ME 3202 - Project P3-24 Golf-Accessible Wheelchair

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Contributions: Akin did the original solidworks design and assembly, as well as writing the task specifications, goal statements, and added the alternative design sketches. Matt added the driving dyad and wrote the introduction, background research, some of the design descriptions, the motion study animation, and editing the report. Winston wrote some of the design descriptions, the conclusion, the assembly drawing, as well as construction of the prototype. Mehdi wrote the majority of the design descriptions, changed the size for iteration 2 of our main solution, the solidwork drawings, photorealistic rendering, and put together and maintained our prototype.

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Abstract

During this project, we set out to design and prototype a mechanism that enables a paraplegic individual with upper body strength to transition from a seated to a standing position while in a wheelchair, with the specific goal of allowing them to play golf. Unlike existing commercial solutions, which are expensive, bulky, and replace the user's everyday wheelchair, our design focused on creating a compact, lightweight add-on that could be integrated into a standard wheelchair without obstructing normal use.

We developed a six-bar mechanism derived from a four-bar linkage with a driving dyad. This design provided one degree of freedom and guided the user to a slightly bent, natural slightly bent, standing posture suitable for swinging a golf club. We fabricated our solution from laser-cut plywood and assembled using pin joints. The results confirmed the feasibility of our design, though there were aspects we did not consider. Limitations such as friction, plywood flexibility, and the thickness of the nail head highlighted areas for refinement. Overall, the project demonstrated a simple, mechanical linkage system for a sit-to-stand wheelchair attachment. This accomplishment provides a strong foundation for future work toward a realistic device that proves accessibility in recreational sports.

Introduction

Golf is an activity that challenges the body physically and mentally. The inclusiveness of those with disabilities has been harder to incorporate than other sports, such as basketball. Golf requires the ability to stand, turn, and lift off the ground, making this a very difficult sport for those without lower body strength or functionality. To solve this, we are designing a mechanism that allows a paraplegic with existing upper body strength to play golf again. Using our knowledge of 4-bar linkages, we can combine these skills to create a mechanism to push the person from the seated position to a standing position with a slight bend, not obstructing their arms in order to provide them the opportunity to swing a golf club and enjoy that experience again.

Background Research

Historically, the game of golf has struggled to reach the disabled community, but with recent technological advances, this community has unlocked the ability to join the trend and play as well. Individuals who are unable to play due to paralysis in their lower body have the option to use motorized golf carts for transportation and lifting assistance around the course. However, these vehicles are expensive and limited, so a solution for a cheaper model is necessary.

The best selling model right now is called Paragolfer, which is an all-terrain, standing power wheelchair allowing individuals to stand upright to play golf (Weber 2023). While it represents a successful commercial solution, it is a large system that is a replacement to the user’s everyday wheelchair rather than a component you can add and remove.

A report written by graduate students at Yanshan University, proposed a solution to this problem. They suggested using a 8-bar linkage with sliding elements to allow the bars to adapt a simple scissor lift for the desired motion path using pistons and motors (Shi et al., 2021).

Unlike the graduate students' design, which relies on powered pistons and motors for motion, our system achieves a similar path through mechanical linkages. By incorporating the driving dyad into a 4-bar linkage and extending it into a 6-bar system, our design provides similar functionality but with simpler, more reliable manual control using a crank and rocker bar. Additionally, rather than positioning the mechanism beneath the seat as in the scissor-lift approach, our linkage is integrated directly into the seat structure itself. This integration reduces bulk and complexity.

Goal Statements

The goal of this project is to design a wheelchair-integrating lifting mechanism that allows a paraplegic with upper body strength to transition safely from a seated to a standing position. By fulfilling this goal, the system will restore the user's ability to stand for recreational athletic activity, such as golfing, while maintaining the full utility of the wheelchair in daily use.

Task Specifications

These specifications define the project's scope and requirements. First, the system should be stable, reliable, and not obstruct normal wheelchair use, enabling the user to stand and play golf without sacrificing mobility or needing to change the construction of the wheel chair. Also, the mechanism must support the user's full body weight in both seated and standing positions without risk of collapsing or bending. It must provide stability to prevent tipping during a golf swing. The device should also be operated by the user with no outside assistance, relying on a push and pull lever. The transition from sitting to standing should take less than 5 seconds and have a maximum acceleration of 0.5 m/s^2. Moreover, the design should be lightweight and compact, adding less than 20% to the overall wheelchair weight. It should fit onto standard wheelchair frames without major modification. Finally, the mechanism must include padding and straps to prevent discomfort or injury during lifting and standing. Standing posture should align the user in a natural position for swinging a golf club with the proper tilt and angle.

