ENGINEERING

McMaster University

Project Four – Power in Community:

Designing a device for a painter who experiences lymphedema:

"Qsupport"

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial T10

Team Fri-09

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Submitted: April 14, 2021

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Academic Integrity Statement

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Executive Summary

After attending the client visit sessions, the following problem statement was generated: *"Design a device to assist a client who experienced previous ailments resulting in chronic pain, to hold up their arm and relieve strain while painting in their home environment. As a result, will allow them to paint with one hand, freeing their second hand"*. It was clearly identified that the client's livelihood of painting is very difficult with her current ailments and pain. This problem statement helped our team develop a device which will provide the client freedom in using her non-dominant hand while the device supports her painting arm, providing relief and comfort so that she may paint for a longer duration minimizing discomfort. The final prototype, titled "Qsupport" provides the client with support and freedom as it will support the arm that she paints with and no longer needs to use her other hand as a support. This in turn will maximize her productivity, ease the client's chronic pain, and increase and the amount of time she will be able to paint as she will be in a more comfortable state in comparison to using both her arms.

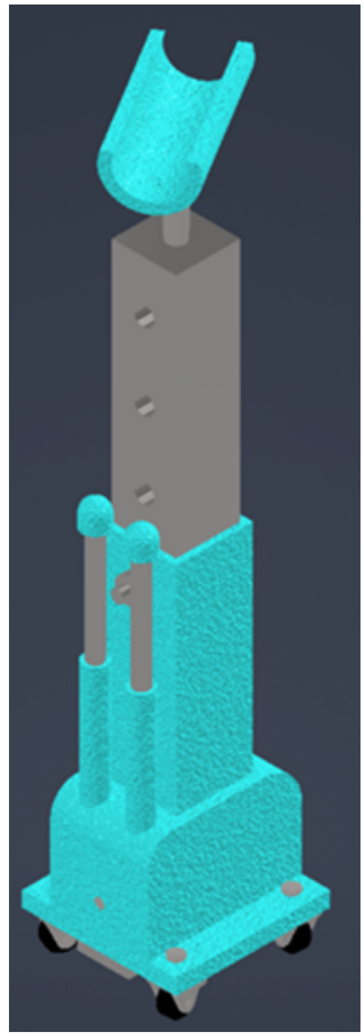


Figure 1: Qsupport Device

The final prototype is a mobile support which gives the client omnidirectional motion as she paints. In addition to support, this device also gives the client freedom with her second arm as she paints with her dominant arm. The final design consists of three main features. The main arm brace, adjustable heights, a 2-dimensional hinge, and a unique breaking mechanism [Figure 1.]. The main arm brace is located at the top of the design and is where the client will place her arm. The brace is lined with silk, which is the preferred material for the client's skin, which will maximize her comfort as she paints. The design also includes adjustable heights at 4 different levels which allow the client to paint on a variety of different size paintings. A 2-dimensional hinge connects the brace to the main stand, which allows the client to move her painting arm in the X-Y plane, which allows her to freely paint across the plane of the canvas. The final benefit of this prototype is the locking mechanism, which implements a lock for the wheels of the device. The locking mechanism utilised the clients body weight to lift and drop and anchor as to the preference of the user.

If the team were provided with more time and resources, it would be the priority to facilitate the development of a tangible prototype. The team would at the very least create a 3-D printed model on a smaller scale to understand the device and its mechanisms. Additionally, there are a variety of wheels, materials, and structure that the team to utilise rather than being limited to the materials available on Autodesk. Having a physical aspect to the prototype would also help the team understand the feasibility and set realistic goals for specific materials. A physical prototype would also help the team understand the motion and how the user would interact with the device. As a result, a physical model would also help the team develop practical and efficient test plans which would likely include physical testing through a set of testing users. The most important aspect of a physical prototype would be the ability to get valuable feedback from the client which would help improve the design and its mechanisms. Additionally, the next steps for the team could also involve a stress simulation and even an aerodynamic simulation. These simulations would be able to help the team draw important conclusions on the viability of the design, which can in turn help the device reach its maximum potential.

Introduction

The client is a painter who experiences chronic pain as a result of Lymphedema and Fibromyalgia. Lymphedema is a condition where parts of the body begin to swell, which is caused by the weakening of the lymphatic system. Common symptoms include swelling, feeling of tightness, aching, stiffness, and reduced movement in affected areas. Fibromyalgia on the other hand includes muscle fatigue, joint rashes, unrefreshed sleep, trouble thinking or remembering, cramps in the lower abdomen, headache, and depression. The client reports that throughout a painting process, they may need to shift their position from standing, sitting, and all the way to having to lie down to cope with the discomfort she experiences. Particularly, the client must often hold up one arm with another arm, to alleviate pain and continue with their painting. These issues strip the control they have over when and how long they paint – many times being forced to stop by their body.

Therefore, it was the team's responsibility to provide a solution by answering our refined problem statement: "Design a device to assist a client who experienced previous ailments resulting in chronic pain, to hold up their arm and relieve strain while painting in their home environment. As a result, will allow them to paint with one hand, freeing their second hand". From this, the team up came with the main objectives of: Comfort, Convenience of Mobility, and Sturdiness. Comfort was chosen to alleviate existing pains or discomforts the client experience. Convenience of mobility so that adjusting positions or poses would be easy instead of adding to further troubles. Sturdiness so the device can survive multiple, and frequent usage and movements. The team did not encounter many hard constraints, the only one being that the client could only lift to a maximum of 2 kgs. More 'broader' constraints – that fall more into objectives category, includes: smaller size to avoid intruding on client workspace, must be moveable in all 360 direction to avoid hindering painting abilities, and that it must have a height adjusting system.

Existing ideas/solution centered around supporting arms of client mostly do not account for the client's specific situation. Compression sleeves exist to encourage circulation around the arms by a targeted compression at specific muscle areas [1], however this has proven by the client to be ineffective – and otherwise does not directly support their arms. A similar but more direct method is that of inflatable supporting layers. Refer to figure 2. Where an inflatable tube is attached to a joint that needs supporting and provides a soft cushioning that is easy to inflate/deflate.

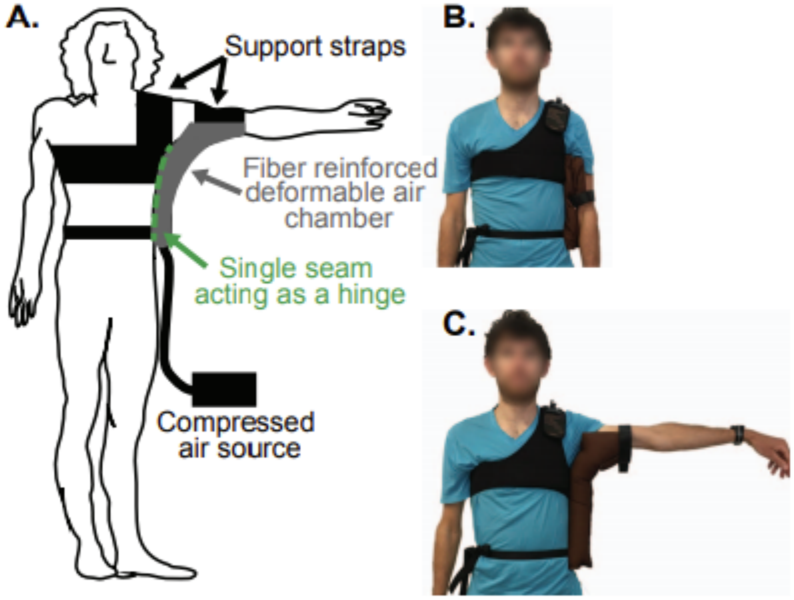


Figure 2: Inflatable tube mechanism

The issue, however, is that this doesn't account for movements that the client must be able to do.

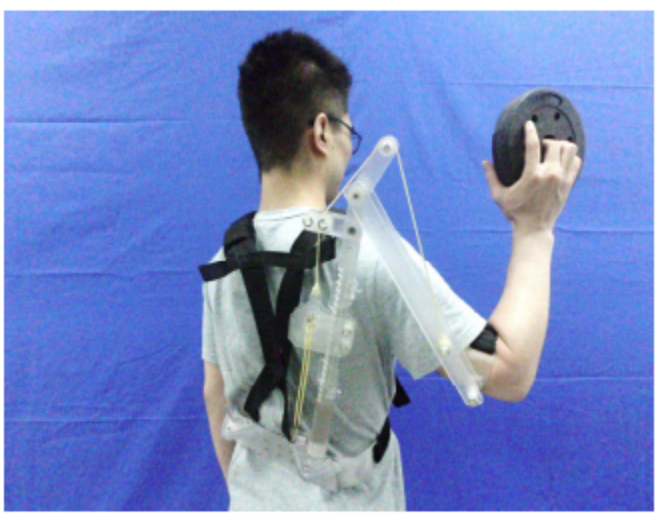


Figure 3: Rigid motor support mechanism

Methods that do account movement is another mechanism that straps directly to the back of the user and provides motion support through motors. Refer to figure 3. This mechanism is especially designed to help bear weight and lift objects, which initially seems perfect for the situation. However, team Fri-09 does not have access to motors/systems, and the client cannot support the device on their back without pain – making this option also unusable.

Mostly existing supporting mechanisms either do not account for movement, or are done with complex electrical motor systems, or do not account for the client's full body health obstacles.

Conceptual Design

When hearing about the client's physical limitations, we had thought of many different devices that we can create to help our client with everyday hobbies or chores. Some ideas for gardening, cooking, and other areas of painting. After listening to the client's story and how painting heals her, we decided that a device to help with the client's painting is the best thing we can create because that is one of her daily activities.

Our reason for choosing the morph chart for our functional analysis is to easily convey and visualize our product's functionality and explore alternative methods of achieving our goal. After discussion, we found out that our group consisted of visual learners. Hence, we decided that a morph chart would be the best method for the whole group to be on the same page while giving every member a strong understanding of the functions and respective means. Once we decided on picking an arm rest for our client, we had to think about our main functions and the means to these functions. [Refer to figure 8.] For our arm support, all our means were focused on comfortability as one of our main objectives. For the adjustability of our device, we focused on how our client can change the height of the arm rest. For our transportation method, we were deciding how our client can move the device around after device use. All our functions relate back to our objective tree.

When we originally had our eight concept sketches, everyone created their ideas using their imagination and what they saw in the different means. When we looked them over, we realized our concepts lacked a good way to adjust the height while painting. This was a big problem because we want this device to be very easy to use at any height and angle. We looked through the eight concepts and found one [figure 10 concept 7] that we can easily work with to add height adjustability. We then worked on our refined sketches and each took one of our initial sketches and added more detail to it. Once again, Aidan's design [figure 11 concept 4] matched what we wanted to see in our final design. We looked through all our objectives and constraints and decided that this concept would match perfectly with what we visioned from the start. When we started working on our final design, our biggest priority was to add a 360-degree motion for the arm support itself. This was very important in our design as that function will make this device effective. Once completed, we worked on different ways to adjust the height of the device. We were thinking about using resistance to lock the device. However, we realized that it would take a lot of force to adjust which would be a big problem for our client. We decided on adding four different heights, which would allow our client to draw wherever she wants on the canvas. Adjusting the height involves a plug and four different holes. The client would remove the plug to adjust the height, and then put the plug back in to lock it. It was very simple, secure, and did not need a lot of excess force to use it.

When creating our decision matrix, we started thinking about our main objectives. Therefore, we ended up going with feasibility, comfortability, ease of adjustment, structure, and arm support. Feasibility was how easy the device would be to create. Comfortability is how comfortable the device would be for the client to use. Ease of adjustment is how easy it is to transport the device and adjust the height. Structure is how strong the device is and how long it will take to break. Arm support is how much the top part of the device supports her arm for. We do not want a device that cannot support her arm. When ranking these factors as seen in figure 5, we had a tough time trying to figure out which factors were higher rated than the other ones. We decided to go with feasibility as the highest weighted because if we cannot create the device, then the rest of the factors are useless. Comfort was also very highly weighted because if the device is not comfortable for the client, she will not want to use it and the whole device would be useless. Arm support was also highly rated for the same reason as comfort. If the device cannot support her arm for a long time, it is inefficient and will not be very useful. Although ease of adjustment and structure are low weighted, we believe that all factors are very important for our final design. If one of the factors are not met, the whole device will not be great. Now onto the final weighted decision matrix (figure 9). When giving the scores out for the decision matrix. We started off by picking one design that will be a "base design" that we based our scores off. We also made the designer of the concept rate their own concept first and then everyone put in their input if we should change or keep the scores. In the end, Aidan's design came with the highest score which we agreed on. The refined concept had a lot of potential to add things on it that would make the final product the way we imagined it to be.

We got plenty of feedback from the TA's, IAI's, and science students which we are very grateful for. One suggestion that came up many times was which material are we planning to use. Since we needed to think about that, we asked our materials expert Qais to look at our objectives and create two different graphs on granta. We were either going with carbon fiber or high carbon steel. Although we would've liked to use high carbon steel because of its much cheaper price. The weight of the device would have tripled, so we ended up going with carbon fiber. It cost us a bit more money - however, the noticeable weight difference justified the cost. Carbon fiber is also a very strong material, and this upgrades to increase the strength of the device which gives the device longevity. One suggestion we implemented was a wheel stopper so the device wouldn't move during painting, we felt like this was an essential part. As previously stated, the wheels had to be added so the device is easily moveable, and this suggestion was a great one.

Final Proposed Design

Description of Final Design and how it works

When creating this device, we wanted this to be an easy-to-use tool that the client is excited to use. That is why simplicity was a key consideration for the features. We have three main features that the client will be using. The first is obviously the arm support [figure 14]. The client rests her arm in the designated spot and can freely move her arm in a 360-degree motion. The second feature is the height adjustability [figure 14]. We had many different ideas, but we ended with plug idea. As seen in [figure 14], there are four different heights that the client can choose from. She will put the plug inside the height of her choice, and it will be secured there until she wants to go to a different height. That is, when she removes the plug, adjusts the height and puts the plug back in to continue working. This design is easy to use and does not need a lot for force to remove and put the plug in. Our last feature is the gripper for the wheels. This solves the main problem with the wheels, preventing it to move randomly while our client is painting. Looking at [figure 14], there are two main poles that the client must push to change how the gripper acts. If the client pushes down on the left pole, the gripper pushes down and hits the ground, fully stopping the wheels. If the client pushes down on the right pole, the gripper moves up and the device is free to move again. We could have added only one pole and made it a push/pull system. However, we did not want the client to pull up on the pole as that might take a lot of force that would make her uncomfortable. We decided that pushing down on a separate pole will be much easier, as it allows her to use part of her body strength instead of overexerting her arms.

Specifications

Specification of the device includes height adjustment positions of 136.8 cm, 121.9 cm, 106.9 cm, 91.9 cm, from highest to lowest. These numbers are measured from the center bottom of the inside of the arm holder, down to the bottom tips of the wheels. These numbers were obtained through the comparison of the client's heights to various predicted heights their arm may reach during their painting process. The arm holder itself measures 30 cm in length, as an approximation of a person's forearm. This was obtained through general googles of forearm lengths, as well as measurements of team members. The website "The Physics Factbook" gives data ranging from low 20's to high 20's [2]. As the client has stated that any coverings of their arm should not be restrictive, we have decided an up rounding of the average forearm measurements would be suitable - in this case, 30 cm. Lastly, the devices base was purposefully minimized to take up less space, 30 by 30 cm to not be unbalanced by the arm holder, but no bigger than it.

