CADD 216
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Vancouver, WA
98663

2/25/2020

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1933 Fort Vancouver Way
Vancouver, WA
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Subject: **FireBot Project**

Dear Professor Kysar;

This report outlined below is the final deliverable for the assignment assigned by you at the beginning of this quarter.

This report outlines our design and prototyping process for the engineering competition this quarter. We have included designs and all the necessary calculations and simulations to determine the feasibility of our design.

Thank you for taking the time to read this report and please don’t hesitate to respond with any questions.

Sincerely,

CADD 216

Matthew Walker, Patrick Foley, Steven Shepard, Versha Carter, Chris Reisner & Robert Langlois

CADD 216 - Engineering Competition (FireBot)

Team: CADD 216

Steven Shepard - Tech Specialist
Patrick Foley - Recorder
Matthew Walker - Project Lead
Versha Carter - Recorder
Robert Langlois - Reflector

Submitted to
Professor Kysar
CADD 216

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Executive Summary

This report finalizes our solution to the engineering competition. In it, we have detailed our design process. Starting with our intent and brainstorming. The next sections show our drawings and Solidworks models and simulations that we created to help in the solution. This also shows our coding direction and outlines our thought process behind that. The next section shows the calculations we did to test our design ideas. We ran multiple equations and simulations to help understand the loads happening in the cup/arm servo so we didn't overload the electronics and to check for heat resilience of the assembly. After the competition, we added some considerations for our next iteration should there be one.

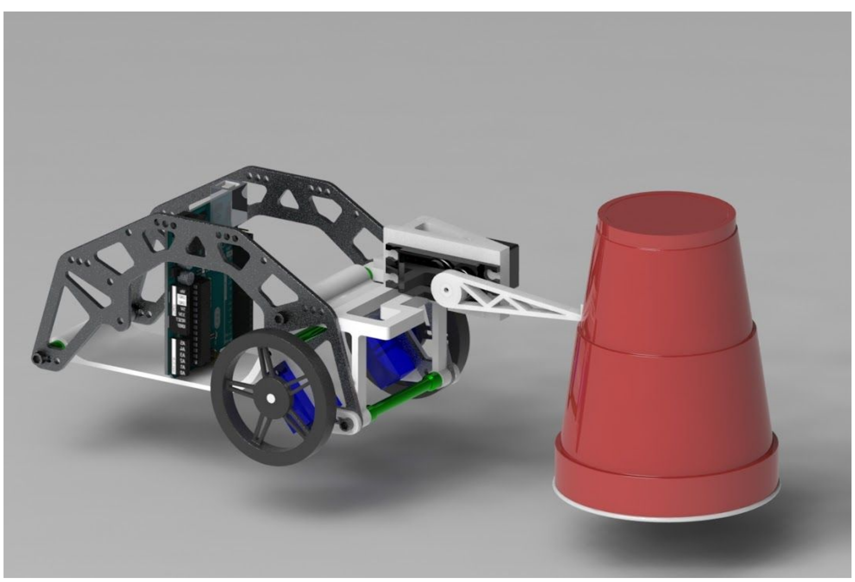
Introduction

This report was created by Team CADD 216 to show our design and testing process for the engineering competition during the Winter 2020 quarter at Clark College. The competition required an autonomous robot to navigate a simulated classroom environment and then smother an electronic tea light that is meant to simulate a real fire. The difficulty lies in the programming of the robot. This is the team's first real attempt at programming with Arduino so the learning curve was steep but by dividing our tasks amongst the team we were able to accomplish the goals outlined in the project guidelines. Included in this report are the calculations used to check the servos and the material that we chose were adequate. The 3D models were designed to test our ideas are also included to show the level of complexity we achieved in our assemblies.By utilizing 3D printing to create a lot of our parts and assemblies making prototyping and geometry corrections a breeze. The robot was complete and was able to compete in the engineering competition (placing second overall) on March 6th and the report deliverables were ready before March 13th showing the team did well with staying on task and delegating responsibilities.

Design Documentation

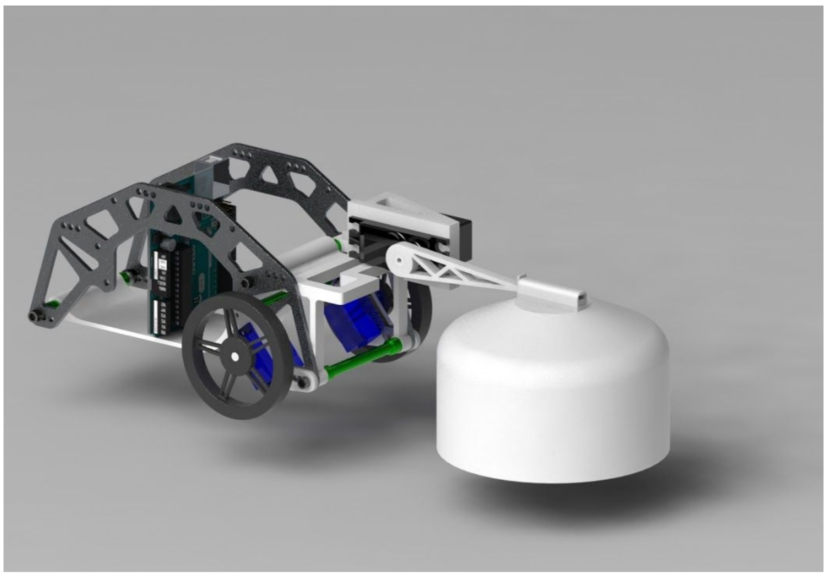
Initially, the team had a solid idea to make a simple 2 wheel drive robot that rotates in place too turn. During further discussion 3 iterations on this concept and how to extinguish the candle were discussed they are listed below.

Fig. 1 - Concept (solo cup too big)



The initial design concept had 2 ultrasonic sensors and 2 light sensitive diodes. The plan was to use the ultrasonic sensors to map the room while the robot ran an object avoidance algorithm. It would be using the light sensitive diodes to search for the tea light as it maps the room and avoids objects scattered about. As the team worked through this the lack of coding caught up and realized the scope was much too large.

Fig. 2 - Concept 2 (not accounting for tealight on box)



For the final iteration we went with a simple distance calculation approach. By first calculating how far each wheel turns every millisecond, then utilizing autocad we recreated the floor plan and plotted a coordinate system within the floor plan. Knowing the distance needed to travel then dividing by wheel speed would give us the milliseconds needed to move the distance needed. To turn a simple command for the wheel servos to turn opposite each other for a certain time period.

By deciding to go with the top mounted servo it simplified our coding process. It allowed for centralized placement of the cup making aiming the robot and cup easier. By also making sure the arm was just long enough to set the cup right in front of the nose to further help the placement accuracy.(Fig. 3)

Fig. 3 - Final Design

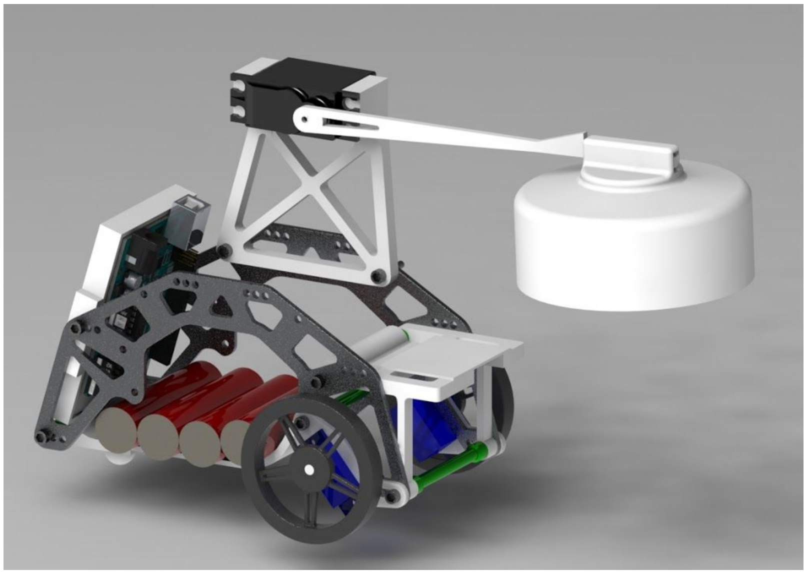


Table 1 - Bill of Materials

Item	*Cost $ USD*	*Quantity*	*Retailer*
Wheel Motors/servos	*13.89*	*1 (pkg 2)*	*Amazon*
Arm Servo	*8.91*	*1 each*	*Amazon*
¼" Aluminum Tubing	*.20 per/inch*	*6 inches*	*Hobby lobby*
PLA plastic	*.029 per/gram (3.625)*	*125 grams*	*Amazon*
Raspberry Pi	*8.91*	*each*	*eBay*
Arduino	*3.83*	*each*	*eBay*
Breadboard	*5.69*	*each*	*Amazon*
Jumper Wires	*8.49*	*1 set*	*Amazon*
Aluminum Frame	*16.00*	*1 (2 pcs)*	*Axial.com*
Frame Assembly Screws	*3.00*	*1 pkg (12 pcs)*	*Axial.com*
Total$	*73.55*		