Design Descriptions

Initially our group began by examining the desired range of motion, and looking at simple four-bar mechanisms that provide that. We decided that using two-position synthesis would be the ideal way to model the motion and find a working mechanism. Looking at the vertical motion that the golfer would take on standing up, we decided that the four bar mechanism must include a sliding ground joint, as well as a crank to initiate the action. We wanted the golfer to have a slight bend in their stance as that is the stance golfers take for good results, rather than directly vertical. Our group also considered the placement of the mechanism, so that the golfer would have as much freedom to swing as possible, ensuring no interference above, or around the golfer's swing path. After drawing several basic diagrams, we decided that the ideal place to put the mechanism is on the sides of the wheelchair and integrating itself in the chair seat, so that the space above the wheelchair is completely unobstructed. Additionally, another issue we encountered early on was restricting the movement of the link that would attach to the golfer. As demonstrated in Figure 1:

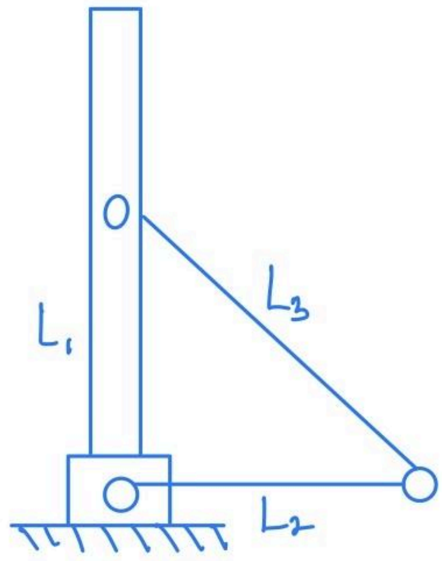

Figure 1: a mechanism that has two tether ropes pulling up the chair to make the seat stand more vertical

This solution failed because a full rotation of the crank would result in the links attached to the golfer bending at angles that would result in grave injury or harm to the golfer. Around this time, our group was looking at current professional designs, and saw an issue. A golfer needs to angle their body in order to maximize their swing, and our initial mechanism only provided a vertical translation, and did not provide the angle that is required in a golf swing, which is a slight bend in the knees and back.

Another solution we considered was building a new wheelchair with an integrated sit-to-stand mechanism. The concept rotated the seat-back joint to move the user from sitting to standing, as illustrated in Figure 2. We did not pursue this approach because it would require a full frame redesign, substantially more material, and higher cost. Packaging the mechanism would also demand detailed 3D modeling to control overall thickness, and an out-of-plane z-axis cross-link to synchronize the left and right sides and prevent racking. Given the added complexity, weight, and expense, we set this option aside.

