ME 429: MECHANICAL AND THERMAL DESIGN

SENIOR PROJECT

Due date: May 30, 2023

Automated Pill Dispenser

Project Report
Group E

Advisor: Prof. Dr. Hasan Bedir

Ali Batur Karakullukcu - 2018405075
Ahmet Muhammed Dağdelen - 2018405114
Fatma Başak Rakıcı - 2018405141

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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 for deployment 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 92.75$ (1852,57TL).

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.

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] .

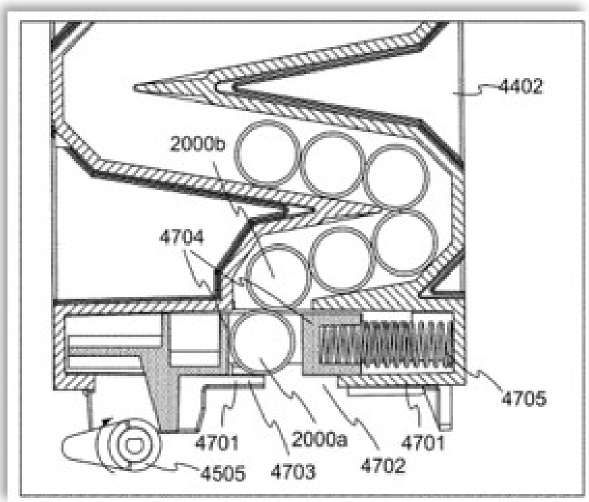


Figure 1: Spring dispenser drawing [2].

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].

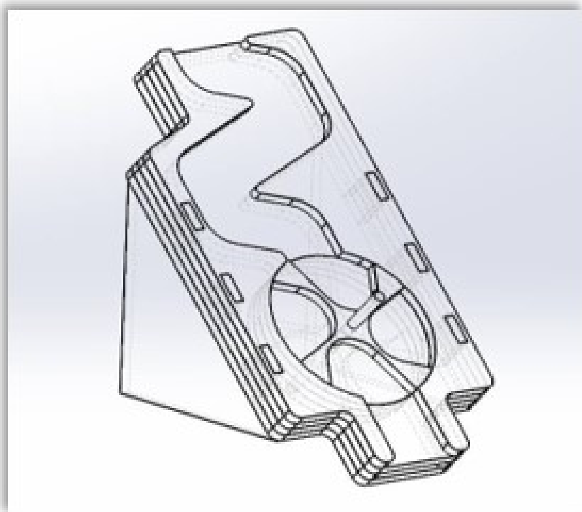


Figure 2: Turning plate drawing [3].

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].

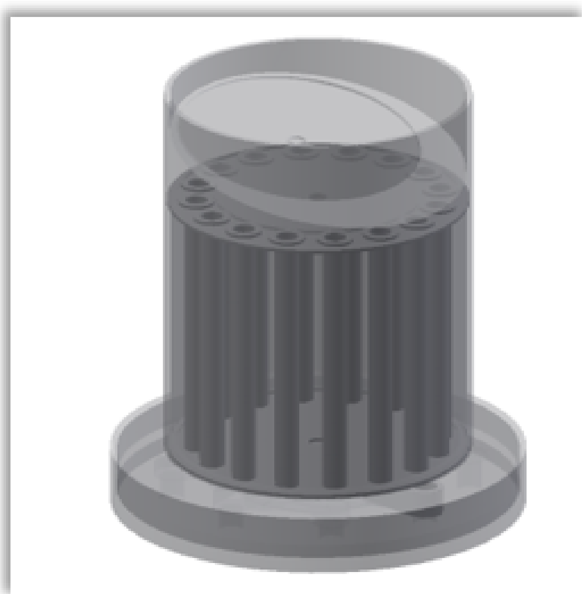


Figure 3: Tube dispenser drawing [4].

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

Detailed Design and Analysis

3.1 Pump Selection

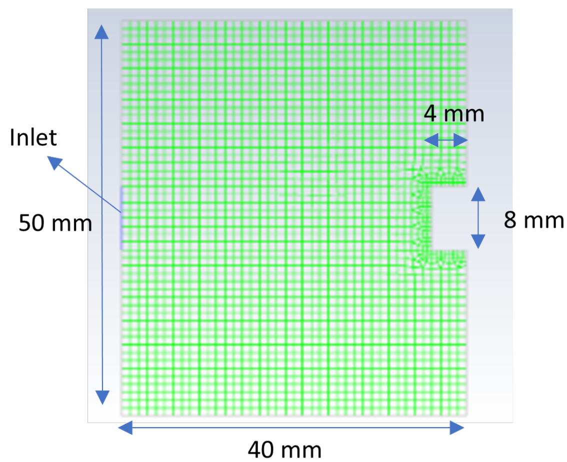


Figure 5: Pill chamber mesh and dimensions.

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.

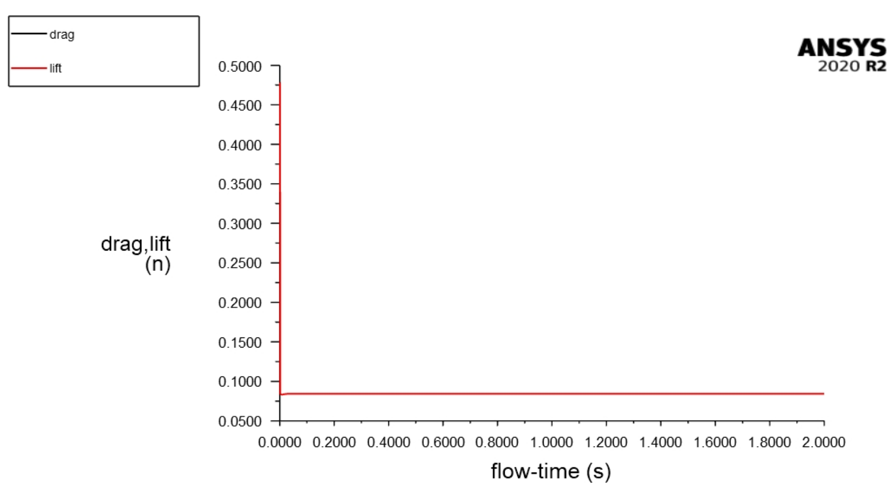


Figure 6: Change in force exerted on the pill over time.

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

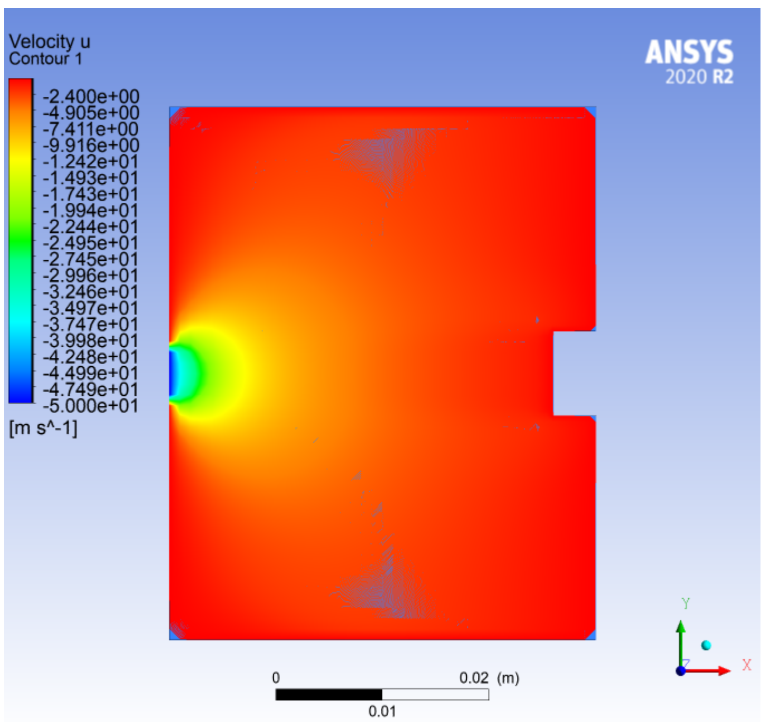


Figure 7: Velocity field inside the pill chamber.

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 light weight. The velocity field corresponding to these specifications is provided in Figure 7. The selected pump 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

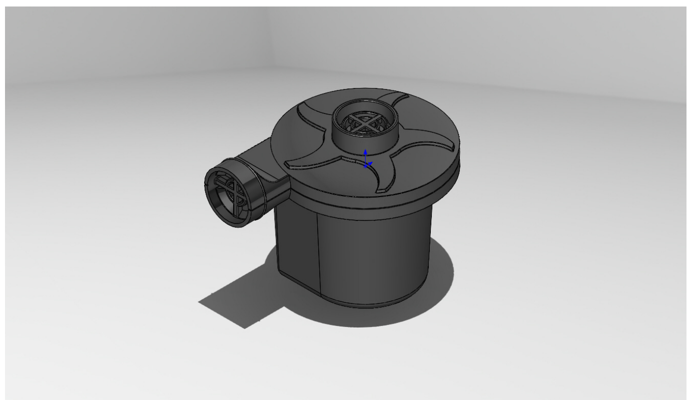


Figure 8: The chosen air pump.[7]

The pump has 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. Pump options with lower safety factor provided was applicable; however, they needed bigger dimensions for the pipe placement and higher cost contrary to their lower performance. Thus, the low price and high performance option is chosen for design simplicity and feasibility.

3.2 Part Design

The automated pill dispenser is designed to provide the user with pills they need in correct amount and in 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 to vacuum gripper, cups, turning plate and the shell design.

3.2.1 Vacuum Gripper Design

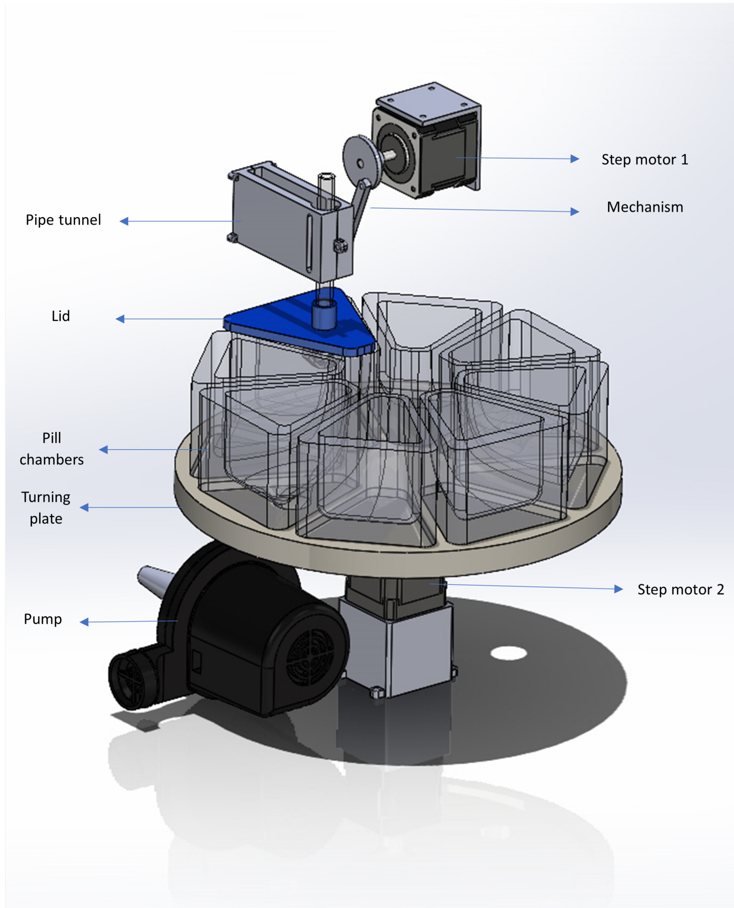


Figure 9: Gripper mechanism: overall parts.

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 is introduced and the pipe and the chambers are controlled according to that. For the pipe movement, Step motor 1 is used , which is attached to the mechanism allowing pipe to move inside the pipe tunnel and the lid as in Figure 9. The pipe tunnel is attached to the front wall aligned with the discharge outlet. Pump is attached with an elastic pipe. Pipe is attached to the mechanism with the help of smaller parts such as pipe ring and the pipe end as in Figure 10. Pipe end and the pipe ring are attached to the pipe with the help of a glue. Step motor 2 controls the pill chambers via controlling the turning plate as in Figure 9.

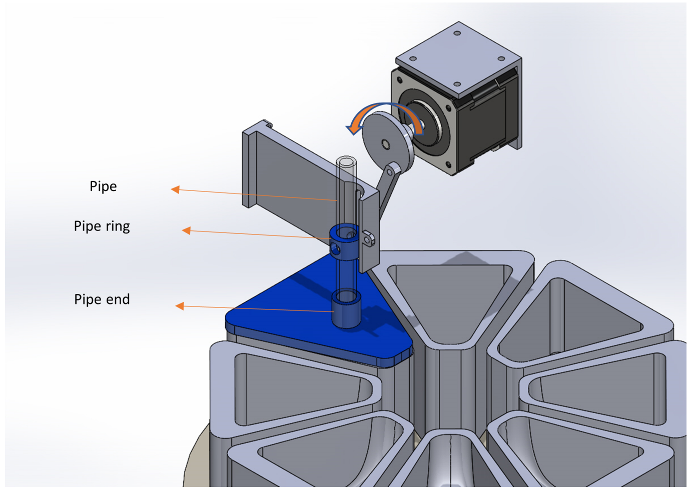


Figure 10: Pipe assembly.

The step motor 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 11. When the pipe ring moves up and down, the pipe end move with it; however, the lid movement is constrained by the pipe end and the chamber walls. So when the pipe starts moving up it carries the lid after the pipe end touches the lid. When the pipe starts moving down, the lid touches the chamber walls at some point and afterwards the pipe moves forward allowing the gripper mechanism to move. Mechanism 1 and 2 are attached with 2 mm screws and nuts allowing the rotational movement while inhibiting the translation. Then, the pipe ring is attached to the pipe tunnel slot and mechanism 2 in order to allow the rotational movement to become linear movement. Pipe ring moves linearly inside the slot with the help of 2 mm screw and nut.

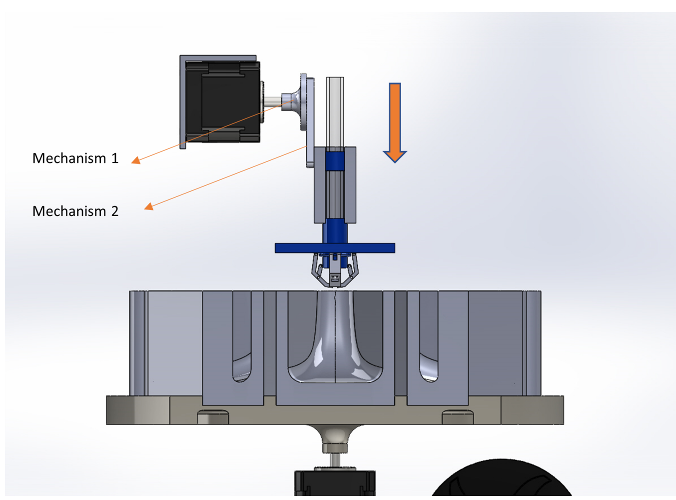
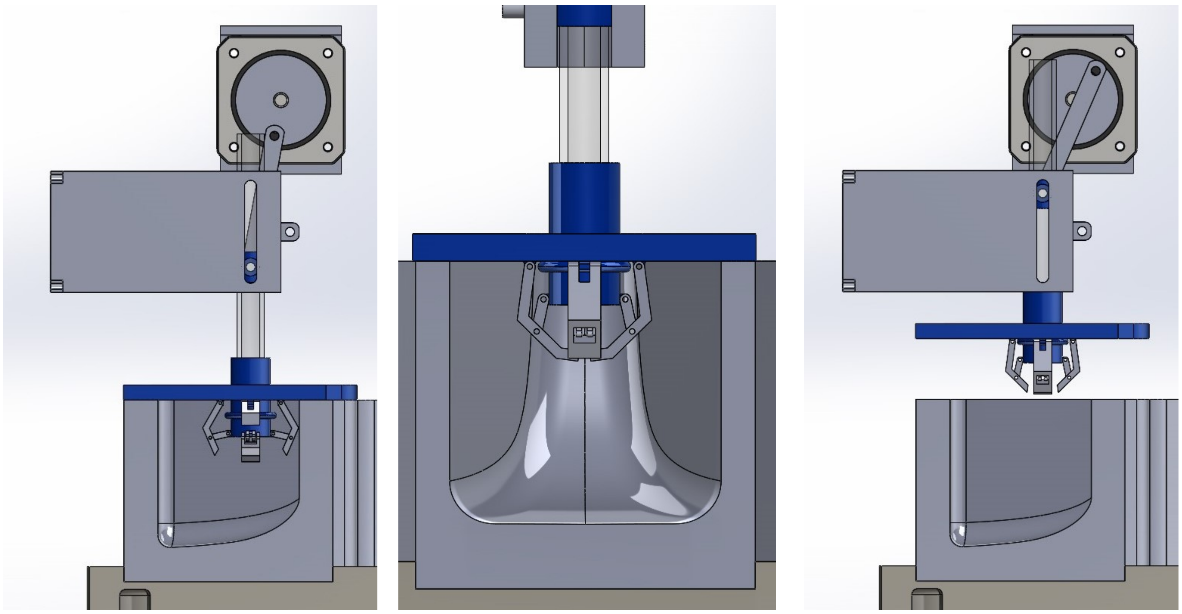


Figure 11: Mechanism movement illustration.

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. To provide these qualifications, the vacuuming of the pill is not enough. 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, the gripper mechanism is added to the pipe end.



(a) (b) (c)

Figure 12: 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 at its lowest state as in Figure 12a, the claws open up to allow the pill to get stuck on the tip of the pipe. After that the pipe end moves upward while the lid stays in the same place allowing the claw to close up as in Figure 12b, making sure that the pill is inside and will not fall. When the pipe ring at its highest state as in Figure 12c, the claws move up to allow pill chambers to rotate and align with the discharge chamber while it has the pill inside the claws. When the alignment is accomplished, the mechanism makes the same movement rotating the step motor for another 180°. The gripper takes the shape in Figure 12a allowing pill to fall inside the cup when the vacuuming is finished. Going from lowest to the highest state 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. The claw movement is facilitated by the movement of the lid and the pipe end. The claws are attached to the lid from their roots and they are 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.

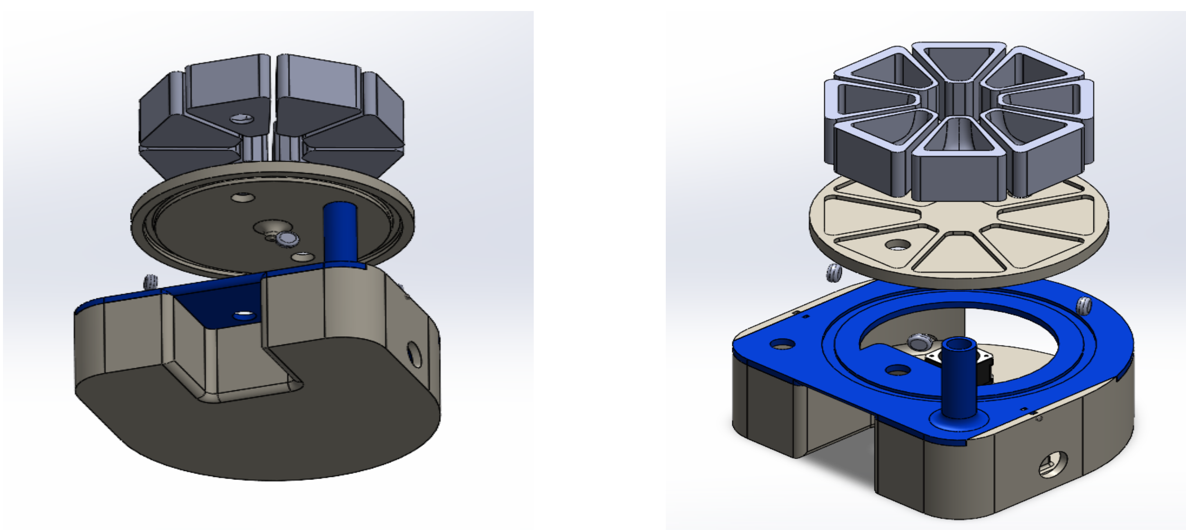
3.2.2 Cups and Bottom Plate Design

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

The exploded view of the cups and bottom plate assembly can be seen in Figure 13.



(a) (b)

Figure 13: Exploded view of the cups and bottom plate assembly.

