GNG1103

Design Project User and Product Manual

HEAT MASTER 3.0

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Table 1. Glossary

Term	Acronym	Definition
Arduino Uno	Arduino	"**Arduino Uno** is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button" (Arduino Uno rev, 2021)

1 Introduction

This User and Product Manual provides the information necessary for individuals to effectively use the Heat Master 3.0 and for prototype documentation. This manual will go through an overview of the product, set-up and usage, troubleshooting and support and tests done on the prototype. A general understanding of the prototype parts and how the prototype functions will be explained to anyone choosing to purchase, set up/deploy, maintain or remove the product. For security and privacy considerations, it is necessary to purchase the Heat Master 3.0 to have access to the user and product manual contents.

2 Overview

A need exists for the University of Ottawa to deploy portable heated sidewalks that can melt snow and ice providing a safer environment for all on-campus while maintaining environmental sustainability and being cost-effective.

The fundamental needs of the user were to design a heated sidewalk that is safe, sustainable, and cost-efficient.

Compared to other heated sidewalks currently on the market, ours is one of few that is removable. Most of them are permanent products that require a lot more work for installation and maintenance.

Figure1. Image of the completed prototype.

This product melts snow in 5 seconds in a wide temperature range while being light and easily storable, quick and simple to set up, easily cleanable, and user friendly.

This product operates via an Arduino, an outlet, a switch, and a temperature and humidity sensor. The mat is connected to an outlet that only turns on if the temperature sensor senses a temperature of 0°C or less. The outlet can also be made to run power by manually flipping the switch.

2.1 Cautions & Warnings

Prior to the usage of the Heat Master 3.0, it is necessary to understand that the improper handling of electricity through the sidewalk's outlet can lead to injury or even death.

3 Getting started

The simplicity of the Heat Master 3.0 only requires its cord to be plugged into an outlet to turn on and unplugged to turn off.

3.1 Set-up Considerations

The system is made of a heating pad encased in a wood material covered in rubber. This is plugged into an Arduino-controlled outlet.

Table 2. Specifications of the Heat Master 3.0

Specifications	Values
Input Power	110-120V
Output Power	1500W
Output Capacity (Energy Used)	Maximum 10A
Weight	3 lbs
Dimensions	57 cm in length x 29.4 cm in width x 3 cm depth/height
Material	3D model wood material (box) and rubber (surface)
Cost	$96.98
Temperature Range	-50℃ to 110℃

3.2 User Access Considerations

This design was made with user access as our top priority. It can withstand being walked on, ran on, jumped on, and wheeled on. It is also very thin so that somebody with a wheelchair can easily get on it. Similarly, bikes would easily be able to ride on it. It is expected that it would be put in put in emergency exits for the use of students and professors.

3.3 Accessing the System

To turn on the system, the outlet connected to the Heat Master 3.0 needs to be plugged into an outlet. Immediately, the sidewalk would be ready to start working. Depending on its external environment's temperature, the heated sidewalk would turn on/off accordingly. The switch connected to the Arduino could also be pressed to manually turn on/off the Heat Master 3.0 regardless of the surrounding temperature.

3.4 Exiting the System

To turn off the Heat Master 3.0, one simply has to unplug the cord connected to the heated sidewalk from the outlet. One can also turn on/off the heated sidewalk by the press of the button located on the switch connected to the Arduino.

4 Using the System

This section will go in-depth on how to use the Arduino system and properly connect everything.

4.1 Arduino/Wiring

When it comes to connecting the Arduino and the coding of it, this is a simple system. For the Arduino, a total of 8 pins is required to connect the DHT22 and 5V relay to the Arduino. Instructions for connection are below with diagrams provided.

1. Connect pin 1 of the DHT22 to the positive side of the breadboard, pin 2 of the DHT22 to digital pin 7 and pin 4 of the DHT22 to GND on the Arduino.
2. Take another pin and connect it from the positive side of the breadboard to 5V on the Arduino.
3. Next, take one pin and connect it from the GND on the 5V relay to digital pin 8. Now take two pins and connect them to INS and INS2 on the 5V relay. Then connect either one of the pins to the positive side of the breadboard and the negative side of the breadboard. With that, the wiring is done and the breadboard/Arduino should look similar to the figure below.