Discussion & Calculations

Since most of the parts for the robot were old bits and pieces the team had laying around. To check for smooth operation running our calculations on the arm servo and cup assembly. As this was the most static of our assemblies and the most crucial to success. By utilizing a free body diagram, knowing the torque of the servo, the weight and dimensions of arm and cup. We were able to calculate the Stress and Load (to verify correct material choice and thickness) in the arm. We calculated deflection of the arm under loaded conditions (to verify the robot would not break or drop the cup due to deflection). These calculations told the team that the arm would buckle before deflecting. Adding thickness helped this. We also found our original servo to be lacking in torque so we then ended up using a bigger servo in the final design iteration.(Fig.4)

Calculation Variables:

- Arm weight - 2 gram
- Cup Weight - 28 gram

- 1gram = 0.0098 N
- 0.27 N

- Arm Length - 158.75 mm

- SERVO TORQUE 280 oz/in
- 1 oz/in = 7.06 N/mm force

- 1,977.23 newton millimeters (N mm)

Fig. 4- Showing FBD load/ shear/ moment diagram of loaded arm

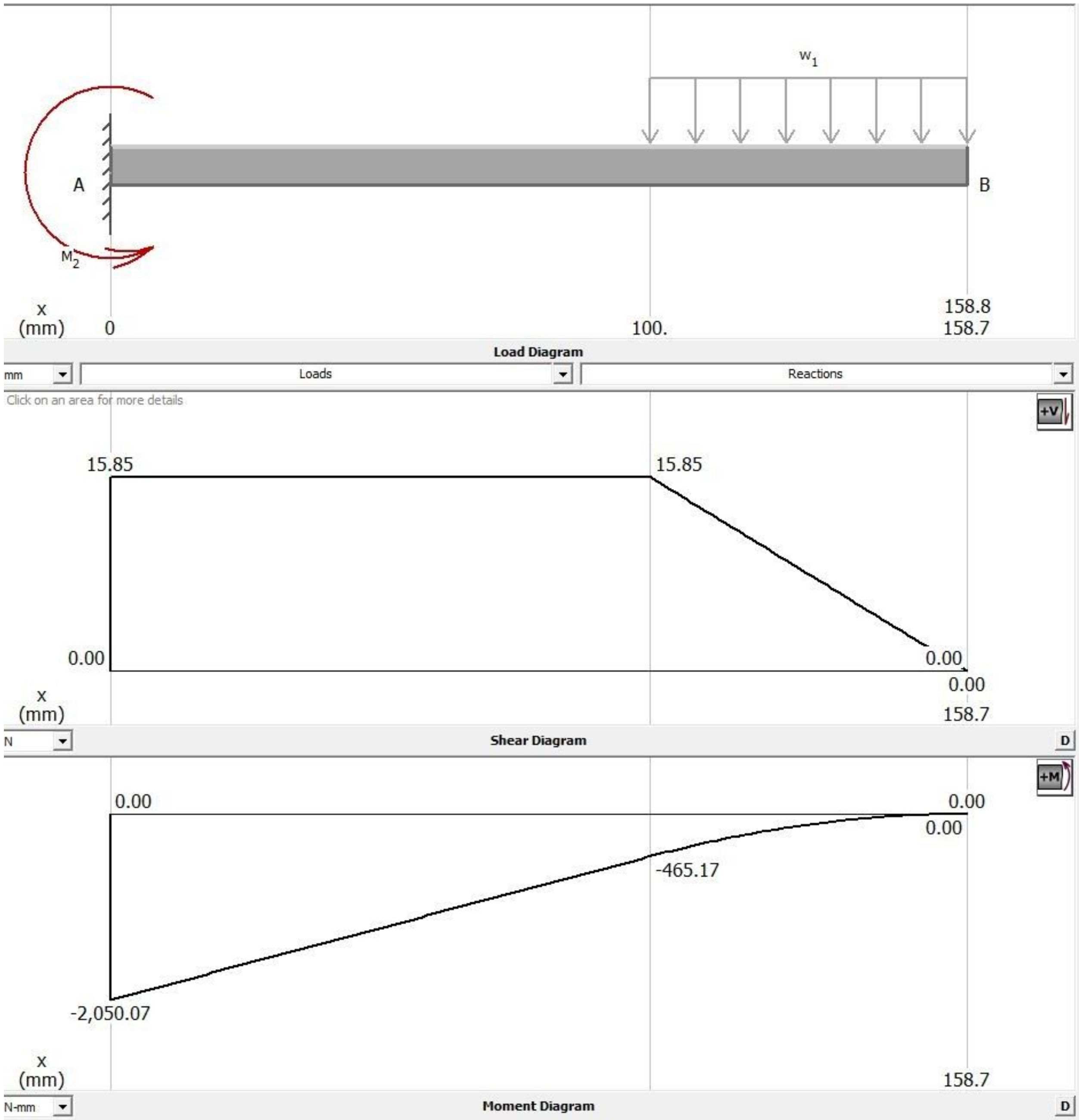


Fig. 5 - Turning Calculations

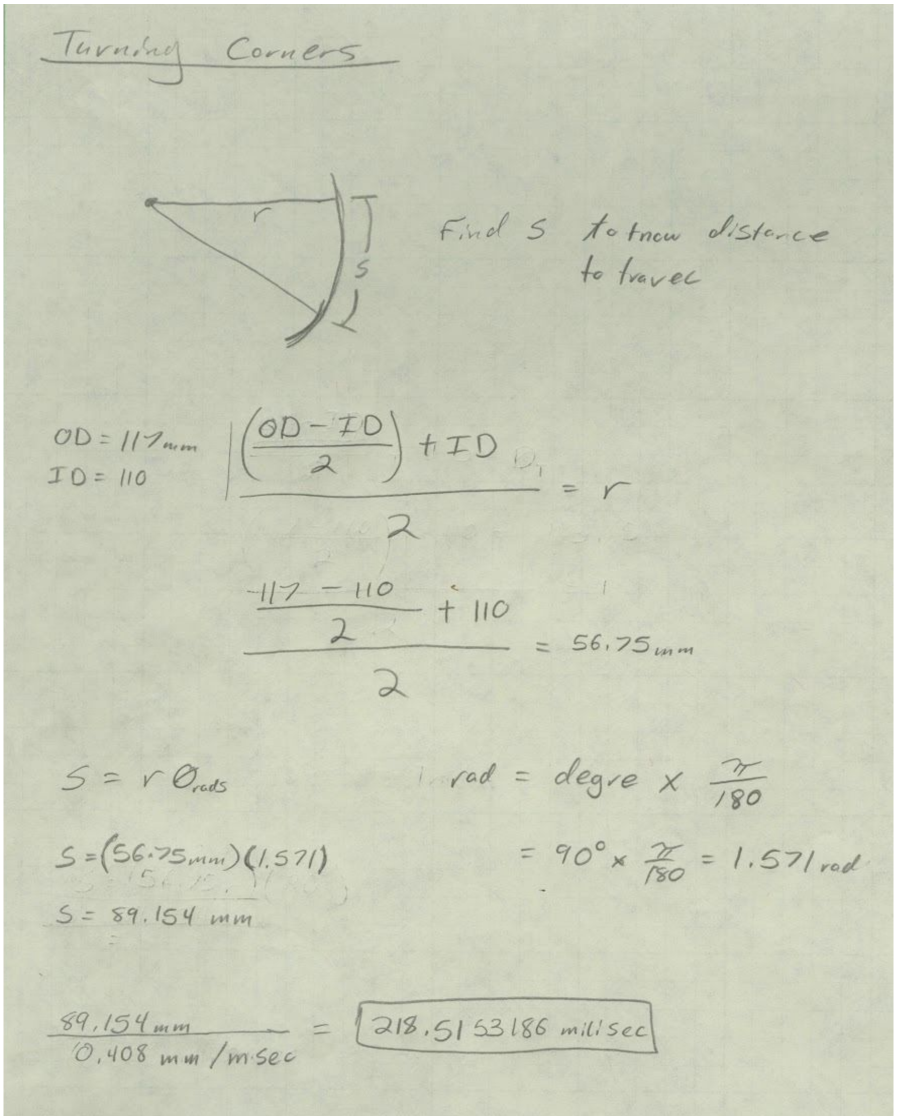
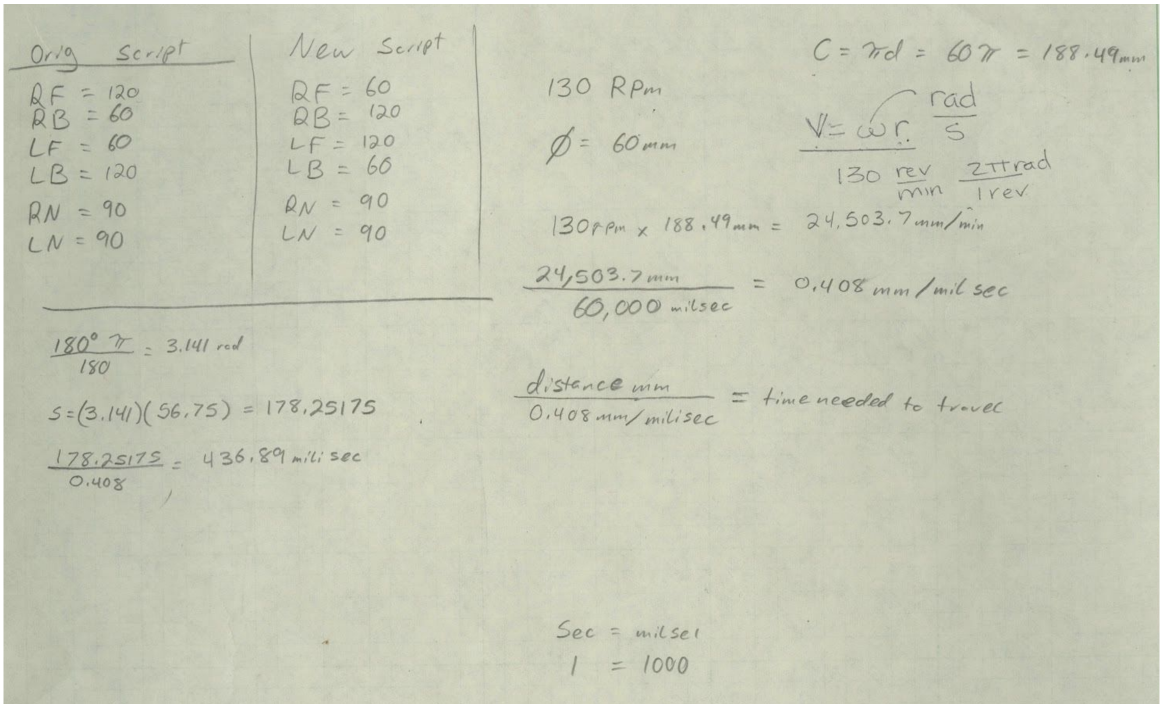


Fig. 6 -Distance calculation



Below are the results of the simulations we ran to check the feasibility of our final design in real world situations. The first simulation exercise we ran was to test the load and deflection of the loaded arm and cup. We found it to be well within the competition boundaries. The next simulations were run to test the safe temperatures that the robot could operate in. Real world applications with a fire would complicate our robot as most of our parts are made of ABS. We decided to test the wheel as they were most crucial to the success of the mission if they melted to the point they got stuck to the floor. We concluded that the wheels would fail at around 200 degrees so future iterations would have to move away from plastic as a material used.

Fig. 7 - Wheel failure @ 200 degrees

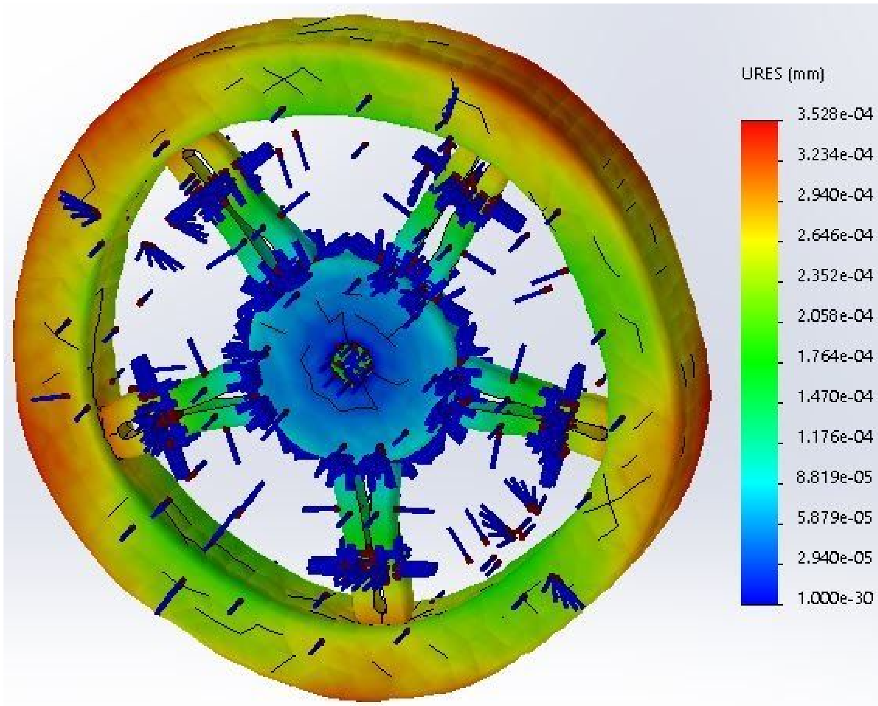


Fig. 8 - Wheel @ 100 degrees

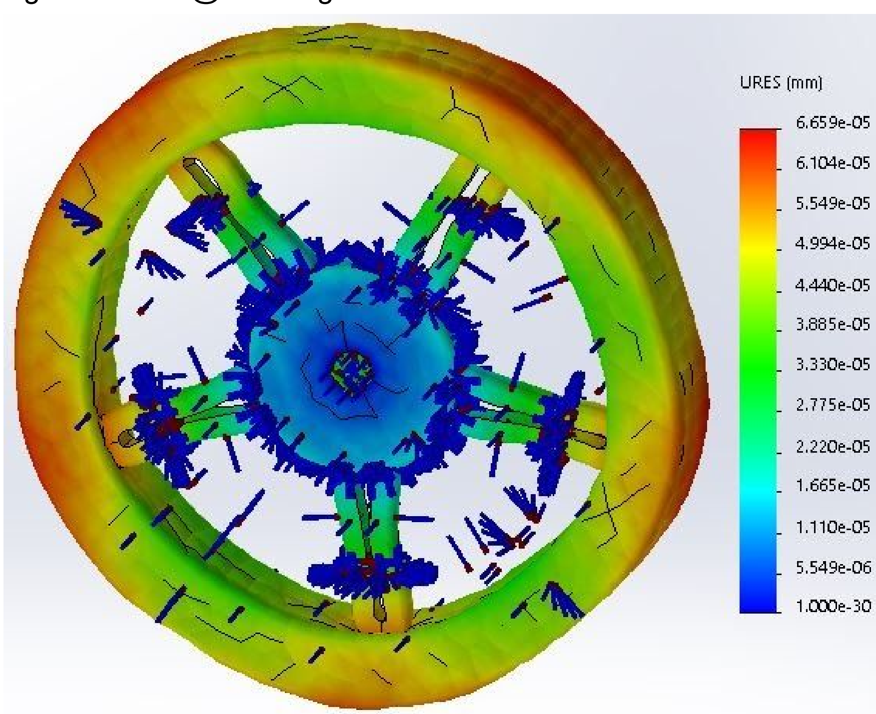
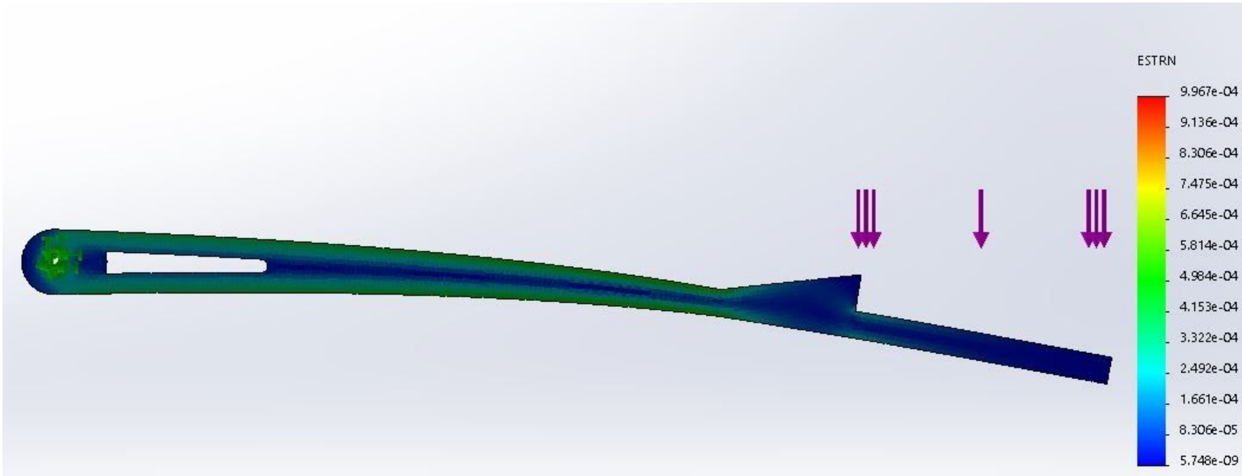


