Water Pump Final Report

A Peristaltic Pump by Thursday Team Five

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To: Prof. Guy Hoffman, Julia Ahrens, and Matthew Menis
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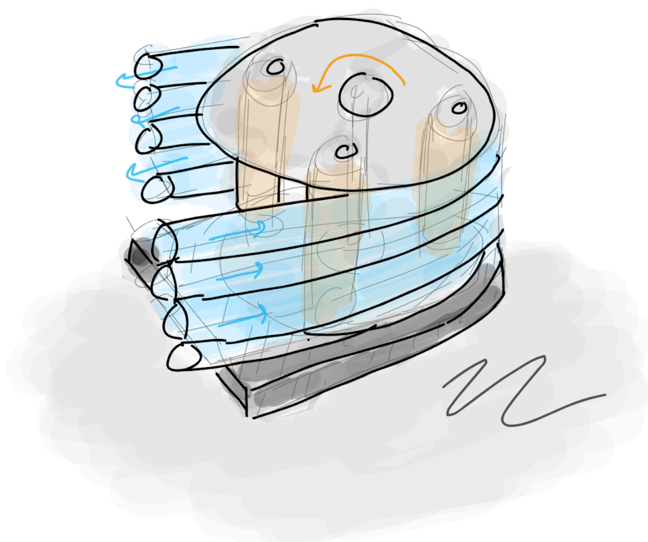
Subject: A11 - Water Pump Final Report



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Design Process

Function of the Peristaltic Pump

The peristaltic pump is a type of displacement pump that is used to drive fluids from one location to another. It consists of a rotor, rollers, a pump casing and flexible tubing. The pump undergoes a rotary motion which causes the rollers attached to the rotor to compress the tubes along the pump casing. The rotor uses pressure to force the fluids to move through the tubes by alternating between compression and relaxation. The area where the tube is under compression is “closed”, forcing the fluid to move through the tube and the area that is relaxed or “open”, allows the fluid to flow into the tube and this cycle repeats itself until it is stopped.

Design Choices and Process

When the group first met, they decided upon creating something functional but also somewhat ambitious. The team agreed that although a piston pump would be simpler to design and manufacture, they wanted to go with a more uniquely designed peristaltic pump. Additionally, a gear and lobe pump would have been much more difficult to manufacture compared to a peristaltic pump. The team also liked the idea of a peristaltic pump because having the fluid contained within the tubes of a peristaltic pump would minimize any leakage that may occur.

The team’s design process was driven by two major elements: the requirements of the pump and the cost of parts. Another secondary design factor was the manufacturing time for each part. The team decided to minimize the manufacturing time and complexity of each part by considering the design on a component-by-component basis. The team wanted to maximize the volumetric flow rate for the peristaltic pump. To maximize this rate, the team decided to use a large number of tubes (see tubing design). Once the number and size of tubes was determined, the rest of the pump structure could be designed. After the pump structure was designed, the details of the pump rotor and rollers were decided. This process led the team to design a pump that was well equipped to handle the requirements. To minimize costs, the team kept a spreadsheet of costs and attempted to minimize the cost for each individual part. Designs were made based on available stock and manufacturing costs.

Tubing Design

Once the team decided on a peristaltic pump, the team did the throughput calculations for their preliminary design. This included using the surgical tubing and large diameter PVC pipe that was available through the Emerson shop. In doing so, the team found that their theoretical maximum throughput for a single tube in the pump was around two liters per minute as shown in the throughput and power calculations section. This was more than the one liter per minute that was required, however the team wanted to have a much larger theoretical throughput and thus a large factor of safety because of the constraints of a single day of testing. The way that the team decided on four tubes was through a series of adjustments made to what the team believed would actually be pumped from the theoretical calculations. The first adjustment was that the team believed the pump might not spin as fast as calculated based on spin up time (see power and throughput calculations). The second was that the team did not think the pump could actually achieve no backflow as that would require very precise tuning which the team did not have time to design for. In taking these into account, the team decided that it would be better to have two tubes compared to one. However, once the team had decided that, the team thought about how much of a factor of safety was desired, and decided to double the tube count so that even if two of them stopped working entirely, there would still be a sufficient amount of water pumped. This final step turned out to be a very good decision, as for the pump's first successful test, 1.4 liters had been pumped in the allotted minute. However, some of the tubes were unoperational, so if the pump had not had the extras it may have not pumped at all.

Structure Design

The team's first consideration when constructing a peristaltic pump were the limitations regarding materials for the base and outer housing and how these would affect the shape and size of the pump. A peristaltic pump needs a rounded inner surface to roll the tubes against with rollers. The team devised three options that would be large enough to produce a pump with: pipes purchased from the Emerson shop, large-diameter pipes purchased from McMaster, or any material that could be shaped into a rigid, rounded surface. The team found that large tubes from McMaster were prohibitively expensive and rounding sheet metal or any other material would be difficult. The team decided to use the large PVC pipe available from the Emerson shop as the outer pipe. This outer pipe would drive a large majority of the dimensions for the rest of the peristaltic pump. The final PVC pipe design is shown in Figure 3a.

The PVC tube needed to be held in place at the top and bottom of the pump. This was accomplished by laser cutting acrylic into shapes that could hold the rounded top and bottom of the pipe. The team decided to make the circular grooves in the acrylic relatively large to prevent the PVC tube from bowing outwards. The bottom acrylic plate was screwed directly to the base plate to firmly secure the bottom of the PVC tube. Likewise, the top holding plate was secured to the face plate with vertical bolts. Additionally, this design required that the drive shaft be supported at the top of the pump. The team decided to use this acrylic plate to also support the drive shaft. Although acrylic is not a bearing material, the coefficient of friction between the acrylic and the steel shaft is low enough to be acceptable without the use of a bearing or bushing. The final acrylic plates are shown in Figures 4a and 4b.

The design of the base was driven by the parts that needed to be attached to it and the plate that the pump is attached to on the test rig. One design consideration that the team made was the bearing for the drive shaft. The team decided on a flanged bearing so that the bearing would not fall out. Other parts that needed to be bolted to the base were the faceplate and bottom acrylic holding plate. The location for these bolts were chosen to maximize the strength of the connection while not jeopardizing the integrity of the base plate or connected element. Bolts were placed close to the edges of the part without weakening the part. The base plate design is shown in Figure 5a.

The faceplate design was mostly driven by the number and size of the input/output tubes, the height of the pump, and the width of the pump. The number and size of the tubes was previously determined by the team when considering the quantity of water that the pump needed to move. The design of the faceplate includes holes for the input and output tubes that could hold the tubes in place. There are also holes at the top and bottom of the faceplate to allow for attachment to the base and the acrylic roof piece. The faceplate is shown in Figure 6a.

Rotor Design

The rotors refer to the acrylic circular elements that hold the rollers in place and attach rigidly to the drive shaft.

The large PVC pipe had an inner diameter of about 4”. This inner diameter drove the dimensions of the rotors since the rotors had to be sized to hold the rollers, while still being small enough that the peristaltic tubing would not be pinched by the rotors. The rotor was made from laser cut acrylic since it was easy to design for and manufacture. The rotor has a hole for the drive shaft, two through holes for the lockbar (lego) to connect to, and 3 holes for the rollers. The rotor is shown in Figure 7a.

To connect to the drive shaft, the team decided to use a D-shaft design. The team had two ideas for this design. The first design was similar to a shaft collar. It would use two set screws to hold the collar to the shaft. Two more screws would then hold the collar to the rotor. The team’s next idea was to cut a flat in the shaft and then use a lockbar to connect the shaft to the rotor. The lockbar could then be bolted to the rotor so that the rotor would be unable to move relative to the shaft. These lockbars (referred to as D-shaft inserts or legos by the team due to their shape) are shown in Figure 8a.

The shaft was one of the last designs that the team created. The dimensions of the shaft were determined by the required length of shaft to interface with the provided sprocket. The flat areas of the shaft were determined by the location of the rotors. During the design process, the team also decided to add a flat area to the end of the shaft to help hold the shaft to the sprocket more securely. The shaft is shown in Figure 9a.

Roller Design

The team realized that one of the major issues with a peristaltic pump design is determining the proper amount of pressure to apply to the flexible tubing. Applying too little pressure does not push enough water to be effective. Applying too much pressure dramatically increases the friction in the system and seizes the mechanism. To combat this problem, the team decided to design adjustable rollers that could be adjusted to apply different pressures to the tube. To accomplish this, the rollers have offset attachment bolt holes. These allow the roller to be rotated to different positions where the roller applies different levels of pressure. The roller can then be screwed down to the acrylic rotors so that they are locked in place.

The design of this offset was made to apply pressure at the two extremes of the system. The first extreme of almost no pressure applied to the tube, with the rollers just touching the outside of the tubing. At the other extreme, the tube is compacted entirely such that the rollers would be touching the inside of the PVC pipe. The team decided that the optimal tube pressure had to be in this range, so this design would give the best results for optimization.

Another consideration in the design of the rollers is the friction between the rollers and the tubes. The team decided to alleviate this problem by using another ‘sleeve’ around the internal roller. This sleeve was a delrin tube purchased from McMaster. Delrin was chosen for its low friction, relatively low price and durability. This delrin roller could easily be cut to size and added to the assembly to drastically reduce the friction in the system.

Overall, this roller design allowed the team to optimize the pressure applied to tubes, while minimizing the friction between the tubing and the rollers. One final consideration for this design was the manufacturing of the rollers. After some deliberation, the team realized that the offset bolt hole could be completed on the mill. This meant that the rollers were easy to machine and manufacture. The final design of the roller is shown in Figure 10a.

Initial Design Sketches

Initial sketches included overall design characteristics and detailed views of specific components and functions (Figure 1a). Several roller designs were drawn and considered in detail including self-adjusting and manually-adjusting options that could change the pressure applied to the peristaltic tubes. Different options can be seen in these sketches, including a manually adjustable one by way of rotation around an offset screw, which the team ended up selecting (Figure 1b). More finalized sketches include several overall dimensions to aid in more detailed CAD drawing (Figure 1c), and some cleaner color images which were used in the team's design presentations (Figure 2a-2c).

Challenges During Fabrication

Several challenges came up during the fabrication of the pump including issues related to machining the components the team designed and individual team members having to isolate due to COVID-19.

The team's final design for the rollers included an offset screw hole that allowed the team to rotate them and manually adjust the pressure against the flexible tubes. Although this appeared to be a simple part, the offset hole proved more difficult to machine than expected because of its asymmetry. The team consulted staff at the Emerson Machine Shop and decided to make the offset hole on the mill instead of the lathe as initially designed. The overall cylinder was turned and parted to size then put into a collet for use on the mill. Using an edge finder tool, those manufacturing were able to locate the center of the part then offset a drill to create the required hole.

