ENGINEERING

McMaster University

Design Project 4 – Not a Pun, It's Real Life

ONE-WHEEL By Wheel Estate Corp.

IBEHS 1P10 – Health Solutions Design Projects

Tutorial 05

Team 36 (Wheel Estate Corp)

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Submitted: April 10, 2022

Table of Contents

Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

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X 

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Kyle St. Louis 400399251

X 

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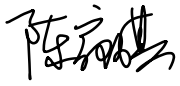
Wanqi (Anna) Chen 400357073

X 

Executive Summary

Over the past couple of decades, the number of wheelchairs users has more than doubled, with an estimated 1.85% of the population requiring one [1, 2]. The most common causes of wheelchair qualifications are neuromuscular disorders, as they directly affect the functionality of the body's nerves and muscles [3]. Among these neuromuscular disorders, multiple sclerosis (MS) repeatedly appears amongst the top contributors, with 90% of MS patients exhibiting symptoms of muscle fatigue/weakness and spasticity. Studies have shown that 61% of patients with MS report using a manual wheelchair, with 59% of this population saying that wheelchair failed to meet their mobility needs [3].

Nadina Gregory is a MS patient currently using a manual wheelchair. Nadina was diagnosed with multiple sclerosis 22 years ago and transitioned to a mechanical wheelchair 17 years later when her walking became laboured. Homogenous to 92% of MS patients, Nadina's symptoms have manifested themselves asymmetrically, resulting in a great disparity in strength between her arms [4]. Nadina's right arm now lacks the strength to push its corresponding wheelchair wheel forward due to muscle spasticity. Consequently, she consistently veers towards the right as she tries to travel forwards. Additionally, Nadina is adamantly against electric wheelchairs as she feels that it would diminish her autonomy and independence, both traits in which she holds in high regard. Essentially, Nadina would require an omnidirectional manual wheelchair that enables her to counterbalance the muscle atrophy in her right arm.

One-Wheel™ by Wheel Estate Corp was designed to empower users to reclaim their mobile independence. This wheelchair add-on allows its users to operate the wheelchair singlehandedly and change directions with ease. In Nadina's case, she would use her currently unaffected left arm to control the wheelchair. Inspired by cars' transmission lever, One-Wheel™ is effective and intuitive, requiring minimal force to operate.

The finalized design consists of a wheelchair axle that is locked into place using a spring-loaded pin. When the hand-lever is moved, the pin is pulled into the axle through a system of pulleys, which enables the wheels to rotate separately. Ideal materials would be economic and with a low coefficient of friction to reduce required force and increase its lifespan**.** This design directly addresses the primary concern of MS patients with asymmetrical muscle spasticity. By enabling the user to reclaim their autonomy in mobility, One-Wheel™ is providing Nadina with a method to increase her quality of life whilst staying conscious of her sense of independence.

One-Wheel™ is an extremely marketable product with the potential to expand beyond MS to all neuromuscular disorders with muscle fatigue symptoms. It differentiates itself from its competitors by its status as merely an add-on, and as such can be applied to existing wheelchairs. This makes it a significantly more economic and less noticeable alternatives to its bulky competitors that price up to hundreds of dollars.

Overall, One-Wheel™ by Wheel Estate Corp provides Nadina with an economic way to reclaim her mobility by way of an omnidirectional mechanical wheelchair without compromising her sense of autonomy.

Main Body

Summary of Design Objectives

Milestone 1 Need Statement (Updated)

Nadina has been diagnosed with Multiple Sclerosis for 22 years, which has caused a significant decrease in her autonomy and range of motion due to spasticity. Consequently, she has been forced to depend on others and her wheelchair for mobility and everyday tasks, thereby reducing her independence. Create a design that will improve Nadina's range of motion and/or mobility, empowering her to reclaim her independence and decrease her reliance on others for basic everyday tasks.

Refinements / Updates to Design Objectives

Objectives:

- Should be comfortable
- Should be affordable
- Should be user-friendly
- Should be inconspicuous
- Should be a passive/non-electrical device
- Should have a very intuitive design with not much explanation required

Constraints:

- Must be able to be used independently
- Must not get in the way of everyday tasks
- Must not be too bulky
- Device must not require a significant amount of force to be used / activated

Functions:

- Facilitates independent motion
- Improves range of motion (directly or indirectly)

Background and Research Summary

Our design's primary purpose is to address the difference in strength between Nadina's arms making her unable to steer her wheelchair herself. Nadina has suffered from multiple sclerosis for 22 years, and consequently, her muscle strength has deteriorated to the point where she relies on a wheelchair and caregiver to move. Her right arm is more prone to muscle spasticity than her left, leading to a significantly weaker right arm. Consequently, her manual wheelchair consistently veers towards the right as she attempts to move forwards. Nadina has also voiced her distaste for electric wheelchairs, claiming that it impeded her autonomy and independence.

Our solution directly addresses Nadina's needs, as it gives her greater maneuverability with her wheelchair without compromising her autonomy by resorting to an electric wheelchair. Our design employs a mechanism that connects the two wheels of Nadina's wheelchair, allowing her to move straight forward without shifting towards one direction. The wheels can also be disconnected through a lever, allowing her to make turns. The wheelchair's axles would be connected through a spring-loaded pin, locking them together and allowing them to roll as one. These axles would ideally be fabricated from stainless steel – a lightweight and versatile material that would not impede the functionality of the wheelchair [5]. It is also easy to mass produce, allowing our design to be more economically accessible [6]. The outer axle is lined with holes across its surface, allowing the pin to extrude through the single hole of the inner tube thus two wheels can roll together. The material of this pin would remain wood, but it shall be upgraded to hickory wood for its distinctive rigidity and hardness [7]. This pin is pushed up by a metal spring, whose material shall remain metal, but its thickness should be slightly increased to reduce chances of breakage. Controlled by a hand-lever on the armrest of the wheelchair, the spring moves up and down, adjusting the pin's position through a system of pulleys, string, and a custom 3D-printed housing. The string and pulleys would be replaced with copper, making them more durable and resistant to tension [8]. Copper's low coefficient of friction would also reduce the force required to activate the system, further benefiting the wheelchair user. Finally, the current 3D filament would be manufactured using a simple polished polycarbonate plastic, an economic material that is able to withstand the constant friction of the string/wire [9]. As a result, the ideal design would have improved strength, durability, lifespan, as well as minimized required activation force.

Providing Nadina with a method of getting further range of motion from her wheelchair, One-Wheel improves her sense of independence, and with cost-effective materials, our solution becomes accessible and affordable to everyone. Future iterations of the One-Wheel will include stronger materials for the ease of the client and improve the efficacy of the solution. With strong and low maintenance materials, our solution is optimal for users like Nadina who wish to be more independent and regain their autonomy.

Description of Proposed Solution

The purpose of our design is to increase Nadina's independence by allowing her to user wheelchair to its full extent with only her left hand. Due to muscle spasticity in her right arm Nadina is unable to drive both wheels at the same rate thus making it difficult to travel straight forwards. By locking the axles of the wheels together she is only required to use one arm to drive both wheels at the same time. She can disconnect the axles with a hand-lever, allowing her to turn. By allowing her to drive her wheelchair with one arm she regains her independence and can use her wheelchair to its full extent regardless of having a weaker right arm. Our design connects the axles of the wheels together by a user-driven pin locking mechanism to allow for forward and turning motions. *Figure 1* demonstrates how the axles connect.

Figure 1:

The axle of one wheel surrounds the other and contains multiple holes for pin alignment and axle locking, while the inner axle only has one hole that lines up perfectly with the pin movement.

The inner axle of the left wheel contains a housing for the pin, spring, and pulley, where the spring assists the pin's movement to lock and unlock the axles. *Figure 2* demonstrates our pin housing.

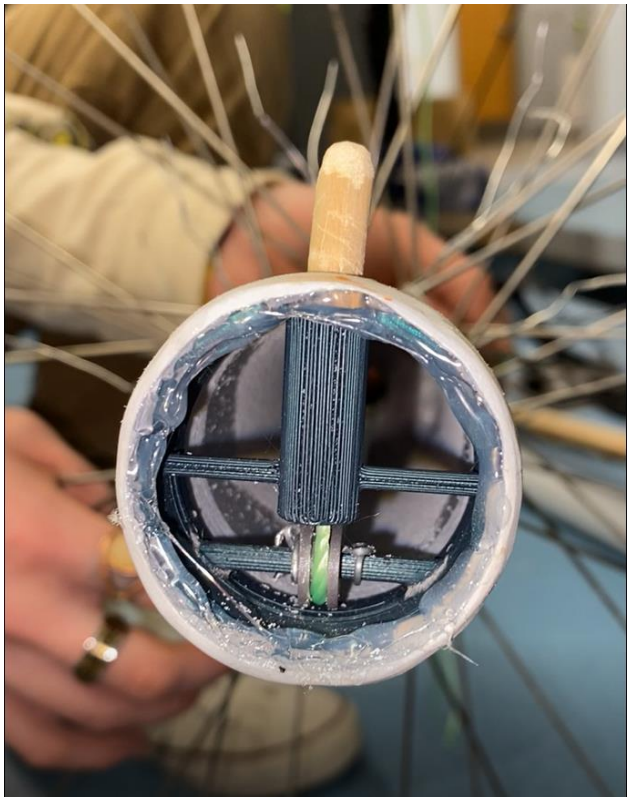


Figure 2:

As the string is pulled on through the pulley system by the lever it pulls down the spring, which in turn pulls down the pin to disengage the wheel axles.

A pulley system consisting of three pulleys allows for the redirection of applied force from user input to the pin. *Figure 3* demonstrates how the user controls the mechanism. This pulley system begins immediately below the spring and allows for the change in direction of force applied to the spring, directly pulling the spring downwards. Traveling out of the left wheel's axle (specific to Nadina's Case) the string (cable) turns around another pulley to travel upwards to the handle location. Around another pulley, the string can be pulled forwards by the lever and engage/disengage two axles with the help of the pulley system.

Figure 3(a-c): The string attached to the pin and 3-pulley system provides access to the user to unlock and lock the axles as needed. On the other end, the string is connected to a hand lever on the armrest of the wheelchair, where the user can control the engagement of the axles.

In the future our product will serve as a modification to any manual wheelchair, and the handle will be customized to the side the user specifies. One-Wheel will serve as an easier mode of transportation for wheelchair users and help them regain some of their independence. Future iterations of the One-Wheel plan to incorporate a stronger cable for the pulley system and an improved method of attaching this cable to a locking handle.

Product Identification

Function

- Allow users with varied forces from right and left to control the wheelchair with one hand to steer straight forward or turn with a user-driven mechanism.

Key features

- Single axle and hand lever
- Customizable: user can disconnect and connect the axles at their discretion, allowing the design to be used by a variety of clients.
- Ease of use/ User friendly: requires simple, quick, and low-force motions to accommodate all environmental conditions and user preferences.
- Inconspicuous: our design features a small connecting axle and a hand lever. The non-electrical design makes One Wheel less noticeable.

Appearance:

- Small addition to standard manual wheelchair
- Single axle connected to both drive wheels
- Spring and pulley system hidden within axle
- Arm push-lever on left side of wheelchair
- Connected through left drive wheel axle to pulley system

Usage

Instructions:

- When our client Nadina wants to steer straight using only her left hand, she can connect the two wheel's axles together using the hand lever on her left. In the default position, the spring-loaded pin will connect the two axles together though the holes on the axles. As a result, Nadina can steer the wheelchair straight without using the right hand.
- When she wants to make turns, Nadina can then disconnect the two wheel's axles through shifting the hand lever. The change of position of the hand lever will pull on the string and thus the pin so the two wheels are disconnected. Then Nadina can use her left hand to control solely the left wheel to make turns easily.

Ergonomics:

- To better fit with our client Nadina's need, we designed our hand lever to be at the left side of the wheelchair on the armrest. Thus, Nadina does not need to bend herself or reach out when connecting and disconnecting the wheel axles.
- The spring we used for the pin is not too strong that requires a lot of force for it to function, so Nadina can easily use her left arm to pull the lever to connect and disconnect the axles. The spring is not too weak either, so Nadina only needs to pull a very minimum distance for the lever to disconnect the axles and use the wheelchair.

Reliability:

- The One-Wheel's pulley system and inner spring mechanism are unreliable. At times they will come loose or even break. Most of this can be attributed to poor materials in the assembly and inadequate support for load bearing structures (i.e., the axles).
- In the future, with iterations to material choice as well as improved designs, the reliability will improve tremendously to satisfy customers.

Standards and Safety

- Currently, the safety of the One-Wheel is limited with the medium fidelity prototype, many health hazards exist with stray nails and an exterior pulley system easily damaged. If properly used, the device will cause no harm to the user, however in the future, alterations need to be made.
- Potential future iterations of the One-Wheel™ can include a more inconspicuous housing for the pulley system and stronger connection to the handle of the user access.
- As of now, the prototype does not meet safety standards for wheelchairs, there are no brakes for emergencies, there is no security measures for the safety of the user at all, most of this should come with future iterations of the prototype.

Citations

[1] B. Sapey, J. Stewart, and G. Donaldson, “Increases in wheelchair use and perceptions of disablement,” Disability & Society, vol. 20, no. 5, pp. 489–505, 2005. [Accessed Apr. 08, 2022].

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[5] U. F. O. Themes, “Wheelchairs and seating systems,” Musculoskeletal Key, 12-Jul-2016. [Online]. Available: https://musculoskeletalkey.com/wheelchairs-and-seating-systems/. [Accessed: 09-Apr-2022].

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[7] Home Depot, “Types of lumber,” The Home Depot, 2022. [Online]. Available: https://www.homedepot.com/c/ab/types-of-lumber/9ba683603be9fa5395fab90567851db. [Accessed: 10-Apr-2022].

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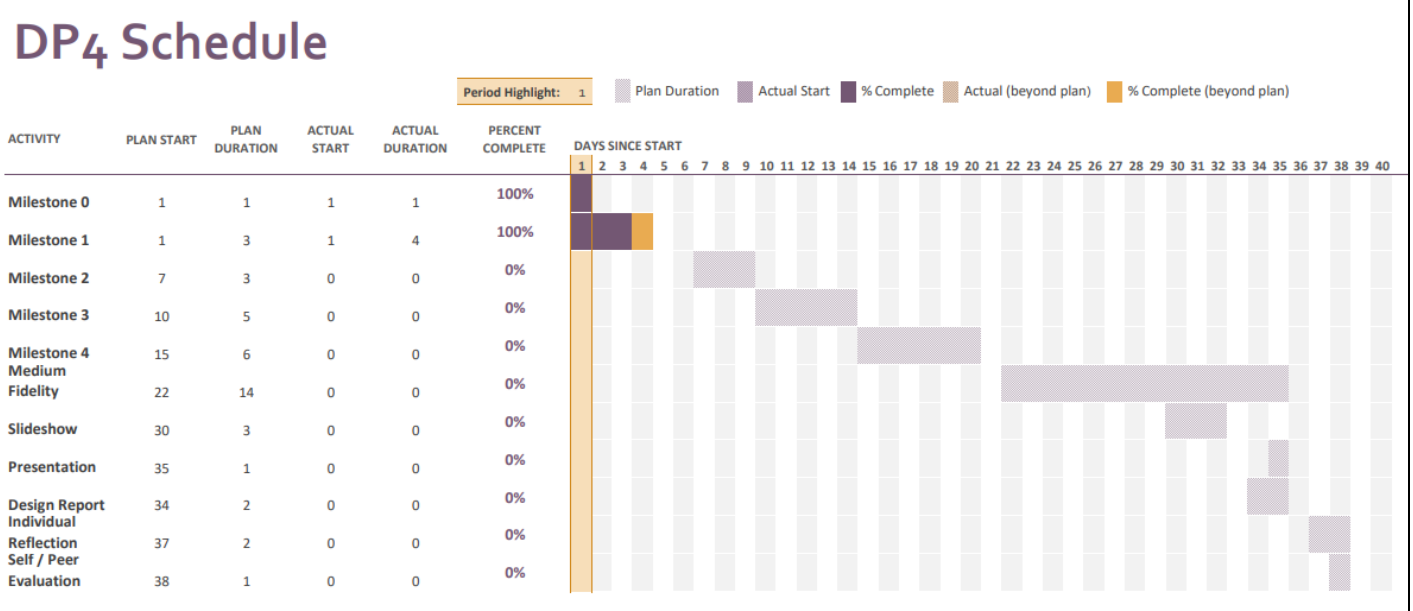
[9] V. Lerch, G. Gary, and P. Hervé, “Thermomechanical properties of polycarbonate under dynamic loading,” Journal de Physique IV (Proceedings), vol. 110, pp. 159–164, 2003.

