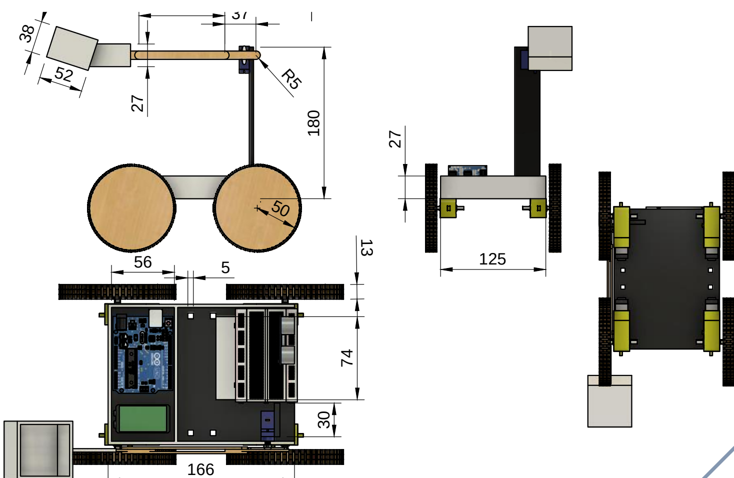
B06 Team6 Report

Hang Tian (A0239127A)
Wang-Li Zehan (A0234099X)
Yeo Jean Shyang, Bryan (A0233902M)
Zhou Yifan (A0239177U)



National University of Singapore
EG1311

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Our team began our journey in Semester 1 of AY2020-2021.

Report Summary

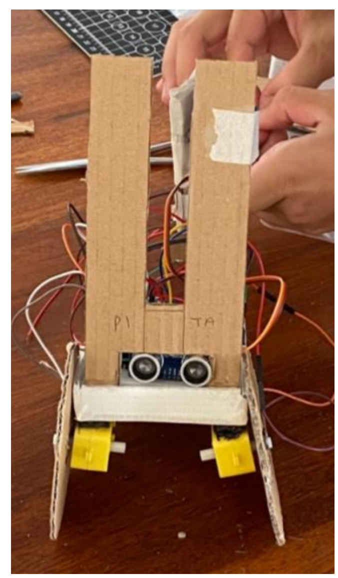
Weeks 2 & 4 - Tutorials 1&2 (Forming the basic template):

Our group first met in Tutorial/Lab 1. After getting to know each other, we split the tasks based on each other's strengths to ensure efficiency. We then began constructing the template project provided by the professors. The project provided us a sense of the very basic fundamentals needed for our final project. Such skills include **learning how to upload motor codes to Arduino**, **how to set up the connections on the breadboard** and **putting together the frame of the project**. With an understanding of these skills, we applied them in the coming weeks while building our project.

Week 5 – Team Discussion 1 (Birth of PITA 1.0):

In this report, the term "team discussion" refers to meetups outside of class. Additionally, we will be going through the lessons learnt during the project design process, as well as describe the challenges we faced and how we overcame them.

Our prototype was given the name PITA (Prototype In-Training Again) due to the arduousness of getting it to run successfully. We built PITA 1.0 mainly out of cardboard as we had not finalised the design. However, we realised it was not feasible **as cardboard does not provide strong structural integrity**. Due to it succumbing to bending stress easily, the components in PITA often underwent deformation. For instance, the cardboard wheels folded inwards due to the weight of the prototype, causing it to divert from its course of direction. From this we gathered that **we had to use a more stable and firm material for PITA**. Nonetheless, we continued using cardboard in future PITA versions as we were still prototyping.



Furthermore, **connection issues occurred rapidly as the copper wire heading of battery holder was not fixed in place**. We solved this by **gluing the copper wire heading to a standard wire with a male pin**. This change improved the wire connection tremendously.

Moreover, PITA 1.0 included only 2 motors as our initial calculations allowed us to construct our vehicle with the lightest weight possible.[i] The 2 front wheels were each attached to a motor, while the 2 rear wheels were attached to a rod to form a rear-axle.[ii] The idea was to use free propelling in the rear wheels while the front wheels were powered by motors. However, **we found that the structure for the rear wheels was too unreliable as there was excessive space between the rod and the motor coupler**. This led to room for swaying movement, which severely affected the movement of the vehicle. However, we stuck with this idea for the next prototype as we wanted to test if the project could work with only 2 motors.

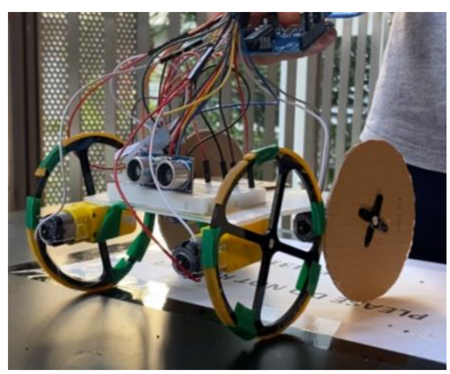
WEEK 6 - TUTORIAL 3 (UPGRADING PITA):

In our 3rd lab together, we discussed other aspects of PITA that we could improve. As we continued our “two-wheel drive” idea, we realised we really needed to **change the flimsy cardboard wheels**. Hence, we designed our first acrylic wheels using Fusion360. This meant we **replaced the cardboard wheels with stronger and firmer acrylic ones**, which we will be using in the next prototype.

WEEK 7 & RECESS WEEK – TEAM DISCUSSIONS 2&3 (EVOLUTION TO PITA 2.0)

With the help of laser cutting, we constructed a brand-new rear-wheel axle with entirely acrylic materials.[iii] We also printed new acrylic wheels and began assembling the next prototype, PITA 2.0. Eventually, we found that the **wheels could not obtain enough traction**.[iv] Hence, we came up with two potential solutions. The first was to **hot glue a rubber band along the circumference of the wheel**, increasing the amount of friction between the wheel and the area in contact with the wheel. Additionally, we added “groves” along the tyre that would help improve the grip of the wheel.[v] The other solution was to **use rear wheels that were proportionally bigger than the front wheels**.[vi]

Unfortunately, we later discovered that the rear wheel axle was impractical as **using laser cutting meant that the rod had square edges**, not round and smooth ones.[vii] Furthermore, the **rod was extremely fragile due to its thin width**. Therefore, we decided to fall back onto the idea of **using 4 motors as part of our “4-wheel drive”** in PITA 3.0.

