3V 5V Micro Submersible Mini Water Pump (Pack of 4pcs) EK1893	4	10.98		
			-SUBTOTAL-	127.03
ELECTRICAL				
2V/1120mAh (17Wh) battery from EVE.	1	9.95		
Induction Set - Power	1	35.67		
Heating Pad	1	15.99		
Soldering Iron with Solder	1	39.99		
Gloves	3	22.7		
PCB Boards	3	50		
PCB IC Components		50		
			-SUBTOTAL-	214.35
THERMAL				
Ametherm SL32 1R030 (Pack of 2) NTC Thermistor, SG379 HVAC, Inrush Current Limiter 1 Ohm Ohm ±20% 1.18" (30mm)	2	10.95		
Hermetically Sealed Thermistor Sensors	1	59.02		
			-SUBTOTAL-	69.97
			GRAND TOTAL	411.35

As the deadline for the final budget approached, the students were able to put more time into each component of the budget. All additional testing material, shipping costs, and a cushion were taken into consideration during the creation of the final budget. As part of the final budget, decision matrices were heavily used in the selection of components and materials. From the heating source to the insulation, each line item involved some amount of design and research. By using decision matrices, an organized list was created. The decision matrices can be seen in **Appendix F**. The final budget was submitted on 11/10/2021 and had a grand total of $580.25. This detailed final budget can be seen in **Appendix D**.

Once the final budget was submitted, the students needed to pay close attention to the budget including how much they purchased and any changes that may have occurred. To ensure that they did not go over budget, a data sheet was created to keep track of all money spent, what was left to purchase, and how much cushion remained. The students had a plan in place to ensure that if the cushion became too small, they would begin reaching out to potential donors to ensure that they would not exceed the budget. Overall, the budgeting process was a long and detailed process that involved the use of decision matrices and proper management skills.

Throughout the bench testing and integration process, there were many edits and changes made to the design. These changes impacted the parts that were ordered. This was expected and is the reason why a cushion was added to the budget. Despite the changes, the team still remained within the budget. A final breakdown of the budget including all components ordered can be seen in **Appendix D**.

Chapter 11: Gantt Chart/Schedule

A very important aspect of the project involved creating a detailed schedule. This schedule highlighted the important milestones, tasks, and events during the first and second semester of the project. The schedule adapted and changed over the course of the semesters as new information was obtained. Even though the schedule did change, the overall structure was maintained. To create a visual representation of the schedule, a Gantt chart was created. To make this Gantt chart, Microsoft Project was utilized. Microsoft Project allowed for a critical path method to be used. Additionally, there were many other resources available including resource loading, updating the percent complete, and determining high risk dates. Throughout the semester, the Microsoft Project file was updated to ensure that the students had a visual representation of the schedule.

The fall semester Gantt chart included important milestones such as the first meeting with advisor, first meeting with Joe Zanetti, Interim Design Presentation, Final Presentation, and Mayo Business Plan submission. Additionally, the fall semester Gantt chart included events such as finalizing the preliminary design, ordering long lead materials, final design, ordering remaining materials, manufacturing prototype, and preparing Mayo Business submission. The spring semester Gantt chart included milestones such as ordering components, bench testing, final integration, final testing, and Final Presentation. The final Gantt charts can be seen in Appendix D: Team Management.

Creating a schedule was an important part of the management process. Creating a schedule allowed for a clear map of tasks, deadlines, and responsibilities. Despite a shared management role, the task of creating and maintaining the Gantt chart was given to one person. This was done to ensure that multiple copies of the schedule were not created and to ensure that the task could be properly kept up with and managed without confusion on whose responsibility it was. Two separate Gantt charts were made for fall and spring semester to maintain accuracy. If the students created one giant Gantt chart, it would have been difficult to predict events that were far out while maintaining accuracy. By having two detailed semester Gantt charts, it allowed for each to be high accuracy and easier maintenance.

Chapter 12: Preliminary Testing (Fall Semester)

To prepare for testing and to validate early designs, the students performed preliminary testing. This testing was mainly in three different areas: heating, induction, and part selection verification. The first experiment the students ran was a pump verification test. This test occurred after the selection of the pump for their design. This test was run from 3 to 5 V to test different power inputs. A simple observation made was as power increased, the speed of the pump increased. The students then used water with their selected tube to verify that the water would flow. Overall, this was a very simple test with no data measurements taken. Next, the students did more detailed experimentation with the heating components. Using the four ceramic heating rods, students heated water. The power setting was at 12 Volts at 30 Amps and the temperature was measured using a thermistor over 11 minutes. Before the power supply was turned on, the team waited 6 minutes to get an accurate ambient temperature. From here, the data was plotted. Additionally, using the purchased exterior mug, the degradation of temperature over time was measured. The graphs for both of these experiments can be seen below in ***Figure 30*** and ***Figure 31***.

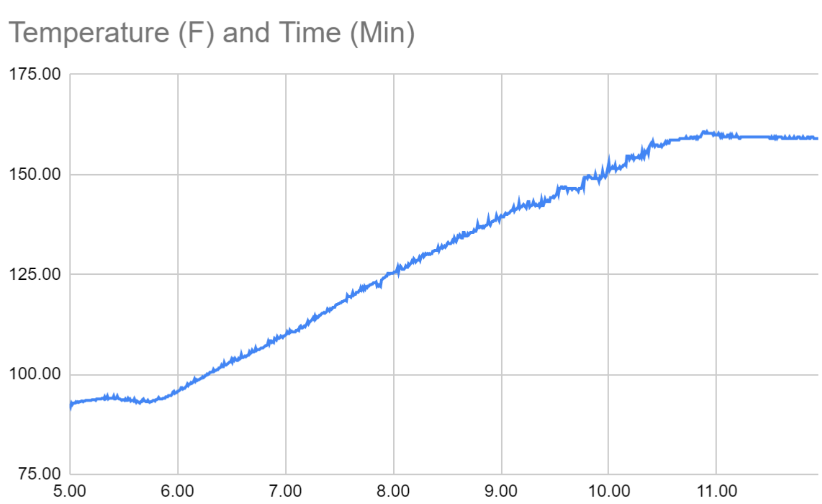


Figure 30: Temperature vs. Time chart

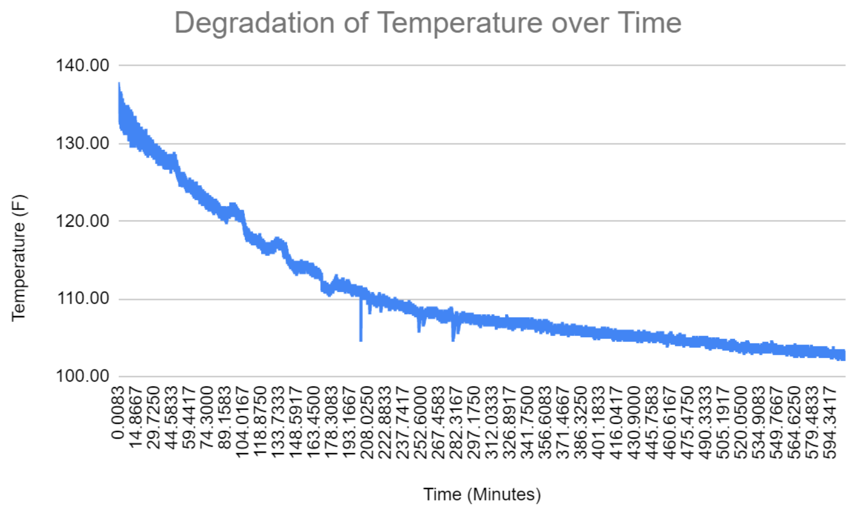


Figure 31: Degradation of Temperature over Time

Detailed procedures can be found in ***Appendix H***. These experiments were preliminary experiments conducted during the fall semester. There were many flaws in the experiment setup including inaccuracies in how much water was used, the power selected, and more. These experiments were valuable as they provided the students with experience in testing and allowed for different setups to be explored. However, these experiments were not very accurate and were not further analyzed. More detailed testing was done during spring semester to validate the design.

Lastly, another verification test was performed using induction pads. The test was simply lighting an LED to insure that the induction pads worked when held close together. This was a preliminary test that will need to be repeated in greater detail later on. The induction pads used were not the ones selected for the final design, as these induction pads were too large to fit into the mug.

Chapter 13: ANSYS Analysis

A major concern of the project is safety. Due to the mug's small space, the high temperatures involved, and the sensitive electronics, there was a need to ensure the overall safety of the mug. One concern in particular was the overheating of electronics. In order to determine whether or not the electronics would overheat, and determine if there is a need for a cooling device, ANSYS was used to map out the temperatures in the mug. The major area of concern was the bottom of the mug, where the electronics would be stored. In order to simulate this, the mug assembly needed to be imported into ANSYS. Heat needed to be applied on the heat rods. Additionally, the convection due to the water needed to be taken into consideration, as the inner layer would contain water. However, a slight flaw is that by applying the convection to the inner layer, it assumes that the entire inner layer is filled with water, while in reality only a portion of the inner layer is filled with water. Another challenge was finding the correct convection coefficient. Since this is forced convection, the range of convection coefficients for water ranges from 100 to 15,000W/m^2 K. In order to solve for the convection coefficient using the methods learned in heat transfer, a mass flow rate is needed. Since this information is not known, the students intend on doing more research to figure out a way to find this experimentally or to come up with a more accurate estimate. For the preliminary simulation, a convection coefficient of 1000 W/m^2 K was used. This was chosen due to the fact that it yielded realistic results. However, the students intend on repeating this analysis once a more accurate convection coefficient is determined. Additionally, due to the fact that there will be insulation applied inside of the mug, an insulated boundary layer condition can be applied to the inner layer. The heat flux applied was determined using the power for each rod and the area of the rods. Using the individual wattage of the thermal heating rods as well as This heat flux ended up being 15,767W/m^2 K. The time for the simulation was set to be 6 minutes to correspond with the calculated time for heating. The simulation was run for both steady state and transient. These results can be seen in ***Figure 32*** and ***Figure 33***.

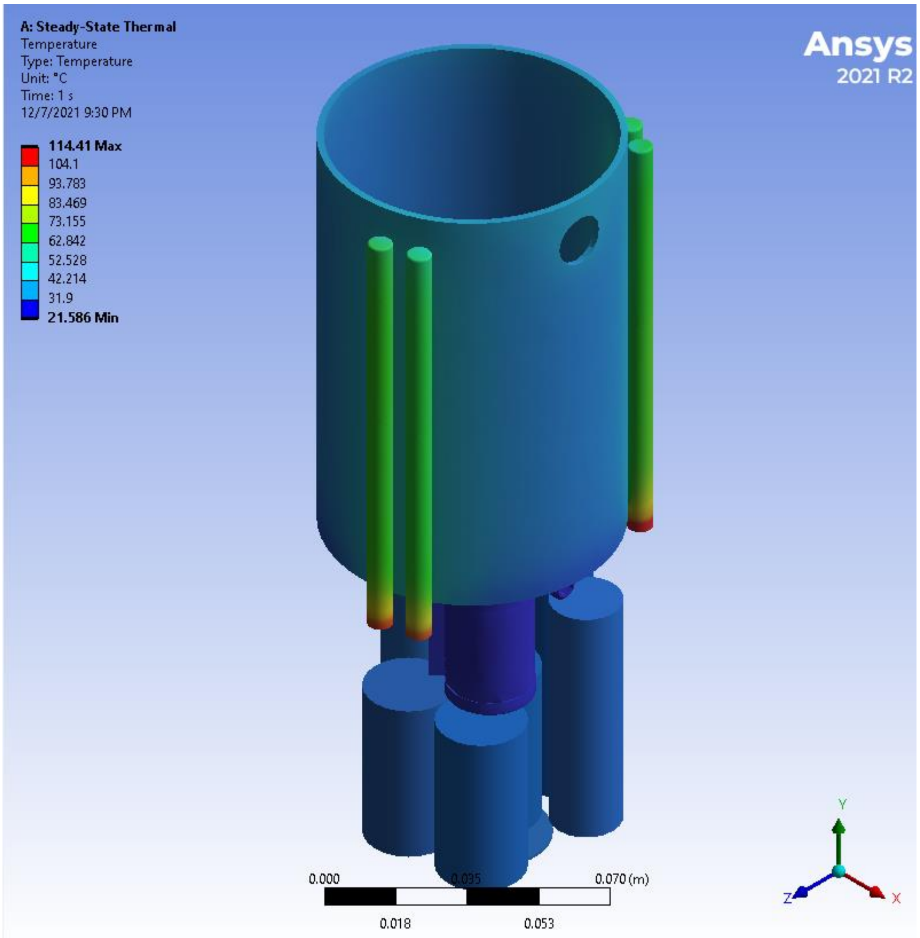


Figure 32: Preliminary ANSYS Steady State

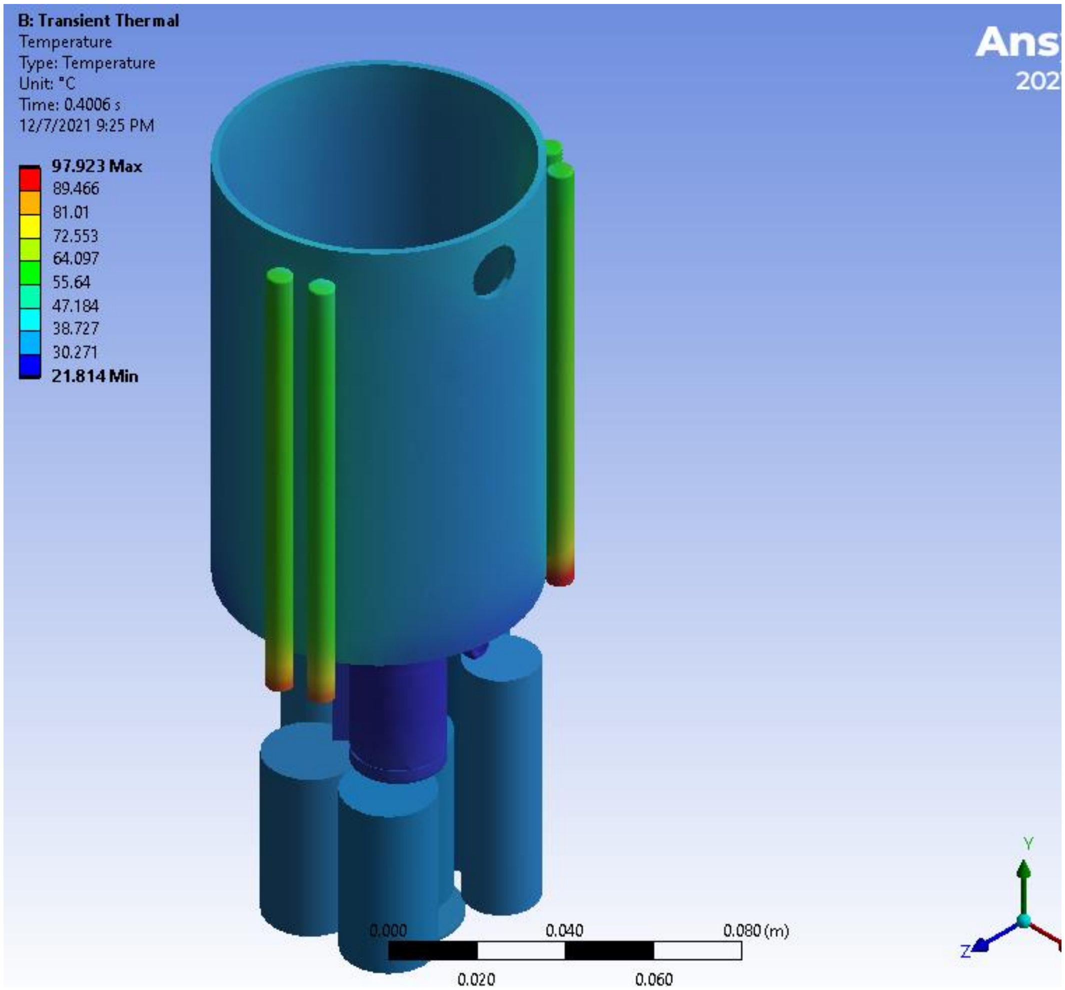


Figure 33: Preliminary ANSYS Transient

The maximum temperature reached was 114 degrees Celsius. This occurred in the rods as expected. None of the electronics exceeded 40 degrees Celsius, which determined that they were not at risk of overheating. However, as the design evolves, the students intend on updating the ANSYS simulation to keep a close eye on these temperatures. Additionally, during integration, bench testing will be done to ensure that none of the electronics are at risk of overheating, as this is the biggest safety concern of the project.

For the transient analysis, the heat flux was applied for a total of 360 seconds. This time end was used to accommodate for the update time and optimization for the coffee to brew (which in this case was 6 minutes). Below is the table for the tabular data for the first half of the transient analysis as well as the respective plot for this Ansys simulation.

Table 4: Tabular Data for Ansys Transient Thermal Analysis (0-180s)

Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	0.1	21.681	109.95	43.643
2	0.16012	21.72	107.34	43.396
3	0.22024	21.75	104.77	43.173
4	0.4006	21.814	97.923	42.588
5	0.94167	21.941	96.277	41.127
6	2.5649	22.16	86.81	37.969
7	7.4346	22.342	59.987	33.224
8	12.435	22.451	42.603	30.751
9	17.435	22.494	34.395	29.471
10	22.435	22.231	34.308	28.794
11	27.435	22.104	34.246	28.423
12	32.435	22.047	34.193	28.209
13	37.435	22.021	34.146	28.077
14	42.435	22.01	34.108	27.988
15	47.435	22.123	34.073	30.248
16	52.435	22.18	34.462	31.352
17	57.435	22.258	35.703	31.921
18	62.435	22.338	36.299	32.218
19	67.435	22.406	36.603	32.374
20	72.435	22.458	36.761	32.458
21	77.435	22.495	36.844	32.503
22	82.435	22.521	36.888	32.527
23	87.435	22.537	36.911	32.541
24	92.435	22.515	33.881	30.224
25	97.435	22.451	33.867	29.072
26	102.43	22.366	33.854	28.46
27	107.43	22.244	33.843	28.125
28	112.43	22.105	33.832	27.932
29	117.43	22.045	33.822	27.814
30	122.43	22.02	33.812	27.736
31	127.43	22.009	33.803	27.679
32	132.43	22.004	33.795	27.635
33	137.43	22.09	33.787	29.804
34	142.43	22.148	33.779	30.615
35	147.43	22.216	33.773	30.788
36	152.43	22.275	33.766	30.633
37	157.43	22.312	33.76	30.306
38	162.43	22.324	33.754	29.888
39	167.43	22.315	33.749	29.421
40	172.43	22.291	33.744	28.925

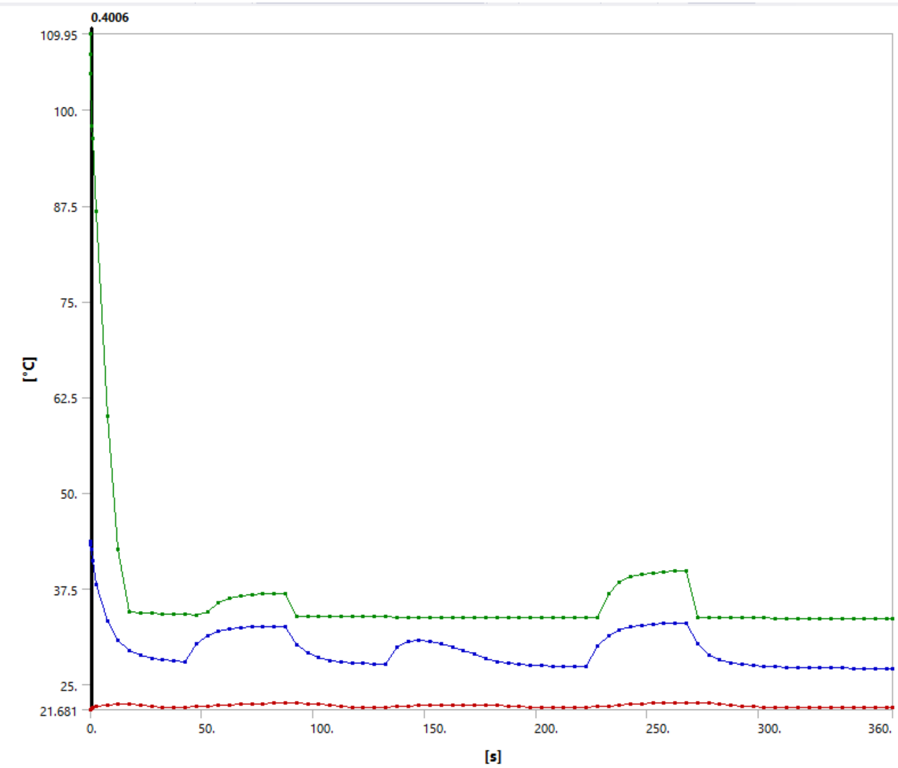


Figure 34: Plot for the Transient Thermal Analysis (0-360 Seconds)

During the spring semester, the decision was made to remove the batteries from the mug. Due to the new calculations of voltage presented with the opportunity to increase the number of batteries to a uniform size and voltage. From the updated optimization calculations, the number of thermal heating rods will be reduced from four to two. This meant that the risk of overheating was no longer a concern. Instead, the students performed further ANSYS to see how hot the inner layer would become. The results can be seen in ***Figure 35***, ***Figure 36***, and ***Figure 37***.

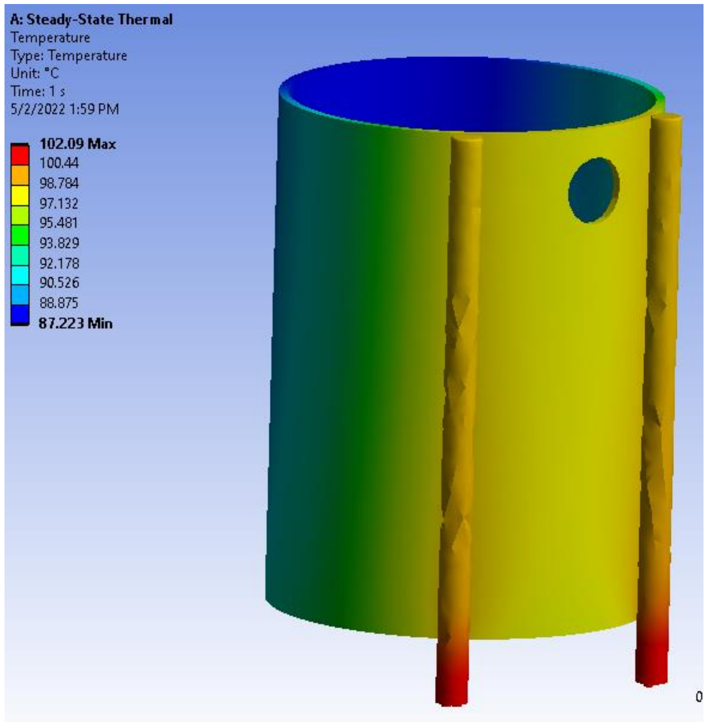


Figure 35: Steady State Thermal

Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	1.	87.278	101.53	94.894
2	2.	87.33	101.13	94.841
3	3.	87.382	100.8	94.794
4	4.	87.434	100.51	94.751
5	5.	87.486	100.24	94.711
6	6.	87.538	99.985	94.675
7	7.	87.59	99.753	94.642
8	8.	87.642	99.539	94.611
9	9.	87.694	99.34	94.583
10	10.	87.747	99.156	94.556
11	11.	87.799	98.986	94.532
12	12.	87.851	98.827	94.509
13	13.	87.903	98.678	94.488
14	14.	87.956	98.54	94.468
15	15.	88.008	98.41	94.45
16	16.	88.06	98.288	94.432
17	17.	88.113	98.173	94.416
18	18.	88.165	98.065	94.4
19	19.	88.218	97.963	94.386
20	20.	88.27	97.866	94.372
21	21.	88.322	97.774	94.359
22	22.	88.374	97.687	94.346
23	23.	88.427	97.619	94.334
24	24.	88.479	97.574	94.323
25	25.	88.531	97.528	94.312
26	26.	88.583	97.482	94.302
27	27.	88.634	97.437	94.292
28	28.	88.686	97.391	94.282
29	29.	88.737	97.346	94.273
30	30.	88.789	97.301	94.264
31	31.	88.84	97.257	94.255
32	32.	88.891	97.213	94.247
33	33.	88.942	97.169	94.239
34	34.	88.992	97.126	94.231
35	35.	89.042	97.083	94.224
36	36.	89.092	97.04	94.216
37	37.	89.142	96.998	94.209
38	38.	89.192	96.957	94.202
39	39.	89.241	96.916	94.196
40	40.	89.29	96.875	94.189
41	41.	89.338	96.835	94.183
42	42.	89.387	96.796	94.176
43	43.	89.435	96.757	94.17
44	44.	89.482	96.718	94.164

Figure 36: Tabular Data

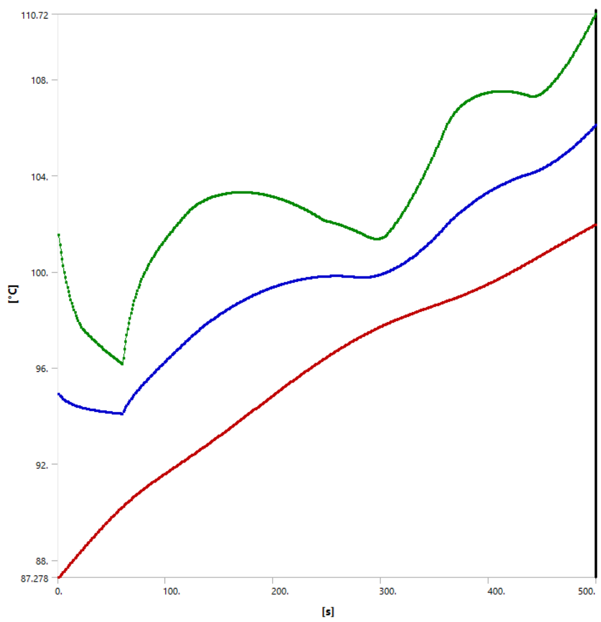


Figure 37: Plot for the Transient Thermal Analysis

Chapter 13: Bench Testing

A crucial element of this project was to ensure that everything was functional before assembling the final mug. This was due to the safety concerns as well as the fact that once things were in place it would be nearly impossible to fix. The team came up with a list of experiments they wanted to perform before everything was finalized. The experiments included: Full Battery Testing, Pump Verification, Battery Charging, and Bluetooth System Verification. All of the procedures with datasheets can be found in ***Appendix I: Bench Testing Procedures***. Additionally, filled-out datasheets can be found in ***Appendix J: Bench Testing Results***.

