SENIOR PROJECT

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Automated Pill Dispenser

Project Report
Group E

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Nomenclature

ρ	Density
E	Young's modulus or Elastic Modulus
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
LCD	Liquid Crystal Display
LED	Light Emitting Diode
PLA	Polylactic Acid
TFT	Thin Film Transistor

Abstract

This report presents the development of an innovative automated pill dispenser designed in Spring 2023 and manufactured in Fall 2024. The dispenser employs a rotating pill chamber and an air pump for efficient pill management, specifically targeting elderly patients and those with complex medication regimes. The design process involved comprehensive research, mathematical modeling, and simulations to optimize performance within design and cost constraints. Despite minor compromises on the dimensions, production costs are below the budget of 100$ with 75.60$ (2276,99).

1. Introduction

1.1 What is an automated pill dispenser?

An automated pill dispenser is a device that dispenses medication at pre-specified times. These devices have a compartment for each pill, an internal clock, and an alarm system. When the pre-set time to take the medicine arrives, the dispenser takes the pill from the compartment that the specified pill is stored, and then dispenses the pill, often accompanied by an alarm or other notification. These devices can vary widely in complexity and functionality, ranging from basic models that simply open compartments at pre-set times to more advanced versions that connect to smartphones, provide reminders, and even track medication adherence.

1.2 Why is it needed?

For individuals who need to take multiple medications at different times of the day, or people with diseases like Alzheimer's, or even a person in daily life stress, it can be challenging to adhere to medicine intake as prescribed. Non-adherence can lead to ineffective treatment, worsening of disease, increased health care costs, and even death. According to World Health Organization, non-adherence with treatment can contribute to approximately 50% of treatment failures, resulting in roughly 125,000 deaths and up to 25% of hospital admissions annually within the United States [1]. The purpose of automated pill dispensers is to improve medication adherence, ensuring that people take their medications on time, in the right amounts, and in the right way.

1.3 Problem Definition

An automated pill dispenser with 30cm x 30cm x 30cm in size for home usage at a cost of 100$ is aimed to be designed. The solution for the problem defined, should be able to cover:

1. How will different type of pills be stored inside the dispenser.
2. How will the pills be taken from their preserved areas.
3. How will the dispenser ensure taking only one pill at each time.
4. How will the machine alert users that time to take the pill has come.

2. Overview of Possible Solutions

2.1 Methods

2.1.1 Spring Dispenser

In the spring dispenser as in Figure 1, pills get in line in a pipe structure to be dispensed one by one. Spring is pushed by a cam and the pill filling the slot between the cam and the spring is pushed towards a hole and it leaves the small chamber. This simple mechanism requires a pipe that will align the pills one by one; however, pills vary in shape and sizes. The pipe structure should be suitable for every pill which is impossible [2] .

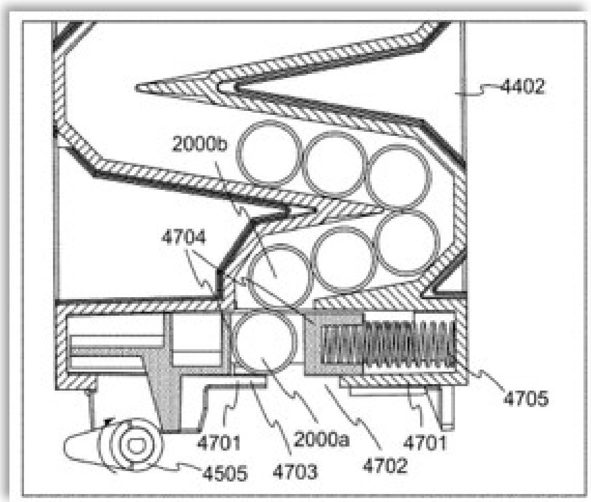


Figure 1: Spring dispenser drawing [2].

2.1.2 Turning Plate

In the turning plate as in Figure 2, the pills get in line inside a slide and the plate with slots for pills turn to fill the slots. When the pill is inside the slot, the plate turns 180° to discharge the pill. This system allows pills to be dispensed one by one; however, the pills may got stuck inside the pill slots or there maybe more than one pill in one slot depending on the pills size and shape. In order to avoid these inconveniences, the pill slide and the slots should be designed specifically for that pill size which is not feasible[3].

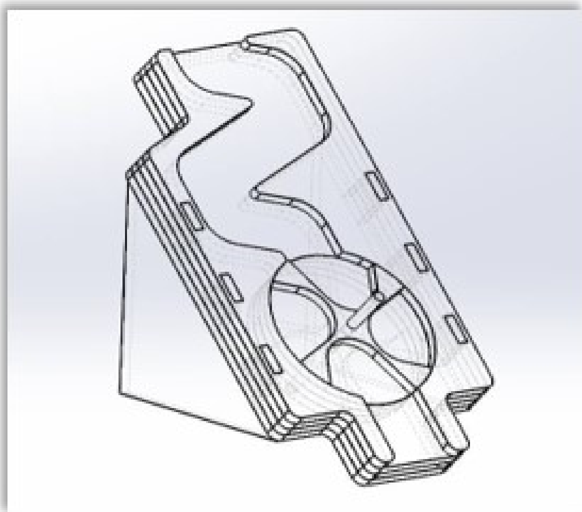


Figure 2: Turning plate drawing [3].

2.1.3 Tube Dispenser

In the tube dispenser in Figure 3, filling the tubes and the pill dispensing is two different tasks to be completed. First with a turning plate with slot and slope, the pills are directed to the tubes to be aligned one by one. When the plate turns, the pills fall from the slot one by one ensuring they fall inside the tubes. After that, the pills can be dispensed from the bottom of the tubes with the help of a plate which turns and opens the corresponding tube with the pill. This system is rather complex and the pill tubes should change with the size and shape of the pill which is not feasible. Also, the geometry need the dispenser to be tall and slim which makes it difficult to design and fit the electronic parts inside[4].

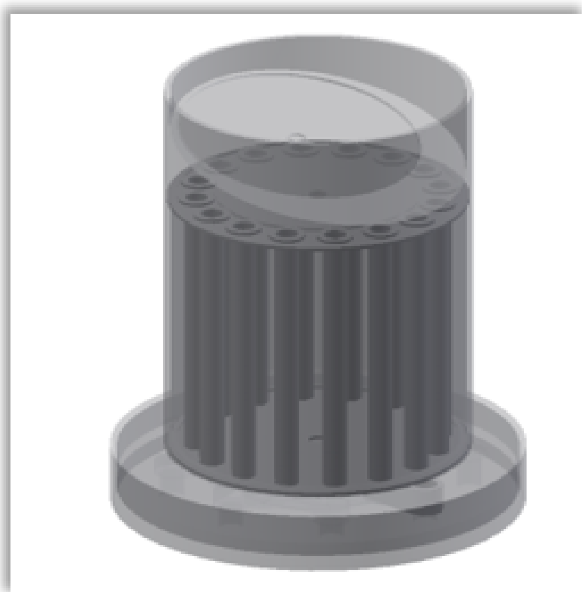


Figure 3: Tube dispenser drawing [4].

2.1.4 Vacuum

The vacuum gripper dispenser basically grips the pill inside the chamber using the suction of the air as in Figure 4a. The pipe end allows the pill to stay on the tip of the pipe and not go inside the pipe. The pill is gripped and dropped in another box to be taken by the user. The mechanism allows used to fill the chambers easily as in Figure 4. It is feasible for every shape and size of the pills making the design more realistic. The vacuum gripper does not exert any force on the pill, thus it does not damage the pills and cause any accumulation of dust[5].

(a) Gripper [5]

(b) Pill chambers [5]

Figure 4: Components in Vacuum Pill Dispenser: (a) Gripper, (b) Pill Chambers.

2.2 Comparison and Method Selection

The methodologies are compared based on different customer criteria. Customer criteria are prioritized based on their importance. Then every mechanism is compared based on these criteria. The vacuum gripper is the most feasible, reliable and easy as it is observed in Table 1.

Table 1: Mechanism Comparison Table

Customer Criteria/Mechanisms	Importance	Spring Dispenser	Turning Plate	Tube	Vacuum
Cost	3	1	3	8	4
Reliability	4	7	4	5	8
Easy Usability	1	6	5	1	9
Durability	1	6	8	7	2
Feasibility	3	3	5	3	8
Complexity	2	4	9	8	3
Comprehensiveness	5	4	4	2	9
SCORE		82	89	81	130

3. Detailed Design and Analysis

3.1 Pump Selection

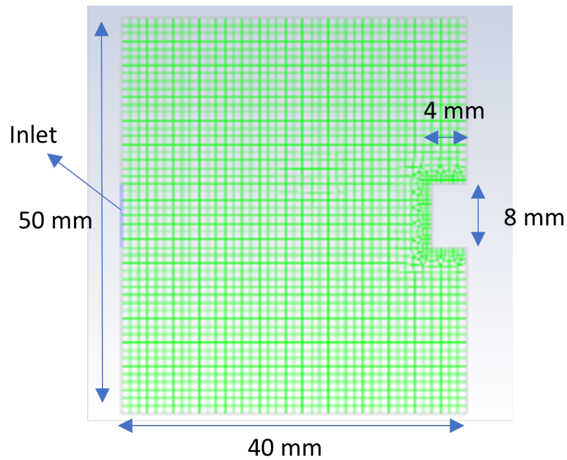


Figure 5: Pill chamber mesh and dimensions.

After the design of the pill chambers, the pump for the vacuum gripper needs to be chosen. To analyze the vacuum requirement, different dimensions of the pipe and suction air flow rate are tried out. The dimension of the chamber is kept constant. For an extreme case, the pill is chosen to be a larger pill type such as antibiotics. The pill is centered in the chamber bottom and the lift force is calculated on its walls. To simplify the analysis, the chamber is taken as a square as in Figure 5. The inlet is changed between 6-10 mm. The pill has dimensions of $18 \times 8 \times 4$ mm, and the narrow side is taken into consideration. The inlet velocity is taken as -25 m/s and -50 m/s. The transient analysis is conducted for 2 seconds with 0.001 seconds time step. The mesh is refined around the pill walls. Element size for the rest of the mesh is 0.001 m.

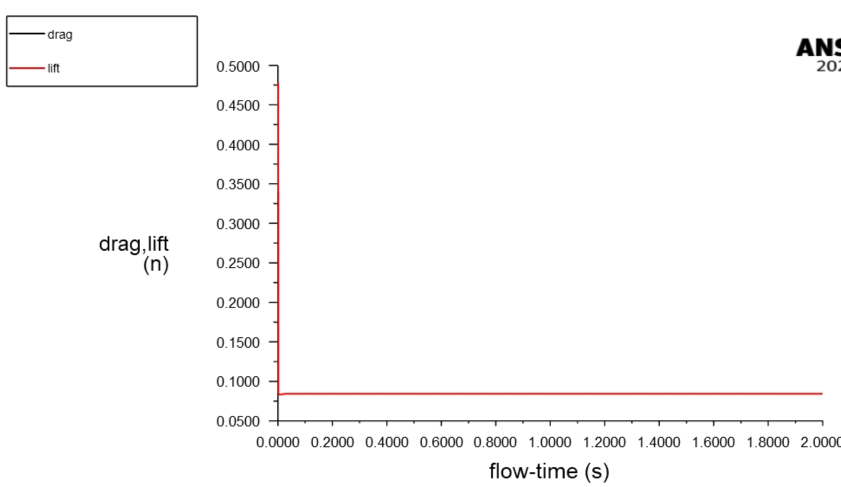


Figure 6: Change in force exerted on the pill over time.

Drag is plotted with respect to the time change as in Figure 6. The drag is maximum when the vacuuming starts due to the maximum available air at the start. The air density decreases significantly but the final drag force should be enough to carry the load for one pill. The following results in Table 2 are accumulated from the analysis of the various pipe diameters and inlet velocities.

Table 2: Pump requirements for different dimension

h (m)	D(m)	Drag (N)	V (m/s)	Q(LPS)	Q(LPM)
0.060	0.008	0.063	50.000	2.513	150.796
0.080	0.008	0.016	50.000	2.513	150.796
0.040	0.008	0.032	25.000	1.257	75.398
0.040	0.006	0.020	25.000	0.707	42.412
0.040	0.010	0.016	25.000	1.963	117.810
0.040	0.006	0.084	50.000	1.414	84.823
0.040	0.008	0.127	50.000	2.513	150.796

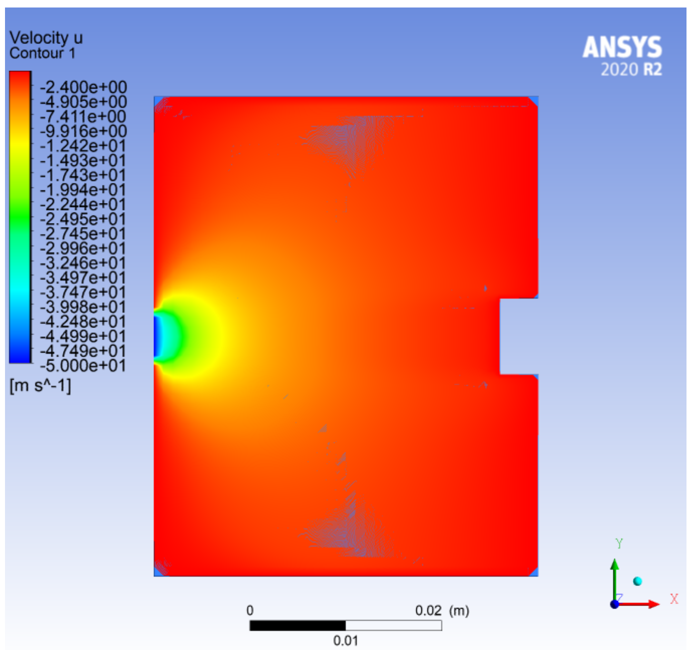


Figure 7: Velocity field inside the pill chamber.

The maximum weight that should be carried is 0.005 Newtons. The ones exceeding this value are in the shades of green. From the table, it is also can be shown that the smaller flow rates are given in green colors as well. To choose compact pump that will correspond the dimensional constraints of the design, the minimal flow rate with the maximum drag force should be chosen. The row which is all green would be the optimum choice thus the pipe with 6mm diameter and the pump which can provide 85 LPM will be selected. The pump needs to work with DC 12V and is lightweight. The velocity field corresponding to these specifications is provided in Figure 7. The first pump selected is shown in Figure 8 with following specifications [6].

Model: HT-187A
Material: Plastic ABS
Voltage: DC12V - 14,4 V
Power: 50 W
Pressure: 3600 Pa
Flow rate: 300 LPM
Weight: 200 g

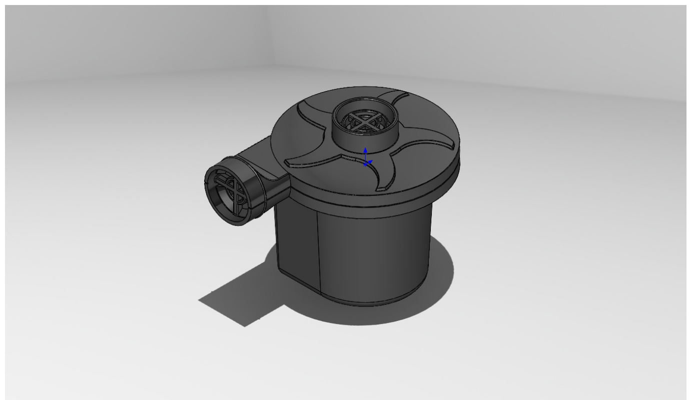


Figure 8: The first air pump[7].

The pump had a higher flow rate capacity than needed but the provided specifications in the data sheet are the maximum allowed performance values thus they need to be perceived within a safety factor. The pump choose in the previous design was hard to find in Turkey's market. Thus, an equivalent pump was found with following specifications shown in Figure 9 [8]:

Model: Summit
Material: Plastic ABS
Voltage: DC12V
Power: 35 W
Pressure: 3310 Pa
Flow rate: 350 LPM
Weight: 386 g

Figure 9: The final air pump[8].

After the current experiments conducted on the pump, the pump was seem to be providing only 20 W. Thus the suction was not enough to lift the pill from a distance although the suggested flow rate was below the air pump's specification. The analysis provided previously does not satisfy the specifications of the pump itself. Thus the vacuum gripper works when the pipe touches the bill and it carries it well after that. Also, the pump changes the power supplied as the exhale pipe area changes when a research was done on the similar air pump data sheets shown in Figure 10 [9]. When the pipe diameter gets smaller, the specified volumetric flow produced by the pump decreases. This might be one of the reasons we cannot reach the full potential of the air pump we purchased. This could be solved by increasing the pipe diameter which will risk the pills to get stuck inside the pipe. The cover on the tip of the pipe can avoid that risk also leading to reduction in the power supplied.

Figure 10: Performance of the air pump based on the flow inlet diameter [9].

Minimize the effects of the previously mentioned factors, we could have used an AC vacuum pump with higher power such as BestWay Air Pump shown in Figure 11 with following specifications [10]:

Model: BestWay
Material: Plastic ABS
Voltage: AC220V
Power: 110 W
Weight: 520 g

Figure 11: The stronger air pump[10].

When the pipe end is close but not touching the pill, the velocity of air created by the pump will allow the pill to be lifted and when it touches the pipe end the power and the pressure difference created by the pump should be sufficient to carry the load of the pill. The later condition is easier to accomplish so when the pump was chosen, the emphasis was on the volumetric flow rate. For the pump with 110 W power, the flow rate information was not provided and DC motor was a safer choice. However, the final pump chosen and used does not provide the power nor the flow rate mentioned in the data sheet. In order to accommodate the lack of flow rate, the pipe should be closer to the pills so that it could touch it because it is easier to create the pressure difference.

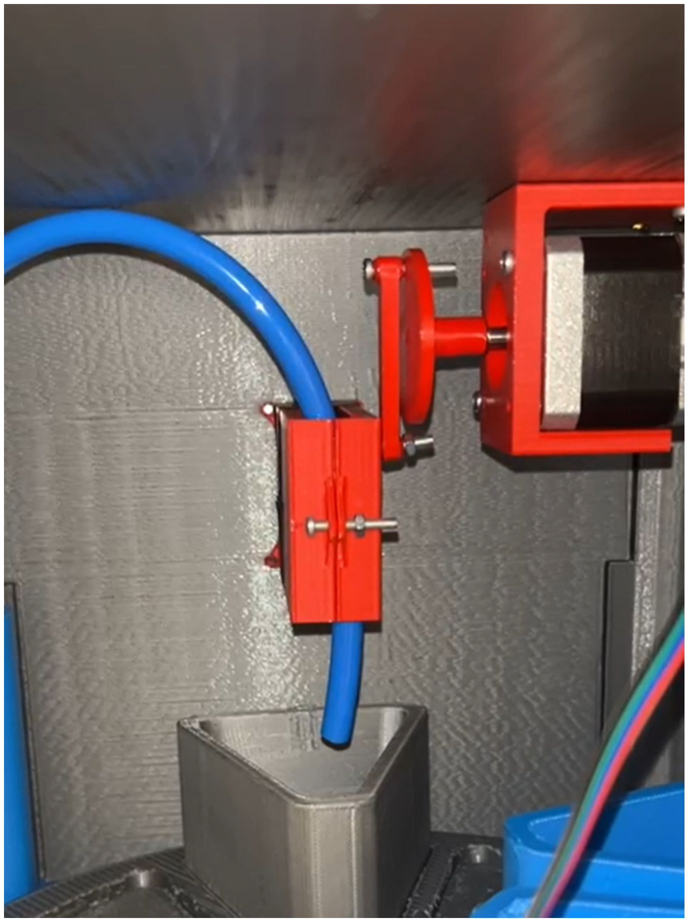


Figure 12: The curved tip of the pipe.

Moreover, the length and small diameter of the pipe result in head loss. To eliminate that, the pipe size could be larger however, with the increased diameter, when the pipe is bent, the curvature of the pipe results in a tension inside the pipe ending in a curved pipe as in Figure 12. Because a linear motion is crucial, the smaller pipe diameter is needed for mechanism movement performance. A stronger vacuum could solve the problem in mechanism range and pipe dimensions.

3.2 Part Design

The automated pill dispenser is designed to provide the user with the pills they need in the correct amount and at the correct time. As the mechanism, the vacuum dispenser is chosen and it is improved to meet the design constraints. The mechanical design part is divided into the vacuum gripper, cups and bottom plate, and the shell design.

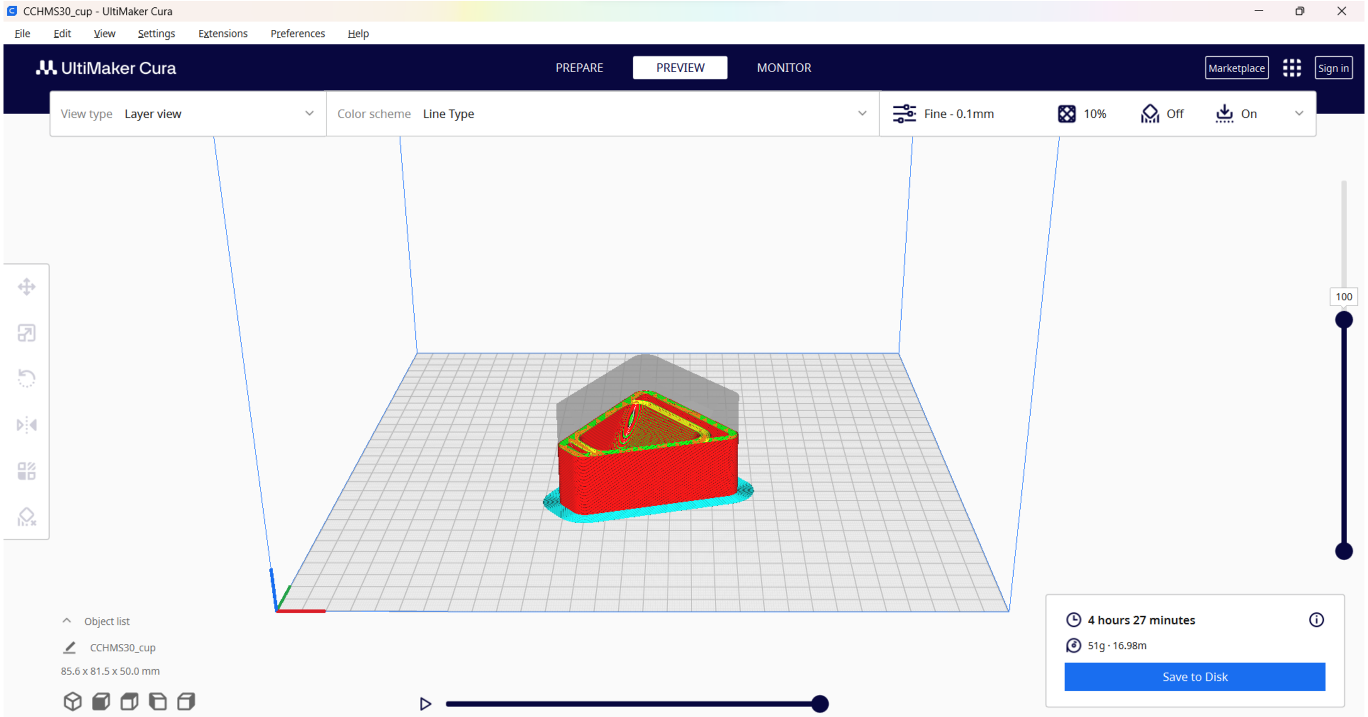
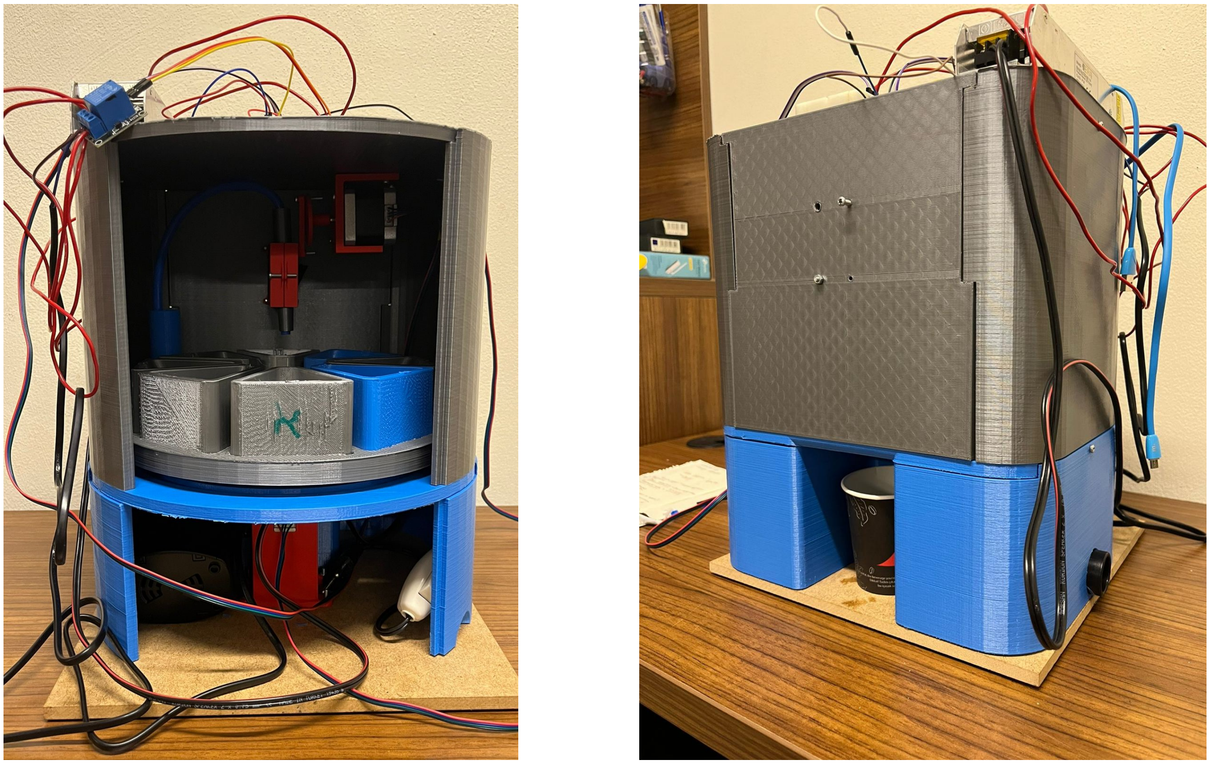


Figure 13: Ultimaker Cura for arranging the printing options.