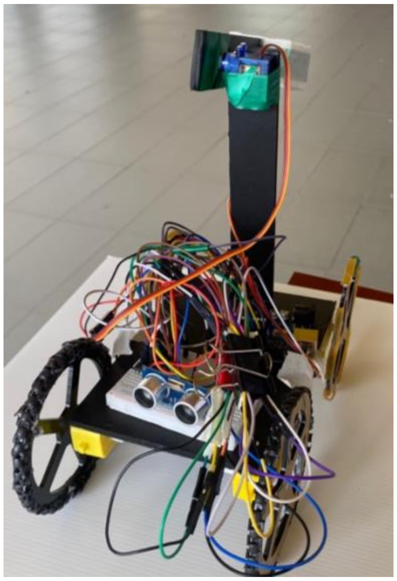


WEEK 8 – TUTORIAL 4 (THIRD TIME IS THE CHARM? PITA 3.0)

In this week, we printed a new set of 4 acrylic wheels, where we **adopted a 5-spoke wheel design**.[viii] With the addition of 2 motors, we faced the issue of **wire entanglement** and simply dealt with it by **trimming and removing any excess wires we had carried over from PITA 2.0**. We also **changed the battery used from 6V to 9V** as **we faced a lot more mechanical traction due to the 4-wheel drive**.[ix]

WEEK 9 – TEAM DISCUSSION 4 (A TROUBLING TUESDAY)

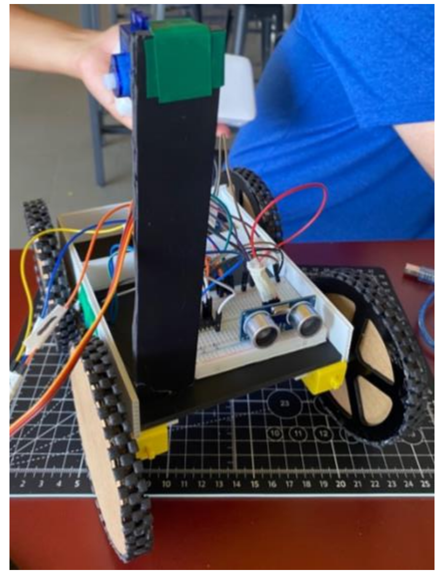
As we assembled PITA 3.0, we decided to create yet another chassis with new dimensions and a new material. Since we were nearing the end of our design, we used the **black foam board as the final material for the chassis** because **it was a strong and stable material**. Additionally, the **bigger dimensions ensured that the pressure exerted on the chassis by the components would be more evenly distributed**.[x] This ensured that no parts of PITA would be bending. Upon assembly, the structural integrity was expectedly solid.



Furthermore, we decided to try using the **friction mat tyres** alongside the rubber band tyres. Eventually we found out not only did that our new tyres provide the same amount of traction, but it was also a lot tidier as we were able to **glue the friction mat tidily along the wheels**. With these changes, PITA 3.0 was raring to go

However, as we placed it on the obstacle course, we were still faced with **a bit of wire entanglement**. As the motors were glued to the bottom of the chassis, the wires were placed along the sides of the chassis, causing it to be caught by the wheels. Furthermore, PITA was constantly manoeuvring off the course due to an **unequal amount of traction on each wheel**. Finally, the **servo code was not properly synchronised with the manoeuvre code**, which caused our catapult to go off at the wrong time. As we attempted to fix the wire entanglement, the metal contacts on 2 motors got ripped off accidentally. It was extremely worrying at first, as the deadline for the obstacle course was less than 1 week away. However, we regained our composure and headed back to the lab to ask for replacement parts. With this in mind, we deduced that if we solved these **3 main issues**, our project was near completion.

WEEK 9 – TEAM DISCUSSION 5 (A SUCCESSFUL SATURDAY)



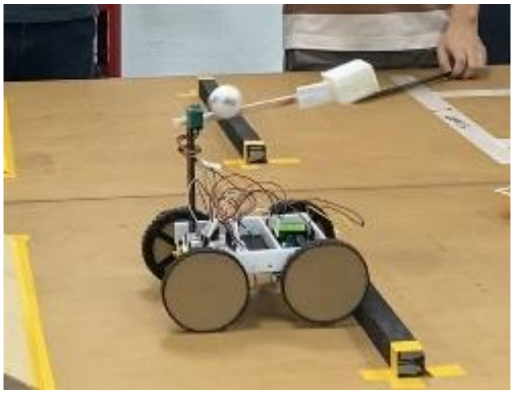
We then completely rebuilt a PITA 4.0 from scratch since the motors on PITA 3.0 broke. Every component was either replaced with a new one, or completely redesigned. Once again, we built a **new chassis that had small holes** that allowed the wires of the motor to pass through without getting tangled with the wheels. We also replaced the last 2 rubber band tyres with friction mat ones. Moreover, **the width of the wheels was thickened** by gluing a cardboard replica onto our acrylic wheel, which increased the traction with the floor. Lastly, we completely **rewrote the code for the servo motor** which allowed it to activate our catapult effectively, just as we had planned it from the start. These were the solutions we put in place to tackle the 3 main issues we faced as mentioned earlier.

In addition, we **added borders to the chassis** just to **ensure that the components of the circuit do not fall off or slide around** during the course. We even **implemented compartments that separated and organised the circuit board and Arduino board** to **increase the tidiness of the circuit**.

With these changes, we brought PITA 4.0 back to the obstacle course. In its first attempt, our project was able to cross the bump and ramp and stop exactly 5 cm away from the wall. Furthermore, the servo worked, and our catapult launched the ball over the wall.

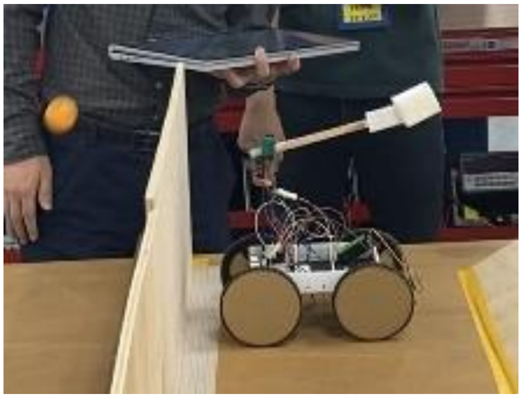
Finally, the miracle happened. It was as if we fitted the final piece of the puzzle. The new PITA 4.0 passed the obstacle course without fail. We attempted the course again and again, and with each attempt we were met with the same successful results! The fruits of our labour had paid off and we were guaranteed to ace the obstacle course.

