EG1311 Final report - B19 Team 5:

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PART I: INTRODUCTION

The aim of this project is to build a robotic car that is able to travel over a 3cm bump and a 10 cm tall ramp, sense an obstacle (in our case a wall) and stop within 5 cm from it, and finally launch a ping-pong ball using a catapult over the wall (30 cm high).

PART II: DESIGN MECHANISM

With the given tasks, we had to consider the following elements to design the robot:

1. The Body
   - With the given size constraints of 30cm X 30 cm X 30 cm and the task to make the robot as lightweight as possible. We decided on a simple rectangular board platform to tape all required components onto it, inspired by the initial template which did the job of holding the components but needed a slightly larger surface area to place all components comfortably.
2. The Wheels
   - In order to travel over the bumps and ramps, the radius of the wheel had to exceed the size of the small bump and have sufficient friction to be able to travel over the ramp without slipping down.
3. The Launching Mechanism
   - The group decided on a catapult as it is reliable and straightforward to implement using the servo given
   - The catapult arm had to be long enough to be able to launch the wall over the wall while staying within the given size constraints. It needed to be sturdy so that it does not bend with the rotation each time. Finally, it needed to be lightweight to align with the project objectives of making an overall lightweight robot.
   - The group decided to use polypropylene due to its relatively sturdy and lightweight characteristics. In terms of the arm length, it was designed to be as tall as the wall when mounted on the robot body. We designed a holding box, attached at the end of the arm, slightly larger than the size of the ping pong ball's diameter (40 mm) to carry it during the journey.
4. Placement of components
   - The catapult arm was placed at the front so that it remains within the size constraints even when the arm moves to the back.
   - The sensor needs to be placed at the front of the robot so that wires and other components on the body are not detected as obstacles.
   - The servo needs to be placed so that the attached catapult arm can rotate without obstructing other components and launch the ball over the wall
   - The components need to be evenly distributed on the body to ensure the robot is stable during its journey and does not topple over.

PART III: PROTOTYPING AND PROBLEM-SOLVING

PROTOTYPE 0

Using the given template, we tested out the robotic car so that we can observe and change the design of the car accordingly. From the given template, the car did not manage to travel over the both bump and ramp.

Difficulties and Issues Identified	Improvements and How We Overcame Them
The wheels are too small, thus they cannot go past the obstacle which is a lot bigger than that	Increase the size of the wheels from a radius of 3cm to 5cm. This is because the ramp height and bump height are 10cm and 3cm respectively, and the wheel radius needs to be greater than the bump height to go over.
The cardboard is too flimsy to be used for the body and wheels, making the robot car unstable.	To improve the stability of the robot, we will be using a lightweight but relatively sturdy polypropylene for the body of the car and acrylic for the wheels. The polypropylene body was made slightly larger than the template given to give us more flexibility to organise the components in a stable manner.
Having only two wheels is very unstable and makes the car slanted.	We decided to use four wheels so that the car will be straight and more stable. We also decided to design jagged edges to allow the robot to grip onto the obstacles while crossing over which will also improve its stability.

PROTOTYPE 1

Despite our improvements to the template, we realised that the robot was still unstable and kept toppling when travelling.

Difficulties and Issues Identified	Improvements and How We Overcame Them
Thus, we decide that it might be because the wheels are too thin.	To counter this, we decide to wrap the wheels with cardboard to increase the thickness of the surface in contact with the ground. [Figure 4 - Shows thicker cardboard layer wrapped around the wheels]
It was difficult to secure this cardboard layer around the wheels.	We redesigned and reprinted our wheels to have cut holes on their face to create spokes. This allowed us to maneuver tape around the wheel to better secure the cardboard layer while also making the wheels lighter. [Figures 1 and 2]

The cardboard layer around the wheels meant we lost the grip from the jagged edges of the acrylic wheels.	We secured a rubber band around the cardboard layer to increase the friction.

PROTOTYPE 2

Difficulties and Issues Identified	**Improvements and How We Overcame Them**
The thick part of the wheels from the cardboard layer and the body were brushing against each other preventing the wheel from being able to rotate properly. [Figure 3]	We cut holes on the edges of the body platform to create space for clearance and prevent any contact with the wheels, allowing them to turn without obstruction. [Figure 4]
The wires from the motors would tend to get tangled with the wheels and the spurs as it rotated.	We cut holes inside the body to allow the wires to be connected through and under the platform and then taped down all long wires to prevent too much movement on the robot body as it travelled around. [Figure 16 - Template of the body shows the cutouts for wires]
The exposed ends of the wires connecting the battery holder would come loose very easily as the robot moved around.	We extended the wire and attached them to wires with pins to have more secure connections on the breadboard. We did this by stripping the new wires and twisting the 2 exposed ends together. We taped the twisted connections to further improve stability.
The robot stopped moving in front of the ramp.	We discovered the sensor needs to be raised so that it does not detect the ramp as an obstacle and stops in front of it. Thus, we designed a lightweight tower, constructed of cardboard to attach the sensor at an elevation of 10 cm above the body platform. This ensured that no other obstacles other than the 30 cm wall would be detected by the sensor. [Figure 19]

PROTOTYPE 3

In this final prototype, we focused on implementing the launching mechanism. As mentioned, the arm of the catapult is required to be strong and of sufficient length. So to start off with, we constructed an arm that when mounted on the body, at its highest point, was the same height as the wall over which the ping pong ball needs to be launched.