3D printers made available by the mechanical engineering department were used in the manufacturing process of the designed parts. The CAD files created in Solidworks were saved in .stl format and sent to the technician responsible for the 3D printers. After arranging the printing options, such as infill, support, printing speed, layer thickness, etc., in the UltiMaker Cura environment, the parts were sent to MakerBot Replicator2 and MakerBot Replicator z18. An example of using Ultimaker Cura for one of the parts, namely one of the cups without a hole, is shown in Figure 13. The infill rate is shown to be 10%, the mass of the PLA that will be used is 51 grams, and the duration is estimated as about 4 and a half hours. As fasteners, 3mm diameter metric bolts and nuts were used to put together the assembly. The finalized assembly can be seen in Figure 14.



(a) (b)

Figure 14: Finalized assembly of the automated pill dispenser.

3.2.1 Vacuum Gripper Design

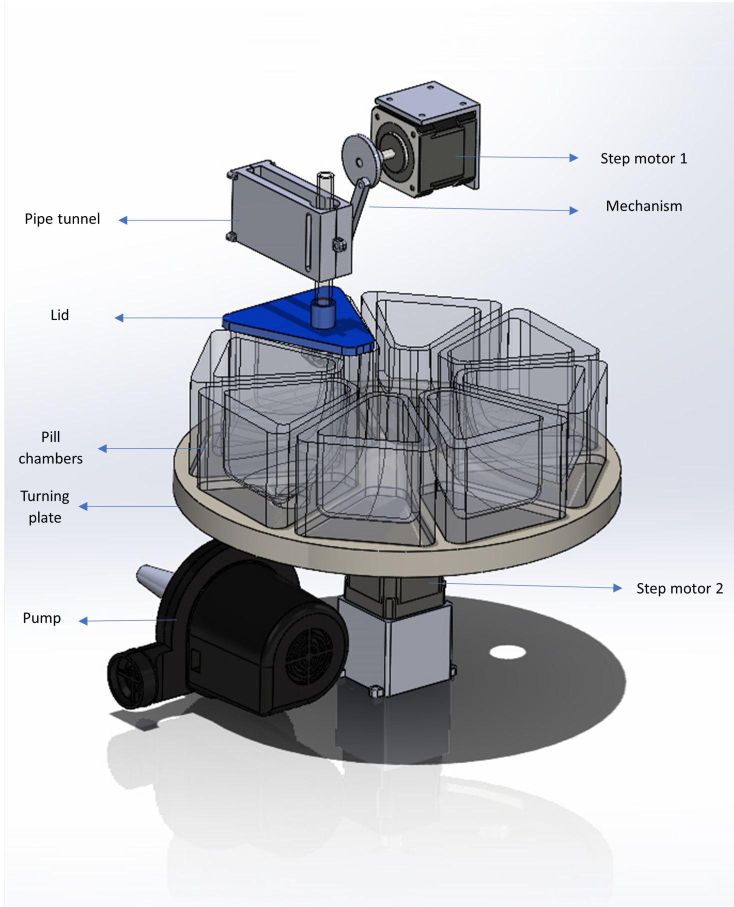


Figure 15: Gripper mechanism: overall parts - old design.

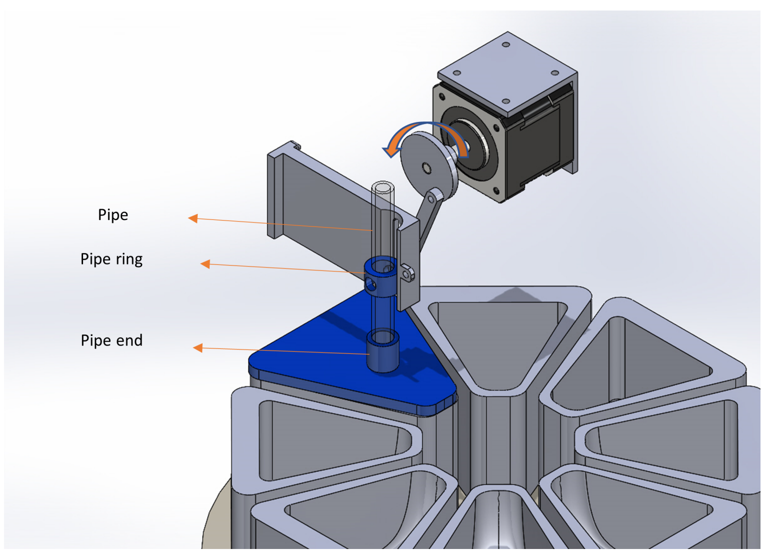


Figure 16: Previous pipe assembly.

The automated pill dispenser uses vacuum gripper to pick and drop the pills according to the user's needs. It should pick the right pills to dispense and give the user correct pills in correct amount while collecting the pills wanted inside a cup. To satisfy this design objective, two degrees of freedom was introduced and the pipe and the chambers were controlled according to that. For the pipe movement, Step motor 1 was used , which was attached to the mechanism allowing pipe to move inside the pipe tunnel and the lid as in Figure 15. The pipe tunnel was attached to the front wall aligned with the discharge outlet. Pump was attached with an elastic pipe. Pipe was attached to the mechanism with the help of smaller parts such as pipe ring and the pipe end as in Figure 16. Pipe end and the pipe ring were attached to the pipe with the help of a glue. Step motor 2 controlled the pill chambers via controlling the turning plate as in Figure 15.

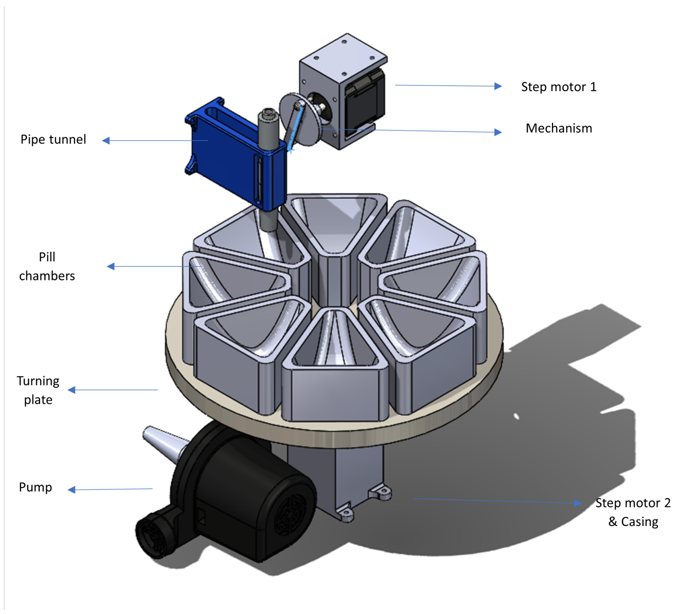


Figure 17: Gripper mechanism: overall parts - final design.

In the manufacturing process of the design, some design features were found to be unnecessary and some needed to be improved for better operation or strength. Final look of the design is shown in Figure 17. Step motor cases were altered to accommodate the mounting and the loads of the step motors. Pipe tunnel was changed to be a single part without assembly to minimize the vibration and relative movement of the separate parts with the movement of the mechanisms. Also the pipe ring and the pipe end is simply combined to become a new version of the pipe ring shown in Figure 18.

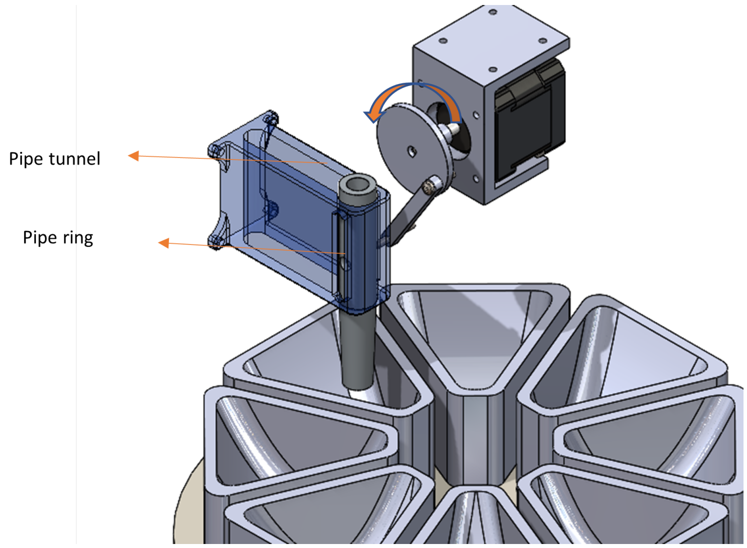


Figure 18: Final pipe assembly.

The step motor still rotates the mechanism 1 which exerts the rotation movement to the mechanism 2 to move the pipe ring up and down allowing a linear movement of the pipe withing a distance range as in Figure 19. When the pipe ring moved up and down, the pipe end moved with it; however, the lid movement was constrained by the pipe end and the chamber walls. So when the pipe started moving up it carried the lid after the pipe end touched the lid. When the pipe started moving down, the lid touched the chamber walls at some point and afterwards the pipe moved forward allowing the gripper mechanism to move. Mechanism 1 and 2 were attached with 2 mm screws and nuts allowing the rotational movement while inhibiting the translation. Then, the pipe ring was attached to the pipe tunnel slot and mechanism 2 in order to allow the rotational movement to become linear movement. Pipe ring moved linearly inside the slot with the help of 2 mm screw and nut.

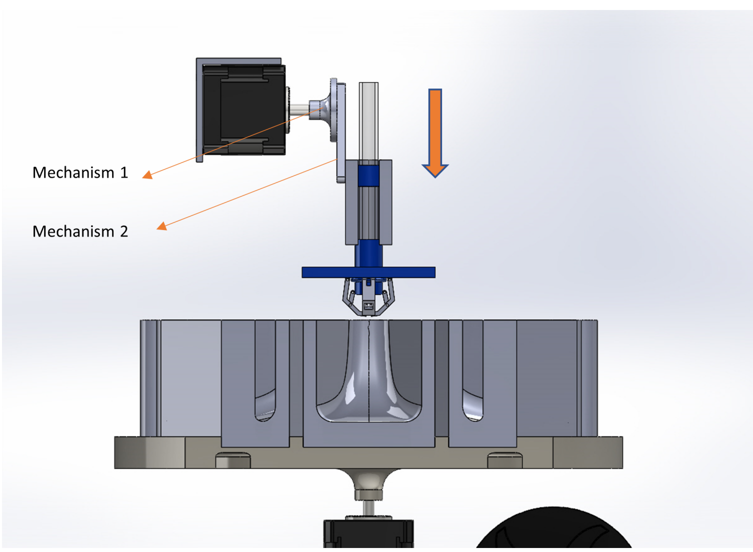


Figure 19: Previous version of mechanism movement illustration.

With the updates on the design shown in Figure 20, the lid was removed because the gripper design was canceled. After realizing that the suction was sufficient to hold the pills along the movement the gripper parts were dismissed. The claw movement was facilitated by the movement of the lid and the pipe end. The claws were attached to the lid from their roots and they were attached to the pipe from their center with another rod. The assembly uses 1 mm screws and nuts to minimize the claw dimensions. This is needed to provide the claw a movement ability inside the chamber without touching the pills inside the chamber or the chamber walls. The manufacture of claws and mounting needed to be very precise and the minimal dimensions made it very hard to manufacture with printers. When the gripper was dismissed, the need for the lid was idle.

While the fundamentals of the mechanism stayed the same, the range of the linear motion needed to be maximized to reach the bottom of the pill chambers and lift the pill high enough that it will not touch the chamber walls while they rotate to discharge the pill to the dispenser chamber. Thus, the mechanism 1 diameter was increased and the slots for the step motor was altered to fit the shaft design perfectly. Moreover, the pipe ring was elongated because the pipe had an initial tension causing it to curve and not go inside the chamber in a linear motions. Increasing the surface area of the part covering the tip of the pipe allowed the pipe to remain straight and sustain the linear motion. For further simplification, all of the holes corresponding to bolts were changed to 3 mm in diameter.

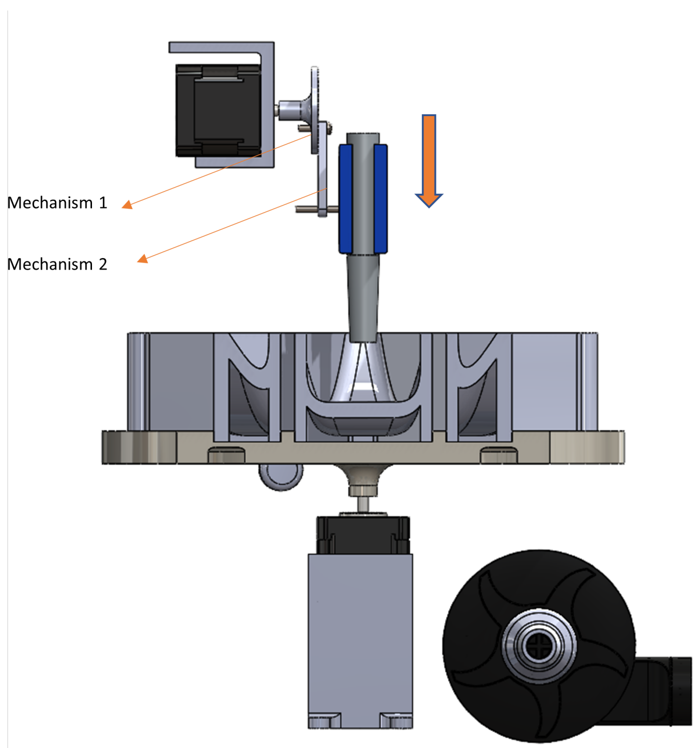
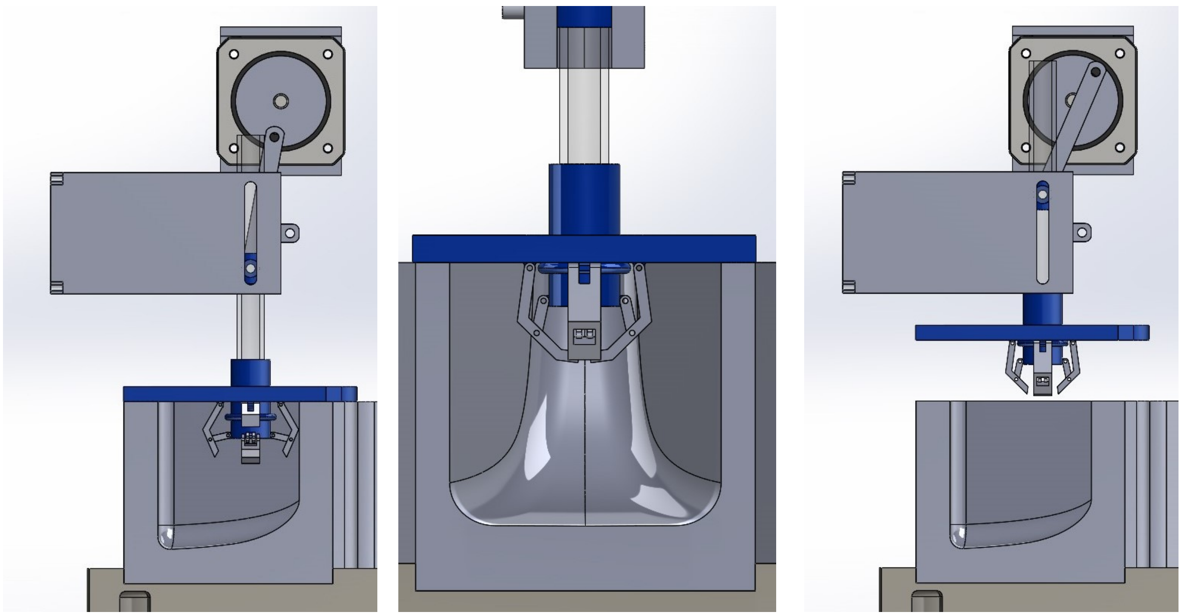


Figure 20: Final version of mechanism movement illustration.

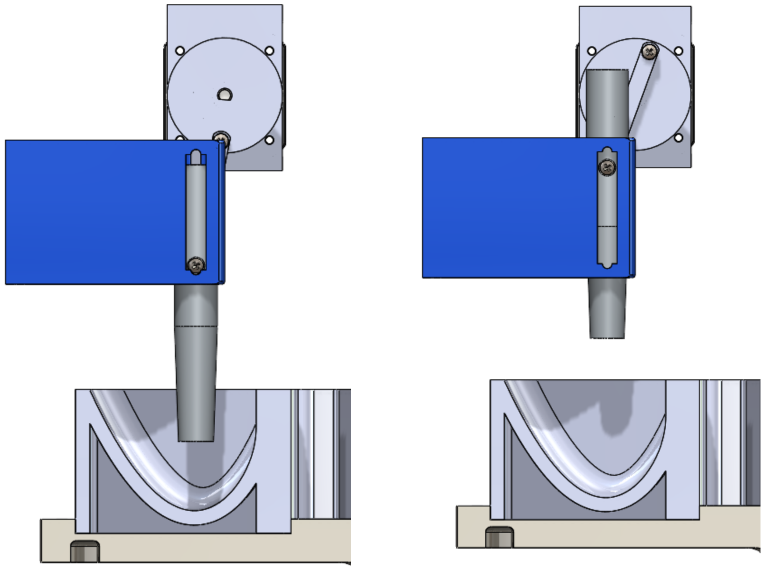
The main purpose of the mechanism is to grab the pill by vacuuming it first and then dropping it to the discharge chamber allowing pills to accumulate inside the dispenser cup while protecting it from falling inside the dispenser or other chambers causing errors in the final cup. When the pill is vacuumed, it stops at the tip of the pipe end and the pipe moves up to allow the turning plate to rotate and align with the discharge chamber allowing pill to fall to the final cup when the vacuuming stops. However, the vacuuming may fail to keep the pill at the tip of the pipe. To avoid that from happening, in the initial design, the gripper mechanism was added to the pipe end.



(a) (b) (c)

Figure 21: Gripper mechanism when the pipe is in its lowest and the highest positions.

The gripper mechanism works just like a robotic arm. In this design, the claw movement is provided by the linear movement of the pipe end with respect to the lid. When the pipe ring was at its lowest state as in Figure 21a, the claws opened up to allow the pill to get stuck on the tip of the pipe. After that the pipe end moved upward while the lid stayed in the same place allowing the claw to close up as in Figure 21b, making sure that the pill is inside and will not fall. When the pipe ring was at its highest state as in Figure 21c, the claws moved up to allow pill chambers to rotate and aligned with the discharge chamber while it had the pill inside the claws. When the alignment was accomplished, the mechanism made the same movement rotating the step motor for another 180°. The gripper took the shape in Figure 21a allowing pill to fall inside the cup when the vacuuming was finished.



(a) (b)

Figure 22: Final pipe end mechanism when the pipe is in its lowest and the highest positions.

With the final design alterations, going from lowest to the highest state still takes 180° clockwise movement of the step motor and going from highest to lowest takes another 180° clockwise movement. Step motor always turns in the same direction allowing a smoother movement. In the final design, when the pipe ring is its lowest position as in Figure 22a, it starts to vacuum and while it is vacuuming, it goes to its highest position as in Figure 22b. The chambers rotate to find the discharge chamber and the vacuuming stops when the pipe ring is its highest position. These parts are printed using PLA with 20 percent infill and mounted together as shown in the Figure 23.

Figure 23: Final manufactured version of the design.

3.2.2 Cups and Bottom Plate Design

The pill cups are designed to contain 30 pills comfortably. There are a total of 8 cups, 6 of which will contain the pills and 2 of which will function as discharge cups where there are holes concentric with the hole on the plate. The previous geometry of the cups was altered so that the pills were collected right where the pipe end would meet the pills. The cross-sectional geometry was upgraded to a curve with its lowest point coinciding with the central axis of the pipe.

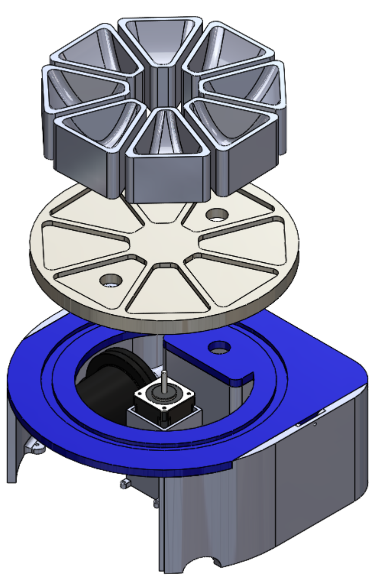
The plate carrying the cups, namely the bottom plate, has 8 indentations with the cups' exact shapes. There are two symmetrically located holes on the plate, as well, corresponding to the holes on the cups. A cylindrical extension is centered on the bottom side of the bottom plate where the stepper motor will be attached.

Since it was not wanted to load the stepper motor with axial forces, a bearing mechanism was designed to make the shell carry the bottom plate, cups, and pills. An annular canal was cut on the bottom face of the bottom plate to form the upper surface of the bearing. Another annular canal with the same geometry was created on the plate's top surface to form the bearing's lower surface. 4 cylindrical wheels were designed to be placed between the surfaces to complete the bearing design.