WEEK 10 – TUTORIAL 5 (FINAL TRIAL)



The day had arrived. The team's morale had never felt higher as we had passed the obstacle course successfully several times during the previous team discussion. Each team was only given two official runs which the professors would be grading us on. With a slight angle deviation between the catapult arm and the ball holder, we set up PITA 4.0 for the official test run. We confidently put PITA 4.0 on its first test run. Unfortunately, **we did not consider the slight angle deviation**, and the **ball fell out of the ball holder as it crossed the ramp**.

Nonetheless, we were unfazed and went back to the drawing board. We deduced that the angle of the catapult arm was too high which caused the ball to fall out. **After slightly lowering the angle of the catapult arm**, we attempted the obstacle course again outside the lab and to nobody's surprise, it passed the course successfully.



Hence, we returned back to the lab and placed PITA 4.0 for its second and last test run. We held our breaths as we witnessed PITA cross the first bump and ramp successfully. The ball was still in place, unlike the previous run where it fell out right after the first bump. As it rolled down the ramp, it managed to stop in time. Now the moment of truth, the servo motor was activated, and the catapult arm swung. The ball was launched, and it successfully made it across the wall. Finally, our beloved PITA 4.0 passed its course without fail!

We heaved a huge sigh of relief upon witnessing this. It felt as though we had just witnessed our very own child take its very first steps and score its first goal. It was extremely rewarding when we received the marks that we worked hard for. Furthermore, we were the first group to finish the obstacle course during that lab despite our miscalculations earlier that day. This made our achievement even more sweet!

Appendix

Closing Thoughts

In conclusion, our group would like to close off with our reflections. Although we were just 4 Electrical Engineering students with little to no experience in assembling a robot, it felt really rewarding when we finally passed our project. By building on each other's strengths in coding or assembling, we were able to create a very strong synergy during every tutorial and team discussion.

Furthermore, everyone in the group was very cheerful and up-lifting, which helped us to pull through and help each other when a member was struggling with a certain task. This was evident when we were hitting a brick wall for the first 6 weeks and got frustrated whenever we hardly made any progress. Nonetheless, we told ourselves to calm down and take a step back to recollect the lessons we have learnt from each discussion. Therefore, it felt surreal looking back at the past 10 weeks. Not only did the 4 of us became slightly better engineers, but we also became better friends and teammates as well!

Lastly, we would like to sincerely thank our Professors and TA's for helping us. Without them, it would be hard to believe that we were able to successfully pass the course.

Thank you for reading our report!

- B06 Team6 -

Photograph of Final Robot

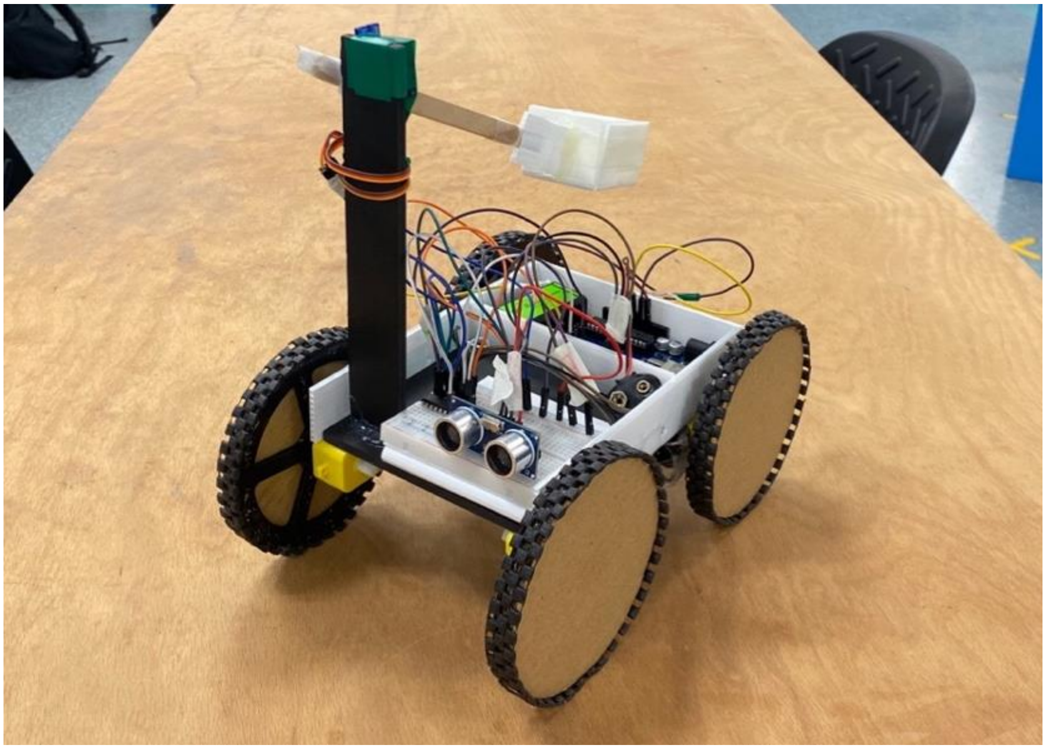
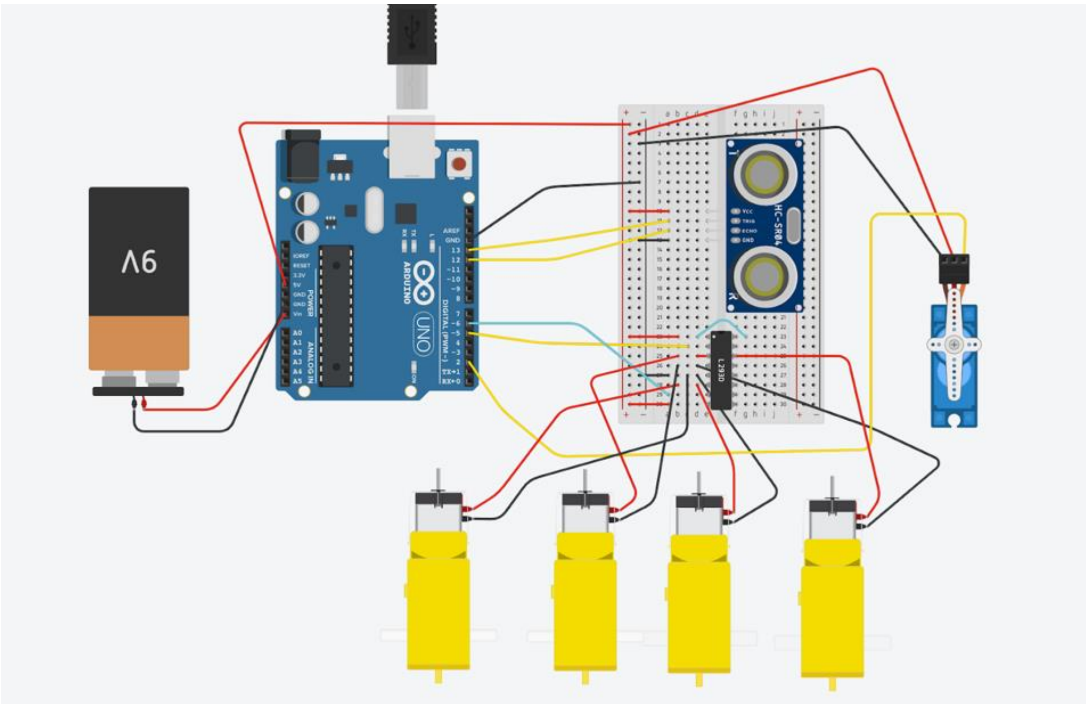


