Construction Manual
Project Semester 2023

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Contents

1 Introduction

This construction manual is for the True Random Number Generator(TRNG) which was built during a student project semester. This TRNG uses a Triple-Pendulum as its noise source. It was continuously developed and improved over the course of 3 months. This manual describes the final prototype with all its components and how to build it as it is today.

2 Components

2.1 Tools

Tool Nr.	Tool Name
T1	3D Printer
T2	Laser Cutter
T3	Soldering Tools
T4	Hot-Glue-Gun
T5	Superglue
T6	WD 40
T7	Saw
T8	Drill

2.2 Electronic components

Electronic Nr.	Component
E1	Raspberry Pi 3b
E2	Relay
E3	INA 219 module
E4	12V DC motor
E5	23V DC lifting magnet
E6	Raspberry Pi fan
E7	Camera for Raspberry Pi

2.3 Material

All dimensions are stated in length x width x depth

Material Nr.	Material
M1	Wooden plank 30x40x2.5 cm
M2	Wooden plank 20x39x2.5 cm
M3	Wooden plank 15x13x3 cm
M4	Wooden plank 40x15x0.5 cm
M5	Wooden plank 22x17x0.5 cm
M6	Wooden plank 22x22x0.5 cm
M7	2 wooden poles 50x4x4 cm
M8	2 metal bars with 123 cm length with M8 holes
M9	Round wooden plate with a radius of 7.5 cm
M10	Wooden stick 100x1x1 cm
M11	4 mounting brackets
M12	Strap
M13	Threaded rod 19 cm M8
M14	9 bolt nuts
M15	5 thin nuts
M16	5 ball bearings
M17	Conductive aluminum tape
M18	Hinge
M19	Weights to balance out the pendelum
M20	Counterweight for lifting magnet (weights the same as the lifting magnet)
M21	2 gearwheels matching the strap
M22	3 carrera sliding contacts
M23	Wood screws
M24	Zip ties
M25	10 short threaded rods M8
M26	2 rubber bands
M27	Hooks
M28	2 meter camera cable
M29	Jumper cables
M30	Square black wooden plank 0.2x7x7 cm
M31	Round piece of wood with the radius of the gearwheel
M32	2 wooden sticks 2.5x10.5x1.5 cm
M33	Aluminum plate to enhance
M34	Wingnuts
M35	2 sleeves for the lifting magnet and the counterweight

2.4 3D printed materials

Material Nr.	Material
D1	Pendelum arms
D2	Raspberry Pi casing
D3	Relay casing
D4	Camera casing

2.5 Repository

TrueRandomNumberGenerator

3 Building instructions

3.1 Precautions

Before building the TRNG make sure you have all materials and tools listed above. 3D print all the parts using the complimentary files. All parts should be printed using pearl white PLA printing material.

The measurements can be scaled up or down if desired.

3.2 Drilling and sawing

First, take the board [M1] and drill holes into it as shown on Image 1. Now drill holes into the board [M2] as shown on Image 2. Make sure not to drill all the way through The holes have to be 0.8 cm in width.

Take one of the wooden poles [M7] and drill a hole 41 cm high and big enough for the threaded rod [M13] to fit through.

Take the round wooden plate [M9] and drill holes into it as shown on Image 3. (The size of the holes for the lifting magnet and the counterweight can be adjusted depending on the lifting magnet and weight you are using) The lifting magnet and its counterweight should be able to fit into the two bigger holes.

Drill a hole at each end of the wooden sticks [M32].

Now take the board M6 and saw it as shown on Image 4.

3.3 Ground boards

Take the 2 wooden planks [M1] and [M2]. Mark the center of the planks and install the wooden pole, where you drilled a hole into, on the [M1] Board [M7]

using the mounting brackets [M11] and screws [M23] as shown on Image 5. Now install the other pole on the other board using the same technique. Make sure the poles are leveled out.
For the next step take 4 of the short threaded rods [M25]. Glue the short threaded rods into the holes that you drilled earlier into [M1]. Do the same on the other ground board [M2] using another 4 short threaded rods. Connect the two ground boards using the metal bar [M8]. The distance from pole to pole should later be adjusted to the camera.
Fixate the bar [M8] on the threaded rods using the wing nuts [M34].

3.4 Drive pulley

Take the sleeves [M35] and glue them in line with the holes for the lifting magnet and the counterweight. Take the smaller round piece of wood [M31] to create a distance between the gearwheel [M21] and the counterweight. This ensures that the lifting magnet can run freely. Screw together the bigger round plate [M9], the smaller round plate [M31] and the gearwheel [M21] as shown on Image 6. Now use the conductive aluminum tape [M17] to isolate the edge of the bigger round plate [M9]. Put the lifting magnet and the counterweight into their sleeves [M35] and fixate them using the hot-glue gun [T4] and superglue [T5]. Now connect one wire of the lifting magnet to the gearwheel and the other one to the isolated edge. To fixate them use the aluminum tape [M17].

3.5 Pendulum

Take two of the Pendulum arms [D1] and superglue bearings [M16] into the middle hole and in one outer hole where the red circle indicates as it is shown on Image 7. Take the third Pendulum arm, glue one bearing into the middle hole and screw the black square [M30] onto one end. Take one of the arms with two bearings and put a weight [M19] into the left over hole (The weight should be around 220 g; this can vary). Take the second arm with two bearings and connect the middle bearing with the outer bearing of the first arm using a short threaded rod [M25] as follows: flat nut [M15], Pendulum arm, 2 bolt nuts, Pendulum arm, flat nut. It is also shown on Image 8. Now connect the second and third arm using the same technique so the Pendulum looks like it is shown in Image 9.

The middle Pendulum arm should also have a counter weight in the empty hole. The weight has to be adjusted to the Pendulum and the way it swings.

3.6 Installing the pendulum

Take the long threaded rod [M13] and put two bolt nuts [M14] on it approximately 7 cm from the top. Put one more bolt nut on it approximately 2 cm from the top. Then put the Pendulum on it using the hole as shown on Image 10. Secure the Pendulum using a flat nut [M15] so it sits on the very top of the

threaded rod as shown on Image 11. Now on the opposite end of the threaded rod put on the drive pulley with the lifting magnet facing the Pendulum. Adjust the two bolt nuts you put on earlier to get the distance between Pendulum and lifting magnet right as it is shown on Image 12. The red circle shows where the pin emerges from the lifting magnet. Put some of the WD 40 [T6] into the hole of the drive pulley to avoid squeaking. Take the long end of the threaded rod [M13] and put it through the hole. Put on two more bolt nuts [M14] to secure the construct on the pole.

3.7 Casing

Take the top of the 3D printed Raspberry Pi casing [D2] and install the fan [E6]. Install the Raspberry Pi casing [D2] and the relay casing [D3] on the back side of the ground board [M1] similar as shown on Image 13. It is important to install the casings in such a way that the cables can run freely. Put the Raspberry Pi [E1] and the Relay [E2] into their casings. Install the INA 219 module [E3] on the pole using two screws [M23] as it is shown on Image 13.

3.8 Engine

Take the wooden plank [M3] and install it on the ground board [M1] as follows: Align the midpoint of the longer side of the plank with the pole as shown on Image 14. Take one of two wooden sticks [M32] which should be rounded and on top fitted with a piece of aluminum to make it more resistant. Then install them like it is shown on Image 15 to secure the engine on the board.

3.9 Sliding contacts

To make the sliding contact the wooden stick [M10] has to be sawed to smaller pieces depending on the distance from the pole to the construct with the round wooden plate [M9] as seen on Image 16 to Image 20. Attach the carrera sliding contacts [M22] to the wooden stick [M10]. Then solder the cable to the contact. Now attach the sliding contacts on the pole [M7] as shown on Image 16 to Image 20. Use the hooks [M27] and the rubber bands [M26] to ensure the sliding contacts constantly touch and make connection.

3.10 Wiring

Connect all electrical components as it is shown on Image 21. The connections to the lifting magnet are replaced by the sliding contacts.

3.11 Camera

Plug in the camera cable [M28] into the camera [E7] and into the Raspberry Pi as shown on Image 22. To make sure the camera sits at a perfect height use the Raspberry Pi to display the camera's perspective. Mount the camera at a

height so the Pendulum is fully inside the cameras view using the 3D printed camera casing [D4]. To achieve that, move the Pendulum by hand and extend all arms in all directions and make sure the black square is always seen. This can also be adjusted by the metal bars [M8] and the distance from pole to pole.

3.12 Coding

Import the code from the complementary repository and download all needed packages. Now test all components. Make adjustments if necessary.

3.13 Cover

Take the board [M4] and install it on the board [M3] as shown on Image 22 using two screws [M23]. On the side install the board [M5] using two screws [M23] as shown on Image 24. For the top attach the hinge [M18] onto the boards [M5] and [M6] as shown on Image 24. The before sawed out parts should fit perfectly on the pole as shown on Image 25. If it does not fit, adjust it so the box closes and it wont interfere with the round wooden plate [M9].

3.14 Finish

The TRNG is now fully assembled and ready to generate true random numbers.