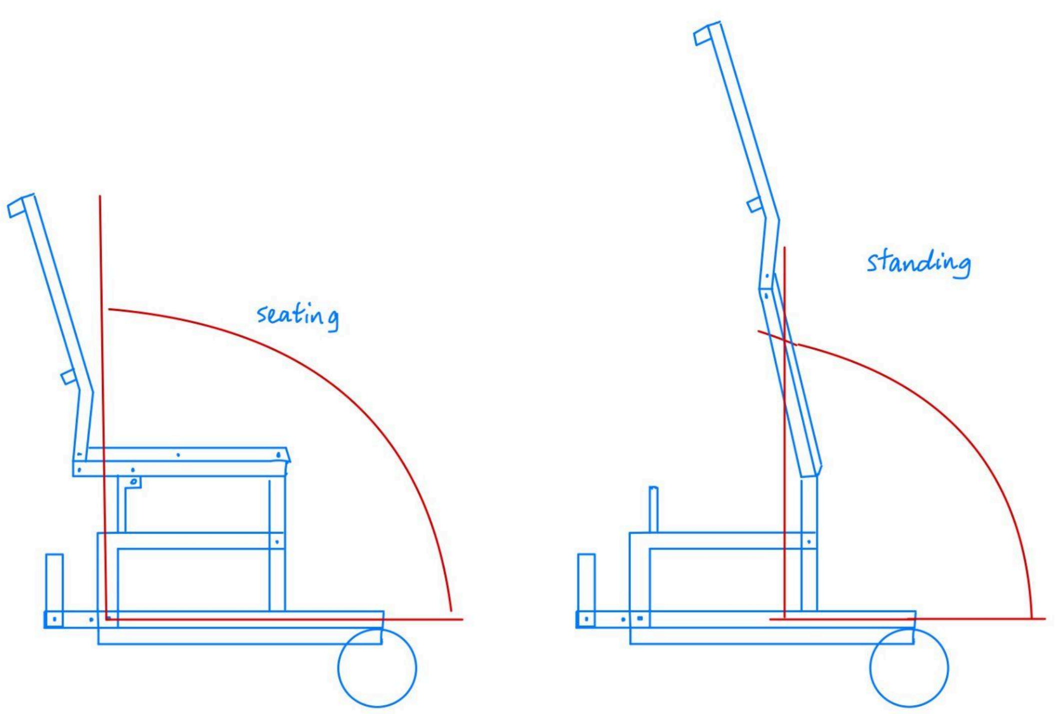

Figure 2: Initial solution involving integrated wheelchair design

We also evaluated a non-conventional variant inspired by Figure 1 that would stabilize the user by immobilizing the golfer's lower body with a restraint/harness integrated into the chair. We rejected this concept because it would compromise comfort and autonomy, create risks of pressure injury and impaired circulation, complicate rapid egress in an emergency, and would likely be unacceptable for recreational use.

After determining that the alternative solution would not work, the solution that our team arrived at was adding a driver dyad to the initial crank, which would transform that link into a rocker undergoing a controlled range of motion. The proposed mechanism has only one degree of freedom, as shown in the Mobility Gruber Equation below.

$$M = 3(L\text{-}1) - 2J_1 - J_2 \tag{1}$$

$$M = 3(6\text{-}1) - 2(7) - 0 = 1$$

The proposed mechanism also meets the Grashof conditions desired for the project guidelines . Our team then began modelling the mechanism in Solidworks.

We began working on our first solidworks design. The lengths of the bars were picked based on what would make the motion viable for a small-scale mechanism. Both the four-bar and driving dyad sections of the mechanism were checked so that the Grashoff conditions for each section were met, and that the mechanism was able to move as intended. However the crank in the driving dyad was designed as 11 mm instead of 35 mm. This meant that when the mechanism would be sent off to be laser cut, the crank would not be retrievable, as the minimum length or width for any laser cut piece must be 38.1 mm.

Our group split off into two teams to explore two possible solutions. The first solution involved adjusting the crank piece to 44 mm, and then increasing the length of every other link proportionally so that the Grashoff Conditions for both the four-bar and driving dyad sections of the mechanism are met. After deriving the minimum link lengths, we generated a scaled mechanism that had the same motion as the original mechanism. The main issue with the proposed design was that some of the link lengths would be over a foot long. Given the structural instability of 0.5 inch plywood, our group figured that the mechanism had a high chance of breaking once it was physically assembled. A remedy that was explored was proportionally increasing the width of all the members so that they would be less likely to fracture. With the holes remaining the same size, the added width of the pieces would provide enough support to stay functional after use.

The other part of our group acted on solution 2, which was to adjust the width of the driving dyad crank so that it wouldn't fall through the plywood from the laser cutter. The width of the crank was adjusted to 40 mm, while the length of the crank was kept at 11 mm. This means that the new solution is very small and very unorthodox looking. We ultimately decided to laser cut both solutions and so we can better decide which system provides more safety, can potentially be more stable, and works better after a physical assembly. After briefly exploring potential alternatives, our group decided to adopt the original proposed solution, as seen in the assembly drawing in Figure 3.

ITEM NO.	PART NUMBER	QTY.
1	Linkage1	1
2	Ground	1
3	Linkage3	1
4	Linkage2	1
5	DrivingDyad_shortbar	1
6	DrivingDyad_longbar	1

