Rube Goldberg Machine

Operation manual
of
Individual Steps design

Team 02

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1 Introduction

The objective of this manual is to guide the user on how to operate the following steps. Compliance with the operation manual will automatically ensure correctness and it will also improve the efficiency of the operator. Operating procedures for all the developed individual steps are presented in the subsequent section. This report also includes the list of parts used during fabrication of the individual steps of the Rube Goldberg Machine (RGM). Every machine needs a regular maintenance in order to maintain is consistency and reliability. Hence routine maintenance procedure for each individual steps of RGM is also explained in this operation manual. Troubleshooting for all the individual steps is also presented in the following subsections that will help the team in tracing and correcting the faults through a logical and systematic approach.

2 System Designs

Total 10 individual steps has been fabricated by the team. All the design of individual steps along with their operating procedures has been explained thoroughly in the following sub-section in order to guide the user. This section includes the part list, operating procedure, maintenance and troubleshooting for each individual step.

2.1 Wood Spiral Staircase Design

Different views of the spiral staircase step design has been presented in **Figure 1**. As seen in the figure, A DC motor is connected to a PVC pipe and a thick rope is wrapped around the pipe in the spiral shape. As motor rotates, a ball will travel from the bottom to the top with the help of rope and falls on the stairs, and on the last stair there is a sensor that will turn off the DC motor and makes another servo move which will trigger the next step.

Figure 1: Different views of the spiral staircase step

2.1.1 List of parts

This section will list all the critical parts and components of the wood staircase design.

- PVC PIPE
- Thick rope
- Wood Spiral Staircase design

- DC Motor
- Button Switch
- Ball
- Thin Metal Pin
- Rubber
- Servo
- Sensor

2.1.2 Operation

The following procedure needs to be followed in order to avoid any mistake:

- PVC PIPE with thick rope attached to it as shown in the **Figure 1** above to work as Archimedean screw
- The PVC PIPE is connected to a DC motor that spins the pipe and makes the ball go up.
- The system is triggered by turning the switch on that is connected to the DC motor from behind.
- The system will be turned off once the ball touches the sensor in the last s
- The battery can be replaced from behind if the system power dies.

2.1.3 Maintenance

This section will cover the maintenance of the design:

- Ensure the battery is alive to make the Archimedean screw working
- Make sure there's no obstacles in the wood staircase and let the ball fall.

2.1.4 Troubleshooting

To troubleshoot the design, first information should be gathered on the issue. The following methodology needs to be adopted to troubleshoot the spiral stair case design:

- If the motor is not spinning, change the battery even if problem persist change the motor itself.
- In case of ball not reaching at the top, Check whether the rope is properly wrapped.
- If the ball is not reaching at the bottom, there may be any obstacle in the stairs which needs to be removed.

2.2 Catapult Design

Figure 2 shows the different views of the catapult. The catapult is loaded with the help of spinner attached to it and it launches the object as the thin metal pin is removed after the loading. The spinner and metal pin is clearly shown in **Figure 2.b.** The catapult will be connected to a programmable multifunction time delay relay that will trigger a two different linear actuator on different time sets in order to make the step resettable. The programmable multifunction is shown below in the Arduino Kit section.

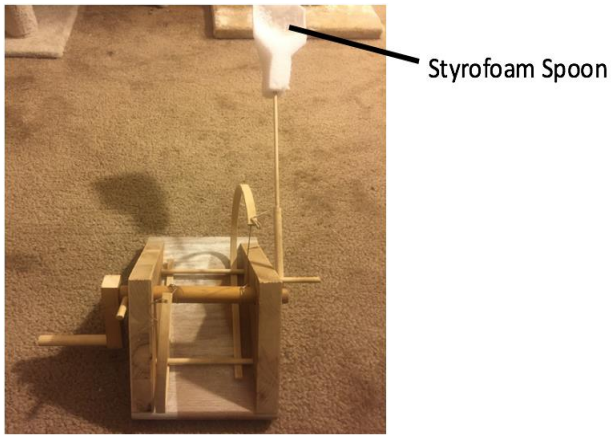

Figure 2a: Top view of catapult

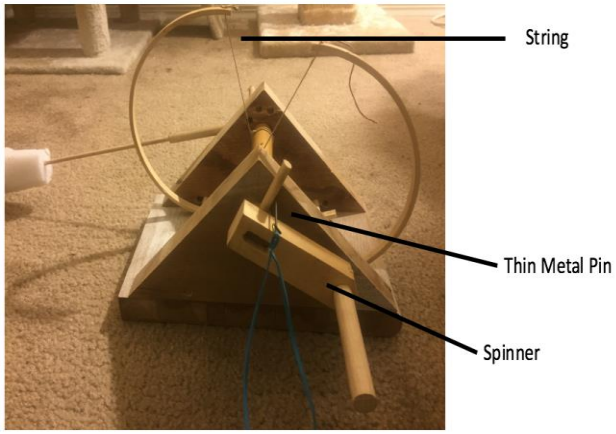

Figure 2.b: Front view of catapult

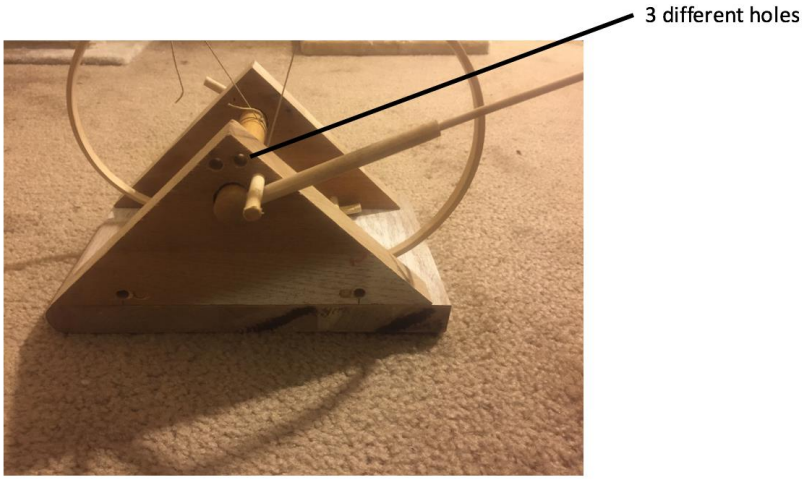

Figure 2.c: Rear view of the catapult

2.2.1 List of parts

The catapult design consists of the following parts:

- The whole design is made from wood, the geometric shapes part formed the shape of the catapult.
- 2x Strings
- Styrofoam
- Medium weight ball

2.2.2 Operation

Operating procedures of the catapult step is as follows:

- The spinner works on moving the firearm by tightening the strings that are attached to different wood sticks
- A thin metal can be inserted as shown in **Figure 2** that stops the spinner from moving.
- Put the ball in the Styrofoam spoon & launch.
- There are 3 different holes to adjust the firearm to where it stops. It helps achieve different trajectory.

2.2.3 Maintenance

This section will cover the maintenance of the design.