Fig. 9 - beam deflection showing minimal movement (.00009967 mm)



Testing and Analysis

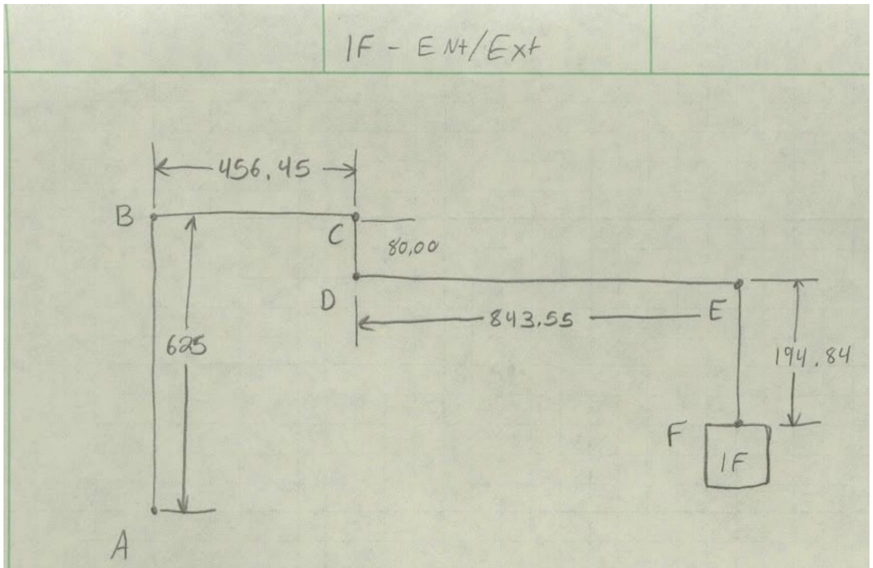
During testing the team found that the servos were not spinning at the same rate due to voltage differences; by adjusting the voltage by using a multimeter and slowly moving the potentiometer on the wheel servos until they both were reading the same voltage. During the competition our robot continued to list along its path showing the fix did not solve the servo problem. Also during the competition it was easy for the bot to tip as it was quite top heavy. Analysing our performance during the competition the team was happy with the success achieved.

Conclusion & Recommendations

To conclude this report. This team began this project with no coding knowledge and a bit of apprehension on how to attack the problem. After the initial team meeting where we delegated responsibilities, went over everyone's strengths and got the final version of the competition rules. The team was confident we would at least move over the start line. This was a challenging and fun project. After coming second in the competition it proved the viability of our robot. The biggest obstacle to overcome was the servo motors not spinning at the exact same rate so the robot listed to one side or the other as it moved. The next iteration would upgrade to stepper motors. Allowing finer control of the motors while knowing what position the robot was left facing. Also on competition day the robot kept getting stuck on walls to avoid this crafting a bumper or fascia on the robot would allow it to slide against obstacles. To make a real world application of this design we would have to upgrade to an all metal build with protection for the electronics. Thank you for your time in reading this report, Team CADD216 is looking forward to applying these skills to our sustainable futures.

