

THE LIGHTWEIGHT STAIRCASE LIFT

ME 102B Fall 2020 Final Project

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PROJECT DESCRIPTION

Taking into account topics on flexible transmission and linkages, for the final ME 102B project I decided to pursue designing a system that would help bring objects up and down stairs. I often run into situations in which I'm juggling several things while walking down the stairs, and have on more than one occasion tripped, dropping and spilling everything. In addition, I know that my grandparents are starting to sometimes have more trouble getting up and down the stairs, and it would potentially make things easier if they didn't also have to worry about carrying things at the same time. The following system is what I was able to come up with. It is comprised primarily of lightweight aluminum and acrylic, and is not intended to carry very heavy loads. Sliding is accomplished through an interaction between steel and Teflon, which provides good, low-friction contact.

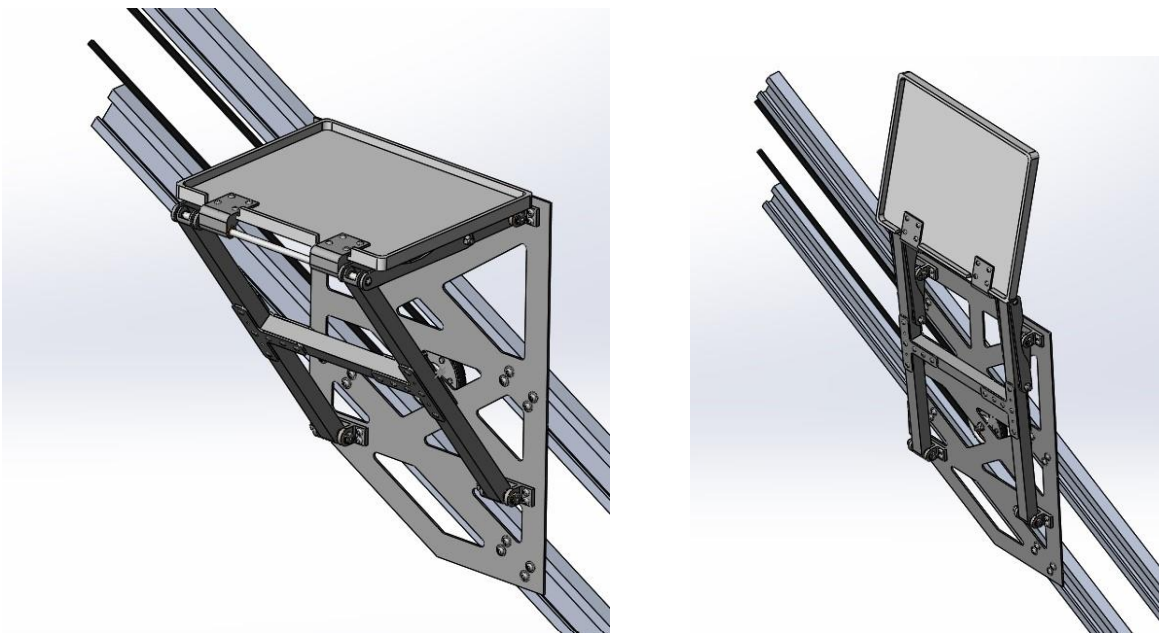


Figure 1: Expanded and folded configurations of the lift design

In addition to traveling up and down, it is desirable for the system to be able to be folded up when not in use, as to not impede the use of the stairway. To do this, a four-bar linkage was used, which allowed the system stability when expanded, but also allowed it to be easily moved and pushed aside. When designing this, both the length of the links, and the spacing between them was critical to consider to gain the appropriate range of motion, but also avoid interference. For the majority of the rotating joints sleeve bearings were used, rather than ball or roller bearings. This is because friction is not as much of a concern in these cases, as there is no continuous rotation, and the rotation in the arm is accomplished manually. Ball bearings are used however, in the pulley.