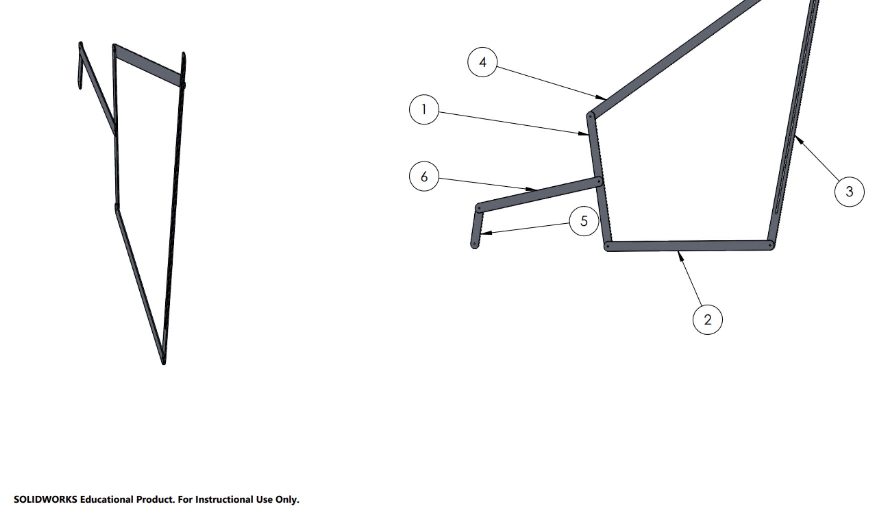

Figure 3: View of mechanism with bill of materials

We checked the Grashoff conditions of both the driving dyad and four-bar sections of the mechanism to ensure full movement was possible, as seen in the respective Grashof Condition Inequalities below.

$$44 \text{ mm} + 185 \text{ mm} < 180 \text{ mm} + 80 \text{ mm} \tag{2}$$

$$160 \text{ mm} + 400 \text{ mm} < 400 \text{ mm} + 240 \text{ mm} \tag{3}$$

Once our group laser cut the mechanism, we put together the four bar linkage with a sliding mechanism and one degree of freedom, which was only needed since our starting position was seated and our final was standing. A driving dyad was then used to regulate the mechanism to prevent manual user input and limit the ultimate length the rocker bar would oscillate. Below is an assembly view of the final build with the bill of materials as well as the photorealistic rendering of the assembly, as seen in Figures 4 and 5 respectively.

ITEM NO.	PART NUMBER	QTY.
1	Linkage1	1
2	Ground	1
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5	DrivingDyad_shortbar	1
6	DrivingDyad_longbar	1

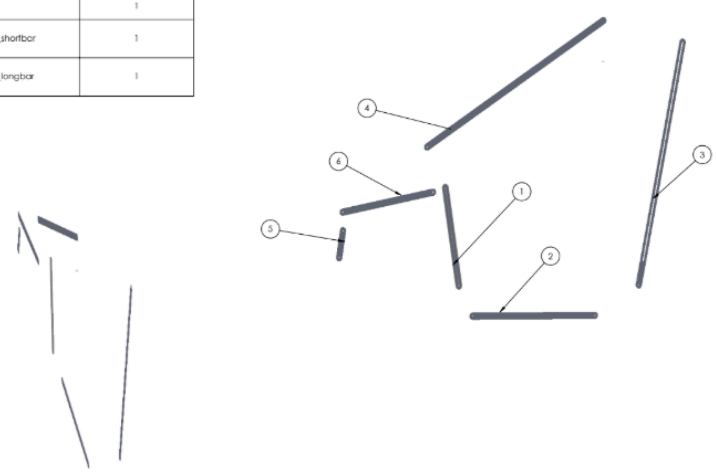


Figure 4: exploded view of mechanism with bill of materials

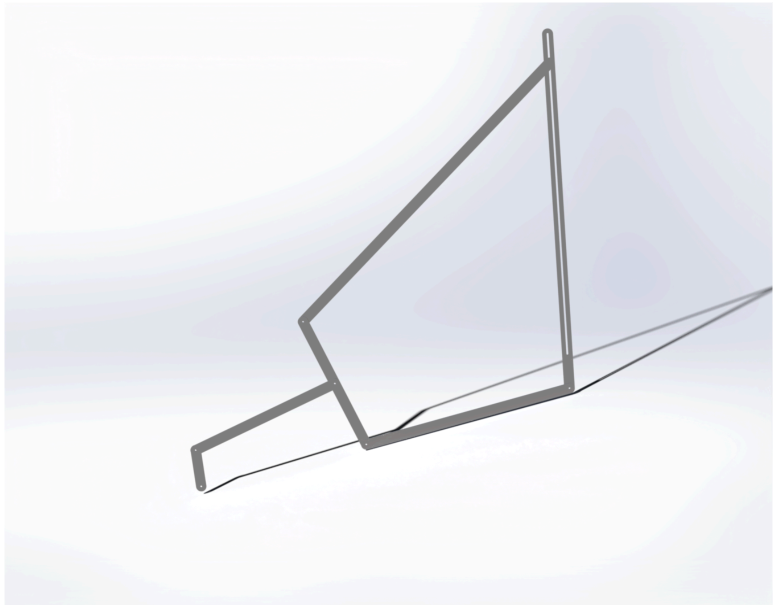


Figure 5: Rendered view of the assembly

Results

We laser-cut a scaled design that lengthened links to keep a conventional crank, which achieved smoother actuation. The final design solution was a six-bar lifting mechanism derived from a four-bar linkage with an added driving dyad. The linkage produced the desired posture and provided controlled stability in the standing position, as seen in Figure 6.