Appendix

Map and distance calculation's Firespot 1



AB. $\frac{625}{0.408} = 1,531.86$

BC. $\frac{456.45}{0.408} = 1,118.75$

CD. $\frac{80.0}{0.408} = 196.078$

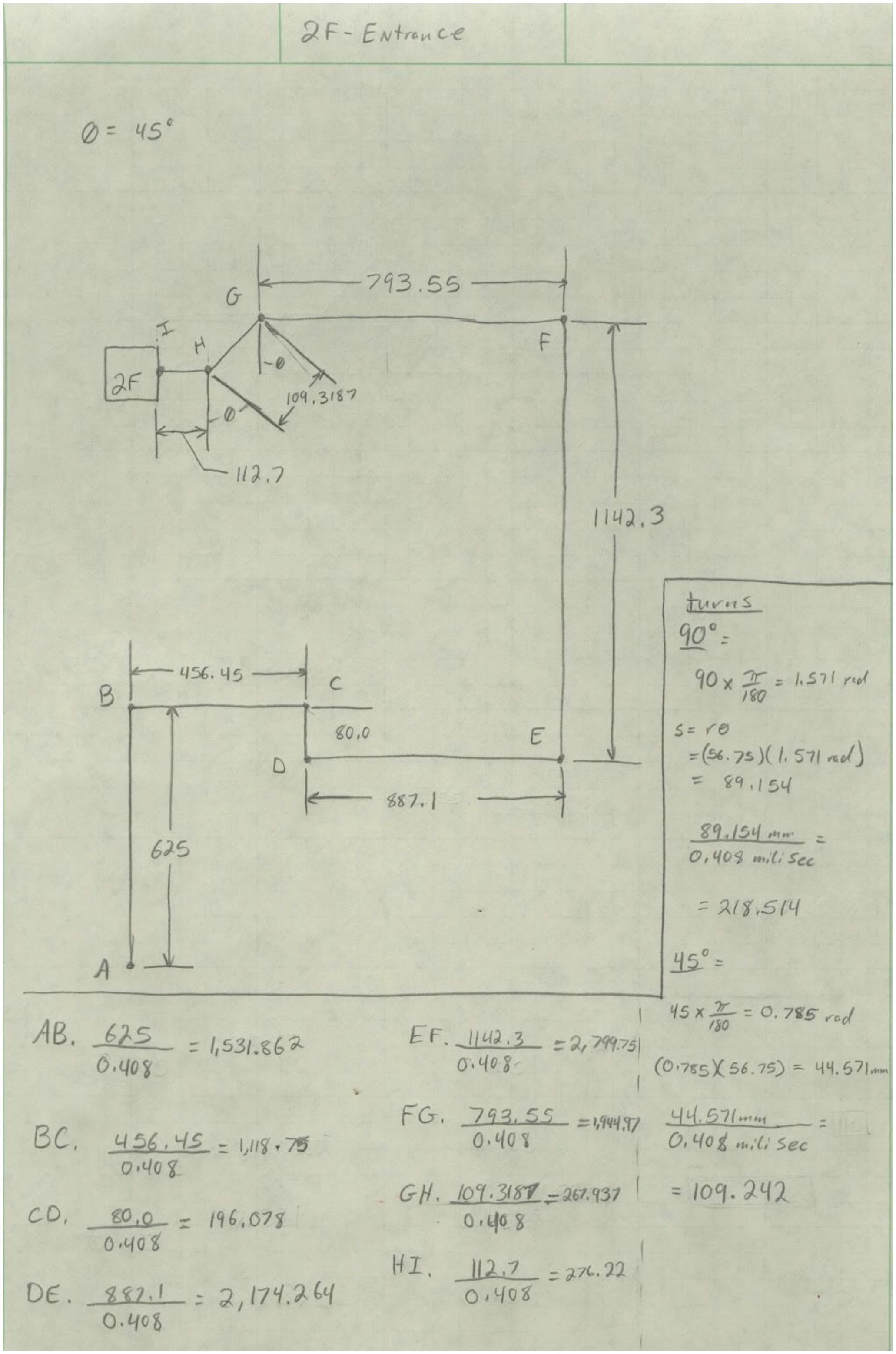
DE. $\frac{843.55}{0.408} = 2,067.52$

EF. $\frac{194.84}{0.408} = 477.549$

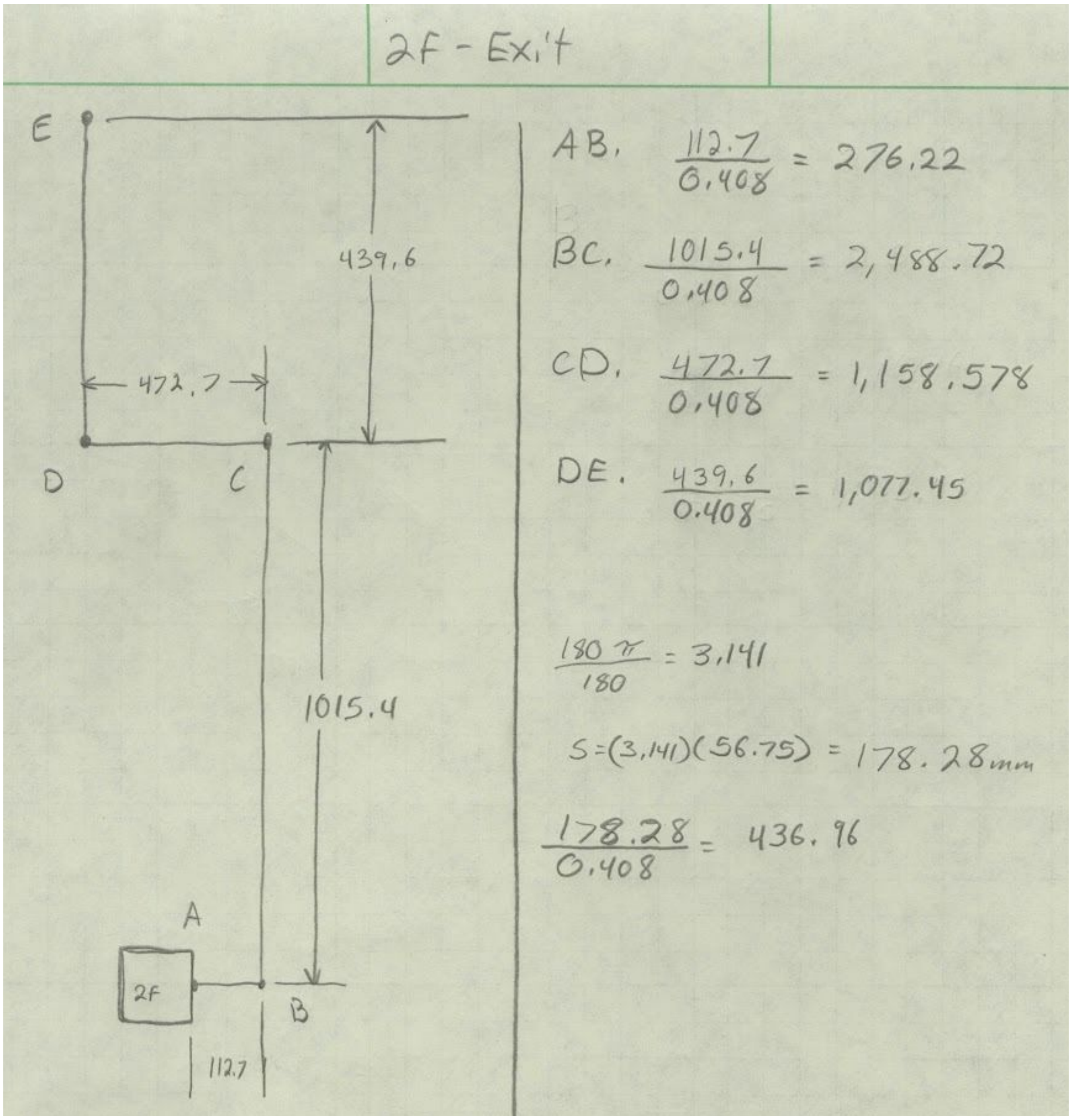
B-Exit

$\frac{2440}{0.408} = 5,980.392$

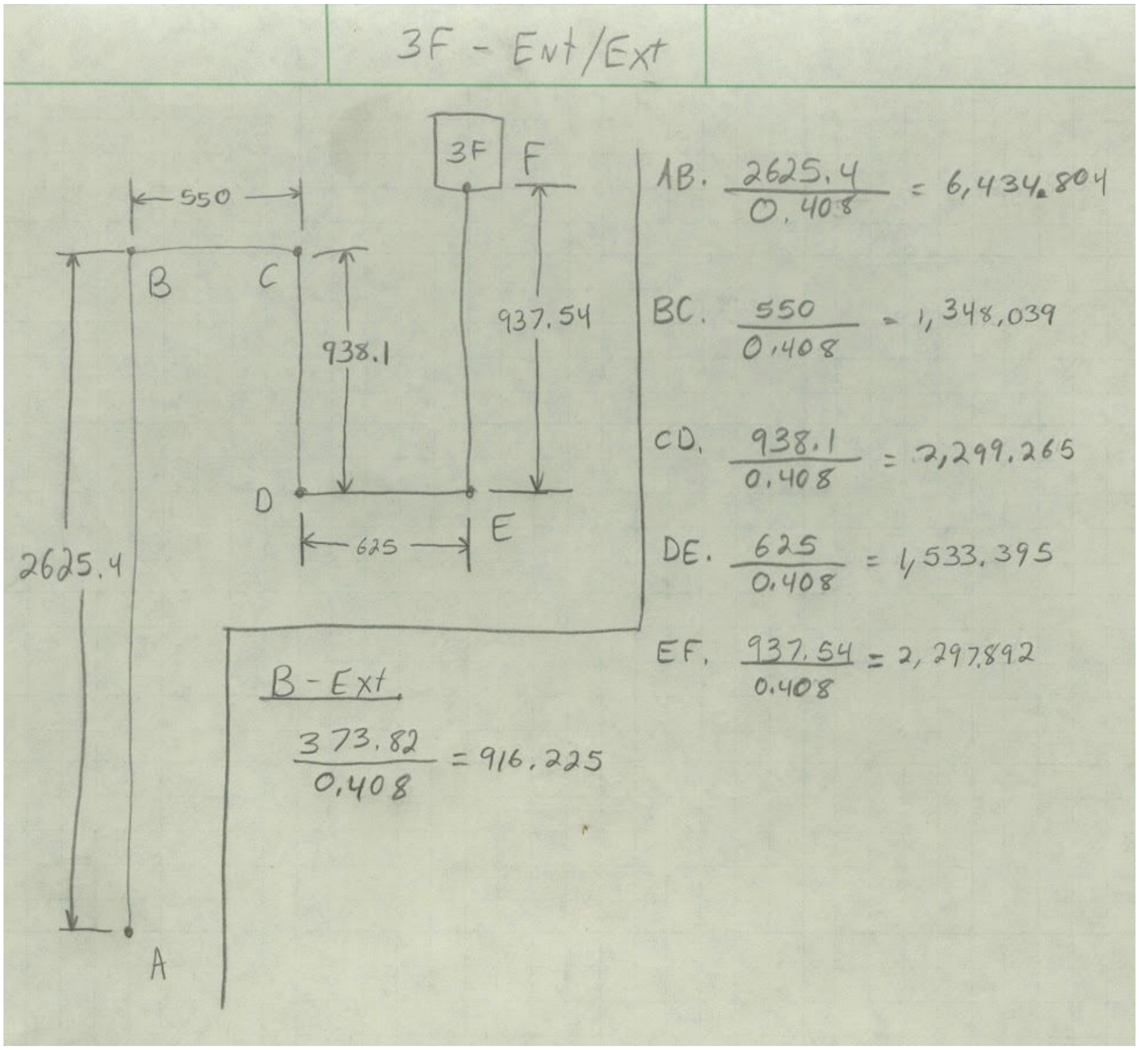
Map and distance calculation's Firespot 2 entrance