Appendices

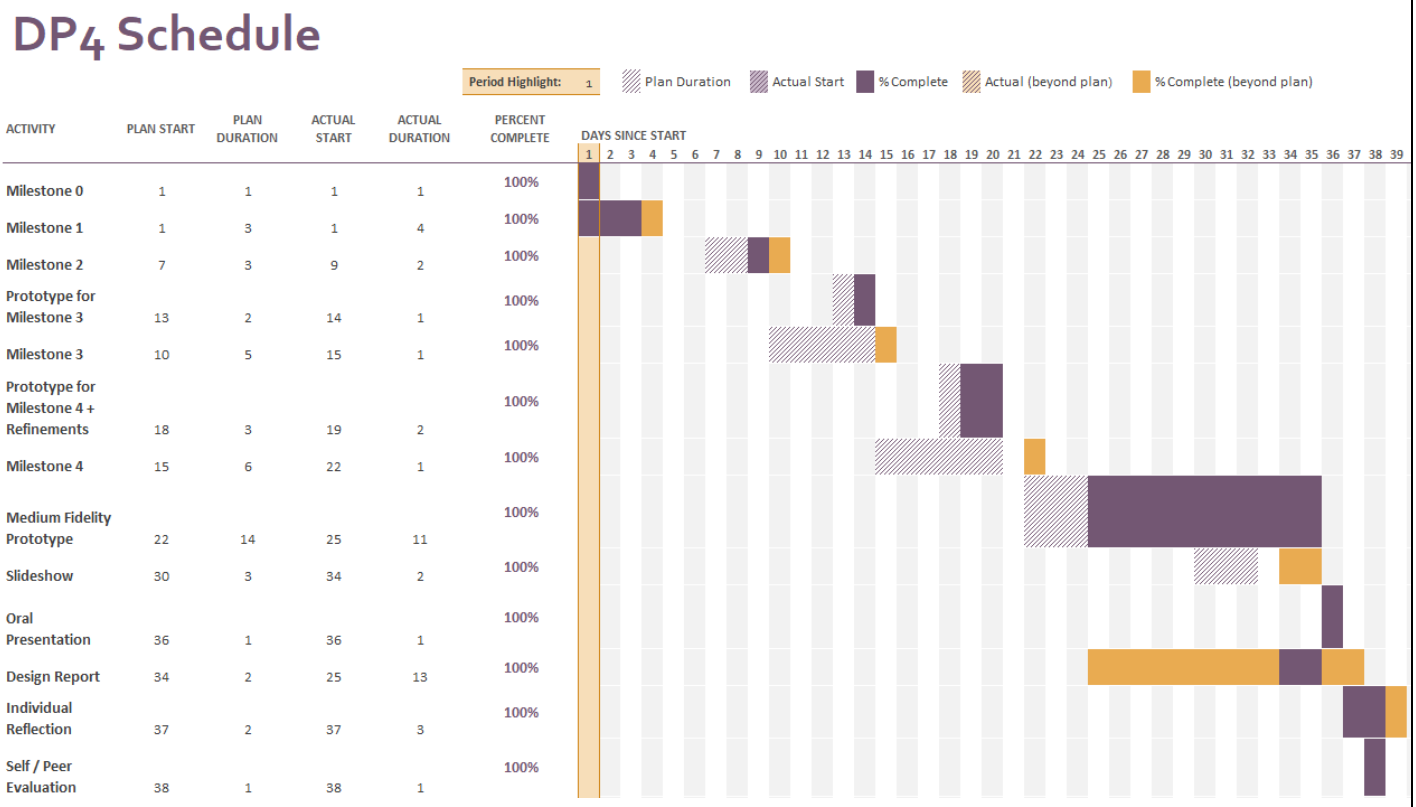
Appendix A: Project Schedule

Figure A1. Preliminary Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	3	1	4	100%
Milestone 2	7	3	0	0	0%
Milestone 3	10	5	0	0	0%
Milestone 4	15	6	0	0	0%
Medium Fidelity	22	14	0	0	0%
Slideshow	30	3	0	0	0%
Presentation	35	1	0	0	0%
Design Report	34	2	0	0	0%
Individual Reflection	37	2	0	0	0%
Self / Peer Evaluation	38	1	0	0	0%

Figure A2. Final Gantt Chart



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Milestone 0	1	1	1	1	100%
Milestone 1	1	3	1	4	100%
Milestone 2	7	3	9	2	100%
Prototype for Milestone 3	13	2	14	1	100%
Milestone 3	10	5	15	1	100%
Prototype for Milestone 4 + Refinements	18	3	19	2	100%
Milestone 4	15	6	22	1	100%
Medium Fidelity Prototype	22	14	25	11	100%
Slideshow	30	3	34	2	100%
Oral Presentation	36	1	36	1	100%
Design Report	34	2	25	13	100%
Individual Reflection	37	2	37	3	100%
Self / Peer Evaluation	38	1	38	1	100%

Figure A3. Logbook of Additional Meetings and Discussions

Monday, March 07, 2022 @ 8:00 PM

Attendance

Role	Name	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	Yes
Administrator	Kyle St. Louis	Yes
Coordinator	Alexander Diab-Liu	Yes
Subject Matter Expert	Wanqi (Anna) Chen	Yes

Meeting Minutes

- Completed Milestone 1
  - Need Statement
  - Objectives/Constraints
  - Engineering Specifications

Post-Meeting Action Items

- None

Monday, March 14, 2022 @ 8:00 PM

Attendance

Role	Name	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	Yes
Administrator	Kyle St. Louis	Yes
Coordinator	Alexander Diab-Liu	Yes
Subject Matter Expert	Wanqi (Anna) Chen	Yes

Meeting Minutes

- Completed Milestone 2
  - Went through Pugh matrix
  - Decided on an idea (Wheelchair axle with separating mechanism)

Post-Meeting Action Items

- Complete Low Fidelity Prototype

Thursday, March 24, 2022 @ 5:00 PM

Attendance

Role	Name	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	Yes
Administrator	Kyle St. Louis	Yes
Coordinator	Alexander Diab-Liu	Yes
Subject Matter Expert	Wanqi (Anna) Chen	Yes

Meeting Minutes

- Pre-Meeting
  - Independently brainstormed ideas for the mechanism to attach/detach the wheel axles
  - Explored the pros and cons of the designs
- Meeting
  - Decided on the attaching/detaching mechanism to be a spring based design that is activated by a petal near Nadina's feet
  - Built the low-fidelity prototype for Milestone 4

Post-Meeting Action Items

- Research specific bike mechanisms, try and gather materials for final design

Appendix B: Scheduled Weekly Meetings

Figure B1. Weekly Design Studio Agenda's

No Agenda for Week 1, since roles had not yet been assigned

FRIDAY, MARCH 11, 2022 @ 12:30 PM

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Giulia Morris-Cefis**	**morrig13**	**NO**
Administrator	**Kyle St. Louis**	**Stlouk1**	**YES**
Coordinator	**Alexander Diab-Liu**	**diabliua**	**YES**
Subject Matter Expert	**Wanqi (Anna) Chen**		**YES**
Guest			

AGENDA ITEMS

1. TA update
   - Giulia isn't here today, but she has given the team her own preliminary work for milestone 2 (TA's should know this already)
   - We've chosen to work with Nadina, hoping to create something that will give her some independence back
   - QUESTION: does our 'product' have to specifically incorporate a coding and modelling part, or is that up to us?
2. Preliminary gantt chart is complete, everyone should take a quick look to see if there's anything that needs to be changed before being submitted
3. In today's design studio we will generate some ideas, and make preliminary sketches
   - We need to set up a meeting for someday during the coming week to complete our concept evaluation together

Friday, March 18, 2022 @ 12:30 PM

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Giulia Morris-Cefis**	**morrig13**	**YES**
Administrator	**Kyle St.Louis**	**stlouk1**	**YES**
Coordinator	**Alex Diab-Liu**	**diabliua**	**YES**
Subject Matter Expert	**Anna Chen**	**chenw142**	**YES**

Agenda Items

1. TA meeting
   - Share our preliminary design
   - Intentions to mix multiple designs together
2. Design Review
   - Giulia (manager) to present design and low-fidelity prototype
   - Alex (coordinator) to take notes on feedback
   - QUESTIONS:
     - Do you think this is feasible?
     - What do you think the best way to connect and disconnect the axis would be?
     - Would it be better to leave it completely mechanical, or incorporate an electric aspect to change the axis?
     - Would a mechanism with gears, or a simple latch be strong enough to hold the wheels together?
     - Should we include bike pedals? (Briefly explain)
     - Should we make it detachable, or should it be a permanent modification?
3. Discuss design refinements
   - From the feedback we received, or new information we've gained is there any part of our design that we should change?
   - Refinements to be recorded on milestone worksheet

Friday, March 25, 2022 @ 12:30 PM

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	morrig13	YES
Administrator	Kyle St.Louis	stlouk1	YES
Coordinator	Alex Diab-Liu	diabliua	YES
Subject Matter Expert	Anna Chen	chenw142	YES

Agenda Items

1. TA Meeting
   - Share new prototype
   - Discuss any concerns with creating our medium fidelity prototype
2. Design Review
   - Giulia (manager) to present design and low-fidelity prototype
   - Alex (coordinator) to take notes on feedback
   - QUESTIONS:
     - How to stop the string twirling? (Something on the pedal that turns as well, or should we find a way to make the spring system stationary)
     - How much support should be on the pulley system?
     - How should we connect the wire, pin, and spring?
     - Would pedal or hand lever work better in terms of force needed etc?
3. Design Refinements
   - From the feedback we received, or new information we've gained is there any part of our design that we should change?
   - Refinements to be recorded on milestone worksheet

Figure B2. Weekly Design Studio Meeting Minutes

Friday, March 04, 2022 @ 1:30 PM

Attendance

Role	Name	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	Yes
Administrator	Kyle St. Louis	Yes
Coordinator	Alexander Diab-Liu	Yes
Subject Matter Expert	Wanqi (Anna) Chen	Yes

Meeting Minutes

- Decided on meeting to finish milestone 1, since design studio was only 1 hour
- Completed Milestone 0
  - Assigned Administrative Tasks to each group member
  - Take team photo and upload it
- Discussed about the details of Nadina and Kevin

Post-Meeting Action Items

- Go over the recordings of Nadina and Kevin
- Think about which one each group member is more interested in

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Giulia Morris-Cefis**	**morrig13**	**NO**
Administrator	**Kyle St. Louis**	**Stlouk1**	**YES**
Coordinator	**Alexander Diab-Liu**	**diabliua**	**YES**
Subject Matter Expert	**Wanqi (Anna) Chen**		**YES**
Guest			

Meeting Minutes

1. TA Meeting
    a. Explained Roles, Attendance
    b. TA Advice: Make sure to keep the designs feasible, and not to be too broad
2. Additional Questions for Nadina
    a. What cream does she use that helps her sleep?
    b. What kind of massages are beneficial for people with MS?
    c. Can she pedal without any help? Is it equal on both sides? How much force can she pedal with?
    d. To what extent can she use her wheelchair by herself?
    e. How much motion does she have reaching across her body?
    f. Why doesn't she use a pedalling wheelchair?
    g. What is the easier movement Nadina can do with her left hand?
3. Mid-Design Studio TA Meeting
    a. Make sure that she can put it on by herself
    b. Don't overcomplicate a problem

Post-Meeting Action Items

1. *Meeting on Monday at 8:00 to finalize Design [Everyone]*
2. *Finish Low Fidelity Prototype [Everyone]*

Friday, March 11, 2022 @ 12:30 PM

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Giulia Morris-Cefis**	**morrig13**	**NO**
Administrator	**Kyle St. Louis**	**Stlouk1**	**YES**
Coordinator	**Alexander Diab-Liu**	**diabliua**	**YES**
Subject Matter Expert	**Wangi (Anna) Chen**		**YES**
Guest			

Meeting Minutes

1. TA Meeting
    a. Explained Roles, Attendance
    b. TA Advice: Make sure to keep the designs feasible, and not to be too broad
2. Additional Questions for Nadina
    a. What cream does she use that helps her sleep?
    b. What kind of massages are beneficial for people with MS?
    c. Can she pedal without any help? Is it equal on both sides? How much force can she pedal with?
    d. To what extent can she use her wheelchair by herself?
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    g. What is the easier movement Nadina can do with her left hand?
3. Mid-Design Studio TA Meeting
    a. Make sure that she can put it on by herself
    b. Don't overcomplicate a problem

Post-Meeting Action Items

1. *Meeting on Monday at 8:00 to finalize Design [Everyone]*
2. *Finish Low Fidelity Prototype [Everyone]*

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	**Giulia Morris-Cefis**	**morrig13**	**YES**
Administrator	**Kyle St.Louis**	**stlouk1**	**YES**
Coordinator	**Alex Diab-Liu**	**diabliua**	**YES**
Subject Matter Expert	**Anna Chen**	**chenw142**	**YES**

Meeting Minutes

1. TA Meeting
    a. Find questions to ask Design Reviewers
    b. Explore methods to attach/detach axle connection of wheels
2. Design Review
    a. Weighting of axle
        i. Will the force be enough?
    b. In terms of lever
        i. Clamp to limit turning (Way to connect it)
    c. Bike
        i. No need
        ii. Already been commercialized
        iii. Removes need for wheel axle mechanism

Post-Meeting Action Items

1. *Meet next Thursday [Team]*
2. *Brainstorm connection ideas for prototype [Team]*

Friday, March 25, 2022 @ 12:30 PM

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	morrig13	YES
Administrator	Kyle St.Louis	stlouk1	YES
Coordinator	Alex Diab-Liu	diabliua	YES
Subject Matter Expert	Anna Chen	chenw142	YES

Meeting Minutes

1. TA Meeting
    a. Positive feedback for our refinements
    b. Advice to not get Pidgeon-holed into a specific idea, since we were having problems with the twisting of the thread
    c. Consider making the spring able to spin
2. Group Discussion
    a. Dividing Final Deliverables
        i. Group
            1. Executive Summary
            2. Presentation & Scripting
            3. PowerPoint Presentation (Submitted by Kyle)
            4. Video
            5. CAD Model of inner mechanisms
            6. Medium Fidelity Prototype
        ii. Alex
            1. Background and Research Summary with Anna
            2. Summary of Design Objectives
        iii. Kyle
            1. Description of Proposed Solution with Giulia
            2. Usage
        iv. Giulia
            1. Description of Proposed Solution with Kyle
            2. Product Identification
        v. Anna
            1. Background and Research Summary with Alex
            2. Reference List
            3. Standards and Safety
3. Design Review
    a. What if the pin misses the hole continuously?
        i. Potentially coming up with other potential designs
            1. Similar to standard cars, manually engage and disengage using some type of lever?
            2. Clutch mechanisms
    b. Make sure it doesn't require too much force
    c. Pedal is not necessarily realistic because of force

