EG1311 Design and Make
Lab Report

B12 Group 4

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<u>**Project Design Process**</u>

I. 1st Prototyping Stage (Template Project)

Wheels: We started off with 2 cardboard wheels following the template provided, but soon realised that the wheel surface was too slippery to go up the ramp as there was no friction.

Base: A cardboard base was also used for the surface holding the arduino and breadboard. However, the cardboard was too weak to support the weight above it and broke after several runs.

Motors: Our initial build had 2 motors, which made it unstable and lacked the power to move over the bump. The back of the robot was also dragging along the ground.

II. 2nd Prototyping Stage (Move Across Obstacle Course & Stopping Before The Wall)

Wheels: The cardboard wheels used in the template project had many limitations: (a) the cardboard material was not sturdy, (b) the width was too small and (c) it lacked grip and friction to scale over the first block. Thus, to solve these problems, we implemented the following solutions:

(a) The cardboard material was replaced with acrylic to provide more stability to the robot. Additionally, acrylic is more durable and resistant to wear and tear than cardboard, allowing a longer lifespan of the overall robot.
(b) Small diameter results in the robot not being able to climb over the first obstacle as the motors will get stuck on the bump due to its close proximity to the ground. Hence, we eventually designed our wheels to have a radius of 4.5cm to prevent collision of the motors with the bump.
(c) The wheels, now made with acrylic, were smooth and had insufficient grip to climb over both the bump and the ramp. We initially considered cutting grooves into the wheel to enable it to hook onto the surface of the bump to scale over it. However, we decided to attach either the anti-slip mat sheet or rubber band to the circumference of the wheel instead as the grooves do not provide enough friction for the robot to climb over the ramp. We finally settled on the rubber band as it wraps around and holds onto the wheel better.

Figure 1. *Wheels With Anti-slip Mat Sheet*

Figure 2. *Wheels With Rubber Band*

Motors: Our first build after the template project had 4 motors to ensure stable power distribution to the wheels and to ensure that our robot could go through the course smoothly. However, (a) the number of motors was a significant weight on the base and (b) the power source to the motor together with the weight would result in the robot moving very slowly across the course. To address this, we changed the following:

(a) We went with a 3 motor design, where we would use a smaller base to hold the first 2 motors, then stick an ice-cream stick under the base and attach the 3rd motor to the end of the stick, and attach 2 wheels to the final motor. This model would save the weight of 1 motor and help to reduce stress on the motor. The addition of the ice cream stick also allows for the robot to be more compact.

(b) We realised that despite using the 9V battery to power the whole setup, we were using the 5V port on the arduino to power all the motors. We changed this so that the motors would be connected to the 9V source, maximising the power input to the motors and allowing the robot to move much quicker and easily scale the obstacles.

Ultrasonic Sensors: The ultrasonic sensor sometimes detects the ramp or bump when the robot approaches them. To prevent the ultrasonic sensor from mistakenly detecting the ramp or bump and stopping the robot prematurely, we angled the sensor slightly upward by bending its pins. This adjustment redirects the sensor's pulse away from the ground, allowing the robot to stop appropriately before the wall that is taller than the robot.

III. 3rd Prototyping Stage (Catapult + Reverse)

Wiring: Initially, we connected the 3 motors to 3 different output pins and ground pins of the motor driver which allowed the robot to traverse in the forward direction. However, we were faced with the hurdle of reversing the direction of the motors. Fortunately, after careful research of the motor driver as well as aid from the teaching assistants, we realised we could connect each wire of a motor to different output pins of the motor driver. Through the arduino code to change the output pins' magnitude from high to low respectively, we can manipulate the current to flow in either direction which allows the motor to spin in opposite directions.

Catapult: Our dilemma was to choose between a) a slingshot cannon design and b) a catapult design for our ball launcher:

a) The slingshot cannon utilises the servo as a trigger to release a rubber band which will then eject the ball. However, this results in more added weight to the robot due to its bulky design.

b) The catapult system consists of a ball holder (a square box made of cardboard for our design) supported by a lever which is attached to the servo motor. The rapid rotation of the servo motor results in the ball being thrown quickly. Due to its light-weight design compared to the heavier slingshot cannon design, we decided to settle with the catapult system design.

Base: We also faced a few challenges with the base being made from cardboard. The weak structure of the cardboard meant that it was also hard to mount the weight without the material losing its firmness. It would mean we would essentially have to start from scratch after a few runs with the cardboard as it started to fall apart. We then decided to switch the base to corrugated cardboard as it was much stronger and firmer while also being about the same weight as the initial cardboard, hence the weight gain was not significant.

IV. Final Prototyping Stage (Final Run & Modification)

1st Graded Run: In preparation, we fixed the 4 1.5V and 1 9V batteries onto the robot as well as securing all loose wirings to ensure that the connections remain stable throughout the run. Our first run went smoothly with a measured weight of 390g, which was the lightest robot in the section so far.

2nd Graded Run: We decided to further reduce the weight of our robots through the following modifications:

a) **Wheels:** We modified the back wheels such that they were made of cardboard which reduced the overall weight of the robot.

