Project Deliverable C
Detailed Design and BOM

GNG2101 [D]
Introduction to Product Development and Management for Engineers and Computer Scientists

To
Professor Rubina Lakhani
Project Manager Cecilia Lou

By
Saksham Kohli 300241798
Sharmark Mohamed Said 300291042
Nick O'Brien 300109435
Alec Plourde 300108326

Submission Date: February 7th, 2023

University of Ottawa
Faculty of Engineering

Table of Content

Introduction **2**

Client Feedback **2**

Detailed Design **3**
- Assembly 3
- Parts 4
  - Shoulder Platform 4
  - 2” Pipe 5
  - Pipe Fitting-Spring Connecting 6
  - 6” Pipe 7
  - Base Plate 7
  - Compression Spring 8
  - ¼”-20 Thread Nut 8
  - 8” Stainless Steel Bolt 9
  - 4” Stainless Steel Bolt 9

Bill of Materials **10**

Required Skills and Resources **11**

Time Requirement **11**

Product Assumptions **12**
- Manufacturing/Cost Assumptions 13

Conclusion **13**

Introduction

In this report, our team will be expanding on our chosen concept by outlining a detailed design which will include material selection, dimensions, and a list of how each part will be manufactured. In addition, our team will list our bill of material to manage our budget of 100 dollars and will also double as a parts list with a link showcasing where the part was acquired from. Client Feedback was also received from our client during client meet 2 on February 1st which will be outlined below

Client Feedback

The second client meeting for concept generation went very well. The problem statement, client needs, and various concepts were presented for feedback and comments. The client first helped us elaborate on a few missing needs and metrics that could help us fully understand our device requirements. A few key aspects that he mentioned were the response/setup time for the device as a new metric, along with the addition of emphasizing the ability of our device to assist with the exercise motions as a need. Upon sharing our concept ideas, our client had no personal favourites and this also allowed us to gain a new perspective on concept ideas. For example, restricting the right (working) arm to match the left arm is a possible alternative solution. Upon showing our final concept, the client was pleased with our idea and emphasized the importance of deciding on appropriate TRL ratings before starting the next deliverable.

Detailed Design

Assembly

In this section, a CAD model assembly of our design will be shown including all parts. A detailed drawing showing all three views and an isometric view can be found below. For a more in-depth view of each individual part, please see the parts section. All parts will be connected via screws or nuts and bolts.