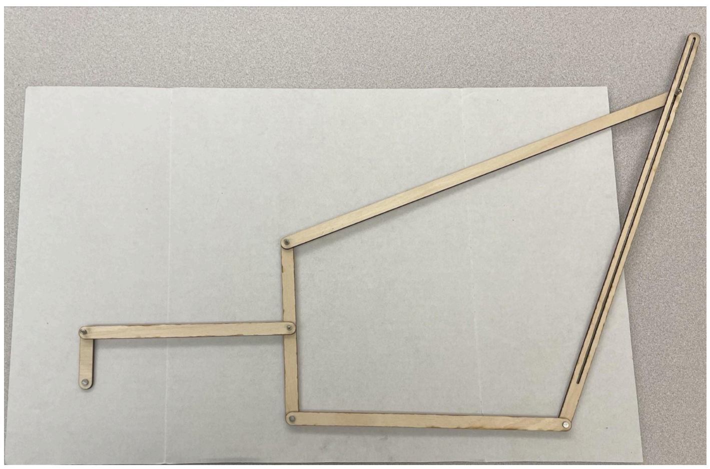


Figure 6: Our final prototype after laser cutting and assembly with pins and cardboard.

Additionally, a linear acceleration analysis in Solidworks, assuming a constant crank velocity of 120 rpm, yielded a maximum magnitude of 0.24 m/s^2, as seen in Figure 13 in the Appendix. Similarly a velocity analysis with a constant crank velocity of 120 rpm, yielded 0.824 m/s. However, issues such as joint friction, the flexibility of plywood, and unaccounted forces like gravity limited the realism of the results.

Conclusion

Our project displays a six-bar lifting mechanism, derived from a four-bar linkage, to enable a paraplegic individual to stand for golfing. We learned a lot particularly when the laser cutting constraints required us to redesign our mechanism. This highlights the importance of designing for manufacturability. By prototyping two solutions, we selected and validated the best version that confirmed the kinematic model we had in mind. While this prototype provides a strong foundation, we believe that further development is needed to achieve a usable product. For instance, we had errors in our mechanism due to friction, nail thickness, and a failure to account for gravity. If we were to refine our design, it would have the potential to become a practical solution that enhances the golfing experience for players with disabilities.

Bibliography

A. Guillaume, S., Bennett, T., Allen, P. M., Morrison, A., Hawkes, R., & Jayabalan, P. (2023). The global state of play: A study of the demographic characteristics of disability golfers. *PM & R : the journal of injury, function, and rehabilitation*, *15*(10), 1309–1317. https://doi.org/10.1002/pmrj.12955

B. Shi, X., Lu, H., & Chen, Z. (2021). Design and Analysis of an Intelligent Toilet Wheelchair Based on Planar 2DOF Parallel Mechanism with Coupling Branch Chains. *Sensors*, *21*(8), 2677. https://doi.org/10.3390/s21082677

C. Weber, Natalie. (2023). Paragolfer All-Terrain Mobility Chair. *David's Chair*. https://davidschair.org/paragolfer-all-terrain-mobility-chair/