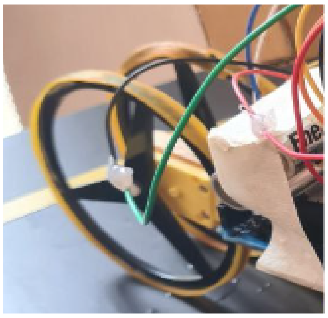

***Figure 3**. Acrylic Rear Wheels*

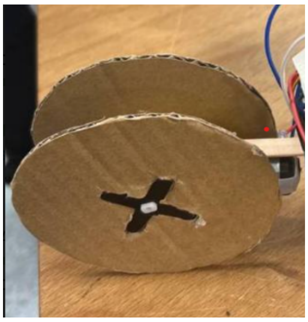

***Figure 4**. Cardboard Rear Wheels*

b) **Catapult [Ball Holder]:** We changed the box design of the ball holder to a claw design to further reduce the weight.

c) **Catapult [Lever]:** Changing the material of the catapult lever (originally made out of ice-cream sticks) to the black corrugated polypropylene material allowed the lever to maintain its rigidity while effectively reducing the weight of the robot.

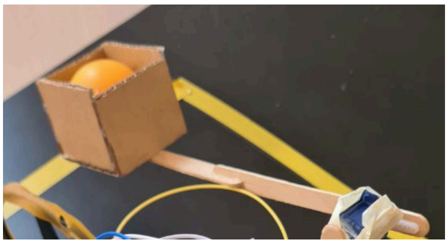

***Figure 5**. Initial Catapult Design*

***Figure 6**. Adjusted Catapult Design*

With the above implementations finalised, we passed the graded run with minimal hiccups, clinching the title of the lightest robot in the section with a weight of 371.8g.

V. Lessons and Challenges

As a team, our main goal was to achieve the maximum amount of points possible for the project, so we pushed ourselves to use as little resources as possible while ensuring maximum functionality of the robot per the course requirements.

This was the first challenge we faced as a group, as we found it hard to balance organising the electrical components onto the robot with its functionality and weight to ensure we could get at least the 9 points of fulfilling the movement requirements, and not being the heaviest in the tutorial group. We found ourselves using the more lightweight materials provided, such as the cardboard at first, but found it lacked the rigidity and strength required to keep the shape of the robot. So, we further reinforced it with ice cream sticks. We also had to change to acrylic wheels as we found them to be the most stable and most reliable option due to the nature of the material.

For our final prototype, we pushed even further and changed out the main cardboard base with corrugated board, and for our catapult we also changed the arm from ice cream sticks to thin pieces of corrugated board as we found it was lighter and did not compromise on strength or rigidity. We also managed to replace our back wheels with cardboard as we found that the front wheels provided enough power and grip to push our robot through the course and backwards to the starting point, maximising weight savings. All in all, as a group we learned that balancing form and function is key in engineering in order to maximise results.

Another lesson we learnt in the process was that in engineering, repeated and continuous tests and trials are needed in order to ensure a smooth and flawless operation of the final product. We learned this due to how the ever changing nature of the prototype resulted in us having to continuously tweak and change the code and repeating runs on the test course outside the lab so that we can ensure our robot was up to standard.

Finally, we faced another challenge in the form of random setbacks. This involved random parts of our project seemingly refusing to stop working or functioning properly. The first incident that occurred during our first session was the template robot refusing to work despite everything being connected and the code being correct. After rewiring everything the robot suddenly worked, despite no change being done to how it was wired originally. We also experienced a setback 2 weeks before the final run with our breadboard breaking apart, which forced us to almost fully remake the robot as not only everything had to be rewired, but the main body of our robot was also affected as it was originally made of cardboard and got torn apart as a result of it not being able to withstand the weight above, hence forcing us to redesign the main base of the robot with corrugated cardboard. We learnt to adapt and improvise and to try every single possibility when faced with issues and setbacks, and learnt that progress is never linear, especially in engineering.

