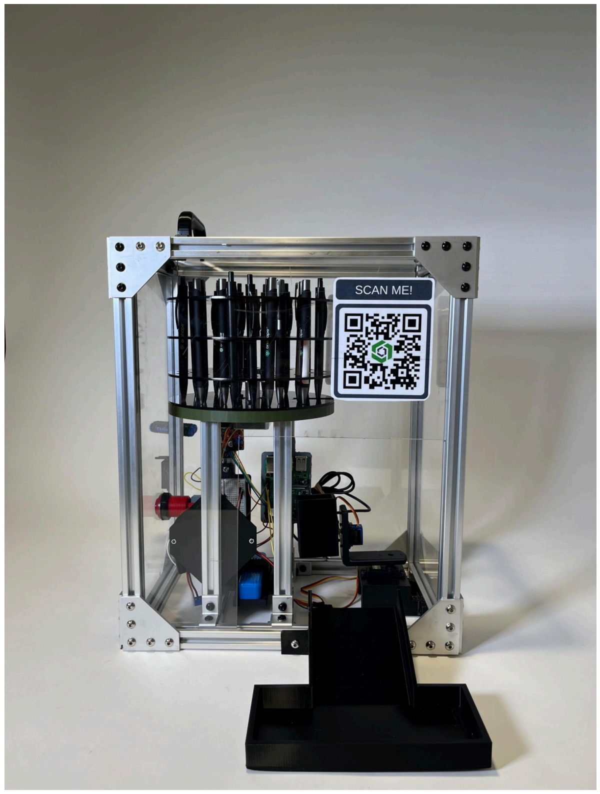

Onshape Pen Pal Report

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Client Company: Onshape
Client Contact: Chris Tilton
12 November, 2025

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Executive Summary:

The following report summarizes the work completed by Jana Dia, Karim Al-Haffar and Haley Leimbach on their senior design project at Tufts University in Medford, Massachusetts.

Onshape is a cloud based computer aided design software (CAD). The platform offers web browser based access, specializing in collaboration and design management. The Onshape education team, who frequently attends conferences to promote Onshape and its capabilities, were looking for a device to automate retrieving attendees information, while dispensing Onshape branded pens in a memorable way.

Our team developed a rotating cylindrical pen dispenser integrated with a two degree of freedom robotic arm and cloud based data collection system. The mechanism features a stepper motor driven cylindrical pen holder with offset vertical holes capable of holding 26 pens. The pen holder rotates a specific amount of steps, aligning one pen with an opening below. When dispensed, the rotating arm catches it and delivers it to the user via a slide. The entire assembly is housed within an 8020 aluminum extrusion frame enclosed by clear acrylic panels, allowing attendees to safely observe the internal mechanisms.

For data collection, users scan a custom QR code directing them to an Airtable form. After submitting their contact information, it is stored in Airtable for future use by Onshape education. A Raspberry Pi immediately detects new airtable updates and triggers the dispensing sequence. This integration provides Onshape with easily accessible contact data and creates a seamless user experience. The device operates entirely on Lipo battery power, requiring no wall connections> Additionally, it meets TSA requirements for air travel, allowing Onshape to travel around the country with the device.

Engineering analysis validated the structural design, with calculations confirming that the 20-20 series aluminum extrusion supported the base of the design. The final prototype successfully demonstrates automated sing-pen dispensing, reliable data collection, and engaging processes within a compact and portable footprint suitable for conference environments. The device weighs under 20 lbs, sets up in under 5 minutes, and can dispense 26 pens without refills, providing Onshape with an effective tool for both engagement and outreach at educational conferences.

Introduction:

a) Motivation

The Onshape Education team frequently attends conferences to engage with students and educators, showcasing Onshape's capabilities and promoting its use in academic settings. During these events, the booth often features branded merchandise such as pens to attract attendees and increase brand visibility. However, distributing these items typically involves manual interaction and provides limited engagement opportunities. To make the booth experience more interactive and memorable, the team is seeking a creative solution that both encourages visitor participation and highlights what can be done with Onshape. This device will attract more visitors to the booth, by providing an engaging way to receive an Onshape branded pen. Additionally, the pen will be dispensed only after receiving attendee information. This is especially important, as Onshape will use this information to compile email listings, increasing their educational outreach and customer network.

b) Problem Statement

Conference attendees need to be drawn to the Onshape booth at conferences and once there, their information needs to be collected for future use. Conferences provide Onshape with opportunities to connect with potential customers, but they need a unique way to both attract people to their booth and collect contact information. Our goal is to design a device using Onshape that accomplishes both tasks while highlighting what can be designed with Onshape.

Design Solution:

a) Final set of user needs

It is crucial to find user needs during the design process to ensure that the product built solves real problems, improves usability, and has high user satisfaction. User needs can help guide the entire design process, focusing efforts and providing a clear path of success. In order to develop user needs for the design process, the important stakeholders must be identified. The most influential stakeholder is Onshape and Chris Tilton, the Onshape representative helping with this project. Onshape wishes to use this design project to demonstrate the capabilities of Onshape at the academic level, as well as use the physical pen dispenser at conferences. Another important stakeholder is the attendees at conferences that will be interacting with the product. Their needs drive the design process, as the user must be able to understand how to use the product and be pleased or impressed with the pen dispensing mechanism. A third influential stakeholder is the employees transporting the device to conferences. The device must be able to fit as a carryon device on all airlines and pass through TSA Airport security, as well as be simple to set up once at the conference.

Table 1: User Needs and Requirements

User Need	Description	Importance
Travel friendly	Device must pass through TSA and fit size restrictions for carry-on bags.	1
Data Collection	Attendee information must be collected and stored.	2
Engaging for User	Device must attract attendees to booth and be engaging for them.	3
Dispenses a Single Pen	Device should dispense 1 pen at a time for each survey submitted.	4
Storage of Pens	Device should store a certain amount of pens at a time.	5
Reliability of Device	The device should be able to repeat the function many times.	6
Low Setup Time	Setup time should be minimal.	7
Portable Power Source	The device should not need to connect to the wall outlet.	8
Lightweight design	Lightweight design for ease of travel and setup.	9

Our three most important user needs are travel friendly, data collection, and engaging for users.The most important user need is that the product is travel friendly. Since the PenPal pen dispenser will be used at conferences throughout the country, the product must be able to fit as a carry-on item on an airplane or fit into a carry-on bag. This user need is driving the design process, since if it is not met, Onshape will be unable to travel with and take the product to conferences.

Data collection is another important need of the client. While a large focus of the design is on dispensing a single pen, in order to start the dispensing process, user data must be collected and stored. Onshape wishes to collect information from conference attendees and store it for future use, so the design must dispense a pen only after this data is collected.

Another user need that is greatly driving the design process is that the product must be engaging. The client stressed the need of having a pen dispensed in a way that the user would be impressed and “wowed” once they receive their pen. This user need drives the design process towards methods of dispensing that let the user see the inner workings of the design and have several complex and impressive steps.

b) Final set engineering requirements & relevant standards

The engineering requirements in Table 2 for this device were developed to ensure the system meets critical function, operations, and logistical needs while remaining practical for conference environments. These requirements transfer the user needs into measurable specifications that will guide the design process.

Table 2: Engineering Requirements

Requirement Description	Target Value	Units	Importance
Prohibited items for air travel	0	Number of Prohibited items	1
Maximum Size	20”x12”x9”	Inches	1
Maximum steps to obtain data	2	Number of steps	2
Maximum steps to submit information	2	Number of steps	2
Minimum engagement score	7	Score out of 10	3
Number of pens dispensed per submission	1	Number of Pens	4
Pen Capacity	25	Number of Pens	5
Pens dispensed without intervention	25	Number of Pens	6
Maximum Setup Time	5 Minutes	Minutes	7
Wall Outlet Connections	0	Connections to wall outlet	8
Maximum Weight	20 lbs	Weight	9

The most important requirements relate to portability, air travel compliance, and core functionality. TSA regulation compliance requires that the device contains zero prohibited items for air travel. This requirement directly responds to the user need for easy air travel between conference events. A design incorporating batteries, electronics, or mechanical components must use TSA approved materials to avoid travel issues. In addition, the device must be compatible with the average carry-on size bag. This requirement establishes a maximum size of 22”x14”9”, which is the average airline carry-on limit. The target size is 20”x12”x9", which provides a 2” buffer in 2 dimensions. Meeting this requirement ensures employees can transport the device without checking luggage, reducing risk of damage or loss of the device.

The requirement to store data in an accessible location specifies that obtaining collected information must take no more than two steps. The target value of 2 steps was chosen to promote ease of use for the marketing team that may need to review attendee information. Similarly, easy data collection requires the attendee to submit information in no more than 2 steps. This requirement recognizes that conference attendees don't want to spend a significant amount of time to submit data and receive a pen. A single-step submission process, like scanning a QR code, maximizes participation rate and supports the need for high engagement and data collection.

To quantify engagement, an engagement survey will be given after use during testing of the device. The engagement score requirement goal of 7/10 provides a quantitative check that the device is engaging and creates a memorable interaction. The chosen score represents "good" performance on standard engagement scales and ensures that the device enhances Onshape brand perception, while also collecting data and dispensing a pen.

The requirement of the number of pens dispensed per submission has a target value of 1. This ensures that when a single attendee submits their information, only one pen is dispensed. This maintains inventory control and ensures fair distribution among conference attendees. The pen capacity requirement specifies a target of 25 pens. This value balances portability with operational needs. 25 pen capacity allows the device to operate through a conference without constant monitoring, while keeping the device compact enough to meet size and weight constraints. Similarly, the requirement that 25 pens can be dispensed without intervention directly aligns with pen capacity. This ensures the device can operate autonomously throughout a conference without jamming, requiring adjustment, or needing an operator to troubleshoot. Additionally, autonomous operation reduces staff burden and allows for a consistent user experience.

The maximum setup time requirement has a target value of 5 minutes. This accounts for conference environments where booth setup time may be limited. A low setup time ensures the device can be deployed quickly at the start of each day and moved from location to location without significant downtime. The wall outlet connections requirement has a target value of 0 connections. Our client voiced that they do not want the device to need power from the wall, as it is often unavailable or unreliable at conference venues. Battery operation allows the device to be positioned anywhere within the booth for optimal attendee flow without being tethered to power outlets. The last requirement of a maximum weight of 20 lbs was selected to ensure a single employee can comfortably transport and set up the device. At 20 lbs, the device can be carried by most employees regardless of physical strength, supporting the travel friendly user need.

As for relevant standards to the design, UN 38.3, which is part of the United Nations Manual of Tests and Criteria establishes safety requirements for lithium and lithium-ion batteries. This standard is critical for our device since the engineering requirement specifies no connection to wall power, necessitating the use of rechargeable lithium batteries. UN 38.3

applies to batteries transported on their own or inside a device. This standard requires 8 tests including altitude simulation, thermal cycling, vibration, mechanical shock, external short circuit, impact, overcharge, and forced discharge to ensure battery safety during traveling. We will make sure our device meets this standard by selecting a UN 38.3 certified lithium-ion battery with capacity under 100 Wh. This way, the battery we chose will be compliant with both TSA carry-on regulations and international transportation safety requirements. By adhering to UN 38.3 standards, we ensure the device meets international safety requirements while maintaining the portability that is essential to our user needs.

c) Competitive benchmarking

Competitive benchmarking is used to provide insight into existing solutions within a design space, allowing us to identify gaps in the market and understand why current products do not address our specific user needs. By evaluating commercially available alternatives against our core user needs, we can justify the need for a unique solution and avoid replicating the limitations of existing designs. Additionally, analyzing current solutions helps us brainstorm possible solutions, allowing us to take inspiration from current ideas. Our analysis focuses on three current products that address pen dispensing, but fall short of meeting the most important needs of our problem. Table 3 shows which key user needs are met by the current product, and which user needs they do not solve.

Table 3: Competitive Benchmarking

Product	Travel Friendly	Data Collection	Engaging
Crepoly Pencil/ Pen Dispenser	✓		
SimplyImagine Pen Dispenser for Classroom	✓		
Vendorama Antique Pen Dispenser			✓

The first existing solution analyzed is the Pencil/ Pen Dispenser by Crepoly [2]. This basic mechanical dispenser addresses the engineering requirement of dispensing one pen at a time , however, it fundamentally fails to meet most critical user needs of this project. The device offers no data collection capability and does not engage with the user. The dispensing action does not require any action by the user except pulling a pen and does not allow the user to see any of the inner workings of the dispensing mechanism. The device is simply a passive container that releases pens, offering no engaging elements. Furthermore, while compact and travel friendly, the solution provides no electronic components or data infrastructure that would enable the integrated experience between data collection and pen dispensing our device requires.

Figure 1: Pen Dispenser by Crepoly [1]

The second solution we looked into is the Pen Dispenser for Classroom by SimplyImagine [3]. Like the previous solution, this pencil dispenser demonstrates reliable single dispensing functionality and the ability to hold multiple writing instruments at a time. However, this product lacks any data collection capability, which fails one of the important engineering requirements. This product is optimal for utility and efficiency rather than engagement, which is an extremely important aspect of this project.

Figure 2: Pen Dispenser for Classroom [2]

The third product analyzed is the Antique Pencil Dispenser by Vendorama [4]. This ballpoint pen dispenser represents the most engaging of the three benchmarked solutions, providing visual interest through its transparent panel showcases the internal dispensing mechanism. These features address the engagement requirement by having a visually interesting interaction that invites the user to participate. Additionally, the device successfully dispenses one pen at a time through a user activated mechanism. Despite these engagement advantages, the antique dispenser still fails to meet the data collection requirements that are central to our user needs and is large and bulky, which does not meet the travel friendly user need.. As a purely mechanical solution with no electronic components, the device cannot integrate between data submission and pen dispensing.

Figure 3: Antique Pen Dispenser [3]

Our competitive benchmarking analysis reveals that there is a significant gap in the current market. While the existing pen dispensers successfully dispense a pen using mechanical methods, none satisfy all three most important user needs of our design problem. No current solution has the ability to integrate data collection with engaging, user-activated pen dispensing. Therefore, our design must bridge this gap by combining data collection, interactive user engagement, and compact portability. The benchmarked products provided valuable insights into working dispensing mechanisms and strategies that we can use to adapt and enhance our design.

d) Concept generation & selection

After generating user needs and requirements, and completing competitive benchmarking, it was time to brainstorm and generate our unique solution that would bridge the market gap. To create a system that successfully integrates data collection, user engagement, and reliable pen dispensing, we decided to break down the design challenge into 3 distinct phases. This allows us to address the complex problems through more manageable subsystems. Phase I focused on isolating a single pen and moving it from the storage to the action section. Phase II is where the engaging part happens. This is where the pen will be delivered to the user using a series of mechanisms such as a robotic arm and/or a conveyer belt. Phase III focuses on collecting the user's information through an intuitive interface and storing it in an accessible cloud-based system.

For phases I and II of the design, we generated four initial designs as demonstrated below:

1. Concept design 1(Fig. 4) focuses on phase I of the design challenge and was one of our main dispensing concepts brainstormed. It featured a storage unit at the top of the product that could hold 20 to 25 pens. From that upper storage, one pen would drop and fit in one of the holes in the rotating piece. A motor-driven rotating drum mechanism with four to five pen sized slots sits beneath the storage unit. As the mechanism rotates, gravity causes pens to drop from storage into the slots one at a time. Once one pen is dropped, it will slide down a ramp to a position where the user can retrieve it.

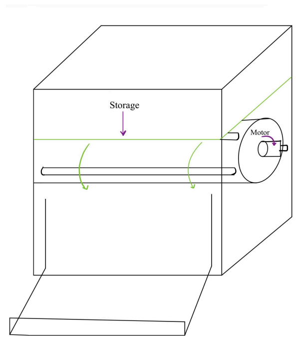


Figure 4: Initial Concept Design 1

2. Concept design 2 (Fig. 5) also features a storage space at the top with a motor attached on the side that dispenses one pen at a time. The dispensing method detailed in design 1 is also utilized here, however, this design further adds on phase II of the project. The pen is dispensed onto a platform. This platform can be moved by a 3 degree of freedom robotic arm, moving the pen to a slide. Once the pen moves by the slide it is accessible to the user.

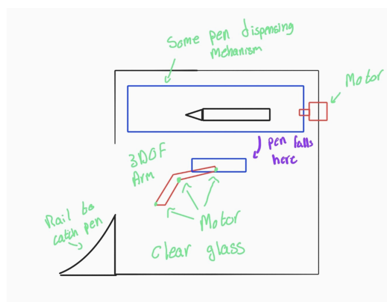


Figure 5: Initial Concept Design 2

3. Concept Design 3 (Fig. 6) features a similar dispensing mechanism to the previous two designs. It features a storage unit at the top and a motor on the side. The motor does a rotating mechanism to rotate the pen and drop them onto the slides. Then, the pen would be dropped and grabbed from the opening.

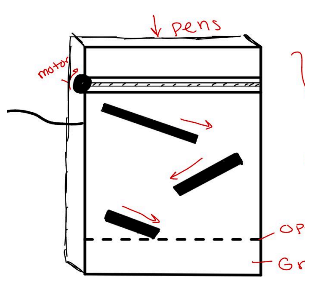


Figure 6: Initial Concept Design 3

4. Concept design 4 (Fig. 7) features a switch in the dispensing process. While trying to brainstorm ideas to combat jamming, we came up with this new design. Pens will be loaded into the device vertically, each having a designated slot. The device would feature 25-30 slots for pens, mapped out in a circular pattern. A central stepper motor mounted at the bottom of the pen holder will spin the holder, aligning a single pen slot with an opening at the bottom. Here one pen will fall and the possibility of jamming is removed.

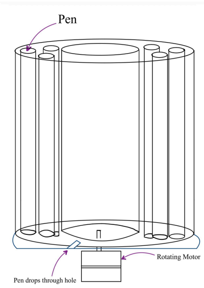


Figure 7: Initial Concept Design 4

For all of our designs, we decided Airtable would be the best method to solve phase III. Chris Tilton instructed us that this would be the best method of data collection, the platform has a very easy to use API and he had previous positive experience using it. To test this design decision, we created an Airtable form and used the API to trigger a stepper motor. We learned that Airtable was extremely successful at collecting information and triggering the electronic response we wanted. Additionally, through this process, we learned that Airtable forms responded significantly quicker than google forms linked to an airtable. Thus, we chose to use airtable forms, data storage, and API to collect and store data.

All four initial concepts successful address several critical user needs and engineering requirements:

- Engaging: Each design incorporated transparent panels showcasing internal mechanisms, which creates visual interest and attracts conference attendees.
- Storage: All designs featured storage units capable of holding 25 to 30 pens.
- Data collection: Each design used electronic components that could be programmed to integrate with a cloud based storage collection method (phase III).
- Travel Friendly: All designs have a compact footprint, ensuring carry-on bag restrictions are met. Additionally, complex electronics requiring batteries prohibited by TSA are not needed for any designs.

The biggest user needs not met by some of the designs are the dispensing of a single pen and repeatability. Jamming is a large concern when thinking about phase I of the project, which we determined to be isolating one pen. While designs 1, 2, and 3 seemingly should not jam in theory, with multiple pen sizes containing unique geometries, jamming is a big possibility. Design 4 addresses and solves the jamming problem by having a pen isolated in its own slot from the start. This way, the user needs of dispensing a single pen and repeating the dispensing process without intervention can be met.

Concept Selection:

Table 4: Design Comparison Matrix

Comparison Matrix										
Initial Design	**Travel Friendly**	**Data Collection**	**Engaging for User**	**Dispenses a Single Pen**	**Storage of Pens**	**Reliability of Device**	**Low Setup Time**	**Portable Power Source**	**Lightweight Design**	**Total User Needs Met:**
1	✓	✓			✓		✓	✓	✓	6
2	✓	✓	✓		✓		✓	✓	✓	7
3	✓	✓	✓		✓		✓	✓	✓	7
4	✓	✓	✓	✓	✓	✓	✓	✓	✓	9

Based on the comparison matrix, we decided to go with design four, which is a design that overcomes jamming, as it was our biggest concern. It is a cylindrical shaped design that has up to 25 holes in it. The holes hold the pens, while the cylindrical piece is rotating using the motor at the bottom. In between the motor and cylindrical piece, there is another piece that has a hole on the side where the pen drops. The key difference between this design and the concepts generated is that this design overcomes jamming by storing the pens vertically rather than horizontally, each in their individual holes.

After deciding on the core dispensing mechanism for the pen dispenser, it was time to choose the engaging actions that occur after the pen is dispensed. Our original ideas for phase II included a conveyer belt, robotic arm, and slide. During our Prototype 1 presentation feedback, we received from fellow students that a robotics arm would be a fun and engaging way to deliver the pen. Based on this feedback and our own evaluation, we chose to focus on the robotic arm and slide, as they felt more engaging than the conveyer belt alternative.

We selected a two degree of freedom robotic arm after realizing the pen only needed to move in two directions. It had to be moved horizontally outside of the footprint of the dispenser, then tilted to drop the pen. This simplified approach reduced complexity compared to a three degree freedom arm. Additionally, the 2-DOF arm requires supporting the weight of just one servo motor and simplifies motor control programming.

The robotic arm and slide combination provides the “wow” factor we sought for user engagement and addresses safety concerns. The robotic arm can move within the footprint of the dispensing mechanism, while the slide can maintain separation from the main portion of the mechanism. The slide allows the user to grab the pen away from all moving potentially harmful electronics and moving mechanical components. This design choice successfully balances engagement, safety, and technical complexity.

e) Engineering Calculations and Analysis Used in Design Process

During the design process, one critical engineering decision was validating the structural integrity of the robotic arm link. Since it was to be made out of PLA, a strong yet brittle material, we needed to ensure the arm linkage could handle the force of catching a dropped pen, along with the weight of the servo motor and pen catch PLA part. We decided to design this part, then complete load analysis on it, confirming that our design is sufficient for the robotic arm. The design of the robotic arm can be seen below in figure 8.

Figure 8: Robotic Arm Link

The first step to complete the load analysis was to create a free body diagram (Figure 9), displaying the important dimensions of the arm, as well as the loading conditions it is under. The robotic arm linkage features a horizontal section measuring 84mm from mounting point to elbow joint. At the critical section (elbow), the cross-section is rectangular with dimensions of 30mm by 8mm. The arm supports the static load of a 9 gram SG90 servo motor, 59.4 gram (0.131lbs) pen catch, and one pen (approx. 10g), totally approximately 78.4g or 0.769 N.

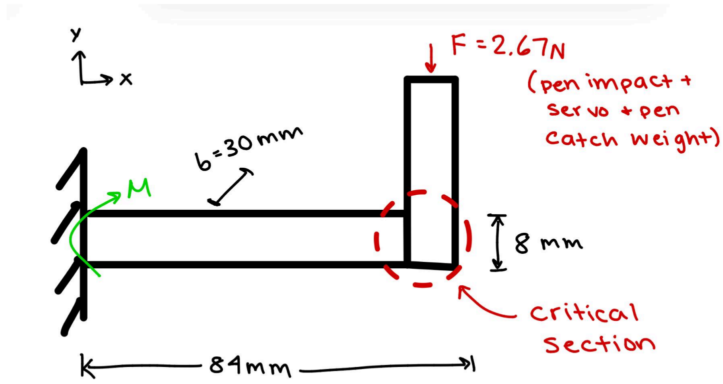


Figure 9: Arm Link Free Body Diagram

Additionally, the design requires the pens to drop 130mm into the catch, creating an impact load significantly greater than the static weight. To calculate the impact force, we first determined the impact velocity using free fall kinematics.

$$v = \sqrt{2gh} = \sqrt{2 \bullet 9.81 \bullet 0.13} = 1.60 \text{ m/s}$$

Assuming the rigid plastic catch decelerates the pen over approximately 5mm, the deceleration is

$$a = v^2/(2d) = 254.7\, m/s^2$$

resulting in an impact force of

$$\text{F\_impact} = m \bullet a = 0.010 \bullet 254.7 = 2.55N$$

Combining this value with the static loads, the total force on the elbow of the linkage during impact is approximately 2.67 N.

For the bending stress analysis, we calculated the moment of inertia for the rectangular cross section. The distance from the neutral axis to the outer edge is c=h/2=4mm. Under impact loading, the maximum bending moment occurs at the elbow:

$$M = FL = 2.67N \bullet 84mm = 224\, N \bullet mm$$

Thus the maximum bending stress is

$$\sigma = Mc/I = (224 \bullet 4)/1,280 = 0.700\, MPa$$

For 3D printed PLA, the typical yield strength is 40 Mpa. We decided to apply a safety factor of 3, which we determined is appropriate for 3D printed parts with potential layer adhesion variability. Thus, the determined allowable stress is $\sigma_{allowable} = 40/3 = 13$ Mpa. The calculated stress of 0.700 MPa is well below this limit.

The engineering analysis confirmed that the robotic arm linkage provides adequate structural performance under structural loading conditions. With a maximum stress of 0.700 MPa against an allowable stress of 13.3 MPa, the design demonstrates substantial safety margins. These calculations validated that the 3D printed PLA linkage would reliably perform throughout repeated dispensing without risk of failure. [1]

f) Description of Final Design Solution.

The final design consists of a rotating cylindrical mechanism for pen storage and dispensing, a supporting structural frame, and an integrated robotic arm along with a slide for pen delivery. It also incorporates mounts for the electrical components, an enclosure for the dispenser, and an allen key holder for quick fixes.

Cylindrical Pen Holder Assembly

The main component of the prototype is the cylindrical pen holder, which is driven by a stepper motor connected through a flanged coupling. The motor enables precise rotational motion to align each pen with the dispensing cut in the acrylic.

This assembly is composed of five layers:

- Three acrylic alignment layers, each with 25 holes designed to hold one pen per slot. The hole diameters were optimized based on previous iterations to minimize play while ensuring smooth insertion and release. The first layer is used to mount the flanged coupling onto it, in order to rotate the assembly when the motor rotates.

- The acrylic support layer, positioned directly above the base, provides a smooth surface for the pen tips to rest on and covers the mounting holes below.

- 3D-printed base mount, which houses counterbores for secure attachment to the structural frame. This base plate holds the entire rotating assembly.

- The flanged coupling is a CNC-machined component that we designed and manufactured to enable rotation of the upper section of the pen dispenser.

The upper three acrylic discs are separated by MakerBeams, which maintain consistent spacing between each layer and provide rigidity while allowing pens to remain vertically aligned. The

[1] The bending stress analysis method used in this section was learned in ME 41: Engineering Design II at Tufts University.

bottom acrylic layer and the 3D-printed base are mounted flush together using screws and heatset inserts to create a stable base for the rotation system.