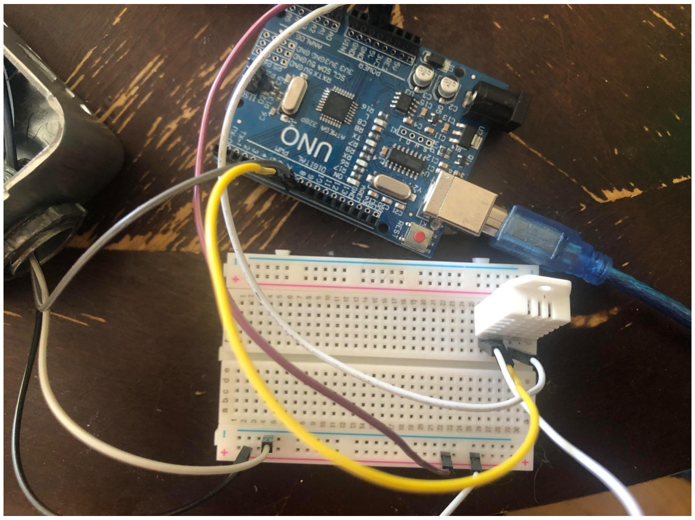
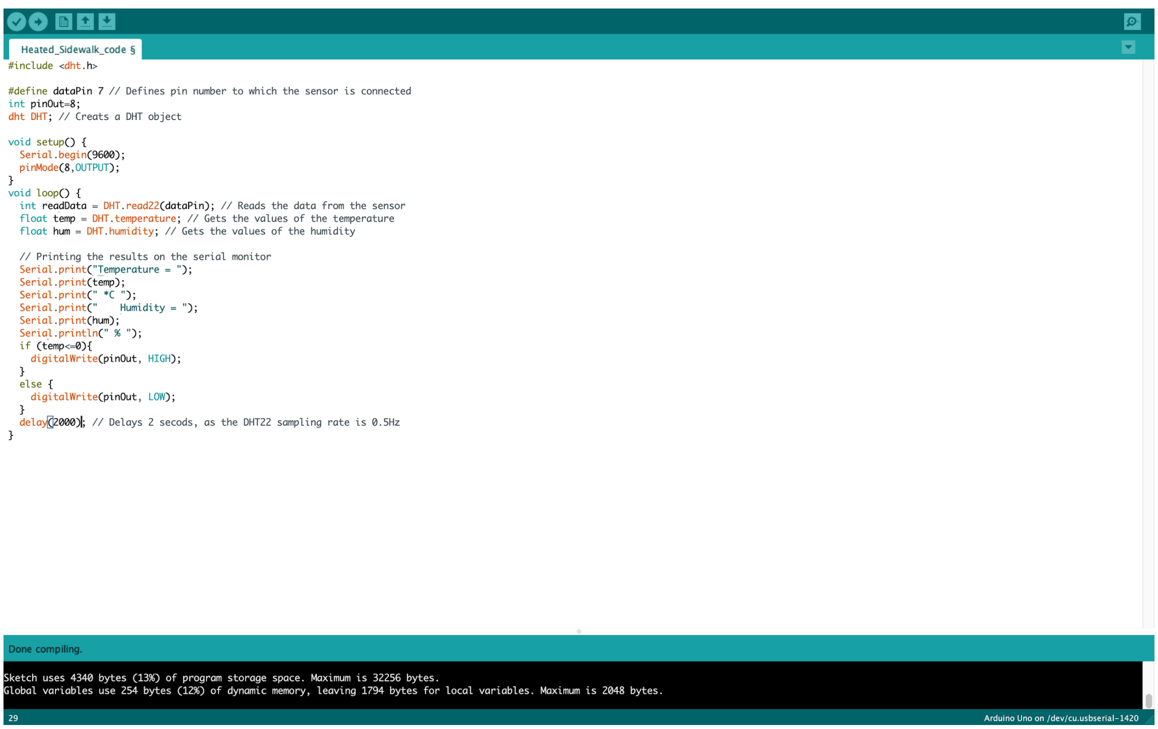