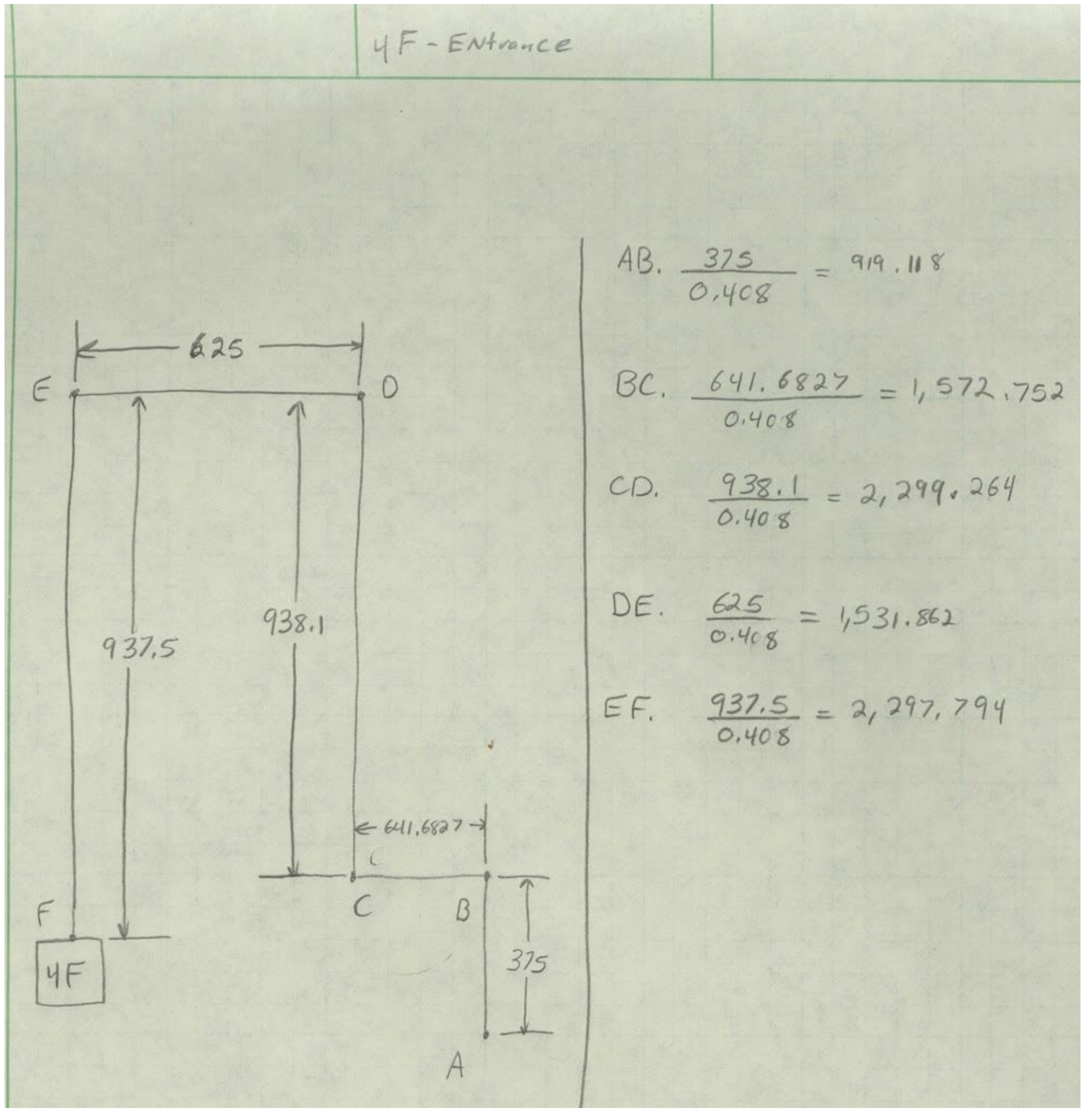
Map and distance calculation's Firespot 2 exit



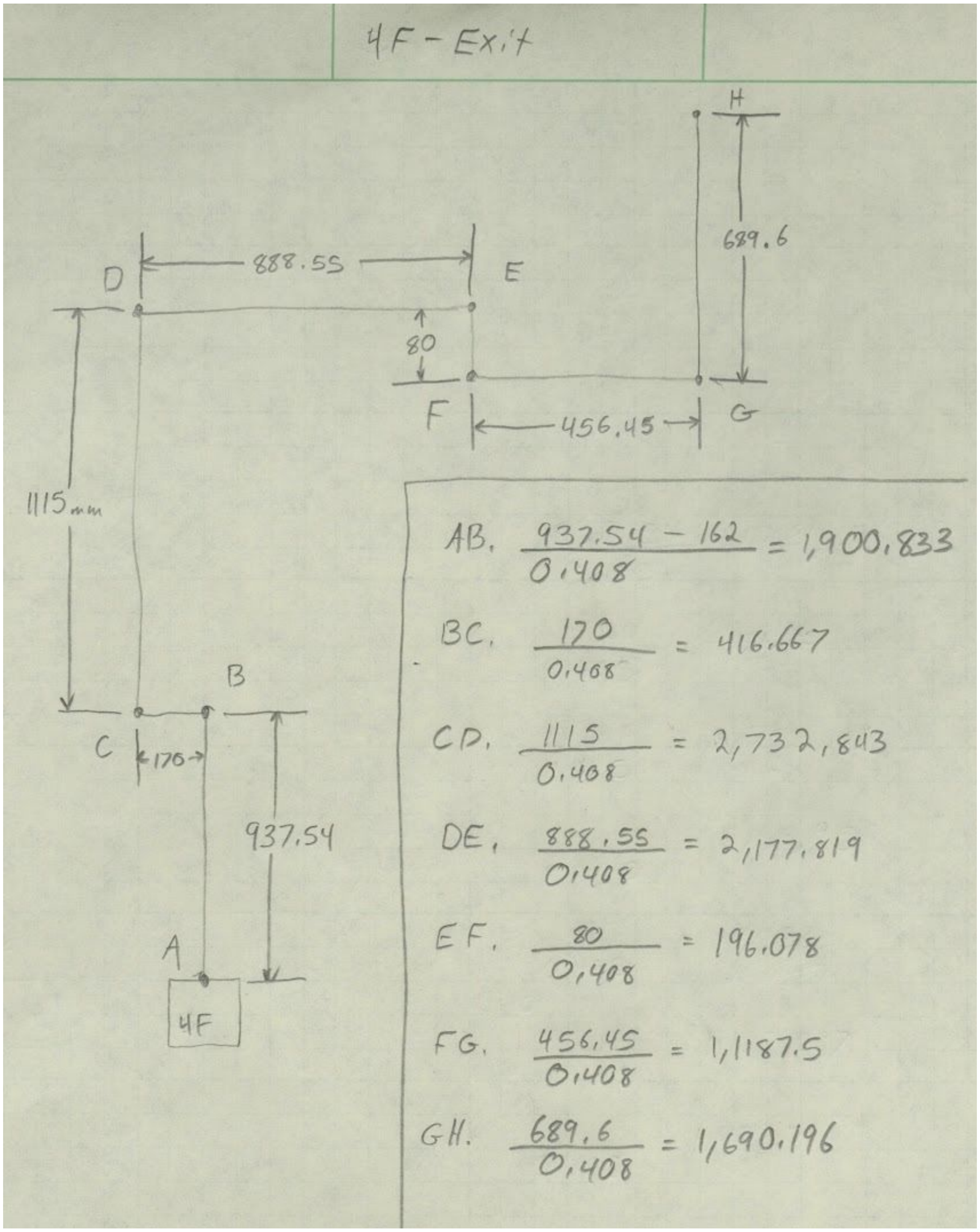
Map and distance calculation’s Firespot 3



