Redesigning the Posterior Pediatric Walker

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Abstract

Cerebral Palsy is a disease that impacts the motor functions of an individual, often limiting individual's ability to walk. Assistive walking devices are available to aid children with cerebral palsy in walking including posterior walkers and gait trainers. However, these devices often limit users socially, restrict their mobility, and can be difficult to maneuver. Posterior walkers can also be very difficult to collapse and adjust, making transporting the walkers very difficult. Further, walkers for children and often need to be replaced due to how quickly children grow. This project aims to create a design that solves these issues and assists the user in walking with proper posture. Through research and several interviews with a family and pediatric physical therapist who have experience with posterior walkers, a three wheeled posterior walker with a unique hinging mechanism was designed using SolidWorks. The walker built according to the selected design is adaptable, user friendly, and aesthetically appealing allowing children with cerebral palsy, ages two to eight, to develop physically and socially. Our goal is to develop a posterior pediatric walker that is adaptable, user friendly, and aesthetically appealing allowing children with cerebral palsy ages two to eight to develop physically and socially

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1.0 Introduction

There are several physical disabilities that impact the normal body movement of a child and Cerebral Palsy (CP) is the most common according to the Autism and Developmental Disabilities Monitoring (ADDM) CP Network. CP impacts motor skills, fine motor skills, sensory skills, and social and emotional development (Reiter & Walsh, 2018). In 2008, the Centers for Disease Control and Prevention found that 41.9% of children with CP had limited walking ability and need to use a hand-held assistive device. The assistive devices include posterior walkers and gait trainers that provide the patient with support and stability.

There are a variety of similar assistive walking devices available, however, these devices have a few distinct differences. Certain types of walkers are compatible with attachments such as suspension or trunk support, while others allow the user to be freestanding. Additionally, some walkers wrap around the back of the user while others wrap around the front. Two of the most common devices are gait trainers and posterior walkers. The gait trainer is designed for children with severe cases of CP and children unable to support their own body weight (Bennink, 2018). The posterior walker is designed for children that are able to support their own weight helping them build strength and develop proper posture (Bennink, 2018). However, both of these walkers are very bulky and can be difficult to use.

Pediatric posterior walkers provide children with several benefits, however, some aspects of the walker limit the user socially, restrict their mobility, and can be difficult to maneuver on various terrains. These walkers typically have four wheels, two handles, and wrap around the back of the user to ensure that the child does not become dependent on the walker and can practice proper posture (Bennink, 2018). However, the design of these walkers can make it difficult for the user to interact with others because of the way the device surrounds the user.

Additionally, other children may be intimidated by this bulky device. These walkers also limit the mobility of the user only allowing very wide turns, if any, and preventing movement in the backwards direction. The wheels on these walkers can also cause difficulty on various terrains moving faster on smooth surfaces than rough ones.

Although there are many variations of pediatric walkers, most commercially available products fail to meet all the needs of the user. By using a pediatric posterior walker, a child affected by CP can improve their posture and ability to walk. However, the design neglects the rapid growth and typical activities of young children. The posture, mobility, and socialization of the user are integral for the development of the child. Having proper posture and mobility enables the user to develop the skills necessary to walk independently of the walker. While the the ability to socialize and interact with others is also an integral part of a child's development. It is important that a user can get access to adaptive equipment that will meet their specific needs. Every child is built differently and affected by cerebral palsy in different areas of the body. Therefore, there is a need for posterior pediatric walker that is adaptable to the various needs of the user.

Our goal is to develop a posterior pediatric walker that is adaptable, user friendly, and aesthetically appealing allowing children with cerebral palsy ages two to eight to develop physically and socially.

2. Background

The range of motor impairments affecting children is wide and contains conditions involving neurologic and musculoskeletal systems. This range includes cerebral palsy, traumatic brain injury, myelomeningocele, spinal cord injury, neuromuscular disease, juvenile rheumatoid arthritis, arthrogryposis, and limb deficiencies (Michaud, 2004). Cerebral palsy is the most common walking motor disability among children, impairing their postural control, reflexes, muscle tone, and muscular coordination (Park, 2001). It is caused by damage to the developing brain during birth (Mayo Clinic, 2016). With this disability, pediatricians involve therapists to work closely with the families to improve the function and participation of the child in everyday tasks. The physical therapist's job is to decide which adaptive equipment can improve the child's development and mobility supporting postural control and partial weight lifting (DePace, 2008).

There are two main types of assistive walking devices, anterior and posterior. Anterior walkers (shown on the right in Figure 1) have been the traditional choice for a walking aid, however, children using the anterior walker have a tendency to lean forward. Posterior walkers are positioned behind the child allowing the child to be in an upright position (shown on the left in Figure 1).

