T.C.
IZMIR KATIP CELEBI UNIVERSITY FACULTY OF ENGINEERING AND ARCHITECTURE DEPARTMENT OF MECHATRONICS ENGINEERING

Mars Rover Project

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A. Introduction

What is desired in the project is the creation of a mechanism that can overcome the obstacles on the given track. Brainstorming was done on what kind of mechanism the desired mechanism should be. After a few ideas were presented, it was agreed to use the system creation method learned in the Mechanism Design course as the final decision. Alizade method was used during the system created from scratch. After creating the mechanism with the Alizade method used, the system was verified with the Grubler method. The number and type of planes used in this method and the mobility of the machine completely depend on the manufacturer, which makes it easier to be original by leaving the manufacturer free. This freedom and originality should be used to be designed so that the obstacles on the track can be easily overcome by the planned mechanism. The mechanism design was made in this vision. The number of mobility in the planned mechanism design shows the number of legs on the plane chosen for this project, that is, the number of wheels for this project. The wheels must make various movements according to the variation of the obstacle on the track. Instead of using an automation system to make the mechanism perform the desired movements, it was agreed to establish a system that receives remote commands. Thus, from the very beginning, how the system would be created and the system of controlling the movement of the created system was determined by a certain logic.

B. Final Idea Process of Mechanism

In the first weeks of the project, we are going to make a rocker-bogie mechanism. But a few weeks later we see that the rocker-bogie system does not coincide with what we learned in the course, so we throw away everything that we progress and start from the beginning with structural design. In this part, we try to give our mechanism an " M " shape, while thinking about the structure design. We made a few different designs and chose the most effective one and then we started working on it. After that, the main details of the final design were formed. As a final design, our mechanism includes links, rigid bodies, joints, wheels, motors, and motor shafts. We prefer triangular platforms for our body we connect our platforms to other links with revolute joints. For the front and back legs, prismatic joints and prismatic links are used to make the design much more balanced when it's moving and climbing. For actuating the mechanism geared dc motors are good for giving torque to the wheels.

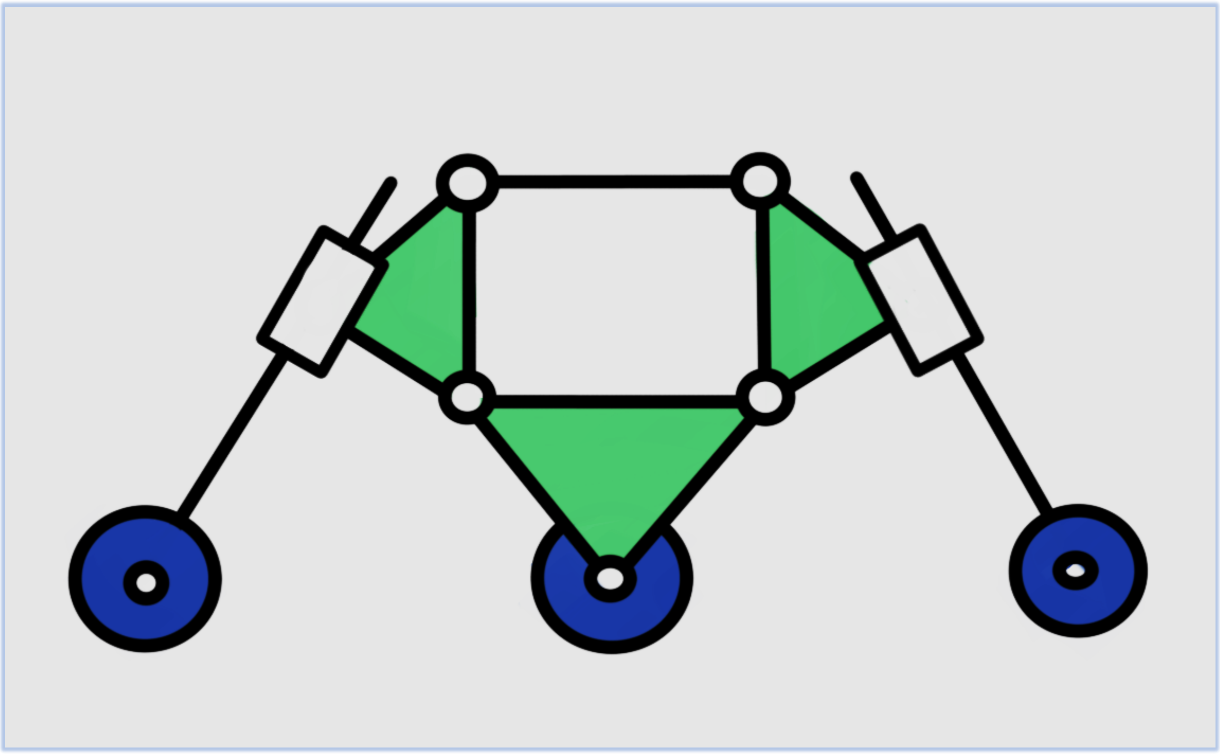
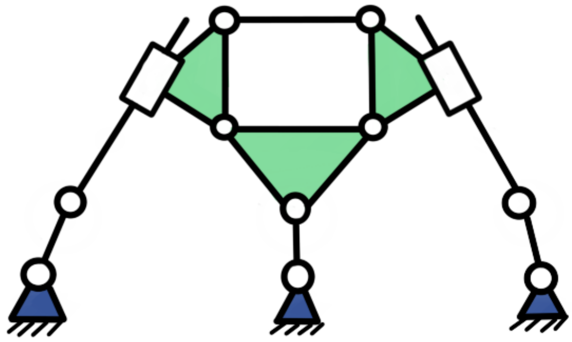