4 Images

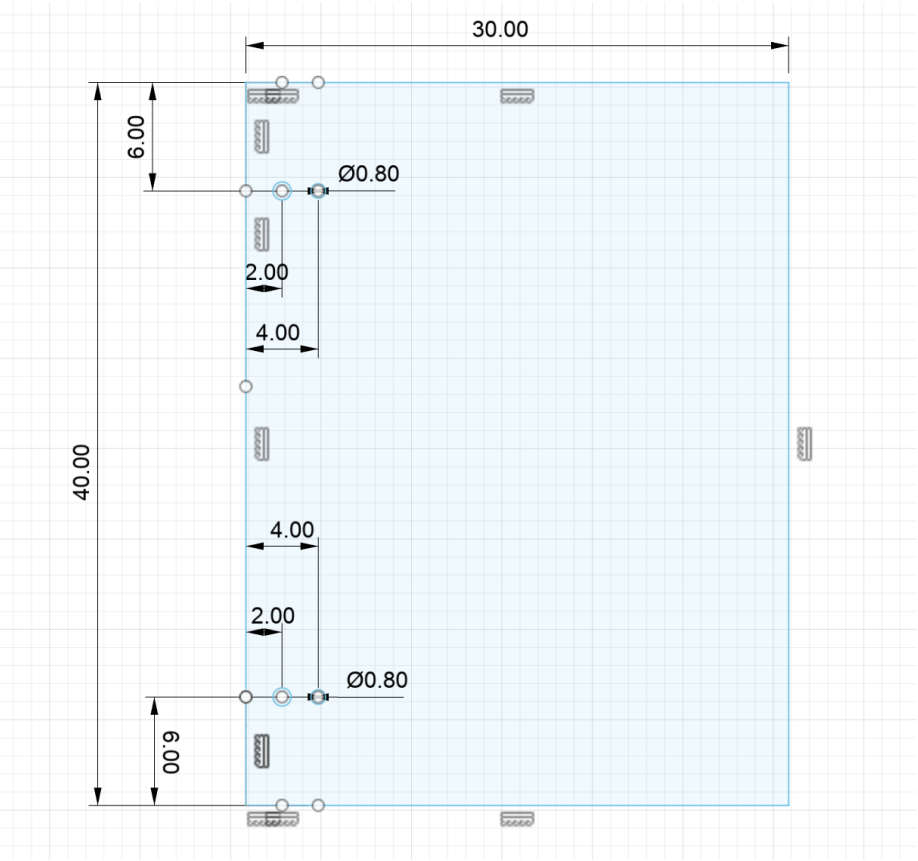

Figure 1: Image 1

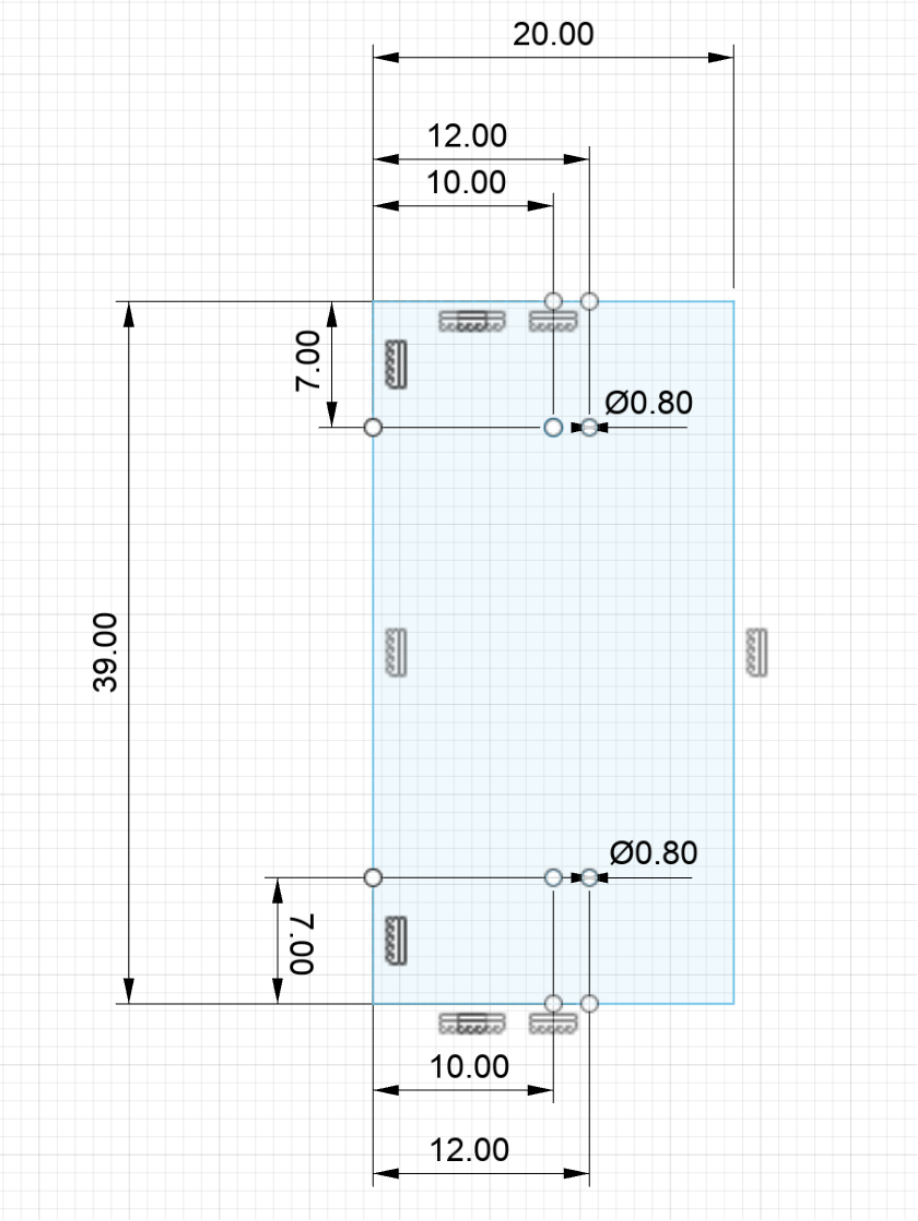

Figure 2: Image 2

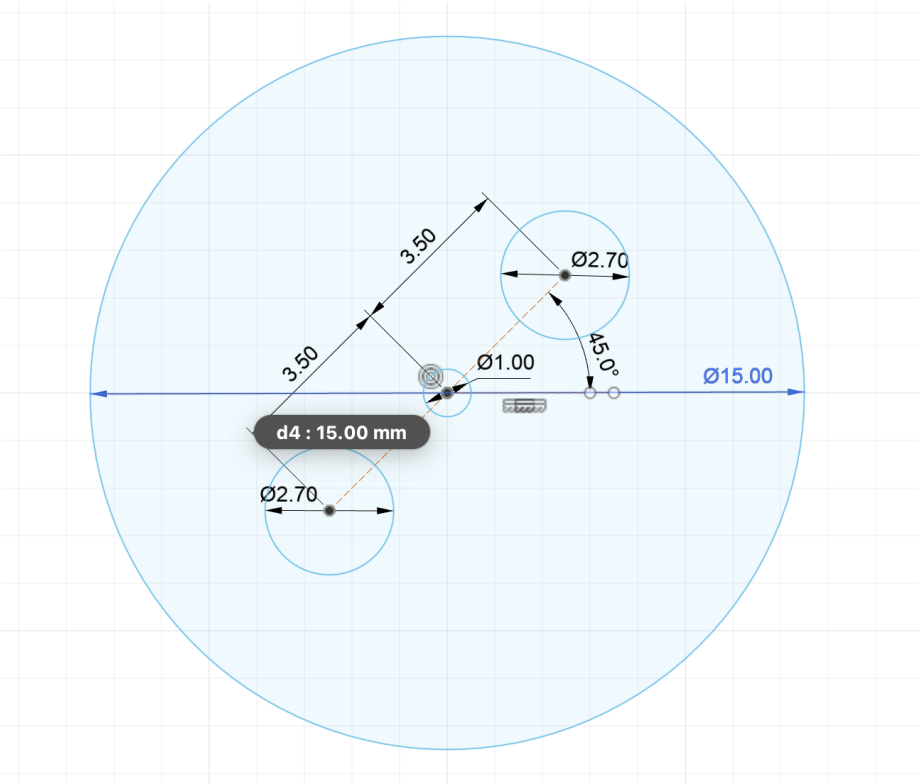

Figure 3: Image 3