Difficulties and Issues Identified	**Improvements and How We Overcame Them**
The catapult arm was too heavy and would tend to pull the servo arm down.	To reduce the weight of the catapult, we decrease the height and change the material used. We decided to use polypropylene instead.
With the shortened catapult arm, the ball was unable to be launched over the wall.	To compensate for the height, we mounted the servo and catapult on the tower which was used to elevate the sensor. We also decreased the angle of rotation on the servo so that the projectile of the ball would reach a greater height.
We noticed our body was not as strong as desired and was causing the attached wheels to tilt while rotating.	We solved this issue by replacing the polypropylene body layer with foam-core that does not have a grain direction and so it is not prone to bending in any plane.

PART IV: LESSONS LEARNT

After several rounds of trial and error, brainstorming, and modification, we finally settled on prototype 3 as our final design since it was able to execute the mission perfectly in every trial.

During the process of designing and building our robot, the group learned several lessons from our mistakes and the difficulties faced.

The transition between Prototype 0 and Prototype 1 was extremely slow as the group was hyper fixated with the complicated wiring which if not done precisely and mindfully led to several damaged Arduino boards. This threw off the group's prioritization which resulted in forgetting to design wheels and get them printed in time for the second tutorial. Thus the majority of the lab session and the two weeks till the next lab session were spent discussing hypothetical ideas that we were unable to test without the wheels. We should have, instead, separated into 2 pairs, one to design the wheels and send them to print while the other pair would continue to work on the Arduino. From this experience we learned the value of starting earlier, planning more, and the importance of physical tests rather than hypothetical ruminations.

We learned the significance of stable wire connections, especially when moving parts are involved. Initially, we had overlooked this, thinking that as long as there is some form of electrical contact, no matter how much the wires moved around, all would work well. However, we eventually had to secure the connections by taping down wires and adding pins to wires that were simply exposed ends. This facilitates debugging the wiring in later stages as well.

We also learned the need for compromise between the 2 objectives: building a lightweight robot versus building a reliable, stable robot. To reach our final prototype, several elements that added to the weight of the robot had to be added (e.g. the tower) in order to make our robot effective in accomplishing the assigned tasks. With much hesitation, we had to let go of the weight aspect to ensure our robot would work every time.

We also observed the significance of the difference in the strength of a material with and without a grain direction. We learned that the structure of materials is an important consideration when choosing from distinct material options to build components with specific requirements.

One of the most nerve-wracking situations faced by the group was the day before the final run. After a couple of test runs, we were unable to get the robot to run smoothly through the obstacle course. The sensor became unreliable, with the robot stopping sporadically and triggering the catapult arm at random moments. We noticed the servo was weak and was slow in rotating the catapult arm leading to the unreliable success of the ping pong ball being launched over the wall. After consulting peers and staff, we realised the source of all the mentioned problems was likely to be partially discharged batteries. So we had to charge the batteries overnight and committed to meet early morning the next day hours before the final run. We were uncertain if charging the batteries would solve the issues and what to do if we found ourselves in the same situation with fully charged batteries. The source of the problems was indeed the batteries and we completed the final run successfully.