Figure 2. The wiring for the Arduino and outlet looks

4.2 Arduino/Coding

The code for the Arduino is also simple to code and input. The code is provided below and simply needs to be inputted into the Arduino IDE software.




```
#include <dht.h>

#define dataPin 7 // Defines pin number to which the sensor is connected
int pinOut=8;
dht DHT; // Creats a DHT object

void setup() {
  Serial.begin(9600);
  pinMode(8,OUTPUT);
}
void loop() {
  int readData = DHT.read22(dataPin); // Reads the data from the sensor
  float temp = DHT.temperature; // Gets the values of the temperature
  float hum = DHT.humidity; // Gets the values of the humidity

  // Printing the results on the serial monitor
  Serial.print("Temperature = ");
  Serial.print(temp);
  Serial.print(" *C ");
  Serial.print("    Humidity = ");
  Serial.print(hum);
  Serial.println(" % ");
  if (temp<=0){
    digitalWrite(pinOut, HIGH);
  }
  else {
    digitalWrite(pinOut, LOW);
  }
  delay(2000); // Delays 2 secods, as the DHT22 sampling rate is 0.5Hz
}
```

Figure 3. Code for the Arduino that controls the outlet.

5 Troubleshooting & Support

Errors that could potentially occur for the Heat Master 3.0 include coding errors, wiring problems, and any frame/surface issue. With a coding error, the heated sidewalk may occur to be off despite being in the necessary temperature range to be on For a wiring issue, the heated sidewalk can appear to be not powered or it could potentially damage the socket that it is connected to. For issues with the frame/surface of the heated sidewalk, the surface may deflect due to excessive weight and damage to the inner system of the sidewalk may occur.

5.1 Maintenance

Doing regular weekly cleaning by washing the surface **only** with soap and water using a cloth. This is to avoid a long-term accumulation of dirt done to the surface of the heated sidewalk.

5.2 Support

For problems regarding coding/wiring, contact Anabui Ogah at aogah096@uottawa.ca
For problems regarding the frame/surface, contact Mackenzie Conrad at mconr051@uottawa.ca

Caution
If any urgent issue occurs with the outlet, please seek professional help from an electrician. Any incorrect wiring could potentially short the outlet and could damage some important parts inside the outlet.

6 Product Documentation

The final prototype was initially supposed to be made of a metal material. Upon arrival at the Makerspace, one of the people there recommended the wood material that the prototype is made of now. He recommended that material because it would not melt due to the heat of the mat and it is water-resistant so the snow would not damage it. We were also originally planning on an Arduino-controlled outlet which we did and it functioned fine. Suddenly it stopped working due to a poor connection. We ended up rebuilding the outlet and it worked perfectly fine. We ensured that all of the wires were properly connected so the same problem would not reoccur. The coding part of the sidewalk was quite difficult. We first obtained the code from a website (Campbell, 2020). After testing that code, the output from the sensor was always 0. After messing around with the wiring and code for many days, we got the code to work and output the correct numbers. The functional code can be seen in Figures 3 or 10.

6.1 Subsystem 1 of prototype

6.1.1 BOM (Bill of Materials)

Table 3. Bill of materials of purchased items used for the Heat Master 3.0

Item	Price ($)	Tax ($)	Total ($)	Place of Purchase
Rubber Paste	17.97	2.34	20.31	Home Depot
Electrical Outlet	2.66	0.35	3.01	Home Depot
Electrical Outlet Box	1.65	0.21	1.86	Home Depot
Connector	7.98	1.04	9.02	Home Depot
Heat Mat	33.49	-	33.49	Amazon
Temperature Sensor	12.98	-	12.98	Amazon
Appliance Control	8.99	-	8.99	Amazon
Power Strip	6.49	0.84	7.33	Amazon