Objectives / Constraints (Metrics)

According to the problem statement, the team came up with a set of objectives to tackle all complications the client has been encountering.

The first objective was the Convenience of mobility. We deduced that the device must be convenient in its mobility, both in terms of transport and mechanism movements. The device should be easy to adjust in height or angle so that it can be compatible for any situation the client desires usage in. This will seek to provide an easier alternative to the client having the manually support their arm – and therefore must be more convenient than using their arm. Additionally, if this mechanism is to be versatile in usage and location, it must be easy to transport to any location the client wants. The metric used for convenience of mobility was mass (kg). The weight of the device is important because the client is constrained to only be capable of carrying 5 lbs comfortably.

The second objective was Sturdiness. Sturdiness was chosen as one of the main objectives. It was also chosen as a primary objective during material selection. The main function of our design is to support the client's arm during painting. The device should be strong enough to support the client's arm, and resist deformation from movements of their arm as they paint. Since painting is an activity that takes a long amount of time, the device should be able to resist wear for long periods of time, as many times during the week as the client desires. Especially that the client uses art as a larger part of their lifestyle, the device will likely be used very repeatedly. The metric used for sturdiness is Young's Modulus. Since Young's Modulus is equal to the Stress / Strain (measure of deformation), we can measure stress by calculating the force applied (N), towards a certain area, divided by its respective Cross-sectional Area (mm^2). On the other hand, we can measure the strain by finding the change of length, (L-LO), in (mm), caused by a certain force, divided by initial length¸(LO), also measured in (mm).

Finally, our last objective was Comfortability. Comfortability was chosen because the device should be able to maximize the client's comfort. The client's main complications are the pain they must endure as a process of their body recovering, and it would be counterproductive if the device added more to their discomfort. The device should provide some sense of comfort or relief to the client during the usage. Since painting takes time, the device should provide consistent comfort during long term use – and should allow the client to work for ideally as long as they would like. The metric used for comfort is the density of the cushion (kg/m^3). Generally, cushion with greater density is more comfortable than a cushion that is not densely packed.

Construction / development methods

Our device has been broken down into two parts, an upper part, which represents all the parts above the adjustable support (exclusive), and a lower part, which represents all the parts below the main base (inclusive). Upon this breakdown, we as a team decided to construct, from a material point of view, our upper part of the device differently than our lower part, due to having more constraints allocated at the upper part of the device.

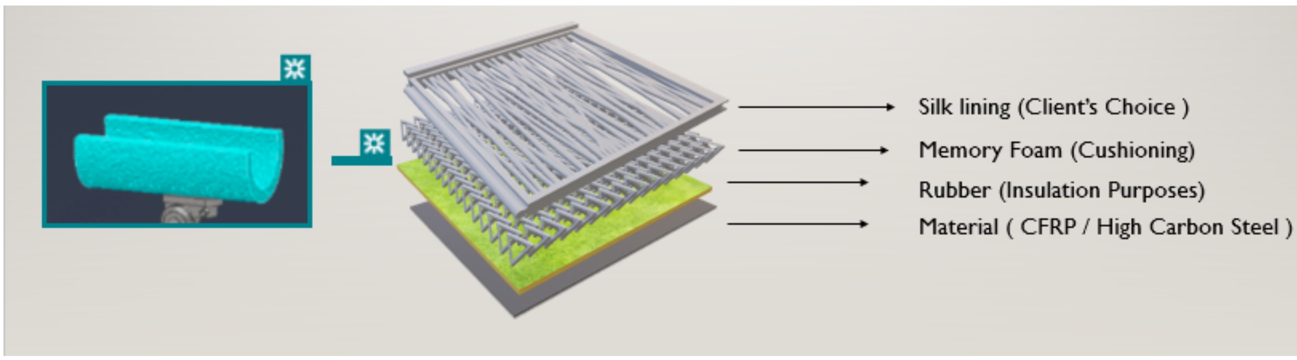


Figure 4: Material Construction for upper part

According to Figure 4, we can see that the upper part consists of 4 layers. First layer is the material layer, which can either be CFRP or High Carbon Steel, depending on the client's budget. The second layer would be a thin layer of rubber, which is used for insulation purposes. Then comes the third layer, which is a Memory Foam layer, which is positioned to increase cushioning, hence increases the client's comfortability. Finally, the last layer is a Silk lining layer, which has been put according to the client's preference, which also tends to increase the client's comfortability.

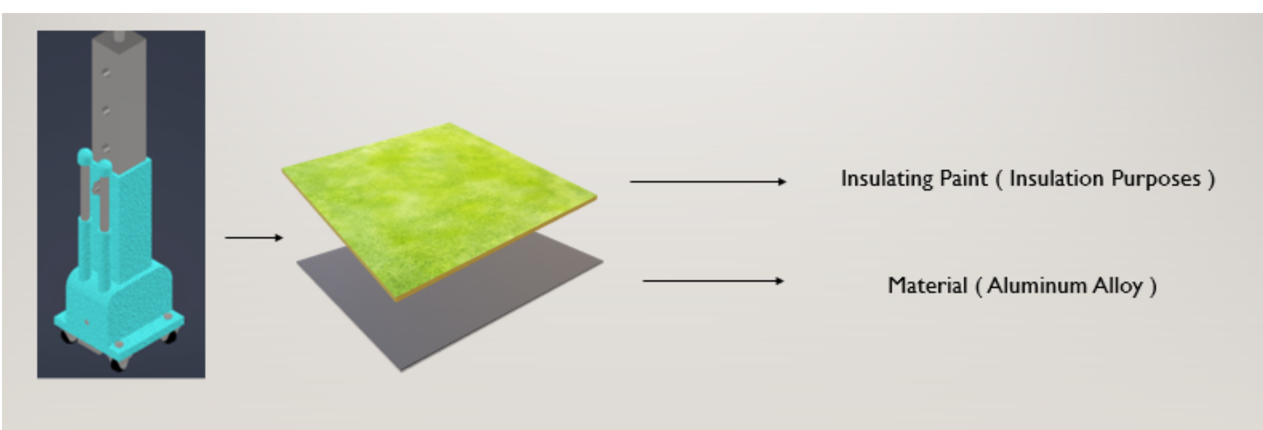


Figure 5: Material Construction of lower part

Looking at Figure 5, we can see that the construction of the lower part consisted of 2 layers. The first layer would be the material layer, which can be either a layer of Aluminum Alloy, or Acetal Resin Black, depending on availability. Reasoning behind choosing a different material than the upper part is that it would benefit our device economical. Aluminum Alloy and Acetal Resin are both considered relatively cheaper than CFRP, and they also satisfy all the objectives retrieved from the problem statement. Lastly, comes a layer of insulating paint, to assure that the device is incapable of conducting electricity.

Having a look at the construction of the Qsupport from a structural point of view, it can be seen that the device consists of multiple parts. The construction of the device can be facilitated through the means of insertion. The main part of the device is the base, which connects 2 parts, the wheels and the adjustable support. The wheels have pegs which are inserted into the base of the device and the adjustable support is inserted into the main shaft of the device. From there, the brace is attached to the adjustable support through insertion of the hinge into both the support and the hinge. The hinge is the main connector between the arm brace and the adjustable support. The rods used for the rubber stopper and the height constraint which limits the height of the device is also implemented through insertion.

Conclusions

Looking back....

Looking back on the project, the team really developed from start to finish. The project started out with a large degree of freedom in the design process and was uncomfortable as the team was only used to specific problems with a relatively fixed solution. With project four came a multitude of different problems experienced by the client, and a variety of solutions which could potentially help her. With the amount of freedom given within this project, the team was able to develop skills in the design process. The team was able to empathize, with the client, which helped develop and define a multitude of problems. After insightful discussion as a group, the team was able to identify one particular problem statement to be the backbone of our design process. From there, we did heavy brainstorming through mediums such as flowcharts, morph charts, the weighted decision matrix. The team dynamic within Fri-09 was the perfect balance of professionalism when it came to our submissions, and casual when it came to team discussions outside of dedicated project time. The team has similar interests and was able to connect with the rest of the group better because of these underlying connections. The group felt as if the design process was perfect with the given time period. One thing that can be changed for the future is the utilization of more brainstorming techniques such as whiteboards or even watching videos on existing solutions to get the teams creative juices flowing. The most important part of the design process are the stages regarding design ideation and problem statement development. The use of creative stimulus during the initial stages would greatly benefit the team and would be considered in the future, for the better the ideation and problem identification, the more effective final device. Overall, Fri-09 was a very resourceful team who utilised all available materials and always took guidance from TA's, IAI's, and peers. Looking back, the experience for the team was smooth sailing from start to finish.

Looking ahead....

While it is true that the team was able to work together and produce a well-functioning device for the client's needs, there are still multiple areas on the design that can be improved if given more time.

One area of improvement pertains to the modelled shapes of the device. The shaping has many areas that can be cut out, decreased in size, or hollowed, to minimize material use and cost, as well as minimizing weight the client lifts during height adjustment. One of the best examples is the center section of the holder, where the device requires the user to unlock the heights, and manually lift or lower to their content before locking. With the client having issues with raising large loads, this section would be a major area to be reworked, and redesigned to be hollowed, and thinner. Additionally, more material can also be removed on many of the edges, producing a rounder and much safer design. The key area where this may apply is the base section, as it is now, the part is sharply rectangular that can turn and spin on the wheels. The perfect foot hazard in other words. This is especially important to avoid as the client is a mother who lives with their children, safety therefore is an important consideration for them.

While the locking mechanism is simple and effective, there could always be more heights that the mechanism can lock to. This will give more height control and options to the client, which may be important to reach all areas on a canvas. This can be done through adding more holes along the sides and wrapping around the middle body sections.

As it is now, the design hits all the functional points, but is both figuratively and literally rough around the edges. Given more time, we believe the team could optimize the design better in terms of weighting, material use, safety, cost, and functionality.

List of Sources

[1] "What are Compression Socks and Sleeves? Your Complete Guide: PRO Compression," procompression.com. [Online]. Available: https://procompression.com/blogs/articles/guide-to-compression-socks-and-sleeves. [Accessed: 13-Apr-2021].

[2] G. Elert, "Size of a Human: Body Proportions," Size of a Human: Body Proportions - The Physics Factbook. [Online]. Available: https://hypertextbook.com/facts/2006/bodyproportions.shtml. [Accessed: 13-Apr-2021].

Appendices

<u>Section 1</u>

Objective Tree:

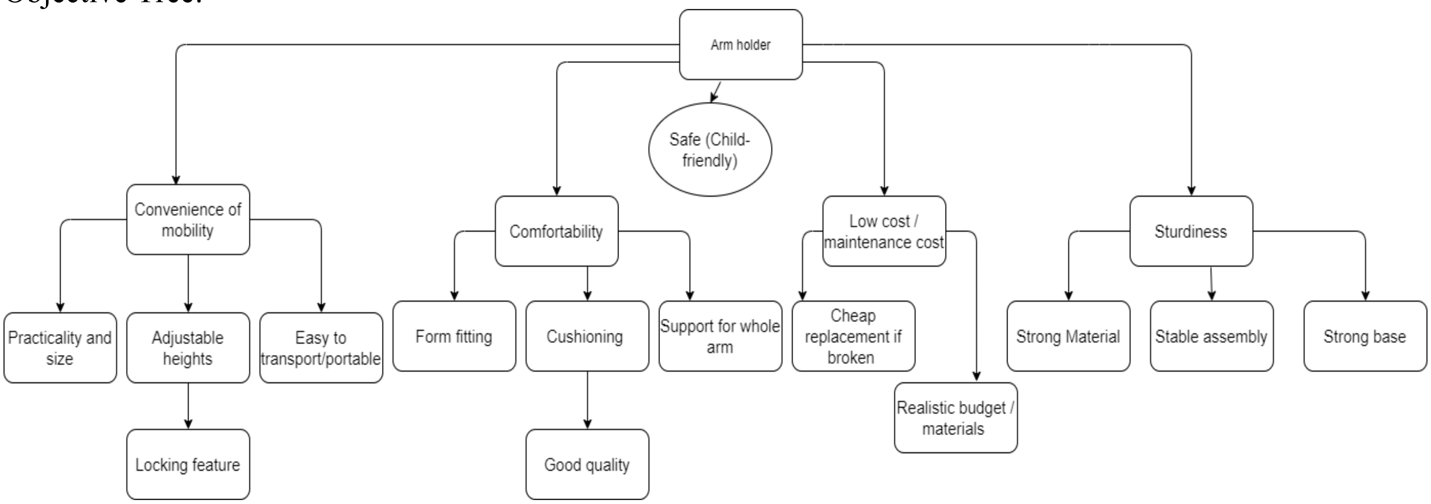


Figure 6. Objective Tree

Figure 7. Client meeting notes

Client meeting notes:

WED Client Visit Notes

Orange text are team comments

Alanna:

- "Do you prefer horizontal or vertical painting on easel"
  - Likes both positions, flat on table top is tricky for joints, not first choice. Depends mainly on day.
  - Paints on whatever surface feels good on moment, which sometimes IS tabletop
    - Good to know what the usual painting surface is.
  - Paints on floor, whole bod on floor besides canvas
- "What are ideal dimensions for something on floor of art space?"
  - Can't come up with ideal dimensions w/out knowing what it is
  - Space between desk and easel behind client is about 4 feet wide, sink to chalkboard wall is around 7 feet.
  - Maximum dimensions that we can make the device
- "How tall are you?"
  - Five foot one and a half
- "When drawing, which part of joint feels most pain?"
  - Depends on what drawing with.
  - Using charcoal/pencil/pencil crayon, can't allow hand to rest on surface at all – since these are materials can't be touched when on paper otherwise for smudging. Pain comes up having to hold her hand to not smudge work.
  - When just sketching, can rest arm which is different
  - Most materials of drawing can't be touched during process.
  - Useful considerations to avoid worsening discomfort
- "What kind of stretching exercises do you do?"