PART V: APPENDIX

Photos from our Journey

Figure 1 - *Cardboard layer not attached securely around the wheel*

Figure 2 - *Wheels secured by leveraging the spokes to wrap tape around.*

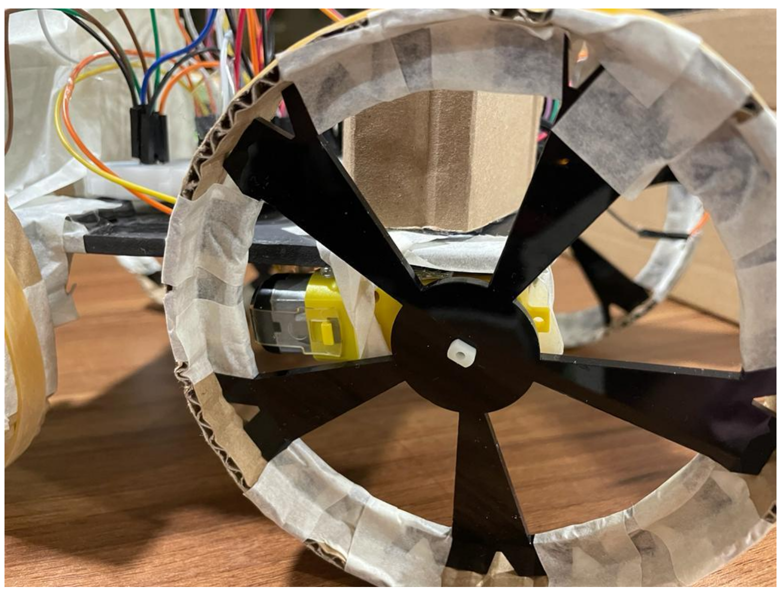


Figure 3 - *Wheels rubbing against the body platform*

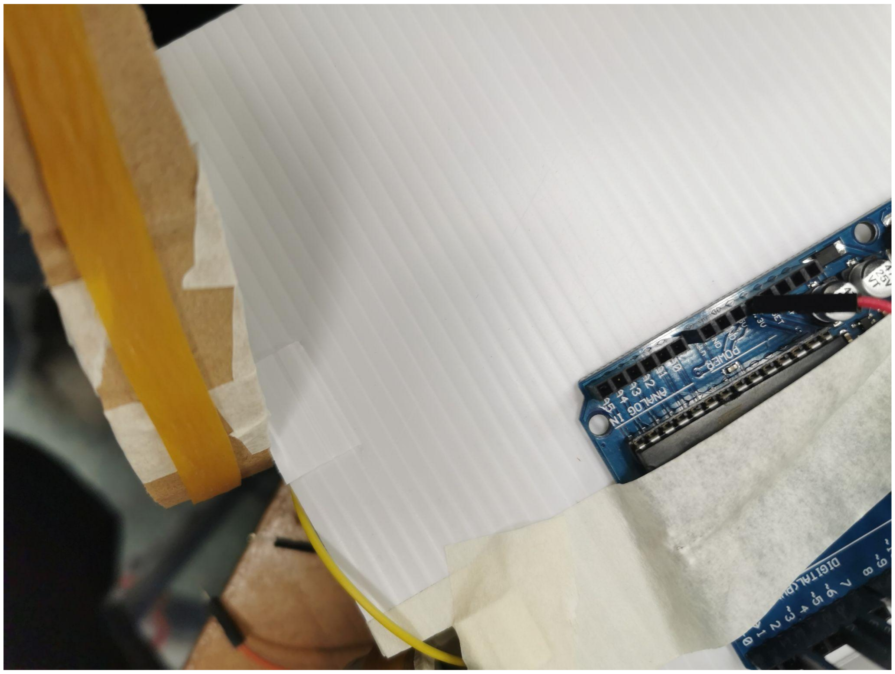


Figure 4 - *Spaces cut along the edges of the body to create clearance for the wheels.*