The first experiment run by the team was the Battery Charging experiment. The 5v 2a induction pads were soldered to an IC charge discharge chip that transferred power from the induction pads into the batteries. Additionally, the IC unit can discharge the batteries to charge the arduino. Unfortunately, the Voltage rating of the batteries were too high for the IC charge/discarge chip and the chip popped and became useless. Fortunately, the team was able to override this experiment through directly charging the battery unit with the power supply. The batteries were able to charge within an acceptable 3 hours. ***Figure 38*** demonstrates the rate discharge characteristics of the 18650 battery. Additionally, ***Figure 39*** is shows the relationship of the charge characteristics.

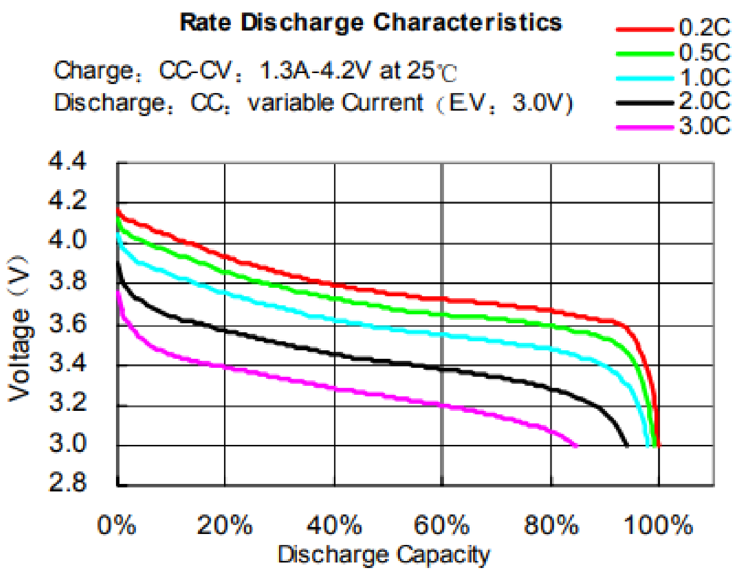


Figure 37: Plot for the Transient Thermal Analysis

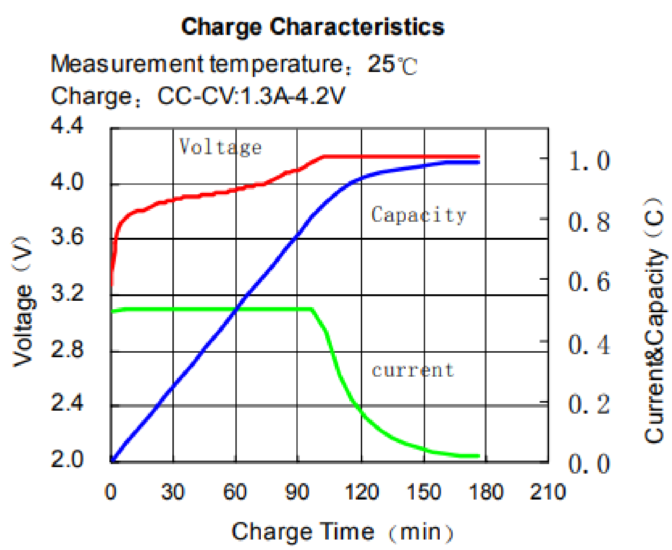


Figure 38: Charge Characteristics

The next experiment conducted was the Pump Verification Experiment. This experiment was mainly used as a way to verify that the tubing was firmly attached to the inner layer and that no leakage occurred. Additionally, the experiment aimed to verify that the pod's placement was correct. However, future experiments would determine if the pod was successful. The first time the experiment was run, it was determined that the speed and aim of the water was correct. Additionally, the pod appeared to be working as intended. However, very slight leakage was noticed. The experiment was repeated after more sealant was applied. This confirmed that the sealant worked as there was no leakage. Images of the experiment can be seen in Figure 39.

Figure 39: Pump Verification Experiment

Next, the Bluetooth System Verification Experiment was conducted. The primary purpose of this experiment was to ensure that the Bluetooth system was working properly and that data could be sent to the phone application. This experiment specialized in understanding the packets of data that was sending between the phone and the Arduino. The team selected a baud rate of 9600 which indicates the file transfer speed to the Bluetooth device. Additionally, understanding the handshake protocol proved difficult as the problem could of been caused by a plethora of issues in either the code, the wiring or the Bluetooth module. Once this issue was fixed, a connection was established and the Bluetooth module can successfully receive and send data.

For the Full Battery Testing Experiment, the entire system would be tested to ensure that everything was working properly. This would be achieved without any components being firmly in place, in case of failure. Unfortunately, due to the issues that arose with the battery charging experiment, the batteries were drained and could not be recharged fully. However, the students were able to run the experiment. The full setup was achieved and the students were able to verify that the app could successfully run the pump, collect thermistor data, and run the heating rods. The students were able to fill the pod with coffee grounds and successfully brew the coffee. However, due to the fact that the batteries were not fully charged, the students were unable to collect data to show the brewing time, as the temperature was hardly increasing. The experiment proved the validity in the setup and the code.

Overall, the bench testing process was extremely valuable. Without performing these preliminary tests, it is very possible that the entire design would have failed on the first attempt. Through bench testing the team was able to make the difficult decision to keep the batteries outside of the mug. While this is not what was intended, it did relieve the safety stresses of the project. The team was able to learn from these experiments and adjust the design accordingly before final integration.

Chapter 14: Final Assembly and Testing

Once bench testing was complete, the mug could be assembled. This process included securely attaching the hot ends, adding the insulation to the mug, securing the batteries, attaching the flip tab to the cap, and finalizing all wiring. Images of the final mug assembly can be seen in ***Figure 40***.

Figure 40: Final Mug Assembly

The final testing phase was the most critical part of testing, as everything was securely locked in place and not many changes could be made at this point. The final testing phase included the following experiments: Brewing Verification and “Drink Test”. All procedures can be found in ***Appendix K: Final Testing Procedures*** and all completed datasheets can be found in ***Appendix L: Final Testing Results***.

The Brewing Verification Test ensured that the mug met all the deliverables. The entire system was run to ensure that the temperature goal was met, the pump functioned correctly, and that the water would brew into coffee. Since the brewing aspect had already been verified in the Full Battery Testing, it was removed as a requirement for this experiment. The students used the final assembled mug to verify that the temperature goals could be reached. Due to the battery issues, the students used a power supply to run this experiment. The voltage and current inputs were set to achievable levels (12 V, 15.5A) that the batteries could have provided. While conducting the experiment, the students noticed that the water closest to the heating rods began to boil almost immediately. As steam started to escape the mug, the students were confident that they would reach their temperature and brewing time goals. However, this is when they noticed that there was something wrong. The temperatures were so hot that the extender had begun to warp. Due to the dangers of inhaling the fumes from the plastic, the experiment had to be stopped. Unfortunately, due to the fact that the inner layer was attached with epoxy to the extender, there was no way to remove it in order to run the experiment again. To do this, the students would have had to manufacture an entirely new inner layer, including new tubing and pump. This was not realistic with the timeline, so the students were unable to successfully run the experiment. If the final design, the extender would not have been made out of 3D printed filament, and would not have warped. Despite not being able to complete the experiment, the students believed that based on the results they were witnessing, the water would have reached their goal temperature. From the limited 4 minutes of data that was collected, the team was able to extrapolate the rest of the data as seen in ***Figure 41***. This was only possible due to knowing that the chage in temperature was a linear relationship, ***Figure 41*** also has a buffer of 5%.

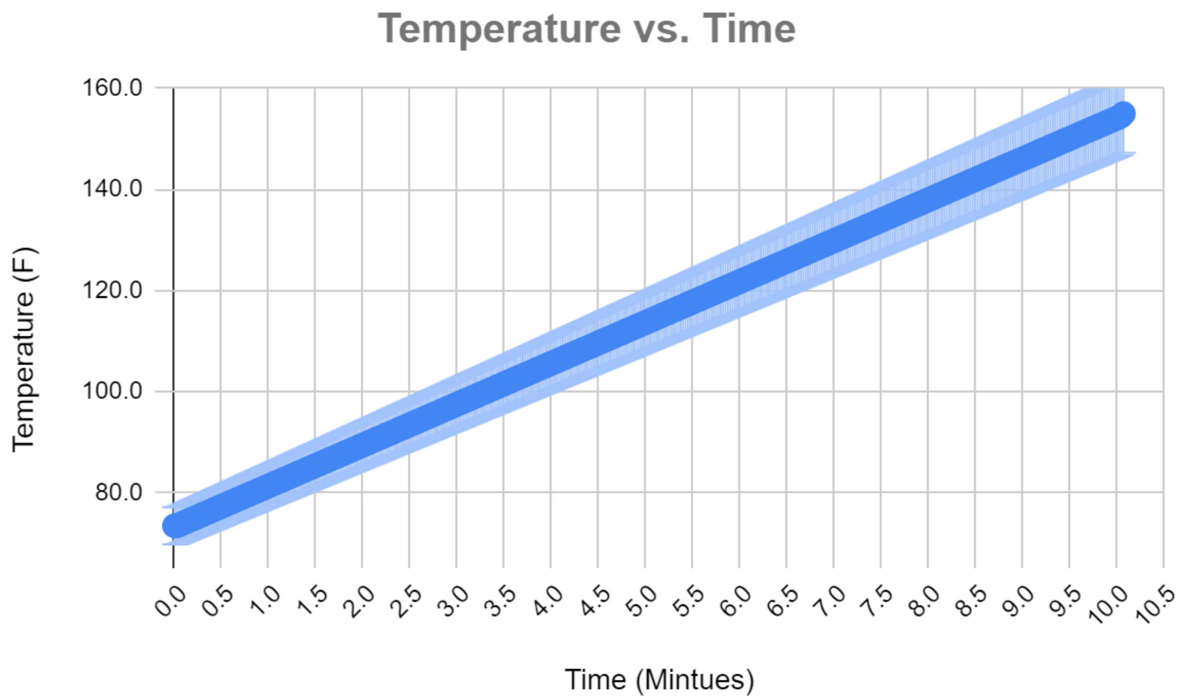


Figure 41: Final Mug Assembly

From this experiment, it was determined that the temperature will reach the temperature of 155F in 10.2 Minutes.

The "Tilt Test" was a verification that the design was secured in place and that during actual drinking no parts would shift. The coffee was not actually drunk due to the fact that the 3D printed components were not food safe, Instead, the coffee was poured over a sink at the angle it would normally be drunk at. This experiment was deemed a success, as none of the internal components shifted.

Chapter 15: Mayo Business Plan Competition

One of the goals of the project was to enter and compete in the Mayo Business Plan competition hosted by The College of New Jersey's School of Business. The team created a 20-page business plan as their initial submission to the competition. The plan highlighted that if Phoenix Mug were to become an official business, it would be profitable. The plan required extensive research into different business related topics including how to create balance sheets, how to create an executive summary, marketing strategies, and more. Unfortunately, the team was unable to advance to the Semi-Finals. However, the experience was extremely beneficial for the team as they were able to learn how to create a business plan. The full business plan submittal can be seen in ***Appendix M: Mayo Business Plan Submittal***.

Chapter 16: Conclusion

The Phoenix Mug is a portable self-heating, self-brewing coffee mug. It addressed the inconvenience and inefficiency of waiting for the coffee to finish brewing before taking it on the road.

Throughout the time spent on the project, the team was able to satisfy the deliverables which utilized functional brewing and heating mechanisms, a successful Bluetooth phone application, and induction charging system within the mug.

The overall process to brew the coffee is extremely user friendly and allowed the perfect cup of coffee to be successfully brewed anytime, anywhere!

Appendix A: Project Overview

Jason Rosen

Jason is a Senior Mechanical Engineering student at The College Of New Jersey. He is the president and founder of the Professional Academic Society for Technical Advancement (PASTA) club, the recruitment chair and treasurer for the Society of Hispanic Professional Engineers (SHPE) club, and the Vice President of the Chess Club on campus. He is interested in product design engineering specifically for consumer electronics after college.

Jessica Ruby

Jessica is a senior mechanical engineer at The College of New Jersey and is involved in many different organizations on campus including Society of Women Engineers (SWE), American Society of American Engineers (ASME), Omicron Delta Kappa Honor Society (ODK), Tau Beta Pi Engineering Honor Society, and Professional Academic Society of Technical Advancement Club. Jessica holds leadership positions in SWE as treasurer and in Professional Academic Society of Technical Advancement Club as secretary. Her goal after college is to work as a design engineer and work her way up to program/engineering management!

Brett Murphy

Brett Murphy is a senior mechanical engineering major at The College of New Jersey. He is the Vice President for the Professional Academic Society of Technical Advancement and currently works as an engineering intern at Nordson EFD. Brett holds leadership positions as the brother at large for the Nu Gamma Chapter of Kappa Delta Rho as well as a 4 time Sergeant at Arms for the Club Baseball Team. He wants to pursue a career in CAD development and prototype design.

Appendix B: Realistic Constraints and Engineering Standards

Department of Mechanical Engineering
School of Engineering
The College of New Jersey

Realistic Constraints and Engineering Standards

PROJECT:____

Team Leader(s):
____

Checklist Completed: ____________________ ____________________ __________
Primary / Technical Advisor [Title and Name] , Signature Date

DIRECTIONS:
This checklist needs to be completed by the team leader(s) and then approved and signed by the technical advisor.

In the self-check column, place a "√" if covered in body of report, a "*X*" if not covered in body of report but is covered in the remarks column (on the reverse side of this page), and a "*N/A*" if not applicable.

In all cases, √, X , or N/A, must include a justification in the remarks column.

Realistic Constraints and Engineering Standards

#	Constraint / Standard Attribute	Self-Check			Reference Page # (in the Report)	Remarks
		Yes "√"	N0 "X"	"N/A"		
1	Economic					(If Applicable) → See Appendix "B-3"
2	Environmental					(If Applicable) → See Appendix "B-3" (/"B-4")
3	Social					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5")
4	Ethical					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
5	Manufacturability					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
6	Sustainability					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
7	Standards					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
8	Public Health					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
9	Safety					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
10	Welfare of the Public					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
11	Global					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)
12	Cultural and Political					(If Applicable) → See Appendix "B-3" (/"B-4"/ "B-5"/......)

Realistic Constraints and Engineering Standards

1. Economic: All projects need to be evaluated to determine if the product's business model is financially stable to become successful.
    a. The average price for a Rtic tumbler mug is priced at around $29.99-$49.99. If the Phoenix Mug were to be mass produced, the team would have the luxury of ordering the same tumbler from a wholesaler with a unit price of $5-7. Other expensive parts can be ordered in bulk with a discount that will ultimately bring down the price of the mug, making it more accessible for the consumer. This mug has a lifespan of 1,800 active hours of brewing, or 18,000 cups of coffee. If the average consumer were to drink 2 cups a day, this mug will last 24.65 years. If the consumer were to buy the Phoenix mug over a Starbucks coffee that will cost $5, they will be saving tens of thousands of dollars over the course of the Phoenix mug's lifespan.

2. Environmental: It is important to consider the environmental effects of a design as a realistic constraint. Due to the nature of the electronics, the consumer can only dispose of the Phoenix as E-Waste. Although environmentally this is a problem, it is currently the best way for an untrained individual to dispose of electronic components. Ideally there would be a method for the user to return the mug to the company, so it could be taken apart and recycled as best as possible. The Coffee pod was designed to be reusable so that it does not use single-use plastic material. Additionally, if a consumer were to use the reusable Phoenix Mug, this would reduce the amount of single use plastic from buying coffee at a store, which is beneficial to the environment, Many of the components used in the Phoenix Mug were selected to favor a long design life. This increases the amount of uses of the Phoenix Mug, which in turn prevents even more plastic waste from buying coffee at chains such as Starbucks or Dunkin.

3. Social: Social constraints involve designing projects that are designed to meet human needs. The goal of this project is to be accessible and used by the average coffee drinker. Some social additions that could be included in future iterations of the product are customizable colors and designs on the outside of the mug. Additionally, the team is making the mug as simple to use as possible to encourage as many people as possible to use their mug.

4. Ethical: The ethical constraint defines the product and takes codes of conduct and standards into consideration.

5. Manufacturability: Manufacturability constraints look at the efficiency of the design. This includes analyzing if the product could be made in a more efficient manner, if it could be more reliable, and if it could be less expensive.
    a. The goal of the phoenix mug is to have a simple design. The original design would have been very difficult to manufacture due to its complex shape. Creating the vacuum seal would have been a challenge for the available machine shop. However, the inner layer was able to be manufactured in the machine shop and was designed to be simple and made out of a common material. In the final design, the cap, pod, and extender would be machined with food-safe plastic. However, this proved to be a challenge with the limited time and resources designated for senior project. For the prototype, 3D printing was used for simplicity,

6. Sustainability: The process of developing a product that utilizes the resources available in the best way possible that does not affect future generations.
    a. The product's pod will be made from renewable materials that will be able to be refilled and reused. This will prevent single-use plastic pods to be used in the system. Once the product's life cycle is done, it will be disposed of as e-waste. The mug will be opened, stripped for its batteries, and its components will be taken apart and recycled. The material chosen for the inner layer was a common material that should be readily available for future iterations.

7. Standards: It is important to refer to all necessary standards when designing. These standards act as guidance in design.The roast level for cupping shall be measured between 30 minutes and 4 hours after roasting using coffee ground to the SCA Standard Grind for Cupping and be measured on coffee at room temperature. The coffee shall meet the following measurements with a tolerance of ± 1.0 units:

8. Public Health: Public health constraints define if the product will better humanity. One main concern for any product is to make sure that it will not be harmful to its consumers.
    a. A concern regarding public health for the Phoenix Mug is ensuring that the design is food safe. The prototype was designed without the intention of remaining food safe. This was due to the limitations of manufacturing food safe plastic. However, the students chose food safe materials whenever possible, including the metal used, the mesh in the pod, and more. Another constraint of this category is the standard concentration of coffee grounds with respect to water. Cleaning the mug is also an issue of public health as if done improperly, will lead to mildew and other harmful bacteria. In the product instructions, detailed instructions regarding cleaning would be provided.

9. Safety: The main priority with the Phoenix mug is guaranteeing safety. Since the mug reaches temperatures up to 140°F, the team must ensure that the mug is perfectly insulated so the user does not burn themselves when touching the exterior of the tumbler. Additionally, the amount of power output from the batteries could pose a potential danger if the mug is not sealed properly. The goal of the team is to insulate and seal every possible area where the mug could leak water. If the electronic components are exposed to high temperatures and moisture, the system could malfunction. Additionally, the heat in the electrical apparatus needs to be maintained under the specified temperature for the batteries, as they could expand and explode, if done improperly. Extreme caution and measures are currently in place to prevent such an outcome.
10. Welfare of the Public: Designing products that do not pose harm to the public and acknowledging that the safety and welfare of the public is a pressing concern.
11. Global: Global constraints look at current global trends and challenges that the world is facing.
12. Cultural/Political: This constraint looks at if a product takes part in any modern trend or governmental/political agenda.

Realistic Constraints and Standards

Realistic Constraints and Standards

1. **Economic**
2. **Environmental**
3. **Social**
4. Ethical
5. **Manufacturability**
6. **Sustainability**
7. **Standards**
8. **Public Health**
9. **Safety**
10. **Welfare of the Public**
11. Global
12. Cultural and Political

The bold constraints are the ones **most** applicable to our project

2

Jason Rosen

Economic

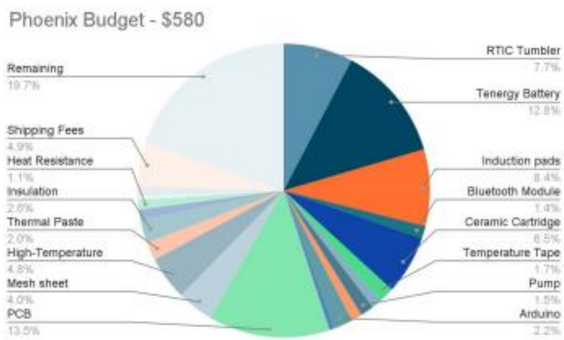
Phoenix Corporation Balance Sheet (USD) December 31st, 2021	
Assets	
Current Assets	264,293.00
Cash & Cash Equivalents	0.00
Accounts Receivable	0.00
Inventory	0.00
Supplies	264,293.00
Total Current Assets	
Long-Term Assets	
Property, Plant, & Equipment	2,000.00
Total Long-Term Assets	2,000.00
Total Assets	266,293.00
Liabilities & Stockholder's Equity	
Current Liabilities	
Accounts Payable	0.00
Notes Payable	0.00
Total Current Liabilities	0.00
Long-Term Liabilities	
Long-Term Debt	100,000.00
Total Long-Term Liabilites	100,000.00
Stockholder's & Equity	
Common Stock	0.00
Retained Earnings	166,293.00
Total Stockholder's Equity	166,293.00
Total Liabilities & Stockholder's Equity	266,293.00

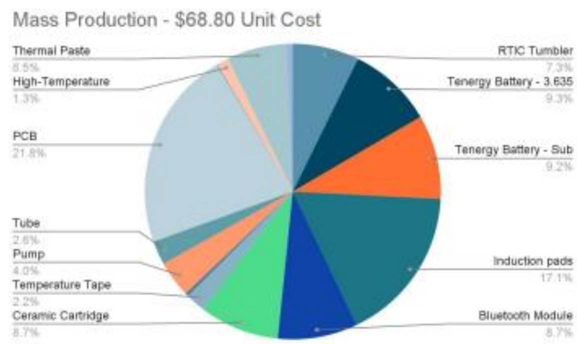
Phoenix Corporation Statement of Cash Flows For the Year Ended December 31, 2022		
Cash Flows from Operating Activities		
Cash Receipts from Operating Activities	209,988.00	
Cash Disbursements from Operating Activities	(123,795.00)	
Net Cash Provided by Operating Activities		86,193.00
Cash Flows from Investing Activities		
Purchase Equiptment	(2,000.00)	
Net Cash Provided by Investing Activities		(2,000.00)
Cash Flows from Financing Activities		
Business Loan	100,000.00	
Interest Expense	(7,500.00)	
Net Cash Provided by Financing Activities		92,500.00
Net Increase in Cash		176,693.00
Cash at Beginning of Period		30,000.00
Cash at End of Period		206,693.00

3

Jason Rosen

Economic





3

Jess Ruby

Environmental

- The design of the pod was highly centered around environmental effects
- By creating a reusable pod, there will be no waste left behind
- Our product aims to replace the usage of other systems such as Keurigs, which all use high amounts of single use plastics
- Unfortunately, due to the nature of the electronics, there is no easy way to recycle the mug as is, many of the internal components would have to be taken apart by qualified personnel. To make up for this, many design decisions have been made to favor a long design life

4

Jess Ruby

Social

- The aim of the Phoenix Mug is to create an easy to use mug that will be accessible to the average coffee drinker
- The product is catered to save the user time and money (in the long run), which is a social need
- Future iterations of the product might have more design choices such as color or style to better fit the needs of the coffee drinker

5

Brett Murphy

Manufacturability

- Tumbler
  - More efficient to purchase
  - Designing exterior is time consuming
- Cap and Pod
  - 3D printed
  - No available food safe plastic able to be manufactured
- Stainless Steel
  - No corrosion or rust
  - Difficult to machine

6

Sustainability

- The product's pod will be made from renewable materials that will be able to be refilled and reused. This will prevent single-use plastic pods to be used in the system.
- 14.7 year lifespan (assuming 2 brews a day) - batteries being limited factor.
- Once the product's life cycle is done, it will be disposed of as e-waste.
- The mug will be opened, stripped for its batteries, and its components will be taken apart and recycled.
- Inner Capsule is designed using stainless steel to ensure no rust or corrosion.