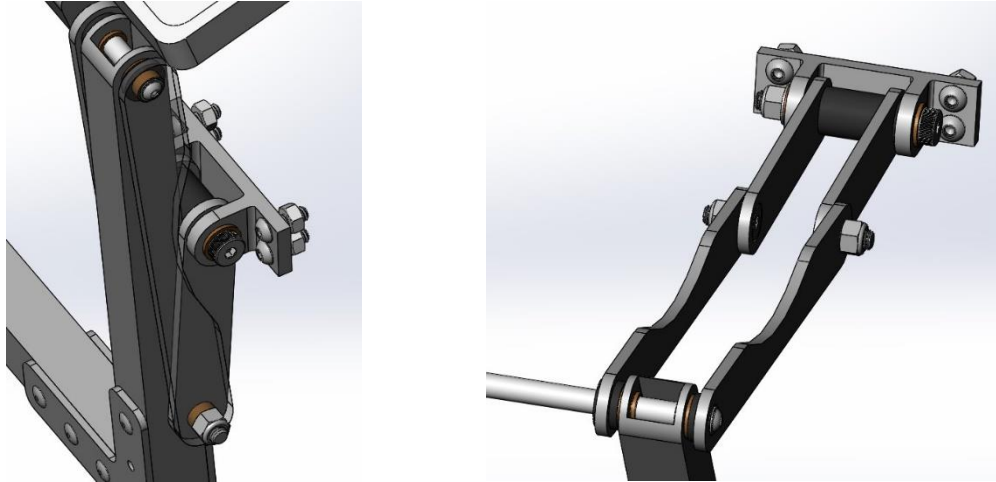


Figure 2: Close up images of the linkage mechanism that allowed for folding of the system. Outermost link in the folded (left) image is made transparent for clarity.

The power transmission portion of the system was not included within the scope of this project, though the pulley and cable are included in the model. A design that could be developed in the future would involve one end of the cable rigidly fixed, while the other is attached to a winch. Turning of the winch with an electric motor would increase or decrease the overall length of the cable, controlling the up and down motion of the lift. A braking mechanism to prevent backsliding would likely need to be included, such as a ratchet and pawl system, in which the pawl would be actuated to release the system when downward motion is desired. On the electronics side, an infrared sensor should be included within the railing, to be able to determine the location and speed of the lift, as well as limit switches to indicate when the system has reached the very top and very bottom. Buttons would be included on both the upper and lower floors to control the movement of the system.