The hole to accommodate the bearing used to support the shaft was also difficult to create due to its large size. The few drills of that size in the shop were dull, and the mill had difficulty with them. Ultimately, the team was able to use an end mill instead of a drill to punch through and create the hole.

The ongoing pandemic also caused several delays in our manufacturing process. More than half of the team had to quarantine due to COVID-19 at some point during the project timeline, which delayed certain parts and assembly. Despite this, the team was able to maintain good communication during these disruptions and moved some initial dates around in order to accommodate necessary changes.

Performance Analysis

The pump was tested with the testing apparatus three times. The first time it was tested, the rollers did not push up against the tubes sufficiently to displace any water. The group had designed the rollers to be adjustable, so that the extent to which the rollers pressed against the tube could be changed. Thus, after the first attempt, the group adjusted the rollers to push further against the tubes. When this adjusted assembly was tested, the pump displaced 1.4 liters of water. In the beginning of this testing period, only two of the tubes had been moving water. As the pump continued to operate, eventually all the tubes began to move water. This occurred towards the end of the minute, so the group decided to test the pump again immediately after it had pumped 1.4 liters. Because all the tubes were “warmed up”, they all began to move water at the beginning of this allotted test minute, and displaced a total of 2.75 liters of water.

Based on the pump’s performance, the group found that ensuring that the rollers are pressed as tightly as possible against the tubes will maximize the amount of water displaced, since the provided motor will allow the rollers to overcome the friction that results from them pressing against the tubes.

Fabrication

Manufacturing and Ordering Analysis

Part	Workshop / Tool	Person Responsible	Manufacture / Order
Rotors and Ceiling	Laser Cutter	Ameera	Manufacture from acrylic, cheap and precise
Rollers	Lathe	Gabriel	Manufacture insides, ordered and cut outside tubes (Delrin) based on low friction needed
D-Shaft Inserts (2)	Mill	Jeff and Alex	Manufacture – specialized shape but easy to machine
D-Shaped Shaft	Mill	Ben and Alex	Manufacture – unable to purchase
Base	Mill	Ben	Manufacture
Walls	Mill	Jeff	Manufacture
Back Wall	Band Saw	Evelyn	Order PVC pipe, modify because shape needs to be changed slightly for base
Assembly	-	Team	Order screws, fasteners, and ball bearing

Most materials and components relating to the peristaltic pump were ordered from Emerson Lab. Components that were more complex or difficult to design and machine such as the ball bearing were ordered from McMaster Carr Website. The group' responsibilities were discussed and assigned beforehand and thus the team had one group member take the role of ordering and procuring the necessary components for the project, another member take charge of the laser cutting process and the rest of the group focus on the manufacturing/machining of the parts (schedule coordinator and integrator). The Parts List chart listed above indicates which components from the Bill of Materials needed to be machined, what tools were necessary to accomplish that and the person responsible for it.

Since acrylic is prone to cracking if it undergoes the machining processing, the team used a laser cutter to cut out the complex parts such as the ceiling and the parts of the rotor. The back wall of the pump was shaped and sawn to length by using the bandsaw and hacksaw as it was too large for laser cutting. Our design's rollers are composed of 2 components; the inner roller made of aluminum and the outer roller made of delrin tubes. The outer roller's stock material was also sawn to length on the bandsaw. On the other hand, the inner rollers produced from the aluminum bars required the lathe since they were smaller and required more vigilance. The base, wall, D-shaft and the shaft inserts of the peristaltic pump were all manufactured and cut on the mill for reasons similar to the inner rollers. On the mill, the back wall component of the pump had 12 holes drilled into it - eight for tubing and four threaded for assembly. The base had five holes drilled into the stock material - one for the bearing and four threaded holes for the assembly. Two D-shaft inserts were milled down to size and each had 2 threaded holes drilled into them. In the end, only one D-shaft insert made it into the design, due to difficulty in how everything fit together.

The final assembly of the peristaltic pump using the various machined and ordered pumps was completed by four members of the team using screws, fasteners, and other parts that had been ordered in advance.

Parts List and Cost Analysis

McMaster Bill of Materials

Parts Description / Details	Quantity	Price
Ball Bearing (6383K245)	1	$13.19
Internal Rollers (Delrin Tube) (8627K219)	1ft	$5.52
	Final Cost	$18.71

Emerson Bill of Materials

	Quant.	**Unit of Measurement**	**Price**
Housing			
Base (½" x 4" Aluminum Bars)	6	in	$7.08
Top (Acrylic Sheet)	1	each	$3.00
Outside Circle (PVC Plastic Tubing)	5.625	in	$1.41
Wall/holes (½" x 4" Aluminum Bars)	4.625	in	$5.46

Motor Shaft (¼” Diameter Steel Rod)	8.75	in	$2.01
Tubing			
Tubes (⅜” ID x ⅝” OD Surgical Tubing)	5	ft	$10.00
Tee Valves (⅜” barbed)	4	each	$3.80
Roller			
Top Caps (Acrylic Sheet)	1	each	$3.00
D Shape Holder (¼” x 2.25” Aluminum Bars)	1.6	in	$0.58
Roller Axles (¾” Diameter x 6” Aluminum Rod)	2	each	$5.00
Fasteners			
¼ - 20 Allen Socket Head Cap Screw (¾”)	14	each	$2.10
¼” flat steel washers	12	each	$0.24
¼ - 20 Allen Socket Head Cap Screw (1”)	6	each	$1.02
		Final Cost	$44.70

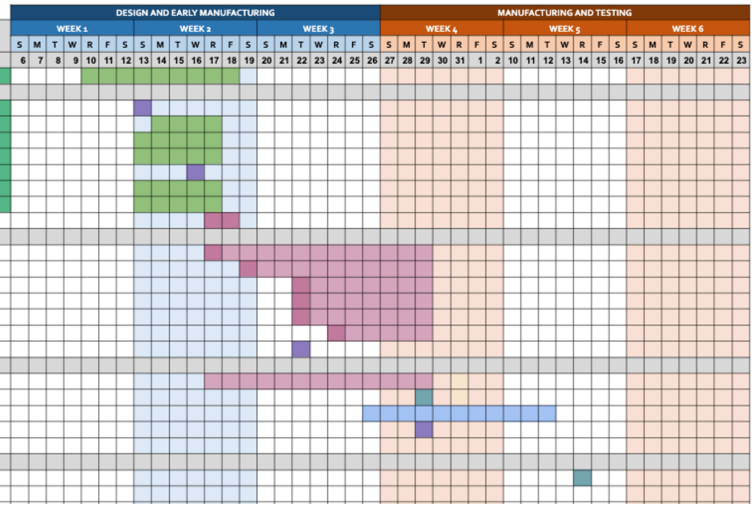
The budget provided for the project was $45 for Emerson Shop and $30 for McMaster Carr. The total cost of fabricating the peristaltic water pump was $63.41. The team used $44.70 of this budget towards materials purchased from Emerson, and $18.71 towards materials purchased from McMaster.

In terms of managing the budget, the team had to make some compromises in order to fit within budget. For instance, the team could not afford regular connectors and instead opted to use plastic tee valves to save money on connectors. By using tee valves, the pump would require two tubes from the peristaltic pump to be connected to one connector.

Fabrication Timeline

Water Pump Schedule

NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	PCT OF TASK COMPLETE
1	**Week 1**				
1.1	Team Charter	All	3/10/22	3/18/22	100%
2	**Week 2**				
2.1	Team Meeting/Checkup	All	3/13/22	-	100%
2.2	Paper Prototype	E, G	3/14/22	3/17/22	100%
2.3	CAD Model/Parts Drawings/Animation	Al, Am, B, J	3/13/22	3/17/22	100%
2.4	Fabrication Plan/Parts List/Cost Analysis	Al, Am, J	3/13/22	3/17/22	100%
2.5	Team Meeting/Checkup	All	3/16/22	-	100%
2.6	Final Presentation	All	3/13/22	3/17/22	100%
2.7	Final Design	All	3/13/22	3/17/22	100%
2.8	Order Parts	E	3/17/22	3/18/22	
3	**Week 3**				
3.1	Rotors (Laser Cut, 2)	Am	3/17/22	3/29/22	
3.2	Rollers (Lathe)	G	3/19/22	3/29/22	
3.3	Lego blocks, Keyed Shaft (Mill)	Al	3/22/22	3/29/22	
3.4	Base (Mill)	B	3/22/22	3/29/22	
3.5	Walls (Mill)	J	3/22/22	3/29/22	
	Pipe (Hacksaw)	E	3/24/22	3/29/22	
3.6	Team Meeting/Checkup	All	3/22/22	-	
4	**Week 4**				
4.1	All Machined Parts	All	3/17/22	3/29/22	
4.2	Final Assembly	All	-	3/29/22	
4.3	Testing	All			
4.4	Team Meeting/Checkup	All	3/29/22	-	
4.5					
5	**Week 5** *Spring break btwn Week 4 and 5				
5.1	Finished water pump	All		4/14/22	
5.2	Analysis/Reflection	All		?	



The team created a Gantt chart describing hard deadlines and internal manufacturing dates that the team has discussed. Initially, the team anticipated that all final parts would be completed by March 29. However, the team's timeline was challenged when four out of six team members caught COVID-19 during the fabrication timeline.

When Alex tested positive on March 21, his machine shift was the day after. This presented a problem because he was responsible for some of the main aspects of the water pump. Ben and Jeff were able to step up and claim responsibility for some of his parts. This ensured that the team would still be able to move production and assembly further, and not require a large amount of waiting to ensure that various parts of the water pump fit together. When Alex returned from quarantine, the team ensured that he was still able to machine for the water pump by leaving him one D-shaft block and half of the keyed shaft to machine. Additionally, three other members of the team tested positive for COVID-19 during assembly, which required other team members to step forward and complete roles that were not initially assigned to them. Despite the internal changes and transfer of roles to various team members, all team members (excluding the schedule coordinator and the integrator) were able to machine one part.

Although the team had laid out a plan for the parts to be finished by March 29, because of all the delays that COVID-19 put in the team's schedule, many internal deadlines had to be pushed back. While the pump's final assembly was completed on April 12 (two weeks later than anticipated), the team was still able to run trials to identify and make necessary adjustments to make sure the pump functioned as intended.

Even though there were changes with the team’s fabrication timeline, the team was still able to complete the project in a timely manner before the deadline of April 14. The open line of communication that the team members had through Slack ensured that everyone was on the same page about the schedule. Additionally, the willingness of other team members to step up when needed allowed for the team to make quick adjustments and changes as needed to the schedule. Thus, the project was completed on time before the April 14 deadline, even though it was later than the team’s anticipated deadlines.