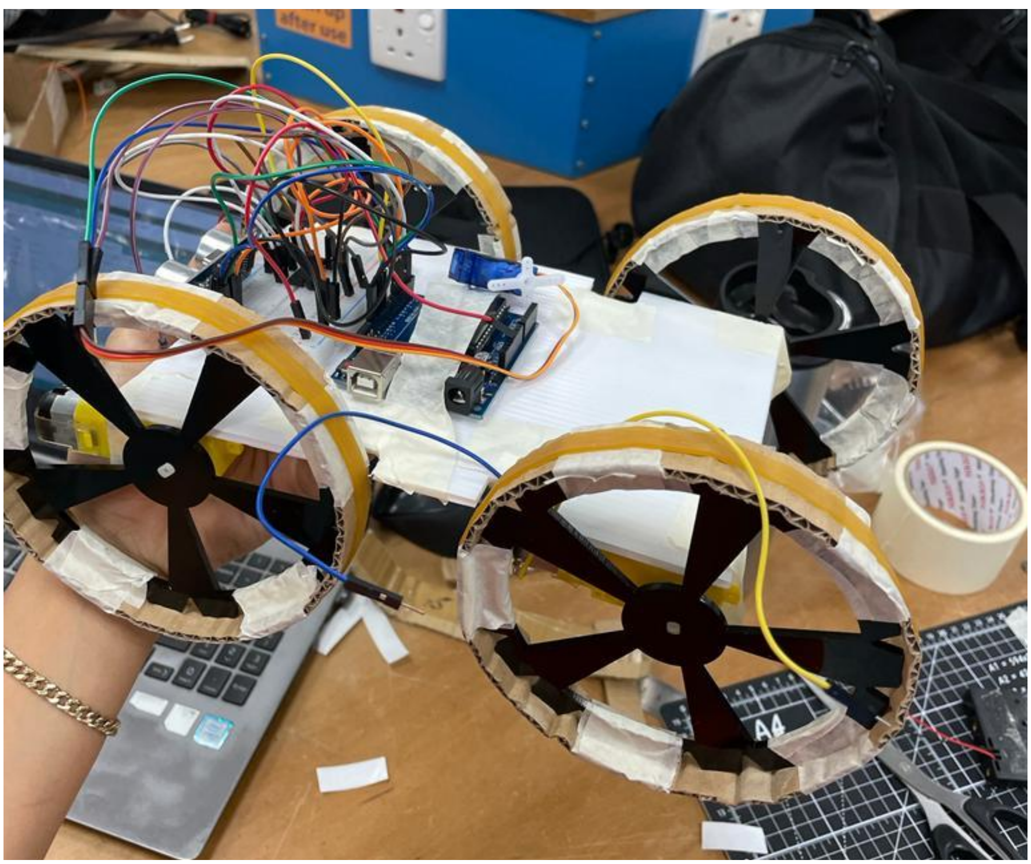


Figure 5 - *Sensor placed at the front of the robot, at a low height*

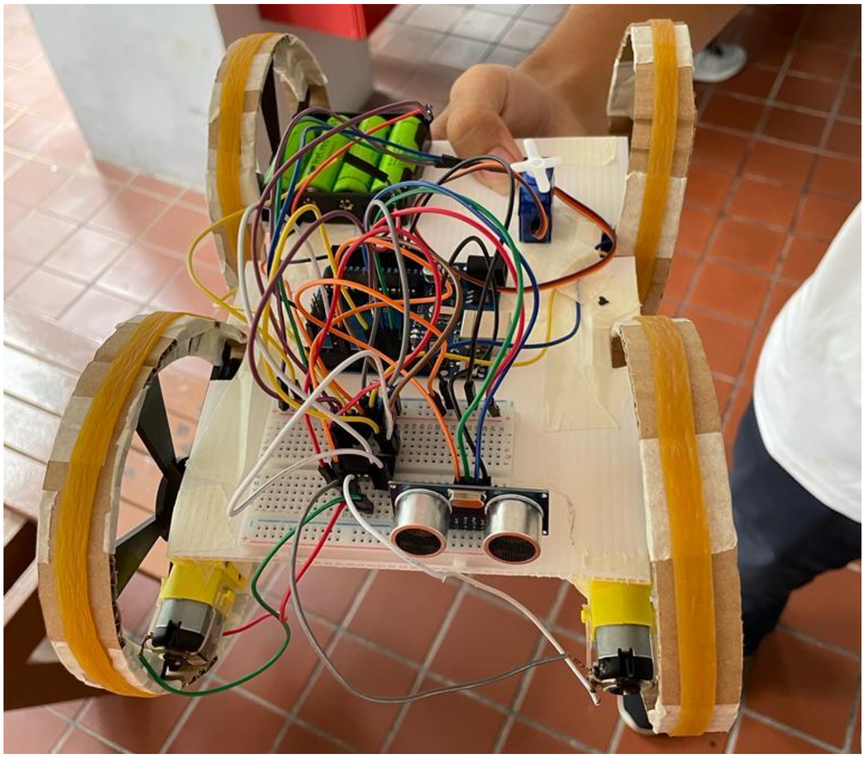
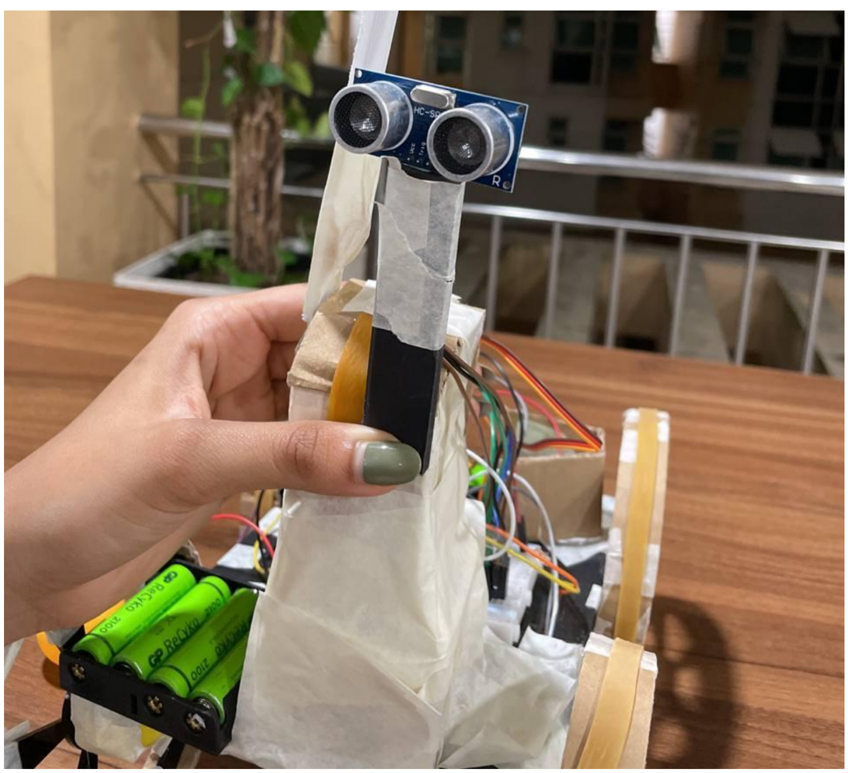


Figure 6 - *Sensor raised at a height by attaching onto the tower.*



Finished Product

Figure 7

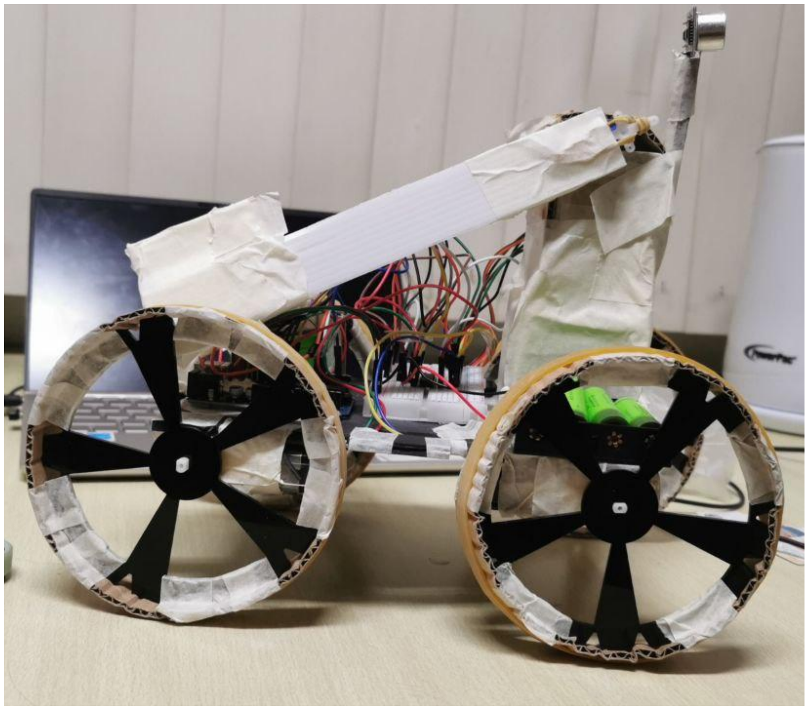
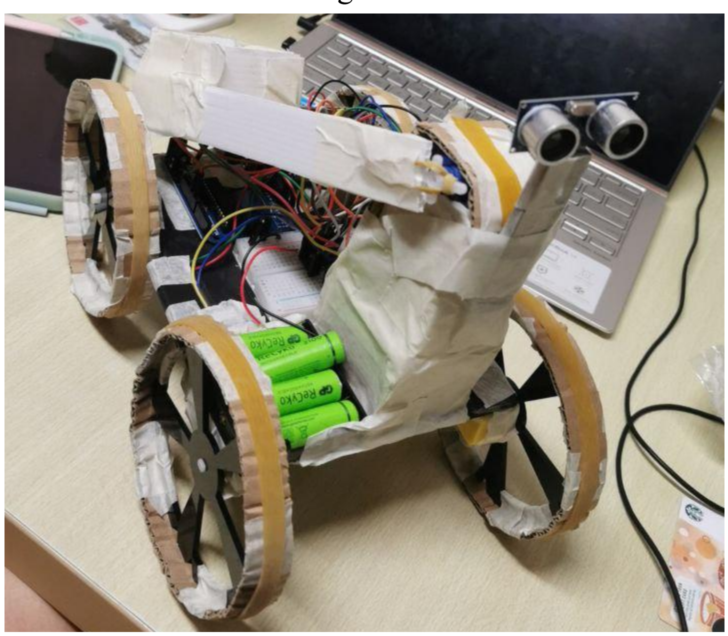