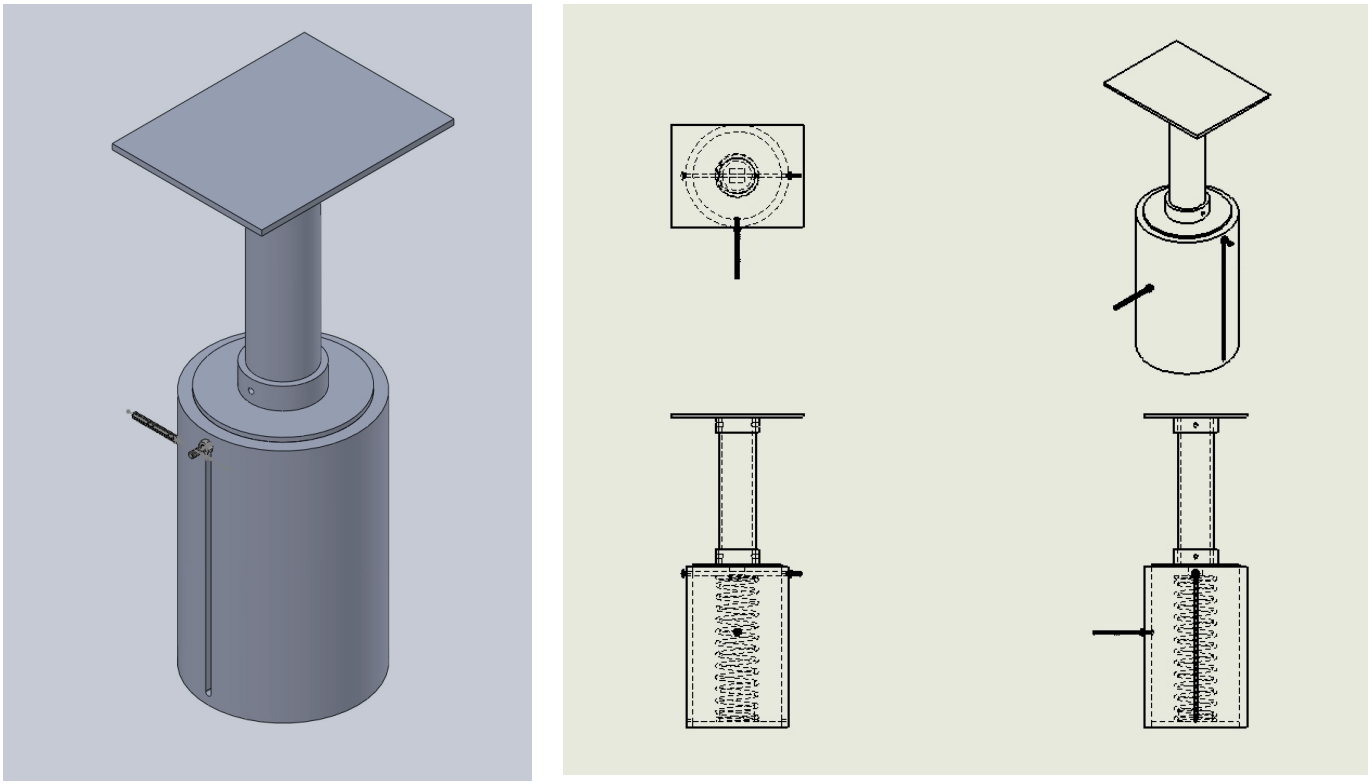

Figure 1: Engineering Model and Drawing of Part Assembly

Parts

In this section, all part drawings will be shown with appropriate dimensions and an isometric view. Each subsection will show its corresponding part. All parts purchased from McMaster Carr have their respective drawings from the website shown below and all links to the source can be found below in the Bill of Materials. All documents below are in IPS.

Shoulder Platform

To manufacture this part, we will be laser cutting the shoulder platform due to its flat geometry and to avoid the risk of warpage seen in the large flat plates during 3D printing. We will then be 3D printing the 2” pipe fitting (same pipe fitting as the pipe fitting-spring connection part) which will be printed due to its 3-dimensional shape and flaps will be added to ensure we can screw the fitting securely to the disk.

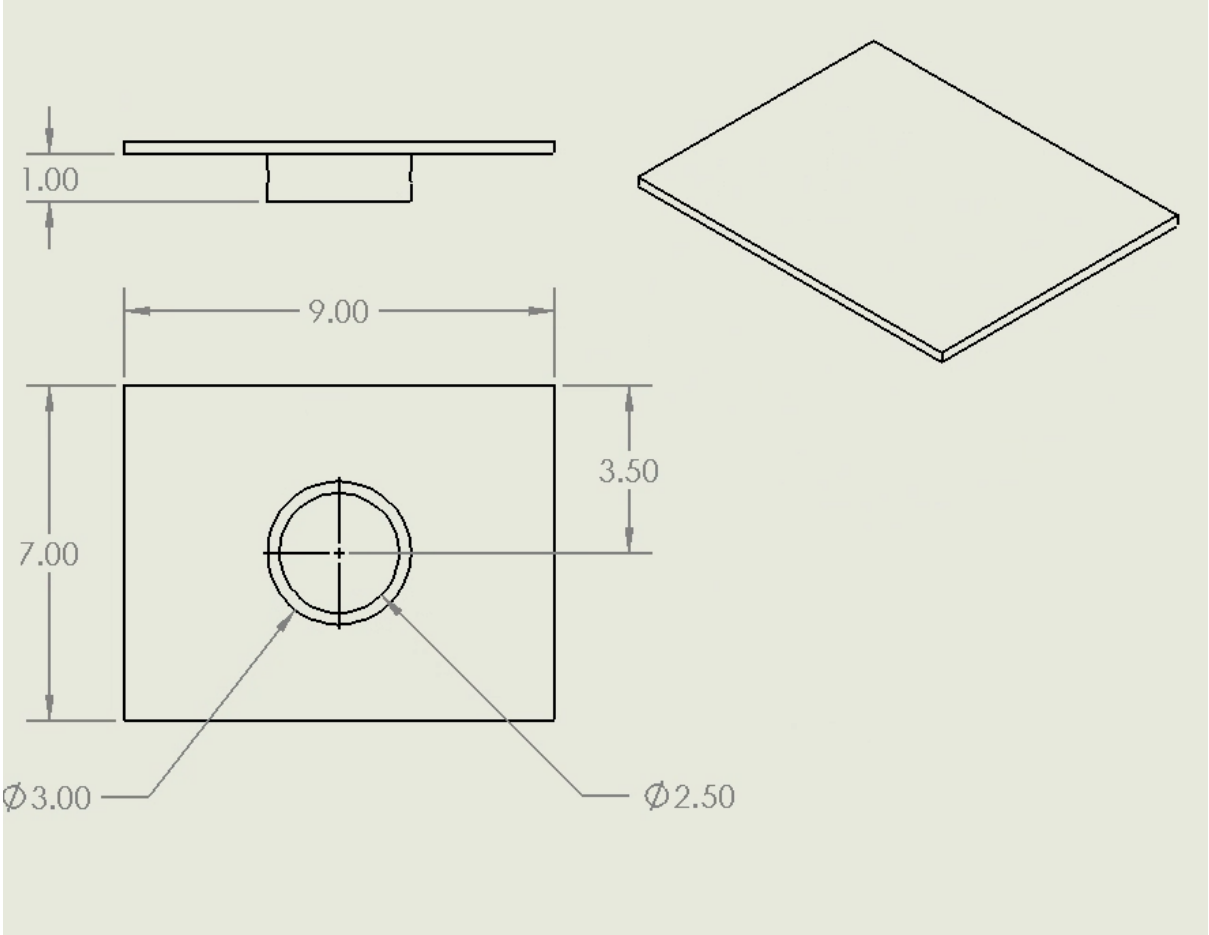

Figure 2: Custom Shoulder Platform Engineering Drawing

2” Pipe

To Manufacture this part, we will be cutting the 2” pipe (4’ in length) to our desired length of 10”. Once our pipe has been cut, we will be drilling 4 holes using the drill press into the side of the pipe as seen below 0.5” from the edges which will be where the bolts secure the pipe to the rest of the assembly.