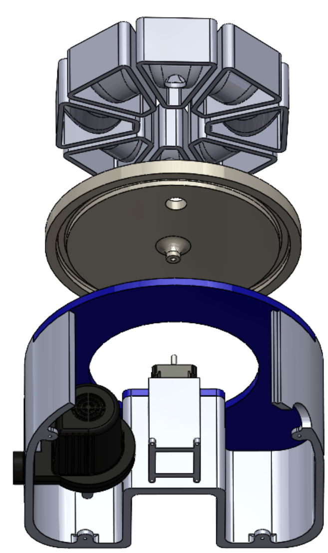
A 3D printer was used again for the manufacturing processes of the parts mentioned in this section. After manufacturing the bottom plate and wheels, the bearing mechanism was assembled. It was observed that the wheels caused friction between the other two parts and prevented the step motor from working properly. The friction was more detrimental to the step motor than the axial force caused by the turning plate without the wheels, which was the previous concern. Therefore, wheels were removed from the automated pill dispenser assembly.

After manufacturing each of the cups, they were sat onto their places on the bottom plate. The sub-assembly was finished after attaching the 3D-printed parts to the stepper motor.

The exploded view of the cups and bottom plate assembly can be seen in Figure 24.



(a)



(b)

Figure 24: Exploded view of the cups and bottom plate assembly.

Manufactured versions of one of the cups with a hole and the bottom plate can be seen in Figure 25. The final assembly of the cups and bottom plate can be seen in Figure 23 along with the vacuum gripper design.

Figure 25: Manufactured versions of one of the cups and the bottom plate.

3.2.3 Shell Design

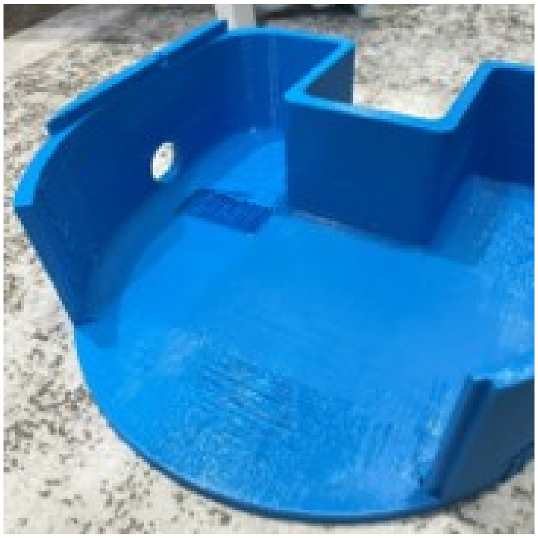
The automated pill dispenser is designed to fit on a regular counter, like a coffee machine. Its length, width, and height are 280mm, 280mm, and 320mm, respectively. The shell is divided into six parts to obtain an easy assembly. Those parts are the bottom, left wall, right wall, front, plate, and top.

The surface of the bottom is shaped to house the suction pump, and there is a hole where the pump exhaust can lean out of the automated pill dispenser. The pump is located on the bottom although the pipe will go through all the way up until the top part since its weight is not wanted to be carried by the top due to space and strength considerations.

There is also a semicircular outlet for electrical cables to go through at the bottom. The stepper motor is designed to be connected to the bottom via an intermediate part called the step table. Other electrical components such as the breadboard, motor drivers, and an integrated micro-controller are planned to be located on the bottom, as well. A cavity is created centered in the bottom to obtain space for the cup where the pill will be dropped.

The bottom part was divided into two parts due to the difficulties experienced during the 3D printing of the part: It took more than 14 hours, and the quality of the final product was extremely poor, so it could not be used in the main assembly. The lower plate of the bottom was separated, and a wooden plate, namely the base part, was added to the assembly. 4 attachment extensions were designed on the current bottom part.

The base part was produced in a carpentry shop. The updated bottom part was produced by a 3D printer. The previous and current versions of the bottom can be seen in Figure 26.



(a)

(b)

Figure 26: The previous and current versions of the bottom part.

The plate contains a discharge hole where the pill leaves the machine. There are two other holes on the sides of the plate, one of which is covered around and elevated to guide the pipe coming from the pump. The other hole is designed for electronic cables to reach from the lower side of the assembly to the upper side.

The thickness is set as 8mm for each part of the shell since they are the parts carrying most of the weight in the assembly. The back of the automated pill dispenser and the front edges are curved to obtain an aesthetic design.

The front part was previously designed to have two circular cutouts where it would be attached to the walls by using fasteners. Later, its design evolved into a sliding joint. It has complementary extensions that contact with similar ones on the walls and the top, ensuring that the part no longer has any degree of freedom. The automated pill dispenser is controlled with the chatbot, so the LCD screen previously located in the front was unnecessary and removed. The 3D-printed final version of the front part can be seen in Figure 27.

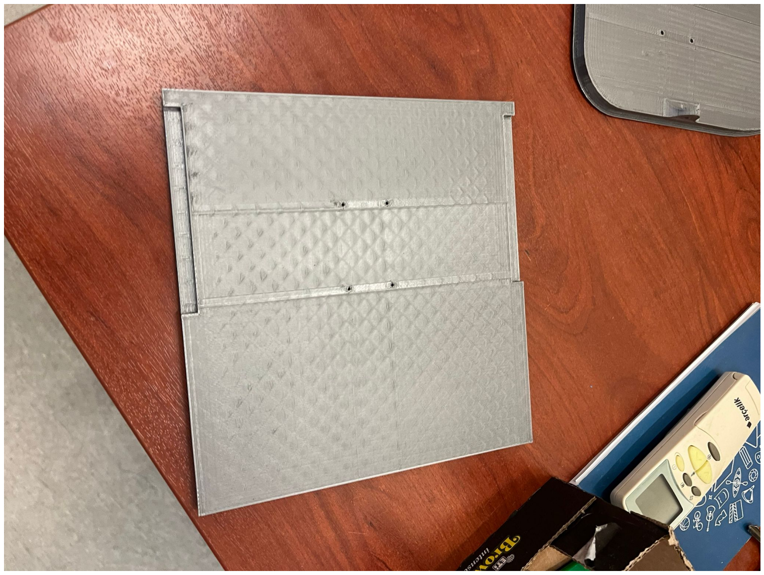
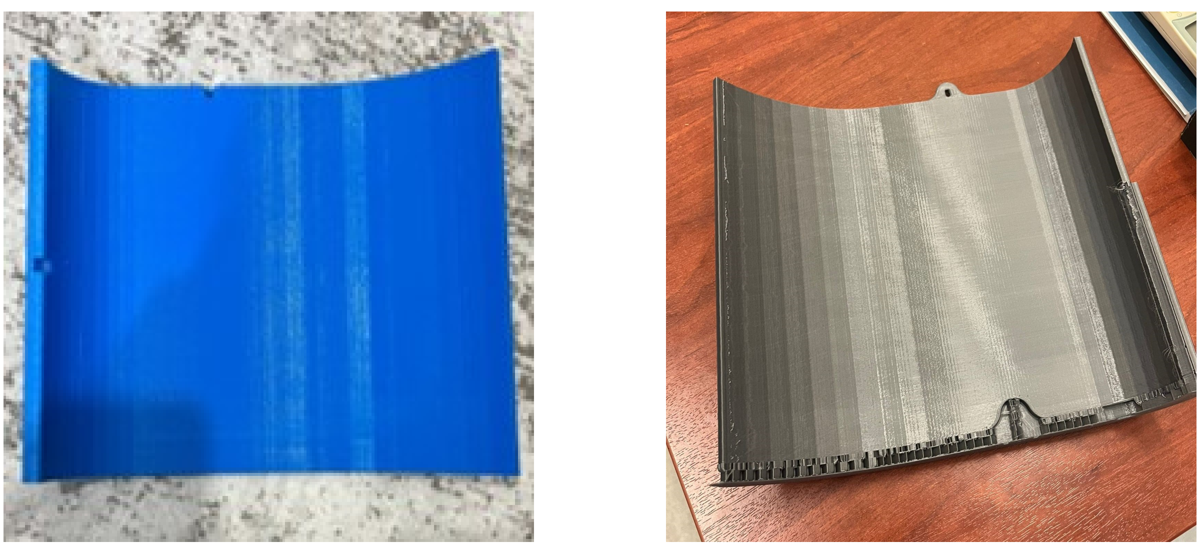


Figure 27: Final manufactured version of the front part.

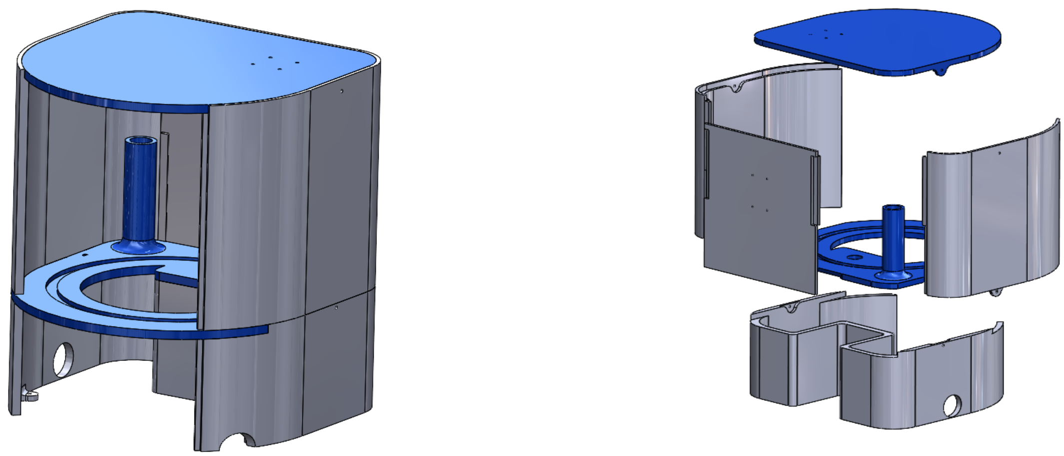
There are two symmetrical walls located on the left and right sides of the assembly. These walls were previously designed with smaller attachment extensions, which led to fractions and separations on the parts when tested on the assembly after their manufacturing by 3D printers due to unexpected excessive moments applied on them. This problem was solved by applying a conventional rule on structural design, which states that a circular cutout of a diameter D should be located at least 2D+1 mm away from an open edge. Following this rule, the extensions on every part of the shell were updated by enlarging them, which provided a more successful mounting. The extension modifications on the walls can be seen in Figure 28.



(a) (b)

Figure 28: The previous and current versions of the walls.

The back of the automated pill dispenser is left open to provide a clear vision of the inside of the device while it works for a more understandable demonstration. Drawings of all the parts involved in the shell design can be seen in Appendix A. The isometric and exploded views of the shell can be seen in Figure 29.



(a) (b)

Figure 29: Isometric and exploded views of the shell assembly.

3.3 Static Analysis

At the end of the mechanical design, the parts carrying loads are detected, and static analysis is conducted. The pills are carried inside the pill chambers, and the chambers are placed on the turning plate. The turning plate is rotated with the step motor, but the step motor should not carry an excessive amount of force on its turning axis. To eliminate that force exerted on the motor shaft, the turning plate was previously placed on top of some wheels. However, the load is carried by the step motor in the current version since the wheels are removed due to problems caused by friction.

For an extreme analysis, the pills are taken to be 3 grams each, and one chamber will hold 30 pills. The pill chambers and the turning plate were printed with PLA material with 10% infill. The material properties are given as in Table 3 [11].

Density	1250	kg/m^3
Yield Strength	60	MPa
Elastic Modulus	3.5	GPa
Poisson's Ratio	0.394	

Table 3: Material properties of PLA

The static analyses were conducted by assuming that the parts would be manufactured with 50% infill, however, they were all 3D-printed with 10% infill. Therefore, each cup without a hole weighed 51 grams, whereas each cup with a hole weighed 49 grams. The mass of the bottom plate is 258 grams, which sums up to 662 grams. After adding the supposed weight of the pills, the total axial force applied to the step motor is calculated to be 1200 grams. In subsubsection 3.4.1, the motor is chosen to be NEMA 17 according to the torque requirements caused by the pills' and the chambers' loads. The motor maximum load graph is shown in Figure 30 displays the maximum loads that can be sustained by the motor for 20000 hours life. The pills, chambers and the rotating plate only exerts approximately 12 N to the shaft in axial direction which is below the limits of NEMA 17. Thus, the wheels were dismissed and the friction caused by their crusty surface was eliminated. The shaft does not bend because the plate attachment is designed such that the moment will not be exerted on the motor shaft.

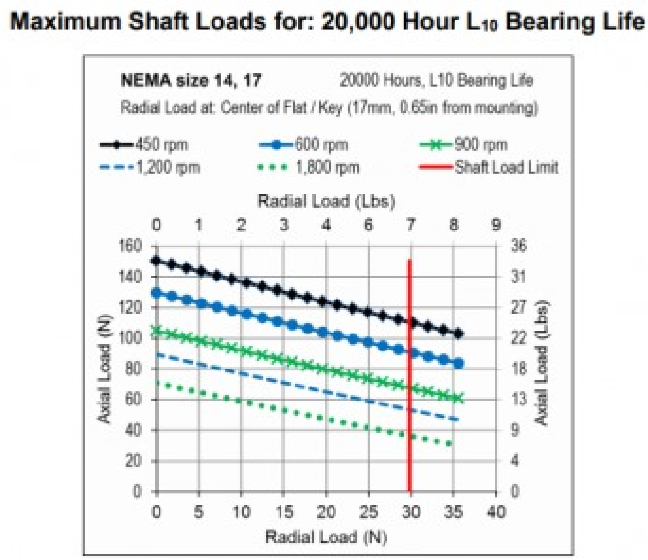


Figure 30: Maximum Axial Shaft Loads for NEMA 14-17 stepper motor[12].

The top of the automated pill dispenser carries the mechanism operating the vacuum pipe and lid movement for the above the pill chambers. The static analysis is conducted based on the step and the case loads. The top will carry 400 grams with the help of 4 bolts. The maximum stress is exerted around the bolts as 1.355 MPa and the maximum displacement is 0.0544 mm. The static analysis is done to understand the impact of the pill load to the turning plate. Turning plate which is called "bottom-plate" in the assembly tree has a maximum displacement of 0.0009 mm and the maximum stress is 71.98 kPa. Finally, all the significant loads and gravity is forced on the shell assembly as a whole and the sensitivity points are detected to be the stationary plate connections with the rest of the shell and the top. The maximum stress is exerted 686.4 kPa and the maximum displacement is 0.0778 mm.

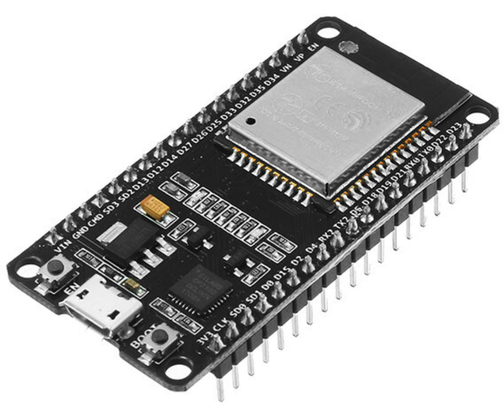
The static analysis results for these parts showing displacement and stress analysis are in Appendix B.

3.4 Electrical Design and Components

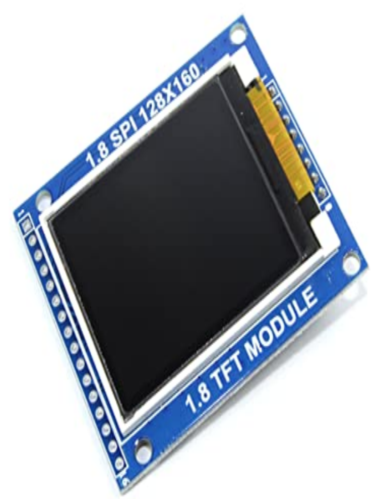
With the mechanical design, the second key component to obtain the required functionality is the electrical design. These functionalities are:

- Communicate with the user.
- Rotate the pill chamber to access selected pill boxes.
- Rotate the crank for the linear mechanism of suction.
- Run the suction pump on command.
- Wirelessly connect with the database.

The circuit satisfying these purposes is given in Appendix C. Drawings are made in Proteus where not every specific component is present. Therefore, components with similar footprint are used and connections are numbered to show corresponding pin connections. For the microcontroller, ESP32 in Figure 31a is picked mainly since it has built-in Wi-fi and Bluetooth modules for the wireless connection. It also outperforms Arduino-Uno in nearly every aspect of computing performance and memory while having smaller dimensions[13]. For alerting the user, the typical Arduino Buzzer and LED's were planned to be used[14]. In addition, a TFT-LED touchscreen in Figure 31b was aimed to be used for the user interfacing, but then use of Telegram to communicate with and notify the user is preferred, which is easier for the user to give commands, and it doesn't create additional cost. One other aspect is that, the pumps and stepper motors were already creating enough noise. Therefore, the buzzer was not needed and is not used for the final device. The components that were not used are still left in the electrical schematic and the Arduino code for educational purposes.



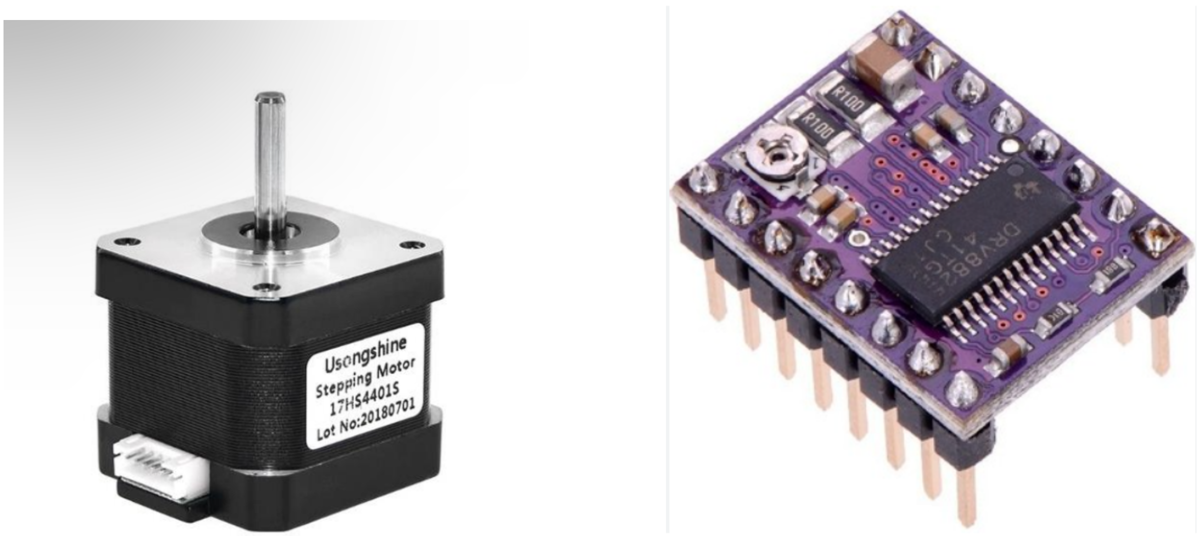
(a)



(b)

Figure 31: High level circuit components: (a) ESP32, (b) 1.8 Inch TFT LCD Screen Module.

For the motions of rotation, NEMA17 stepper motor in Figure 32a is used to satisfy torque requirements as will be explained in subsubsection 3.4.1. For the motor driver, DRV8825 in Figure 32b is used as it is cheap, commonly accessible for purchase in Turkey and compatible with NEMA17 as well as ESP32[15]. Power source that will be used is 220V to 12V 20A. With 2 stepper motor needing a total of 2.4 A and a pump with 2A, with the other components a total of 0.5 A the current requirement of 4.9A [15] is well below the 20A.



(a) (b)

Figure 32: Electric motor circuit components: (a) NEMA17, (b) DRV8825.

To avoid confusion about the connections in the Proteus drawing, the pins on the ESP32 and their corresponding equipment connections for each connection are given below. First part is the equipment and second part is the pin of the equipment and which pin of the ESP 32 they are connected to.

PINS

LED: 22

BUZZER: 21

VACUUM: 19

LCD: CS 10, $RESET$ 15, SDI 11, SCK 12, LED 3.3V, $TCLK$ 12, TCS 34, $TDIN$ 11, TDO 13

STEP1: STEP 16, DIR 17

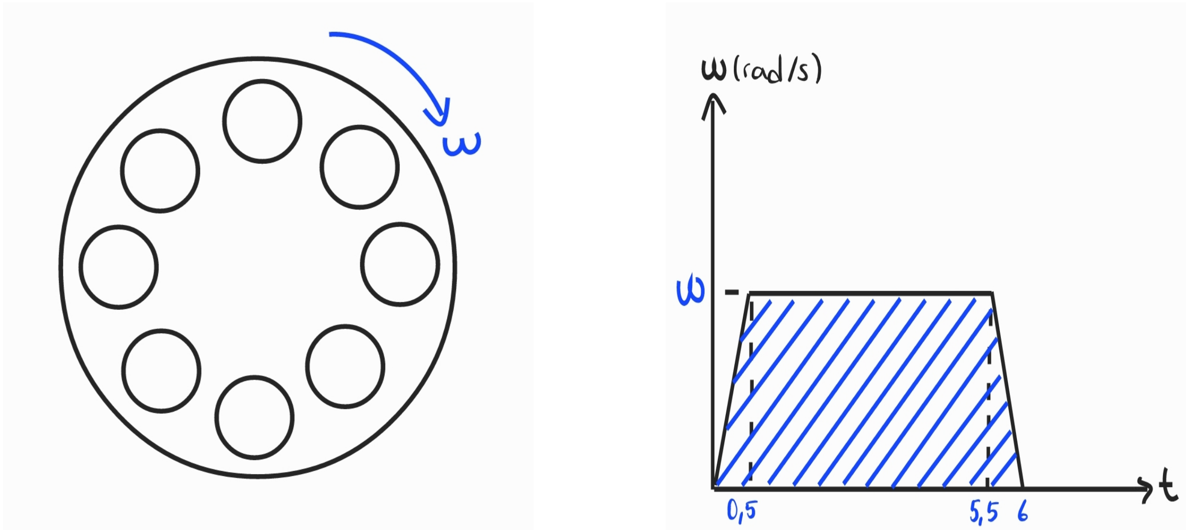
STEP2: STEP 5, DIR 18

RELAY: 32

3.4.1 Step Motor Analysis

The maximum weight the stepper motor can rotate is calculated using the holding torque information provided in the specifications of the NEMA17 stepper motor, which is 0.311 Nm

[16]. A full rotation in 6 seconds is assumed. The radius of the plate is 120 mm.



(a) Rotation of the plate

(b) Radial velocity vs. time graph

Figure 33: Symbolic drawings: (a) Rotation of the plate, (b) Radial velocity vs. time graph.

The rotation of the plate with a radial velocity ω is shown in Figure 33a. The area under the radial velocity vs. time graph shown in Figure 33b should be equal to 2π, which represents a full rotation, shown in Equation 1.

$$2\pi = \frac{11\omega}{2} \tag{1}$$

$$\omega = \frac{4\pi}{11} rad/s \tag{2}$$

The slope of the curve in the beginning is the radial acceleration that the stepper motor should provide to start the rotary motion of the plate, calculated in Equation 3.

$$\alpha = \frac{8\pi}{11} rad/s^2 \tag{3}$$

The formula of the torque provided by the motor depending on the mass moment inertia and the radial acceleration of the plate is illustrated in Equation 4.

$$T = I\alpha \tag{4}$$

The mass moment of inertia can be calculated using the mass and the radius of the plate, assuming the plate is a perfect cylinder, shown in Equation 5.

$$I = \frac{1}{2}MR^2 \tag{5}$$

$$T = I\alpha = \frac{1}{2}MR^2\alpha \tag{6}$$

Finally, the maximum mass of the plate is calculated in Equation 7.