Graphs, Charts, Tables

Power and Throughput Calculations

For our throughput calculations, the team calculated out how much water would be held in one tube at once, and then calculated how much water would be pushed through in one perfect (no backwash) revolution. The team came up with the amount of 8.125 Liters per minute, at least when using 4 tubes.

$2in\ (PVC)\ -\ .25in\ =\ 1.75in$	The radius of the PVC housing minus tubing
$1.75in\ *\ pi\ *\ 2\ =\ 10.9956\ in$	Using the radius to find length of arc traveled
$10.99in\ -\ .43in\ *\ 3\ =\ 9.705in$	Adjusting arc for compressed section from rollers (1)
$3/8\ in\ *.5\ =\ .1875in$	Calculating inner radius of tube
$pi\ *.1875^2\ =\ .110in^2$	Internal Area of the tube (2)
$900rpm\ *\ (9/70)\ =\ 115.7rpm$	Calculating RPM of the sprocket (3)
$.110in^2\ *.9705in\ =\ 1.07in^3$	Using (1) and (2) to in^3/rev (4)
$1.07in^3\ *.016387\ L/in^3\ =\ .017566L/rev$	Converting (4) to L/revolution (5)
$.017566L/rev\ *\ 115.7RPM\ =\ 2.03L/Min$	Using (5) and (3) to calculate L/Min for a tube (6)
$2.03L/(Min\ *\ Tube)\ *\ 4\ tubes\ =\ 8.125L/min$	Using (6) and the tubes number

Initial power calculations estimate the necessary power to achieve our pumping goal within some basic constraints such as tube size and motor gear ratio. The team estimated on the higher side of things in order to have a FOS.

$P = \tau\omega$

ω is from actual pump

τ is τ requirements for lifting water

τ requirements derived from lifting water:

lifting water 1.5 m

We have 4 tubes worth of water:

$3/8''$ ID

total vol of water lifted:

$4\pi r^2 h = 4\pi\left(\frac{3}{16}''\right)^2 1.5m$

$= 4\pi(.0047625)^2 1.5\ [m^3] = .0004275\ m^3$ water

$m_{water} = 997\ kg/m^3 \cdot .0004275 = .4262\ kg$

$F_{water} = mg = .4263 \cdot 9.81 = 4.181\ N$

4.181 N force on the end of the rotor

$r = 1.787\ in = .04539\ m$

$|\tau| = rF = 4.181 \cdot .04539 = .1898\ Nm$

$\omega_1 = 900\ rpm$

ratio $= 9/70$

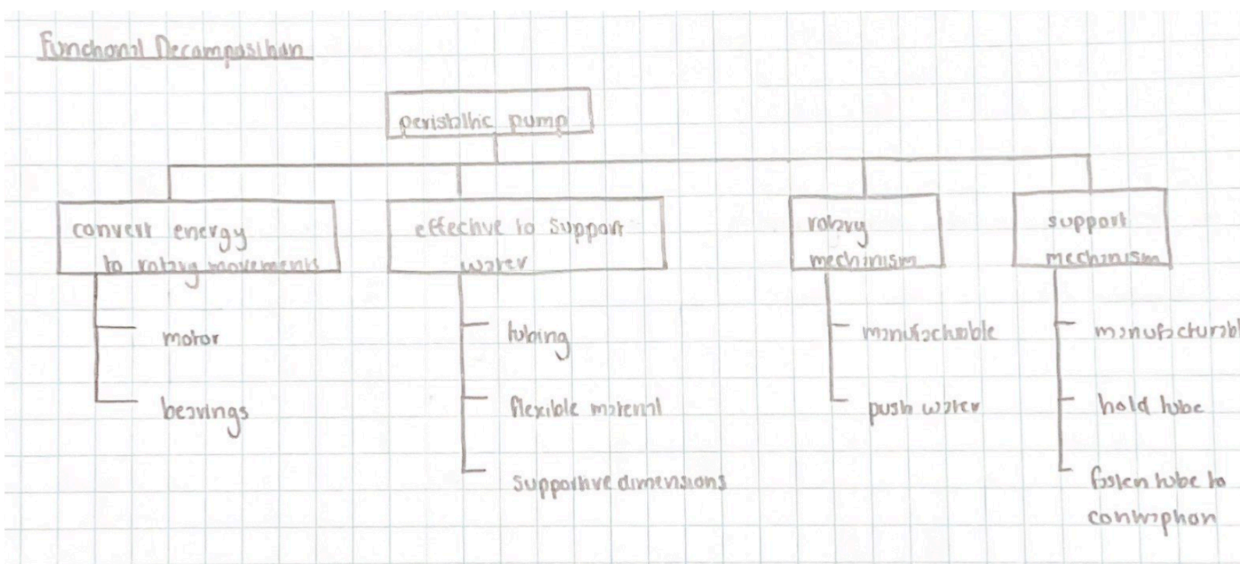
$\omega_{out} = 900\left(\frac{9}{70}\right) = 115.71\ rpm = 1.9285\ rps = 12.12\ rad/sec$

$P = \tau\omega = .1898 \cdot 12.12 = 2.300$ Watts

Motor outputs .75 hp = 559.3 watts

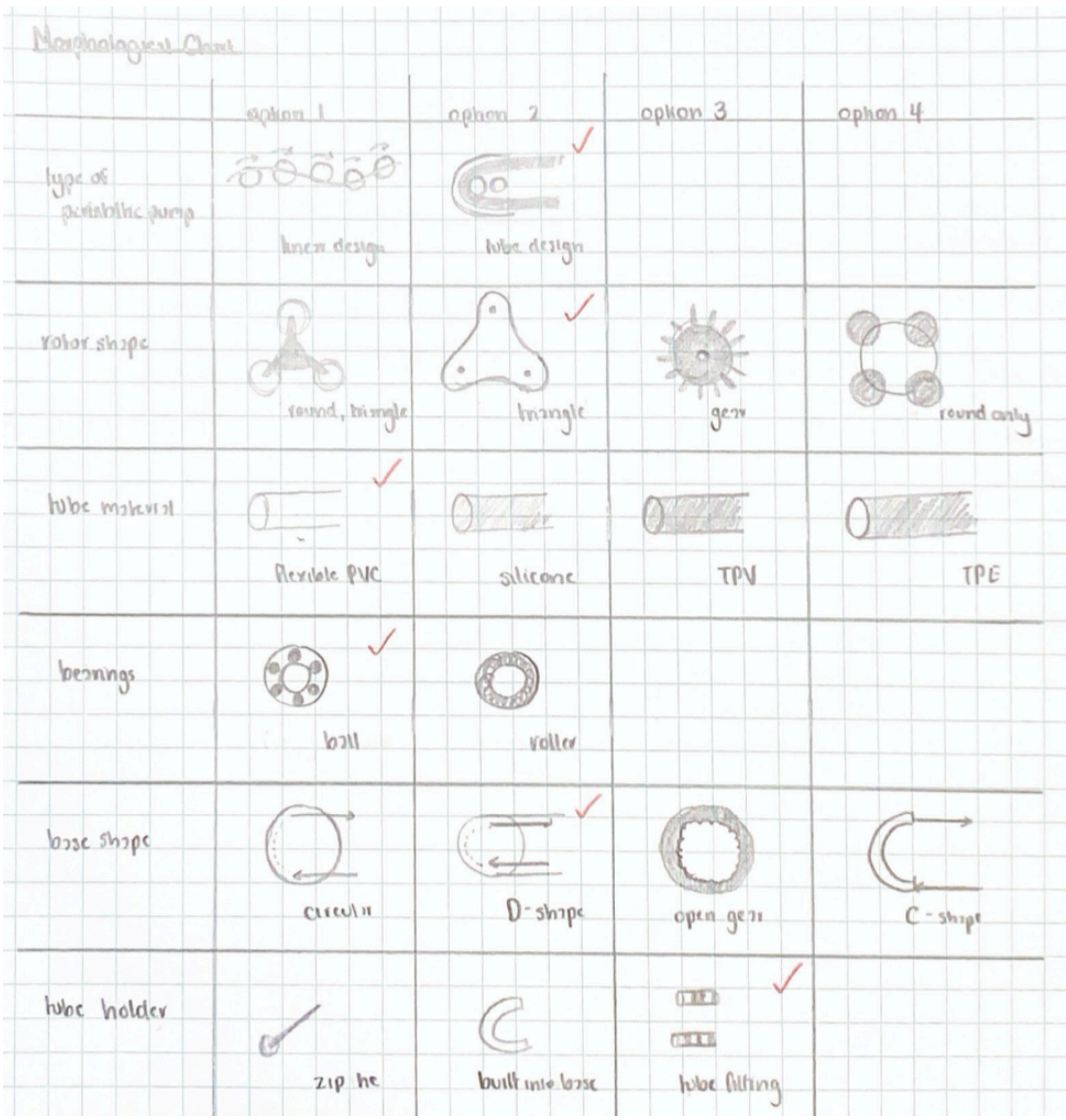
Functional Decomposition

The functional decomposition breaks down the peristaltic pump into individual components that accomplish different tasks for further design analysis. The peristaltic pump was divided into four main components. The first was the ability to convert energy to rotary movement, the second the tubing and water support components, the third the rotary mechanism, and the last the support that would hold all these components together.



Morphological Chart

The morphological chart gives an overview of the possible design decisions for each component of the peristaltic pump. The morphological chart was developed in the very early stages of the water pump project in the initial design review. This chart shows initial design decisions such as the triangular rotor shape, but the team made a number of changes during the design process such as using a round rotor, and increasing the number of tubes.