Appendix

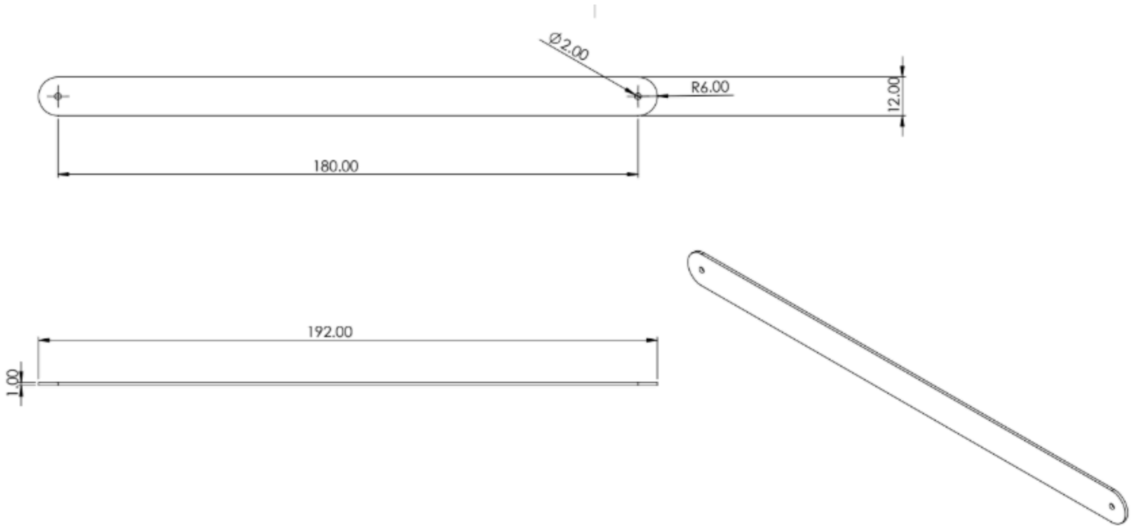


Figure 7: Individual part drawing of the driving dyad long bar.

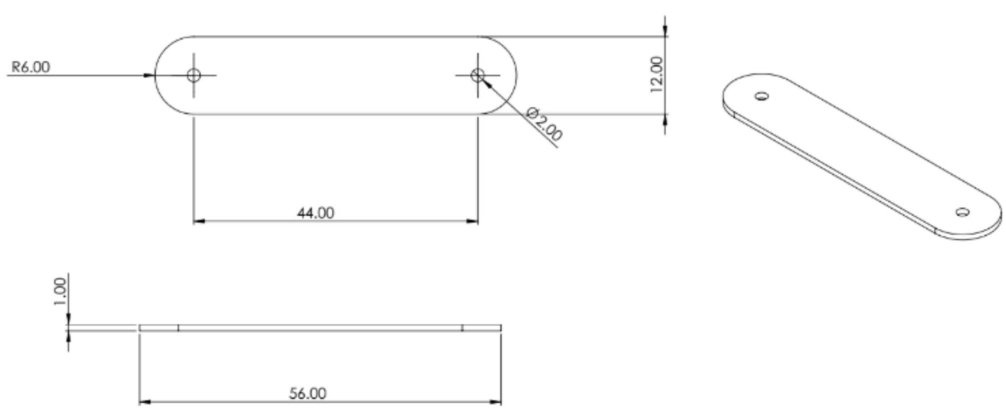


Figure 8: Individual part drawing of the driving dyad short bar.

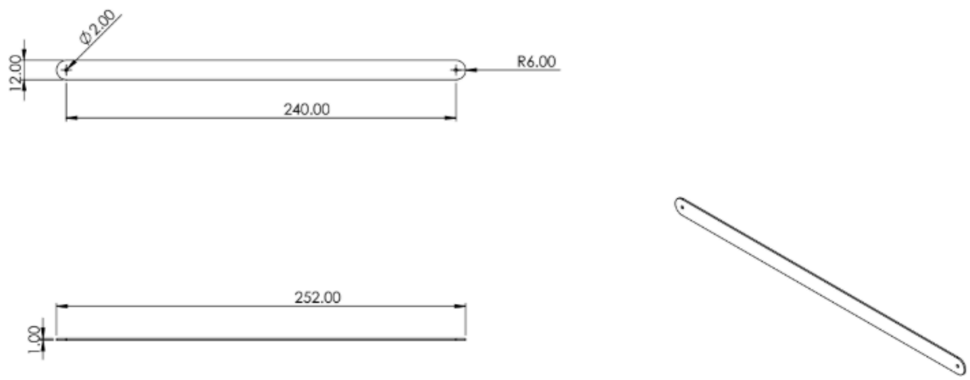


Figure 9: Individual part drawing of the ground bar.