Figure 1: Posterior Walker (Devine Medical, n.d.) vs. Gait Trainer (RehabMart, n.d.)

Anterior and posterior walking devices are divided into two categories: gait trainers and posterior walkers. Both posterior walkers and gait trainers are used to improve a person's stability and mobility encouraging independence (Richardson, 2018). Generally, the walking pattern of the child is related to the amount of energy used to walk. In a study of ten children with a mean age of 9.1 years, mean height of 123.0 cm, and mean body weight of 24.9 kg, it was concluded that posterior walkers reduce the amount of energy exerted and requires less effort (Park, 2001). Gait trainers are designed for individuals who do not have the ability to walk independently offering more support (eSpecial Needs, n.d.) (shown in Figure 2).

Figure 2: The Difference Between Assistive Devices (Richardson, 2018)

Human factors play a huge role in designing a device that is suitable for children to use. Human factors design focuses on producing designs that are able to meet the capabilities, limitations, and needs of the user (Conner, 2015). For example, ergonomic and environmental factors have a huge influence on human factors design. This type of design is especially important in pediatric posterior walkers to ensure that a child is able to operate the device. For example, the walker needs to support a variety of loads as children may vary in height and weight. While supporting these loads, the walker also needs to be light enough so that a child is able to easily maneuver the device. Additionally, the walker needs to fit within a reasonable operating volume so that the child is able to comfortably grip the device while still allowing for accessibility through tight spaces such as doorways.

2.1 Gait Trainers

A gait trainer walker is an assistive walking device that is used by children needing extra support while learning how to walk. The walker has four wheels, two handles, and wraps around the child's body. Along with these features, there are multiple attachments that can be utilized for additional support. There are a variety of gait trainers on the market. One company named Rifton provides three different adjustable sizes: small, medium, and large. Along with the height adjustment offered there are different types of accessories that can be attached for more comfort including but not limited to arm prompts, pelvic support, thigh prompts, and many more. Another feature with this gait trainer is innovative casters that provide more safety to the device. These casters have a variable drag feature that slow down child users that tend to go faster than others (Rifton, 2018).

Another gait trainer manufacturer is R82. The name of this gait trainer model is the Mustang which is able to adjust in height as well as the angel of the chest piece, but it is a very tedious process. The design comes in four different sizes with an angel adjustable center spar as well as castor locks and reverse braking abilities (MedicalEShop R82 Mustang, 2018).

The certain specifications of gait trainers are quite simple. Size and weight restrictions have a linear relationship. Following are sizing specs for the company Rifton. Starting at the smallest of the sizes with a "Mini Pacer" that is 20 ½ inches wide and 22 ½ inches tall and can withstand a weight up to 50lbs. Ending with an “XL New Pacer” that is a width of 31 ½ inches and a length of 39 ¾ inches that can withstand a maximum weight of 250lbs. One of the largest issues with gait trainers is that they do not fold making it difficult to transport (Rifton, 2018). This was one of the major issues voiced in the interview that was had with the mother of a child that has used a gait trainer.

Overall the intent for the gait trainer is to help those children that have little to no chance of ever walking on their own so it is necessary to have a bulky design for it needs to hold the entirety of the child up. But the design can have many different design features to make it friendly to children. For example, new aesthetics implemented to make it more fun for the child and help their social life get better as well.

2.2 Posterior Walkers

A pediatric posterior walker is an assistive walking device for children that provides support. Posterior walkers are designed to be used by individuals who can fully support their own weight and are able to take steps. These walkers also allow the user to steer the device (Noble, 2011). The posterior walker typically has four wheels, two handles, and wraps around the back of the user. These walkers wrap around the back of the user so that the children do not learn to be dependent on leaning forward helping them maintain proper posture they grow and learn to walk (Bennink, 2018). Additionally, there are several aspects of the device where human factors are taken into consideration to ensure that the device meets the capabilities, limitations, and needs of the user. For example, the volume of the device in its operating position, the weight of the device, and the load that the device is able to support are all important factors in assuring that the device can accommodate its user.

A walker currently being sold by Careline Medical, called the "Nimbo Rehab Lightweight Posterior Posture Walker," has an adjustable height to conform to various user sizes and wheels with different settings to either allow for swiveling or preventing the user from turning. The rear wheels are larger than the front wheels and single direction to prevent the device from sliding backwards. In the operating position, the walker is 27 inches in length, 24 inches in width, and stands a minimum of 19 inches high. The walker can adjust to a maximum height of 25 inches high and folds easily for transportation in the non-operating position. The device weighs a total of 10 pounds, and can support a child weighing up to 85 pounds. This is made possible through the usage of aluminum as the primary product material (Careline Medical, n.d.).