Figure B.1.1 Structural Design

C. Calculations



The Alizade's mobility equation:

$$M = \sum f_s - \lambda (N - C - B)$$

$$M = 12 - 3(3 \times 3 - 3 - 3)$$

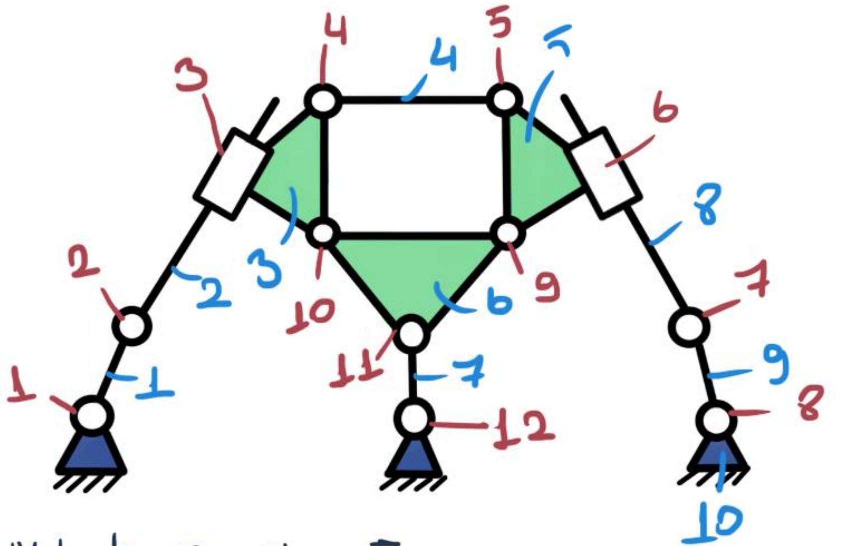
$$M = 3$$

$\sum f_s$ = total degree of freedom of all joints

N = total elements on platforms

C = connections between platforms

B = platforms



$P_3 = 0$

The Grübler's Mobility Formula:

$$m = 3(n-1) - 2P_1 - P_2$$

$$m = 3(10-1) - 2 \cdot 12 - 0$$

$$m = 27 - 24$$

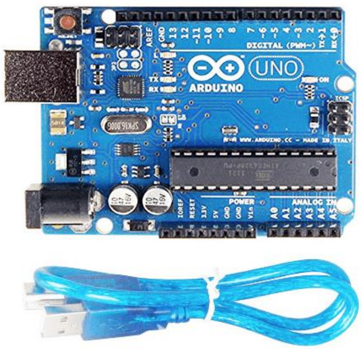
$$m = 3$$

n = total link

P_1 = total 1 DOF joints

P_2 = total 2 DOF joints

D. Used Materials in This Project

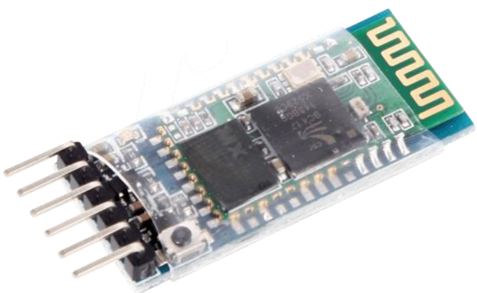


Arduino Uno R3 Clone USB Wire (USB Chip CH340)

Figure D.1.1 Arduino Uno

6V 250RPM DC Gear Motor

Figure D.1.2 DC Gear Motor

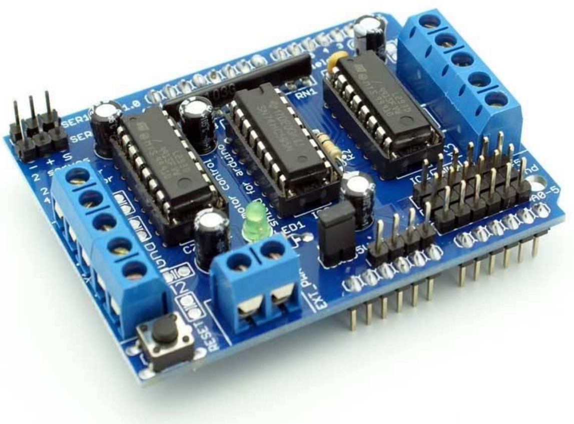


HC05 Bluetooth-Serial Module

Figure D.1.3 Bluetooth Module

KCD11 3-Pin Mini On-Off Switch

Figure D.1.4 Switch



Arduino Motorshield L293D

Figure D.1.5 L293D Motorshield

1200mAH 1.2AH 3.7V Battery

Figure D.1.6 Battery

7.5mm Off-Road Wheel (covered with non-slip mat)