Appendices

Design Sketches

Figure 1a: Initial Sketches of Overall Structure and Rollers

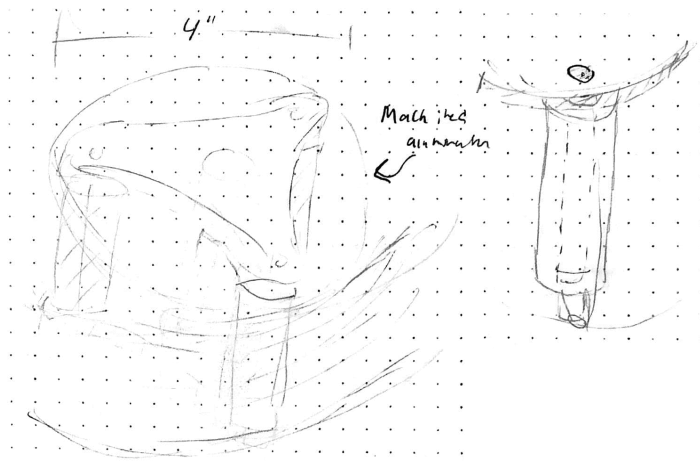


Figure 1b: Possible Roller Configurations in Detail:

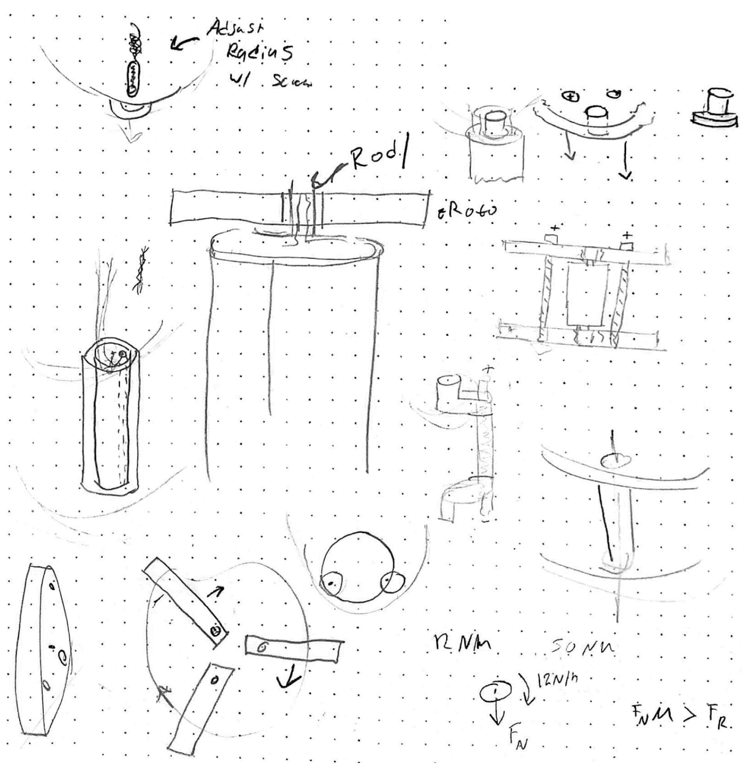


Figure 1c: Overview Sketches with Rough Dimensions:

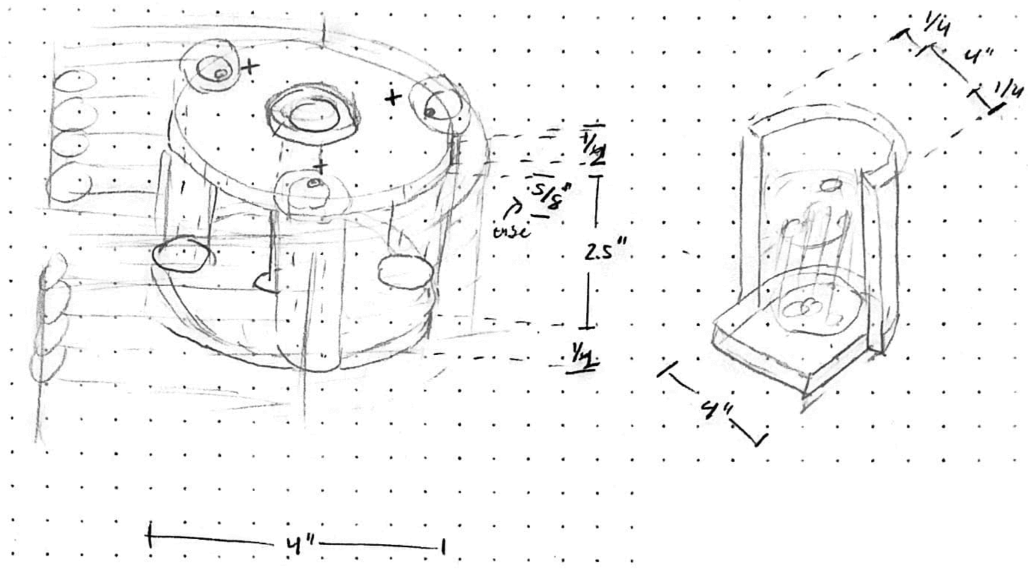


Figure 2a: Presentation Overall View:

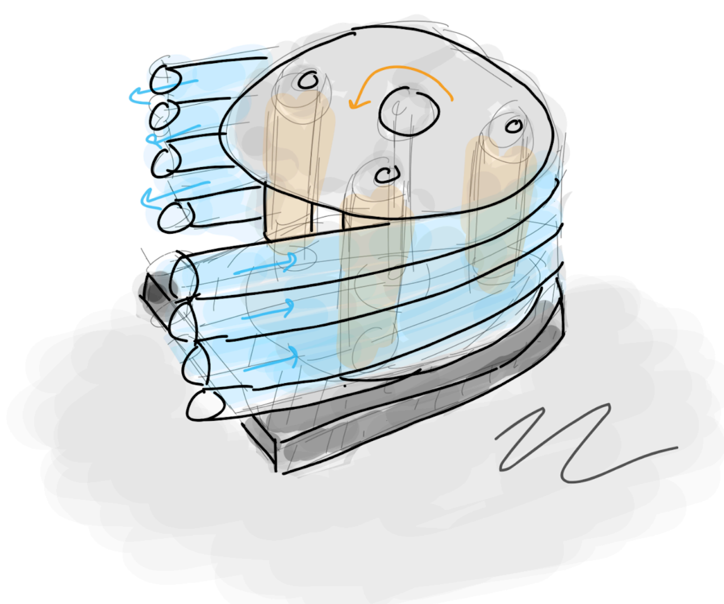


Figure 2b: Presentation Shaft and Block in Detail:

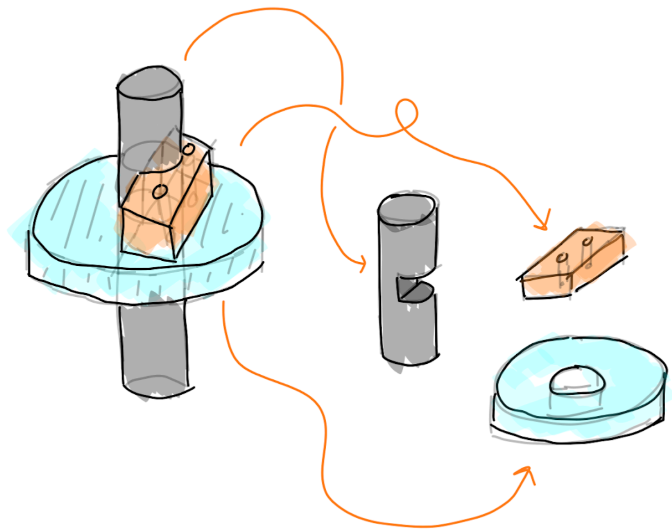
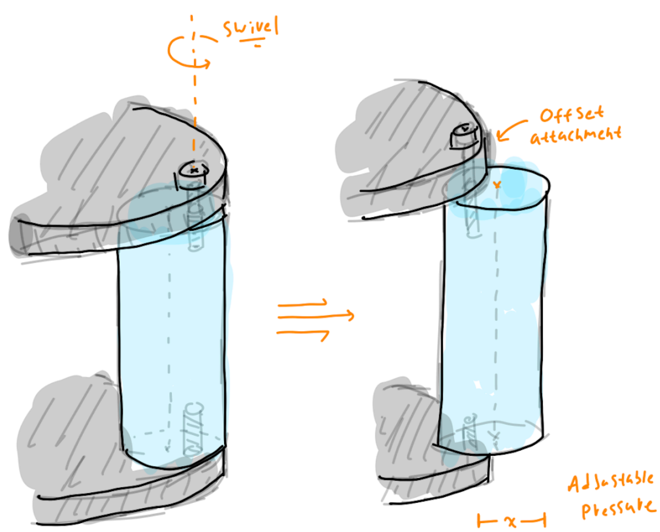


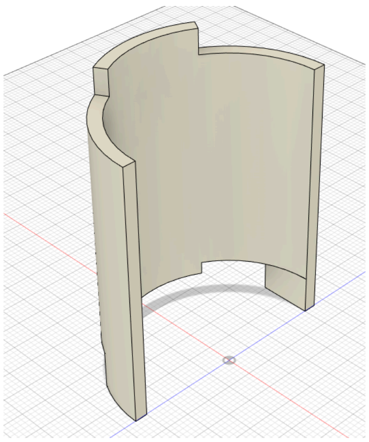
Figure 2c: Presentation Adjustable Roller in Detail:



Individual Part Models

Figure 3a: PVC Pipe Design

Material: PVC
Stock Source: Emerson Shop
Manufacturing Technique: Hacksaw and bandsaw
Tolerancing: .005in



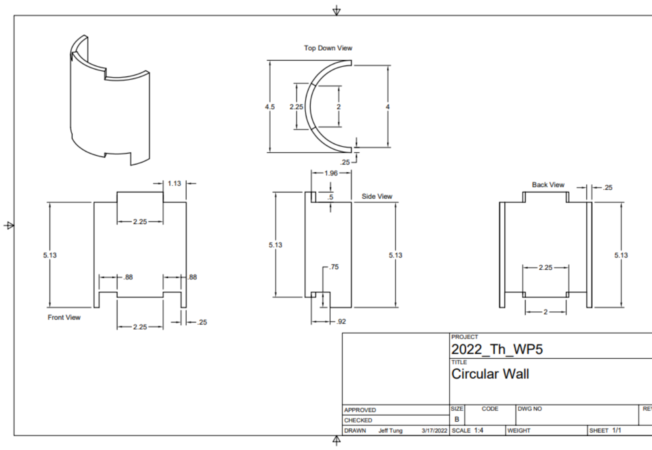


Figure 4a: Acrylic Plates on the PVC Pipe (Fig 1a):

Subcomponents: Top Acrylic Plate (Fig 2b), Bottom Acrylic Plate (Fig 2c)

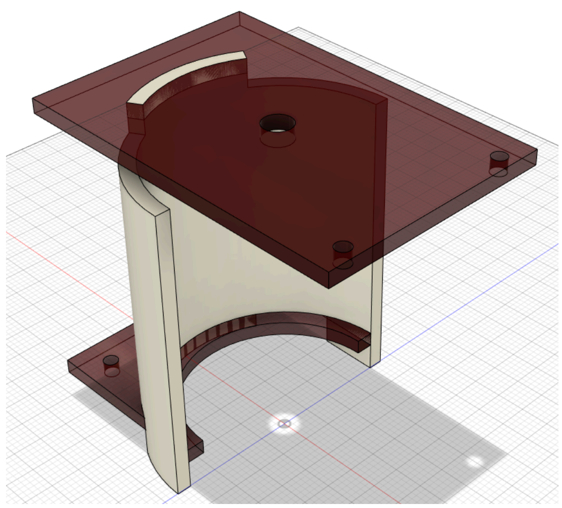
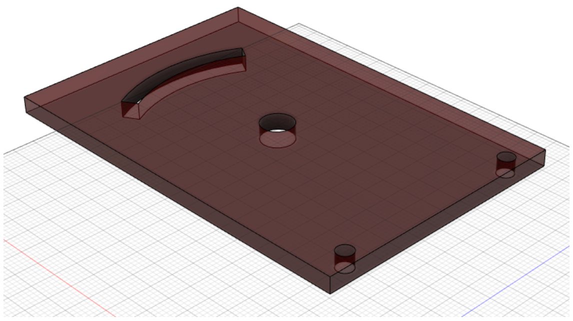