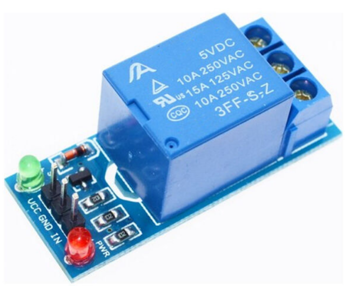
$$M = \frac{2T}{R^2\alpha} = \frac{2(0.311Nm)}{(0.12m)^2 \frac{8\pi rad}{11s^2}} \tag{7}$$

$$M = 18.9kg \tag{8}$$

The total mass that the stepper motor will rotate is 1.2 kg. The data is taken from the Solidworks data. It can be seen that the maximum weight the stepper motor can rotate is almost 15 times the mass we will use. Therefore, this stepper motor is appropriate for our design.

3.4.2 Secondary Electrical Components

To control the pump, an Arduino 5V 1 Channel Relay card is used [17]. Since the air pump is drawing 1.7 A current, it is well under the Relay upper limit of 10 A. One other requirement was to convert 12V supplied by the power source to the 5V required by the ESP32. Since the requirement from ESP32 is around 260 mV the LM2596 with 2A capability was selected [18] . Initially, to check if the pump has gripped a pill a current sensor was planned to be used. When using a multimeter, a difference of 0.1A was observed between the gripped and non-gripped states. Unfortunately, AHS712 which is the only available current sensor in budget range was unable to detect this difference since the measurements from it were changing in values +-0.4 for our current value which is around 1.7 A [19]. An improvement could be using Shunt-type current sensors which are reliable with an error around % 0.5.



(a) 5V Relay Card

(b) LM2596 Voltage Buck Converter

Figure 34: Secondary components: (a) 5V Relay Card, (b) LM2596 Voltage Buck Converter.

The image of final circuitry is given below.

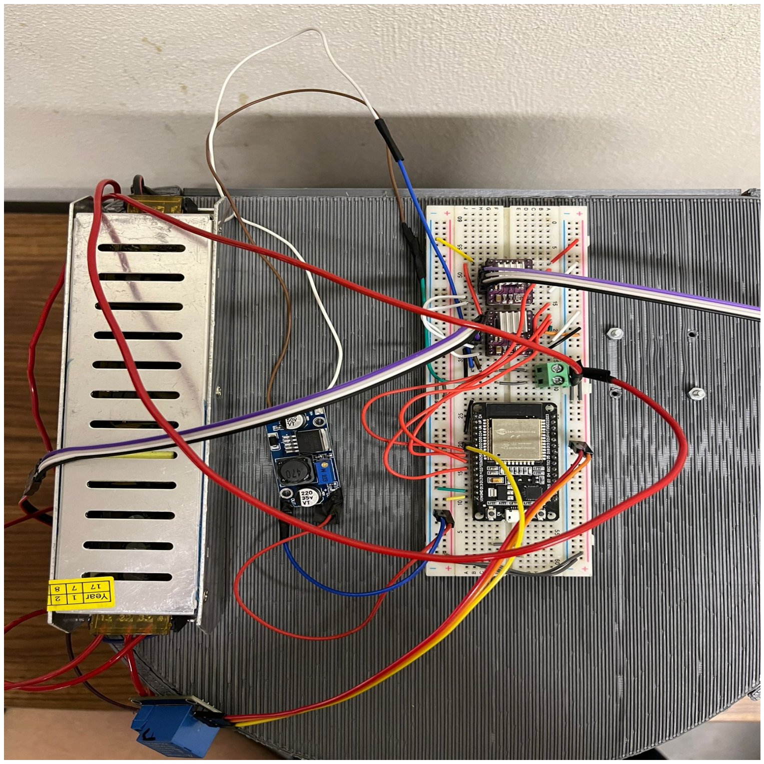


Figure 35: Final cirucit of the design.

3.5 Algorithm

After deciding on the mechanical and electrical components, the required algorithm is decided. Detailed pseudo-code, Google Scripts code and implemented Arduino code is given in Appendix D. Firstly, the input for the medicine adherence calendar is taken from Bluetooth. Then the user insert each different type of pill in a different container. After that, when the pills are inserted to their corresponding containers, if the time to take pill comes, the pill chamber rotates by the first stepper, the required amount of times to take the correct pill. Then, the other servo rotates to get the air pump pipe closer to the pill. When air pump pulls the pill, the air pump pipe goes back to the original configuration, and then the pill box goes back to the original configuration as well. In the initial configuration, container that is under the pump has a hole and the pills released to this container exits the dispenser. When all the pills in the medicine adherence calendar is released from the pill dispenser, it goes back to waiting for another calendar from the Bluetooth.

We have not implemented the date checking since it was out of scope of the engineering functionality. Still, Telegram functionality can interact with the Google Scripts to get medicine information from the Google Sheets. Again, current Arduino code is able to give the selected pill through Telegram prompting. An example interaction with Telegram to give commands to the dispenser is given below.

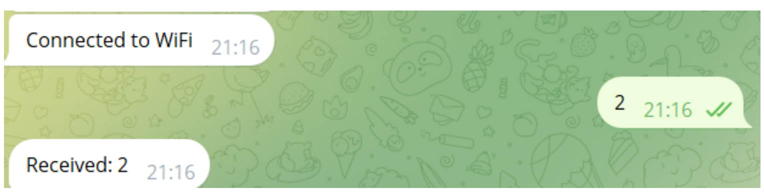


Figure 36: Example command to take the pill in the second pill box.

Further improvements for the algorithm could be to consider the amount of pills left in the box to select how much should the pipe go inside the pill boxes.

3.6 Experimental Results

After finishing the manufacturing phase, all of the parts were assembled. The complete assembly was tested multiple times with applied modifications and on pills of different sizes. After having a sequence of 10 trials on small, medium, and large pills, collected data on the percentage success rate of the automated pill dispenser is shown in Table 4.

Pill Size	Percentage Success Rate*
Small	100%
Medium	70%
Large	50%

Table 4: Success rates of the pill dispenser based on the pill sizes.

4. Cost Analysis

Although the prices are prone to change, the costs for the equipment needed can be seen below in Table 5. M1 bolts and nuts were not sold in small quantities, and therefore it was required to buy a set rather than 12 of each. Shipping cost is not included since all of the equipment are all eligible for free shipping or can be purchased by going to the corresponding physical stores. The cost for the PLA is covered by the Mechanical Engineering Department. We also opted out from using TFT LCD Touchscreen Module, Buzzer and LED's for our final design since we were already past our cost limit by then.

Table 5: Cost Analysis of Automated Pill Dispenser

Equipment	Quantity	Unit Price(TL)	Total Cost(TL)
NEMA 17 Stepper Motor	2	189TL /Piece [20]	378
BreadBoard 830	1	35TL /Piece [21]	35
DRV8825	1	31,5TL /Piece [22]	63
BreadBoard Jumper Cables	1	35,71TL /Piece [23]	35,71
LED	1	0,5TL /Piece [24]	0,5
Arduino Buzzer Module	1	7,51TL /Piece [25]	7,51
Power Supply 220V-12V-20A	1	239TL /Piece [26]	239
12V-5V Arduino Converter Module	1	42,82TL /Piece [18]	42,82
12V Vacuum Pump	1	229,94TL /Piece [6]	229,94
3D Printer PLA	2	231TL /Kg [27]	462
M3 Bolt	20	29,17TL /20 Piece [28]	29,17
M3 Nut	20	5,06TL /10 Piece [29]	10,12
M2 Bolt	5	5,02TL /10 Piece [30]	5,02
M2 Nut	5	10,99TL /5 Piece [31]	10,99
M1 Bolt	12	200TL /Set of 200 [32]	200
M1 Nut	12	Bought together with M1 Bolt [32]	0
Hinge 10x11mm	4	40TL /4 Piece [33]	40
ESP32 Wi-fi Bluetooth Microcontroller	1	155,76TL /Piece [34]	155,76
Multimeter	1	237,03TL /1 Piece [35]	100
5V Relay	1	17.45TL /1 Piece [17]	100
Cable Stripper	1	237,03TL /1 Piece [36]	215
Total Cost			2276,99

5. Conclusion

In this project, an automated pill dispenser is designed, modeled, simulated, manufactured, and eventually assembled. The design aims to address medication management challenges, especially for elderly people with diseases like Alzheimer's or who need to take different medications with complex regimes.

Initially, research was undertaken to see what type of solutions for the mechanism of pill dispensers are done. Then, a rotating pill chamber was chosen with different pill containers and an air pump for dispensing pills.

Accordingly, a basic mathematical model of the system for both the air pump and the pill chamber was created. Multiple iterations with different dimensions were performed in simulations to find an optimal design considering the design and cost requirements. In the manufacturing process, the design was further improved and simplified for better performance. Unnecessary design features and precautions were omitted. All the designed parts were manufactured using the 3D printers provided by the mechanical engineering department. A software to wirelessly control the final product was developed.

The biggest design challenge was to work with an air pump and pipes with head losses as the performance parameters were not provided. The future modifications over improvement suggestions were provided in the report. The pill dispenser reliability was sufficient at this stage. The improvements can enhance the reliability and safety of the dispenser. The pill dispenser is able to provide the user with the correct amount of pills in correct timing using a vacuum gripper. The current value of 2276,99TL for the production is less than the aimed production price of 100$ (2982,29TL as of the time of writing the report). Pseudo code for the algorithm, Arduino code, technical drawings, and electrical circuit drawings can all be found in the Appendix.

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[34] Motorobit. *ESP32S Modül Wifi ve Bluetooth Modülü*. Accessed: May 24, 2023. 2023. URL: https://www.motorobit.com/urun/esp-32s-modul-wifi-ve-bluetooth-modulu?gad=1&gclid=CjwKCAjwscGjBhAXEiwAswQqNIj8Be0M5i0a%2035QZiYUmt_NmZGAmSdH8woZ%20ZqId7ABoCrMIQAvD_BwE.

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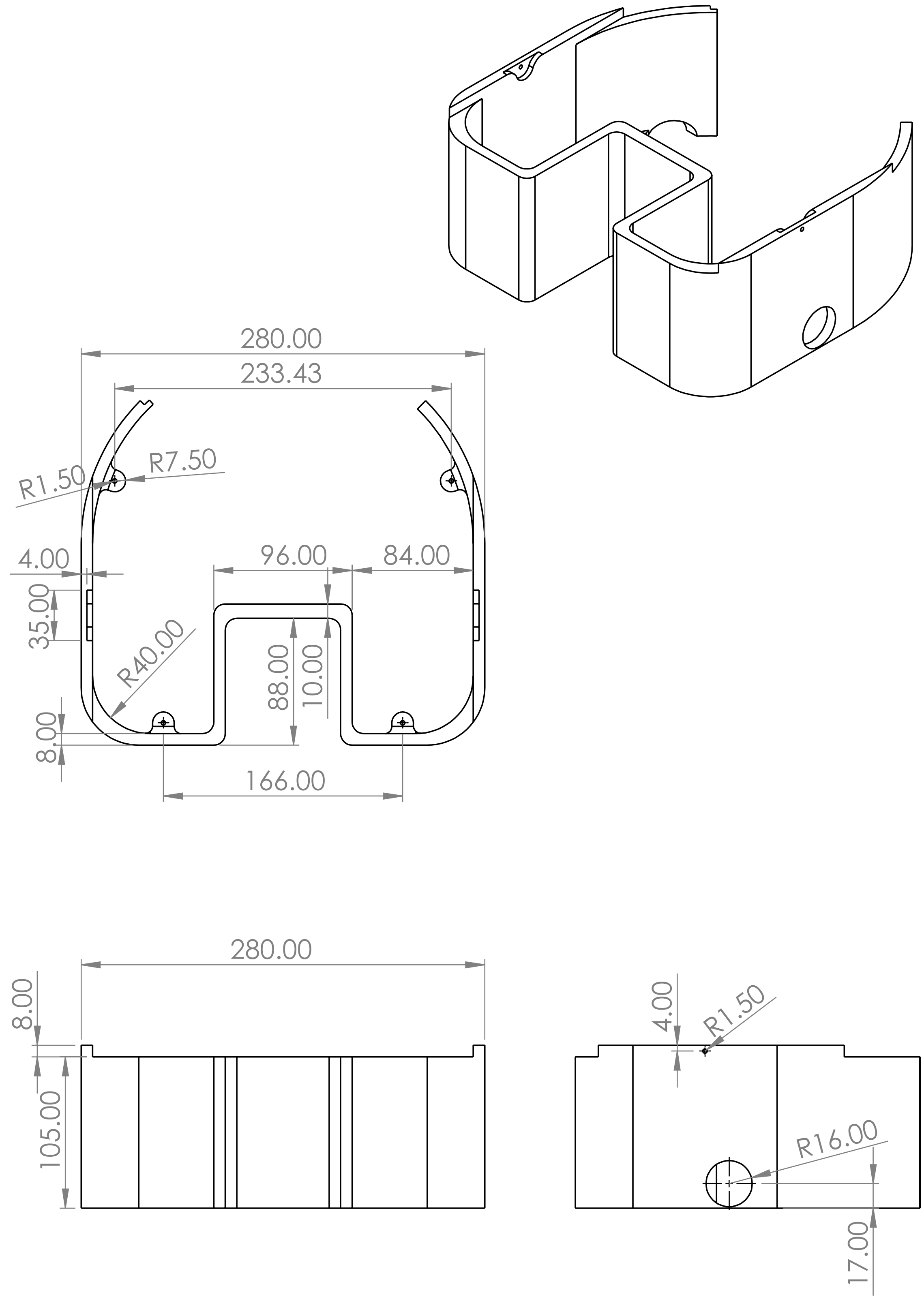
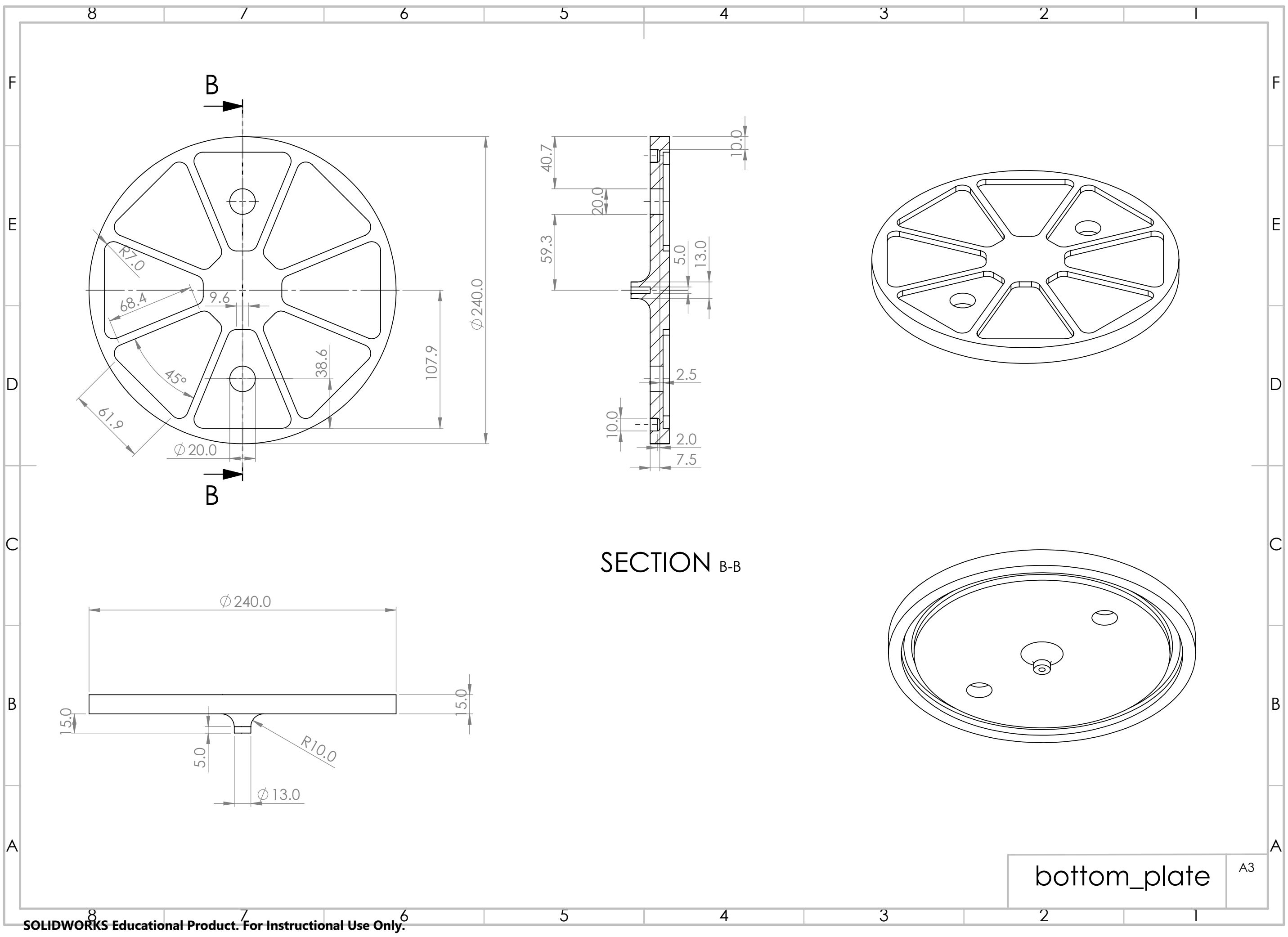
Appendix

A Technical Drawings


280.00
233.43
R7.50
R1.50
4.00
96.00
84.00
35.00
R40.00
88.00
10.00
8.00
8.00
166.00
280.00
8.00
105.00
4.00
R1.50
R16.00
17.00

