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Design the Air Powered Vehicle for Clean and Green Environments

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--*ABSTRACT*--

This project explores the optimization of compressed air vehicles (CAVs) by combining insights, from a review of existing research with practical experimentation. The literature review presents the advantages and challenges of CAVs, emphasizing their potential as a sustainable transportation solution while acknowledging limitations such as range constraints, safety concerns, and infrastructure requirements. The experimental phase of the project focuses on iterative modifications to enhance the performance of a pneumatic engine-driven car. Meticulous sealing, the introduction of ball bearings, and additional enhancements to the axle collectively lead to a substantial improvement in the car's functionality, with the range progressing from an initial 1 meter to a notable 10 meters. The results affirm the importance of a holistic strategy in addressing both engine and mechanical components for optimal CAV performance. These findings contribute valuable insights into the complexity of CAV technology, bridging theoretical considerations from the literature with practical development, thereby guiding future efforts toward sustainable and cost-effective transportation solutions.

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I. INTRODUCTION

The transportation sector plays a crucial role in facilitating economic growth and societal development (Sachan et al.,2020). However, traditional vehicles powered by internal combustion engines contribute significantly to air pollution and climate change. The combustion of fossil fuels releases greenhouse gases, including carbon dioxide (CO2), which traps heat in the atmosphere and leads to global warming. The adverse environmental impacts, coupled with the finite nature of fossil fuel resources, necessitate the exploration of sustainable transportation alternatives (Jiotude et al., 2017). In recent years, there has been a growing interest in electric vehicles (EVs) as a cleaner and more sustainable solution. EVs utilize rechargeable batteries to power electric motors, eliminating direct emissions and reducing dependence on fossil fuels. However, challenges such as limited driving range, long charging times, and the environmental impact of battery production and disposal hinder their widespread adoption. As a result, there is a need to explore alternative propulsion technologies that can address these limitations (Patel et al., 2017). One such technology is air-powered vehicles, which harness the power of compressed air to propel vehicles. Compressed air can be stored in high-pressure tanks and released to generate mechanical energy, driving the vehicle's movement (Setyono, 2021). Unlike traditional combustion engines, air-powered vehicles produce zero tailpipe emissions, offering the potential for cleaner and greener transportation (Ravikumar et al., 2021). Additionally, the use of compressed air allows for fast refueling times, overcoming one of the major drawbacks of EVs. These advantages make air-powered vehicles an attractive option for short-distance commuting and urban transportation (Shivakumar et al., 2023). While the concept of air-powered vehicles is not new, recent advancements in materials, engineering, and energy storage technologies have renewed interest and research in this area. Innovators and engineers are exploring various designs, propulsion mechanisms, and control systems to enhance the performance, efficiency, and practicality of air-powered vehicles (Kumar, 2020). By utilizing renewable energy sources to generate compressed air and addressing the challenges related to energy efficiency and storage, air-powered vehicles have the potential to provide a sustainable and environmentally friendly alternative to conventional transportation.

II. LITERATURE REVIEW

Compressed air vehicles (CAVs) have emerged as a potential alternative to traditional combustion engines, offering a cleaner and more sustainable mode of transportation. Researchers have explored various aspects of CAVs, including compressed air storage tanks, engine design, fuel efficiency, and their viability compared to gasoline and electric vehicles. This literature review aims to provide an overview of the advantages and limitations of CAV technology by combining and comparing the pros and cons discussed in various articles (Kumar, 2020).

2.2 Components of the Pneumatic Engine

Studies have focused on optimizing the design and performance of compressed air storage tanks. Researchers have investigated different materials and geometries to enhance the storage capacity and efficiency of tanks (Kumar, 2020). Improving the storage capacity is crucial since CAVs rely on stored compressed air to generate propulsion. Engine design is another important area of research in CAVs. Scientists have explored innovative methods to convert the expansion of compressed air into useful work. This involves designing efficient piston cylinders and valves that can convert the reciprocating motion of the pistons into the rotational motion of the wheels. The aim is to maximize the energy conversion efficiency and overall performance of the CAVs (Jiotude et al., 2017).

2.3 Advantages of Compressed Air Vehicle

CAVs offer several advantages that make them an appealing alternative to conventional vehicles. Firstly, they produce zero emissions during operation, contributing to the reduction of air pollution and making them environmentally friendly. Additionally, the use of compressed air as a fuel source can be cost-effective, potentially reducing fuel costs and making CAVs an economical transportation option. Moreover, compressed air technology allows for the recovery of kinetic energy during deceleration, increasing overall energy efficiency and minimizing energy waste. Compared to electric vehicles, CAVs also have a simplified design and lower manufacturing costs since they eliminate the need for large, heavy batteries. Compressed air tanks can be disposed of or recycled with less pollution than batteries, and refuelling rates can be comparable to liquid fuels. The lifespan of compressed air tanks is longer than that of batteries, which experience reduced performance over time (Verma, 2008). The lighter weight of CAVs not only contributes to lower manufacturing costs but also results in reduced road damage, leading to lower maintenance costs and less wear and tear on infrastructure. Furthermore, CAVs offer quick refuelling times, as they can be refuelled rapidly by filling the compressed air tanks. This feature minimizes downtime compared to electric vehicles, which require longer charging periods. Lastly, CAV technology has the potential for various applications, making it suitable for a wide range of vehicle types, including family cars, vans, taxis, and industrial vehicles (Shah & Shinde, 2018).

2.4 Fuel Efficiency and Energy Consumption

Fuel efficiency is a critical factor in determining the viability of CAVs. Researchers have conducted studies to analyse the energy consumption and efficiency of compressed air propulsion systems. This includes evaluating the electricity required for compressing air and comparing it to the energy consumed by traditional gasoline and electric vehicles. Understanding the overall efficiency of CAVs is essential for assessing their environmental impact and cost-effectiveness (Singh, 2020).

2.5 Comparative Studies: CAVs vs. Gasoline and Electric Vehicles

Comparative studies have also been conducted to assess the advantages and disadvantages of CAVs compared to gasoline and electric vehicles. These studies consider factors such as emissions, cost, range, and refueling/recharging infrastructure. Researchers have highlighted the potential of CAVs to reduce air pollution and their suitability for specific applications like urban commuting or industrial use (Thakkar, 2018).

2.6 Challenges and Limitations of CAVs

Despite their advantages, CAVs face several limitations and challenges that need to be addressed for their widespread adoption. One of the main limitations is the limited storage capacity of compressed air tanks. This restricts the range and practicality of CAVs, particularly for long-distance travel. Additionally, high-pressure compressed air tanks pose safety risks that need to be addressed through appropriate design and safety measures (Maurya, 2016). Additionally, the infrastructure for refilling compressed air tanks is not widely available, hindering the widespread use of CAVs. Developing a well-established refuelling infrastructure is crucial to overcome this challenge (Kumar, 2020). Another challenge is the complexity of manufacturing CAVs, especially when integrating pneumatic and battery systems in hybrid configurations. This complexity may increase production costs and hinder mass production. Although CAVs can recover energy during braking, the overall energy efficiency may be lower compared to other hybrid systems, such as electric hybrids. Moreover, the storage of air at high pressures can be risky and potentially dangerous, necessitating robust safety measures to ensure the protection of vehicle occupants. Furthermore, further research and development are necessary to validate the commercial and technical viability of compressed air technology for vehicles. The lack of progress and understanding of CAVs also pose challenges to their widespread adoption and commercialization (Sachan et al., 2022).

2.7 Research Gap

A critical project gap emerges when considering the limitations identified in the literature review. The current prototype faces challenges such as restricted travel distances, resource constraints influencing design complexity, and limited testing resources impacting the thoroughness of evaluations. One of the prominent gaps is associated with the energy storage and efficiency of the air storage system, particularly in the context of regenerating compressed air. This deficiency directly influences the vehicle's operational range. Bridging this gap requires a concentrated effort on innovating solutions to overcome these limitations. Strategies may involve enhancing the energy capacity and efficiency of the air storage system, optimizing the design and performance of the pneumatic engine and propulsion mechanisms, and ensuring seamless integration of the compressed air storage system with propulsion mechanisms and control systems. (Fang et al., 2020)

2.8 Summary and Future Implications

In conclusion, compressed air vehicles offer several advantages, including zero emissions, cost-effectiveness, energy efficiency, simplified design, and quick refueling times. However, they also face limitations and challenges related to limited range, infrastructure requirements, manufacturing complexity, energy efficiency trade-offs, safety concerns, and the need for further research and development. To fully realize the potential of compressed air vehicles as a sustainable transportation solution, continuous innovation, infrastructure development, and improved energy efficiency are essential. Addressing these challenges will be crucial for the successful adoption and integration of compressed air vehicles into the transportation sector.

III. METHODOLOGY

3.1 Introduction

This project aims to develop a functional and efficient air-powered vehicle prototype through a comprehensive methodology that encompasses various stages, from problem identification to iterative refinement. The approach leverages a multidisciplinary framework, combining mechanical and electrical techniques while adhering to design thinking principles to drive innovation. The following steps outline the methodology:

3.2 Design Thinking & Research

To obtain the final design before the fabrication of the final prototype, the design thinking process can be done by conducting thorough online research to seek inspiration from various sources. Combining various existing designs that resonated with the identified objective to obtain the prototype blueprint. The subsequent ideation phase involves careful evaluation, after selecting and combining the most promising elements to form a feasible and practical design.

3.3 Mechanical Design

In this project, there are three mechanical designs which consists of the pneumatic engine, the steering system and the compressed air container crafted using 3D printed materials and recycled material respectively. Notably, the design emphasizes on sustainability by using green and recycled materials.

3.3.1 Pneumatic Engine

The purpose of the pneumatic engine is to convert compressed air into kinetic motion, offering an alternative for non-renewable resources. The pneumatic engine relies on the principle that high pressure compressed air possesses significant potential energy which can be converted into kinetic energy to drive the spur gear to propel the mechanical component into motion.

3.3.2 Steering System

The steering system serves as a nexus of command which enable total control of the prototype's direction. By using a central point of connection, it serves as a pivotal point that direct the prototype into a course of action.

3.3.3 Compressed Air Container

Using a recycle bottle as a compressed air storage which pumps high pressured air into the pneumatic engine. This innovative approach contributes to sustainable practices by recycling materials. However, it's crucial to ensure that the bottle can withstand and store the pressured air.

3.4 Electronic Integration

3.4.1 Arduino Uno Board

Arduino uno board connects the Bluetooth Module and Servo Motors, using a mobile connection between an android device and Bluetooth module. This allows for a long-range remote control of the servo motors.

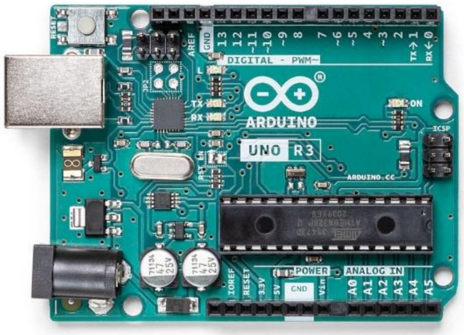


Figure 2 Arduino UNO board

3.4.2 HC-05 Bluetooth Module

The HC-05 Bluetooth module provides wireless communication, operating in the 2.4 GHz ISM band, supporting Bluetooth 2.0 specifications for wireless communication. Its primary function involves serial communication through UART protocols, allowing it to operate as both a Master and Slave device. In Slave mode, the module pairs with other devices as a peripheral, while in Master mode, it can initiate connections as a central device. Pairing establishes secure connections, enabling the bidirectional transmission of data between connected devices. Configurable through AT commands, users can customize settings such as device name, baud rate, and operating mode. The module, typically powered by 3.3V, features LED indicators for status feedback.

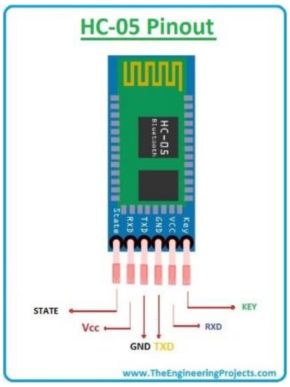


Figure 3 HC-05 Bluetooth Module

3.4.3 Servo Motor

The SG90 micro servo motor operates on the principle of closed-loop control, receiving a PWM signal to determine its position. Comprising a small DC motor, gears, and a potentiometer for position feedback, the internal control circuit compares the desired position with the actual position obtained from the potentiometer. In response, the circuit adjusts the motor's position by driving the DC motor, enabling precise angular control within the servo's limited range of motion, typically around 180 degrees. It is powered by a 4.8V to 6V DC source, emphasizing the importance of a stable and suitable voltage supply for optimal performance.

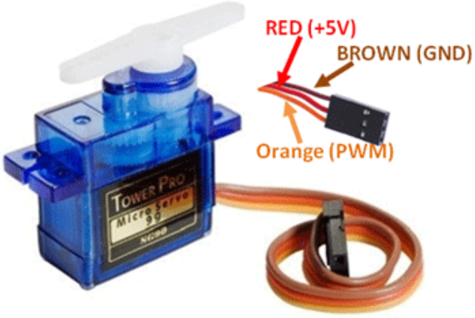


Figure 4 SG90 Micro Servo Motor

3.4.3 Jumper Cables

The purpose of jumper cables is to establish connectivity between different electronic components, forming the essential interconnections that enable the circuit to function as intended. These cables serve as conduits for electrical signals, facilitating the flow of current between components such as resistors, capacitors, integrated circuits, and various sensors. The plan involves strategically placing jumper cables to create the necessary pathways for signals and power to traverse, ensuring proper communication and collaboration between components.

Figure 5 Jumper Cables

3.4.5 Breadboard

The purpose of a breadboard is to provide a versatile platform for prototyping and testing electronic circuits.

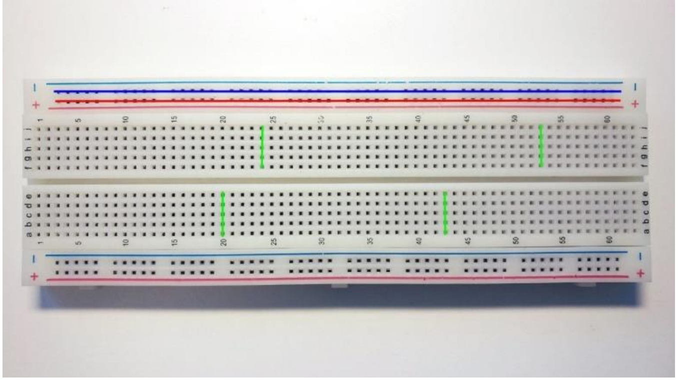


Figure 6 Breadboard

3.5 Software Development

The C++ code defines a structured command system, allowing instructions to be sent via Bluetooth to control the Arduino-based prototype. Hence it allows real time data exchange between the Arduino and the connected Bluetooth module. Thus, enabling the control of the servo motor based on user input.

3.6 Testing and Analysis

Conduct a subjective assessment of the vehicle's distance capabilities by visually observing its movement across the testing space. Note any variations in distance travelled under different conditions.

Assessing the prototype's overall functionality involves evaluating its maneuverability and stability. Maneuverability is gauged by observing how well the vehicle navigates the testing environment, considering turning radius and handling. Stability is assessed during movement, acceleration, and deceleration. These qualitative criteria provide a straightforward evaluation of the prototype's responsiveness and steadiness in different operational scenarios.

3.7 Multidisciplinary Approach

Combining mechanical, electrical techniques, 3D printing and programming for seamless integration in the prototype design. This approach allows for holistic and efficient design by leveraging the strengths of each component. Thus, ensuring the creation of innovative and cohesive project development progress.

3.8 Iterative Refinement

Refine the prototype based on the observation of the overall performance. Conduct multiple tests runs of the air-powered vehicle prototype, carefully observing its overall performance without relying on specific distance measurements. Pay attention to qualitative aspects such as maneuverability, stability, and responsiveness and record the optimal distance travelled.

3.9 Conclusion:

Through the implementation of this comprehensive methodology, which encompasses a variety of equipment, tools, devices, and software, we aim to develop a functional and efficient air-powered vehicle prototype. This multidisciplinary approach, supported by design thinking principles, will enable us to achieve the project scopes and objectives, address challenges, and contribute to the advancement of sustainable transportation solutions.

IV. METHOD

4.1 Mechanical Structure Design

4.1.1 Pneumatic Engine

The pneumatic engine, as shown in Figure 7, encompasses crucial components intricately arranged for a functional unit. This visual representation clarifies the interconnections essential for compressing and utilizing compressed air—a fundamental process vital for the vehicle's propulsion. The detailed arrangement showcased in Figure 8 underscores the design precision, underscoring the critical aspects of efficiency, reliability, and sustainability. Subsequent figures provide in-depth explorations into individual components, offering comprehensive insights into the inner functions of the pneumatic engine. Figure 7 displays the assembled version, while Figure 8 presents an exploded view, both emphasizing the indispensable contribution of each part to the overall functionality of the air-powered vehicle.