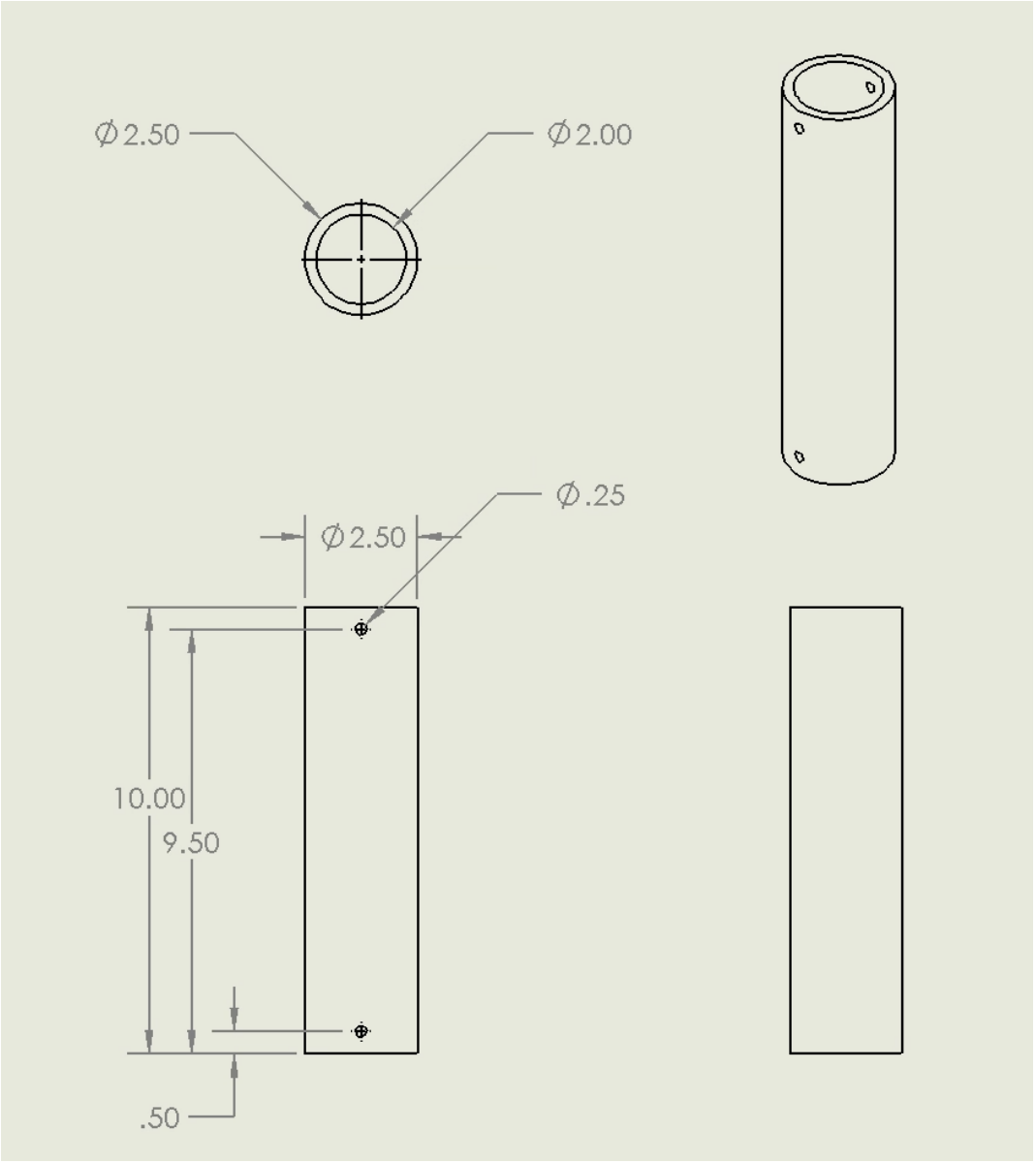

Figure 3: 2” Custom Pipe Engineering Drawing

Pipe Fitting-Spring Connecting

To manufacture this part, we will be laser cutting the 6” disk since it will be much easier to get such a big and flat surface area cut instead of running the risk of warpage incurred when 3D printing parts of similar shape. We will then be 3D printing the 2” pipe fitting (same pipe fitting as the shoulder platform) and the pin clevis on the bottom of the disk due to their more complex geometry but we will be adding flaps to the bottom of these two parts to screw it on securely to the laser cut disk.