- Make sure you don't spin the spinner too much to not break wooden sticks.
- If the strings are cut, its okay it can be easily replaced. Same goes for the styrofoam

2.2.4 Troubleshooting

The following methodology needs to be adopted to troubleshoot the catapult step:

- If the range of catapult is reduced, change the flexible wooden strips
- In case of failure of any parts, just replace the particular part only.

2.3 Arduino Kit Design

The following figure 3 will demonstrate how most of the steps will start and be self resetting by using electrical parts. Each step is using a unique system, wiring, sensors and switches..

- **Figure 3a** was used for the 3D escalator to lift up the escalator and reverse back down. The ball will roll to the top track and then touches the laser sensor that is attached to the top track. Once it hits the touch sensor a LCD monitor will show a black text.
- **Figure 3b,** the system is controlled by a relay that will turn on the hair dryer for 5 seconds then shuts off. The car will hit the steel ball will roll over a touch sensor, that will trigger the magnetic escalator.
- **Figure 3c** The system is controlled by motor drive and a DC motor. Once the wooden car run over the touch sensor in the way down, it will trigger the DC motor to reverse back and pull back the wooden car by a string.
- **Figure 3d** The system is connected to a motor drive, once the ball touches the touch sensor it will trigger the escalator to lift up till the ball drops into the other side. Once the ball drops another hanger will get in a place the carry the ball again.
- **Figure 3e** The system is connected to a water pump by a timer. While the switch is it will turn on for 5 seconds then shuts off automatically.
- **Figure 3f** This is programmable multifunction time delay relay that will trigger a 2 different linear actuator on different time sets in order to make the step resettable.
- **Figure 3g** The system is controlled by a motor drive, the DC motor will work till the ball touches the touch sensor then it will trigger the servo then the whole system will stop.