bottom


B
B
R7.0
68.4
9.6
45°
61.9
38.6
107.9
⌀240.0
⌀20.0
40.7
20.0
59.3
5.0
13.0
10.0
2.5
10.0
2.0
7.5
SECTION B-B
⌀240.0
15.0
15.0
5.0
R10.0
⌀13.0
bottom_plate
A3
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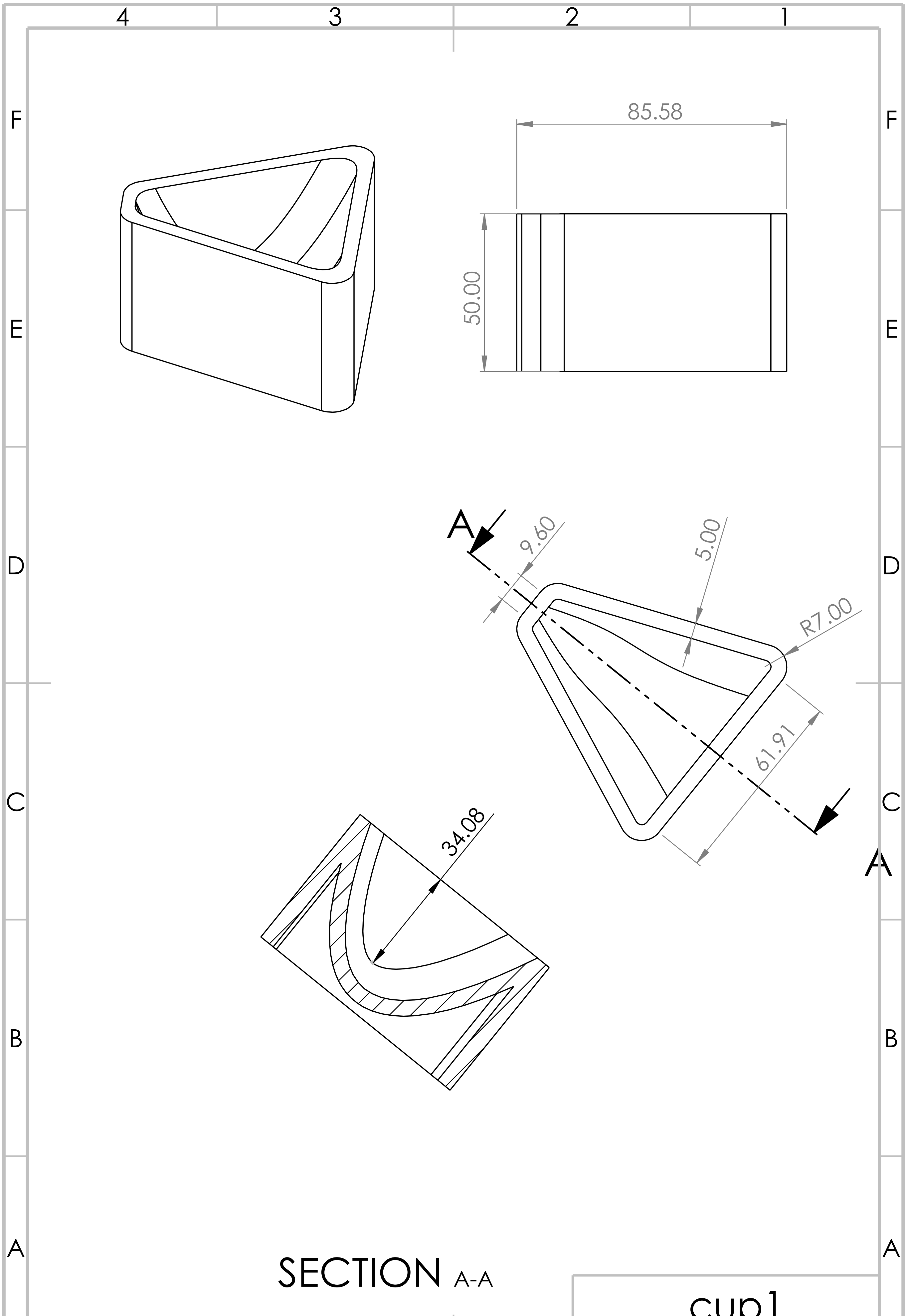
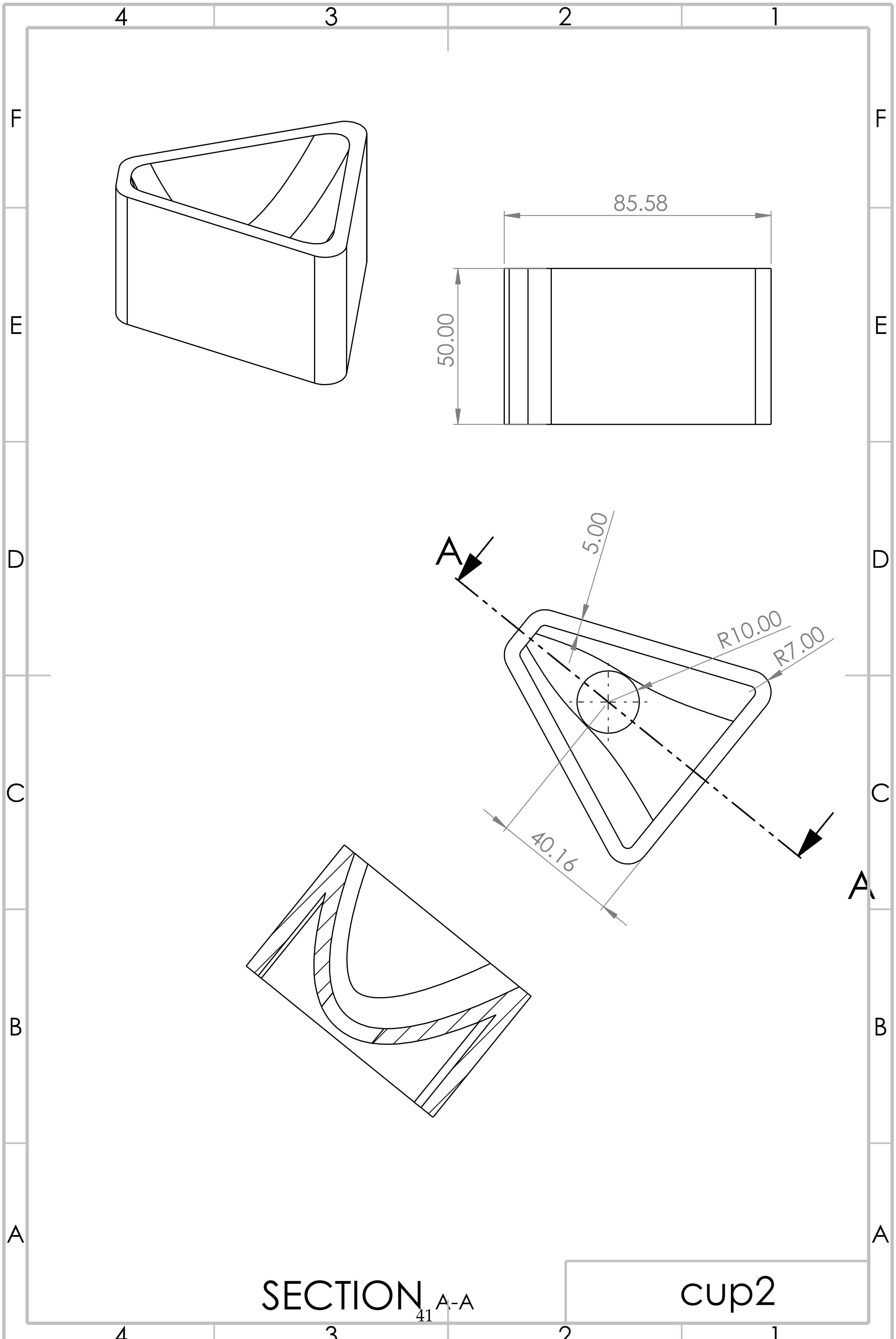
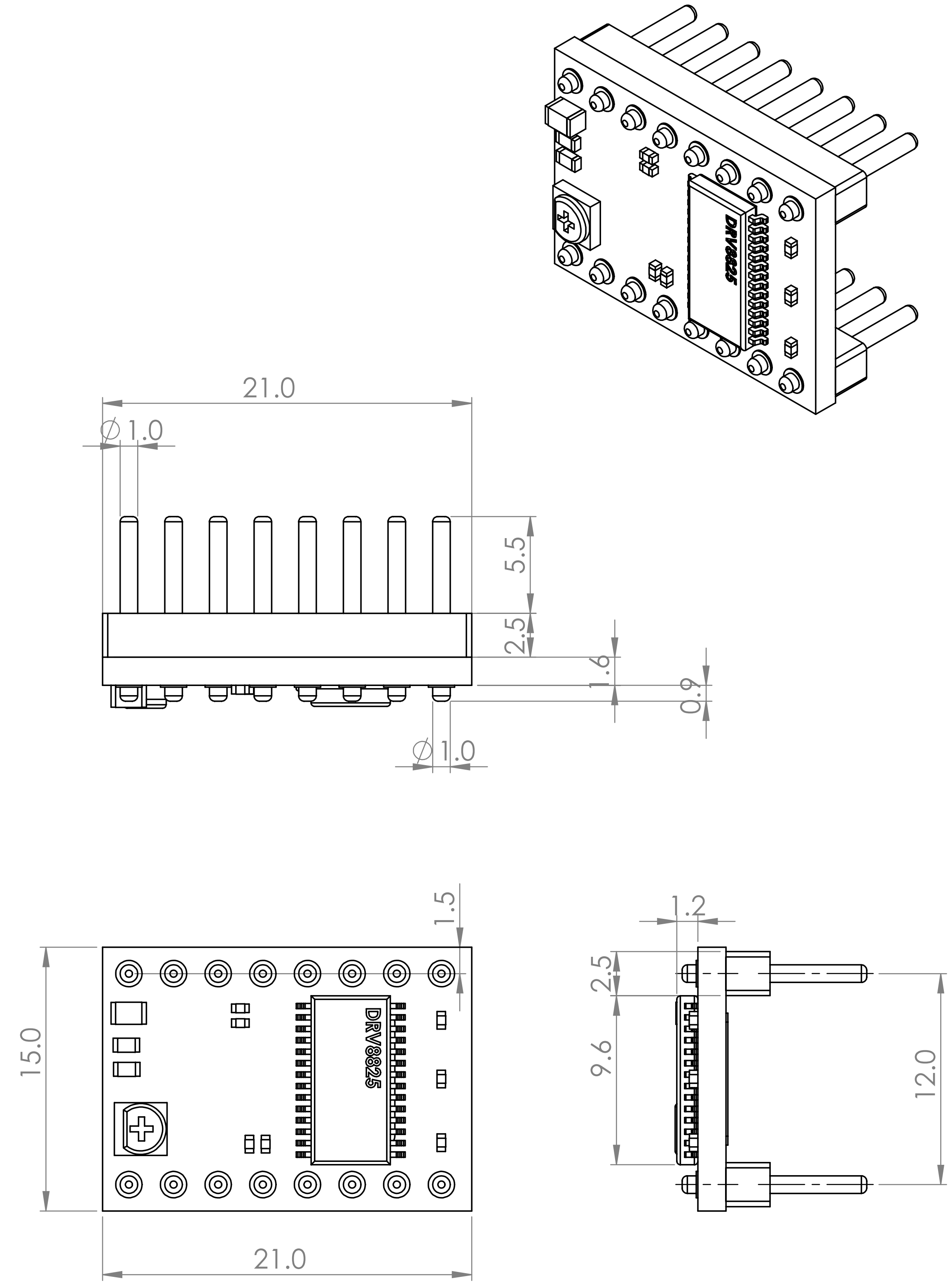
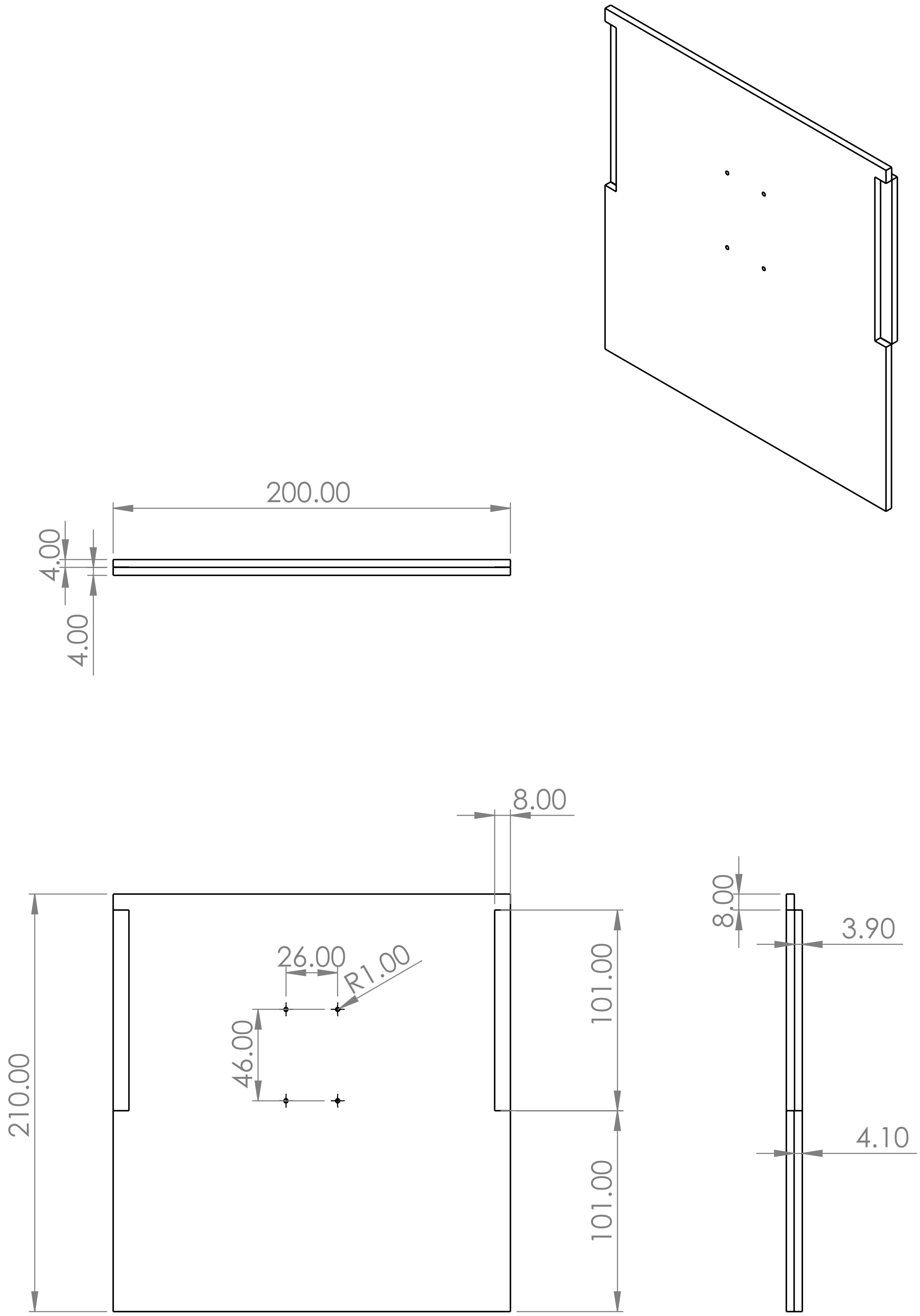