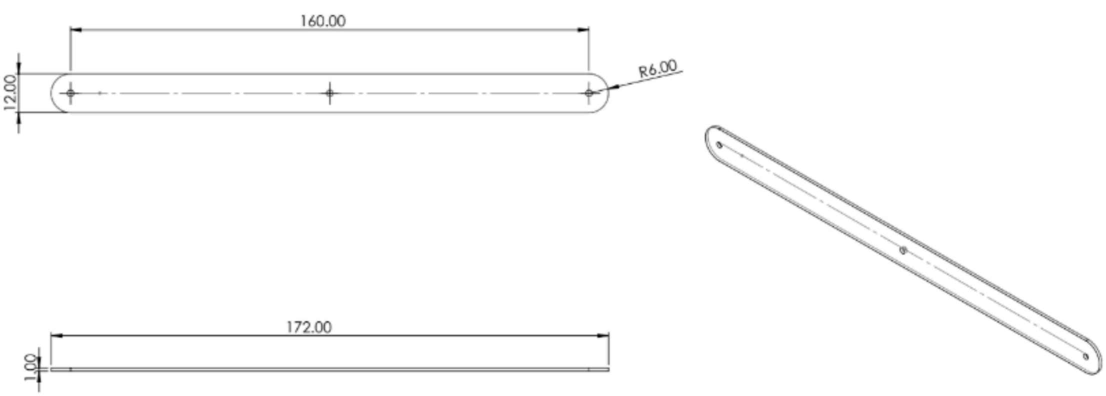


Figure 10: Individual part drawing of link 1.

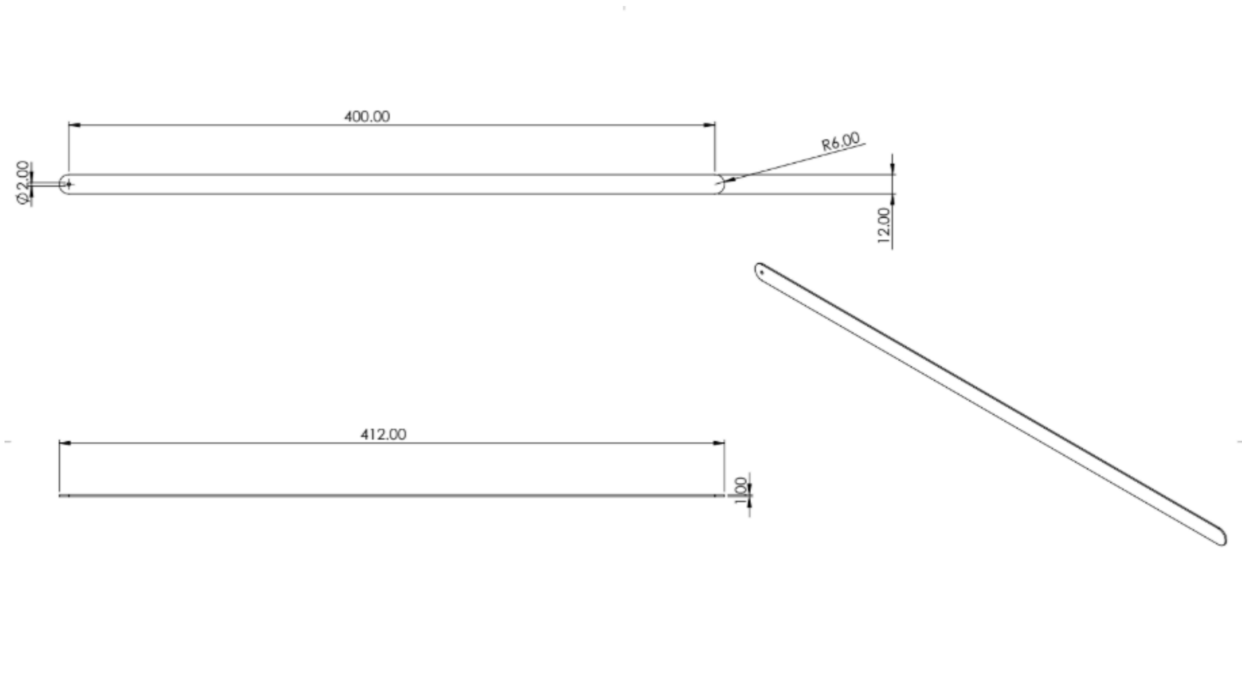


Figure 11: Individual part drawing of link 2.