Figure 4b: Top Acrylic Plate:

Material: .25” Acrylic Sheet
Stock Source: Emerson Shop

Manufacturing Technique: Laser Cutting
Tolerancing: 0.005in



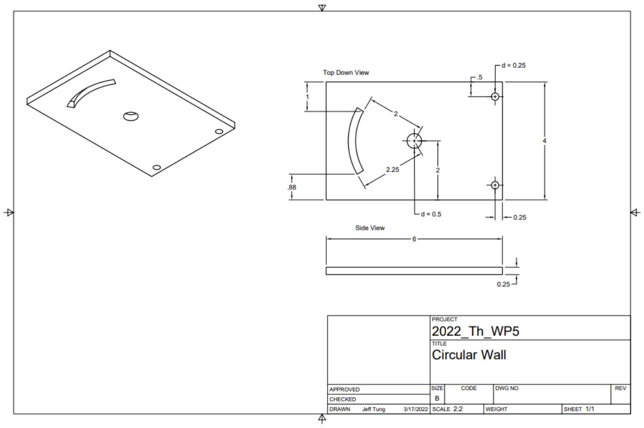
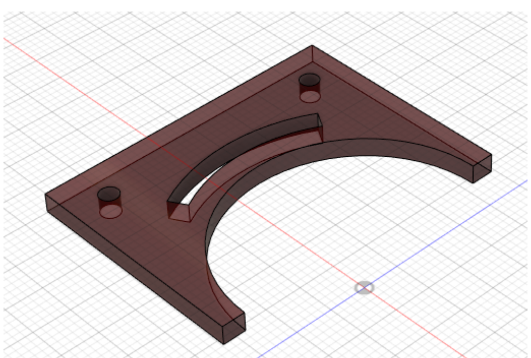


Figure 4c: Bottom Acrylic Plate:

Material: .25” Acrylic Sheet
Stock Source: Emerson Shop
Manufacturing Technique: Laser Cutting
Tolerancing: 0.005in



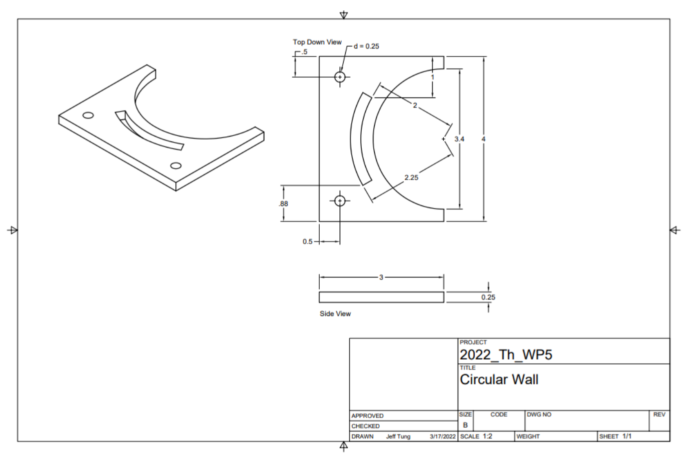


Figure 5a: Base Plate and Part Drawing:

Material: Aluminum 6061
Stock Source: Emerson Shop
Manufacturing Technique: Manual Milling
Tolerancing: .005in

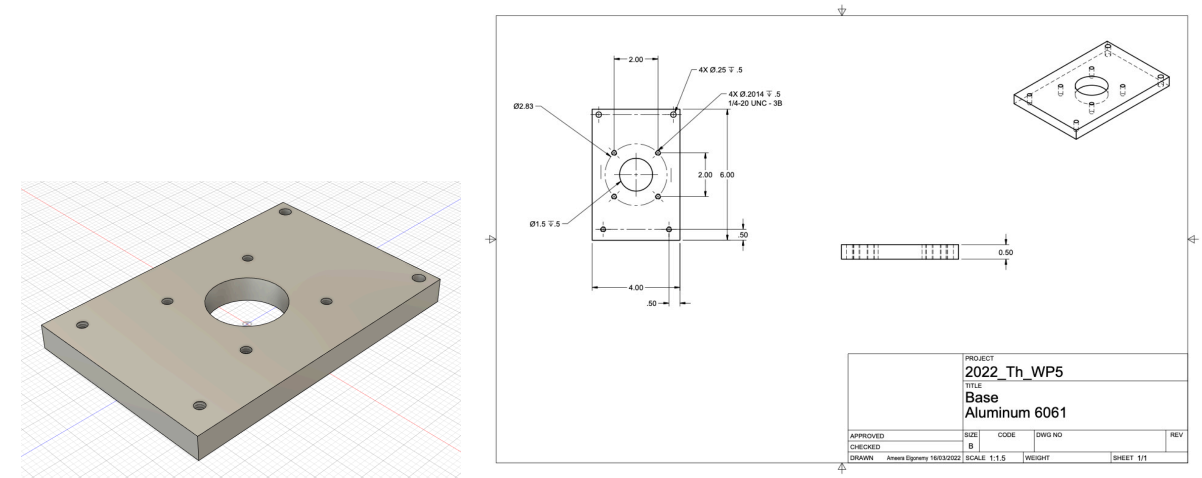


Figure 5b: FaceplateMaterial: Aluminum 6061

Stock Source: Emerson Shop
Manufacturing Technique: Manual Milling
Tolerancing: .005in

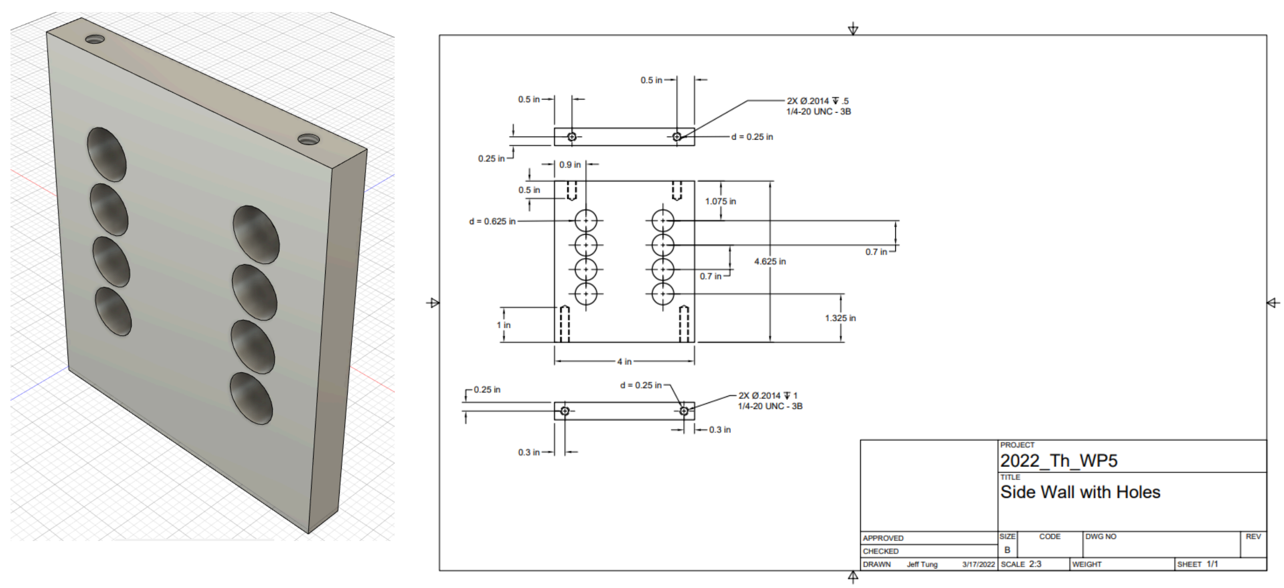


Figure 6a: Rotor

Material: .25” Acrylic Sheet
Stock Source: Emerson Shop
Manufacturing Technique: Laser Cutting
Tolerancing: .005in

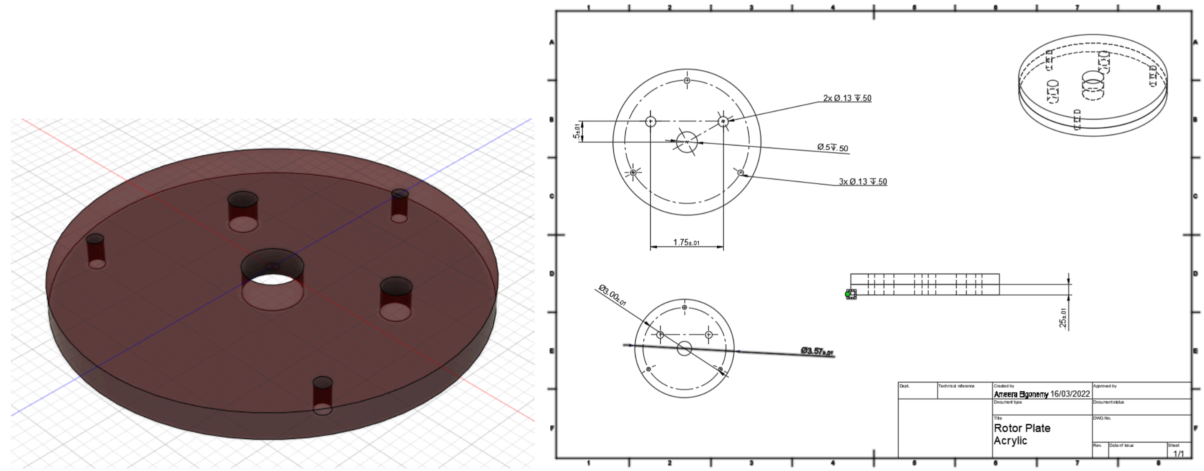


Figure 7a: Lockbars (D-Shaft Inserts) and Part Drawing

Material: Aluminum 6061
Stock Source: Emerson Shop
Manufacturing Technique: Manual Milling
Tolerancing: .005in