Post-Meeting Action Items

1. *Work on Medium Fidelity Prototype (Group)*

Monday, March 21, 2022 @ 5:30 PM

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	morrig13	YES
Administrator	Kyle St.Louis	stlouk1	YES
Coordinator	Alex Diab-Liu	diabliua	YES
Subject Matter Expert	Anna Chen	chenw142	YES

Meeting Minutes

- Checking materials
- Verifying mechanism
- Decided to delegate tasks for the week
    - Obtain wood, other materials for lever
- Plan to CAD the inner mechanism (pulley)
- Checked materials in design studio

Post-Meeting Action Items

1. *Chip away at assigned design report sections [Everyone]*

Monday, April 4 2022 @ 2:30 PM

Attendance

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	morrig13	NO
Administrator	Kyle St.Louis	stlouk1	NO
Coordinator	Alex Diab-Liu	diabliua	YES
Subject Matter Expert	Anna Chen	chenw142	YES

Meeting Minutes

- Assembled front wheels
- Used hacksaw to cut the wood into the correct dimensions
- Hammered in and bent nails to keep wheels in place with wood

Wednesday, April 6, 2022 @ 2:30 PM

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	morrig13	YES
Administrator	Kyle St Louis	stlouk1	YES
Coordinator	Alex Diab-Liu	diabliua	NO
Subject Matter Expert	Anna Chen	chenw142	NO

MEETING MINUTES

- Attached front wheels to back wheels
- Finalized pin-locking mechanism for wheelchair medium fidelity prototype
- Began design of slide deck (presentation)
- Began presentation script/outline

POST-MEETING ACTION ITEMS

2. *Chip away at slides and script [Everyone]*

Thursday, April 7, 2022 @ 2:30 PM

ATTENDANCE

Role	Name	Mac ID	Attendance (Yes/No)
Manager	Giulia Morris-Cefis	morrig13	YES
Administrator	Kyle St.Louis	stlouk1	YES
Coordinator	Alex Diab-Liu	diabliua	YES
Subject Matter Expert	Anna Chen	chenw142	YES

MEETING MINUTES

- Finished assembly of One-Wheel
- Created manual switching, attached supports across the entire wheelchair using nails, screws, wood, drills, and a hacksaw
- Wheelchair broke at 7pm and we had to stay an extra hour to fix it
    - Reapply the glue
    - Reassemble the entire axis

POST-MEETING ACTION ITEMS

3. *Work on slides and script [Everyone]*

Appendix C: Design Studio Worksheets

Insert image here
Figure C1. Milestone 0

MILESTONE 0 – COVER PAGE

Team Number:	36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Wanqi (Anna) Chen	chenw142
Giulia Morris-Cefis	morrig13
Kyle St. Louis	stlouk1
Alexander Diab-Liu	diabliua

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-4 grade.

Please attach your Team Portrait in the dialog box below

MILESTONE 0 – TEAM CHARTER

Team Number: 36

Incoming Personnel Administrative Portfolio:

Prior to identifying Leads, identify each team members incoming experience with various **Project Leads**

	Team Member Name:	Project Leads
1.	Wanqi (Anna) Chen	☒M ☒A ☒C ☐S
2.	Giulia Morris-Cefis	☐M ☒A ☒C ☐S
3.	Kyle St. Louis	☒M ☒A ☒C ☐S
4.	Alexander Diab-Liu	☒M ☒A ☐C ☐S

To 'check' each box in the Project Leads column, you must have this document open in the Microsoft Word Desktop App (not the browser and not MS Teams)

Project Leads:

Identify team member details (Name and MACID) in the space below.

Role:	Team Member Name:	MacID
Manager	Giulia Morris-Cefis	morrig13
Administrator	Kyle St. Louis	stlouk1
Coordinator	Alexander Diab-Liu	diabliua
Subject Matter Expert	Wanqi (Anna) Chen	chenw142

Figure C2. Milestone 1

MILESTONE 1 – COVER PAGE

Team Number:	36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Giulia Morris-Cefis	morrig13
Alexander Diab-Liu	diabliua
Kyle St. Louis	stlouk1
Wangi (Anna) Chen	chenw142

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-4 grade.

MILESTONE 1 (STAGE 1) – CLIENT VISIT QUESTIONS WORKSHEET

Team Number:	36

As a team, prepare a preliminary **list of questions** to ask your client. Enter questions in the space below.

Preliminary List of Questions:

KEVIN:

- What are simple tasks you have found increasingly difficult after your stroke?
- What tasks have you found are not possible using your right hand since your stroke?
- How do exercises at PACE/what exercises at PACE help best with your specific needs?
    - Specific exercises for legs and mobility versus exercises more specified to your hands
- How has your stroke affected your working experience?
- How has the stroke affected going out of your house?
- How has COVID impacted your workout routine, since you are not going to PACE as much do you do physio at home, did this set you back in recovering?
- What is considered long distance for you, is this different every day?
- Which every day tasks have become difficult after your stroke
- Are you able to go out alone, or are you accompanied by someone?

NADINA:

- What is the source of fatigue in your right leg/how much exercise can your right leg withstand before fatigue kicking in?
- What were your initial concerns when you first got your diagnosis?
- What hobbies or interests have you been prevented from enjoying due to your MS diagnosis?
- What tasks around the home do you feel have become increasingly challenging due to your diagnosis?
- How can your working environment/accessibility to resources be improved to improve your experience?
- What problems do you experience with getting around in your wheelchair when going out?
- What do you like doing most with your son? (i.e., Hobbies, games, etc.)
- How has your diagnosis limited/affected your day-to-day interactions around the home?
- What exercises at PACE have best improved your right-side fatigue/mobility?

Document any questions that come up *during* the client visit in the space below.

Additional Questions:

KEVIN
- Do you wish your walker was more compact/transportable?
- Do you find any issues when transporting the walker, getting into the car, etc.

NADINA:
- How can PACE improve their exercises or how can your workout equipment be improved upon?

MILESTONE 1 (STAGE 2) – DOCUMENTATION OF DISCUSSION

Team Number: 36

As a team, document your discussions with the client during their visit.

NADINA:

How has MS affected her life? (Nadina)
- *Her right arm's range of motion is constrained, and there is constant resistance felt in the right arm.*
- *She needs help in many of her daily tasks because of the constrained motion of the right part of the body (the hand and the arm), including*
- *Her muscles are constantly tensioned, causing pain and especially at night, she couldn't fall asleep because of the pain.*
- *She can't stand and walk by herself anymore and she really wants to be able to walk again and exercise, since exercising is a huge part of her life.*

What inconvenience in real life she faced with? (Nadina)
- *Those accessibility design (e.g., those bars in the bathroom), does not really serve the purpose because those who designed them does not really use them. She mentioned about the bar that is at the back of the toilet: "No one really use them".*

What best helps with her muscle tension? (Nadina)
- *The exercise she did helps to relieve the muscle tension and gets her larger range of motion.*
- *She usually goes to PACE at Mac twice every week after COVID hits, so she needs to find a way to exercise more.*
- *She also uses cream before sleep to help with the muscle pain.*
- *She does not go to massage because people there don't really know MS and thus don't really know how to deal with it.*

KEVIN:

What is the biggest everyday impact that you have noticed?

- Kevin's walking is very laboured, he needs a walker now in the home too
- Difficulty using a can opener
- His aphasia makes it difficult for others to understand him
- Although he is very good at using technology

What do you like doing most in your spare time?

- Really likes playing chess

How much has the PACE program helped?

- It has helped a lot
- It helps the most with his mobility and coordination

What exercises do you do the most at PACE and physio?

- Triceps, biceps, weights in general
- He rides the bike a lot

What aspect of your life do you wish you could have back?

- He wishes for his walking back, so many problems have stemmed from just his mobility, coordination, balance issues

What issues do you have with your aphasia?

- They don't find its word specific
- The problem stems from his inability to properly form sounds with his tongue

Specific issues with the can opener?

- Turning the can opener is difficult with his right hand (most movements are difficult with his right side – leg included)
- Has become a lot stronger on his left side from adapting to being "left handed"

Spatial awareness?

- Brushes teeth a lot further away from the sink than he needs to be, when opening the door he's far off from the knob and needs assistance

Assistance vs doing things for him?

- Rose tries to limit how much she helps Kevin because she doesn't want to excessively help him in things he can adapt to or accustom himself to on his own

Hand Dexterity

- The problem is usually due to multiple steps involved in hand activities, opening up a can involves holding it down with his left hand while turning with his right

Walker?

- Could be more compact and transportable
- Uses for balance issues and helps with coordination

Loves riding his bike and ride all the time at home

Weight exercises?

- Chair lifting, shoulder press, tricep workouts

Routine?

- Loves watching news and the view
- Goes to PACE on Tuesdays and aphasia group
- Very mellow in general even before the stroke

MILESTONE 1 (STAGE 3) – NEED STATEMENT

Team Number: 36

Write your Need Statement in the space below. Recall that your need statement should:

→ Have a clearly defined problem (what is the need?)
→ Indicate your client (who has the need?)
→ Have a clearly defined outcome (what do you hope to solve and why is it important?)

NEED STATEMENT:	Nadina has been diagnosed with Multiple Sclerosis for 22 years, which has caused a significant decrease in her autonomy and range of motion as a result of spasticity. Consequently, she has been forced to depend on others and her wheelchair for mobility and everyday tasks, thereby reducing her independence. Create a design that will improve Nadina's range of motion and mobility, empowering her to reclaim her independence and return to the active lifestyle she once enjoyed.

Page Break

MILESTONE 1 (STAGE 4) – CUSTOMER REQUIREMENTS

Team Number: 36

As a team, develop a list of customer requirements that detail what the proposed solution should do and achieve. For each requirement, categorize in parentheses as an objective, constraint or function. As a reminder, requirements ***can be*** *more than one* of the three.

List your customer requirements in this field. Bullet-point format is acceptable. Requirements can be written as either a brief sentence or 2-4 words, whichever is most appropriate. For each requirement, indicate (in parentheses) whether it is an objective, function, or constraint.

Objectives:

- Should be comfortable
- Should be affordable
- Should be user-friendly
- Should be inconspicuous
- Should be a passive/non-electrical device

Constraints:

- Must be able to be used independently
- Must not get in the way of everyday tasks
- Must not be too bulky

Functions:

- Relieves muscle tension
- Facilitates independent motion
- Improves range of motion

MILESTONE 1 (STAGE 5) – ENGINEERING SPECIFICATIONS

Team Number: 36

As a team, translate your customer requirements into a set of engineering specifications, spelling out in precise, measurable detail what the design solution is supposed to do.

List your engineering specifications in this field. Bullet-point format is acceptable. Ensure it is clear what engineering specification aligns with each customer requirement.

- Takes little time to set-up/install (aligns with: independency + user-friendly)
- Uses minimal/cheaper materials + is efficient with use of materials (aligns with: bulkiness and affordability)
- Requires minimal range of motion to use/requires little energy to use (aligns with: range of motion + independency)
- Doesn't interfere with motion when exercising (aligns with: independency)
- Doesn't have sharp edges that might hurt the user and uses organic shapes/comfortable fitting shapes?? (aligns with: independency + user-friendly + comfortable)
- Requires minimal outside sources/"add-ons" (aligns with: independency + inconspicuous)

Figure C3. Milestone 2

MILESTONE 2 – COVER PAGE

Team Number: 36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Kyle St. Louis	Stlouk1
Wanqi (Anna) Chen	chenw142
Alexander Diab-Liu	diabliua
Giulia Morris-Cefis	morrig13

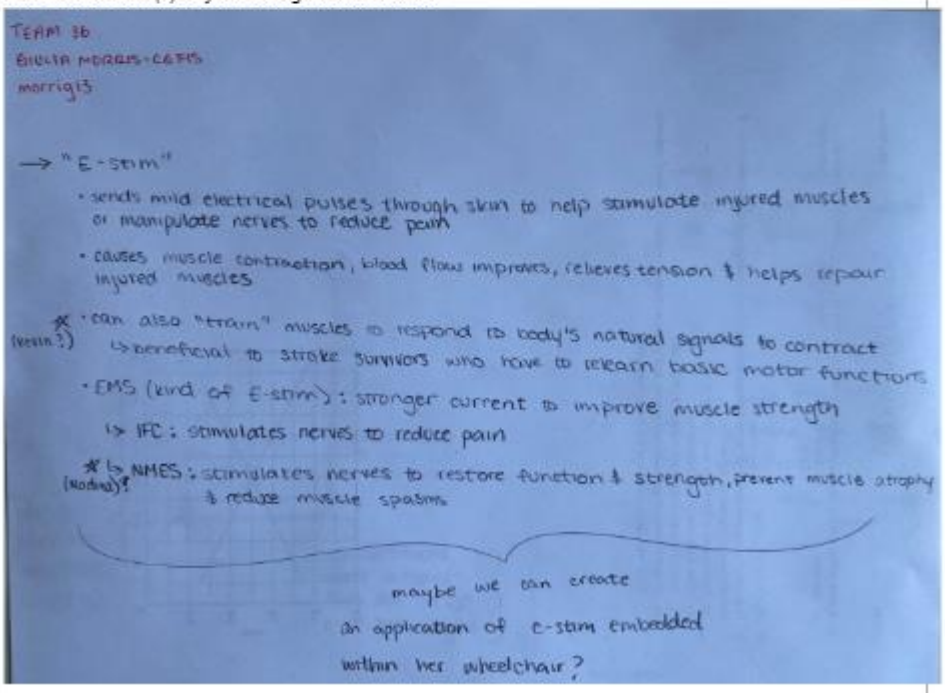
Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-4 grade.