7

Brett Murphy

Public Health/Safety

- The main priority with the Phoenix mug is guaranteeing safety. Since the mug reaches temperatures up to 140°F, the team must ensure that the mug is perfectly insulated so the user does not burn themselves when touching the exterior of the tumbler.
- The goal of the team is to insulate and seal every possible area where the mug could leak water.
- the heat in the electrical apparatus needs to be maintained under the specified temperature for the batteries, as they could expand and explode, if done improperly.
- Extreme causation and measures are currently in place to prevent such an outcome.

8

Brett Murphy

Standards

Codes:

- ASTM E1776-22
- ASTM E1546-21
- ASTM D4307-17(2021)
- ASTM D5425-18
- ASTM F2988-18
- ASTM F2824-10(2020)
- ASTM E1871-17
- ASTM F2916-19
- ASTM A1092-15(2020)

ASTM INTERNATIONAL

(American Society for Testing and Materials)

All Standard Codes apply to the safety (fire/food) and structural properties of the Phoenix Mug

8

THANK YOU FOR YOUR TIME

Does anyone have any questions?
Follow for project updates

engprojects.tcnj.edu/phoenix-mug

PHOENIXMUG

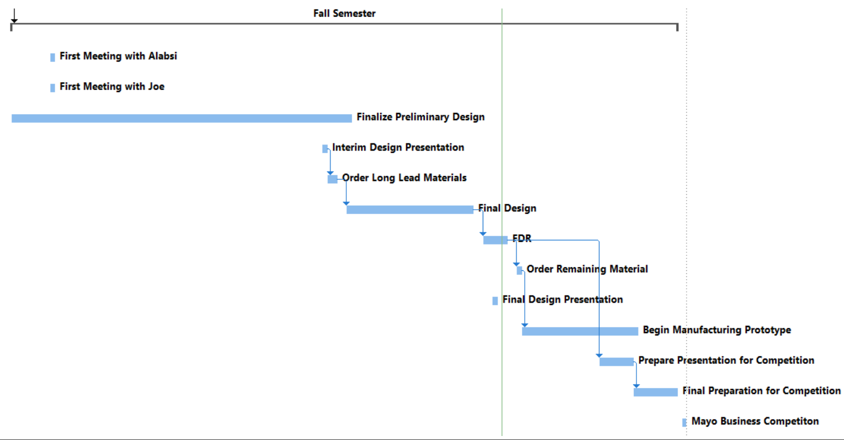
Appendix C: Modern Engineering Tools

- SolidWorks
  - Used in creating all of the models, assemblies, and drawings
- ANSYS Workbench
  - Used for running a steady state and transient state thermal analysis
- Microsoft Project
  - Used for creating the Gantt chart as well as a resource for keeping track of individual roles and tasks
- Microsoft Excel
  - Used to generate graphs and record data from the preliminary testing experiments
- Arduino IDE
  - Used for verifying software to the Arduino
- PUTTY program
  - Used for opening up a serial monitor to download the results of the Arduino program

Appendix D: Team Management

<u>Gantt Chart: Fall Semester</u>

Fall Semester	99 days	Tue 8/31/21	Fri 1/14/22
First Meeting with Alabsi	1 day	Wed 9/8/21	Wed 9/8/21
First Meeting with Joe (Manufacturing)	1 day	Wed 9/8/21	Wed 9/8/21
Finalize Preliminary Design	50 days	Tue 8/31/21	Mon 11/8/21
Interim Design Presentation	1 day	Wed 11/3/21	Wed 11/3/21
Order Long Lead Items	2 days	Thu 11/4/21	Fri 11/5/21
Work on Final Design	20 days	Mon 11/8/21	Fri 12/3/21
Final Design Review	5 days	Mon 12/6/21	Fri 12/10/21
Order Remaining Materials	1 day	Mon 12/13/21	Mon 12/13/21
Final Design Presentation	1 day	Wed 12/8/21	Wed 12/8/21
Begin Manufacturing Prototype on Bench	18 days	Tue 12/14/21	Thu 1/6/22
Prepare Business Plan	5 days	Thu 12/30/21	Wed 1/5/22
Final Preparation for Competition	7 days	Thu 1/6/22	Fri 1/14/22
Mayo Business Competition	1 day	Sun 1/16/22	Sun 1/16/22



Fall Semester	99 days	Tue 8/31/21	Fri 1/14/22
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Work on Final Design	20 days	Mon 11/8/21	Fri 12/3/21
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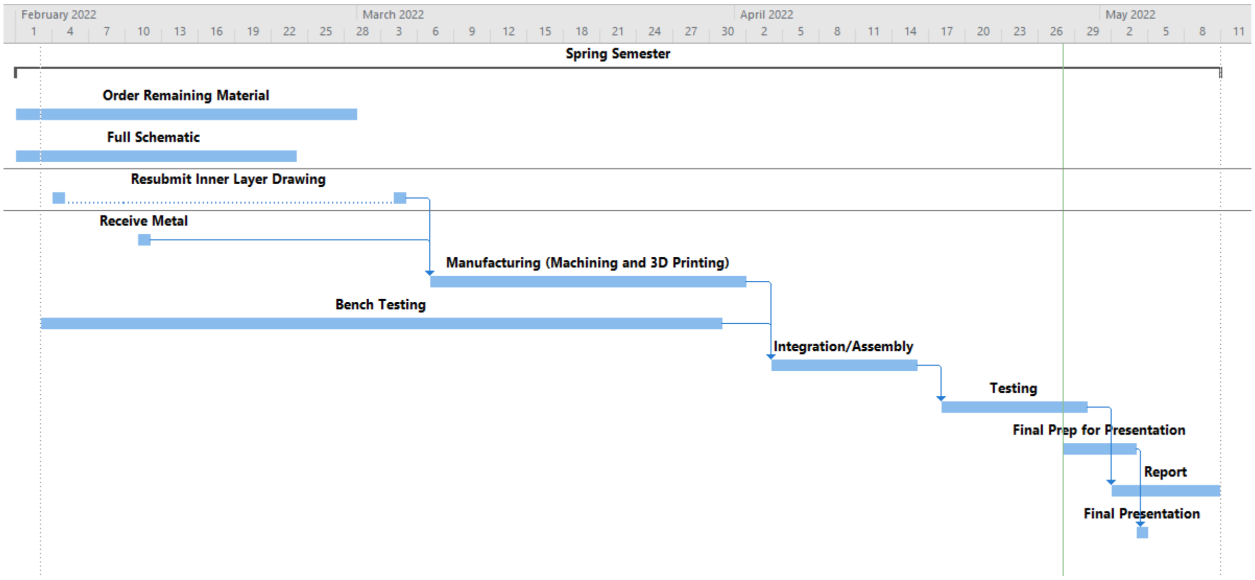
Order Remaining Materials	1 day	Mon 12/13/21	Mon 12/13/21
Final Design Presentation	1 day	Wed 12/8/21	Wed 12/8/21
Begin Manufacturing Prototype on Bench	18 days	Tue 12/14/21	Thu 1/6/22
Prepare Business Plan	5 days	Thu 12/30/21	Wed 1/5/22
Final Preparation for Competition	7 days	Thu 1/6/22	Fri 1/14/22
Mayo Business Competition	1 day	Sun 1/16/22	Sun 1/16/22

Gantt Chart: Spring Semester



Task Name	Duration	Start	Finish
Spring Semester	**71 days**	**Tue 2/1/22**	**Tue 5/10/22**
Order Remaining Material	20 days	Tue 2/1/22	Mon 2/28/22
Full Schematic	17 days	Tue 2/1/22	Wed 2/23/22
Resubmit Inner Layer Drawing	2 days	Fri 2/4/22	Fri 3/4/22
Receive Metal	1 day	Fri 2/11/22	Fri 2/11/22
Manufacture Inner Layer	20 days	Mon 3/7/22	Fri 4/1/22
Bench Testing	40 days	Thu 2/3/22	Wed 3/30/22
Integration/Asseml	10 days	Mon 4/4/22	Fri 4/15/22
Testing	10 days	Mon 4/18/22	Fri 4/29/22
Final Preparation for Presentation	4 days	Thu 4/28/22	Tue 5/3/22
Report	7 days	Mon 5/2/22	Tue 5/10/22
Final Presentation	1 day	Wed 5/4/22	Wed 5/4/22

Meeting Minutes

Meeting Date	Did all members attend?	Did the advisor attend?	Meeting Notes
6/30/2021	Yes	No	Discussed overall plans for the semester including potential meeting times. Discussed the various subsystems involved and decided who was doing each.
7/14/2021	Yes	No	Discussed more specific ideas such as the coffee pod design.
7/21/2021	Yes	No	Discussed creation of the Gantt chart and continued discussing the plans for the semester. Decided to come up with a new name for our project.
7/25/2021	Yes	No	Discussed an agenda for a meeting with our advisor. Came up with a list of questions to ask.
7/27/2021	Yes	No	Continued to prepare for a meeting with our advisor. Decided on the name "Phoenix Mug". Discussed potential logo ideas.
8/4/2021	Yes	Yes	First meeting with our advisor. Discussed our plans for the semester as well as asked many questions regarding the project. Advice received: make decision matrices whenever possible, meetings would be on Wednesday, he will be a source of guidance
8/15/2021	Yes	No	Discussed upcoming events such as the proposal presentation.
9/1/2021	Yes	Yes	In person meeting with our advisor, discussed the progress made over the summer and the plans for the semester
9/1/2021	Yes	No	Filled out our proposal form, began discussing the proposal presentation in more detail.
9/8/2021	Yes	Yes	Reviewed the draft of the proposal presentation, gave us suggestions on what to include in the presentation
9/12/2021	Yes	No	Met to practice presenting the proposal presentation
9/13/2021	Yes	No	Continuation of practicing for the proposal presentation

9/14/2021	Yes	No	Last run of the presentation
9/15/2021	Yes	No	Proposal Presentations
9/22/2021	Yes	Yes	Met with team first to discuss next steps now that the proposal presentation was complete, met with advisor to discuss our plans and ask for advice regarding bench testing
9/24/2021	No, only Brett and Jason	No	Meeting to discuss ordering parts, ordered the mug and other electrical components
9/29/2021	Yes	Yes	Meeting with the team followed by meeting with advisor, discussed the parts we ordered and the bench testing we had planned
10/3/2021	Yes	No	Bench testing including pump verification. Additional planning discussed
10/6/2021	No, Jess at Mayo Business	Yes	Discussed the results of the bench testing and ways to improve the testing
10/13/2021	Yes	Yes	Discussed budget
10/27/2021	Yes	No	Meeting with Sepahpour to present the budget, the budget was approved!
10/31/2021	Yes	No	Meeting to practice presenting for the interim design presentation
11/1/2021	Yes	No	Continued to practice presenting
11/2/2021	Yes	No	Last day to practice presenting
11/3/2021	Yes	No	Interim Design Presentation!
11/17/2021	Yes	No	Began working on the final report, discussed plans for the final design presentation
11/27/2021	Yes	No	Assigned roles for the report, discussed goals before the end of the semester including finalizing drawings, ANSYS, and part decisions
11/29/2021	Yes	No	Discussion of the battery selection and work in ANSYS
12/1/2021	Yes	No	Worked on the final design presentation and report. Finalized models for the presentation

12/5/2021	Yes	No	Finished presentation and began practicing
12/6/2021	Yes	No	Continued to practice presenting
12/7/2021	No, Jess in class	Yes	Showed advisor the presentation, made all necessary changes
12/7/2021	Yes	No	Last day to practice presenting
12/8/2021	Yes	No	Final design presentation!
12/20/2021	Yes	No	Discussed goals and expectations for winter break
12/27/2021	Yes	No	Outlined responsibilities for Mayo Business Plan Competition
12/30/2021	Yes	No	Working session on Mayo Business Plan
1/4/2022	Yes	No	Updated CAD model using the measured dimensions
1/17/2022	Yes	No	Updated Gantt chart for spring semester
1/24/2022	Yes	No	Updated cap design
2/1/2022	Yes	No	Met to order components such as batteries, induction pads, etc
2/2/2022	Yes	No	Met to discuss plans for the semester
2/6/2022	Yes	No	Prepared progress report presentation
2/7/2022	Yes	No	Practiced progress report presentation
2/8/2022	Yes	No	Practiced progress report presentation
2/9/2022	Yes	No	Progress Report Presentation
2/9/2022	Yes	Yes	First meeting of the semester with advisor
2/12/2022	Yes	No	Meeting to discuss manufacturing plans
3/9/2022	Yes	No	Review remaining materials left to order
3/21/2022	Yes	No	Reviewed newly printed parts and components that were delivered
3/23/2022	No, just Jason and Brett	No	Discussed battery charging issue, reviewed solutions
3/26/2022	Yes	No	Discussed bench testing plans
3/30/2022	Yes	Yes	Discussed newly designed parts and plans for testing with advisor
4/2/2022	Yes	No	Ensured that the 3D printed extender fit the mug. Worked on realistic constraints presentation

4/5/2022	Yes	No	Rehearsed presentation
4/6/2022	No, Jess at work	No	Experimented with batteries
4/11/2022	Yes	No	Discussed circuit design to charge batteries
4/13/2022	Yes	No	Ran thermistor code to verify that everything ran correctly, worked on troubleshooting bluetooth
4/18/2022	Yes	No	Added the second hole to the inner layer, adjusted pod design to be reprinted
4/18/2022	Yes	No	Assembled the pump and tube to the inner layer
4/19/2022	No, Brett at FE	No	Added mesh to the pod and verified that it was attached firmly
4/20/2022	Yes	No	Ran pump verification experiment
4/25/2022	Yes	No	Worked on troubleshooting bluetooth
4/26/2022	Yes	No	Re-verified pump, added fill line
4/27/2022	Yes	Yes	Verified bluetooth, discussed status with advisor
4/30/2022	Yes	No	Ran final experiments before assembly
5/1/2022	Yes	No	Ran Full Battery Experiment
5/2/2022	Yes	No	Assembled Mug and ran brewing experiment
5/3/2022	Yes	Yes	Gave mock presentation to advisor
5/4/2022	Yes	Yes	Final presentation!

Safety Essay

The Phoenix Mug is a complex system involving both brewing and heating mechanisms. The mug keeps many different components, both thermal and electrical, in a very small space. Due to this, and the fact that the mug reaches high temperatures, there were many safety concerns that needed to be addressed. The first concern was the risk of the user burning themselves on the mug exterior. To prevent this, the students used a two-layer mug style with a vacuum seal in order to keep the mug exterior cool while keeping the contents warm. The next major concern was the risk of the electronic components overheating. This was a serious threat due to the fact that the mug needed to be designed to keep the liquid warm and due to the limited space available. To prioritize safety, the students designed a battery attachment to keep the batteries from overheating. While this was not their original intention, it ended up being the safest option. Another safety concern arose with the exposed electronic components and heating rods. While unlikely, the user could insert their hand into the mug and would risk touching these components. To prevent this, an extender was designed. This extender blocks off the heating components and insulation from the user, while also holding the inner layer in place. Next, the mug needed a way to safely release the steam to ensure that there was not a buildup of pressure. To achieve this, vents were added to the cap to allow for the steam to escape. Lastly, the temperature of the coffee was a major concern. If the coffee was too hot, this would put the users at risk of being burned or injured. The use of thermistors allowed for regulation of the temperature. Additionally, research was conducted to find the best temperature for drinking coffee to ensure that the coffee was set at the right temperature.

Material List

- RTIC Tumbler
- Tenergy Battery - 3.635V 3500mAh
- Tenergy Battery - Sub C 5000mAh NiMH
- Induction pads
- Bluetooth Module - HC-06
- Ceramic Cartridge Heater
- Temperature Tape
- Thermistors
- Pump
- Boden Tube
- Arduino Mega 2560
- Breadboard kit
- Mesh sheet
- 1080 stainless steel 12in X 12 in X 0.047in
- Thermal Paste
- Insulation
- Bluetooth Antenna
- Heat Resistant Gloves
- Instant Coffee
- Coffee Grounds

Original Approved Budget

This budget included the cost of all materials, including those that the students had already owned. The budget was made early into the semester and many of the components were estimated due to the design not being finalized.

Group Members				**Jason Rosen, Jess Ruby, Brett Murphy**	**Approved by Advisor: Dr Mohammed Alabsi**
Part Name	**Quantity**	**Cost**	**Total Cost**	**Description**	**Link**
RTIC Tumbler	2	$28.53	$57.06	40 oz mug, 2 required: one for testing, one for final prototype	https://www.amazon.com/RTIC-Double-Vacuum-Insulated-Tumbler/dp/B075672691/ref=sr_1_2?dchild=1&keywords=rtic%2B40%2Boz%2Btumbler&qid=1634138584&sr=8-2&th=1
Tube	1	8.99	8.99	Tube for Pump	https://www.amazon.com/Metaland-Silicone-Tubing-Brewing-Winemaking/dp/B08QYWNWYY/ref=sr_1_11?dchild=1&keywords=High%2BTemp%2BFood%2BGrade%2BClear%2BSilicone%2BTubing%2B7.45mm&qid=1632021558&s=home-garden&sr=1-11-catcorr&th=1
Pump	1	$10.98	$10.98	4.5V Pump	https://www.amazon.com/Gikfun-Submersible-Fountain-Aquarium-EK1893/dp/B07BHD6KXS/ref=asc_df_B07BHD6KXS/?tag=hyprod-20&linkCode=df0&hvadid=366337991413&hvpos=&hvnetw=g&hvrand=10785904048043855439&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9003967&hvtargid=pla-787003122719&psc=1&tag=&ref=&adgrpid=74513640845&hvpone=&hvptwo=&hvadid=366337991413&hvpos=&hvnetw=g&hvrand=10785904048043855439&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9003967&hvtargid=pla-787003122719

Mesh sheet	1	$29.99	$29.99	Nylon Mesh Filter Woven Mesh Sheet	https://www.amazon.com/Micron-Nylon-Filter-Off-White-Polyester/dp/B081S71FTN/ref=sr_1_6?dchild=1&gclid=CjwKCAjwqeWKBhBFEiwABo_XBiAzOBQqcq675dP6eHPxcYrER-YbctGFkbNFEdgnp-b__BkgUV6cIBoC5pMQAvD_BwE&hvadid=529518625819&hvdev=c&hvlocphy=2840&hvnetw=g&hvqmt=e&hvrand=6840595726218241802&hvtargid=kwd-362807949511&hydadcr=28106_10744551&keywords=food+grade+mesh+fabric&qid=1633284238&sr=8-6
High-Temperature Aluminized Low-Carbon Steel Sheet,12" x 12" x 0.047"	2	$17.91	$35.82	High-Temperature Aluminized Low-Carbon Steel Sheet, 12" x 12" x 0.047", PN: 5610N21	sheet metal | McMaster-Carr
Tenergy Battery	1	$94.99	$94.99	12V battery	https://power.tenergy.com/at-tenergy-12v-4200mah-nimh-rechargeable-battery-pack-10s1p-50-4wh-30a-rate-tamiya-sbs-config/
Bluetooth Module	1	$10.39	$10.39	Serial Wireless Module BLE 4.0 Bluetooth Module Compatible HM-10	https://www.amazon.com/HiLetgo-Bluetooth-Wireless-Compatible-Arduino/dp/B00WGPKZ8Y/ref=sr_1_1_sspa?dchild=1&keywords=arduino+bluetooth&qid=1632020093&s=electronics&sr=1-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzTFdXMlpUREwzS0ozJmVuY3J5cHRlZElkPUEwNjQ5MDE0MVNTTzZMOUczQVFQRCZlbmNyeXB0ZWRBZElkPUEwMTg5MjE5Mk4xMDVVWFhTTTU3SCZ3aWRnZXROYW1lPXNwX2F0ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=
Induction pads	1	$15.68	$15.68	Induction pad for charging purposes	https://www.amazon.com/transmitter-distance-output-wireless-charging/dp/B076HQGQJ2/ref=pd_sbs_22/134-1624723-

					5269426?pd_rd_w=cJpRf&pf_rd_p=80c0d3b7-327a-454b-88c8-6e53987776ab&pf_rd_r=KSF72D5GBBZ7MDJGX421&pd_rd_r=f7ae021e-0c51-428d-b31b-ddfc507d7d36&pd_rd_wg=btFUu&pd_rd_i=B076HQGQJ2&psc=1
Arduino	1	$15.99	$15.99	Arduino Mega	https://www.amazon.com/ELEGOO-ATmega2560-ATMEGA16U2-Projects-Compliant/dp/B01H4ZLZLQ/ref=sr_1_2_sspa?dchild=1&gclid=CjwKCAjwqeWKBhBFEiwABo_XBkD1NvQ-UB19_Mb4fyGhtqAQgj7sxRqacXQ0uagR5s9PoEkQUtmrkRoCLh8QAvD_BwE&hvadid=241945413818&hvdev=c&hvlocphy=2840&hvnetw=g&hvqmt=e&hvrand=15078348373965873908&hvtargid=kwd-12475568365&hydadcr=24663_10400926&keywords=arduino+mega&qid=1633285570&sr=8-2-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFVTzFZNk4xWlA0RkgmZW5jcnlwdGVkSWQ9QTAyODA1MDkzMFhPNVpLVUVTTTUzJmVuY3J5cHRlZEFkSWQ9QTA0MDUyMTcyTlZRSFdNS0YwNUk4JndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
Breadboard kit	1	$3.65	$3.65	Breadboard, jumper wires, LED's, resistors	https://www.amazon.com/Starter-Breadboard-Jumper-arduino-Education/dp/B07V5Z64QT/ref=sr_1_3?dchild=1&keywords=breadboard+led&qid=1633286329&sr=8-3
PCB	1	$100.00	100	PCB used to condense arduino components	https://www.pcbway.com/HighQualityOrderOnline.aspx

Bluetooth Antenna	1	7.99	7.99	Modular Bluetooth Antenna - to connect mug to a phone application	https://www.amazon.com/HUACAM-5-8GHz-Dual-Band-Wireless-Network-Antenna/dp/B06WD7FZV4/ref=sxin_13_pa_sp_search_thematic_sspa?cv_ct_cx=bluetooth+antenna&dchild=1&keywords=bluetooth+antenna&pd_rd_i=B06WD7FZV4&pd_rd_r=ee3858c9-f8ab-4f3b-9fb7-80d7aa0b0abc&pd_rd_w=ZWfBe&pd_rd_wg=MPdpb&pf_rd_p=f21da57e-06e4-46a5-9148-e2dea2e78384&pf_rd_r=4B7VRE6KR244AWT1M4WQ&qid=1634141311&sr=1-3-a73d1c8c-2fd2-4f19-aa41-2df022bcb241-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzRDFRU09aUVBFU0c5JmVuY3J5cHRlZElkPUEwNjQxOTM4ODlJSFIzWEZaMElBJmVuY3J5cHRlZEFkSWQ9QTA0Njc0OTczOVdJM0ZWNUJKUlg2JndpZGdldE5hbWU9c3Bfc2VhcmNoX3RoZW1hdGljJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ==
Ceramic Cartridge Heater	4	$11.99	$47.96	Cartridge Heater 12V 100W	https://www.amazon.com/Dernord-Cartridge-Electric-Stainless-Replacement/dp/B0741664G5/ref=sr_1_26?dchild=1&keywords=2V+50W+Upgraded+Ceramic+Cartridge+Heater+100w+12v&qid=1632334108&sr=8-26
Temperature Tape	1	$12.98	$12.98	High Temp Tape,EYYUNNI(2 inch X 108 FT)	https://www.amazon.com/Temperature-AIYUNNI-Resistant-Insulation-Anti-Static/dp/B07FDW9PXX/ref=sr_1_1?dchild=1&keywords=temp+tape+300C&qid=1632323166&sr=8-1
Thermistors	1	$7.99	$7.99	10pcs 3D Printer 100K ohm NTC 3950 Thermistors	https://www.amazon.com/HiLetgo-Thermistors-Printers-Temperature-Accessories/dp/B07V6YBFSY/ref=sr_1_9?crid=6KS40HU0K3GR&dchild=1&keywords=thermistor&qid=1632021363&sprefix=thermist%2Caps%2C163&sr=8-9

Thermal Paste	1	$14.88	$14.88	10g Thermal Paste	https://www.amazon.com/Grease%EF%BC%8C4-0w-Compound-Clearner-Computer-Conductive/dp/B098SRGVV7/ref=sr_1_1_sspa?dchild=1&keywords=thermal%2Bpaste&qid=1633287935&sr=8-1-spons&smid=A39AS8BUQ54DMT&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExQ1lRRkdNNzFPNVQyJmVuY3J5cHRlZElkPUEwNjUzODgzMkw0NUZLU00xM0FIQiZlbmNyeXB0ZWRBZElkPUEwODc5MTU0OEk3VzdaNk5LVkJZJndpZGdldE5hbWU9c3BfYXRmJmFjdGlvbj1jbGlja1JlZGlyZWN0JmRvTm90TG9nQ2xpY2s9dHJ1ZQ&th=1
Insulation	1	$19.50	$19.50	Thermal Insulation - Ceramic Fiber Insulation	https://www.amazon.com/Lynn-Manufacturing-Kaowool-Insulation-Fireproof/dp/B07ZQPC43B/ref=sr_1_6?dchild=1&keywords=Aerogel%2Bsheets&qid=1634141676&sr=8-6&th=1
Heat Resistant Gloves	1	$7.99	$7.99	For testing purposes	https://www.amazon.com/Resistant-Silicone-Sopito-Professional-Universal/dp/B0997SQLH5/ref=asc_df_B089VY1V26/?tag=hyprod-20&linkCode=df0&hvadid=475805639906&hvpos=&hvnetw=g&hvrand=11956149136281197258&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=2840&hvtargid=pla-1210015833795&th=1
Instant Coffee	1	$3.14	$3.14	Folgers Instant Coffee (For testing)	https://www.walmart.com/ip/Folgers-Classic-Roast-Instant-Coffee-3-Ounce/22301179?athcpid=22301179&athpgid=AthenaItempage&athcgid=null&athznid=siext&athieid=v0&athstid=CS020&athguid=MBR1Ars1DgmFhRtEQmyi2Hz6tbdz7hWfKz2Q&athancid=null&athena=true
Coffee Grounds	1	$7.59	$7.59	Folgers Classic Medium Roast Ground Coffee (For testing)	https://www.target.com/p/folgers-classic-medium-roast-ground-coffee-30-5oz/-/A-13397813#lnk=sametab

Shipping Fees	1	$36.44	$36.44	Shipping fees calculated using shipping estimates for all applicable items	
5.5% Safety Net	5.50%		$30.25		
Grand Total			$580.25		

Final Budget

This budget outlines all materials that were purchased throughout senior project. It includes items that were provided by the students. The students were able to remain within their proposed budget of $580.25 and had $124.21 remaining in the budget.