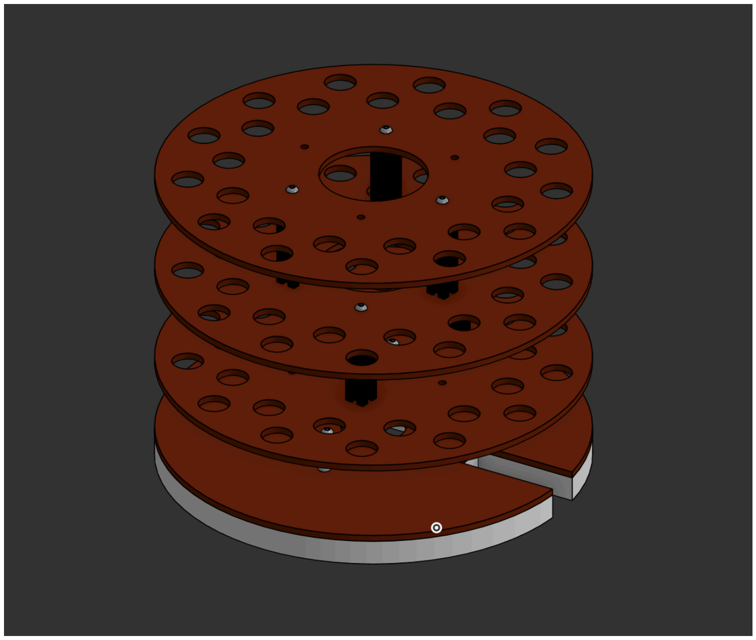


Figure 10: Top View of the Pen Holder Assembly

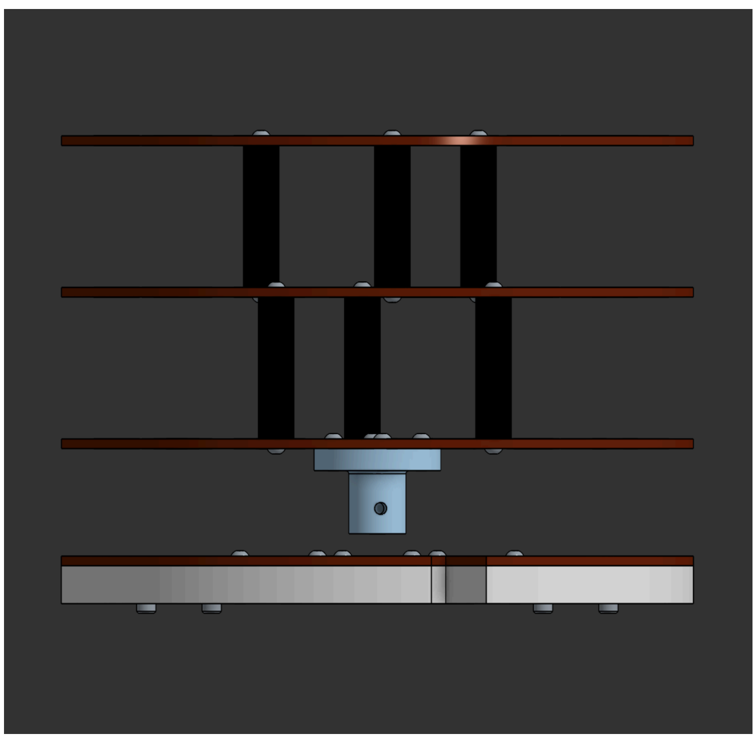


Figure 11: Side View of the Pen Holder Assembly

Structural Frame

The cylindrical pen holder is supported by a modular 8020 aluminum extrusion structure.

- 4 inner legs connect directly to the 3D-printed base via heat-set inserts.

- These legs are fastened to an outer 8020 frame that encloses the whole prototype, with acrylic panels on each side, which provides rigidity and ensures safety by preventing human interaction when the prototype is running.

- The use of 8020 ensures high strength-to-weight ratio, ease of assembly, and compatibility with standard fasteners and corner brackets.

The use of 8020 ensures ease of assembly, safety, and enclosure for the prototype.

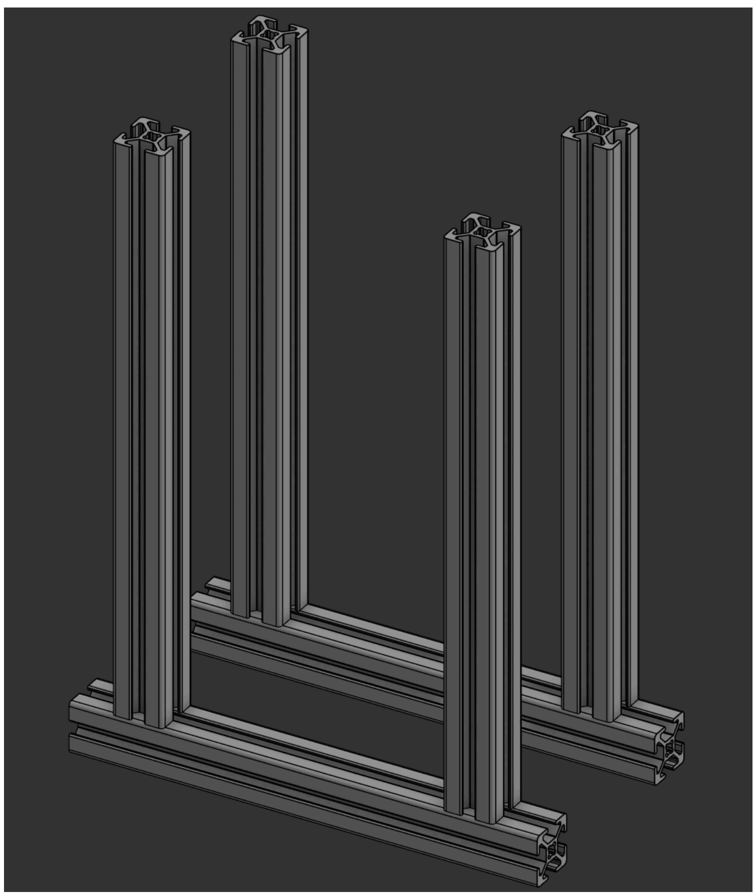


Figure 12: View of the Structural Frame Supporting the Pen Holder

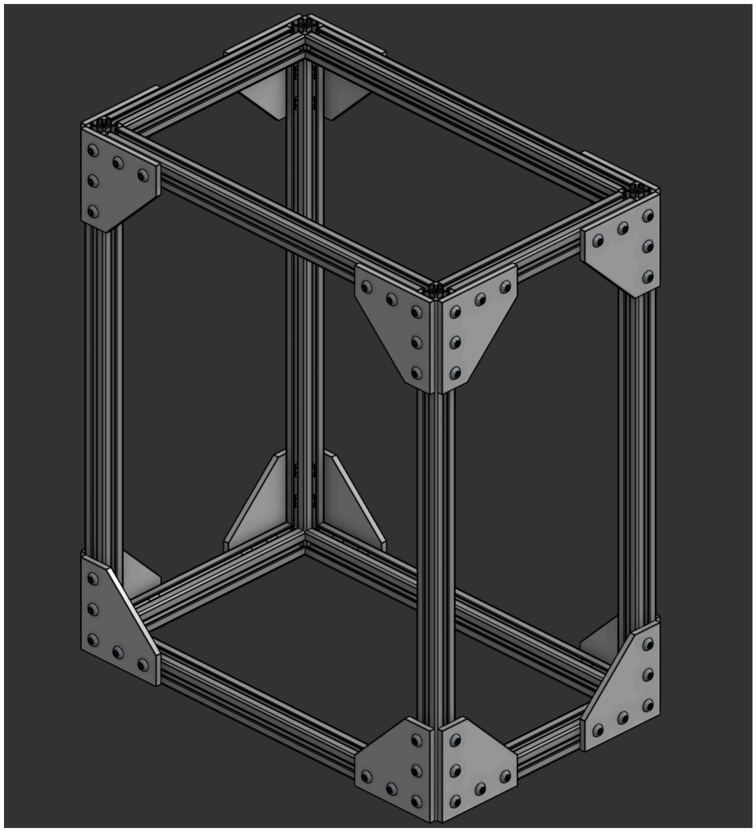


Figure 13: View of the Outer 8020 Frame

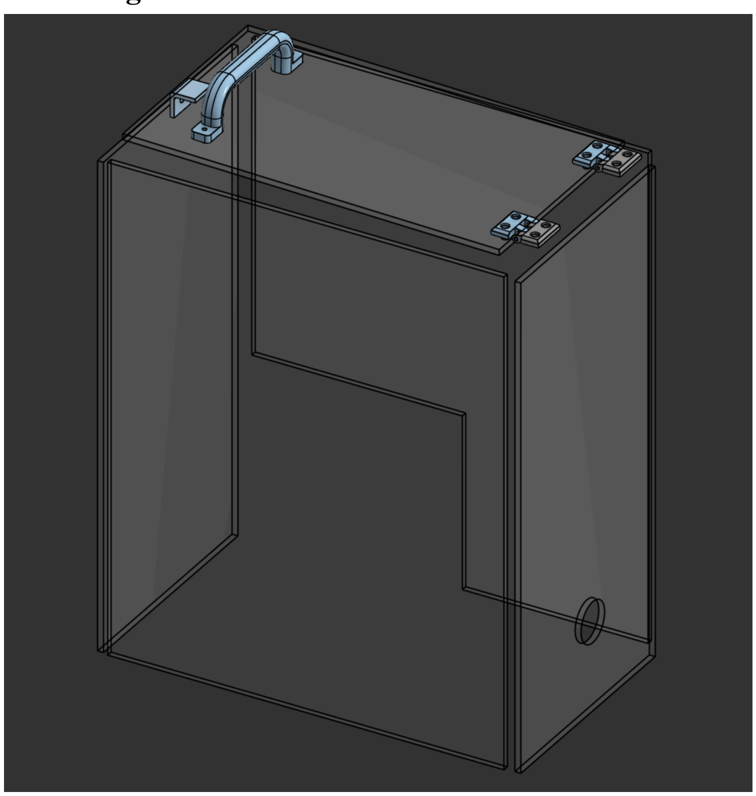


Figure 14: View of the Outer Acrylic Frame

Robotic Arm and Slide Integration

Next to the cylindrical dispenser, a two-degree-of-freedom (2DOF) robotic arm is positioned within the frame. The arm is equipped with a custom carriage end effector designed to capture a single pen as it exits the rotating mechanism. After catching the pen, the arm moves to a predefined location and releases it onto a slide, which guides the pen out of the prototype.

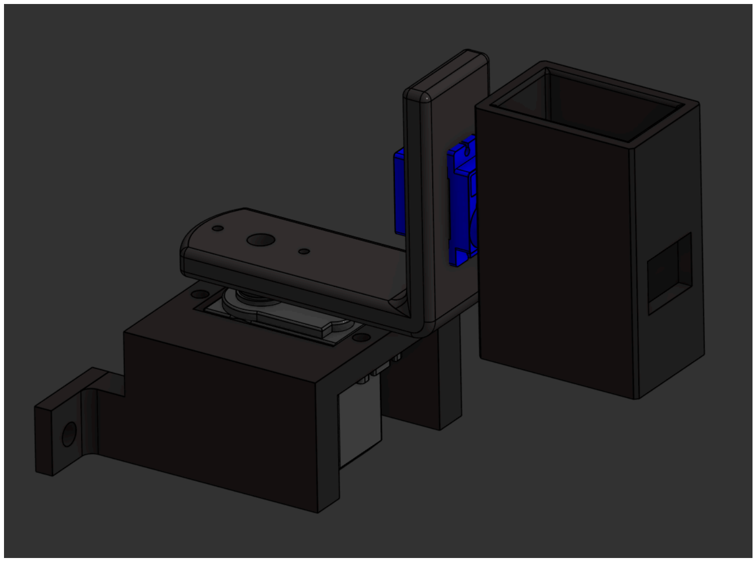


Figure 15: View of the Robotic Arm

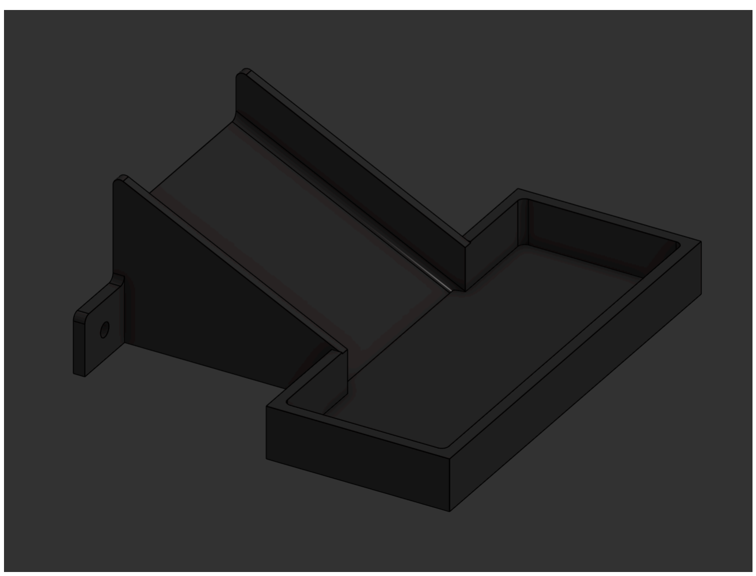


Figure 16: View of the Slide

Electrical Mounts Integration

The design incorporates five mounts for electrical components, including the L298N motor driver, Raspberry Pi, 5V Raspberry Pi battery, breadboard and a battery pack. All components are mounted on the structural beams of the design.

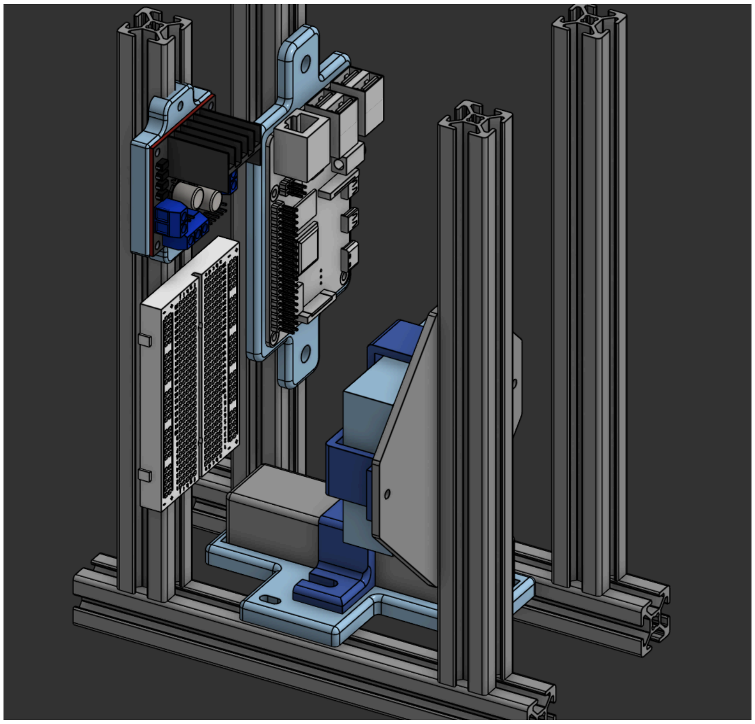


Figure 17: Left View of the Electrical Mounts

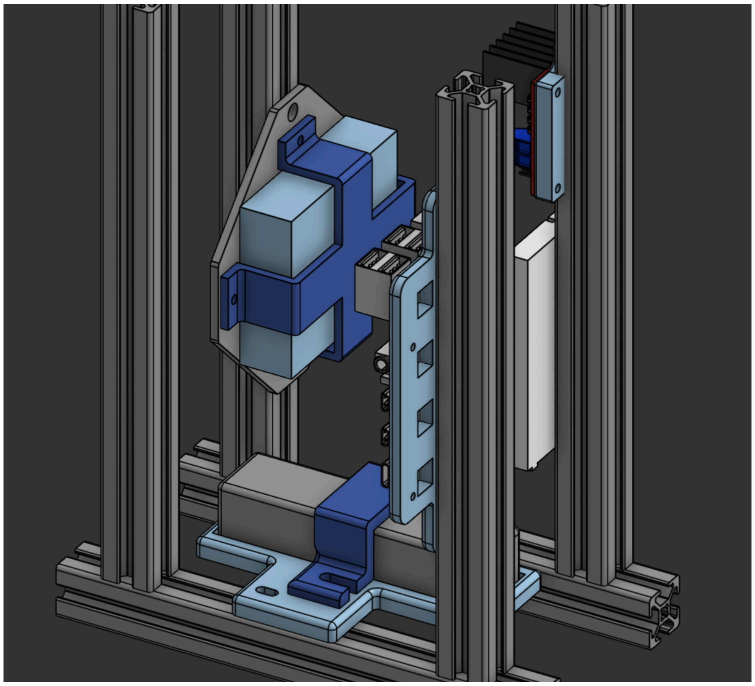


Figure 18: Right View of the Electrical Mounts

Allen Key Holder Integration

The design includes an Allen Key holder intended for quick adjustments during the setup process. It holds two hex keys and two L-keys in 2.5 mm and 3 mm sizes, and is mounted on the outer frame for easy access.

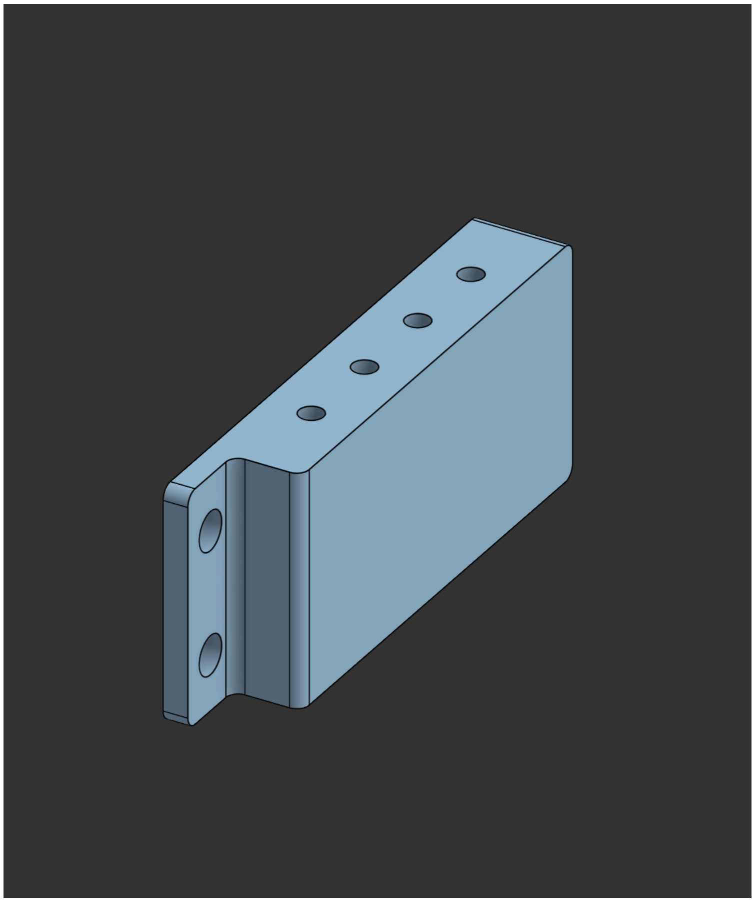


Figure 18: Allen Key Holder

Airtable Integration

This final design features full integration with Airtable for data collection and system automation. A custom Airtable Form is used to collect user information such as name and email. Once a form is submitted, the response automatically syncs with the Airtable database within approximately five seconds. The Raspberry Pi continuously monitors Airtable for new entries and, upon detecting a submission, triggers the control code that moves the dispenser to release a pen. This setup provides a seamless and responsive connection between the user input and the mechanical operation of the device.

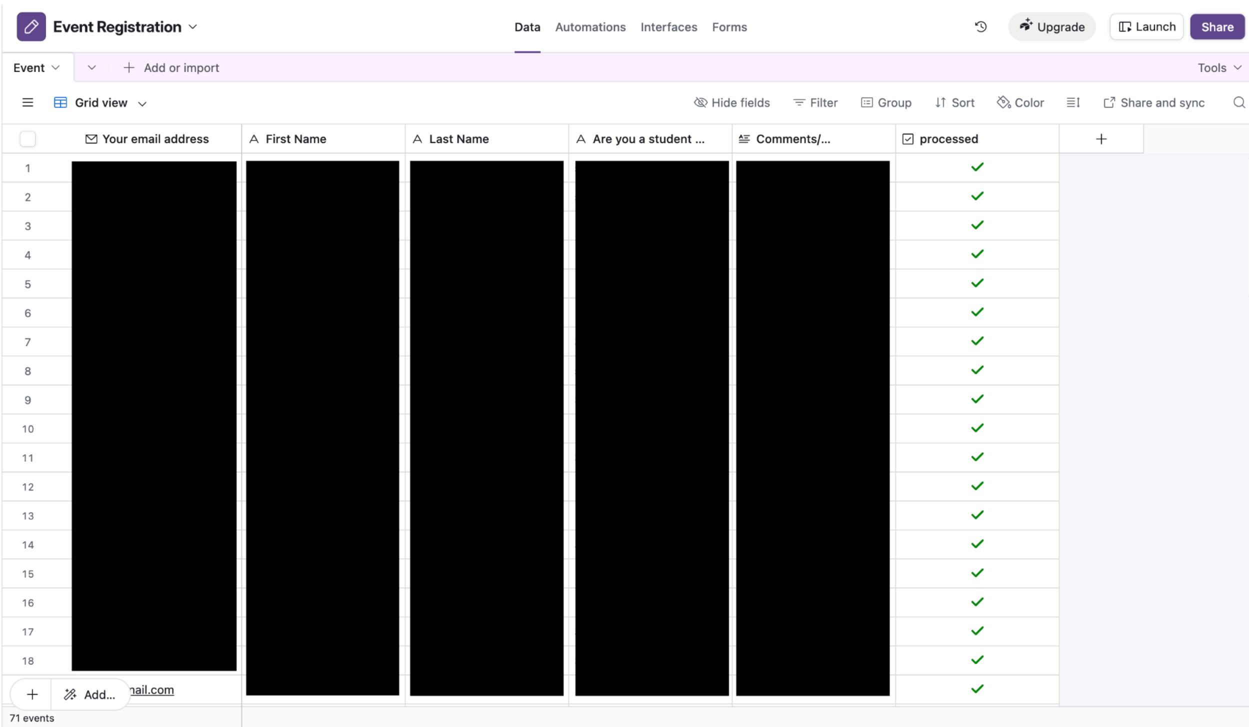


Figure 19: Airtable Registration Database

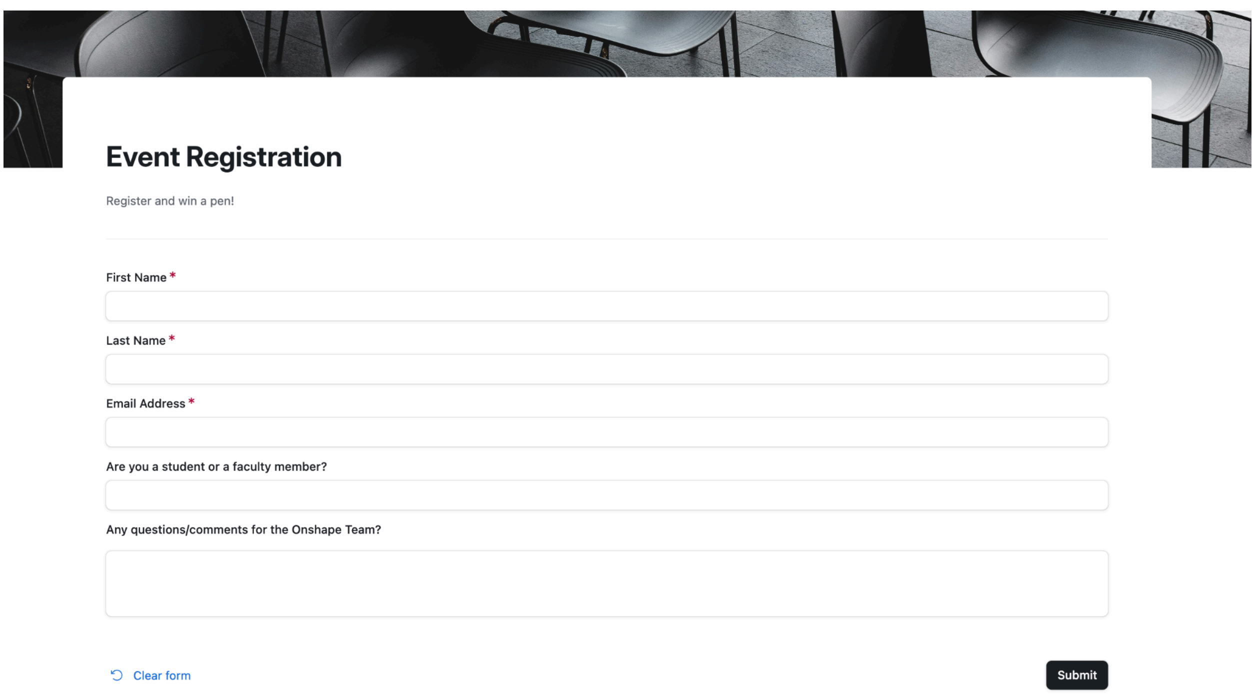
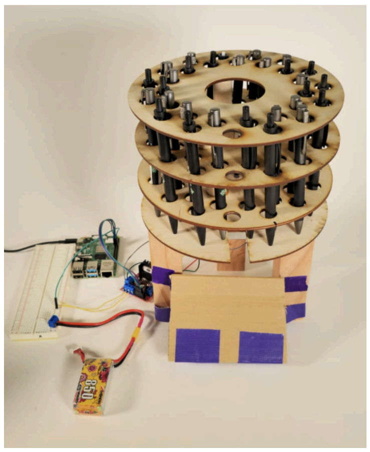
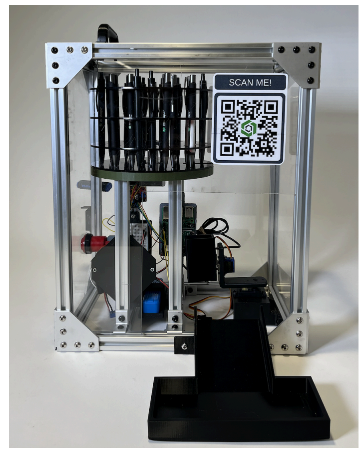


Figure 20: Event Registration Form

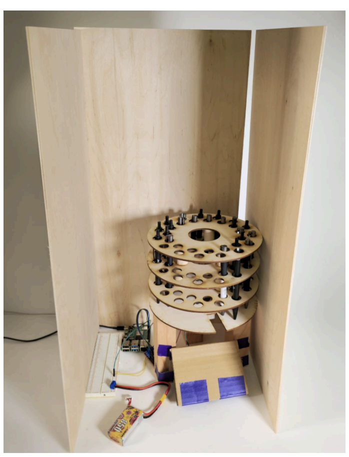
Design Evolution

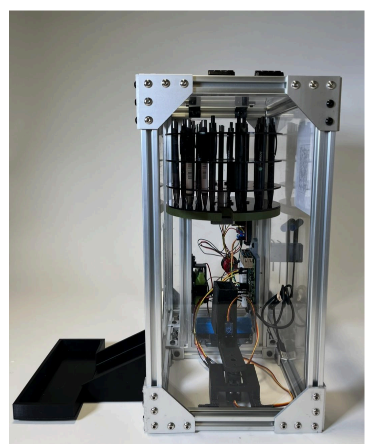
Compared to earlier versions, the final design introduces several key improvements. The slide was originally positioned under the rotating assembly and was used to guide the pen as it falls. However, now the slide is positioned after the robotic arm on the outer frame, and is used to transport the pen from the design to the user.