Links for Materials:
Rubber Paste -
https://www.homedepot.ca/product/flex-paste-flex-paste-black-1-lb/1001577638
Electrical Outlet -
https://www.homedepot.ca/product/leviton-decora-tamper-resistant-receptacle-white/1000660070
Electrical Outlet Box -
https://www.homedepot.ca/product/iberville-utility-box-2-3-8-in-wide-1-7-8-in-/1000106170
Connector -
https://www.homedepot.ca/product/iberville-1-1-2-in-loomex-cable-connector/1000138194
Heat Mat -
https://www.amazon.ca/BAOCHEZZ-Thermostat-Controller-Propagation-Certified/dp/B08S417JGH?pd_rd_w=IiVhF&pf_rd_p=daebd3a6-ea9d-4b90-bdf3-c56d27b97604&pf_rd_r=CD4FW4CS8YEFWFS410D4&pd_rd_r=5d0ec6ad-7f9a-47fb-a701-a214eee766c2&pd_rd_wg=Etb7k&pd_rd_i=B08S417JGH&psc=1&ref_=pd_bap_d_rp_5_i

Temperature Sensor -
https://www.amazon.ca/gp/product/B06Y63YMSS/ref=ox_sc_act_title_6?smid=A34K5WF5Z9R33P&psc=1
Appliance Control -
https://www.amazon.ca/gp/product/B073HX1DK2/ref=ox_sc_act_title_5?smid=A18L48XDTDF0CW&psc=1
Power Strip -
https://www.amazon.ca/gp/product/B077VV4GQC/ref=ox_sc_act_title_2?smid=A3DWYIK6Y9EEQB&psc=1

6.1.2 Equipment list

- 1 x Heat mat
- 1 lb x Rubber paste
- 1 x Arduino
- 1 x Temperature and humidity sensor
- 1 x Appliance control sensor
- 1 x Electrical outlet
- 1 x Electrical outlet box
- 2 x Connectors
- 1 x Power strip
- 2 sheets plywood
- 1 x Putty knife
- 1 x Laser cutter
- 1 x Wirecutter
- 1 x Small screwdriver
- 1 x Scissors

6.1.3 Instructions

The step-by-step process on building the outlet:

1. Take the electrical outlet box ordered and punch in both the front or back parts. After that, install the NS/ME connector. After doing so the electrical box should look like this.

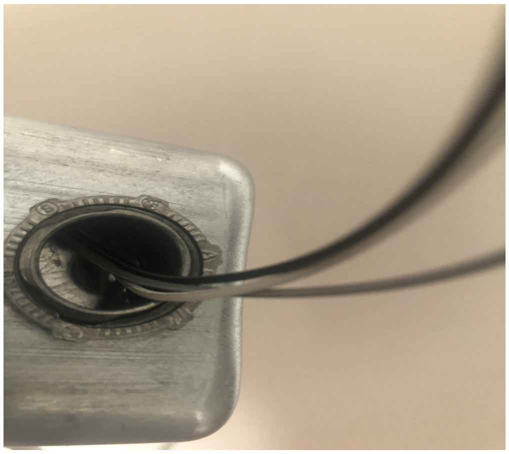


Figure 4. Image of NS/ME connector on the outlet

2. Next, cut the power strip where the red switch meets its end. Then starting from the first cut, cut around 4-6 inches of the white plastic around the cord. Doing this should reveal the green, white and black wires.
3. Cut 4 inches of the black wire. Cut the plastic around the black, green and white wires that are connected to the power strip so that it reveals the copper wires inside. You should have removed ¾ of an inch in total.
4. Now take the black wire that you initially cut off and remove ¼ inch of plastic on both of the ends.
5. Take one end of the cut-off black wire and insert it to the C terminal of the 5V relay.
6. Now take the power strip cord and pull it through the front or back hole of the electrical outlet box.
7. After completing step 6, take the black wire that is connected to the cord and place it in the common C terminal of the 5V relay. After doing steps 3-7 your outlet should look similar to the image below.