85.58
50.00
A
9.60
5.00
R7.00
61.91
A
34.08
SECTION A-A
cup1

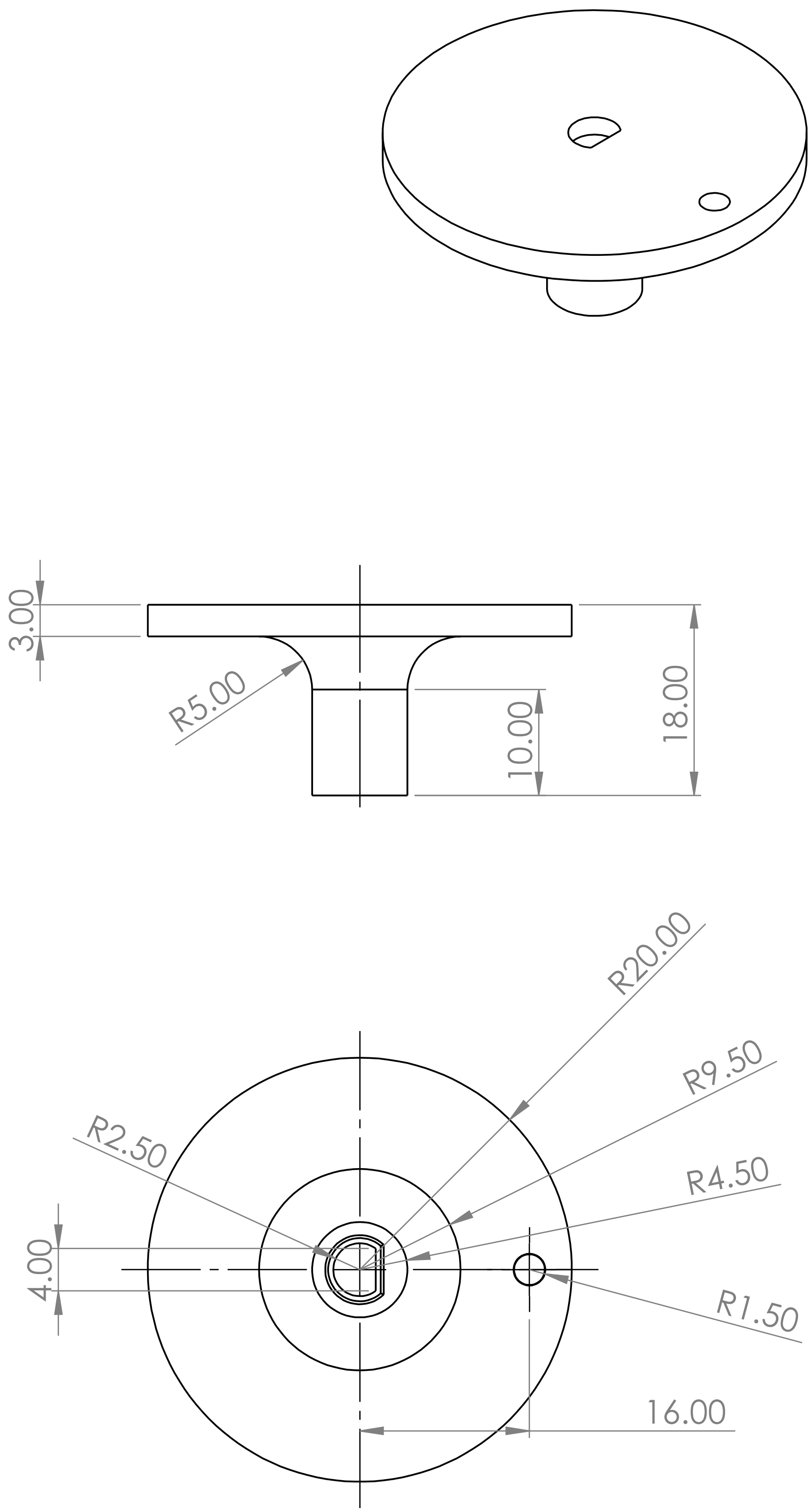

85.58
50.00
5.00
R10.00
R7.00
40.16
A
A
SECTION A-A
cup2



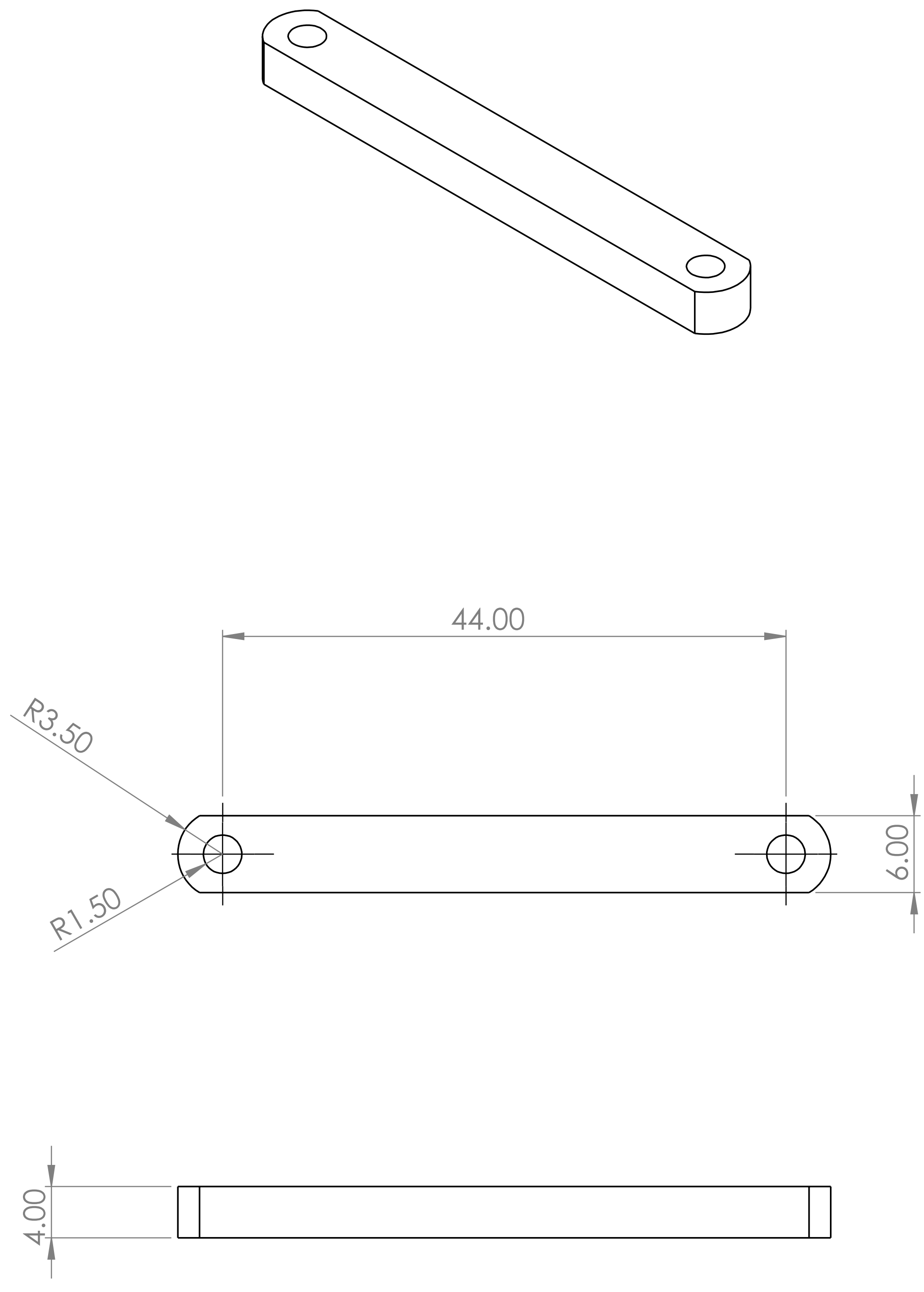
driver


200.00
4.00
4.00
8.00
210.00
26.00
R1.00
46.00
101.00
101.00
8.00
3.90
4.10

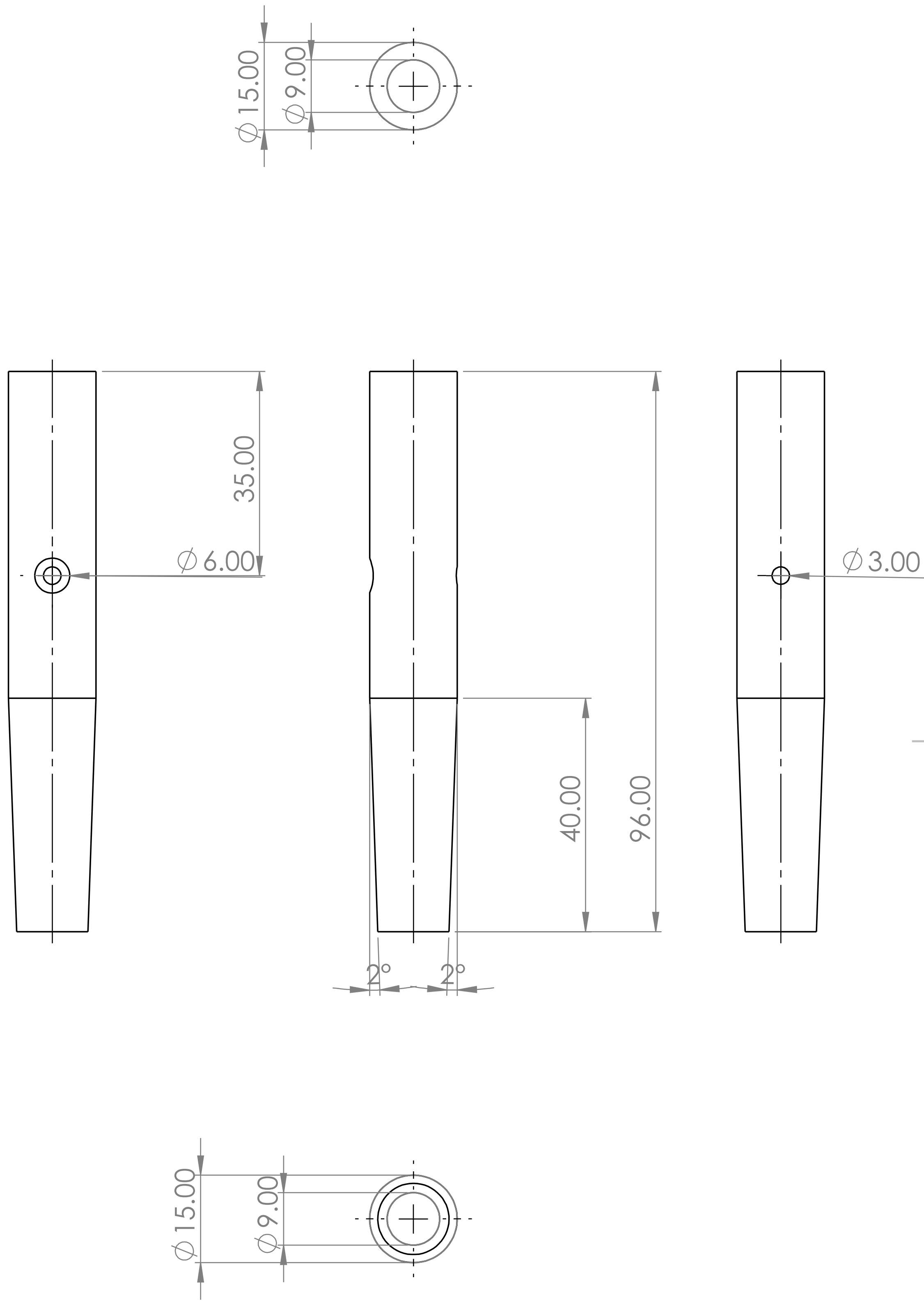
front



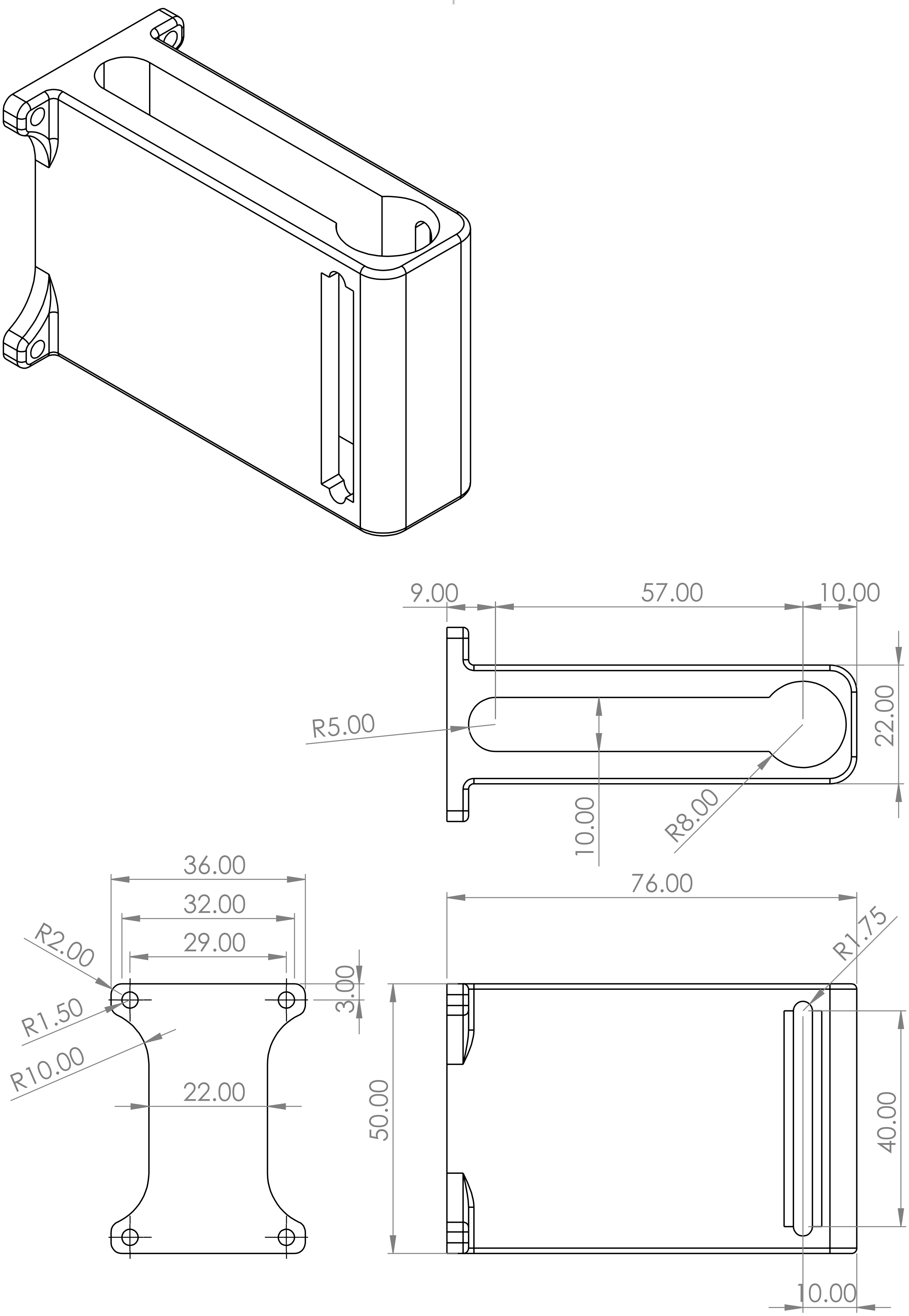
mechanism1



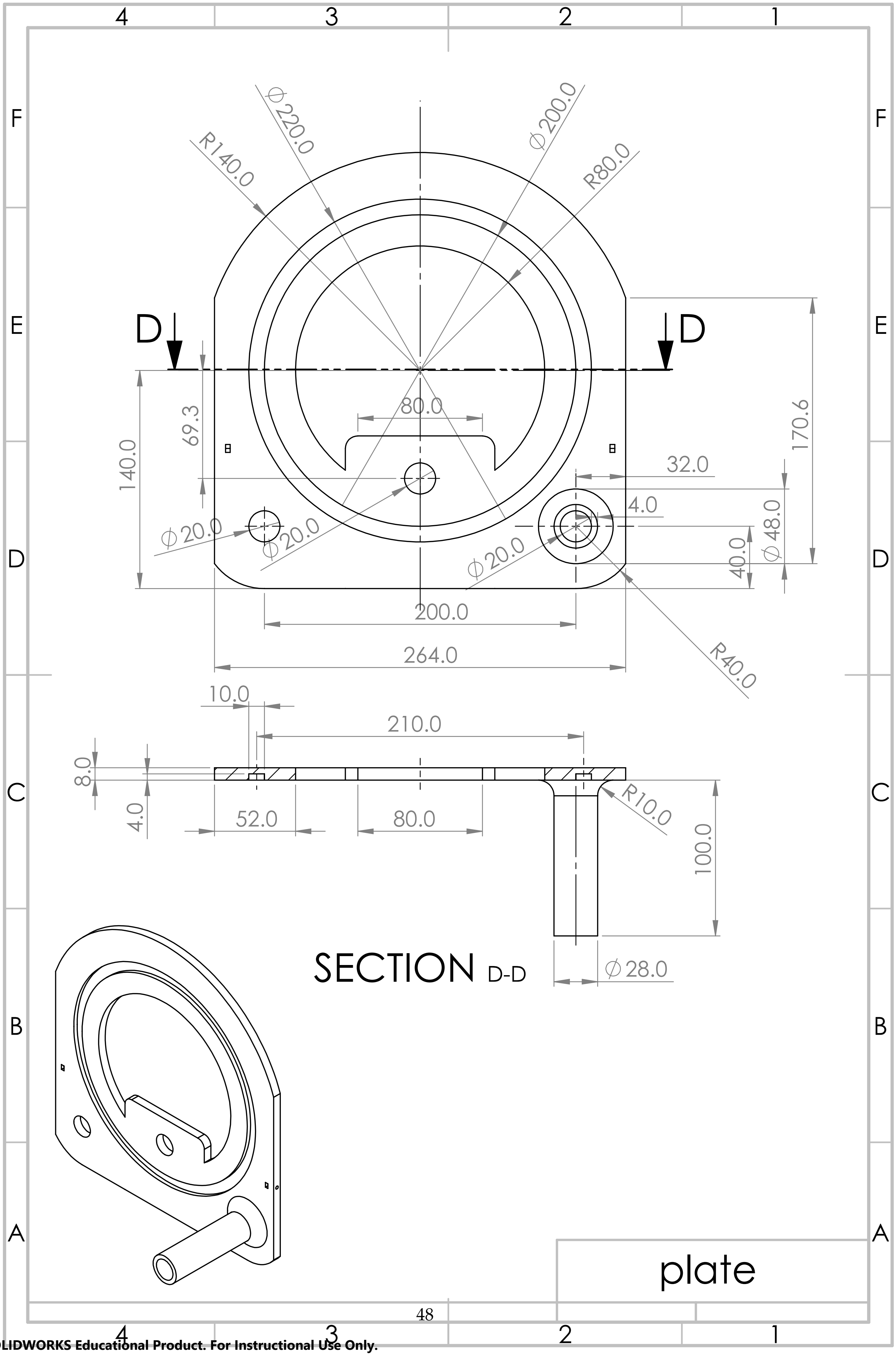
mechanism2



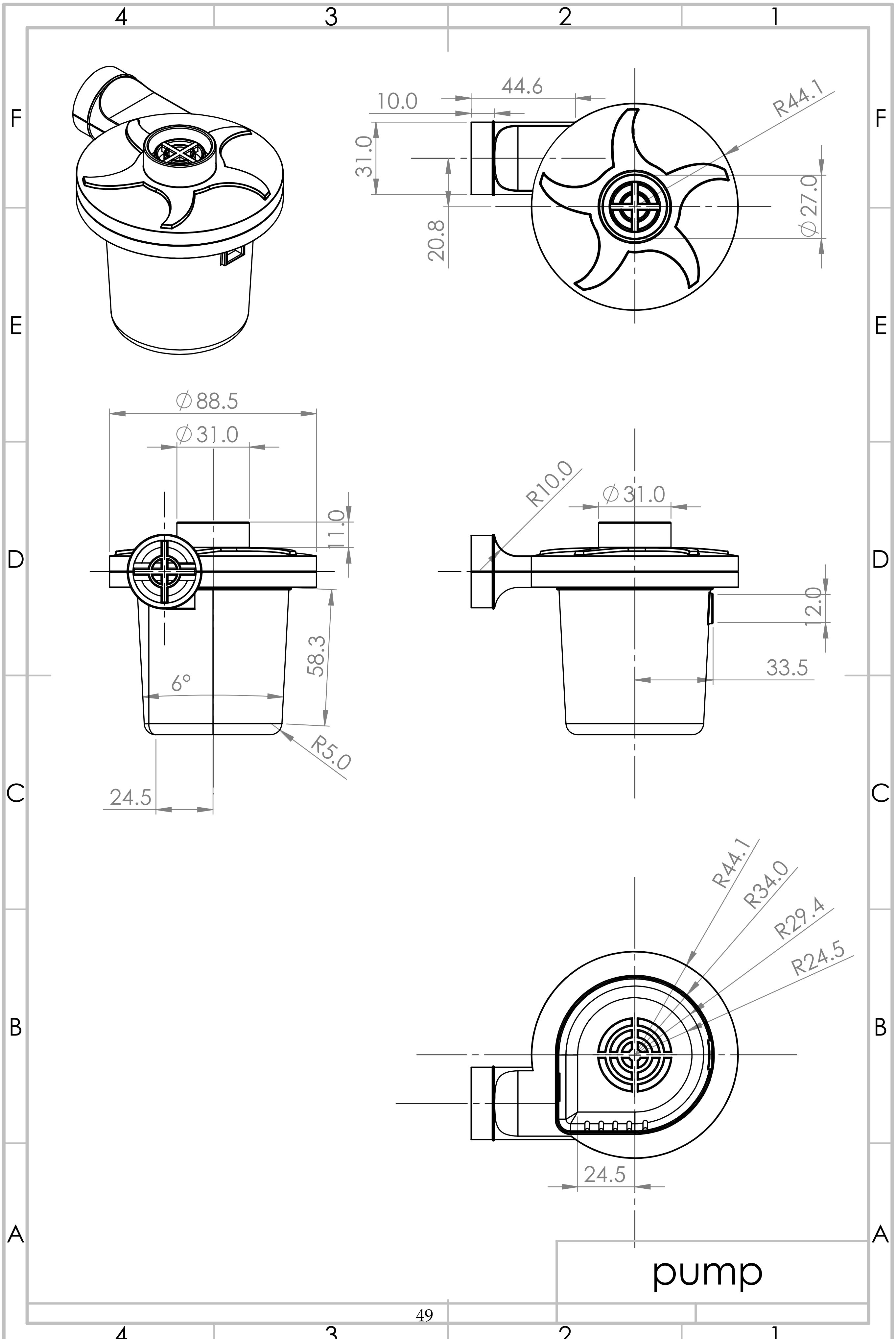
pipe_ring

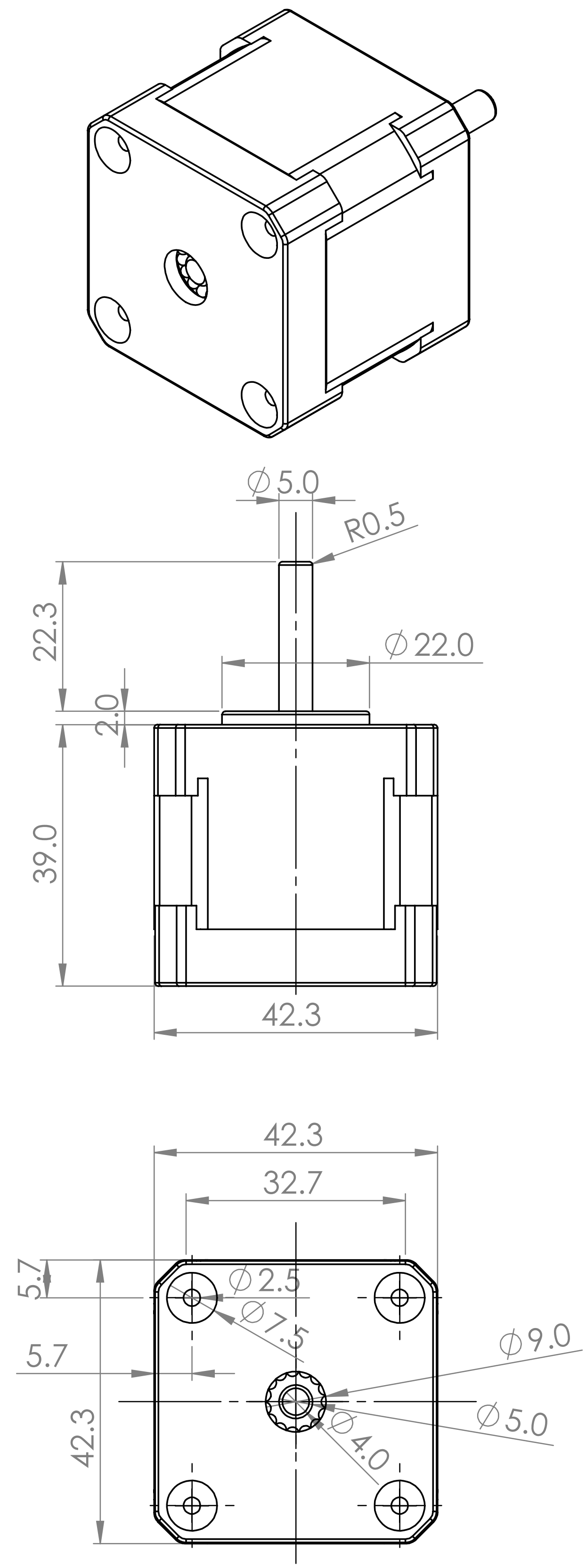

9.00
57.00
10.00
R5.00
22.00
10.00
R8.00
36.00
32.00
29.00
R2.00
R1.50
R10.00
22.00
3.00
76.00
R1.75
50.00
40.00
10.00

pipe_tunnel

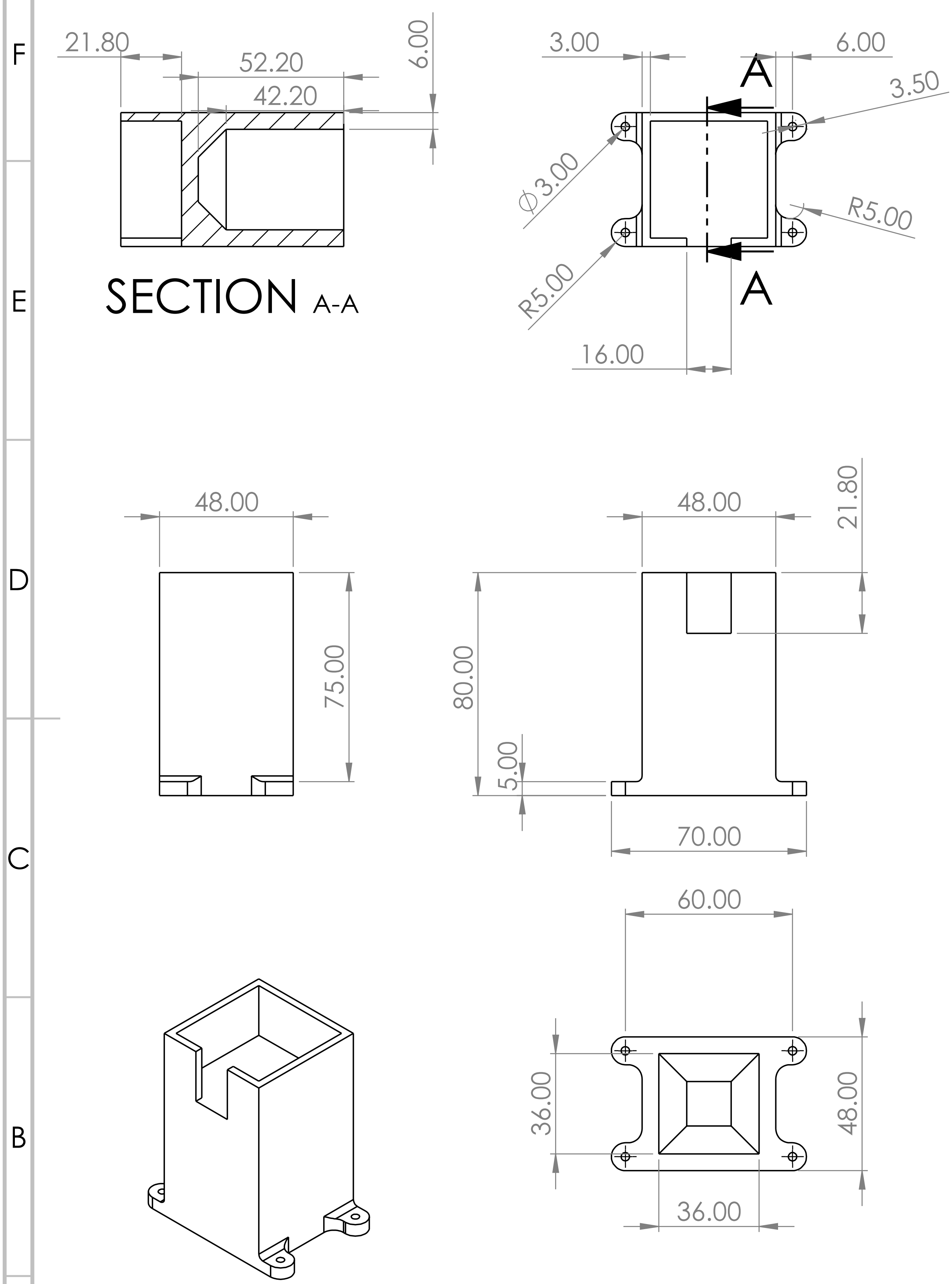


⌀220.0
⌀200.0
R140.0
R80.0
D
D
170.6
80.0
69.3
140.0
32.0
4.0
⌀48.0
⌀20.0
⌀20.0
⌀20.0
40.0
200.0
264.0
R40.0
10.0
210.0
8.0
4.0
52.0
80.0
R10.0
100.0
SECTION D-D
⌀28.0
plate

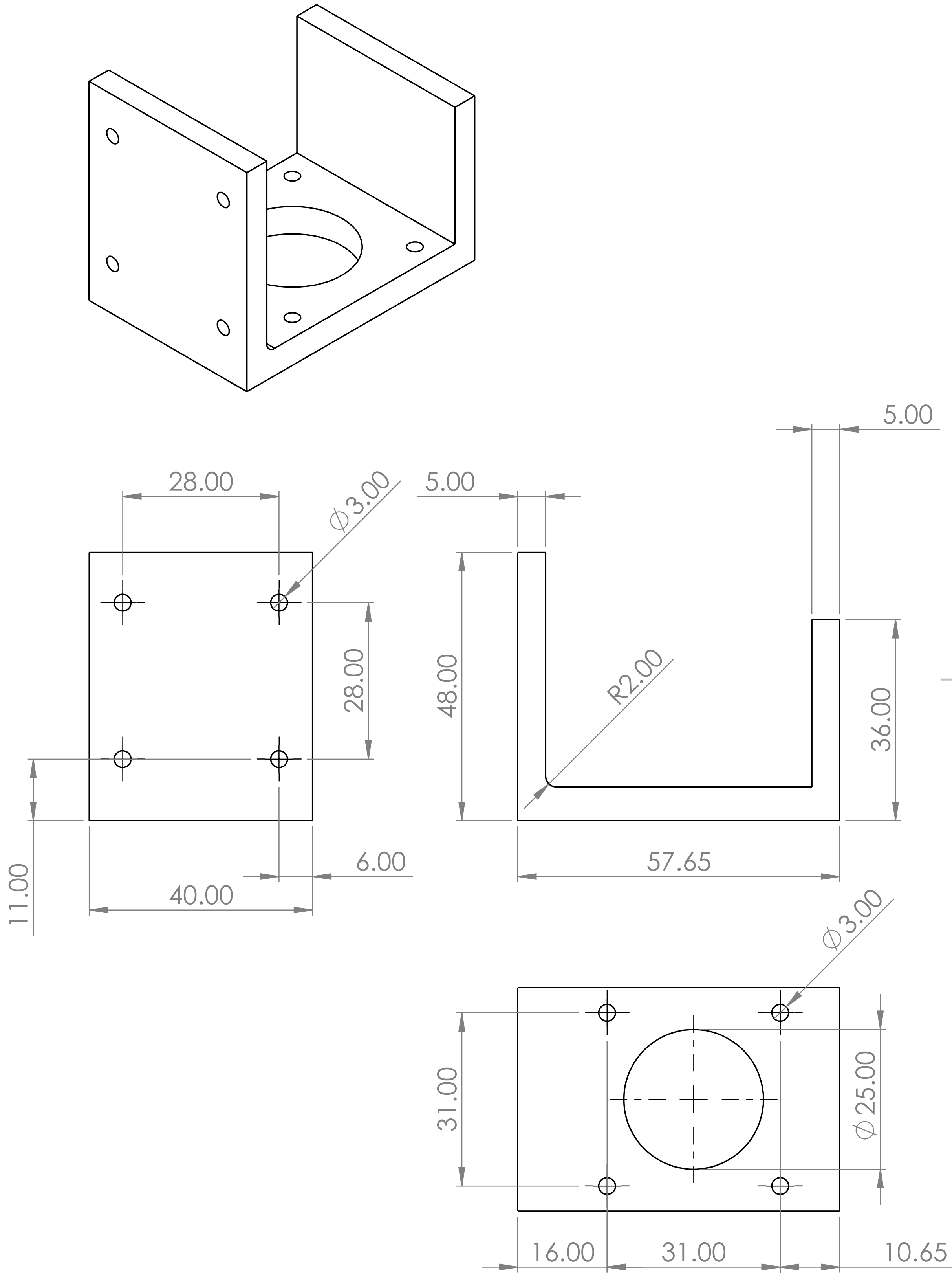

4
3
2
1
F
E
D
C
B
A
10.0
44.6
R44.1
31.0
20.8
⌀27.0
⌀88.5
⌀31.0
11.0
58.3
6°
R5.0
24.5
R10.0
⌀31.0
12.0
33.5
R44.1
R34.0
R29.4
R24.5
24.5
pump



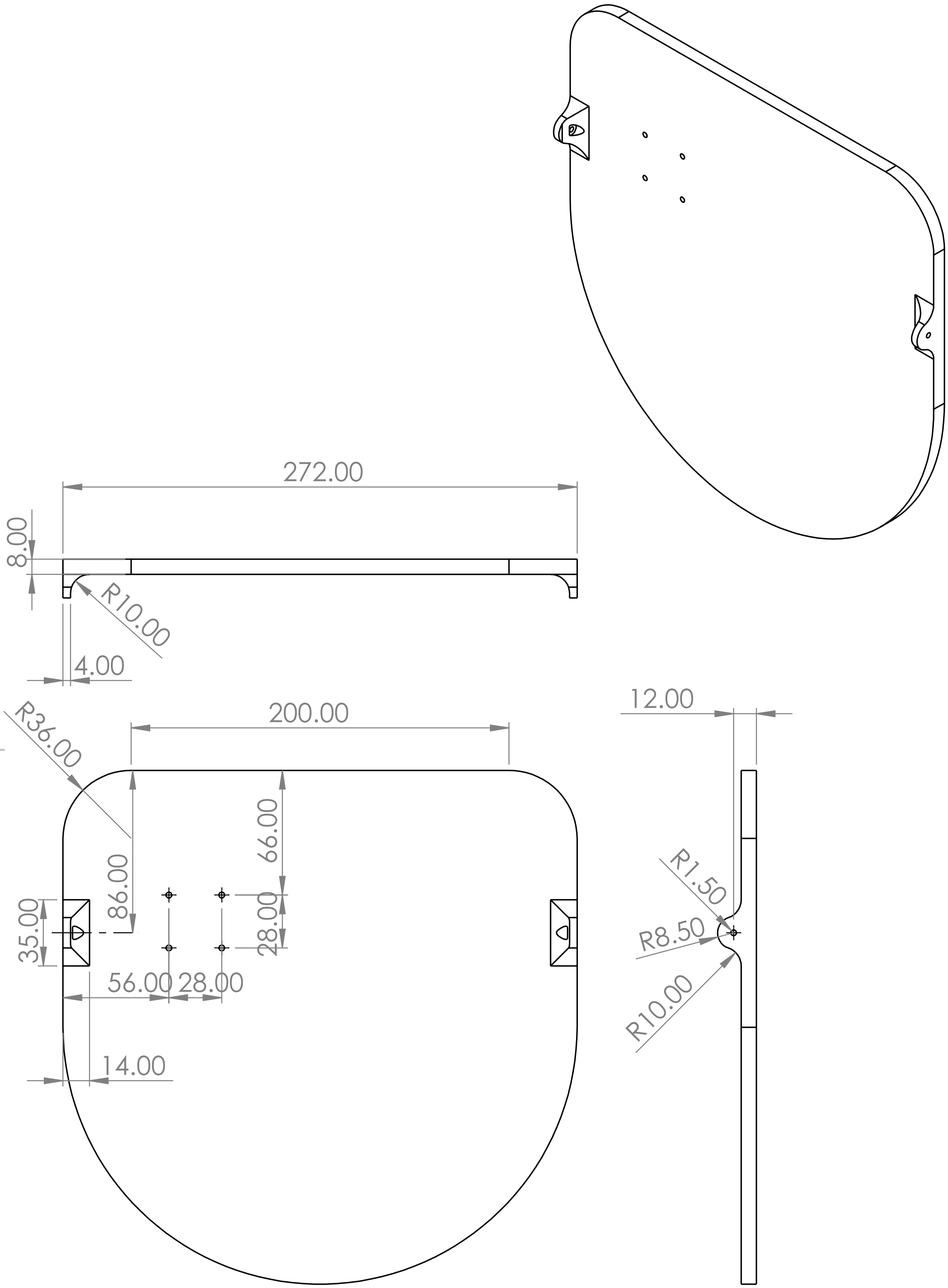
step motor


21.80
52.20
42.20
6.00
SECTION A-A
3.00
6.00
A
3.50
⌀3.00
R5.00
R5.00
A
16.00
48.00
75.00
48.00
21.80
80.00
5.00
70.00
60.00
36.00
48.00
36.00