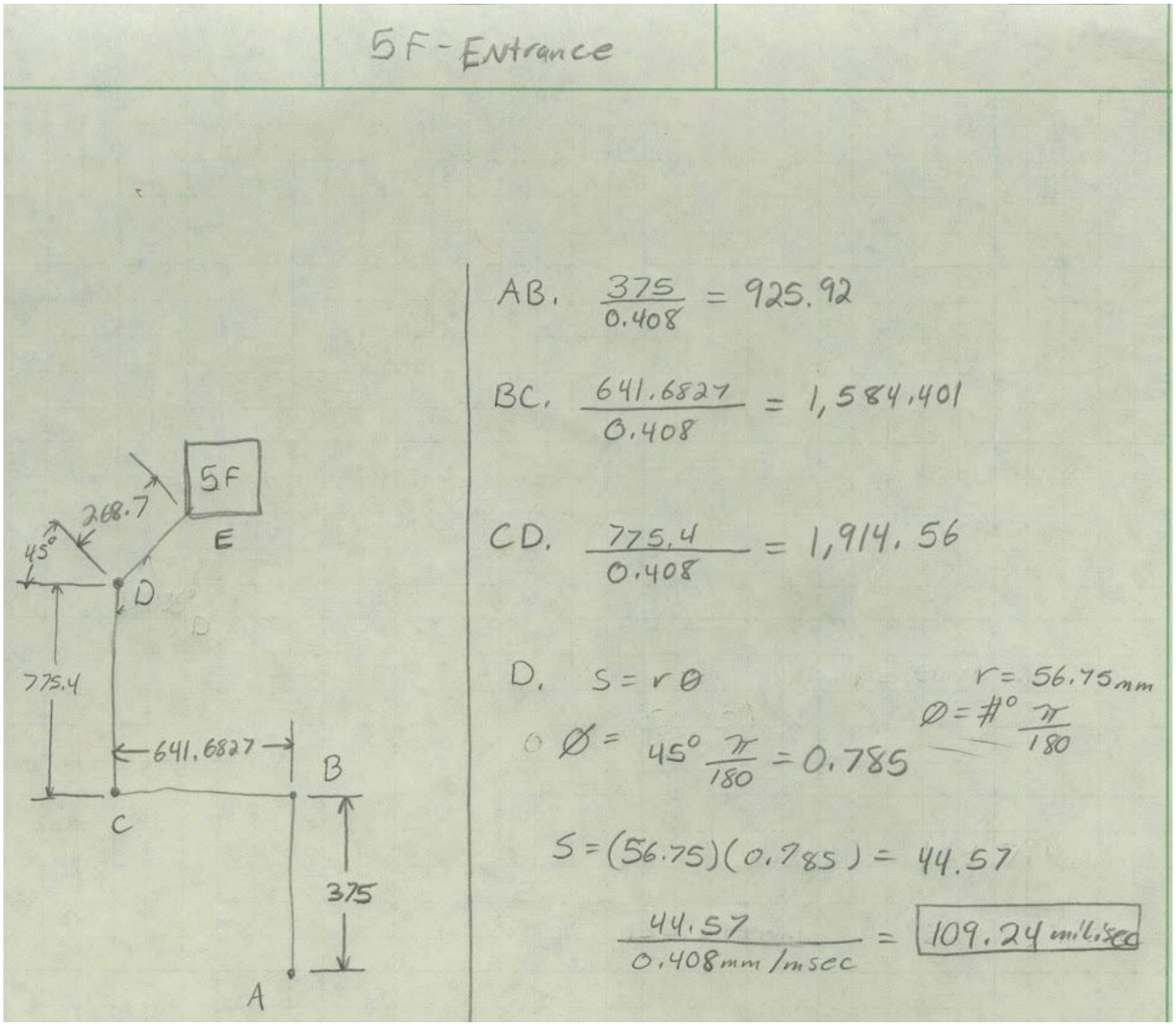
Map and distance calculation’s Firespot 4 entrance



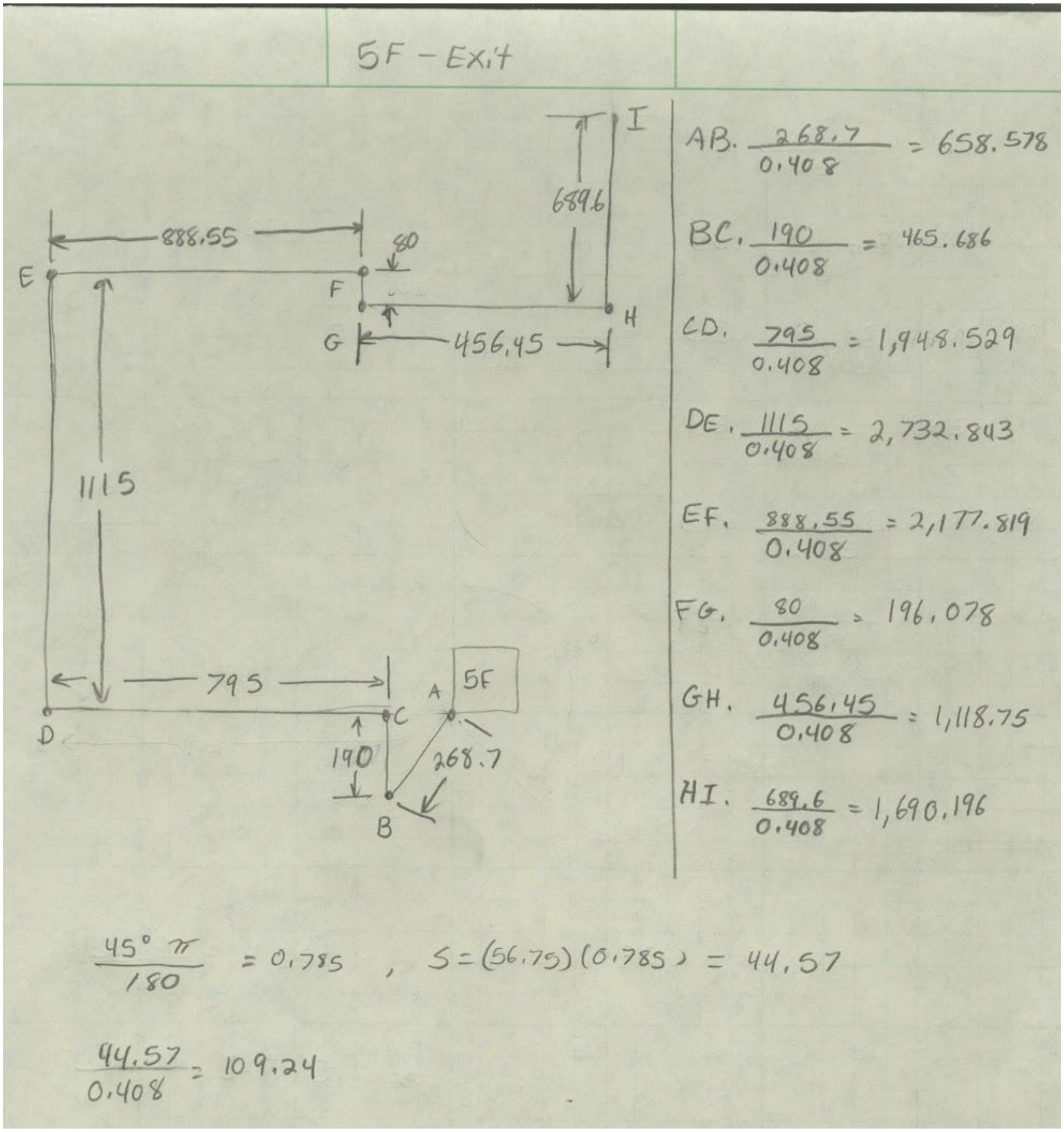
Map and distance calculation’s Firespot 4 exit