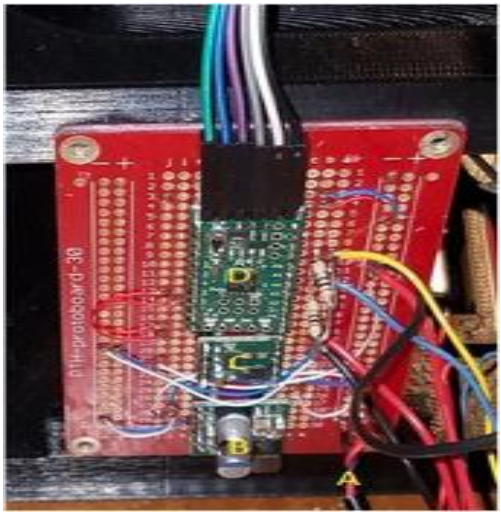

Figure 3a: System for 3D escalator

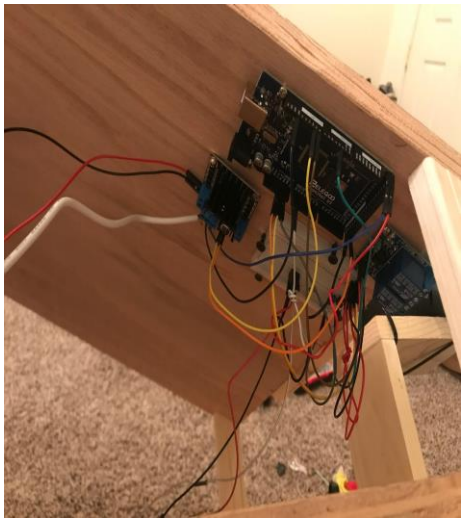

Figure 3b: System for aerodynamic

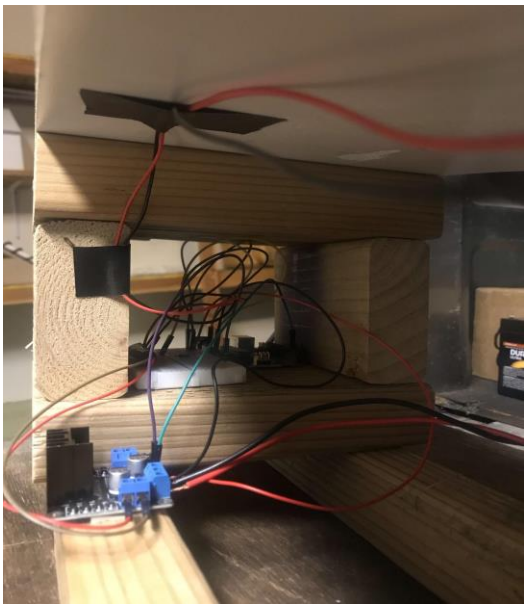

Figure 3c: System for the magnet car

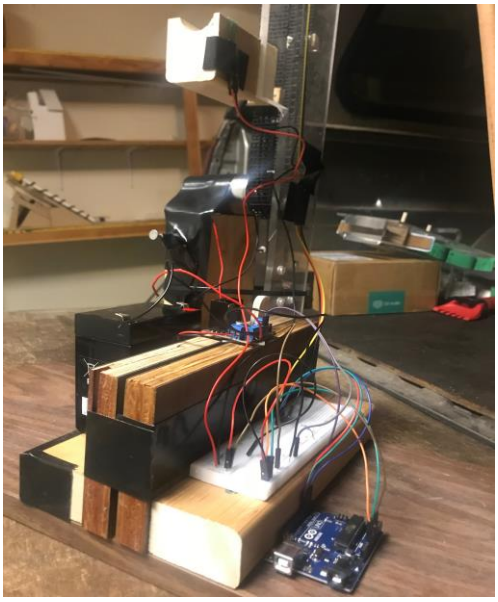

Figure 3d: System for gear escalator

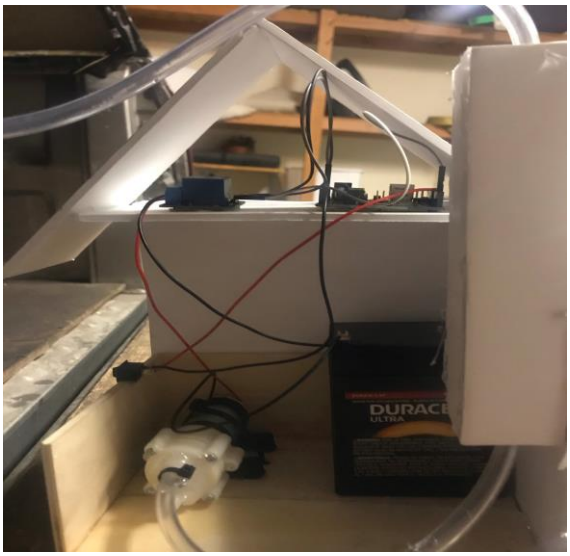

Figure 3e: System for water wheel

Figure 3f: System for the catapult

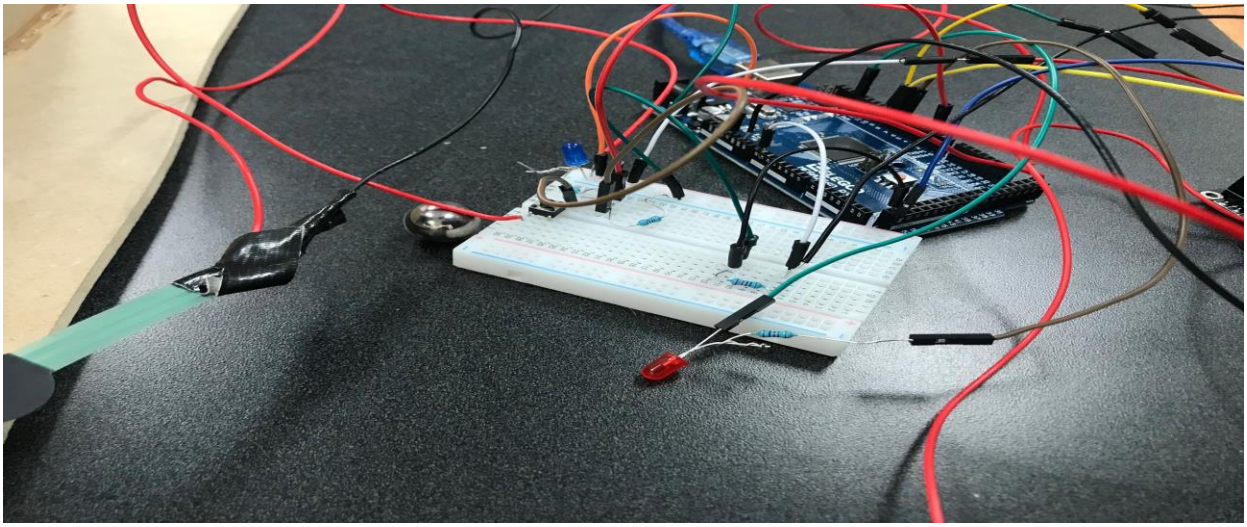

Figure 3g: System for spiral staircase

2.3.1 List of parts

The following parts have been used to fabricate the step that utilizes the Arduino Kit

- Wires
- Two relay
- Four 12V DC motor
- 7 Arduino Uno
- Four motor drive
- LCD 16x2
- Two laser sensor
- Three force sensitive resistor
- Three on/off switches
- Four uctronics dc 12v
- Two linear actuator
- One button switch
- Five light

2.3.2 Operation

Following are the steps needs to be follows in order to operate this step-

- All Arduino kits operates by electricity, switches has been made for some of them and touch and laser sensors will be the start for some of the steps.

2.3.3 Maintenance

This section will cover the maintenance of the design:

- Make sure to change the battery if necessary.

- Protect the Arduino from any liquid.

2.3.4 Troubleshooting

The following methodology needs to be adopted to troubleshoot the catapult step:

- If the sensor is not working properly, consider replacing the battery if the problem still persist replace the sensor.
- Make sure all wires are connected to arduinos and their boards.
- Keep the positive and negative wires connected to the right nodes.

2.4 Bicycle Wheel Design

A figure of the bicycle wheel step design is presented in the **Figure 4.** Base is made in the triangular shape, where the bicycle wheel is attached. Four metal cups are attached around the periphery of the wheel. As the ball falls on the metal cups, due to the weight of the ball, wheel rotates.

Figure 4: Bicycle wheel design

2.4.1 List of parts

This section will list all the critical parts and components of the Bicycle Wheel.

- 4x Metal cups
- Wood Base
- Bicycle wheel (without the tire)
- Plexiglass
- Switch
- Greartisan DC 12V
- Metal Ball

2.4.2 Operation

Operating procedures of the bicycle wheel step is as follows:

- The ball will fall into one of the cups, the weight of ball will rotate the bicycle wheel.
- Plexiglass is adjusted vertically to make the wheel stop moving and drops the ball from the cup.
- Greartisan DC 12V will rotate the bicycle wheel counter clockwise to get the cups to its original point.

2.4.3 Maintenance

This section explains the steps during maintenance of the design:

- Make sure that DC motor works to get the cup to its starting point.
- Adjust the timing
- Make sure the ball weight rotates the bicycle wheel.

2.4.4 Troubleshooting

The following methodology needs to be adopted to troubleshoot the bicycle wheel step:

- If the wheel is not rotating smoothly, lubrication needs to be done.
- In case of malfunctioning of the DC motor, consider replacing the batteries, if the problem still persist change the DC motor.

2.5 Water Wheel Design

Isometric image of the water wheel step is shown in **Figure 5**. Inside the house, a water pump and the batteries are kept. The water will be pumped on leafs of the wheel. As a result wheel starts rotating and a thread attached to the wheel will stretched which will lift the object by taking the assistance from the pulley.

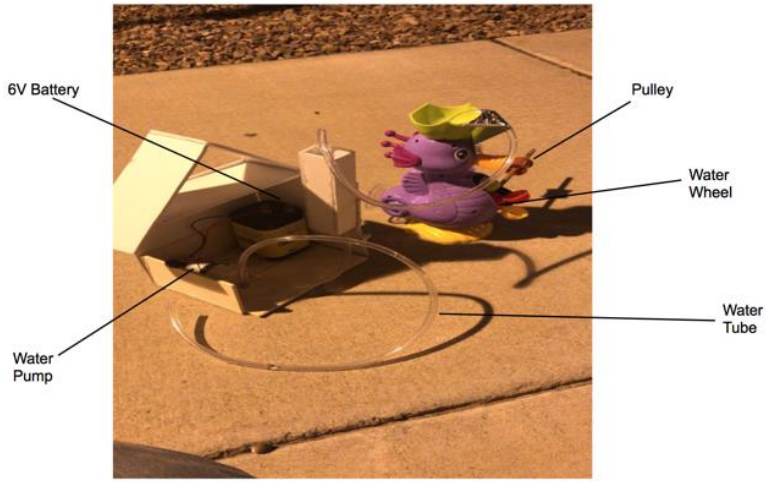

Figure 5: Isometric image of the water wheel step

2.5.1 List of parts

Components/parts used for the fabrication of the water wheel steps are as follows:

- Duck toy (water wheel)
- Water Pump
- Switch
- 6V Battery
- Pulley (round chopstick)
- Water Tube
- Water basket
- Thread spool

2.5.2 Operation

Following are the steps needs to be follows in order to operate this step-

- Water pump will pump the water from the basket through the water tube to rotate the water wheel.
- The round chopstick pulley is attached to the water wheel
- We will put a thread spool on the chopstick allowing it to either pull something directly up from below it or raise or lower something using a pulley or system of pulleys.
- The water pressure is adjusted so that there is right amount of water to spin constantly.
- The house is hiding the battery and the water pump as shown in **Figure 5**.

2.5.3 Maintenance

This section will cover the maintenance of the design.

- Ensure the battery is alive to make the water pump pumps the water.
- Make sure the water pump is moderate to turn the water wheel.