Another walker being sold by Sears, called the "Winado Folding Posture Control Pediatric Posterior Rolling Walker Assist 4-Wheel," also allows for height adjustability and has different wheel settings, but all of the wheels are the same size. However, being made of aluminum alloy, this device weighs 7.7 pounds and can support up to 350 pounds. In the operating position, the walker is 14.37 inches in length, 13.38 inches in width, and stands minimum of 20.71 inches and maximum of 24.61 inches high. The Winado device is also able to fold for transportation in the non-operating position (Sears, n.d.).

The walkers described are just two of the many varieties in the market. In general, posterior walkers use different forms of aluminum since the material is lightweight and capable of supporting a substantial load. It is also common for these walkers to be adjustable in height, however, the range of adjustability may vary between models. Similarly, it is common for these walkers to be collapsible for transportation, but the ease of the collapsibility and volume in the stowed position may also vary between models. Most often, walkers in the stowed position increase in length, and although the width and height are minimized, the increase in length makes storage and transportation very difficult. Converting these devices from the operating to stowed position along with adjusting the height prove to be difficult tasks, as they require a lot of force and movement of several different parts (Bennink, 2018).

Although there are various models of posterior pediatric walkers that are meant to cater to the needs of the user, there are still several issues. For example, in the two walkers described above, the Winado model, can support up to 350 pounds, but it is only 14.7 inches long and 13.38 inches wide. A user requiring this weight support would likely require more space in length and width to operate the device comfortably and effectively. However, the Nimbo walker is approximately 12 inches longer and 10 inches wider, but can only support a maximum of 85 pounds.

The different settings for the wheels can also cause issues for the user. For example, single direction wheels prevent the user from moving backwards forcing the user to turn the entire 180 degree turning radius of the wheels if they need to turn around. Additionally, wheels that lock at certain speeds can also cause issues for the user. If the child is trying to move quickly or travel down a hill, the wheels may lock jolting the user and possibly causing him or her to fall.

It is also important to recognize that not all of the users will face the same challenges, and some users will need stronger reinforcements in different areas. However, it is not common for posterior walkers to come with attachments, therefore; making it difficult to find a device that can support a variety of users with different needs. Sometimes these attachments are the difference between a child using a gait trainer or a posterior walker (Bennink, 2018).

Aside from technical issues, the walkers are not the most child-friendly or aesthetically pleasing devices. For example, many of the walkers are bulky and have very limited color options, if any. This can make the device less aesthetically appealing to both the user and their peers. Additionally, it can be difficult for the user to interact with others because of the bulkiness of the device. The user also needs to be grasping the walker, making them unable to hold anything else, such as toys which also inhibits their ability to interact with others.

Although there are some walkers that satisfy a few of the technical issues mentioned, there is not yet a device that satisfies all of the technical issues in a child-friendly and aesthetically pleasing design.

2.3 Functional Requirements

To design and create a high quality product, we developed a list of functional requirements to ensure that the device addresses all the needs of the user.

The walker must be able to support the load exerted by the user. The average weight of a two- year- old in America is 23 pounds, and the average weight of an eight- year- old is 57 pounds (Disabled World, 2019). Because this walker will be designed for this age range, it will need to be **able to support 15-70 pounds**. This range leaves room for the children that are lighter or heavier than the average weight.

Because it is difficult for a user to adjust to a new walker, it is important that the device is adjustable and capable of growing with the user. The average height of a two- year- old child is 34 inches and the average height of an eight- year- old child is 50.4 inches (Disabled World, 2019). To meet their hands at a comfortable position, the **handle height of the device must be adjustable between 14-30 inches**.

For easier maneuverability, the **wheels must be able to rotate 360 degrees about the y and swivel 360 degrees about the z axis.** This will enable the user to turn with a smaller radius, allowing the user to navigate in a more congested area.