Part Name	Quantity	Cost	Total Cost	Purchased?	Description
RTIC Tumbler	1	$16.40	$16.40	Yes	Ordered a 30 oz tumbler to see if the sizing was okay. Used as a spare mug whenever needed.
Thermistors	1	$7.99	$7.99	Yes	Thermistors used for measuring the temperature in the mug.
Silcone Tubing	1	$8.99	$8.99	Yes	Original tubing ordered. The size ended up being too large, needed to be reordered. Used for preliminary testing.
Heating Rods (Hot Ends)	4	$11.99	$47.96	Yes	4 heating rods ordered, due to design changes only 2 were used.
Bluetooth Module	1	$10.39	$10.39	Yes	HC-06 Bluetooth Module
Induction Pads	1	$25.98	$25.98	Yes	Original induction pad ordered, ended up being too big to be used inside of the mug.
Steel Sheets	2	$22.19	$44.38	Yes	Carbon steel that was ordered. Never used due to changing the design to stainless steel.
Stainless Steel	1	$0.00	$0.00	No	Steel given by Joe Zanetti
RTIC Tumbler	1	$30.08	$30.08	Yes	40 oz mug used for the final prototype.
Induction Pads	1	$15.68	$15.68	Yes	Ordered new induction pads, never used as they were damaged during testing.
Temperature Tape	1	$12.98	$12.98	Yes	Used to attach the heating rods.
Silcone Tubing	1	$6.99	$6.99	Yes	Correctly sized tubing used for the pump.
Nylon Mesh	1	$29.99	$29.99	Yes	Mesh used for the pod.
Batteries	1	$108.21	$108.21	Yes	4 of the same and 3 of the same. Ended up not using the 3 with the tabs due to difficulties in wiring the circuit
Battery Charging Board	1	$8.99	$8.99	Yes	Needed to charge the batteries.
Arduino Mega	1	$0.00	$0.00	No	Used our own Arduino Mega
Arduino Kit (Resistors, wires, etc)	1	$0.00	$0.00	No	Used our own kit
Insulation	1	$22.90	$22.90	Yes	Insulation used to keep the heat in from the heating rods
Thermal Paste	1	$14.98	$14.98	Yes	To be used with the heating rods
Pure Nickel Strips	1	$10.99	$10.99	Yes	For batteries
Pumps	1	$12.28	$12.28	Yes	Pump used
Bluetooth Module	1	$11.39	$11.39	Yes	Ordered multiple bluetooth modules as we had issues with the previous ones
Bluetooth Module	1	$8.49	$8.49	Yes	Ordered multiple bluetooth modules as we had issues with the previous ones
Velcro	1	$9.48	$9.48	Yes	To attach the arduino
Sealant	1	$5.78	$5.78	Yes	To seal the pump
Water Weld	1	$6.78	$6.78	Yes	To seal the pump
Epoxy	1	$28.00	$28.00	Yes	Epoxy used to attach the battery and arduino attachments
Grand Total			$456.04		
Approved Budget			$580.25		
Amount Remaining			$124.21		

Appendix E: Interim Design Presentation

DECISION MATRICES

For our decision matrices we decided to highlight the most important aspects of our design:

- Cap and Pod Design
- Overall Mug Exterior
- Heating System
- Power Source

The highest score represents the **best** choice

2

Overall Cap Design

DECISION MATRIX

	Flip Style	Sliding Style
Cost	2	1
User Friendly	1	2
Sealing	2	1
Manufacturing	2	2
Total	**7**	6

3

Pod Design

DECISION MATRIX

	Design #1	Design #2
Size	2	1
User Friendly	1	2
Environmental	1	2
Simplicity	1	2
Total	5	**7**

Overall Mug Design

DECISION MATRIX

	Mug with Handle	Tumbler	Custom Design
Cost	2	3	1
Sleek Design	2	3	1
Availability/Timeline	3	2	1
Strength of Materials	2	3	1
Total	9	**11**	4

Heating Mechanism

DECISION MATRIX

	Heating Pad	Heating Rods	Induction Heating Coil
Cost	1	3	2
Size	1	3	2
Safety	3	2	1
Power Efficiency	3	2	1
Temperature Range	3	3	3
Total	11	**13**	9

6

Power Source

DECISION MATRIX

	Battery	Walled Power
Cost	1	2
Power Discharge	1	2
Size	1	2
Mobility	2	1
Life Cycle	1	2
Total	6	**9**

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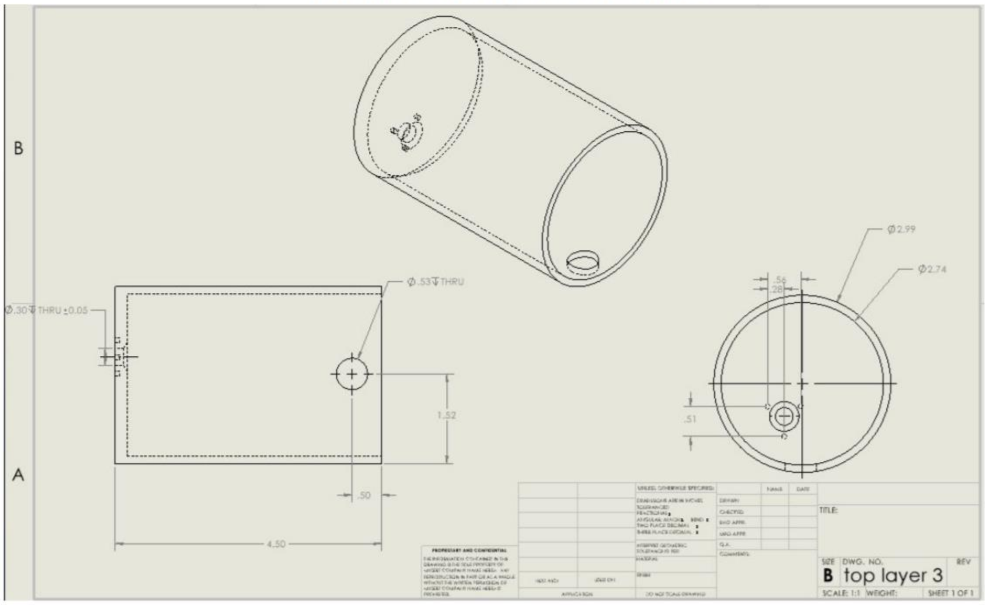
INNER LAYER OF THE MUG



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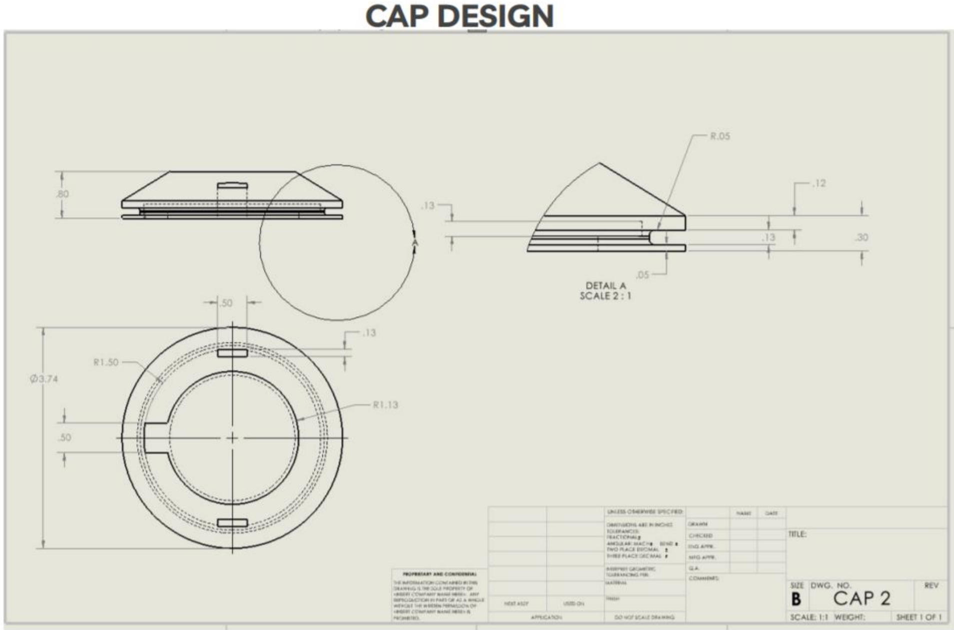
CAP DESIGN



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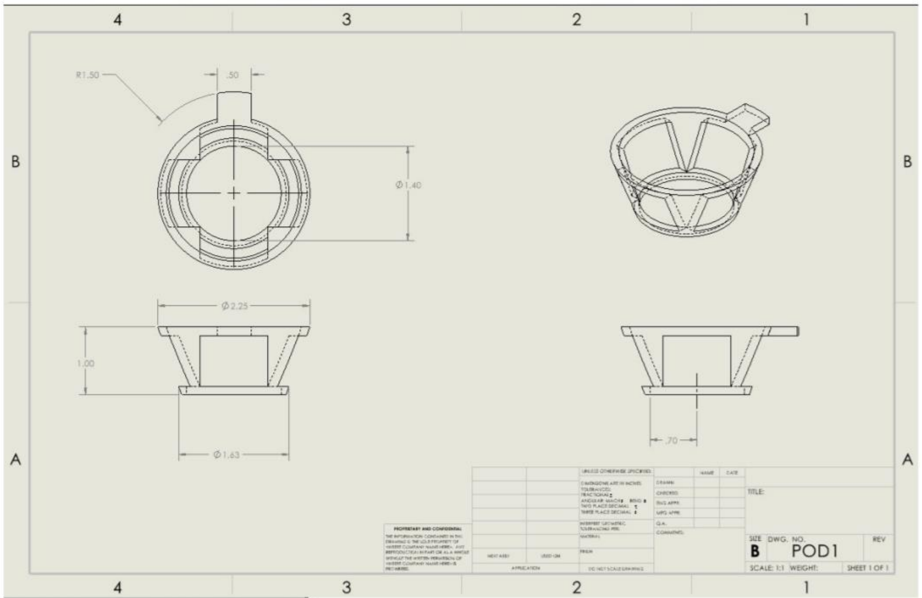
REUSABLE POD DESIGN



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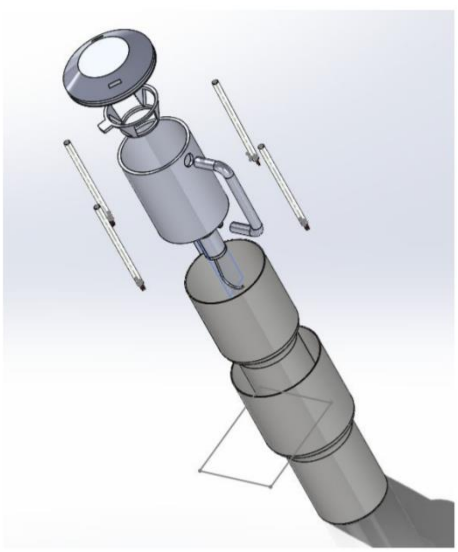
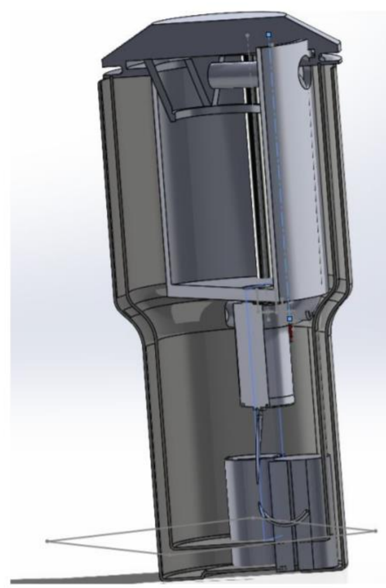
ASSEMBLY





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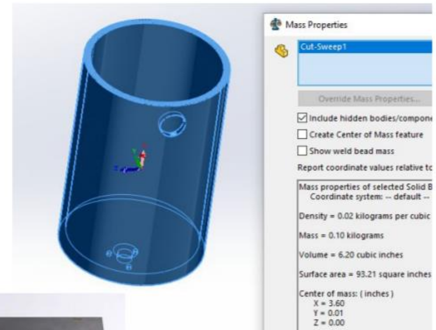
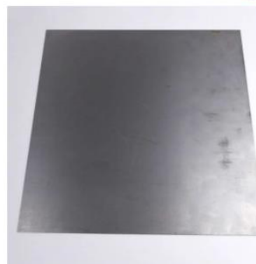
INNER MUG LAYER

- Given the height of the outer tumbler walls are 7.4 inches, the height of the inner cup needs to be 4.5 inches tall.
- Due to the constraint of the average cup holder size being in between 2.75 to 3.15 inches, the inner cup must be at most 3 inches in diameter.
- Due to these changes in dimensions, the amount of fluid ounces contained in the inner cup must be 8-10floz



High-Temperature Aluminized Low-Carbon Steel Sheets

- Yield Strength: 30,000 psi
- Hardness: Not Rated
- Thermal Conductivity of 60.5 W/m*K or 419 Btu in/Hour * ft^2 * F
- Specifications Met: ASTM A463



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Time vs Volume Optimization

Size: 4 oz		Size: 5 oz		Size: 6 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	474.1510574	1	592.6888218	1	711.2265861
2	237.0755287	2	296.3444109	2	355.6132931
3	158.0503525	3	197.5629406	3	237.0755287
4	118.5377644	4	148.1722054	4	177.8066465
Size: 7 oz		Size: 8 oz		Size: 9 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	829.7643505	1	948.3021148	1	1066.839879
2	414.8821752	2	474.1510574	2	533.4199396
3	276.5881168	3	**316.1007049**	3	355.6132931
4	207.4410876	4	237.0755287	4	266.7099698
Size: 10 oz		Size: 11 oz		Size: 12 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	1185.377644	1	1303.915408	1	1422.453172
2	592.6888218	2	651.9577039	2	711.2265861
3	395.1258812	3	434.6384693	3	474.1510574
4	296.3444109	4	325.978852	4	355.6132931

$$Q = m * C_p \Delta T$$

$$Watts = Q/(60 * t)$$

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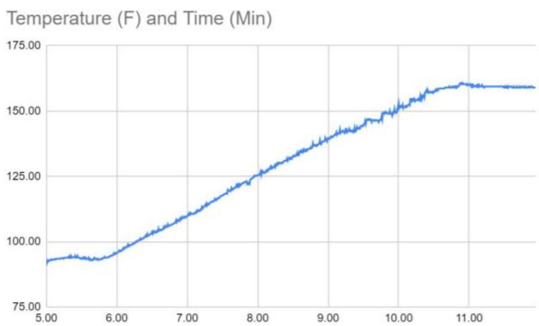
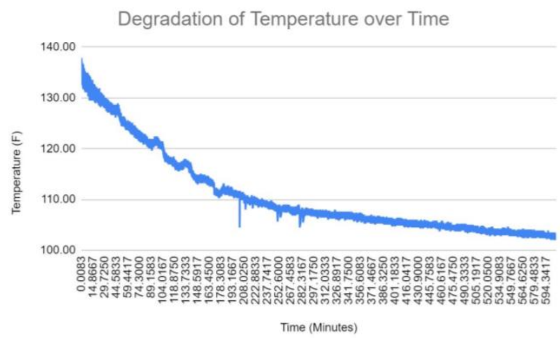
Testing Results





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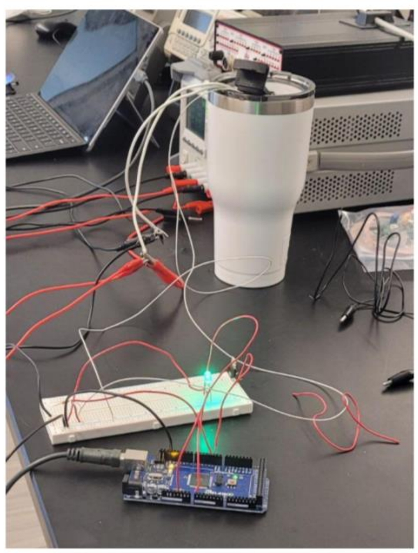
TESTING



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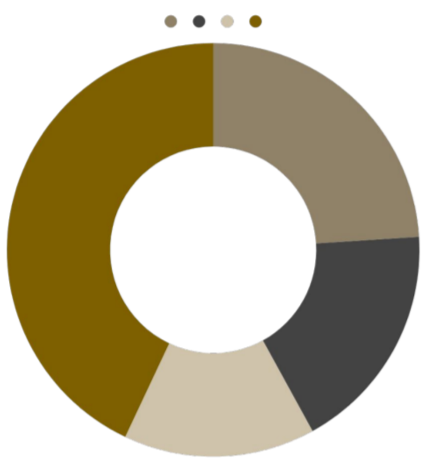
BUDGET

Part Name	Quantity	Cost	Total Cost	Description
RTIC Tumbler	2	$28.53	$57.06	40 oz mug, 2 required: one for testing, one for final prototype
Tenergy Battery	1	$94.99	$94.99	12V battery
Induction pads	1	$15.68	$15.68	Induction pad for charging purposes
Bluetooth Module	1	$10.39	$10.39	Serial Wireless Module BLE 4.0 Bluetooth Module Compatible HM-10
Ceramic Cartridge Heater	4	$11.99	$47.96	Cartridge Heater 12V 100W
Temperature Tape	1	$12.98	$12.98	High Temp Tape,AIYUNNI(2 inch X 108 FT)
Thermistors	1	$7.99	$7.99	10pcs 3D Printer 100K ohm NTC 3950 Thermistors
Pump	1	$10.98	$10.98	4.5V Pump
Tube	1	8.99	8.99	Tube for Pump
Arduino	1	$15.99	$15.99	Arduino Mega
Breadboard kit	1	$3.65	$3.65	Breadboard, jumper wires, LED's, resistors
PCB	1	$100.00	100	PCB used to condense arduino components
Mesh sheet	1	$29.99	$29.99	Nylon Mesh Filter Woven Mesh Sheet
High-Temperature Aluminized Low-Carbon Steel Sheet,12" x 12" x 0.047"	2	$17.91	$35.82	High-Temperature Aluminized Low-Carbon Steel Sheet, 12" x 12" x 0.047", PN: 5610N21
Thermal Paste	1	$14.88	$14.88	10g Thermal Paste
Insulation	1	$19.50	$19.50	Thermal Insulation - Ceramic Fiber Insulation
Bluetooth Antenna	1	7.99	7.99	Modular Bluetooth Antenna - to connect mug to a phone application
Heat Resistance Gloves	1	$7.99	$7.99	For testing purposes
Instant Coffee	1	$3.14	$3.14	Folger's Instant Coffee (For testing)
Coffee Grounds	1	$7.59	$7.59	Folgers Classic Medium Roast Ground Coffee (For testing)
Shipping Fees	1	$36.44	$36.44	Shipping fees calculated using shipping estimates for all applicable items
5.5% Safety Net	5.50%		$30.25	
Grand Total			$580.25	

16

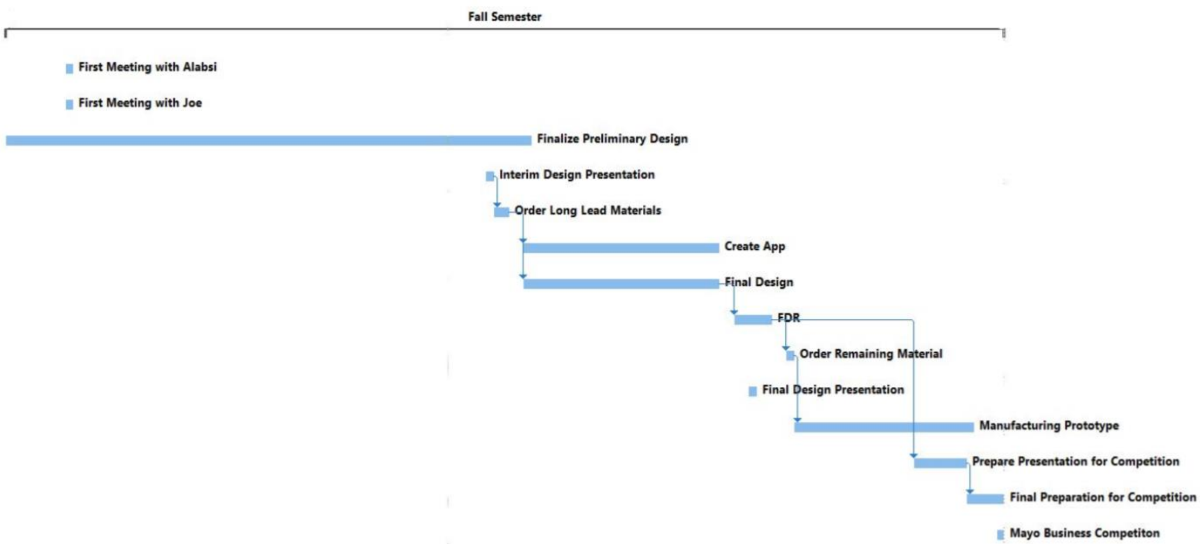
BUDGET BREAKDOWN



OTHER	15%
MECHANICAL	24%
THERMAL	18%
ELECTRICAL	43%

17

GANTT CHART



18

THANK YOU FOR YOUR TIME

Does anyone have any questions?
Follow for project updates

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PHOENIXMUG

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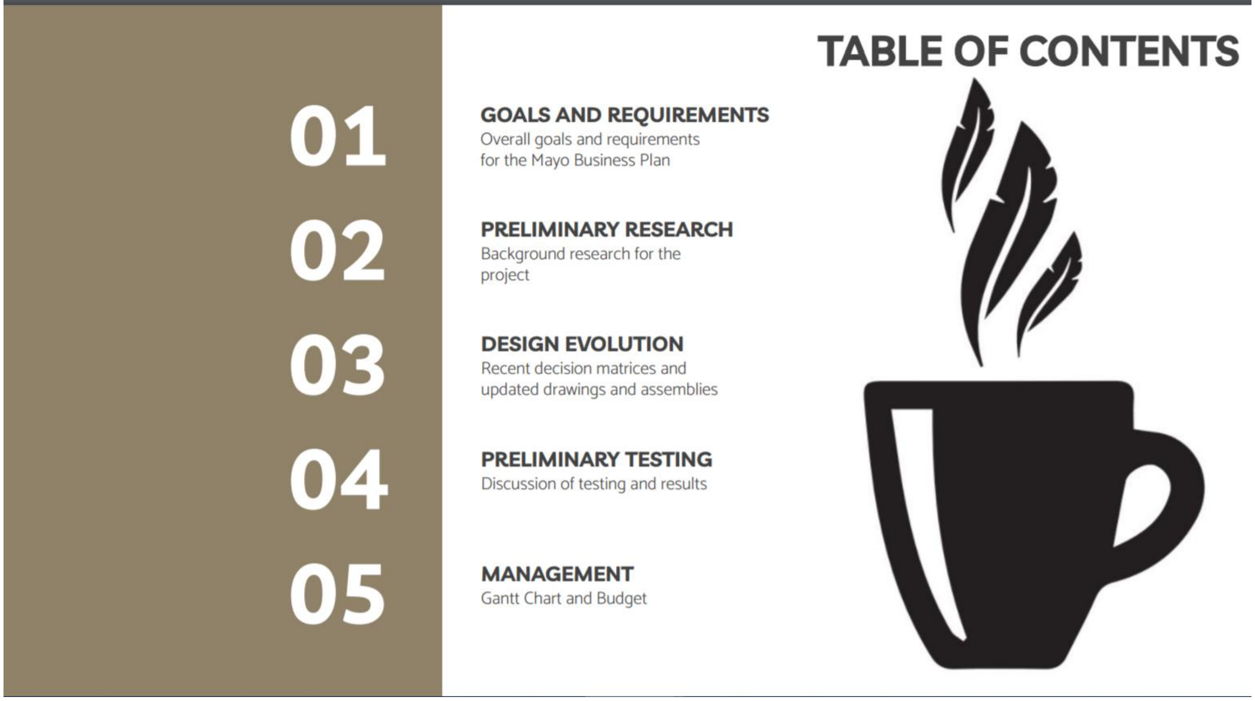
Appendix F: Final Design Presentation (Fall Semester)