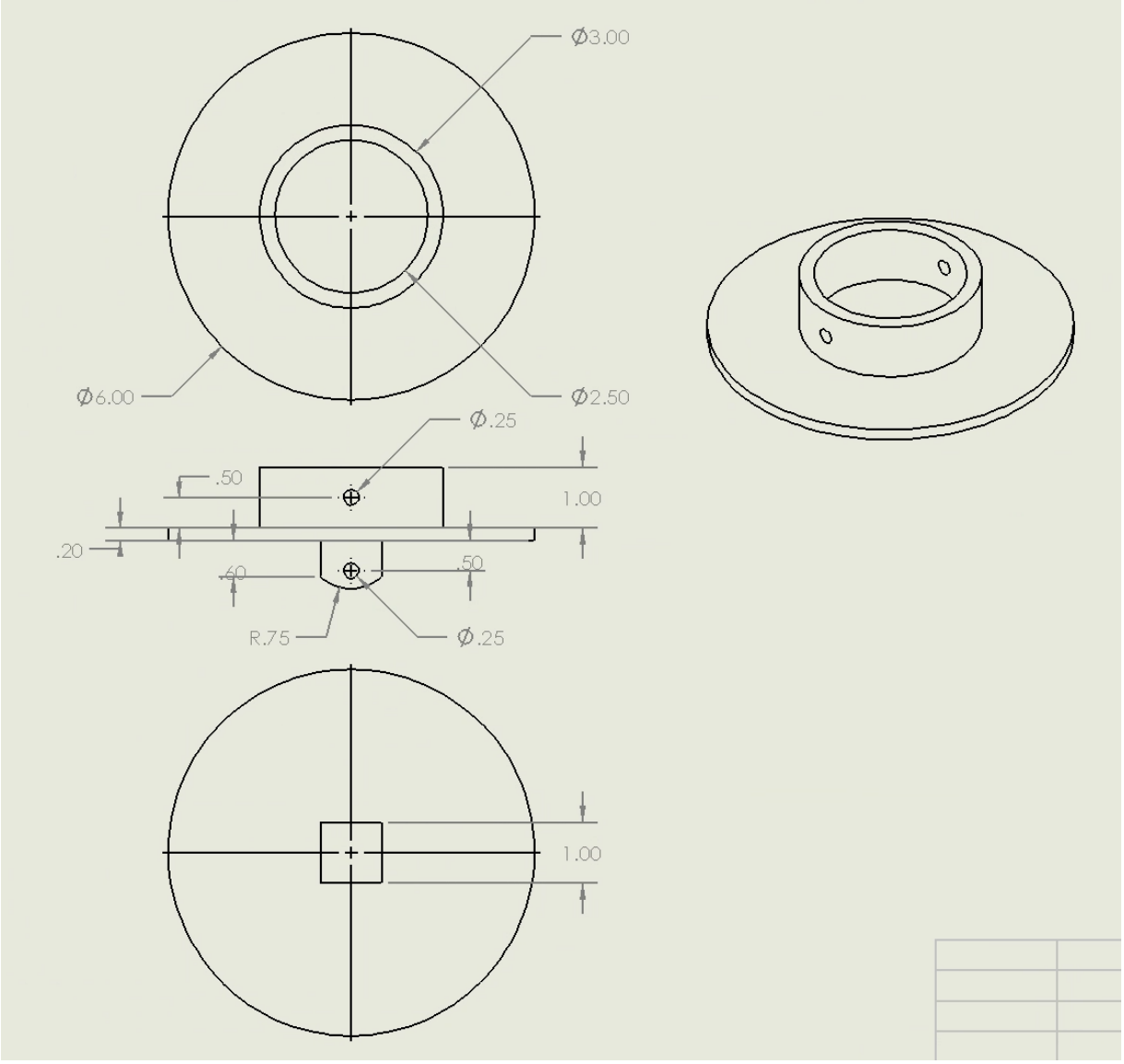

Figure 4: Custom Connection Part Engineering Drawing

6” Pipe

To manufacture this part, we will be taking our 6” PVC scrap pipe and we will be first milling two slots (0.25” x 10”) into the sides of the pipe which will be used as the mechanism to control the vertical movement of the platform and spring. Once these two slots have been milled, we will drill the hole for the handle 6.5” from the bottom of the pipe.