MILESTONE 2 (STAGE 1) – IDEA GENERATION

Team Number:	36

1. As a team, outline several potential concept solutions
   → Your ideas can be sketches are bullet-point descriptions
   → Be creative with the materials you choose and the modifications you propose
   → Be sure to clearly write your Team Number, Name and MacID
2. Take a photo of your work
3. Insert your photo as a Picture (Insert > Picture > This Device).
4. **Do not include more than one sketch per page**

Insert screenshot(s) of your idea generation below



Insert screenshot(s) of your idea generation below

- Device which helps Nadina in working out independently
  - In videos she needs help with maintaining tricep position and with raising her arm to complete bicep curls
  - An arm band which could reduce the difficulty with raising her arm with the weight using resistance bands or tension to help raise her arm and to provide resistance on the way down
  - The arm band could connect to both her bicep/triceps upper arm and her forearm/wrist area
  - Putting weights within the band itself could help reduce the need for her to lift weights herself with her hand.
  - Arm band can
- EMG sensor that lets Nadina know when to stop exercising as to not aggravate her symptoms
  - Records data as time, gives an average of her workout time
  - Will help her avoid unnecessary pain and irritating muscles, helps her sleep
  - Serves as improvement tracker
  - Can be combined with above
- Wheelchair Exercise
  - Like a bike gear, can change resistance of pull
  - Helps her move herself around – increases autonomy
  - Her pulling a band will help move her wheelchair around
  - Can also be combined with elastic idea
- Wheelchair movement
  - Some mechanism which connects the rotation of the wheels of her wheelchair to then use just her left hand to rotate both wheels allowing her to move forwards more
  - Another "gear" in the wheelchair can disconnect the rotation of the wheels and allow her to rotate the wheelchair by rotate solely the left wheel
  - A gear on one wheel can lock in to connect the axes of the wheels to then allow both wheels to move in tandem
- Wheelchair bike
  - We could also have a bike/wheelchair mechanism allowing her to use her wheelchair like a bike pedalling her feet to move her wheelchair forward
  - In the future: we could have a capacitor to store energy in the wheelchair created from her motions to create electricity from a generator

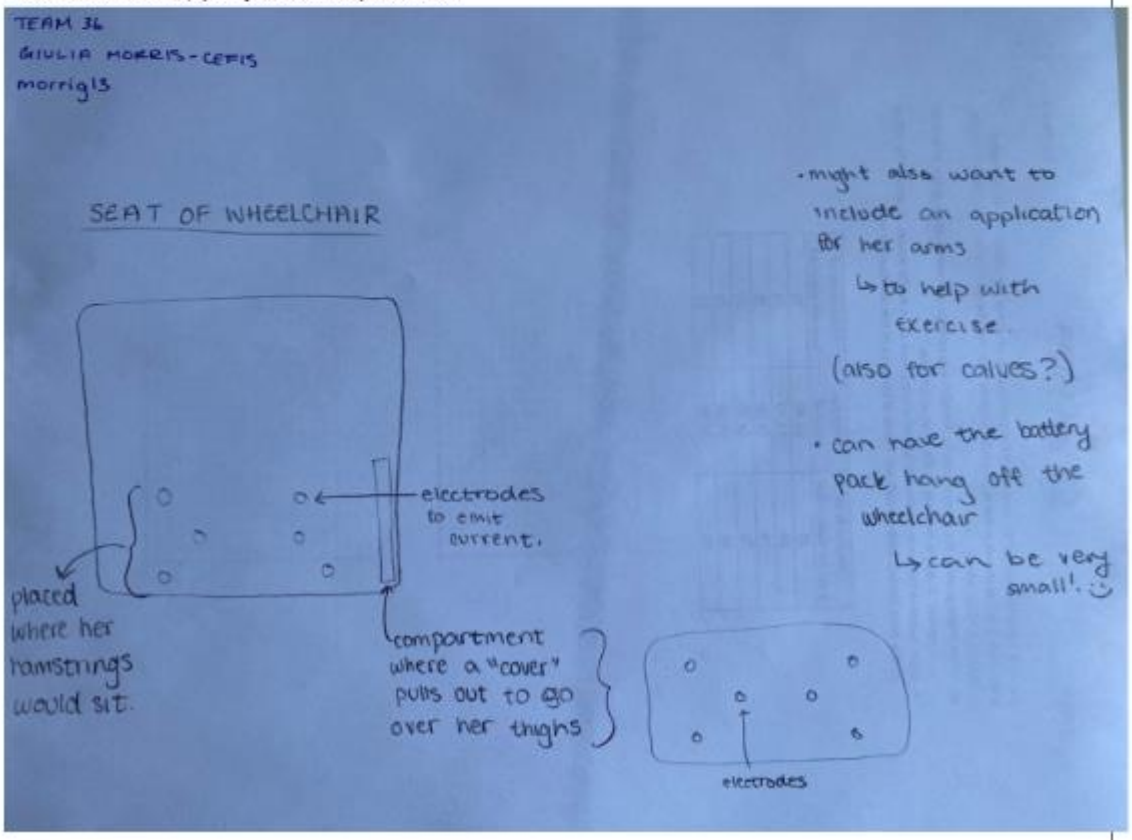
*** Copy-and-paste the above if there is more than one photo

MILESTONE 2 (STAGE 2) – CONCEPT SKETCHES

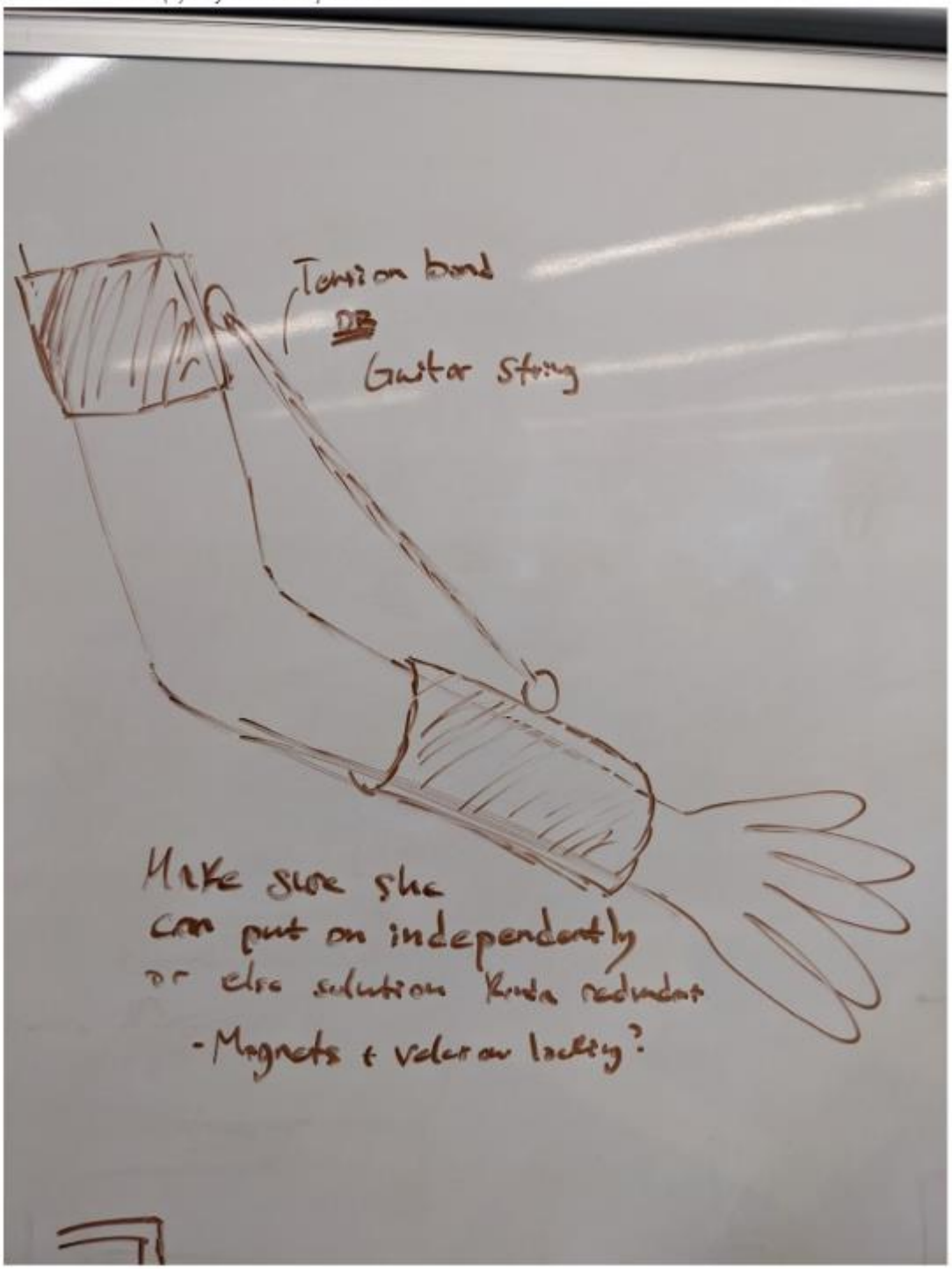
Team Number: 36

1. Complete your sketch on a separate sheet of paper or a whiteboard
   → Be sure to clearly write your Team Number, Name and MacID
2. Take a photo of your work
3. Insert your photo as a Picture (Insert > Picture > This Device).
4. **Do not include more than one sketch per page**

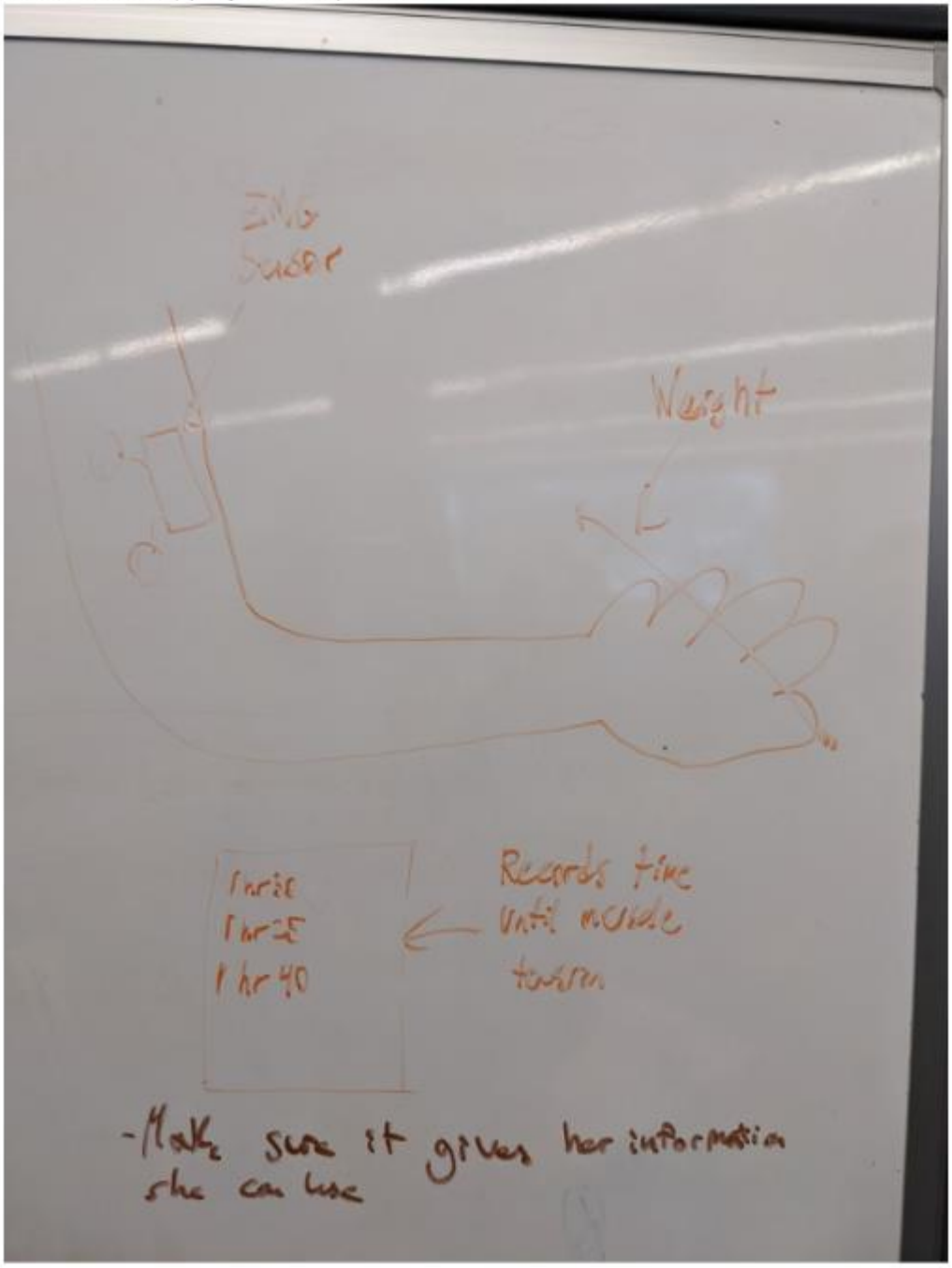
Insert screenshot(s) of your concept sketch



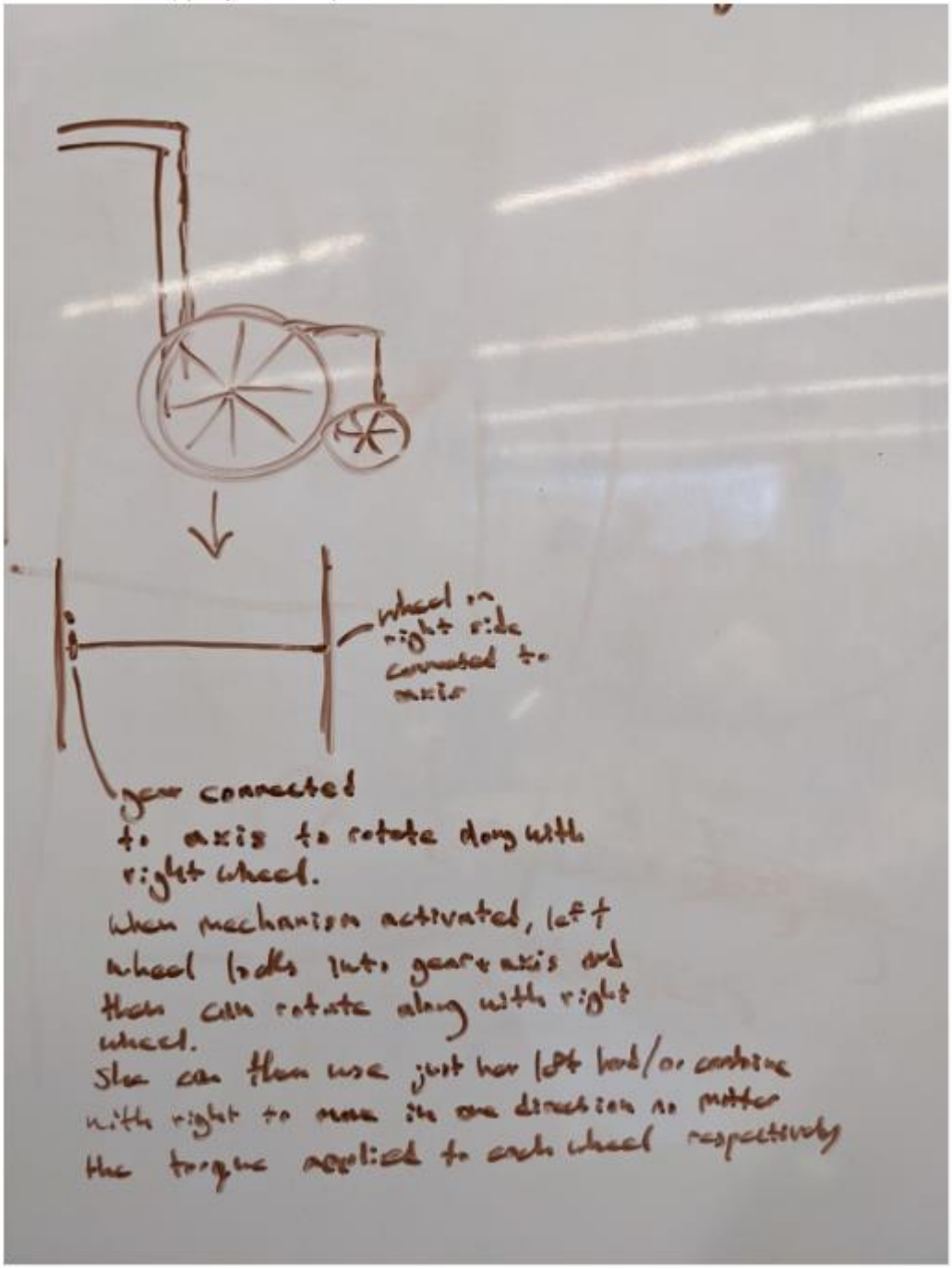
Insert screenshot(s) of your concept sketch