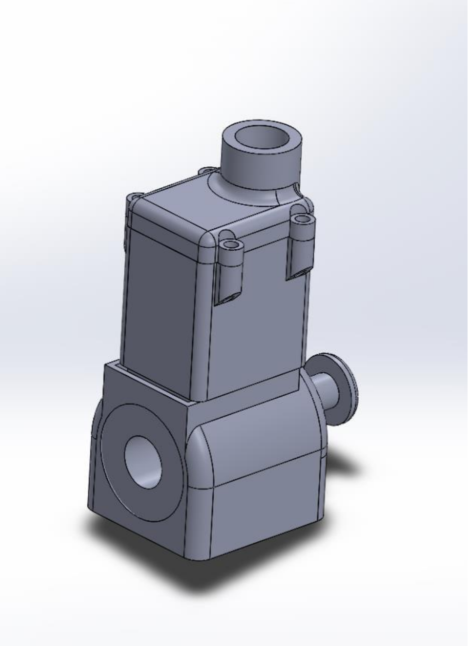


Figure 7 Pneumatic Engine Overview

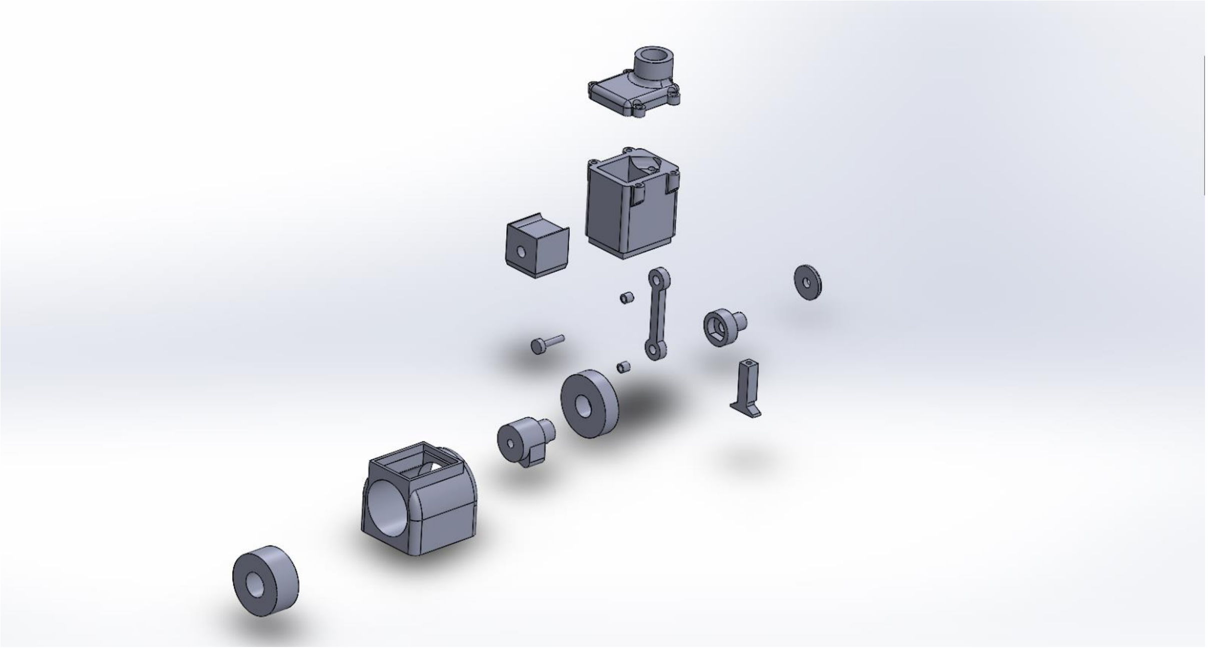


Figure 8 Exploded View of Pneumatic engine

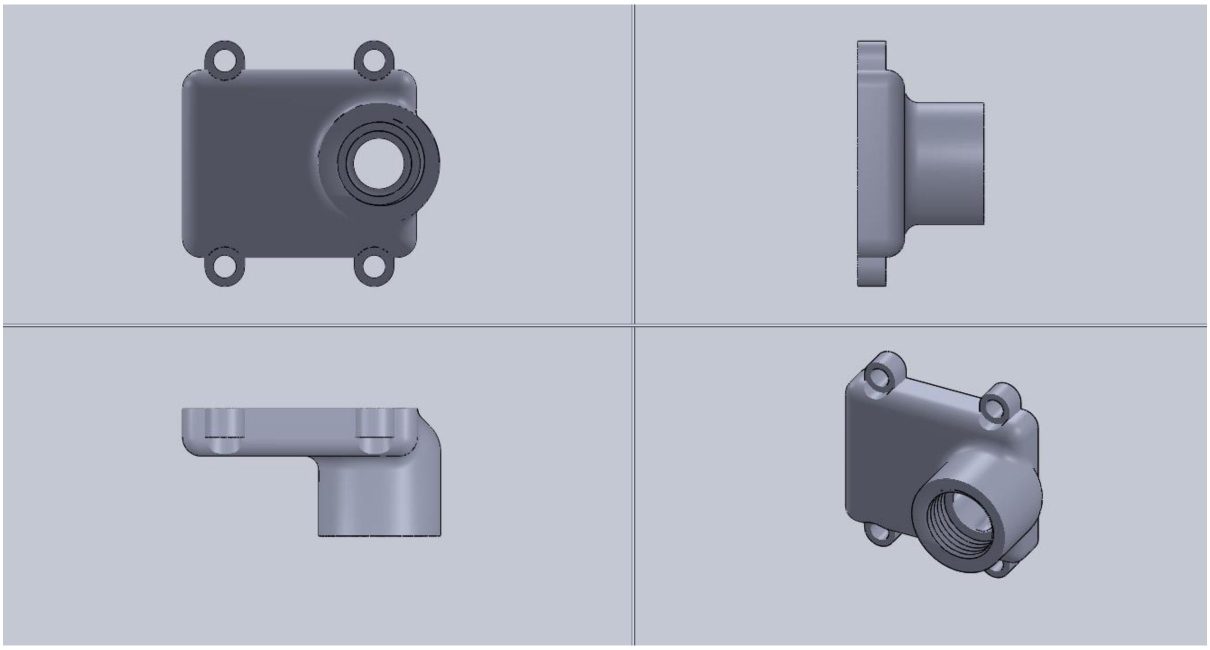


Figure 9 Pneumatic Engine Cylinder Head

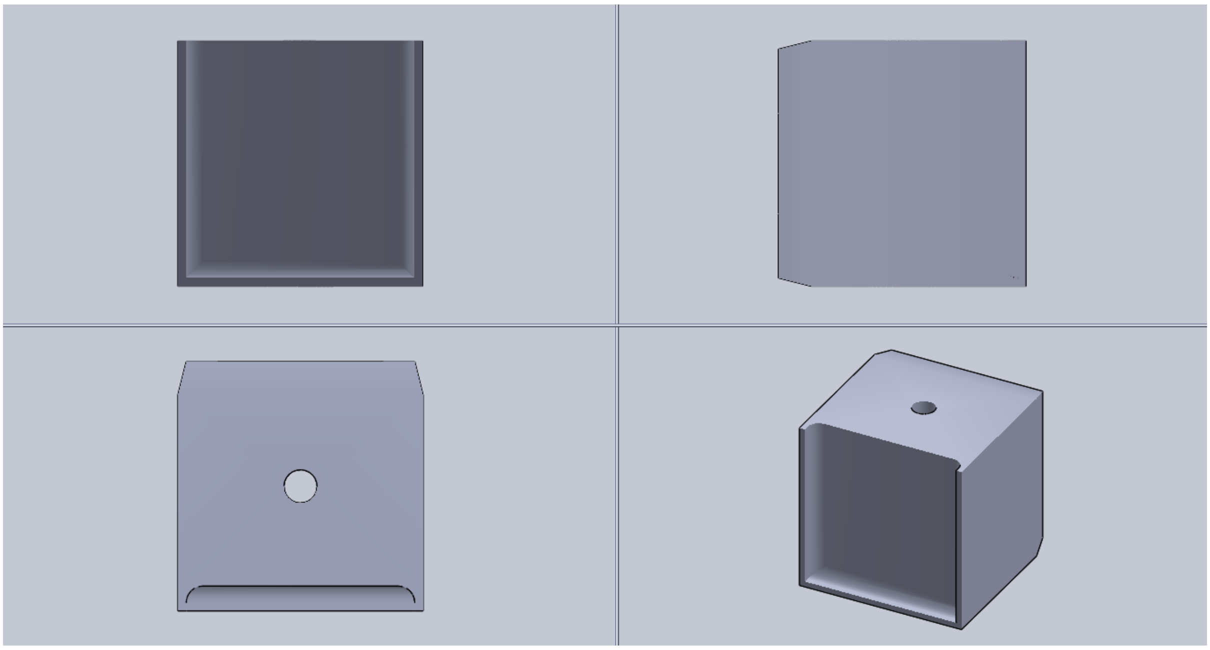


Figure 10 Pneumatic Engine Piston

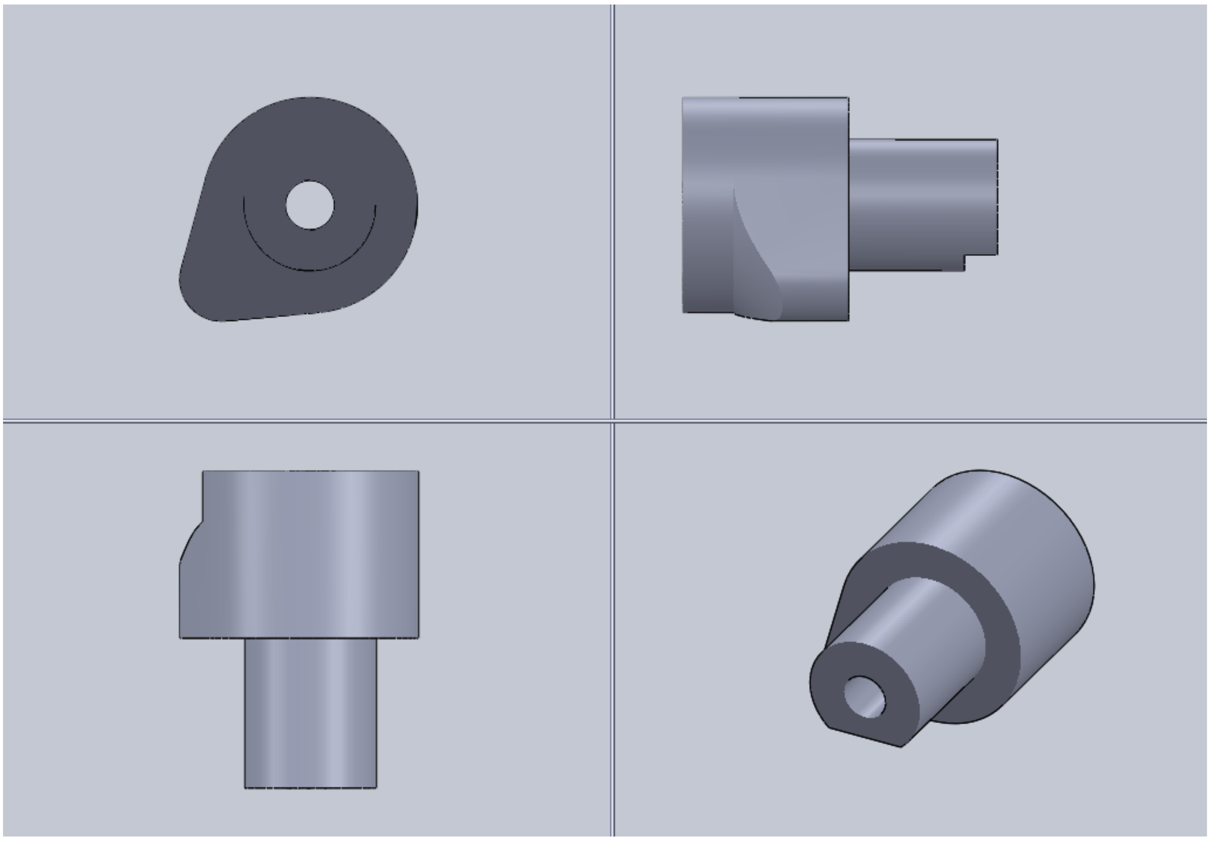


Figure 11 Pneumatic Engine Crankshaft

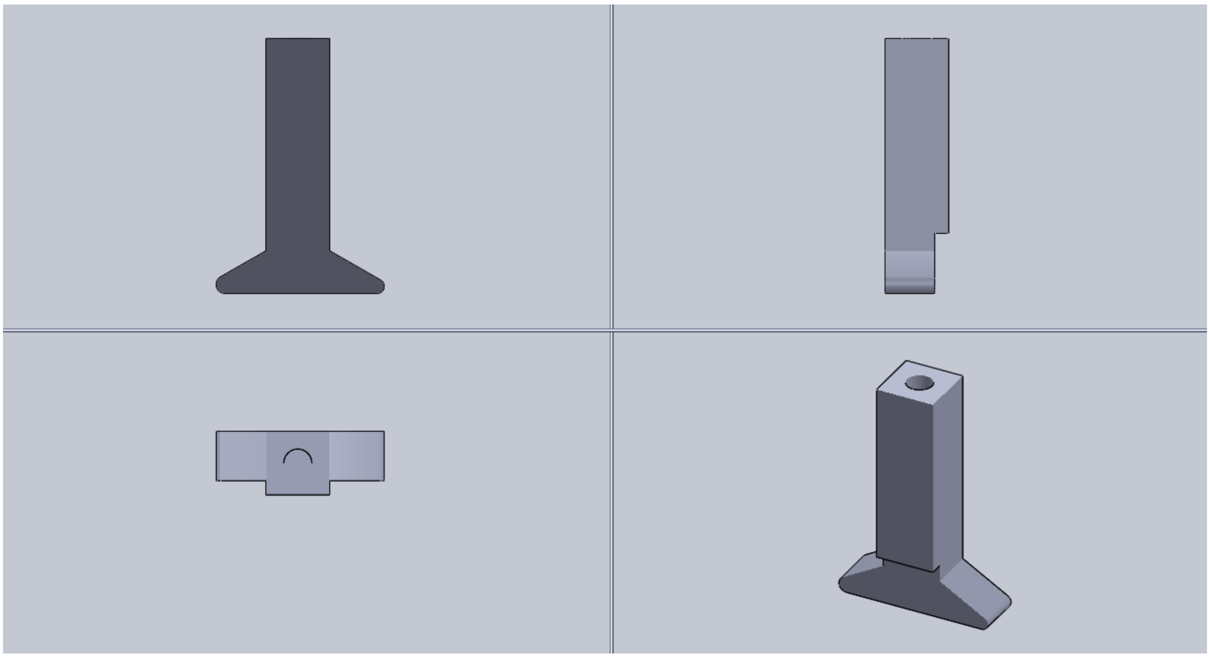


Figure 12 Pneumatic Engine Pushrod

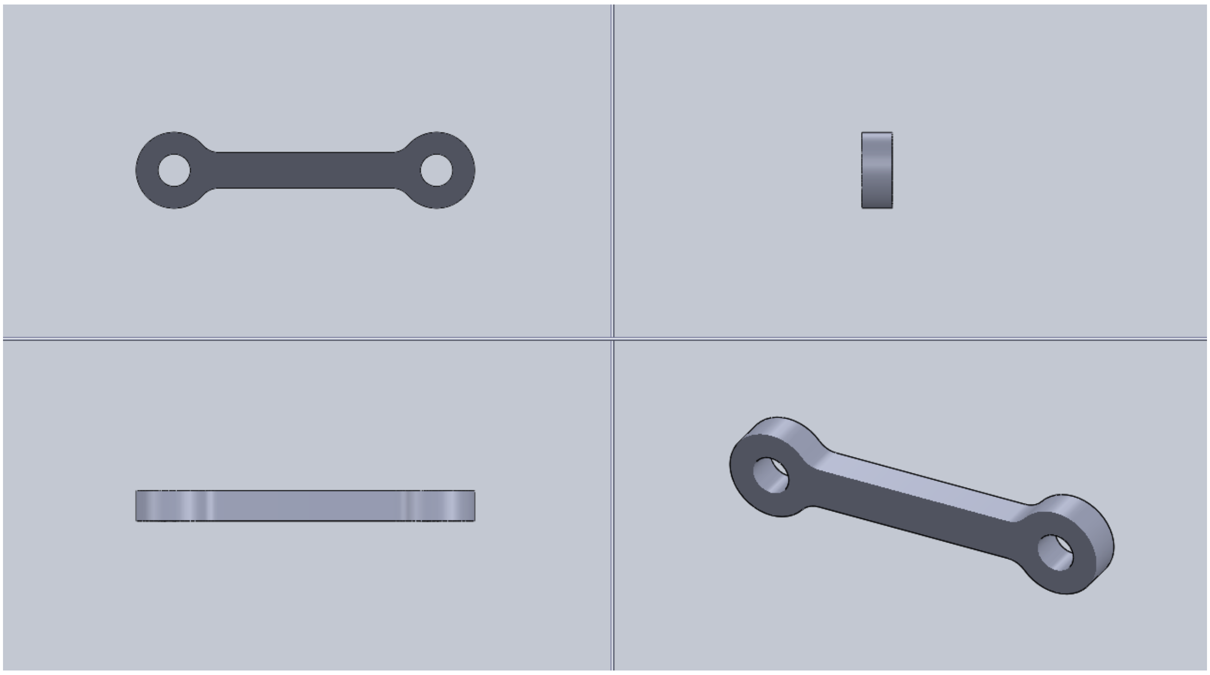


Figure 13 Pneumatic Engine Connecting Rod

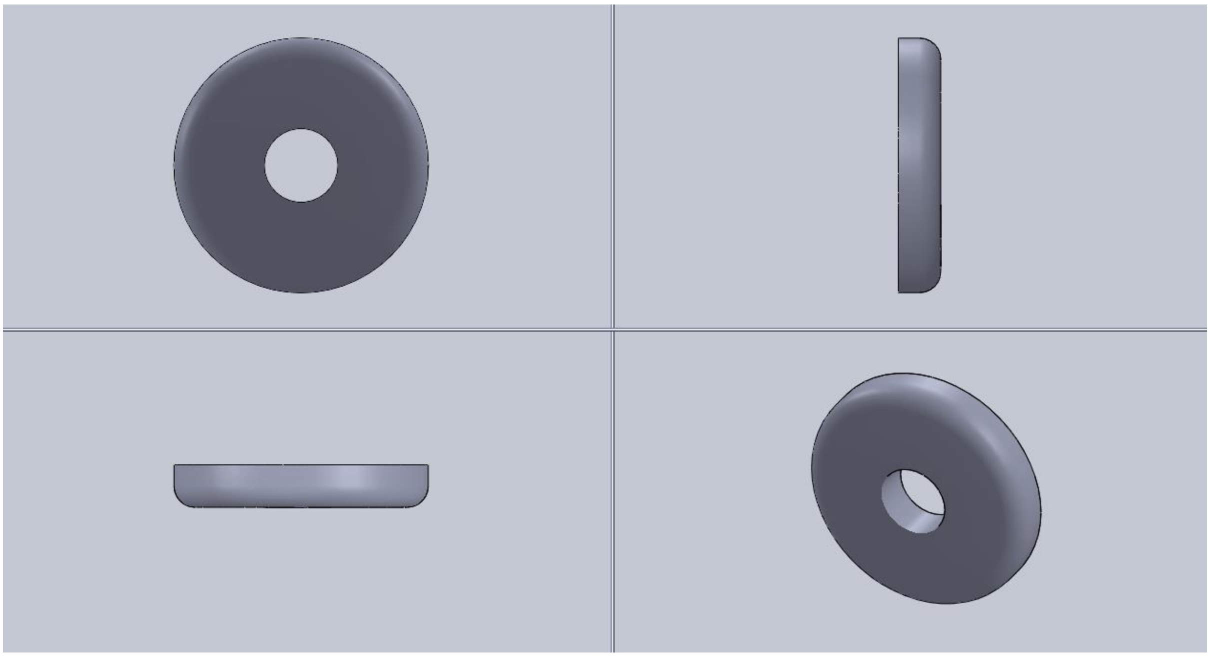


Figure 14 Pneumatic Engine Washer

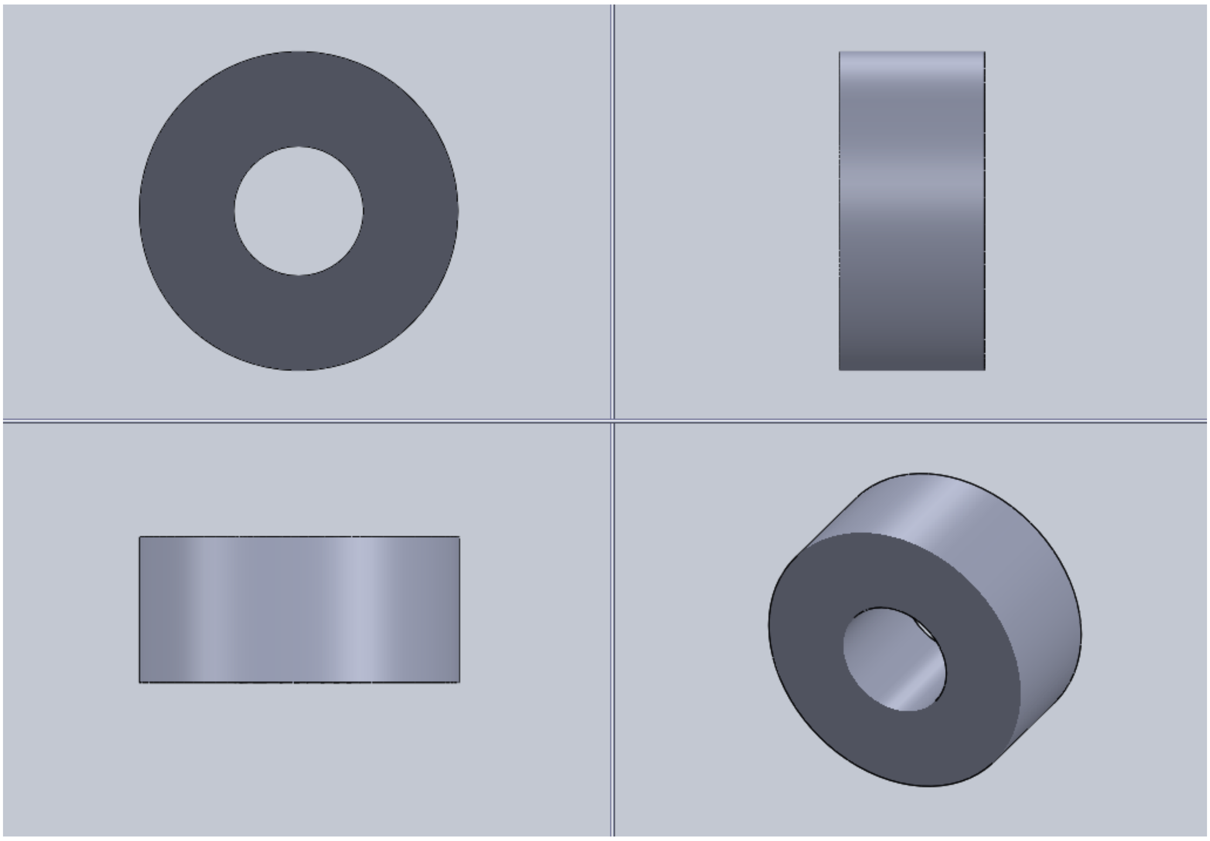


Figure 15 Pneumatic Engine Crank Press Tool

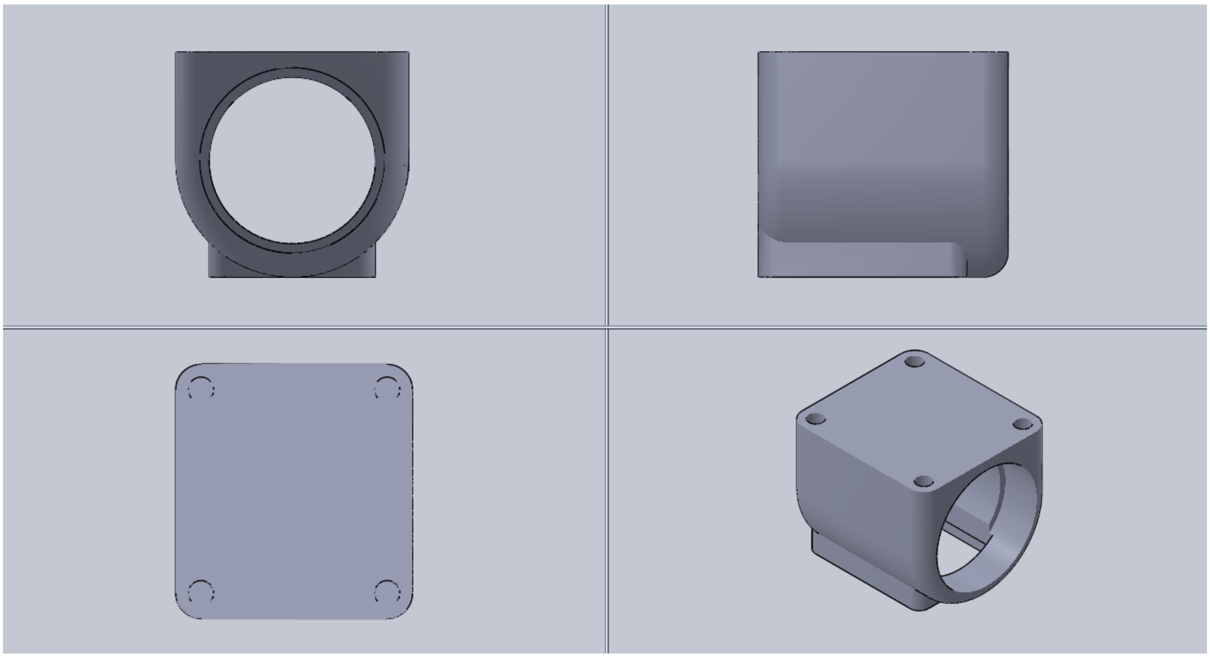


Figure 16 Pneumatic Engine Crank Case

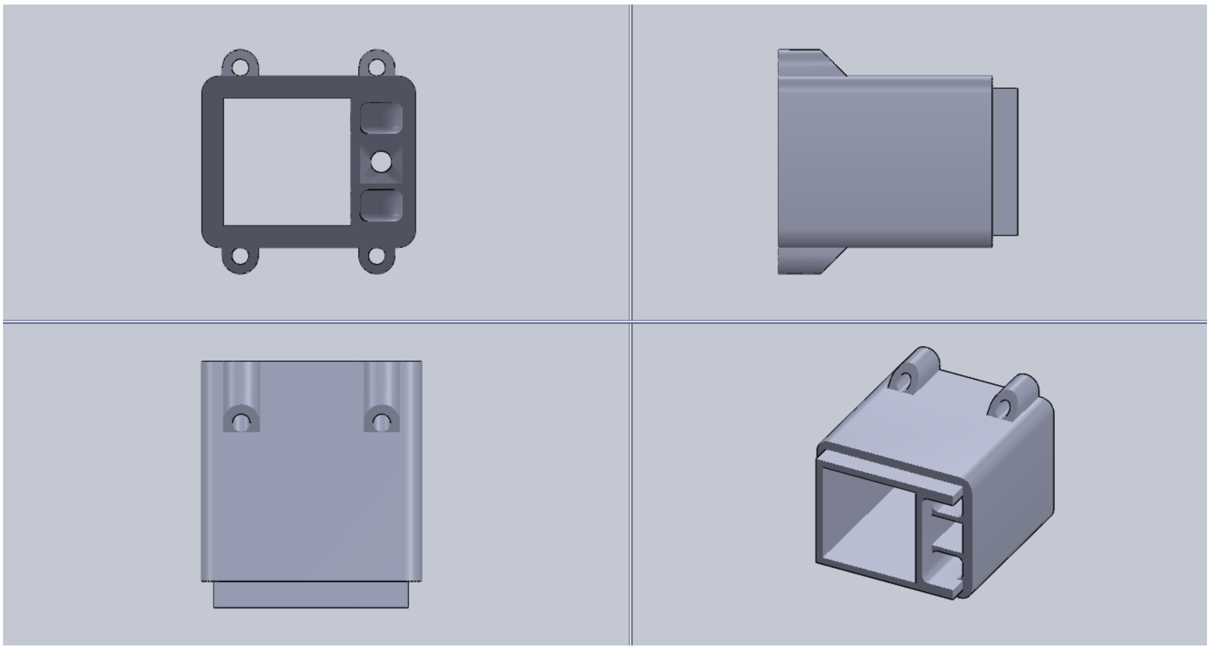


Figure 17 Pneumatic Engine Cylinder

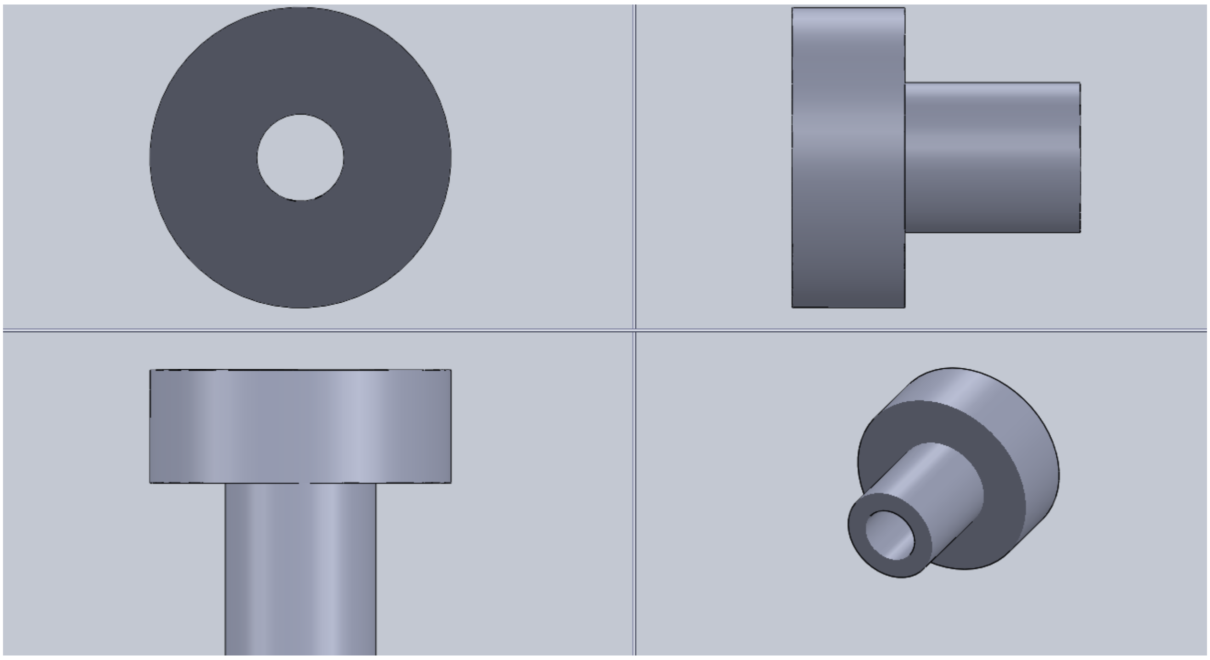


Figure 18 Pneumatic Engine Adapter

Before assembling the pneumatic engine, there are steps to ensure that it works smoothly. Firstly, by sanding the cylinder and piston, as shown in the figure 19, the procedure emphasizes using 1200 grit sandpaper. A separate strip should be attached to a file for the insides of the cylinder, and sanding should occur while maintaining a consistent motion, particularly when sanding the piston in the direction of its intended motion within the engine. Regular fit checks and the use of water as a lubricant during wet and dry sanding contribute to achieving an optimal, smooth surface.

Figure 19 Sanding of Piston and Cylinder

To assemble to pneumatic engine, the front of the crankcase is the end with the larger diameter and the front of the crank case is where the pushrod goes as show in figure 20. Using superglue, attach the two parts together to form the outer shell of the engine.

Figure 20 Attach the Cylinder to the Crankcase

Sand the pushrod to make sure when it is fitted into the cylinder, it falls out due to gravity as shown in figure 21.

Figure 21 Inserting the Pushrod into the Cylinder

Attach the crankshaft into the 608 Ball bearing as shown in figure 22. Then attach the bearing into the crankcase with the crankcase oriented 180 degrees to prevent the pushrod from falling out.

Figure 22 Crankshaft fitted into Ball Bearing then into Crankcase.

Then cut the brass tube of 3mm outer diameter to the correct width of the connecting rod as shown in figure 23 and press the bushings into the connecting rod. Thread a M2 by 10mm bolt into the piston then insert the connecting rod and tighten until the bolt is flushed with the side of the piston as shown in figure 24.

Figure 23 Brass Tube Fitted into Connecting Rod

Figure 24 Connecting Rod into Piston

Insert the piston with the connecting rod into the cylinder, making sure that the bolt head faces the rear of the engine as shown in figure 25.

Figure 25 Piston fitted into Cylinder

Then use another M2 by 10mm bolt to attach the connecting rod to the crankshaft as shown in figure 26.

Figure 26 Connecting Rod Bolted to Crankshaft