2.5.4 Troubleshooting

The following methodology needs to be adopted to troubleshoot the water wheel step:

- If the wheel is not rotating smoothly, lubrication needs to be done.
- In case of malfunctioning of the pump, consider replacing the batteries, if the problem still persist change the pump.
- Adjust the flow rate according to the weight of the object to be lifted.
- If any part fails, replace that particular part only.

2.6 Timing Pulley Escalator Design

Multiple views of the Timing Pulley Escalator design are presented in below **Figure 6**. The DC motor will run the escalator which takes the ball from the bottom to the top. The movement of the escalator is controlled by the sensors attached to the top and bottom of the escalator. As the

ball reaches to the top, it touches the sensor which triggers a signal and display the NAU logo on the screen.

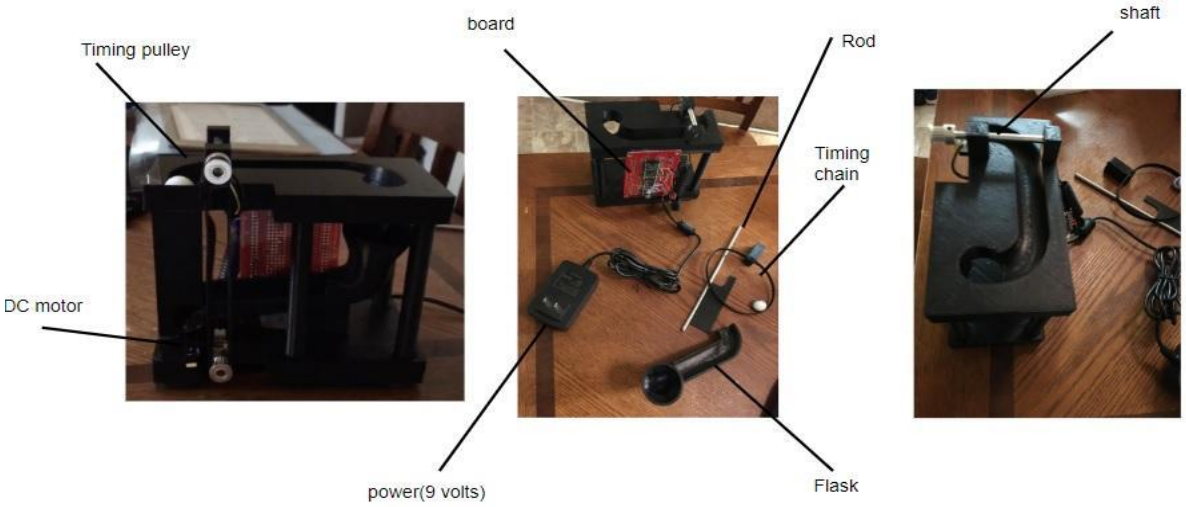

Figure 6: Multiple views of the Timing Pulley Escalator design

2.6.1 List of parts:

This section will list all the critical parts and components of the escalator:

- 2X timing pulley
- Timing chain
- Rod
- Flask
- shaft
- Dc motor
- Board
- Top track
- Lower track
- Marble ball
- Pillars
- Switch
- Touch sensor
- LCD monitor.
- Power (9 volts).

2.6.2 Operation:

Operating procedure of the step shown in **Figure 6** is as follows:

- Once the marble ball is in the system it will roll from top track to bottom track.
- The flask will carry the ball from top track to bottom track.
- The escalator is programmed to lift the ball upward then stops for 2 seconds and go downwards to lift the ball again. Once it hit the switch while going downward, the escalator will lift up immediately.
- While the ball is in the top track.

- While the ball is rolling in the top track, a touch sensor is attached to the track and once it senses the ball an LCD monitor mounted will show NAU logo.

2.6.3 Maintenance:

This section explains the routine maintenance procedure of the above step.

- The power has to be plugged so the escalator can work.
- If the escalator is noting lifting the ball efficiently, the system has to be restarted.
- The escalator can lift the ball 12 times, if more the it will start to show signs of being hot because of the operation.
- If the ball did not catch the escalator in the way down, the system have to be restarted.

2.6.4 Troubleshooting:

The following methodology needs to be adopted to troubleshoot the step shown in **Figure 6**:

- If the escalator is not working, change the battery or the DC motor.
- If the light on the screen becomes dull, change the batteries of the display.
- In case of malfunctioning of the control of escalator, change the sensor.

2.7 CD player

Design of CD player step is shown in **Figure 7**. The car travels on the track and hit the stick attached to the CD player. As a result, CD player rotates and hit the metal rod played at another pathway. Metal rod further hit the ball placed next to it and ball rolls on the pathway.

Figure 7: CD player step

2.7.1 List of parts

This section will list all of the critical parts and components of the CD player step.

- Car
- Car track
- CD player
- CD w/ magnet on a stick
- Ball
- Ball track
- Wooden dowel
- Magnet base on ball track

2.7.2 Operations

Operating procedure of the step shown in **Figure 7** is as follows:

- Place the car on the track on the opposite side of the CD player.
- Align the magnet from the CD player in the car track path
- Place the wooden dowel on the wooden track with the end approximately 2 to 3 in before the fixed magnet.
- Play Steve Ball approximately one in from the other end of the wooden dowel.
- Now you can run the step.
- Now repeat from Step 1.

2.7.3 Maintenance

This section will cover the maintenance of the design.

- Monitor the cars power replaced the batteries if it is getting weak or slow.
- Make sure no obstacles are on either track.
- Check that the CD rotates freely on the CD player.
- Check to ensure that all magnets are securely fastened.

2.7.4 Troubleshooting

The following methodology needs to be followed to troubleshoot the step shown in **Figure 7**:

- Consider replacing the batteries in case of slow movement of the car.
- Remove the contamination of any obstacle on the pathways if the movement of the car or metallic ball is restricted.

2.8 Magnetic Car Step

Step of the magnetic car is presented in the **Figure 8**. Two cars with magnet are place at both the ends of the guide ways. A stick is used to hold the car at the sloped pathways. As the stick is removed, the car place at the sloped pathway will start moving on the pathway. Propelling action of the magnet will trigger the movement of the car placed at another end of the pathways which can be further used to trigger the movement of another car.