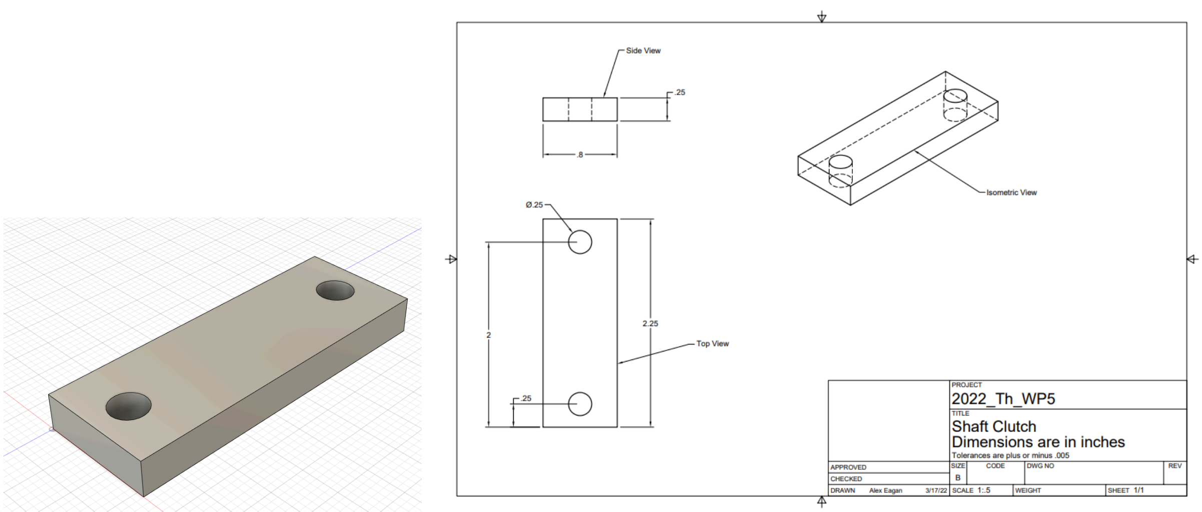


Figure 7a: Shaft and Part Drawing

Material: Steel
Stock Source: Emerson Shop
Manufacturing Technique: Manual Milling
Tolerancing: .005in

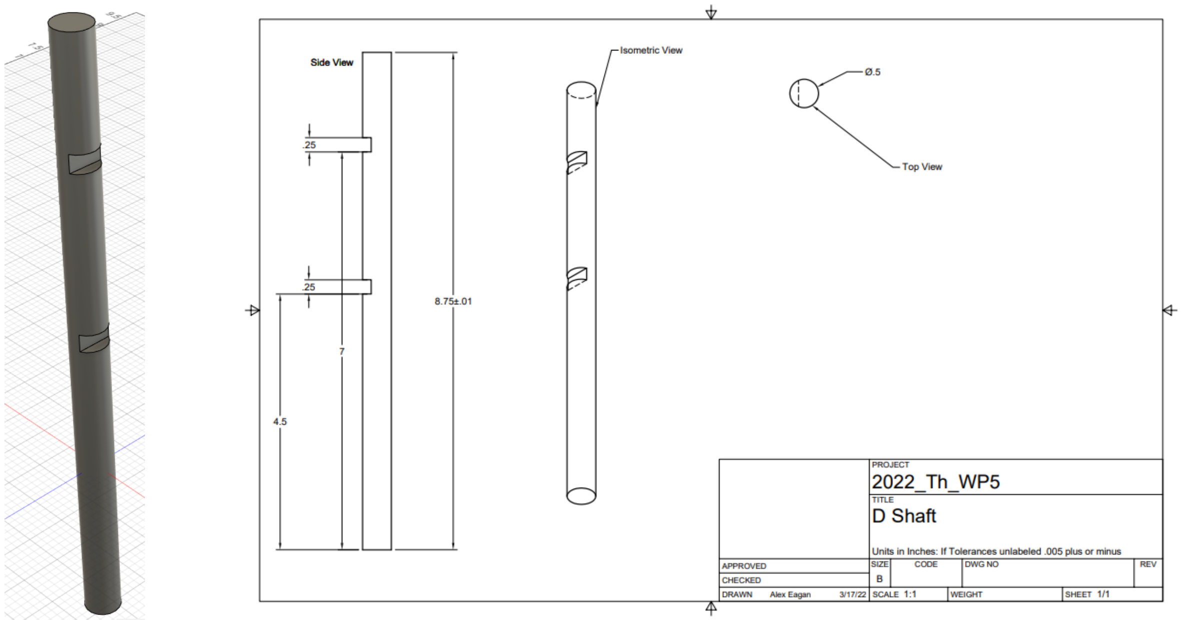


Figure 8a: Full Roller Design

Subcomponents: Roller Body (Fig 8b), Roller Sleeve (Fig 8c)

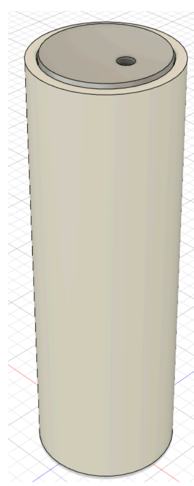


Figure 8b: Roller Body

Material: Aluminum 6061
Stock Source: Emerson Shop
Manufacturing Technique: Manual Milling
Tolerancing: .005in

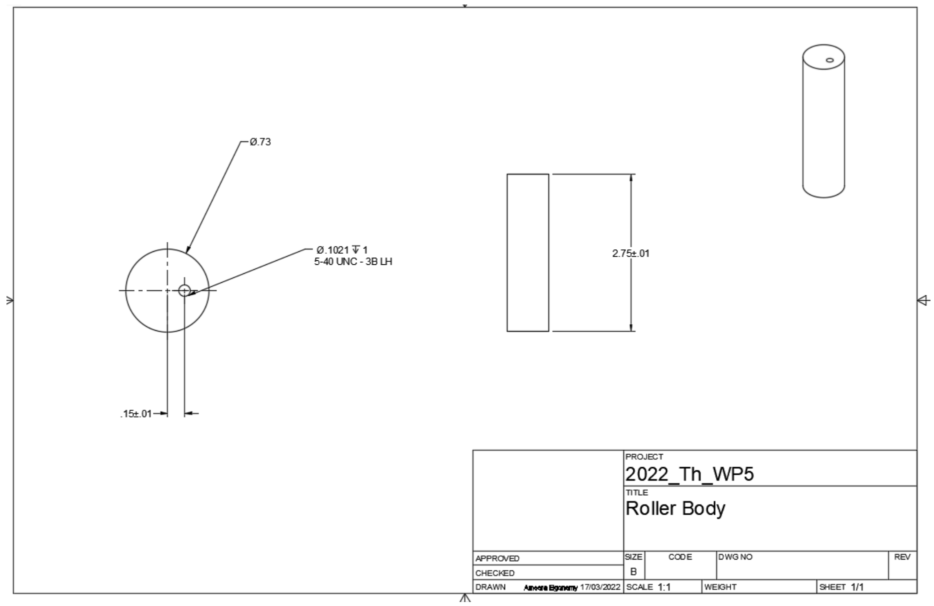


Figure 8c: Roller Sleeve

Material: Delrin
Stock Source: McMaster Carr
Manufacturing Technique: Bandsaw
Length: 2.7 inches
Tolerancing: .005in