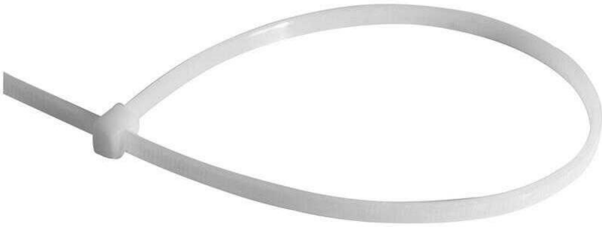
Figure D.1.7 Off-Road Wheel

2.85mm White PLA 3D 1kg Filament

Figure D.1.8 3D Filament

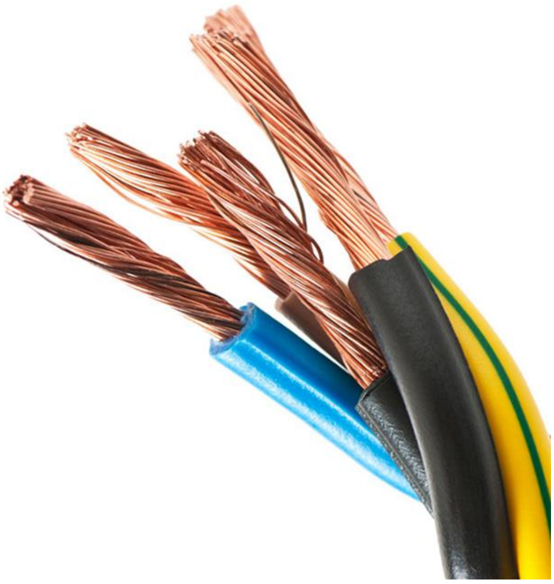
699 ZZ Miniature Bearing 9x20x6

Figure D.1.9 Bearing



Plastic Handcuffs

Figure D.1.10 Plastic Handcuffs



0.5mm NYAF Cable

Figure D.1.11 NYAF Cable

Fast Adhesive

Figure D.1.12 Fast Adhesive

Figure D.1.13 Round Shaft

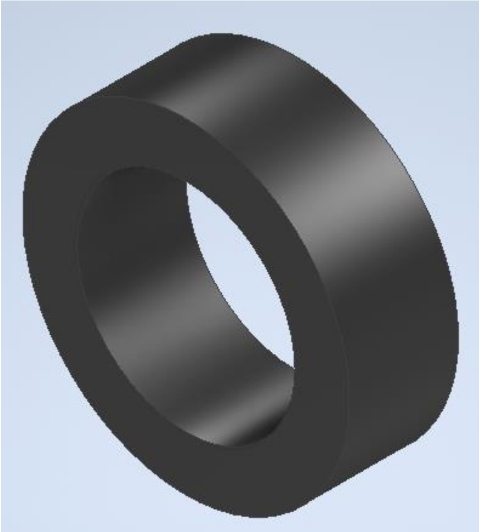


Figure D.1.14 Fixer Part

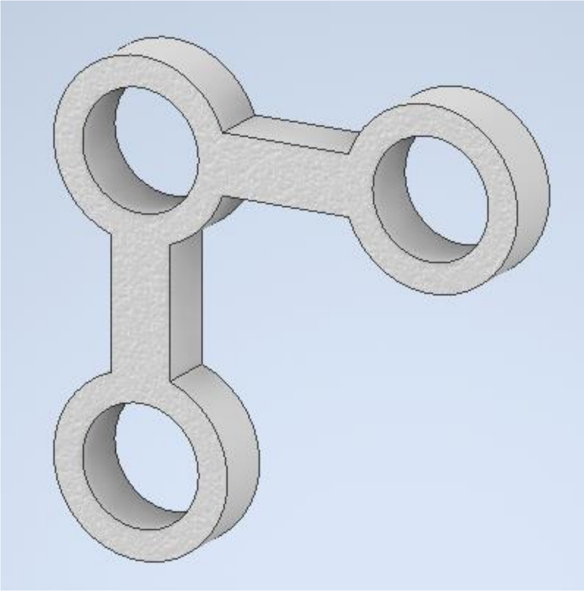


Figure D.1.14 Triangle Fixed Link

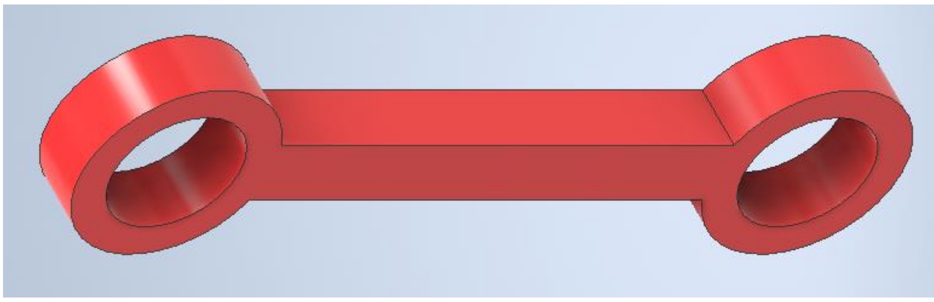