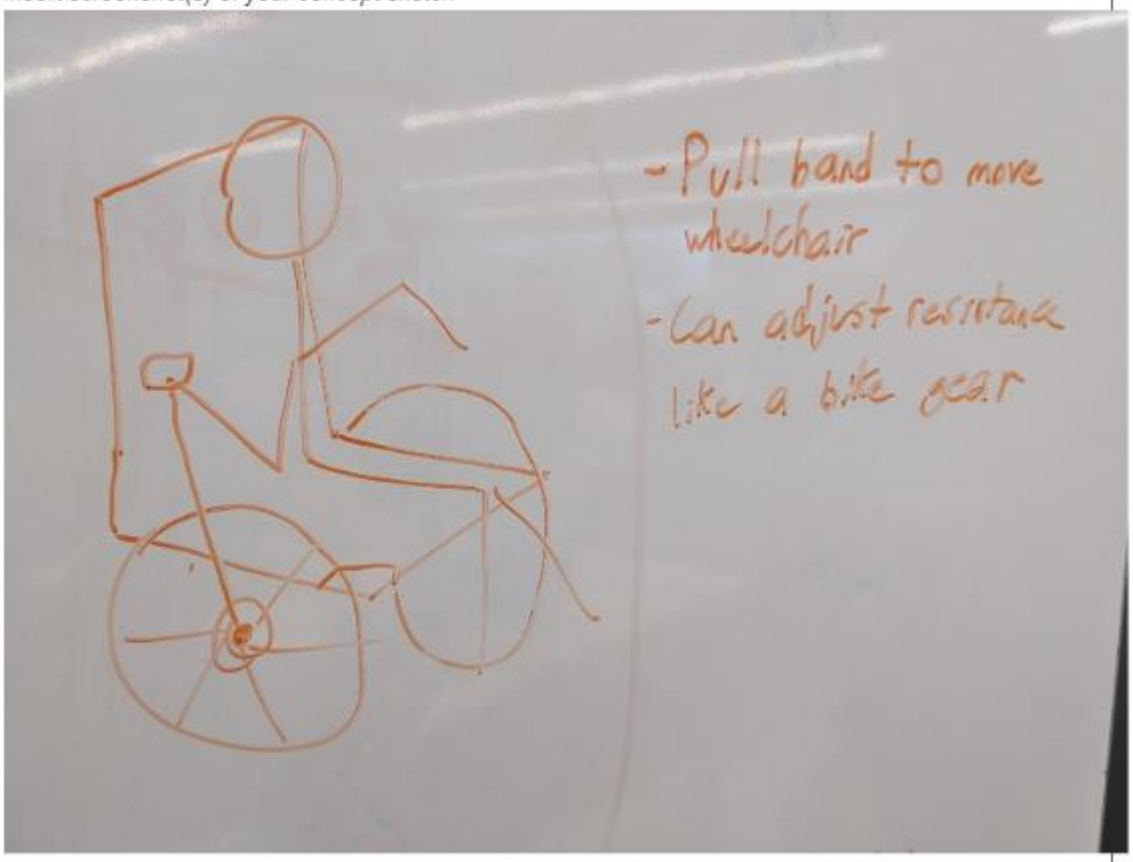
Insert screenshot(s) of your concept sketch



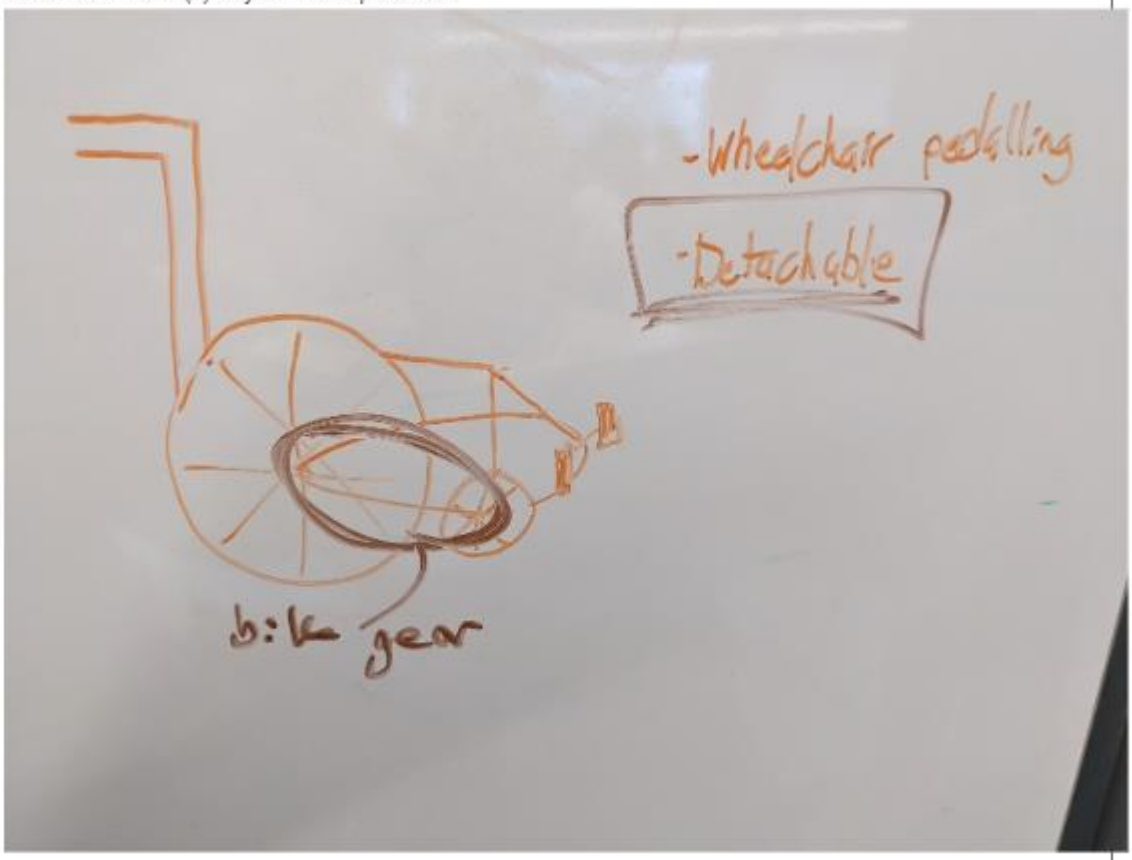
Insert screenshot(s) of your concept sketch



Insert screenshot(s) of your concept sketch



Insert screenshot(s) of your concept sketch



1. As a team, evaluate your concept solutions in the table below
   → List your Criteria in the first column
      - You should include a minimum of 5 criteria
   → Fill out the table below, comparing your designs against a baseline concept (the decision of a baseline concept is arbitrary and entirely up to your team to decide)
      - Replace "Concept 1", "Concept 2", etc. with more descriptive labels (e.g., a distinguishing feature or the name of student author)
      - Indicate a "+" if a concept is better than the baseline, a "–" if a concept is worse, or a "S" if a concept is the same

	Armband	***EMG Sensor***	***E-stim***	***Wheelchair gear***	***Arm band wheelchair motor***	***Biking wheelchair***
Comfortable	0	-1	0	1	-1	-1
Affordable	0	-1	-1	0	-1	-1
User-Friendly	0	-1	0	0	-1	0
Inconspicuous	0	-1	1	1	-1	-1
Passive/non-electric	0	-1	-1	1	0	0
Independent Use	0	-1	1	1	0	0
Not too bulky	0	-1	1	0	-1	-1
Relieves muscle tension/use	0	0	1	-1	0	-1
Facilitates independent motion	0	0	0	0	0	1
Improves range of motion	0	0	0	-1	0	0
Innovative/creative design	0	1	0	1	1	1
Feasibility	0	0	-1	0	-1	-1
Total +	0	1	4	5	1	2
Total –	0	-7	-3	-2	-6	-6
Total Score	0	-6	1	3	-5	-4

2. Indicate the concept(s) you have selected to pursue for further development and testing, include **justification**

We have decided to continue with the wheelchair gear design. This design improves not only her ability to move on her own but is also user-friendly, inconspicuous, affordable, and very feasible. The biking wheelchair concept can also be combined with the gear design to improve upon in future concept discussions if needed.

Another potential design consideration is the arm band, which helps reduce muscle fatigue, as well as allowing for independent muscle exercises.

*** It's perfectly acceptable to consider more than one design at this point.**

3. Briefly describe any **design refinements** that your team will consider for the selected concept. Design refinements include any changes or modifications that deviate from the initial design. These changes or modifications may be based on *other* designs that were proposed but not selected, or they may be derived from discussions during your team's concept evaluation.

- Adding the biking wheelchair add-on is a potential refinement reducing the activity of her arm movement and allowing for increased range of motion with the wheelchair.
    - Adding actual bike gears to make it easier for her to pedal (if this refinement is included)
- An electric generator can be used to store energy from the biking refinement to be used towards moving the wheelchair when in rest
- Combining this concept with the e-stim idea, electric shocks can be used to reduce muscle stiffness and improve muscle activity
- Combining this idea further with the arm movement/exercise action to then move the wheelchair, she can do alternative (potentially easier) movements to then move the wheelchair, if the regular type of motion is too difficult

Figure C4. Milestone 3

MILESTONE 3 – COVER PAGE

Team Number:	36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Wanqi (Anna) Chen	chenw142
Kyle St. Louis	St.louk1
Giulia Morris-Cefis	morrig13
Alexander Diab-Liu	diabliua

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-4 grade.

QUESTIONS FOR DESIGN REVIEW

- Do you think this is a feasible design?
- What is the best way of going about connecting and disconnecting the axel (we were thinking about doing gears and having an option of connecting/disconnecting gears to allow Nadina to change from turning/going forward?
- Should we keep this strictly mechanical or include electronics/software

MILESTONE 3 (STAGE 2) – DESIGN REVIEW #1 FEEDBACK

Team Number:	36

Use the space below to document feedback for your design.

Design Review

a. Weighting of axle
   i. Will the force be enough?
   ii. When using the left hand to turn, there will be an increase in friction on that side

b. In terms of lever
   i. Clamp to limit turning (Way to connect it)
   ii. Latching mechanism to lock in axels
   iii. Car gears which connect axels/disconnect turning axels

c. Bike
   i. No need
   ii. Already been commercialized
   iii. Removes need for wheel axle mechanism

Use the space below to propose design refinements based on the feedback.

For future: adding a small detachable weight to counteract higher pressure from left arm

Lever to attach / detach axles for turning, think about how much force she is going to have to apply to connect axels and how is she going to apply force to transform into this connection mechanism?

- Gearing mechanism can be used to transfer force that Nadina applies

When axels are connected both wheels can rotate together at the same rate. When axel mechanism disconnected. Right wheel can automatically lock allowing Nadina to rotate the left wheel and turn in her wheelchair

PHOTO OF DESIGN:

Figure C5. Milestone 4

MILESTONE 4 – COVER PAGE

Team Number:	36

Please list full names and MacID's of all *present* Team Members

Full Name:	MacID:
Wanqi (Anna) Chen	chenw142
Kyle St. Louis	Stlouk1
Giulia Morris-Cefis	morrig13
Alexander Diab-Liu	diabliua

Any student that is ***not*** present for Design Studio will not be given credit for completion of the worksheet and may be subject to a 10% deduction to their DP-4 grade.

MILESTONE 4 (STAGE 2) – DESIGN REVIEW #2 FEEDBACK

Team Number:	36

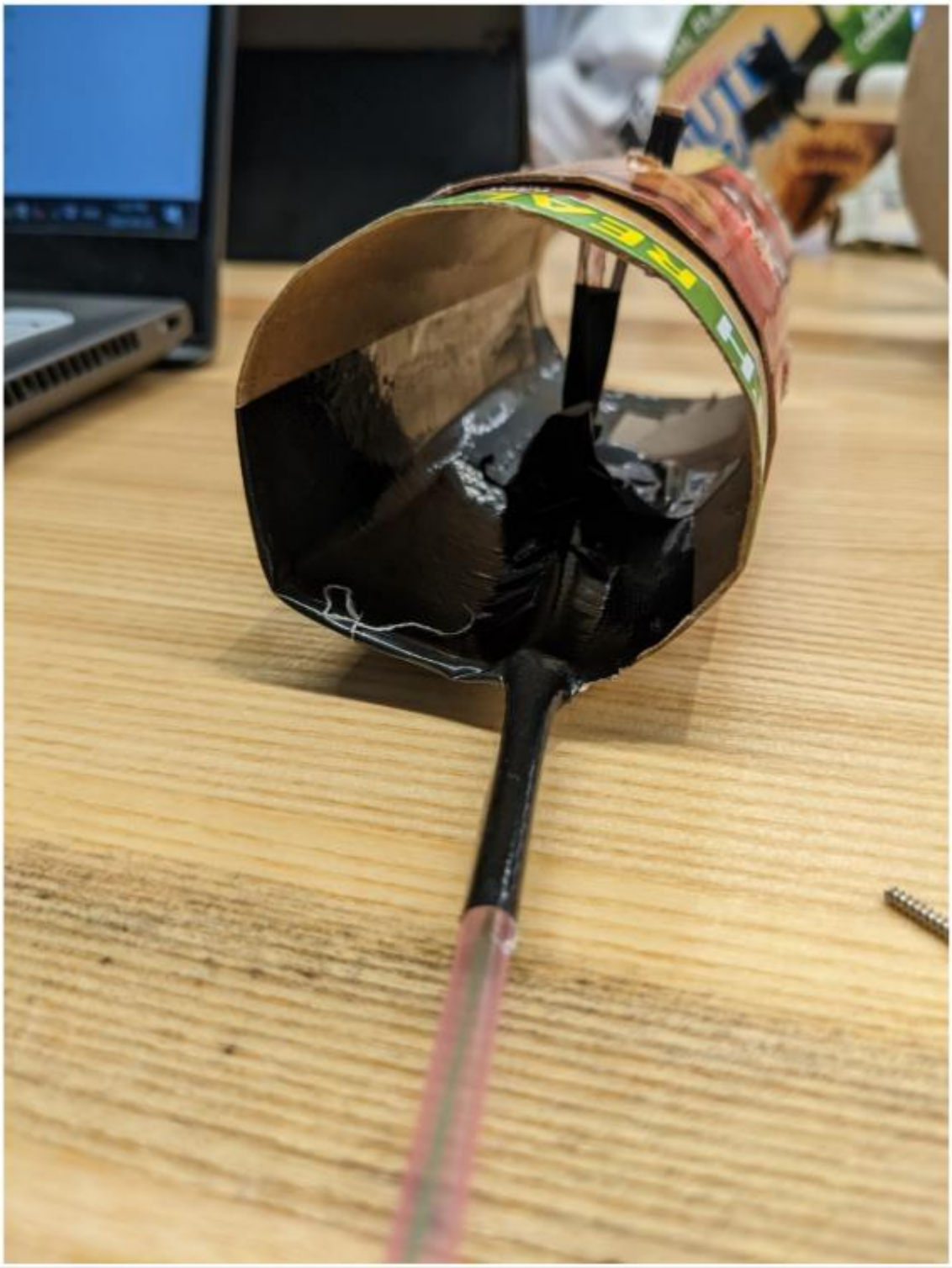
Use the space below to document feedback for your design.

1. What if the pin misses the hole continuously?
    a. Potentially coming up with other potential designs
        i. Similar to standard cars, manually engage and disengage using some type of lever?
        ii. Clutch mechanisms
2. Make sure it doesn't require too much force
3. Pedal is not necessarily realistic because of force

Use the space below to propose design refinements based on the feedback.