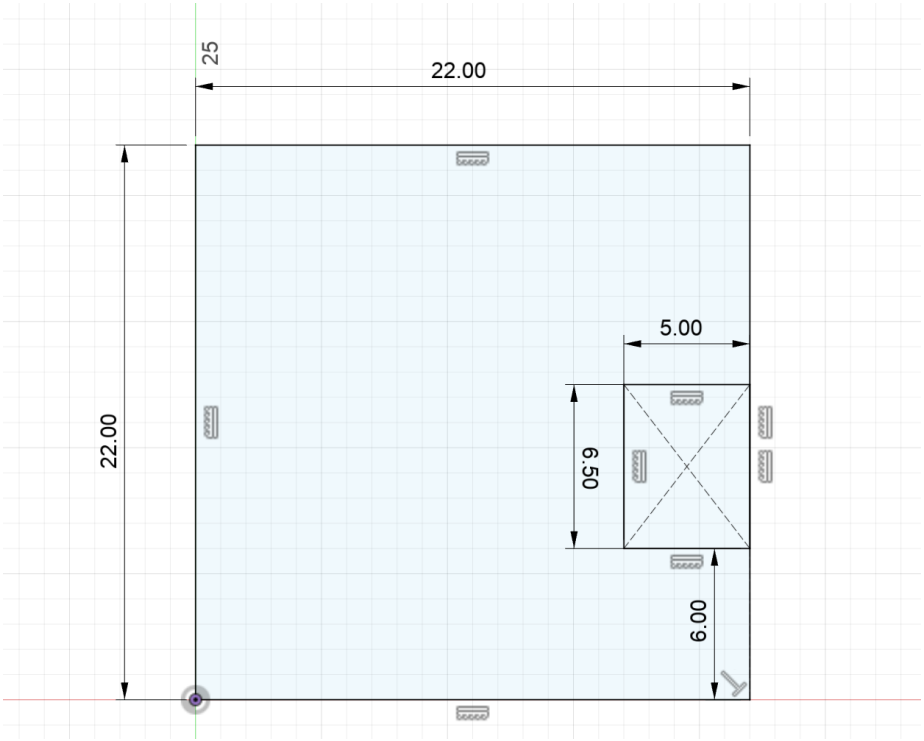

Figure 4: Image 4

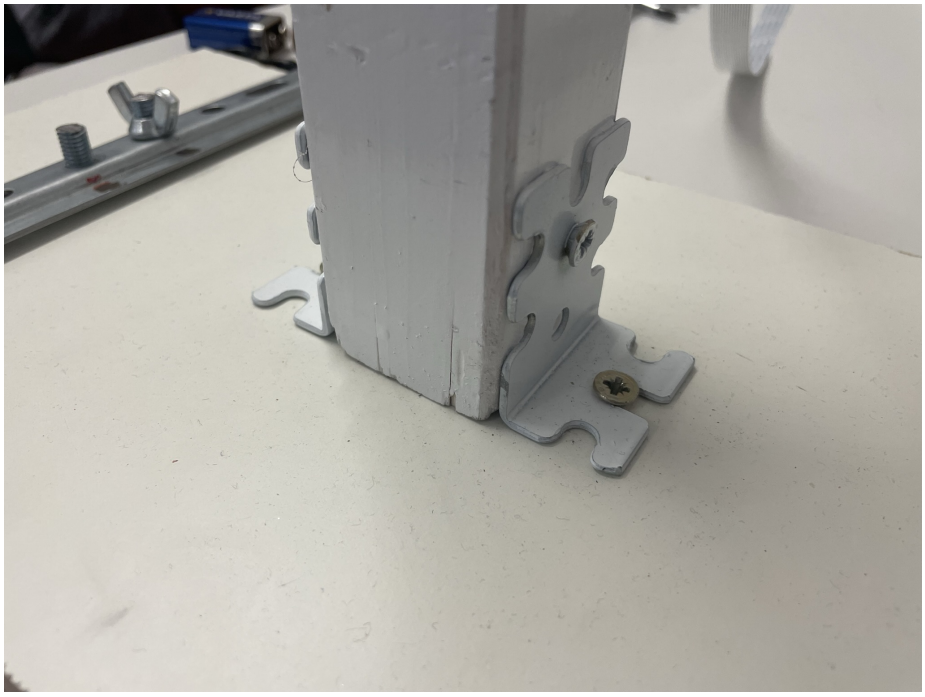

Figure 5: Image 5

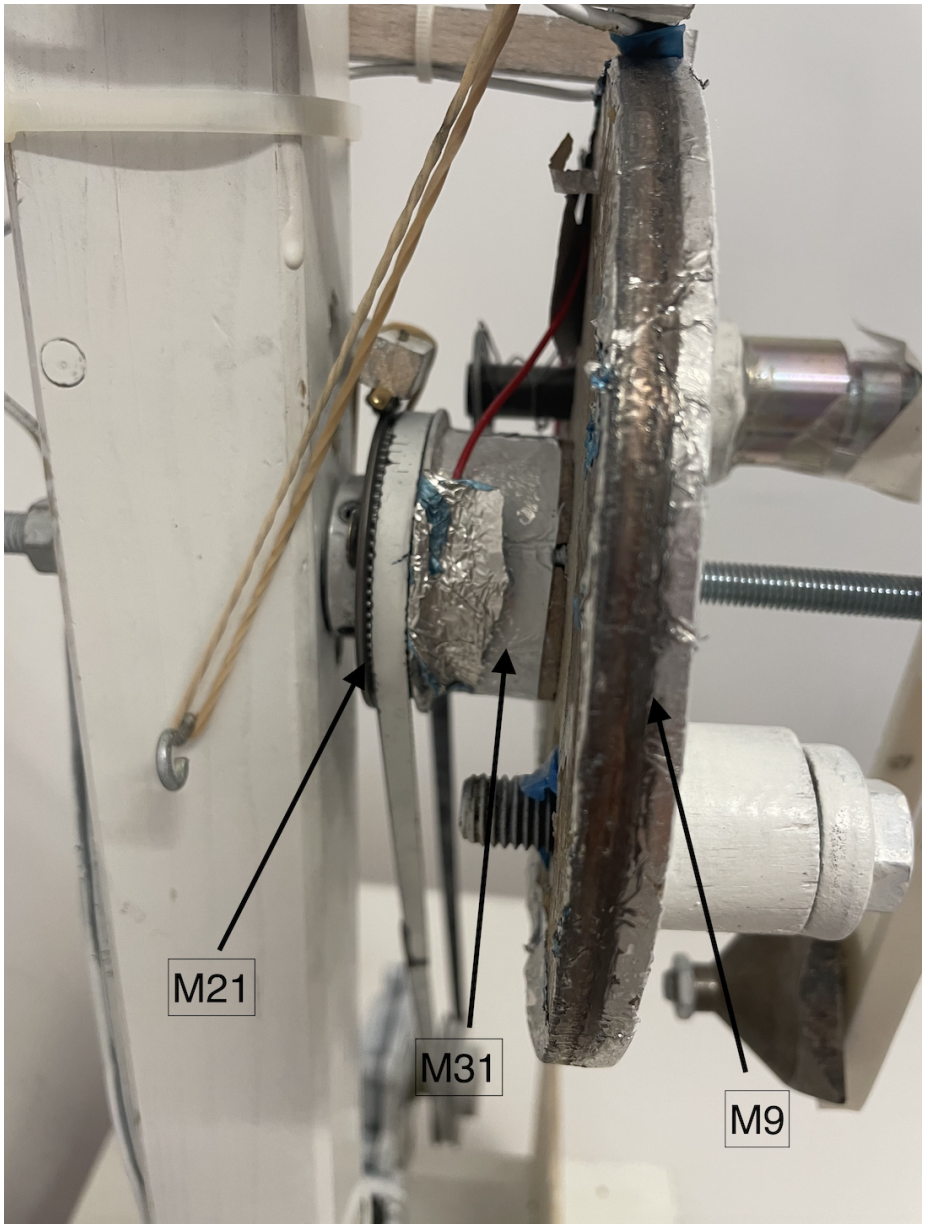

Figure 6: Image 6

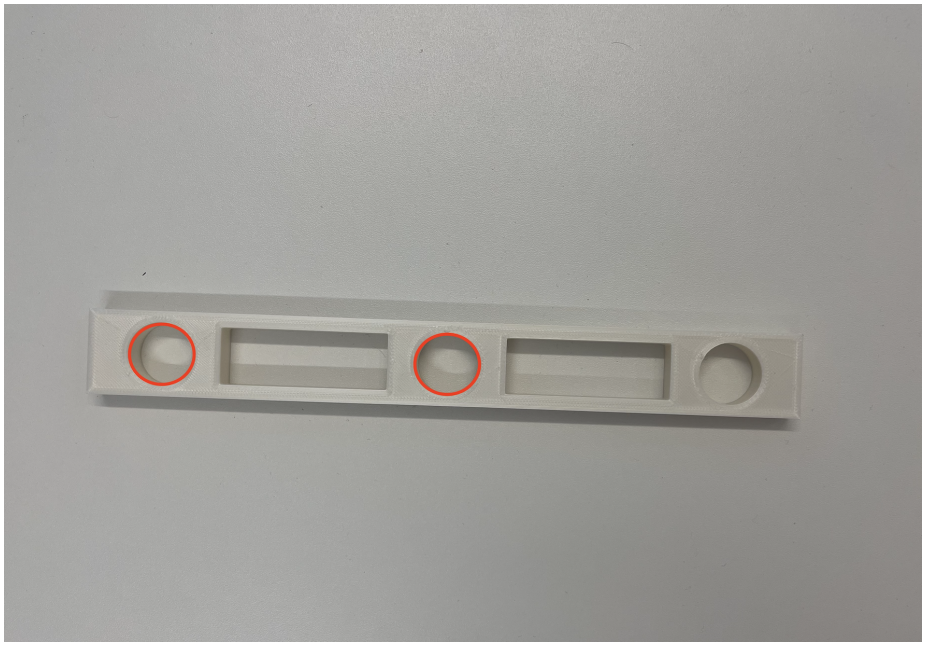