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, an integrated micro-controller, and a buzzer 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 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 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. Back of the automated pill dispenser and the front edges are curved to obtain an aesthetic design.

Back of the automated pill dispenser is left open, and two doors, namely the upper and lower doors, are designed to open and close this space. This open area allows the customer to refill the pills. The thickness of the doors is 4mm, and the doors are connected to the shell via four hinges.

The exploded view of the shell can be seen in Figure 14.

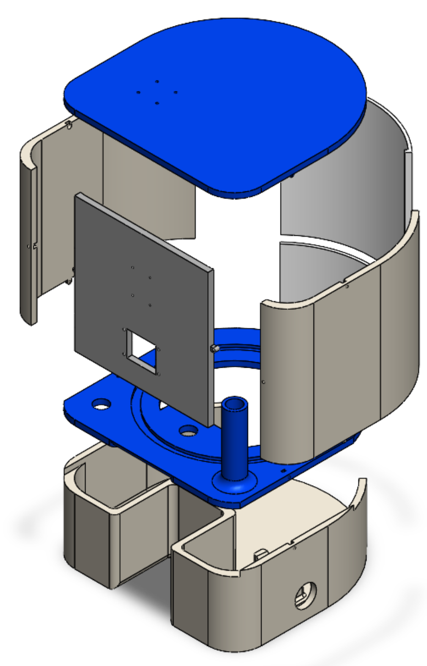


Figure 14: Exploded view of the shell assembly.

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 in the turning plate. The turning plate is rotated with the step motor, but the step motor should not carry any force on its turning axis. To eliminate that force exerting on the motor shaft, the turning plate is placed on top of some wheels, and it turns inside the wheel slot. The load is carried by the wheels and the plate where the turning plate rotates. For an extreme analysis, the pills are taken to be 5 grams each and one chamber will hold 30 pills. The pill chambers and the turning plate are going to be printed with PLA material with 50% infill. The material properties are given as in Table 3 [8].

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

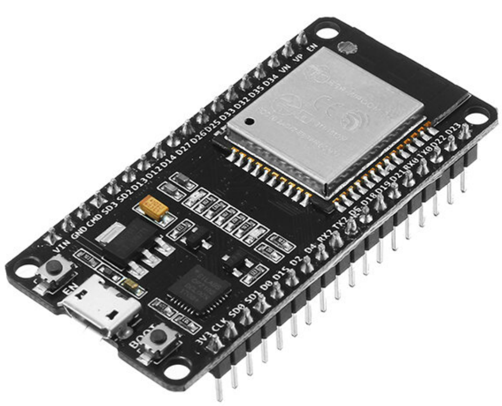
With 50% infill, the plate is 300 grams and the chambers in total are 650 grams. The total mass of the pills, chambers and the plate are 1950 grams. These parts apply force to the stationary plate and the movement facilitator wheels. The static analysis is done to understand the impact of the pill load to the wheel, turning plate and stationary 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. The wheel carries the load of the pills, chambers, and the turning plate. The wheel has a maximum displacement of 0.0011 mm, and the maximum stress is 739.9 kPa. Finally, the stationary plate which is called "plate-v3" in the assembly tree has a maximum displacement of 0.05397 mm and the maximum stress is 406.5 kPa. The maximum stresses in the parts are all below the safety margin due to PLA having 6 MPa yield strength. The roof 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 roof 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. 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 roof. 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

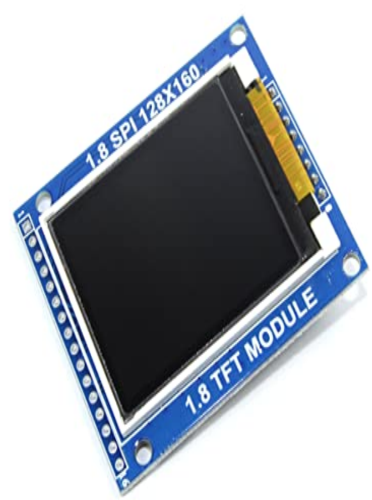
With the mechanical design, the second key component to obtain the required functionality is the electrical design. These functionalities are:

- Alert the user when it is time to take pills which is done by buzzer and LED.
- Rotating the pill chamber and the crank for the linear mechanism suction.
- Rotate the crank for the linear mechanism of suction.
- Run the suction pump.
- Give detailed information to user.
- 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 15a 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[9]. For alerting the user, the typical Arduino Buzzer and LED's are used[10]. In addition, TFT-LED touchscreen in Figure 15b is aimed to be used for the user interfacing and sufficing detailed information need of the users such as which pill is dropped or what dosage is used.



(a)

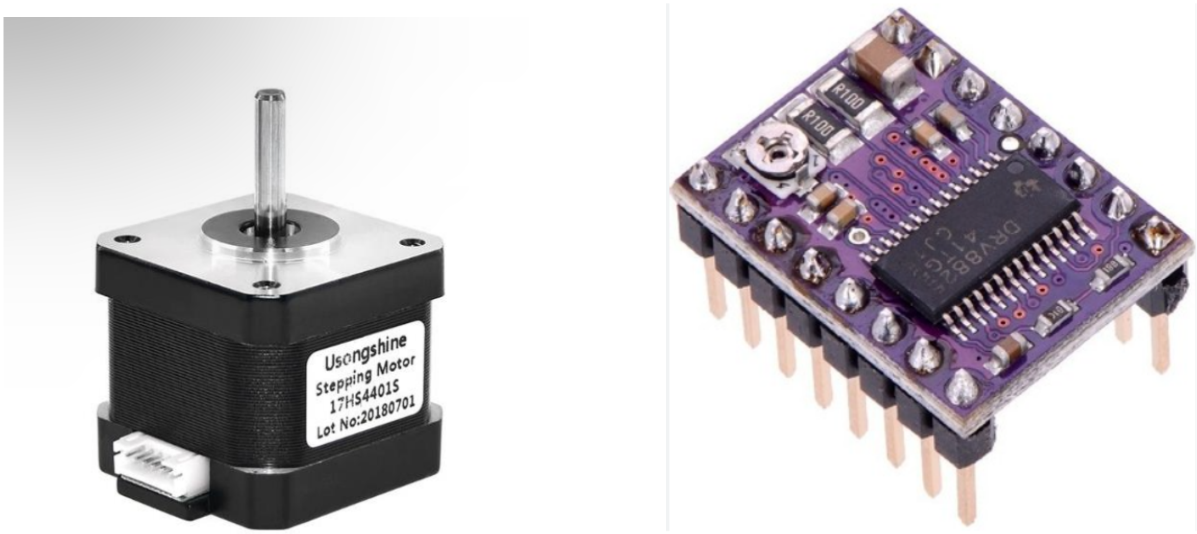


(b)

Figure 15: High level circuit components: (a) ESP32, (b) 1.8 Inch TFT LCD Screen Module

For the motions of rotation, NEMA17 stepper motor in Figure 16a is used to satisfy torque requirements as will be explained in subsubsection 3.4.1. For the motor driver, DRV8825 in

Figure 16b is used as it is cheap, commonly accessible for purchase in Turkey and compatible with NEMA17 as well as ESP32[11]. 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 [11] is well below the 20A.



(a) (b)

Figure 16: Electric motor circuit components: (a) NEMA17, (b) DRV8825

To avoid confusion of 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

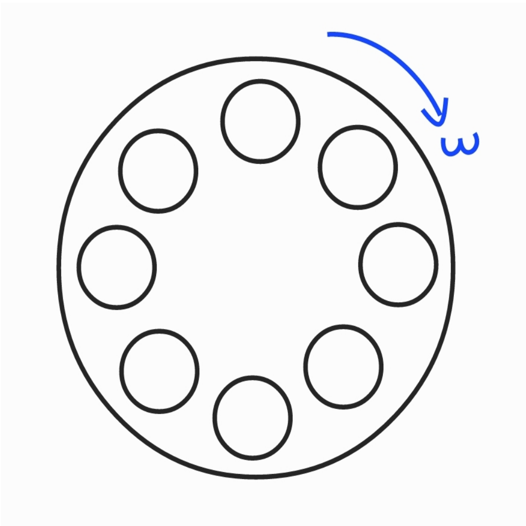
LCD: CS 10, $RESET$ 15, SDI 11, SCK 12, LED 3.3V, $TCLK$ 12, TCS 34, $TDIN$ 11, TDO 13

STEP1: STEP 16, DIR 17

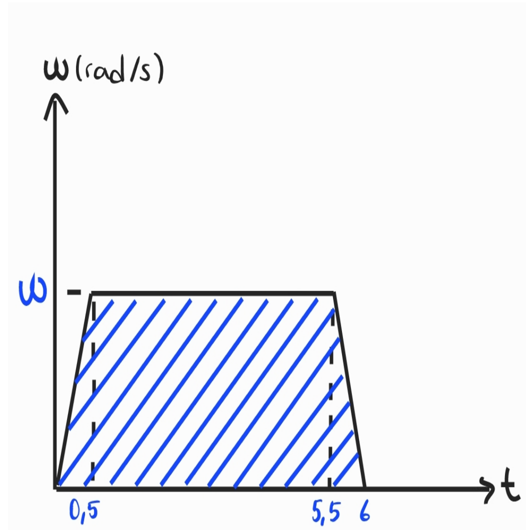
STEP2: STEP 5, DIR 18

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 [12]. 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 17: 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 17a. The area under the radial velocity vs. time graph shown in Figure 17b 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 1.85 kg. The data is taken from the Solidworks data. It can be seen that the maximum weight the stepper motor can rotate is almost 10 times the mass we will use. Therefore, this stepper motor is appropriate for our design.

3.5 Algorithm

After deciding on the mechanical and electrical components, the required algorithm is decided. Detailed pseudo-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.

Cost Analysis

Although the prices are prone to change, the costs for the equipment needed can be seen below in Table 4. 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 equipments are all eligible for free shipping or can be purchased by going to the corresponding physical stores.

Table 4: Cost Analysis of Automated Pill Dispenser

Equipment	Quantity	Unit Price(TL)	Total Cost(TL)
NEMA 17 Stepper Motor	1	189TL /Piece [13]	189
BreadBoard 830	1	35TL /Piece [14]	35
DRV8825	1	31,5TL /Piece [15]	63
BreadBoard Jumper Cables	1	35,71TL /Piece [16]	35,71
LED	1	0,5TL /Piece [17]	0,5
Arduino Buzzer Module	1	7,51TL /Piece [18]	7,51
Power Supply 220V-12V-20A	1	99TL /Piece [19]	239
12V-5V Arduino Converter Module	1	42,82TL /Piece [20]	42,82
12V Vacuum Pump	1	229,94TL /Piece [6]	229,94
3D Printer PLA	2	231TL /Kg [21]	462
M3 Bolt	20	29,17TL /20 Piece [22]	29,17
M3 Nut	20	5,06TL /10 Piece [23]	10,12
M2 Bolt	5	5,02TL /10 Piece [24]	5,02
M2 Nut	5	10,99TL /5 Piece [25]	10,99
M1 Bolt	12	200TL /Set of 200 [26]	200
M1 Nut	12	Bought together with M1 Bolt [26]	0
Hinge 10x11mm	4	40TL /4 Piece [27]	40
ESP32 Wi-fi Bluetooth Microcontroller	1	155,76TL /Piece [28]	155,76
1.8 Inch TFT LCD Touchscreen Module	1	237,03TL /1 Piece [29]	237,03
Total Cost			1852,57

Total cost is estimated to be 1852,57TL.

Conclusion

In this project, an automated pill dispenser is designed, modeled, and simulated in Spring 2023 for the implementation in Fall 2024 . The design aims to address medication management challenges, especially for the elderly people with diseases like Alzheimer's or that needs to take different medications with complex regimes.

Initially, research is undertaken to see what type of solutions for the mechanism of pill dispenser is done. Then it is chosen to use a rotating pill chamber to be used for different pill containers and an air pump for dispensing pills. After finalizing the absorption unit,

Subsequently, a basic mathematical model of the system for both air pump and the pill chamber is created. Multiple iterations with different dimensions are performed in simulations to find an optimal design considering the design and cost requirements.

Since the air pump requirements are as high as 2.5L/s, a product that is not very suitable to our design is used. As a result a compromise on the dimensions of the project is made. While the first dimensions of the dispenser is aimed at 30cm x 30cm x 30cm, the resulted design is 29cm x 29cm x 32cm. Still, the current expected value of 1852,57TL for the production is less than the aimed production price of 100$ (1.997,29TL as of time of writing the report). Pseudo code for the algorithm, technical drawings and electrical circuit drawings can all be found in Appendix.

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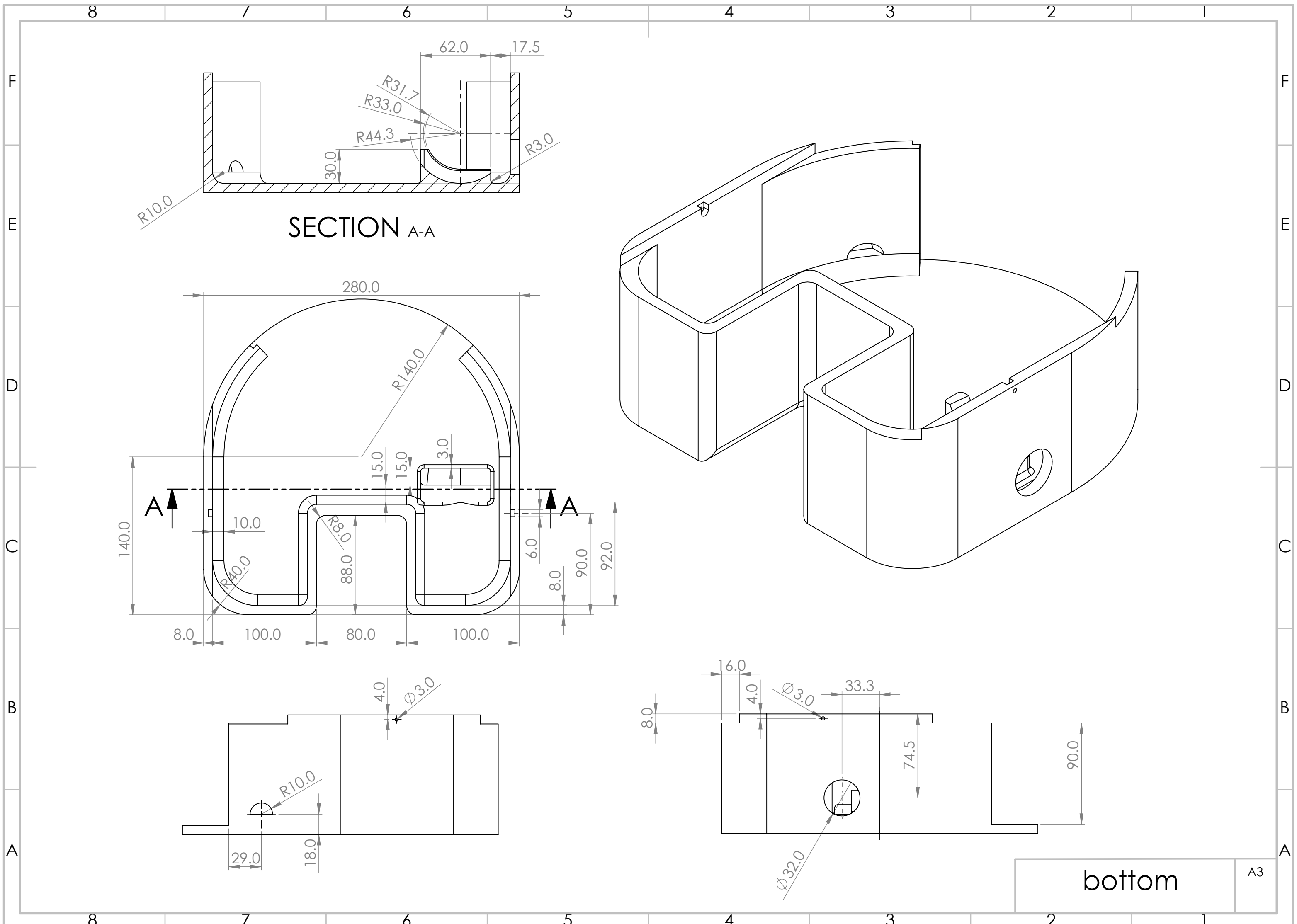
Appendix

A Technical Drawings



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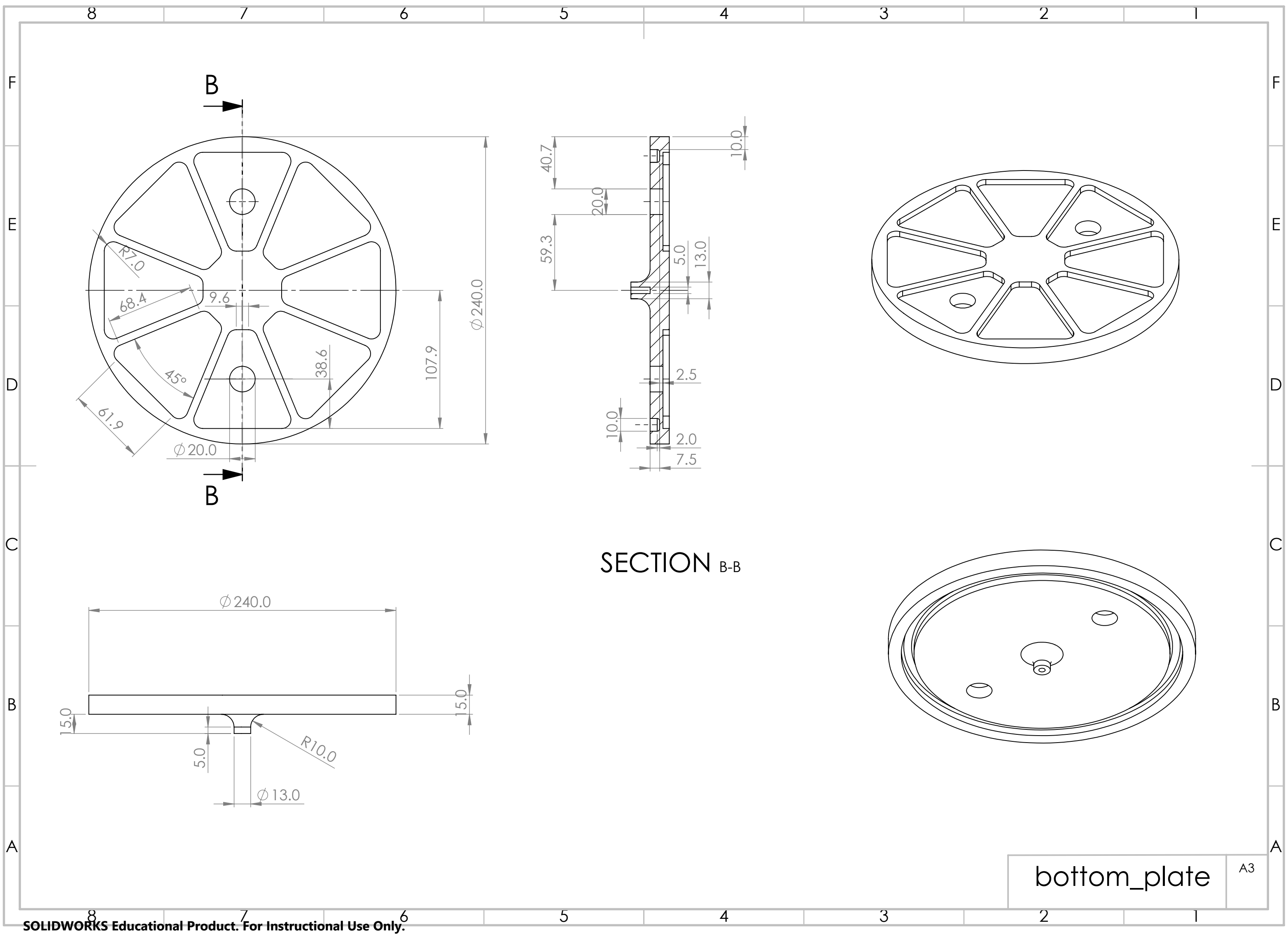
B
B
R7.0
68.4
9.6
45°
61.9
38.6
107.9
∅240.0
∅20.0
40.7
20.0
59.3
10.0
5.0
13.0
2.5
10.0
2.0
7.5
SECTION B-B
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15.0
5.0
R10.0
∅13.0
bottom_plate
A3
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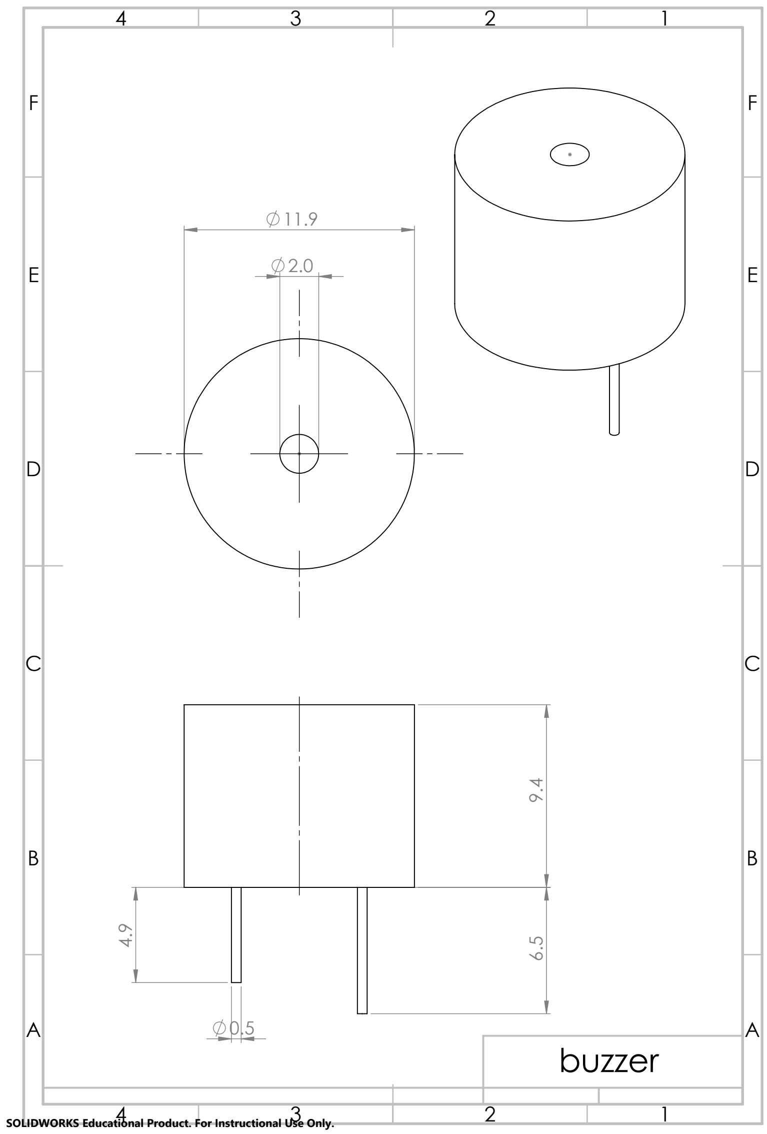