- Hand lever instead of pedal
- Jump rope idea for allowing to string to twirl and release tension
    - Knot that can't pass a hole
- Clutch type mechanism for locking lever in place while turning
    - 'holes' on side of wheelchair for the lever to lock in

PROTOTYPE PHOTOS:



Appendix D: Comprehensive List of Sources

[1] B. Sapey, J. Stewart, and G. Donaldson, “Increases in wheelchair use and perceptions of disablement,” Disability & Society, vol. 20, no. 5, pp. 489–505, 2005. [Accessed Apr. 08, 2022].
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[9] V. Lerch, G. Gary, and P. Hervé, “Thermomechanical properties of polycarbonate under dynamic loading,” Journal de Physique IV (Proceedings), vol. 110, pp. 159–164, 2003.
[10] J. Roland, “E-stim: What it is, how it works, and why it may help you,” *Healthline,* 29-Jul-2019. [Online]. Available: https://www.healthline.com/health/pain-relief/e-stim. [Accessed: 10-Apr-2022].
[11] M. D. John Revord, “All about electrotherapy and pain relief,” Spine, 2022. [Online]. Available: https://www.spine-health.com/treatment/pain-management/all-about-electrotherapy-and-pain-relief. [Accessed: 10-Apr-2022].

Appendix E: Additional Documentation