Figure 7: Image 7

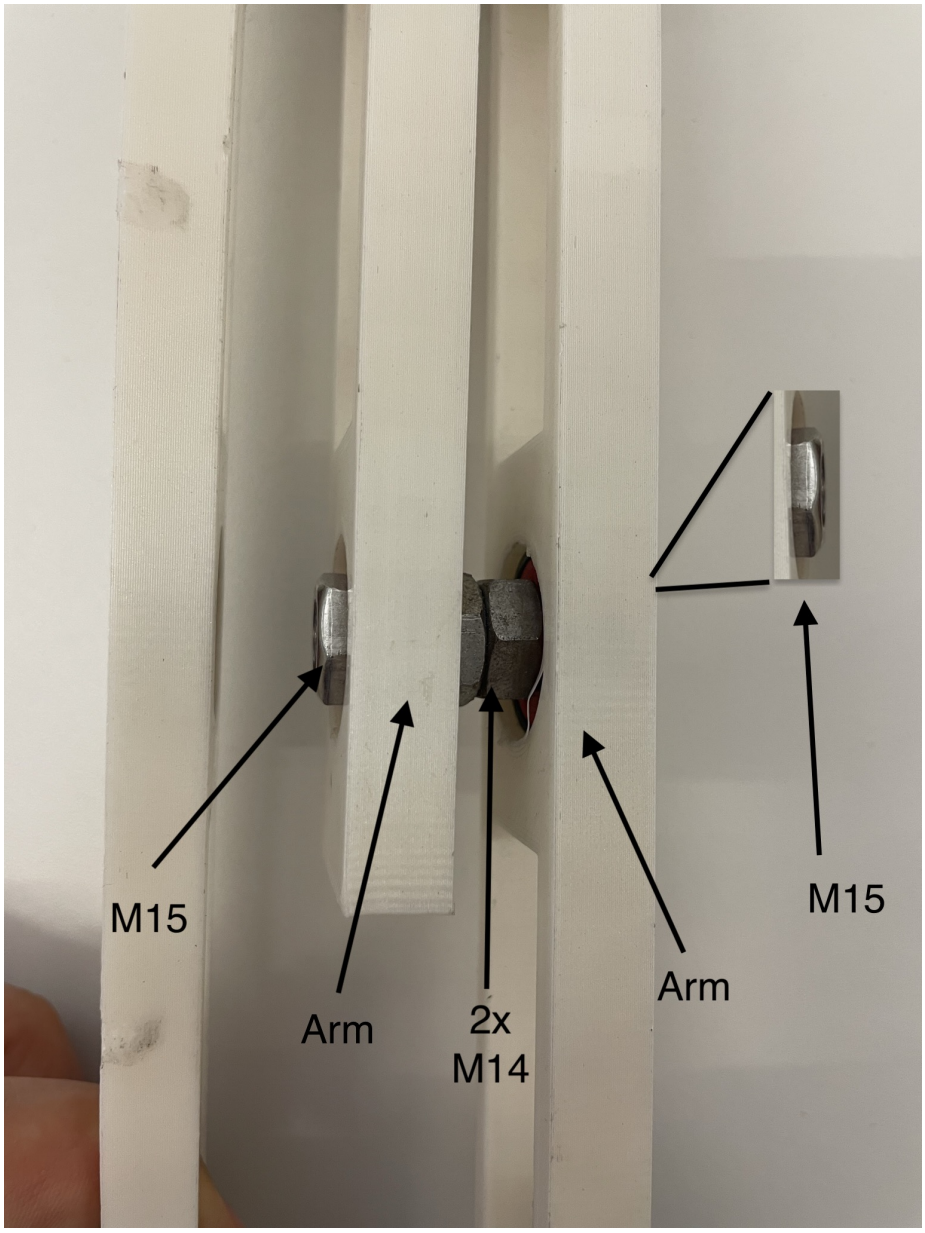

Figure 8: Image 8

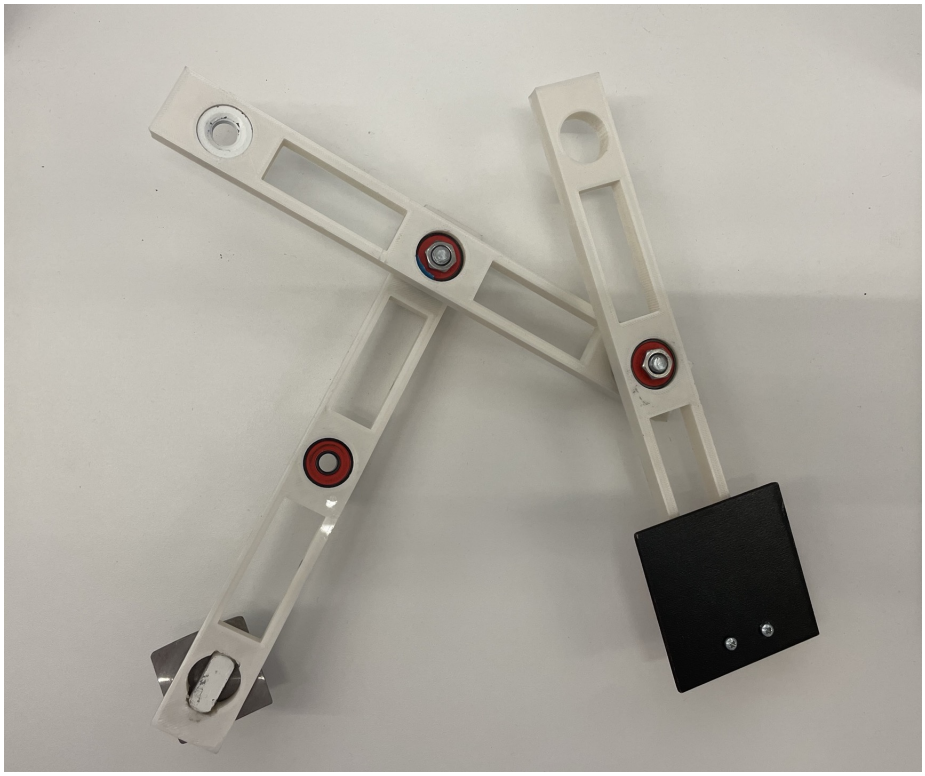

Figure 9: Image 9

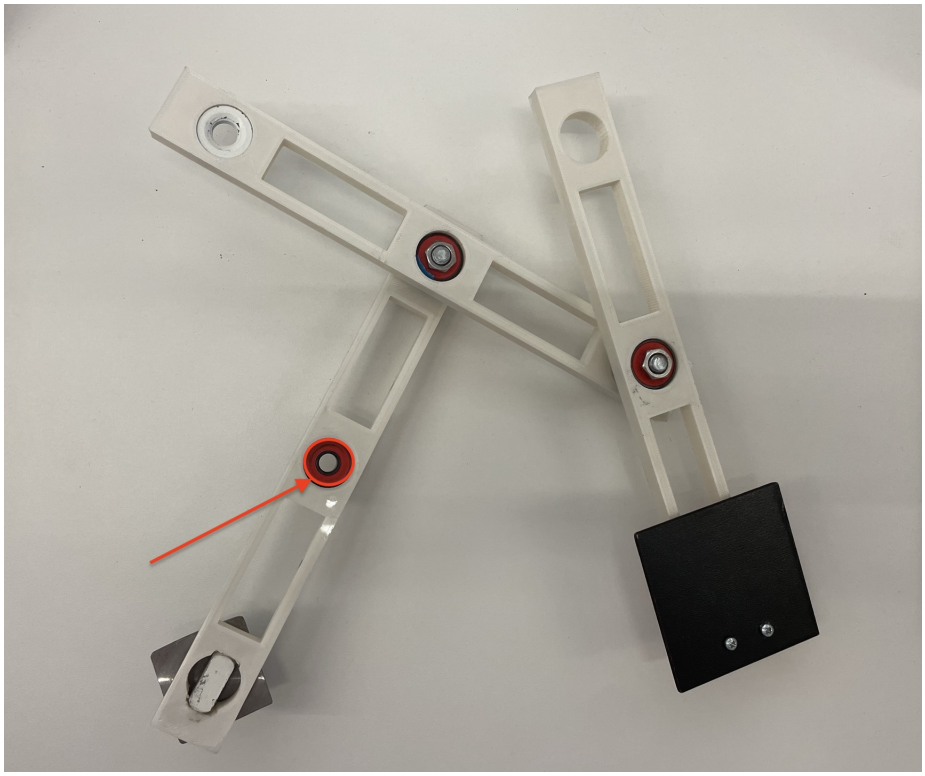

Figure 10: Image 10