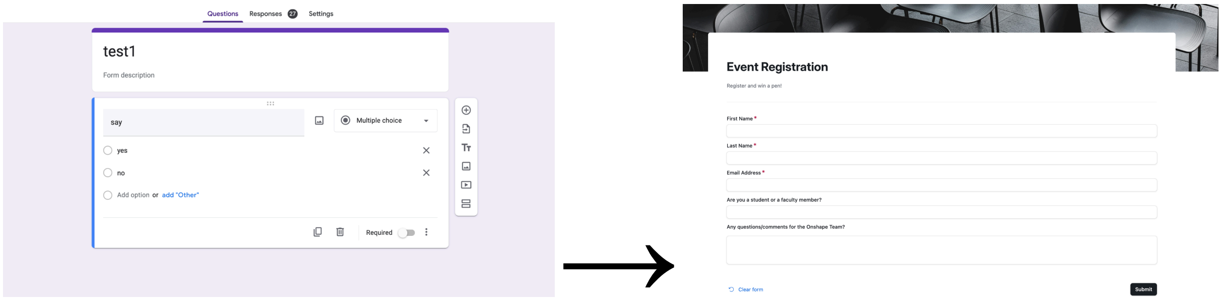


The design also transitioned from a closed cylindrical enclosure to an open layered structure, allowing visibility of pens and internal motion during operation. In addition, optimized hole sizing to improve pen fit and reduce wobble during rotation. Using both acrylic laser cut components and 3D-printed base instead of the original birch wood. This decision was made for easier assembly and for aesthetic purposes.





We switched from using Google Forms to Airtable Forms, as Google Forms took approximately two minutes to sync responses to Airtable after submission. By switching to Airtable Forms, the response time improved significantly from about two minutes to roughly five seconds, and accessing the form was also quicker since the registration database is on the same website.



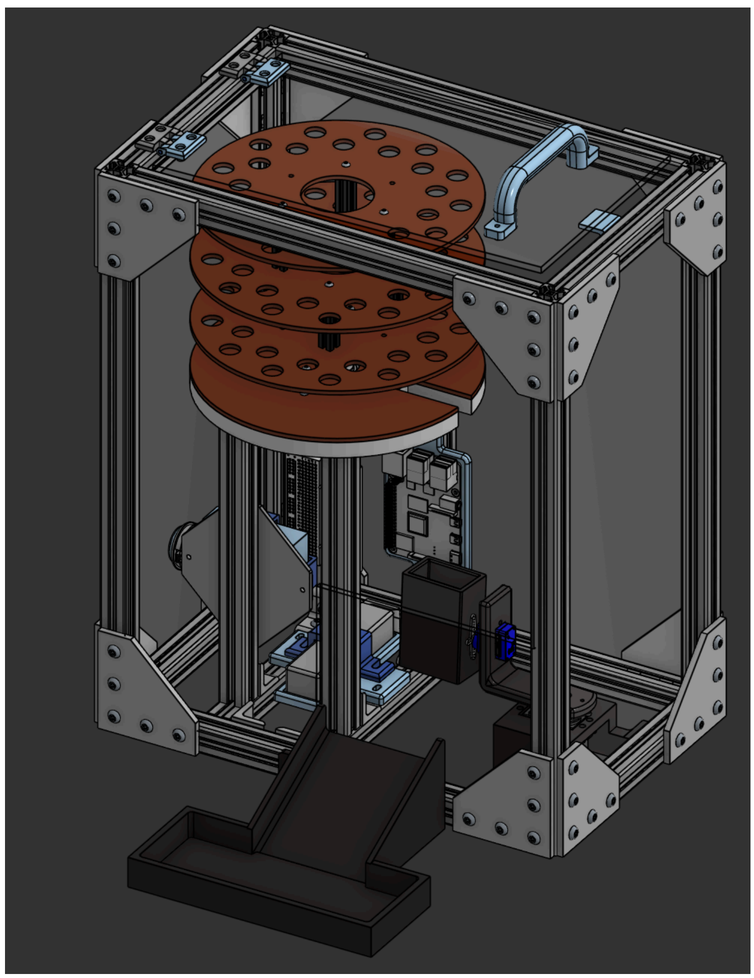


Figure 21: View of Final Design

g) Validation of Design Solution

The final design was validated by comparing the performance of its features against the user needs and engineering requirements. It was validated through engineering calculations and functional testing. Key areas of validation included portability, single-pen dispensing, user engagement, data collection integration, and readiness for use in conference environments.

The structural integrity of the robotic arm was validated through calculations as described in the Engineering Calculations section. The arm was analyzed under loading conditions corresponding to the weight of the servo motor, pens, and the impact force generated by the pen falling. The calculated maximum bending stress of 0.700 MPa was significantly below the allowable stress of 13 MPa, confirming that the arm can safely withstand repeated dispensing cycles without structural failure.

The rotating cylindrical pen holder was validated through repeated testing. The mechanism held 26 pens, and dispensed on per per actuation. Because each pen is isolated in an individual vertical slot, no jamming was observed during testing. This feature satisfies the engineering requirements of dispensing one per at a time and repeating the dispensing mechanism without intervention.

The assembled prototype dimensions were measured and confirmed to be within the target maximum size of 20”x12”x9”, satisfying the airline carry-on constraints. All electronic components, including the Raspberry Pi, stepper motor, and lithium-ion batteries, were selected to comply with TSA regulations. The system operated entirely on battery power and required zero wall outlet connections, satisfying the portable power requirement. Setup testing also demonstrated that the device can be unpacked, powered on, and made operational in under five minutes, meeting the maximum setup time requirement.

As for the data collection, during testing, the users scanned the QR code, submitted information through the Airtable form, and observed the dispenser respond automatically. The Raspberry Pi successfully detected new Airtable entries and triggered the dispensing sequence after form submission. This feature meets the requirements of data collection and reliable linkage between storing data and pen dispensing.

User engagement was validated through informal user testing and observation. Users were drawn to the transparent enclosure and visibly complex internal features, particularly the rotating pen holder and robotic arm. While a formal engagement survey was not conducted due to time constraints, observational feedback from users suggests the design would meet or exceed the target engagement score of 7/10.

To ensure safety and meet the requirement, acrylic panels enclosed all moving components, preventing user contact during operation. The slide delivers the pen outside, maintaining separation between users and the core components of the design. An emergency stop button was also incorporated to immediately stop system operation if necessary. The system completed the full process of data submission, pen isolation, robotic arm transfer, and delivery without requiring manual intervention.

Production Plan and Social/Ethical Considerations

Production Plan

To produce a robust and a lasting version of the dispenser, the design would transition to more durable manufacturing processes and higher quality materials, while maintaining the visual engagement in the product. The current prototype uses laser-cut acrylic, PLA 3D-printed components, CNC machined aluminum, and beams that support the structure and form a frame around it. Several components could be upgraded for longevity and reliability during travels and across many conferences.

For the dispensing system, the inner cylindrical pen holder—currently laser-cut acrylic—would be manufactured from clear polycarbonate using CNC machining. This material preserves the transparent aspect of the design while improving resistance to impact and cracking during transport. The base and motor surrounding components are currently printed in PLA and would be replaced with machined aluminum or resin printing, which offer more stability and wear tolerance from repeated use. The CNC machined aluminum flanged coupling would remain the preferred manufacturing method since its metal component ensures precise alignment and long term reliability.

The structural frame composed of the 8020 aluminum beams is itself a high quality option for long-term use and would remain the core structural supporting system. For a higher quality production build, standardized extrusion lengths would be ordered pre-cut and pre-drilled to reduce variability. The M3x0.5 and M6x1 socket button-head screws and clear enclosure would remain the same.

Electronics would remain in a protected interior compartment to reduce strain on wiring and connectors. The off the shelf stepper motor, Raspberry Pi, and battery would also remain placed in an interior compartment to withstand frequent transport and prevent them from external damage. With these upgrades, the device would meet the conditions expected from a durable and functional product.

For the robotic arm, the mounts can also be CNC machined or resin printing for a more durable design. However, a more sophisticated arm can be built to improve user engagement and excitement. For instance, instead of a pen falling into the carriage of the robotic arm, the pen would fall into a tray and a 3DoF arm with a gripper end effector would pick it up and deliver it to the next station. This can be done through image processing and machine learning to train the arm to do so.

Social and Ethical Considerations

The dispenser engages directly with conference attendees by inviting them to scan the and submit personal information before receiving a pen. While this interaction increases user engagement and enables effective data collection, it raises considerations related to privacy, consent, and data security. Attendee information is collected and stored through Airtable under Onshape's ownership, and it is ethically considered to provide transparent communication about how the data will be used, stored, and protected. The QR code use also presents potential security risks, such as tampering or getting hacked. These risks can be mitigated by securely mounting the QR code, linking it to a verified Airtable form, and regular inspection.

Physical safety is addressed by enclosing all moving components within clear acrylic panels and delivering the pen via a slide that separates users from the mechanical system. An emergency stop button provides additional safety. From a sustainability perspective, the device is designed for repeated reuse across conferences, with a modular structure that allows individual components to be repaired or replaced rather than discarded.

Conclusions and Future Work

a) Strengths of Design Solution

The penpal project successfully bridges the gap between automation and data collection. The final prototype successfully collects necessary data, while showing Onshape's capabilities and providing an enjoyable experience for the user. Its primary strength lies in its reliability and anti-jamming design. By storing the pens vertically and already separated, we overcame a common mechanical failure found in traditional dispensers, which is jamming.

The use of Airtable forms, APIs, and Raspberry Pi provides us with a nearly instantaneous response rate. Also, we implemented a "Queue" in our code to ensure that even if multiple users submit a form at the same time, they all will get their pens in order. This improves the reliability and robustness of the prototype. Furthermore, the use of 8020 aluminum extrusion ensures the device is structurally robust and professional in appearance, while the lightweight acrylic allows for full visibility of the "Onshape-designed" internal components, serving as an effective marketing tool for the software's capabilities.

b) Limitations of Design Solution

The current prototype has a few operational constraints. For instance, it can only store 26 pens at a time. While this is enough for most conferences, it might be less ideal in crowded conferences and would require multiple refills during the conference. The 26 pen limitation is due to the size constraint of the overall prototype.

The use of acrylic panels allows the users to observe the inside of the prototype, hence showcasing Onshape's capabilities. While the device is "travel-friendly," the current acrylic enclosure is prone to scratching and potential cracking if subjected to the rigors of checked luggage or rough handling by TSA

c) Suggestions for Revisions to the Design Solution

Enhanced UI/UX: Integrating a small OLED screen on the front of the frame to provide real-time feedback to the user, such as showing the queue and estimate time before each person receives their pen.

Pen Storage: Improving the storage capacity to hold 50+ pens, either through a different design, or switching to a more modular or dual-layers design that allows more pens to be stored.

Attraction and Engagement: Adding LED lights and/or speakers that play some sort of sounds. This will give the prototype a more arcade game vibe, which can attract more people to the Onshape booth.

AI Attribution

The report was written by all teammates and then ChatGPT was used to improve sentence structure and coherence of writing. Additionally, ChatGPT was used to help develop narrative text to describe user needs and engineering requirements.

References:

[1] Lithium batteries with more than 100 Watt Hours | Transportation Security Administration. (n.d.-e). https://www.tsa.gov/travel/security-screening/whatcanibring/items/lithium-batteries-more-100-watt-hours

[2] Amazon.com : Creproly Stainless Steel pencil Dispenser/pen holder for classroom home restaurant for bulk pencils storage/unwrapped drinking straws storage (silver) : Office products. (n.d.). https://www.amazon.com/Creproly-Stainless-Dispenser-Classroom-Restaurant/dp/B08H78WNZF

[3] Amazon.com: Simplyimagine Pencil Dispenser for classroom, home, office use, teacher supplies - durable acrylic rolling knob pencil holder box - 4" D x 10.5" W x 6.5" H - classroom must haves : Office products. (n.d.-c). https://www.amazon.com/SimplyImagine-Pencil-Dispenser-Holder-Classroom/dp/B083TG19K1

[4] *Tested & working vintage vendorama coin op 10¢ ballpoint pen vending machine*. eBay. (n.d.). https://www.ebay.com/itm/115900050016

[5] 1010. (n.d.-a). https://8020.net/1010.html

Appendices – Technical Documentation:

a) Concepts

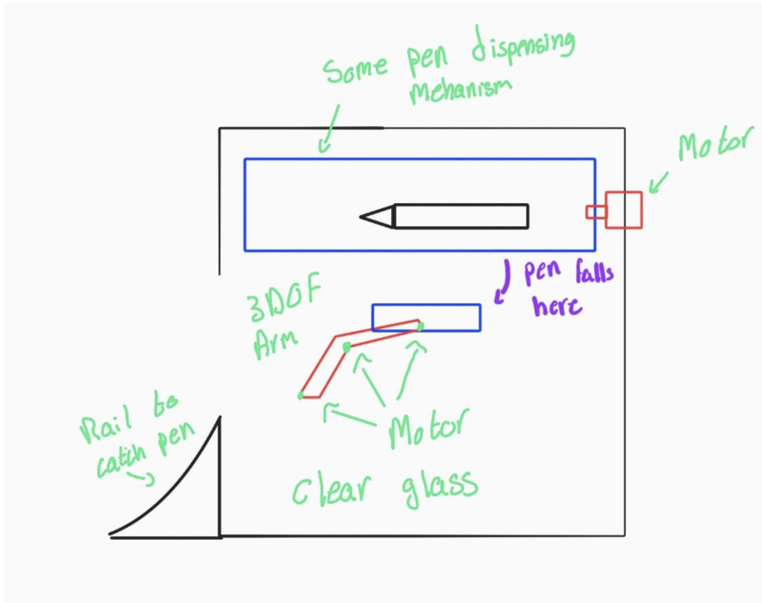


Figure 22: Concept Design

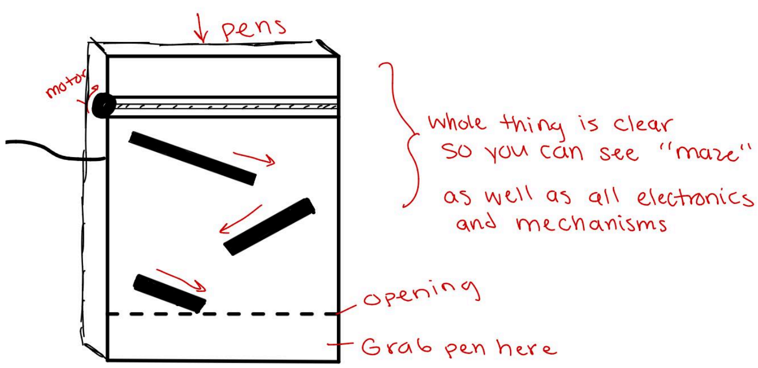


Figure 23: Concept Design

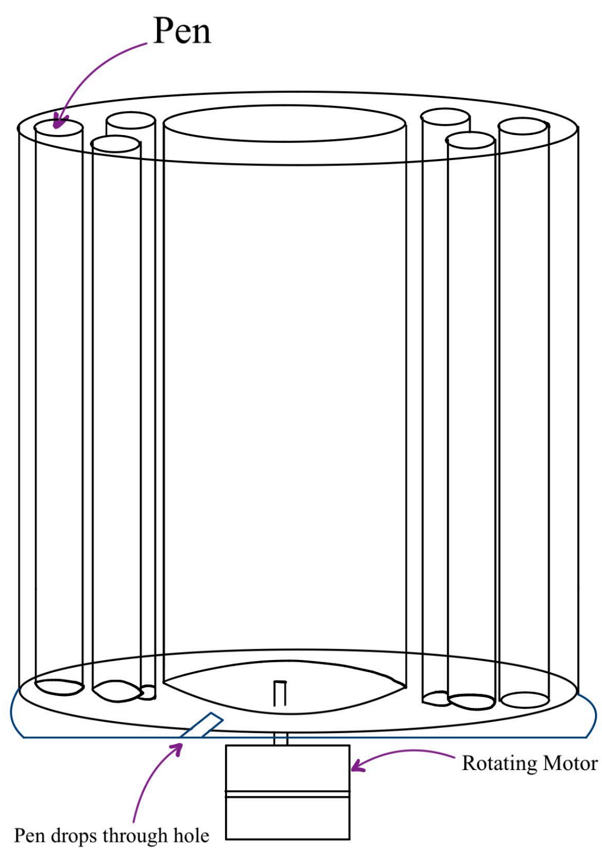


Figure 24: Selected Design for Prototype

b) Matrix of user needs and engineering requirements

Table 5: Matrix of User Needs and Requirement

Matrix of User Needs & Requirements									
	User Needs								
Requirements	**Travel**	**Data**	**Engaging**	**Dispensing**	**Storage**	**Repeatability**	**Setup**	**Power**	**Lightweight**
TSA Approved	x							x	
Maximum size (22"x14"x9")	x								x
Maximum Size									
1 Step to access data		x				x			
1 Step to submit data		x							
Scored an average of 7 on engagement survey			x			x			
Dispenses 1 pen at a time				x		x			
Holds 25-30 pens at a time					x	x			
Repeats dispensing mechanism 25 times				x	x	x			
Setup in <5 mins							x		
0 connections to							x	x	

wall outlets									
<20 lbs	x								x

c) Bill of Materials (BOM)

Part number assignment:

- 100: Made To Spec (MTS) part
- 200: Off The Shelf (OTS) part
- 300: Electronics
- 500: Sub-Assembly

Table 6: BOM For Top Level Assembly (* represents a sub-assembly, - represents multiple or does not apply)

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1*	501	1	Pen Dispenser	Rotating pen dispenser that hold and dispenses 25 pens	-	-	235.5
2*	502	1	Frame Assembly	8020 frame	Aluminium	Mcmaster-carr	108.62
3*	503	1	Robotic Arm	Assembly of robotic arm	-	-	9.14
4*	504	1	Slide Assembly	3D printed slide for pens to fall on + screws	-	-	1.5
5*	505	16	90° Corner Mount	90° corner mount with bolts and T-slot nut	Aluminium	Amazon	41.54
6*	513	1	Acrylic Panels	Acrylic Panel to seal structure	Acrylic	-	107.89
7	309	1	Emergency Button	Emergency Button to shut down system	-	Amazon	2.00

Table 7: BOM For Pen Dispenser

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	101	1	Base Mount Plate	3D printed mount of 8020 legs	PLA	MTS	1.00
2	102	1	Motor Mount Plate	Laser cut plate to hold motor	Acrylic	MTS	6.00
3	103	1	Coupling Interface Plate	Laser cut plate to hold coupling	Acrylic	MTS	6.00
4	104	2	Pen Alignment Discs	Laser cut plate to align pens	Acrylic	MTS	12.00
5	105	1	Flanged Coupling	CNC coupling for stepper motor	Aluminum - 6061	MTS	20.00
6	201	6	MakerBeam	Maker Beam	Aluminum - 6061	MakerBeams	15.00
7	301	1	Stepper Motor	OTS Stepper motor	-	Digikey	14.00
9*	302	1	Raspberry Pi	Raspberry Pi 4 and mount	-	-	66.00
10	303	1	Breadboard	Breadboard	-	Digikey	6.00
11*	513*	1	12 V Battery	12V Rechargeable Battery and Mounts	-	-	28.80
12*	511*	1	Raspberry Pi Battery	5v Battery for powering Pi and its mounts	-	-	9.00
12	512*	1	H-Bridge	H-bridge and Mounts	-	-	3.5
14	306	1	Jumper Wires	Jumper wires kit	-	Digikey	20.00
15	202	4	8020 Legs	10 x 10 80/20 Extrusion	Aluminum	Mcmaster-carr	14.90
16	206	2	8020 Feet	10 x 10 80/20 Extrusion	Aluminum	Mcmaster-carr	9.40

17	203	22	Socket button head screw M3x0.5 x 8	Socket button head screw M3x0.5 x 8 Stainless Steel	Stainless Steel	Mcmaster-carr	3.00
18	204	4	Socket button head screw M6x1 x 8	Socket button head screw M6x1 x 8 Stainless Steel	Stainless Steel	Mcmaster-carr	0.90

Table 8: BOM For Raspberry Pi

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	302	1	Raspberry Pi	Raspberry Pi 4	-	Digikey	55.00
2	108	1	Raspberry Pi Mount	3D printed mount for Pi	PLA	MTS	1.00

Table 9: BOM For 5V Battery

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	109	1	Pi Battery Holder - Base	5v Battery for powering PI	-	Amazon	1.00
2	110	1	Pi Battery Holder - Top	3D printed mount for Pi	PLA	MTS	1.00
3	305	1	Raspberry Pi Battery	5v Battery for powering PI	-	Amazon	7.00

Table 10: BOM For 12V Battery

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	304	1	12 V Battery	12V Rechargeable Battery	-	Amazon	26.89
2	111	1	12 V Battery - Base	3D printed mount for battery	PLA	MTS	1
3	112	1	12 V Battery - Base	3D printed mount for battery	PLA	MTS	1

Table 11: BOM For H-bridge

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	513	1	H-Bridge	L298N H-Bridge	-	Amazon	2.5
2	113	1	H-Bridge Mount	3D printed mount for battery	PLA	MTS	1

Table 12: BOM For Frame Assembly

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	206	4	80/20 Frame Pieces (Length)	10 x 10 80/20 Extrusion (5 ft)	Aluminum	Mcmaster-carr	20.03
2	207	4	80/20 Frame Pieces (Height)	10 x 10 80/20 Extrusion (6 ft)	Aluminum	Mcmaster-carr	23.51
3	208	4	80/20 Frame Pieces (Width)	10 x 10 80/20 Extrusion (3 ft)	Aluminum	Mcmaster-carr	13.10
4	209	16	Corner Brackets	10 x 10 80/20 Corner Brackets	Aluminum	Amazon	51.98
5	210	96	T-slot 10 series nuts	T-slot nuts (Included with Corner Bracket)	Aluminum	Amazon	-
6	211	96	Hex socket cap bolts	Socket Cap Bolts (Included with Corner Bracket)	Aluminum	Amazon	-

Table 13: BOM For Robotic Arm

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	307	1	MG995 Stepper Motor	Stepper motor for moving the arm	-	Amazon	4.20
2	308	1	SG90 Stepper Motor	Stepper motor for moving the arm	-	Amazon	1.35
3	106	1	Arm Linkage	Linkage that holds two stepper motor	PLA	MTS	1
4	107	1	Pen Carriage	Carriage designed to catch pen after it falls from pen dispenser	PLA	MTS	1
4	205	8	Socket button head screw M2x0.5 x 6	Socket button head screw M2x1 x 6 Stainless Steel	Stainless Steel	Mcmaster-carr	1.59

Table 14: BOM For Slide Assembly

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	114	1	Slide	3D printed slide for pens to fall on	PLA	MTS	1
2	203	2	Socket button head screw M3x0.5 x 8	Socket button head screw M3x0.5 x 8 Stainless Steel	Stainless Steel	Mcmaster-carr	0.5

Table 15: BOM for 90 degree Corner Mount

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
4	212	16	90° Corner Brackets	10 x 10 80/20 90° Corner Brackets	Aluminum	Amazon	41.54
5	210	32	T-slot 10 series nuts	T-slot nuts (Included with Corner Bracket)	Aluminum	Amazon	-
6	211	32	Hex socket cap bolts	Socket Cap Bolts (Included with Corner Bracket)	Aluminum	Amazon	-

Table 16: BOM for Acrylic Panels

Item #	Part #	Qty	Name	Description	Material	Vendor	Cost ($)
1	213	2	Side Panel	Acrylic Side panel (Price is total for all panels, 2 X 3/16" 24x36)	Acrylic	Maker Stock	95.90
2	214	1	Top Panel	Acrylic Top panel	Acrylic	Maker Stock	-
3	215	1	Front Panel	Acrylic Front panel	Acrylic	Maker Stock	-
4	216	1	Back Panel	Acrylic Back panel	Acrylic	Maker Stock	-
5	115	1	Handle	Handle to open top panel	PLA	MTS	1
6	116	1	Panel Stopper	Prevents top panel for hitting pen dispenser	PLA	MTS	1
7	217	2	Hinges	Hinges for top panel	Aluminum	Amazon	9.99
8	218	4	M2 Screws for Hinge	Included with Hinges	Aluminum	Amazon	-

d) Video

Please click here to access a video showing our prototype performing a full run. This includes a user scanning the QR code, submitting the form, and followed by dispensing a pen.

e) Software code

```
import os
import time
import requests
import RPi.GPIO as GPIO
from requests.utils import quote
import pigpio
import sys
from datetime import datetime, timezone   # <-- ADDED

# -------- AIRTABLE --------
TOKEN =
"patU1vuEoI8vU3eZE.67a09bc4b198d502ad32dcbf2674a4941f1124d922d190d84ac4a745
36cedf08"
BASE_ID = "appsPzKH3eQrKRnyb"
TABLE_NAME = "Event"

URL = f"https://api.airtable.com/v0/{BASE_ID}/{quote(TABLE_NAME)}"
HEADERS = {
    "Authorization": f"Bearer {TOKEN}",
    "Content-Type": "application/json"
}

# -------- SCRIPT START TIME (CRITICAL) --------
# Only process Airtable records created AFTER this moment
STARTUP_TIME = datetime.now(timezone.utc)

# -------- GPIO SETUP --------
GPIO.setmode(GPIO.BOARD)

# -------- SERVO CLASS (pigpio) --------
class Servo:
    def _init_(self, pin, min_us=544.0, max_us=2400.0,
                 min_deg=-90.0, max_deg=90.0, freq=50):
        self.pi = pigpio.pi()
        if not self.pi.connected:
            raise RuntimeError("pigpiod is not running (sudo systemctl
start pigpiod)")

        self.pin = pin
        self.current_us = 0.0
        self.offset = min_us
```

```
        self.max = max_us
        self.min_deg = min_deg
        self.max_deg = max_deg
        self.slope = (min_us - max_us) / (min_deg - max_deg)

        self.current_us = (min_us + max_us) / 2

    def write_us(self, us):
        us = max(self.offset, min(self.max, us))
        self.current_us = us
        self.pi.set_servo_pulsewidth(self.pin, us)

    def write(self, deg):
        deg = max(self.min_deg, min(deg, self.max_deg))
        self.write_us((deg - self.min_deg) * self.slope + self.offset)

    def read(self):
        return (self.current_us - self.offset) / self.slope + self.min_deg

    def move_smooth(self, target_deg, duration=1.0):
        start_deg = self.read()
        steps = int(duration * 50)
        if steps < 1:
            steps = 1

        step_deg = (target_deg - start_deg) / steps
        step_delay = duration / steps
        current_deg = start_deg

        for _ in range(steps):
            current_deg += step_deg
            self.write(current_deg)
            time.sleep(step_delay)

        self.write(target_deg)

    def off(self):
        self.pi.set_servo_pulsewidth(self.pin, 0)

    def close(self):
        self.off()
        self.pi.stop()
```

```python
# -------- GLOBAL OBJECTS --------
servo1 = Servo(6)      # BOARD 31
servo2 = Servo(16)     # BOARD 36

OUT1, OUT2, OUT3, OUT4 = 11, 13, 15, 16
for pin in (OUT1, OUT2, OUT3, OUT4):
    GPIO.setup(pin, GPIO.OUT, initial=GPIO.LOW)

# -------- CLEANUP FUNCTION --------
def cleanup_all():
    print("\nRunning Cleanup...")
    try:
        servo1.off()
        servo2.off()
        servo1.close()
        servo2.close()
    except Exception as e:
        print(f"Servo cleanup error: {e}")

    try:
        GPIO.cleanup()
    except Exception as e:
        print(f"GPIO cleanup error: {e}")

    print("Cleanup Complete.")

# -------- SAFETY BUTTON SETUP --------
BUTTON_PIN = 37
GPIO.setup(BUTTON_PIN, GPIO.IN, pull_up_down=GPIO.PUD_UP)

def safety_button_callback(channel):
    print("\n!!! EMERGENCY STOP TRIGGERED !!!")
    cleanup_all()
    os._exit(0)

GPIO.add_event_detect(
    BUTTON_PIN,
    GPIO.FALLING,
    callback=safety_button_callback,
    bouncetime=300
)

# -------- STEPPER SETTINGS --------
```