- Yoga
- Based on what body feels that day
- Weight bearing exercises
  - Core work
  - Hand weights
  - Never focuses on same part of body 2 days in a row
- Too high of frequency for any part of body is too much
- Stationary exercise bike
- Sometimes dos more exercises
- Ice Cleats for walking in snow
- Affected by extreme temperatures, pain gets worse
- Sometimes Jiu-Jutsu if feels better

- "Size/area of tightness feeling changes/gets bigger, in terms of lymphedema"
  - Change is by matter of millimeters
- "Favourite paintbrushes? Size of them?"
  - Angled brush bristles allows for more maneuverability for her body n relation to the canvas
    - We can angle our device to allow her to be in a comfortable position
  - Brushes with rounder/sharper tips
    - Doesn't like flatter brushes
    - These brushes feels more like "writing"
  - Smaller brushes are hard to hold and work with
  - Smaller brush = worse cramps
  - Bigger brushes have more to hold onto
- "Would less weight on body help to paint for longer times?"
  - Yes absolutely, which is why client sometimes lays onto ground
  - Perhaps we can someway avoid weight, also applies
- "Do you only use dominant hand/arm or also switch when painting?"
  - Very one hand dominant, not able to paint with left hand
  - Often uses left to hold right
  - Helps us determine what hand to design device for
- "What do you want to do more of in gardening?"
  - Grow own medicine
  - Flowers
  - Experience of gardening in and around home
- "How often do you use medical devices in terms of painting?"
  - Uses vests, garments, sleeves etc almost once every day.
  - Cannot paint without them
    - Helps us determine the amount of space between the client and our device.
  - Cannot weight bear without them.
- (Footage of what medical devices look like are in video, around maybe 1 hour 14 minutes in?)
- Lays side by side of painting, as well use elbows to support (not too clear on this was hard to record down for me)
- Has to constantly shift weight, as body tells client
- Keeps cane right outside bathroom, step stool in kitchen and bathroom, very few accessibility devices I kitchen/bathroom.
- Are days where would prefer to be able to paint in bed, as sometimes client HAS to be in bed.
- "How do feel about Velcro?"
  - As long as not touching skin, it's too rough
    - This is good to know so we know which material to not use

- "Largest painting ever done?"
  - About ten feet by ten feet, mixed media project
  - Largest painting without other components is the one behind her (39 ½ by 39 ½ inches)
- "When do you have more pain? Is there a pattern?"
  - Wakes up feeling spinal column is quite stiff
  - Reduces after doing some movements
  - Pain increases from 4 PM and onward
- "If it's super humid, is there a specific humidity or weather condition affect how you feel on a particular day?"
  - Feels impacted by sudden weather changes, does seem to flare around that time.
  - Hardest is the cold, colder it is, harder the pain is.
  - Heat is better than cold
  - Extreme temperatures of any kind affect the lymphedema
  - Make sure support will not become too warm or insulated
- "Issues doing errands/similar?"
  - Limited by how far can walk, how far can carry
  - Doesn't drive anymore
  - Has to carefully plan out, mobility devices, what can carry, transportation options, budgets in case need of cab or uber
  - Started to task designate more of harder tasks, had PSW help them before quarantine
  - Hardest part is navigating with disabilities in a world where people are expected not to have disabilities.
- "Favourite colour?"
  - Bright colours
  - Sometimes turquoise, sometimes red?
  - Aesthetic considerations
- "Material cause irritations?"
  - No to gluten materials (eg. Paper Mache)
  - Rough edges such as Velcro
  - Preference for cotton and silk
    - This is good for our cushioning material
- Turns painting many times when working on paintings, so they can work on all edges and areas of painting from seated position.
- Helps give better image of work process, if we design any attachments to canvas.
- "Are any paint containers hard to open, how do you manage materials side of it?"
  - Buys paint containers with flip tops
  - Jars are really hard to use/open
  - Has little food containers to contain mixed colours
    - Jars are probably different due to different thread
  - Uses these specimen containers to also contain paint, much harder work to get open
  - In case we want to including any sort of holder, this would be helpful information
- "Difficulties of preparing food?"
  - Difficulty with cutting vegetables, particularly harder ones
  - Tried to have PSW purchase cut versions of cut vegetables
  - Sometimes cooks potato whole before cutting
  - Has a lot of harder vegetables like squashes in family diet, but are so hard to cut
- "When outstretching arm to paint, what is best configuration of paint that causes least discomfort?"
  - When wrist is in alignment with arm, holding wrist at angle increases long term discomfort
- "When painting, are small detail work harder than big strokes?"

    - Yes, harder for joints and muscles
    - Provides additional information on movement in painting, and specifies areas of difficulty
- "Do you feel forced to paint on floor as part of pain or enjoy painting on floor?"
    - Would not paint on floor if not necessary to be able to paint
    - Not first choice to go to
    - Paints on floor for variety of reasons
    - Increases feelings of stabilization
- "When standing to paint, does forearm/arm gets tired or standing gets tired first?"
    - Arm gets tired first
    - Arm exhaustion is a more important point of discomfort
- "What exercises do you do with the ankle weight?"
    - Core exercises, involves different leg lifts and fluttering with core being stabilized
    - Can do a full L set
- "Have you had difficulties with pushing/pulling?"
    - Yes, pushing is easier because can pin arms to body using torso to bear weight of pushing
    - Pulling is harder for lymphedema effected areas. Have no pulled/weaved without pain, discomfort and quitting since diagnosis of lymphedema.
    - Struggles with pushing and pulling vacuum cleaner
    - Considerations of movement, and how client might control/move around device
- "Are plants in window sills or spread out all over the house?"
    - Spread out all over the house
- Does best with symmetry
    - Has hard time walking even with cane if uneven
- Any straps must be not restrictive
- Texture of compressive gear has similar texture of really really thick tights
- Very stretchy
- Vest is nylon, spandex, and…something else? (literally as a quote)
    - Like a bra from movies of 1970s (also literal quote)
- "Opinion on painter's mall stick?"
    - Never used, and doesn't know what it is
    - Stick is used in oil painting, leaned against canvas and leans painting arm on it
    - Still never heard or used it, but thinks it sounds awesome
    - Potential inclusion of design?
- Gripping things with arms outstretch, are cups easier
- "What do you think most intuitive question is?"
    - From all of students who asked questions
    - Questions that allowed client to explore how important it is for them to paint; how much it allows them to be in the world. These questions feel important and gets to heart why this is important to them

Section 2

Figure 8. Morph Chart

Morph Chart:

Function	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5	Mean 6
Support arm	Cushionin g (Wool)	Foam	Table platform	Rope Harness	Cotton and silk	Inflatable component to cushion and support
Adjustable size/form	Locking feature	Moveabl e joints	Force (resistivity)	Buttons	Hinges	Pulley mechanism
Transporta tion method	Wheels to move around	Drag using rope	Sliding feature	Detaching & attaching feature	Pickup handle (Similar to bag)	

Figure 9. Decision Matrices

Decision Matrices:

Weight Matrix

	Feasible	Comfort	*Ease of Adjustment*	Structure	Arm Support	**Weight**
Feasible	1	1	1	1	1	5
Comfort	0	1	1	1	1	4
Ease of Adjustment	0	0	1	1	0	2
Structure	0	0	0	1	0	1
Arm Support	0	0	1	1	1	3

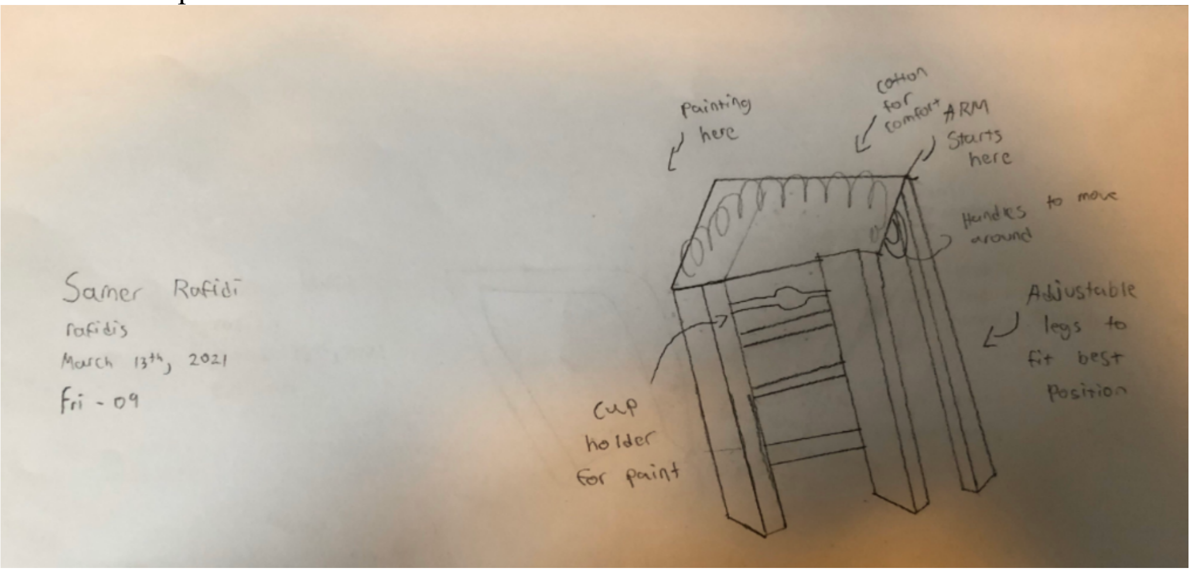
Weighted Decision Matrix

	Weight	One pole stand (Samer)		Xx_Holder_of_Arm_xX_360_Xx (Aidan)		Multi-adjustable Handle (Qais)		Hanging Hammock (Hank)	
		Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Feasibility	5	5	25	5	25	4	20	3	15
Comfort	4	3	12	5	20	5	20	4	16
Ease of Adjustments	2	3	6	3	6	2	4	4	8
Structure	1	4	4	3	3	2	2	3	3
Arm Support	3	3	9	4	12	4	12	4	12
TOTAL		18	56	20	66	17	58	18	54

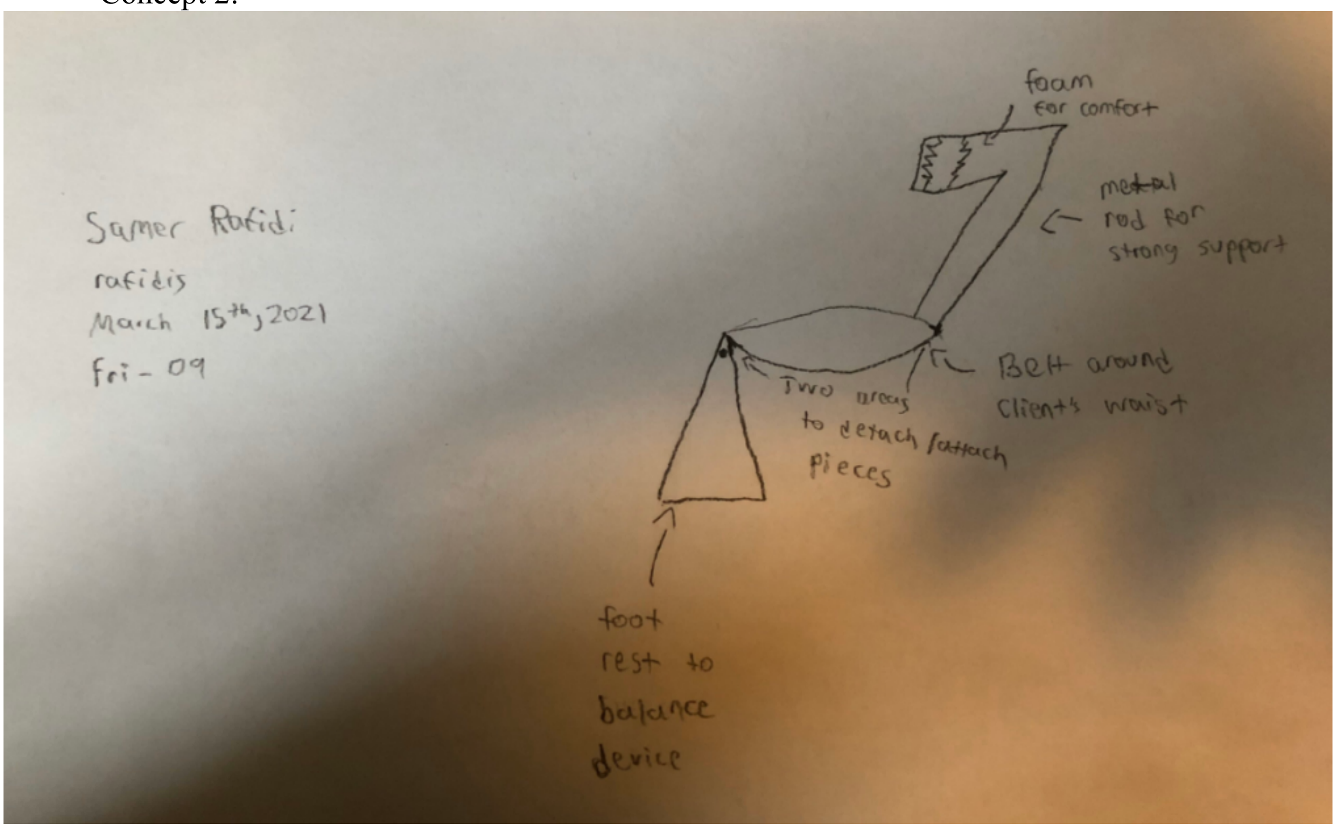
Sketches:

Figure 10. Concept Sketches

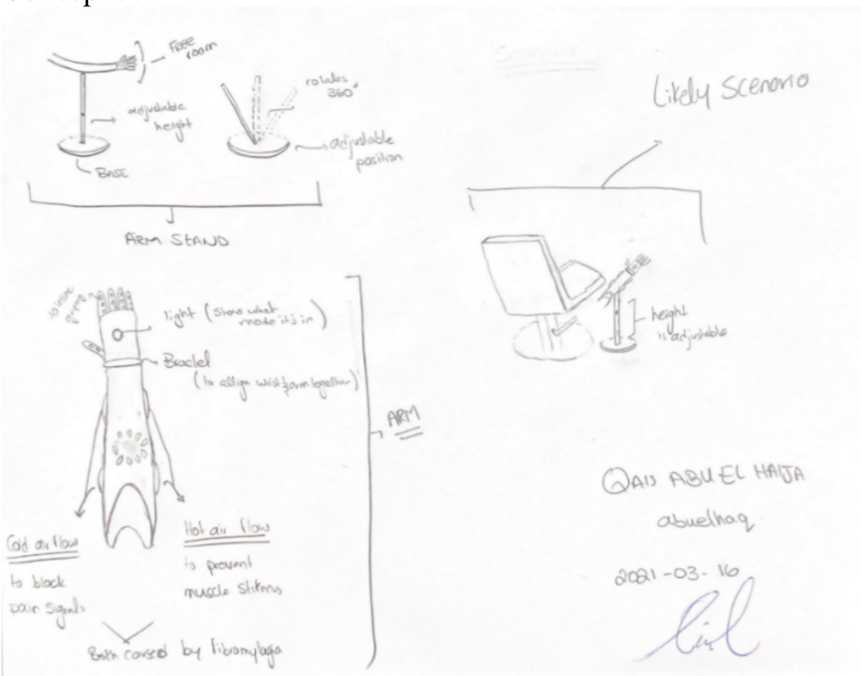
Concept 1:



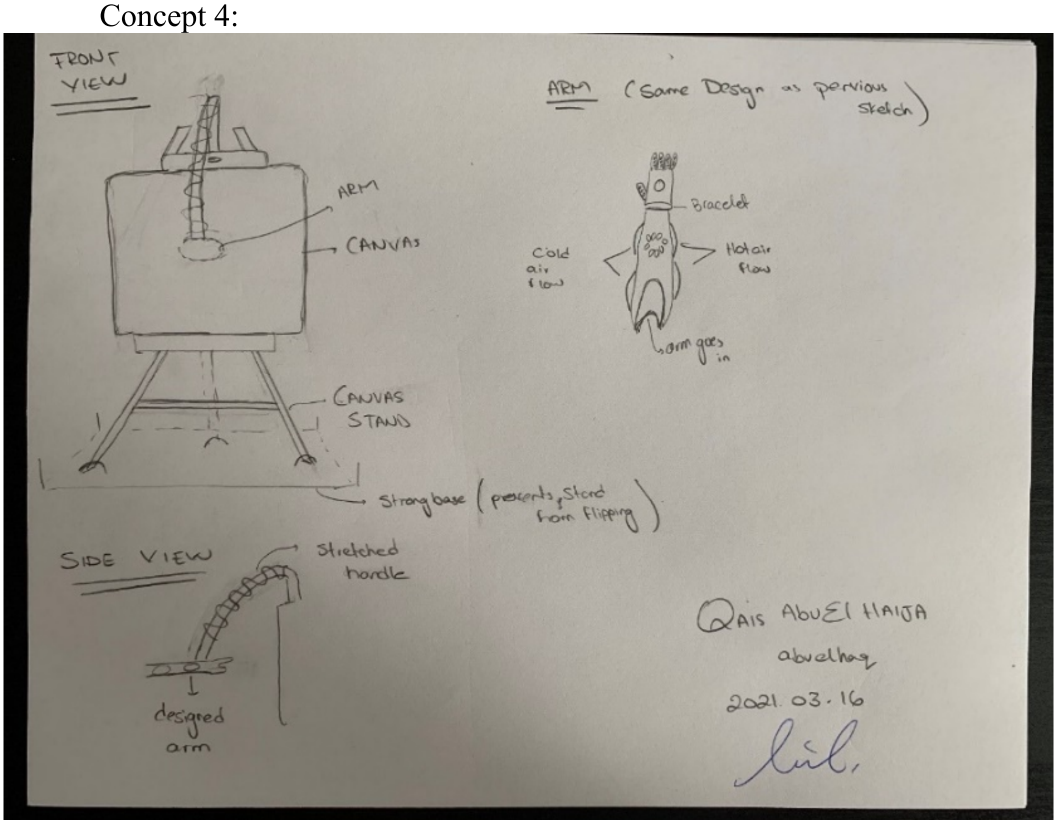
Concept 2:



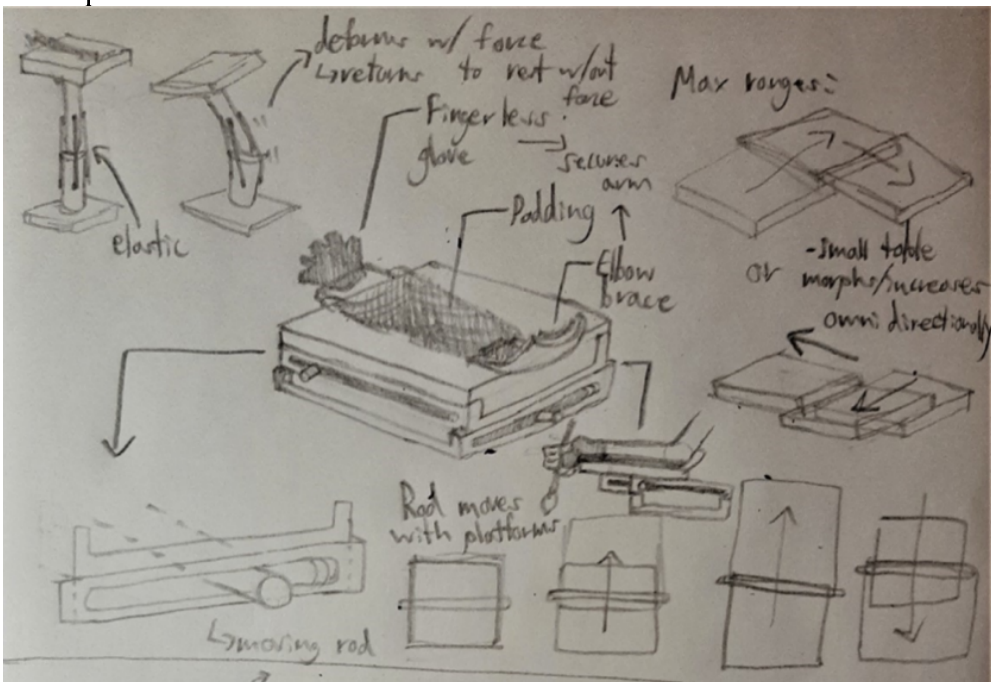
Concept 3:



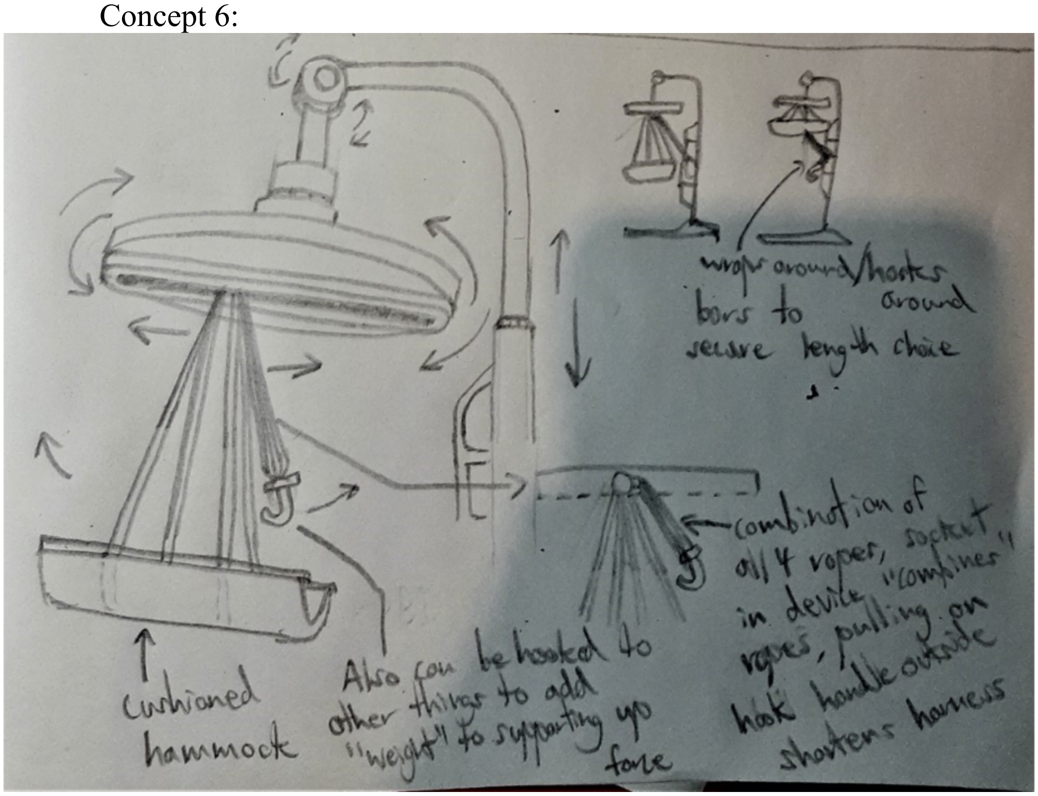
Concept 4:



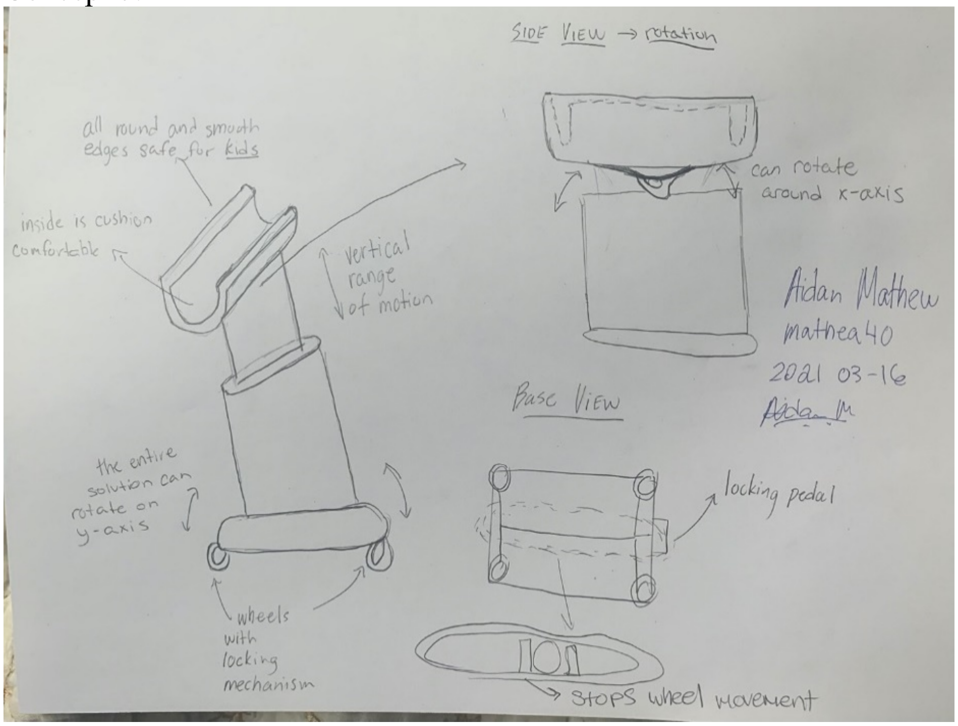
Concept 5:



Concept 6:



Concept 7:



Concept 8:

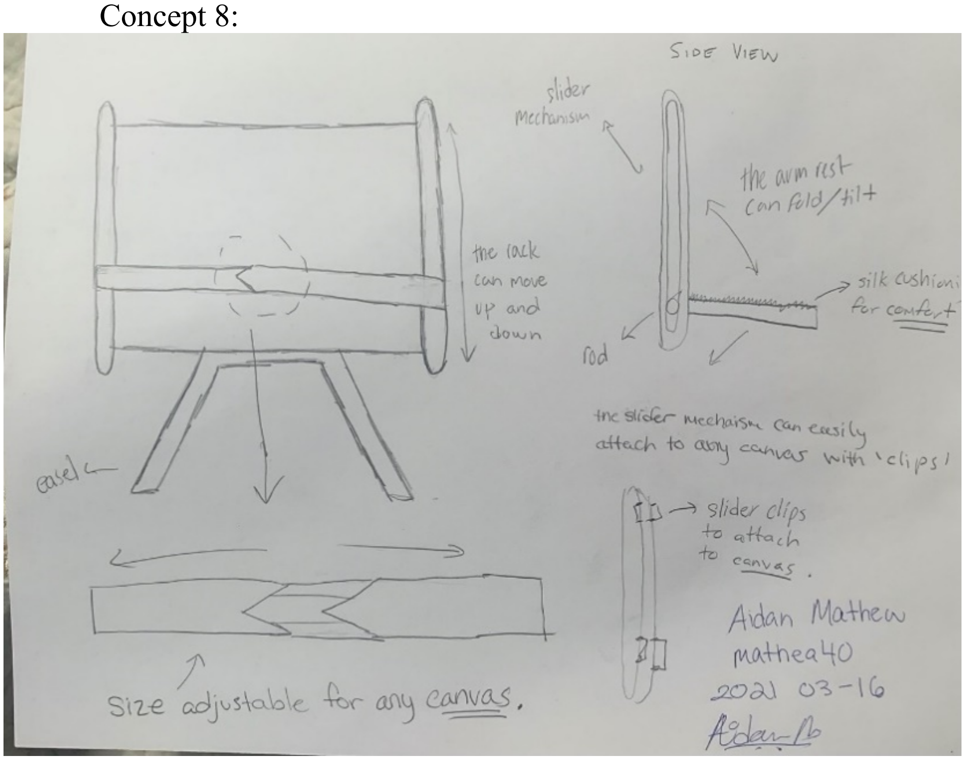
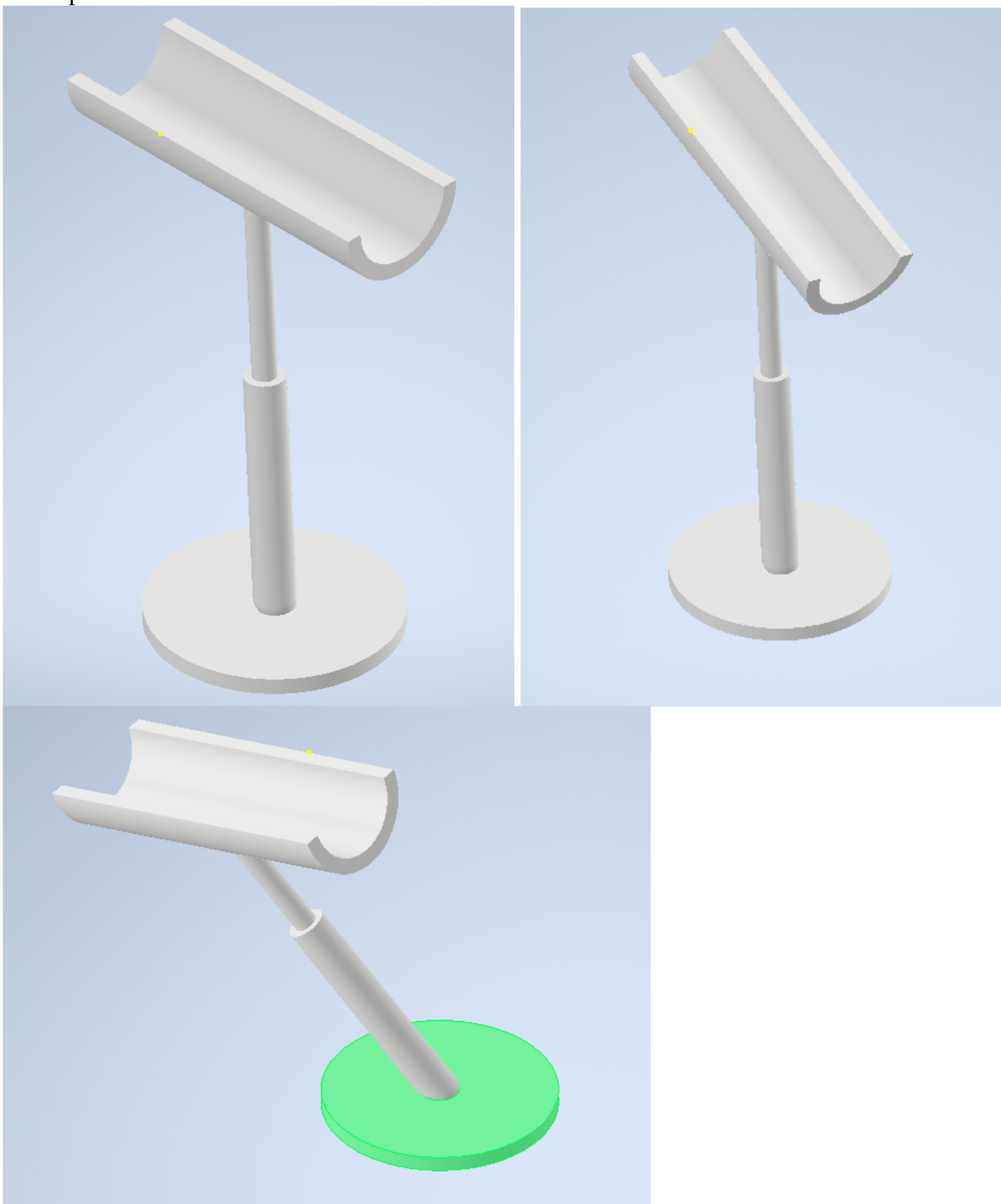
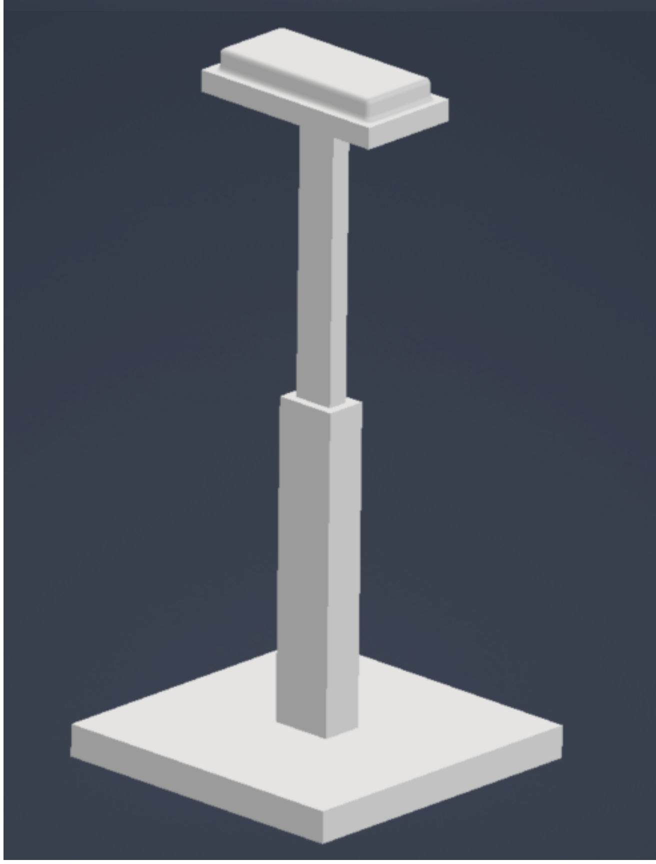