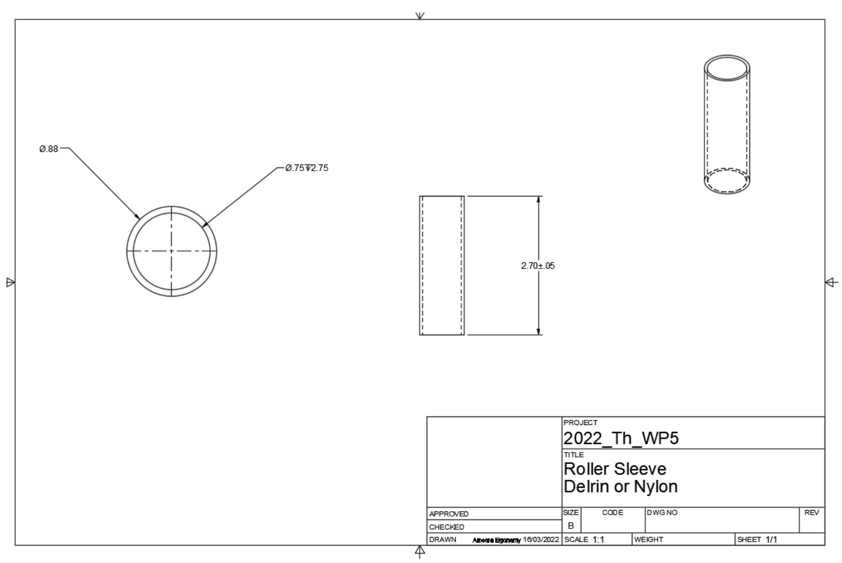


Figure 9a: Exploded View

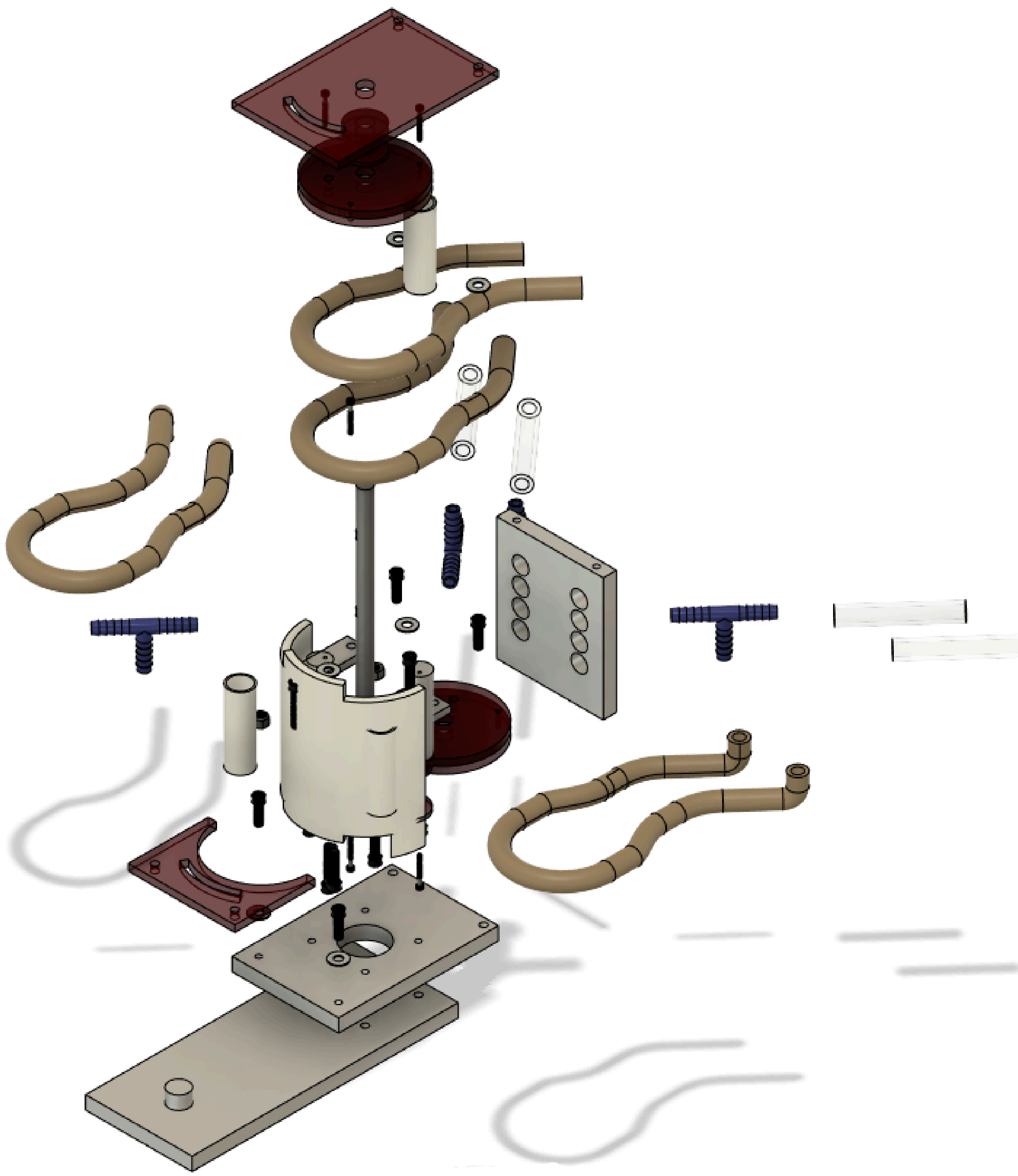


Figure 10a: Full Rendered Model, Top View

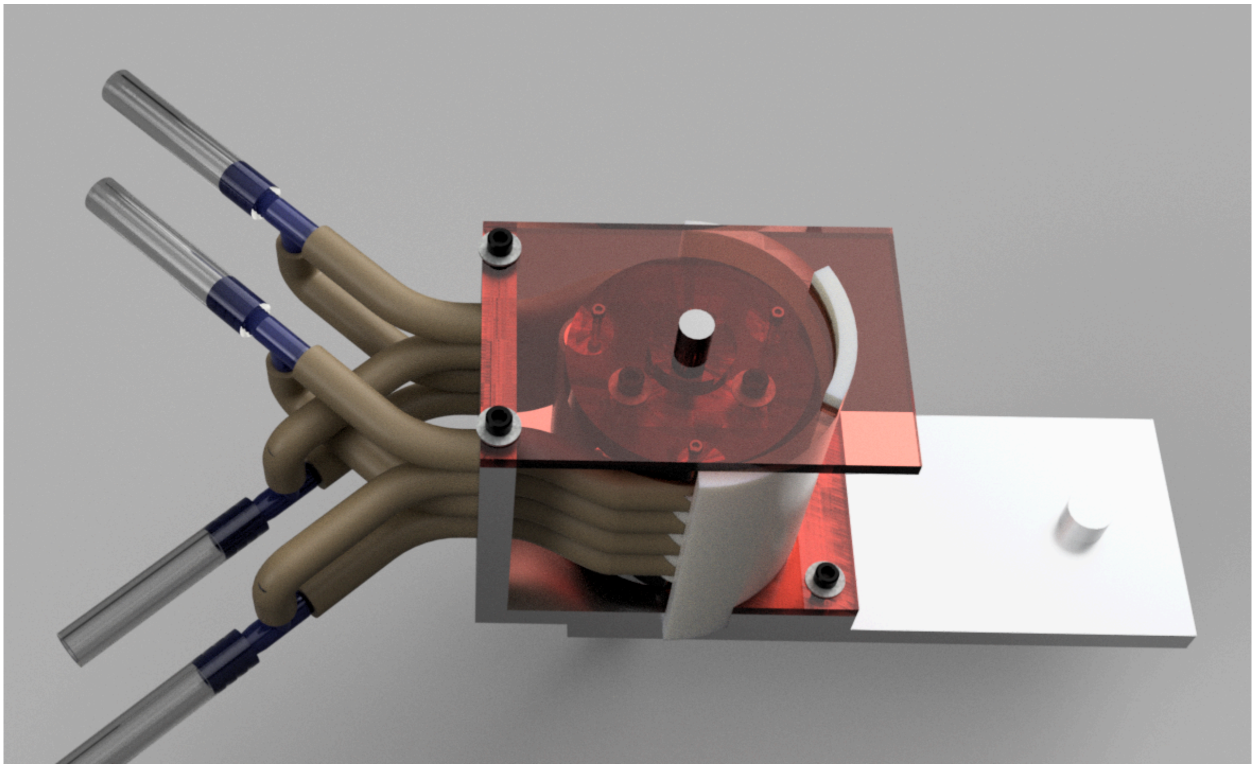


Figure 10b: Full Rendered Model, Rear View

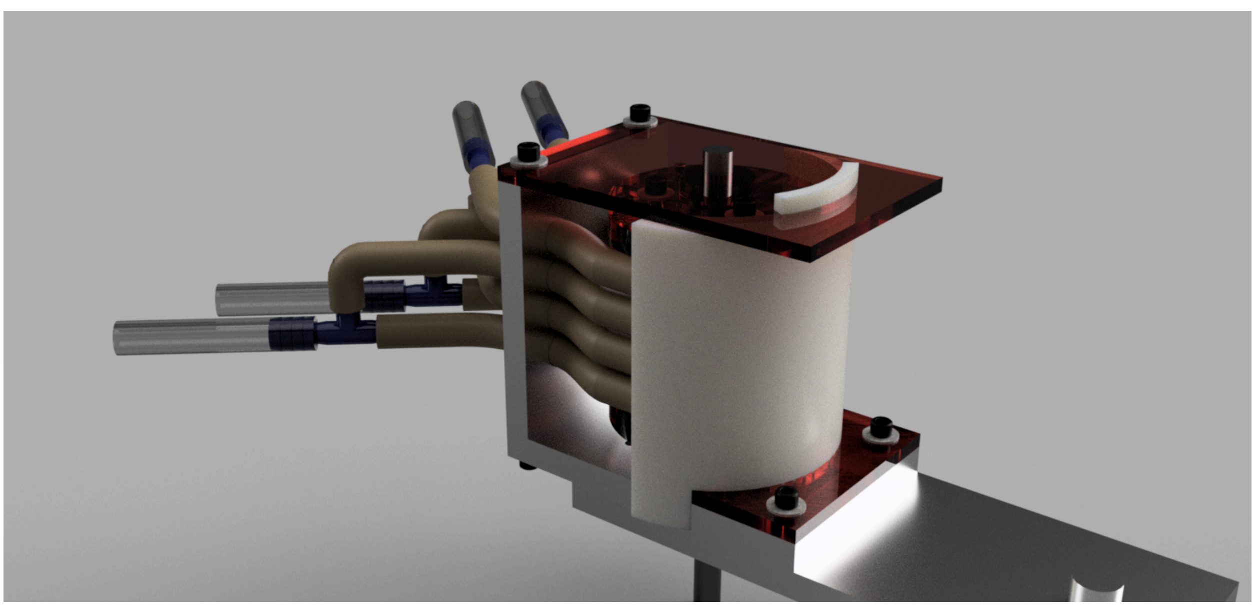
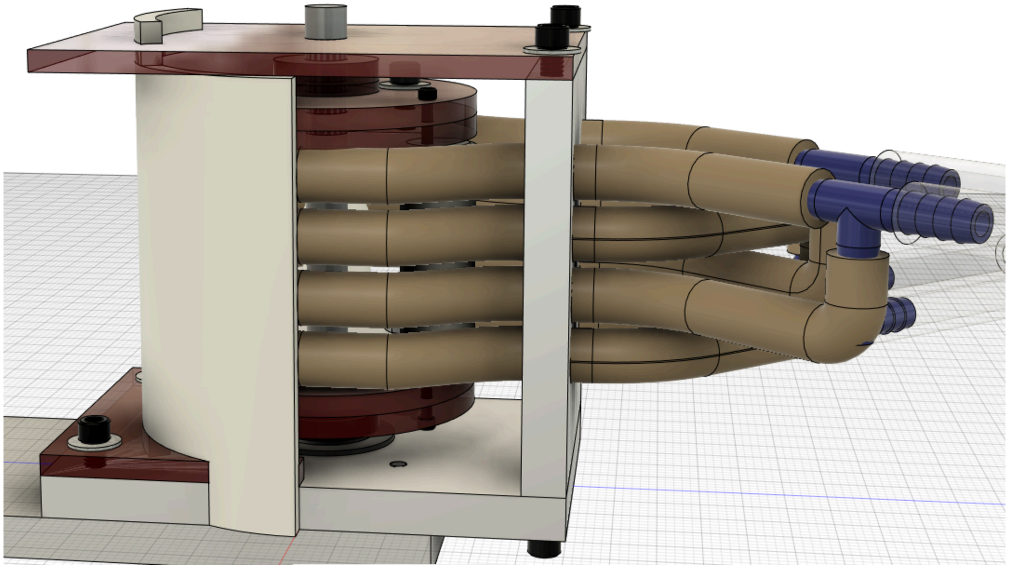
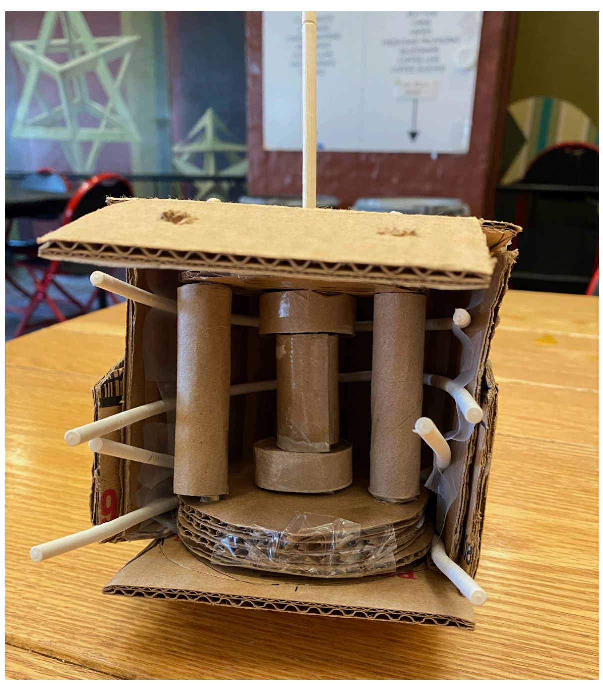