Figure 8



CAD Rendering of Final Model

Figure 9 - Right View

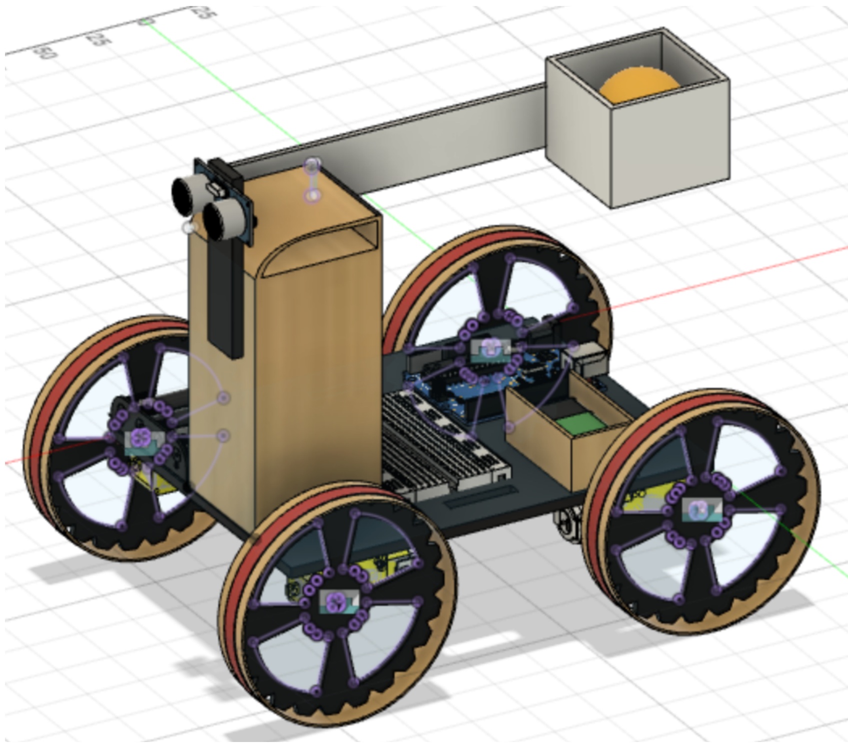


Figure 10 - Left View

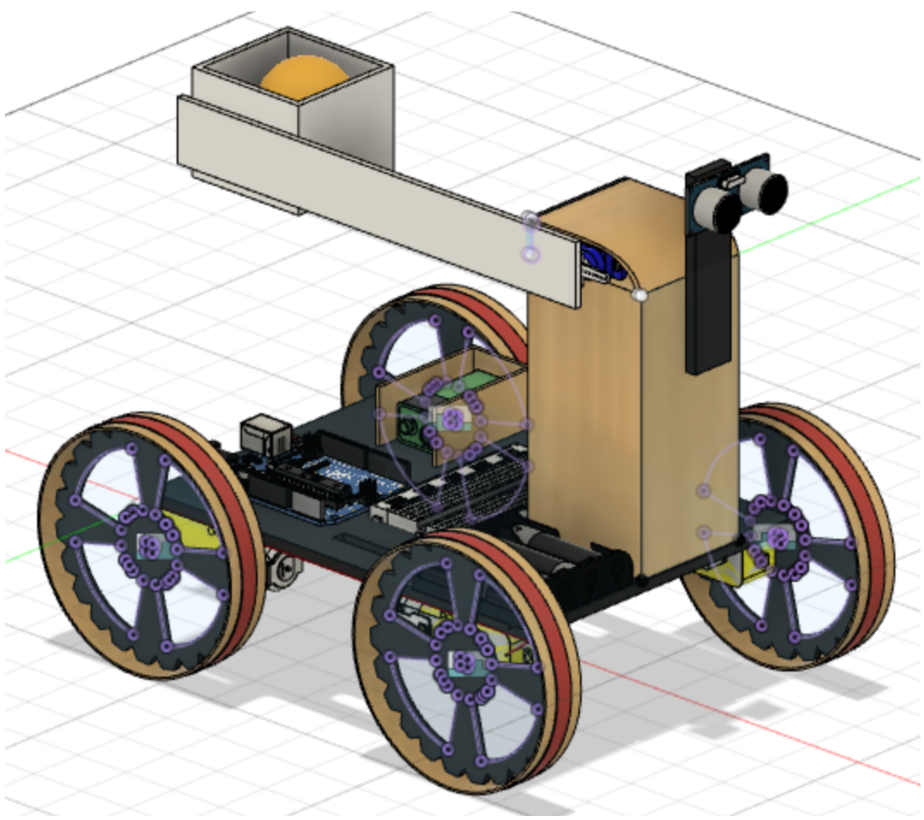
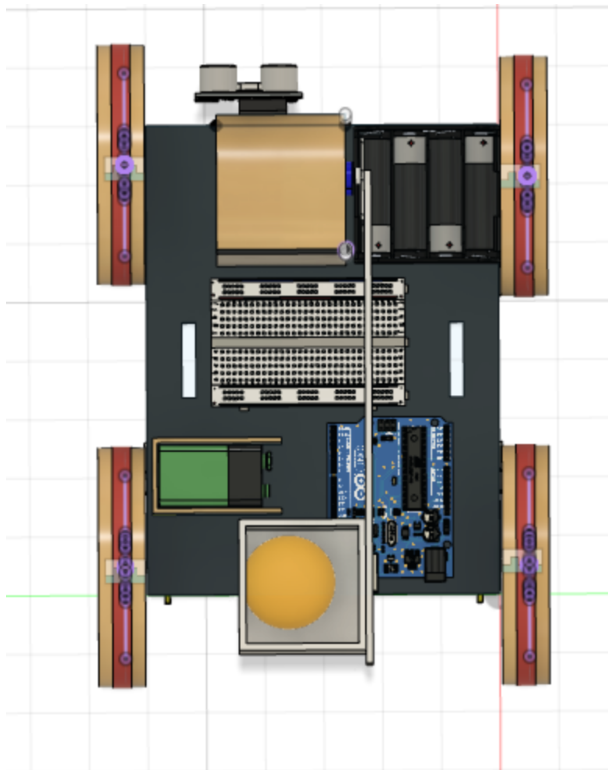
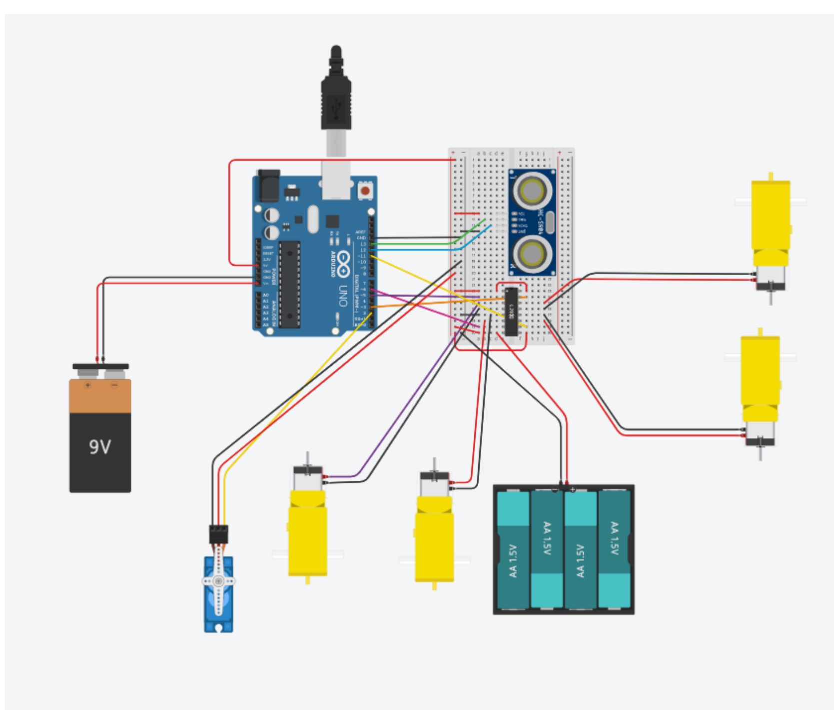