Figure 11. Initial Prototypes

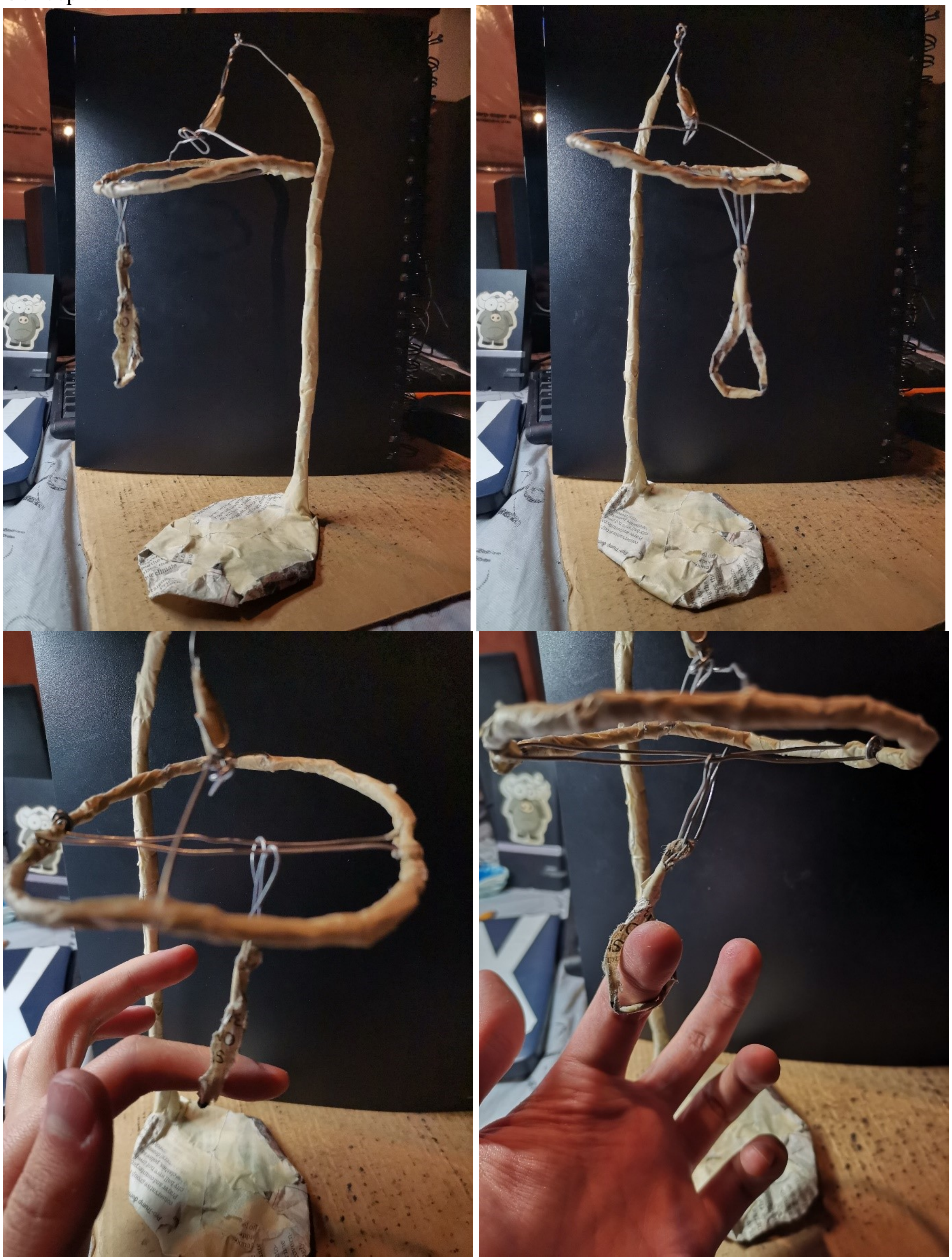
Initial Prototypes:
Concept 1:



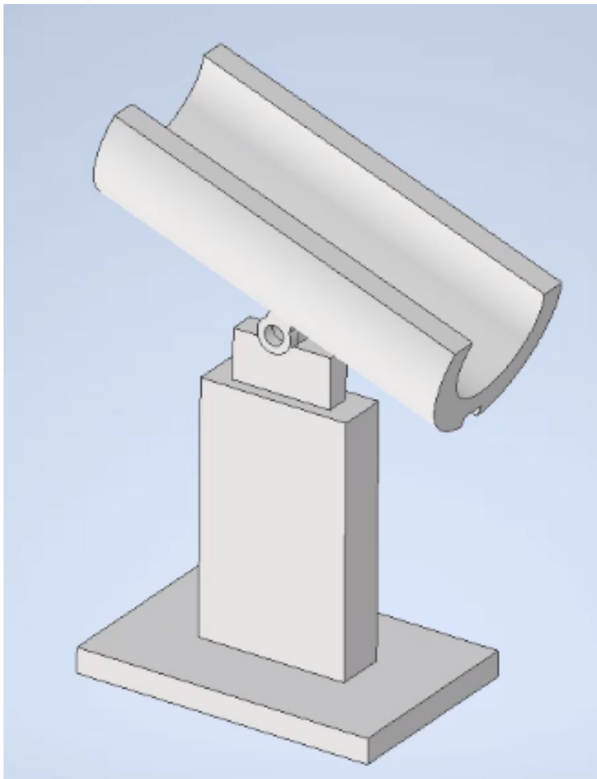
Concept 2:

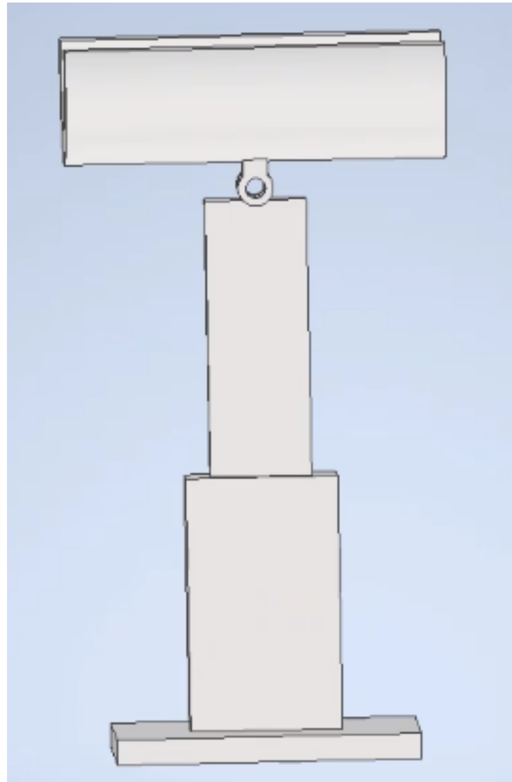


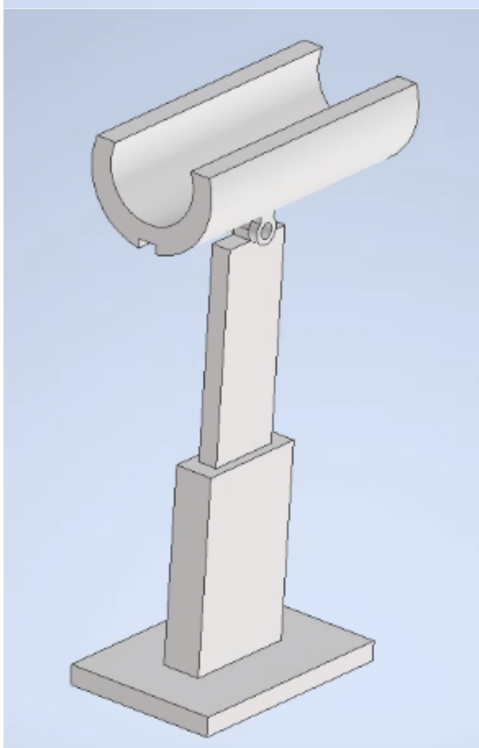
Concept 3:



Concept 4:







Design Review Notes:

Initial Design Review:

Figure 12. Initial Design Review

Feedback from IAIs, TAs, and Science Students:

- *Like the idea of the side to side*
- *Good idea for cushioning*
- *How would we help her grip paint brush?*
- *Have we done any physical testing or simulation testing?*
- *Material?*
- *Add a clamp or something for the adjustable height*
- *Will this device help her spinal position*
- *What is height of the device*

Final Design Review:

Figure 13. Final Design Review

<table>
<tr><td>Include feedback from peers in this row.
- If implement wheels, may need some breaks to keep it stopping
Q: Does it force her to stand up?
A: Can allow her to stand and sit
Feedback: Could try to maybe attach to chair? Help her sit down more, built to accommodate more sitting down positions?
Q: Does arm tighten depending on how thin her arm is? Will the width be stable?
A: No, width will be fixed,
Feedback: Maybe make the arm adjustable so she at least has control?
Q: Really love adjustability, but will this be positioned right beside table? Or will it be bent, is that how you envision it?
A: Will probably be close to canvas
Feedback: Length could be restricting, and should accommodate her arm bending, it seems a bit long right now. Arm might hit against length of U-shape if her arm was bent.</td></tr>
<tr><td>Include feedback from science students in this row.
They liked the mobility aspect (changing height and rotation of arm holder)
Is this device easy to move?
What materials are we using?
If we add wheels, make sure we have breaks for them so the device doesn’t move around
Length a bit long, might be uncomfortable</td></tr>
<tr><td>If applicable, include feedback from the client in this row.
N/A</td></tr>
</table>

Section 3

Final Prototype:

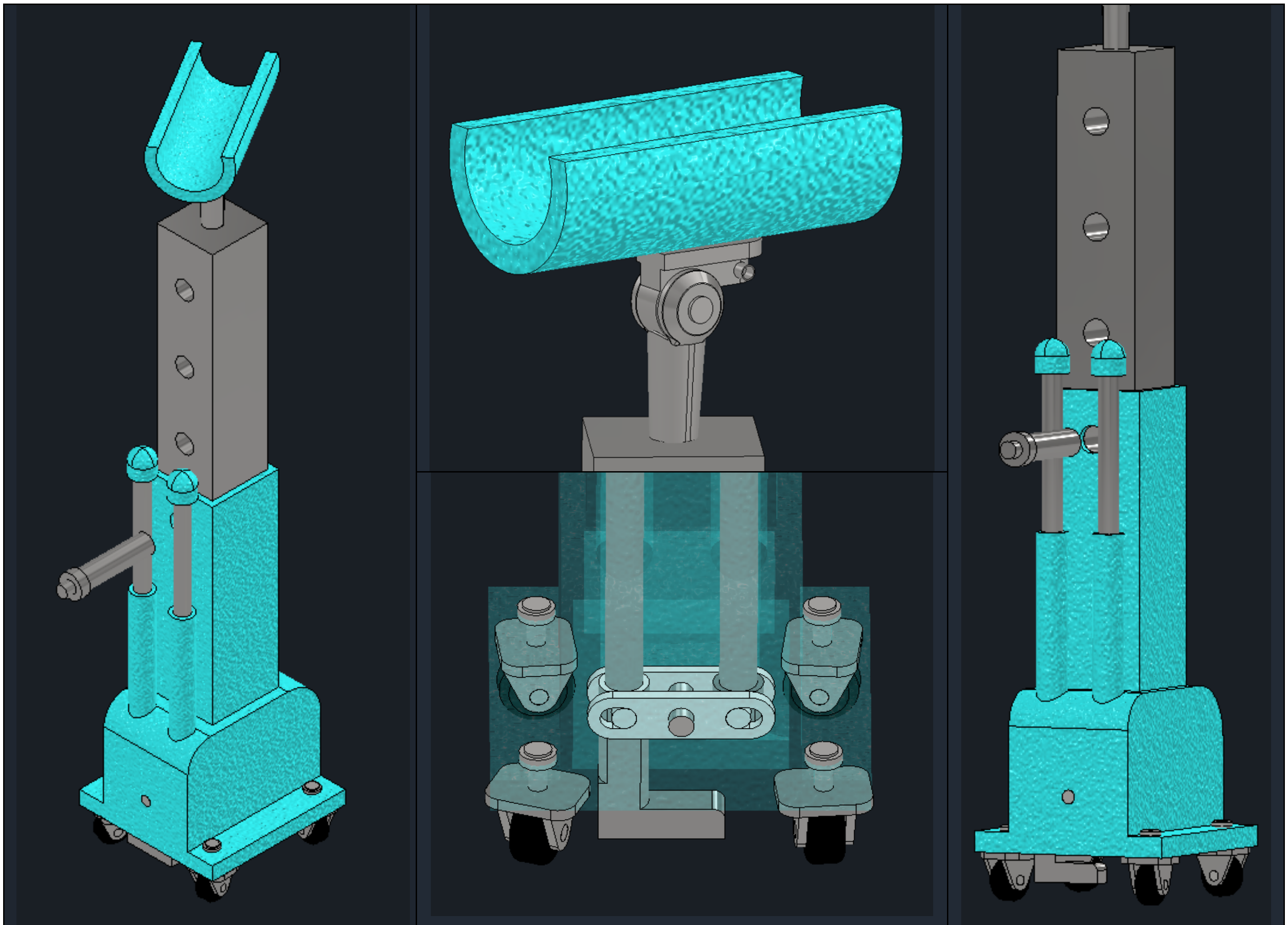


Figure 14. Final prototype

Bill of Materials

Item	Part Number	Thumbnail	BOM Structure	Unit QTY	QTY	Material	Mass	Volume	Price per Kilogram (CAD / kg)	Price per Part (CAD)	Estimated Cos
1	Body		Normal	Each	1	Acetal Resin, Black	16.519 kg	11592311.984 mm^3	10.67 - 12.4	$182.00	$182.00
2	Adjustable Support		Normal	Each	1	CFRP	13.556 kg	9479825.832 mm^3	46.2 - 51.3	$662.00	$662.00
3	Arm holder		Normal	Each	1	CFRP	2.210 kg	1545531.382 mm^3	46.2 - 51.3	$108.00	$108.00
4	Plug for height		Normal	Each	1	CFRP	0.340 kg	237582.944 mm^3	46.2 - 51.3	$16.59	$16.59
5	Bracket		Normal	Each	1	CFRP	0.178 kg	124351.062 mm^3	46.2 - 51.3	$8.69	$8.69
6	Middle Section		Normal	Each	1	CFRP	0.139 kg	97378.958 mm^3	46.2 - 51.3	$6.78	$6.78
7	Wheel		Normal	Each	4	Rubber	0.070 kg	75763.931 mm^3	2.02 - 2.23	$0.15	$0.60
8	Wheel_Holder		Normal	Each	4	Aluminum 6061	0.197 kg	72902.619 mm^3	3.01 - 3.64	$0.65	$2.60
9	Mid bar		Normal	Each	2	Aluminum 6061	0.115 kg	42671.239 mm^3	3.01 - 3.64	$0.37	$0.74
10	WheelMech_Middle		Normal	Each	1	Aluminum 6061	0.059 kg	21991.149 mm^3	3.01 - 3.64	$0.19	$0.19