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3
2
1
F
E
D
C
B
A
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9.4
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∅0.5
buzzer
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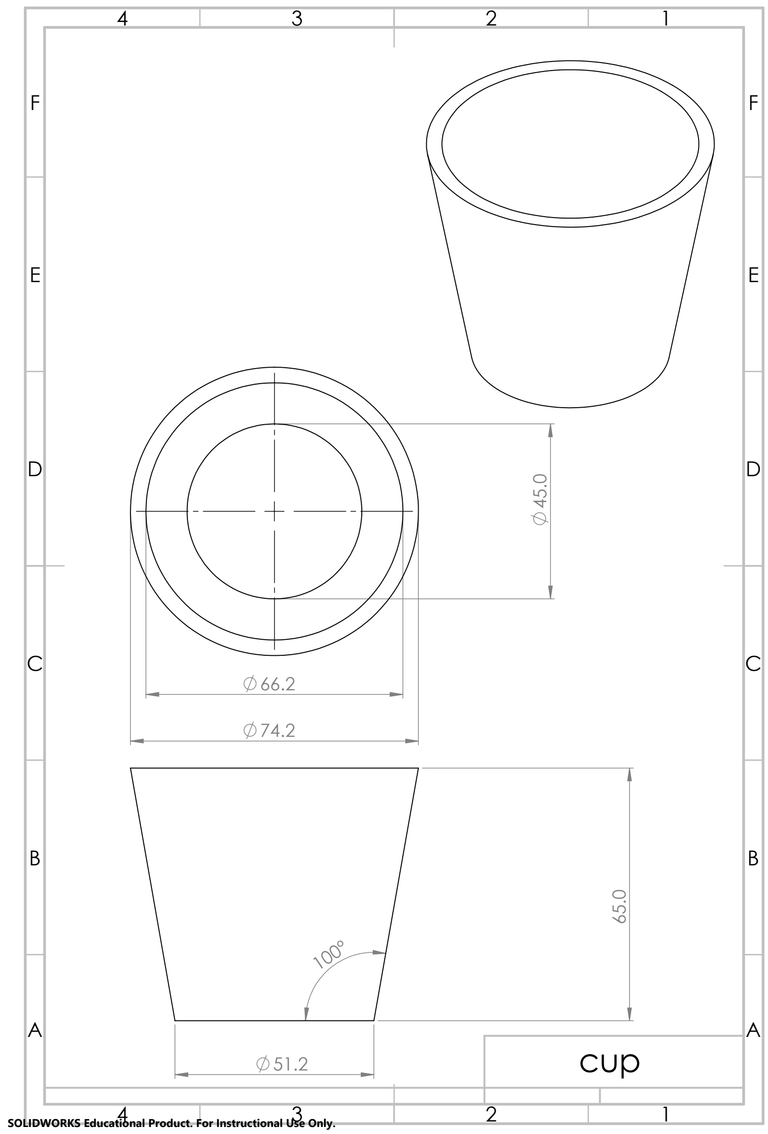

∅45.0
∅66.2
∅74.2
65.0
100°
∅51.2
cup
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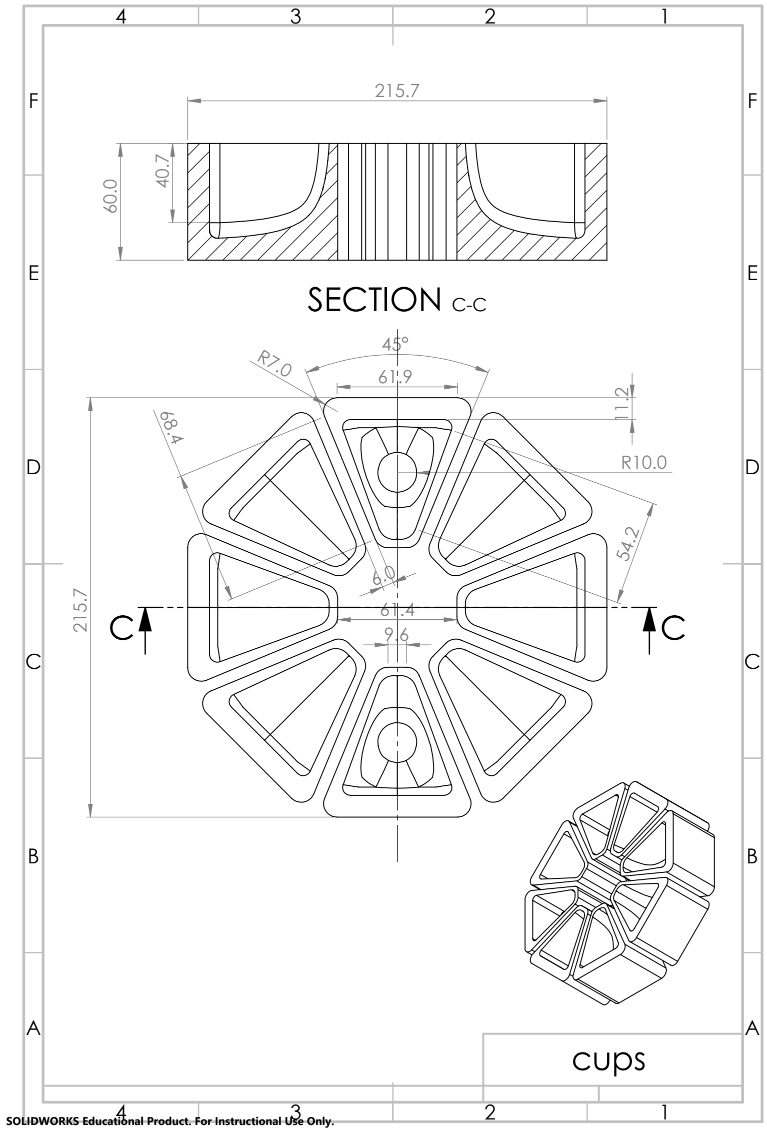
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SECTION C-C
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215.7
C
C
cups
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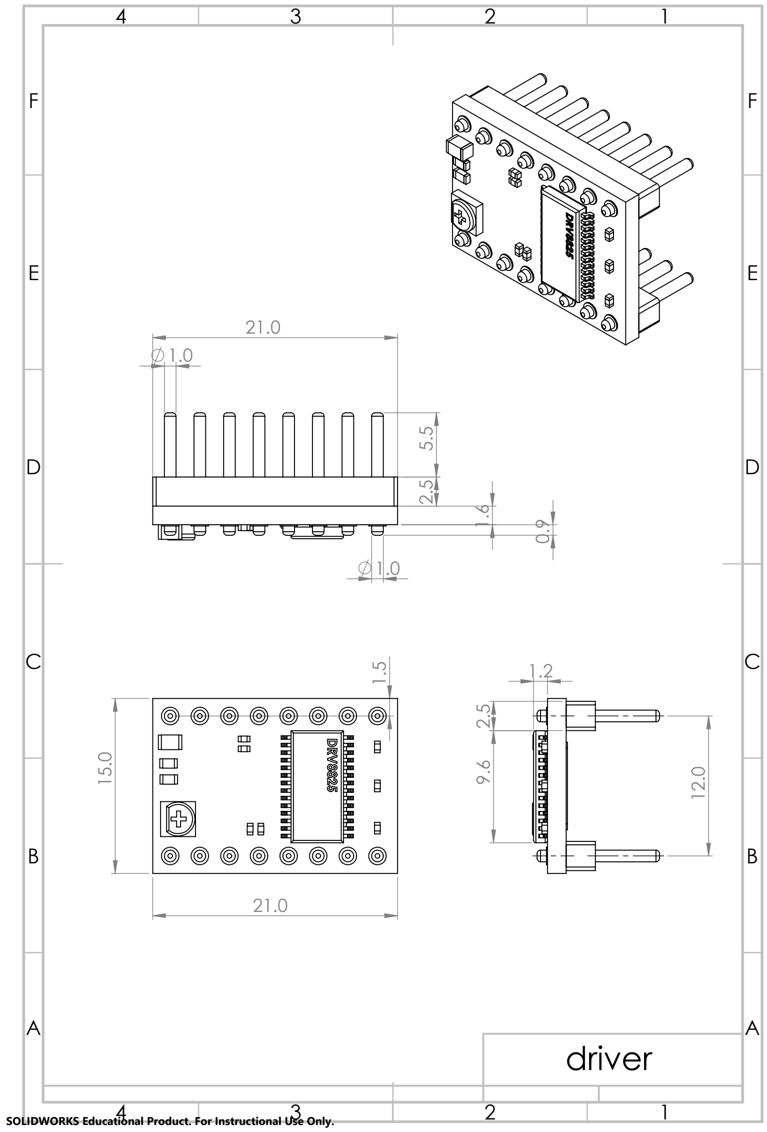
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0.9
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12.0
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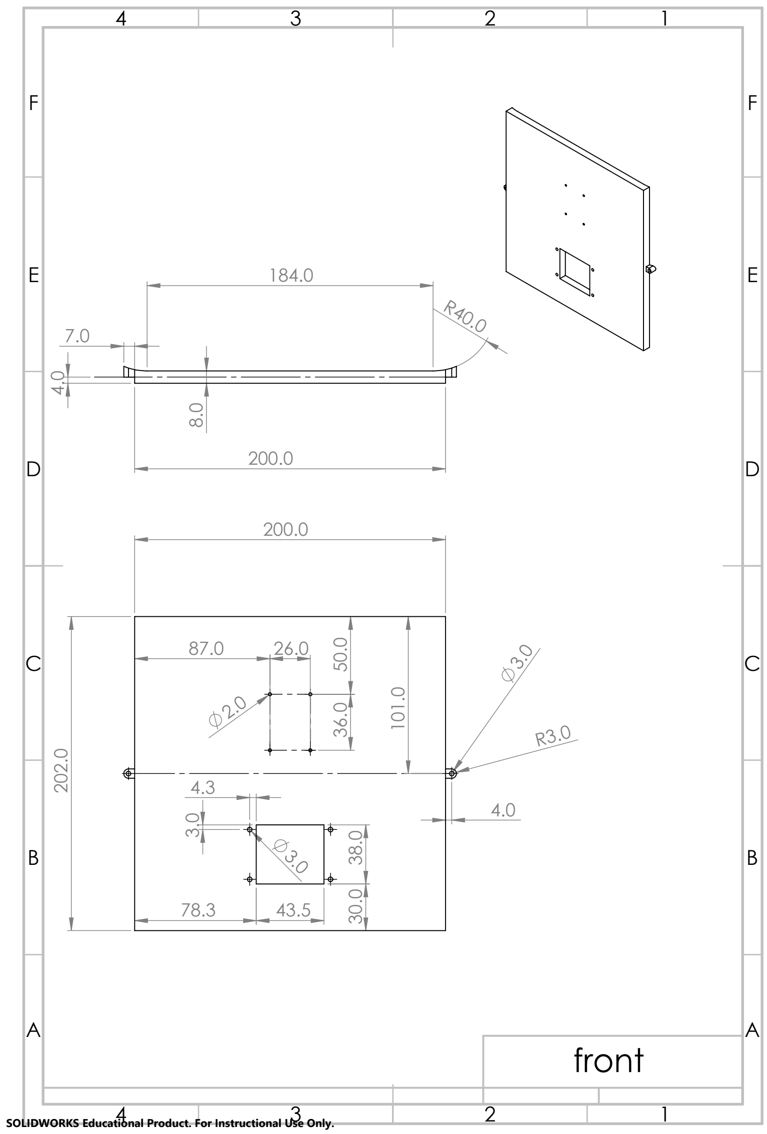
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200.0
87.0
26.0
50.0
Ø2.0
36.0
101.0
Ø3.0
R3.0
202.0
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3.0
Ø3.0
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30.0
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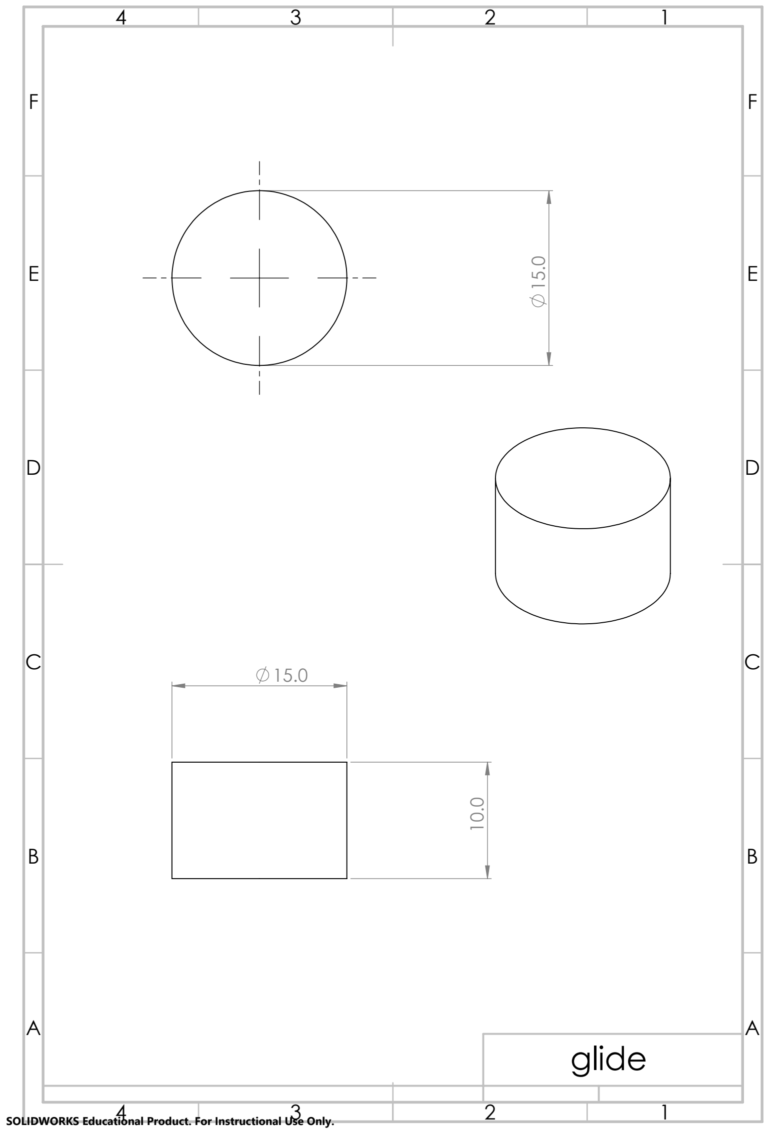
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Ø15.0
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glide
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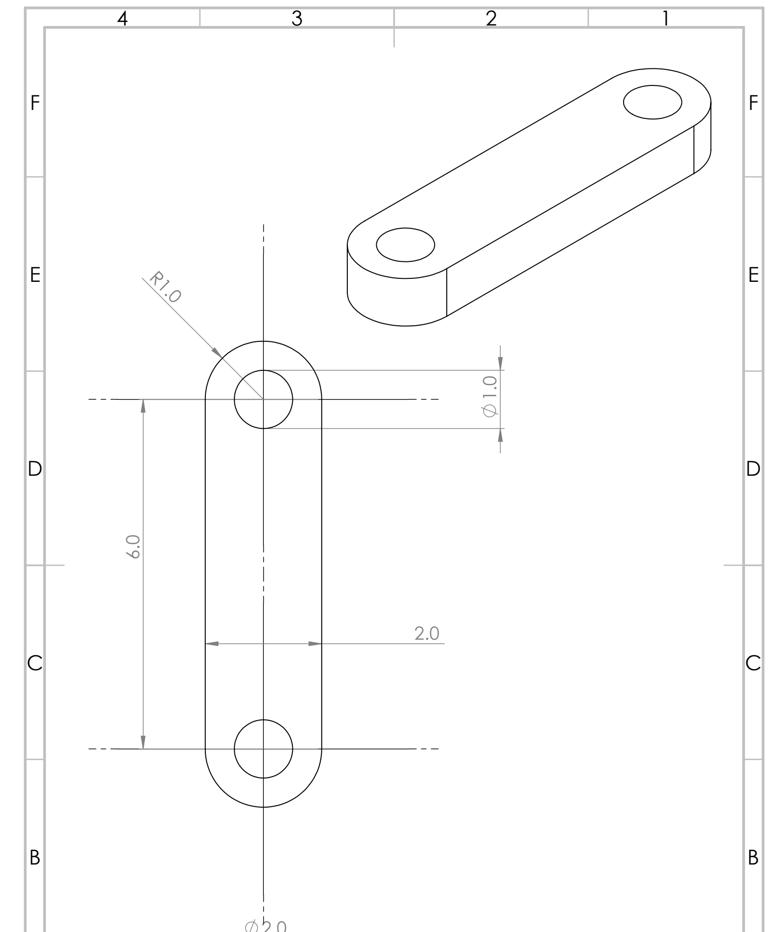
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1.0
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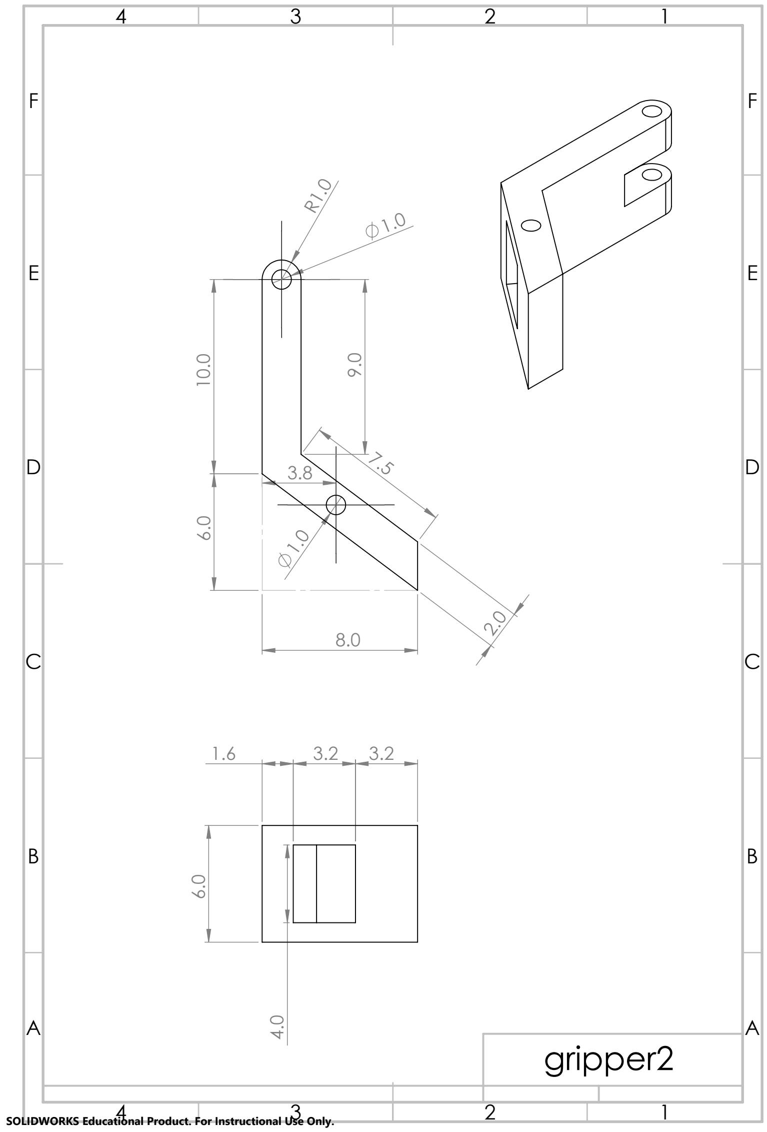
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4.0
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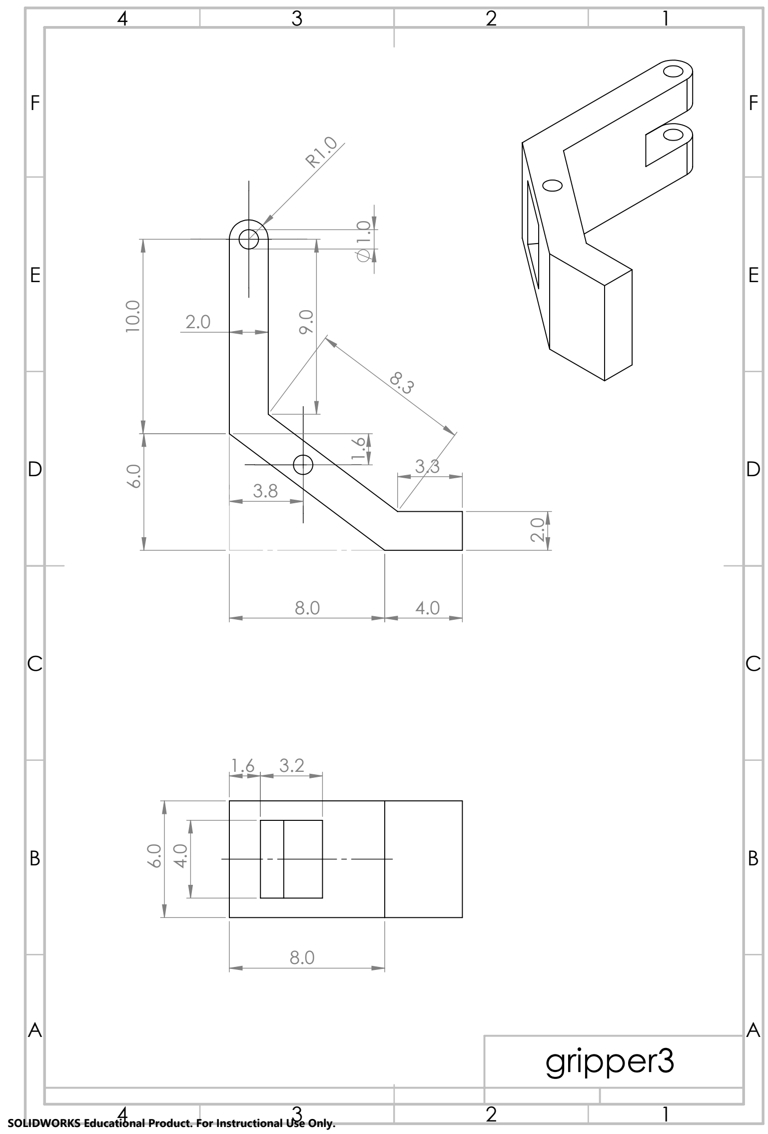
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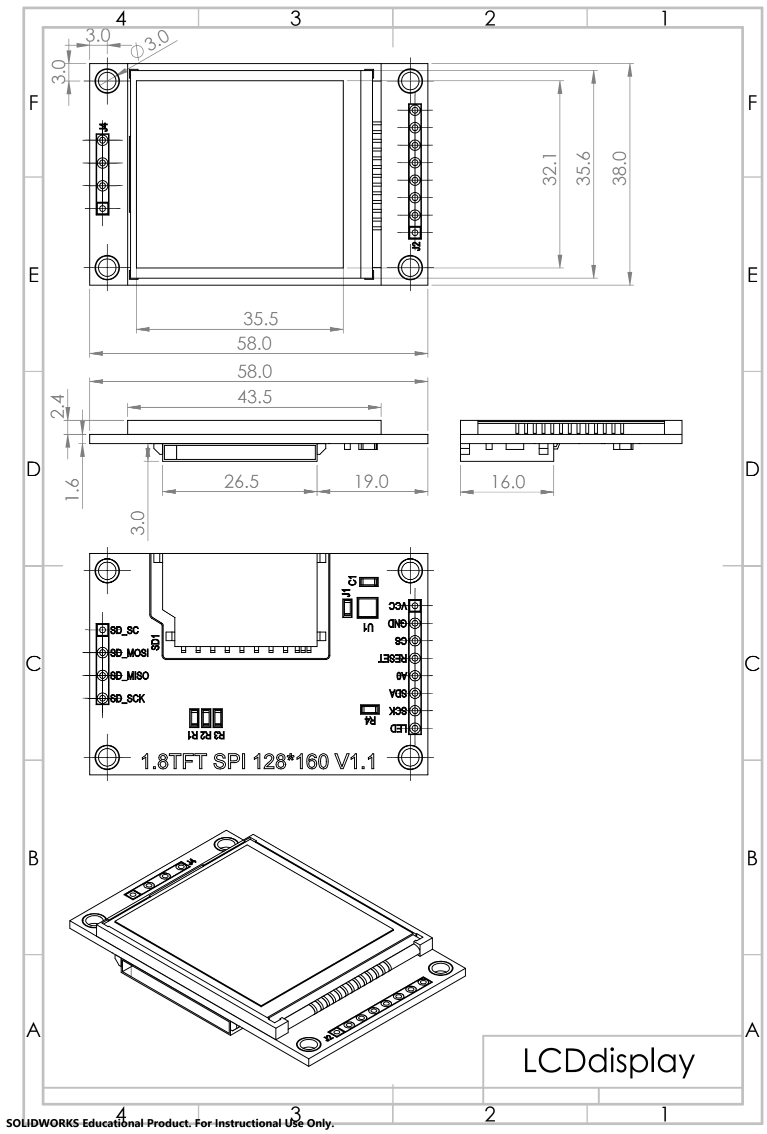