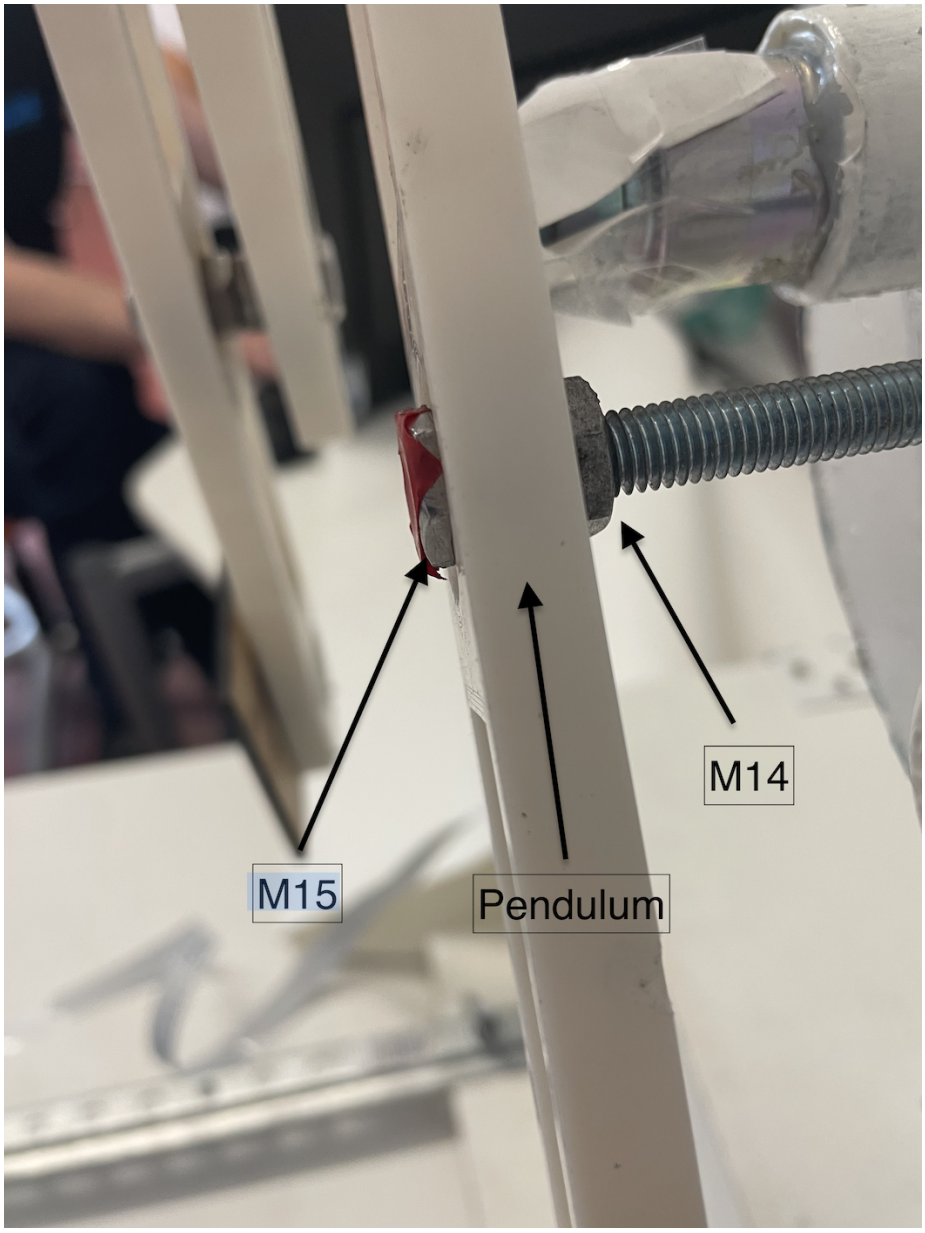

Figure 11: Image 11

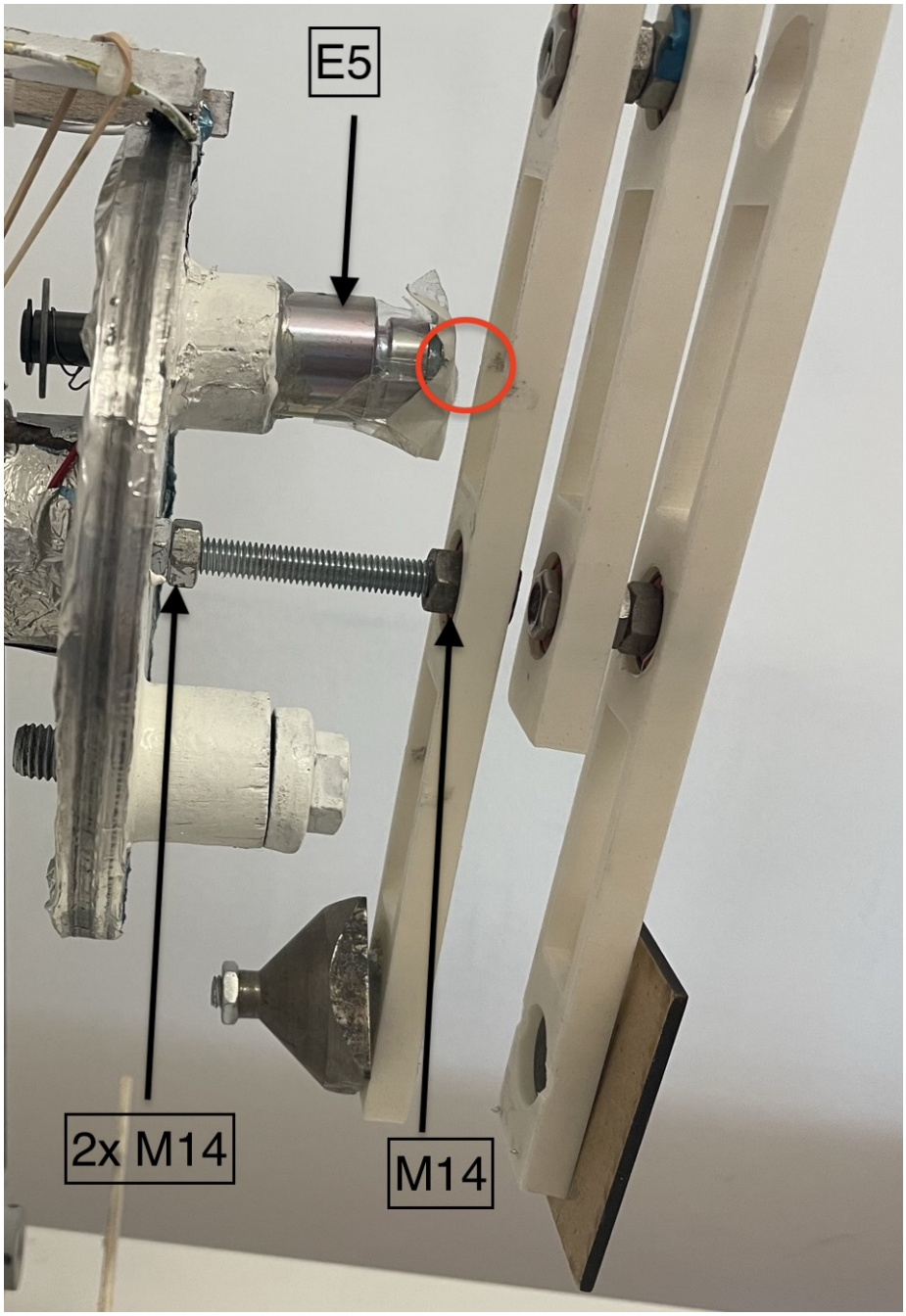

Figure 12: Image 12

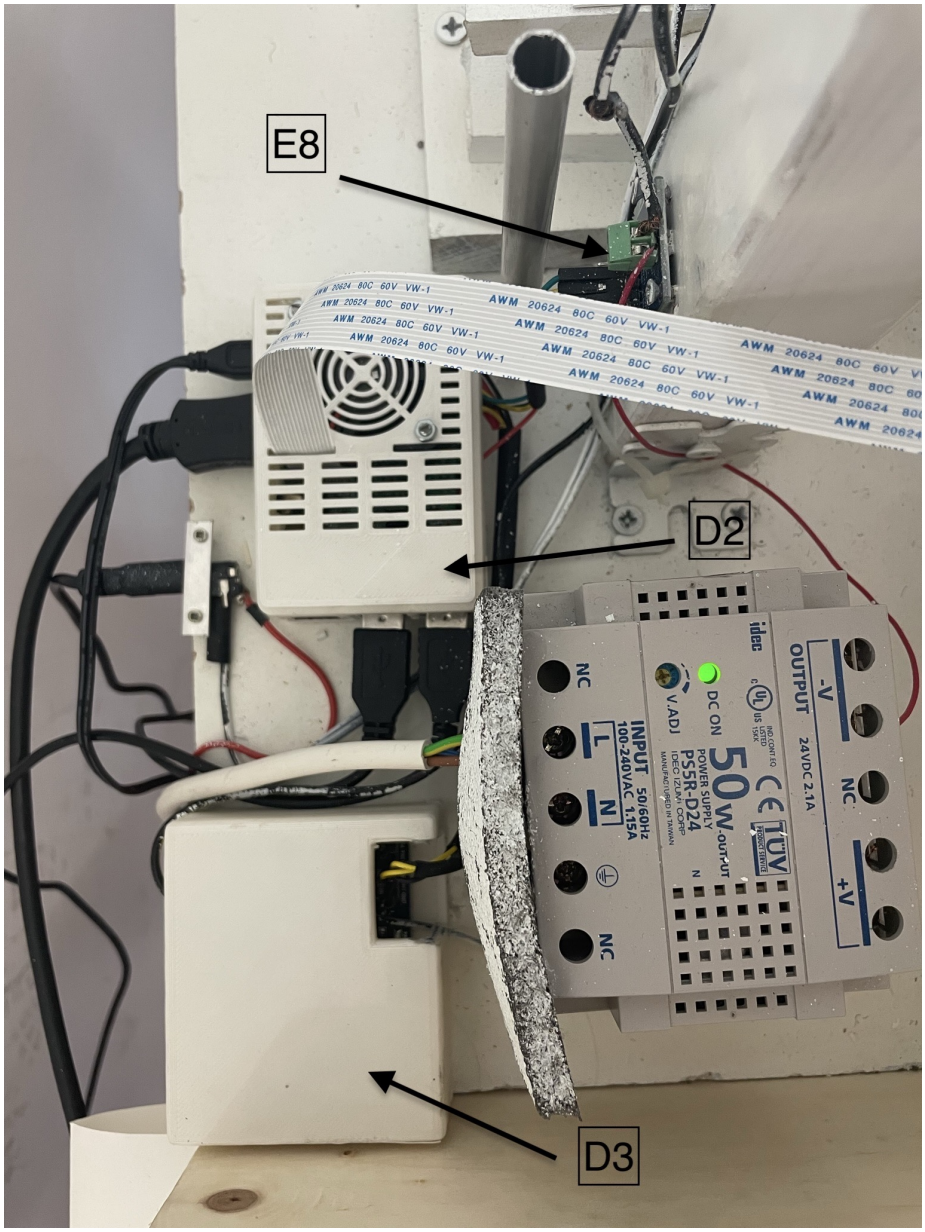

Figure 13: Image 13