Figure 11 - Top View



TinkerCad Circuitry Diagram

Figure 12 - TinkerCad Circuitry



Arduino Source Code

```
#include <Servo.h>
Servo servo;
int servo_pin = 2;
int TRIG_PIN = 13;
int ECHO_PIN = 12;
int MOTOR_PIN1 = 6;
int MOTOR_PIN2 = 5;
int MOTOR_PIN3 = 11;
int MOTOR_PIN4 = 10;
float SPEED_OF_SOUND = 0.0345;

void setup() {
  pinMode(MOTOR_PIN1, OUTPUT);
  pinMode(MOTOR_PIN2, OUTPUT);
  pinMode(MOTOR_PIN3, OUTPUT);
  pinMode(MOTOR_PIN4, OUTPUT);
  pinMode(TRIG_PIN, OUTPUT);
  digitalWrite(TRIG_PIN, LOW);
  pinMode(ECHO_PIN, INPUT);
  servo.attach(servo_pin,660,2400);
  Serial.begin(9600);
}

void loop() {
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);
  int microsecs = pulseIn(ECHO_PIN, HIGH);
  float cms = microsecs*SPEED_OF_SOUND/2;
  Serial.println(cms);
```

```
if (cms < 9) {
  digitalWrite(MOTOR_PIN1, LOW);
  digitalWrite(MOTOR_PIN2, LOW);
  digitalWrite(MOTOR_PIN3, LOW);
  digitalWrite(MOTOR_PIN4, LOW);
  delay(1000);
  servo.write(95);
  delay(5000);
  servo.write(0);
  delay(1000);
 } else {
  digitalWrite(MOTOR_PIN1, HIGH);
  digitalWrite(MOTOR_PIN2, HIGH);
  digitalWrite(MOTOR_PIN3, HIGH);
  digitalWrite(MOTOR_PIN4, HIGH);
 }
 delay(10);
}
```

Structural Components - Fabrication and 2D CAD Templates

COMPONENT	QUANTITY	MATERIAL	FABRICATION
Wheels	4	Arcylic	Laser Cutting
Wheel Outer Layer	4	Cardboard	Pen Knife
Sensor Support	1	Foamcore	Pen Knife
Body Platform	1	Foamcore	Pen Knife
9V Battery Holder	1	Cardboard	Pen Knife
Catapult	1	Polypropylene	Pen Knife
Servo Tower	1	Cardboard	Pen Knife