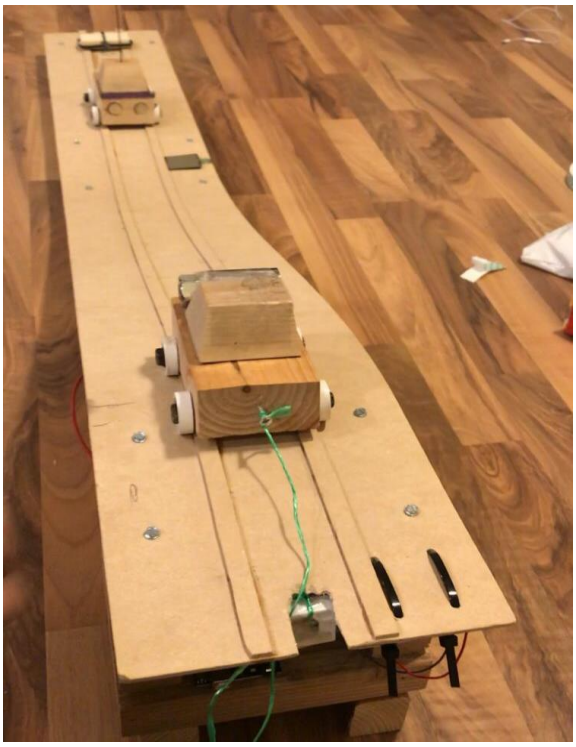

Figure 8: Magnetic car

2.8.1 List of parts

The parts used for the fabrication of the magnetic car step is listed below:

- A car with weight in the rear
- A car
- Wooden track
- A spring mounted to push the car back
- A string to pull the car
- DC motor

2.8.2 Operation:

Operating procedure of the steps presented in the **Figure 8** are as follows:

- Push the first car back which is placed in the upper side of the track. And it will collide with the second car that is placed down side of the wooden track.

- Due to collision second car will be pushed back towards spring and it will pushed back and it will hit the first car.
- After that DC motor will start and it will reset the car to its original position.
- Now you can run the step.
- Now repeat from Step 1.

2.8.3 Maintenance

This section will cover the maintenance of the design.

- Ensure that the weight is securely fastened. Keep some super glue on ready just in case.
- Always be sure there are no obstacles on the track.
- Check the wheels periodically to ensure they are moving freely.

2.8.4 Troubleshooting

The following methodology needs to be followed to troubleshoot the magnetic car:

- Replace the magnet with the higher propelling power in case of lack of propelling action.
- If the car is not moving freely on the pathways, replace the car itself.

2.9 Aerodynamics Design

Figure 9 shows the design of the aerodynamic step. The car start moving upward on the triangular board due to the thrust force generating by blowing the air with the help of blower. As it reaches at the top, it hits another ball to start it's movement to the downward of the board base.

Figure 9: Aerodynamic step design

2.9.1 List of parts

This section will list all of the critical parts and components of the aerodynamics car step.

- Measure tape
- Pencil
- Chalk line
- 1/8” wood drill bit
- 3” 8 Nos impact bit screws.
- 1” wood 6 Nos screws.
- 2” square screws 2 Nos.
- Skill saw
- Bit heads
- Table saw
- Vinyl tubing
- Screen meshing
- Aluminum flashing
- 10 gauge wire
- 12 Volt DC motor

- Sprockets and gears
- Plastic chain
- Blower dryer
- Wooden board
- Furring strips
- Metal ball 3/8”
- Neodymium magnets
- Car with balloon
- Small wood piece for leg for the base zip ties.
- Tiny screws to hold down electrical boards.

2.9.2 Operation:

Operating procedure of the step shown in **Figure 9** is as follows:

- First step is to locate the Black button to activate the Hair Dryer for 3 seconds. Also check the elevator has 3 round magnets and check the screw underneath the metal ball and make sure there are 4 round magnets.
- Press the button for at least one second to start the hairdryer. This will engage the electricity to activate the hairdryer. Hairdryer is generating the pressure force on the small plastic car to travel up the ramp and engage with the small metal ball. After 5 seconds the hair dryer will turn off and car will come back to its original position.
- Due to the engagement of the car with the metal ball energy will transfer from the car to the metal ball will be make ball to travel down through the clear vinyl tubing and through small path which will bring the metal ball to the starting point of the magnetic elevator. When the ball is traveling to the path toward the magnetic elevator, there is small electrical sensor that will activate the magnetic elevator. Then the metal ball will attach with the round magnets and it will go upward direction toward starting point.
- The metal ball will travel up mesh and it will disengage from the round magnets and it will be launched from the magnets to a folded aluminum plate. This plate will engage with the ball and it will slow down the metal ball in order to bring it back to its starting position.

2.9.3 Maintenance

This section will cover the maintenance of the design.

- Ensure that the battery is alive
- Always make sure that there are no obstacles on the track.
- Check the wheels periodically to ensure they are moving freely.

2.9.4 Troubleshooting:

The following methodology needs to be adopted to troubleshoot the step shown in **Figure 9**:

- Replace the balloon if it burst during the operation.
- Change the car in case of malfunctioning of the car.

Appendix

CAD drawings of the design steps selected .for the fabrication are presented in **Figure 10 to 17.** Audrino kit is used at the two steps:

- Escalator Step
-

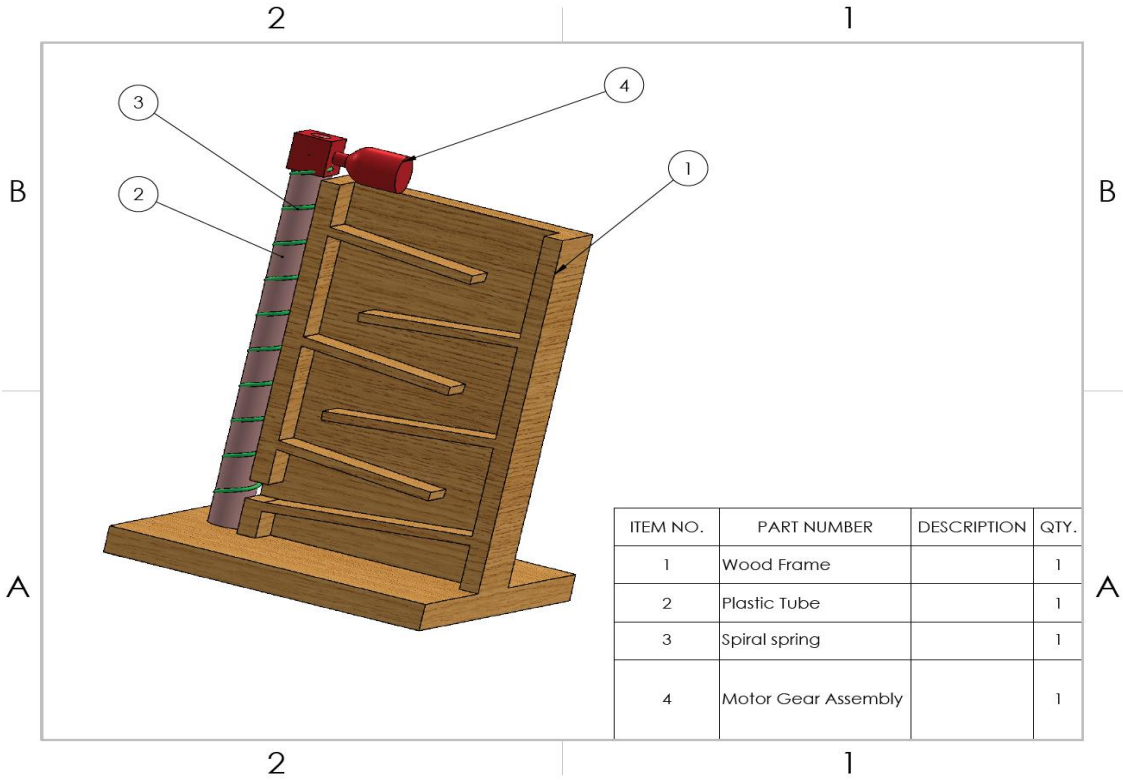

Figure 10: Wood Staircase

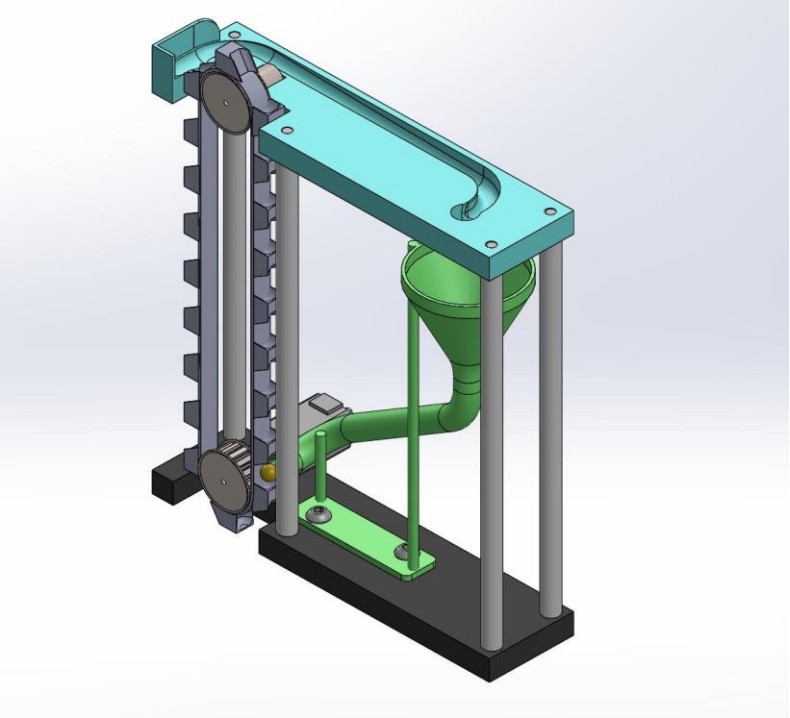

Figure 11. Escalator

Figure 12. CD player

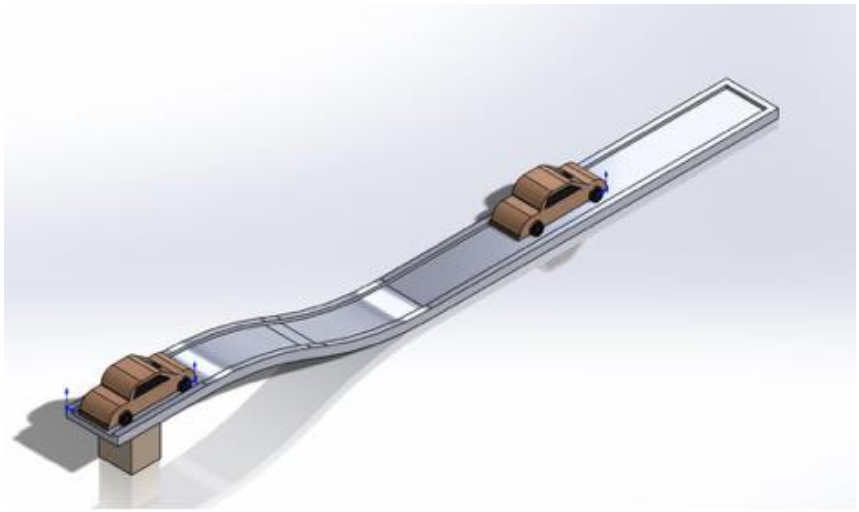

Figure 13. Car track

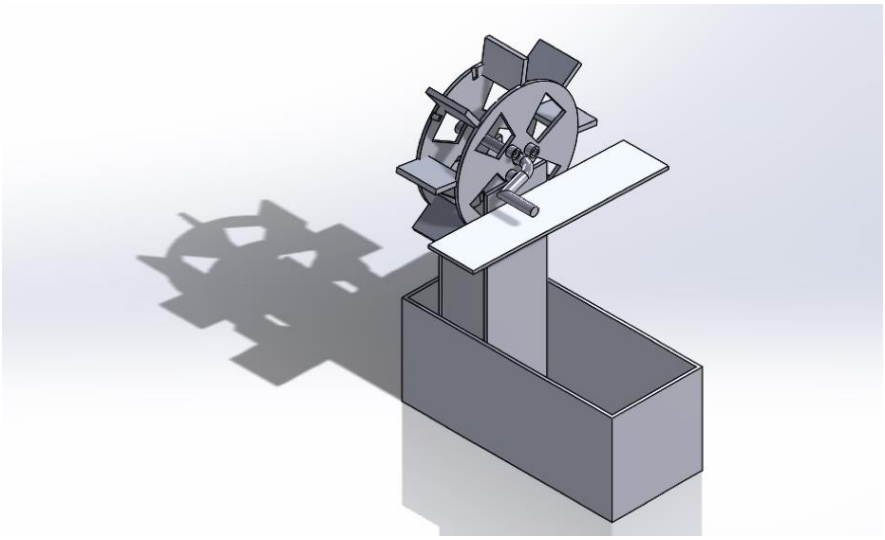