Figure 15. Bill of Materials

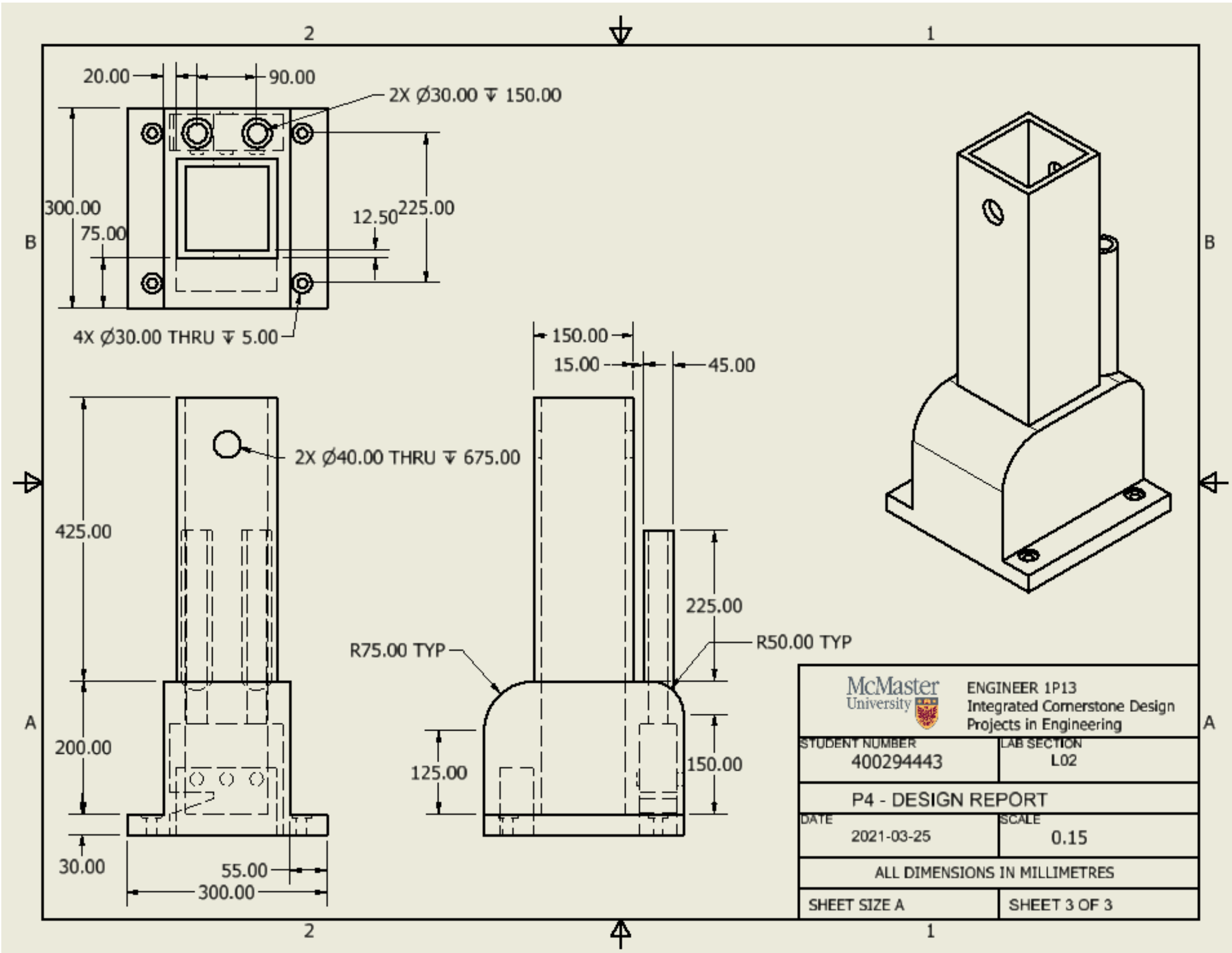
Total Weight: 33.5 Kg (Approximation)

Estimated Cost: 989.17 CAD (Raw Materials)

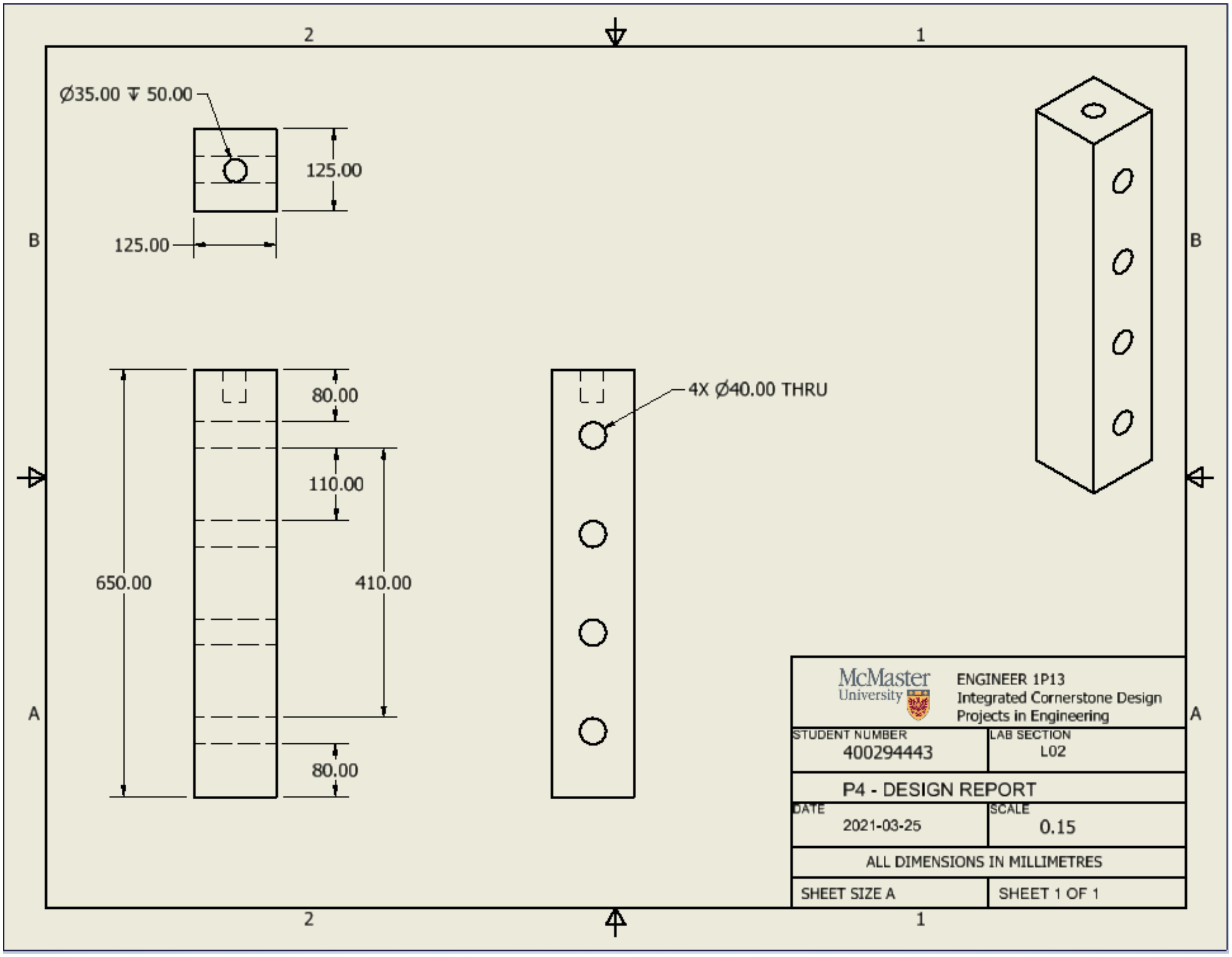
Engineering Drawings:

Figure 16. Engineering Drawings

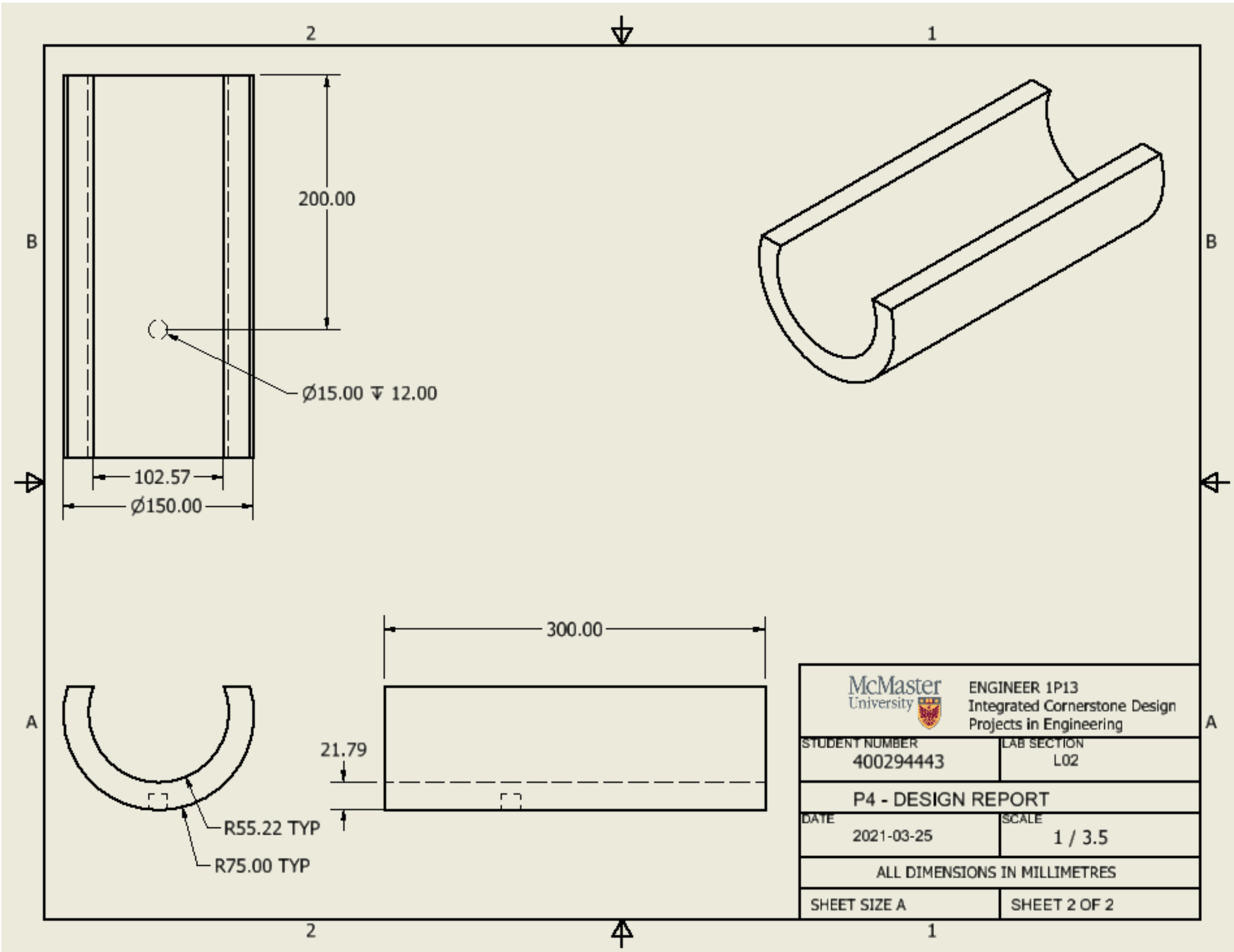
Main base:



Adjustable Support:



Arm Holder: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Integrated Cornerstone Design
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L02
P4 - DESIGN REPORT
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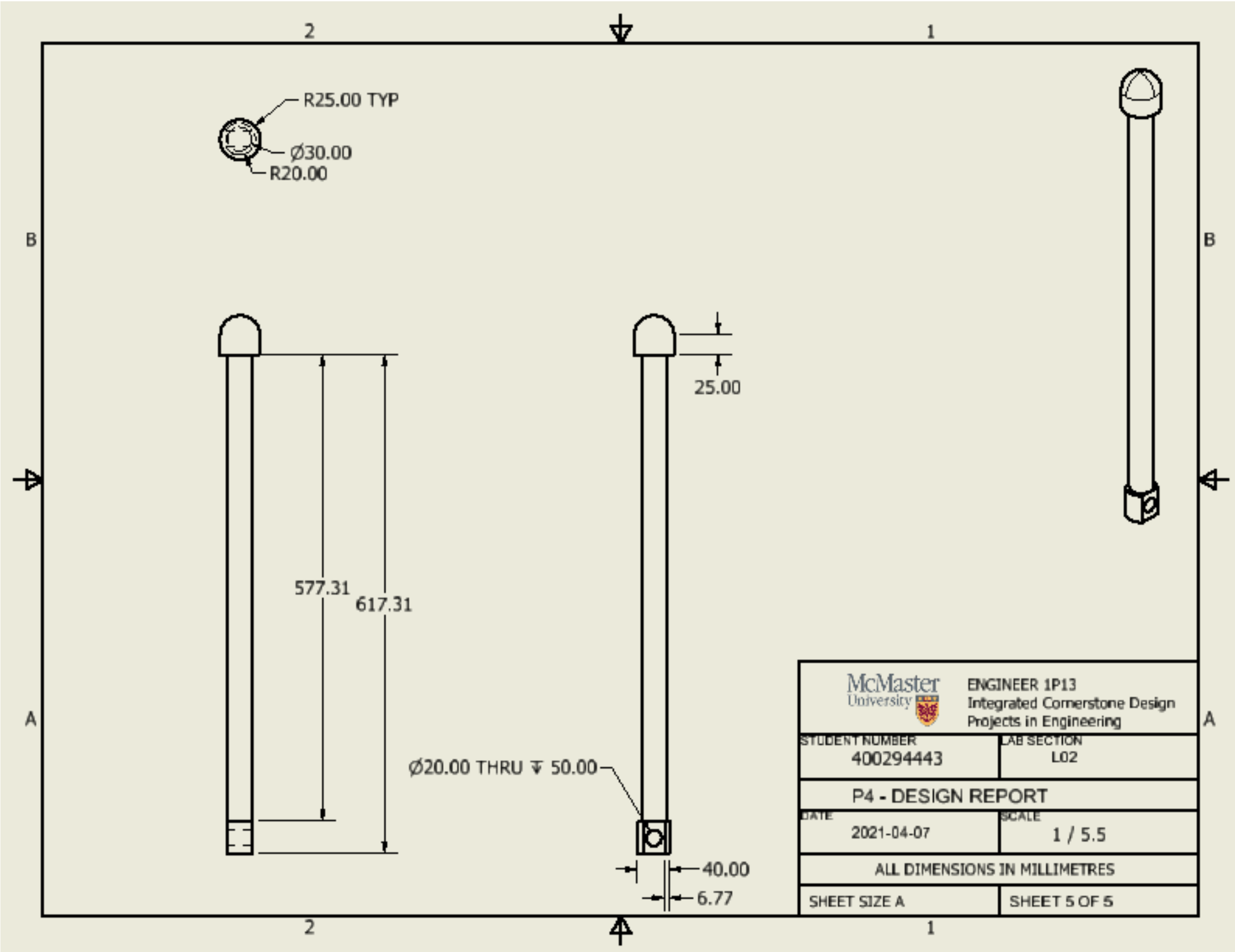
SHEET 2 OF 2

Main Lever:



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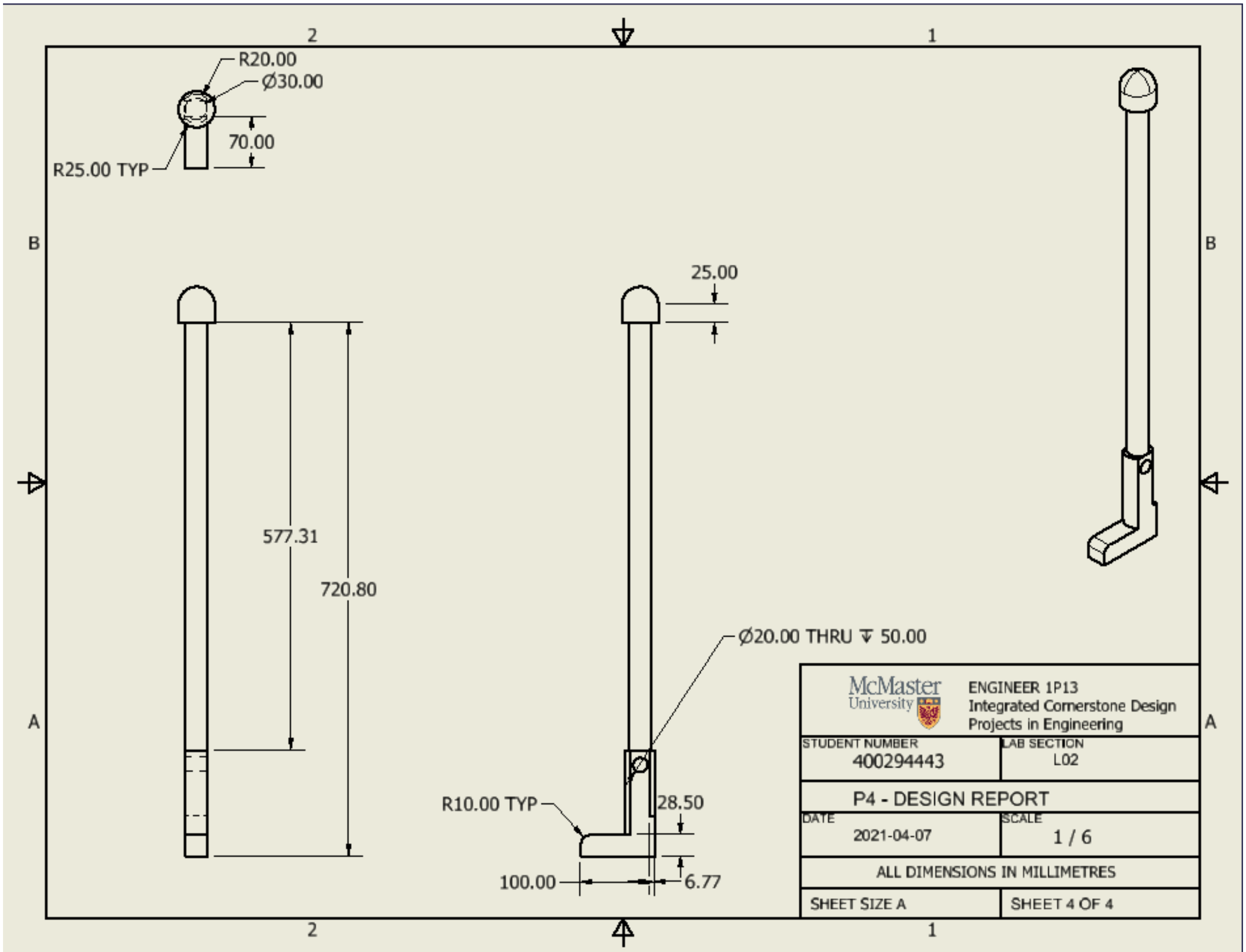
SHEET 5 OF 5

Side Lever: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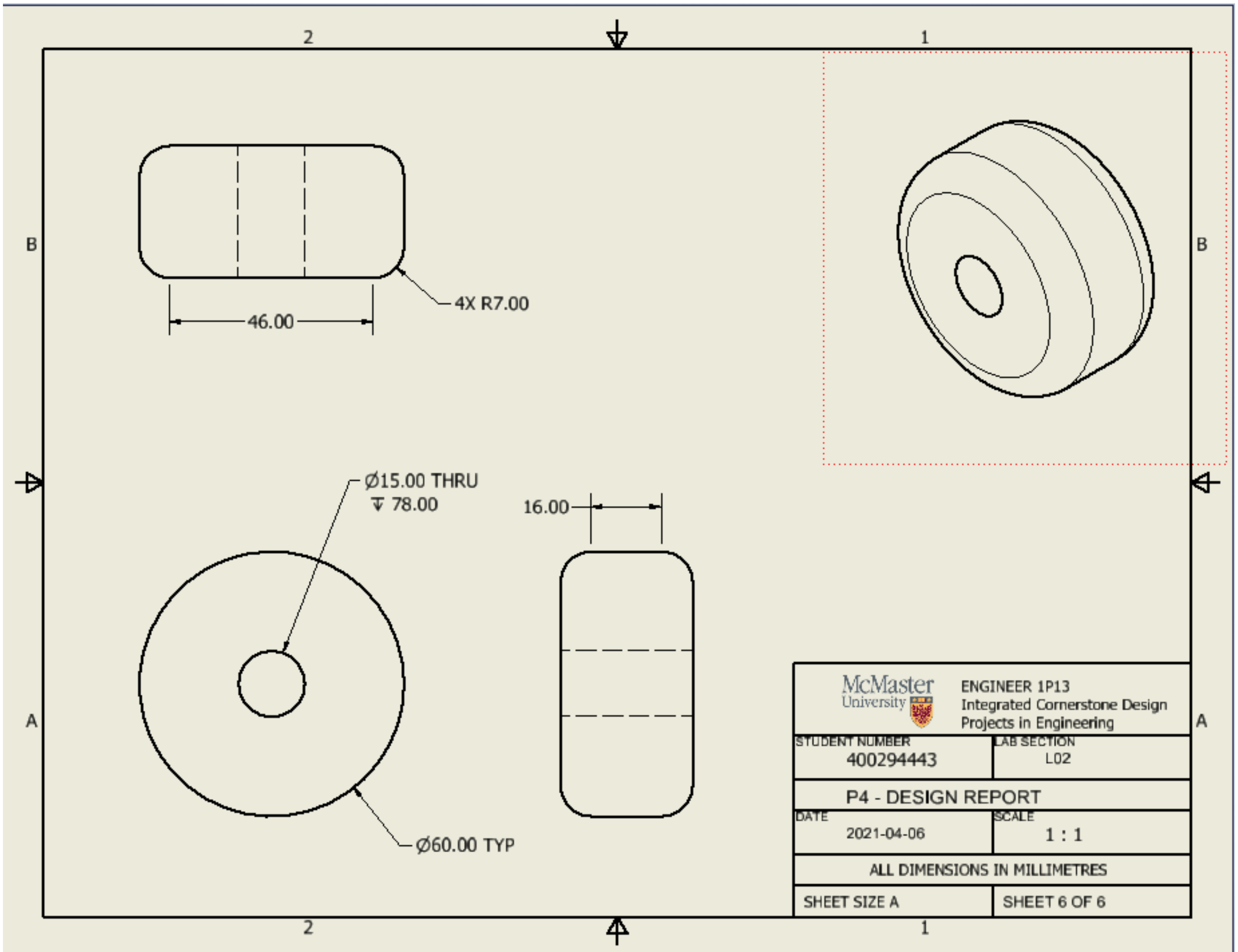
SHEET 4 OF 4

Wheels: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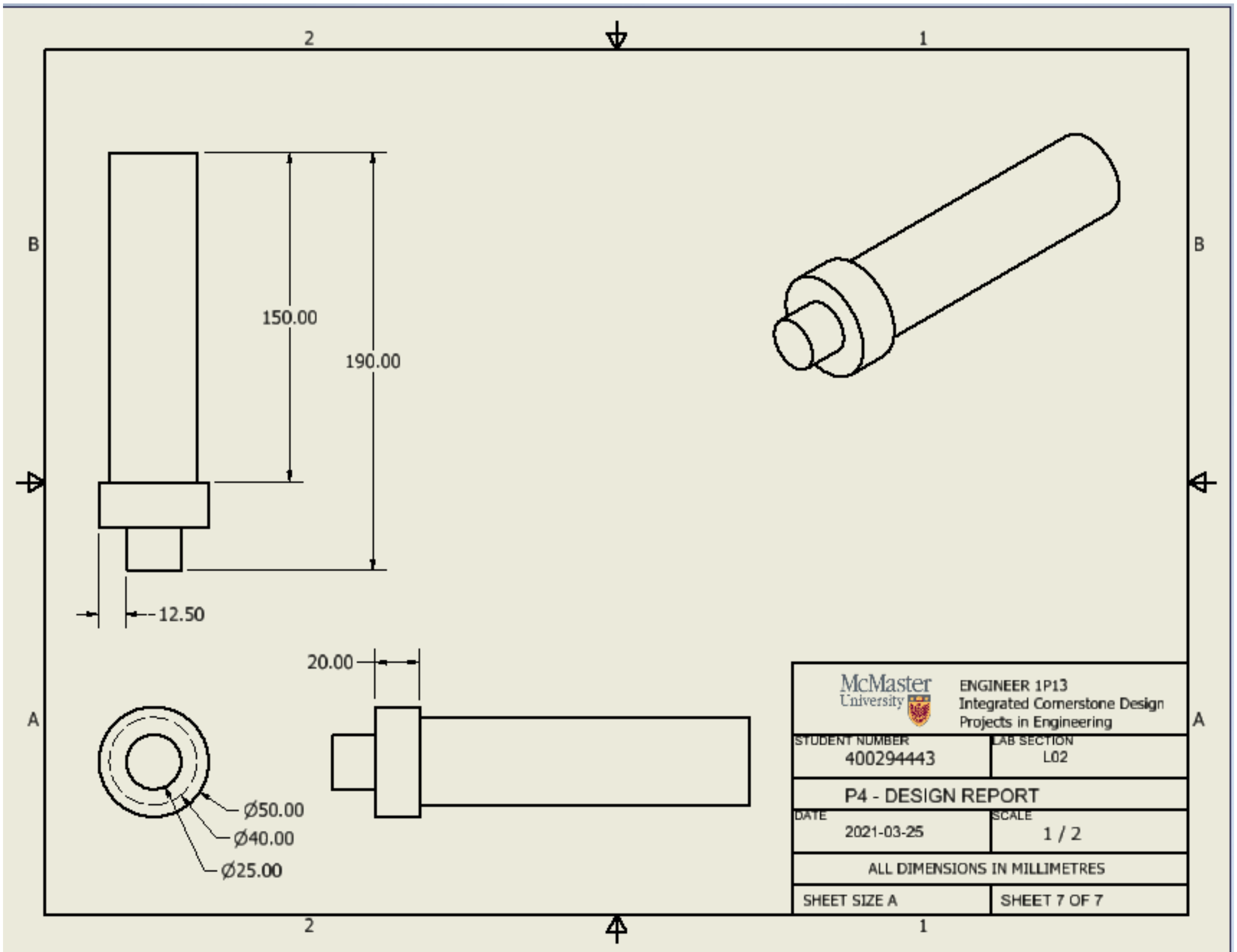
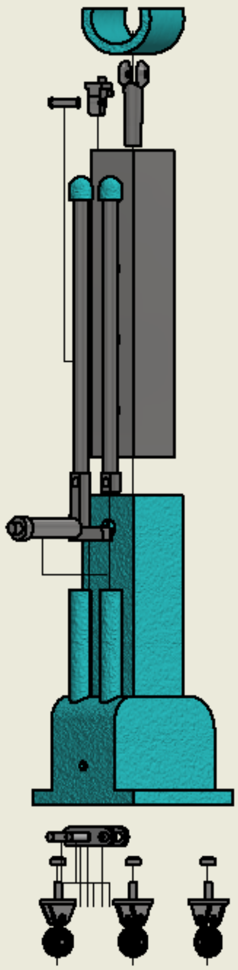
Plug (To adjust height):



Exploded View:



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Body
2	1	Adjustable Support
3	1	Bracket
4	1	Middle Section
5	1	Screw
6	1	Arm holder
7	1	Plug for height
8	4	Wheel_Holder
9	4	Wheel
10	4	Wheel_Axle
11	4	Wheels_Head
12	2	Mid bar
13	2	Lever_main
14	2	Wheel_Mech_Pin
15	1	WheelMech_Middle