Image of TinkerCAD



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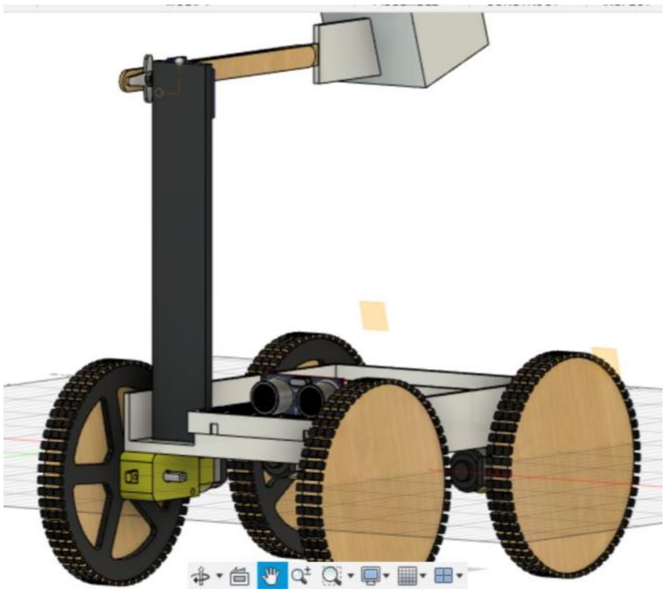
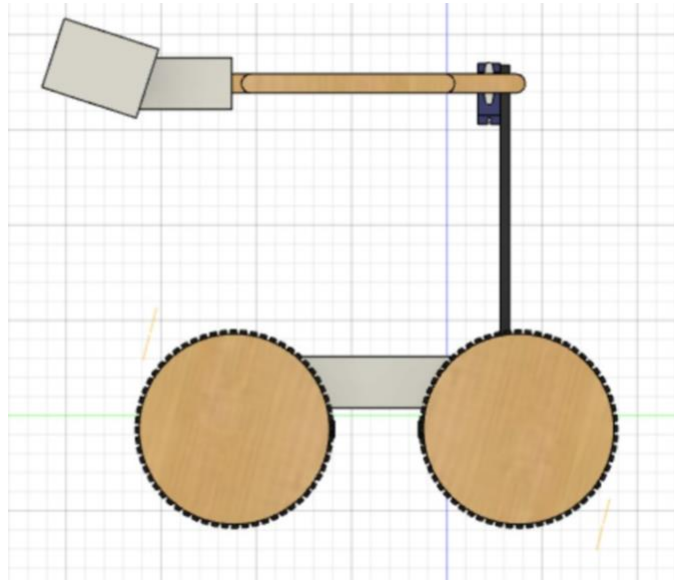
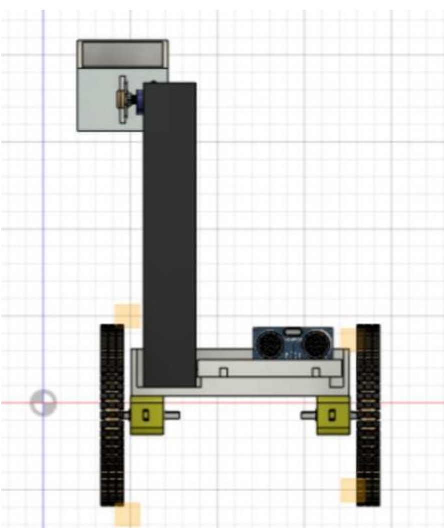
CAD Rendering[xi]