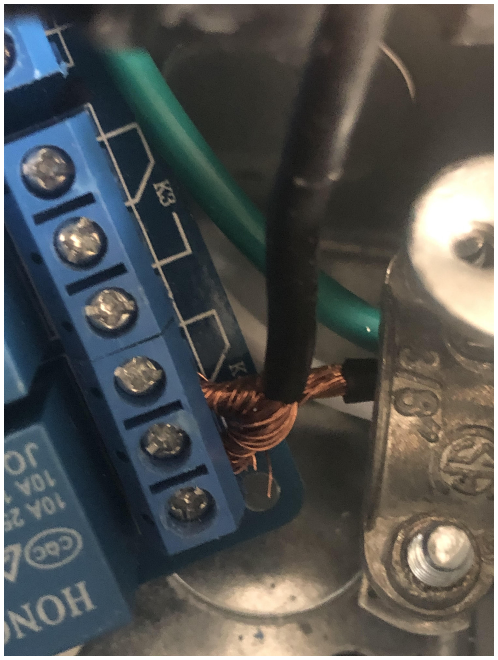


Figure 5. Image of 5V relay with black wires connected to it.

8. Next. take the green wire and wrap the copper wires around the green screw on the outlet and screw it tightly. On the same side of the outlet, wrap the shite cord and wrap it around the white screw and screw it tightly to the outlet. On the right side with gold screws, take the other end of the black wire that is connected to the C terminal of the relay repeat the same process as done for the green and white screws. After completing this process the outlet should look like this.

Figure 6. Image of the gold side of the outlet

Figure 7. Image of the silver side of the outlet

9. Lastly, tuck the relay inside the outlet box and screw the outlet onto the box. The final product should look like this.

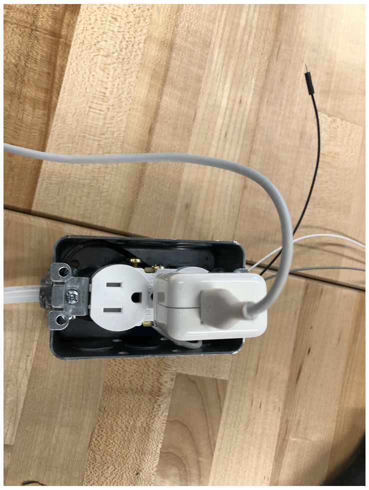


Figure 8. Image of the completed Outlet.