Figure D.1.15 Straight Link

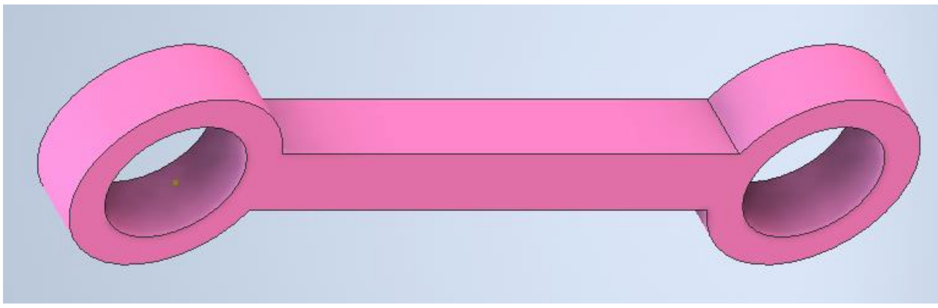


Figure D.1.16 Straight Link

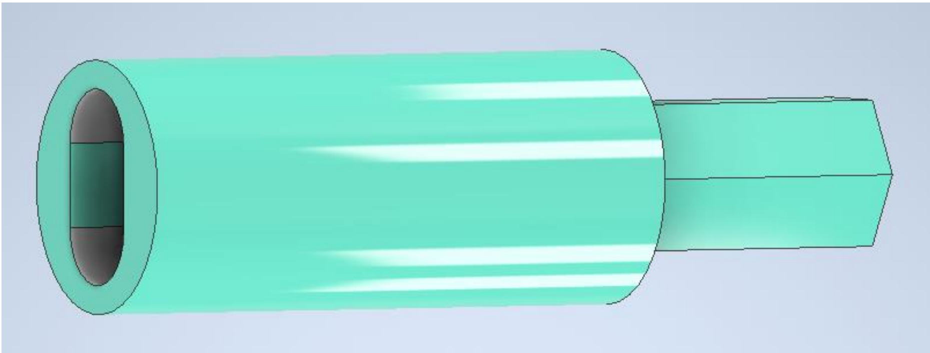


Figure D.1.17 Bearing and Wheel Shaft

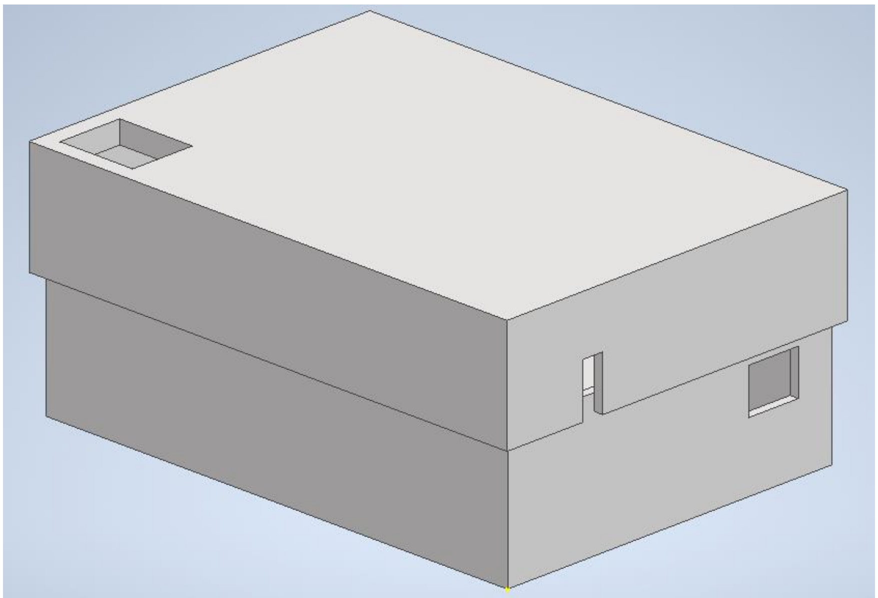


Figure D.1.18 Electrical Box

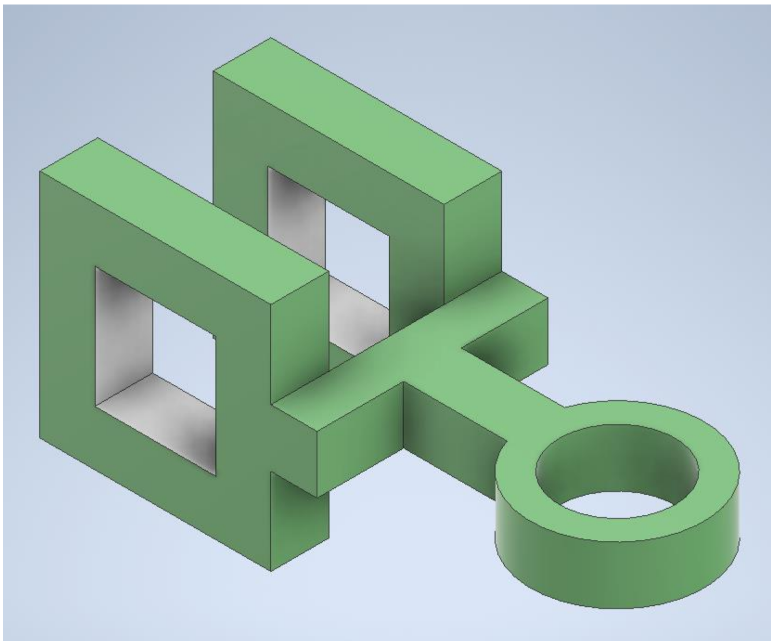


Figure D.1.19 Prismatic Joint

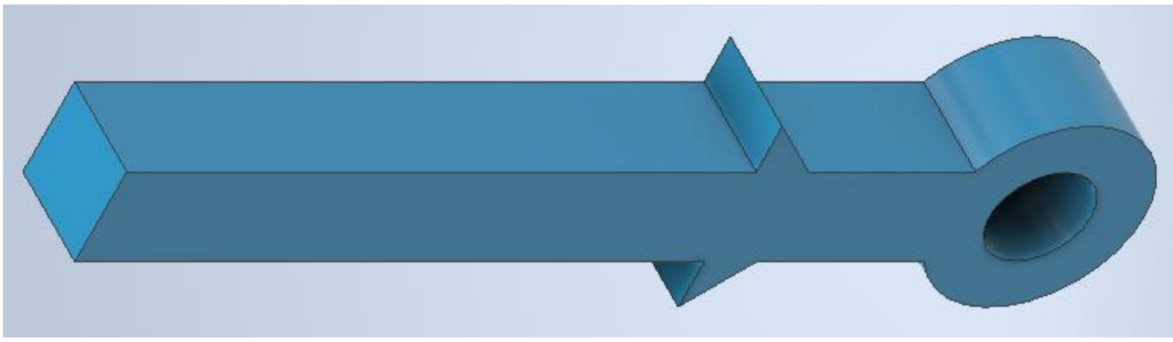


Figure D.1.20 Prismatic Link

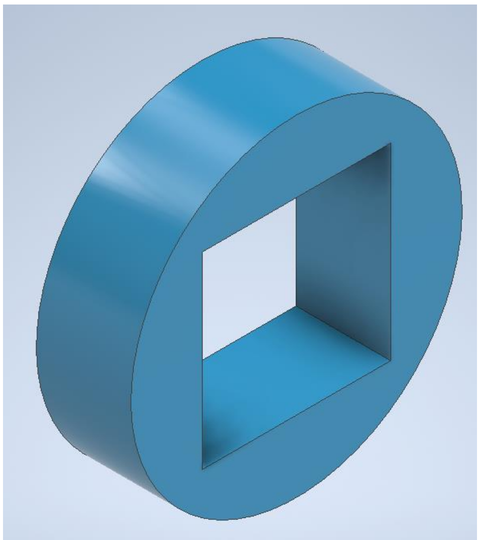


Figure D.1.21 Prismatic Link Fixer

E. Manufacturing of the Design

1. Assembly of the Design

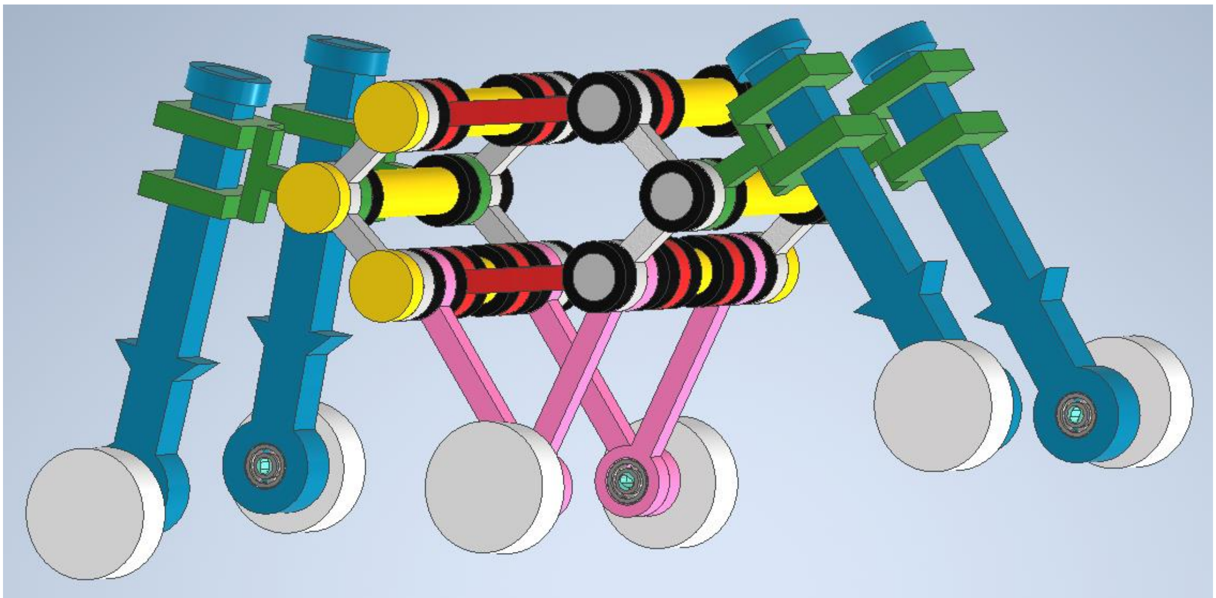


Figure E.1.1 Assembly.