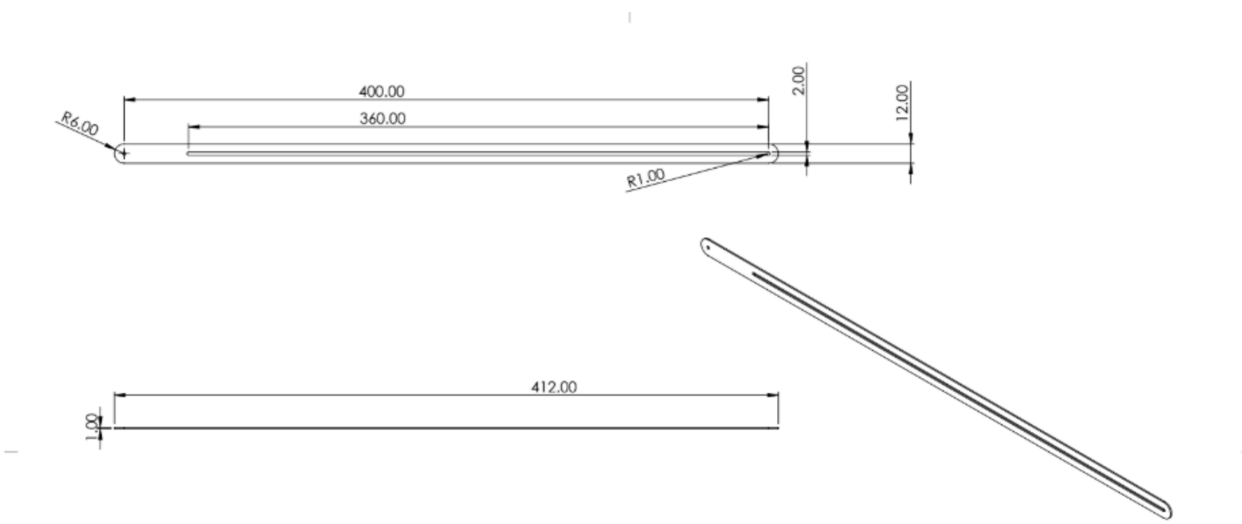


Figure 12: Individual part drawing of link 3.

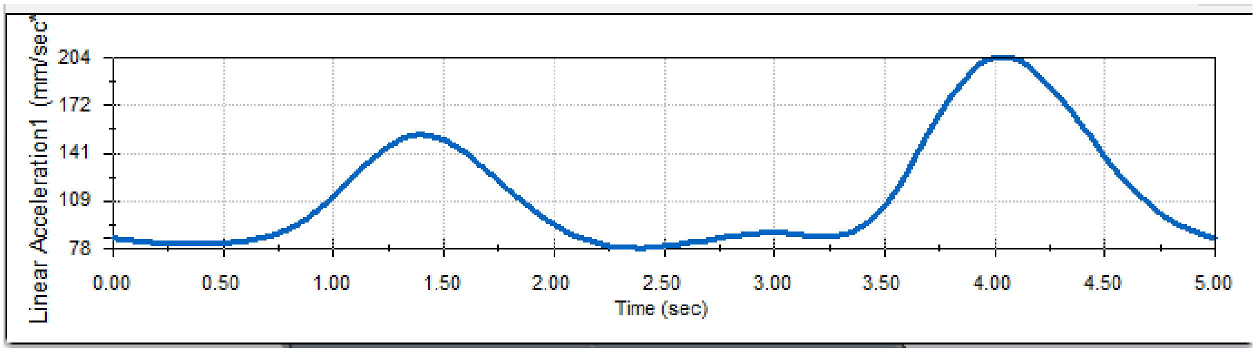
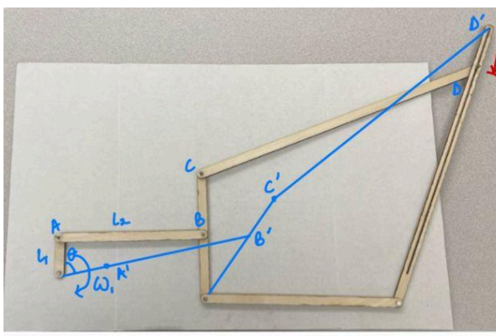


Figure 13: Acceleration analysis with a rotor velocity of 120 rpm. The maximum linear acceleration is about 0.24 m/s^2.



$l_1 = 44mm$, $x = 90mm$

$l_2 = 180mm$

$$\cos\theta = \frac{l_1}{l_1 + l_2}$$

$$\cos\theta = \frac{44}{224}$$

$\theta = 78.6718^\circ$

$\theta = 1.373\ rad$

$\omega_1 = 120rpm \equiv 4\pi\ rad/s$

$$t_1 = \frac{\theta}{\omega_1} = 0.10927s$$

$$V_D = \frac{DD'}{t_1} = \frac{x}{t_1}$$

$$V_D = \frac{90mm}{0.10927s} \approx 824\ mm/s \equiv 0.824 m/s$$

Figure 14: Maximum velocity calculations assuming 120 rpm.