Appendix

1. Final Robot

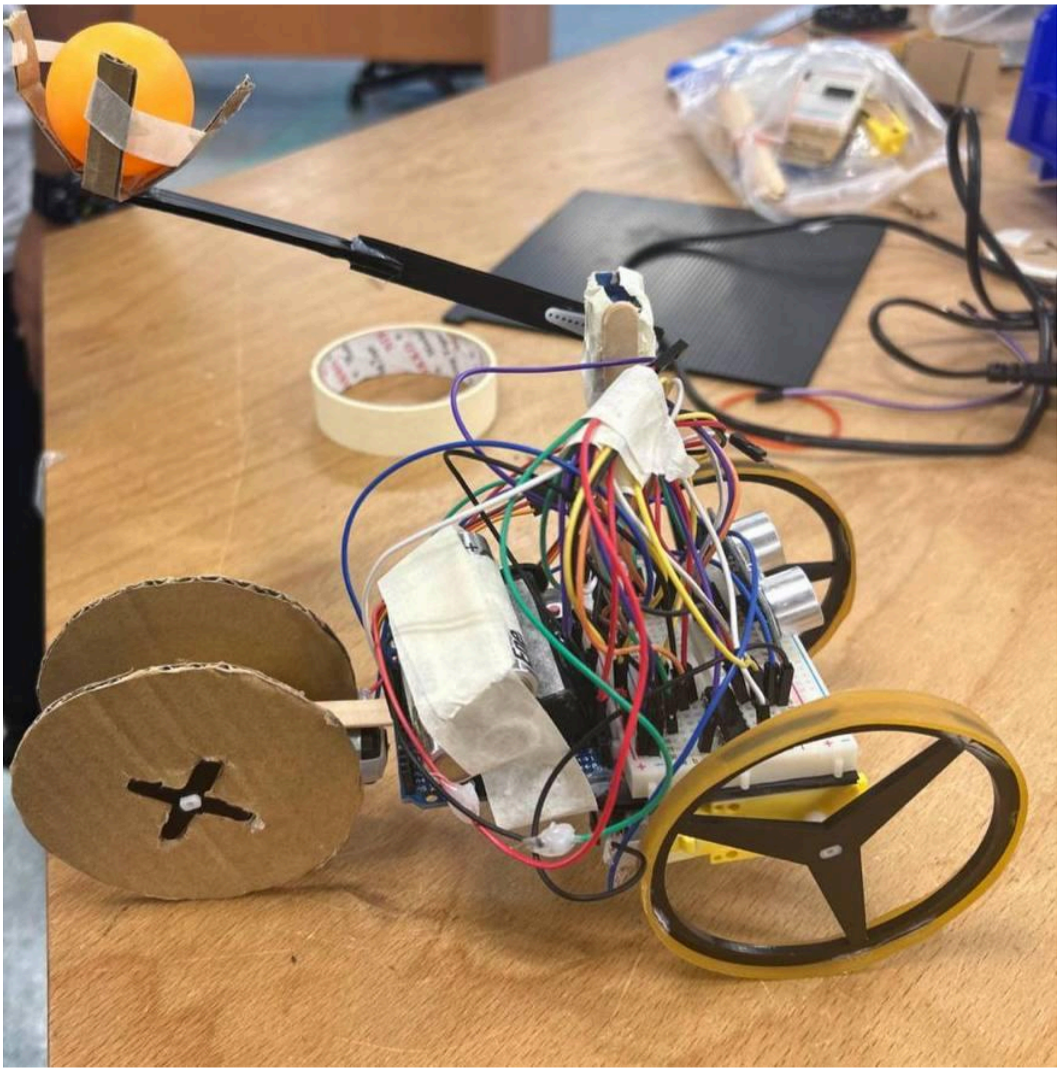

***Figure** 7. Photo of Final Robot*

2. CAD Rendering of Final Robot

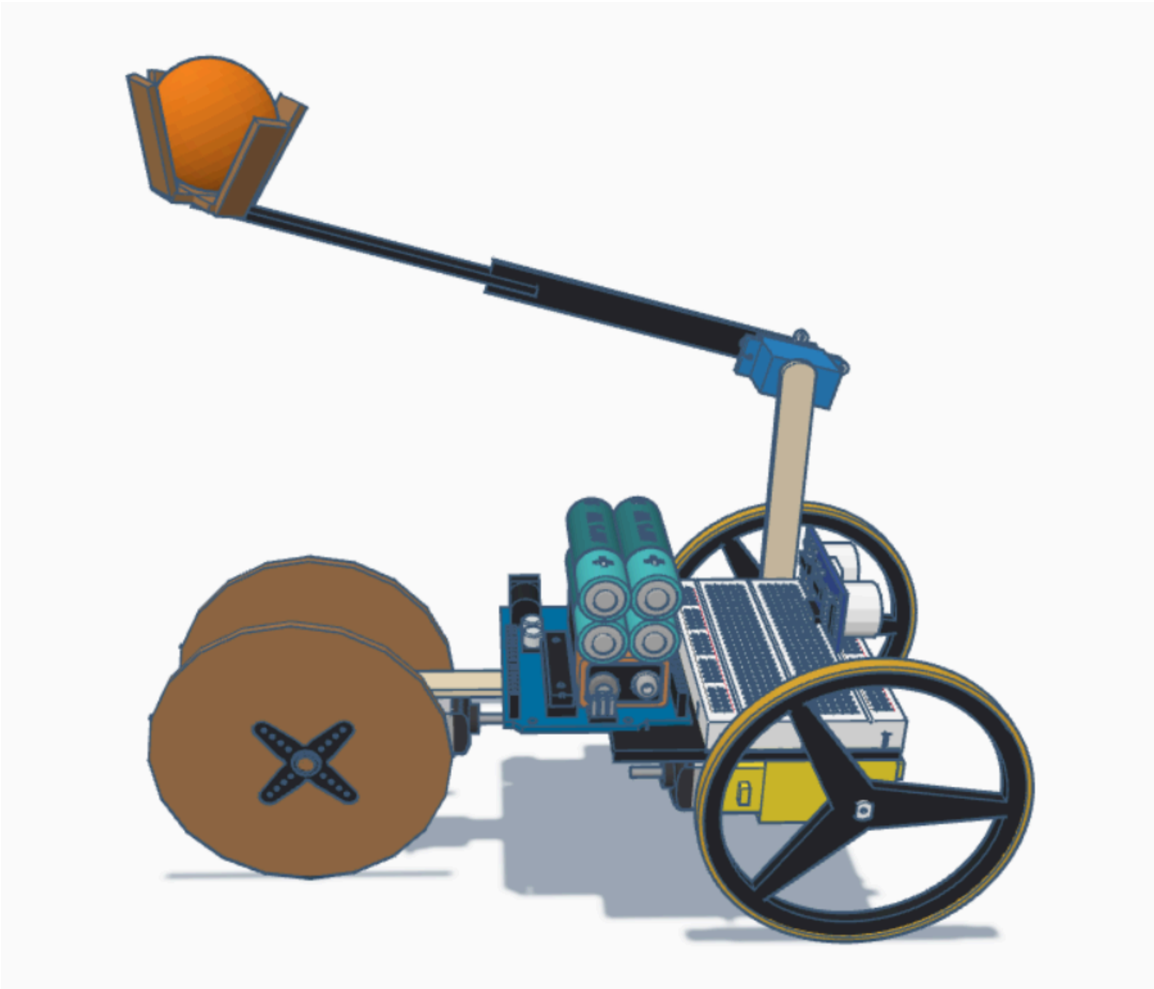

Figure 8. *CAD Rendering of Final Robot*

3. TinkerCAD Diagram

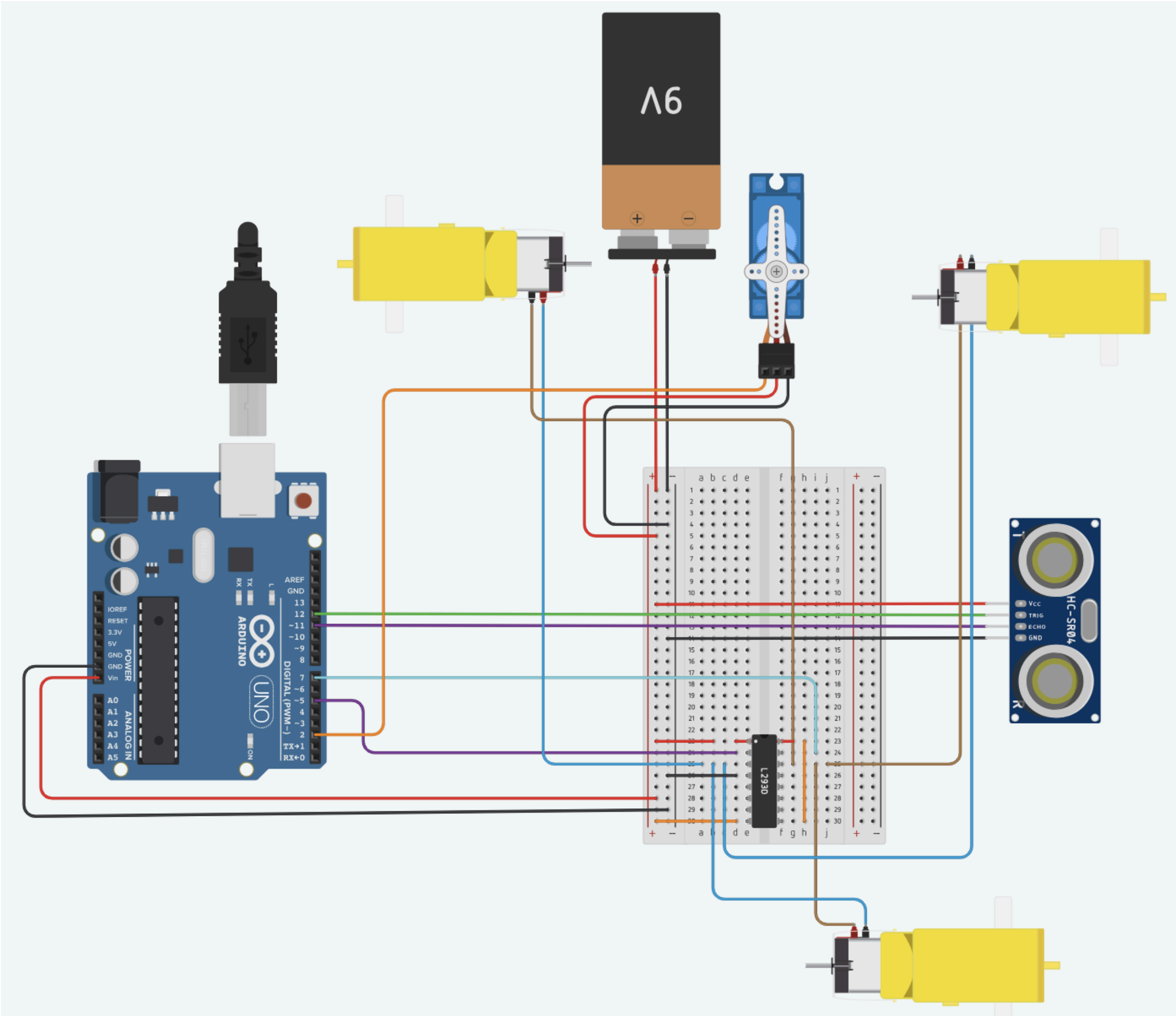

Figure 9. *TinkerCAD Diagram of Wiring*

4. Arduino Source Code

```
#include <Servo.h>

Servo servo;

int TRIG_PIN = 12;
int ECHO_PIN = 11;
int MOTOR_PIN_FORWARD = 5;
int MOTOR_PIN_BACKWARD = 7;
int SERVO_PIN = 2;
float SPEED_OF_SOUND = 0.0345;
int throws = 0;

void setup() {
  // put your setup code here, to run once:
  pinMode(MOTOR_PIN_FORWARD, OUTPUT);
  pinMode(MOTOR_PIN_BACKWARD, OUTPUT);
  pinMode(TRIG_PIN, OUTPUT);
  digitalWrite(TRIG_PIN, LOW);
  pinMode(ECHO_PIN, INPUT);
  servo.attach(SERVO_PIN, 500, 2500);
  Serial.begin(9600);
  servo.write(0);
}

void loop() {
  // put your main code here, to run repeatedly:
  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 <= 11 && throws <= 0) {
    digitalWrite(MOTOR_PIN_FORWARD, LOW);
    digitalWrite(MOTOR_PIN_BACKWARD, LOW);
    delay(50);
    if (throws == 0) {
      servo.write(85);
      delay(500);
      servo.write(30);
```

```
      delay(500);
      throws = 1;
    }
    delay(50);
  } else {
    if (throws > 0) {
      digitalWrite(MOTOR_PIN_FORWARD, LOW);
      digitalWrite(MOTOR_PIN_BACKWARD, HIGH);
    } else {
      digitalWrite(MOTOR_PIN_FORWARD, HIGH);
      digitalWrite(MOTOR_PIN_BACKWARD, LOW);
    }
  }
  delay(10);
}
```