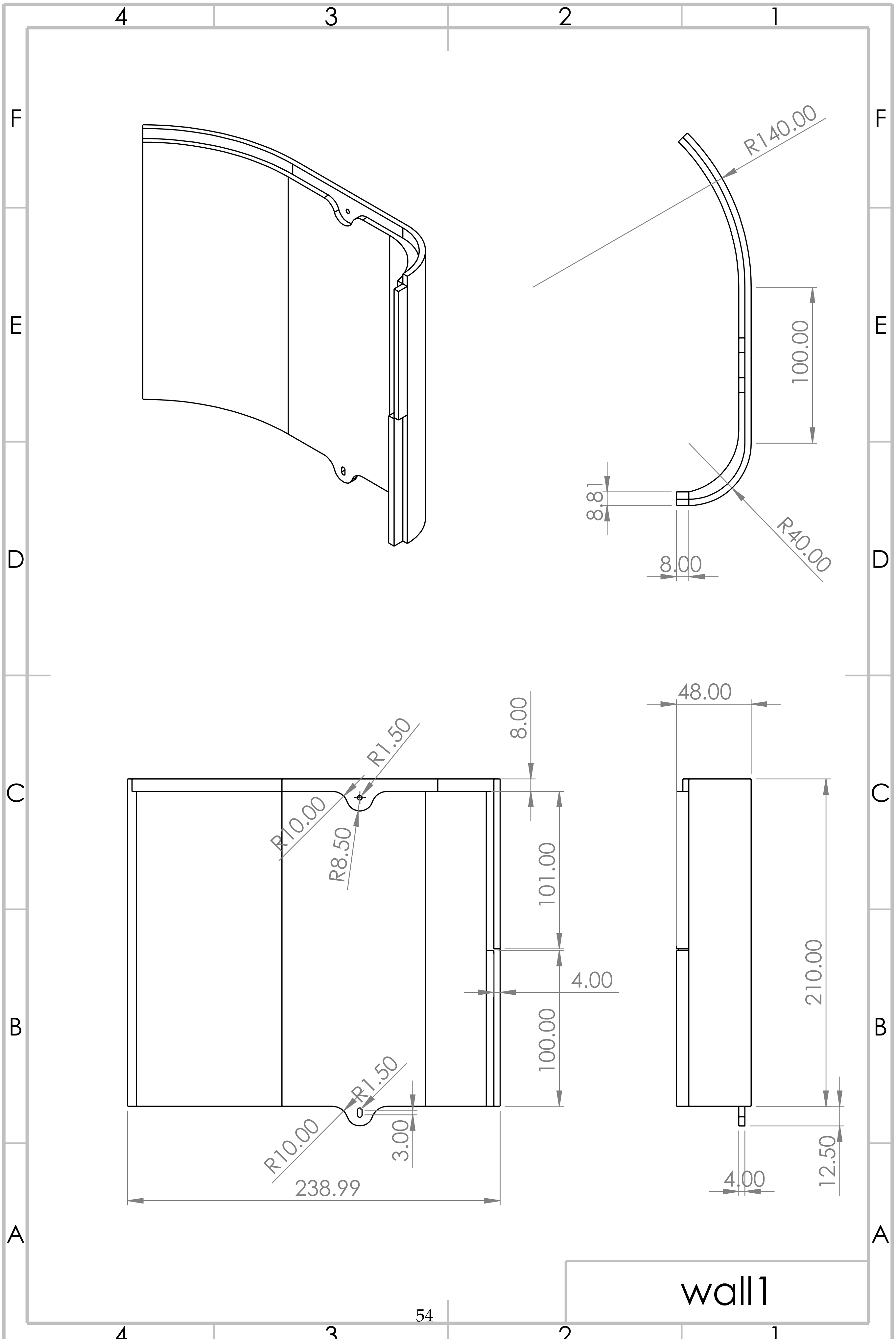
step_table

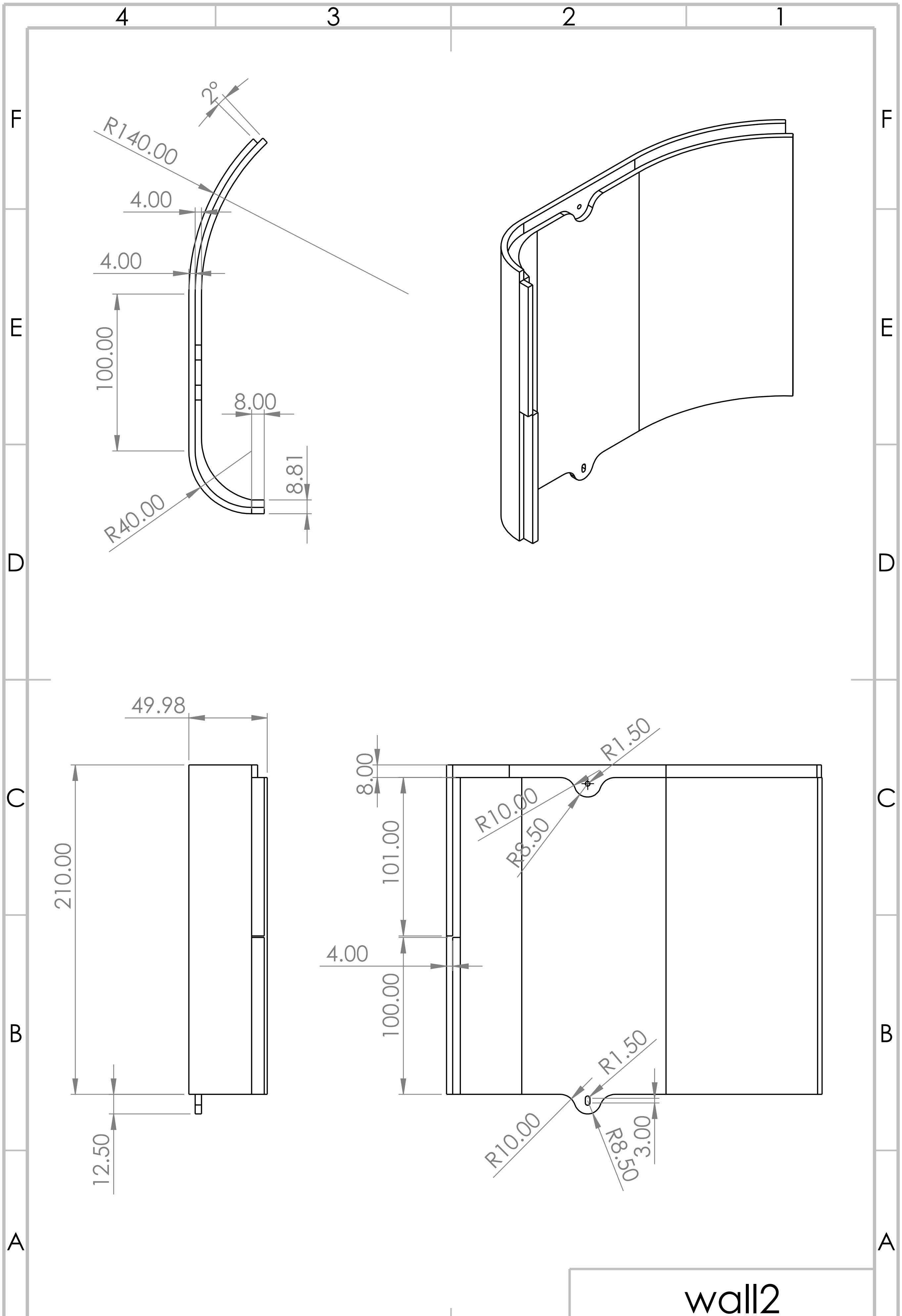


stepper_case

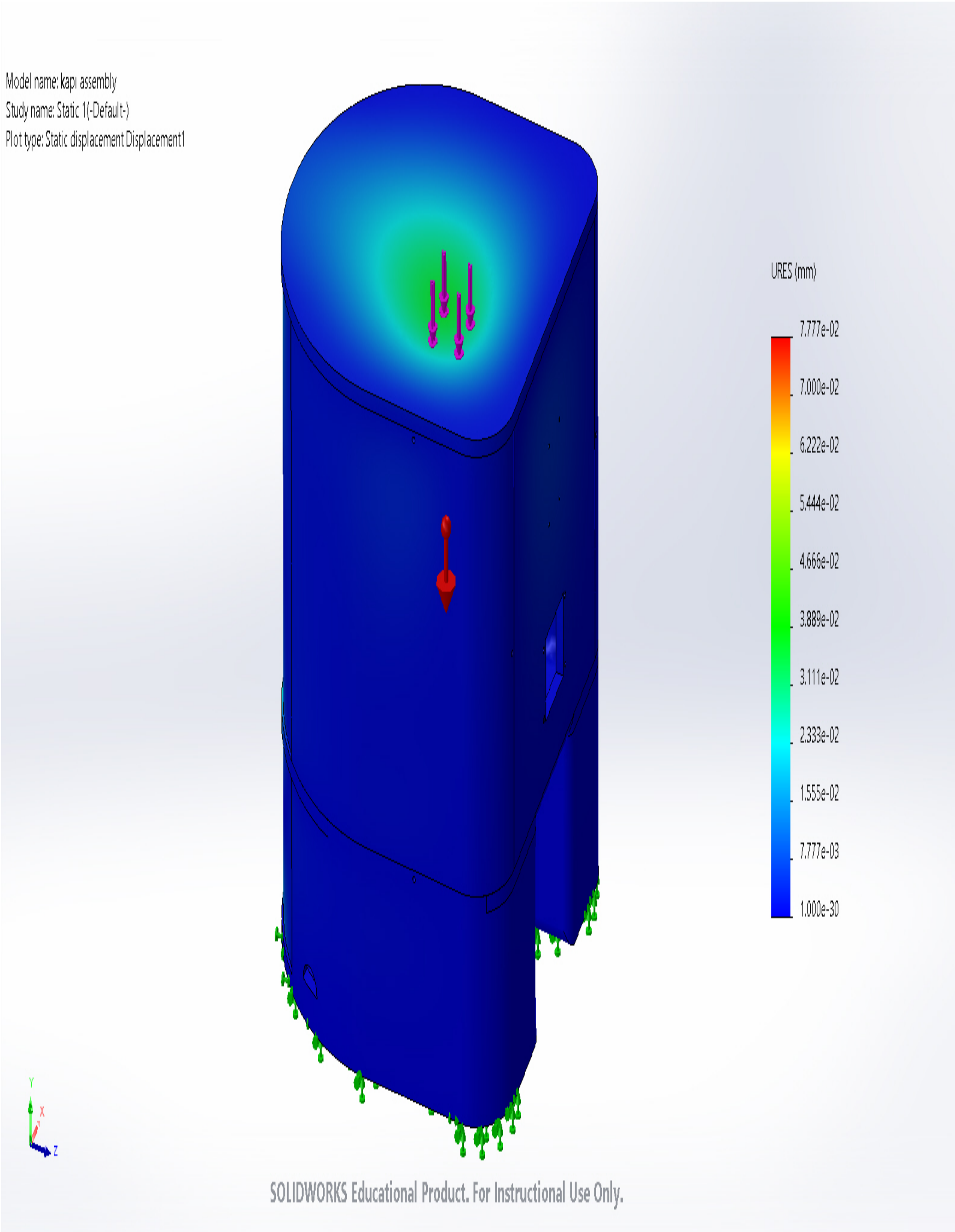

272.00
8.00
R10.00
4.00
200.00
R36.00
86.00
66.00
35.00
28.00
56.00
28.00
14.00
12.00
R1.50
R8.50
R10.00

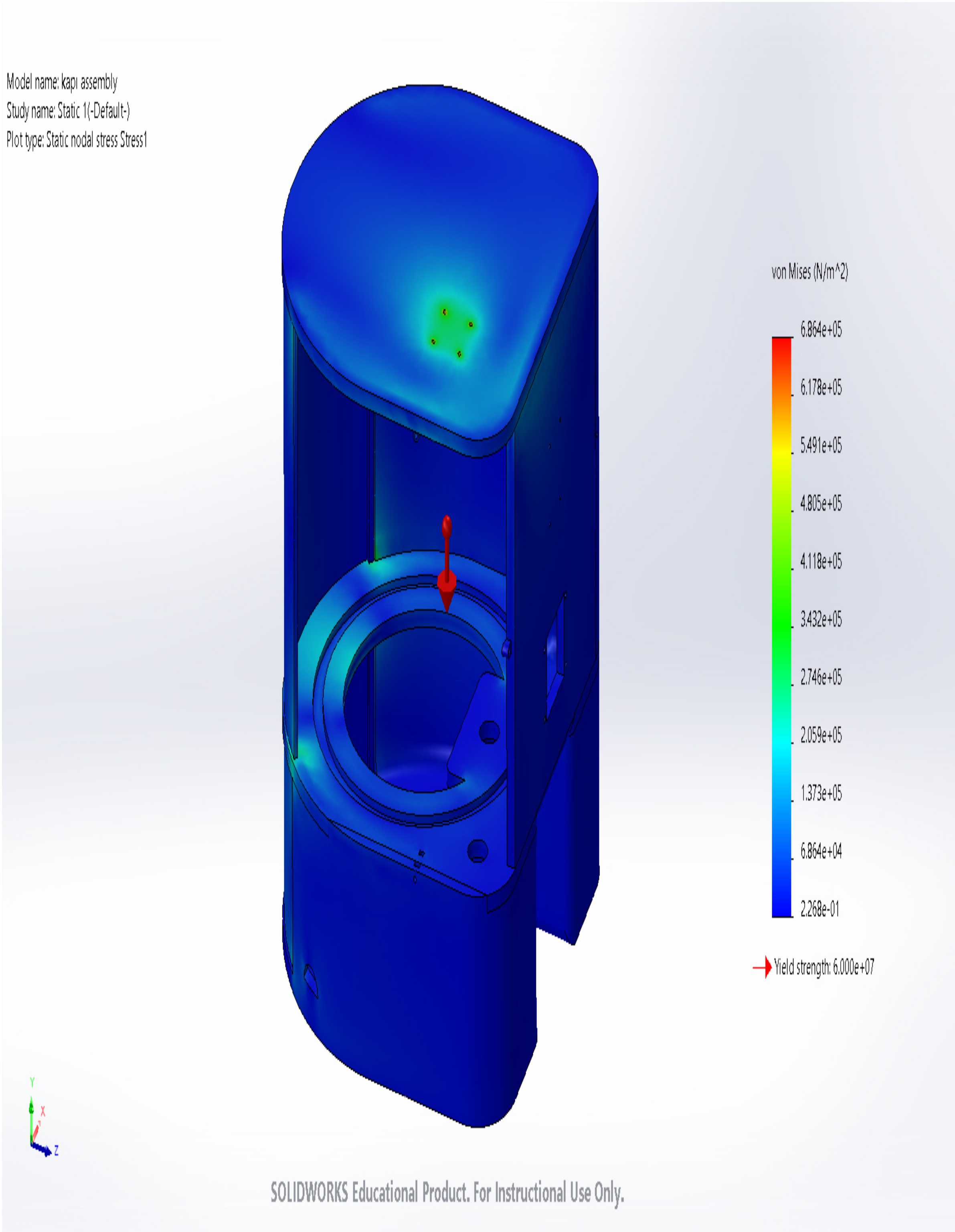
top


R140.00
100.00
8.81
8.00
R40.00
48.00
8.00
R1.50
R10.00
R8.50
101.00
4.00
210.00
100.00
R1.50
R10.00
3.00
238.99
12.50
4.00
wall1


4
3
2
1
F
E
D
C
B
A
2°
R140.00
4.00
4.00
100.00
8.00
8.81
R40.00
49.98
210.00
12.50
8.00
R1.50
R10.00
R8.50
101.00
4.00
100.00
R1.50
R10.00
R8.50
3.00
wall2