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⌀3.0
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J2
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38.0
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2.4
1.6
26.5
19.0
16.0
3.0
SD_SC
SD_MOSI
SD_MISO
SD_SCK
SD1
C1
J1
U1
VCC
GND
CS
RESET
A0
SDA
SCK
LED
R4
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LCDdisplay
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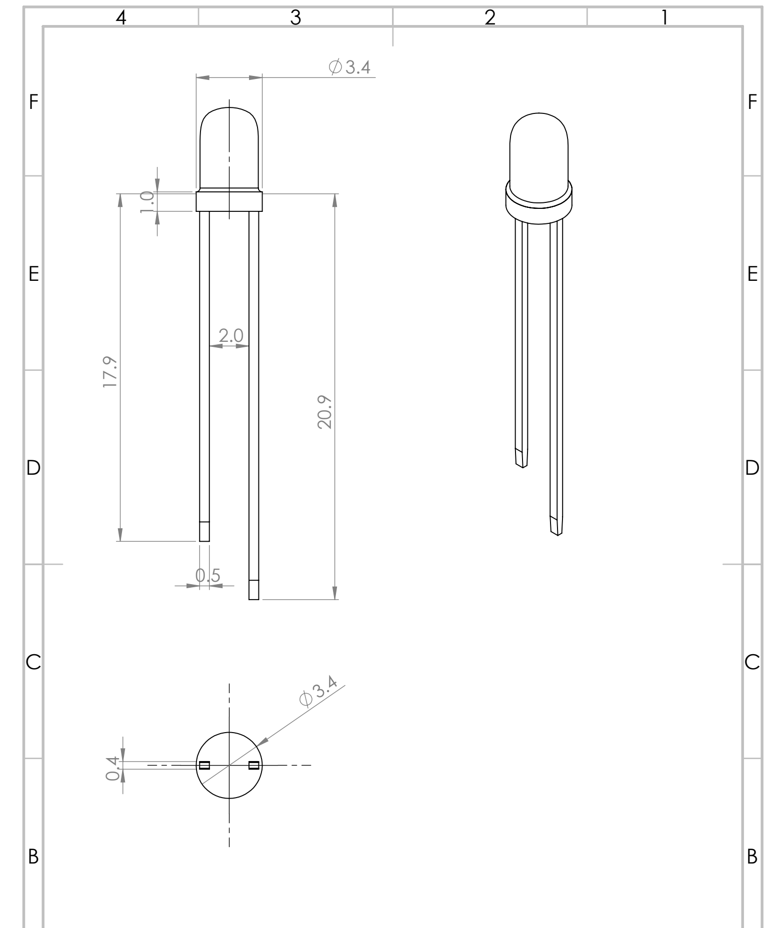

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0.4
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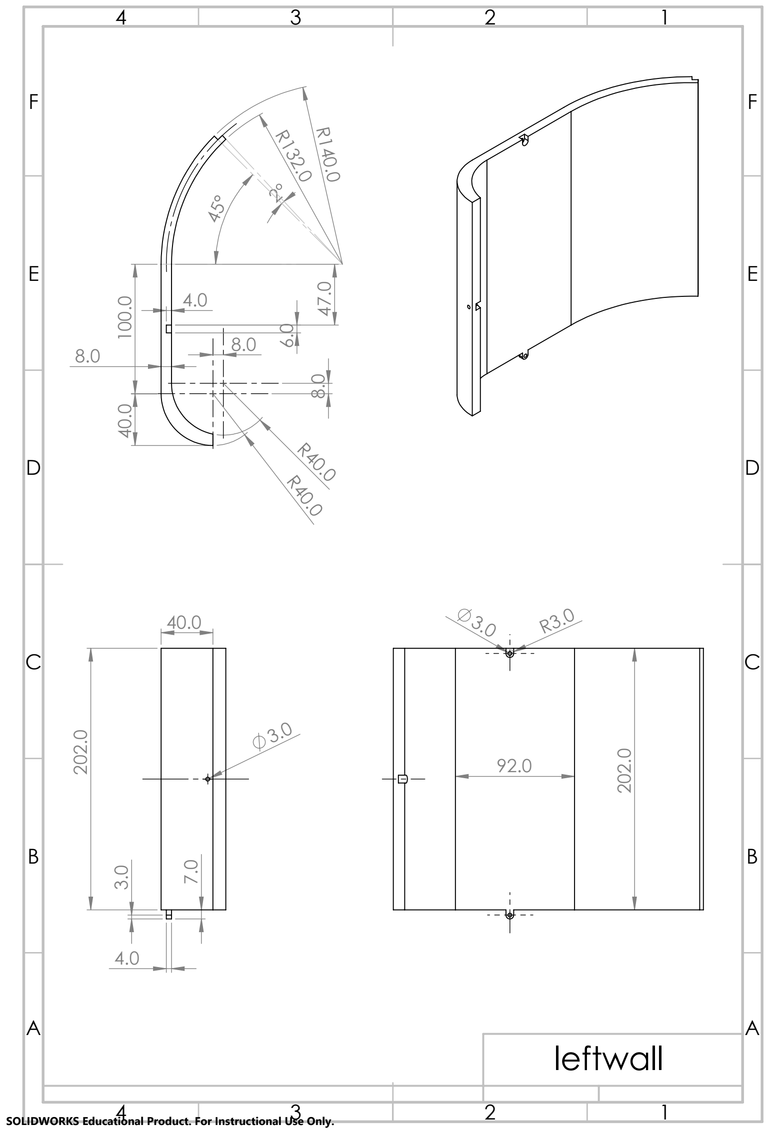

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2°
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8.0
6.0
8.0
8.0
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R40.0
R40.0
40.0
202.0
⌀3.0
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202.0
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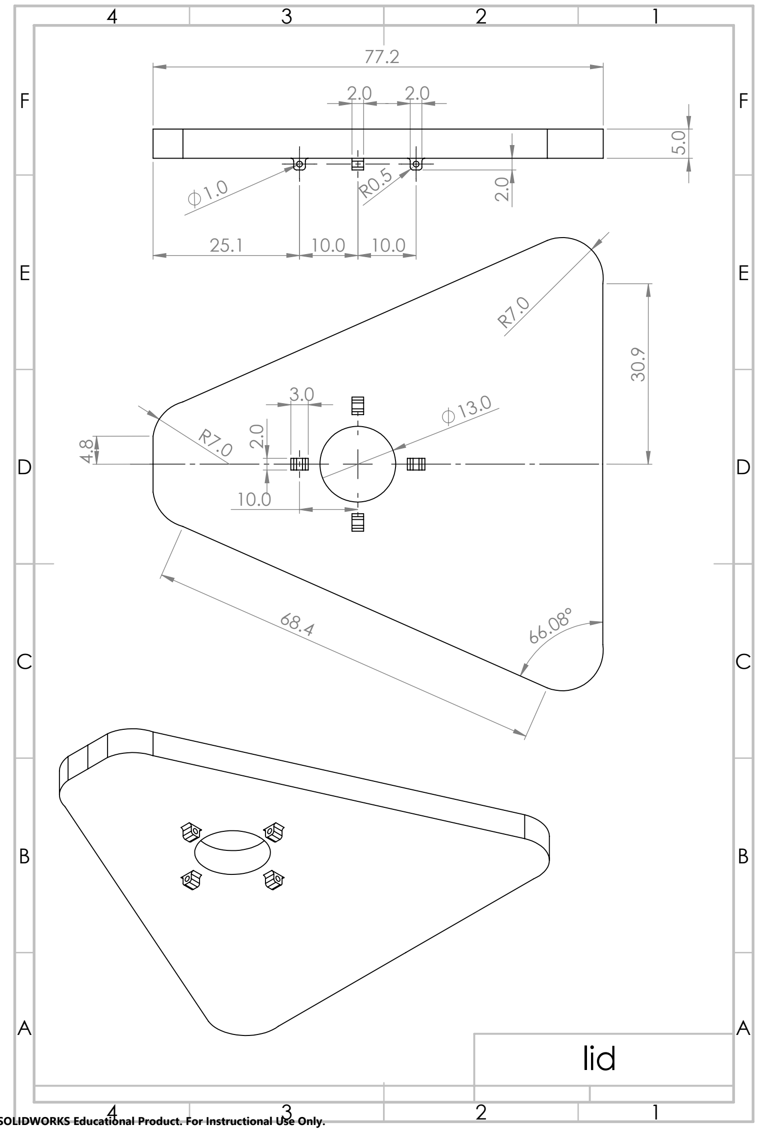

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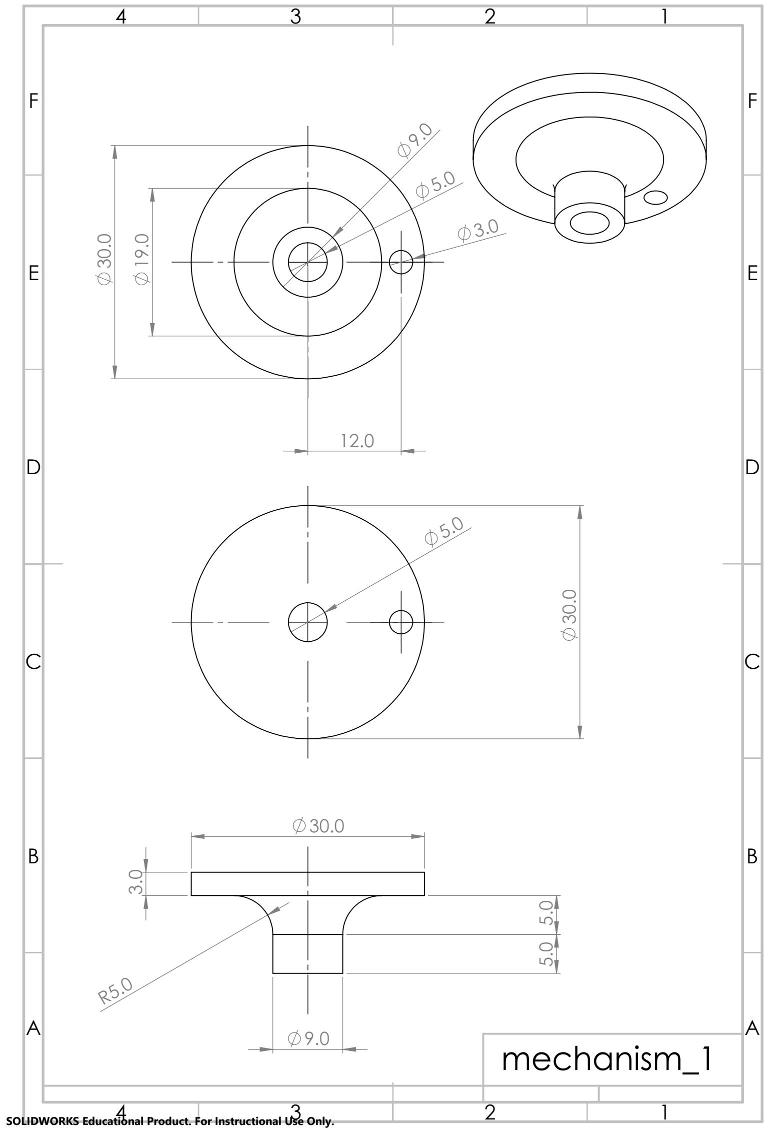

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F
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B
A
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⌀5.0
⌀3.0
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⌀19.0
12.0
⌀5.0
⌀30.0
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R5.0
⌀9.0
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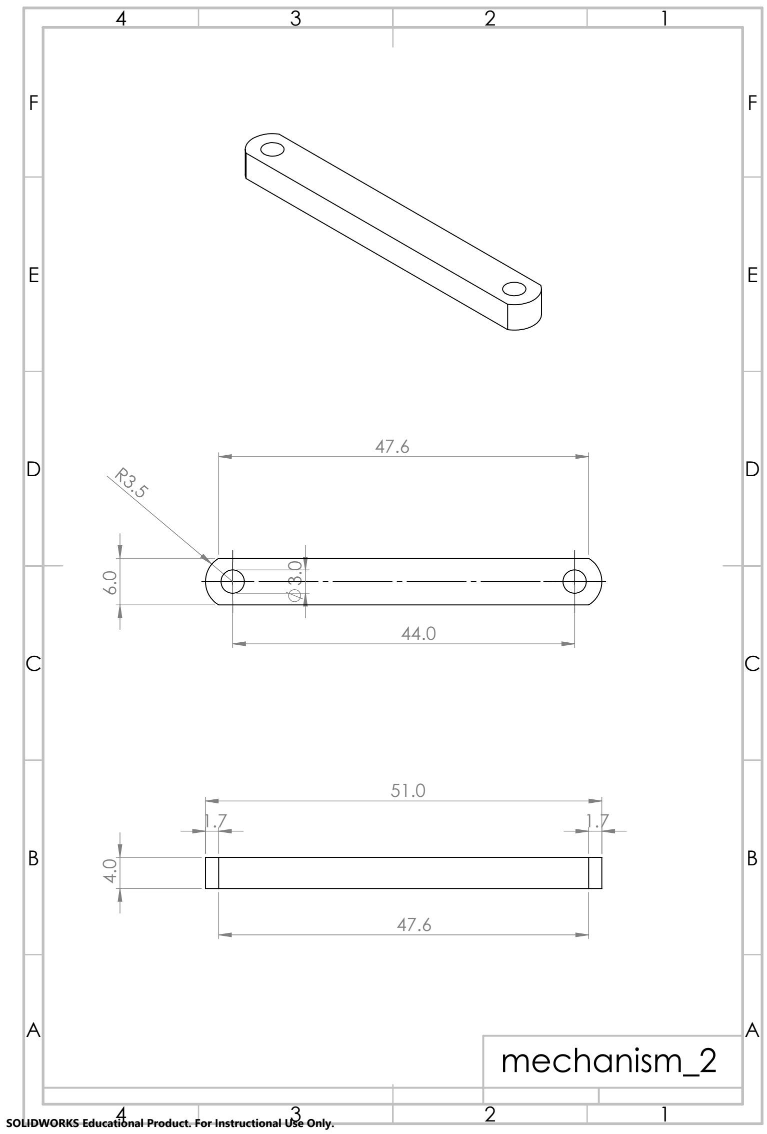