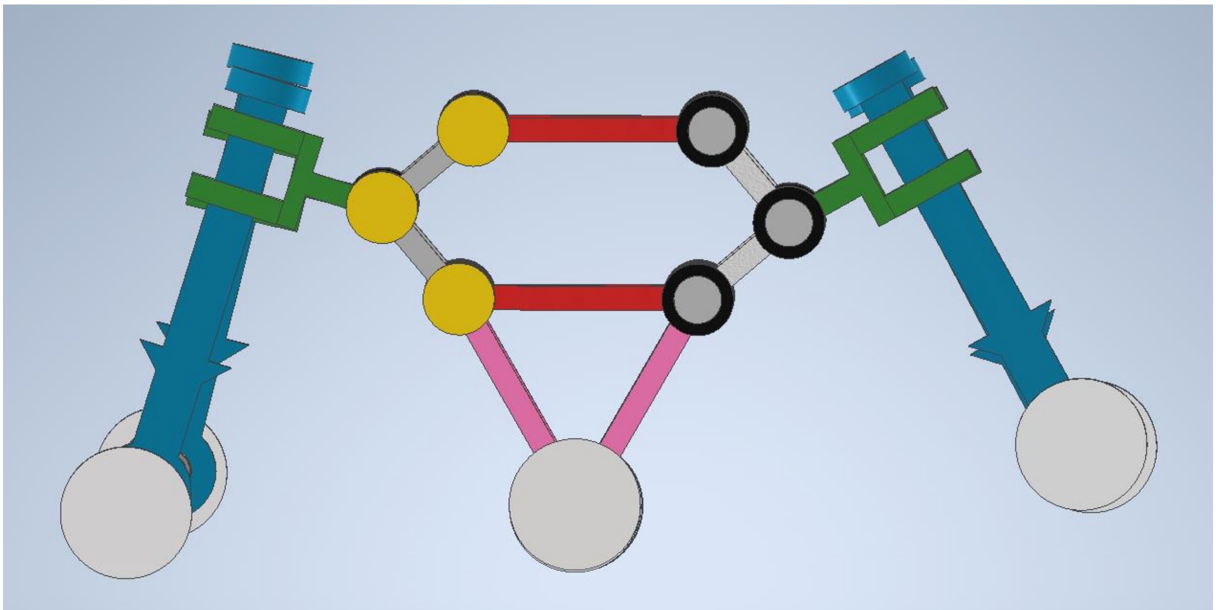


Figure E.1.2 Assembly.

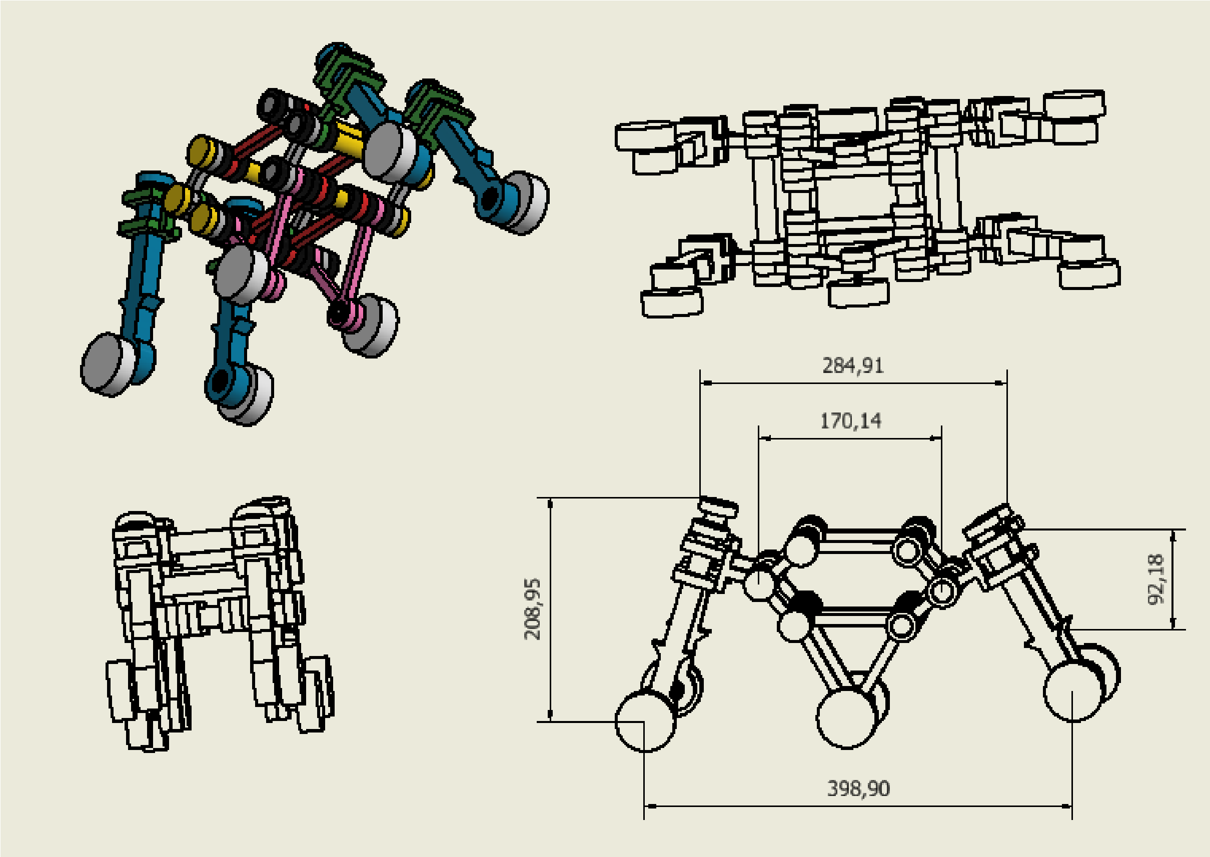


Figure E.1.3 Technical Drawing of Assembly.

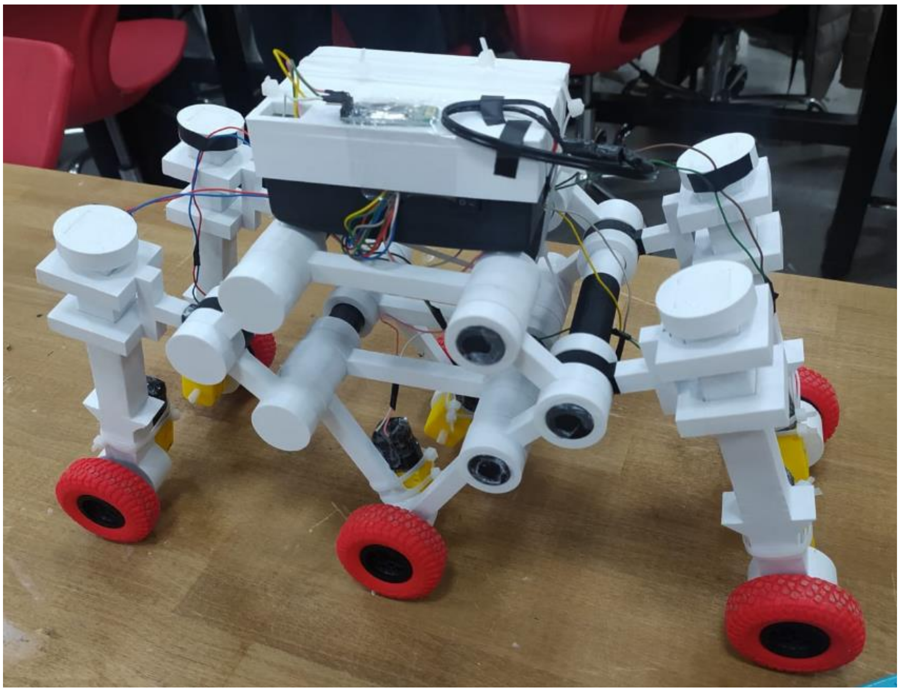


Figure E.1.4 Design.