B Static Analysis Results




Model name: kapı assembly
Study name: Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
6.864e+05
6.178e+05
5.491e+05
4.805e+05
4.118e+05
3.432e+05
2.746e+05
2.059e+05
1.373e+05
6.864e+04
2.268e-01
Yield strength: 6.000e+07
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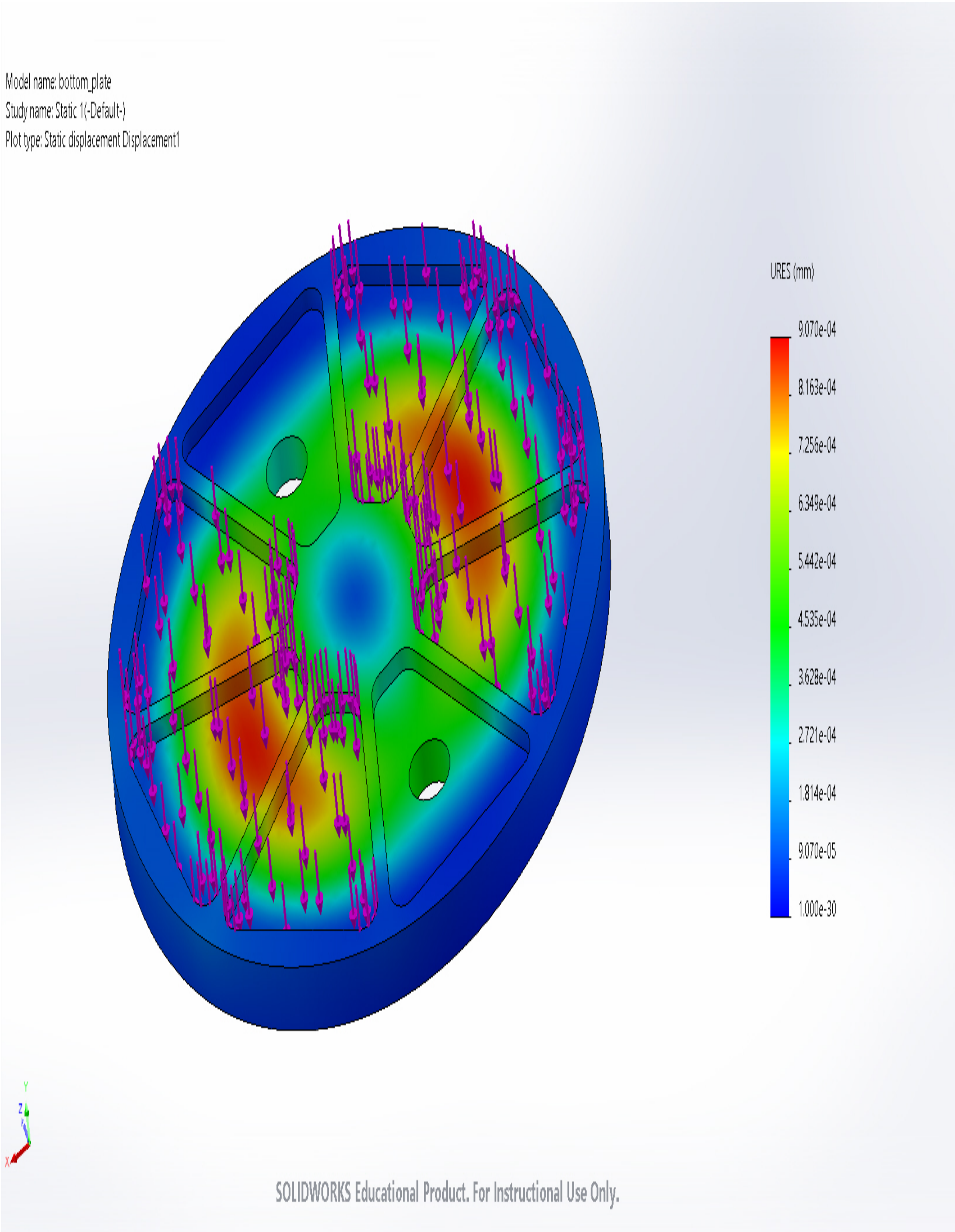
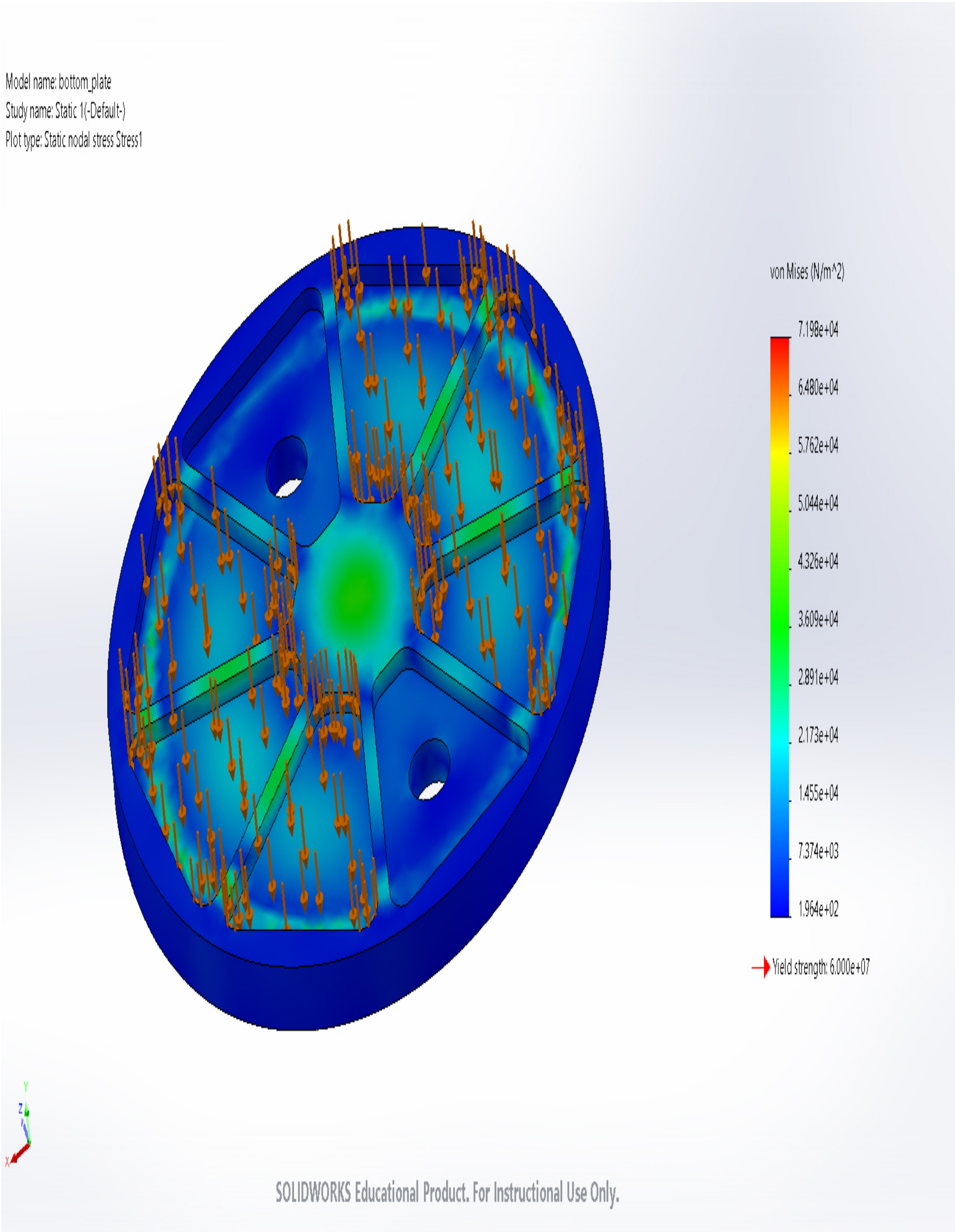
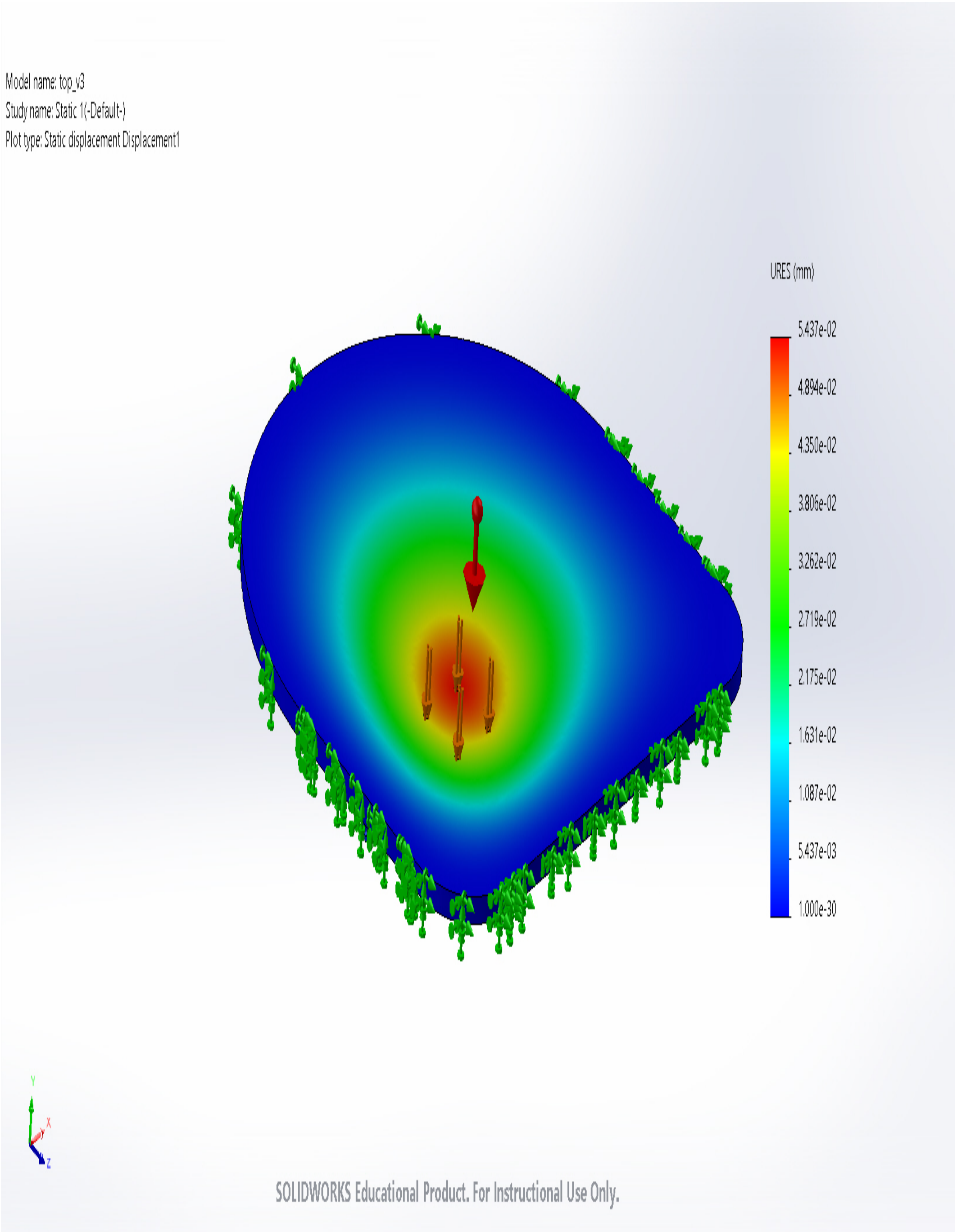
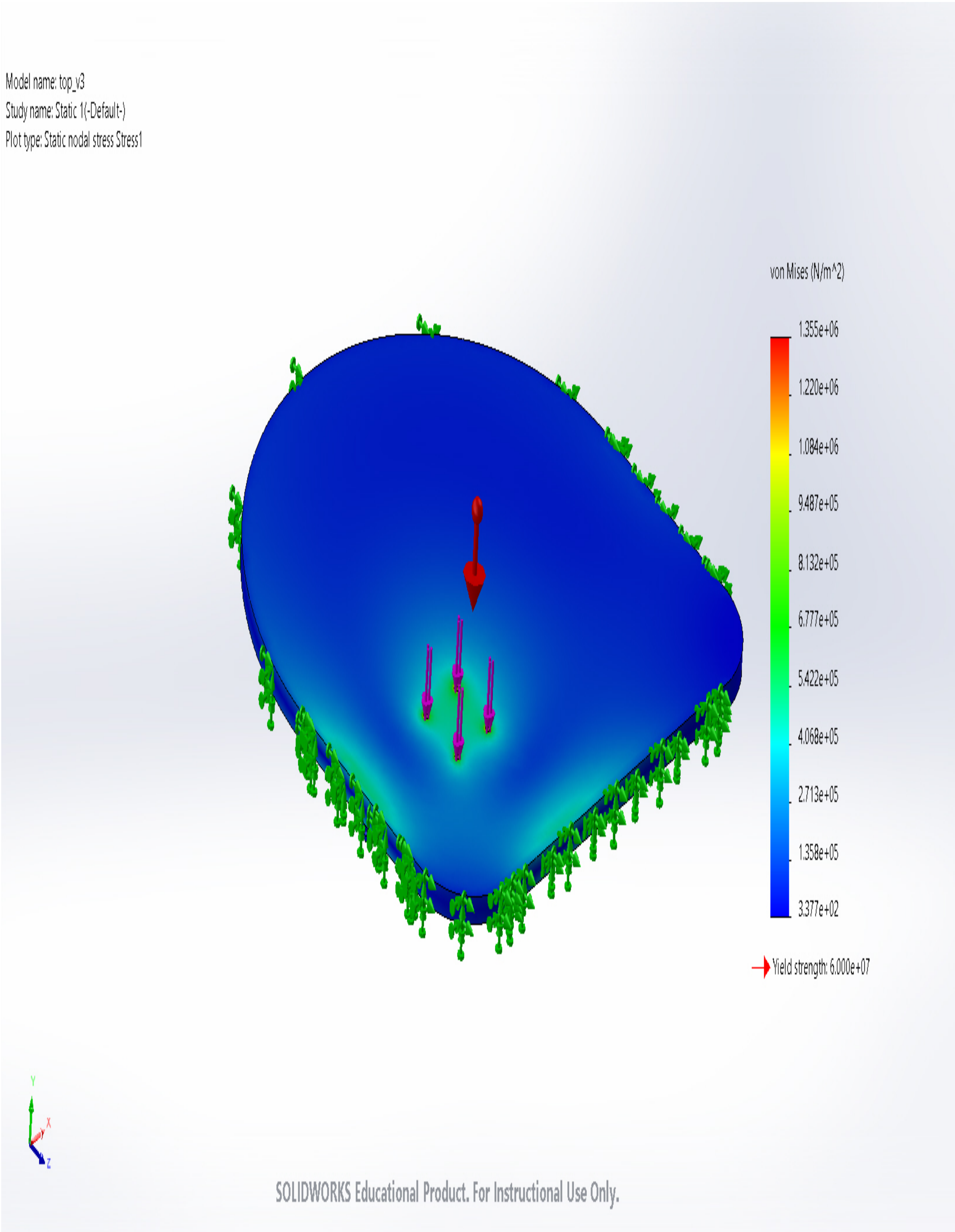
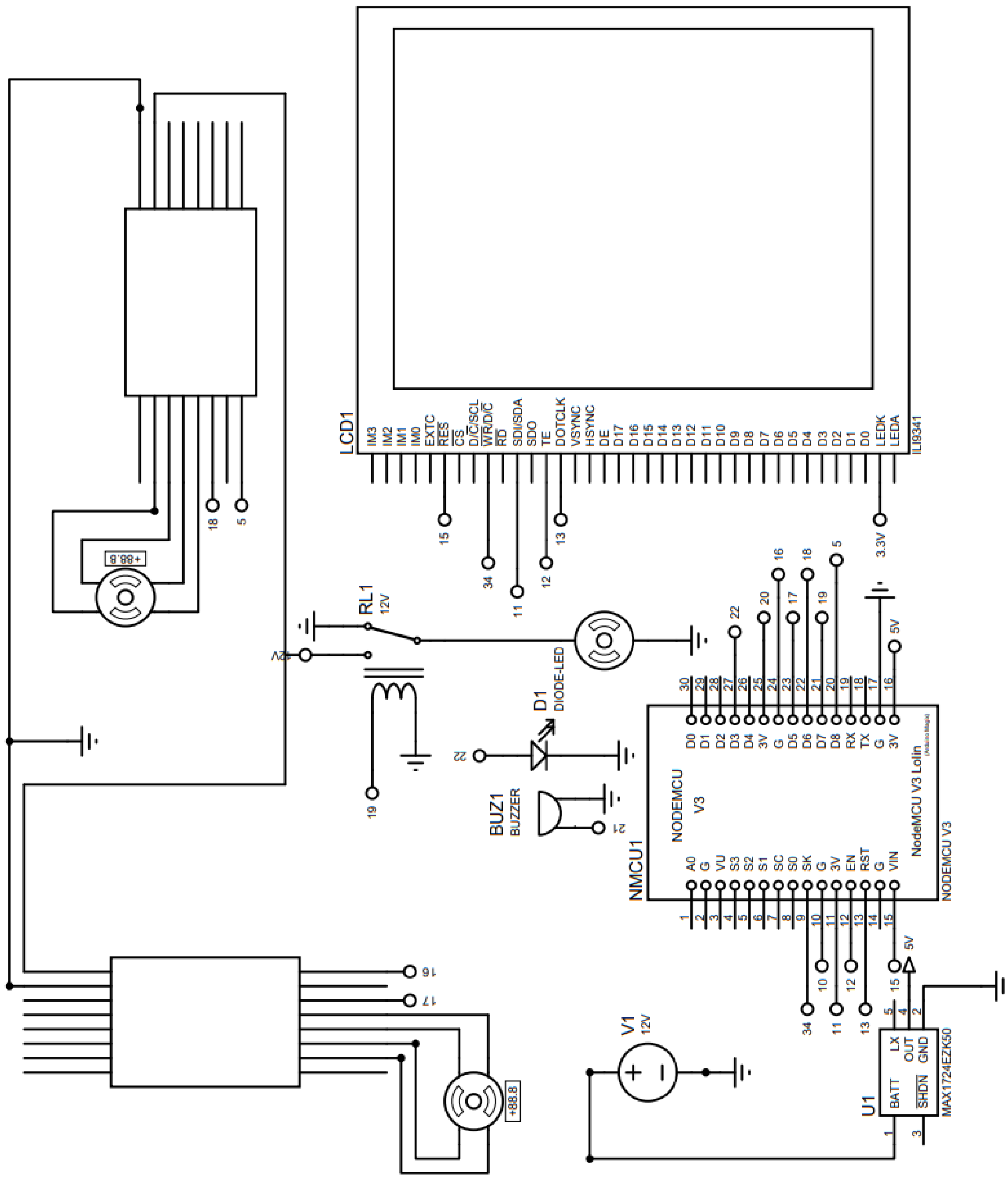

Model name: bottom_plate
Study name: Static 1(-Default-)
Plot type: Static displacement Displacement1
URES (mm)
9.070e-04
8.163e-04
7.256e-04
6.349e-04
5.442e-04
4.535e-04
3.628e-04
2.721e-04
1.814e-04
9.070e-05
1.000e-30
SOLIDWORKS Educational Product. For Instructional Use Only.


Model name: bottom_plate
Study name: Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
7.198e+04
6.480e+04
5.762e+04
5.044e+04
4.326e+04
3.609e+04
2.891e+04
2.173e+04
1.455e+04
7.374e+03
1.964e+02
Yield strength: 6.000e+07
SOLIDWORKS Educational Product. For Instructional Use Only.


Model name: top_v3
Study name: Static 1(-Default-)
Plot type: Static displacement Displacement1
URES (mm)
5.437e-02
4.894e-02
4.350e-02
3.806e-02
3.262e-02
2.719e-02
2.175e-02
1.631e-02
1.087e-02
5.437e-03
1.000e-30
Y
X
Z
SOLIDWORKS Educational Product. For Instructional Use Only.


Model name: top_v3
Study name: Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
1.355e+06
1.220e+06
1.084e+06
9.487e+05
8.132e+05
6.777e+05
5.422e+05
4.068e+05
2.713e+05
1.358e+05
3.377e+02
Yield strength: 6.000e+07
Y
X
Z
SOLIDWORKS Educational Product. For Instructional Use Only.

C Electrical Circuit



D Algorithm

Algorithm 1 Automated Rotation and Messaging System

```
procedure SETUP
    Initialize pins and WiFi
    Connect to WiFi
    Send initial message to Telegram
end procedure
procedure MAIN LOOP
    while true do
        if new messages from Telegram then
            Process each message
            Extract chat ID and command
            Perform operation based on command
        end if
    end while
end procedure
procedure PERFORMOPERATION(chat_id, steps)
    Validate steps
    Retrieve rotation steps for given box
    Rotate table for first step
    Rotate pump motor
    Activate relay
    Rotate pump motor in opposite direction
    Rotate table for second step
    Deactivate relay
    Rotate table for third step
end procedure
```

Arduino Code

```
#include <HTTPClient.h>
#include <WiFiClientSecure.h>
#include <UniversalTelegramBot.h>
#include <ArduinoJson.h>  // Include the ArduinoJson library
#include <map>
#include <tuple>
const char* ssid = "*****";  // Replace with your WiFi credentials
const char* password = "*****"; // Replace with your WiFi credentials
const char* scriptURL = "*****"; // Replace with your Google Script URL
#define BOTtoken "****"  // your Bot Token (Get from Botfather)
WiFiClientSecure client;
UniversalTelegramBot bot(BOTtoken, client);

unsigned long bot_lasttime;   // last time messages' scan has been done
HTTPClient http;
int httpCode;


// Define a map to store the rotation steps for each starting box
std::map<int, std::tuple<int, int, int>> rotationSteps = {
    {0, std::make_tuple(0, 3, 5)}, // For box 0: 0, 2, 6 rotations
    {1, std::make_tuple(1, 2, 5)}, // For box 1: 1, 1, 6 rotations
    {2, std::make_tuple(2, 1, 5)}, // For box 3: 3, 3, 2 rotations
    {4, std::make_tuple(4, 3, 1)}, // For box 4: 4, 2, 2 rotations
    {5, std::make_tuple(5, 2, 1)}, // For box 5: 5, 1, 2 rotations
```

```
    {6, std::make_tuple(6, 1, 1)}  // For box 7: 7, 3, 6 rotations
};


# If Touchscreen is used the pin numbers should changed accordingly to previous pins.
const int STEP1 = 33;
const int STEP2 = 25;
const int STEP2_EN = 26;
const int STEP1_DIR = 27;
const int  steps_per_rev_bottom = 800;
const int  steps_per_rev = 800*180/180;
const int  steps_per_rev_bottom_req = 100;
const String personal_chat_id = "*****";

#define RELAIS 32 //Relay pin
#define BUZZER_PIN 2 // Buzzer pin
#define LED_PIN 4    // LED pin

void setup()
{
  Serial.begin(115200);
  pinMode(STEP1, OUTPUT);
  pinMode(STEP2, OUTPUT);
  pinMode(STEP2_EN, OUTPUT);
  pinMode(STEP1_DIR,OUTPUT);
  pinMode(RELAIS,OUTPUT);
    pinMode(BUZZER_PIN, OUTPUT);
  pinMode(LED_PIN, OUTPUT);
  WiFi.begin(ssid, password);

  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);


  }


  //readColumnData("A");
  client.setInsecure();
  bot.sendMessage(personal_chat_id,"Connected to WiFi", "");


}
void loop()

  {

    if (millis() - bot_lasttime > 1000) { // Check for new messages every second
    int numNewMessages = bot.getUpdates(bot.last_message_received + 1);

    while (numNewMessages) {
      for (int i = 0; i < numNewMessages; i++) {
        String chat_id = bot.messages[i].chat_id;
        String text = bot.messages[i].text;

        if (text.toInt() != 0) { // Check if the text is a number
          int steps = text.toInt();
          bot.sendMessage(bot.messages[i].chat_id,"Received: "+ bot.messages[i].text, "");
          performOperation(chat_id,steps); // Perform operation with the received number of steps
        } else {
          // Handle other text messages or commands if needed
        }
      }
      numNewMessages = bot.getUpdates(bot.last_message_received + 1);
    }
    bot_lasttime = millis(); // Update the last time messages were checked
  }

}

```

```
void rotateTable(int steps) {
  for(int i = 0; i < steps; i++) {
    digitalWrite(STEP2, HIGH);
    delayMicroseconds(3000);
    digitalWrite(STEP2, LOW);
    delayMicroseconds(3000);
  }
}

void rotatePumpMotor(bool direction) {
  digitalWrite(STEP1_DIR, direction ? HIGH : LOW);  // Set motor direction

  for (int i = 0; i < steps_per_rev; i++) {
    digitalWrite(STEP1, HIGH);
    delayMicroseconds(500);
    digitalWrite(STEP1, LOW);
    delayMicroseconds(500);
  }
}

void performOperation1(int steps) {
  // Enable and rotate the table
  digitalWrite(STEP2_EN, LOW);
  delay(1000);
  rotateTable(steps * 100);
  delay(5000);

  // Rotate the pump motor in one direction
  rotatePumpMotor(false);
  delay(4000);

  // Activate the relay
  digitalWrite(RELAIS, HIGH);
  delay(5000);

  // Rotate the pump motor in the opposite direction
  digitalWrite(STEP2_EN, LOW);
  rotatePumpMotor(true);
  delay(500);
  rotateTable(steps * 100);
  delay(1000);

  // Deactivate the relay
  delay(5000);
  digitalWrite(RELAIS, LOW);
  delay(5000);

  rotateTable(steps * 600);
  delay(1000);

}


void performOperation(String chat_id, int steps) {
    // Ensure the startBox is within the valid range

    // Retrieve the rotation steps for the given box
    auto rotations = rotationSteps[steps];
    int firstStep = std::get<0>(rotations);
    int secondStep = std::get<1>(rotations);
    int thirdStep = std::get<2>(rotations);

    // Enable and rotate the table for the first step
    digitalWrite(STEP2_EN, LOW);
    delay(1000);
    rotateTable(firstStep * 100);

    delay(5000);

```

```
    // Rotate the pump motor in one direction
    rotatePumpMotor(false);
    delay(4000);

    // Activate the relay
    digitalWrite(RELAIS, HIGH);
    delay(5000);

    // Rotate the pump motor in the opposite direction
    digitalWrite(STEP2_EN, LOW);
    rotatePumpMotor(true);
    delay(500);

    // Rotate the table for the second step
    rotateTable(secondStep * 100);

    delay(1000);

    // Deactivate the relay
    delay(5000);
    digitalWrite(RELAIS, LOW);
    delay(5000);

    // Rotate the table for the third step
    rotateTable(thirdStep * 100);

    delay(1000);
        digitalWrite(BUZZER_PIN, HIGH); // Turn the buzzer on
      // Blink LED
  for (int i = 0; i < 5; i++) {
    digitalWrite(LED_PIN, HIGH);
    delay(500);
    digitalWrite(LED_PIN, LOW);
    delay(500);
  }
      digitalWrite(BUZZER_PIN, LOW); // Turn the buzzer off

}
```

Listing 1: Arduino Code for Automated System

```
#include <WiFi.h>
#include <HTTPClient.h>
#include <WiFiClientSecure.h>
#include <UniversalTelegramBot.h>
#include <ArduinoJson.h>  // Include the ArduinoJson library
const char* ssid = "****";  // Replace with your WiFi credentials
const char* password = "****"; // Replace with your WiFi credentials
const char* scriptURL = "***"; // Replace with your Google Script URL
const int MAX_MEDICINES = 8; // Maximum number of medicines you expect
String medicineNames[MAX_MEDICINES];
int medicineQuantities[MAX_MEDICINES];
// Initialize Telegram BOT
#define BOTtoken "****"  // your Bot Token (Get from Botfather)
WiFiClientSecure client;
UniversalTelegramBot bot(BOTtoken, client);

unsigned long bot_lasttime;   // last time messages' scan has been done
HTTPClient http;
int httpCode;



void setup() {
  Serial.begin(115200);
    WiFi.begin(ssid, password);

    while (WiFi.status() != WL_CONNECTED) {
      delay(1000);
```

```
      Serial.println("Connecting to WiFi...");
    }
    Serial.println("Connected to WiFi");

    //readColumnData("A");
    client.setInsecure();
}

void loop() {
  if (millis() - bot_lasttime > 1000) {  // Only check for new messages every 1 second
    int numNewMessages = bot.getUpdates(bot.last_message_received + 1);

    while (numNewMessages) {
      Serial.println("got response");
      for (int i = 0; i < numNewMessages; i++) {
        bot.sendMessage(bot.messages[i].chat_id, bot.messages[i].text, "");
        if(bot.messages[i].text == "update"){readColumnData("B");}
      }
      numNewMessages = bot.getUpdates(bot.last_message_received + 1);

    }

    bot_lasttime = millis();
  }
}

void readColumnData(const char* column) {
  readColumn(column);

  if (httpCode > 0) {
    String payload = http.getString();
    Serial.println("Received data: " + payload);

    // Parse JSON payload
    DynamicJsonDocument doc(1024);
    deserializeJson(doc, payload);
    JsonArray arr = doc.as<JsonArray>();
    for (JsonVariant v : arr) {
      Serial.println(v.as<String>());
    }
  } else {
    Serial.println("Error on HTTP request");
  }

  http.end();
}

void readColumn(const char* column) {

  HTTPClient http;
  String url = String(scriptURL) + "?action=readColumn&column=" + column;
  http.begin(url);
  http.setFollowRedirects(HTTPC_STRICT_FOLLOW_REDIRECTS);
  httpCode = http.GET();
  Serial.print("HTTP Response Code: ");
  Serial.println(httpCode);}
```

```
// Test function to simulate an HTTP GET request
function testDoGet() {
  var simulatedEvent = {
    parameter: {
      column: 'B'  // You can change this to test different columns or remove it to test the default
    }
  };

  var result = doGet(simulatedEvent);
  Logger.log(result.getContent());
```

```
}

function doGet(e) {
  var sheet = SpreadsheetApp.openById('*****').getSheetByName('Sheet1');

  // Retrieve the column parameter from the HTTP request or default to 'A'
  var column = (e && e.parameter && e.parameter.column) ? e.parameter.column : 'A'; // ...
    Defaults to 'A'

  // Get all values in the specified column, starting from row 2
  var lastRow = sheet.getLastRow(); // Get the last row number
  var range = sheet.getRange(column + '2:' + column + lastRow); // Adjust range to start ...
    from row 2
  var values = range.getValues();

  // Flatten the 2D array to 1D and filter out empty values
  var flattenedValues = values.flat();
  var nonEmptyValues = flattenedValues.filter(function(value) {
    return value !== "";
  });

  // Convert array to a string for output
  var output = JSON.stringify(nonEmptyValues);

  return ContentService.createTextOutput(output);
}
```
Listing 2: Google Scripts Test Function Code