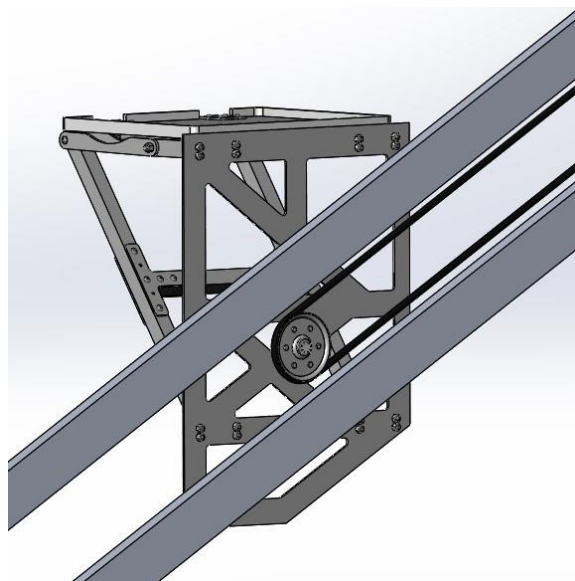


Figure 3: Pulley System

BILL OF MATERIALS

Component Name	Vendor	Qty.	Total Price	Relevant Part/Assembly
Raw Material				
A500 Rectangle Steel Tube 3 x 1 x 3/16 Wall 12 Ft. Length	Metals Depot	1	\$105.00	Railing
6061-T6511 Aluminum Flat 1x 3 1-1/2 Ft. Length	Metals Depot	1	\$34.70	Carriage, Hinges
6061-T6 Aluminum Sheet 1/8" Thick 2 x 4 Ft.	Metals Depot	1	\$131.96	Backing Plate, Brackets
Chemical-Resistant Slippery Teflon PTFE U-Channel 1/16" Wall Thickness Thick 19/32" High x 1/2" Wide 1 Ft. Length	McMaster-Carr	1	\$13.71	Sliding Surface
6061-T6 Aluminum Square Tube 1 x 1 x 1/8 Wall 6 Ft. Length	Metals Depot	1	\$25.82	Tube Arms, Cross Bar
6061-T6 Aluminum Plate 0.190 (3/16)" Thick 1 x 1 Ft.	Metals Depot	1	\$37.50	Plate Arms
Rotary Shaft Nitride-Coated 1045 Carbon Steel 3/8" Diameter, 18" Long	McMaster-Carr	1	\$11.04	Shaft
Clear Scratch and UV Resistant Cast Acrylic Sheet 12" x 24" x 1/4"	McMaster-Carr	1	\$29.77	Table Top
6061-T6511 Aluminum Flat 1-3/4 x 2 1 Ft. Length	Metals Depot	1	\$38.88	Table Top Connector
Hardware				
Oil-Embedded Flanged Sleeve Bearing for 3/8" Shaft Diameter and 1/2" Housing ID, 1/4" Long	McMaster-Carr	20	\$17.60	Hinges, Tube Arms, Shaft
Oil-Embedded Bronze Sleeve Bearing for 3/8" Shaft Diameter and 1/2" Housing ID, 3/16" Long	McMaster-Carr	4	\$2.44	Plate Arms
Alloy Steel Shoulder Screw 3/8" Shoulder Diameter, 2-1/8" Shoulder Length, 5/16"-18 Thread	McMaster-Carr	4	\$26.80	Hinges
Ultra-Low Profile Shoulder Screw 3/8" Shoulder Diameter, 1/4" Shoulder Length, 5/16"-18 Thread	McMaster-Carr	4	\$33.68	Plate Arms
Assorted LDPE Unthreaded Spacers 3/4" OD, for 3/8" Screw Size	McMaster-Carr	1	--	Hinges, Arms
316 Stainless Steel Washer for 1/4" Screw Size, 0.281" ID, 0.625" OD, Pack of 100	McMaster-Carr	1	\$7.11	Hinge
High-Strength Steel Nylon-Insert Locknut Grade 8, 5/8"-18 Thread Size, Pack of 5	McMaster-Carr	1	\$3.43	Hinge, Arms, Pulley
18-8 Stainless Steel Button Head Hex Drive Screw 1/4"-20 Thread Size, 3/4" Long, Pack of 50	McMaster-Carr	1	\$7.39	Hinge Mounting, Backing Plate Mounting
Medium-Strength Steel Hex Nut Grade 5, Zinc-Plated, 1/4"-20 Thread Size	McMaster-Carr	1	\$4.88	Hinge Mounting
18-8 Stainless Steel Button Head Hex Drive Screw 10-32 Thread Size, 1" Long, Pack of 50	McMaster-Carr	1	\$6.16	Shaft Retention
316 Stainless Steel Washer for Number 10 Screw Size, 0.203" ID, 0.438" OD, Pack of 100	McMaster-Carr	1	\$3.64	Shaft Retention
Aluminum Blind Rivets with Aluminum Mandrel Domed Head, 3/16" Diameter, for 0.251"-0.375" Material Thickness, Pack of 100	McMaster-Carr	1	\$7.08	Cross Bar
18-8 Stainless Steel Button Head Hex Drive Screw 10-32 Thread Size, 3/4" Long, Pack of 100	McMaster-Carr	1	\$8.58	Table Top
18-8 Stainless Steel Hex Nut, Pack of 100	McMaster-Carr	1	\$3.77	Table Top
Pulley for Wire Rope for Horizontal Pull, with Bearing, for 3/8" Diameter Rope, 3/4" Wide	McMaster-Carr	1	\$16.71	Pulley
Black Oxide Alloy Steel Low-Profile Shoulder Screw 3/8" Shoulder Diameter, 1" Shoulder Length, 5/16"-18 Thread	McMaster-Carr	1	\$8.42	Pulley