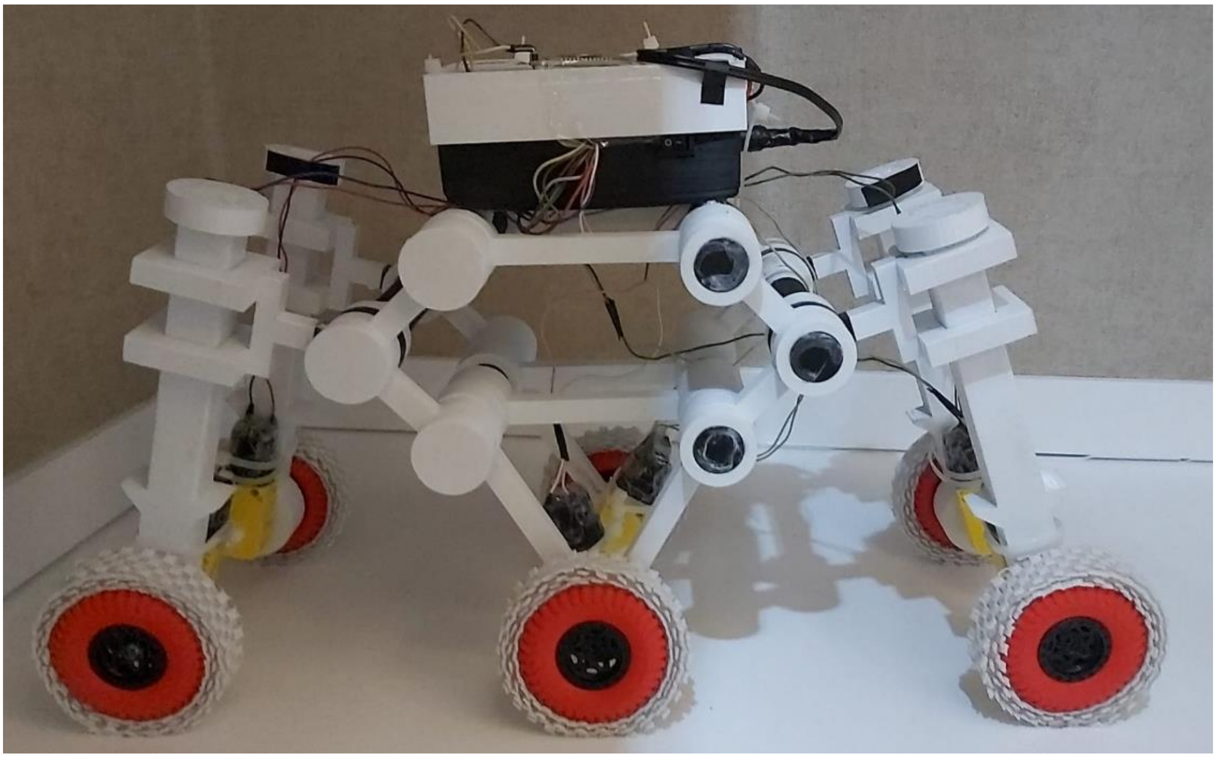


Figure E.1.5 Final Design.

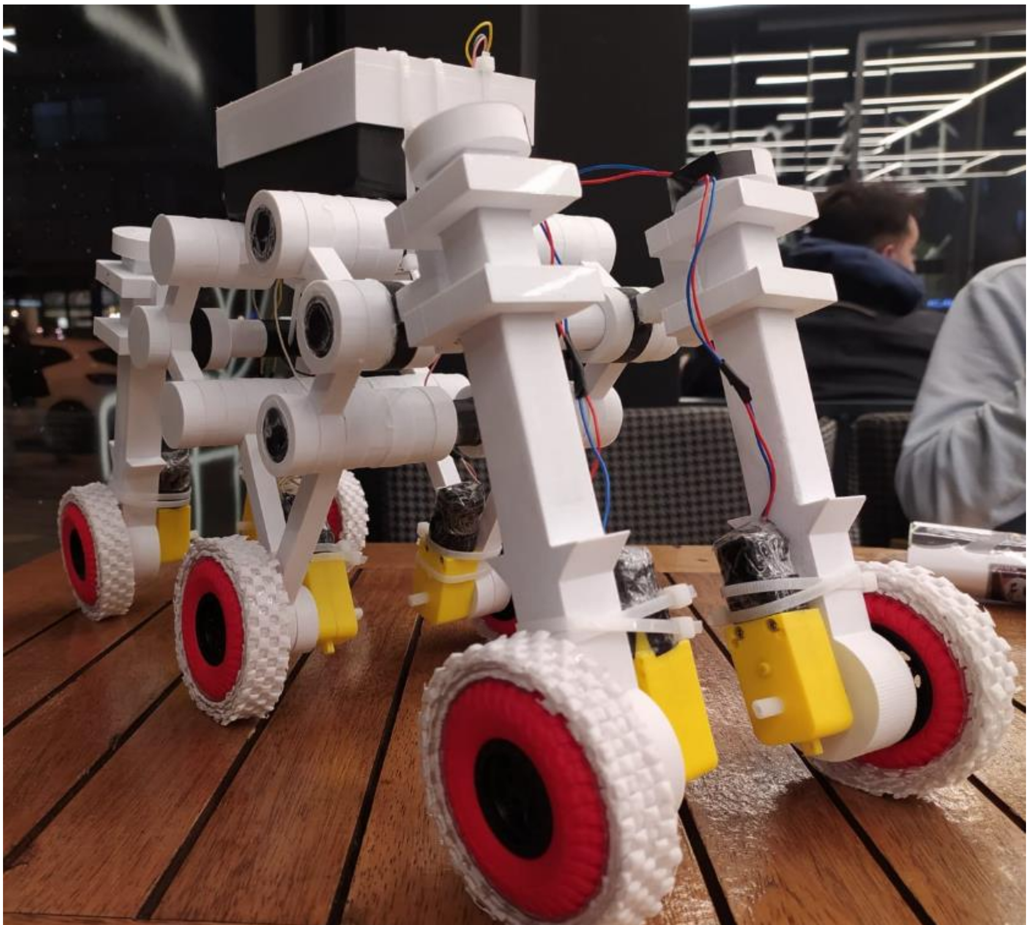


Figure E.1.6 Final Design.