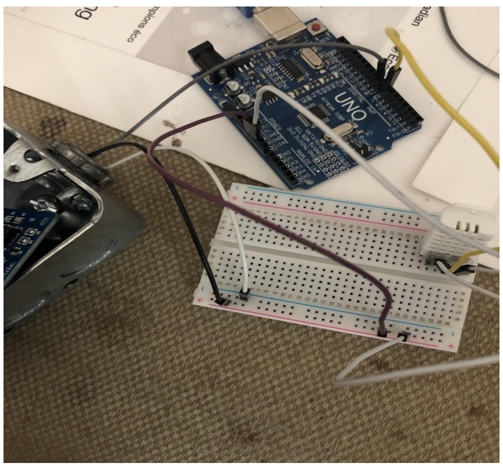
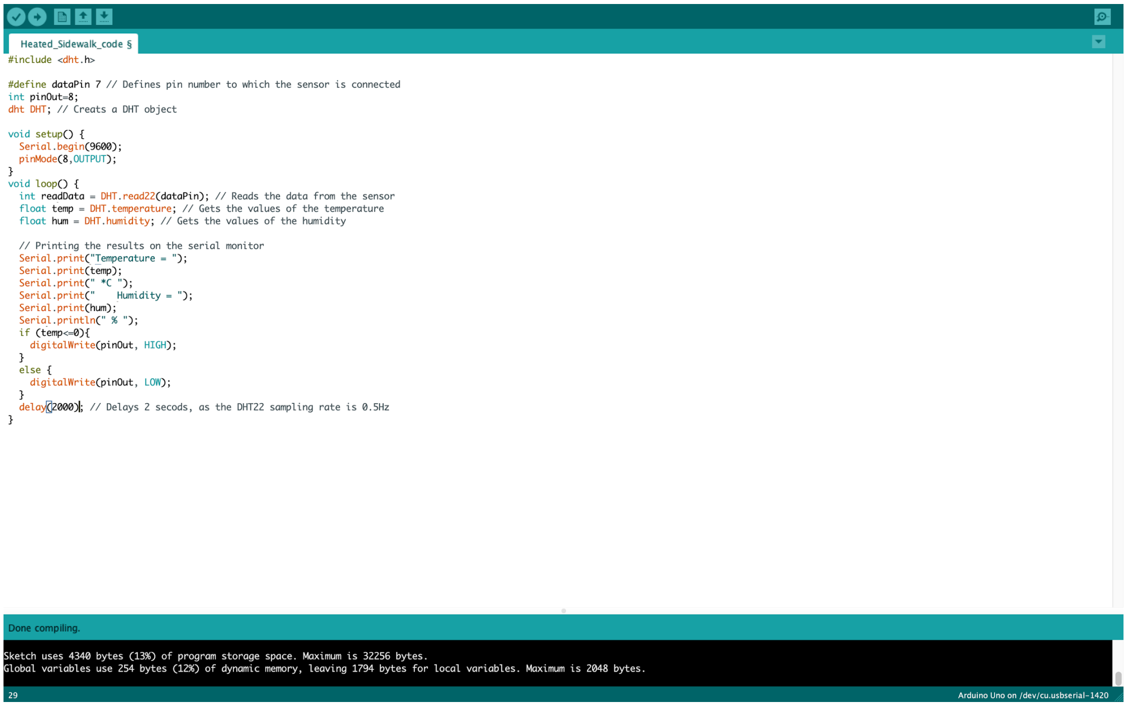


Figure 9. How the wiring for the Arduino and outlet looks




```
#include <dht.h>

#define dataPin 7 // Defines pin number to which the sensor is connected
int pinOut=8;
dht DHT; // Creats a DHT object

void setup() {
  Serial.begin(9600);
  pinMode(8,OUTPUT);
}
void loop() {
  int readData = DHT.read22(dataPin); // Reads the data from the sensor
  float temp = DHT.temperature; // Gets the values of the temperature
  float hum = DHT.humidity; // Gets the values of the humidity

  // Printing the results on the serial monitor
  Serial.print("Temperature = ");
  Serial.print(temp);
  Serial.print(" *C ");
  Serial.print("    Humidity = ");
  Serial.print(hum);
  Serial.println(" % ");
  if (temp<=0){
    digitalWrite(pinOut, HIGH);
  }
  else {
    digitalWrite(pinOut, LOW);
  }
  delay(2000); // Delays 2 secods, as the DHT22 sampling rate is 0.5Hz
}
```

Figure 10. Code for the Arduino

With these steps done, the outlet should be able to turn on and off depending on the temperature you want. The temperature can be changed by simply changing the number 0 in “if (temp<=0)”. All that’s left to do is plug the sidewalk into the outlet and it should be good to go.

To make the actual heated sidewalk 10 in x 20.75 in

1. Start with a wood slab that is approximately 57 cm in length, 29.4 cm in width and 5 cm in height.
2. Once you have the wood slab of the measurements mentioned in step 1, you now want to cut out a hole in the slab that is approximately 52.7 cm in length, 25.4 in width and 3 cm in height. Also cut a hole on the shorter side of the rectangle so that the plug has a place to go through.
3. Now drill one small hole in one of the corners for the right side and diagonally do the same for the side on the left.
4. Finally, place the heating pad inside the wood slab and cover only the entire surface but the holes in rubber paste. The entire can of rubber paste should be used when covering the pad. The final product should look like the figure below.