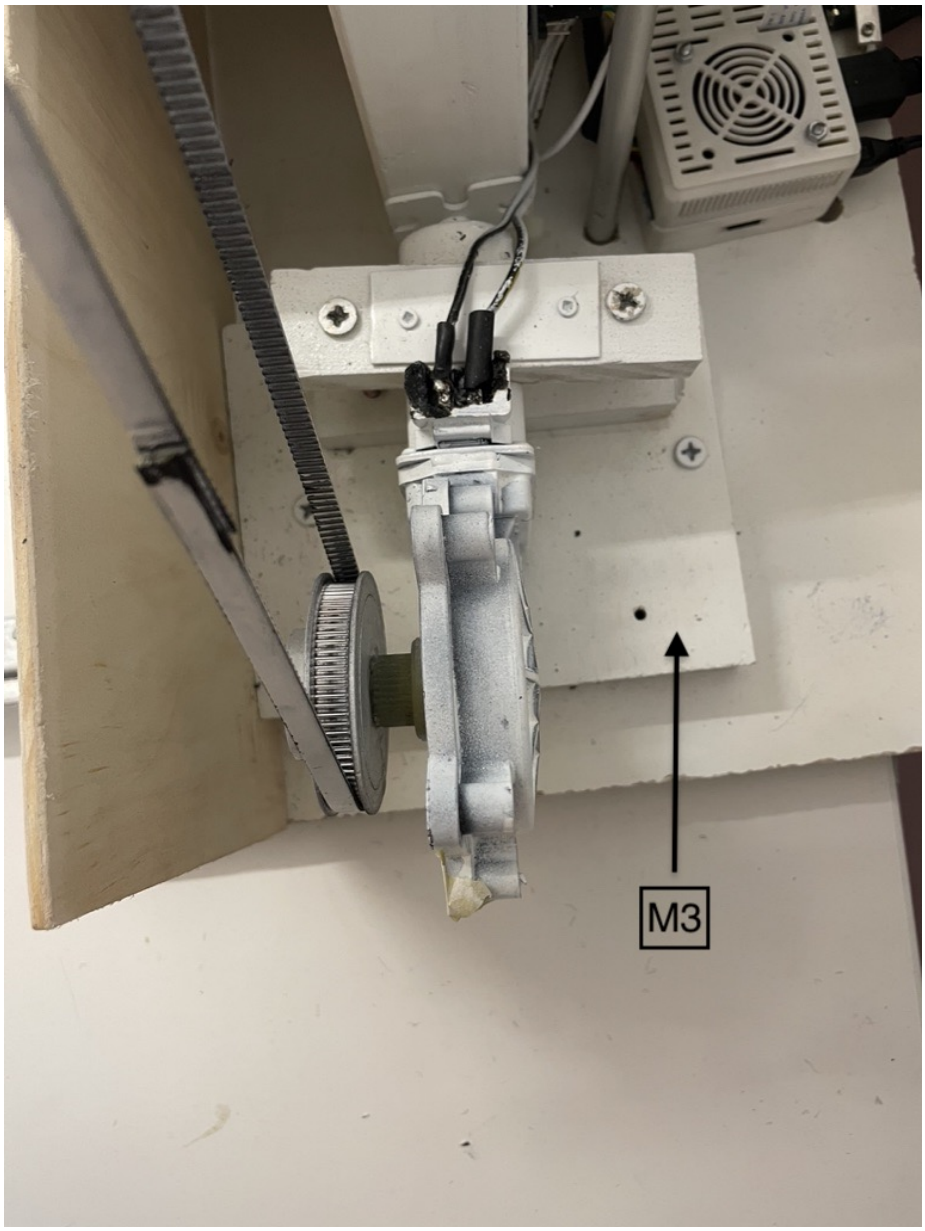

Figure 14: Image 14

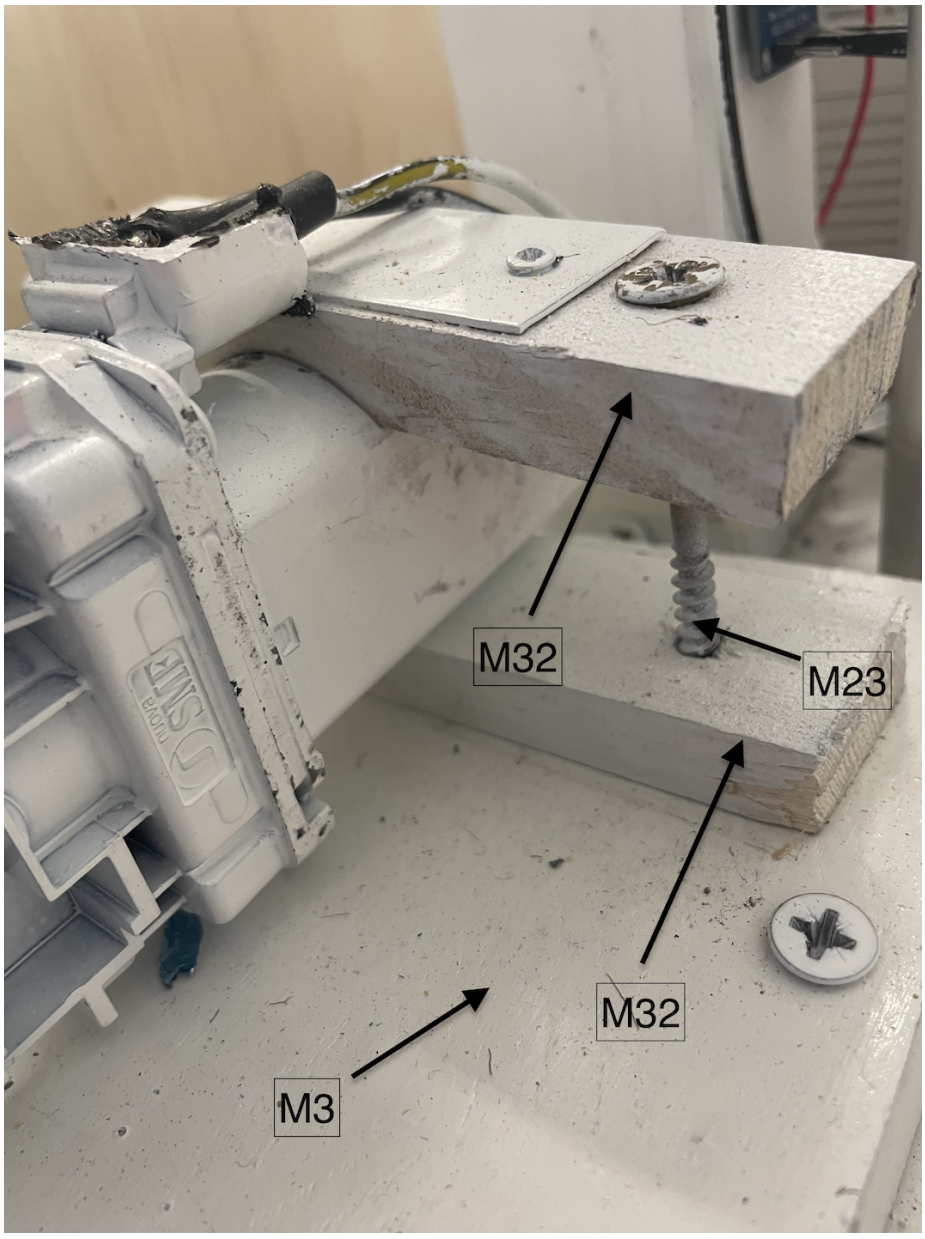

Figure 15: Image 15

Figure 16: Image 16

Figure 17: Image 17

Figure 18: Image 18

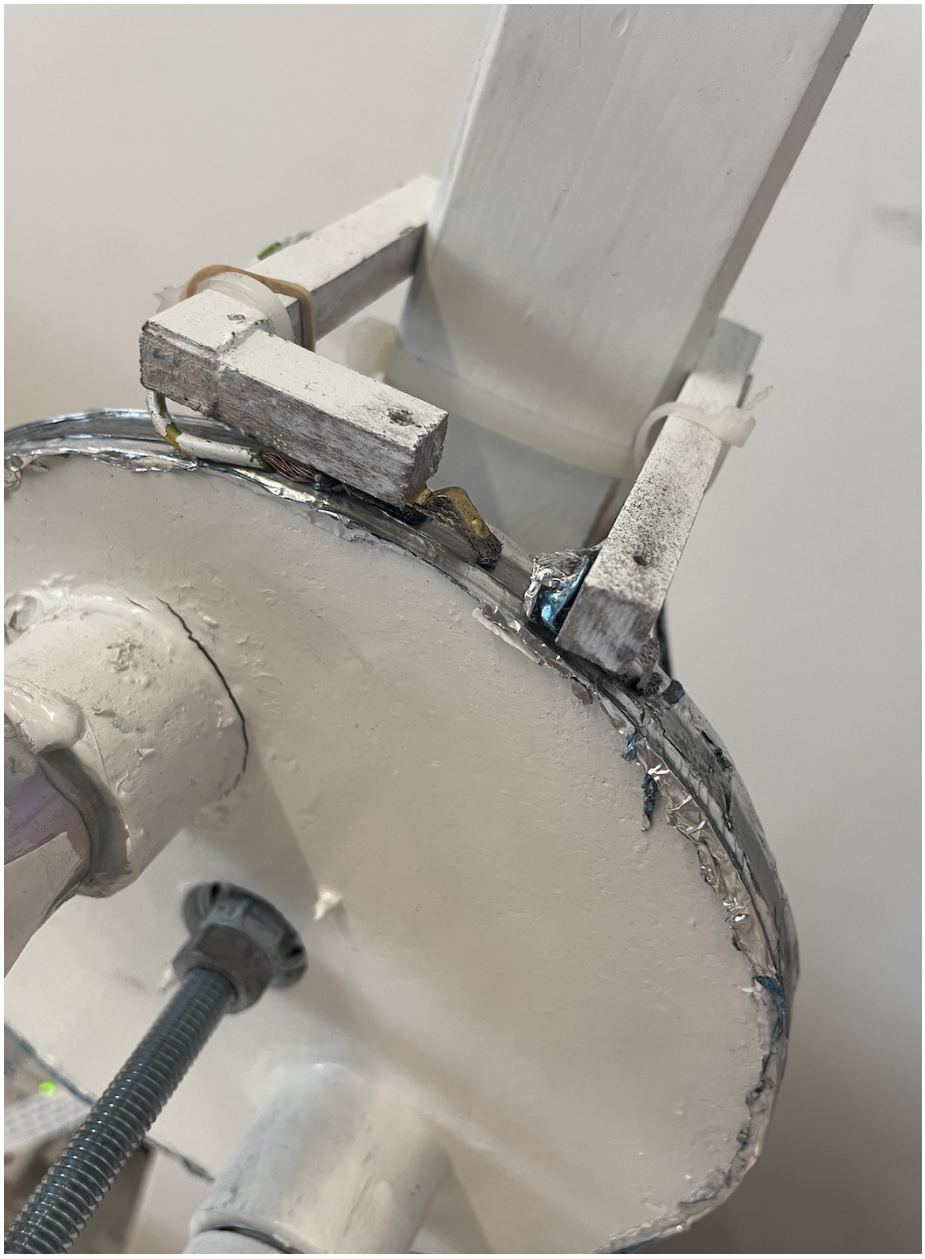