Insert a M2 by 20mm bolt into the pushrod from the top of the engine and make sure to not tighten it down all the way as it needs to be adjusted at the later point. To lubricate the piston to make it move smoothly, WD40 silicone spray was used. Cut a 0.5mm thick rubber sheet to the dimension of 20mm by 25mm to fit it between the cylinder head and cylinder to prevent air from escaping. Make sure to cut a hole for the M2 by 20mm bolt to fit through. Fit a G 1/8 Male to Push In 6mm, threaded-to-tube connection style pneumatic fitting after fitting a rubber O ring and a 6mm diameter ball into the cylinder head as shown in figure 27.

Figure 27 Fit O ring and 6mm Ball into Cylinder Head

The pneumatic engine assembly will be completed as shown in figure 28.

Figure 28 Completed Assembly of Pneumatic Engine

Hardware Required:
- 6pcs M2x10 Bolt
- 1pc M2x20 Bolt
- 1pc M3x25 Bolt
- 1pc 608 bearing
- 1pc 1.5 litre Plastic bottle
- 1pc Presta valve (for tubeless tires)
- 2pcs Pneumatic fittings
- 1pc Rubber O-ring OD 8mm Cross section 2mm
- 1pc 6mm Ball pellet
- Brass tube ID 2mm OD 3mm (only need 6mm length)
- PVC clear tube ID 4mm OD 6mm
- 0.5mm thick rubber sheet
- 2.5mm thick rubber sheet
- Bike pump or compressor

The 3D printing settings for the intended project are meticulously configured to ensure precision and optimal results. The nozzle diameter is set at 0.2mm, providing fine details, while the print width is maintained at 0.25mm for controlled extrusion. Each layer is crafted with a height of 0.1mm, contributing to the overall resolution of the printed object. To enhance structural integrity, six top and bottom layers, as well as six outer walls, are implemented. The infill, set at 50%, employs a rectilinear pattern, striking a balance between solidity and material efficiency. The chosen material for the printing endeavor is PLA, a versatile and widely used thermoplastic. The print speed is moderated at 50mm/s to ensure a steady and controlled deposition of material. Temperature control is vital, with the nozzle set at 220°C and the bed at 40°C, optimizing adhesion and preventing warping during the printing process. These settings collectively form a well-tailored configuration aimed at achieving the desired print quality and structural integrity.

4.1.2 Steering System

The steering system represents the linchpin of control, seamlessly orchestrating the directional control with finesse. Acting as a central nexus, it seamlessly bridges the connection between operator and vehicle, ensuring precise and responsive manoeuvring.

Figure 29 Assembled Steering System

The first step to assemble the steering system will be to align the Wheel hub with the Central Mount with a M5 by 45mm Bolt as shown in figure 30. A single washer was placed between the Wheel Hub and the Central Mount to allow the Wheel Hub to swivel smoothly while distributing load, preventing looseness, and providing protective measures when the fastener is engaged. This component is replicated to match the opposite side of the steering system.

Figure 30 Wheel Hub Aligned with Central Mount

Two Steering Arm will be attached to the Central Control Plate as shown in figure 31. When using a single arm, parallel steering geometry can lead to tire scrubbing. Therefore, two arms were employed to minimize the likelihood of this occurrence.

Figure 31 Steering Arms Connected to Central Control Plate

The Front Wheel with the 608 Ball Bearing fitted will be bolted to the Wheel Hub using an 8mm bolt as shown in figure 32.

Figure 32 Front Wheel with Ball Bearing Fitted to Wheel Hub

Below, I will present the SolidWorks 3D drawings of each individual steering system component.