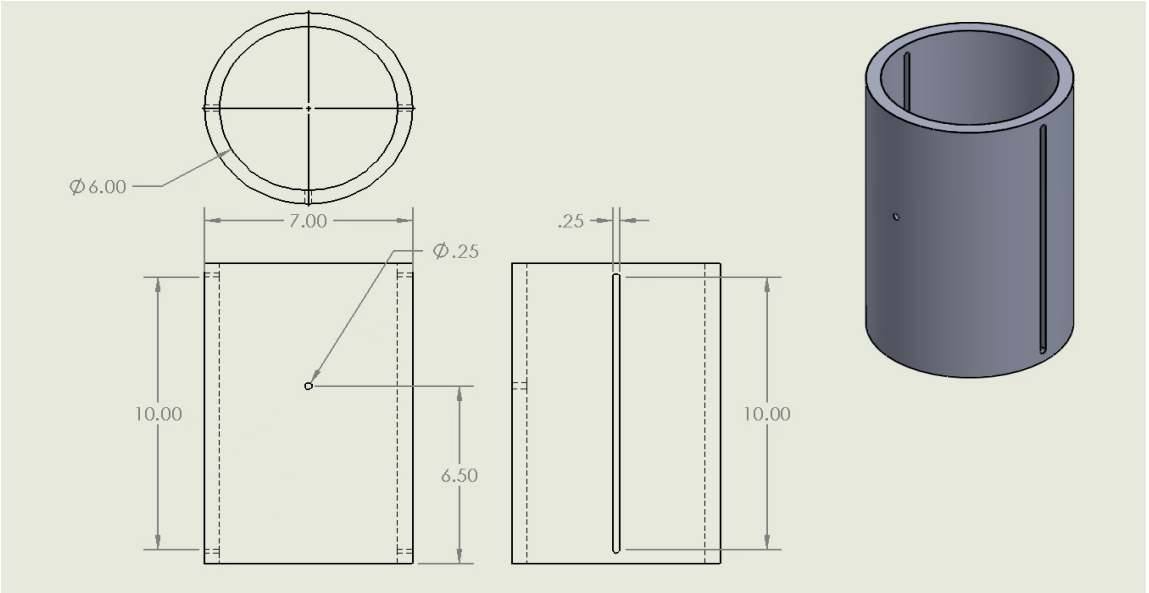

Figure 5: Custom Pipe Engineering Drawing

Base Plate

To manufacture this part, we will be laser cutting three disks of ⅜” thickness. Two of the disks will be 2.34” in diameter (these two disks will be stacked on top of each other) and the last disk will be 6” in diameter. To connect the three disks together, we will screw them together.

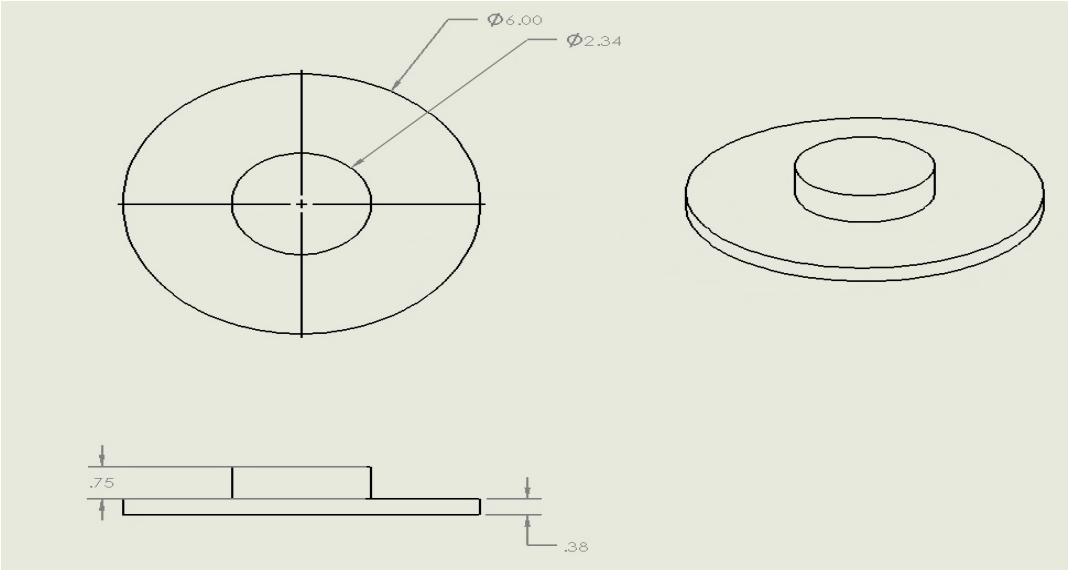

Figure 6: Base Plate Engineering Drawing

Compression Spring

This part will be purchased from McMaster-Carr.

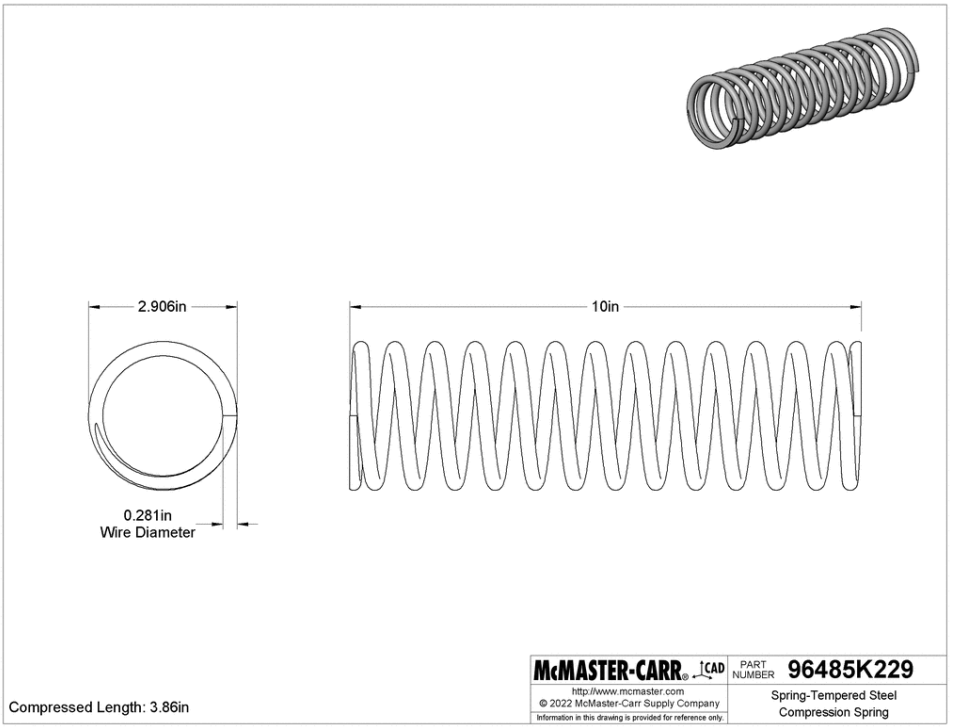

Figure 7: McMaster Carr Compression Spring Drawing

¼”-20 Thread Nut

This part will be purchased from McMaster-Carr.