FABRICATION AND ASSEMBLY PROCESS

The fabrication of this system is relatively straightforward, requiring only a few different manufacturing processes. The two dimensional sheet metal components (backing plate, brackets, plate arms) can be cut using water jet, while the acrylic components can be laser cut. The flanges of the table top can be welded to the base plate using an solvent-based glue such as Weld-on 4, which should provide a sufficient bond. Several components need to be machined. The tube arms and cross bar should be cut to the appropriate lengths using a band saw or chop saw, and holes should be drilled for rivets and sleeve bearings using a drill press or mill. Press flanged sleeve bearings into the tubes, and non-flanged sleeve bearings into the plate arms using an arbor press. Rivet the two tube arms to the cross bar with the four brackets. Cut the shaft to length and thread both ends. Manufacture the hinge bases out of stock material using the mill. Press sleeve bearings in, and bolt to the backing plate. The same should be done for the carriage, and the Teflon U-channels should fit tightly against the metal. Bolt one railing onto the stairway wall, measuring to ensure that it is parallel to the staircase. Slide the carriages, attached to the backing plate, in, and use this to align and screw the second railing into the wall. Remove sliding system, and attach the tube arm system to lower hinge bases using a shoulder bolt and 3/16" spacers. Attach the smaller plate arms to the upper hinge bases, separated by a 1" spacer, with 1/16" spacers on each side. Connect to larger plate arms using small shoulder bolts.