Figure 10. *Arduino Code of Robot*

5. 2D CAD Drawings

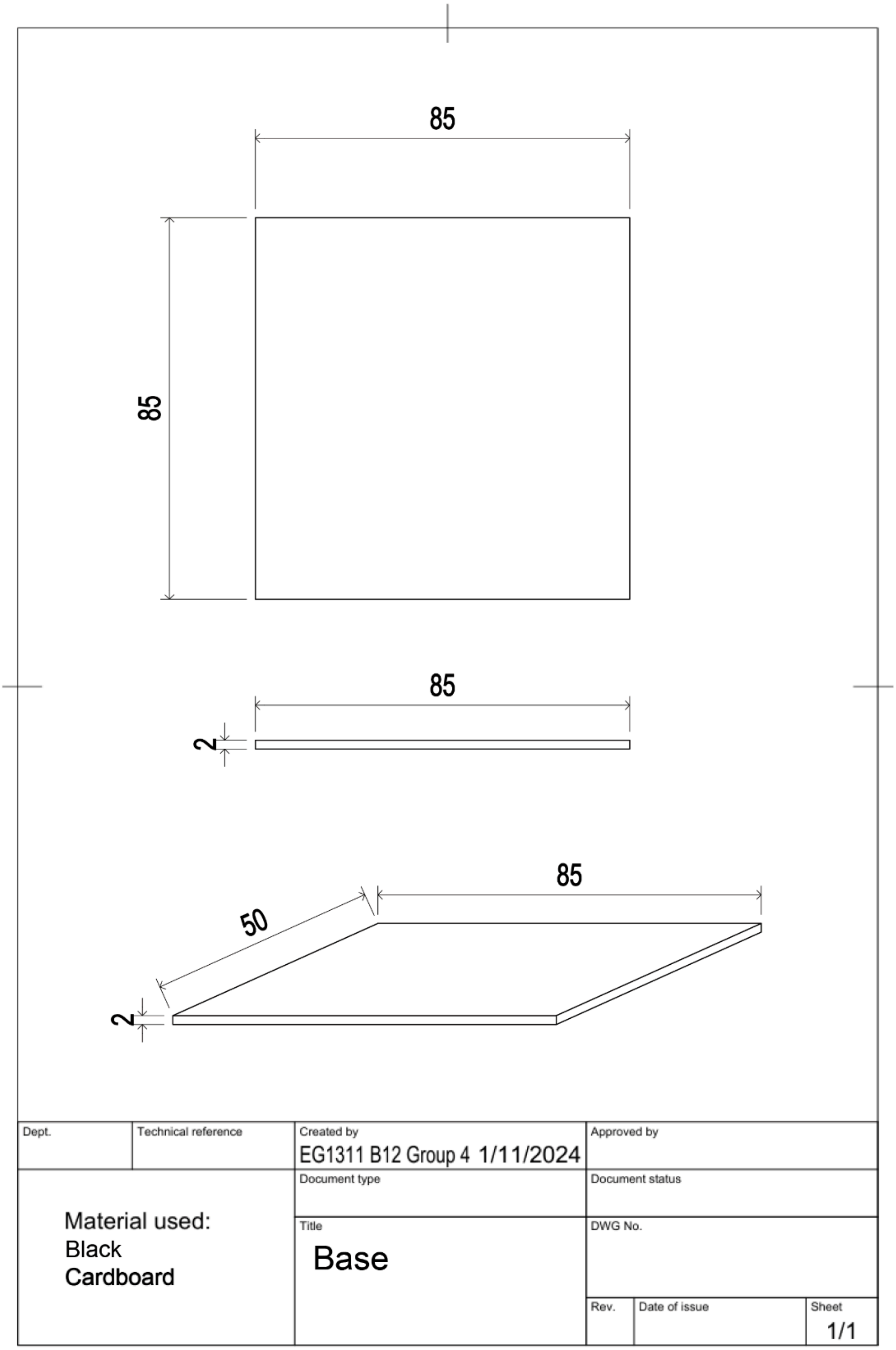

Figure 11. *2D CAD Drawing Dimensions of Base*