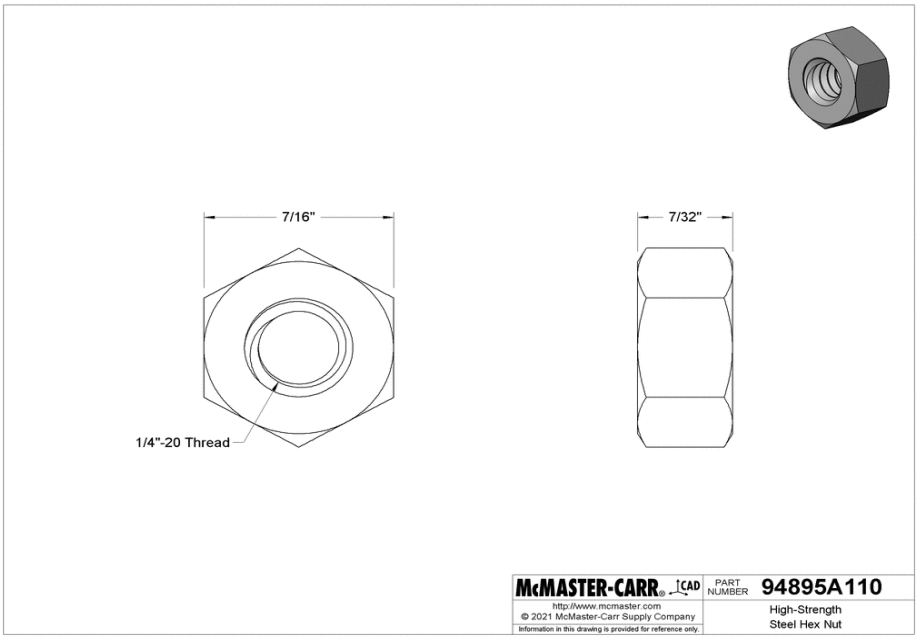

Figure 8: McMaster Carr Thread Nut Drawing

8” Stainless Steel Bolt

This part will be purchased from McMaster-Carr.

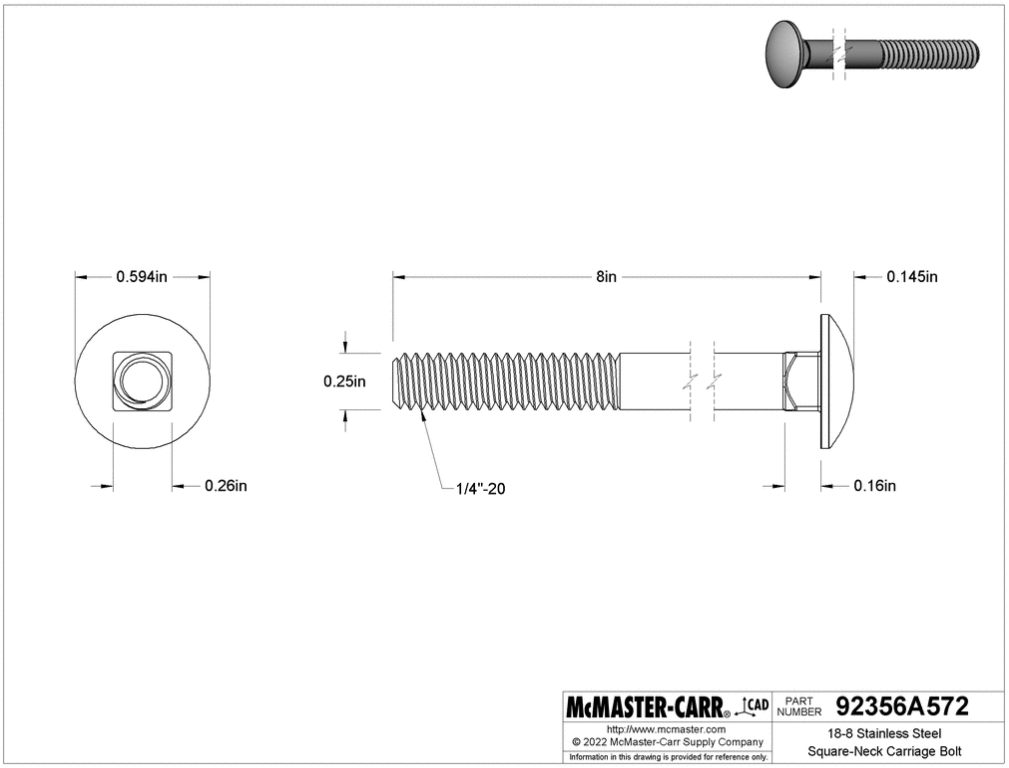

Figure 9: McMaster Carr 8” Stainless Steel Bolt Drawing

4” Stainless Steel Bolt

This part will be purchased from McMaster-Carr.