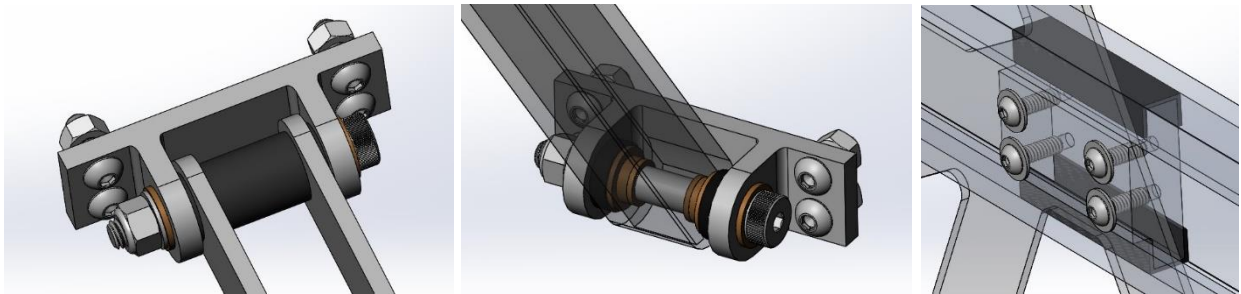
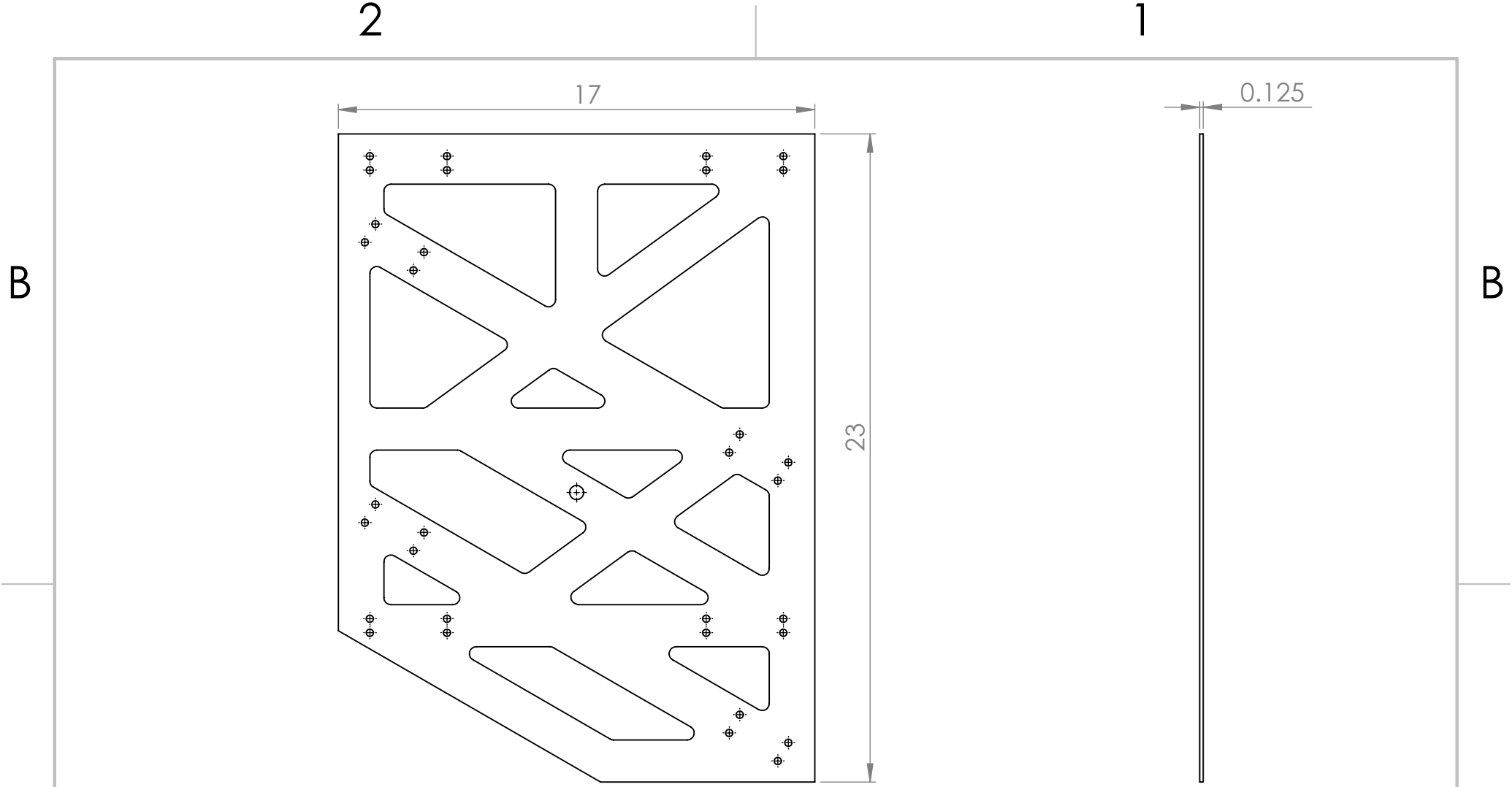