GOALS AND REQUIREMENTS

Our overall goals for our project are:

1. Development of a phone application
2. Development of a heating mechanism
3. Development of a brewing mechanism
4. Development of a minimalist design

Additionally our requirements for the Mayo Business Plan Competition include:

5. Submission by 1/16/22 consisting of:
   - Short pitch video
   - 20 page business plan
   - Final CAD drawings
   - Preliminary prototype completion
6. Completion of all required LinkedIn Learning Modules by 1/16/22
7. Revise and resubmittal if selected for Semi-finals
8. Final Presentation before judges if advanced to the Finals

1

PRELIMINARY RESEARCH & OPTIMIZATION

- Average Commute: 27.6 minutes
- Average time to get ready for work: 30 minutes
- Average time to brew coffee: 5 minutes
- Coffee Brewing Temperature: 195˚F
- Coffee Drinking Temperature: 120-155˚F

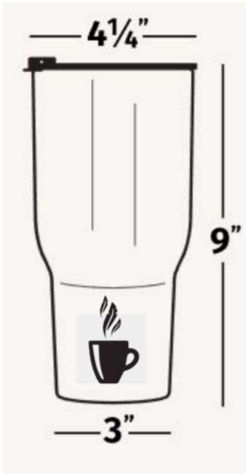
Size: 4 oz		Size: 5 oz		Size: 6 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	474.1510574	1	592.6888218	1	711.2265861
2	237.0755287	2	296.3444109	2	355.6132931
3	158.0503525	3	197.5629406	3	237.0755287
4	118.5377644	4	148.1722054	4	177.8066465
Size: 7 oz		Size: 8 oz		Size: 9 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	829.7643505	1	948.3021148	1	1066.839879
2	414.8821752	2	474.1510574	2	533.4199396
3	276.5881168	3	**316.1007049**	3	355.6132931
4	207.4410876	4	237.0755287	4	266.7099698
Size: 10 oz		Size: 11 oz		Size: 12 oz	
Time (m):	Watt (W)	Time (m):	Watt (W)	Time (m):	Watt (W)
1	1185.377644	1	1303.915408	1	1422.453172
2	592.6888218	2	651.9577039	2	711.2265861
3	395.1258812	3	434.6384693	3	474.1510574
4	296.3444109	4	325.978852	4	355.6132931

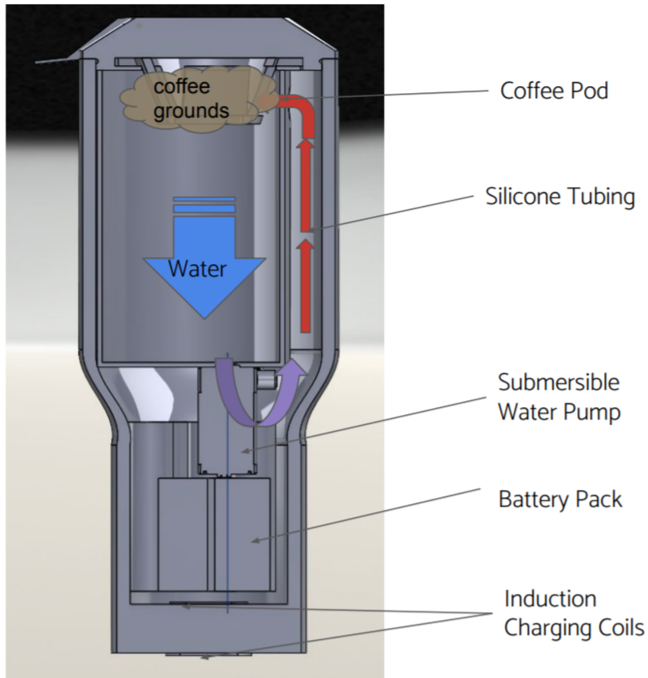
$$Q = m * C_p \Delta T$$

$$Watts = Q/(60 * t)$$

2

HOW IT WORKS





3

ALTERNATE DESIGNS

- Since the interim design presentation, there have been a few more design changes to the electrical subsystems
- In particular, the battery configuration and charging system were further analyzed

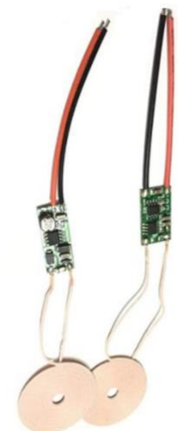
The <u>highest</u> score represents the <u>best</u> choice

4

Charging Mechanism

DECISION MATRIX

	Charger	Induction Pads
Cost	1	2
Safety	1	2
Size	2	1
Mobility	1	2
User Friendliness	1	2
Total	6	**9**



5

Batteries

DECISION MATRIX

	1.2 V Batteries in series	Combination of wattages + parallel/series
Cost	1	2
Capacity	1	2
Size	1	2
Simplicity	2	1
Total	5	**7**

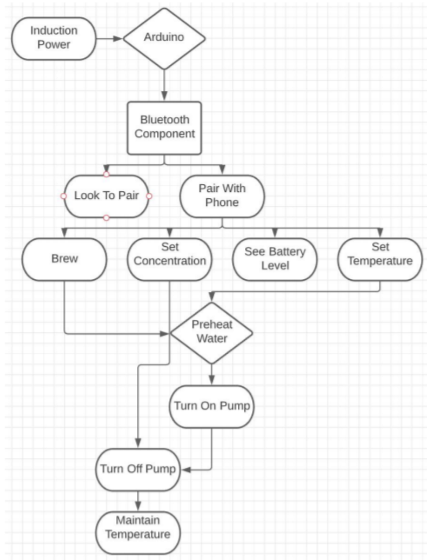
Battery Combination:

3x 5000mAh 1.2V Sub C
4x 3500mAh 3.635V

29,000 mAh 15.74V 10A
157.4 Watts - 2:54 Per Charge

6

Logic Diagram

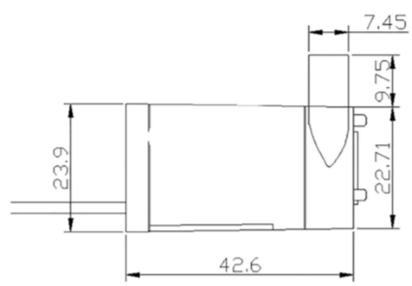


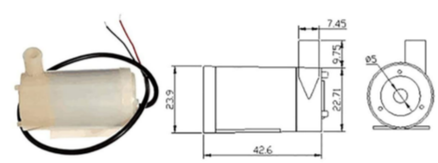
7

Pump Specifications

Submersible Mini Water Pump

- Voltage range (V): DC2.5-6v
- Rated voltage: DC3V or 4.5V
- No load of water discharge capacity: 100L / H
- Load rated current: 0.18A
- Use: diving type
- The pump is a DC pump, 3V pump with DC3-4.5V power supp (Can not be used directly with 220V AC voltage)Voltage range DC2.5-6v





Model	Voltage Scope (DC)	Current (A)	Power (W)	Max Water Head (M)	Max Flow Rate (L/H)	Starting Voltage	waterproofing grade
JT-DC3W-3	3V	0.12	0.36	0.35	80	1	IP68
JT-DC3W-4.5	4.5V	0.18	0.91	0.55	100	1	IP68

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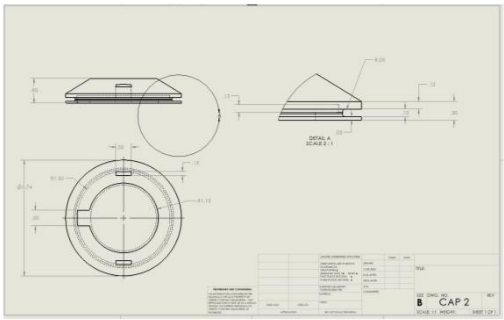
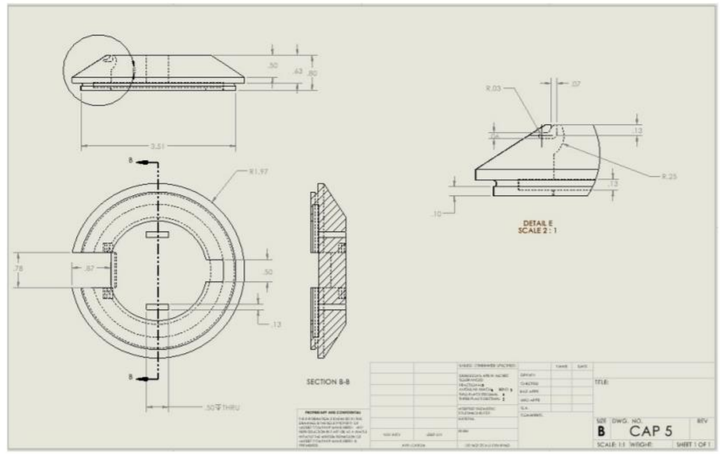
CAP DESIGN

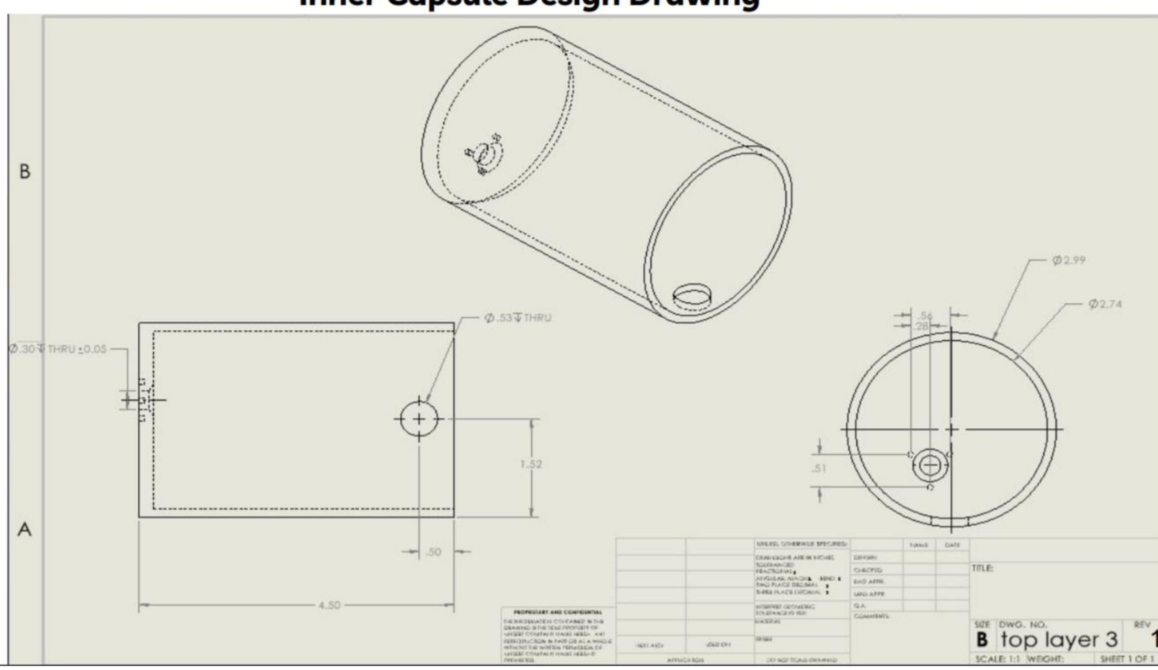


Previous Cap Design

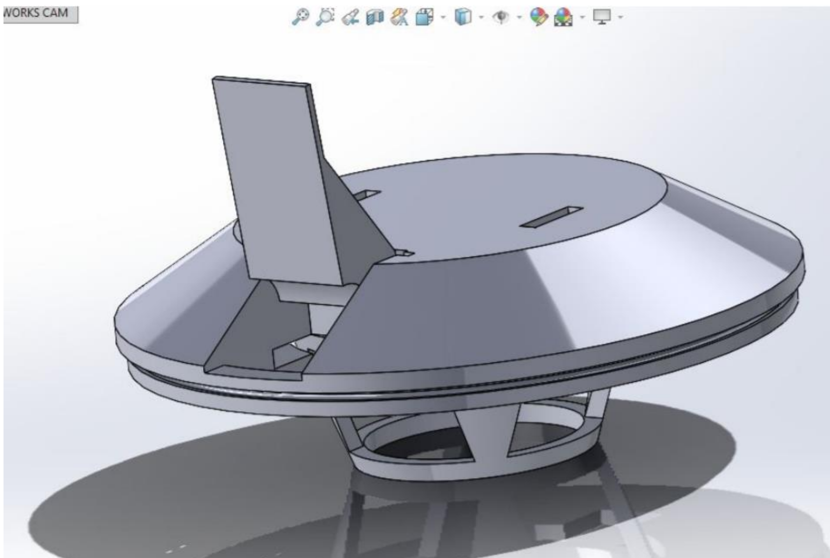


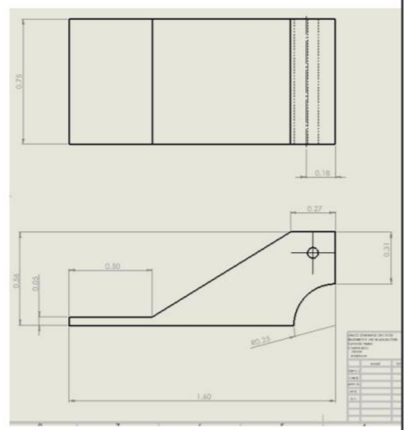
Current Cap Design

Inner Capsule Design Drawing



CAP AND POD ASSEMBLY





Comments:

- The Flip Tab is secured using a Dowel Pin, 4037 Alloy Steel, 1/16" Diameter, 1" Long
- The Coffee pod will have a mesh inlay not shown in model

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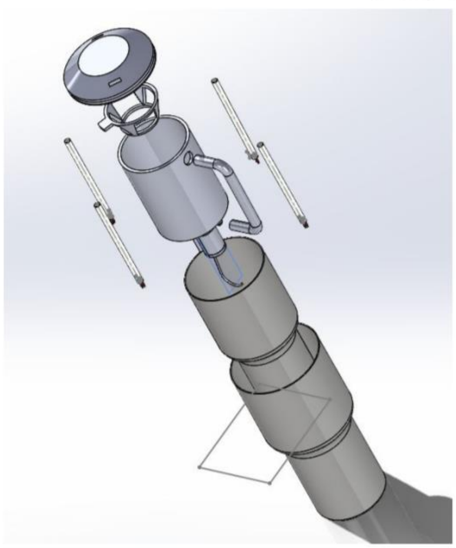
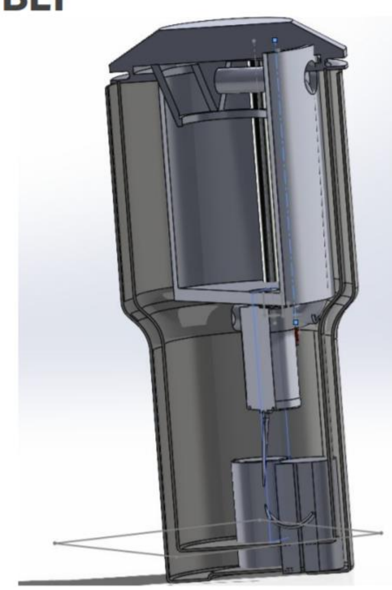
PREVIOUS ASSEMBLY





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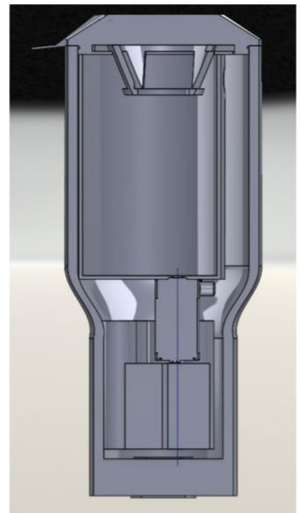
CURRENT ASSEMBLY



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PRELIMINARY TESTING

1. Heating Experiment
    - Using the 4 heating rods, did an experiment to see the temperature of the water as time progressed
    - Additionally, measured the time it would take to cool
2. Pump test
    - Basic experiment to see the pumps functionality and speeds at different power inputs
3. Induction Testing
    - Test to verify that induction pads would work
    - Set up experiment to light an LED
    - Tested by placing induction pads through different materials
    - More detailed testing still needed once the mug arrives

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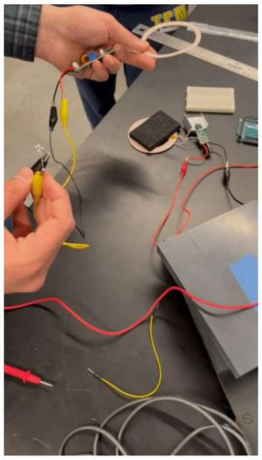
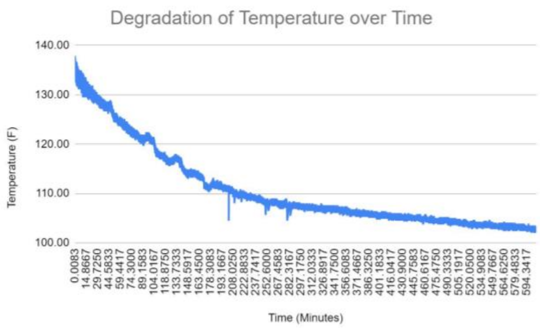
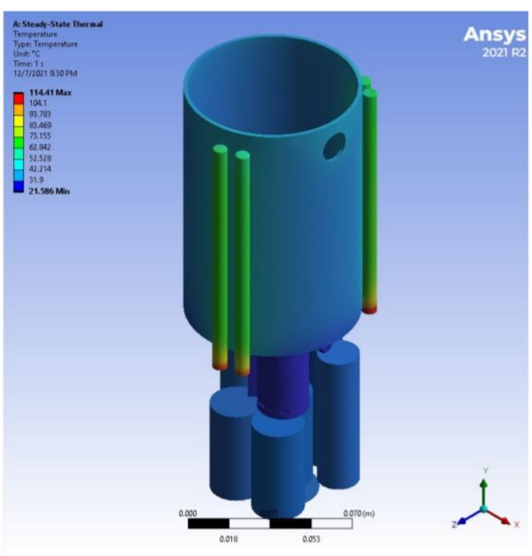
RESULTS & CALCULATIONS

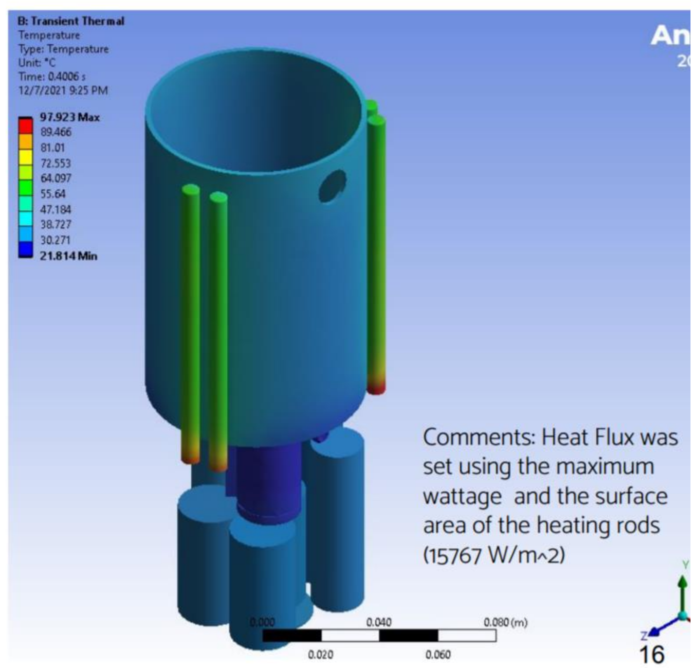




Size: 8 oz	
Time (m):	Watt (W)
1	948.3021148
2	474.1510574
3	316.1007049
4	237.0755287
5	189.660423
6	158.0503525
7	135.4717307
8	118.5377644
9	105.3669016
10	94.83021148

ANSYS TEMPERATURE DISTRIBUTION

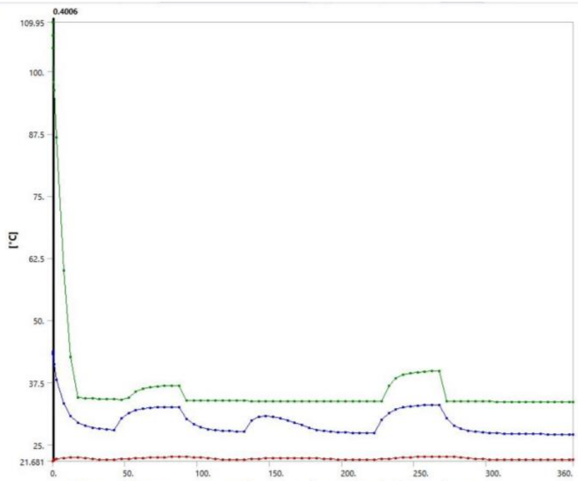




Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	0.1	21.681	109.95	43.643
2	0.16012	21.72	107.34	43.396
3	0.22024	21.75	104.77	43.173
4	0.4006	21.814	97.923	42.588
5	0.94167	21.941	96.277	41.127
6	2.5649	22.16	86.81	37.969
7	7.4346	22.342	59.987	33.224
8	12.435	22.451	42.603	30.751
9	17.435	22.494	34.395	29.471
10	22.435	22.231	34.308	28.794
11	27.435	22.104	34.246	28.423
12	32.435	22.047	34.193	28.209
13	37.435	22.021	34.146	28.077
14	42.435	22.01	34.108	27.988
15	47.435	22.123	34.073	30.248
16	52.435	22.18	34.462	31.352
17	57.435	22.258	35.703	31.921
18	62.435	22.338	36.299	32.218
19	67.435	22.406	36.603	32.374
20	72.435	22.458	36.761	32.458
21	77.435	22.495	36.844	32.503
22	82.435	22.521	36.888	32.527
23	87.435	22.537	36.911	32.541
24	92.435	22.515	33.881	30.224
25	97.435	22.451	33.867	29.072
26	102.43	22.366	33.854	28.46
27	107.43	22.244	33.843	28.125
28	112.43	22.105	33.832	27.932
29	117.43	22.045	33.822	27.814
30	122.43	22.02	33.812	27.736
31	127.43	22.009	33.803	27.679
32	132.43	22.004	33.795	27.635
33	137.43	22.09	33.787	29.804
34	142.43	22.148	33.779	30.615
35	147.43	22.216	33.773	30.788
36	152.43	22.275	33.766	30.633
37	157.43	22.312	33.76	30.306
38	162.43	22.324	33.754	29.888
39	167.43	22.315	33.749	29.421
40	172.43	22.291	33.744	28.925

ANSYS TEMPERATURE DISTRIBUTION II



Plot of Transient Thermal ANSYS Simulation

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BUDGET

Part Name	Quantity	Cost	Total Cost	Description
RTIC Tumbler	2	$28.53	$57.06	40 oz mug, 2 required: one for testing, one for final prototype
Tenergy Battery	1	$94.99	$94.99	12V battery
Induction pads	1	$15.68	$15.68	Induction pad for charging purposes
Bluetooth Module	1	$10.39	$10.39	Serial Wireless Module BLE 4.0 Bluetooth Module Compatible HM-10
Ceramic Cartridge Heater	4	$11.99	$47.96	Cartridge Heater 12V 100W
Temperature Tape	1	$12.98	$12.98	High Temp Tape,AIYUNNI(2 inch X 108 FT)
Thermistors	1	$7.99	$7.99	10pcs 3D Printer 100K ohm NTC 3950 Thermistors
Pump	1	$10.98	$10.98	4.5V Pump
Tube	1	8.99	8.99	Tube for Pump
Arduino	1	$15.99	$15.99	Arduino Mega
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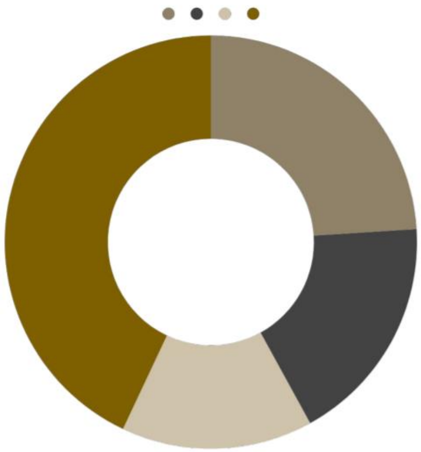
5.5% Safety Net	5.50%		$30.25	
Grand Total			$580.25	