TEMPLATES

Figure 13 - Wheel

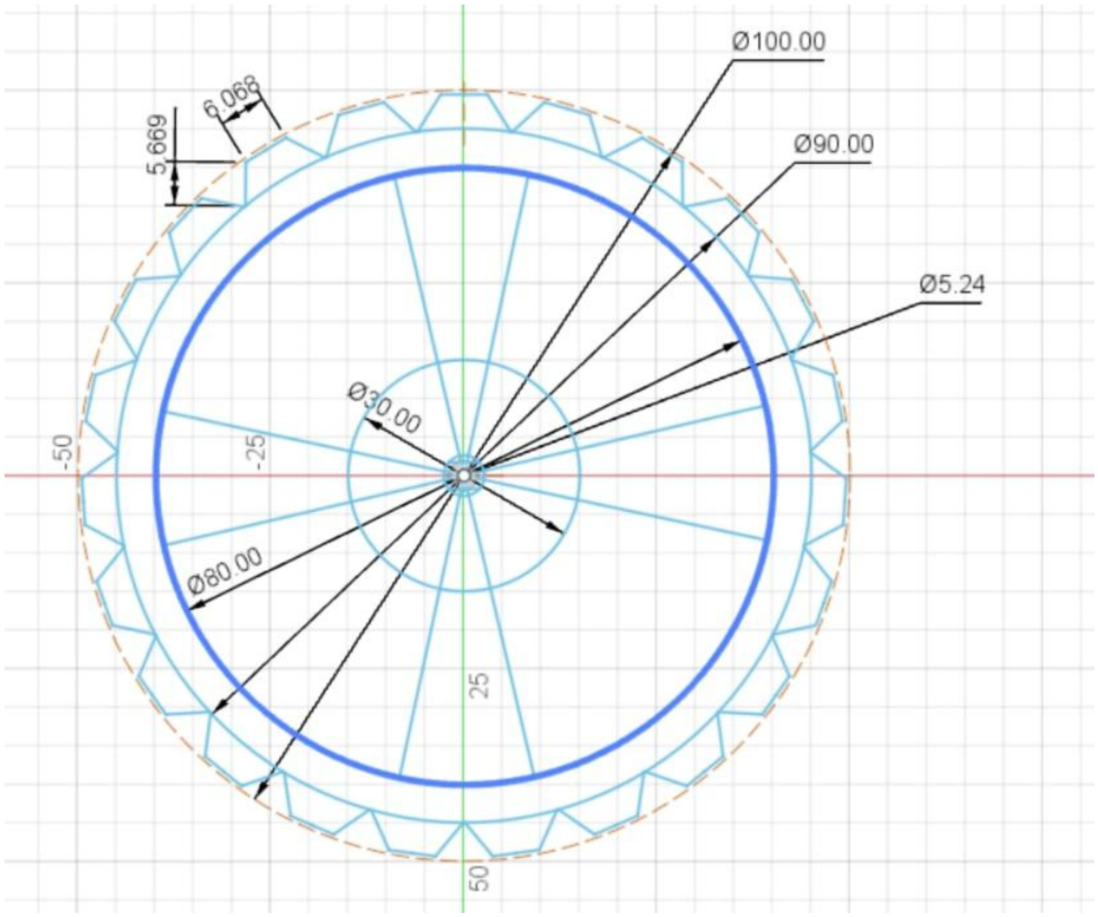


Figure 14 - Wheel Outer Layer

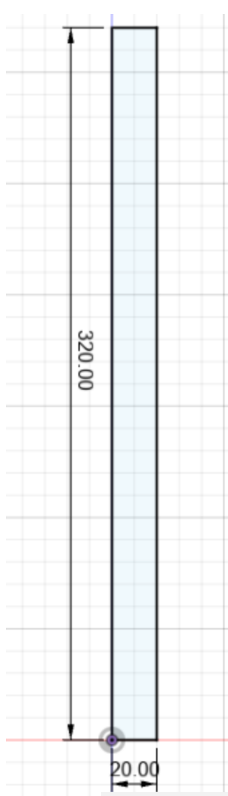


Figure 15 - Sensor Support

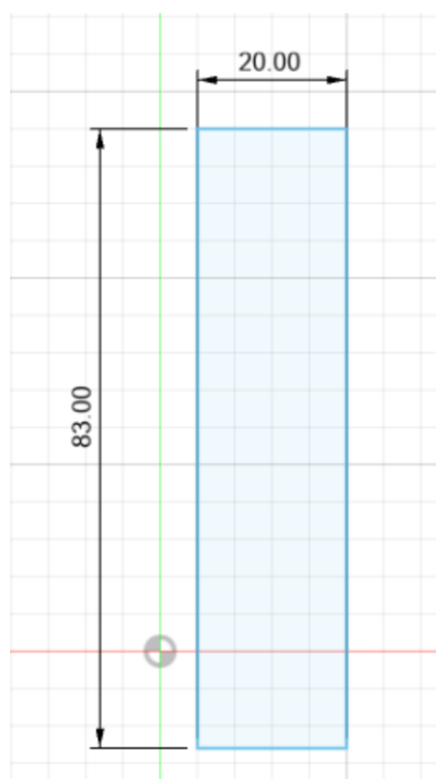