Figure 19: Image 19

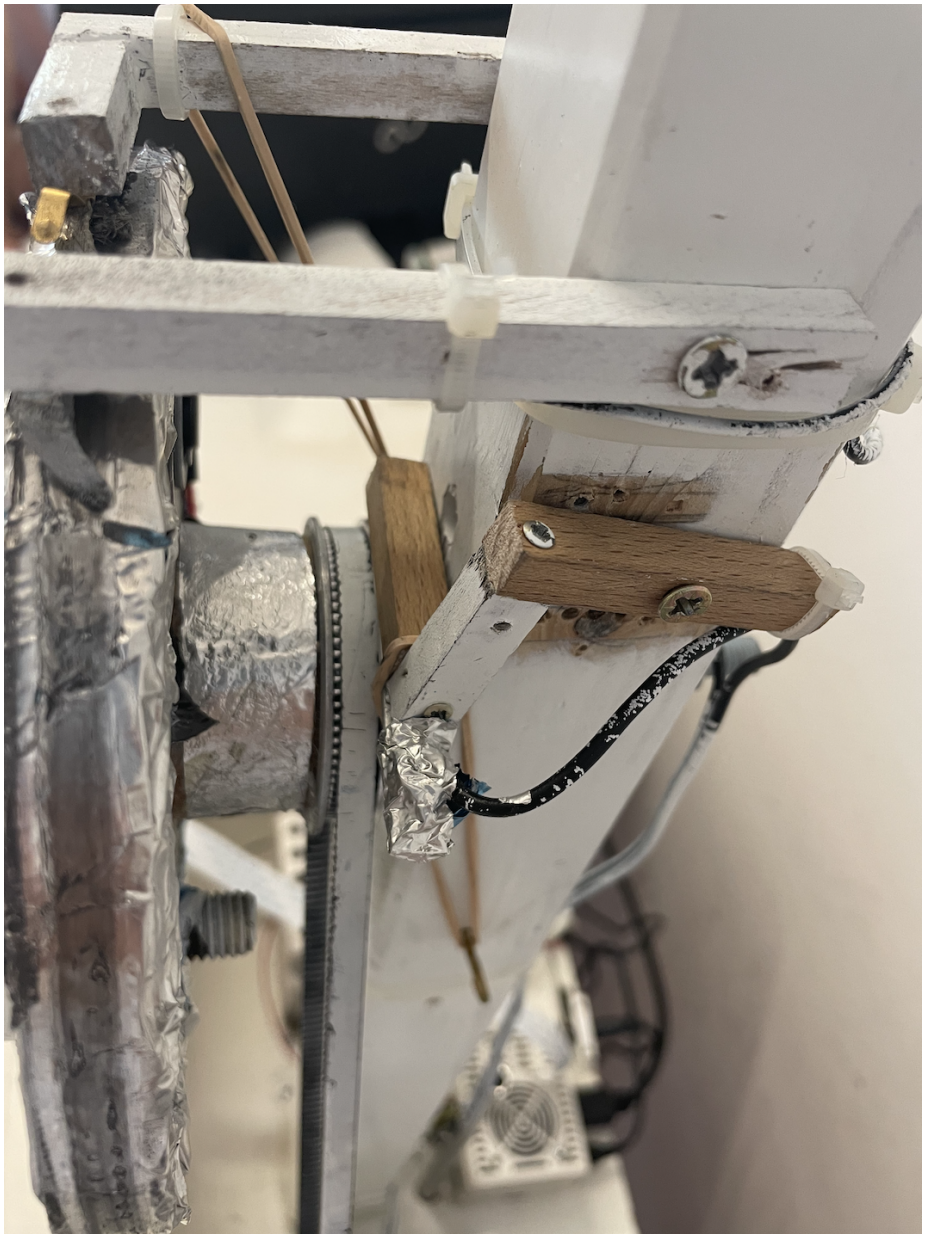

Figure 20: Image 20

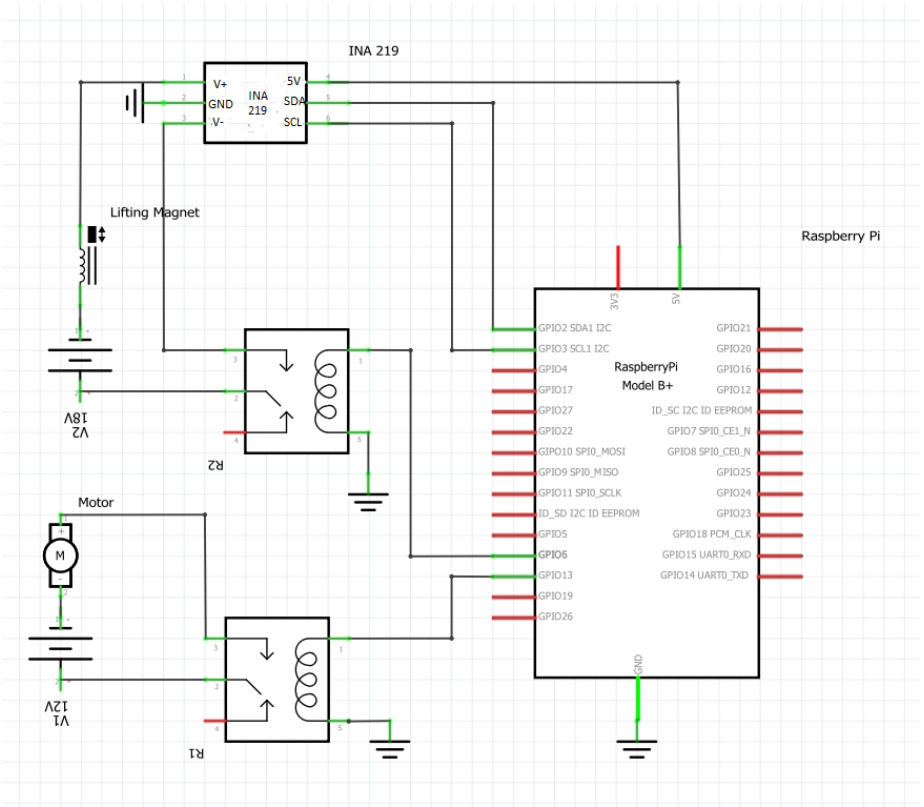

Figure 21: Image 21

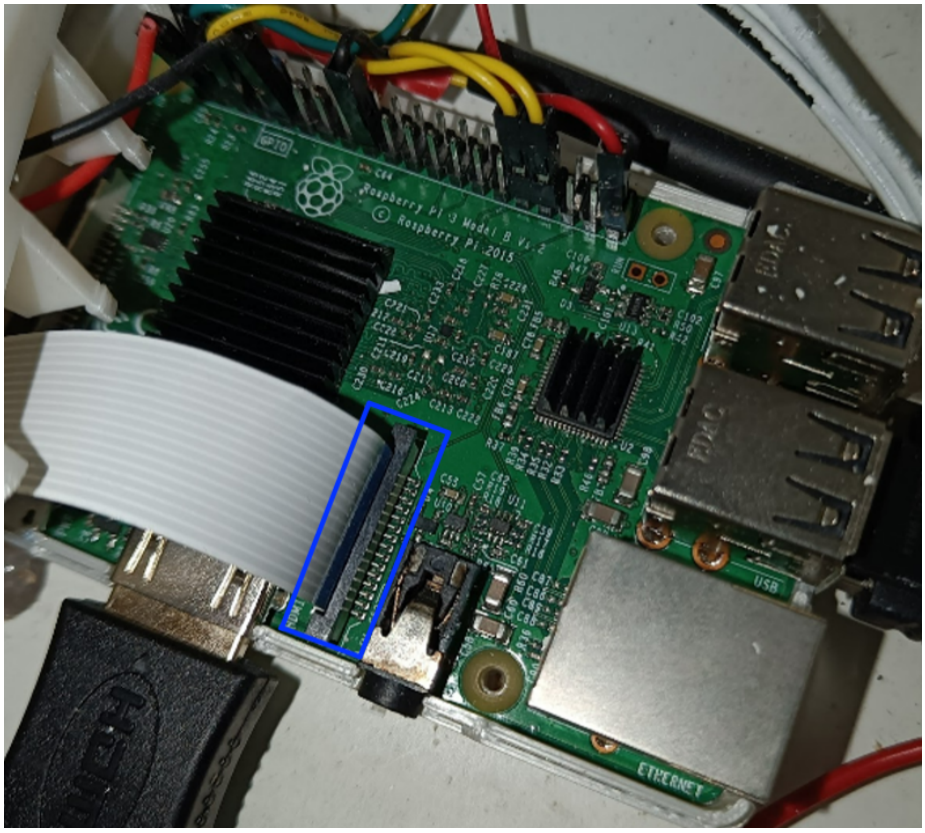