18

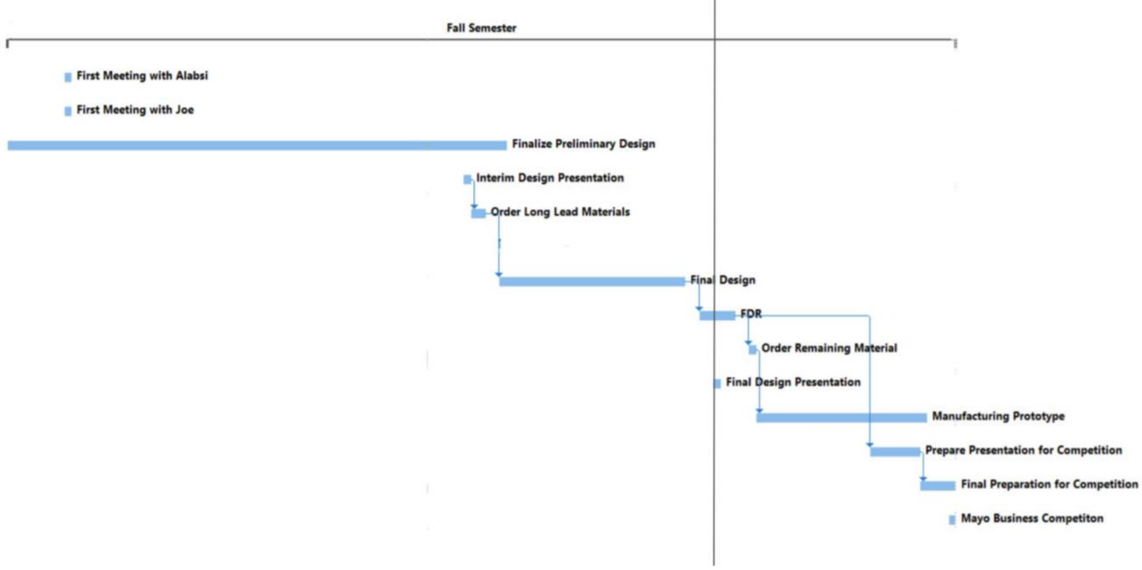
BUDGET BREAKDOWN



OTHER	15%
MECHANICAL	24%
THERMAL	18%
ELECTRICAL	43%

19

GANTT CHART



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REALISTIC CONSTRAINTS

1. Economic
2. Environmental
3. Social
4. Ethical
5. Manufacturability
6. Sustainability
7. Standards
8. Public Health
9. Safety
10. Welfare of the Public
11. Global
12. Cultural and Political

The highlighted constraints are the ones **most** applicable to our project

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FUTURE

Goals for next semester

- Complete a working prototype by March in time for the Mayo Business Finals
- Finalize design and component selection for the PCB board integration
- Begin verification testing no later than March

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THANK YOU FOR YOUR TIME

Does anyone have any questions?
Follow for project updates

engprojects.tcnj.edu/phoenix-mug

PHOENIXMUG

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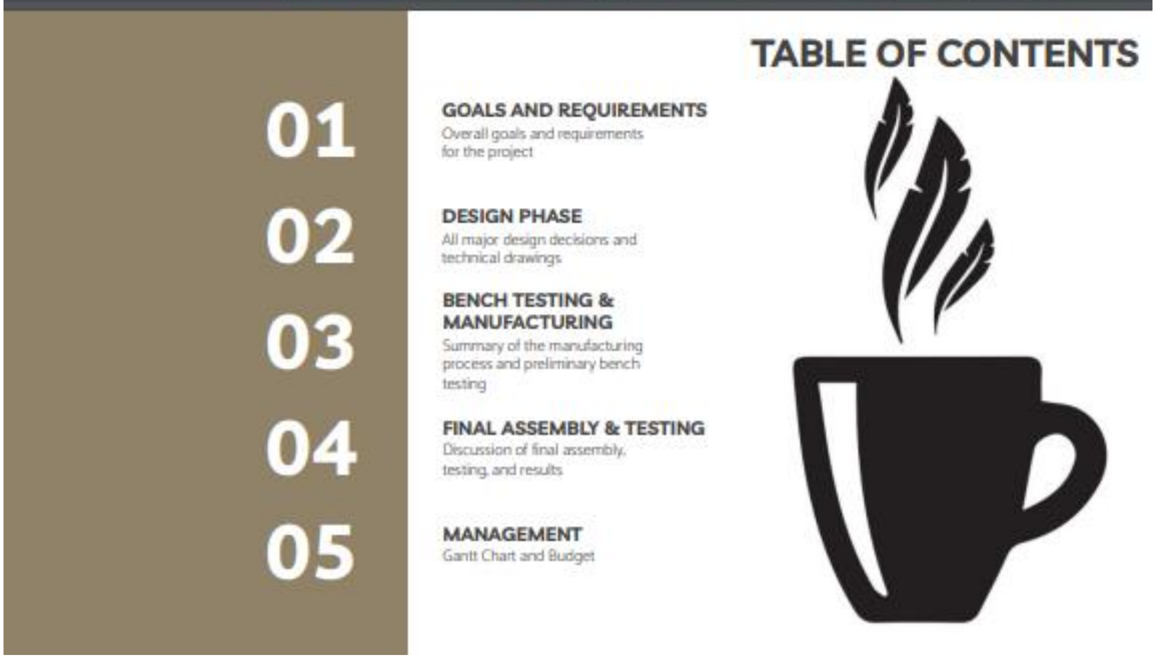
Appendix G: Final Design Presentation (Spring Semester)



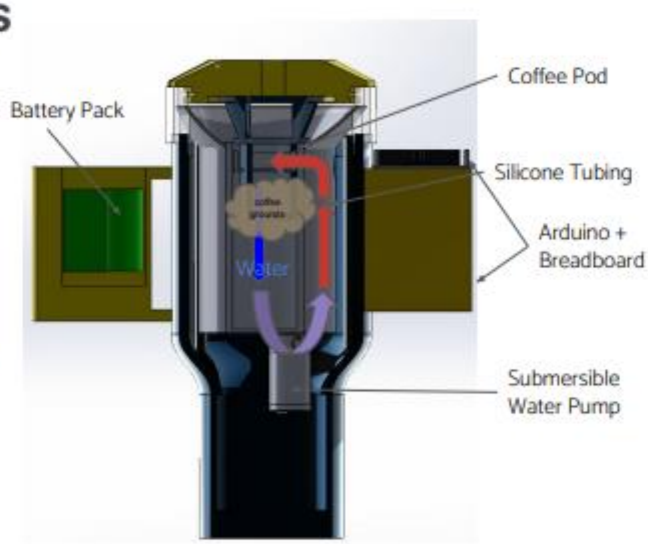
GOALS AND REQUIREMENTS

Our overall goals for our project are:

1. Development of a phone application
2. Development of a heating mechanism
3. Development of a brewing mechanism
4. Enter the 2021-22 Mayo Business Plan Competition
    a. Create 20 page business plan
    b. Video pitch
    c. Complete required LinkedIn Modules

1

HOW IT WORKS



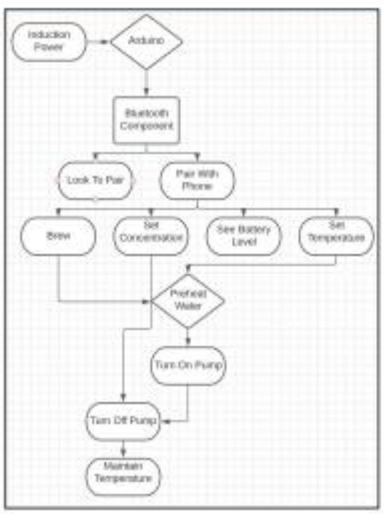
2

DESIGN PHASE

- Electrical/Computer
  - Complete circuit design
  - Bluetooth Design
  - Pump Specifications
- Thermal
  - Brewing time optimization
  - Heating mechanisms
- Mechanical
  - Inner Layer
  - Extender
  - Cap & Pod Assembly
  - Battery Attachment

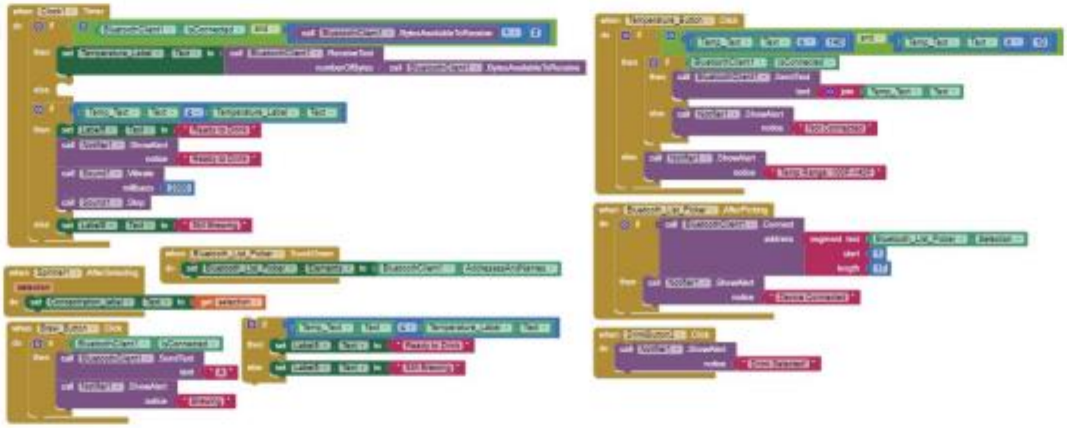
3

LOGIC DIAGRAM / PHONE APPLICATION



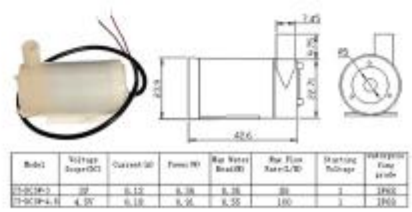
4

BLUETOOTH: PHONE APPLICATION



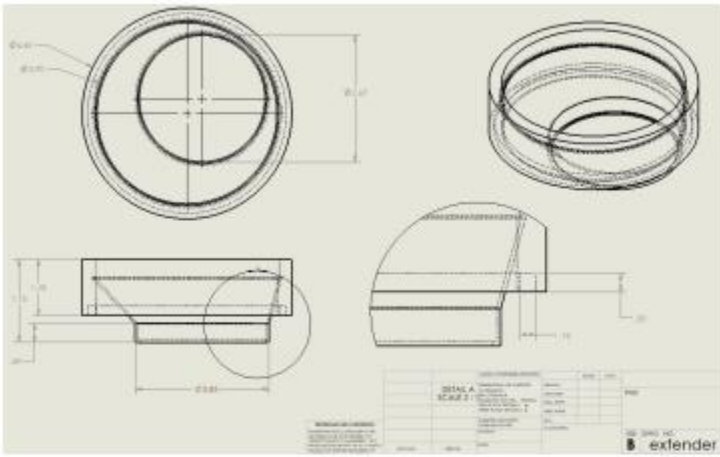
5

ELECTRONICS



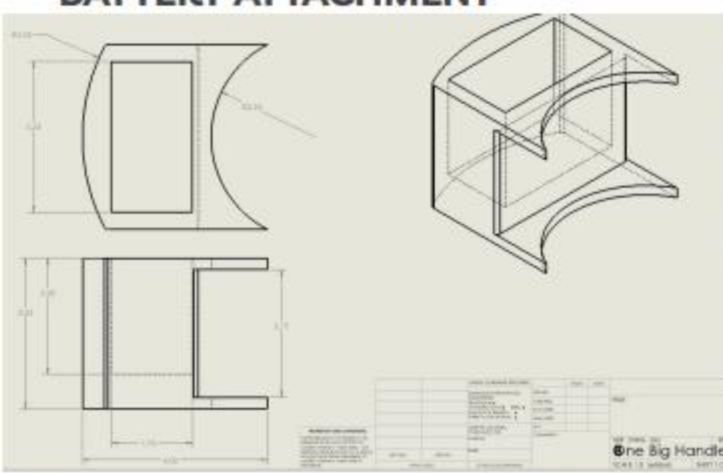
6

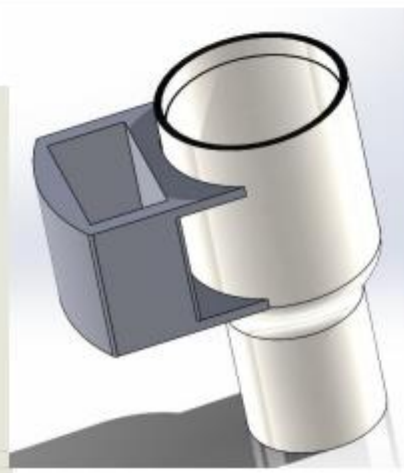
LID EXTENDER



7

BATTERY ATTACHMENT

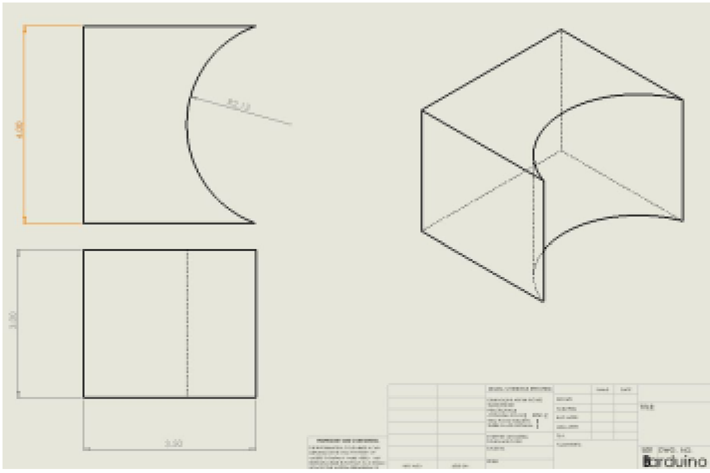




Comment: Due to weight imbalance, the mug will contain a counterweight for stability

8

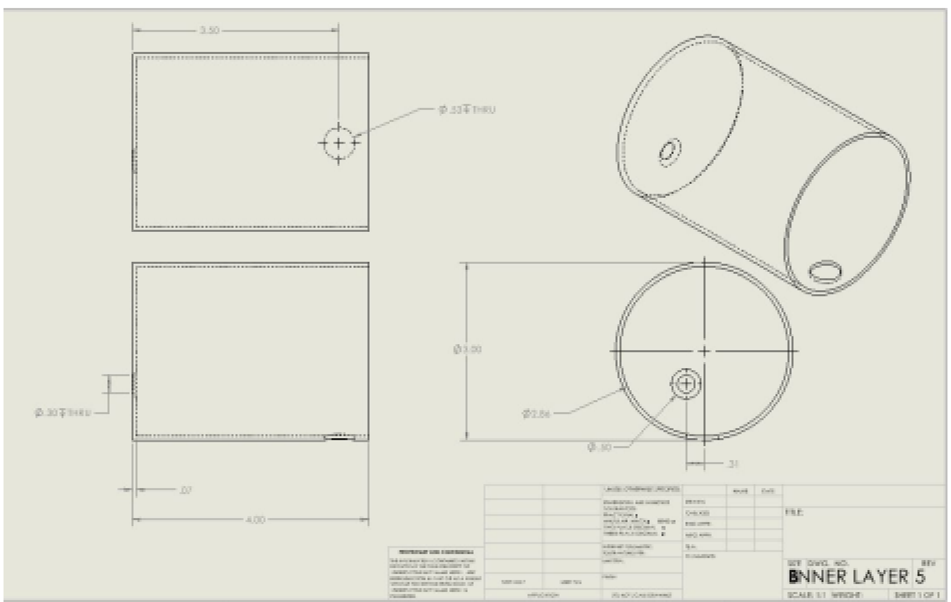
ARDUINO ATTACHMENT



Comment: Original plan was to secure the Arduino and breadboard to the battery attachment, however there was a weight imbalance, so this design was created as a solution.

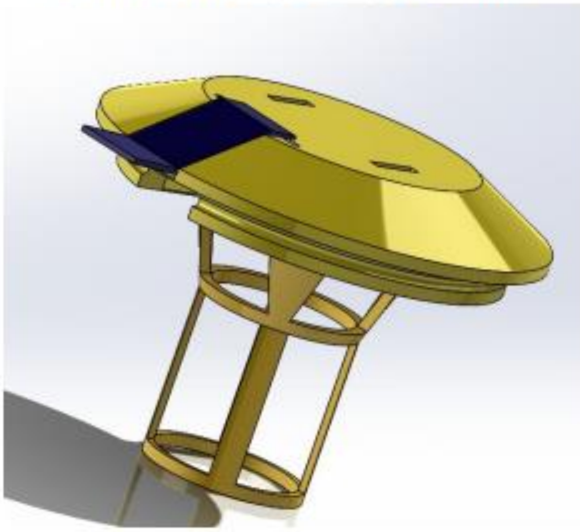
9

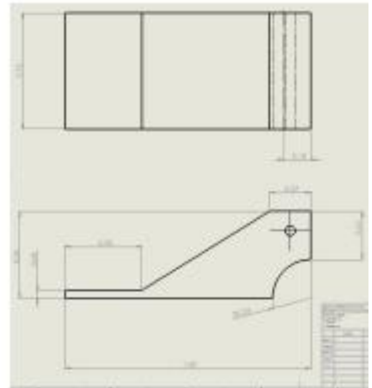
INNER LAYER



10

CAP AND POD ASSEMBLY





Comments:

- The Flip Tab is secured using a Dowel Pin, 4037 Alloy Steel, 1/16" Diameter, 1" Long
- The Coffee pod has a mesh inlay not shown in model

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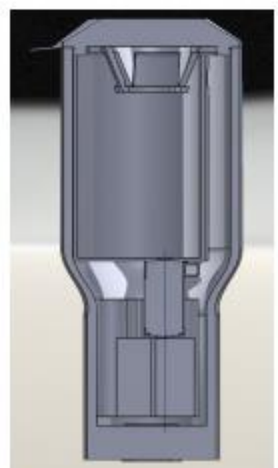
PREVIOUS ASSEMBLY



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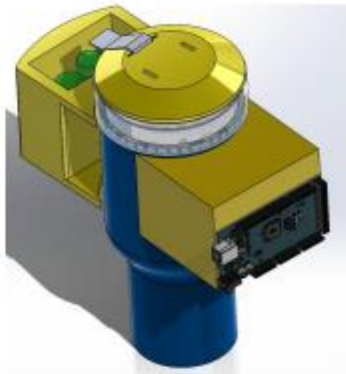
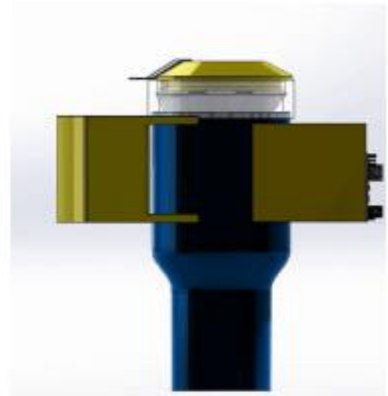
CURRENT ASSEMBLY





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THERMAL SYSTEM

Time (Minutes)	Watts Needed
1	948.3021148
2	474.1510574
3	316.1007049
4	237.0755287
5	189.660423
6	158.0503525
7	135.4717307
8	118.5377644
9	105.3669016
10	94.83021148
11	86.20928316
12	79.02517623

- During the design phase, the students made the decision to reduce the number of heating rods from 4 to 2.
- This was due to the spatial constraint. If 4 were used, they would have been too close to the tube which could have resulted in the tube warping or melting

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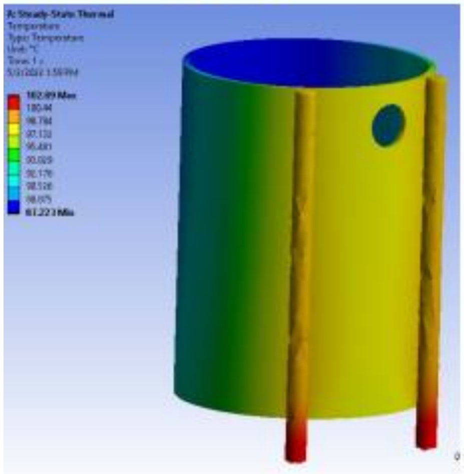
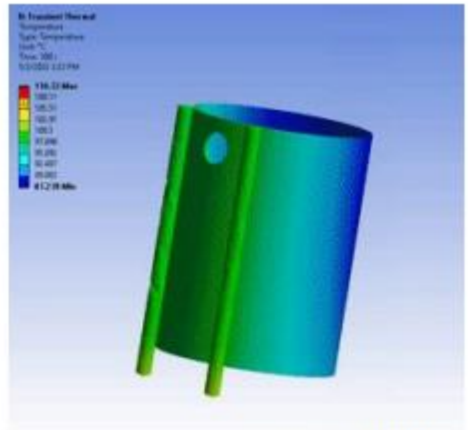
ANSYS TEMPERATURE DISTRIBUTION





Comments: Heat Flux was set using the maximum wattage and the surface area of the heating rods (15767 W/m^2)

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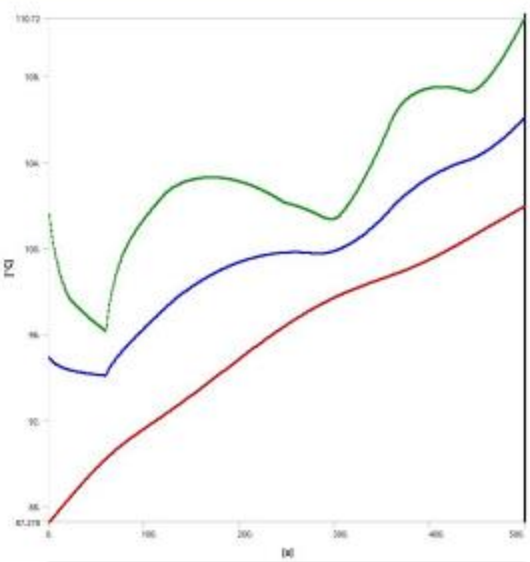
ANSYS TEMPERATURE DISTRIBUTION II

Tabular Data

	Time [s]	Minimum [°C]	Maximum [°C]	Average [°C]
1	1.	87.276	101.53	94.894
2	2.	87.33	101.13	94.847
3	3.	87.382	100.8	94.794
4	4.	87.434	100.51	94.751
5	5.	87.486	100.24	94.711
6	6.	87.538	99.985	94.675
7	7.	87.59	99.753	94.642
8	8.	87.642	99.539	94.611
9	9.	87.694	99.34	94.583
10	10.	87.747	99.156	94.556
11	11.	87.799	98.986	94.532
12	12.	87.851	98.827	94.509
13	13.	87.903	98.678	94.488
14	14.	87.956	98.54	94.468
15	15.	88.008	98.41	94.45
16	16.	88.06	98.288	94.432
17	17.	88.113	98.173	94.416
18	18.	88.165	98.065	94.4
19	19.	88.218	97.963	94.386
20	20.	88.27	97.866	94.372
21	21.	88.322	97.774	94.359
22	22.	88.374	97.687	94.346
23	23.	88.427	97.619	94.334
24	24.	88.479	97.574	94.323
25	25.	88.531	97.529	94.312
26	26.	88.583	97.482	94.302
27	27.	88.634	97.437	94.292
28	28.	88.686	97.391	94.282
29	29.	88.737	97.346	94.273
30	30.	88.789	97.301	94.264
31	31.	88.84	97.257	94.255
32	32.	88.891	97.213	94.247
33	33.	88.942	97.169	94.239
34	34.	88.992	97.126	94.231
35	35.	89.042	97.083	94.224
36	36.	89.092	97.04	94.216
37	37.	89.142	96.998	94.209
38	38.	89.192	96.957	94.202
39	39.	89.241	96.916	94.196
40	40.	89.29	96.875	94.189
41	41.	89.338	96.835	94.183
42	42.	89.387	96.796	94.176
43	43.	89.435	96.757	94.17
44	44.	89.482	96.718	94.164



Plot of Transient Thermal ANSYS Simulation

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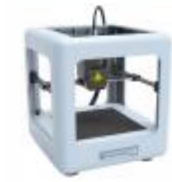
MANUFACTURING