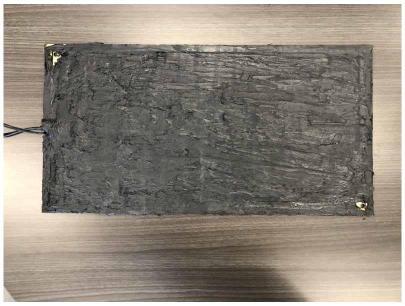


Figure 11. The final look at the heated sidewalk.

With that last step, your heated sidewalk is now ready to operate. Just plug it into the premade outlet, set the temperature to tell it when to turn off and you have now made the Heat Master 3.0.

Note: If there are any problems with the building and operation of the sidewalk please refer to 5, 5.1 and 5.2 for troubleshooting support and steps to take to handle your problem.

6.2 Testing & Validation

Several tests were conducted on the Heat Master 3.0 to test its capabilities and limitations.

Table 4. The Heat Master 3.0's final test plan.

Test ID	**Test objective** **(Why)**	**Description of the prototype used and of the basic test method** **(What)**	**Stopping criteria**
1	Deflection of the sidewalk and the weight capacity **De-risking**	This was tested by placing weights at certain points of the sidewalk and verifying if there is an unneeded bend on the surface. Cost estimate ≅ $0 Physical test.	300 pounds

2	Signal of the Arduino **Functionality**	This is testing to make sure the Arduino code is properly sending signals to the wiring and the pins are set up properly. Cost estimate ≅ $0 Physical and analytical test.	Arduino code goes through and the heated sidewalk reacts accordingly.
3	Attachment of sidewalk to the ground **Functionality**	This test is to see if the sidewalk is properly secured to the ground when deployed. When deployed we can observe the sidewalk in high winds, running, walking, etc. and note any unexpected movement. Cost estimate ≅ $0 Physical test.	When the sidewalk can attach to the ground and other sidewalks without dangerous or unsafe movement.
4	How long it takes to heat up to the desired temperature **Learning**	This test measures how long the sidewalk takes to heat up to the desired temperature range. Cost estimate ≅ $0 Physical test.	When the desired temperature range is reached and maintained.
5	If heated sidewalk melts snow (near) instantaneously. **Functionality**	This test measures if the heated sidewalk does indeed melt snow as it falls. Cost estimate ≅ $0 Physical test.	When the snow has melted on the mat within a few seconds of contact with the surface of the mat.

The following results were obtained for the tests described above:

Table 5. Results obtained from tests done on the Heat Master 3.0 with any shortcomings/ commentary noted.

Test ID	Test Description	Results	Notes
1	Deflection of sidewalk	The sidewalk was walked on and jumped on by every individual on our team on every corner of the mat. It showed no sign of deflection or bend. We also wheeled a regular chair over it with one of our members seated on top of it (simulating a wheelchair) and the mat remained in its initial structure throughout the test.	-
2	Signal of Arduino	The Arduino receives signals from the humidity and temperature sensor and thus, activates the Heat Master 3.0 accordingly.	-
3	Attachment of the sidewalk	The sidewalk upon attachment should not move as the pins would hold it in place adequately.	We didn't have the physical pins but they were designed for on CAD with careful thought of the geometry of the sidewalk in mind.
4	Time to heat mat	To get from 24.7℃ to 27.7℃, it took 4 minutes 37 seconds and 78 milliseconds.	This was done inside at room temperature which made it easier to melt the snow. Also, the mat already started at a relatively warm temperature so that decreased its necessary temperature gradient.
5	Heated sidewalk melts snow	Snow from outside was brought onto the heated sidewalk and it almost instantaneously melted the snow. It was recorded to have melted the snow in 5 seconds.	This was also done at room temperature so that influenced the time it took to melt the snow to some extent.

Additional Notes:

Temperature test

To melt a small pack of crushed ice, it requires 5 seconds and to recover the temperature lost it takes another 5 - 10 seconds. Knowing that snow falling from the sky is way smaller than the pack of crushed ice that we used, the energy required is less. Therefore the time for melting and temperature recovery is way less.