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R3.5
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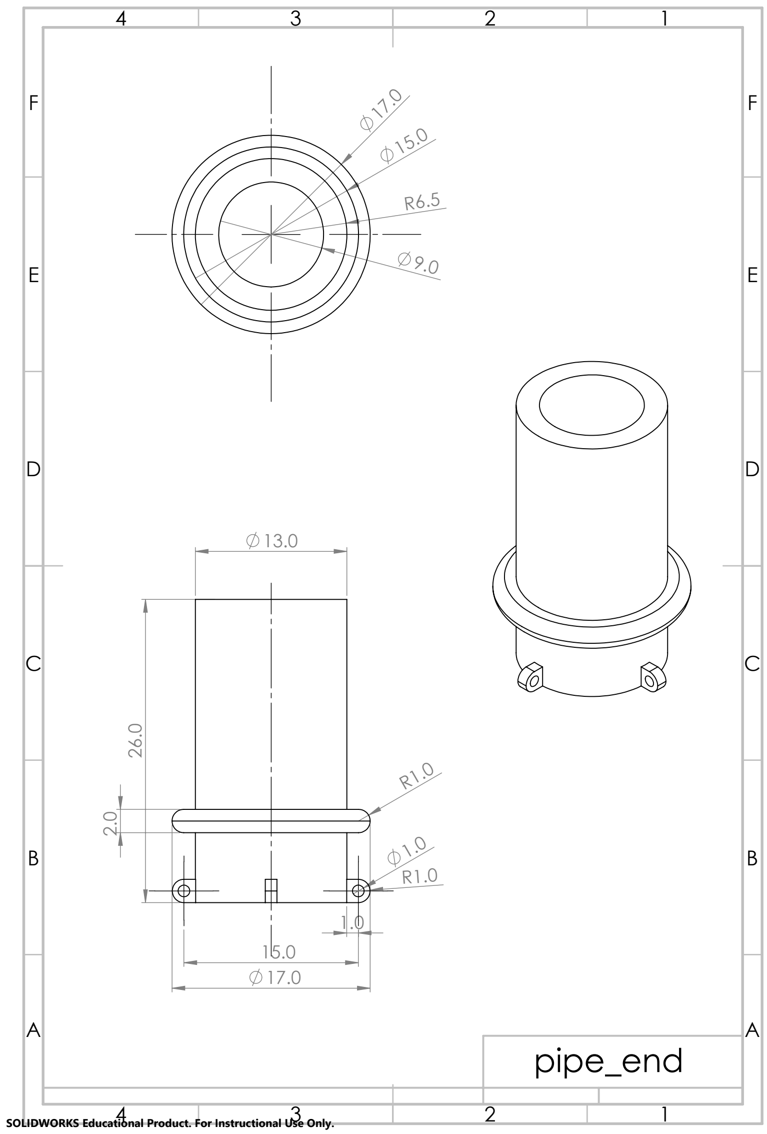
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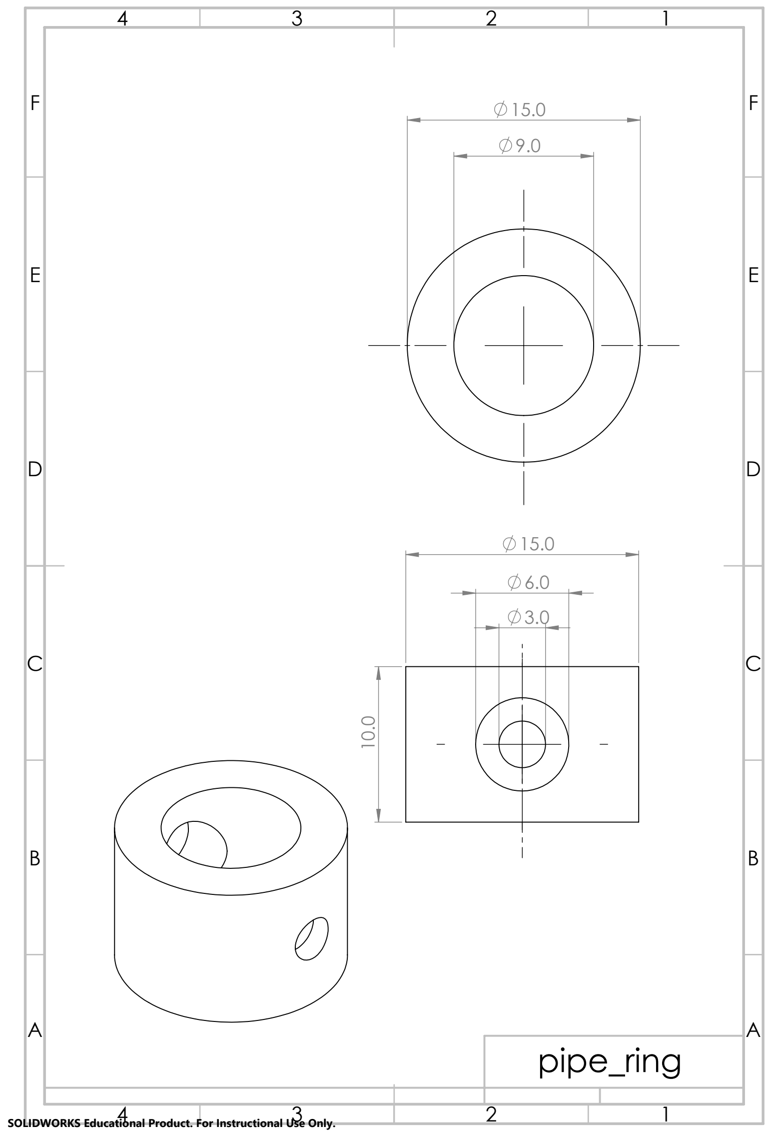
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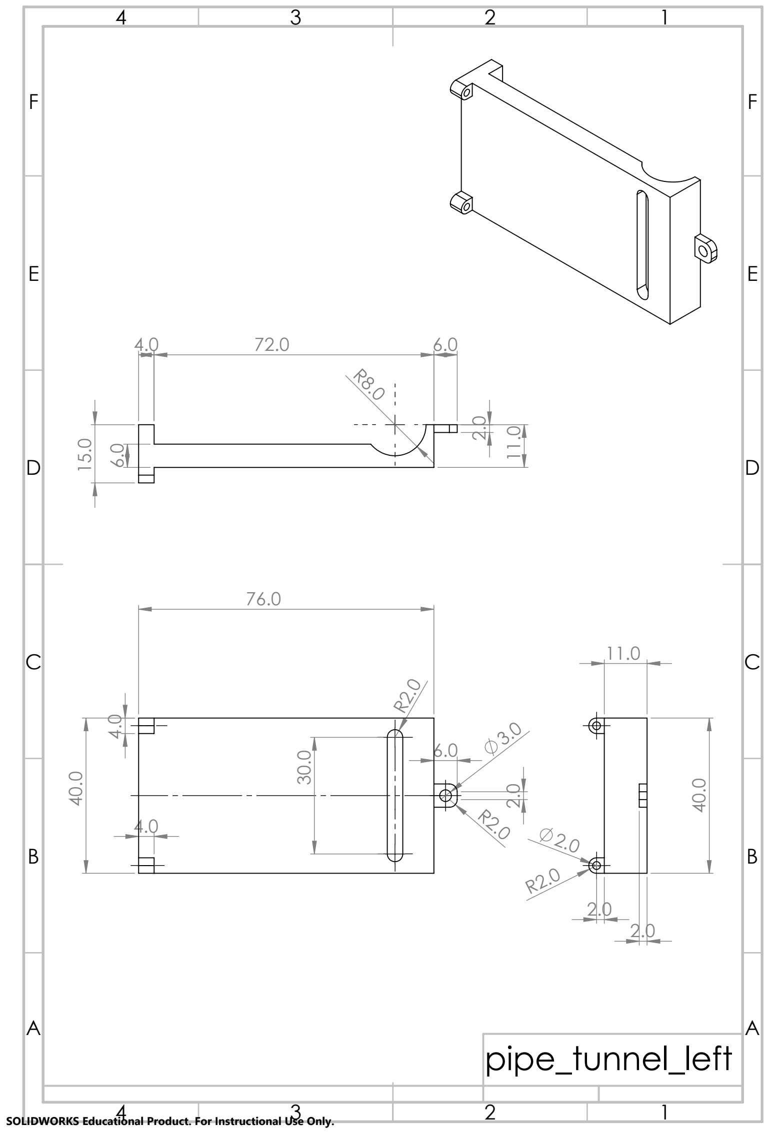
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6.0
⌀3.0
30.0
40.0
2.0
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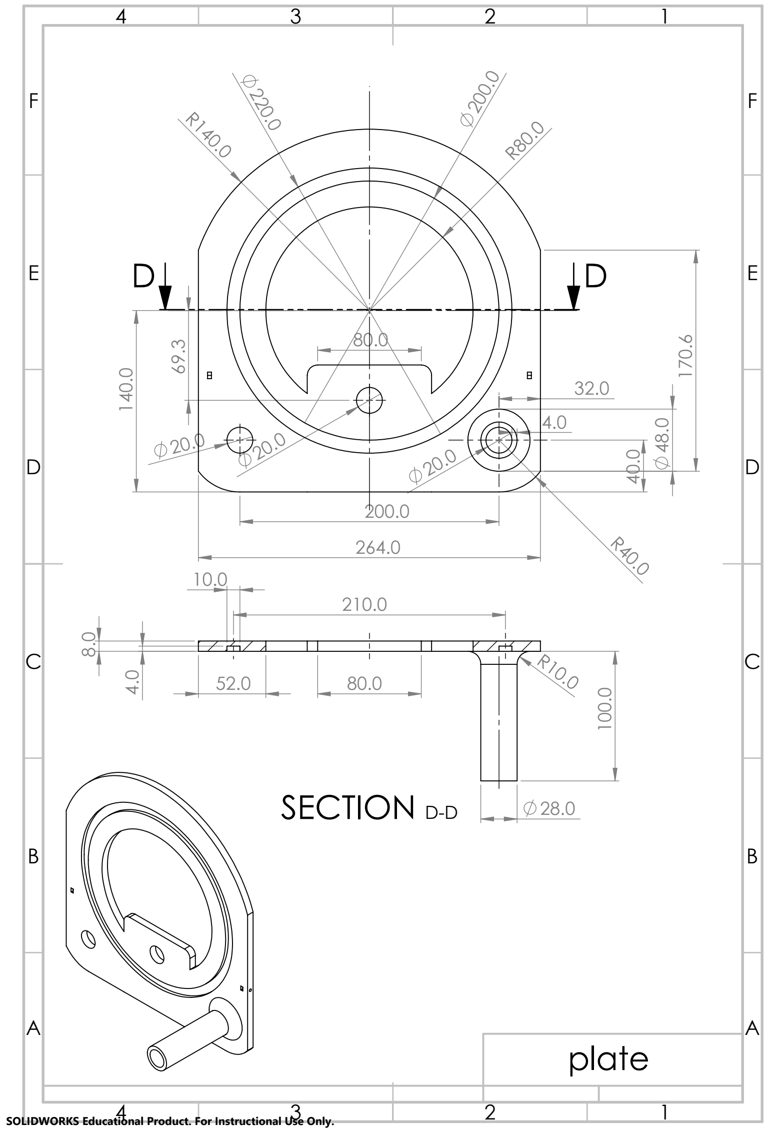
SOLIDWORKS Educational Product. For Instructional Use Only.



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D
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140.0
170.6
32.0
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Ø48.0
40.0
Ø20.0
Ø20.0
Ø20.0
200.0
264.0
R40.0
10.0
210.0
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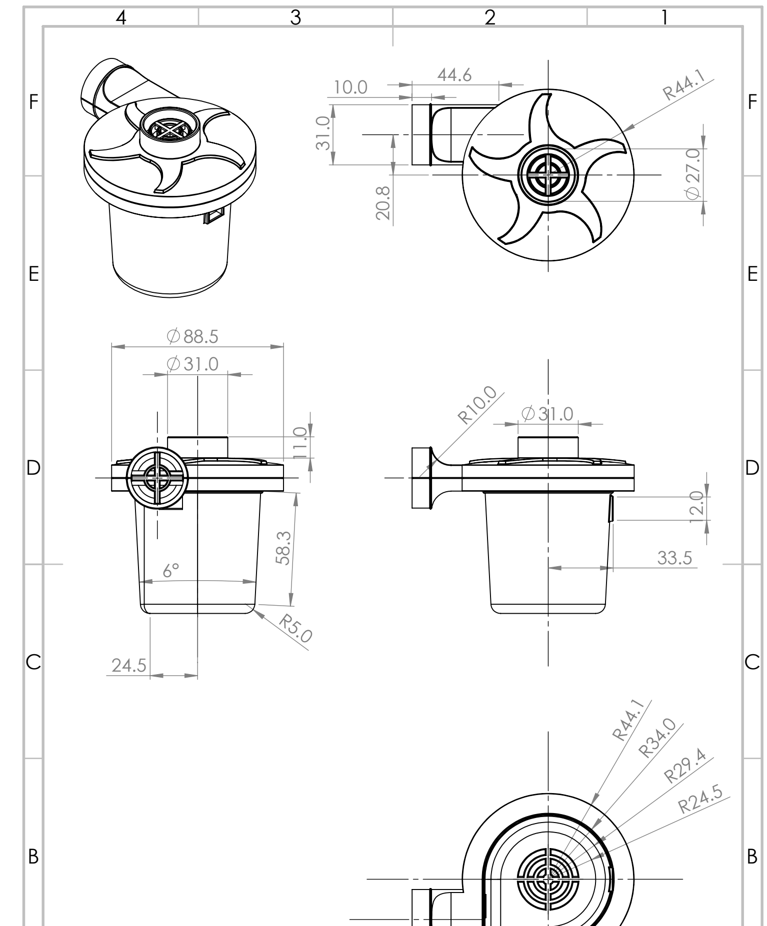

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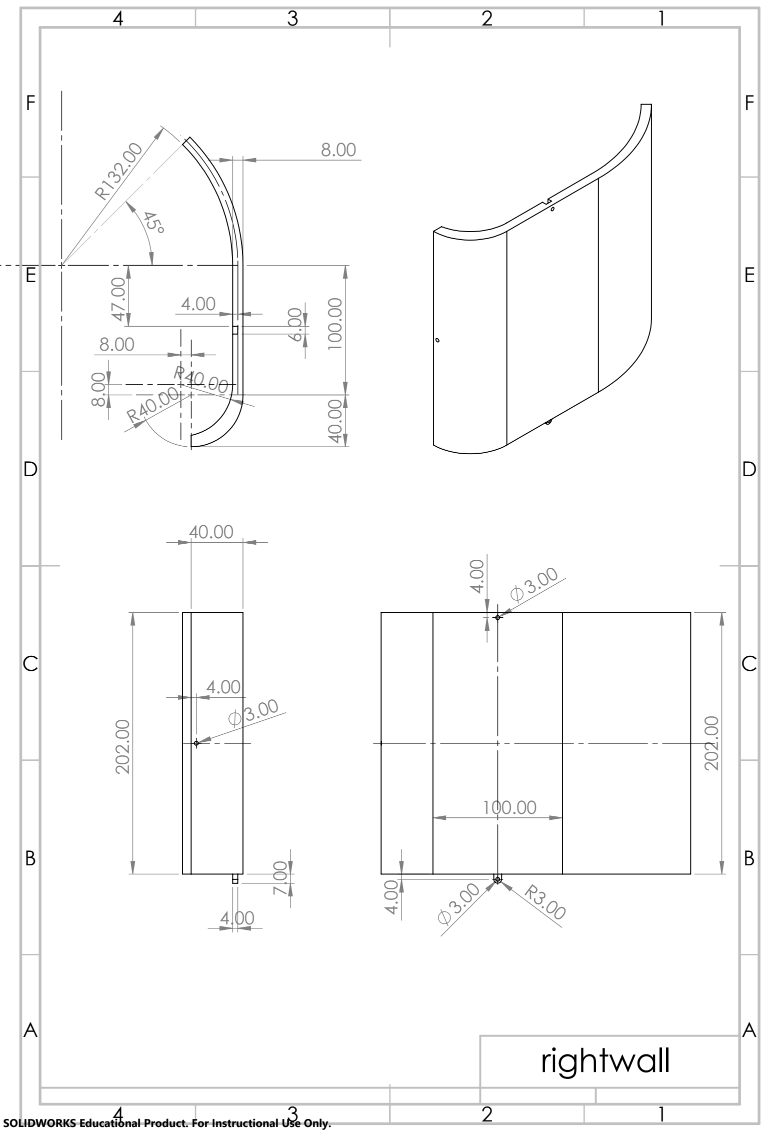
44.6
R44.1
31.0
20.8
∅27.0
∅88.5
∅31.0
11.0
58.3
6°
R5.0
24.5
R10.0
∅31.0
12.0
33.5
R44.1
R34.0
R29.4
R24.5
24.5
pump
SOLIDWORKS Educational Product. For Instructional Use Only.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8.00
47.00
4.00
6.00
100.00
8.00
8.00
R40.00
R40.00
40.00
40.00
202.00
4.00
⌀3.00
7.00
4.00
4.00
⌀3.00
202.00
100.00
4.00
⌀3.00
R3.00
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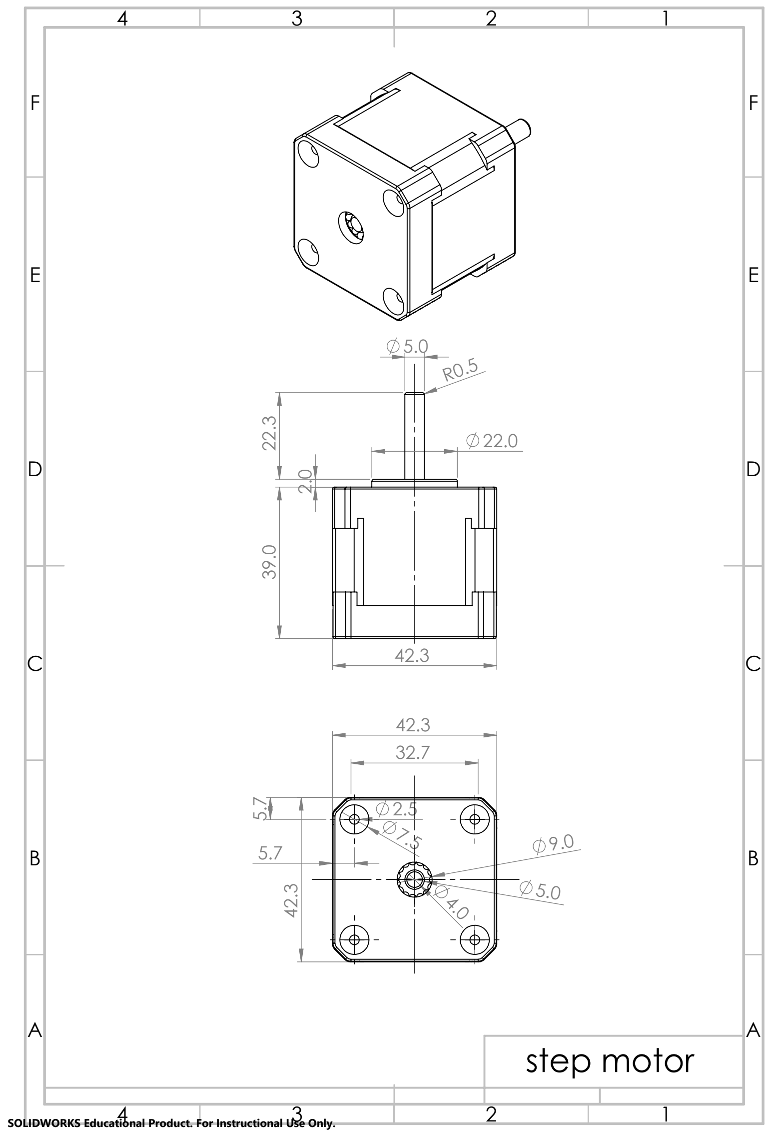