- Most of the components were 3D printed:
  - Cap
  - Pod
  - Extender
  - Battery Attachment
- The inner layer was manufactured using stainless steel
  - Sheet metal roller
  - Milling machine
  - Waterjet
  - Grinding belt
  - Welding



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3D PRINTED COMPONENTS

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INNER LAYER

Comments:

- There is a fill line indicating where the user should fill the water to (8 oz)
- Made out of Stainless Steel

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BENCH TESTING

- Pump Verification
  - Experiment to confirm that the pump setup is fully sealed and functioning properly
- Battery Charging Experiment
  - Experiment to verify that the batteries can be charged once fully discharged
- Bluetooth Experiment
  - Experiment to confirm that the bluetooth system is functioning and that the Arduino and phone application are in sync
- Full Battery Experiment
  - Confirms that the batteries can support all systems. Additionally, measures the water temperature and time needed to brew

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PUMP VERIFICATION

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BATTERY CHARGING EXPERIMENT

- IC Charge Discharge Unit
- Basic Set-up
- Problems:
  - Overload of power into IC unit
- Solution:
  - Rerouting the batteries
    - Limit Power into Hot Ends

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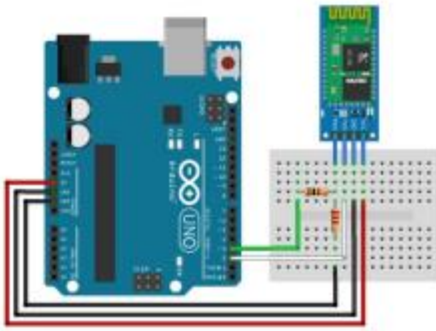
BLUETOOTH EXPERIMENT




```
#include <SoftwareSerial.h>
SoftwareSerial BTserial(10,11); // RX | TX
// Connect the HC-06 TX to the Arduino RX on pin 2.
// Connect the HC-06 RX to the Arduino TX on pin 3 through a voltage divider.
//

//Temp code

int ThermistorPin = 0;
int Vo;
float R1 = 10000;
float logR2, R2, T, Tf, Tc;
float c1 = 1.009249522e-03, c2 = 2.378405444e-04, c3 = 2.019202697e-07;
float n;
float idealTemp;
void loop()
{
  n=n+1.5;

  Vo = analogRead(ThermistorPin);
  R2 = R1 * (1023.0 / (float)Vo - 1.0);
  logR2 = log(R2);
  T = (1.0 / (c1 + c2*logR2 + c3*logR2*logR2*logR2));
  Tc = T - 273.15;
  Tf = (Tc * 9.0)/ 5.0 + 32.0;

 if (BTserial.available()){
    Serial.write(BTserial.read());
    //idealTemp = BTserial.read();
    //if (BTserial.read() == 'A'){
    digitalWrite(8, HIGH);
    digitalWrite(7, HIGH);
```

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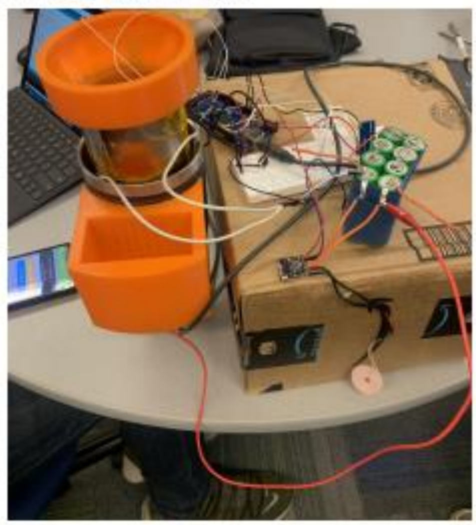
FULL BATTERY EXPERIMENT



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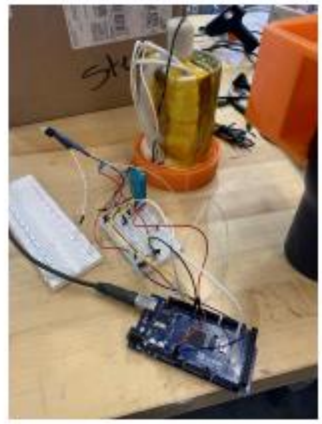
FINAL ASSEMBLY & TESTING

- Once all subsystems were verified, the team could begin final assembly
- After final assembly, final testing could be completed
- These experiments included:
  - Tilt Test
    - Verify that none of the internal components shift when the mug is tilted in the drinking position
  - Brewing Experiment
    - Final experiment to ensure that the entire process works and that the water successfully brews



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FINAL ASSEMBLY

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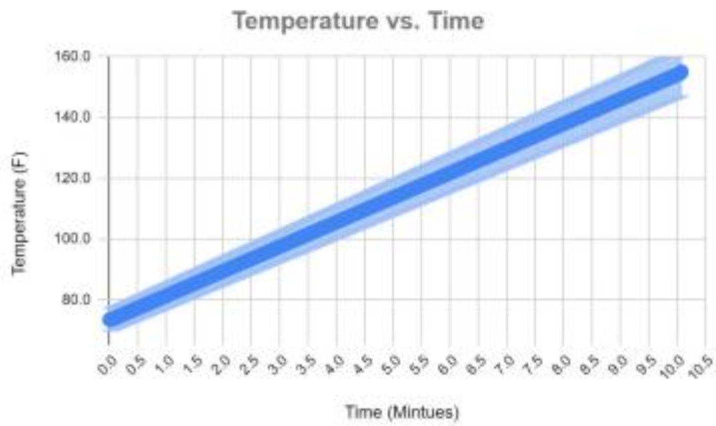
FINAL TESTING



*Data was only recorded for the first 4 minutes

*Remainder of data was extrapolated assuming linear relationship and a 5% deviation.

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FINAL TESTING

- Extender began to melt, likely due to the impact of the hot steam
- Limitation of the project was the fact that machining plastic would not have been feasible, which is what led to the decision to 3D print the components
- Since the melting plastic was a safety hazard, the experiment was ended

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MANAGEMENT

- Budget
  - Breakdown of budget
- Gantt Chart
  - Schedule that the team followed throughout the semester
- Realistic Constraints & Engineering Standards
  - Summary of applicable realistic constraints and standards
- Future Improvements

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BUDGET

Part Name	Quantity	Cost	Total Cost	Purchased?	Description
RTIC Tumbler	1	$16.40	$16.40	Yes	Ordered a 10 oz tumbler to see if the sizing was okay. Used as a spare mug whenever needed.
Thermistors	1	$7.99	$7.99	Yes	Thermistors used for measuring the temperature in the mug.
Silicone Tubing	1	$8.99	$8.99	Yes	Original tubing ordered. The size ended up being too large, needed to be reordered. Used for preliminary testing.
Heating Rods ([illegible])	4	$11.99	$47.96	Yes	4 heating rods ordered, due to design changes only 2 were used.
Bluetooth Module	1	$10.29	$10.29	Yes	HC-06 Bluetooth Module
Induction Pads	1	$25.88	$25.88	Yes	Original induction pad ordered, ended up being too big to be used inside of the mug.
Steel Sheets	2	$22.19	$44.38	Yes	Carbon steel that was ordered. Never used due to changing the design to stainless steel.
Stainless Steel	1	$0.00	$0.00	No	Steel given by Joe Zanetti
RTIC Tumbler	1	$30.08	$30.08	Yes	40 oz mug used for the final prototype.
Induction Pads	1	$15.88	$15.88	Yes	Ordered new induction pads, never used as they were damaged during testing.
Temperature Tape	1	$12.98	$12.98	Yes	Used to attach the heating rods.
Silicone Tubing	1	$8.99	$8.99	Yes	Correctly sized tubing used for the pump.
Nylon Mesh	1	$20.99	$20.99	Yes	Mesh used for the pad.
Batteries	1	$108.22	$108.22	Yes	4 of the same and 3 of the same. Ended up not using the 3 with the tabs due to difficulties in wiring the circuit.
Battery Charging Board	1	$8.00	$8.00	Yes	Needed to charge the batteries.
Arduino Mega	1	$0.00	$0.00	No	Used our own Arduino Mega.
Arduino Kit (Resistors, wires, etc)	1	$0.00	$0.00	No	Used our own kit.
Insulation	1	$22.99	$22.99	Yes	Insulation used to keep the heat in from the heating rods.
Thermal Paste	1	$14.88	$14.88	Yes	To be used with the heating rods.
Pure Nickel Strips	1	$10.99	$10.99	Yes	For batteries.
Pump	1	$12.28	$12.28	Yes	Pump used.
Bluetooth Module	1	$11.39	$11.39	Yes	Ordered multiple bluetooth modules as we had issues with the previous ones.
Bluetooth Module	1	$6.49	$6.49	Yes	Ordered multiple bluetooth modules as we had issues with the previous ones.
Velcro	1	$9.48	$9.48	Yes	To attach the arduino.
Sealant	1	$6.78	$6.78	Yes	To seal the pump.
Water Weld	1	$6.78	$6.78	Yes	To seal the pump.
Epoxy	1	$20.00	$20.00	Yes	Epoxy used to attach the battery and arduino attachments.
Grand Total			[illegible]		
Approved Budget			[illegible]		
Amount Remaining			[illegible]		
Total for [illegible] to be reimbursed		[illegible]			
Total for [illegible] to be reimbursed		[illegible]			

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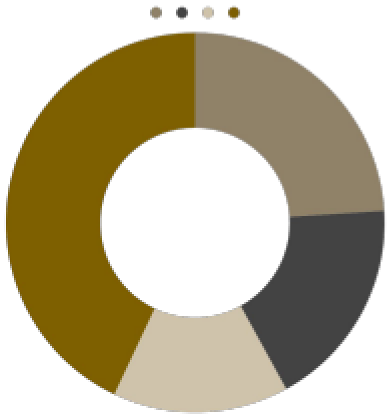
BUDGET BREAKDOWN



OTHER	15%
MECHANICAL	24%
THERMAL	18%
ELECTRICAL	43%

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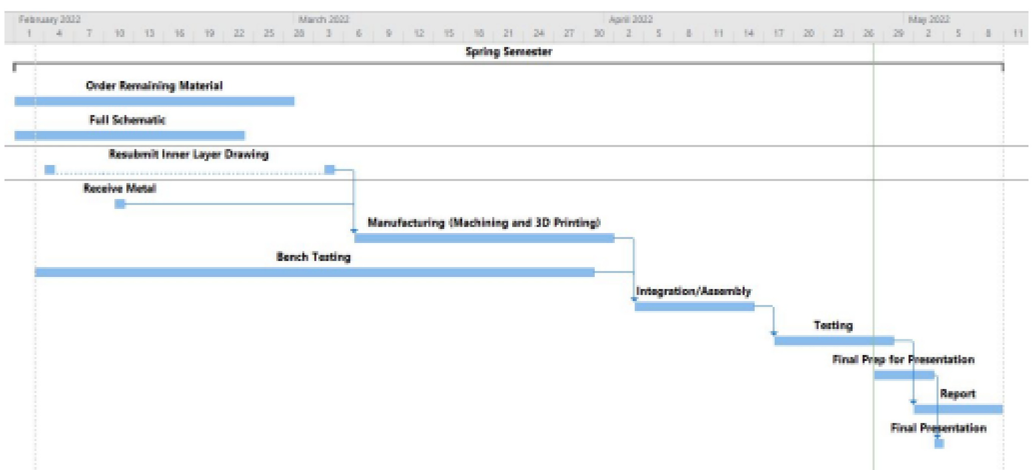
GANTT CHART



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Realistic Constraints and Standards

1. **Economic**
2. **Environmental**
3. **Social**
4. Ethical
5. **Manufacturability**
6. **Sustainability**
7. **Standards**
8. **Public Health**
9. **Safety**
10. **Welfare of the Public**
11. Global
12. Cultural and Political

ASTM INTERNATIONAL

The bold constraints are the ones **most** applicable to our project

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Potential Improvements

FUTURE

- Passive / Active cooling system problem
- Custom outer layer
    - Re-configure electronic system
- Injection molding
    - Food/Thermal safe materials

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THANK YOU FOR YOUR TIME

Does anyone have any questions?
Follow for project updates

engprojects.tcnj.edu/phoenix-mug

PHOENIXMUG

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Appendix H: Experiment Apparatus Procedure (Fall Semester)

a. Heating System

Apparatus

The apparatus for this lab includes the following materials:

Figure 42: RTIC Double Wall Vacuum Insulated Tumbler, 40 oz

The insulated tumbler in ***Figure 42*** served as the housing for the transient analysis conducted in this lab. The tumbler is able to hold up to 40 fluid ounces of water, however only 13 oz of water was used in this experiment.

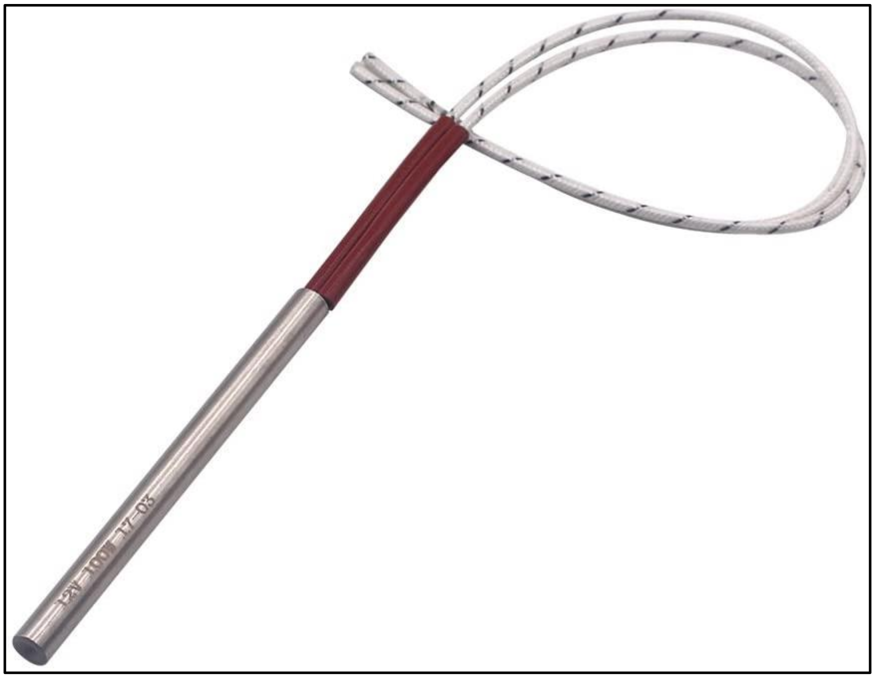


Figure 43: 4 DERNORD Cartridge Heater 12V 100W Electric Hot Rods

The two electric hot ends depicted in ***Figure 43*** were placed into the water housed inside the tumbler and were connected to a power supply. These hot rods were used as the primary heating element in the experimental apparatus and allowed for collecting the changing transient temperature data.

Figure 44: 3D Printer NTC 3950 Thermistors

The 3950 Thermistors as shown in ***Figure 44*** were housed inside of the tumbler and used to record the temperature data when receiving time step input from the Arduino, the temperature data was imported to the Arduino.

Figure 45: Arduino Mega 2560

The Arduino depicted in ***Figure 45*** allowed the temperature data to be collected and stored at every time step. This was later exported to a spreadsheet using the software Putty.

Figure 46: 100K Ohm Resistor

The resistor used in ***Figure 46***, is to step down the voltage going into the thermocouple. One main benefit to adding a resistor is to reduce the noise and make the data points more accurate.

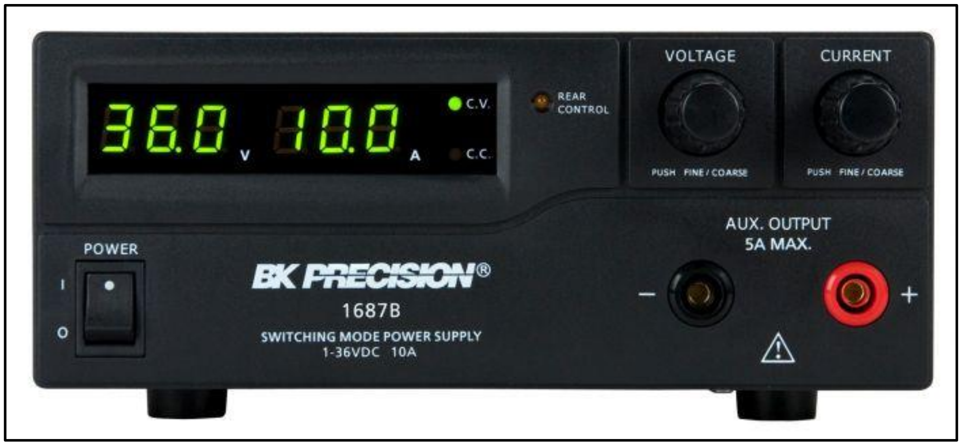


Figure 47: 12V 30A Adjustable Power Supply

Finally, ***Figure 47*** describes the 12V 30A Adjustable Power Supply on which a value of 200 watts was transmitted to the hot ends, thus causing the system to heat up over time.

Methods

Firstly, the 40 oz. mug was filled with 13 ounces distilled room temperature water (87 Degrees Fahrenheit). The temperature of the water was recorded and this was indicated to be the initial temperature value at t = 0s to t = 360s. The 4 hot ends were then connected to the power supply set to 360 watts (12V 30A) prior to being placed into the water, this is in order to ensure that the heat generated from the hot ends are consistent over the entire transient analysis period. Next, the thermistor was hooked up to the Arduino in order to record the temperatures over each time step (0.5s). The analysis was run until the temperature reached 160 degrees Fahrenheit for each trial upon which the power supply was turned off and transient analysis continued during the water cool down period. Finally, the thermistor data was exported by use of the software Putty prior to beginning the theoretical analysis.

Appendix I: Bench Testing Procedures

Pump Verification Test

Objective: Ensure that the pump works once attached to the tubing and inner layer. Verify that the pod's location works.

Materials:

- Inner Layer Setup:
    - Pump attached to tubing attached directly to the inner layer
- Cap
- Pod
- Extender
- Voltage Source

Steps:

1. Fill the inner layer with a small volume of water.
2. Connect the pump to the voltage source.
3. Set the voltage to 5V.
4. Visually inspect the flow to ensure that the speed and angle of flow is up to standard.
5. Turn the voltage back down to 0V.
6. Attach the pod and cap together.
7. Attach the pod, cap, and extender to the inner layer.
8. Set the voltage to 5V.
9. Inspect through the hole in the cap to ensure that the water is passing through the pod correctly. Note: This is a preliminary test, final verification using coffee grounds will verify that the pod is set up correctly.
10. Sign off on the attached data sheet to confirm that this experiment was completed.

Induction Experiment
Experiment Purpose: Measure power transfer through the Mug

Materials:
1. LED (Red) - 1.5-4 Volts Operating
2. 40-ounce Mug
3. Induction Receiver and Transmitter
4. Jumper wires (4)
5. Power Supply

Procedure:

1. Place the Induction Receiver in the bottom of the inside of the mug.
2. Place the Induction Transmitter in the bottom of the mug.
3. Plug in Induction Transmitter to the Power supply using 2 Jumper wires
4. Plug the Induction Transmitter to the Red LED using 2 jumper wires
5. Turn on Power-Supply and Set it to 1.5 volts
6. Record experiment with a video recording.
7. Amp up power supply to up to 4V
8. Record the progression from step 7
9. Replace the LED with voltmeter
10. Compare the output vs the input power of the inductors to measure power transfer and possibly power loss

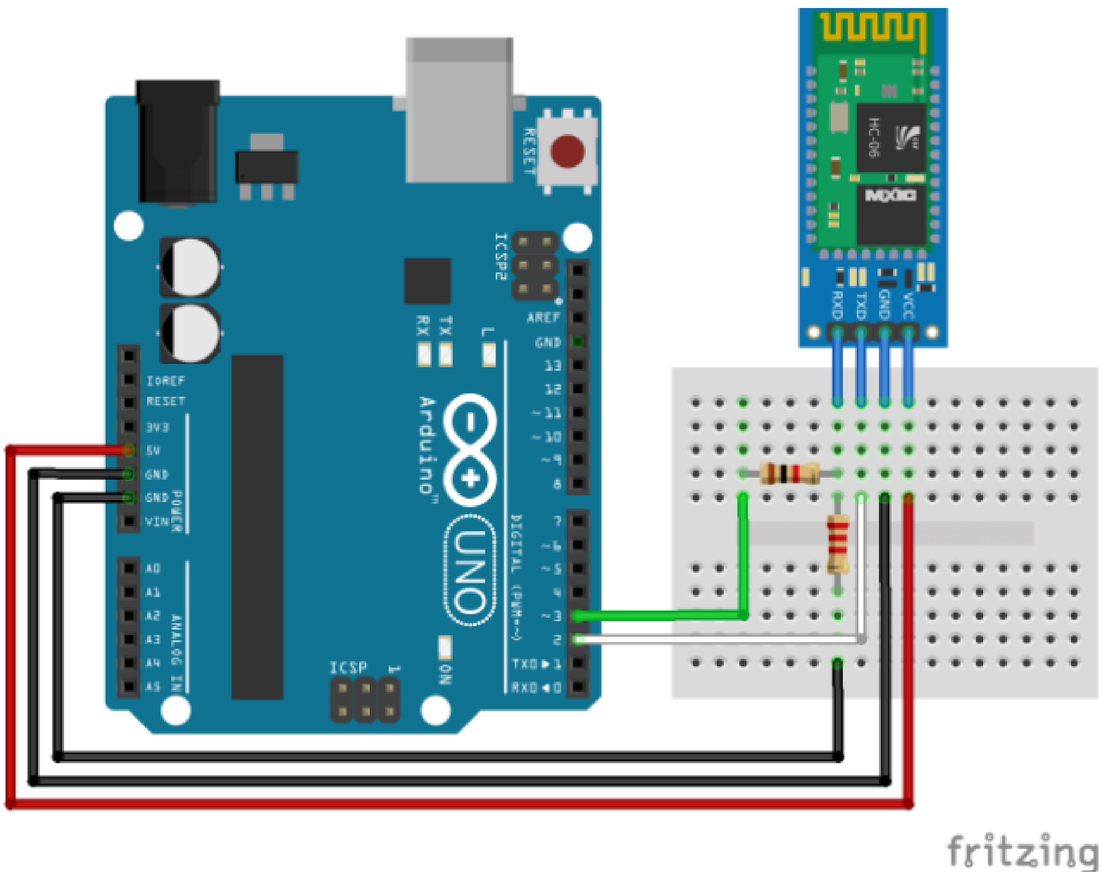
Bluetooth System Experiment

Objective: Confirm that the Bluetooth applications work

Materials:
Bluetooth Module
Arduino
Wire
Resistors (1k, 2k)
Breadboard
Android Phone

Procedure:

1. Confirm that the Arduino setup matches the following schematic:



WARNING : We use pin 2 and 3 of Arduino Uno. Depending on the microcontroller, some pins may not support SoftwareSerial communication. Especially, Arduino Mega, Micro and Leonardo. Check the documentation.

2. Once setup is complete, verify that the Arduino can be contacted through the following code:

```
void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  Serial.println("Hello World!");
}
void loop() {
}
```

3. Once confirmed, use the following code to setup the bluetooth:

```
#include <SoftwareSerial.h>
SoftwareSerial hc06(2,3);
void setup(){
  //Initialize Serial Monitor
  Serial.begin(9600);
  Serial.println("ENTER AT Commands:");
  //Initialize Bluetooth Serial Port
  hc06.begin(9600);
}
void loop(){
  if (hc06.available()){
    Serial.write(hc06.read());
  }
  if (Serial.available()){
    hc06.write(Serial.read());
  }
}
```

4. Next, use the following code to ensure the bluetooth is paired:

```
#include <SoftwareSerial.h>
SoftwareSerial hc06(2,3);
String cmd="";
float sensor_val=0;
void setup(){
  //Initialize Serial Monitor
  Serial.begin(9600);
  //Initialize Bluetooth Serial Port
  hc06.begin(9600);
}
void loop(){
  while(hc06.available()>0){
```

```
    cmd+=(char)hc06.read();
  }

  //Select function with cmd
  if(cmd!=""){
    Serial.print("Command recieved : ");
    Serial.println(cmd);
    // We expect ON or OFF from bluetooth
    if(cmd=="ON"){
        Serial.println("Function is on");
    }else if(cmd=="OFF"){
        Serial.println("Function is off");
    }else{
        Serial.println("Function is off by default");
    }
    cmd=""; //reset cmd
  }
  // Simulate sensor measurement
  sensor_val=(float)random(256); // random number between
0 and 255

  //Write sensor data to HC06
  hc06.print(sensor_val);
  delay(100);
}
```

5. Finally, confirm that the smartphone application successfully links to the Arduino. (Not sure what else to say or what else needs to be addressed in this procedure)

Battery Overheating Experiment
Objective: Ensure that the batteries are not at risk of overheating when the mug is operating

Materials:
40 Oz Tumbler
Extender
Lid
Inner Layer
2 Hot Ends
2 Thermistors
Transistor
4 Batteries
Arduino
Optional:
Pump
Tube
Insulation

Procedure:
1. Discharge the batteries
2. Charge the batteries directly into the power supply.
3. Measure the temperature of the batteries
4. If the temperature is above 120F come up with possible solutions that will be able to cool the batteries within a short period of time.