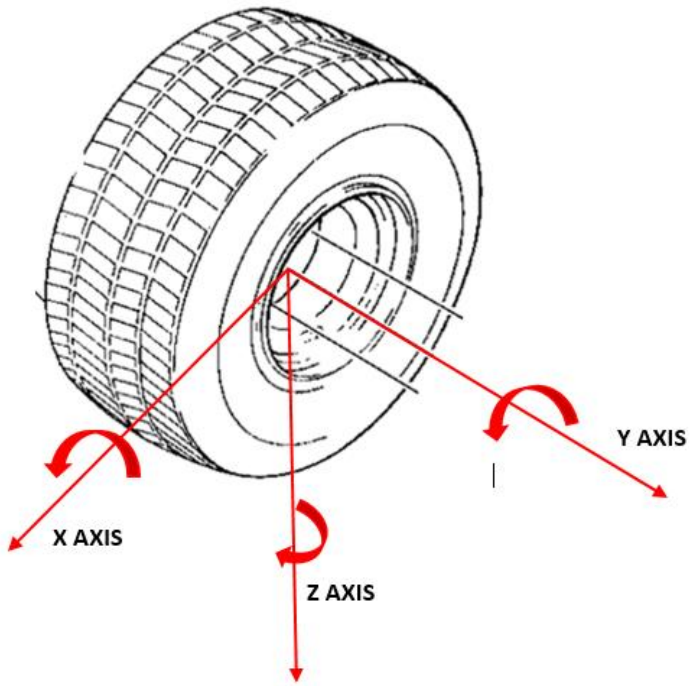

Figure 3: Coordinate System

If the user is not strong enough to control the device on certain terrains, such as inclines or smooths surfaces, the device could become dangerous for the user. To avoid this danger, the device **must have brakes that self-activate when the wheels are moving at high or increasing velocity.**

Because the target user is a young child with low strength, the device must be lightweight so that he or she can operate the device with ease. To ensure ease of use, the device **must weigh no more than 20 pounds.**

Large and bulky devices can be inconvenient and difficult to transport. Therefore, the device must also be collapsible so that the user can fit the walker in small areas such as a car. **In the stowed positions the walker must not exceed 12X12X30 inches and 30x30x36 inches in the operating position.**

Table 1: Functional Requirements

Number	Functional Requirement
1	able to support 15-70 pounds
2	Height must be able to adjust between 14-30 inches
3	wheels must be able to rotate 360 degrees about the y and swivel 180 degrees about the z axis.
4	must be able to come to a full stop within 6 inches of activating the brake
5	must weigh no more than 20 pounds.
6	In the stowed positions the walker must not exceed 12x12X16 inches and 30x30x12 inches in the operating position.

2.4 Bonus Features

In addition to the functional requirements, we developed a list of bonus features to differentiate our design from posterior pediatric walker currently available in the market.

The most important selling point for a pediatric walker is to be **aesthetically pleasing**. It is important to a young child that the device is pleasing to the eye so that they do not stand out from their peers. This will also **encourage and allow for interaction with others** in social situations.

The device must also have the ability to house attachments. Each user has different needs and it is unrealistic to assume that one walker will accommodate everyone. A more reasonable solution would be to have one device that can be adjusted to a user's needs by adding adjustments and supports.

The materials used for the handles on a walker can cause the user discomfort. **The handles on this device must be comfortable.** They should be made out of a forming yet supportive material that is shaped to fit comfortably in the user's hand.

Table 2: Selling Points

Letter	Selling Point
a	aesthetically pleasing
b	allow the interaction with others
c	have the ability to house attachments
d	handles must be comfortable for the user.

2.0 Design Concepts

Existing posterior pediatric walkers are not compatible for the lifestyle of the children using them or their families. Through research, we found the greatest issues to be that existing pediatric posterior walkers were bulky, difficult to maneuver and collapse, and did not adjust with the growth of the user. Therefore, we brainstormed different ways improve these issues. From brainstorming, researching, and interviewing a family and physical therapist familiar with these devices, the team developed four preliminary designs that improve the functionality and adjustability of this device.

The first design we developed resembled existing designs with four legs, four wheels, and a rectangular structure that wrapped around the user. In this design we focused on adding wheels that could swivel, were multidirectional without locking, and able to travel on all terrain contrasting the wheels on existing walkers that locked and only moved in the forward direction. However, we realized that this design did not address the issues of bulkiness and could possibly provide too much mobility, therefore being less supportive and possibly negatively impacting the user's posture.

Our second design was an iteration of the first design, with four legs and four swiveling wheels. However, this design incorporated handles angled at 45 degrees. The angled handles control the user's mobility provided by the swiveling wheels. The handles allow the user to push the device rather than pull in behind them encouraging proper posture.

Our third design focused on reducing the bulkiness of the device without compromising the support or mobility of the walker. This design had two legs with swiveling wheels in the front and one leg with a stationary wheel in the back. The front swiveling wheels provide the user with mobility while the wider stationary back wheel provides stability while limiting the mobility of the front wheels. This design reduces the bulkiness of the device by wrapping around the user more closely.