Ø5.0
R0.5
22.3
Ø22.0
2.0
39.0
42.3
42.3
32.7
5.7
Ø2.5
Ø7.5
5.7
Ø9.0
Ø5.0
Ø4.0
42.3
step motor
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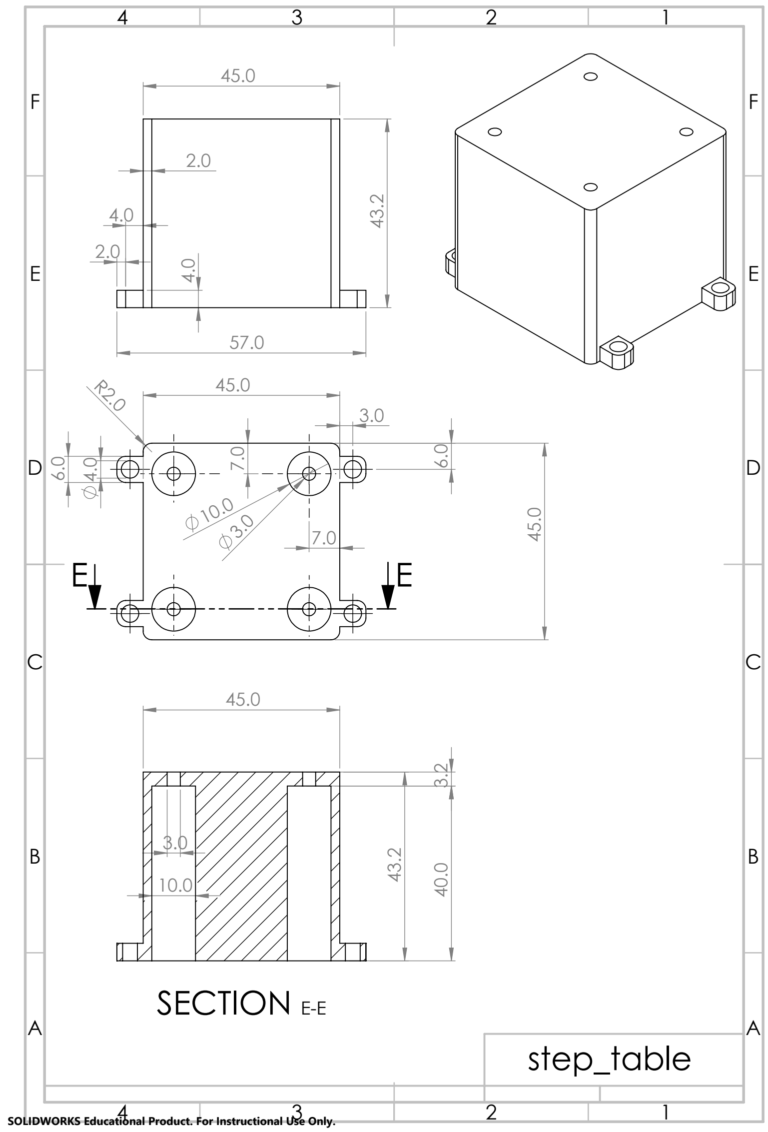
45.0
2.0
4.0
2.0
4.0
43.2
57.0
R2.0
45.0
3.0
7.0
6.0
6.0
⌀4.0
⌀10.0
⌀3.0
7.0
45.0
E
E
45.0
3.2
3.0
10.0
43.2
40.0
SECTION E-E
step_table
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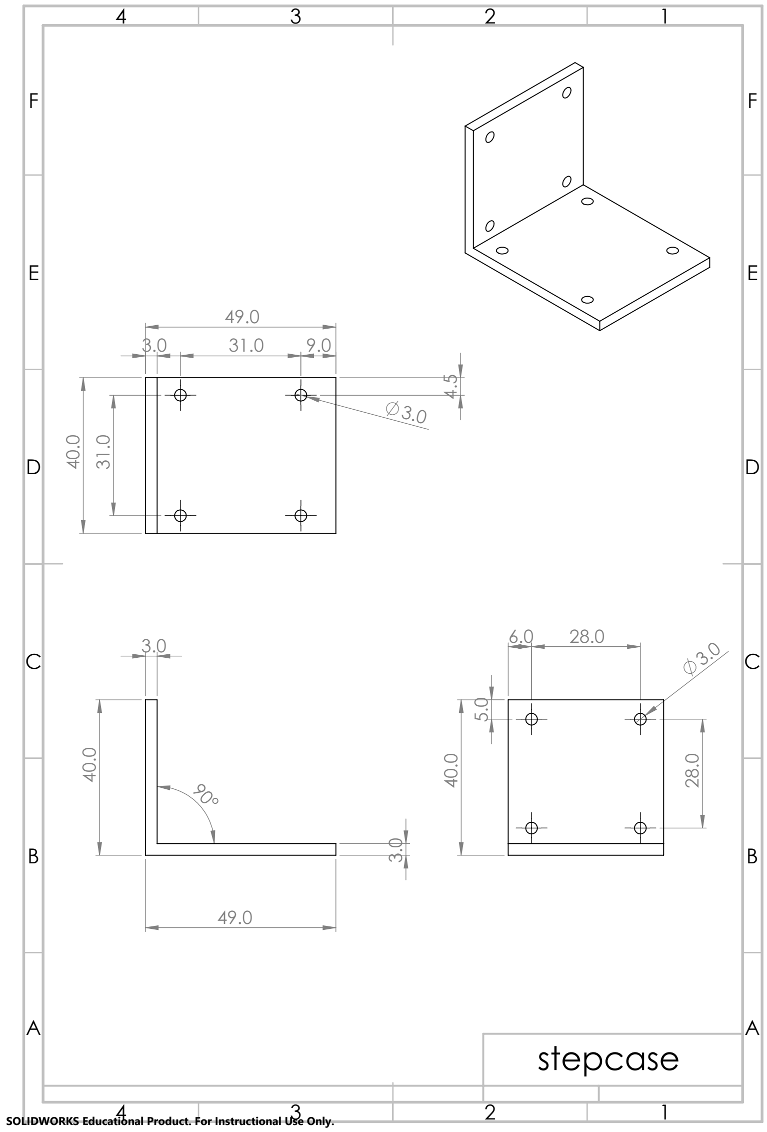

4
3
2
1
F
E
D
C
B
A
49.0
3.0
31.0
9.0
4.5
∅3.0
40.0
31.0
3.0
40.0
90°
3.0
49.0
6.0
28.0
∅3.0
5.0
40.0
28.0
stepcase
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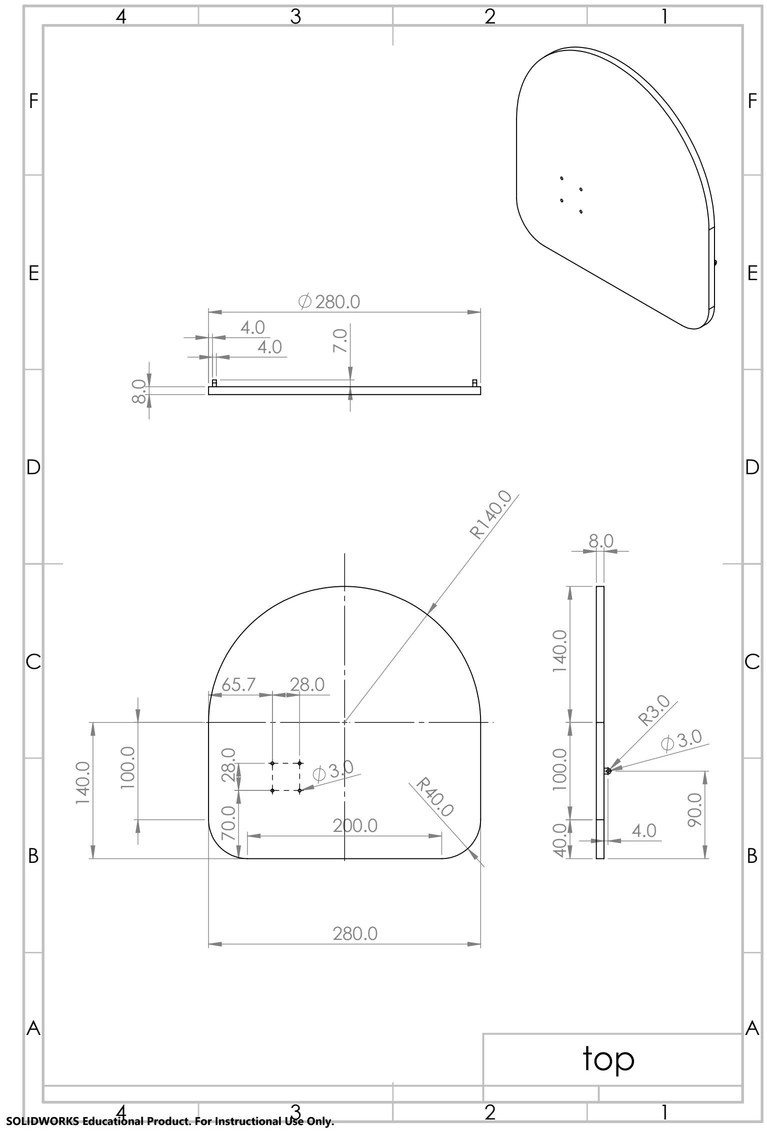

∅280.0
4.0
4.0
7.0
8.0
R140.0
8.0
140.0
65.7
28.0
R3.0
∅3.0
100.0
140.0
28.0
∅3.0
R40.0
100.0
70.0
200.0
40.0
4.0
90.0
280.0
top
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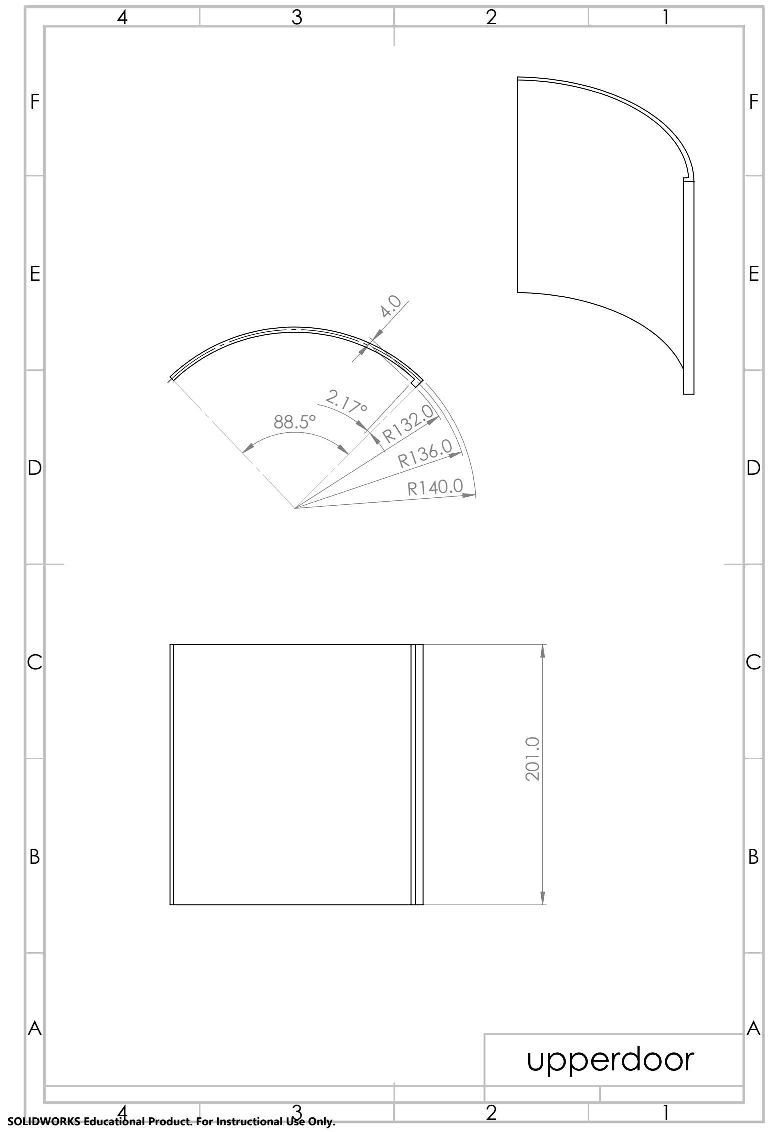
4.0
2.17°
88.5°
R132.0
R136.0
R140.0
201.0
upperdoor
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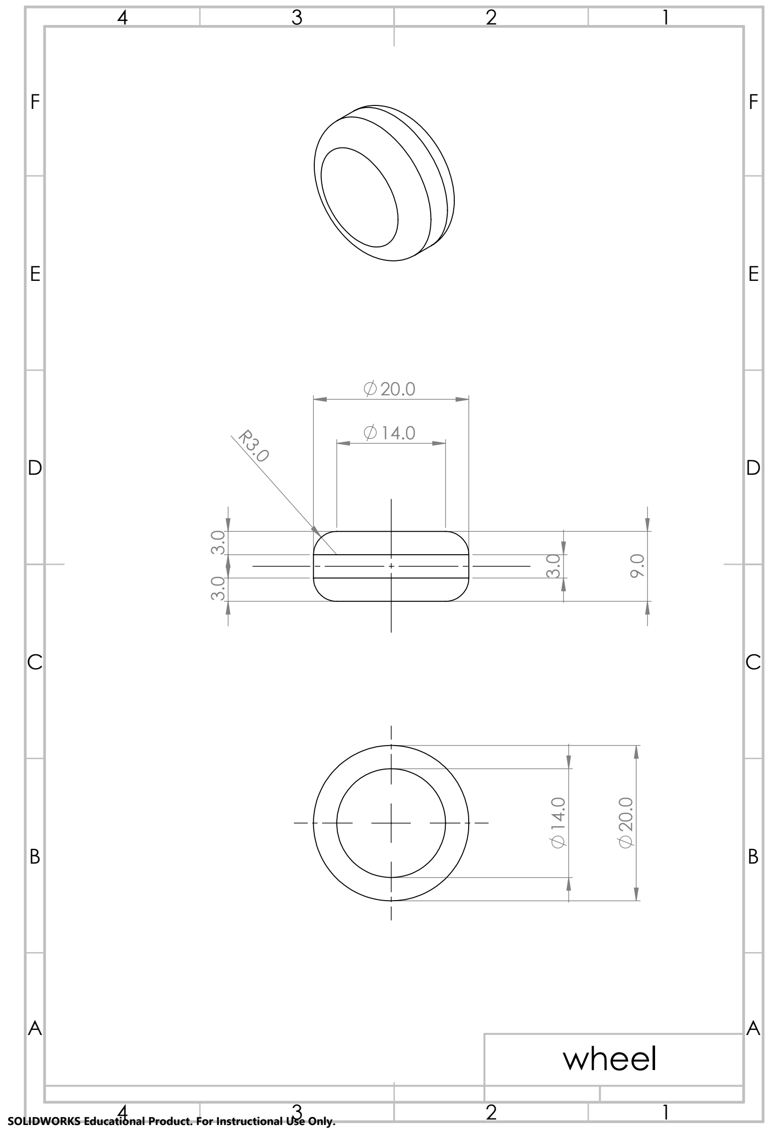

4
3
2
1
F
E
D
C
B
A
Ø20.0
Ø14.0
R3.0
3.0
3.0
3.0
9.0
Ø14.0
Ø20.0
wheel
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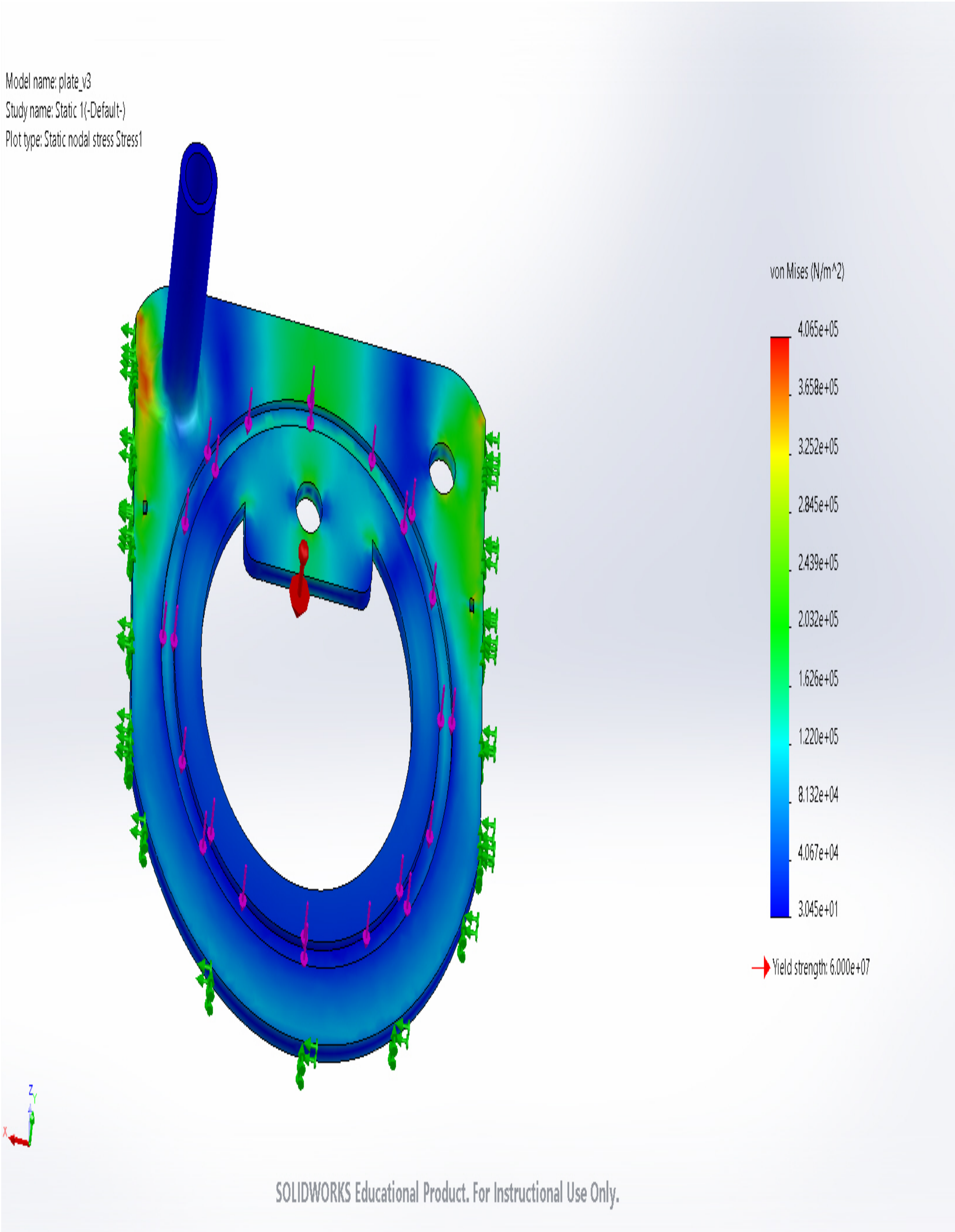
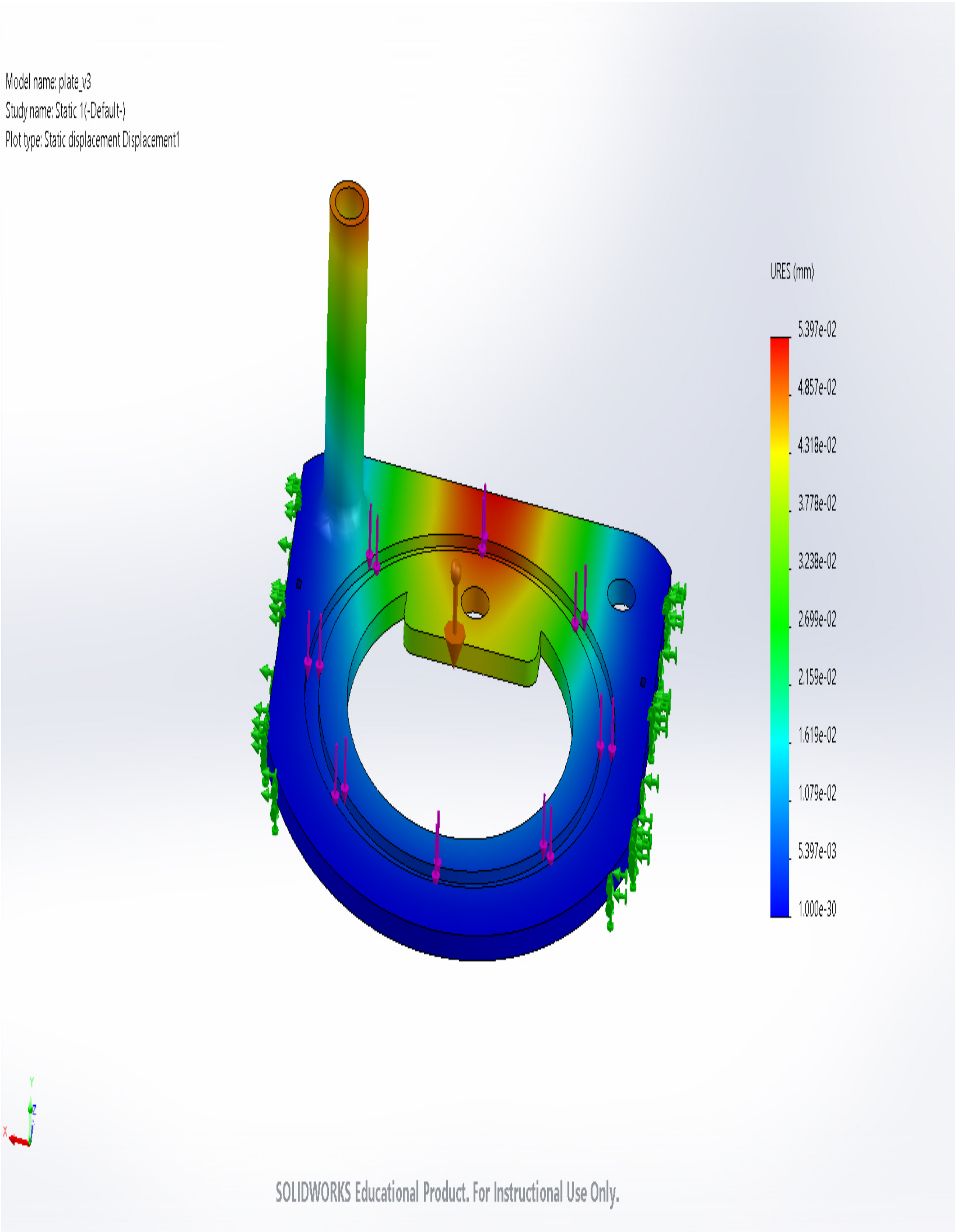
B Static Analysis Results