Figure 14. Waterwheel

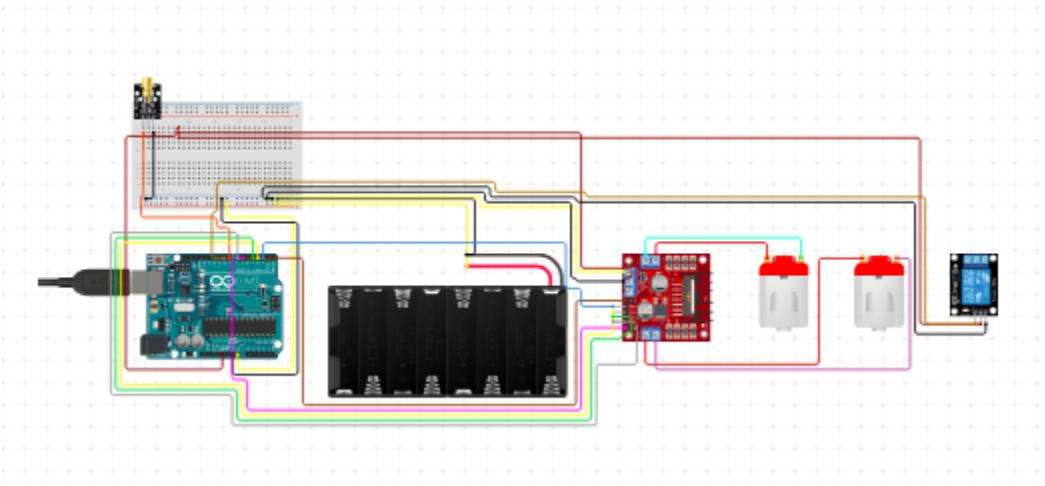

Figure 15. Arduino Kit 1

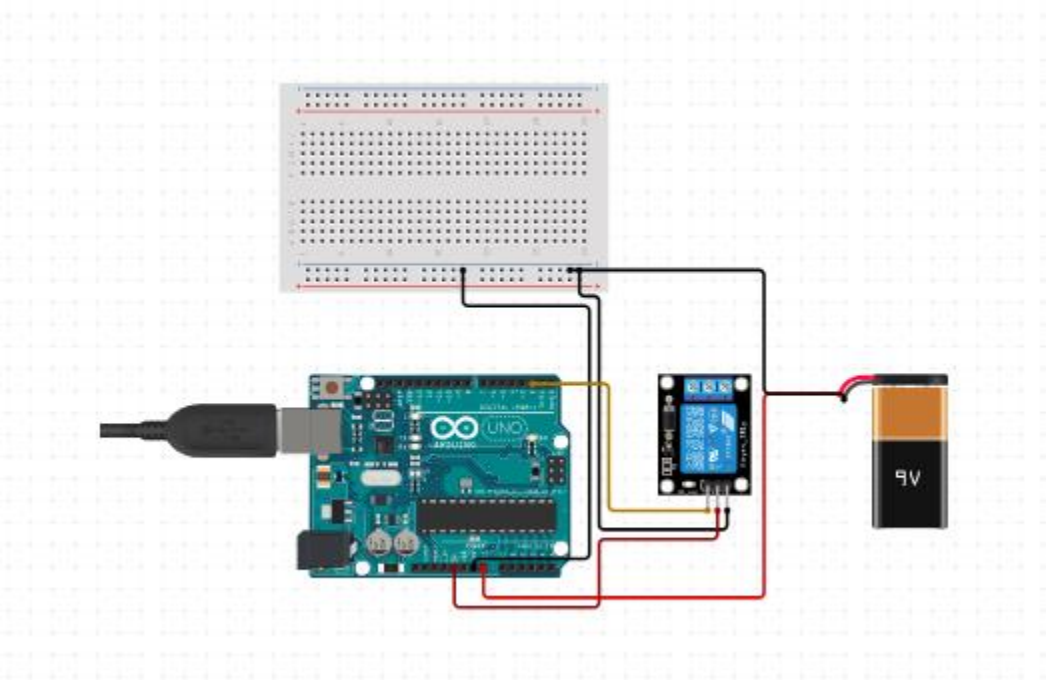

Figure 16. Arduino Kit 2

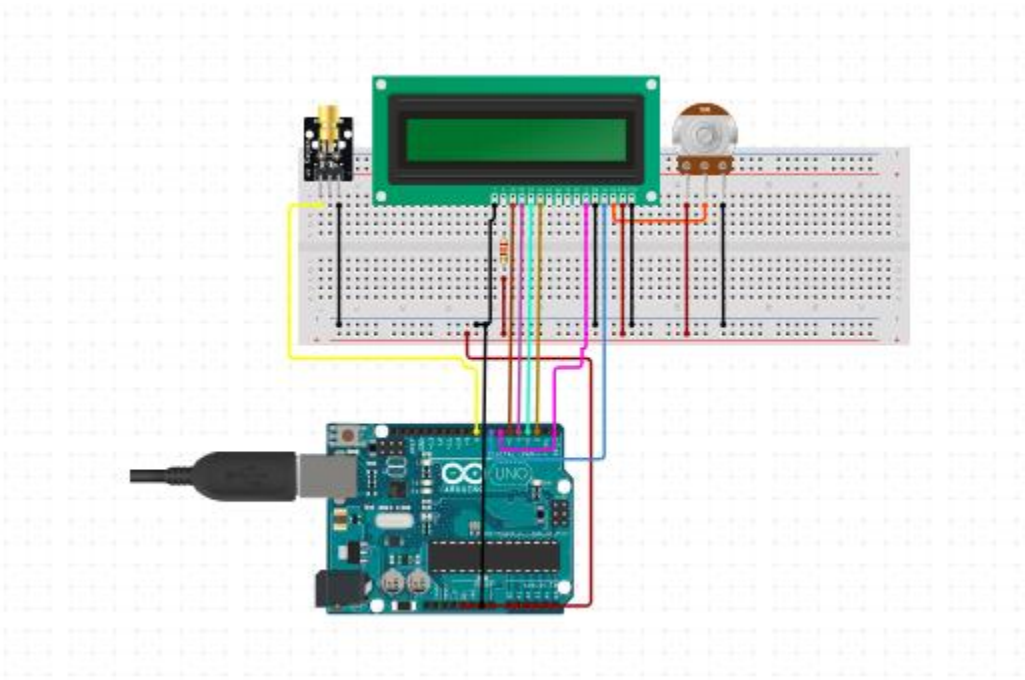

Figure 17. Arduino Kit 3