2. Software of the Design

```
#include <AFMotor.h>


AF_DCMotor motor1(1, MOTOR12_1KHZ);
AF_DCMotor motor2(2, MOTOR12_1KHZ);
AF_DCMotor motor3(3, MOTOR34_1KHZ);
AF_DCMotor motor4(4, MOTOR34_1KHZ);
```

Figure E.2.1 Motor Pins Code.

First in the arduino code of our project, the pins of the motors are assigned.

```
char command;

void setup()
{
  Serial.begin(9600);
}
```

Figure E.2.2 Bluetooth Module Code.

In this part, the Baud Rate is adjusted according to our Bluetooth Module.

```
void loop(){
  if(Serial.available() > 0){
    command = Serial.read();
    Stop();
    switch(command){
    case 'F':
      forward();
      break;
    case 'B':
       back();
      break;
    case 'L':
      left();
      break;
    case 'R':
      right();
      break;
    }
  }
}
```

Figure E.2.3 Directions Code.

Next, stop of our project and the directions it will go are assigned to the corresponding keys in the application that allows us to remotely control it from the phone.

```
void forward()
{
  motor1.setSpeed(255);
  motor1.run(FORWARD);
  motor2.setSpeed(255);
  motor2.run(FORWARD);
  motor3.setSpeed(255);
  motor3.run(FORWARD);
  motor4.setSpeed(255);
  motor4.run(FORWARD);
}

void back()
{
  motor1.setSpeed(255);
  motor1.run(BACKWARD);
  motor2.setSpeed(255);
  motor2.run(BACKWARD);
  motor3.setSpeed(255);
  motor3.run(BACKWARD);
  motor4.setSpeed(255);
  motor4.run(BACKWARD);
}
```

```
void left()
{
  motor1.setSpeed(255);
  motor1.run(BACKWARD);
  motor2.setSpeed(255);
  motor2.run(BACKWARD);
  motor3.setSpeed(255);
  motor3.run(FORWARD);
  motor4.setSpeed(255);
  motor4.run(FORWARD);
}

void right()
{
  motor1.setSpeed(255);
  motor1.run(FORWARD);
  motor2.setSpeed(255);
  motor2.run(FORWARD);
  motor3.setSpeed(255);
  motor3.run(BACKWARD);
  motor4.setSpeed(255);
  motor4.run(BACKWARD);
}
```

Figure E.2.4 Motor Directions and Speeds Code.

In these parts, the maximum speeds of the motors are defined and the rotations that the motors will perform clockwise or counterclockwise are defined.

```
void Stop()
{
  motor1.setSpeed(0);
  motor1.run(RELEASE);
  motor2.setSpeed(0);
  motor2.run(RELEASE);
  motor3.setSpeed(0);
  motor3.run(RELEASE);
  motor4.setSpeed(0);
  motor4.run(RELEASE);
}
```

Figure E.2.5 Motor Stop Code.

Finally, the minimum speeds of the motors were defined and the code was written to make the motors stop as soon as we released the button.

3. Electronics of the Design

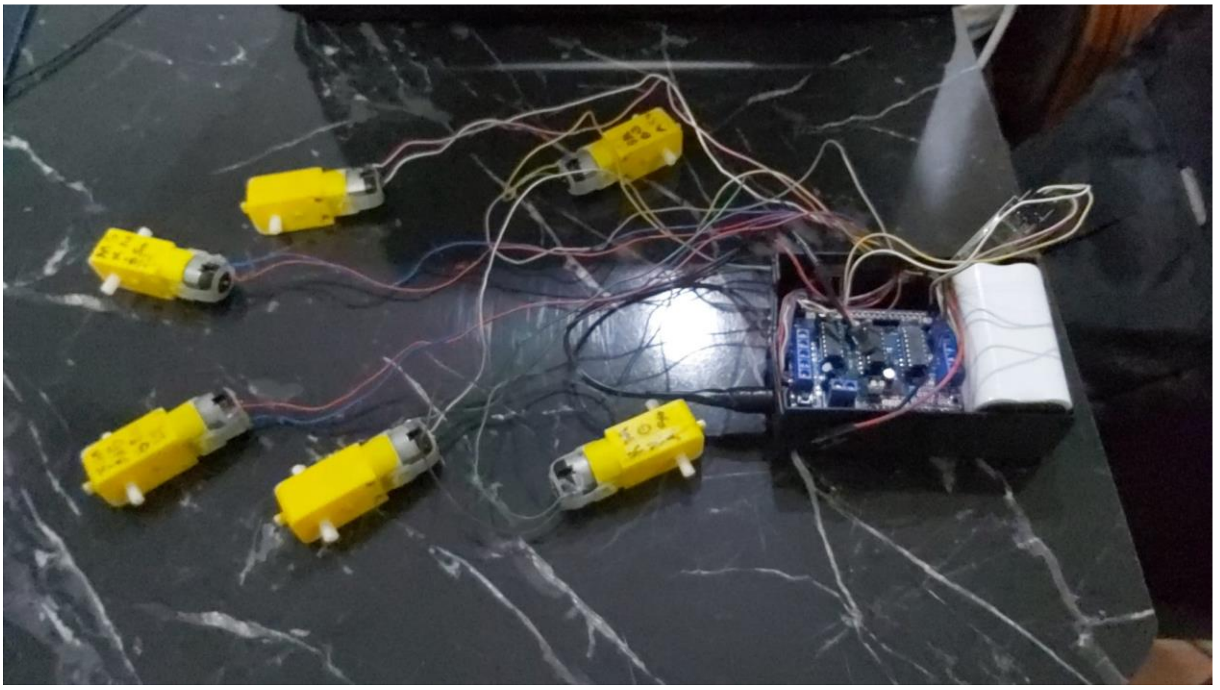


Figure E.3.1 Electrical Connections for the Electrical Box and Motors.