Model name: plate_v3
Study name: Static 1(-Default-)
Plot type: Static displacement Displacement1
URES (mm)
5.397e-02
4.857e-02
4.318e-02
3.778e-02
3.238e-02
2.699e-02
2.159e-02
1.619e-02
1.079e-02
5.397e-03
1.000e-30
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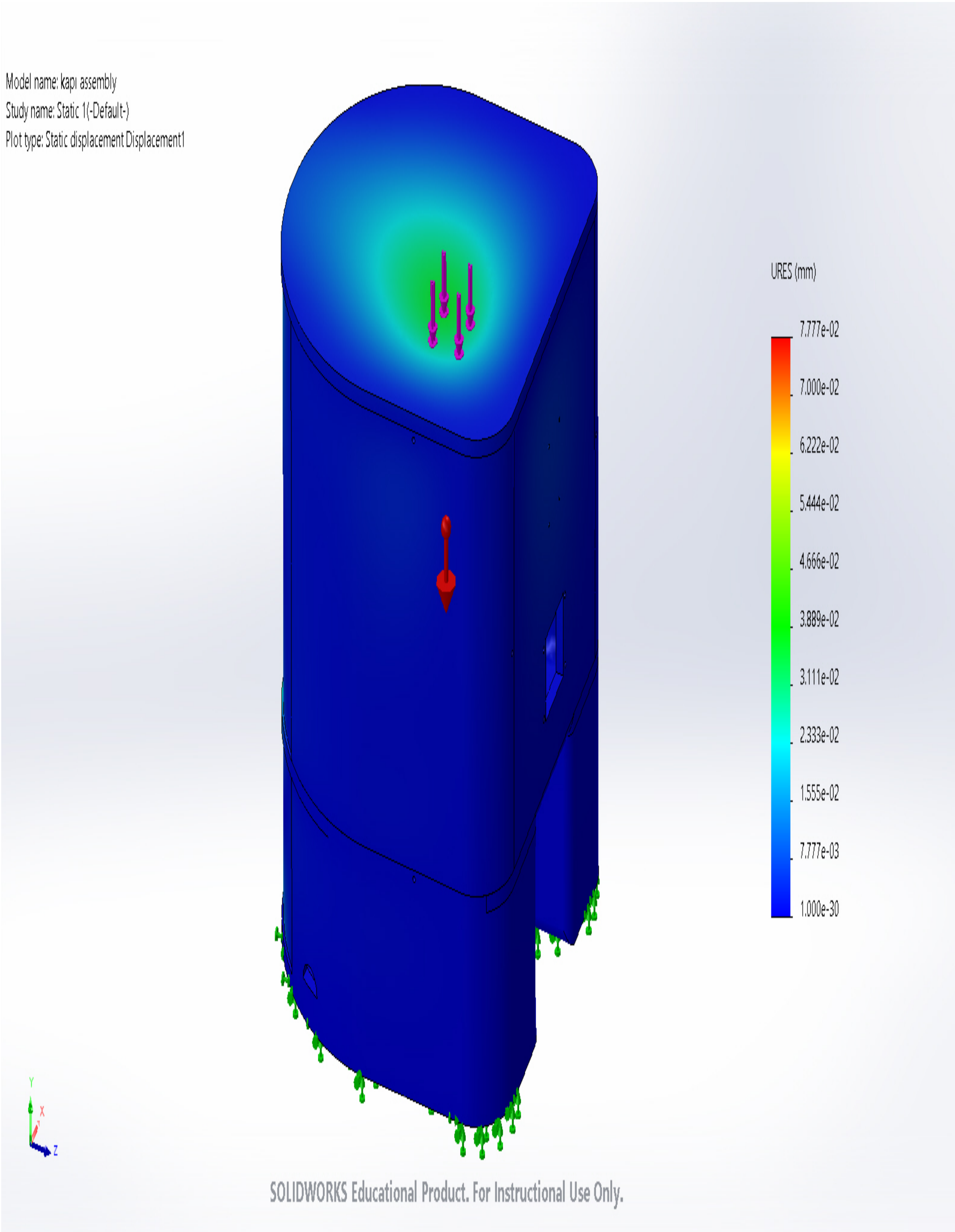

Model name: kapı assembly
Study name: Static 1(-Default-)
Plot type: Static displacement Displacement1
URES (mm)
7.777e-02
7.000e-02
6.222e-02
5.444e-02
4.666e-02
3.889e-02
3.111e-02
2.333e-02
1.555e-02
7.777e-03
1.000e-30
Y
X
Z
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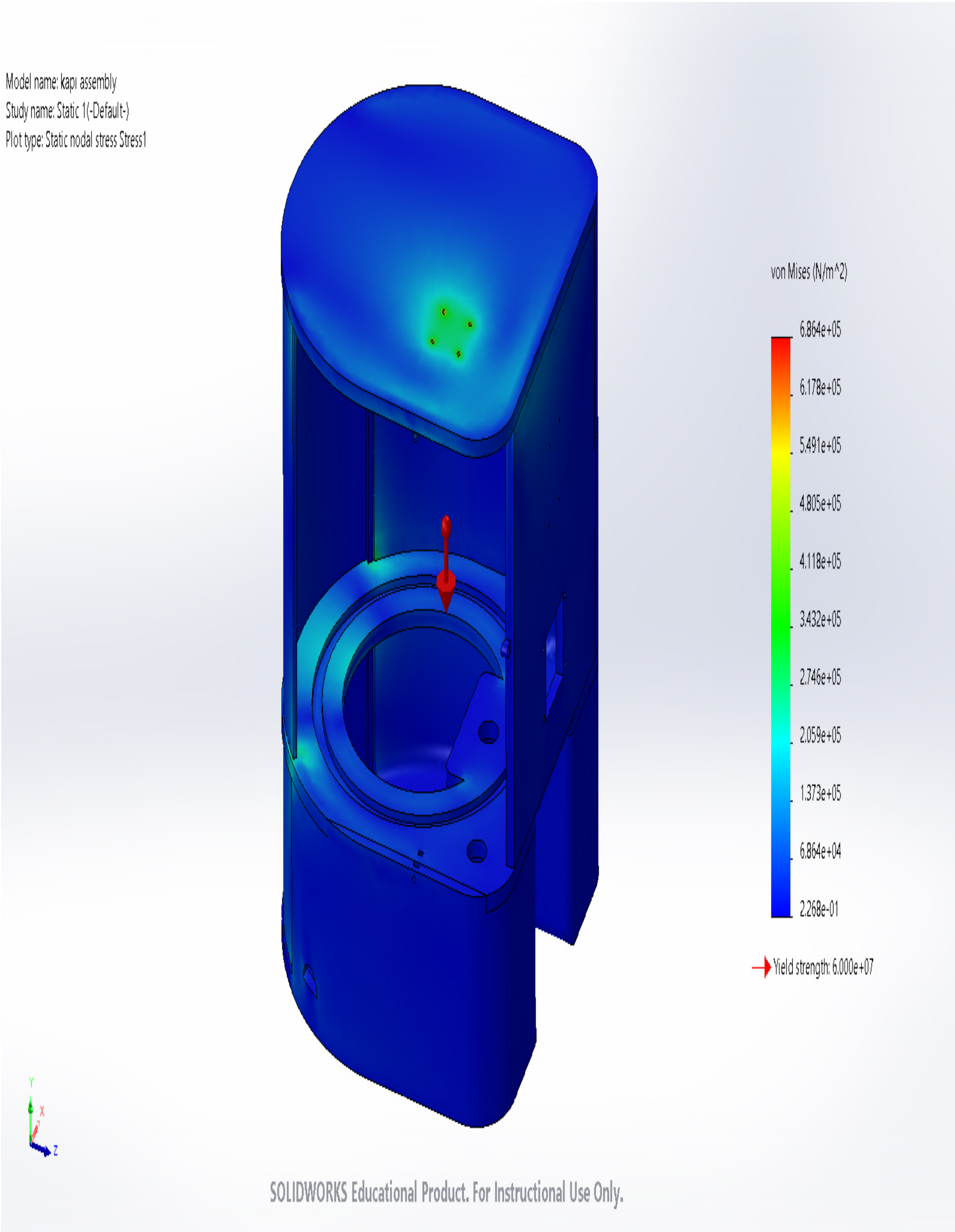
Model name: kapı assembly
Study name: Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
6.864e+05
6.178e+05
5.491e+05
4.805e+05
4.118e+05
3.432e+05
2.746e+05
2.059e+05
1.373e+05
6.864e+04
2.268e-01
Yield strength: 6.000e+07
Y
X
Z
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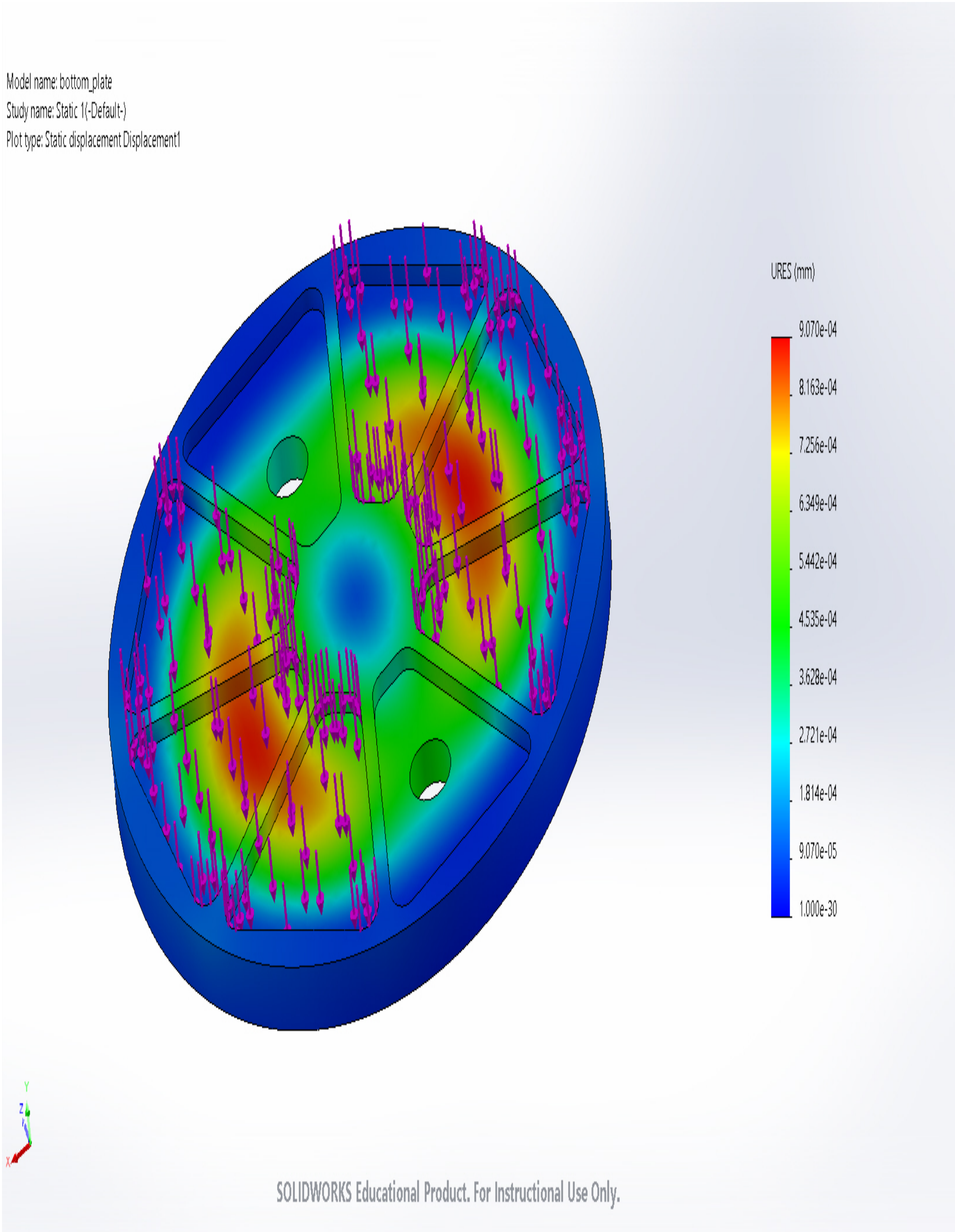
Model name: bottom_plate
Study name: Static 1(-Default-)
Plot type: Static displacement Displacement1
URES (mm)
9.070e-04
8.163e-04
7.256e-04
6.349e-04
5.442e-04
4.535e-04
3.628e-04
2.721e-04
1.814e-04
9.070e-05
1.000e-30
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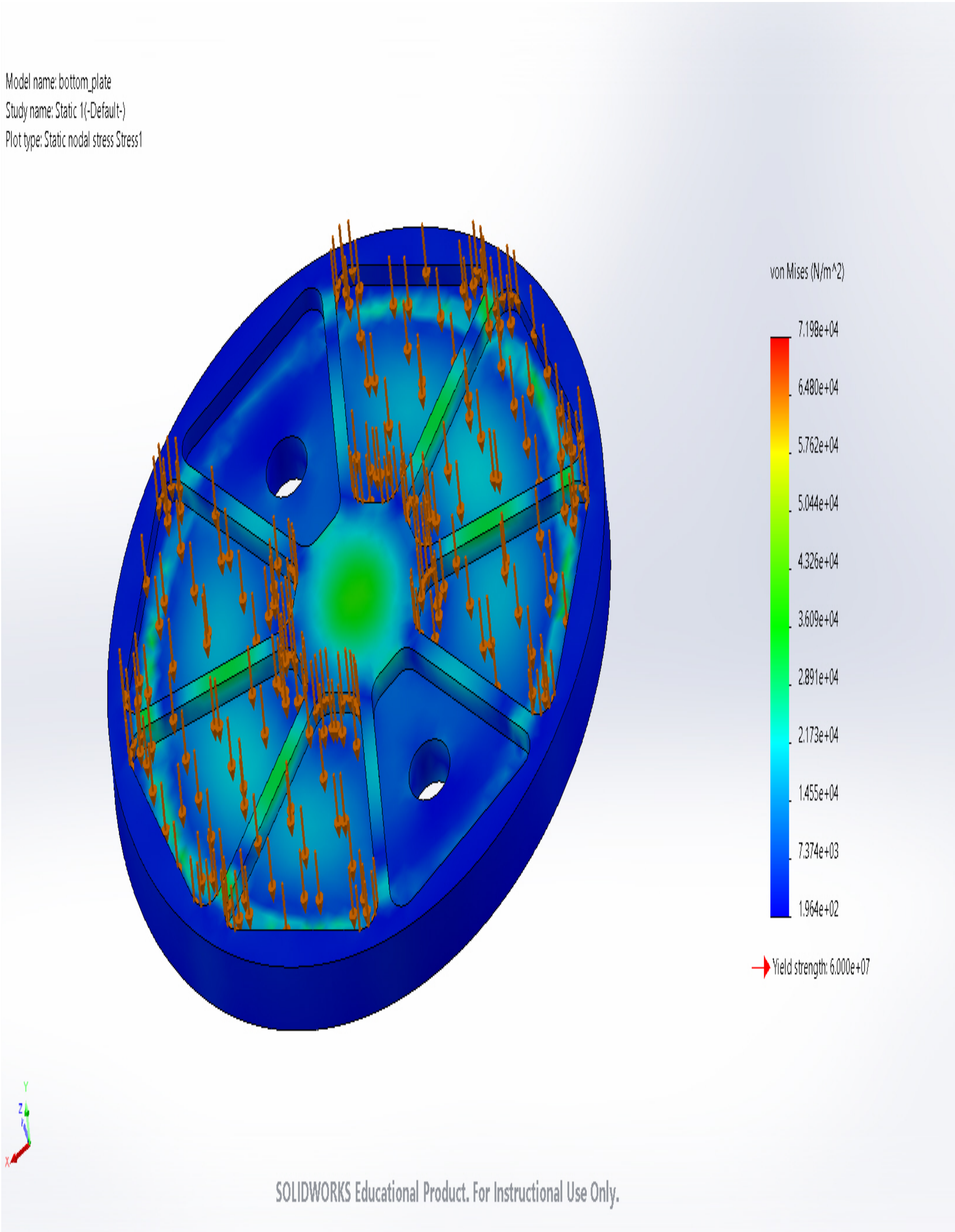
Model name: bottom_plate
Study name: Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
7.198e+04
6.480e+04
5.762e+04
5.044e+04
4.326e+04
3.609e+04
2.891e+04
2.173e+04
1.455e+04
7.374e+03
1.964e+02
Yield strength: 6.000e+07
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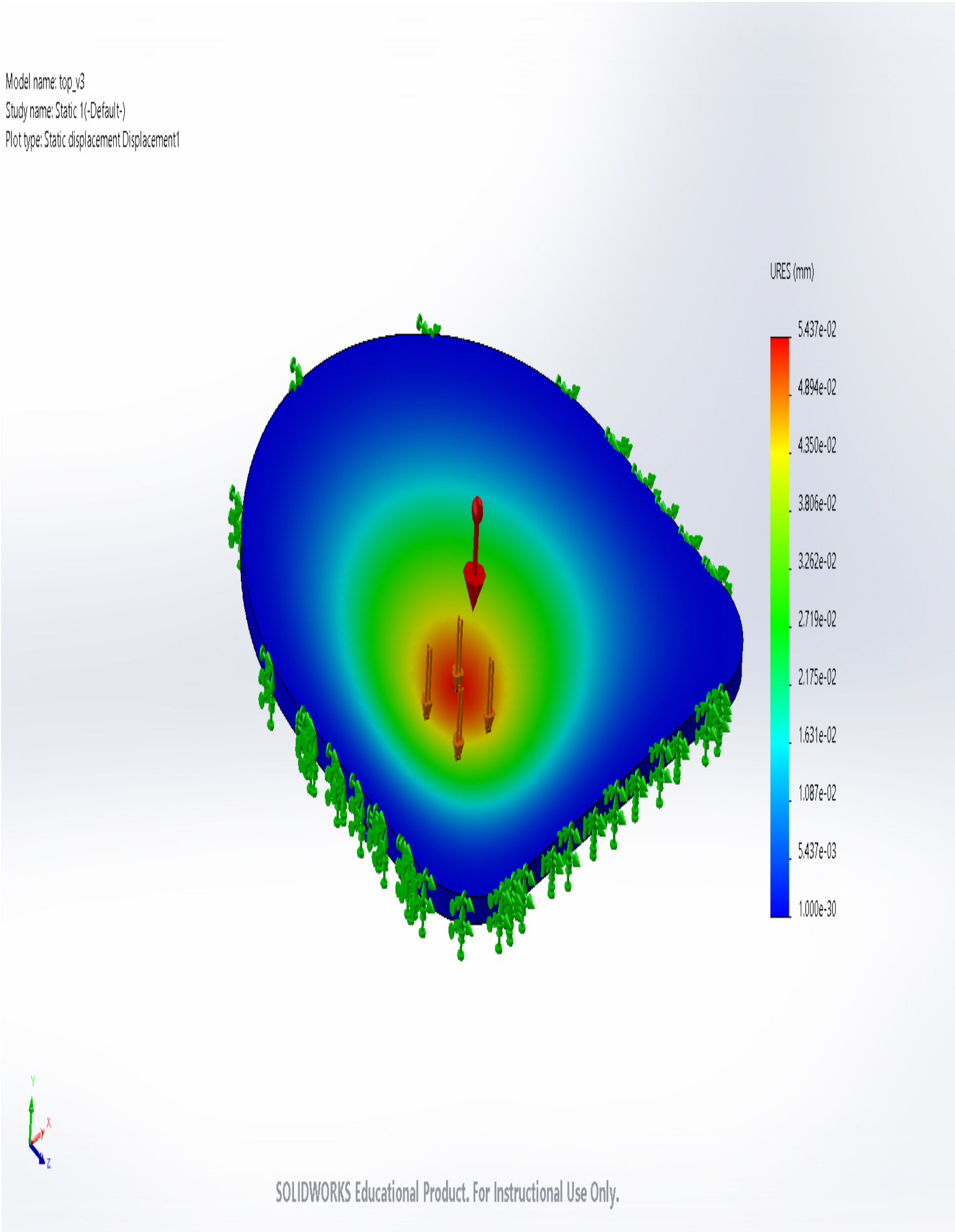
Model name: top_v3
Study name: Static 1(-Default-)
Plot type: Static displacement Displacement1
URES (mm)
5.437e-02
4.894e-02
4.350e-02
3.806e-02
3.262e-02
2.719e-02
2.175e-02
1.631e-02
1.087e-02
5.437e-03
1.000e-30
Y
X
Z
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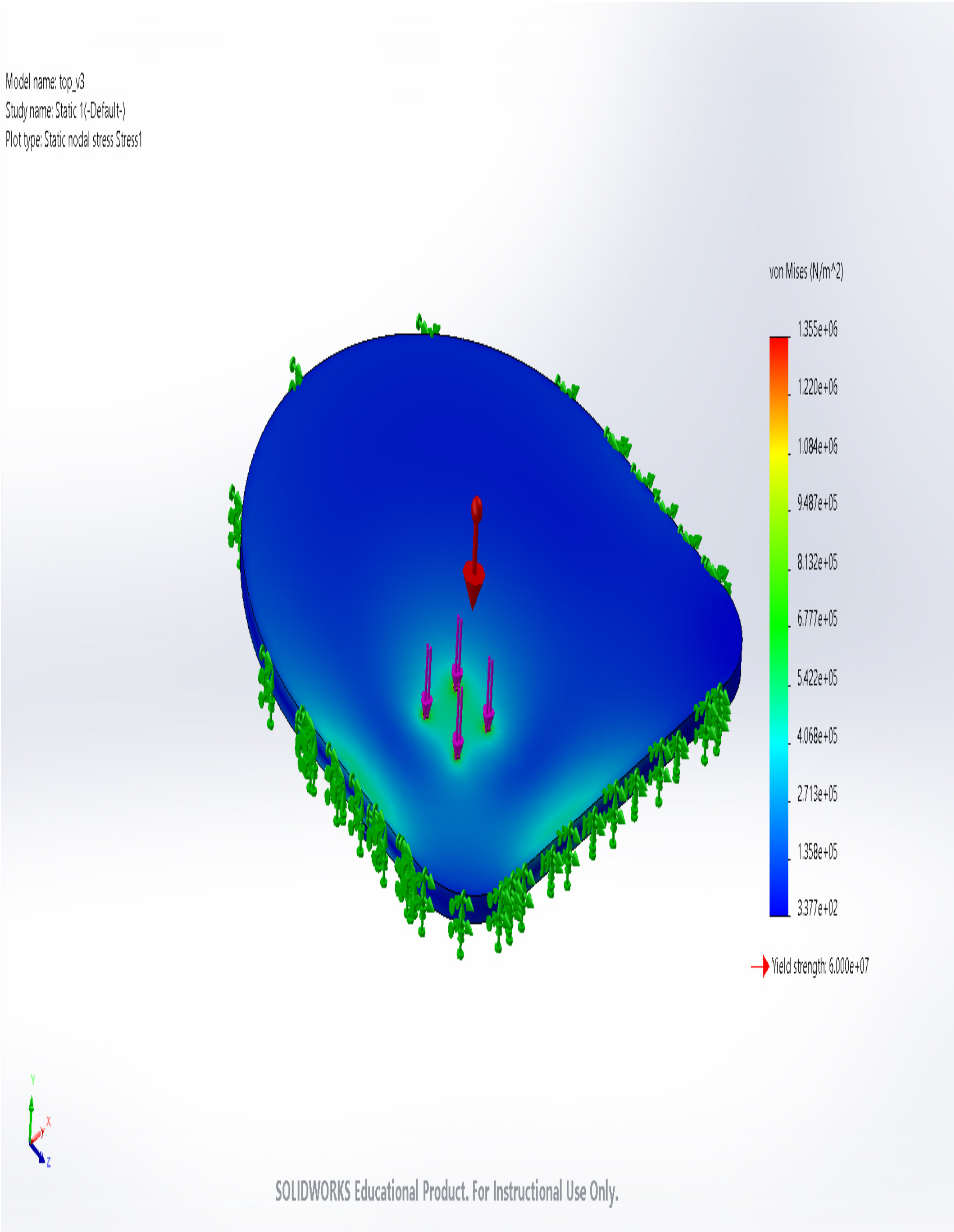
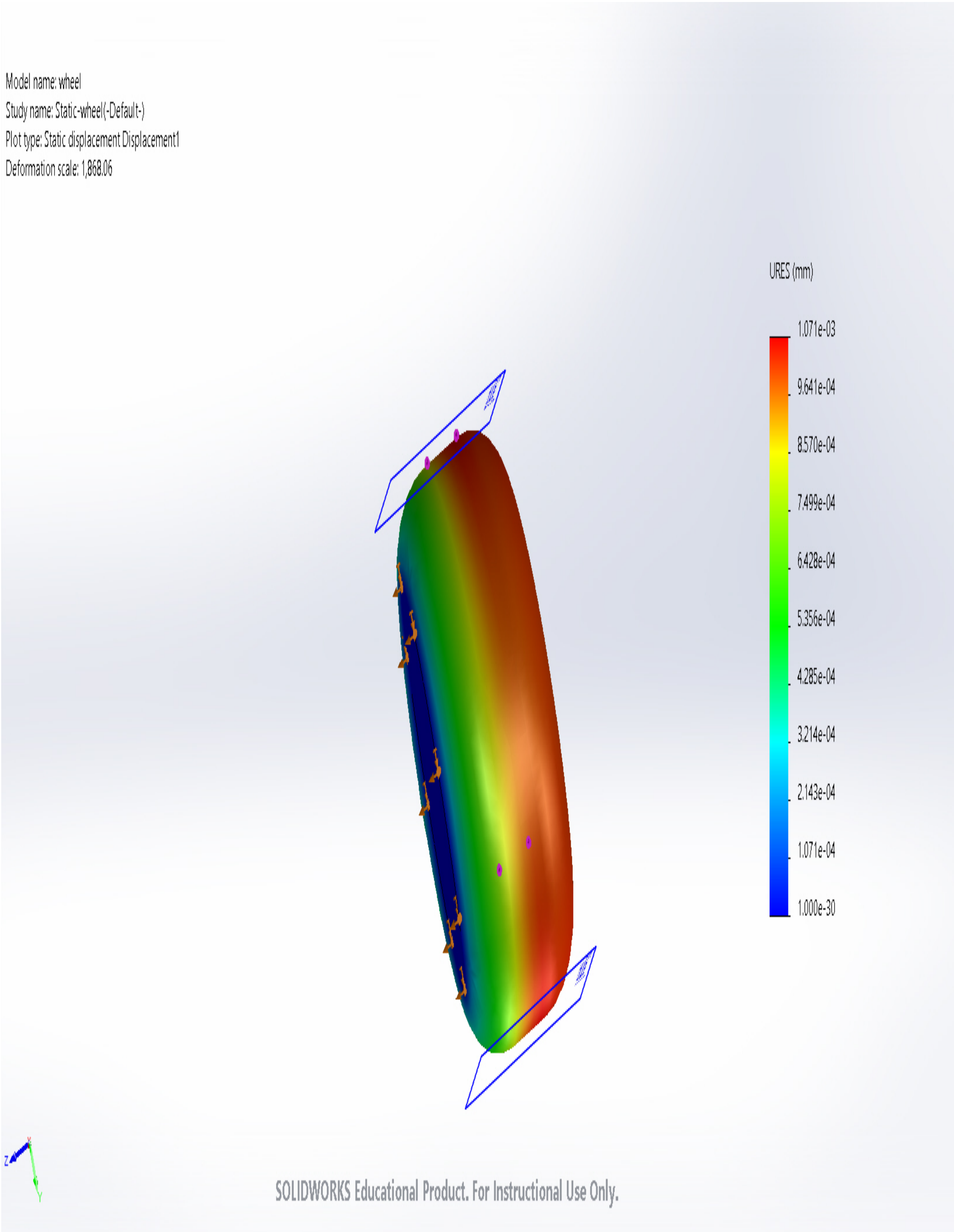