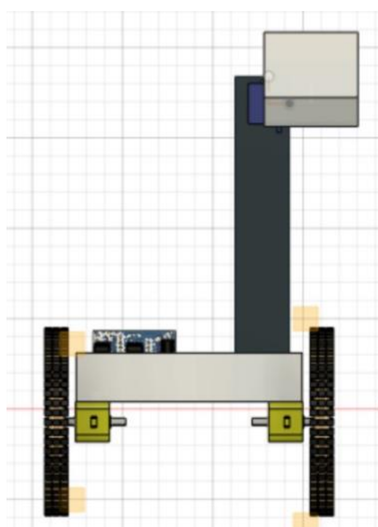
Full Body View



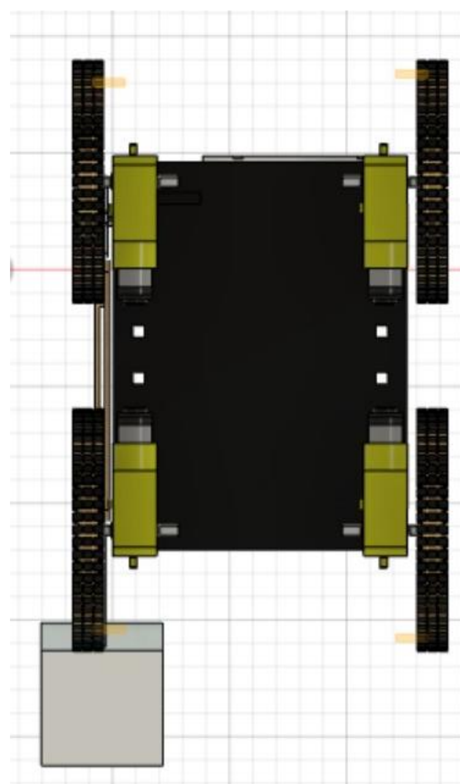
Side view



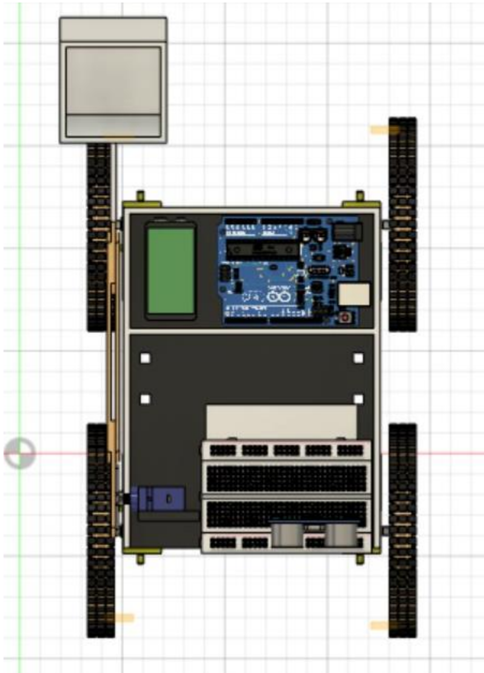
Front view



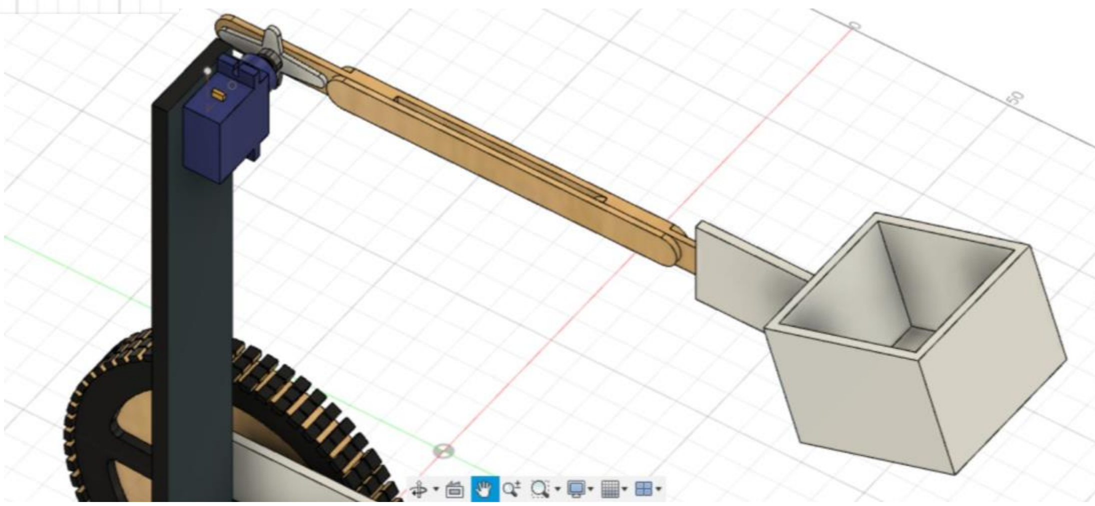
Rear view

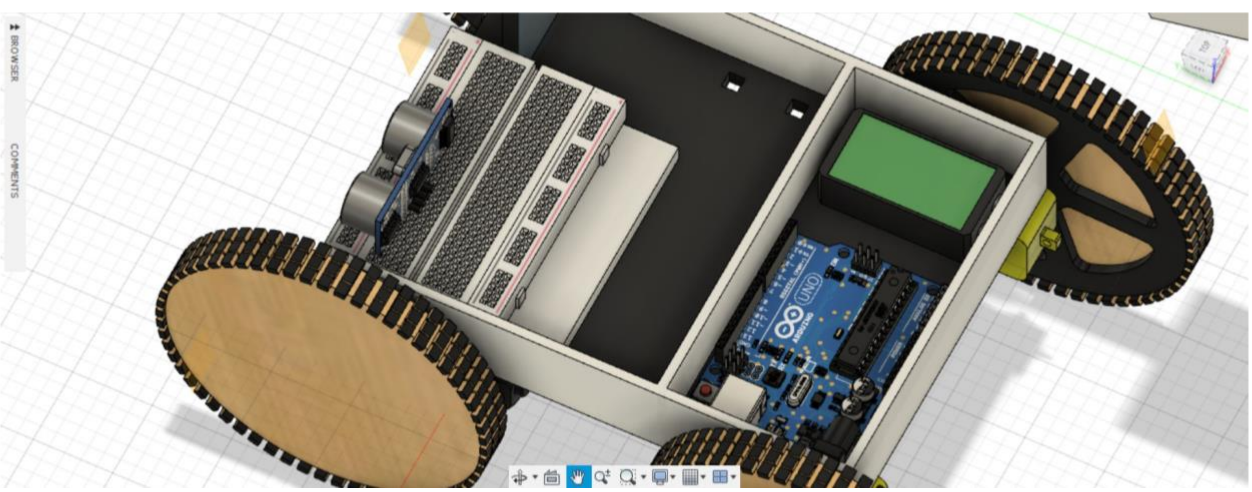


Bottom view

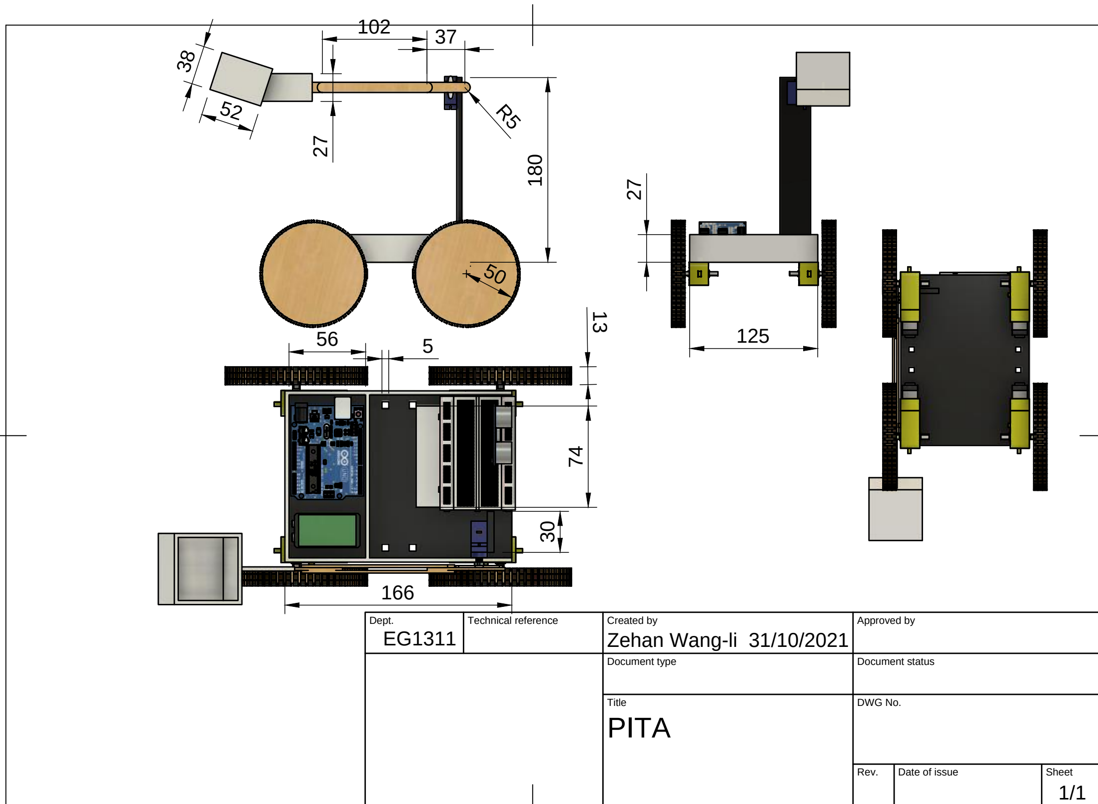


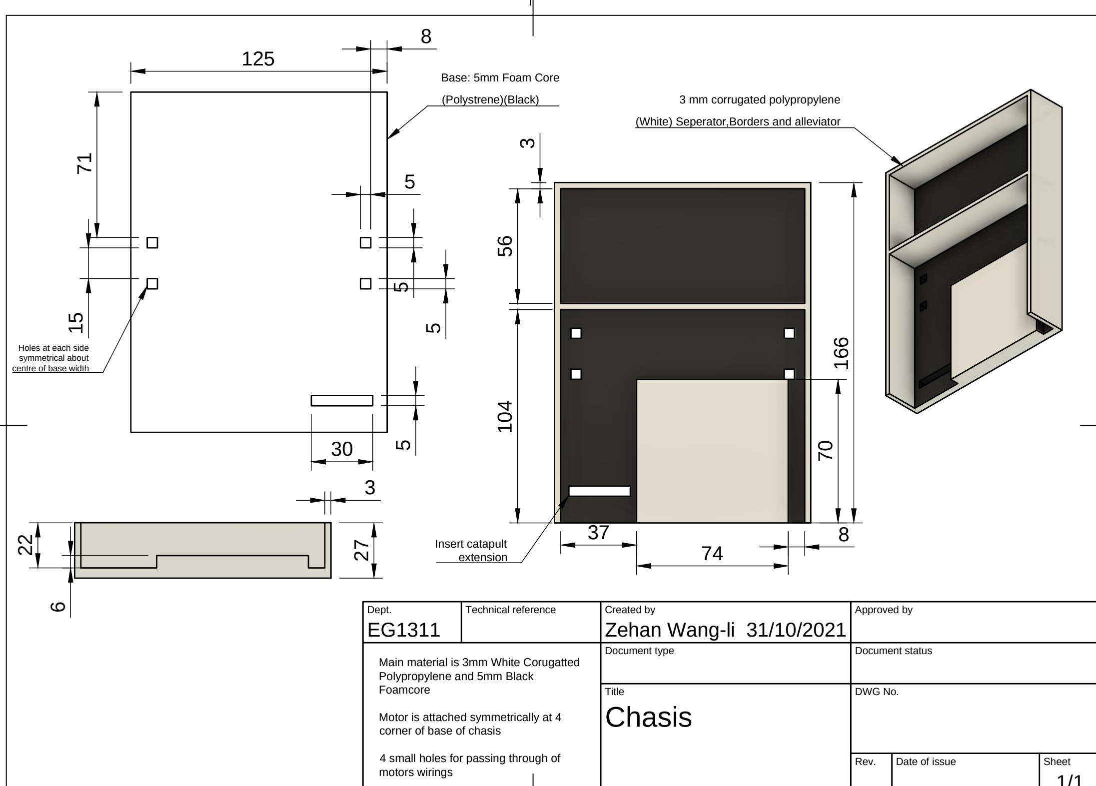
Top view