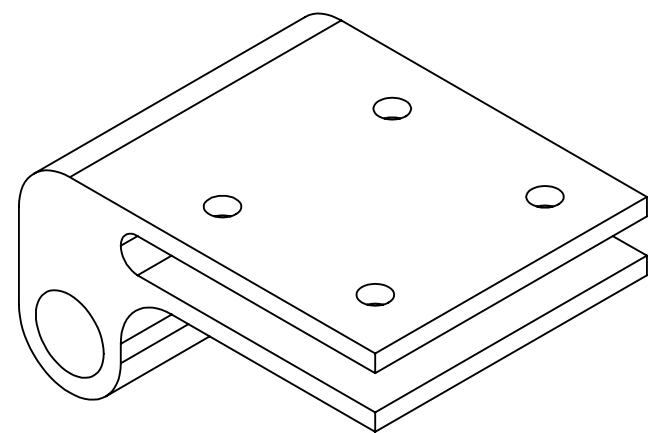
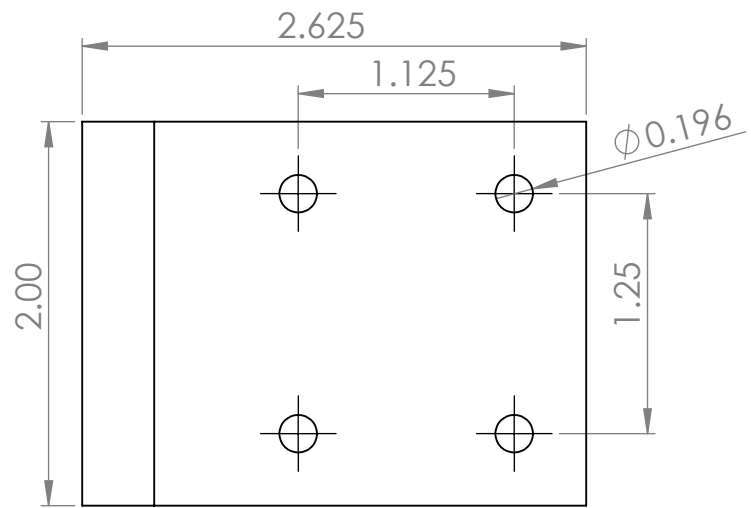
Figure 4: Configuration of the top hinges (left), bottom hinges (center), and carriage assembly (right)

Fabricate the table top connector, press sleeve bearings in, and attach to the acrylic table top component. Bolt a washer onto one end of the shaft, then slide it through a 1/8" spacer, one plate arm, the tube arm, a second 1/8" spacer, the other plate arm, and a 1/16" spacer. Then, slide the table top connectors through, and repeat the same process on the other side, before constraining the system with another washer and screw. Attach the pulley to the center hole in the plate using a shoulder bolt, and slide the system into the railings, ensuring that it is able to move freely. Insert bolts through spacers at the bottom ends of the railings to prevent the system from falling out. Install the motor and power transmission system at the top of the stairs, connecting with the pulley.