Figure 22: Image 22

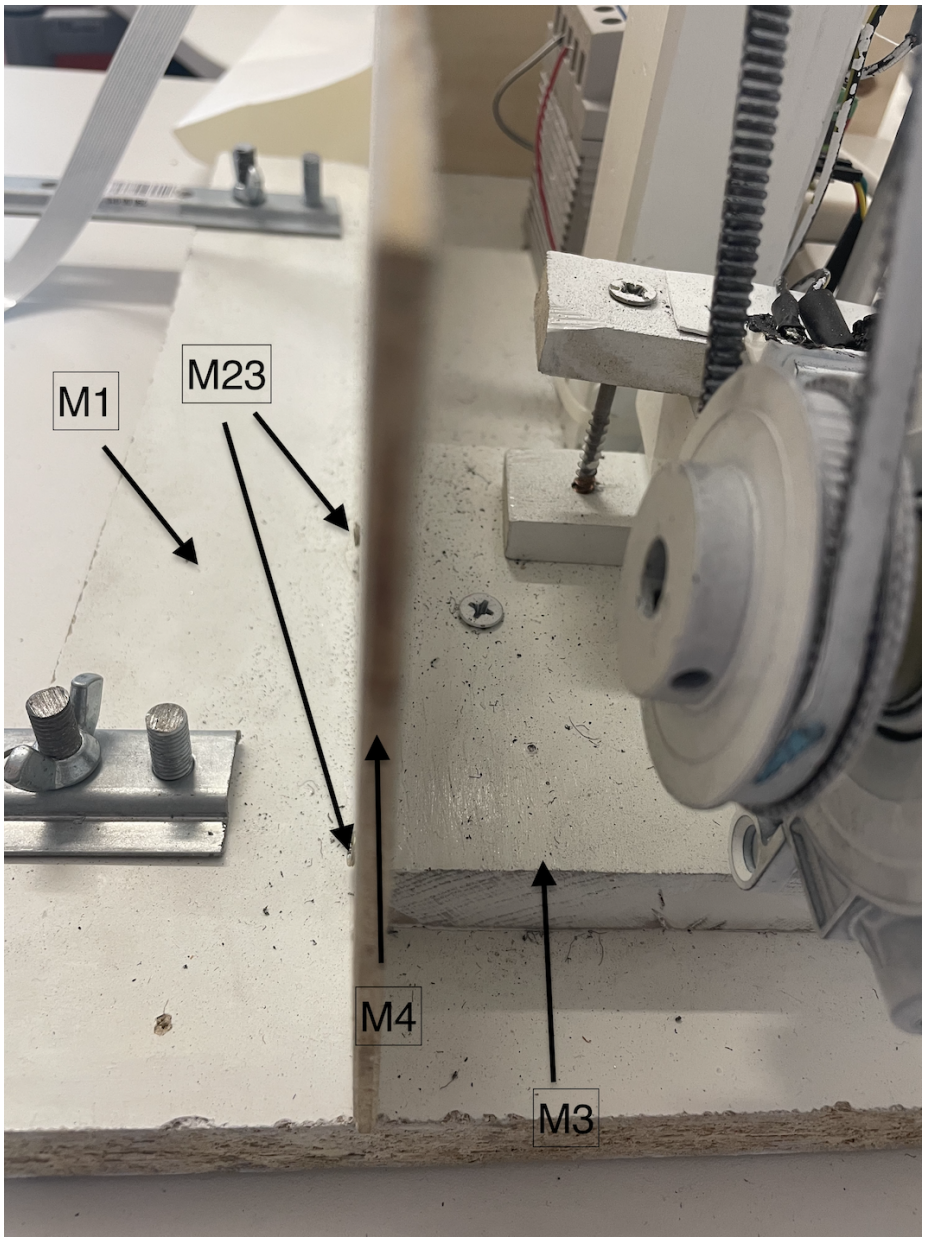

Figure 23: Image 23

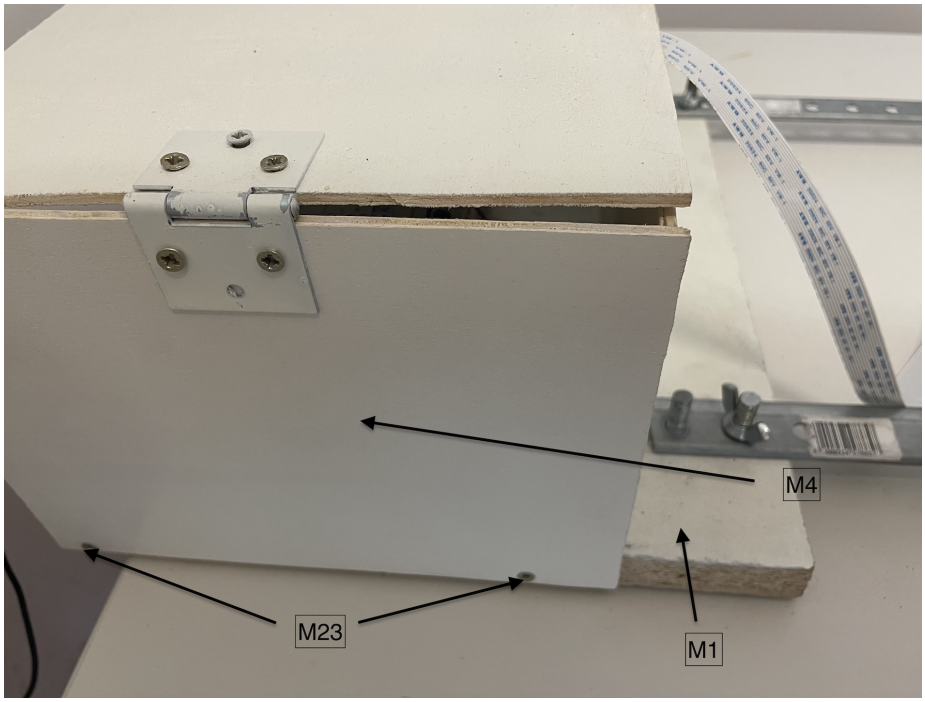

Figure 24: Image 24

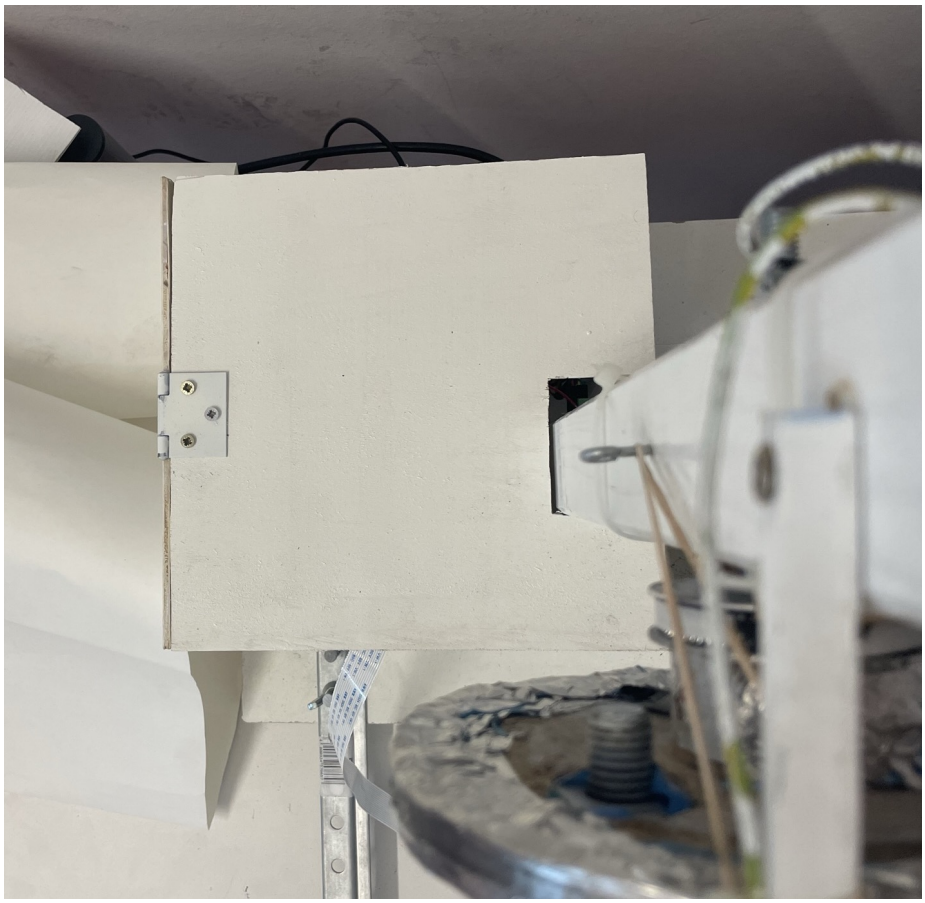

Figure 25: Image 25