Weight capacity test
For this test we had five adults walking over the prototype for two minutes straight and had some of them stand on every part of the prototype; we concluded the prototype can handle the weight of a couple of persons and the inner part where wires belong are protracted properly.

Draining system test
By tilting the prototype after it accumulated a certain amount of water, we were able to get the angle necessary for the prototype to drain its water. Considering the angle is a bit higher can potentially cause problems to the handicap community, we had to use an angle that drains water a little slower due to a less tilted angle.

Looking at the notes and commentary provided, it is evident that there were shortcomings in the tests conducted. For the first test, we did not use extremely heavyweights to test the maximum deflection of the sidewalk. In the future, implementing that would give users and creators of the heated sidewalk a better idea of its strength. As for the signal of the Arduino, the temperature and humidity sensor did end up working and detecting the surrounding temperature and as such, turning on/off the Arduino. For the manual override, however, since it's operated by a switch connected to the Arduino, anyone who wants to turn on/off the Heat Master 3.0 has to go outside physically and press the switch. In the future, creating a program in the form of a website or app such that one can turn on/off the heated sidewalk from their phone or laptop would be a major improvement. In terms of the attachment of the sidewalk, because our budget did not permit the purchase of the pins which would hold the heated sidewalk down, we were unable to test this feature. In the future, obtaining the pins and installing the sidewalk to the pre-existing sidewalk and testing its ability to stay in place would fulfill this criterion. The team required to heat the mat could be better tested if the mat were to already be outside in cold temperatures and then the time required to heat it would be taken. That would simulate the real activity that would occur. The same would apply for the last test conducted, testing the melting functionality of the mat at real temperatures would give a better gauge of the Heat Master 3.0's ability.

7 Conclusions and Recommendations for Future Work

In the future, LED lights activated by a photosensor attached to the Arduino can be added to the side of the Heat Master 3.0 for better visibility in the dark. This will make the sidewalk much safer and usable any time of the day. Adding a program connected to the Heat Master 3.0 to track its current temperature as well as turn it on/off using a website or application would further our design significantly. Having the heated sidewalks that are used in emergency exits have green rubber would also be beneficial as it would distinguish the emergency exits and the colour green calms people when they are in a state of panic. In terms of testing, adding UV and corrosion tests for the Heat Master 3.0 and testing its performance with regular usage for some time would enable a better understanding of the performance and longevity of the product.

All of our prototype upgrades help address the problem statement initially founded. The mat is a cost-effective way to melt snow and ice efficiently while being safe for everyone. It is operated by a heating pad covered in a rubber material controlled by an Arduino with a temperature sensor. The steps to build the prototype are: build the outlet, cut the wood material to fit the heating mat, put the mat in the wood mould, cover the top with the rubber material, connect the Arduino to the outlet, copy the Arduino code into the Arduino IDE software and finally plug in the mat into the outlet. The cost of this prototype is $96.98. The tests helped us upgrade our previous prototypes to the comprehensive Heat Master 3.0.

8 Bibliography

Arduino Uno Rev3. Arduino Uno Rev3 | Arduino Official Store. (n.d.). https://store.arduino.cc/usa/arduino-uno-rev3.

Campbell, S. (2020, July 15). *Turn any appliance into a smart device with an Arduino-controlled power outlet*. https://www.circuitbasics.com/build-an-arduino-controlled-power-outlet/.

APPENDICES

8 APPENDIX I: Design Files

Table 6. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
MakerRepo Repository	https://makerepo.com/tebaatr/796.gng1103thespartansgroup9heatedsidewalk	March 9, 2021
Sidewalk Commercial	https://www.youtube.com/watch?v=i9JUF1QIfFw&t=1s	March 29, 2021
Arduino Controlled Outlet	https://www.circuitbasics.com/build-an-arduino-controlled-power-outlet/	July 15, 2020
Arduino Definition	https://store.arduino.cc/usa/arduino-uno-rev3	2021