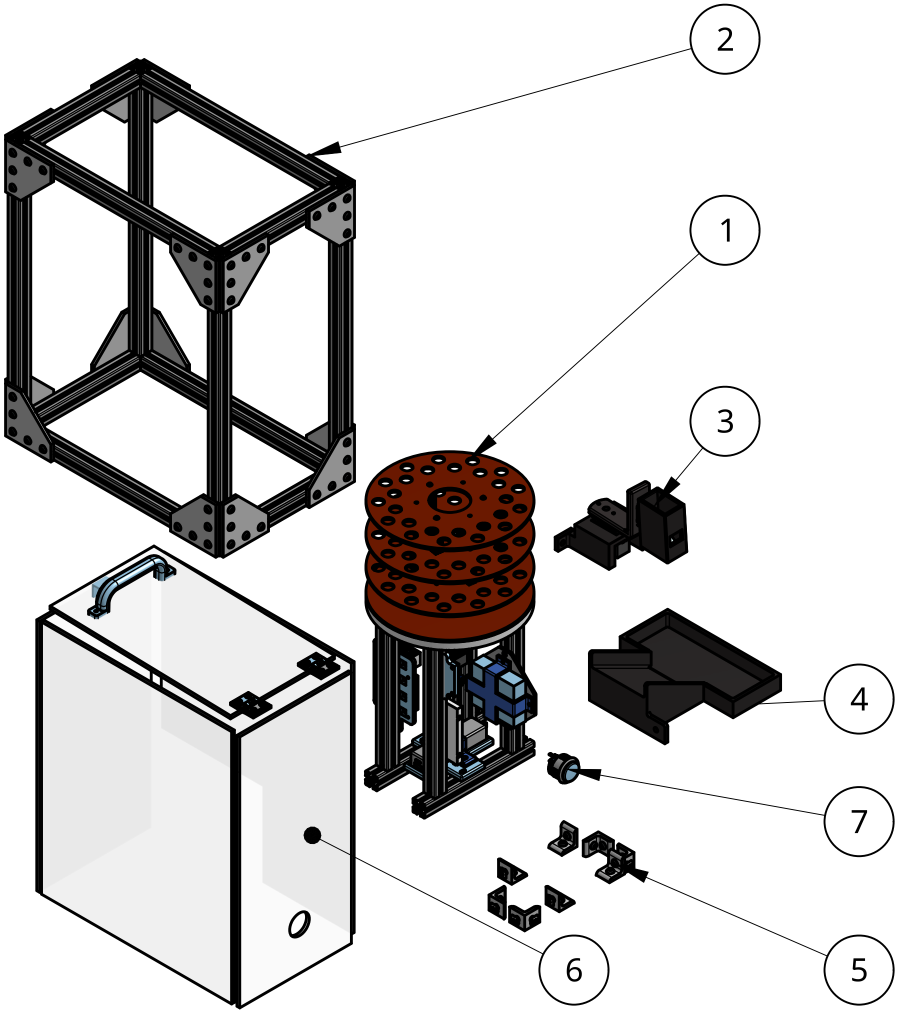
```python
STEPS_PER_REV = 200
DEGREES = 15
step_delay = 0.03
steps_to_move = int(STEPS_PER_REV * (DEGREES / 360.0))

sequence = [
    (1, 0, 1, 0),
    (0, 1, 1, 0),
    (0, 1, 0, 1),
    (1, 0, 0, 1)
]

def run_motor():
    current = 0
    for _ in range(steps_to_move):
        a, b, c, d = sequence[current]
        GPIO.output(OUT1, a)
        GPIO.output(OUT2, b)
        GPIO.output(OUT3, c)
        GPIO.output(OUT4, d)
        time.sleep(step_delay)
        current = (current + 1) % 4

    for pin in (OUT1, OUT2, OUT3, OUT4):
        GPIO.output(pin, GPIO.LOW)

# -------- SERVO LOGIC --------
HOME_1 = -3
HOME_2 = 55
TARGET_1 = 20
TARGET_2 = -60

servo_state = "unknown"

def go_home(delay=1.0):
    global servo_state
    servo1.move_smooth(HOME_1, duration=1.0)
    servo2.move_smooth(HOME_2, duration=1.0)
    time.sleep(delay)
    servo_state = "home"

def go_target():
    global servo_state
```

```
    servo1.move_smooth(TARGET_1, duration=1.0)
    time.sleep(0.5)
    servo2.write(TARGET_2)
    time.sleep(0.5)
    servo_state = "target"

def servo_cycle():
    if servo_state != "home":
        go_home()
    time.sleep(3)
    go_target()
    time.sleep(1)
    go_home(delay=1.0)

# -------- AIRTABLE HELPERS --------
def check_airtable():
    formula = "NOT({processed})"
    try:
        r = requests.get(
            URL,
            headers=HEADERS,
            params={"filterByFormula": formula},
            timeout=10
        )
        r.raise_for_status()
        records = r.json().get("records", [])

        valid_records = []
        for rec in records:
            created_str = rec.get("createdTime")
            if not created_str:
                continue

            created_dt = datetime.fromisoformat(
                created_str.replace("Z", "+00:00")
            )

            # Only accept records created while Pi is running
            if created_dt >= STARTUP_TIME:
                valid_records.append(rec)

        return valid_records
```

```
    except Exception as e:
        print(f"Airtable check failed: {e}")
        return []

def mark_done(rec_id):
    data = {"fields": {"processed": True}}
    r = requests.patch(f"{URL}/{rec_id}", headers=HEADERS, json=data,
timeout=10)
    r.raise_for_status()
    print("Marked done:", rec_id)

# -------- MAIN LOOP --------
def main():
    global servo_state

    go_home()
    queue = []
    pending_ids = set()

    print("System Ready. Press Button on Pin 37 to Emergency Stop.")

    try:
        while True:
            records = check_airtable()

            for rec in records:
                rec_id = rec["id"]
                if rec_id not in pending_ids:
                    queue.append(rec_id)
                    pending_ids.add(rec_id)

            if queue:
                rec_id = queue.pop(0)
                pending_ids.remove(rec_id)

                if servo_state != "home":
                    go_home()

                run_motor()
                servo_cycle()
                mark_done(rec_id)

            time.sleep(1)
```

```
    except KeyboardInterrupt:
        cleanup_all()
    except Exception as e:
        print(f"Unexpected error: {e}")
        cleanup_all()

if _name_ == "_main_":

    main()
```

f) Technical Drawings



Item	Quantity	Part number	Name	Material
1	1	501	Pen Dispenser	-
2	1	502	20 20 Frame Assembly	Aluminum
3	1	503	Robotic Arm Assembly	-
4	1	504	Slide	PLA
5	8	505	90 deg Corner Mount Assembly	Aluminum
6	1	513	Panels Assembly	-
7	1	309	Emergency Stop	N/A

B

A

ANGULAR = ± °

SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/18/2025
CHECKED		
APPROVED		

MATERIAL -

FINISH

Onshape - PenPal #2

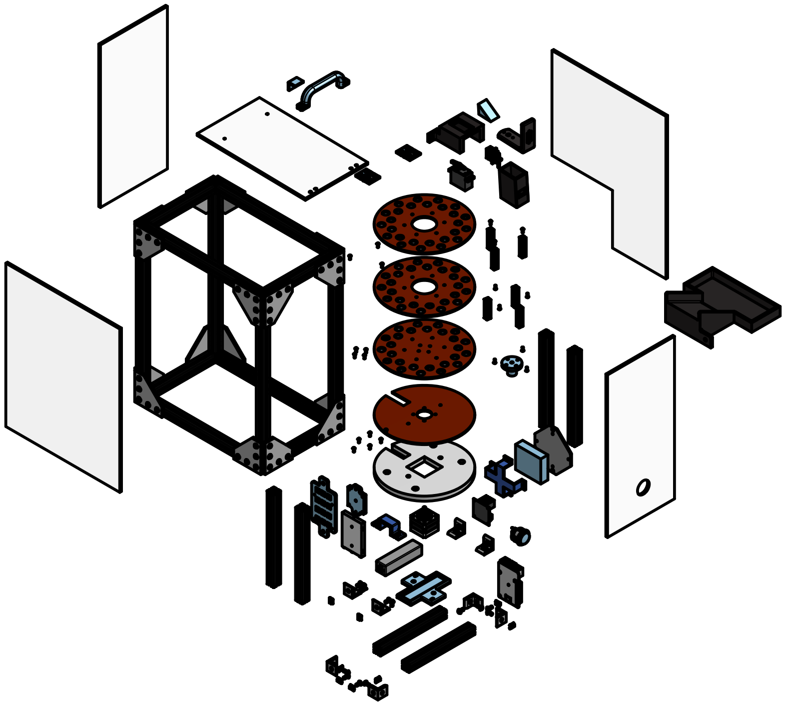
TITLE

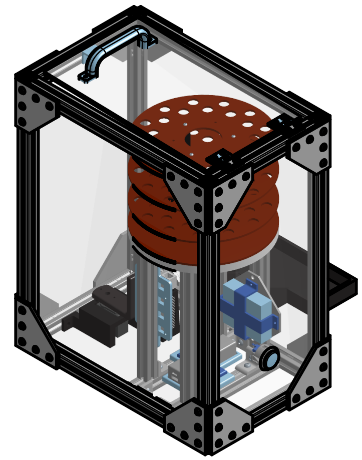
PenPal Assembly

SIZE A | DWG NO. 023 | REV. 02

SCALE 1:9 | WEIGHT | SHEET 1 of 2

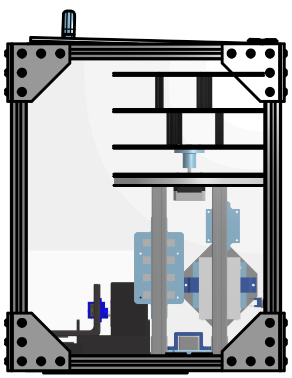
2 1



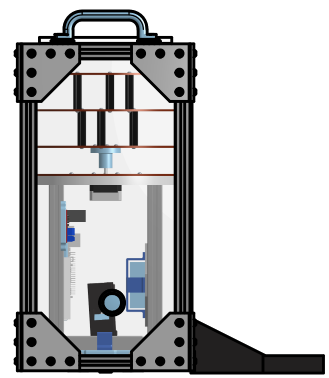


SCALE 1:10

B



SCALE 1:10



SCALE 1:10

A

ANGULAR = ± °

SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/18/2025
CHECKED		
APPROVED		

MATERIAL	FINISH
-	

Onshape - PenPal #2

TITLE

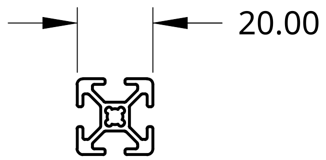
PenPal Assembly

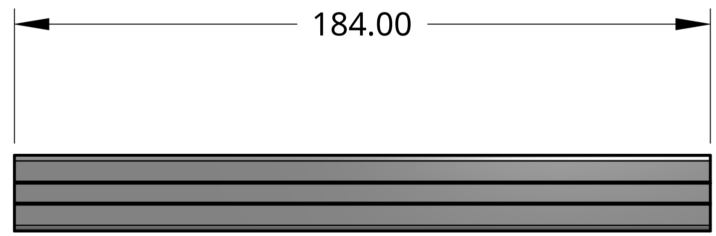
SIZE	DWG NO.	REV.
A	023	02

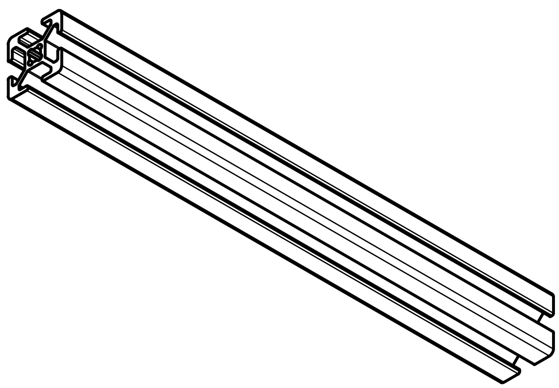
SCALE	WEIGHT	SHEET
1:15		2 of 2

2 1

2 1







B B

A A

UNLESS OTHERWISE SPECIFIED,
DIMENSIONS ARE IN INCHES
.XX = ±.0-
.XXX = ±.00-
.XXXX = ±.000-
ANGULAR = ± °
FRACTIONAL = ±
SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	HALEY LEIMBACH	11/03/2025
CHECKED		
APPROVED		

MATERIAL: Aluminum

FINISH:

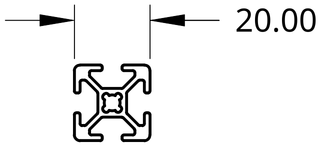
Onshape Penpal - #2

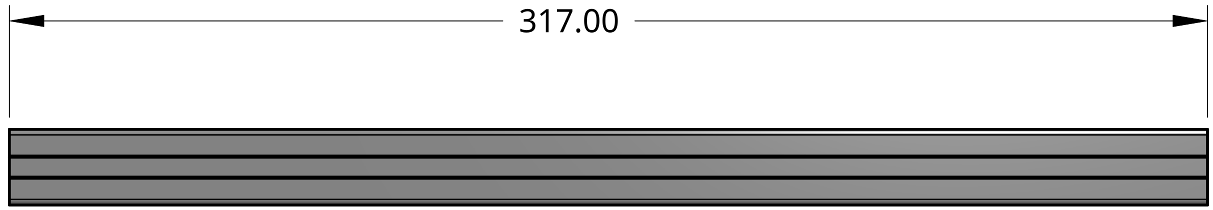
TITLE: 2020 Front/Back Frame Leg

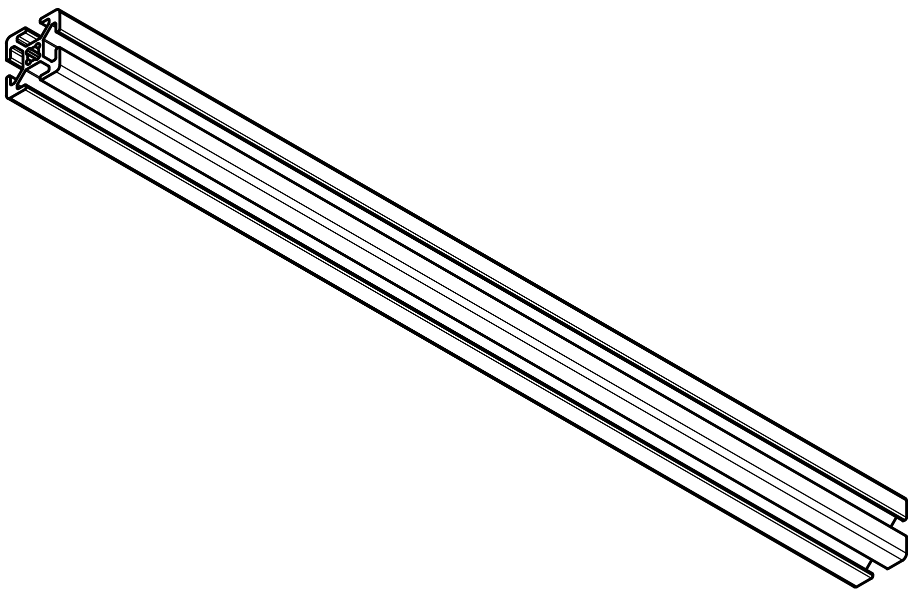
SIZE	DWG NO.	REV.
A	20	B

SCALE	WEIGHT	SHEET
1:2		1 of 1

2 1







UNLESS OTHERWISE SPECIFIED,
DIMENSIONS ARE IN INCHES
.XX = ±.0-
.XXX = ±.00-
.XXXX = ±.000-
ANGULAR = ± °
FRACTIONAL = ±
SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	HALEY LEIMBACH	11/03/2025
CHECKED		
APPROVED		

MATERIAL	FINISH
Aluminum	

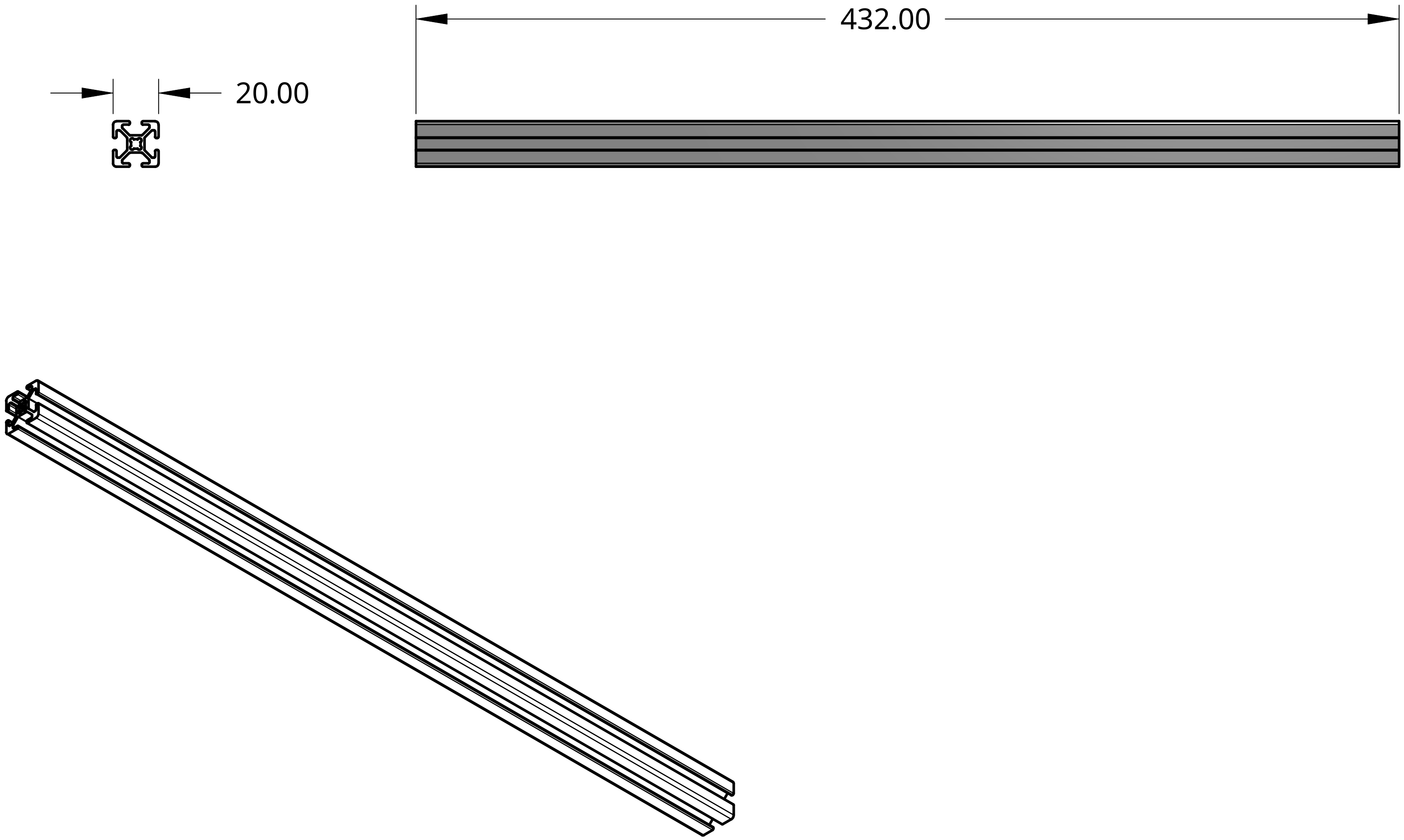
Onshape Penpal - #2

TITLE

2020 Side Frame Leg

SIZE	DWG NO.	REV.
A	21	B

SCALE	WEIGHT	SHEET
1:2		1 of 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES .XX = ±.0- .XXX = ±.00- .XXXX = ±.000- ANGULAR = ± ° FRACTIONAL = ± SURFACE FINISH		NAME	DATE
	DRAWN	HALEY LEIMBACH	11/03/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL: Aluminum	FINISH	

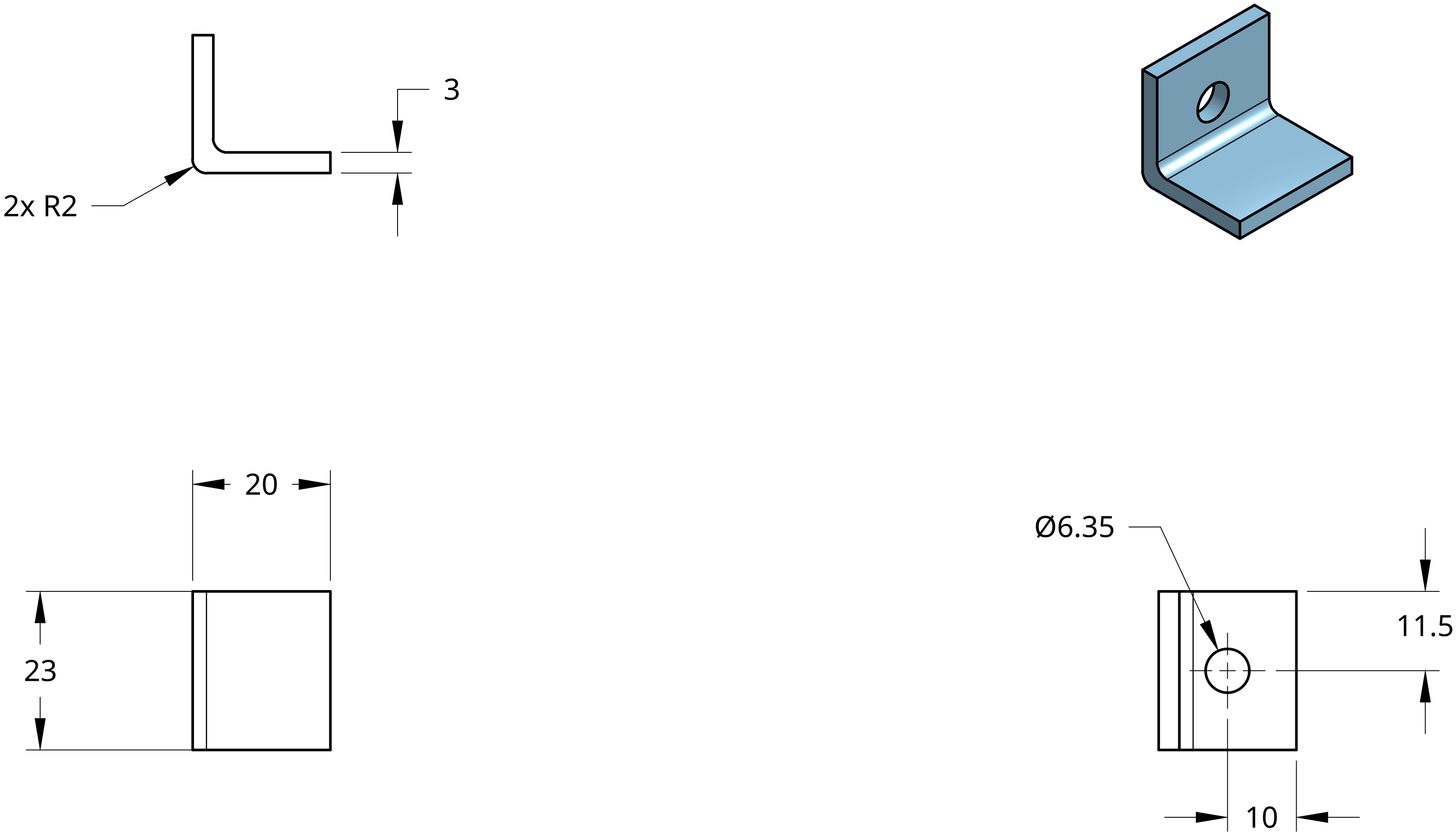
Onshape Penpal - #2

TITLE: 2020 Vertical Frame Leg

SIZE	DWG NO.	REV.
A	19	B

SCALE	WEIGHT	SHEET
1:3		1 of 1

2 1

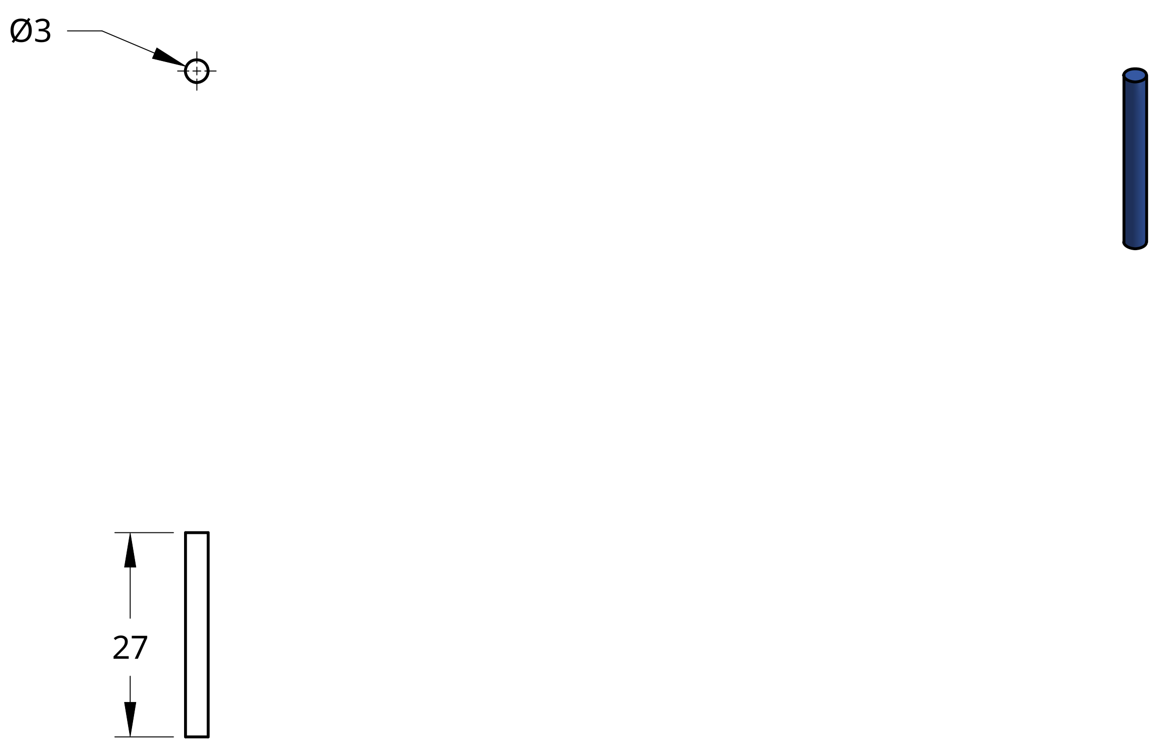


B

A

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE	Onshape - PenPal #2
	DRAWN	KARIM AL-HAFFAR	12/18/2025	TITLE Panel Stop
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A · DWG NO. 036 · REV. 02
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH		SCALE 1:1 · WEIGHT · SHEET 1 of 1