EXPLODED VIEW
SCALE 1 / 11

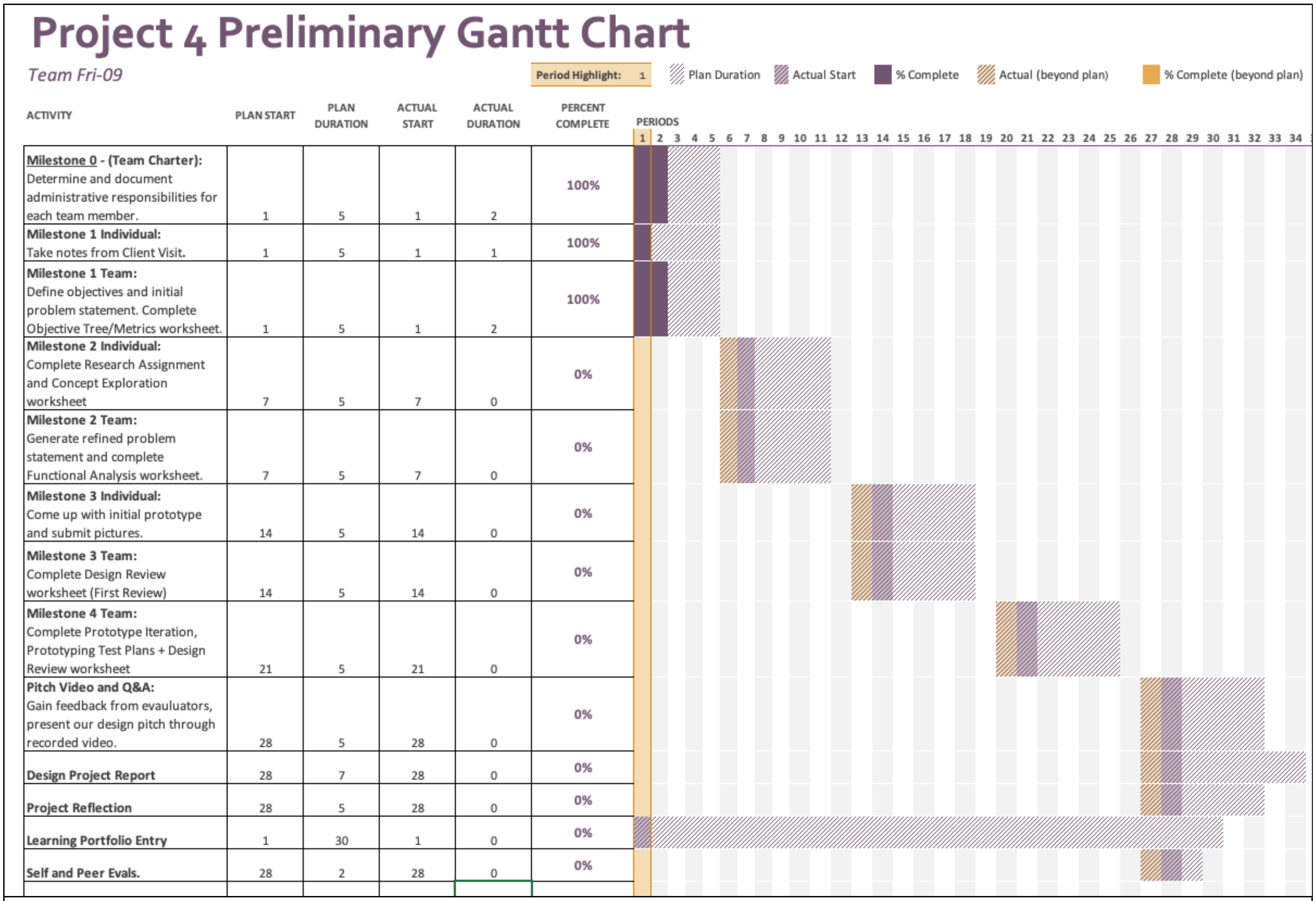
McMaster University

ENGINEER 1P13
Integrated Cornerstone Design
Projects in Engineering

STUDENT NUMBER	LAB SECTION
400294443	L02
P4 - DESIGN REPORT	
DATE 2021-03-25	SCALE 1 / 11
ALL DIMENSIONS IN MILLIMETRES	
SHEET SIZE A	SHEET 6 OF 6

Section 4

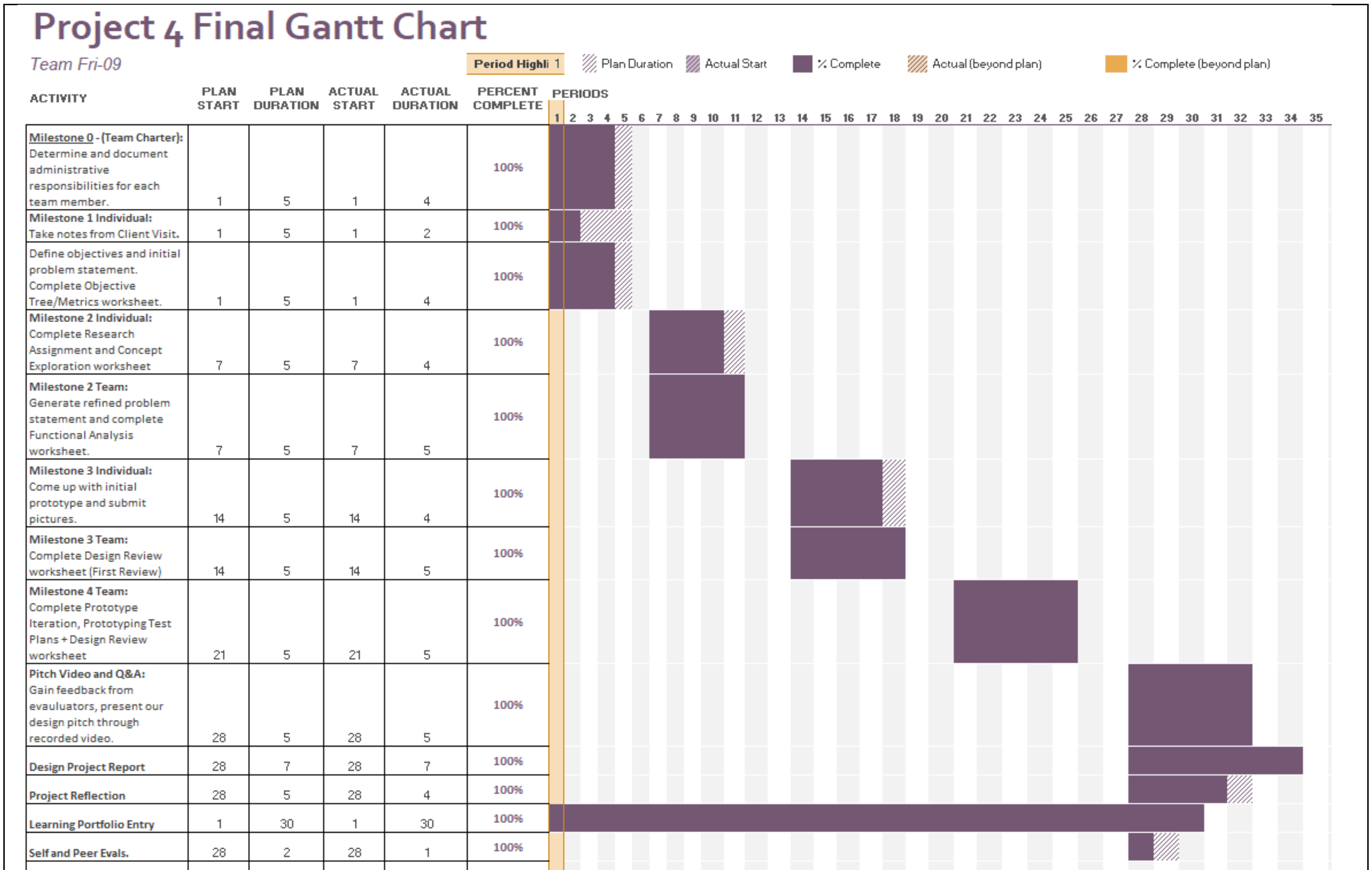
Initial Gantt Chart:



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 - (Team Charter): Determine and document administrative responsibilities for each team member.	1	5	1	2	100%
Milestone 1 Individual: Take notes from Client Visit.	1	5	1	1	100%
Milestone 1 Team: Define objectives and initial problem statement. Complete Objective Tree/Metrics worksheet.	1	5	1	2	100%
Milestone 2 Individual: Complete Research Assignment and Concept Exploration worksheet	7	5	7	0	0%
Milestone 2 Team: Generate refined problem statement and complete Functional Analysis worksheet.	7	5	7	0	0%
Milestone 3 Individual: Come up with initial prototype and submit pictures.	14	5	14	0	0%
Milestone 3 Team: Complete Design Review worksheet (First Review)	14	5	14	0	0%
Milestone 4 Team: Complete Prototype Iteration, Prototyping Test Plans + Design Review worksheet	21	5	21	0	0%
Pitch Video and Q&A: Gain feedback from evauluators, present our design pitch through recorded video.	28	5	28	0	0%
Design Project Report	28	7	28	0	0%
Project Reflection	28	5	28	0	0%
Learning Portfolio Entry	1	30	1	0	0%
Self and Peer Evals.	28	2	28	0	0%

Figure 17. Initial Gantt Chart

Final Gantt Chart:



Project 4 Final Gantt Chart

Team Fri-09

Period Highli 1 | Plan Duration | Actual Start | % Complete | Actual (beyond plan) | % Complete (beyond plan)

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0 - (Team Charter): Determine and document administrative responsibilities for each team member.	1	5	1	4	100%
Milestone 1 Individual: Take notes from Client Visit.	1	5	1	2	100%
Define objectives and initial problem statement. Complete Objective Tree/Metrics worksheet.	1	5	1	4	100%
Milestone 2 Individual: Complete Research Assignment and Concept Exploration worksheet	7	5	7	4	100%
Milestone 2 Team: Generate refined problem statement and complete Functional Analysis worksheet.	7	5	7	5	100%
Milestone 3 Individual: Come up with initial prototype and submit pictures.	14	5	14	4	100%
Milestone 3 Team: Complete Design Review worksheet (First Review)	14	5	14	5	100%
Milestone 4 Team: Complete Prototype Iteration, Prototyping Test Plans + Design Review worksheet	21	5	21	5	100%
Pitch Video and Q&A: Gain feedback from evauluators, present our design pitch through recorded video.	28	5	28	5	100%
Design Project Report	28	7	28	7	100%
Project Reflection	28	5	28	4	100%
Learning Portfolio Entry	1	30	1	30	100%
Self and Peer Evals.	28	2	28	1	100%

Figure 18. Final Gantt Chart

Logbook of Additional Meetings & Discussions (Fri-09)

Date	Time	Event Description
March 18, 2021	9:00 PM – 10:17 PM	Completed Milestone 3: Team Fri-09 worked on completing Decision Matrix, particularly ranking everyone’s designs using the criteria weighted in-lab. Additionally, the team also held discussions and critique of each other’s designs and came up with the two that would be presented.
March 30, 2021	7:00 PM – 8:43 PM	Completed Milestone 4: Team Fri-09 worked on completing testing plans of milestone 4 both present and future. Additionally, completed discussion on how design concept was refined.
April 8, 2021	9:00 AM – 11:30 AM	Began Presentation Video: Began discussion on what each section of the video is, and the responsibilities for each team member. Team members began to brainstorm points and content for their sections, as well as discussing with team about content. Began working on slides for video.
April 8, 2021	1:50 PM – 5:05 PM	Worked on and Finished Presentation Video: Team Fri-09 worked on finishing up the presentation slides, and going through multiple recording processes to get a final take. Video takes usually consisted of shooting a take, then going back to see what else could be shortened, what is missing from requirements, and what additional touches could be done to make the video better.
April 10, 2021	8:00 PM – 9:35 PM	Worked on Final Design Report: Team Fri-09 went through the Design Report requirements, to sort out responsibilities and split up work for the report. Then spent working on discussed sections
April 14, 2021	6:00 PM - 9:32 PM	Finishing of Final Design Report: This meeting centers on completing the Final Design Report. Individual members before this meeting had team assigned sections and responsibilities to complete in the report. This meeting acts as a team review of everyone’s work and to ensure consistency in presentation of the report. Any final unfinished work is wrapped up by the team and any outstanding discussions are discussed.

Section 5

Source Materials Database

[1] P. Education and U. Health Network, "How to Manage Your Lymphedema." Accessed: Mar. 08, 2021. [Online].

[2] Fibromyalgia: an environmental scan. Jesse & Julie Rasch Foundation, 2014.

[3] N. Roitenberg and A. Shoshana, "Physiotherapists' accounts of fibromyalgia: role uncertainty and professional shortcomings," Disability and Rehabilitation, vol. 43, no. 4, pp. 545–552, 2019.

[4] NHS choices, Feb-2019 [Online] Available: https://www.nhs.uk/conditions/fibromyalgia/causes/#:~:text=Fibromyalgia%20is%20often%20triggered%20by,a%20viral%20infection. [Accessed: 13-Mar-2021].

[5] D. Foltz-Gray, B. Upham, B. P. Dunleavy, and K. Jackson, "14 Gadgets to Relieve Fibromyalgia Pain: Everyday Health," EverydayHealth.com. [Online]. Available: https://www.everydayhealth.com/fibromyalgia/14-gadgets-to-relieve-fibromyalgia-pain/. [Accessed: 13-Mar-2021].

[6] L. Baillie, "Natural remedies for 10 fibromyalgia symptoms," A.Vogel Herbal Remedies, 08- Feb-2021. [Online]. Available: https://www.avogel.co.uk/health/musclesjoints/fibromyalgia/natural-remedies-for-10-common-fibromyalgia-symptoms/. [Accessed: 13-Mar-2021].

[7] "Distal median nerve dysfunction: MedlinePlus Medical Encyclopedia," MedlinePlus. [Online]. Available: https://medlineplus.gov/ency/article/000691.htm#:~:text=This%20condition%20occurs%20when%20the,injure%20the%20median%20nerve%20directly. [Accessed: 13-Mar2021].

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[9] C. S. Simpson, A. M. Okamura, and E. W. Hawkes, "Exomuscle: An inflatable device for shoulder abduction support," in Proceedings - IEEE International Conference on Robotics and Automation, Jul. 2017, pp. 6651–6657, doi: 10.1109/ICRA.2017.7989785.

[10] Z. Du et al., “Mechanical Design and Preliminary Performance Evaluation of a Passive Arm-support Exoskeleton,” in 2020 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Oct. 2020, pp. 3371–3376, doi: 10.1109/IROS45743.2020.9341290.

[11] A. Koenig, U. Keller, K. Pfluger, A. Meyer-Heim, and R. Riener, “PASCAL: Pediatric arm support robot for combined arm and leg training,” in Proceedings of the IEEE RAS and EMBS International Conference on Biomedical Robotics and Biomechatronic, 2012, pp. 1862–1868, doi: 10.1109/BioRob.2012.6290263.

[12] B. Sherwin, “Artists with Disabilities: Dealing with a physical or mental disability as an artist | FineArtViews.”. [Online]. Available: https://fineartviews.com/blog/35330/artists-with-disabilities-dealingwith-a-physical-or-mental-disability-as-an-artist [Accessed: 13-Mar-2021].

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