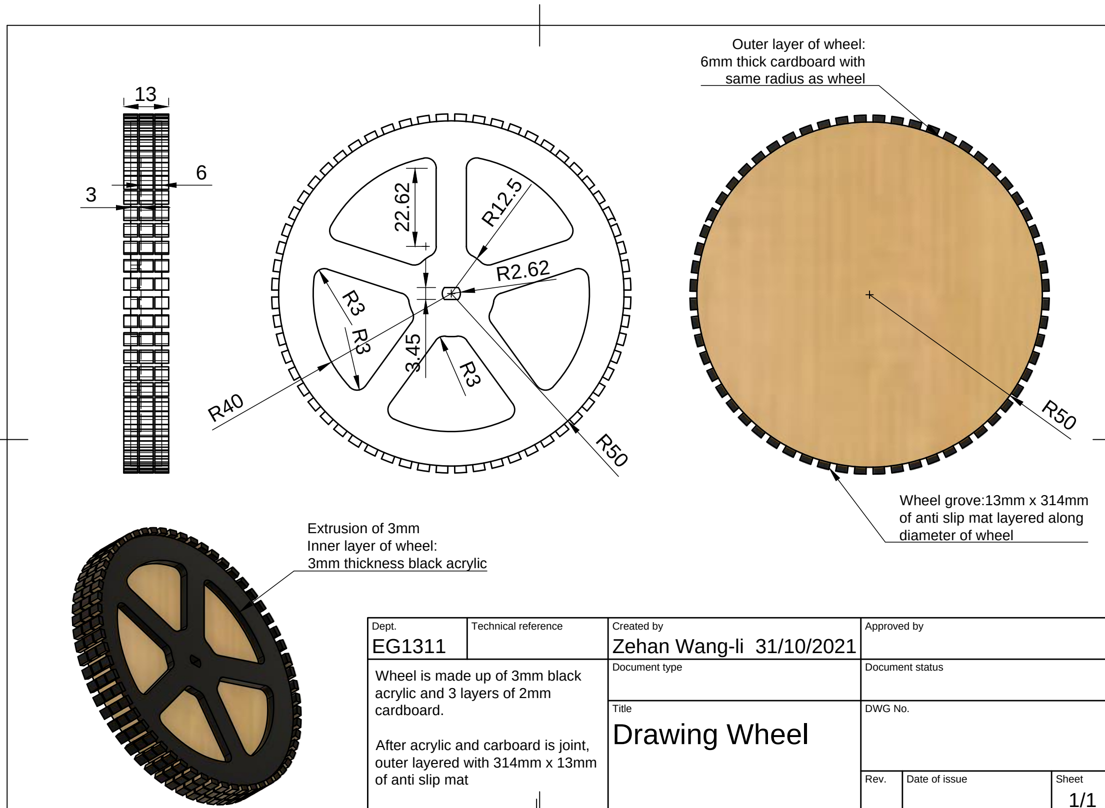


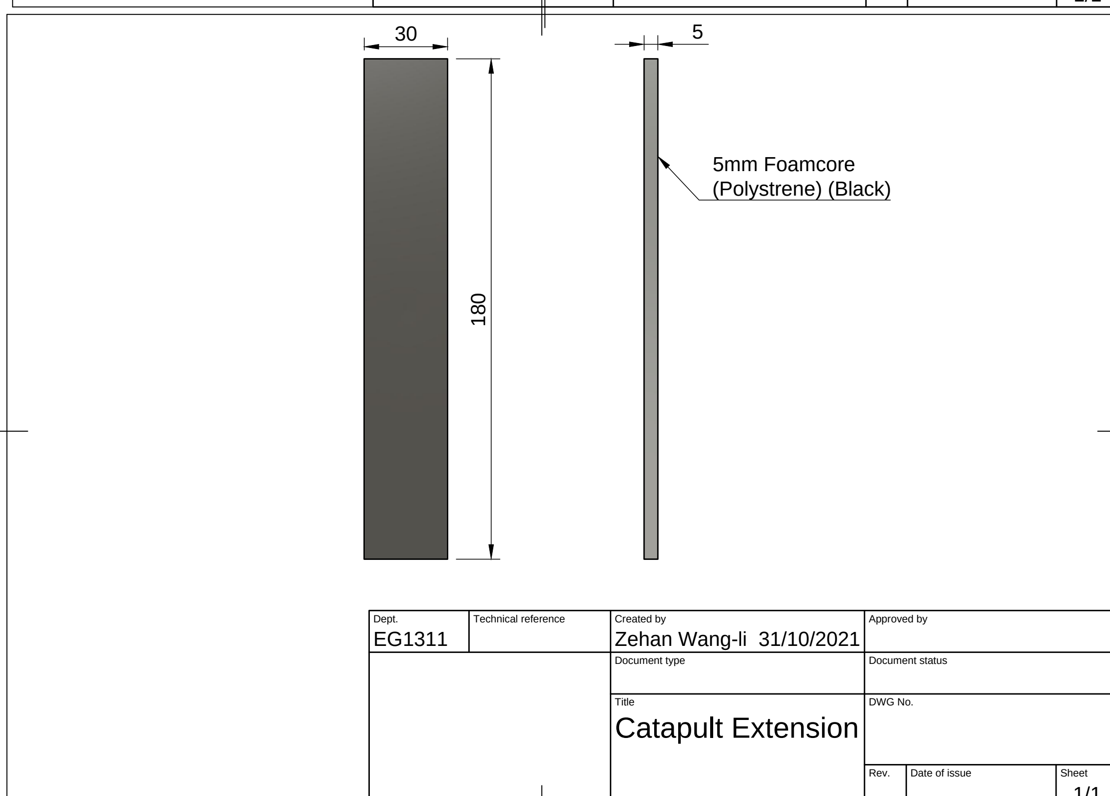


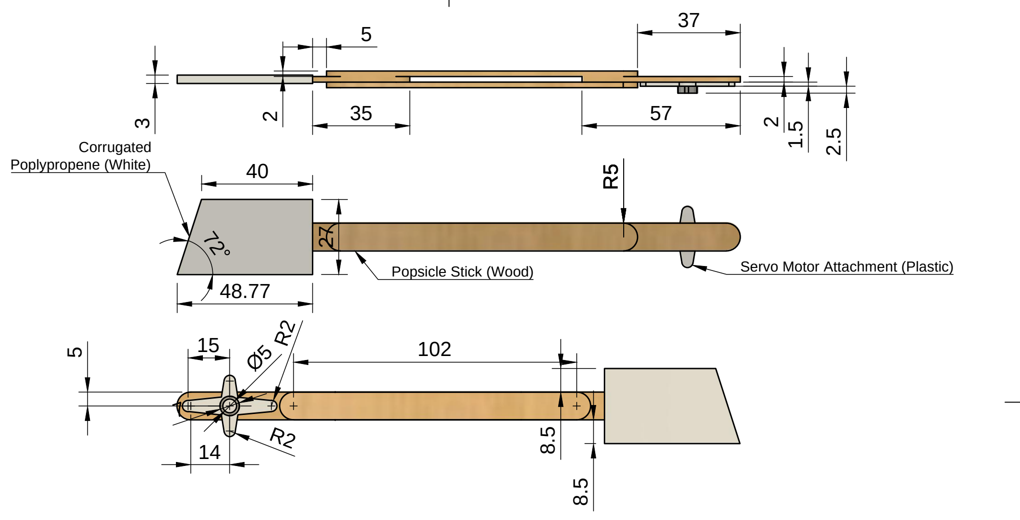
CAD Drawings



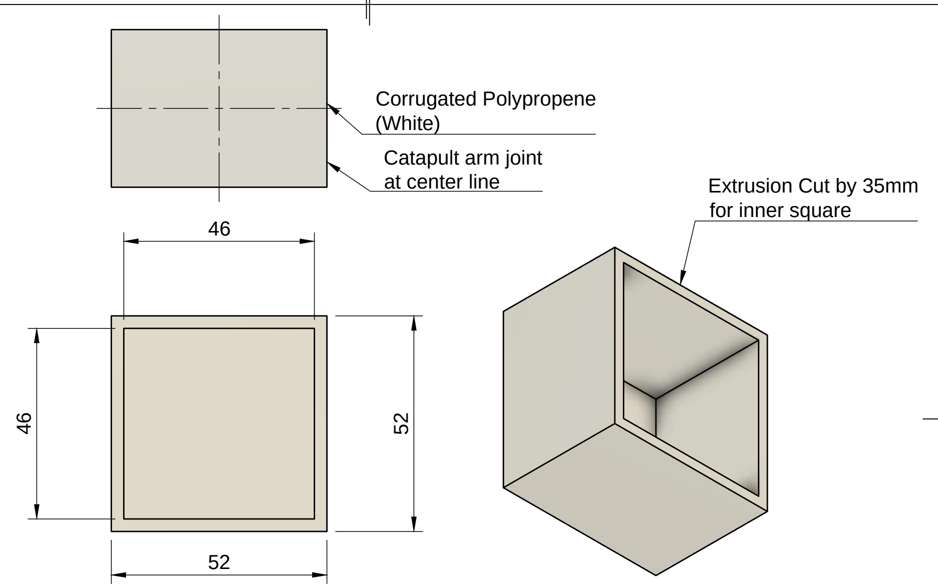



13
6
3
22.62
R12.5
R2.62
R3
R3
3.45
R3
R40
R50
Outer layer of wheel:
6mm thick cardboard with
same radius as wheel
R50
Wheel grove:13mm x 314mm
of anti slip mat layered along
diameter of wheel
Extrusion of 3mm
Inner layer of wheel:
3mm thickness black acrylic
Dept.
EG1311
Technical reference
Created by
Zehan Wang-li 31/10/2021
Approved by
Wheel is made up of 3mm black acrylic and 3 layers of 2mm cardboard.
After acrylic and carboard is joint, outer layered with 314mm x 13mm of anti slip mat
Document type
Document status
Title
Drawing Wheel
DWG No.
Rev.
Date of issue
Sheet
1/1