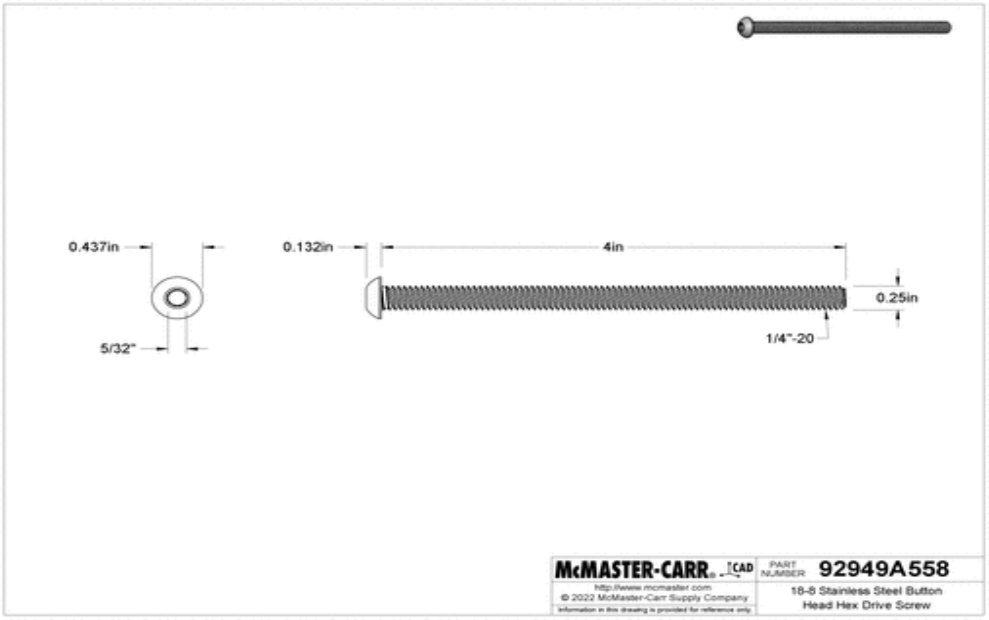

Figure 10: McMaster Carr 4” Stainless Steel Bolt Drawing

Bill of Materials

Table 1: Bill of Materials

Parts	Quantity	Unit	Cost	Link
1 foot 6” PVC Pipe	1	EA	$0	Repurposed Scrap
2” PVC Pipe	1	EA	$5.49 + ($9.97 Shipping)	Lowes
Compression Springs 10” Long, 2.906” OD	1	EA	$27.75	McMaster
8” Stainless Steel Bolt	1	EA	$5.84	McMaster
¼”-20 Thread size Bolt	4	EA	$6.00/100 Bolts	McMaster
4” Stainless Steel Bolt	3	EA	$8.31/10	McMaster
Pipe Fitting	1	EA	$0	To Be Laser Cut
Base Plate	1	EA	$0	To Be Laser Cut
Shoulder Platform	3	EA	$0	To Be Printed
Laser Cutting Cost			$0.55 *	
3D Printing Cost			$5.40*	
Price			$69.31	
Price (Include HST)			$78.32	

*See Manufacturing/Cost assumption for laser cutting and 3D printing cost assumptions and calculations

Required Skills and Resources

For our final conceptual design, various skills and resources are required to complete and manufacture each working part. A few of the various resources/skills available that will help with our design can be seen below:

- Manual Mill: The manual mill at the Brunsfield centre will be used in order to create the 10” x 0.25” slot on each side of the main 6” pipe for our device. This slot is necessary in order to allow for proper movement of the connecting bolt. Proper knowledge and skill will be required to precisely cut a slot on both sides of a cylindrical shape.

- Laser cutting: The laser cutter in the Makerspace will be used for a variety of parts in our design. For the base plate design (see Parts section), the laser cutter will be used in a 3-step process. We will first laser cut the main 6” diameter plate with a maximum laser thickness capacity of ⅜”. The second and third steps of the process

are to laser cut two identical plates of 2.34” in diameter. Each piece will comply with laser cutter capacity as their thickness will be 0.375”. The assembly of the base plate system will require basic hand tool knowledge/skills to successfully screw all three pieces together. The same main 6” disk will also be cut to use for the pipe fitting-spring connection piece.

- 3D printing: The 3D printers in the Makerspace will be used for two separate parts in our design. Due to the need for specific 3D parts, we will not be able to laser-cut certain parts. We will be 3D printing two 2” pipe fittings which will go onto the shoulder platform and on the pipe fitting-spring connection and we will be 3D printing a makeshift rod clevis which will connect the bolt into the slot on the 6” pipe to the platforms.

- Drill Press: The drill press at the Brunsfield Center will be used to drill numerous holes into our pipes to allow for bolts to be installed to safely fix our parts together. A ¼” hole will be drilled into the 6” section to install the bolt for the handle. Four separate ¼” holes will be drilled into the 2” pipe so we can bolt both ends of the pipe to the shoulder platform and to the custom pipe fitting. Finally, two more ¼” holes will be drilled into our custom pipe fitting to connect to the 2” pipe using a nut and bolt.