For this project, 1 Arduino Uno, 1 L293D Motor Shield, 6 Geared DC Motors, 1 HC-05 Bluetooth Module, 1 Electrical Box, Sleeving Cables, 1 Switch, and 1 Li-Po battery were used. First, the Motor Shield was placed on the Arduino. Then the Arduino code was written and the Bluetooth Module was connected to the Motor Shield. The Motor Shield can drive up to 4 DC Motors, but 6 DC Motors were used in our Project. For this reason, 4 DC Motors used in our project were connected in series, in pairs. In this way, the Motor Shield connections were made as if 4 DC Motors were used in our project. The Motors connected are the Motors used in the front and middle legs. Then Li-Po Battery and Switch were connected to Motor Shield. Next, Arduino, Motor Shield and Li-Po Battery were put inside the Electrical Box. Finally, The Bluetooth Module was passed through the hole on the top of the Electrical Box and attached to a wooden stick so that it could have a better reception area. For the waterproofing of the DC motors used in our project, the parts of the DC motors for the cable connection were glued with hot silicone and the DC motors were covered with electrical tape.

F. How the Design Works?

We start our 6 DC gear electric motors with the power we get from our 1200mAh 1.2AH 3.7V Lithium Polymer rechargeable battery. Our motors are connected to the link closest to it with a clamp, so it does not interfere with movement. Each motor provides the movement of only one of our wheels.

Our bearings, which can transfer the power of our motors in the best way, are located in the slots at the end of the links. The connection between the motor and the wheel is provided thanks to the bearings passing through these bearings and best fit sized.

Thanks to the two prismatic joints we have made to the links to which our front (x2) and rear (x2) wheels are connected, our links can adjust the height level according to the obstacles that our mechanism may encounter. In other words, it can be said that it acts as a suspension. There is no need for direct electrical power for this system -prismatic joint- which can be adjusted completely mechanically on its own. Our prismatic joints are stationary and positioned at 110 degrees to our ternary links. Our prismatic joints move in two directions in themselves only on one axis.

There are three double-sided ternary links in our body -our ternary links consist of two fixed links and three joints - It is not exactly in the form of a triangle. Structural design should not confuse. - and there is one binary link. With these, a branch loop is formed. Thanks to this, we maintain the main form of the mechanism, ensuring the movement of our body as a whole. It is also powerful enough to carry the circuit box - especially the 1200mAh 1.2AH 3.7V Lithium Polymer rechargeable battery. Our middle wheel, which we have positioned at the end of the downward-facing ternary link of our body, makes a rotational movement around itself only with the power given by the motor, unlike our front and rear wheels. most of the weight of the circuit box and the mechanism is carried by our middle wheels.

The diameter of each of our wheels is 7.5 cm in total and there is a non-slip layer with a thickness of 2 cm at the outermost part. Thanks to this layer, the ground retention of our mechanism increases.

Due to these, our mechanism continues on its way by ensuring its movement according to the commands given from outside and reducing the impact of the obstacles it encounters as much as possible. Thanks to the branch loop on the main body, it does not break its shape and our wheels provide as much road holding as possible.

G. Bill of Materials (BOM)

	Material	Quantity	Price
1	Arduino UNO	1	₺ 120
2	DC Gear Motor	6	₺ 90
3	Bluetooth Module	1	₺ 90
4	Switch	1	₺ 5
5	DC Motor Driver	1	₺ 100
6	LI-PO Battery	1	₺ 150
7	Round Shaft	6	3D*
8	Triangle Fixed Link	4	3D*
9	Straight Link	8	3D*
10	Fixer Part	30	3D*
11	Prismatic Link Fixer	4	3D*
12	Prismatic Link	4	3D*
13	Prismatic Joint	4	3D*
14	Bearing and Wheel Shaft	6	3D*
15	Electrical Box	1	3D*
16	Tape	2	₺ 30
17	Fast Adhesive	1	₺ 25
18	Plastic Handcuffs	1	₺ 28
19	0.5 mm NYAF Cable	4	₺ 7
20	Bearing	8	₺ 140
21	Non-Slip Material	1	₺ 65
22	Wheel	6	₺ 400
23	1 KG Filament (Total 3D*)	1	₺ 250
		TOTAL	**₺ 1.500**

Table G.1.1 Bill of Materials (BOM)

H. Conclusion

In this project, we were trying to reach nearly all design requirements and, in many respects, exceeded the original design goals. At first, we were thinking of making a rocker-bogie system, but then we wanted our design to be unique, so we made a structural design on paper using the Alizade mobility equation. We try to decide the correct structural design after working on our other design. After that we continue with the inventor driving, we draw all parts After that we continued with the inventor driving, we draw all parts one by one in the inventor program. It can be seen in Figures D.1.13 to D.1.21. First, we drew round shafts all mechanisms build around on these shafts then we should be able to fix the same part, so we drew Fixer Part and Triangle Fixed Link. After that we add Straight Links to connect the back and front of the mechanism and middle wheels. Then for the wheel legs we design Prismatic Links and connect them with Prismatic Joint. After we design some additional parts like Bearing and Wheel Shaft, Electrical Box, Prismatic Link Fixer. There were some things we didn't calculate when printing parts in 3D printing. Some parts weren't going exactly as we wanted, so we had to reprint some parts, some parts broke while we were assembling, we had to print them again because we print them at twenty percent infill. This cost us 140+ hours on printing part only. Finally, we come to the assembly part, we want some parts to be fixed, we used glue for them, so the mechanism can move as we want. When the assembly part was finished, we made the motor connections and tried it. It was working as we wanted until it came to the ladder part of the barrier, the shafts going to the middle wheel got stuck on the platform and slide. We thought that we could solve this problem by increasing the diameter of the wheels and we increased the diameter of the wheels with a non-slip mat. Then it will work properly. For now, the rover can only move there are climbing stairs If we continue to move forward with the project The rover developed by this project has been specifically designed to facilitate future work. With the development of technology, it can become more useful with the cameras attached to the mobile vehicle that can be used for reconnaissance purposes. With the development of a larger model, it can be used to transport people and materials over rough terrain or in areas with obstacles such as stairs. It could also be developed as a low-cost rover that could be sent to gather information about the Martian surface.

i. References

For Calculations:

Mechanism Design: Analysis and Synthesis

Engineer: George N. Sandor

Author: Arthur G Erdman

For Design:

https://www.cadcrowd.com/3d-models/buggy-car

https://youtu.be/NOZZMsMAGh0

For Electrical Circuit:

https://www.alldatasheet.com/datasheet-pdf/pdf/22432/STMICROELECTRONICS/L293D.html

https://components101.com

For Software:

Arduino library DC motor controlled

Arduino library Bluetooth module software