Figure 10c: Side view



Paper Prototype

Fig. 11a: Paper Prototype



Images of Final Product

Figure 12a: Final Product Side View:

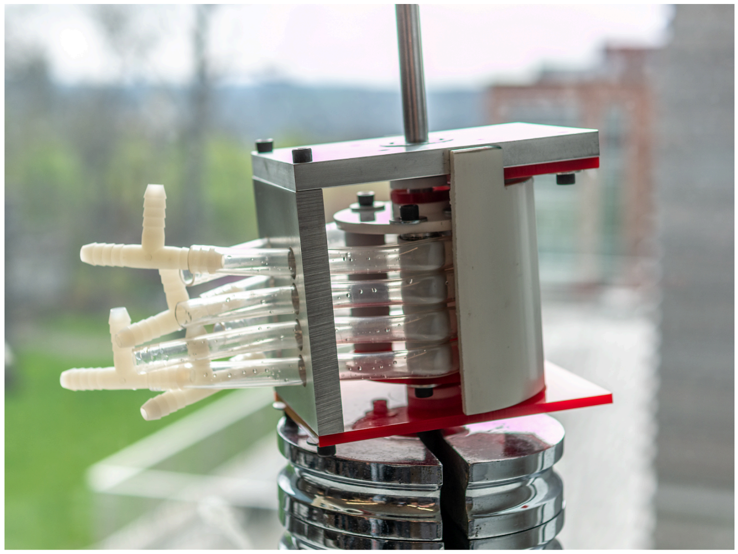


Figure 12b: Final Product Front View:

Figure 12c: Final Product Rotor Detail:

Original Team Charter

To: Prof. Guy Hoffman, Julia Ahrens, and Matthew Menis
From: Team 5 Members Evelyn Chiu, Ben Dodson, Alex Eagan, Ameera Elgonemy, Gabriel Ewig, and Jeff Tung
Date: March 15, 2022
Subject: Team Charter

Team 5 Members	Email
Evelyn Chiu	ewc55@cornell.edu
Ben Dodson	bzd4@cornell.edu
Alex Eagan	aje58@cornell.edu
Ameera Elgonemy	aae39@cornell.edu
Gabriel Ewig	gre27@cornell.edu
Jeff Tung	jt563@cornell.edu

Team Logistics and Coordination

Document Storage and Communication

The team will use Google Drive for sharing and storing text documents, images and other files. Slack will be used to communicate while not together, and team members should send short updates to the general Slack channel once individual tasks have been completed. Fusion 360 will be used for CAD designs and drawings, and all relevant files will be stored in the shared Fusion folder. With all of these mediums, team members are expected to follow reasonable naming and organization structures to make sure that different files are easily accessible and understandable by other members of the group. All members of the team will check the Slack channel and text group message at least once a day Monday through Friday, and will check Google Drive and Fusion 360 as needed. For urgent communication, text messaging will be used.

Outside Resources

Zotero will be used as a citation manager to store and cite relevant sources in any final reports that the team turns in. Because not all team members have experience with or currently use Zotero, links to relevant sources will also be stored in a shared Google Doc that everyone has access to. Gabriel Ewig, as the documentation coordinator, will be responsible for periodically keeping Zotero up to date and making sure that resources the team has used show up in any final publications.

Meeting Times

The team plans to meet on Tuesdays at 7:00 pm in Upson Hall. Exceptions to this meeting are prelims and individual conflicts, and when these arise, the team member with the conflict will notify the other members via Slack. The team's backup meeting time is Thursdays at 5:15 pm in Upson Hall. A general When2Meet link has been sent to the team Slack to coordinate other times to meet if necessary.
At the end of each meeting, the team will confirm the next meeting's time and location to ensure that every member is on the same page.

Teamwork and Collaboration

Specialized Skills for Each Member

Evelyn Chiu is skilled at organization and managing team progress and deadlines. She is a current team lead for her project team, so she has experience managing different trades, ensuring every team member understands expectations, and tracking project progress.

Ben Dodson has used Autodesk Inventor for multiple years and is well acquainted with the basics of CAD and design. He has specialized in CAD for large and complex assemblies on his project team as well as the integration of these assemblies.

Alex Eagan has confidence in his ability to machine using the mill based on his previous manufacturing experiences. Additionally he is familiar with the coordination of efforts to produce a working system from incorrectly manufactured parts.

Ameera Elgonemy frequently uses CAD (Autodesk Inventor) for her project team. She also has experience leading a team, ensuring that reasonable deliverables are set, and tracking an individual's process as she was a subteam lead for her project team.

Gabriel Ewig has additional experience machining with the metal lathe. Last winter, he learned to use the lathe and worked on a number of hobby projects using one at a local maker space in Ithaca.

Jeff Tung is experienced with innovative design and has generated many concept sketches. He is experienced with Autodesk. He is also confident in his ability to use the metal lathe based on prior experiences.

Schedule Coordinator Responsibilities: Evelyn Chiu

Evelyn Chiu will be the schedule coordinator. This position requires ensuring that each team member understands expectations and deadlines for design and manufacturing; the schedule coordinator will manage a calendar of manufacturing and design deadlines and assign deliverables to each team member that can be completed within a reasonable time frame.

Finally, the schedule coordinator will ensure that every team member understands the progress of another team member before each individual deadline by managing and updating the team's Gantt chart.

Design Integrator/Coordinator Responsibilities: Ameera Elgonemy

Ameera Elgonemy will be the Design Integrator/Coordinator. Her responsibilities include managing the manufacturing of components and assigning different team members parts and assemblies for the water pump. She will also overview the creation of specific parts and assign members specific components and parts of the pump assembly to complete. Finally, she will integrate the overall design of the different water pump components.

CAD Lead: Ben Dodson

The CAD lead will be the coordinator of the overall CAD design for this project. They will review the overall assembly to ensure that the entire assembly is coherent and functional. Additionally, they will guarantee that there are no missing fasteners, conflicting parts, or interferences. Although individual members of the team will be personally responsible for specific parts, the CAD lead will ensure that these parts will assemble correctly and are feasibly manufacturable.

Documentation Coordinator: Gabriel Ewig

Gabriel Ewig will be the documentation coordinator for the project. He will keep track of the resources and information that the team generates and work towards making sure that they are easily understandable and accessible to team members and other people that might look at the project. Although writing assignments and content are the responsibility of all members on the team, Gabriel will be responsible for coordinating this work and making sure that individual team members have the resources they need to complete it.

Mill Lead: Alex Eagan

The mill lead would be the coordinator of the production and usage of the mill machine. He will reiterate to their group members the basic steps and rules one should follow when using the mill to limit as many accidents as possible. He will also overlook shop drawings regarding the mill.

Lathe Lead: Jeff Tung

The lathe lead would be the coordinator of the production and usage of the lathe machine. He will reiterate to their group members the basic steps and rules one should follow when using the metal lathe to limit as many accidents as possible. He will also overlook shop drawings regarding the lathe.

Other Design and Manufacturing Responsibilities

All members are expected to contribute to the CAD and manufacturing of individual parts that will go into the overall assembly. Members will present their individual designs for a part to the rest of the team before manufacturing. All members are expected to contribute to all reports, presentations, and collaborative documents.

Consequences and Expectations

Consequence for Missing an Internal Deadline

Team members should make every effort to meet internal deadlines and communicate progress with the team. If a team member is unsure they can meet a deadline, they should communicate with the other group members to ask for help or find ways to redistribute the work before it becomes too late. If a team member misses an internal deadline without prior notification or proper justification, they will be required to bring food for the entire team in the next meeting.

Grade-Impact Consequences

If a team member commits an egregious offense and incurs a grade-impact consequence, evidence of this offense will be sent to Professor Hoffman, Julia Ahrens, and Matthew Menis within three business days of the offense. Documentation of the offense will include: the specific violation of the team charter or violation of another agreement and evidence of the violation. Evidence can include, but is not limited to, blank or missing work, a group photo at a team meeting with a missing member, or unfinished/incomplete work. All members of the team will be CC'd on this email.

Draft Schedule

Water Pump Schedule

NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	PCT OF TASK COMPLETE
1	**Week 1**				
1.1	Team Charter	All	3/10/22	3/18/22	100%
2	**Week 2**				
2.1	Team Meeting/Checkup	All	3/13/22	-	100%
2.2	Paper Prototype	E, G	3/14/22	3/17/22	100%
2.3	CAD Model/Parts Drawings/Animation	Al, Am, B, J	3/13/22	3/17/22	100%
2.4	Fabrication Plan/Parts List/Cost Analysis	Al, Am, J	3/13/22	3/17/22	100%
2.5	Team Meeting/Checkup	All	3/16/22	-	100%
2.6	Final Presentation	All	3/13/22	3/17/22	100%
2.7	Final Design	All	3/13/22	3/17/22	100%
2.8	Order Parts	E	3/17/22	3/18/22	
3	**Week 3**				
3.1	Rotors (Laser Cut, 2)	Am	3/17/22	3/29/22	
3.2	Rollers (Lathe)	G	3/19/22	3/29/22	
3.3	Lego blocks, Keyed Shaft (Mill)	Al	3/22/22	3/29/22	
3.4	Base (Mill)	B	3/22/22	3/29/22	
3.5	Walls (Mill)	J	3/22/22	3/29/22	
	Pipe (Hacksaw)	E	3/24/22	3/29/22	
3.6	Team Meeting/Checkup	All	3/22/22	-	
4	**Week 4**				
4.1	All Machined Parts	All	3/17/22	3/29/22	
4.2	Final Assembly	All	-	3/29/22	
4.3	Testing	All			
4.4	Team Meeting/Checkup	All	3/29/22	-	
4.5					
5	**Week 5** *Spring break btwn Week 4 and 5				
5.1	Finished water pump	All		4/14/22	
5.2	Analysis/Reflection	All		?	

DESIGN AND EARLY MANUFACTURING			MANUFACTURING AND TESTING		
WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6
S M T W R F S	S M T W R F S	S M T W R F S	S M T W R F S	S M T W R F S	S M T W R F S
6 7 8 9 10 11 12	13 14 15 16 17 18 19	20 21 22 23 24 25 26	27 28 29 30 31 1 2	10 11 12 13 14 15 16	17 18 19 20 21 22 23

This schedule contains all the dates of the team's meetings outside of class, as well as all major due dates that the class requires. Internally, this schedule contains the team's due dates for designs and manufacturing, as well as design, manufacturing, and testing cycles.

Desired Grade

The team has discussed the grade that she/he desires for the pump project and understands the expectations that have been set forth. The team understands that each member needs to perform to the best of their abilities and that if for any single item the member in charge does not believe will be completed to the grade desired, the team will discuss alternatives and/or compromises for said item.