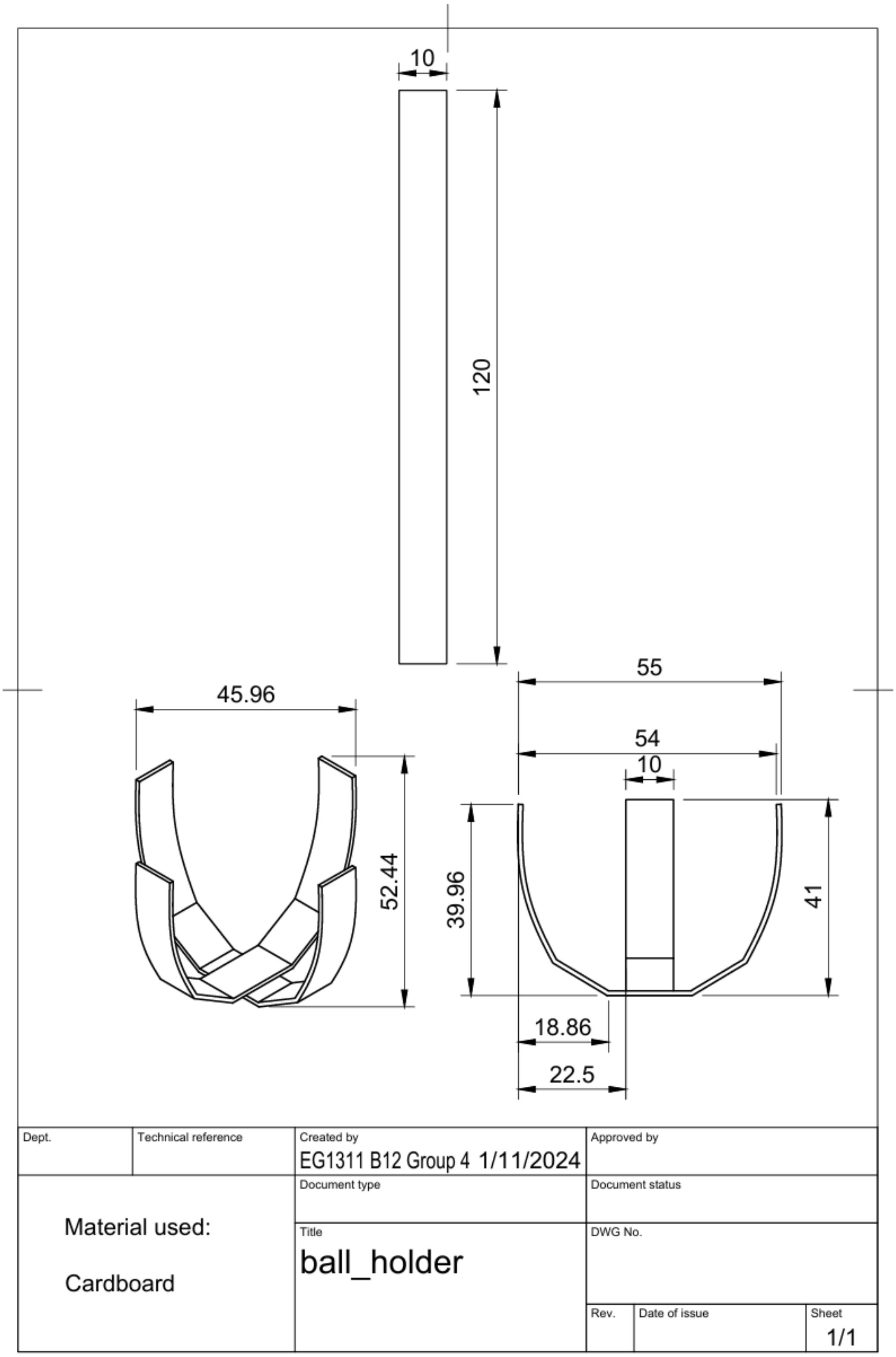

Figure 12. *2D CAD Drawing Dimensions of Ball Holder*

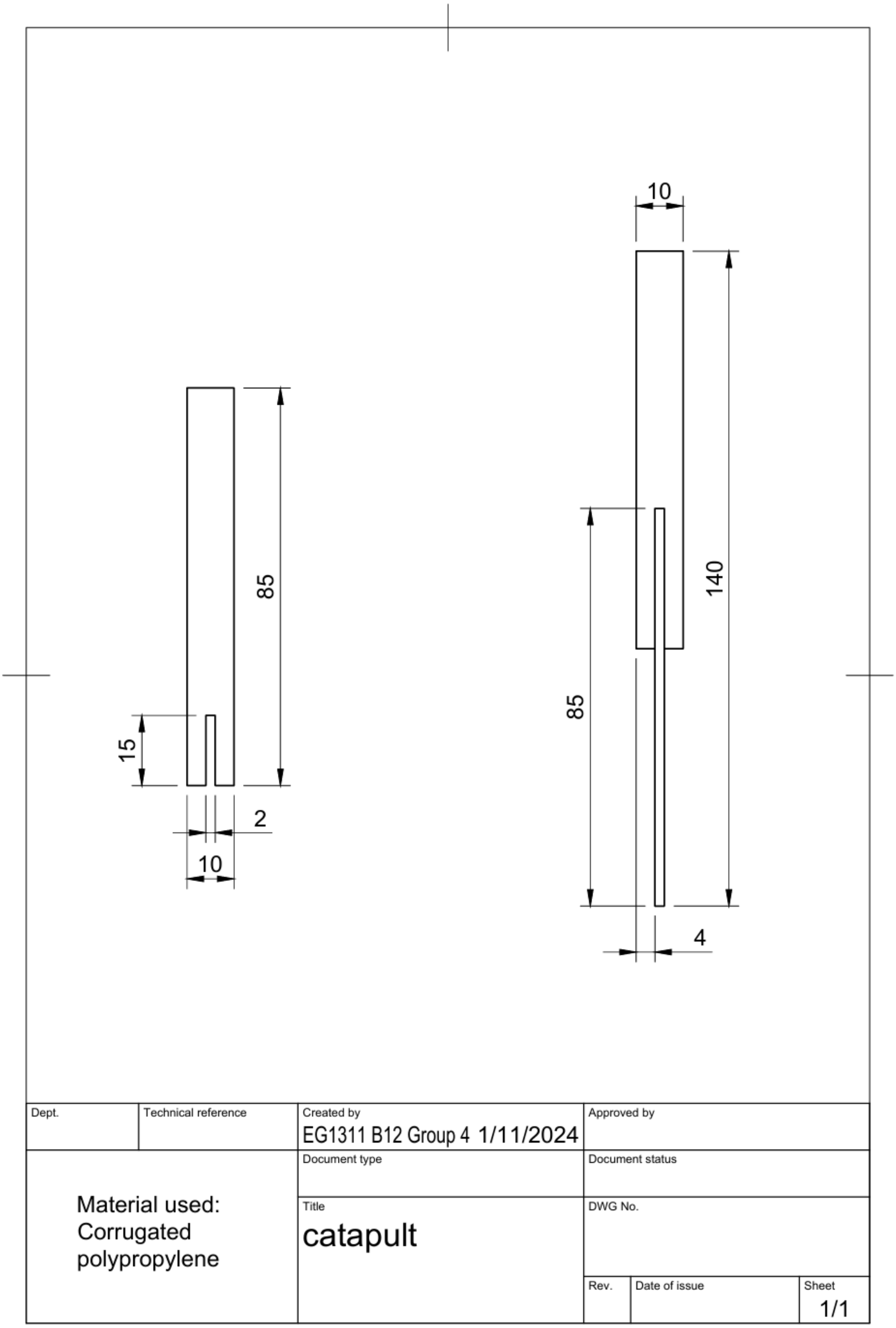