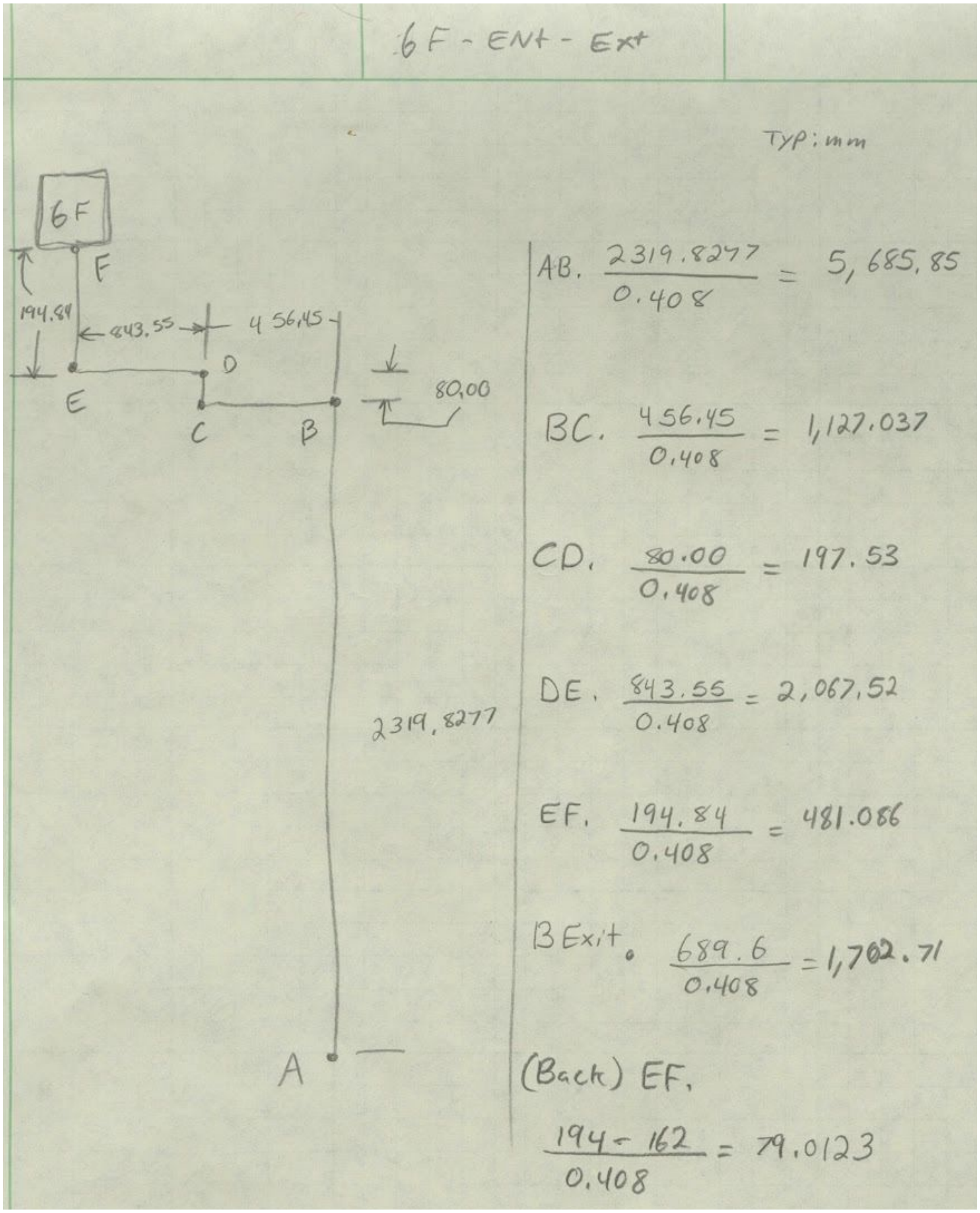
Map and distance calculation's Firespot 5 entrance



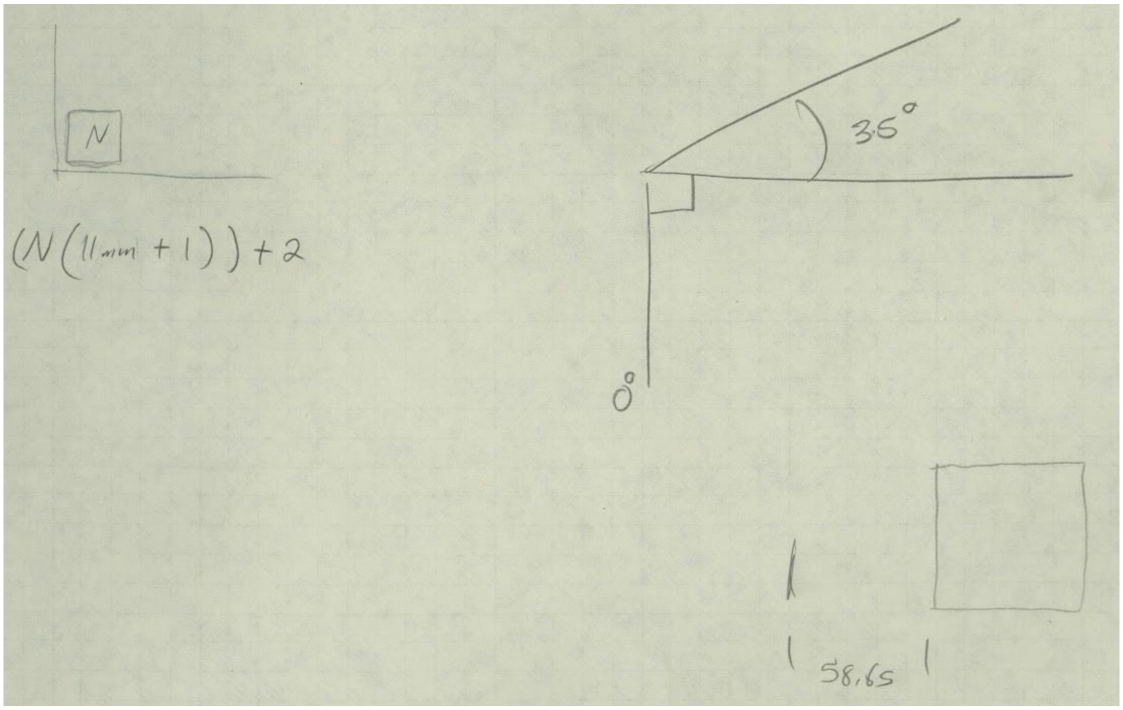
Map and distance calculation’s Firespot 5 exit



Map and distance calculation's Firespot 6



Arm candle clearance angle



The code ran on competition day

```
//3F - ENT/EXT

#include <Servo.h>


const int RF = 60;
const int RB = 120;
const int LF = 120;
const int LB = 60;
const int RN = 90;
const int LN = 90;

Servo leftMotor;
Servo rightMotor;

Servo myservo;

int pos = 90;

void setup()
```

```
{

  rightMotor.attach(11);
  leftMotor.attach(10);

  myservo.attach(9);
  myservo.write(125);

}

void loop()
{
 //ENTRANCE

  //AB.
    rightMotor.write(RF);
    leftMotor.write(LF);
    delay(6434.804);

  //STOP
    rightMotor.write(RN);
    leftMotor.write(LN);
    delay(1000);

  //right turn to BC.
    rightMotor.write(RB);
    leftMotor.write(LF);
    delay(437.02);

  //STOP
    rightMotor.write(RN);
    leftMotor.write(LN);
    delay(1000);

  //BC.
    rightMotor.write(RF);
    leftMotor.write(LF);
    delay(1348.039);

  //STOP
    rightMotor.write(RN);
    leftMotor.write(LN);
    delay(1000);
```

```
//right turn to CD.
  rightMotor.write(RB);
  leftMotor.write(LF);
  delay(437.02);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//CD.
  rightMotor.write(RF);
  leftMotor.write(LF);
  delay(2299.265);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//Left turn to DE.
  rightMotor.write(RF);
  leftMotor.write(LB);
  delay(437.02);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//DE.
  rightMotor.write(RF);
  leftMotor.write(LF);
  delay(1533.395);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//left turn to EF.
  rightMotor.write(RF);
```

```
  leftMotor.write(LB);
  delay(437.02);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//EF.
  rightMotor.write(RF);
  leftMotor.write(LF);
  delay(2154.14);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//Drop cup
   myservo.write(90);
   delay(1000);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

  rightMotor.write(RB);
  leftMotor.write(LB);
  delay(183.823);

  myservo.write(125);
  delay(1000);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

  rightMotor.write(RF);
  leftMotor.write(LB);
  delay(873.92);
```

```
 //STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);


//*****EXIT*******

 //EF.
  rightMotor.write(RF);
  leftMotor.write(LF);
  delay(2114.06);

 //STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

 //Right turn to DE.
  rightMotor.write(RB);
  leftMotor.write(LF);
  delay(437.02);

 //STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

 //DE.
  rightMotor.write(RF);
  leftMotor.write(LF);
  delay(1533.395);

 //STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

 //Right turn to CD.
  rightMotor.write(RB);
  leftMotor.write(LF);
  delay(437.02);
```

```
//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//CD.
  rightMotor.write(RF);
  leftMotor.write(LF);
  delay(2299.265);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//Left turn to BC.
  rightMotor.write(RF);
  leftMotor.write(LB);
  delay(437.02);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//BC.
  rightMotor.write(RF);
  leftMotor.write(LF);
  delay(1348.039);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
  delay(1000);

//Right turn to B-EXIT.
  rightMotor.write(RB);
  leftMotor.write(LF);
  delay(437.02);

//STOP
  rightMotor.write(RN);
  leftMotor.write(LN);
```

```
    delay(1000);

  //B-EXIT.
    rightMotor.write(RF);
    leftMotor.write(LF);
    delay(916.225);



}
```