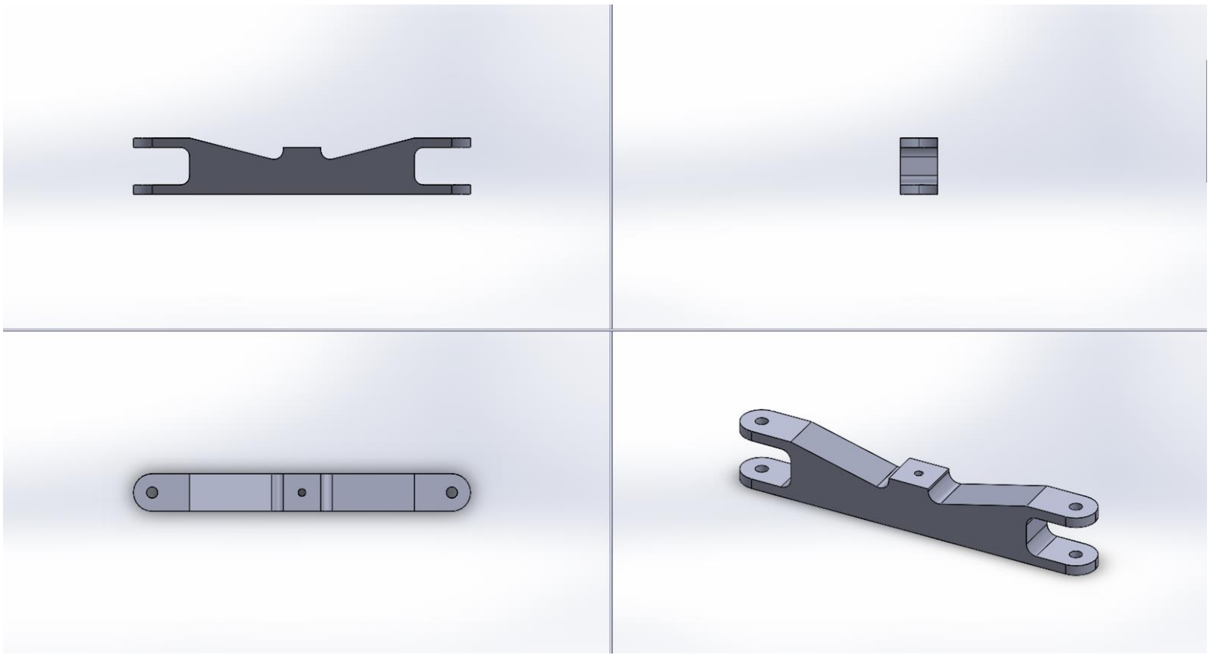


Figure 33 Central Mount

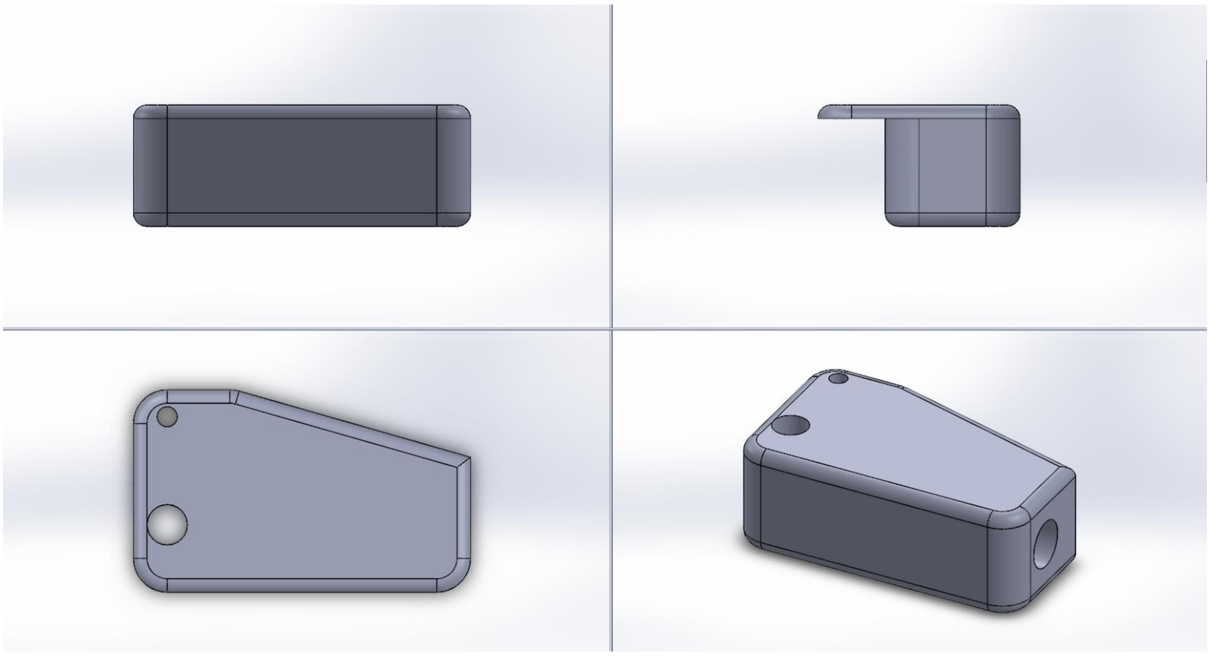


Figure 34 Left Wheel Hub

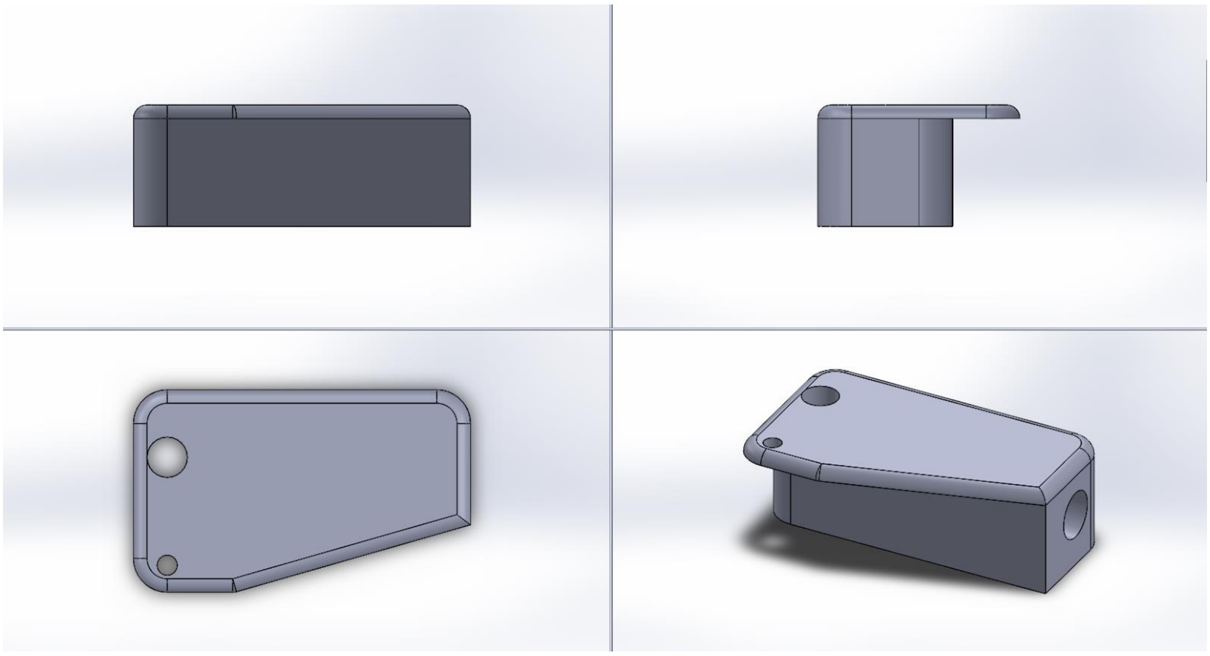


Figure 35 Right Wheel Hub

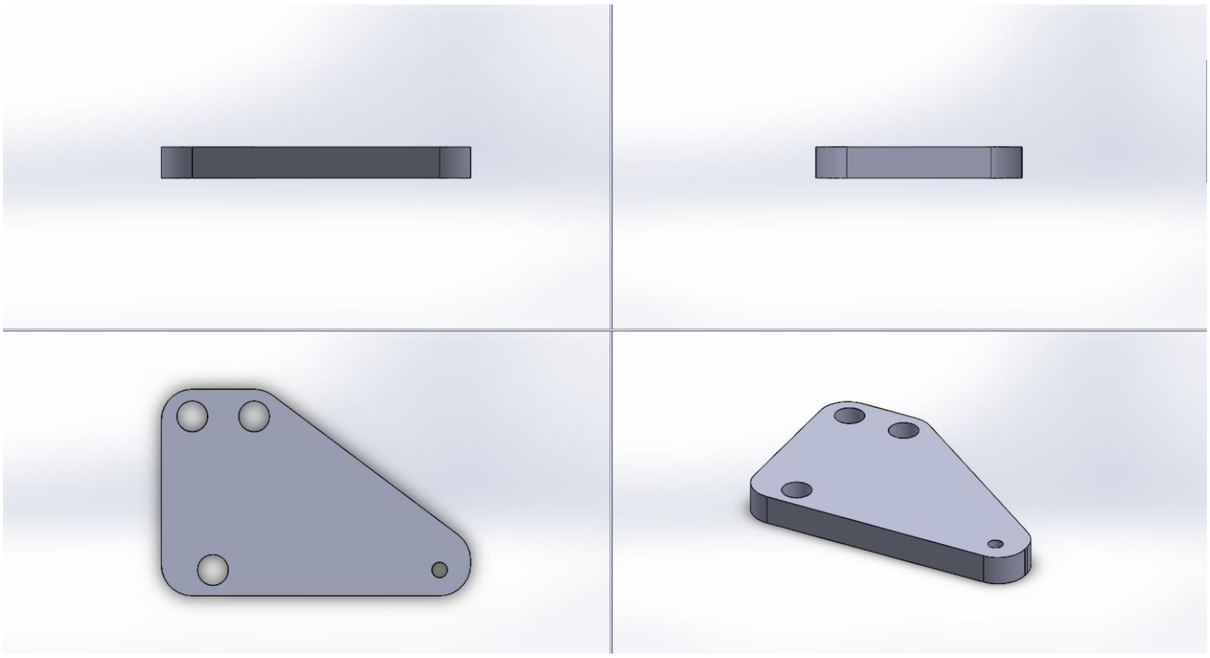


Figure 36 Central Steering Plate

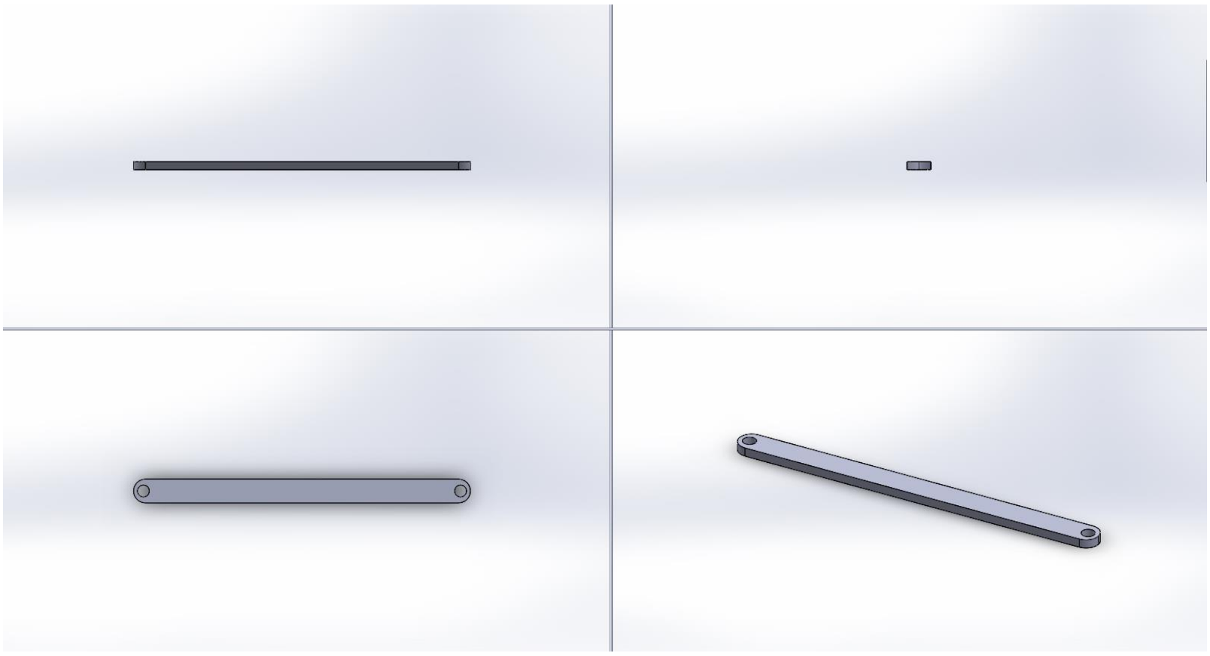


Figure 37 Steering Arm

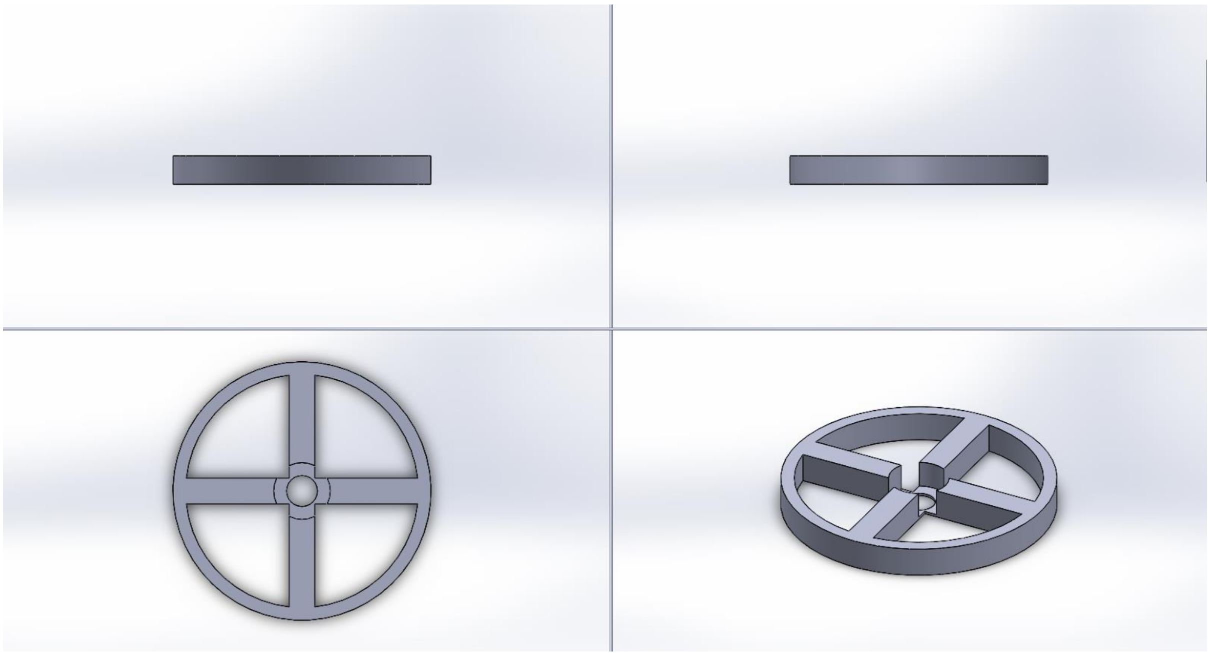


Figure 38 Front Wheel with Ball Bearing Mount

4.1.3 Compressed Air Storage

The Compressed Air Storage comprises of a few recycled materials. A 1.5 litre recycled bottle, a Presta valve obtained from an old bicycle wheel tube along with cut-outs of thin rubber tube which will be used as an air seal, a rubber tube with an outer diameter of 6mm and inner diameter of 4mm obtained from an old fish tank air pump and a G 1/8 Male to Push In 6mm, threaded-to-tube connection style pneumatic fitting as shown in figures 39 to 41.

Figure 39 Recycle 1.5 Litre Bottle

Figure 40 Presta Valve with Cut-outs of Rubber Tube

Figure 41 Rubber Hose from an Old Fish Tank Air Pump and Pneumatic Fitting

To assemble the Compressed Air Storage, a rubber O ring with an outer diameter of 9mm will be needed as shown in figure 42.

Figure 42 Rubber O Ring 9mm Outer Diameter

Place the O-ring at the base of the Presta Valve, as shown in figure 43. Figure 44 illustrates the placement of the O-ring at the base of the Presta Valve. Subsequently, depict the process of drilling a 6mm hole at the bottom of the 1.5-liter bottle and using an aluminium rod or an old hanger to insert the Presta Valve securely into the bottle through the 6mm hole. Clearly show the tightening of the Presta Valve Nut to lock it firmly and attach the valve adapter at the tip to enable connection to a bicycle pump.

Figure 43 O Ring Fitted to the Presta Valve

Figure 44 Presta Valve Fitting and Fastening

Drill an 8mm hole into the bottle cap then add 2 rubber sheets with on both sides of the bottle cap with a 7.5mm hole in them. Place the pneumatic fitting through the rubber sheets and bottle cap then tighten it with an M8 nut ash shown in figure 45.

Figure 45 Pneumatic Fitting Fasten to Bottle Cap

The tighten the bottle cap back to the 1.5litre bottle and make sure it is fastened securely.

4.1.4 Air Flow controller

The air flow controller consists of two parts which acts as a clamp on the rubber tubing.

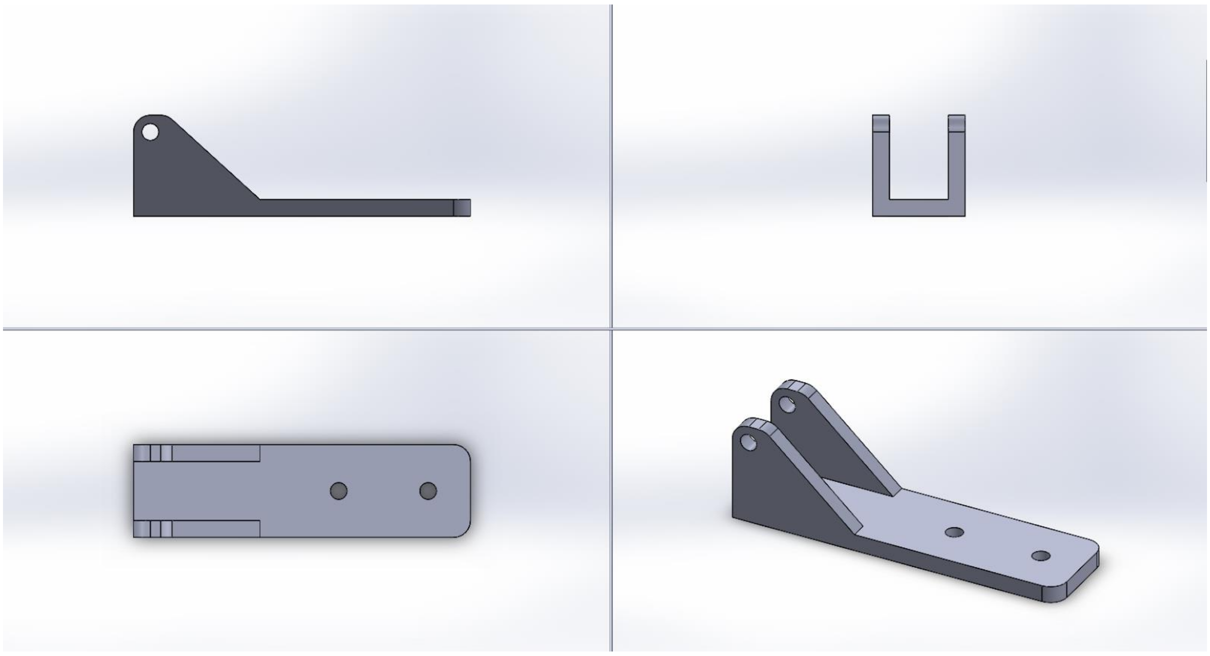


Figure 46 Air Flow Controller Housing

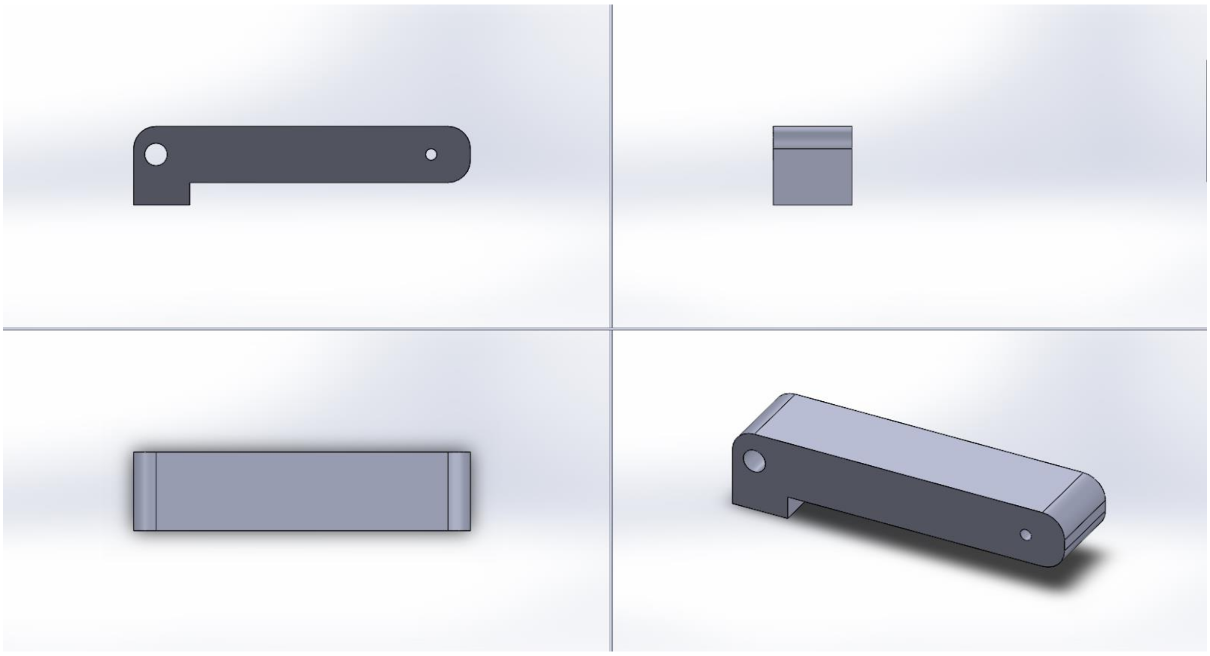


Figure 47 Air Flow Controller Clamp

The rubber tubing will be inserted between the air flow controller housing, secured in place by a clamp bolted to the housing above the rubber tubing.

Figure 48 Air Flow Controller

4.2 Electronic Design and Assembly

This section explains how the electronic components are connected to the prototype's Arduino board and it shows the step-by-step wiring details which includes diagrams and schematics.

Components Used:

1. Arduino UNO board
2. HC-05 Bluetooth Module
3. Servo motor
4. Bread Board
5. Android Phone
6. Arduino USB cable

Software Used:

1. Arduino IDE
2. Dabble for Android

4.2.1 Arduino Uno board

This part explains the connection between the Arduino Uno board to the Bluetooth Module and Servo Motors. This connection gives control of the servo motors from far away using an Android device. By linking the Arduino Uno and the Android device wirelessly through the Bluetooth module, they can make the servo motors work from a distance. The schematic diagram in figure 49 shows the wiring connection.

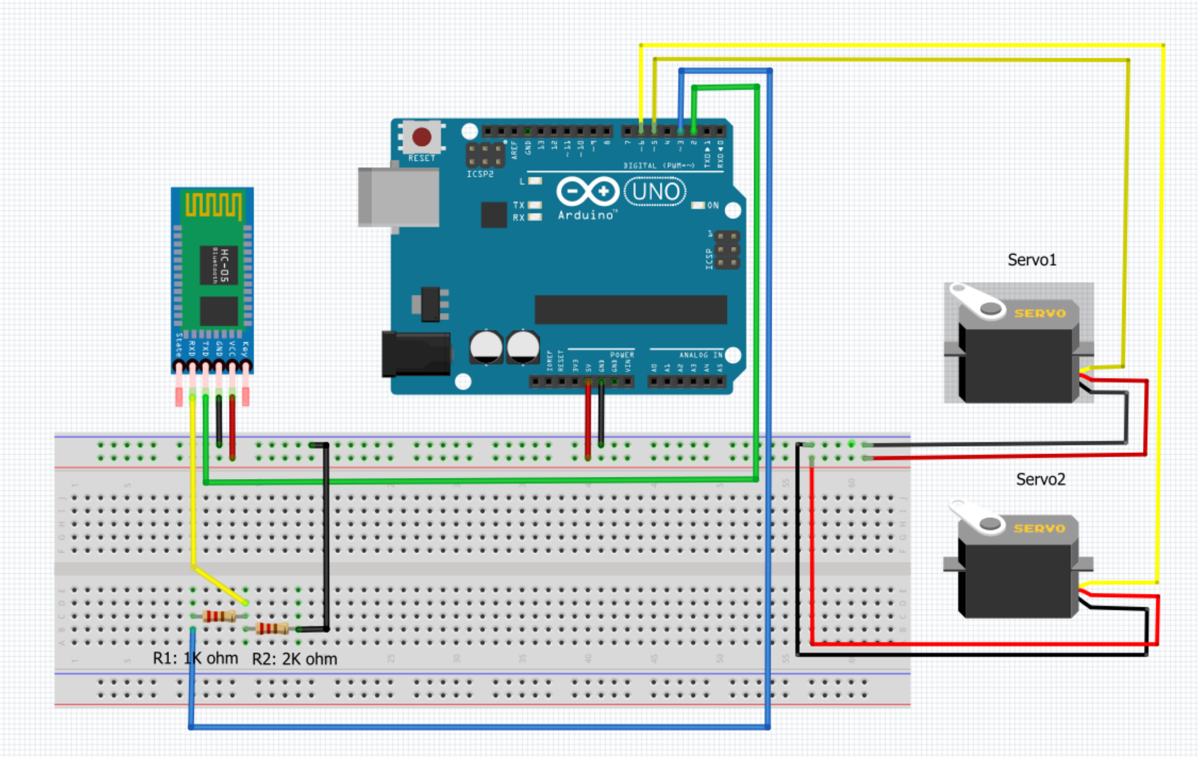


Figure 1 Schematic of Arduino UNO Board

Arduino UNO Board Pin Layout

Pin 3 (TX):	Connect to HC-05 Bluetooth Module TX pin
Pin 2 (RX):	Connect to HC-05 Bluetooth Module RX pin with voltage divider circuit)
Pin 5:	Servo 1
Pin 6:	Servo 2

Table 1 Arduino UNO Board Pin Layout

4.2.2 Voltage Divider Rule

A voltage divider is often used with the HC-05 Bluetooth module to ensure that the voltage levels are within the acceptable range for the module. The HC-05 typically operates at 3.3V, while some Arduino boards, like the Arduino Uno, provide 5V logic levels. Connecting the HC-05 Bluetooth module directly to the Arduino board may damage it due to the higher voltage logic level. Hence, a voltage divider is introduced to reduce the 5V logic level to 3.3V. A typical voltage divider consists of two resistors, which in this case a 1k Ohm resistor and a 2k Ohm resistor as show in figure 50.

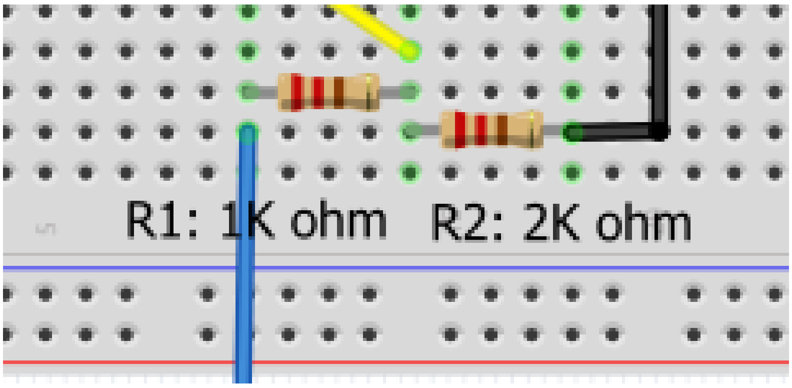


Figure 2 1k and 2k Ohm Resistors

- The colour codes for 1k ohm (1kΩ) and 2k ohm (2kΩ) resistors are as follows:

- 1k Ohm Resistor (Brown-Black-Red):

  First Band (Digit 1): Brown
  Second Band (Digit 2): Black
  Multiplier (Zeros): Red
  Reading from left to right, the colour bands represent 1, 0, and two zeros, yielding a resistance of 1,000 ohms or 1kΩ.

- 2k Ohm Resistor (Red-Black-Red):

First Band (Digit 1): Red
Second Band (Digit 2): Black
Multiplier (Zeros): Red
Reading from left to right, the colour bands represent 2, 0, and two zeros, yielding a resistance of 2,000 ohms or 2kΩ.

The calculations are shown below:

$$V_{in} = 5V\left[\frac{2}{2+1}\right] = 3.33V$$

$$V_{out} = V_{in}\left[\frac{R2}{R1+R2}\right] = 2.5V$$

Figure 51 shows the drawing layout of the voltage divider rule.