Figure 16 - Body Platform

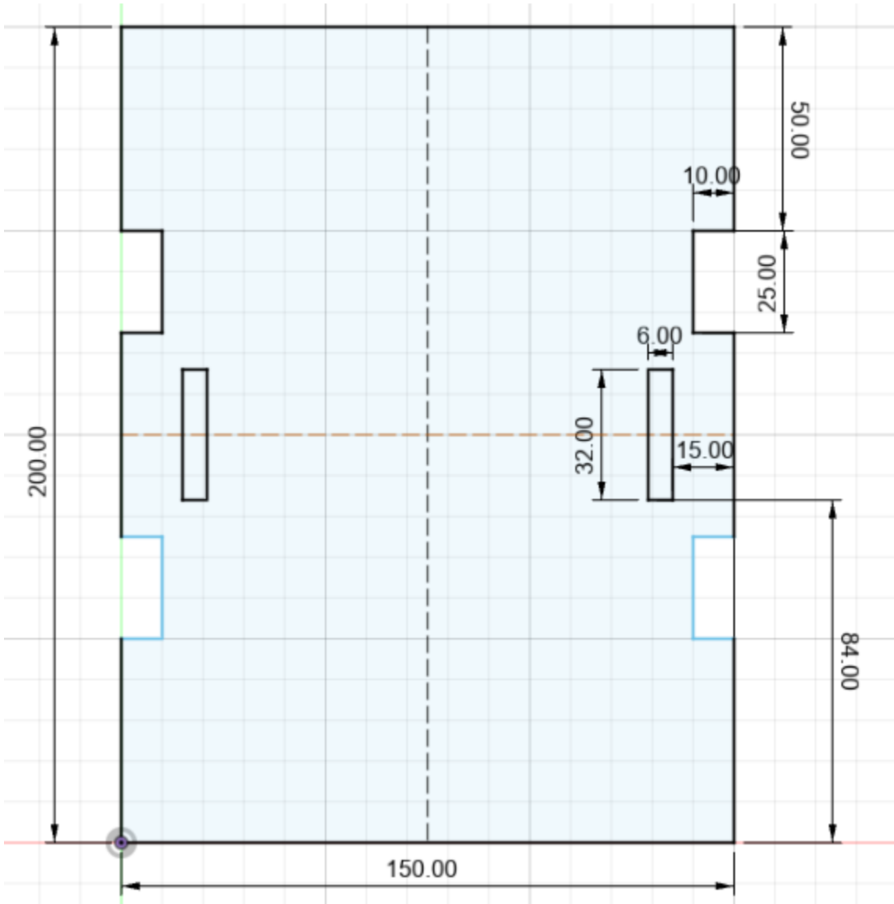


Figure 17 - Battery Holder

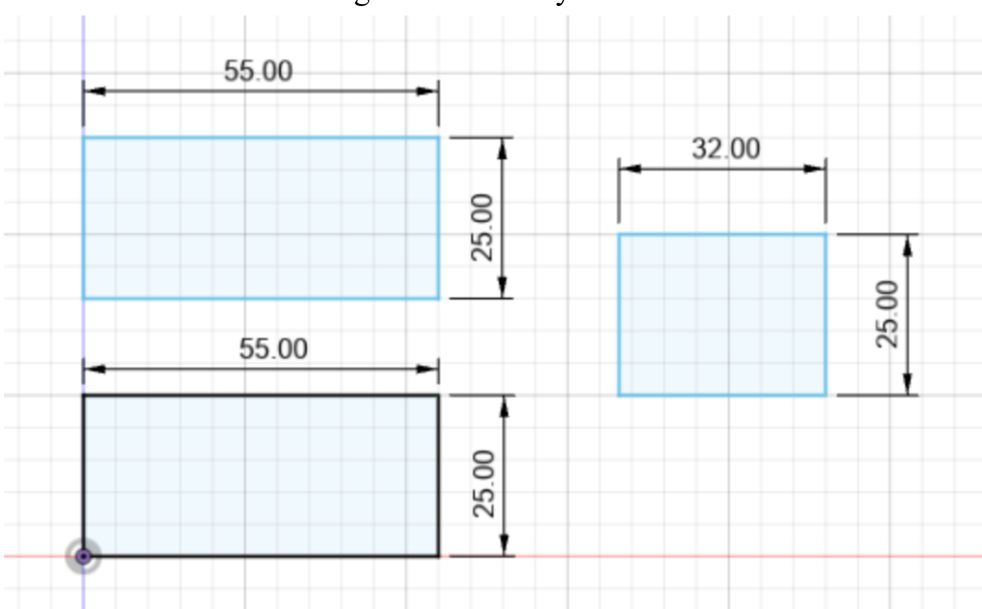


Figure 18 - Catapult Arm and Basket

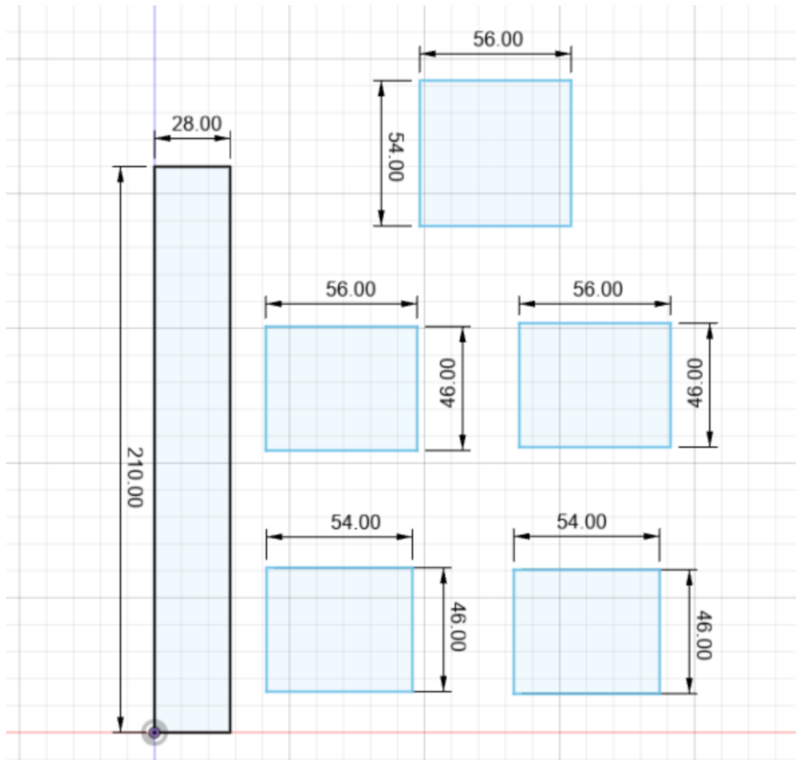


Figure 19 - Servo Tower