"Full Battery Testing" Procedure

Objective: To verify that the batteries can power the major systems and verify how long it will take for the water to reach the proper temperature

Sub-Objective: Provide a method for the battery life to be visible to the user either from Bluetooth system or just generally visible to the user.

Materials:
40 Oz Tumbler
Inner Layer
Arduino
2 Hot Ends
4 Batteries
Pump
Tube for Pump
Thermistor
Transistor
Thermal Tape
Scale

Procedure:

1. Set up the circuit to match the following diagram:

(insert diagram here: can be a rough sketch, or an image of how to setup the arduino, if creating a diagram is too difficult, then include a detailed step by step explanation on how to set everything up)

   Do not connect the batteries at this time.

2. Block off the hole in the inner layer. To do this, use a nut and screw. Verify that no water leaks out. If water is leaking, tighten the screw.
3. Fill the inner layer with 8 ounces of water. Measure the 8 ounces by using a scale. Ensure that the scale is properly set to 0 to ensure that the weight of the container is not accounted for.
4. Attach the two hot ends to the exterior by using the thermal tape. Ensure that nothing else comes into contact with the hot ends, as this is a safety hazard.
5. Ensure that the circuit matches the diagram shown in step one. If yes, then connect the batteries to the circuit to start the experiment.
6. Record the temperature of the water. This will be achieved using the data automatically collected. Once the temperature reaches **155°F,** the batteries can be disconnected.
7. Once disconnected, begin to measure the temperature every 30 seconds as previously done. Reset the time to 0. Continue until the temperature is between **120-145ºF.**

Appendix J: Mayo Business Plan Submission

Team Phoenix **Mayo Business Plan Competition** **Q1 2022**

<u>The Phoenix Mug</u>

Jason Rosen[1] , Jess Ruby[1], Brett Murphy[1]

[5] **Undergraduate, Mechanical Engineering Department, The College of New Jersey, Ewing, NJ, USA**

Table of Contents

Executive Summary

This business plan outlines a portable self-brewing and self-heating mug, branded as “Phoenix Mug”. A general overview of the coffee and warm beverage industry reveals a demand for a cheaper and more portable alternative to current solutions. Furthermore, current brewing alternatives utilize single-use plastic units that are both wasteful and are difficult to be broken down. As a result, single use brewing pods continue to contribute to the ever so growing waste piles around the world. This demand presents an opportunity to provide consumers with a cheaper, portable and environmental alternative to a trendy and growing market. The primary demographic for this mug are Gen X, Gen Z, and Millennials and we will target them through social media and influencers related to warm beverages. Financial forecasts indicate that the Phoenix Mug will realize a net gain of $134,000 in the first year of operations. If scaled up to 25 manufacturing employees at 2026, the mug will take in a net gain of $39,150,000 that year. Given this demand for a cheaper, portable and more environmentally friendly alternative, the team is confident that the Phoenix Mug has the potential to be both scalable and sustainable for years to come.

Business Overview

The Phoenix Team's mission is to provide the market with an easy to use, portable, eco-friendly, self-brewing and self-heating mug. This idea stemmed from the frustrations of drinking cold and stale coffee after a long commute to work, paying for expensive coffees before class, and using bulky, complicated, and expensive brewing devices on camping trips. By providing means for a simple-to-use and portable mug, the consumer is able to brew the perfect cup of coffee, anywhere, anytime regardless of the situation. With the target audience being warm beverage drinkers, the mug can be adaptable to multiple beverages such as coffee, hot-chocolate and tea. The company will begin with small-scale manufacturing to dedicate more resources to an aggressive social media campaign. This company will be incorporated, which would bring along benefits such as asset protection through limited liability, corporate identity creation and the ability to easily raise credit and capital.

Operating Plan
Strategic company operations will be divided into three phases:

Phase 1:

This phase has a high emphasis on R&D and Pre-Launch Marketing. Phase 1 spans the two quarters of 2022.

R&D:

This task consists of continuing to develop and conduct market research for the Phoenix Mug, so that the customer can get the best product possible. The first strategy is to finish creating the minimal viable product so that the team can start beta testing the product with local consumers. At the start of this R&D period, provisional utility patents will be filed so that the Phoenix team will have a competitive advantage in having exclusive rights to both self-brewing and the pod structure.

Pre-Launch Marketing:

The team will utilize popular social media platforms such as Instagram, Youtube and TikTok to advertise the mug. A budget of $8,000 will be dedicated in 2022 to pay for becoming sponsors for popular and trendy influencers in the coffee industry. Pre-ordering on Kickstarter will be utilized so that the team will be able to start collecting funds to mass produce the product. The main goal of this first campaign is to raise awareness about this product and start to gather market research such as features that the consumers will like to see in future iterations of the mug. Additionally, by showing that there is a need for this product, the team will have greater success at getting additional funding from investors.

Phase 2:

This phase includes the initial production stages with product marketing. Phase 2 spans the last 2 quarters of 2022 and the entirety of 2023.

Initial Production:

In order to reduce the cost of the mug, the team plans to secure multiple manufacturers to produce the various components in mass quantities. By doing so, the price per unit is reduced from $265 to $68.80. This will also reduce the overall retail price of the product to $174.99. Once the parts are ordered, the team plans on renting a small 4000 square foot warehouse and hiring 5 people for $20 an hour to build 1200 mugs in 2022. From the data from the Pre-Launch Marketing Campaign in Phase 1, the team plans on integrating new features on the mug which will provide more consumer usability. Additionally, the team plans on outsourcing the design of the package, so that the user will be able to get the high quality feel of the product as soon as they receive the package.

Marketing:

Further marketing initiatives during phase 2 is explained in the section titled “Sales and Marketing”.

Phase 3:

This phase focuses on scaling production and nationally securing distribution partners.

Scaled Production:

A focus on scaling production by hiring new team members in both the manufacturing and marketing departments to scale production and awareness of the product on the national and international scale.

Distribution Partners:

If Phase 1 and Phase 2 are successful, distribution partners will need to be secured to further the awareness of the product. Further goals to talk to major market competitors such as Dunkin’ and Starbuck to both rent the patent for the pod structure and place the Phoenix Mug on their shelves will be achieved at this time.

Gantt Chart of Operating Plan:

Phase	Task	2022		2023		2024		2025	
1	R&D								
	Pre-Launch Marketing								
2	Initial Production								
	Marketing								
3	Scaled Production								
	Distribution Partners								

Market Analysis

According to IBISWorld, Consumers spent $46.2 billion on coffee in 2021 and has an economic footprint of 1.6% of the total U.S gross domestic products[1]. This figure is forecasted to grow at a Compounding Annual Growth Rate (CAGR) of 2.20% from 2021 to 2026[2]. More importantly it is also predicted that by 2025, 83% of spending and 21% of volume consumption will be attributed to out-of-home consumption[1]. According to the National Coffee Association (NCA), 62.0% of US adults drink coffee on a daily basis, 42% of which are aged 25-39[3]. From this analysis on the total addressable market, it can be concluded that entering this growing market will be an opportunity for sustainable profitability.

Within this large addressable market, our target demographic is focused on Gen X, Millennial, and Gen Z consumers who enjoy coffee and other warm beverages on the run. The team wanted to cater to a large demographic as we understood the misery of drinking cold and stale coffee after a long commute to work, paying $5 for a cup of coffee before class, and using complicated brewing devices on camping trips. Although this target audience is broad, many time-strapped consumers moved toward drinking gourmet instant coffee, which attributes to a high demand for portable coffee pods such as K-cups. Our product was also designed around fixing a flaw in the portable coffee industry as most competitors utilize single use plastic pods to hold the coffee. By creating a pod that can be used multiple times, the product will provide an alternative to competitors products, as ours will have a reduced environmental footprint. This shift will target the Millenial and Gen Z demographics.

Another significant aspect of the market is the barrier to entry. Although 47.2% of the market share is made up of Starbucks and Dunkin' brands[1], our team will only need to focus on the cost for building a network of suppliers, manufacturers, distributors and retailers, as well as material cost and intellectual property. Throughout this business plan, we will, or already have, addressed overcoming these barriers to entry.

Product

The Phoenix Mug is the first portable self contained, brewing and heating mug designed specifically for our consumers lifestyle. The ability to quickly brew everything from coffee, hot chocolate and tea anytime, anywhere has never been more accessible or convenient.. The product also includes a phone application where users can pair their mug directly to the app, giving them the capabilities to set the type of drink and brew directly on the application. Unlike other products on the market, we offer consumers an easy to use alternative to enjoy a hot beverage on the road while reducing their environmental footprint through reusable pods.

The product works by having the user prep the mug by filling the mug with water, and inserting a filled reusable pod into the cap. Whenever the user wants to brew a cup of coffee, they open their phone application, select the type of drink they want and press brew. From here, the mug will heat the water to the proper temperature and when the proper concentration is reached, the coffee is ready for consumption. The overall process is simple for the user and is designed with safety as the number one priority. ***Figure 1*** depicts the functionality of the Phoenix Mug. Additionally, the mug has the ability to self-clean if the user selects the self-clean on their app after they add water and a cleaning agent into the mug. Detailed drawings of our product can be seen in ***Figure 2*** and ***Figure 3.*** In the future, the company plans to provide multiple volume sizes by utilizing more advanced battery technology.

Competitive Analysis

When it comes to portability, environmental concerns, and ease of use, the Phoenix Mug has an advantage over its competitors. Most major competitors that promote self-brewing devices sell stand alone coffee makers where the consumer is bound to the location of the maker. Additionally, these competitors utilize single use plastics, which are harmful for the environment. Other competitors who promote self-heating mugs, only warm previously hot liquid. Leading competitions within the coffee brewing industry, such as Starbucks, Keurig, Nespresso, and Ember Mug, have managed to minimize consumer cost by reducing the unit cost due to scaling.

- A typical beverage drinker who buys starbucks, will spend \$6 per visit. Assuming they visit Starbucks 5 times a week, they would spend \$1,560 per year. Starbucks receives 37.8 million customers per month which accounts for 36.2% of the Coffee & Snack Shop market in the US[1].
- Keurig, owned by the Dr. Pepper Snapple Group, sells both the non-portable brewing mechanism and the single-use plastic coffee pods known as K-cups. The non-portable brewing mechanism will cost between \$60-\$250[4]. However, each pod will cost \$0.75. If the consumer drinks two cups a day, over the course of the year, they would spend \$547.50 on K-cups alone.
- Nespresso, owned by Nestle, sells both non-portable brewing mechanisms and single-use plastic coffee pods. The non-portable brewing mechanism will cost between \$150-\$600[5] and the average pod cost is \$1.15 for 7.77 ounces of coffee. If the consumer drinks two cups a day, over the course of the year, they would spend \$876 on the pods alone.
- The Spirited Mug, owned by HitModern, is a mug with a unique brewing process involving the use of a magnetic stirring rod. These mugs are individually priced at \$30[6]. The main drawbacks with this product are the lack of a heating system and the ability to only accommodate dissolvable freeze-dried coffee.

In order to successfully appeal to consumers, the Phoenix Mug both focuses on the creation of a new product which highlights the best features of each of the competitors while retaining the advantage of being eco-friendly. Outlined in ***Table 1***, Is a competitive analysis assessment which compares the competitiveness for the Phoenix Mug, Nespresso, Ember Mug, and Keurig. The Phoenix Team plans on filing a utility patent application for the ability to brew and heat up beverages in a portable mug. This will give the team a competitive advantage when it comes to producing a unique product. Filing a patent allows the company to claim the intellectual property of the Phoenix Mug's function and method of brewing. Having this type of leverage prevents other competitors from stealing the functions and drawings of each of the components to the mug.

Another factor to take into consideration is the longevity of the product itself. According to the manufacturers of our competitors, the life span for the Keurig and Ember mug are 5 and 6-8 years respectively[7]. Due to the simple design of the Phoenix Mug and the properties of the materials, the life span should be expected to extend to 14.5 years with the battery life being the limiting factor. The ability to have a life span that lasts more than double than the next competitor, gives the Phoenix Mug another competitive advantage.

Sales and Marketing

Since the Phoenix Mug is designed for a diverse age group, it is necessary to explore marketing strategies to capture each age group. A big marketing tool that our team intends to utilize is social media. Since the main target audience of our product is Gen X, Millennials, and Gen Z, social media is a great platform to use to increase awareness of our product. To capture Gen X and Millennials, Facebook ads will be utilized. To cater to Gen Z and Millennials, Instagram and TikTok will be the primary focuses of social media marketing.

Facebook advertisements are extremely popular and easy to use. The Ad Manager allows for our team to set a daily budget as well as what type of action will be paid for. These actions include views, clicks, and downloads[9]. For our ads, we would highlight the differences between our products and what is currently available. The main difference being that our product brews the coffee directly in a mug, which is a truly portable form that is not currently on the market. Additionally, some other features to highlight would be the reusable coffee pod and charging capabilities.

Additionally, The Phoenix Mug will utilize TikTok as part of its social media marketing. TikTok has become one of the biggest social media platforms. However, the advertisement process is a bit more expensive and caters towards large companies. However, the Phoenix Mug intends on creating a profile that will feature the product and participate in many viral trends as a way to reach Gen Z and Millennial audiences. Another way the team intends on using TikTok is through the use of influencers. By teaming up with influencers, it will allow for our product to reach even larger audiences. Additionally, there is a lot of evidence to support that using influencers as a form of marketing is extremely beneficial as recent surveys show 90% of respondents believe influencer marketing is an effective form of marketing[8].

In order to sell and distribute Phoenix Mug, we plan on using different methods as the company grows. To begin, we plan on using Kickstarter. Using Kickstarter will allow for pre-orders so that we can begin selling our product. As the company grows, we will first partner with small retail stores before moving up to major retail stores such as Walmart and Costco as well as using our own website and Amazon. In partnering with retail stores, we would have them sell our mug at their physical locations. Additionally, we will offer our product on our own website. At the beginning, we would limit the amount of mugs sold through our website to ensure a smooth shipping process. As the company grows, we will partner with shipping companies to allow for more sales to be made through our website. Due to its growing size, we are also planning on using Amazon to sell our mugs. As the product grows, there is potential to create custom pods to team up with coffee chains such as Dunkin and Starbucks, but that would likely not be explored until the company grew.

Management Team

Our management team consists of three mechanical engineering students at the College of New Jersey. Although we all have engineering backgrounds, each member of the team offers a wide-range of expertise to handle both engineering and business challenges. Each member is in contact with friends or family members in the business world who provide guidance on the appropriate estimations and business practices.

Managers:

Jason Rosen - Co-Founder, COO and CFO

Mr. Rosen is a senior mechanical engineering major with experience in product development and prototyping. He has expertise in finance and electronics. He is involved in a few clubs on campus including, the Professional Academic Society of Technical Advancement Club, the American Society of Mechanical Engineers (ASME), The Society of Professional Engineers (SHPE), Chess Club, and Theta Tau. He also has an affinity for adapting products to meet the consumers standards based on changing trends. Mr. Rosen's curiosity to be well rounded when it comes to creating a start-up will be useful when it comes to co-lead a successful team.

Jessica Ruby - Co-Founder and CMO

Ms. Ruby is a senior mechanical engineering major at The College of New Jersey and is involved in my different organizations on campus including Society of Women Engineers (SWE), American Society of Mechanical Engineers (ASME), Omicron Delta Kappa Honor Society (ODK), Tau Beta Pi Engineering Honor Society, and Professional Academic Society of Technical Advancement Club. Jessica holds leadership positions in SWE as treasurer and in Professional Academic Society of Technical Advancement Club as secretary. Her goal after college is to work as a design engineer and work her way up to program management.

Brett Murphy - Co-Founder and CTO

Mr. Murphy is a senior mechanical engineering major at The College of New Jersey who specializes in the design of the inner capsule as well as the pod and cap designs. Mr. Murphy uses his skills in solidworks and Ansys to accurately model the Phoenix Mug to ensure that all of the components are successfully integrated into the main assembly. Additionally, he is also involved in the American Society of Mechanical Engineers and serves as one of the Founding Fathers in the Kappa Delta Rho Nu Gamma Chapter. He is also involved in club sports as the shortstop and sergeant at arms on the TCNJ Club Baseball team.

Financial Plan

1200 units is the predicted unit production for the 2022 fiscal year. We plan on initially selling the mug at a retail price of $174.99 per unit . This price is competitive with other products in the home brewing and the portable mug markets. At this price point, the price will exceed the variable cost, which insures both long and short term profitability when scaled to higher volumes. Assuming production will begin in 2022, the income statement will project both sales and pricing for the fiscal 2022 year.

Phoenix Corporation
Income Statement
For the Year Ended December 31, 2022

		Total	Per Unit
Sales Revenue - Mug		209,988.00	174.99
Sales Revenue - Pod		57,600.00	4.00
Cost of Goods Sold			
Materials	82,560.00		
Labor	4,800.00		
Total COGS		87,360.00	72.80
Gross Profit		180,228.00	102.19
Operating Expenses			
Rent	25,935.00		
Equipment Purchased	2,000.00		
Marketing	8,000.00		
Overhead	2,500.00		
Total Operating Expenses		38,435.00	32.03
Operating Profit		141,793.00	70.16
Interest Expense		7,500.00	6.25
EBIT		134,293.00	63.91
Tax Expense			0.00
Net Income		134,293.00	63.91

As the income statement shows, given a sales volume of 1200 Phoenix mugs, the company will yield a net profit of $134,293.00 in 2022. The largest of the expenses being materials costing $82,560.00 per 1200 units and rent costing $25,935 (3,990 square feet at $6.50 per square foot per year). A total of $2,000 will be allotted to equipment. The team also plans on participating in a moderate to aggressive marketing campaign with a budget of $8,000. Additionally, a budget of $2,500 is given to overhead.

In order to support the initial cost of goods, the team will need to take out a 5-year loan of $100,000 at a 7.5% APR. Alternatively, to reduce personal liability, and improve the team's chances at getting seed money, the team plans on raising money through a campaign on Kickstarter. This will also provide a greater outreach through marketing.

It is estimated that it will take one working hour to produce 5 mugs which translates to 240 hours per all 1200 mugs. This results in a $4,800 labor cost at $20 per hour. Data from our income statement is then used as a basis for our projected balance sheet for the end of the 2022 year.

Phoenix Corporation Balance Sheet (USD) December 31st, 2021	
Assets	
Current Assets	264,293.00
Cash & Cash Equivalents	0.00
Accounts Receivable	0.00
Inventory	0.00
Supplies	264,293.00
Total Current Assets	
Long-Term Assets	
Property, Plant, & Equipment	2,000.00
Total Long-Term Assets	2,000.00
Total Assets	266,293.00
Liabilities & Stockholder's Equity	
Current Liabilities	
Accounts Payable	0.00
Notes Payable	0.00
Total Current Liabilities	0.00
Long-Term Liabilities	
Long-Term Debt	100,000.00
Total Long-Term Liabilites	100,000.00
Stockholder's & Equity	
Common Stock	0.00
Retained Earnings	166,293.00
Total Stockholder's Equity	166,293.00
Total Liabilities & Stockholder's Equity	266,293.00

The shown balance sheet is based on the assumption of winning $30,000 from the MBPC. All revenues are assumed to have been received and expenses paid in cash. Supplies and inventory are consumed through production and sales. The information on the cash flow statement is derived from the income statement and the balance sheet.

Phoenix Corporation Statement of Cash Flows For the Year Ended December 31, 2022		
Cash Flows from Operating Activities		
Cash Receipts from Operating Activities	209,988.00	
Cash Disbursements from Operating Activities	(123,795.00)	
Net Cash Provided by Operating Activities		86,193.00
Cash Flows from Investing Activities		
Purchase Equiptment	(2,000.00)	
Net Cash Provided by Investing Activities		(2,000.00)
Cash Flows from Financing Activities		
Business Loan	100,000.00	
Interest Expense	(7,500.00)	
Net Cash Provided by Financing Activities		92,500.00
Net Increase in Cash		176,693.00
Cash at Beginning of Period		30,000.00
Cash at End of Period		206,693.00

The investments made in the production equipment will allow for an increased production in the 2023' financial year. Additionally, the team will have a total of $206,693.00 by the end of the 2022 year. A near total distribution of the cash flow will be re-invested to insure continued operations as a $22,000 per year will be taken out to pay off the loan. With this cash flow, a projected unit production of 2300 is predicted. Overall, this business model will yield a projected cash flow of $299,502.00 in 2023. Since, the limiting factor in production is labor, if 25 people are employed for 40 hours per week, the Phoenix team can produce 261,000 mugs per year. As shown in ***Table 2***, Assuming sales could match capacity, this volume will achieve an EBIT of $39,153,655.00.

Conclusion

The Phoenix Mug is the first portable self brewing and heating coffee mug. The product combines aspects of both portable coffee mugs and self-heating mugs to make a user-friendly mug that can brew coffee within itself. This eliminates the stress of getting ready for work and prevents the user from drinking cold coffee during their long commute. The Phoenix Mug has a wide audience range and will be joining a $46.2 billion industry. Our product aims to allow the user to brew the perfect cup of coffee anytime and anywhere. Overall, through the support of the Mayo Business Plan Competition, Phoenix Mug has great potential for future growth.

Table 1: Competitive Strength Assessment

Competitive Strength Assessment (rating scale: 1 = very week, 10 = very strong)										
		Phoenix Mug		Nespresso		Ember Mug		Keurig	
Key Success Factor	Importance Weight	Strength Rating	Weighted Score	Strength Rating	Weighted Score	Strength Rating	Weighted Score	Strength Rating	Weighted Score
Retail Presence	0.1	7	0.7	10	1	8	0.8	10	1
Environmental Sustainability	0.15	9	1.35	4	0.6	7	1.05	3	0.45
Ease of use	0.15	8	1.2	5	0.75	8	1.2	6	0.9
Portability	0.15	10	1.5	2	0.3	10	1.5	2	0.3
Price Point	0.15	4	0.6	7	1.05	6	0.9	8	1.2
Self-Brewing	0.15	10	1.5	10	1.5	0	0	10	1.5
Maintain Heat	0.15	10	1.5	0	0	10	1.5	0	0
Totals	**1**		**8.35**		**5.2**		**6.95**		**5.35**

Table 2: Income Statement for Maximum Manufacturing Capacity (25 employees)

Phoenix Corporation Income Statement For the Year Ended December 31, 2022			
		Total	**Per Unit**
Sales Revenue - Mug		45,672,390.00	174.99
Sales Revenue - Pod		12,528,000.00	4.00
Cost of Goods Sold			
Materials	17,956,800.00		
Labor	1,044,000.00		
Total COGS		19,000,800.00	72.80
Gross Profit		39,199,590.00	102.19
Operating Expenses			
Rent	25,935.00		
Equipment Purchased	2,000.00		
Marketing	8,000.00		
Overhead	2,500.00		
Total Operating Expenses		38,435.00	0.15
Operating Profit		39,161,155.00	102.04
Interest Expense		7,500.00	0.03
EBIT		39,153,655.00	102.01
Tax Expense			0.00
Net Income		39,153,655.00	102.01

Figure 1: Schematic of Product Functionality

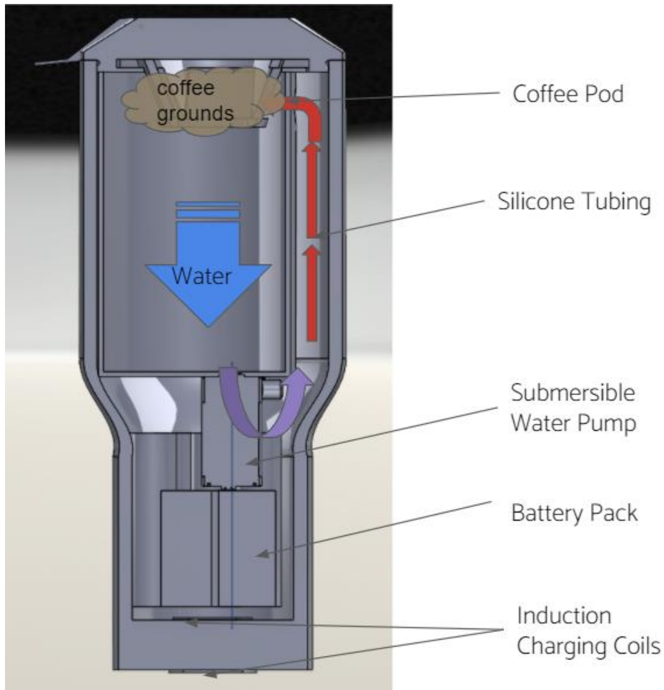


Figure 2: CAD model of Phoenix Mug

Figure 3: Expanded CAD model of Phoenix Mug

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