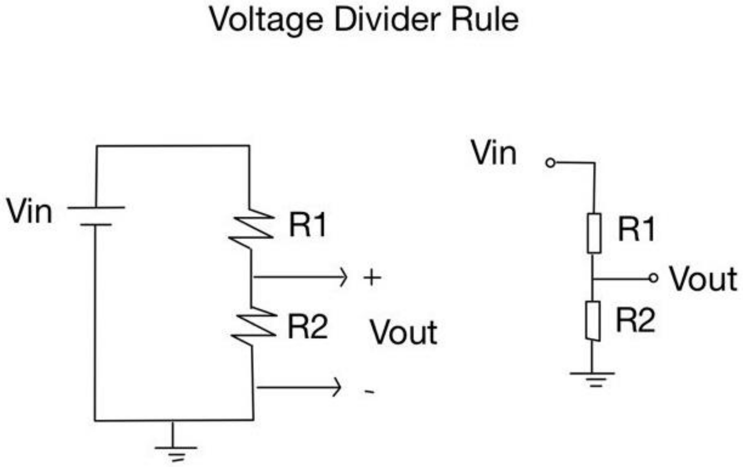


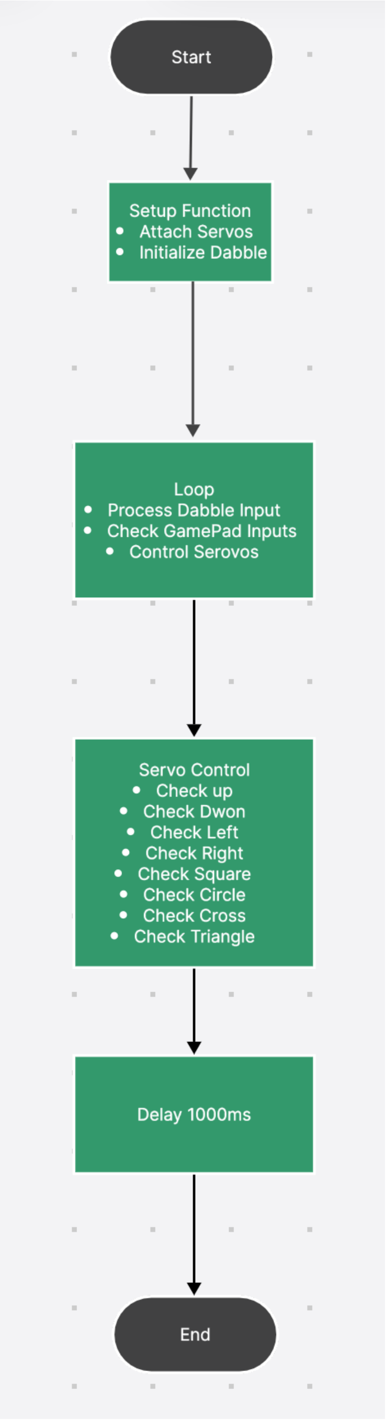
Figure 3 Drawing Layout of Voltage Divider

4.3 Software Integration

This section explains how the integration of software using the Arduino IDE, Dabble app on android device and C++ code.

4.3.1 Flow Chart

This basic flow chart outlines the main functions of the code which include setup, loop and servo control based on the mobile gamepad's input. Each block represents condition check.



The Arduino program is designed to control two servo motors by using the Dabble app and writing C++ code. These servo motors are connected to pins 5 and 6 representing Servo1 and Servo2, respectively. The program continuously reads inputs, from the Dabble Gamepad module as shown in figure. It specifically looks for directions (UP, DOWN, LEFT, RIGHT) and shapes (Square, Circle, Cross, Triangle) pressed on the Gamepad. When a specific button is pressed, the corresponding servo motor moves to a set angle. For example, pressing UP arrow makes servo1 move to 90 degrees, allowing the prototype vehicle to move straight. Subsequently, LEFT arrow moves servo1 to 180 degrees to turn left, RIGHT arrow to 0 degrees to turn right, and DOWN arrow to 60 degrees to turn right with a larger radius. Similarly pressing Square moves servo2 to 90 degrees to allow full flow of the air to pass through the rubber hose, Circle to 120 degrees, Cross to 150 degrees and Triangle to 180 degrees, allowing least air flow through the rubber hose. After each movement there is a delay of 1000 milliseconds to ensure stability. Overall, this program allows real time control of servo motors using the Gamepad interface provided by the app.

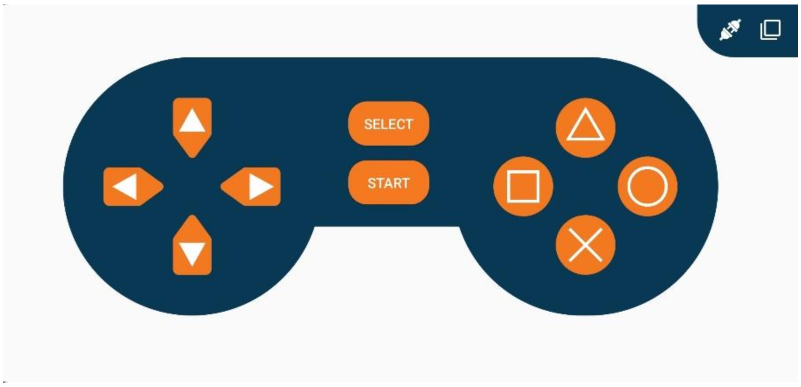


Figure 4 Dabble Controller Interface

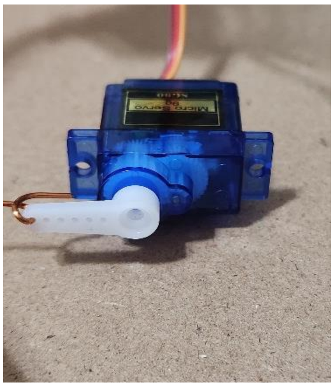


Figure 5 Servo 1 at 0 Degrees

4.3.2 Step by Step Setup

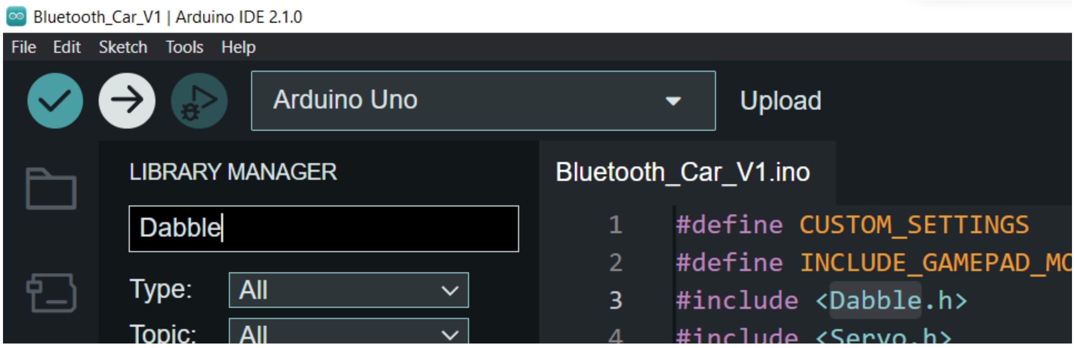
In this section, the setup will be shown step by step which explains how to connect the Arduino IDE and Dabble app.

First to download the Arduino IDE software on the laptop and Dabble app on the Android device with the logo shown in figure 54.

Figure 6 Arduino IDE and Dabble App

Then connect the hardware based on the schematic shown in figure 49. Open the Arduino IDE, connect the hardware to the laptop using the USB-Type B to USB-Type A cable. On the Arduino IDE software, select the tools tab and select the board and port. In order to check which port belongs to the UNO board, open the control panel to view device to find the com number connected.

Subsequently, open the C++ code file and download the necessary library needed for the Dabble App which can be done by clicking on the sketch tab, include library then manage library. Search for the Dabble library by STEMpedia then install the 1.5.2 version. Upload the code by clicking onto the arrow as shown in figure 55.



Dabble

```
#define CUSTOM_SETTINGS
#define INCLUDE_GAMEPAD_MO
#include <Dabble.h>
#include <Servo.h>
```

Figure 7 Upload Code on Arduino IDE

After successfully uploading the code, open the Bluetooth setting on the android device and connect the HC-05 Bluetooth module. Then open the Dabble app to select the game console tab which then be ready to operate.

4.4 Mechanical and Electronic System Assembly

The main component of the system consists of the Pneumatic Engine, Steering system, and they Compressed Air Storage. These main components are connected by the Arduino Board which gives commands to drive the prototype.

For the mechanical system, air is introduced into the compressed air storage using a bicycle pump causing high pressure to be accumulated. The released of this high-pressured air into the pneumatic engine via the rubber hose, pushes the piston which rotates the crankshaft connect to the spur gear. Thus, driving the spur gear forward. When a larger spur gear engages with the smaller gear, it results in a torque increase in output since torque is inversely proportional to the radius (or diameter) of the gear. Hence enabling lower energy required for the system.

For the electronic system, the Bluetooth mobile controller sends a set of digital signals to the Arduino UNO board which commands the servo motor via the user input. From the controller there are two sets of four buttons which commands the two respective servo motors. The signal from each button causes a change in angles of the servo motor arm (0, 60, 90, 180 degrees) shown in figure 56. For the servo motor that controls the Steering System, 0 degrees will steer the vehicle extreme right while 180 degrees the opposite direction with the angles in between provides intermediate steering direction. For the servo motor that connects the air flow controller through the rubber tubing, different angles (90, 120, 150, 180 degrees) will affect the amount of compressed air being let through the rubber tube, thus affecting the speed of the vehicle shown in figure 57.

Figure 8 Steering System Controlled Via Servo Motor 1

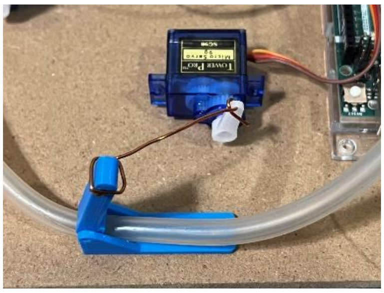


Figure 9 Air Flow Controller Connected to Servo Motor 2

V. TESTING AND DISCUSSION

5.1 Performance Assessment

5.1.1 Quantitative Assessment

In the initial phase of the project, the car demonstrated a limited range, covering only 1 meter. This served as the baseline performance against which subsequent modifications were measured. Recognizing the need for improvement, the project proceeded with a systematic approach to enhance the car's overall performance.

The first significant adjustment involved the meticulous sealing of the engine. Using a 0.5mm thick rubber sheet to cover the top of the pneumatic engine, this provides a seal so as when the compressed air is flowing through, most of the air will be kept within the engine. This modification yielded a notable improvement, allowing the car to cover 3 meters. The enhanced engine sealing addressed fundamental issues, laying the foundation for subsequent advancements. Subsequent additional sealings were the usage of superglue

A pivotal milestone was achieved with the introduction of ball bearings to the engine. This innovation significantly reduced friction within the engine components, resulting in a remarkable increase in performance. The car, now equipped with ball bearings, traversed approximately 7 meters, showcasing the positive impact of this mechanical enhancement.

Building upon this success, the project then focused on the axle, incorporating additional ball bearings. This adjustment not only improved the overall stability of the car but also facilitated smoother rotations. As a result, the car achieved 10 meters without relying on air resistance. This marked a substantial leap in performance, emphasizing the importance of addressing both engine and mechanical components for optimal functionality.

In summary, the project's iterative approach to modifications led to a progressive enhancement in the car's performance. Each phase of adjustment contributed to overcoming limitations, and the cumulative effect showcased a tangible improvement in the car's functionality. These results underscore the significance of a holistic strategy in optimizing the performance of mechanical systems.

Future iterations and fine-tuning hold the potential for further advancements, as the project continues to explore avenues for refinement and innovation.

5.1.2 Qualitative Assessment

Initial testing of the prototype, the vehicle vibrates vigorously which in turn loosen the screw on the Steering System. This affects the vehicle stability, causing it to not move in its intended direction. After experiencing tire scrubbing due to having a single steering arm with the wheels of the vehicle set in a parallel configuration, two steering arms are employed to address the issue. The addition of a second steering arm allows for a more intricate steering geometry which allows for the converging of the front wheels during motion. By allowing the wheels to pivot at varying angles, the two-arm steering system significantly reduces tire scrubbing, enhancing overall maneuverability and stability.

In the first printing of the prototype spur gear, the gear had a lower thickness and lower infill resulting in warping issues, thus reducing the engagement between the spur gears and looser “bites”. Adjustments were made to increase the thickness and infill of both the drive and driven gear to ensure a more effective mesh, optimizing their interlocking functionality for improved performance within the overall system.

Lastly, the prototype shows great responsiveness to receiving signals from the Bluetooth Mobile Controller. This responsiveness enhances the overall user experience, providing precise and reliable control over the prototype's functionalities. The successful implementation of this wireless control aspect marks a significant achievement in the prototype's design and functionality, showcasing its capability to seamlessly interpret and execute commands from the Bluetooth Mobile Controller.

5.2 Project Limitations

The pursuit of innovation in utilizing compressed air for vehicle propulsion is accompanied by scientific and engineering challenges that delineate the project's limitations. A significant constraint arises from the intricate thermodynamic considerations associated with attempting to simultaneously utilize and replenish compressed air while the vehicle is in motion. The fundamental principles of thermodynamics, specifically the First Law, emphasize the conservation of energy. In this context, diverting energy for air compression during the propulsion phase introduces complexities in maintaining an efficient energy balance. The process of compressing air involves a non-trivial conversion of mechanical work to heat, and capturing additional air while the vehicle is in motion requires careful consideration of energy input and losses. Moreover, the current project design does not incorporate a mechanism to effectively address these thermodynamic challenges, acknowledging the limitations in simultaneously optimizing propulsion and capturing ambient air. Consequently, the project's scientific boundaries align with the intricate interplay of energy conversion and thermodynamic constraints, urging a focus on enhancing the efficiency of the propulsion system through pre-compressed air storage.

5.3 Future Improvements

To improve the distance travelled by the vehicle, air resistance can be greatly reduced by giving the prototype a streamlined shape. By giving it a teardrop profile, it allows air to flow smoothly around the vehicle reducing drag, which improves the speed and range.

Introducing the use of engine belt can improve the engagement of the spur gear and increase the meshing between the gears. This facilitates a smoother transition of power between the gears, reducing the likelihood of sudden jolts or disruptions in the driving motion, enhancing the precision and stability between "bites" of the spur gear.

VI. CONCLUSION

6.1 Accomplished Project Question

The addition of the Presta Valve to the Air Storage Container stands out as a pivotal feature, enabling the efficient storage of compressed air through the use of a bicycle pump. Addressing the question on design features to increase functionality has led to considerations such as aerodynamic enhancements, lightweight construction, and innovative propulsion mechanisms. These features not only optimize performance but also contribute to the overall efficiency and usability of air-powered vehicles.

In addressing the imperative of ensuring the reliability and performance of air-powered vehicles, substantial enhancements have been implemented. Notably, improvements to the spur gear involved an increase in thickness, a strategic measure to prevent warping and fortify the gear against operational stresses. This modification underscores a commitment to durability and contributes significantly to the overall reliability of the vehicle's transmission system. Additionally, a pivotal refinement in the steering system has been introduced by transitioning from a single steering arm to the integration of two steering arms. This deliberate adjustment aims to mitigate tire scrubbing, a factor crucial to maintaining stability during vehicle operation. These targeted modifications exemplify a proactive approach to engineering challenges, where iterative adjustments driven by real-world testing result in a more reliable and optimally performing air-powered vehicle.

The integration of the compressed air storage system, propulsion mechanisms, and control systems is seamlessly achieved in our air-powered vehicle design. The mechanical system efficiently utilizes a bicycle pump to pressurize and introduce air into the Compressed Air Storage, which, upon release, propels the Pneumatic Engine. This, in turn, drives the spur gear to propel the vehicle forward. The torque optimization mechanism, achieved through the engagement of different-sized gears, contributes to the overall efficiency of the propulsion system. The electronic system, controlled by a Bluetooth mobile controller and Arduino UNO board, harmoniously directs the Steering System and Air Flow Controller. Specific servo motor angles govern steering direction, while controlled air flow adjustments influence the vehicle's speed. The synergy between these components ensures a smooth and integrated operation of the entire air-powered vehicle, aligning with the objective of seamless integration of propulsion, storage, and control systems.

6.2 Addressed Project Objectives

In conclusion, the pursuit of the outlined objectives has resulted in the successful development of an innovative air-powered vehicle prototype that aligns with the principles of efficiency, sustainability, and seamless control.

Objective 1 was realized through the integration of compressed air stored in a 1.5litre bottle, a purposeful propulsion mechanism which is the pneumatic engine whose concept was a steam engine, and a Mobile Bluetooth controller controlled by Arduino programming software. This harmonious integration ensures optimal and efficient operation of the vehicle.

Objective 2 was achieved by employing a combination of machining and 3D printing techniques to construct a lightweight prototype using hollowed tube as the axle and PLA plastic for the 3D printed parts. The utilization of a pneumatic engine has proven effective in powering the vehicle, ensuring both smooth and reliable movement.

Objective 3 saw the prototype undergo comprehensive testing and analysis, focusing on key performance metrics such as distance travelled and overall functionality. The results of these tests affirm the success of the prototype in meeting the outlined objectives, marking a significant step forward in the development of air-powered vehicles that embrace innovation, sustainability, and performance.

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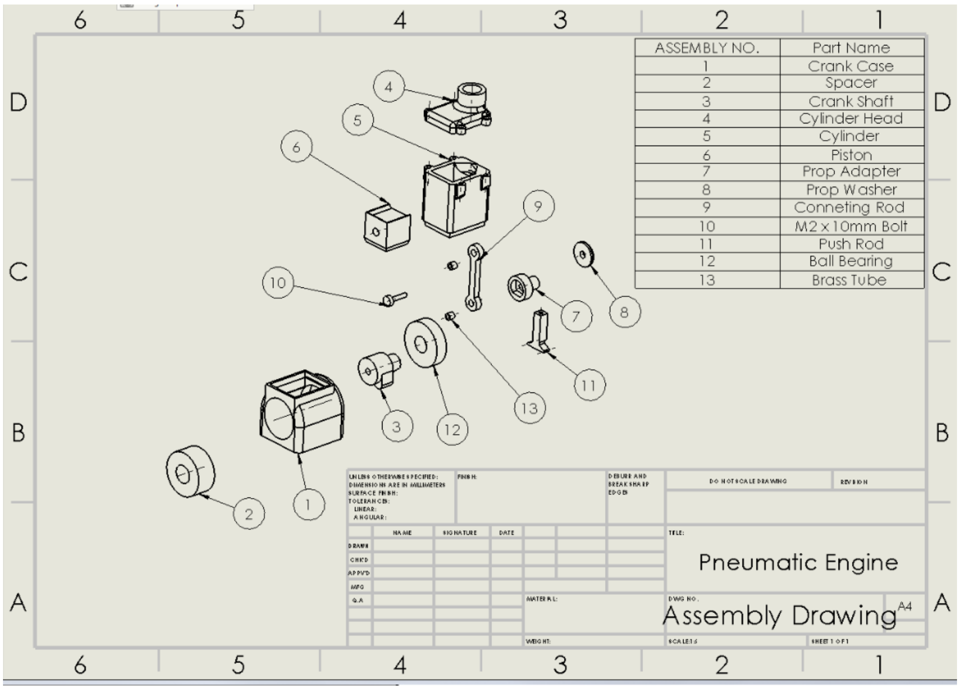
APPENDIX A

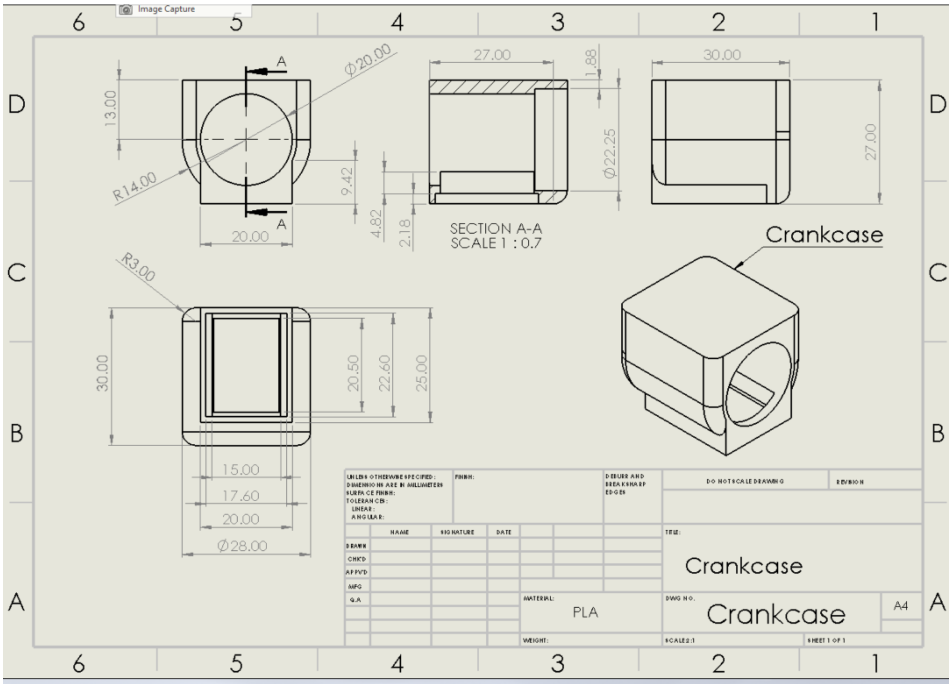
Mechanical Drawing



ASSEMBLY NO.	Part Name
1	Crank Case
2	Spacer
3	Crank Shaft
4	Cylinder Head
5	Cylinder
6	Piston
7	Prop Adapter
8	Prop Washer
9	Conneting Rod
10	M2 x 10mm Bolt
11	Push Rod
12	Ball Bearing
13	Brass Tube