***Figure 13**. 2D CAD Drawing Dimensions of Catapult*

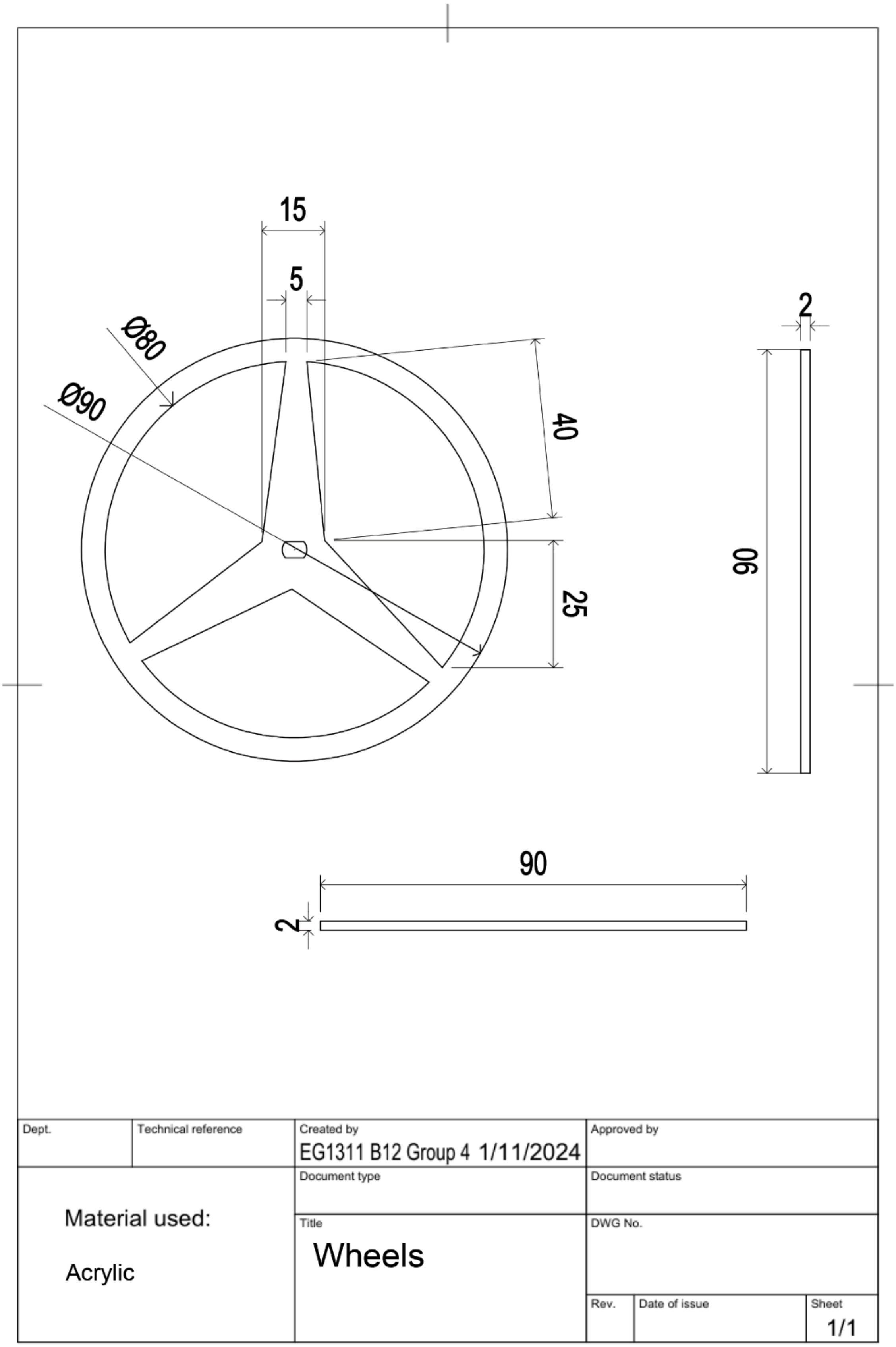