Time Requirement

To estimate the time required to complete our final prototype, we decided to split up the final prototype into steps which are part approval, part manufacturing, part assembly, and assembly testing. The part approval step is the first step to our final prototype process which involves getting our parts approved in addition to the lead time on receiving the parts. We estimate to have all our parts approved by February 14th and accounting for reading week, we estimate to have received all parts by February 28th. The part manufacturing step is the next step in the process. In total, we have three parts that need to be drilled, one part that needs to be milled, two parts which require laser cutting and one part which requires 3D printing. In total, we estimate the machine shop work to take at most one full day of time. During this day in the machine shop, we will hopefully be simultaneously printing and 3D printing our parts but gaining access to the 3D printer in the Makerspace can sometimes be challenging so we will estimate these tasks to take three days to print and laser cut. Once all our parts have been manufactured, we can begin assembling our parts. All our parts are fairly simple and only require nuts and bolts to assemble which should at most take us one more full day to accomplish. The final step in this process will be the testing phase. This step will be a more rigorous step to which we would like to allocate a full week. Our team would like to ensure that our product satisfies all our design criteria and target specification and to do this, we will conduct numerous tests over a week using our high-fidelity, physical comprehensive prototype.

Product Assumptions

Table 2: Product Assumption

Types of product assumption	Severity	Likelihood	Explanation

Resources	High	Low	We believed that by the time we're building our product all materials, tools, equipment, and teammates will be there. This assumption could be changed in the future if we can't obtain what we need to conduct our product or if some of our team members aren't in their best condition or don't show up for unknown reasons. The chances of this happening are low due to us always communicating and knowing all the materials, equipment, and tools we need very well.
Adapt to changes	High	High	We assumed that if our solution doesn't work or if the product we build is limited to functionality that we would probably change some stuff in order to make it work. We're very aware that what we planned for our project won't go the way we intended and we're very sure our project will have changes to it.
Cost	High	Medium	Currently, we assumed that our final cost would be $78.32 which is much less than our cost target but that could be changed later in the future if some materials don't satisfy our solution or if we want extra materials. We believe that we'll manage to spend under $100 for our product. The cost is definitely something that will change by the end of our final product.
Unplanned work that must be accommodated	High	low	There will be moments when team members are unable to do tasks that were assigned to them due to them being sick or being absent. In those moments, we'll have to get that work done. As a team, we help each other and believe that this type of product assumption won't have a major effect on our design since we have experienced this kind of problem.
Time	Medium	low	We have been keeping track of submitting the deliverables on time and we believe that we'll get all work done on time later in the future. Being unable to stay on track with the deliverables or not getting work done on time would have a major effect on our project.
Skills/Tools	Medium	Low	When doing our prototypes we'll need skills that are required to get the tools we need to do our prototypes. We assumed that all team members know how to use a 3D printer, mill, laser cutting, and drill press.
Product Functionality	Medium	Medium	Our plan is to create a functioning product for the client and we assumed that we'll have a fully functioning product at the end of our project. That assumption might not become possible since we

			might have some aspect of our product that doesn't function. The severity of this type of assumption is medium since we're fine with having some parts of the product that don't function.

Manufacturing/Cost Assumptions

To estimate our price for manufacturing our parts using 3D printers and laser cutting, we will be assuming that the cost of PLA per gram is $0.05 and the price for a sheet of MDF is approximately $20 for a sheet of 4' x 8' x ⅜". For our laser cut parts, we need two 6" disks (28.27 in^2/disks) and two 2.34" disks (4.3in^2/disk) and a platform of 9" x 7" (63in^2) for a total of 128.14 in^2 of material. A full sheet of MDF is 4608 in^2/sheet which puts our cost at approximately $0.55. For 3D printing, we are utilizing the industry average of $0.05/g of PLA. From Solidworks, we are able to see we will need to print 5.319 in^3 of parts. Since PLA has a density of 1.24 g/cm^3 which is equal to 20.31996 g/in^3 for a total of $5.40.

Conclusion

In conclusion, from our second client meeting, we learned to broaden our design approach along with ensuring we clearly understand the needs of the client. With the feedback in mind, we solidified our design concept with specified details about each individual part. From our design, we were able to break down each individual piece along with how it will be constructed/assembled together. This has been expressed with clear explanations along with detailed engineering drawings and 3D models. Each section of this deliverable also clarified the skills and resources required to accomplish and build our device. A few of the highlighted resources required are- the laser cutter, the 3D printer, and the manual mill. In order to ensure our design concept was feasible in regards to our designated budget, a detailed BOM was constructed with a total of $78.32 calculated which clearly fits inside our allocated budget. Another crucial aspect in determining the feasibility is the time required to build our device. A detailed plan was outlined which highlighted a few weeks to obtain all materials, along with a few days to build and assemble our design. Lastly, a full week was assigned to thoroughly test each aspect of our prototype to ensure its functionality. An estimated breakdown of prices per part was also created to better indicate where the money will be used. Finally, as a group, we accessed our final design by listing all assumptions we will be making towards the success of our project.