TITLE: Pneumatic Engine

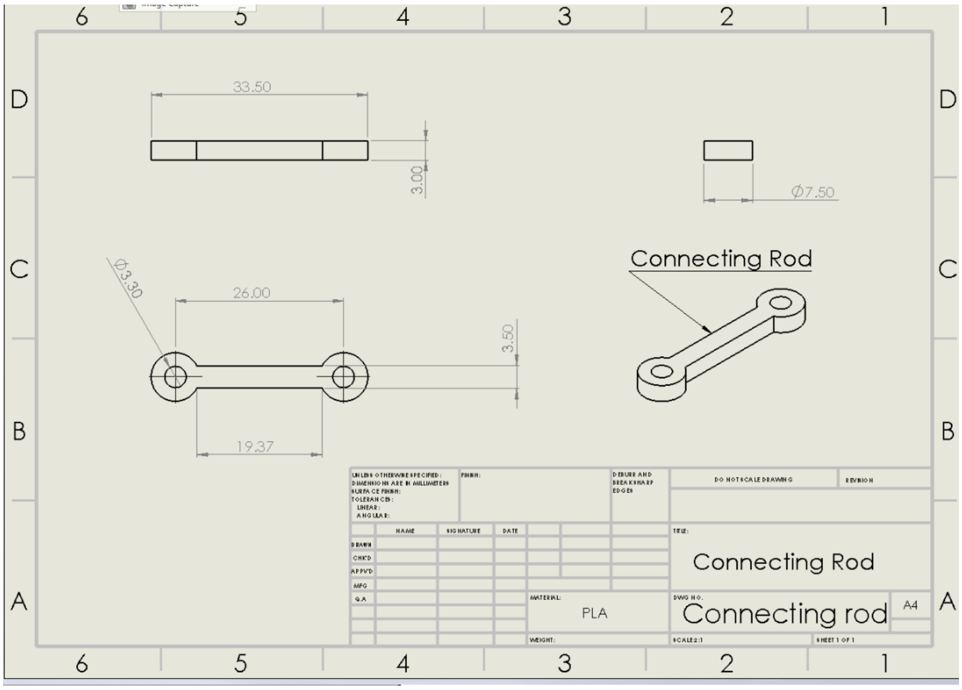
DWG NO. Assembly Drawing A4

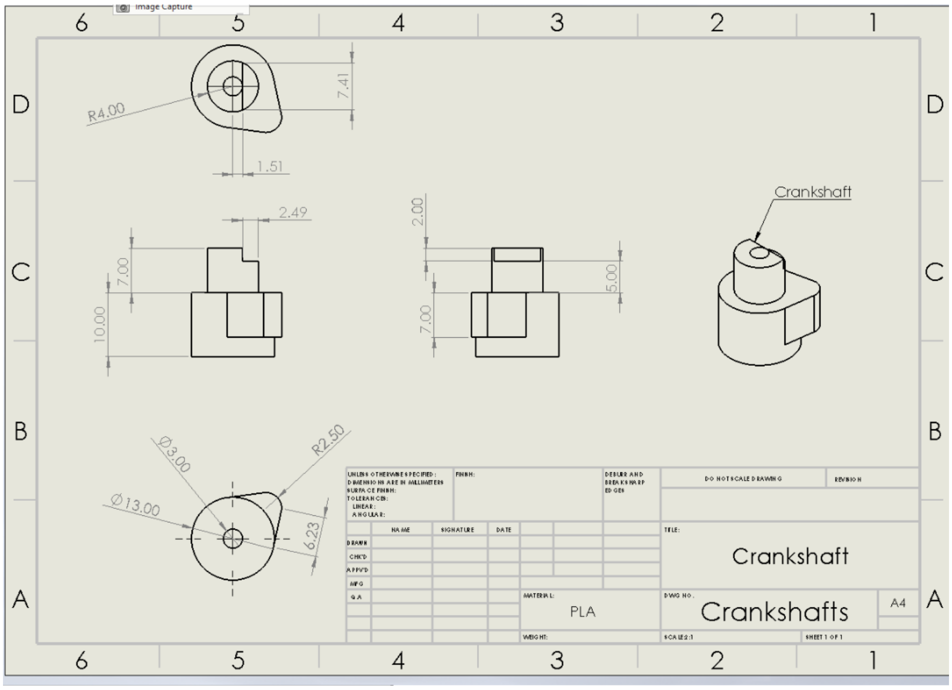


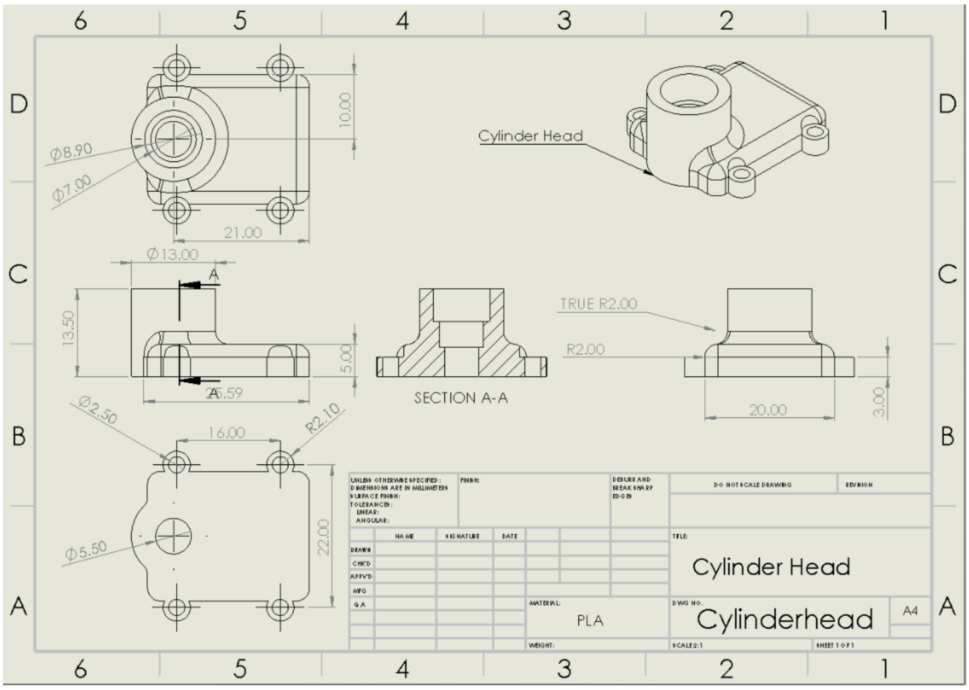
TITLE: Crankcase

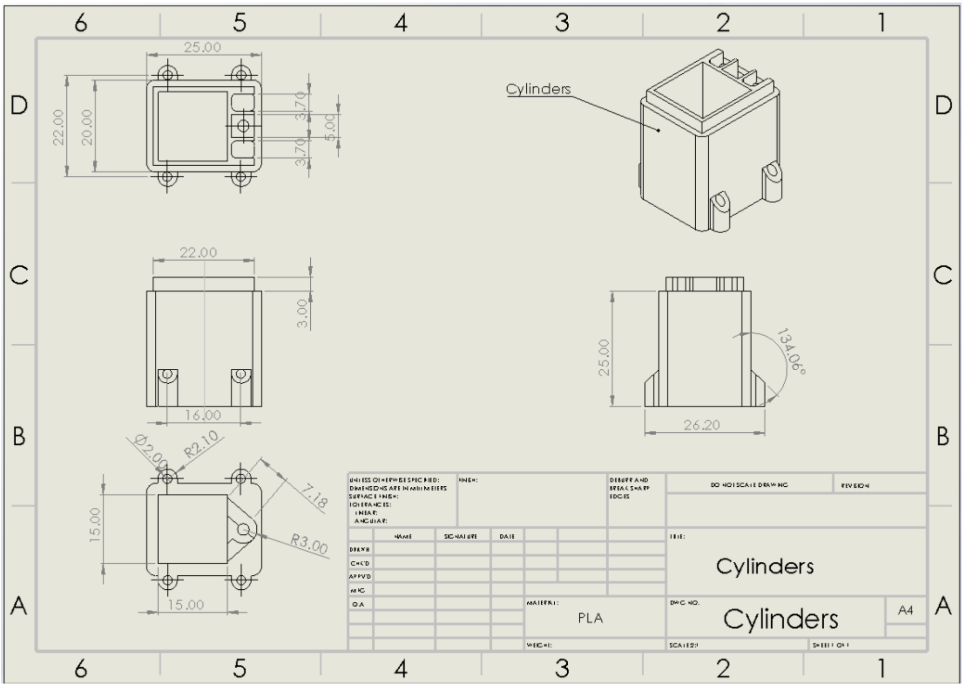
MATERIAL: PLA

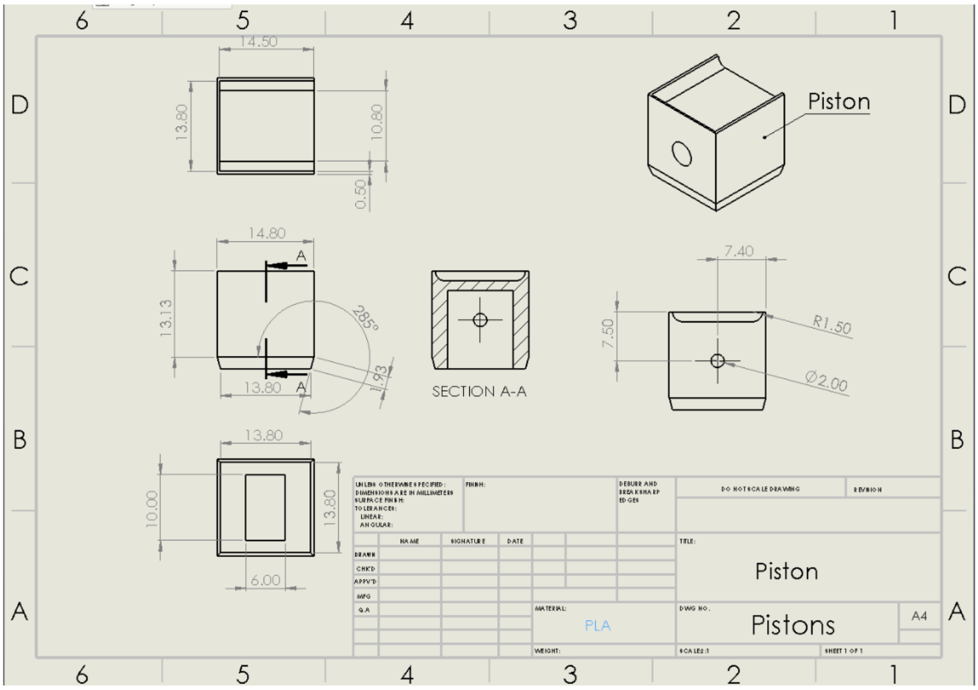
DWG NO. Crankcase A4

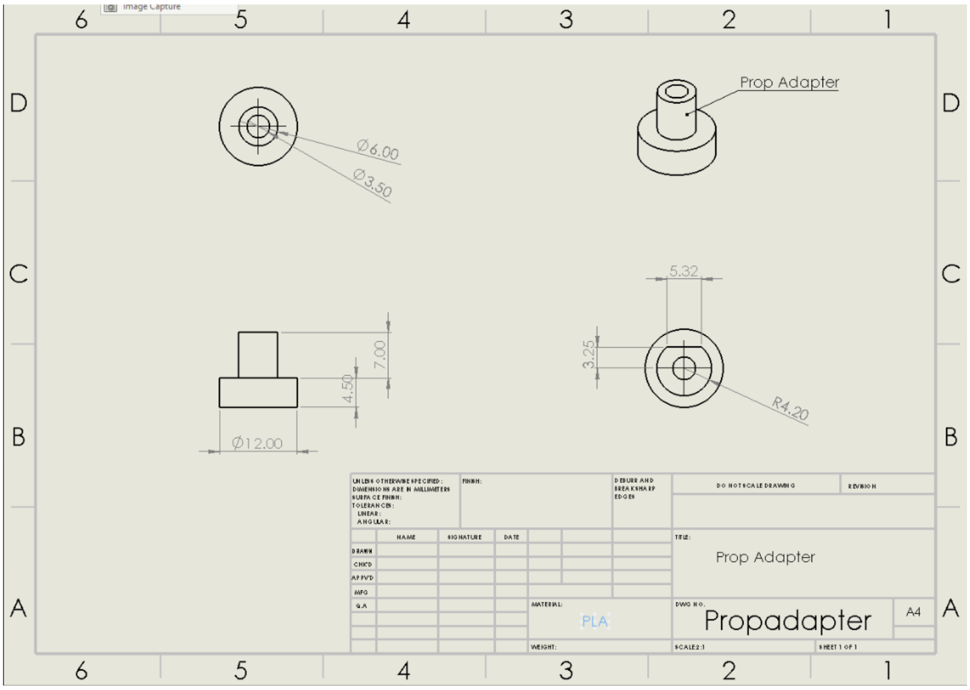

33.50
3.00
Ø7.50
Connecting Rod
Ø3.30
26.00
3.50
19.37
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Connecting Rod
MATERIAL:
PLA
DWG NO.
Connecting rod
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1
6
5
4
3
2
1
D
C
B
A


R4.00
7.41
1.51
2.49
7.00
10.00
2.00
5.00
7.00
Crankshaft
Ø3.00
R2.50
Ø13.00
6.23
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Crankshaft
MATERIAL:
PLA
DWG NO.
Crankshafts
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1
6
5
4
3
2
1
D
C
B
A


Cylinder Head
Ø8.90
Ø7.00
10.00
21.00
Ø13.00
A
13.50
5.00
25.59
SECTION A-A
TRUE R2.00
R2.00
20.00
3.00
Ø2.50
16.00
R2.10
Ø5.50
22.00
Cylinder Head
PLA
Cylinderhead
A4


Cylinders
25.00
22.00
20.00
3.70
5.00
3.70
22.00
3.00
16.00
25.00
134.06°
26.20
Ø2.00
R2.10
7.18
R3.00
15.00
15.00
Cylinders
PLA
Cylinders
A4


Piston
14.50
13.80
10.80
0.50
14.80
A
13.13
285°
1.93
13.80
A
SECTION A-A
7.40
7.50
R1.50
Ø2.00
13.80
10.00
13.80
6.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
PLA
WEIGHT:
TITLE:
Piston
DWG NO.
Pistons
A4
SCALE2:1
SHEET 1 OF 1


Prop Adapter
Ø6.00
Ø3.50
5.32
7.00
4.50
3.25
R4.20
Ø12.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
PLA
WEIGHT:
TITLE:
Prop Adapter
DWG NO.
Propadapter
A4
SCALE2:1
SHEET 1 OF 1

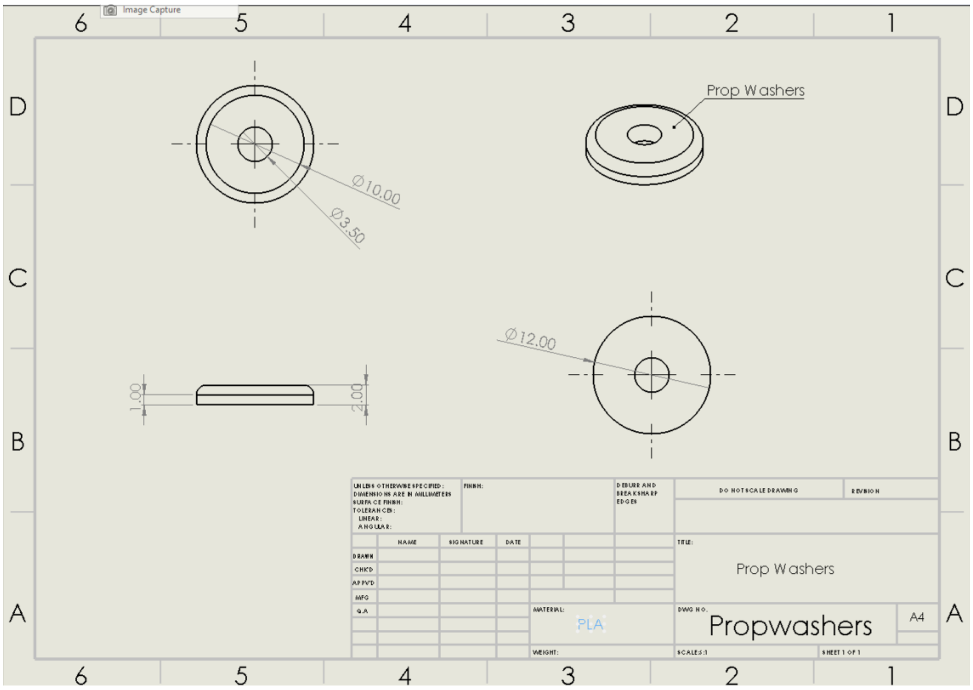


Image Capture
Prop Washers
Ø10.00
Ø3.50
Ø12.00
1.00
2.00
DO NOT SCALE DRAWING
REVISION
TITLE:
Prop Washers
MATERIAL:
PLA
DWG NO.
Propwashers
A4
WEIGHT:
SCALE 5:1
SHEET 1 OF 1
DRAWN
CHK'D
APPV'D
MFG
Q.A
NAME
SIGNATURE
DATE
FINISH:
DEBURR AND BREAK SHARP EDGES
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:

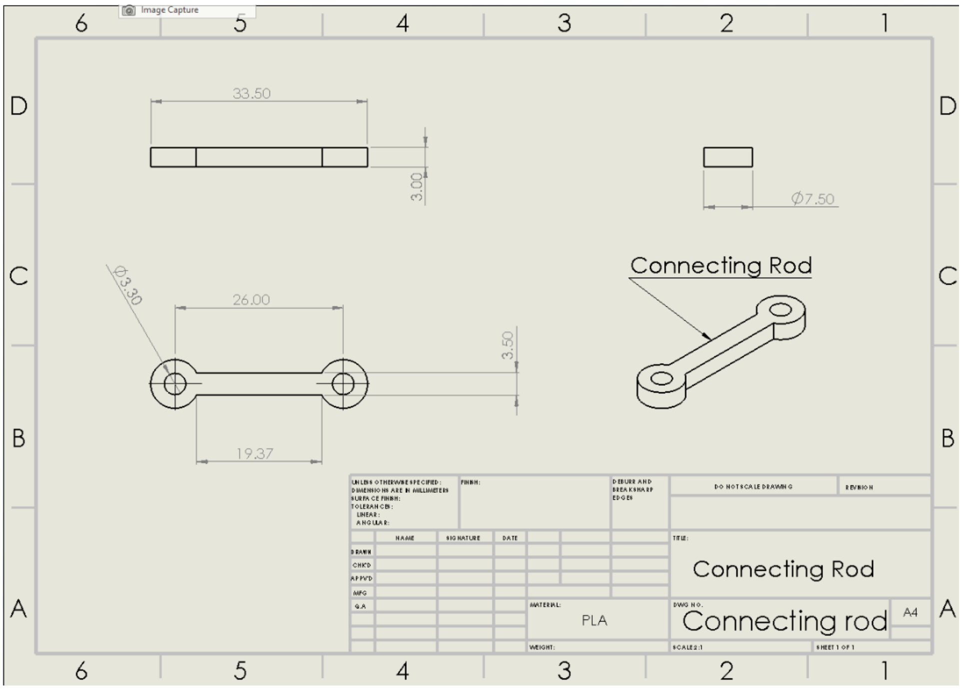
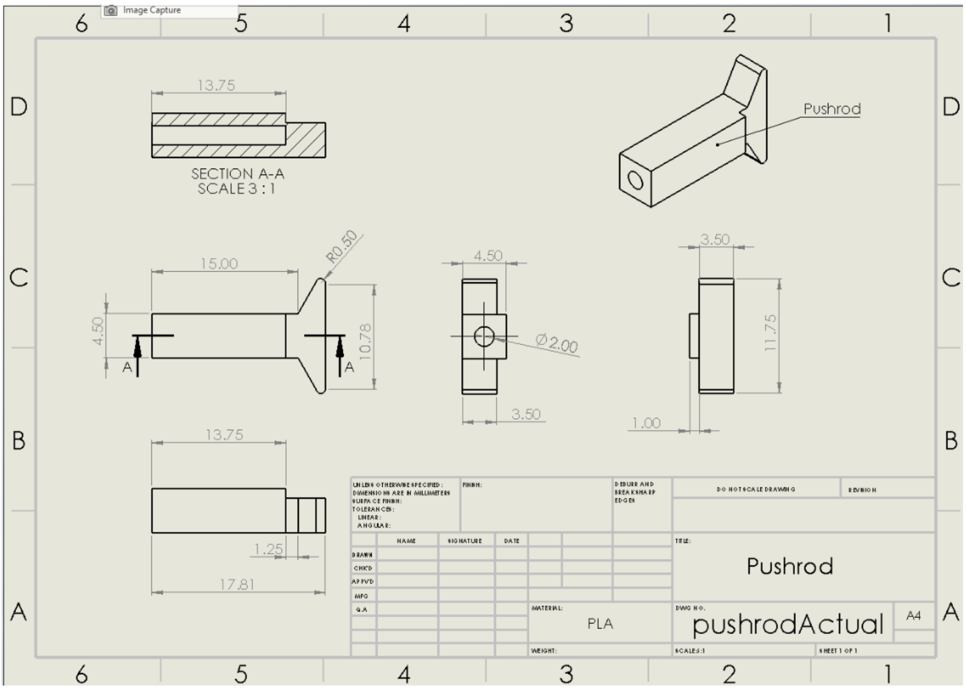
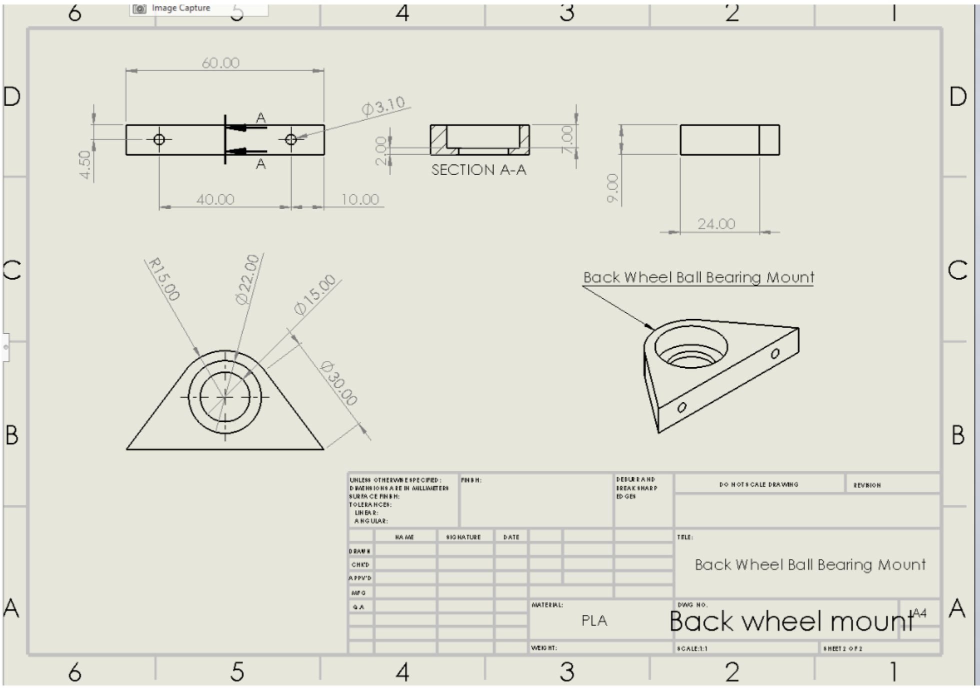
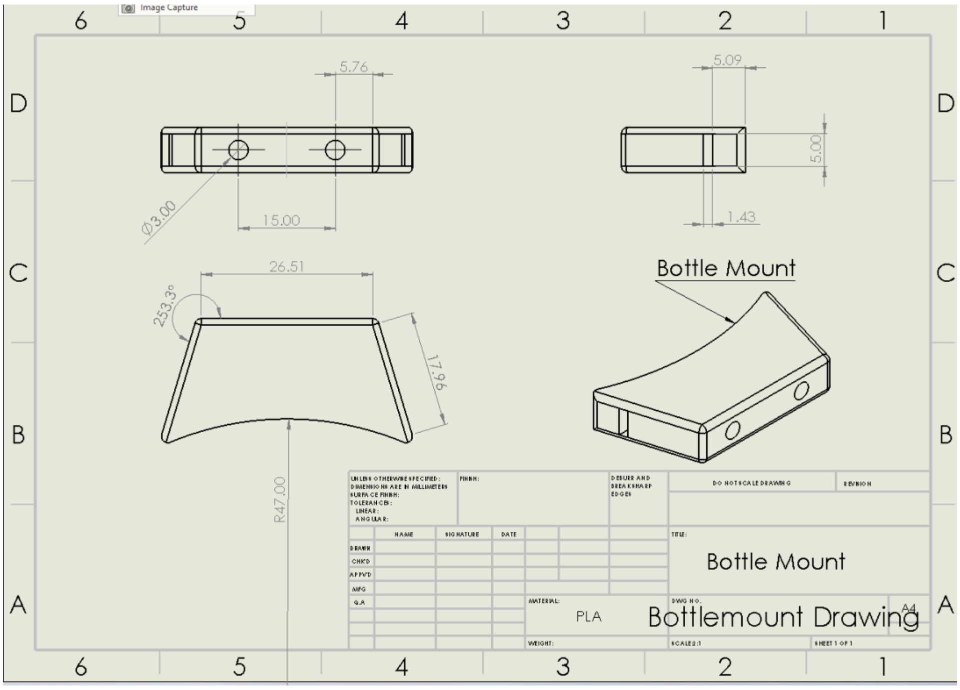
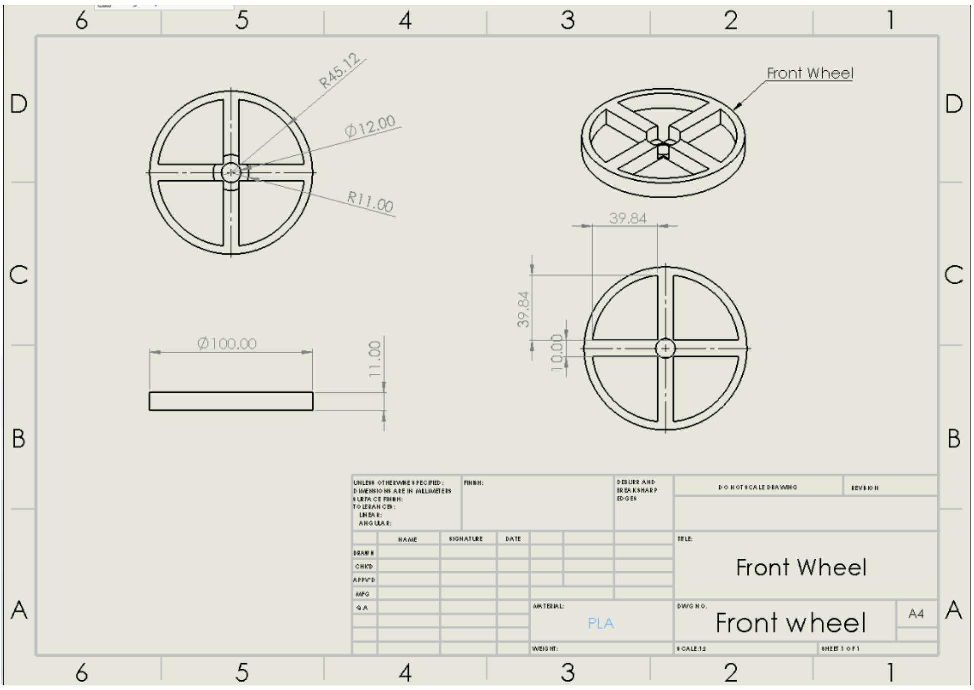


Image Capture
33.50
3.00
Ø7.50
Connecting Rod
Ø3.30
26.00
3.50
19.37
DO NOT SCALE DRAWING
REVISION
TITLE:
Connecting Rod
MATERIAL:
PLA
DWG NO.
Connecting rod
A4
WEIGHT:
SCALE 2:1
SHEET 1 OF 1
DRAWN
CHK'D
APPV'D
MFG
Q.A
NAME
SIGNATURE
DATE
FINISH:
DEBURR AND BREAK SHARP EDGES
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:


13.75
SECTION A-A
SCALE 3 : 1
Pushrod
15.00
R0.50
4.50
10.78
A
A
4.50
Ø2.00
3.50
3.50
11.75
1.00
13.75
1.25
17.81
TITLE:
Pushrod
MATERIAL:
PLA
DWG NO.
pushrodActual
A4


60.00
Ø3.10
4.50
A
A
40.00
10.00
2.00
7.00
SECTION A-A
9.00
24.00
R15.00
Ø22.00
Ø15.00
Ø30.00
Back Wheel Ball Bearing Mount
TITLE:
Back Wheel Ball Bearing Mount
MATERIAL:
PLA
DWG NO.
Back wheel mount
A4


5.76
5.09
Ø3.00
15.00
5.00
1.43
26.51
253.3°
17.96
R47.00
Bottle Mount
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Bottle Mount
MATERIAL:
PLA
DWG NO.
Bottlemount Drawing
A4
WEIGHT:
SCALE:2:1
SHEET 1 OF 1
6
5
4
3
2
1
D
C
B
A


R45.12
Ø12.00
R11.00
Front Wheel
39.84
39.84
10.00
Ø100.00
11.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Front Wheel
MATERIAL:
PLA
DWG NO.
Front wheel
A4
WEIGHT:
SCALE:1:2
SHEET 1 OF 1
6
5
4
3
2
1
D
C
B
A

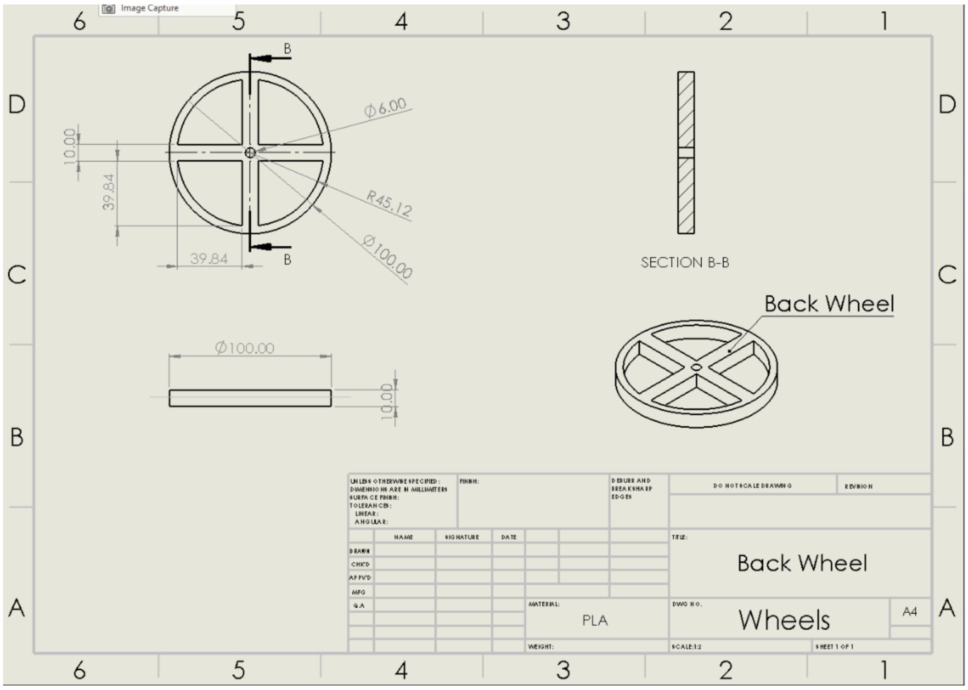


Image Capture
B
Ø6.00
10.00
39.84
R45.12
39.84
B
Ø100.00
SECTION B-B
Back Wheel
Ø100.00
10.00
PLA
Back Wheel
Wheels
A4
SCALE:1:2
SHEET 1 OF 1

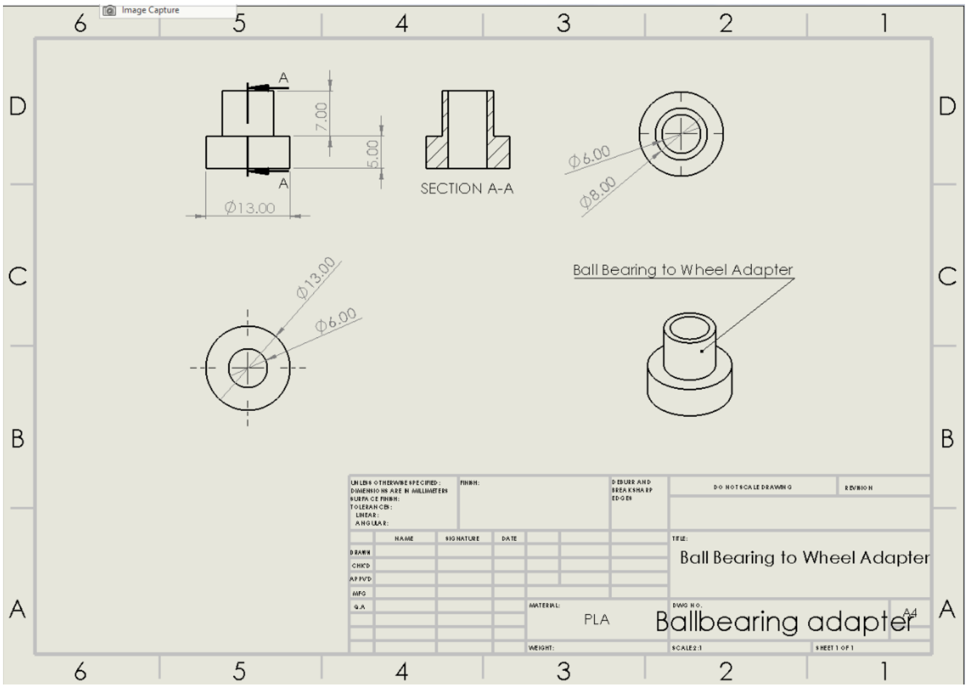


Image Capture
A
7.00
5.00
A
Ø13.00
SECTION A-A
Ø6.00
Ø8.00
Ball Bearing to Wheel Adapter
Ø13.00
Ø6.00
PLA
Ball Bearing to Wheel Adapter
Ballbearing adapter
A4
SCALE:2:1
SHEET 1 OF 1

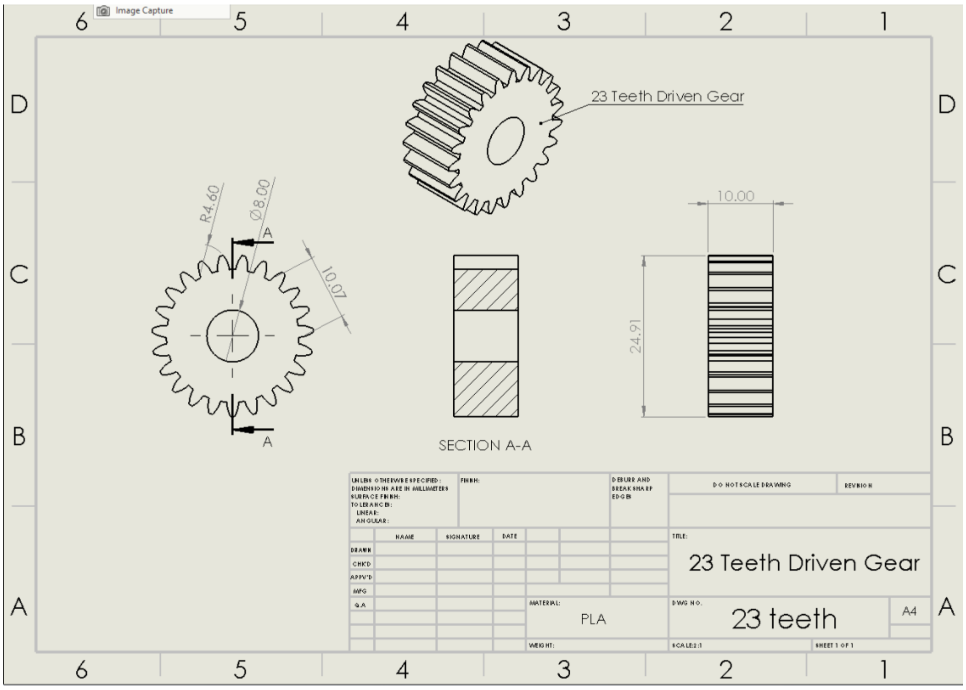


Image Capture
23 Teeth Driven Gear
R4.60
Ø8.00
10.07
A
A
10.00
24.91
SECTION A-A
DO NOT SCALE DRAWING
REVISION
TITLE:
23 Teeth Driven Gear
MATERIAL:
PLA
DWG NO.
23 teeth
A4
SCALE 2:1
SHEET 1 OF 1
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
WEIGHT:
FINISH:
DEBUR AND BREAK SHARP EDGES
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
6
5
4
3
2
1
D
C
B
A