Figure E1. First iteration of the combined axles

Figure E2. Failed 3D prints

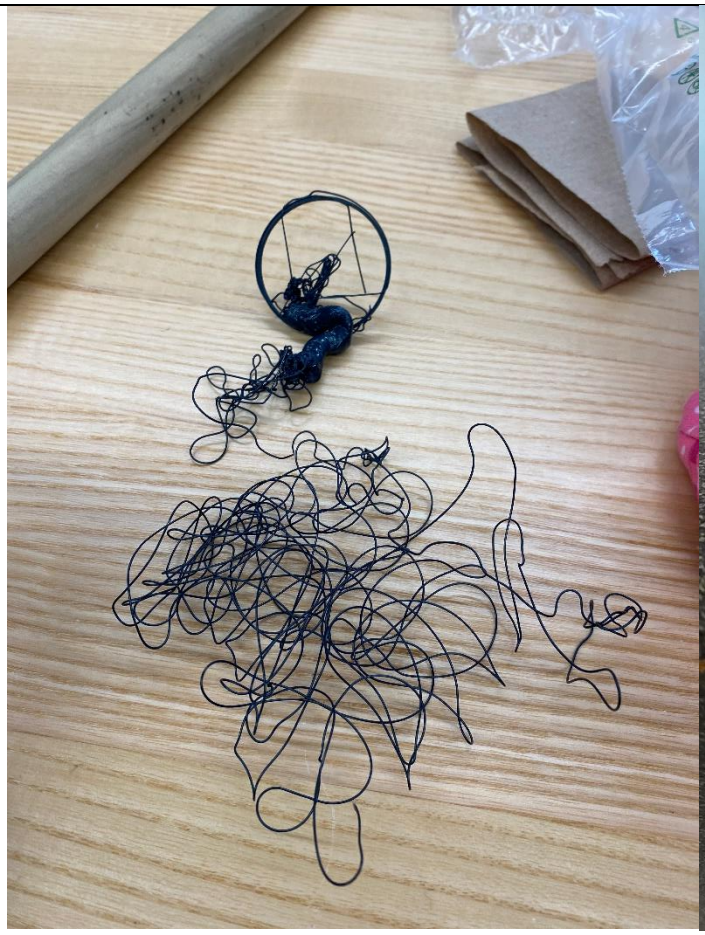


Figure E3. Woodworking process

Figure E4: Pin/Spring Housing Fully Dimensioned Engineering Drawing

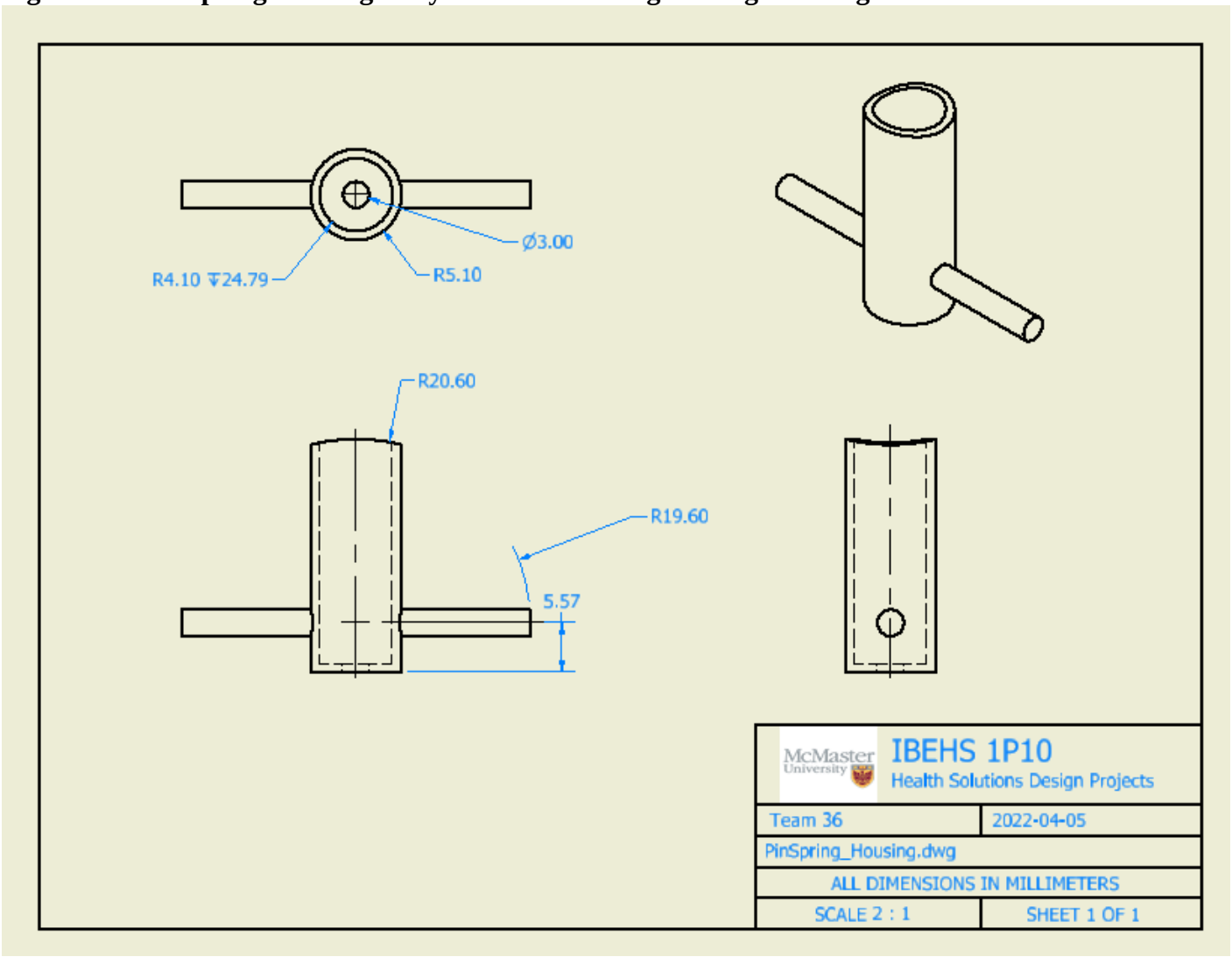


Figure E5: Pipe Fitting fully dimensioned engineering drawing

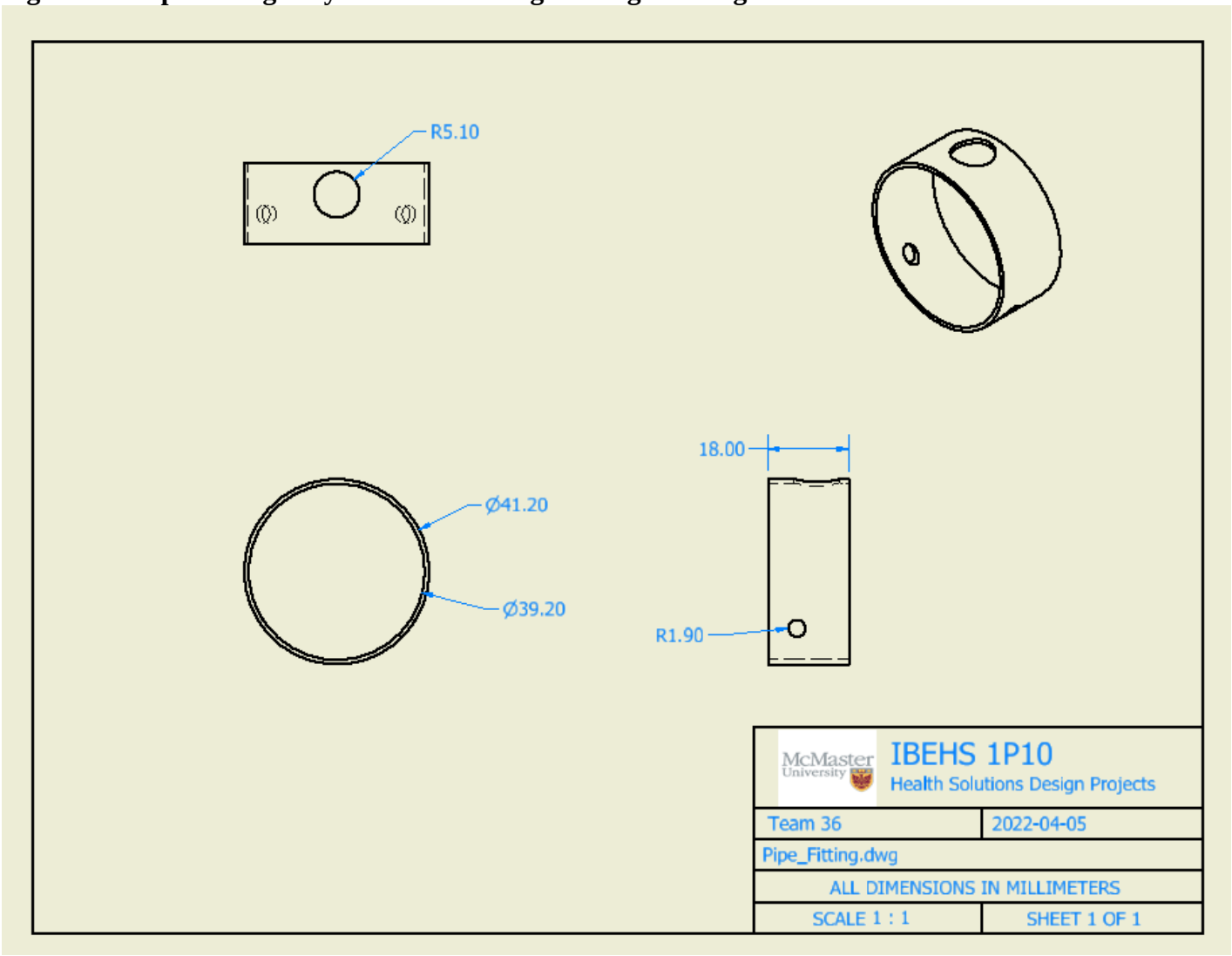


Figure E6: Pulley Rod fully dimensioned engineering drawing

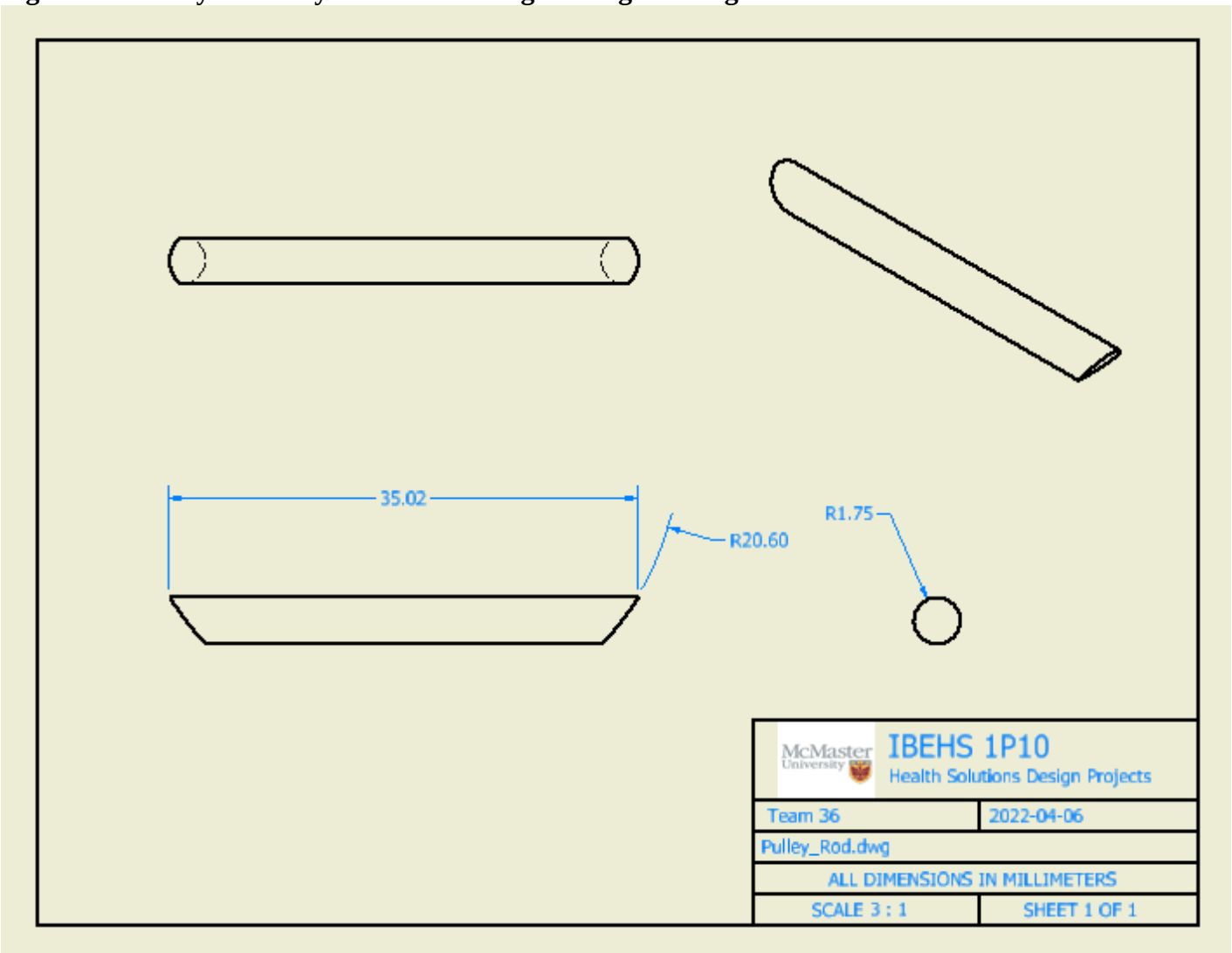


Figure E7: Pulley fully dimensioned engineering drawing

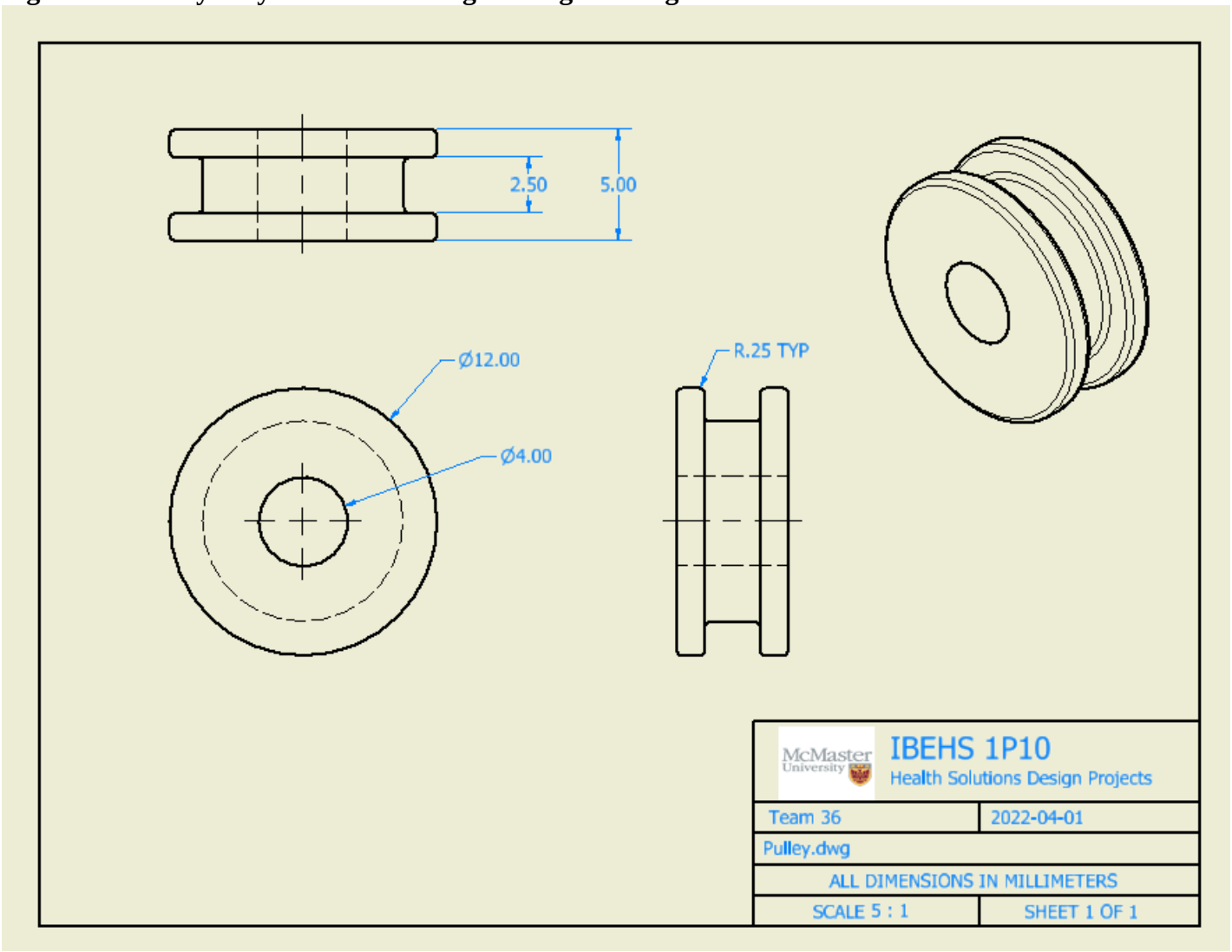


Figure E8: Full Mechanism assembly drawing

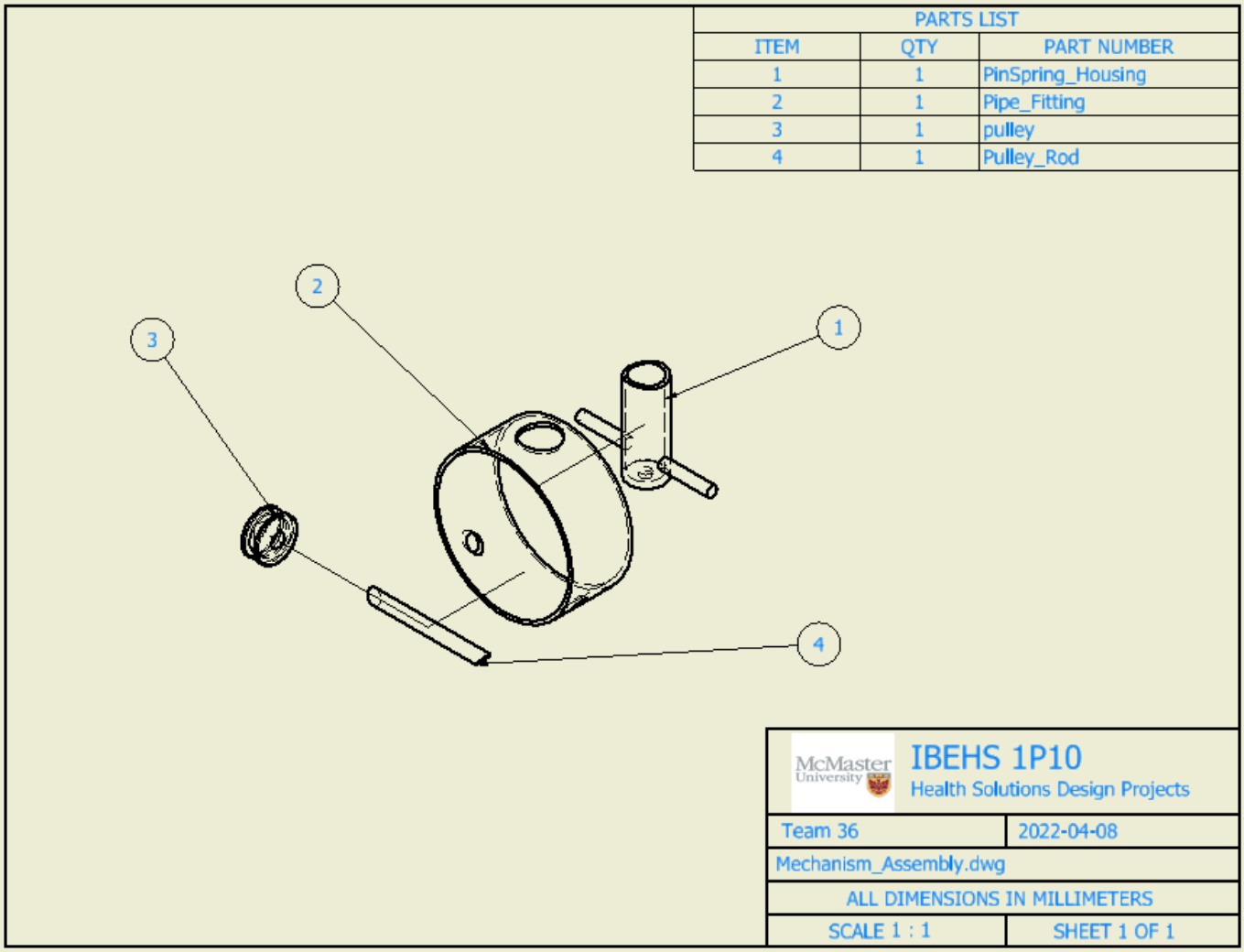


Figure E9: Pin/spring modelling view

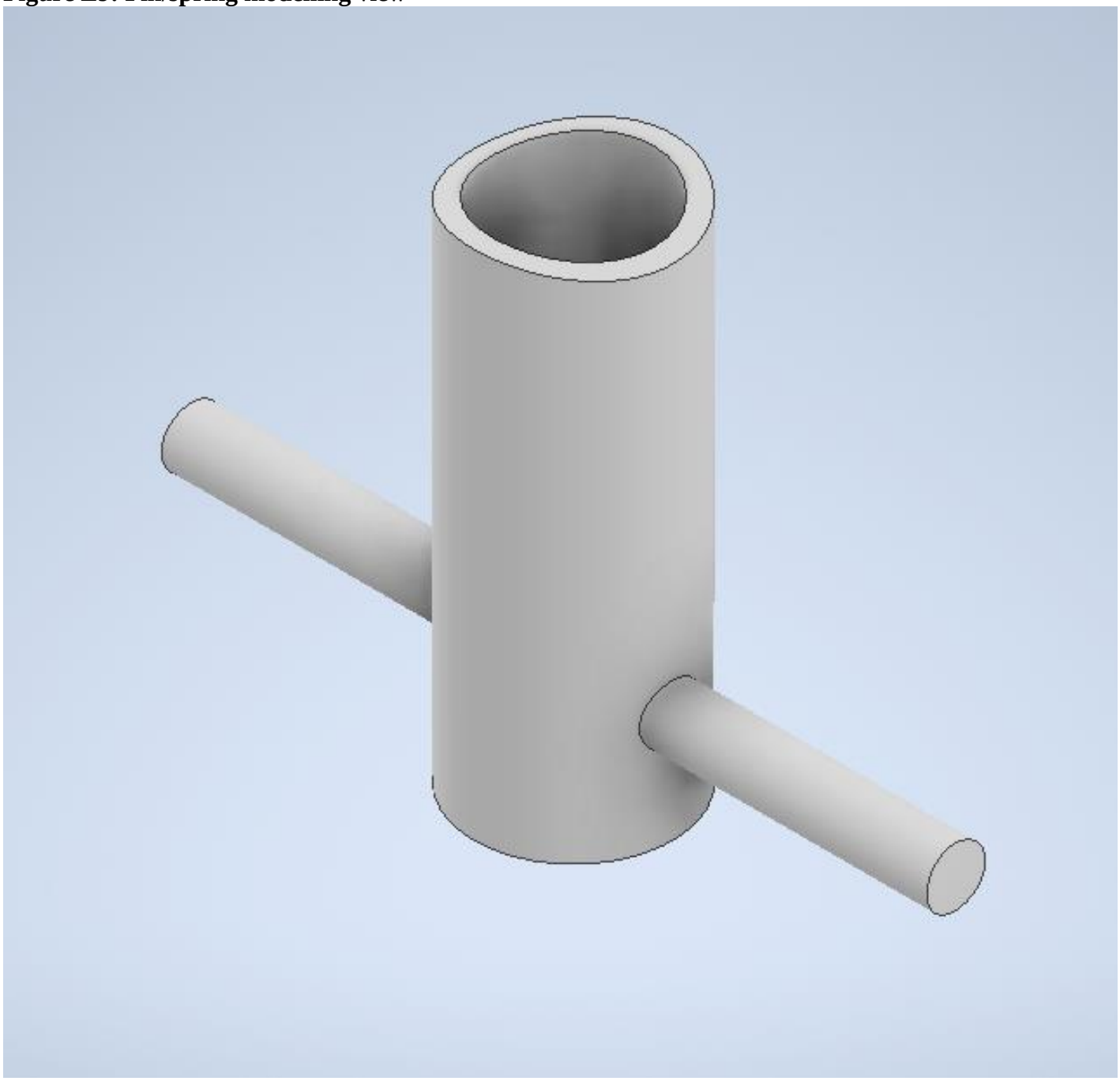


Figure E10: Pipe fitting modelling view

Figure E11: Pulley rod modelling view

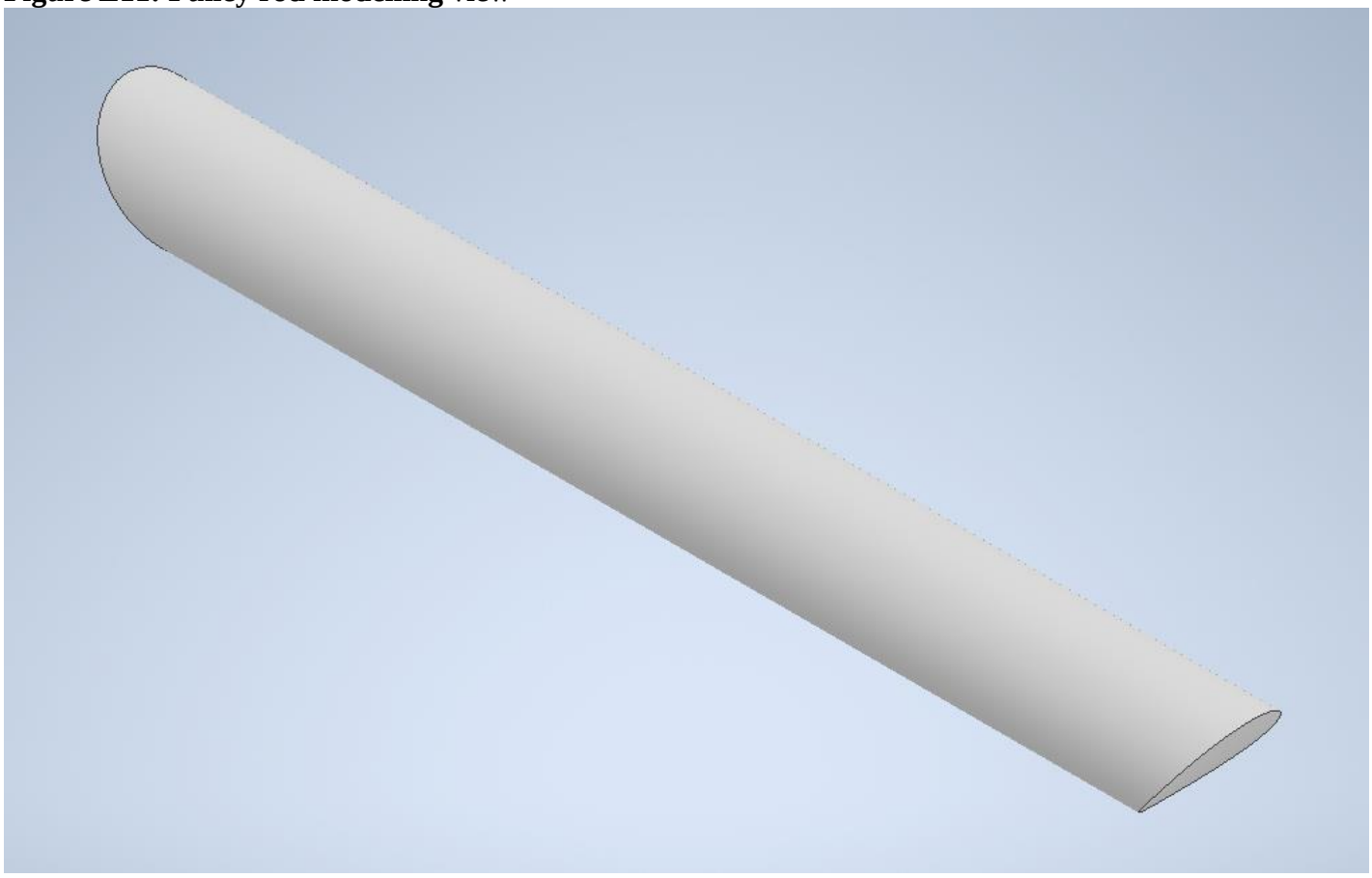


Figure E12: Pulley modelling view

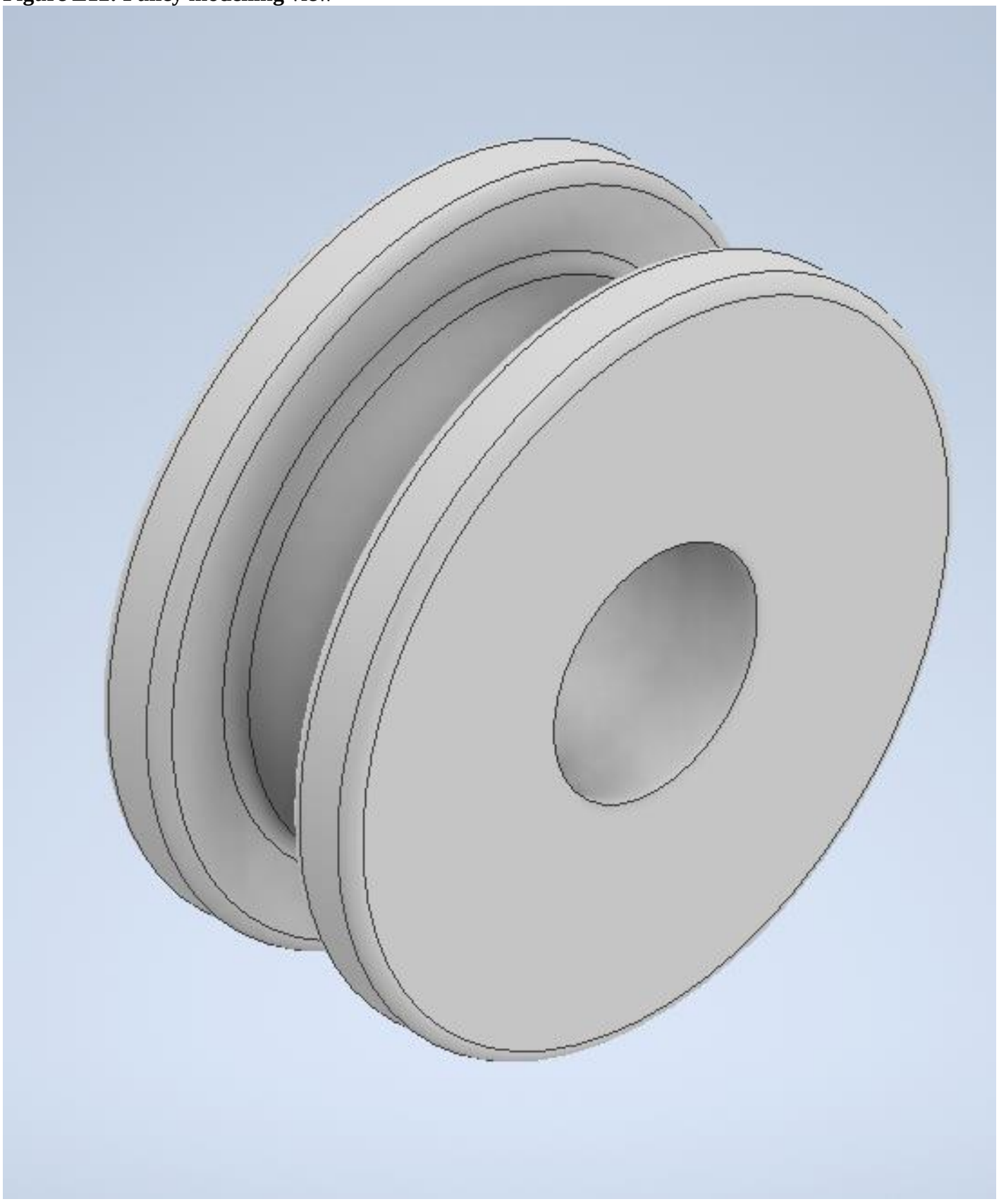


Figure E13: Mechanism Assembly model view

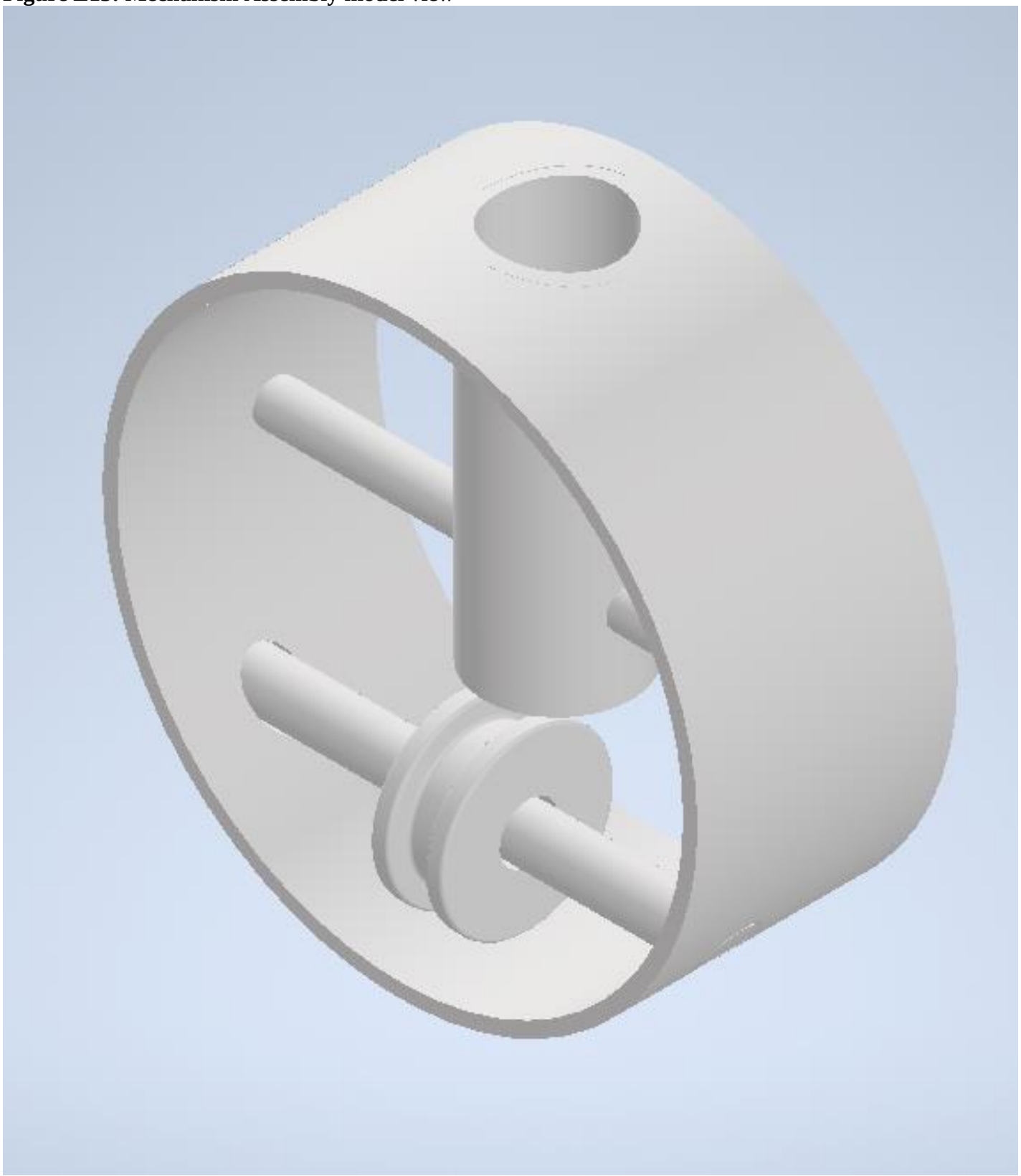
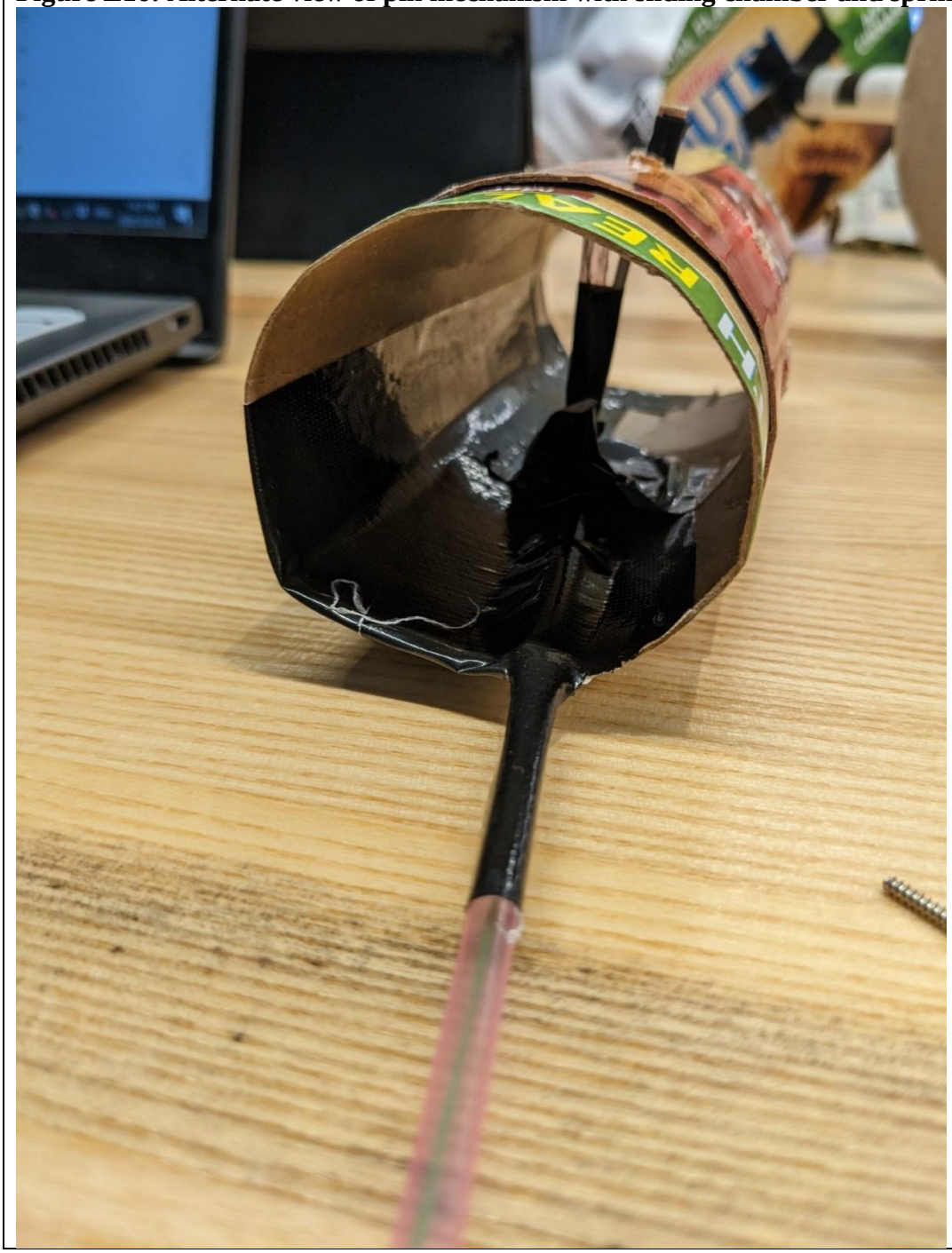


Figure E14: Initial prototype of axle set up and pin locking mechanism

Figure E15: Secondary prototype of locking pin mechanism