Model name: top_v3
Study name: Static 1(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
1.355e+06
1.220e+06
1.084e+06
9.487e+05
8.132e+05
6.777e+05
5.422e+05
4.068e+05
2.713e+05
1.358e+05
3.377e+02
Yield strength: 6.000e+07
Y
X
Z
SOLIDWORKS Educational Product. For Instructional Use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


Model name: wheel
Study name: Static-wheel(-Default-)
Plot type: Static displacement Displacement1
Deformation scale: 1,868.06
URES (mm)
1.071e-03
9.641e-04
8.570e-04
7.499e-04
6.428e-04
5.356e-04
4.285e-04
3.214e-04
2.143e-04
1.071e-04
1.000e-30
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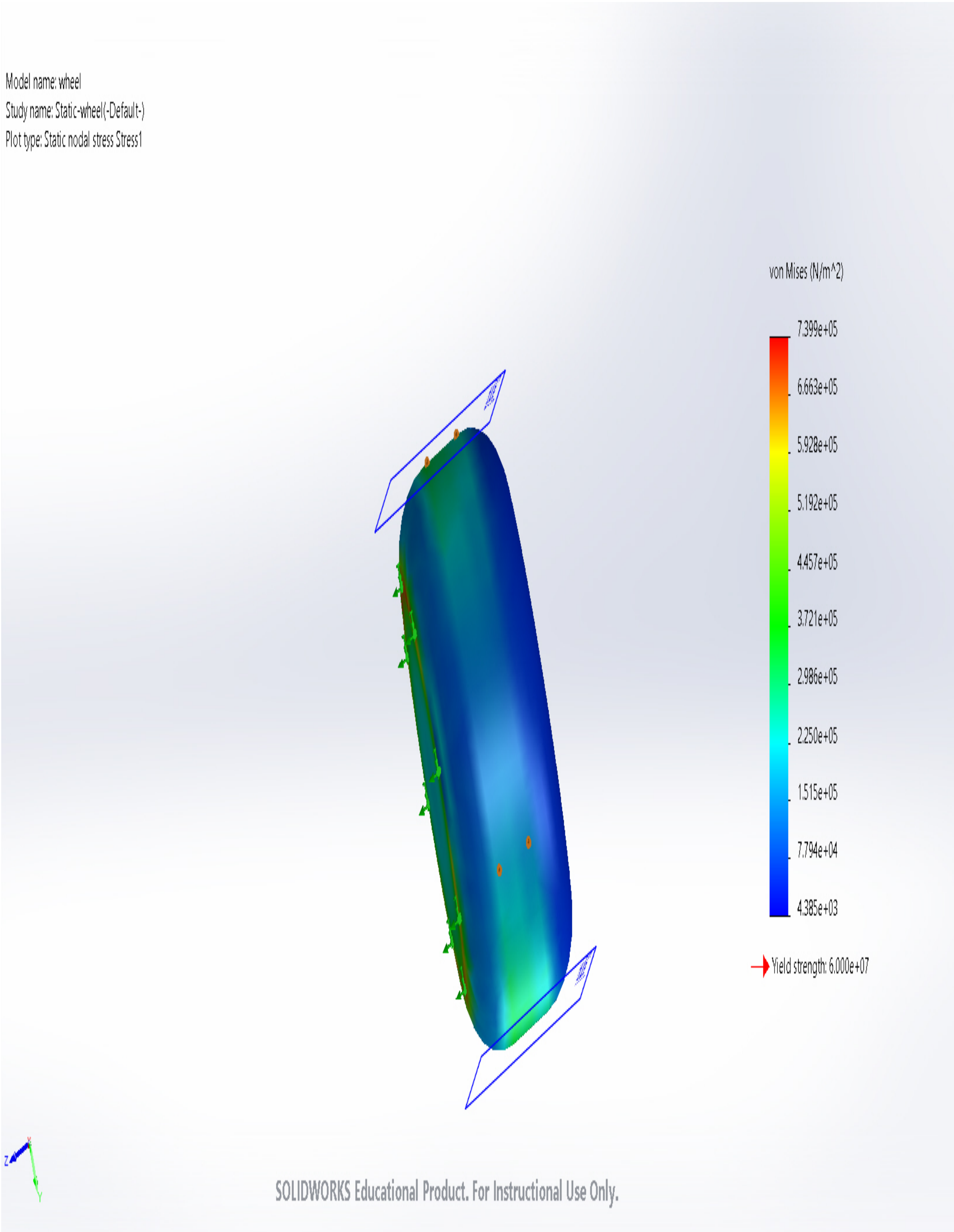
Model name: wheel
Study name: Static-wheel(-Default-)
Plot type: Static nodal stress Stress1
von Mises (N/m^2)
7.399e+05
6.663e+05
5.928e+05
5.192e+05
4.457e+05
3.721e+05
2.986e+05
2.250e+05
1.515e+05
7.794e+04
4.385e+03
Yield strength: 6.000e+07
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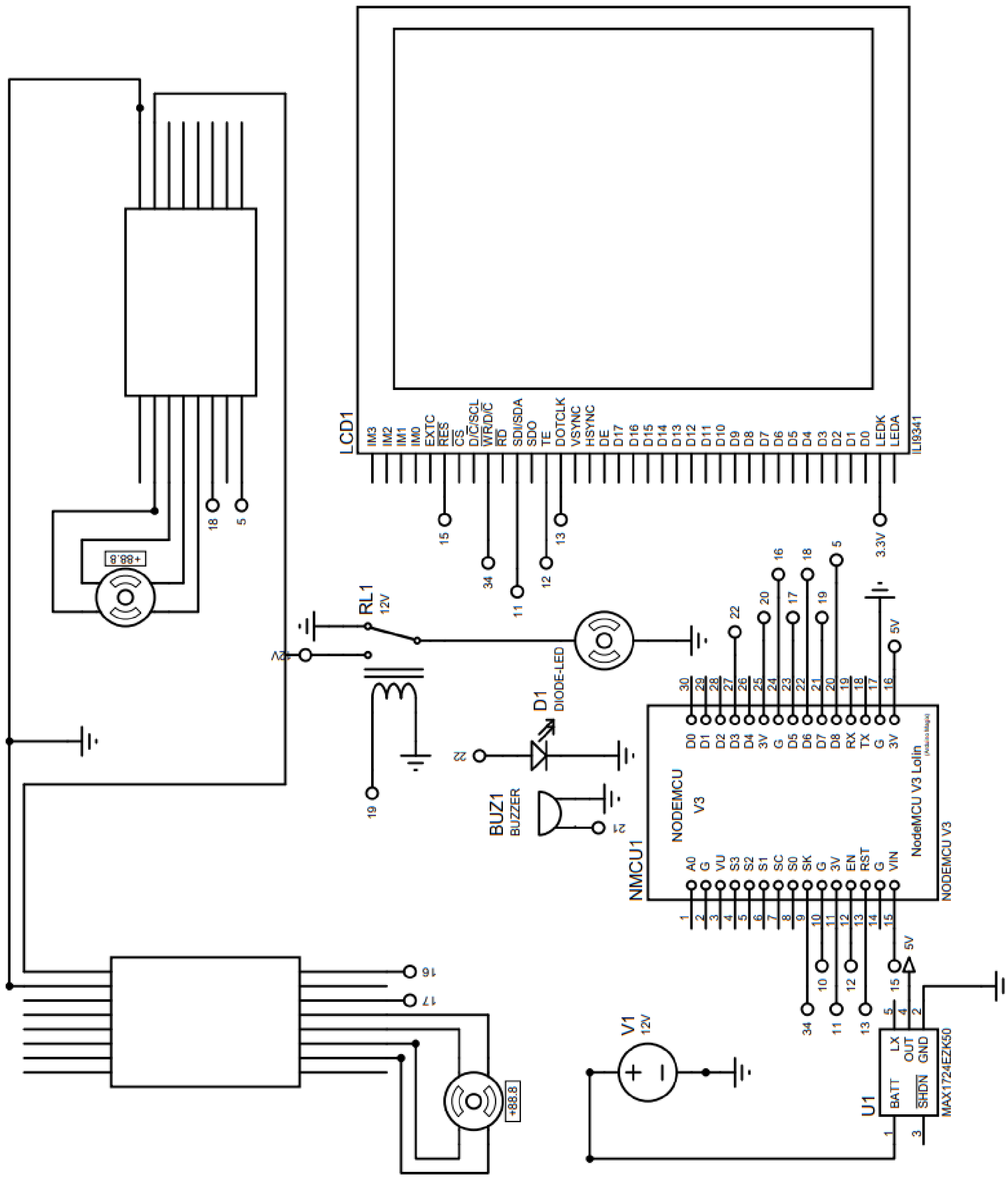
C Electrical Circuit



D Algorithm

Algorithm 1 Automated Pill Dispenser

```
class Medicine:
    String name
    Time date_to_take

procedure SETUP
    define_pins()
    turn_count ← 0
    medicine_library ← {}
    filled ← False
    setup_bluetooth()
    setup_wifi()
    rotation_required
    rotation_required_2_pump
end procedure

procedure GIVE_MEDICINE(medicine)
    box_to_rotate ← medicine_library[medicine.name]
    rotate_box(box_to_rotate, rotation_required)
    vacuum_take_one_pill()
    rotate_box_reverse(box_to_rotate, rotation_required)
    release_pill()
end procedure
```

Algorithm 2 Automated Pill Dispenser-Continued

```
procedure MAIN
    if filled == False then
        while True do
            medicine_array ← receive_bluetooth()
            if medicine_array is not null then
                break
            end if
        end while
        if wait_for_user_click() == 'medicine refill' then
            for each medicine in medicine_array do
                if medicine.name not in medicine_library.keys() then
                    medicine_library[medicine.name] ← turn_count
                    print(medicine.name)
                    rotate_boxes(rotation_required)
                    turn_count ← turn_count +1
                    if wait_for_user_click_continue() == 'continue to next medicine' then
                    end if
                end if
            end for
            filled ← True
        end if
    end if
    if filled == True then
        current_time ← get_current_time()
        for each medicine in medicine_array do
            if medicine.date_to_take ¡ current_time then
                medicine_array.remove(medicine)
                give_medicine(medicine)
            end if
        end for
    end if
end procedure
```