Figure 14. *2D CAD Drawing Dimensions of Front Wheels*

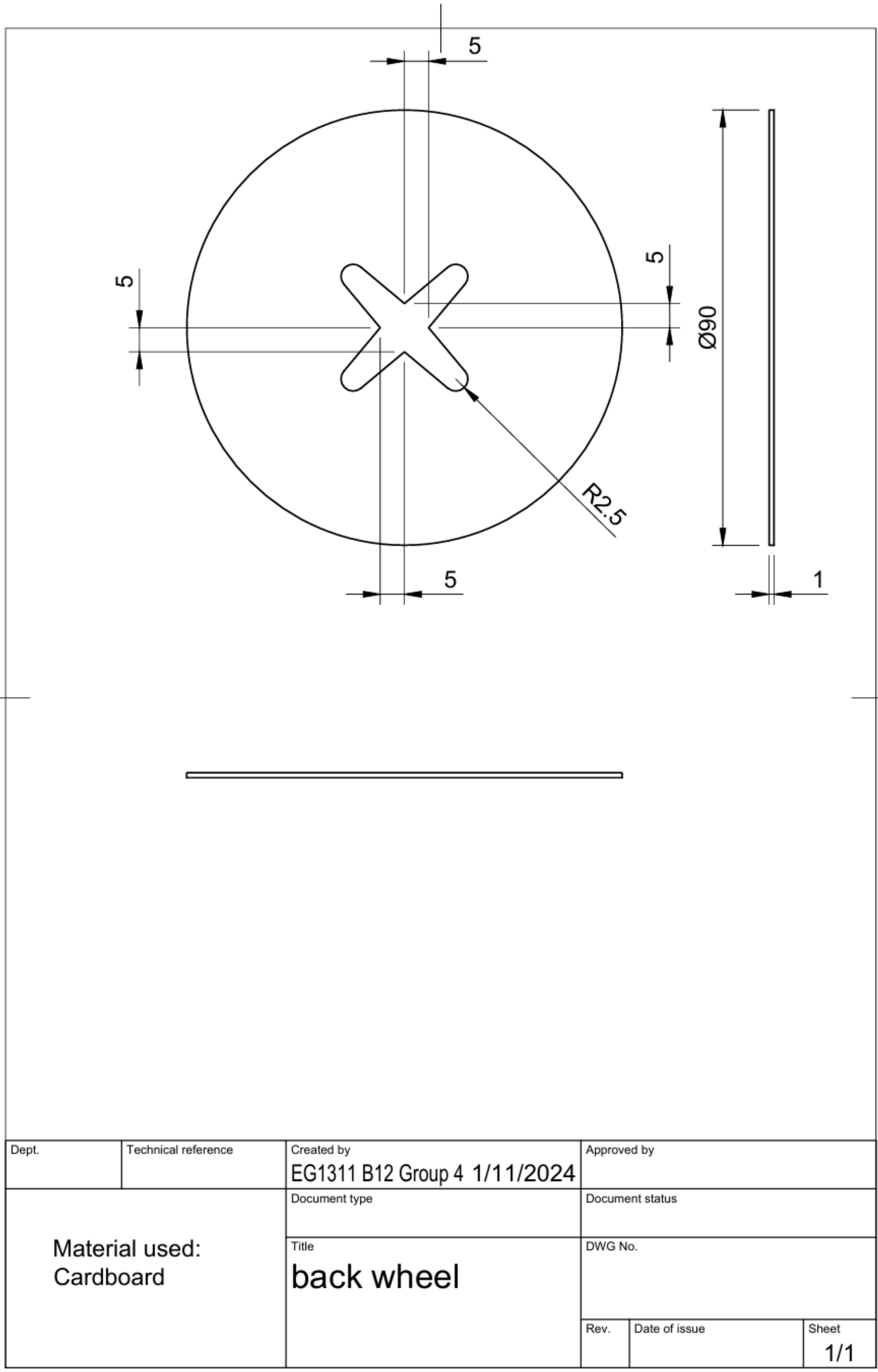

Figure 15. *2D CAD Drawing Dimensions of Back Wheels*