Figure E16: Alternate view of pin mechanism with sliding chamber and spring



Appendix F: Fabrication Process

We first connected the two bike wheels together using a PVC pipe: we drilled holes around the end of the pipe and uses wires to connect it to the wheels. We cut the PVC pipe into two pieces so we can choose to connect or disconnect the two wheels.

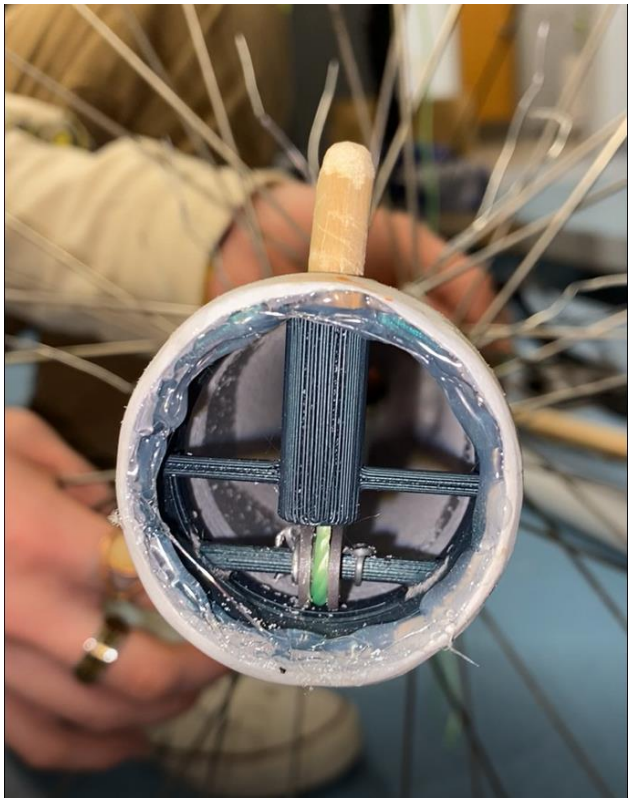
Figure F1. Two-wheel axles combined by PVC pipes

We then cut the planks we bought from Home Depot and put the two casters together to support the whole wheelchair prototype.

Figure F2. Connecting the casters with pins and planks

We then 3D printed the pin housing and cut the wood stick to make the pin. We then put the pin, the housing, the thread, and the spring together to make the connecting device.

Figure F3. Connecting Device (pin housing, pin, thread, and spring)



We then use nails and planks to build the whole frame of our prototype, connecting the wheels and the casters, connecting the pin with the lever.

Figure F4. Using nails to connect the planks and the casters

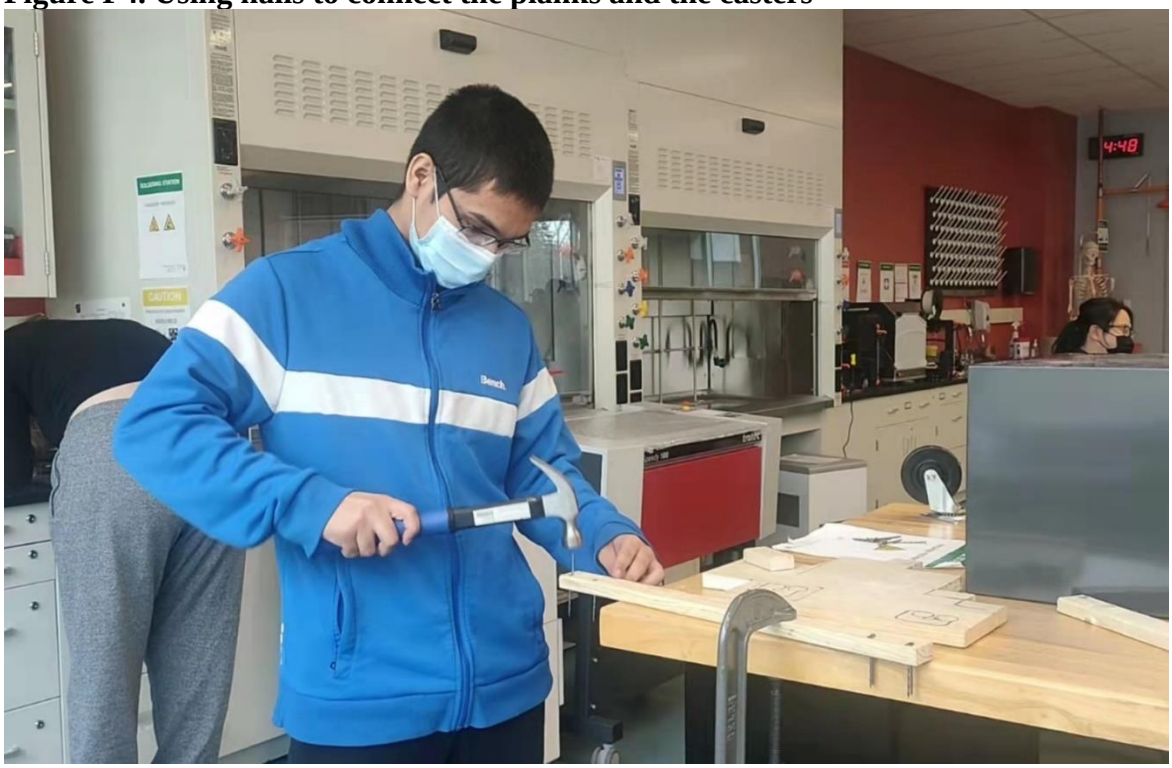


Figure F5. Drilling Holes Through the Planks