30
5
180
5mm Foamcore
(Polystrene) (Black)
Dept.
EG1311
Technical reference
Created by
Zehan Wang-li 31/10/2021
Approved by
Document type
Document status
Title
Catapult Extension
DWG No.
Rev.
Date of issue
Sheet
1/1



Dept.	Technical reference	Created by	Approved by
EG1311		Zehan Wang-li 31/10/2021	
		Document type	Document status
		Title: Catapult arm	DWG No.
			Rev. / Date of issue / Sheet 1/1



Dept.	Technical reference	Created by	Approved by
EG1311		Zehan Wang-li 31/10/2021	
		Document type	Document status
		Title: Catapult Holder	DWG No.
			Rev. / Date of issue / Sheet 1/1

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;
float SPEED_SOUND = 0.0345;

void setup(){
    pinMode(MOTOR_PIN1, OUTPUT);
    pinMode(MOTOR_PIN2, OUTPUT);
    pinMode(TRIG_PIN, OUTPUT);
    digitalWrite(TRIG_PIN, LOW);
    pinMode(ECHO_PIN, INPUT);
    servo.attach(servo_pin,540,2000);
    Serial.begin(9600);

}

void loop(){
    digitalWrite(TRIG_PIN, HIGH);
    delayMicroseconds(60);
    digitalWrite(TRIG_PIN, LOW);
    int microsecs = pulseIn(ECHO_PIN, HIGH);
    float cms = microsecs*SPEED_SOUND/2;
    Serial.println(cms);
    if (cms < 10) {
        digitalWrite(MOTOR_PIN1, LOW);
        digitalWrite(MOTOR_PIN2, LOW);
      for (int i = 0; i <= 180; i++) {
      servo.write(i);
      delay(5);

      }
      for (int i = 180; i >= 0; i--) {
      servo.write(i);
      delay(5);

      }
    } else{
        digitalWrite(MOTOR_PIN1, HIGH);
        digitalWrite(MOTOR_PIN2, HIGH);
    }}
```

References

[i] We found the spec sheets of the motor online. Based on our rough calculations, one motor would produce 1.2W, 0.288Nm using 6V, and 1.8W, 0.432Nm using 9V. Assuming the chassis, wheels and other minor supporting structure were to be made of acrylic, our robot would come in at a weight of 650g. With 2 motors running on 9V, there is an acceleration of about $0.2ms^{-2}$. This in theory should be able to pull the car across the obstacles, assuming no power loss occurs in other parts of the system and the tyres can exert the power onto the ground.

[ii] The rear-axle was made using a trimmed ice cream stick that was smoothened with sandpaper. Meanwhile, the wheels were made of cardboard hot glued onto the motor coupler and the tyre were simply made of hot glue. We also placed hot glue on both ends of the ice cream stick to prevent wheels from escaping the stick during its natural rotation

[iii] This new acrylic rear-axle consists of 2 components: a shaft with square cross section that connects the rear wheels together, a shaft holder with circular hole that allows free rotation of the shaft, and can be mounted to the chassis.

[iv] The wheels with friction mat tyres was free spinning at the first obstacle. This clearly shows that the tyres did not have enough traction despite the motors' power.

[v] This was inspired by rally gravel tires, which were made of a soft compound to maximise grip on smooth surfaces, while having grooves in along the tyres to grip on gravel surface. Using this ideology, we cut out grooves to latch onto the obstacle which would help to pull it over, and used a soft rubber band surface to maximise grip on ramp and other parts of the course.

[vi] Previously, the front wheels were 5.5cm in radius, and rear wheels were 6.1cm. This was to allow the centre of gravity of the robot to shift in front. However, it was not enough and hence we upsized the rear wheels to 7cm in radius in hopes to shift even more weight in front.

[vii] The machine was only able to laser cut in 2D. The lack of smooth edges meant that the rear-axle could not spin properly, which hindered the robot from moving off from its original point at all.

[viii] This was because an odd number of spokes allowed for a more stable wheel structure as compared to wheels with even spokes. Although no problems arose from the earlier wheel design, we felt that this change was necessary as it added an extra layer of structural integrity into PITA.

[ix] With the tremendous increase in traction due to our prototype having 4 wheels, wheel slips were more forgivable. Our tyre design has also evolved that going over both obstacles was no longer an

issue. Therefore by using a 9V battery, we allow the motor to output more torque to finish the course more easily.

[x] With a wider track width, PITA can handle more lateral G force. Although there are no turns in this course, it is always good to raise the physical limits of our vehicle so it can handle the course more easily. A long wheelbase makes the car more stable in a straight line. This is because if the car wants to turn (either intentionally or not), the rear wheel will serve as a limiter to not allow the front wheels to change direction. Hence, the longer the wheelbase, the more stable it is on the straight line, which is the intended outcome for this project.

[xi] For the components that were not modelled manually:
Arduino UNO CAD model obtained online from GrabCAD Library on date 30/10/2021 at link:
https://grabcad.com/library/arduino-uno-in-fusion-360-format-1
-Ultrasonic Sensor CAD model obtained online from GrabCAD Library on date 30/10/2021 at link:
https://grabcad.com/library/ultrasonic-sensor-hc-sr04-1
-Yellow DC Motor CAD model obtained online from Thingiverse Community on date 30/10/2021 at link:
https://www.thingiverse.com/thing:4094970
-Breadboard CAD model obtained online from Autodesk Gallery on date 30/10/2021 at link:
https://gallery.autodesk.com/projects/140202/arduino-breadboard-83x55mm?searched=
-Servo Motor CAD model obtained online from Autodesk Gallery on date 30/10/2021 at link:
https://gallery.autodesk.com/projects/129430/sg-90-servo?searched=