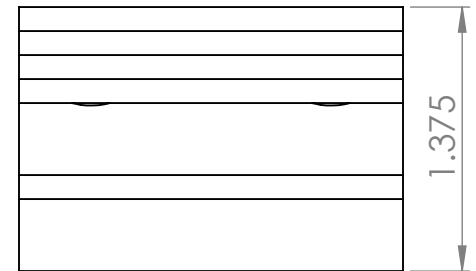
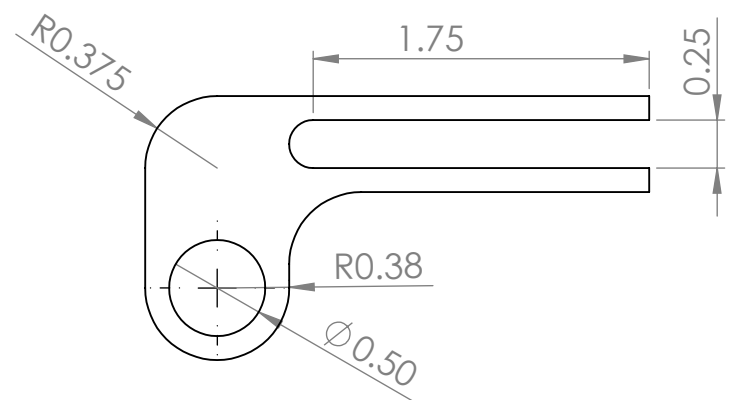
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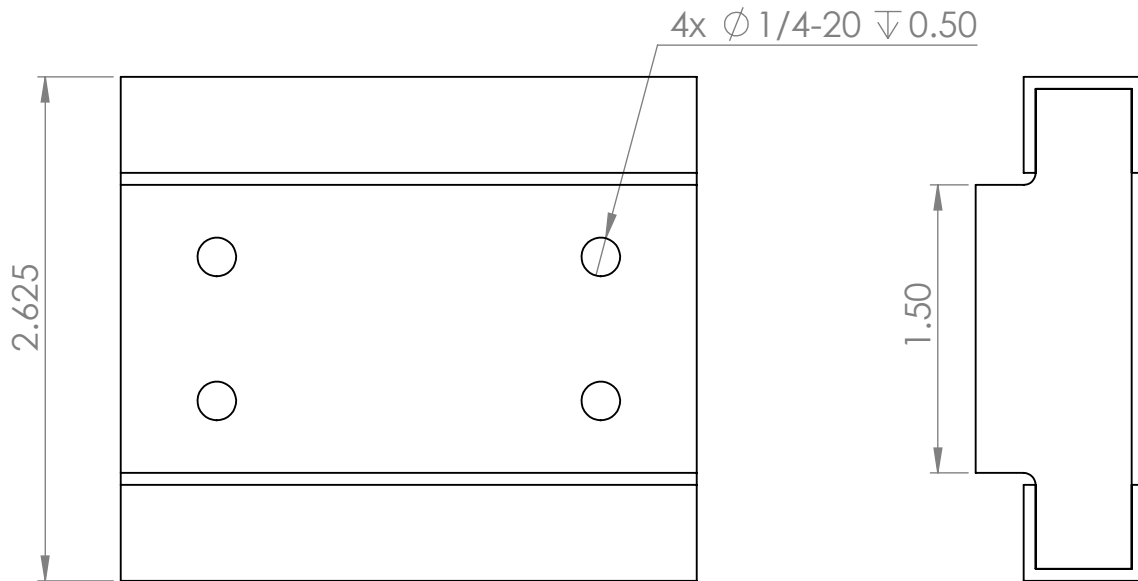
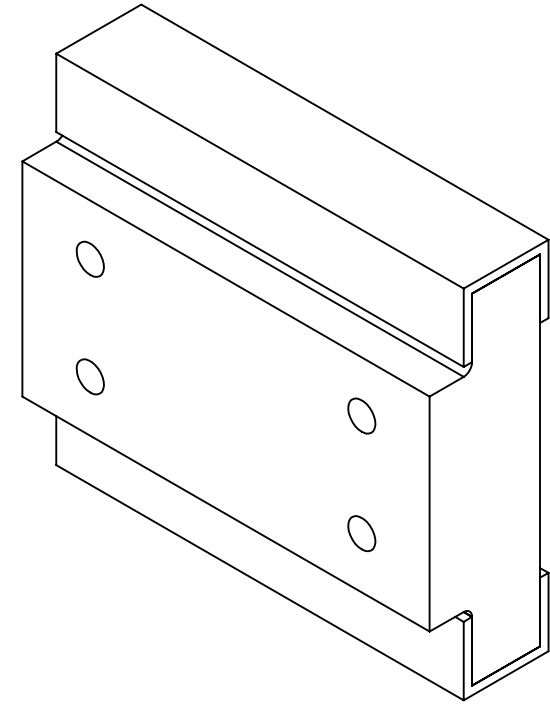
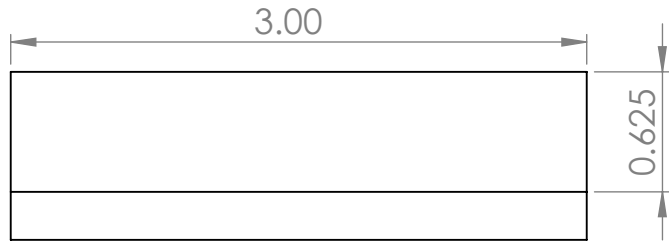
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