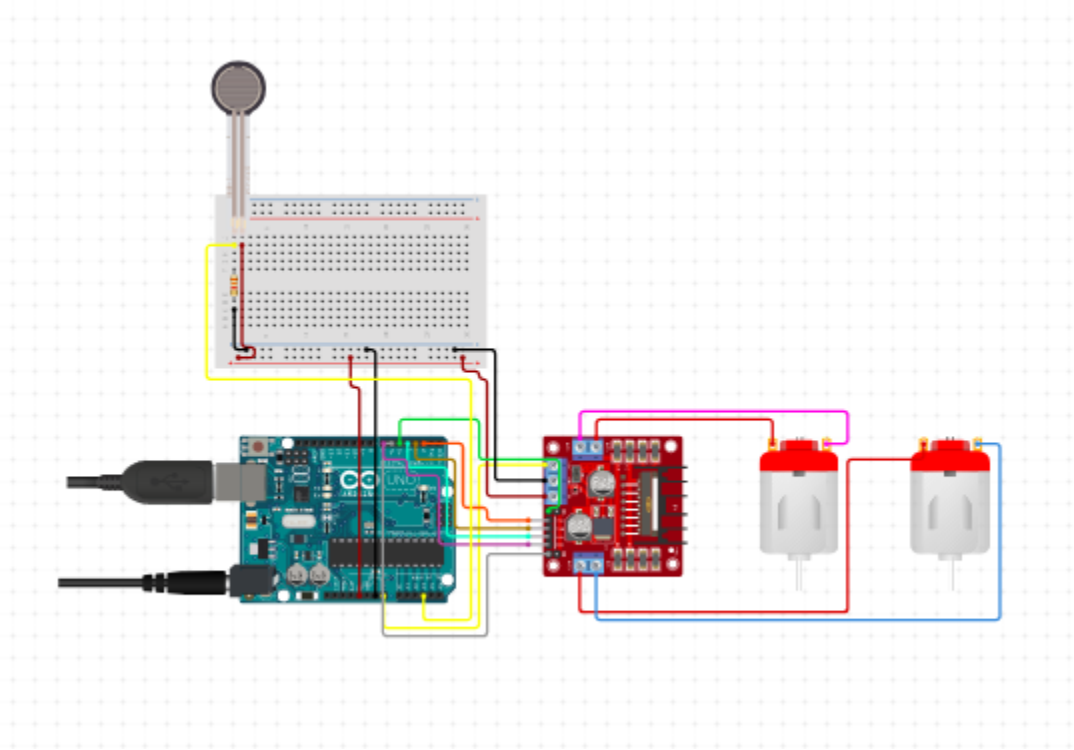

Figure 18. Arduino Kit 4

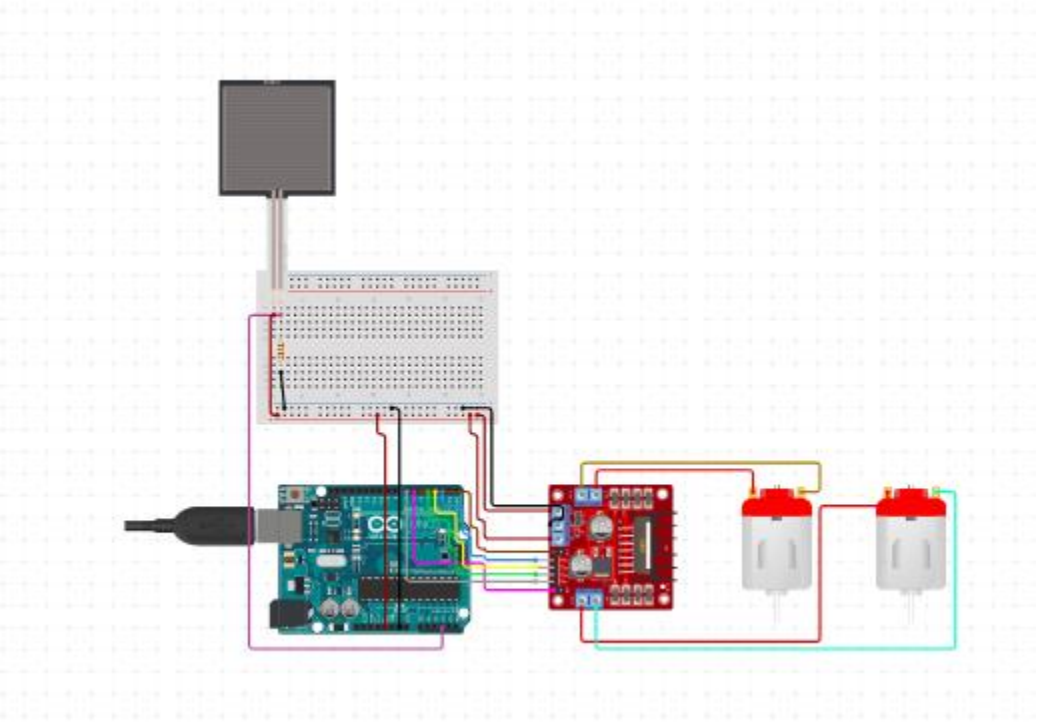

Figure 19. Arduino Kit 5

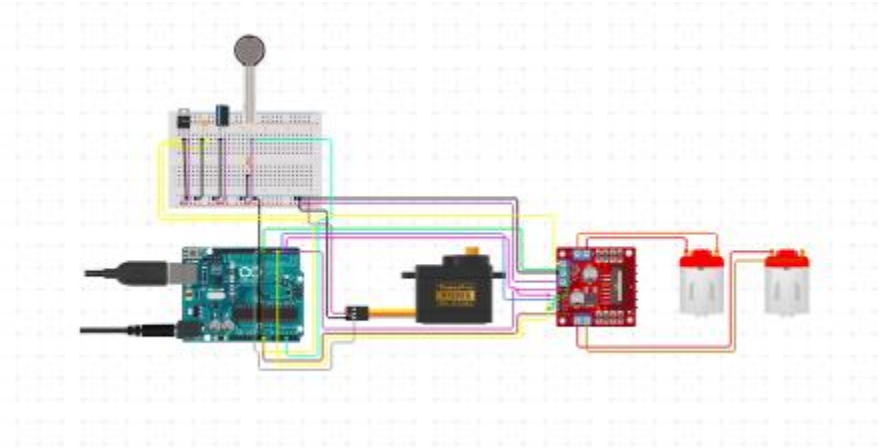

Figure 20. Arduino Kit 6

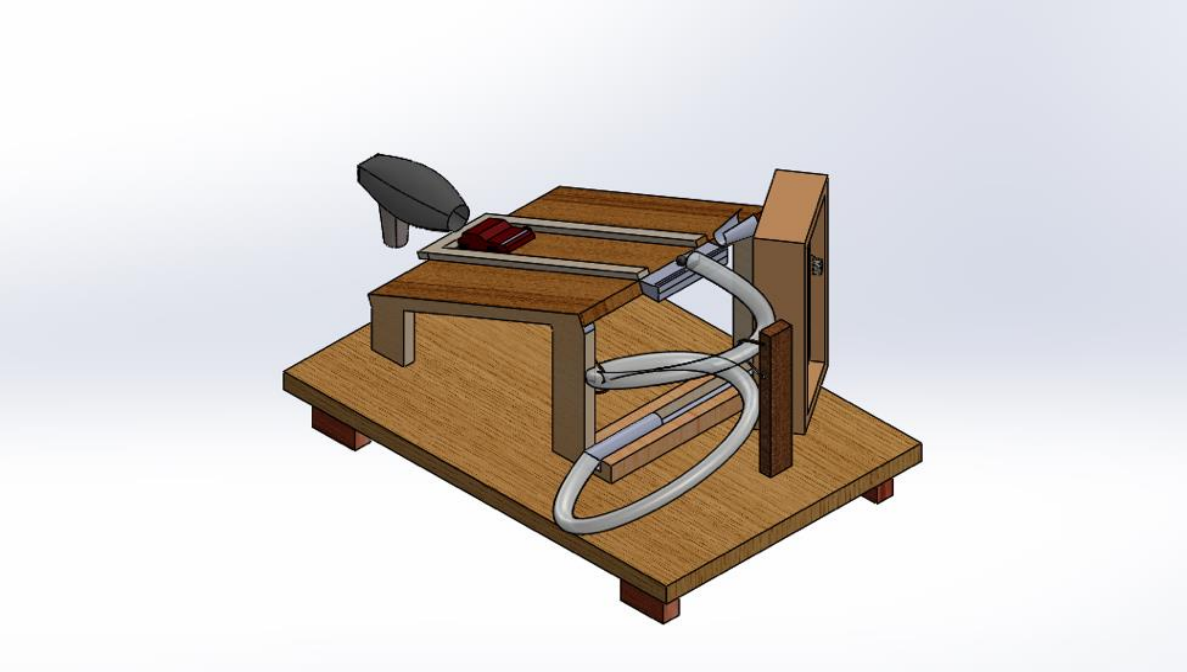

Figure 21. Aerodynamic Car Design