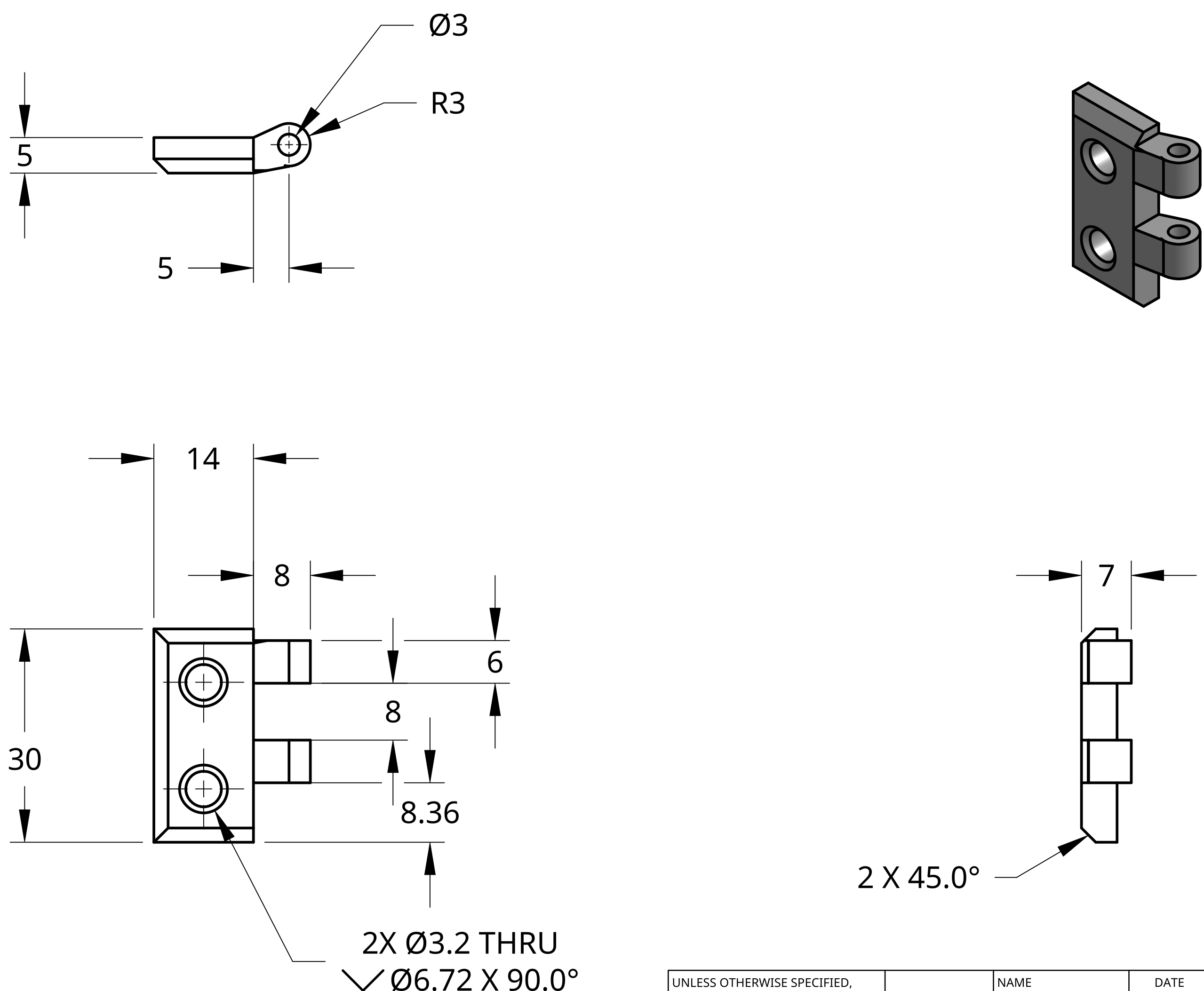
2 1



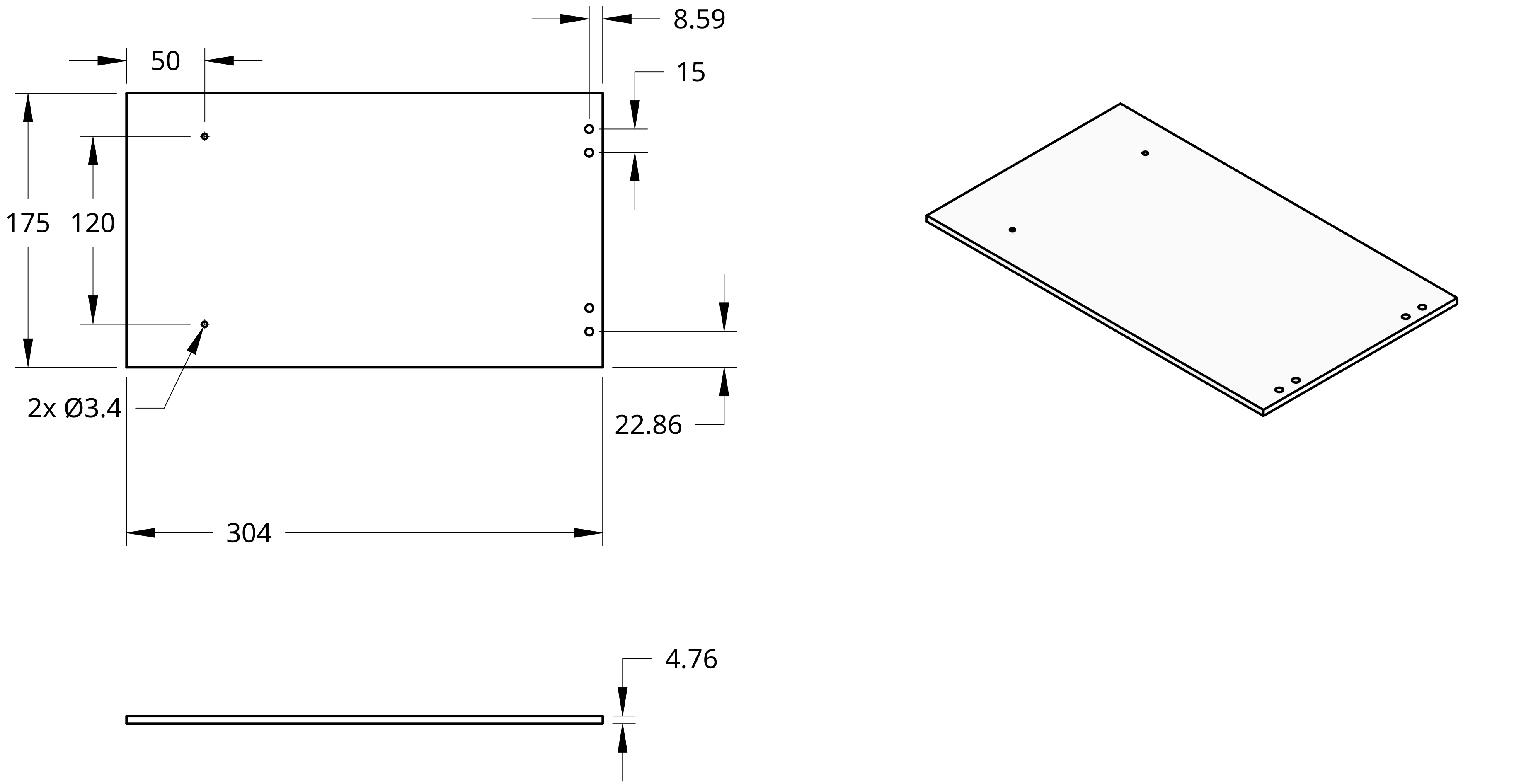
B

A

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS		NAME	DATE	Onshape - PenPal #2
ANGULAR = ± °	DRAWN	KARIM AL-HAFFAR	12/18/2025	TITLE
SURFACE FINISH	CHECKED			Hinge Pin
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A · DWG NO. 035 · REV. 02
THIRD ANGLE PROJECTION	MATERIAL Aluminum	FINISH		SCALE 1:1 · WEIGHT · SHEET 1 of 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE	Onshape - PenPal #2			
	DRAWN	KARIM AL-HAFFAR	12/18/2025	TITLE			
	CHECKED			Hinge			
	APPROVED						
DO NOT SCALE DRAWING							
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A	DWG NO. 034		REV. 02
THIRD ANGLE PROJECTION	MATERIAL Aluminum		FINISH	SCALE 1:1	WEIGHT	SHEET 1 of 1	



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE
	DRAWN	KARIM AL-HAFFAR	12/18/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL Acrylic	FINISH	

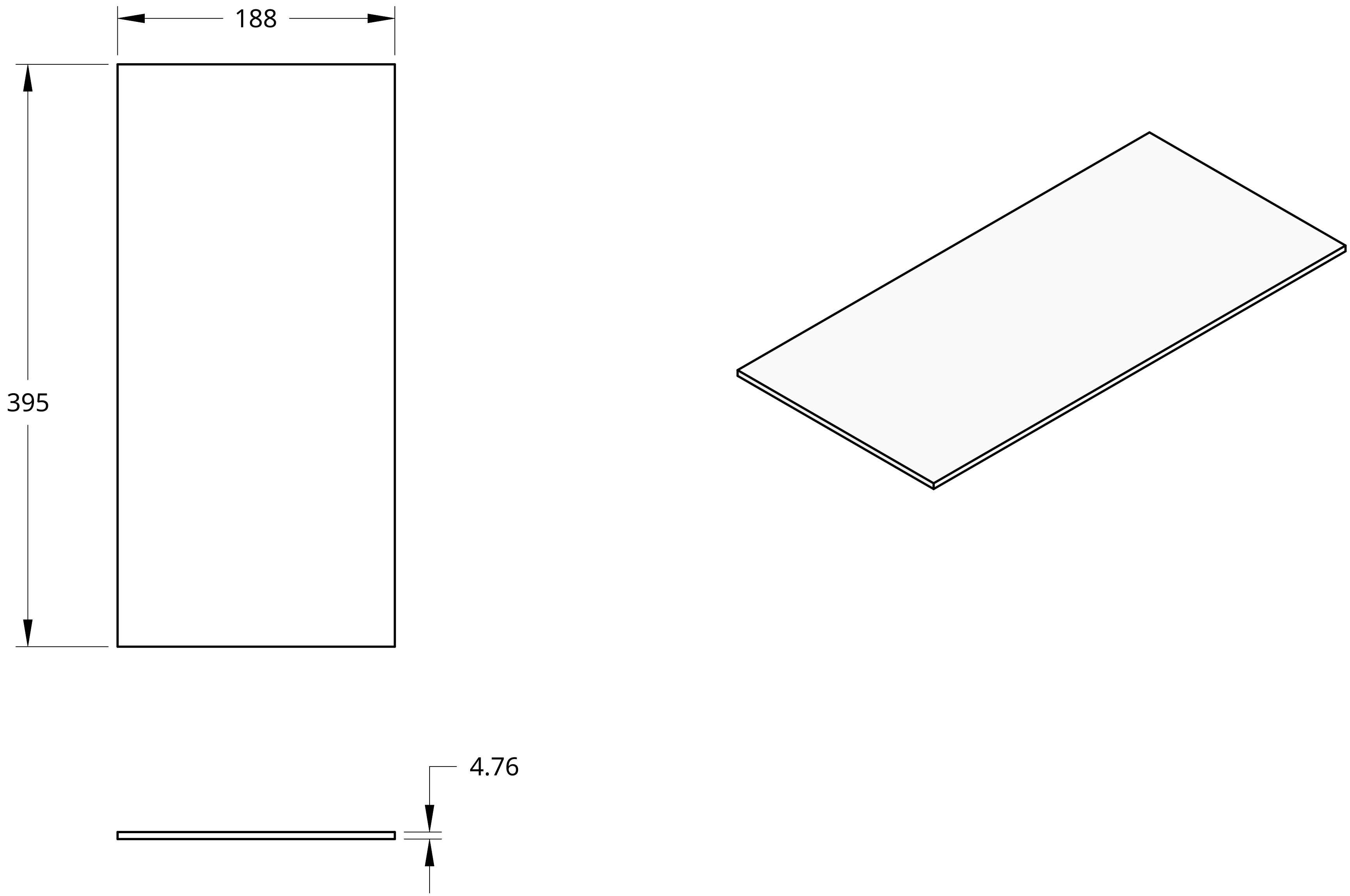
Onshape - PenPal #2

TITLE

Top Panel

SIZE	DWG NO.	REV.
A	033	02

SCALE	WEIGHT	SHEET
1:4		1 of 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE
	DRAWN	KARIM AL-HAFFAR	12/18/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL Acrylic	FINISH	

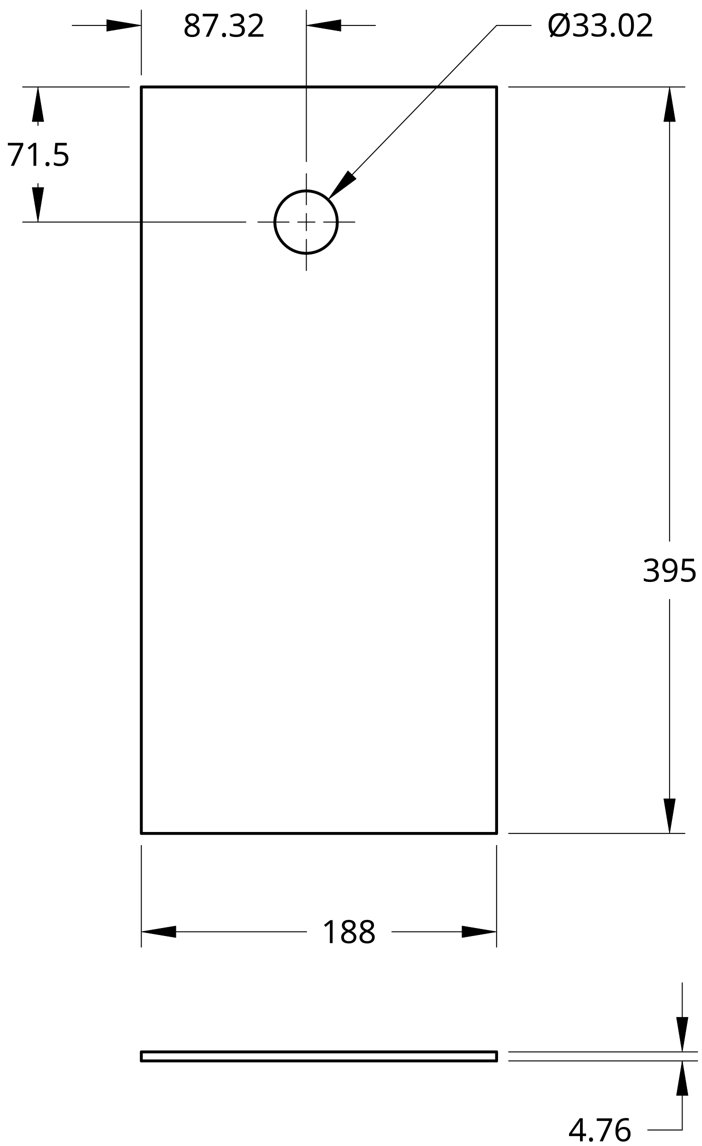
Onshape - PenPal #2

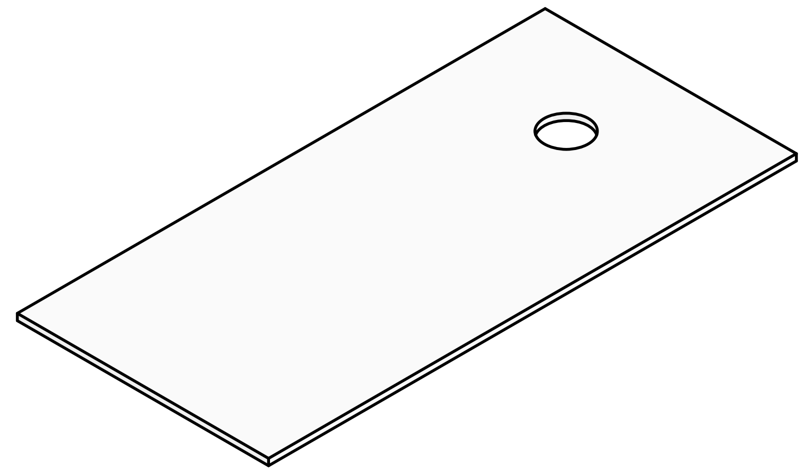
TITLE

Side Panel

SIZE	DWG NO.	REV.
A	032	02

SCALE	WEIGHT	SHEET
1:4		1 of 1





UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE
	DRAWN	KARIM AL-HAFFAR	12/18/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL Acrylic	FINISH	

Onshape - PenPal #2

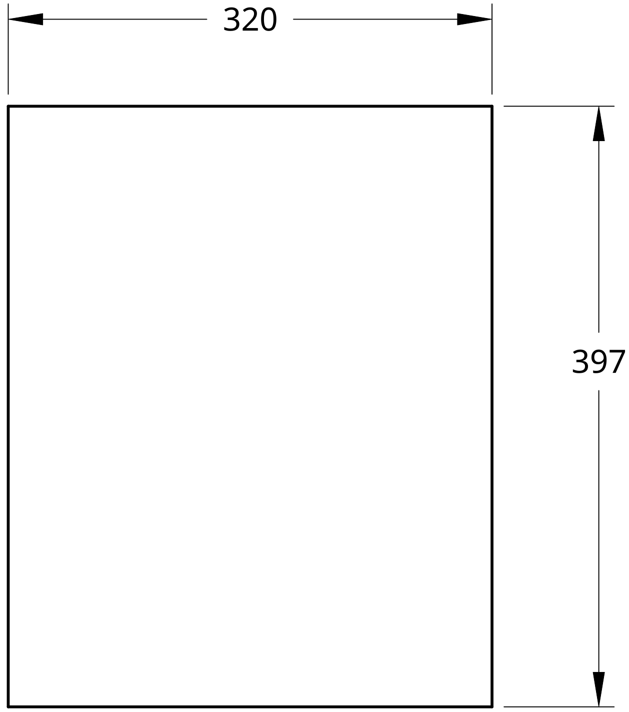
TITLE

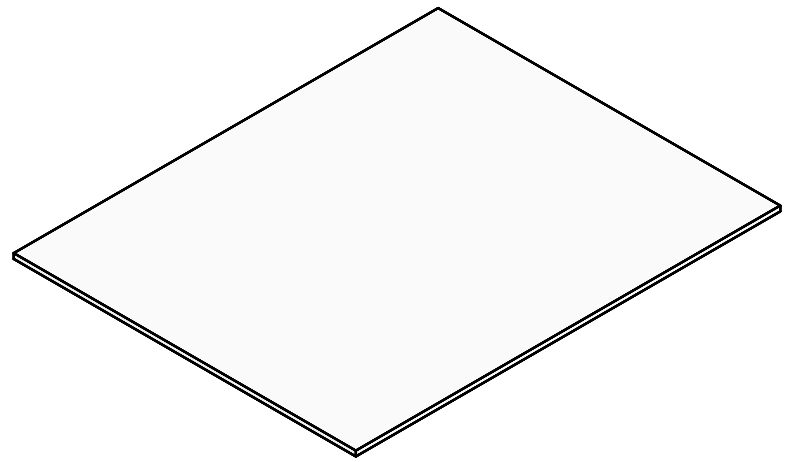
Side Panel With Hole

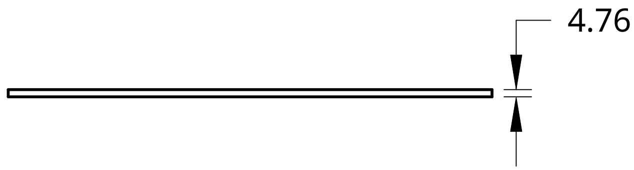
SIZE	DWG NO.	REV.
A	031	02

SCALE	WEIGHT	SHEET
1:4		1 of 1

2 1







B

A

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE
	DRAWN	KARIM AL-HAFFAR	12/18/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL Acrylic	FINISH	

Onshape - PenPal #2

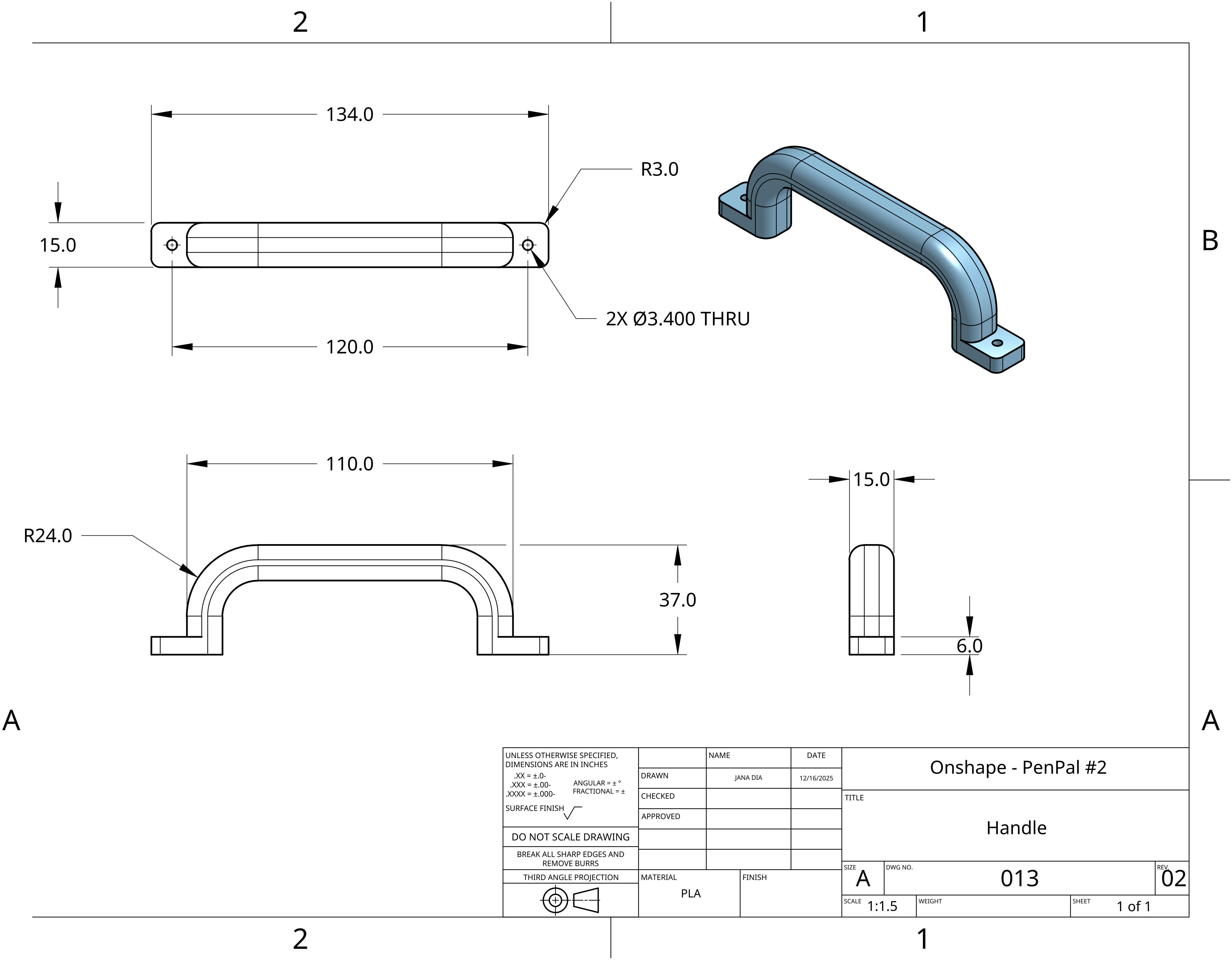
TITLE

Back Panel

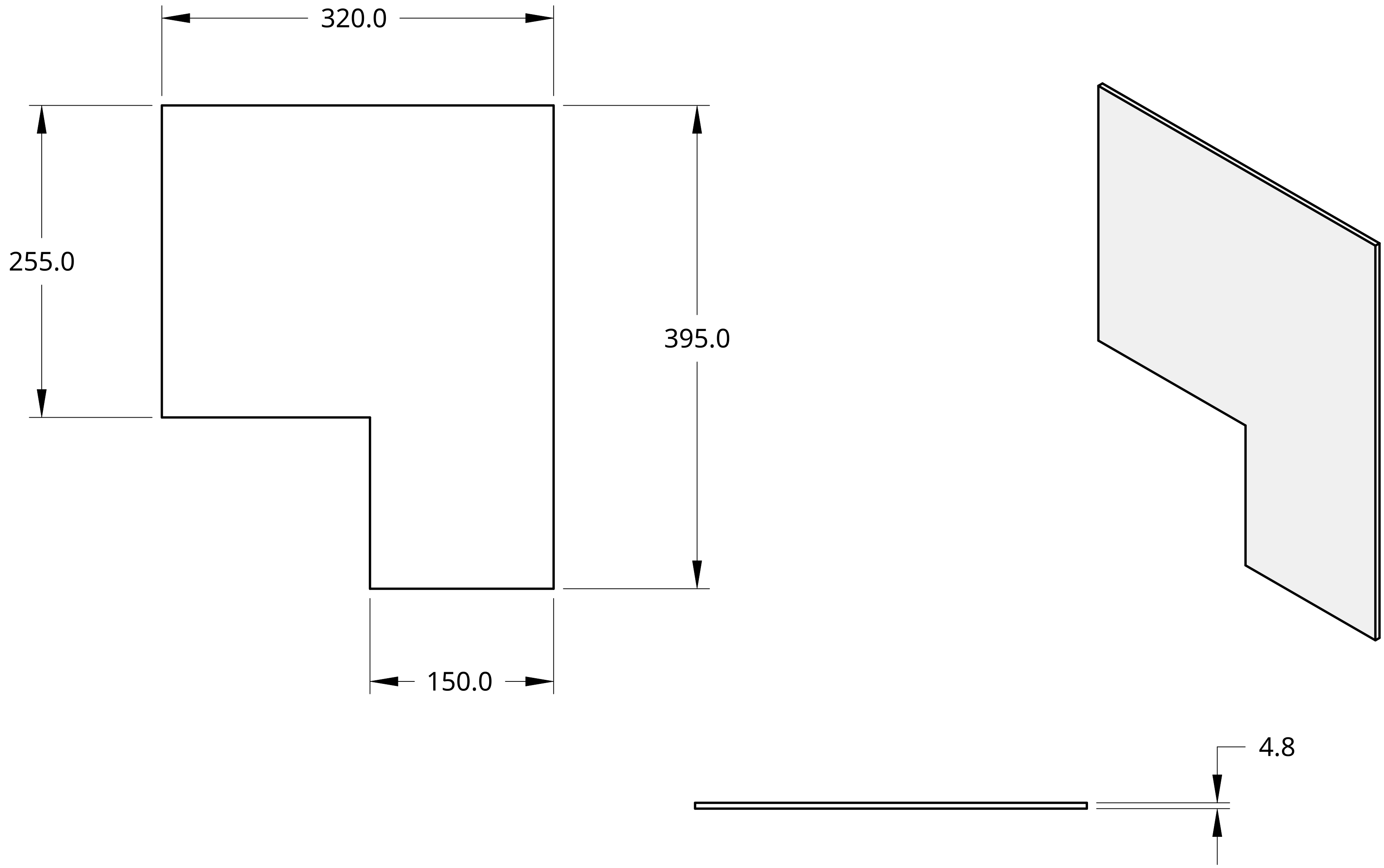
SIZE	DWG NO.	REV.
A	030	02

SCALE	WEIGHT	SHEET
1:5		1 of 1

2 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES .XX = ±.0- .XXX = ±.00- .XXXX = ±.000- ANGULAR = ± ° FRACTIONAL = ± SURFACE FINISH		NAME	DATE	Onshape - PenPal #2
	DRAWN	JANA DIA	12/16/2025	TITLE
	CHECKED			Handle
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A · DWG NO. 013 · REV. 02
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH		SCALE 1:1.5 · WEIGHT · SHEET 1 of 1



UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES
.XX = ±.0-
.XXX = ±.00-
.XXXX = ±.000-
ANGULAR = ± °
FRACTIONAL = ±
SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

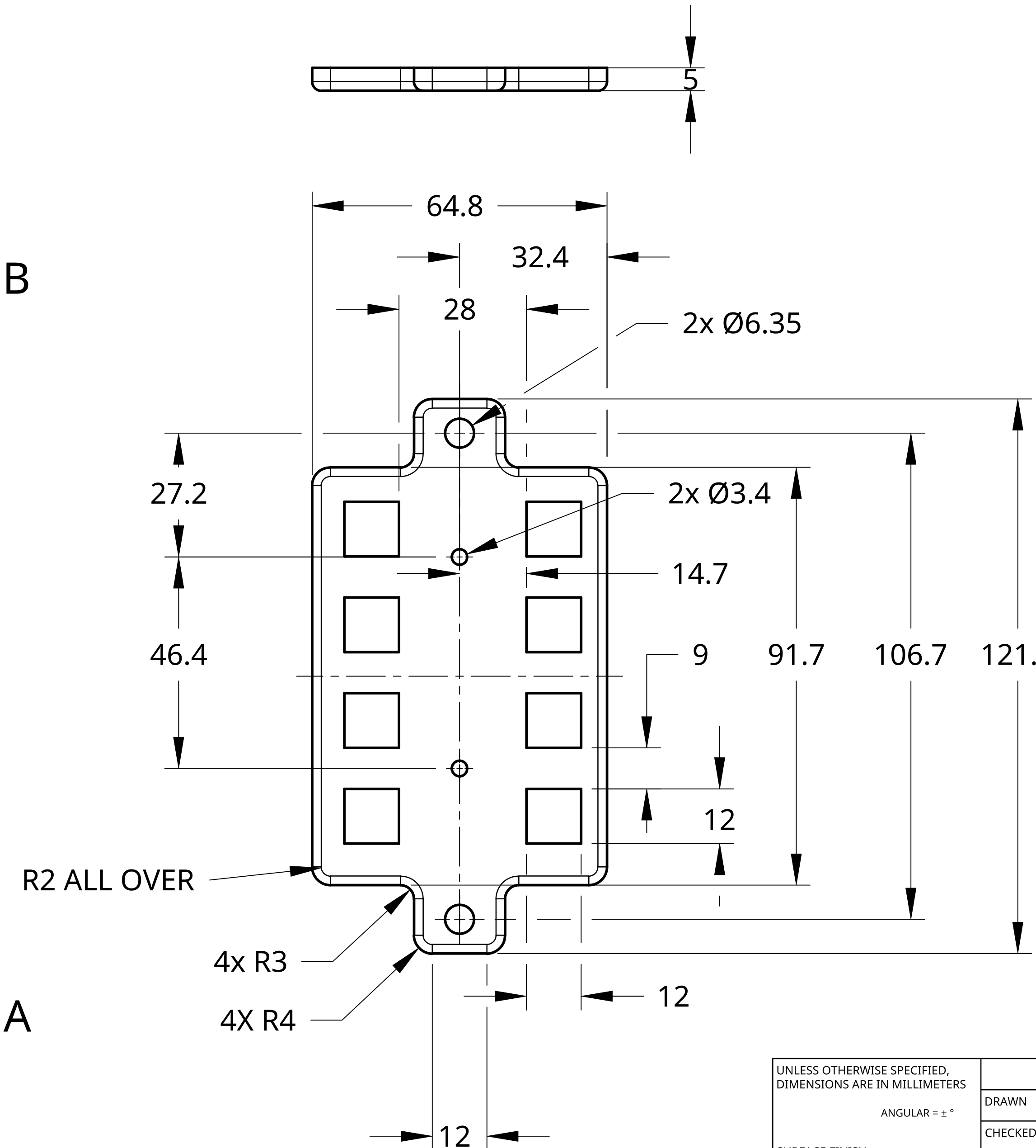
	NAME	DATE
DRAWN	JANA DIA	12/17/2025
CHECKED		
APPROVED		

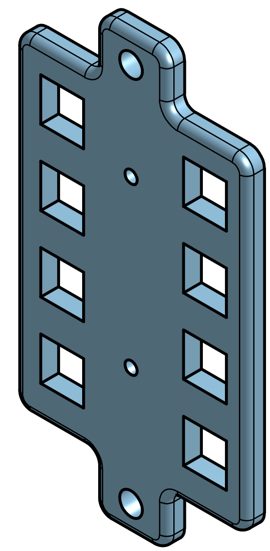
MATERIAL: Acrylic
FINISH:

Onshape - PenPal #2

TITLE: Front Panel

SIZE: A
DWG NO.: 012
REV.: 02
SCALE: 1:5
WEIGHT:
SHEET: 1 of 1





UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS
ANGULAR = ± °
SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/16/2025
CHECKED		
APPROVED		

MATERIAL: PLA

FINISH:

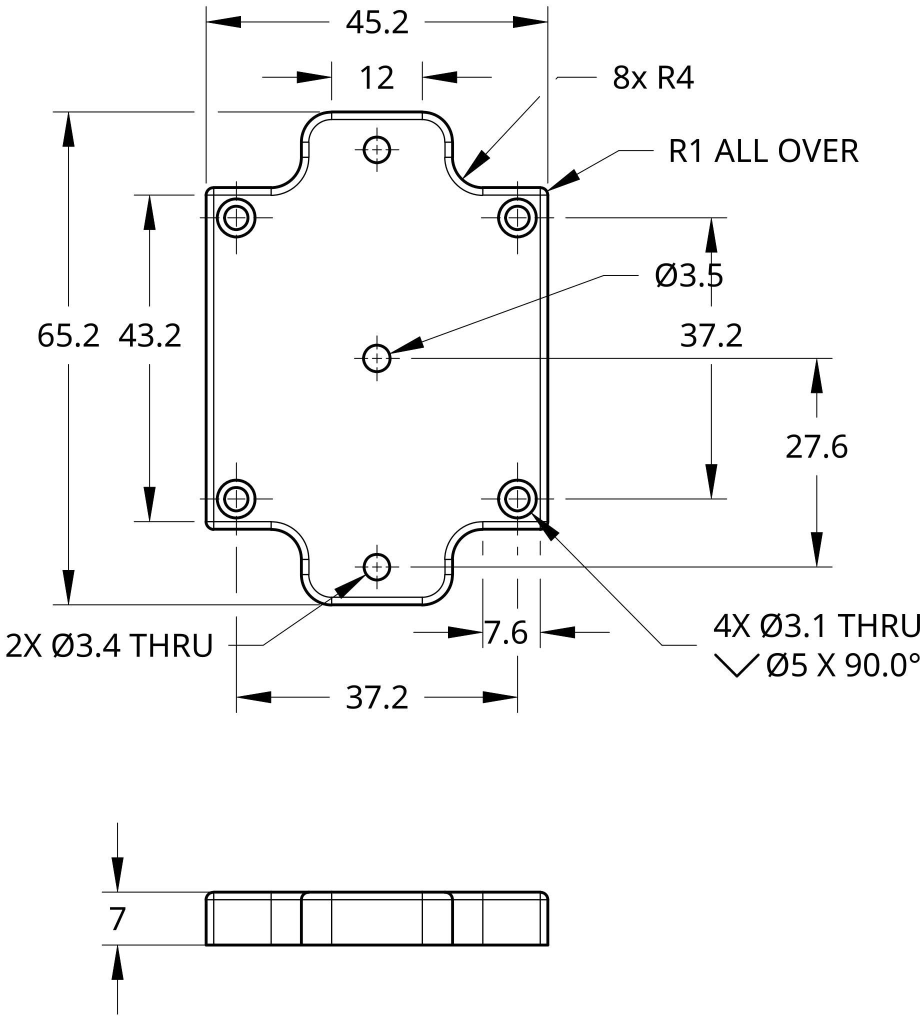
Onshape - PenPal #2

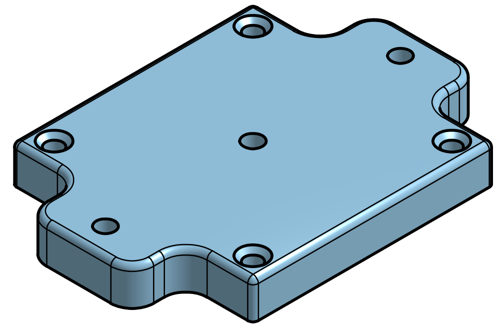
TITLE: Pi Mount

SIZE: A | DWG NO.: 007 | REV.: 02

SCALE: 1:1.5 | WEIGHT: | SHEET: 1 of 1

B



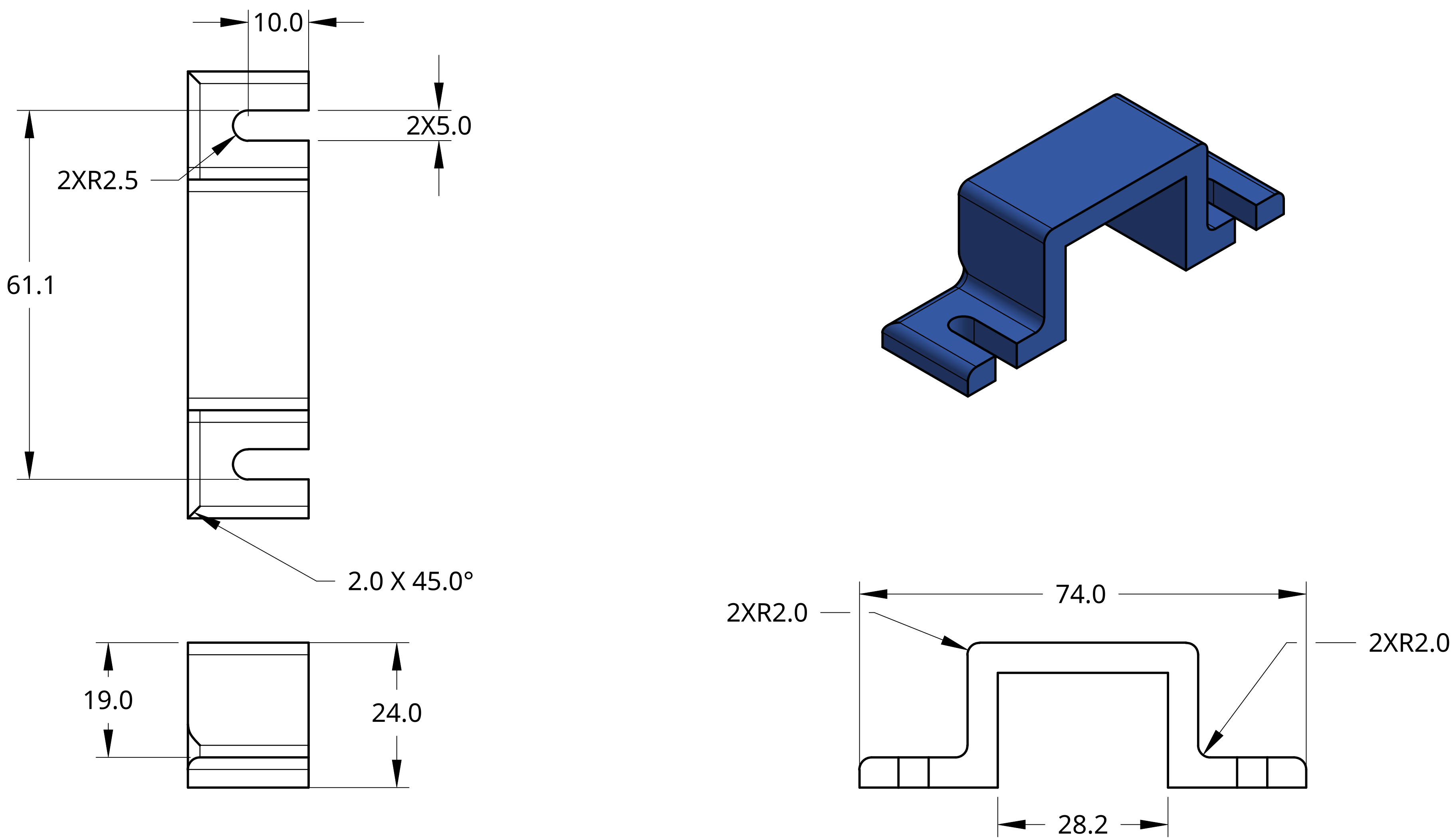


B

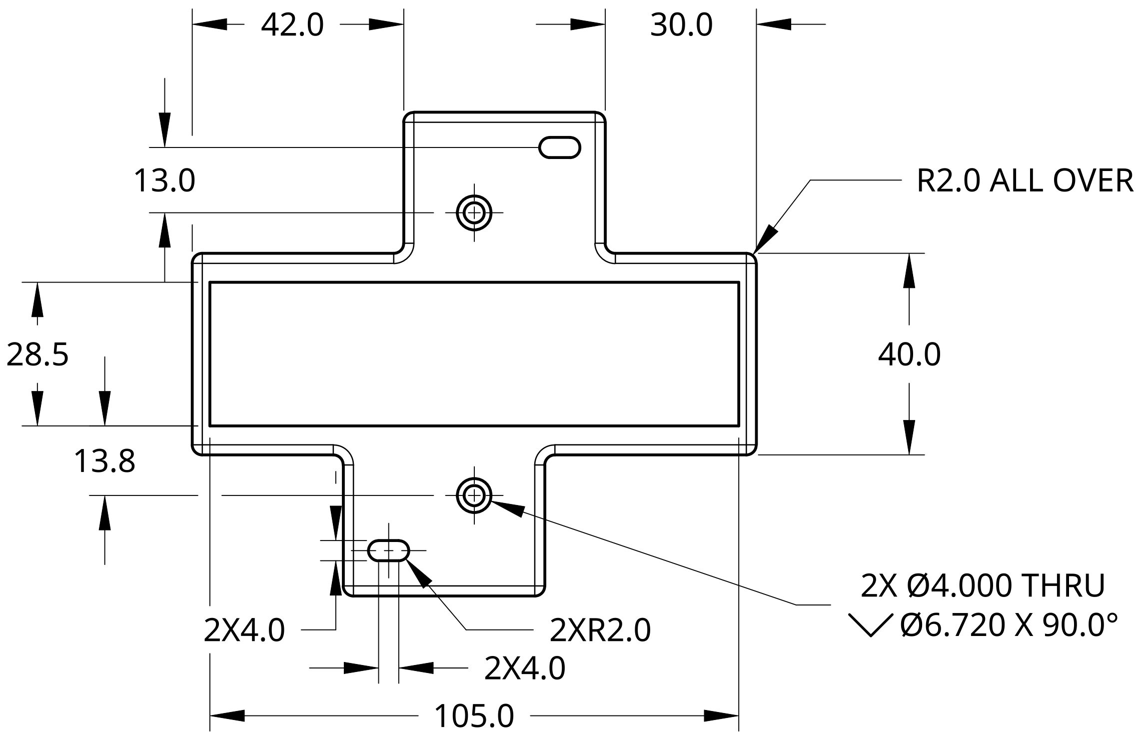
A

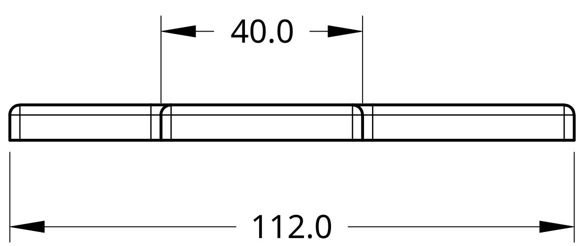
A

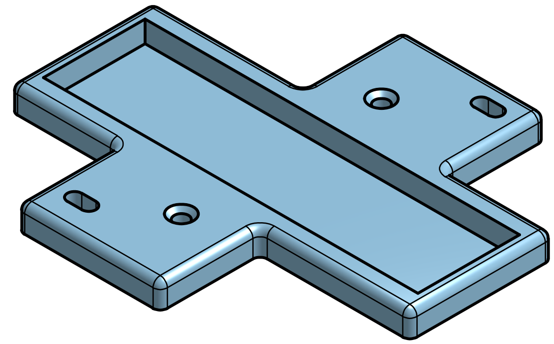
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE	Onshape - PenPal #2
	DRAWN	KARIM AL-HAFFAR	12/16/2025	TITLE H-Brige Mount
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A · DWG NO. 002 · REV. 02
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH		SCALE 1:1 · WEIGHT · SHEET 1 of 1



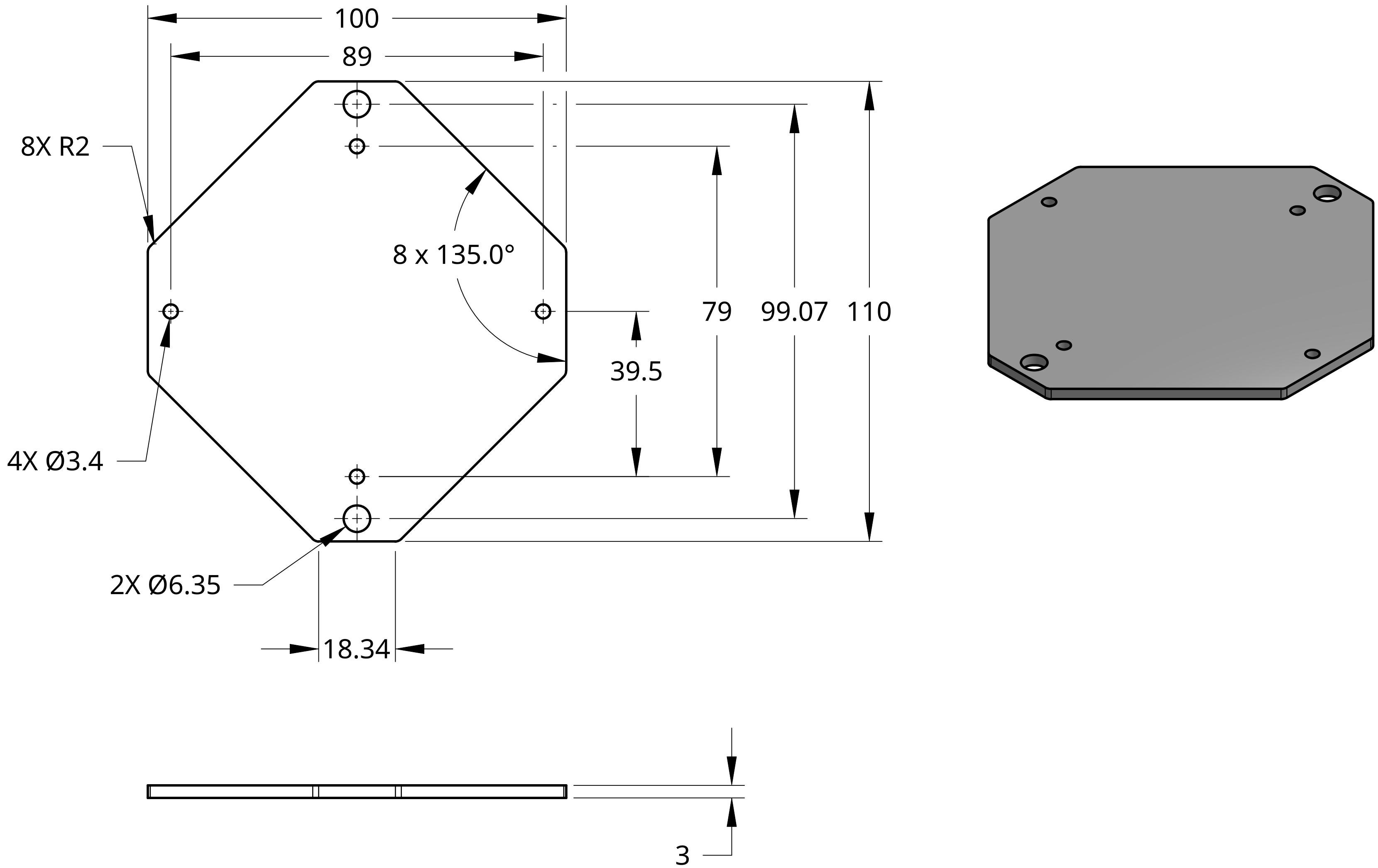
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES .XX = ±.0- .XXX = ±.00- .XXXX = ±.000- ANGULAR = ± ° FRACTIONAL = ± SURFACE FINISH		NAME	DATE	Onshape - PenPal #2
	DRAWN	JANA DIA	12/16/2025	TITLE Pi Battery Holder Top
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A · DWG NO. 011 · REV. 02
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH		SCALE 1:1 · WEIGHT · SHEET 1 of 1







UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES .XX = ±.0- .XXX = ±.00- .XXXX = ±.000- ANGULAR = ± ° FRACTIONAL = ± SURFACE FINISH		NAME	DATE	Onshape - PenPal #2
	DRAWN	JANA DIA	12/16/2025	TITLE Pi Battery Holder Base
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A · DWG NO. 010 · REV. 02
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH		SCALE 1:1.5 · WEIGHT · SHEET 1 of 1



UNLESS OTHERWISE SPECIFIED,
DIMENSIONS ARE IN MILLIMETERS

ANGULAR = ± °

SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/16/2025
CHECKED		
APPROVED		

MATERIAL: PLA

FINISH:

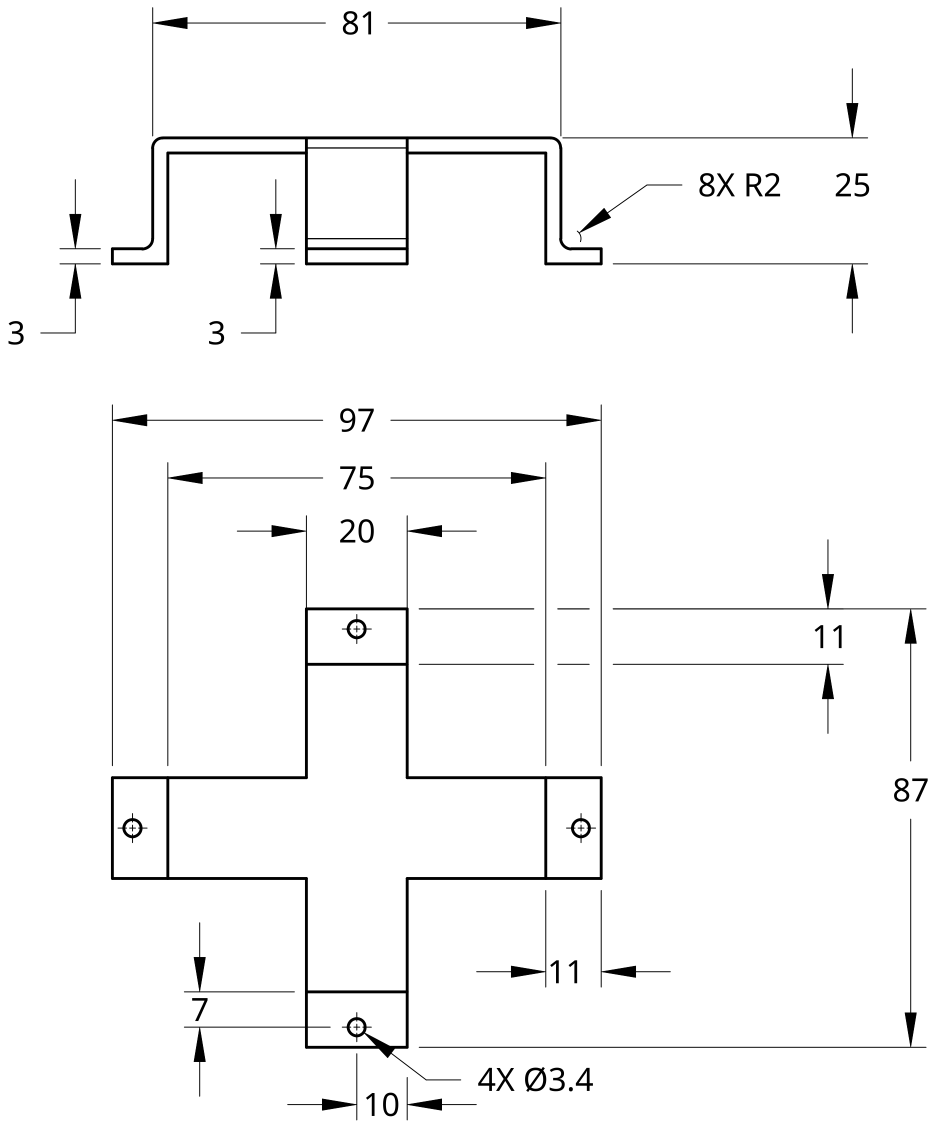
Onshape - PenPal #2

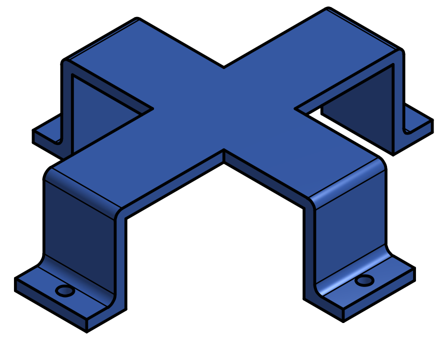
TITLE

12 Batterry Mount - Base

SIZE	DWG NO.	REV.
A	005	02

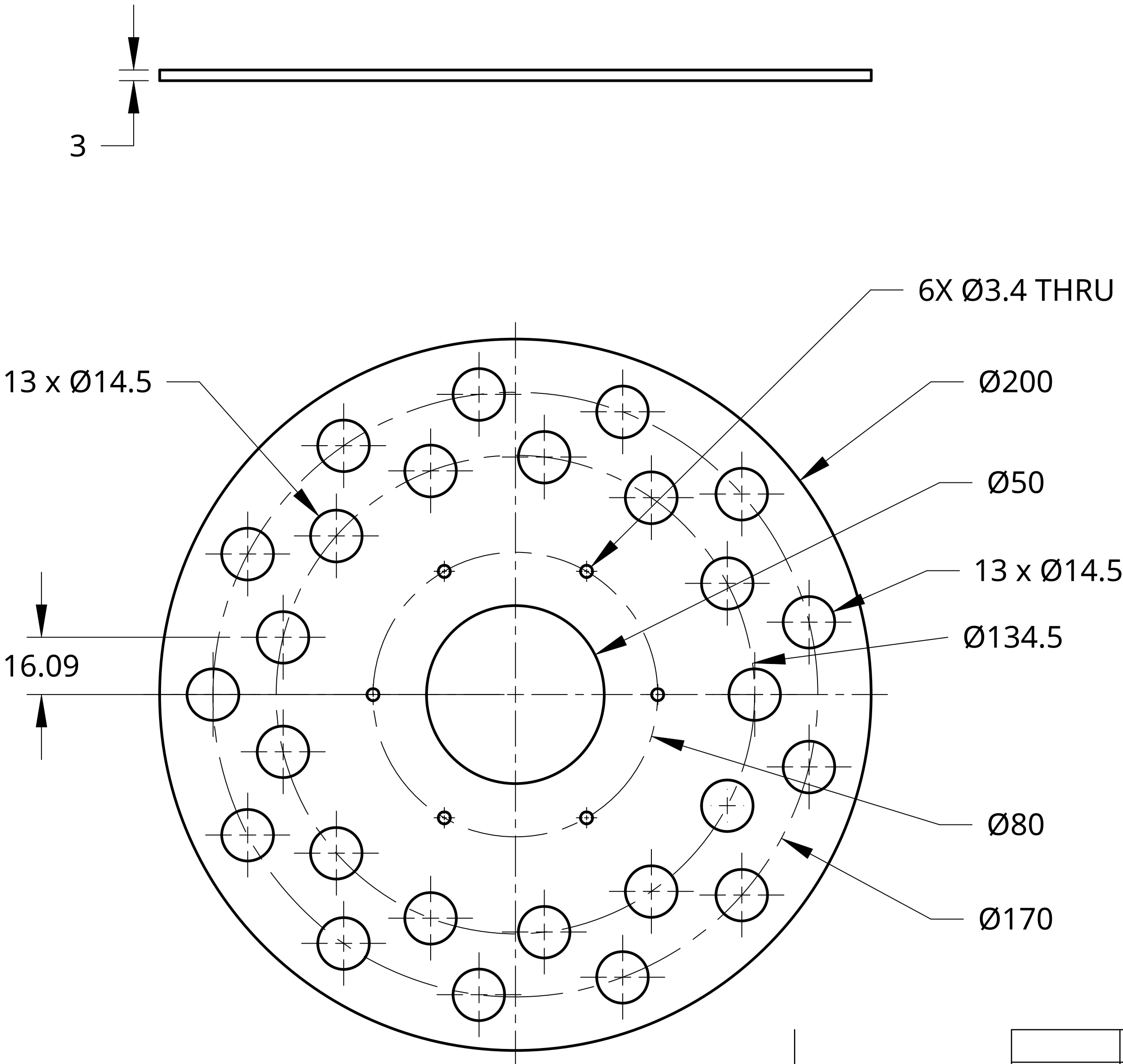
SCALE	WEIGHT	SHEET
1:1.5		1 of 1

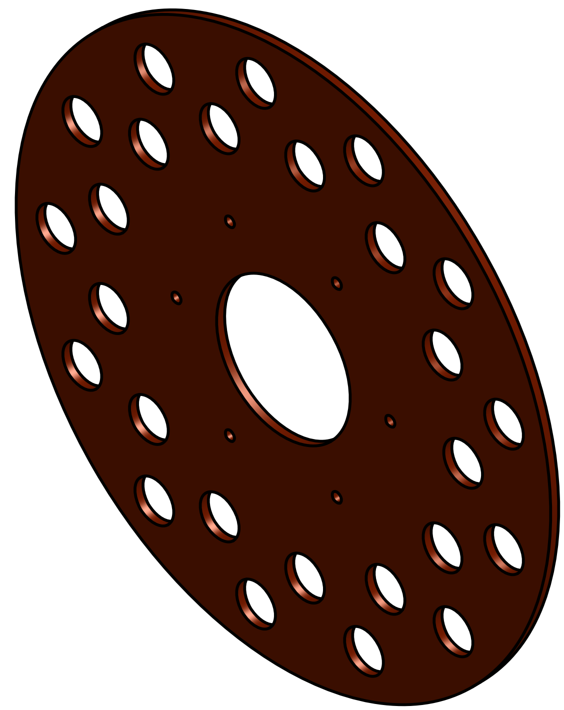




UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE
	DRAWN	KARIM AL-HAFFAR	12/16/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH	

Onshape - PenPal #2			
TITLE 12 Batterry Mount - Top			
SIZE A	DWG NO. 006		REV. 02
SCALE 1:1.5	WEIGHT	SHEET 1 of 1	





ANGULAR = ± °

SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/17/2025
CHECKED		
APPROVED		

MATERIAL: Acrylic

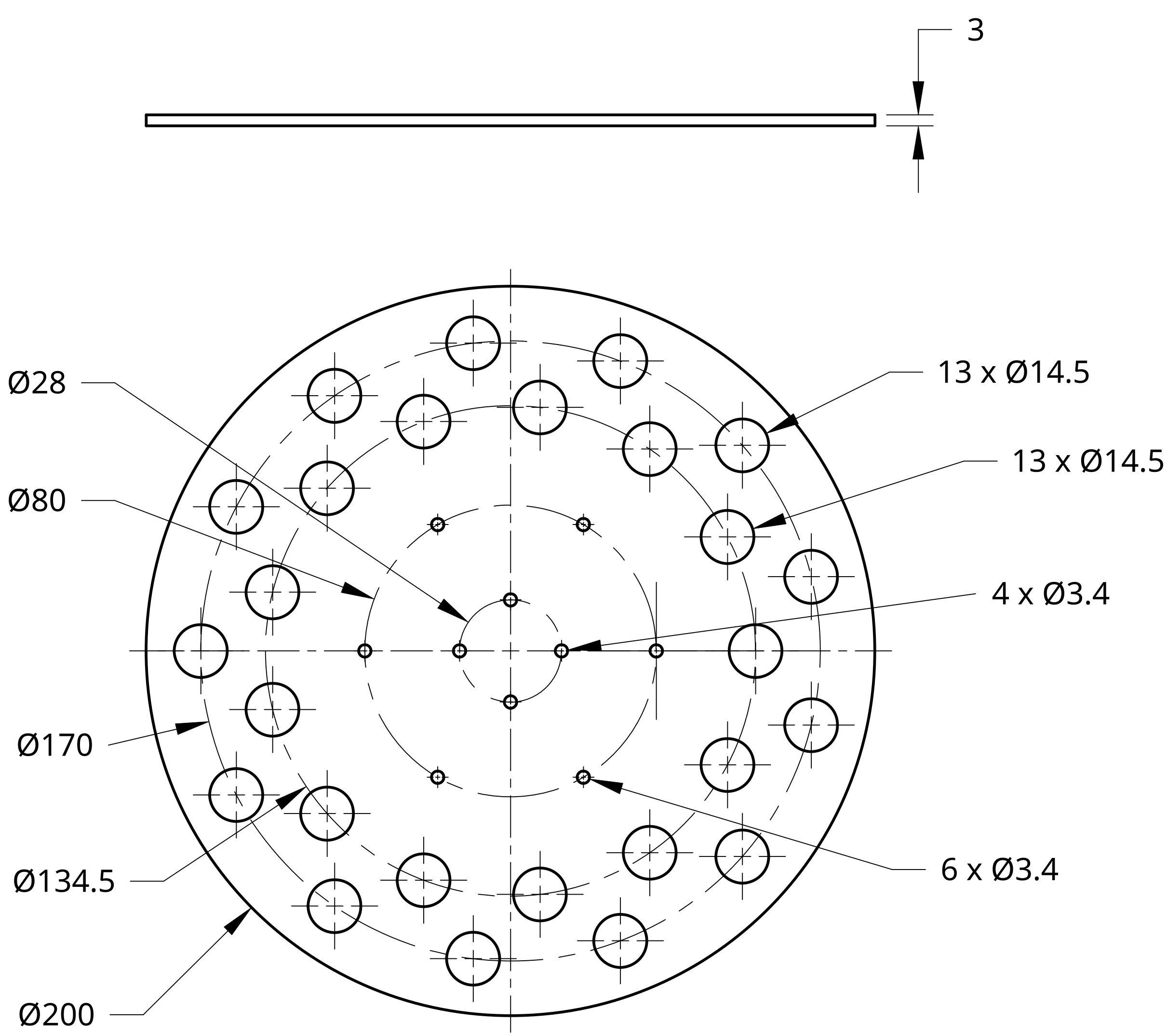
FINISH:

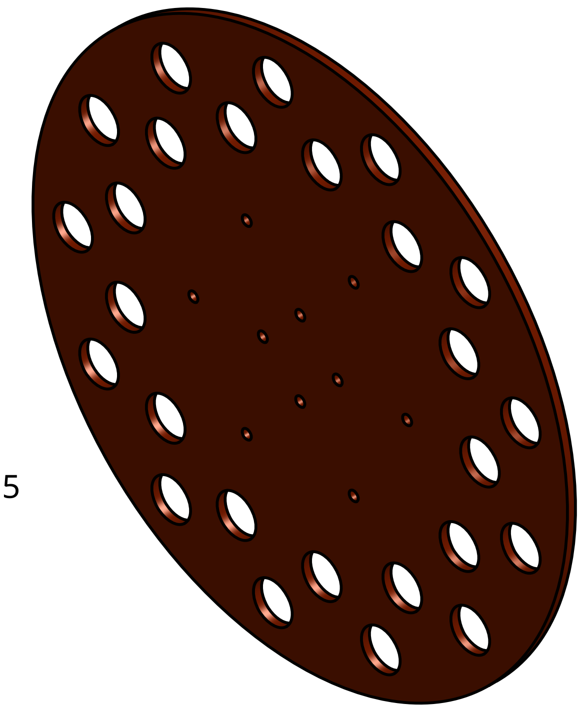
Onshape - PenPal #2

TITLE: Pen Allignment Disk

SIZE	DWG NO.	REV.
A	017	02

SCALE	WEIGHT	SHEET
1:2		1 of 1





ANGULAR = ± °

SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/18/2025
CHECKED		
APPROVED		

MATERIAL: Acrylic

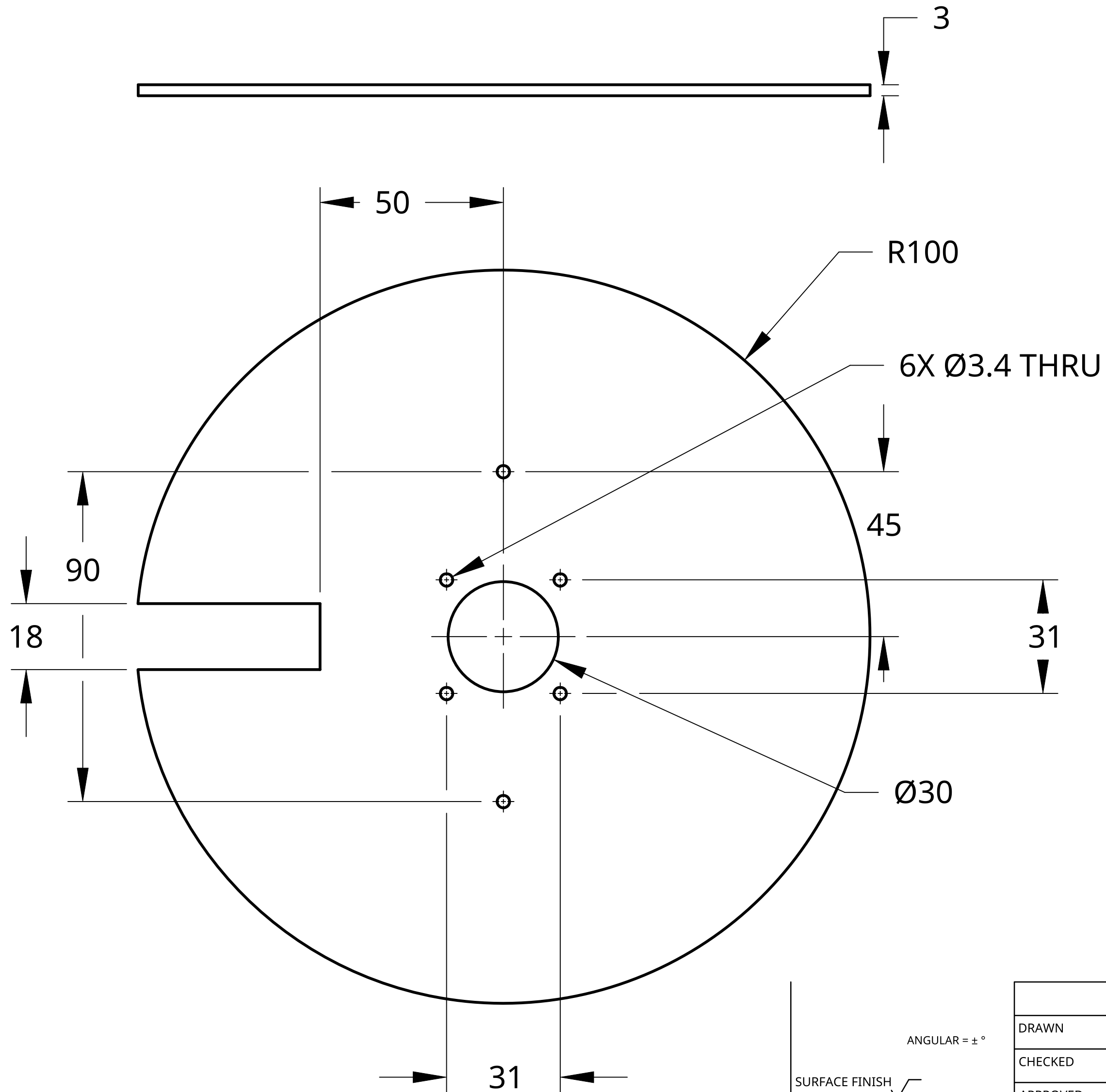
FINISH:

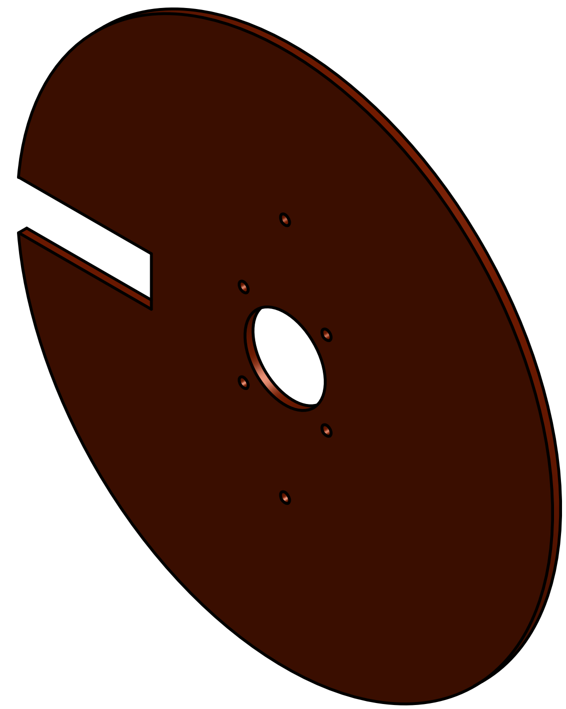
Onshape - PenPal #2

TITLE: Coupling Interface Plate

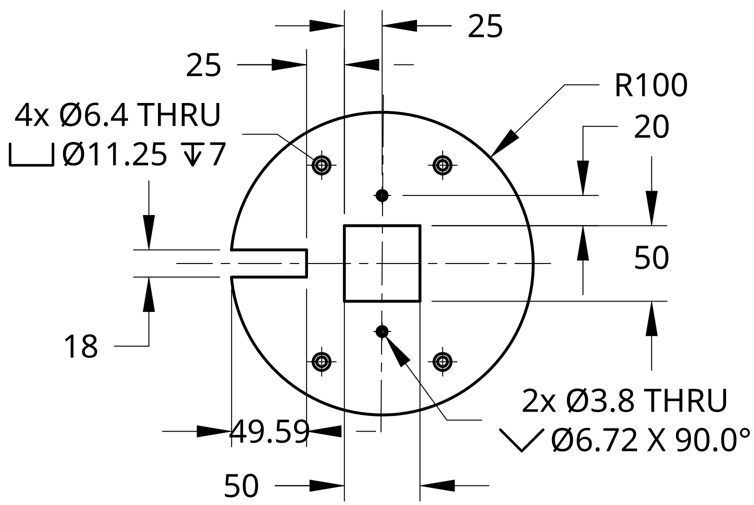
SIZE	DWG NO.	REV.
A	037	02

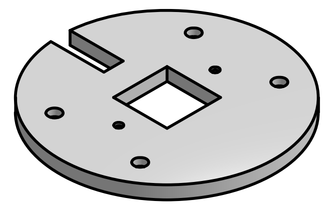
SCALE	WEIGHT	SHEET
1:2		1 of 1

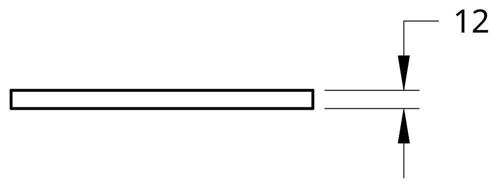




ANGULAR = ± °		NAME	DATE	Onshape - PenPal #2
SURFACE FINISH	DRAWN	KARIM AL-HAFFAR	12/17/2025	TITLE: Motor Mounting Plate
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				SIZE: A
BREAK ALL SHARP EDGES AND REMOVE BURRS				DWG NO.: 018
THIRD ANGLE PROJECTION	MATERIAL: Acrylic	FINISH		REV.: 02
				SCALE: 1:2
				WEIGHT
				SHEET: 1 of 1



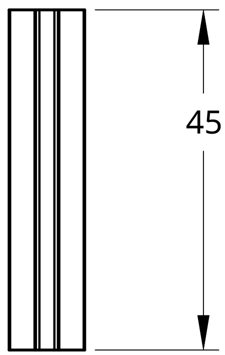


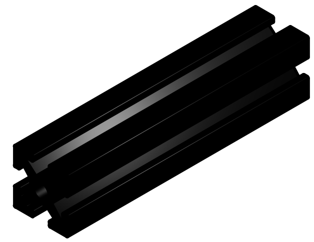


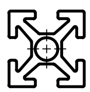
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE	Onshape - PenPal #2	
	DRAWN	KARIM AL-HAFFAR	11/03/2025	TITLE	
	CHECKED			Base Mount Plate	
	APPROVED				
DO NOT SCALE DRAWING					
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A	DWG NO. 001 / REV. 02
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH		SCALE 1:5 / WEIGHT	SHEET 1 of 1

2 | 1

B

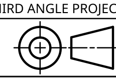






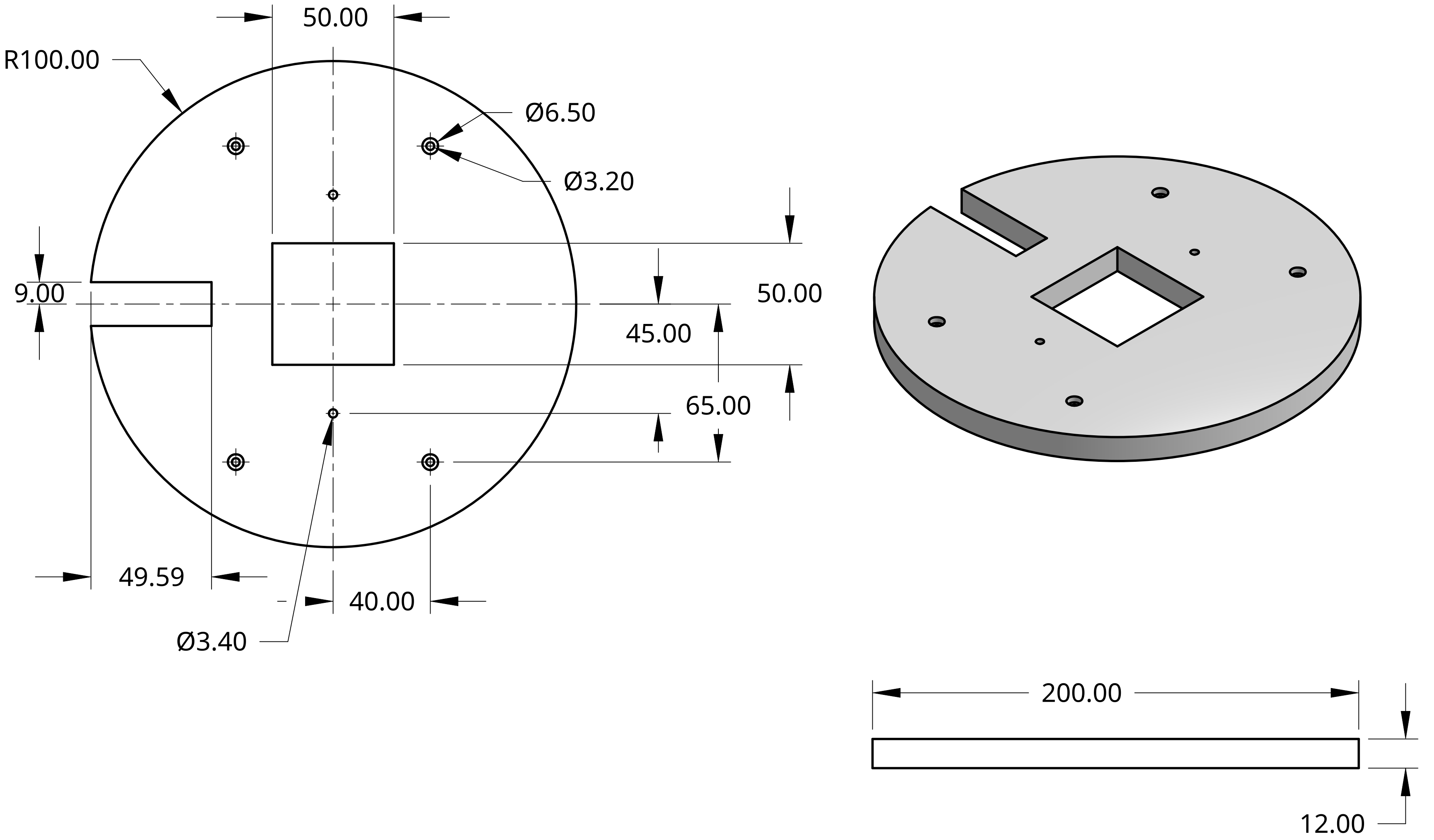
A

ANGULAR = ± °		NAME	DATE
SURFACE FINISH	DRAWN	KARIM AL-HAFFAR	12/17/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL: Aluminum	FINISH	



Onshape - PenPal #2			
TITLE: MakerBeams			
SIZE: A	DWG NO.: 016		REV.: 02
SCALE: 1:1	WEIGHT	SHEET: 1 of 1	

2 | 1



UNLESS OTHERWISE SPECIFIED,
DIMENSIONS ARE IN INCHES
.XX = ±.0-
.XXX = ±.00-
.XXXX = ±.000-
ANGULAR = ± °
FRACTIONAL = ±
SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	HALEY LEIMBACH	11/03/2025
CHECKED		
APPROVED		

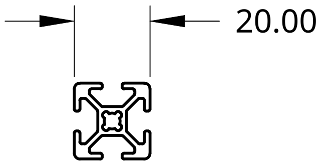
MATERIAL: PLA

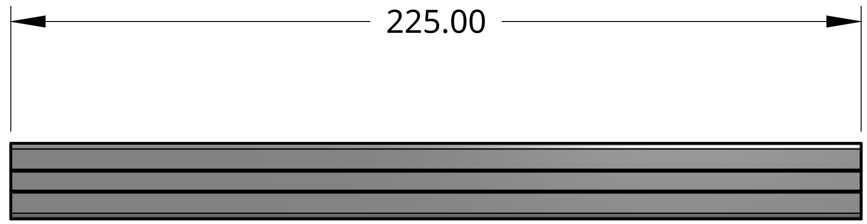
FINISH:

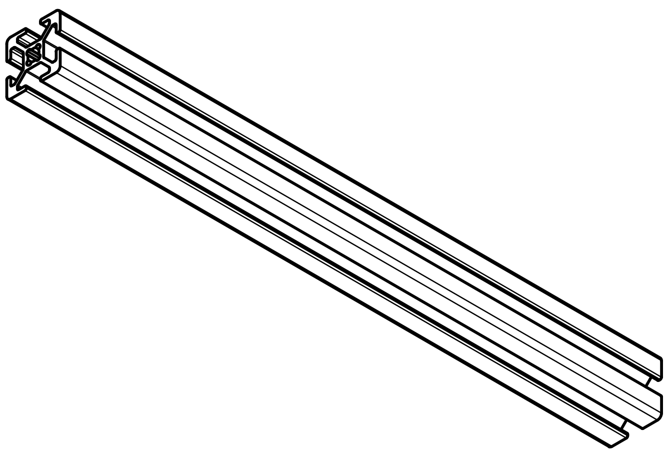
TITLE: Base Mounting Plate

SIZE: A | DWG NO.: | REV.: A

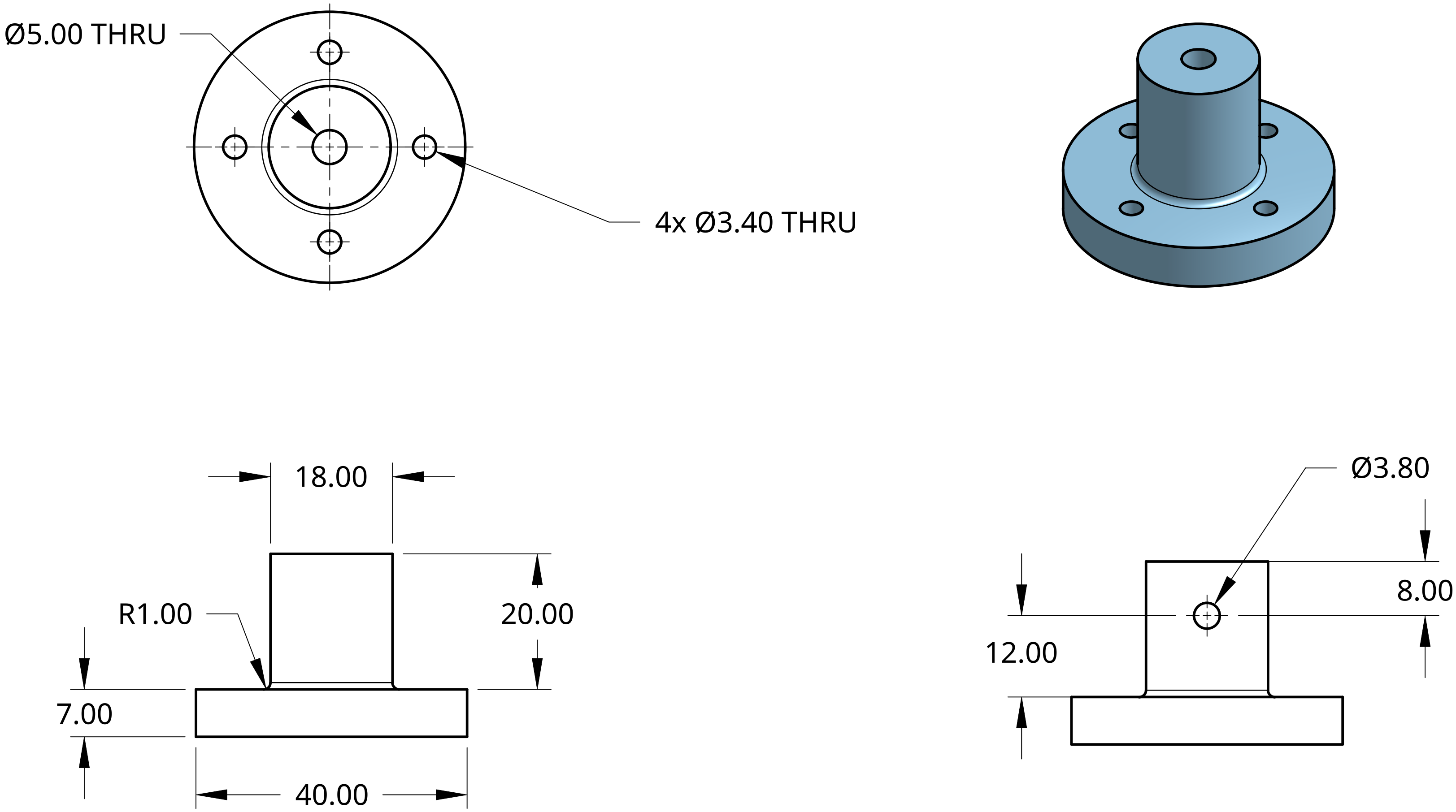
SCALE: 1:2.5 | WEIGHT: | SHEET: 1 of 1







UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN INCHES .XX = ±.0- .XXX = ±.00- .XXXX = ±.000- ANGULAR = ± ° FRACTIONAL = ± SURFACE FINISH		NAME	DATE	Onshape Penpal - #2
	DRAWN	HALEY LEIMBACH	11/03/2025	TITLE 2020 Base Leg
	CHECKED			
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A — DWG NO. 22 — REV. B
THIRD ANGLE PROJECTION	MATERIAL Aluminum	FINISH		SCALE 1:2 — WEIGHT — SHEET 1 of 1



UNLESS OTHERWISE SPECIFIED,
DIMENSIONS ARE IN INCHES
.XX = ±.0-
.XXX = ±.00-
.XXXX = ±.000-
ANGULAR = ± °
FRACTIONAL = ±
SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	JANA DIA	11/03/2025
CHECKED		
APPROVED		

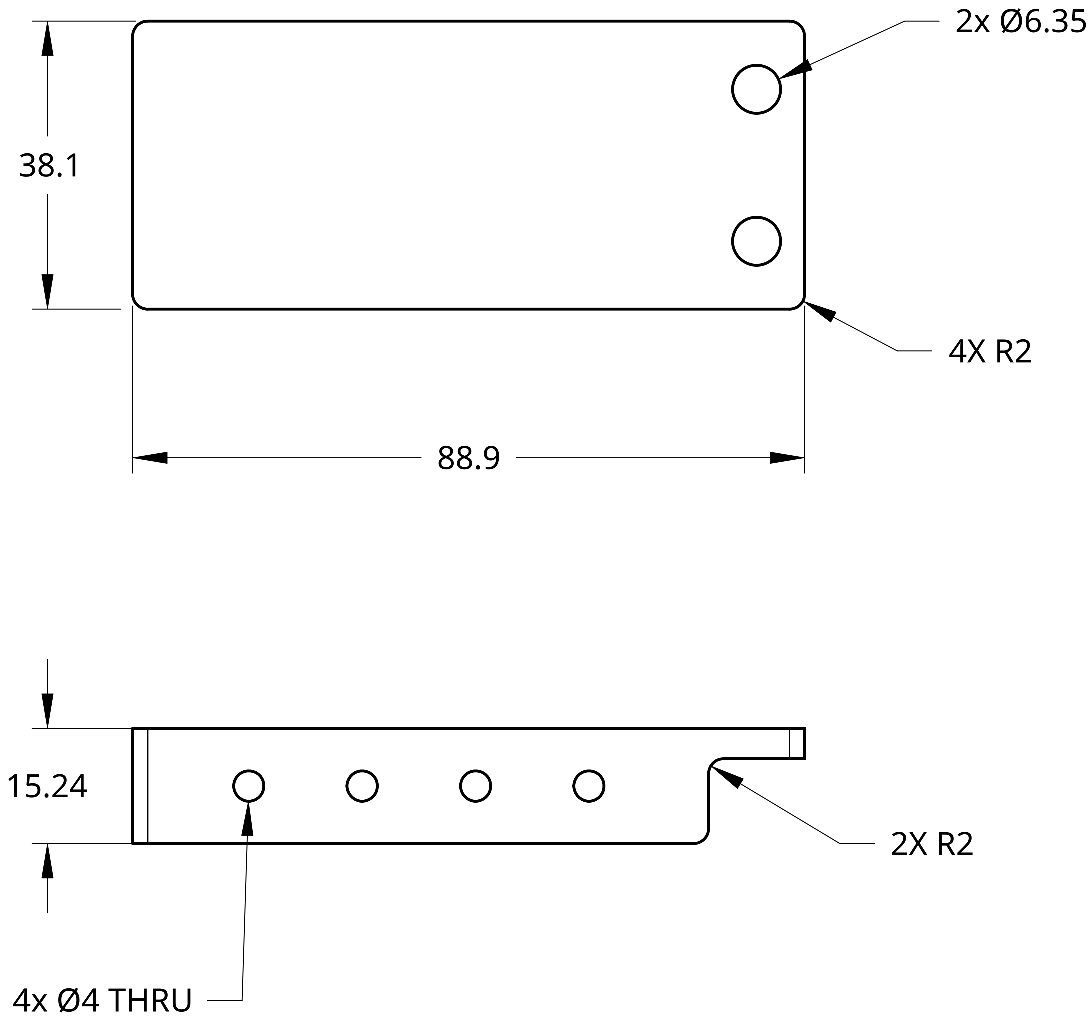
MATERIAL: Aluminum

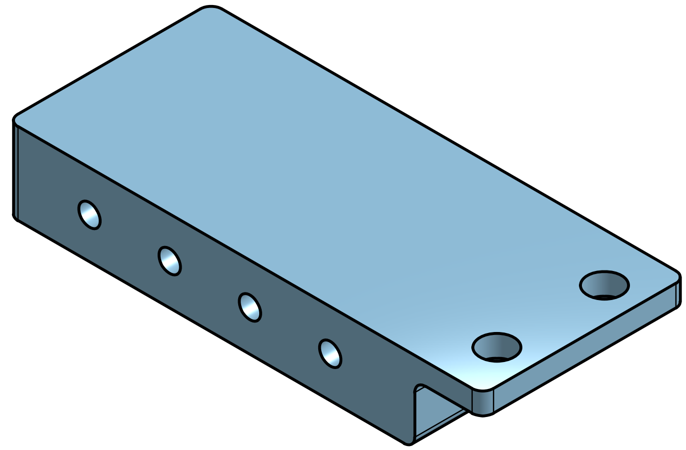
FINISH:

TITLE: Flange Coupling

SIZE	DWG NO.	REV.
A	040	B

SCALE	WEIGHT	SHEET
2:2		1 of 1





	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/17/2025
CHECKED		
APPROVED		

ANGULAR = ± °

SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

MATERIAL	FINISH
PLA	

Onshape - PenPal #2

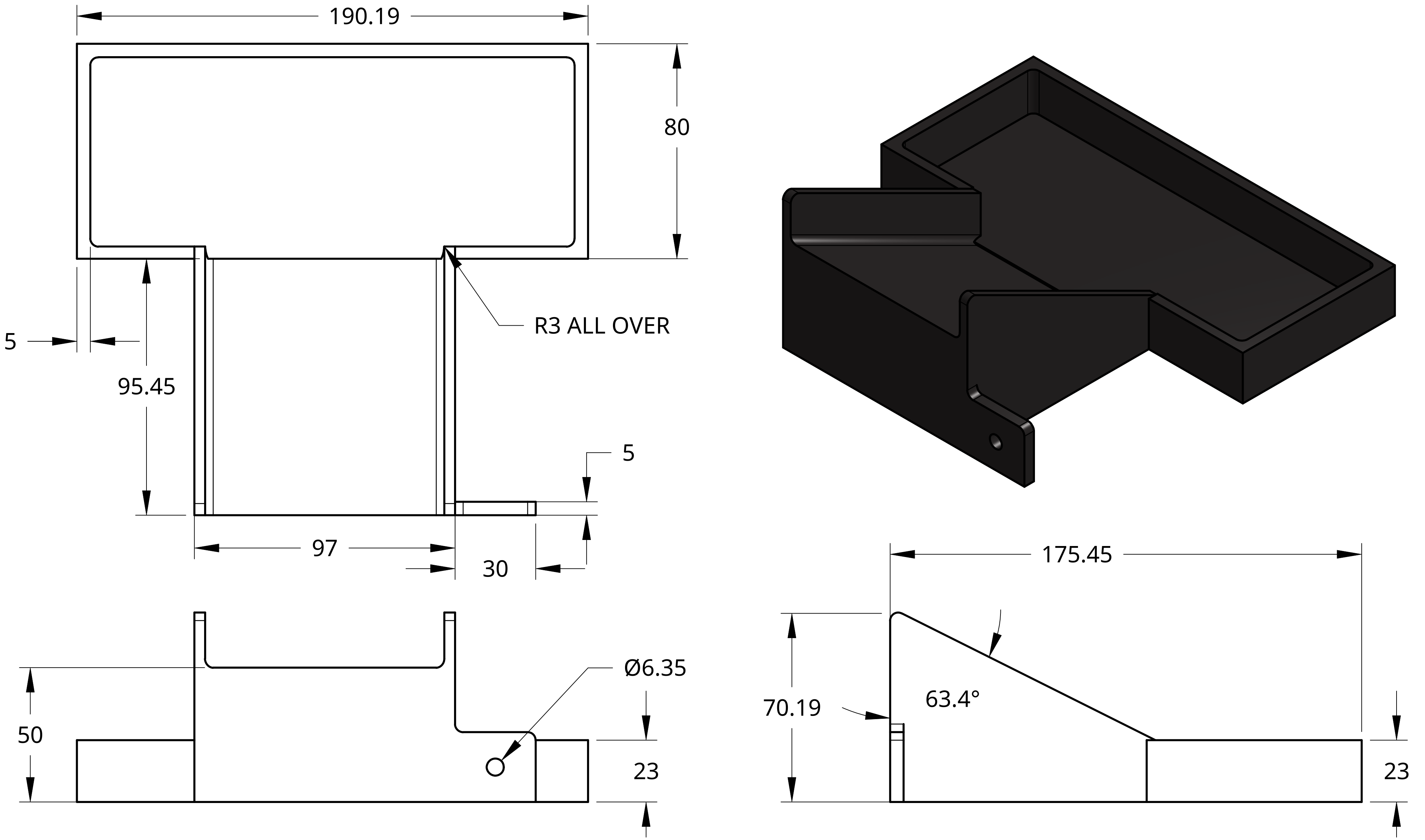
TITLE

Allen Key Holder

SIZE	DWG NO.	REV.
A	015	02

SCALE	WEIGHT	SHEET
1:1		1 of 1

2 1



B
A

UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE
	DRAWN	KARIM AL-HAFFAR	12/16/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH	

Onshape - PenPal #2

TITLE

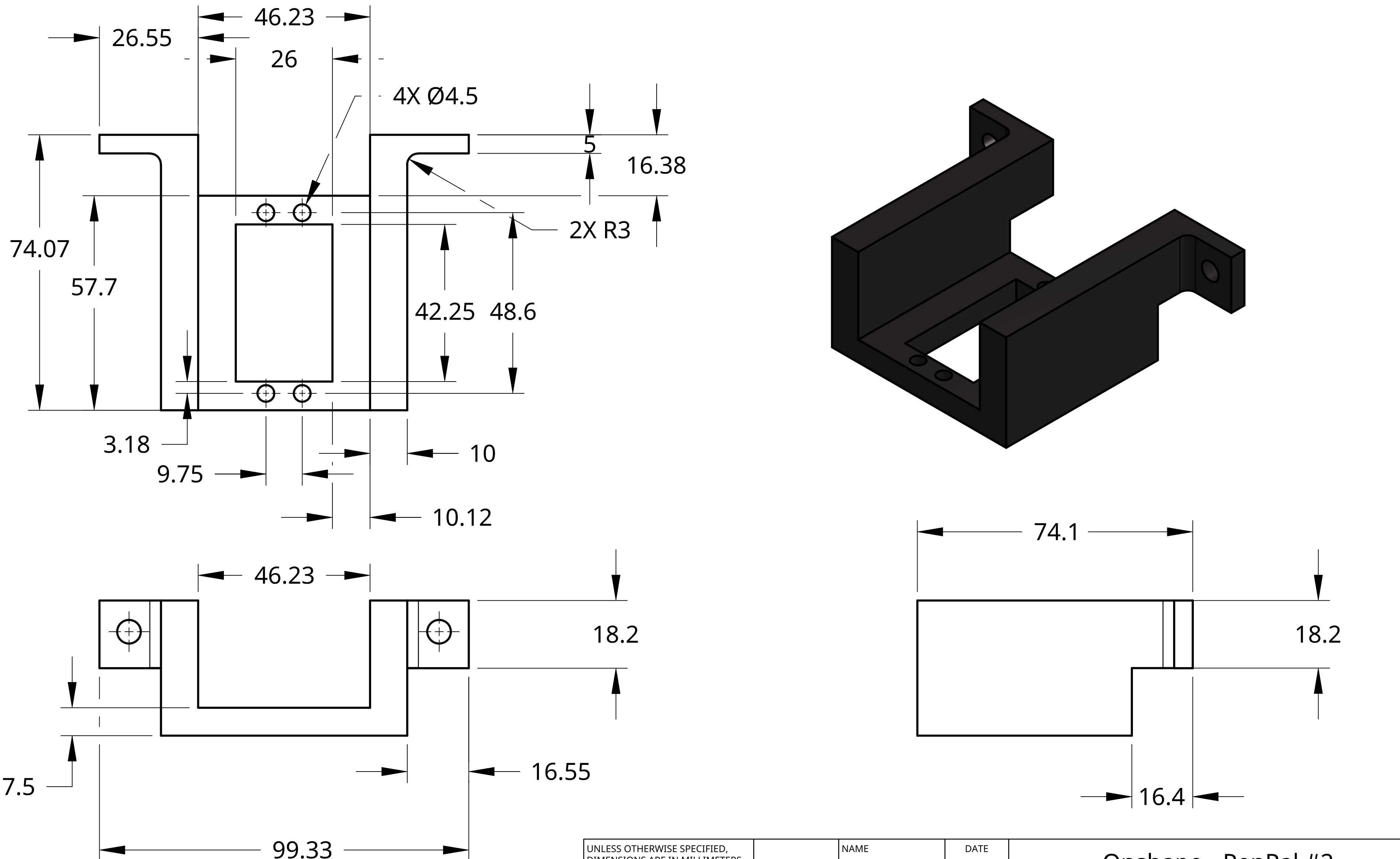
Slide

SIZE	DWG NO.	REV.
A	014	02

SCALE	WEIGHT	SHEET
1:2		1 of 1

2 1

2 | 1

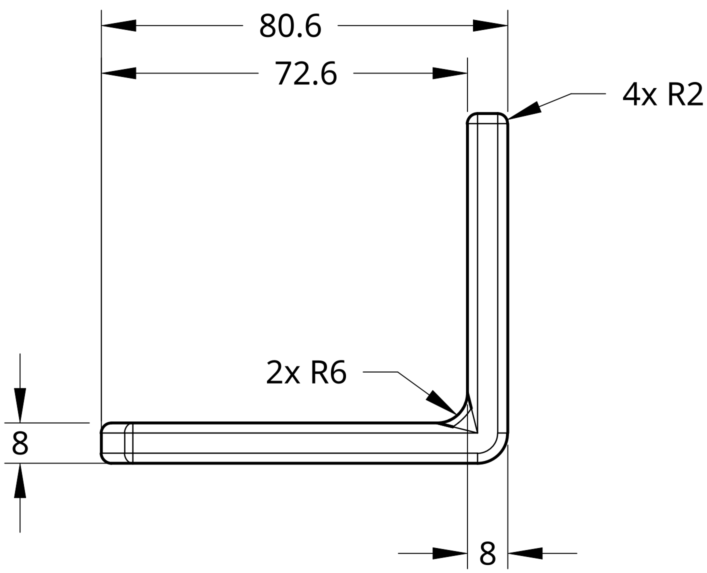


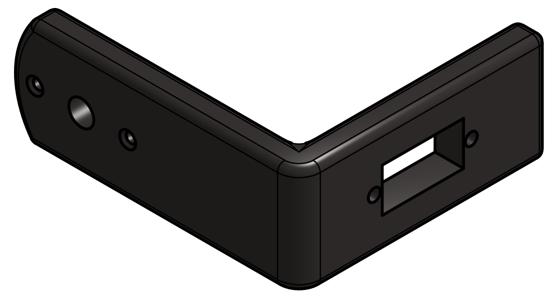
B

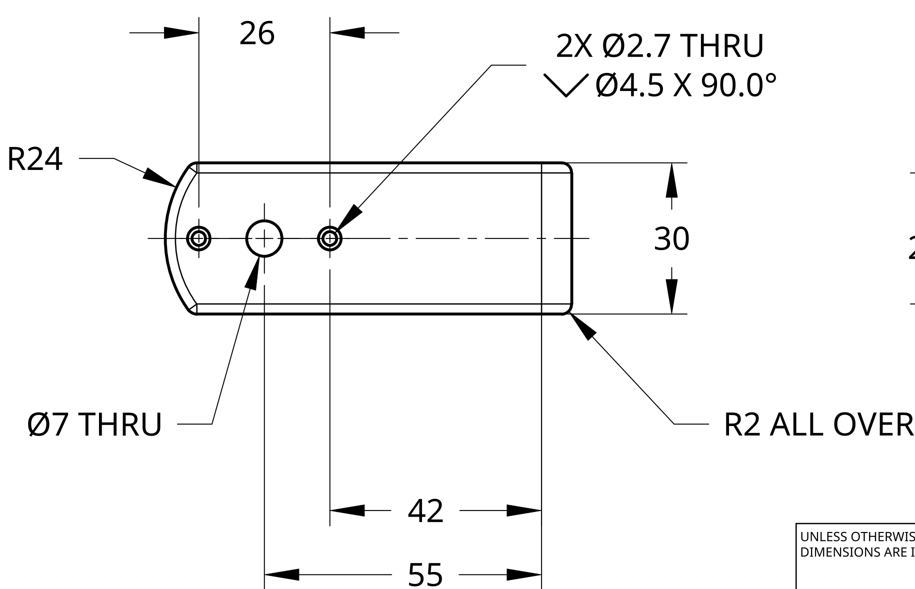
A | A

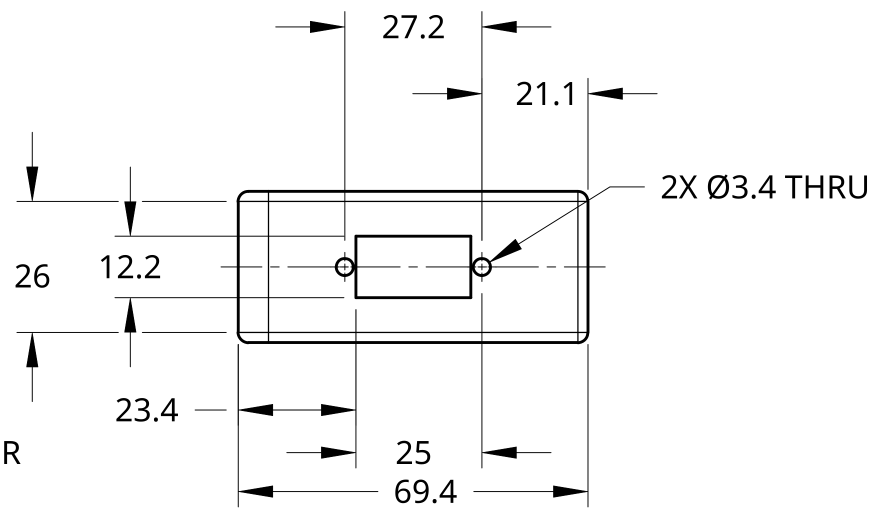
UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE	Onshape - PenPal #2
	DRAWN	KARIM AL-HAFFAR	12/17/2025	
	CHECKED			TITLE Servo Mount
	APPROVED			
DO NOT SCALE DRAWING				
BREAK ALL SHARP EDGES AND REMOVE BURRS				SIZE A — DWG NO. 010 — REV. 02
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH		SCALE 1:1.5 — WEIGHT — SHEET 1 of 1

2 | 1









UNLESS OTHERWISE SPECIFIED, DIMENSIONS ARE IN MILLIMETERS ANGULAR = ± ° SURFACE FINISH		NAME	DATE
	DRAWN	KARIM AL-HAFFAR	12/16/2025
	CHECKED		
	APPROVED		
DO NOT SCALE DRAWING			
BREAK ALL SHARP EDGES AND REMOVE BURRS			
THIRD ANGLE PROJECTION	MATERIAL PLA	FINISH	

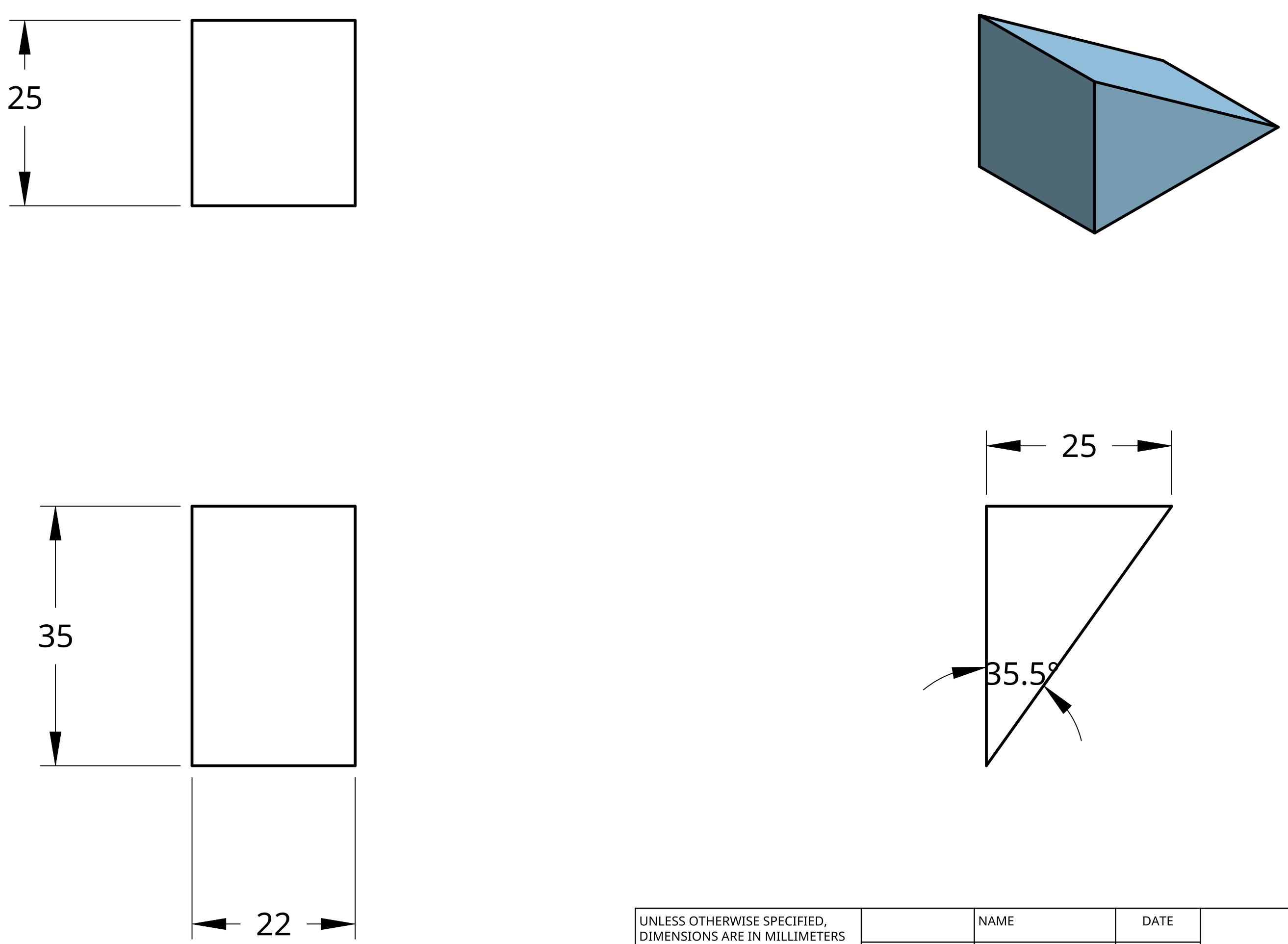
Onshape - PenPal #2

TITLE

Robotic Arm - Linkage

SIZE	DWG NO.	REV.
A	009	02

SCALE	WEIGHT	SHEET
1:1.5		1 of 1



UNLESS OTHERWISE SPECIFIED,
DIMENSIONS ARE IN MILLIMETERS

ANGULAR = ± °

SURFACE FINISH

DO NOT SCALE DRAWING

BREAK ALL SHARP EDGES AND REMOVE BURRS

THIRD ANGLE PROJECTION

	NAME	DATE
DRAWN	KARIM AL-HAFFAR	12/16/2025
CHECKED		
APPROVED		

MATERIAL	FINISH
PLA	

Onshape - PenPal #2

TITLE

Pen Angle

SIZE	DWG NO.	REV.
A	008	02

SCALE	WEIGHT	SHEET
1:1		1 of 1