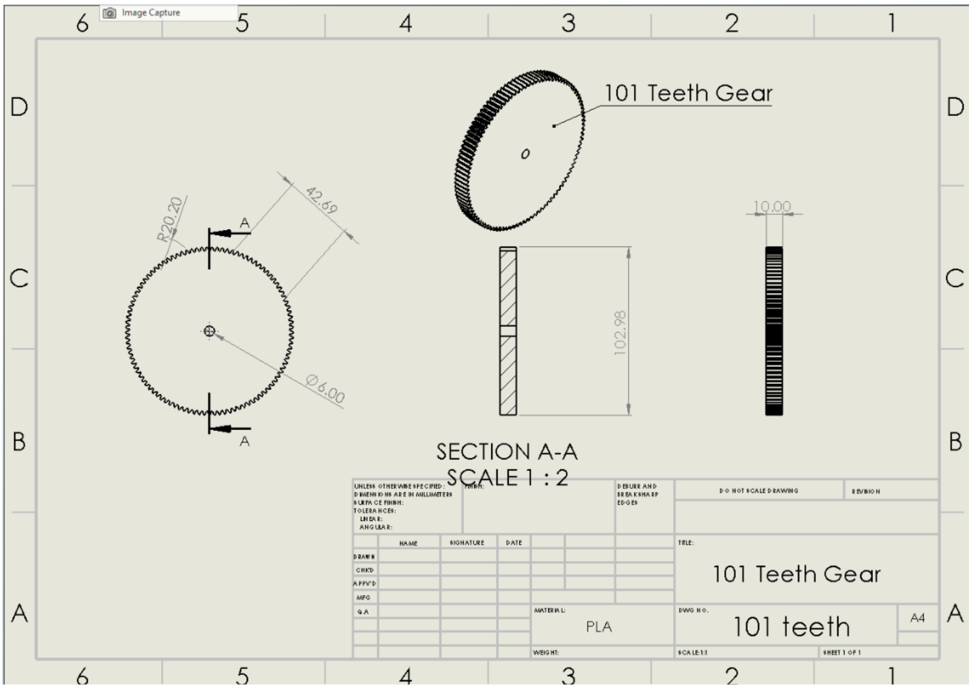
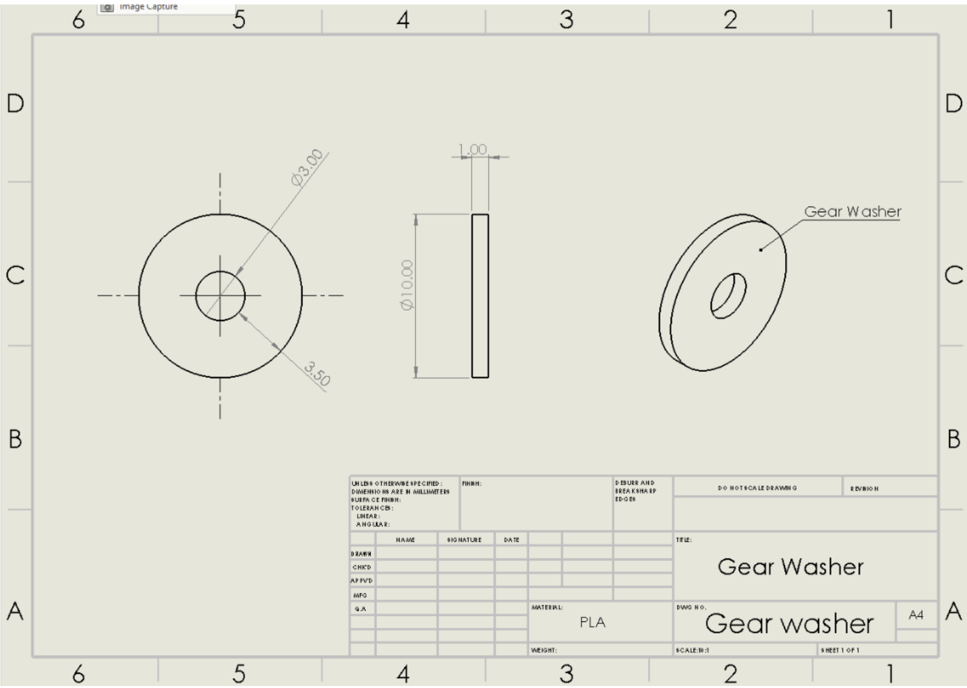
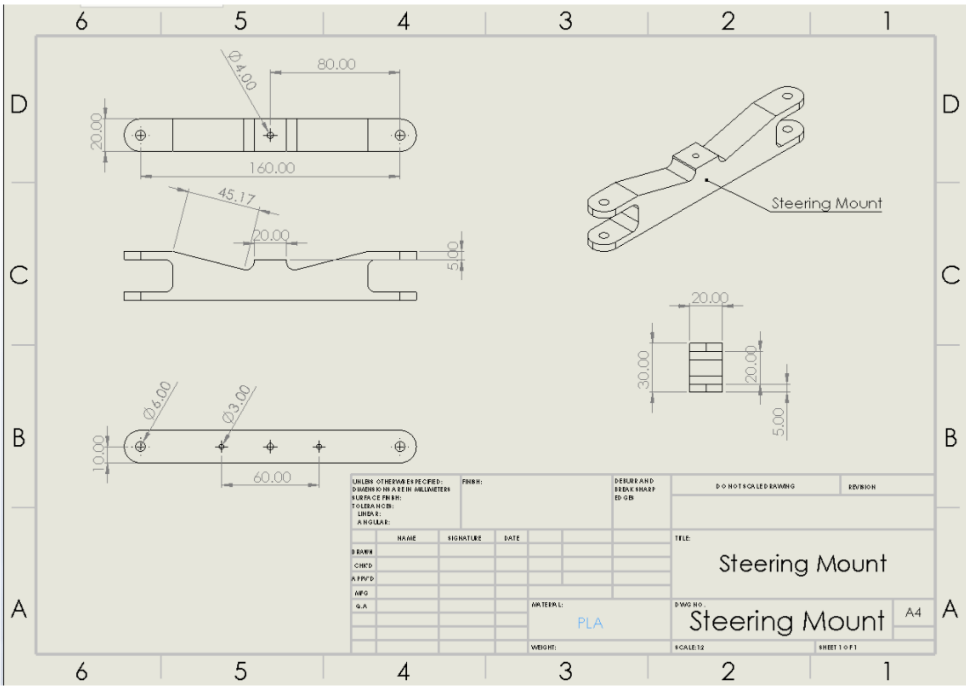
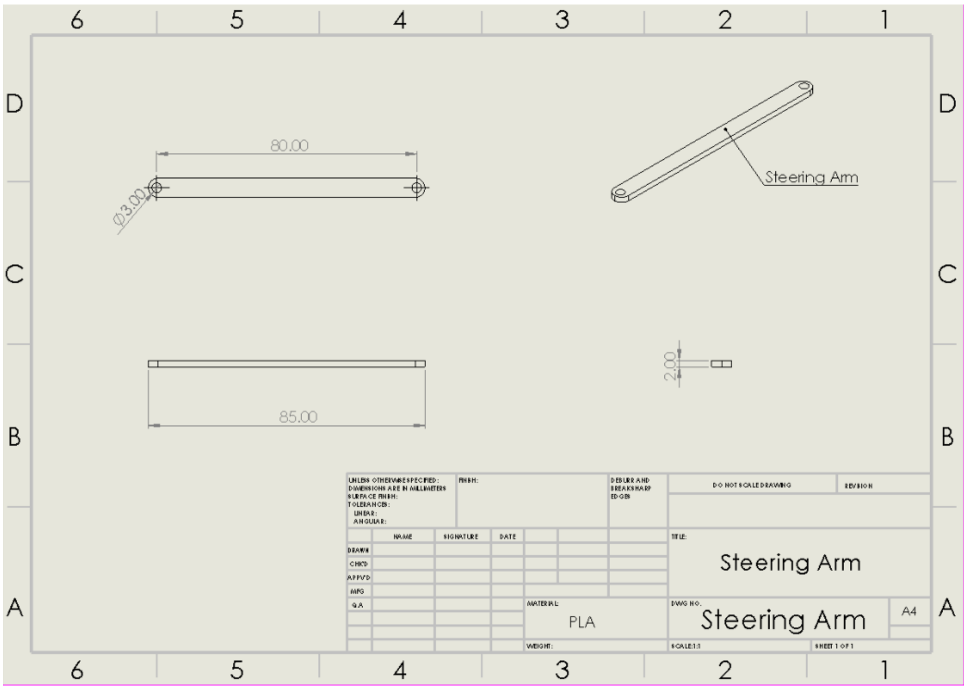
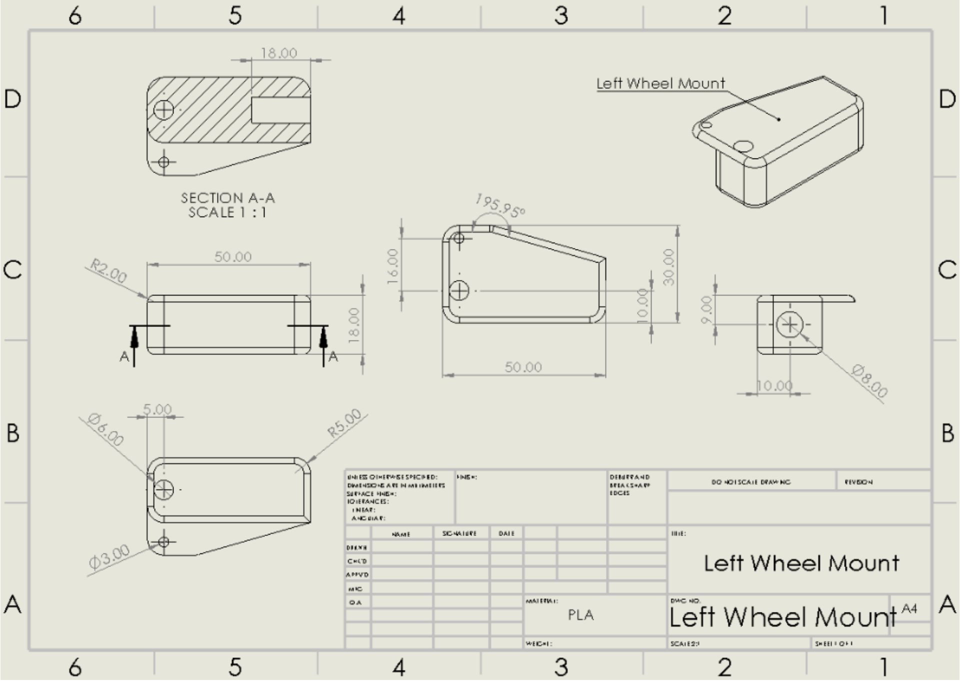


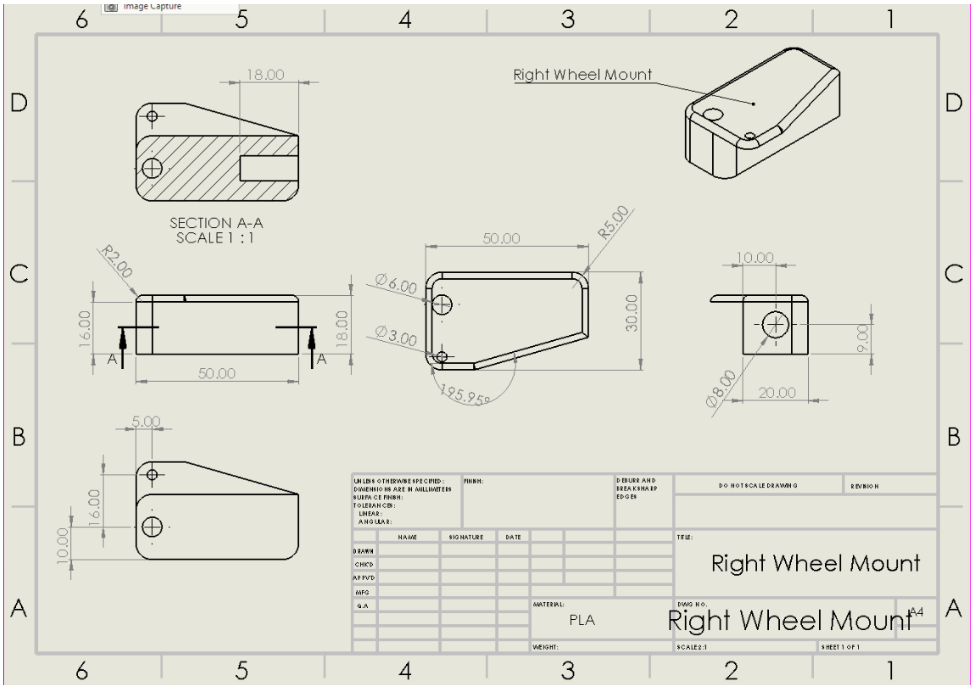
Image Capture
101 Teeth Gear
R20.20
42.69
Ø6.00
A
A
10.00
102.98
SECTION A-A
SCALE 1 : 2
DO NOT SCALE DRAWING
REVISION
TITLE:
101 Teeth Gear
MATERIAL:
PLA
DWG NO.
101 teeth
A4
SCALE 1:1
SHEET 1 OF 1
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
WEIGHT:
FINISH:
DEBUR AND BREAK SHARP EDGES
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
6
5
4
3
2
1
D
C
B
A

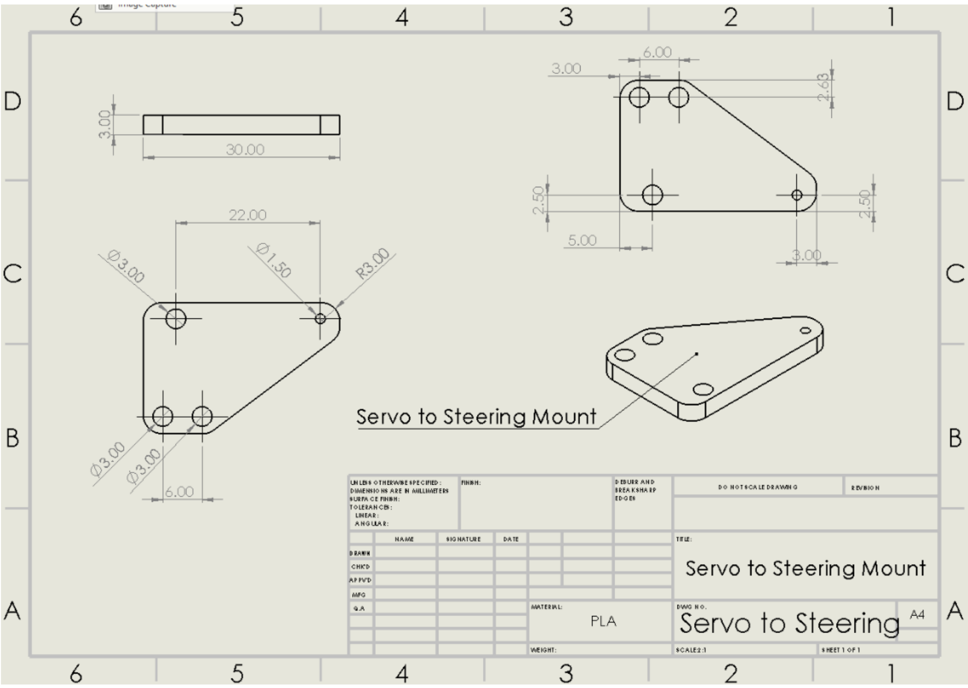

Ø3.00
3.50
1.00
Ø10.00
Gear Washer
TITLE:
Gear Washer
MATERIAL:
PLA
DWG NO.
Gear washer
A4
SCALE:1:1
SHEET 1 OF 1


Ø4.00
80.00
20.00
160.00
45.17
20.00
5.00
Steering Mount
20.00
30.00
20.00
5.00
Ø6.00
Ø3.00
10.00
60.00
TITLE:
Steering Mount
MATERIAL:
PLA
DWG NO.
Steering Mount
A4
SCALE:1:2
SHEET 1 OF 1


80.00
Ø3.00
Steering Arm
85.00
2.00
DO NOT SCALE DRAWING
REVISION
TITLE:
Steering Arm
MATERIAL:
PLA
DWG NO.
Steering Arm
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1


18.00
Left Wheel Mount
SECTION A-A
SCALE 1 : 1
195.95°
R2.00
50.00
16.00
30.00
A
A
18.00
10.00
9.00
50.00
10.00
Ø8.00
5.00
Ø6.00
R5.00
Ø3.00
DO NOT SCALE DRAWING
REVISION
TITLE:
Left Wheel Mount
MATERIAL:
PLA
DWG NO.
Left Wheel Mount
A4


Right Wheel Mount
SECTION A-A
SCALE 1 : 1
18.00
R2.00
16.00
18.00
50.00
A
A
50.00
R5.00
Ø6.00
Ø3.00
30.00
195.95°
10.00
9.00
Ø8.00
20.00
5.00
16.00
10.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
PLA
WEIGHT:
TITLE:
Right Wheel Mount
DWG NO.
Right Wheel Mount
A4
SCALE:2:1
SHEET 1 OF 1
6
5
4
3
2
1
D
C
B
A


3.00
30.00
22.00
Ø3.00
Ø1.50
R3.00
Ø3.00
Ø3.00
6.00
6.00
3.00
2.63
2.50
5.00
2.50
3.00
Servo to Steering Mount
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
PLA
WEIGHT:
TITLE:
Servo to Steering Mount
DWG NO.
Servo to Steering
A4
SCALE:2:1
SHEET 1 OF 1
6
5
4
3
2
1
D
C
B
A

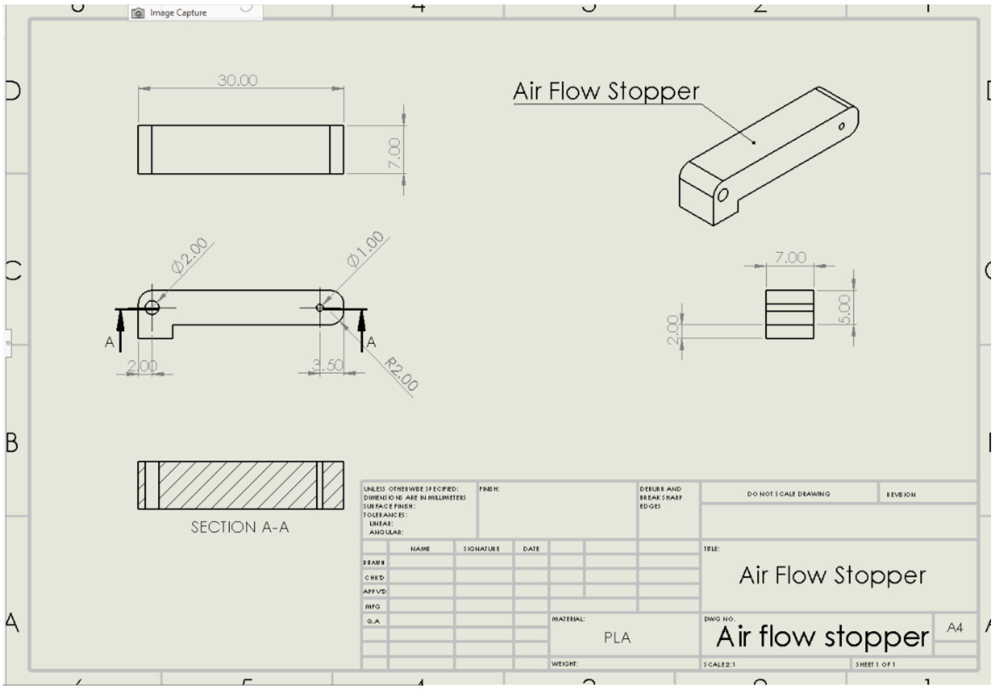


Image Capture
30.00
7.00
Air Flow Stopper
Ø2.00
Ø1.00
A
A
2.00
3.50
R2.00
7.00
2.00
5.00
SECTION A-A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Air Flow Stopper
MATERIAL:
PLA
DWG NO.
Air flow stopper
A4
WEIGHT:
SCALE2:1
SHEET 1 OF 1
D
C
B
A

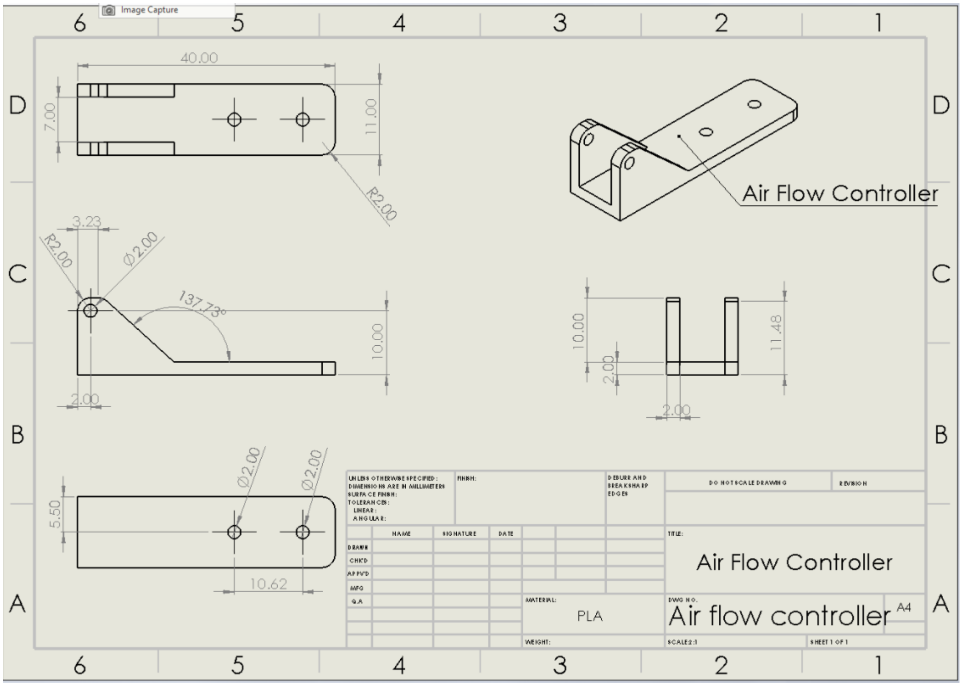
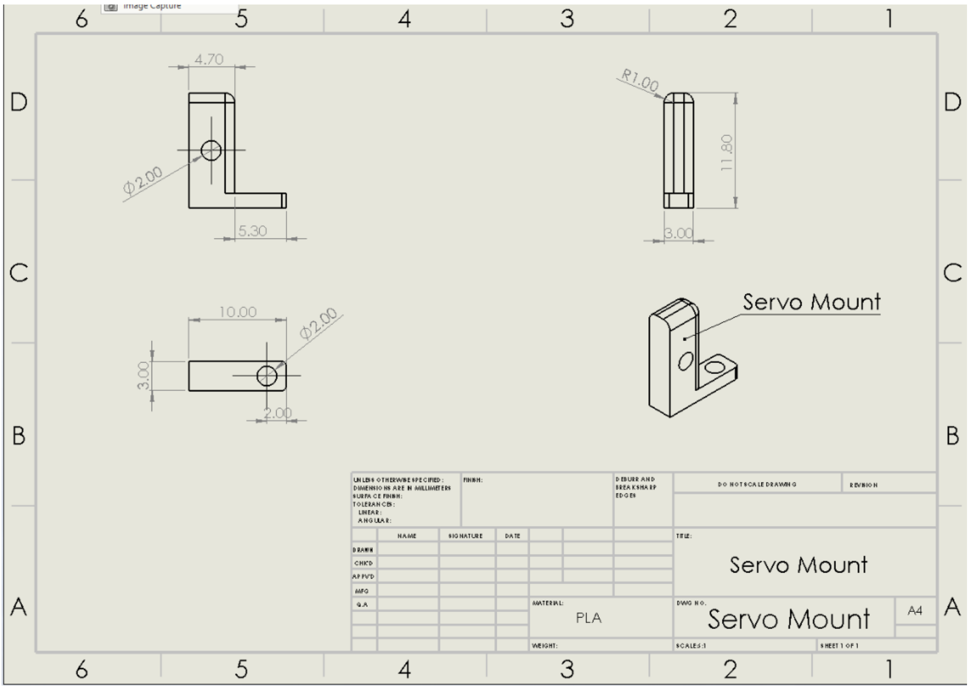


Image Capture
6
5
4
3
2
1
40.00
7.00
11.00
R2.00
Air Flow Controller
3.23
R2.00
Ø2.00
137.73°
10.00
2.00
10.00
2.00
11.48
2.00
Ø2.00
Ø2.00
5.50
10.62
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
Air Flow Controller
MATERIAL:
PLA
DWG NO.
Air flow controller
A4
WEIGHT:
SCALE2:1
SHEET 1 OF 1
D
C
B
A



APPENDIX B

Arduino Code:

```
#define CUSTOM_SETTINGS
#define INCLUDE_GAMEPAD_MODULE
#include <Dabble.h>
#include <Servo.h>

Servo servo1;
Servo servo2;

int motor1=5;
int motor2=6;

void setup()
{
  // put your setup code here, to run once:
  servo1.attach(motor1);
  servo1.attach(motor2);

  Dabble.begin(9600, 2, 3);
}

void loop()
{

  Dabble.processInput();
  if (GamePad.isUpPressed())
  {
  Serial.print("UP");
  servo1.write(0);
  delay(1000);
  }

  if (GamePad.isDownPressed())
  {
```

```
   Serial.print("DOWN");
   servo1.write(60);
   delay(1000);
  }

  if (GamePad.isLeftPressed())
  {
   Serial.print("LEFT");
   servo1.write(90);
   delay(1000);
  }

  if (GamePad.isRightPressed())
  {
   Serial.print("RIGHT");
   servo1.write(180);
   delay(1000);
  }

   if (GamePad.isSquarePressed())
  {
   Serial.print("Square");
   servo2.write(90);
   delay(1000);
  }

  if (GamePad.isCirclePressed())
  {
   Serial.print("Circle");
   servo2.write(120);
   delay(1000);
  }

  if (GamePad.isCrossPressed())
  {
   Serial.print("Cross");
   servo2.write(150);
   delay(1000);
  }

  if (GamePad.isTrianglePressed())
  {
   Serial.print("Triangle");
   servo2.write(180);
   delay(1000);
  }

}
```

APPENDIX C
Final Assembly