The third design successfully reduced the operating size while increasing the mobility of the device. Still we wanted to incorporate features to improve posture, collapsibility, and adjustability. To do this, we combined our second and third iteration. The fourth design included 45 degree angled handles on the three wheeled structure enhancing the user's posture while controlling the user's mobility. We designed a hinging device on the back leg and a slider on the top of the device to easily lock the device into a stowed position, which greatly decreased the overall size consumed by the device. We also incorporated five different height positions to make the walker adjustable as the child grows.

4.0 Synthesis and Analysis

After developing four design concepts, we compared our designs with existing designs. Through this research, we found the designs with four wheels to be strong and stable. However, walkers with three wheels did not exist on the market requiring us to perform an analysis to determine which materials would be strong enough to support the user. The hinging and collapsing mechanism on our final design also needed to be analyzed to ensure the pin and wheel axle would not shear or tear out with the applied load.

Below, Figure 4 shows the final design for the posterior pediatric walker. The average weight of the user is 70 pounds, therefore, to incorporate outliers to this average as well as any additional force, we doubled this weight performing our analysis with a load of 140 pounds. This load would be applied on the handles labeled N and O in Figure 4.

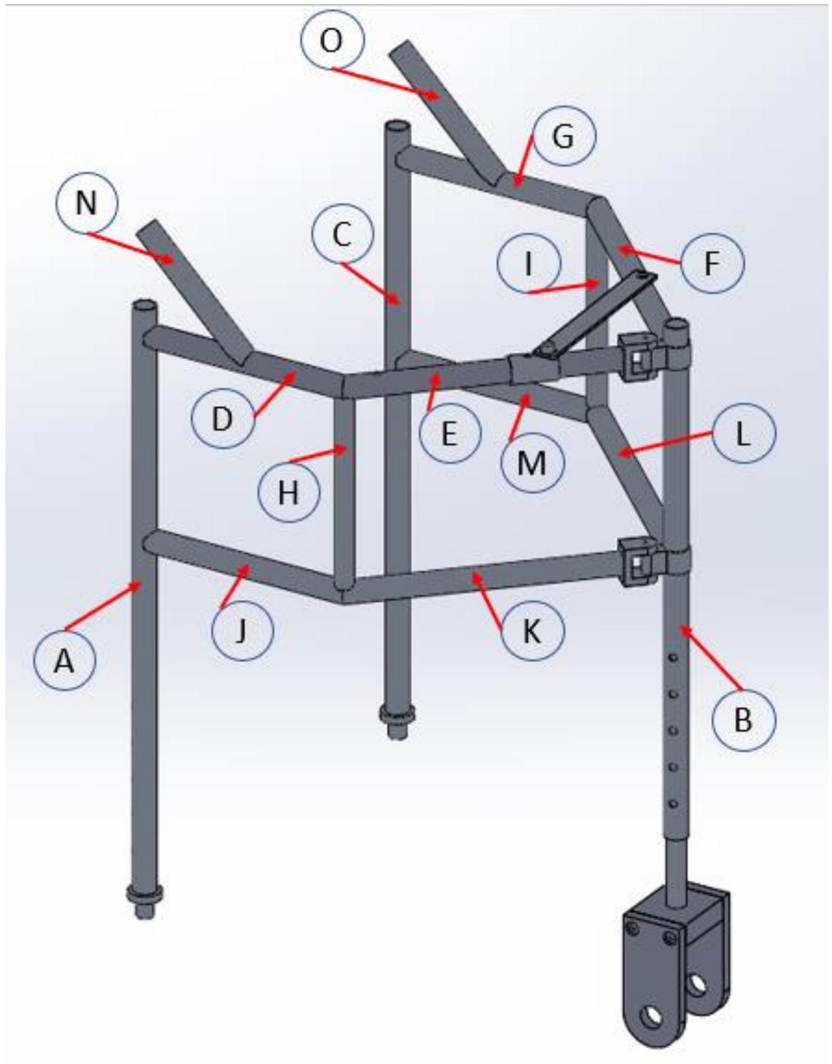

Figure 4: Final Design of the Posterior Pediatric Walker

The collapsing and hinging mechanism required a pin, so we began by analyzing the shear and tearout stresses labeled in Figure 5 to determine the material for the pin. This is shown in the calculation in Appendix A. The shear strength of the pin is 1,267.58 psi and the tearout stress is 2,800 psi. We chose to use steel for the pin because it is inexpensive, easy to manufacture, and met our design requirements with a yield strength of 87,924.44 psi.

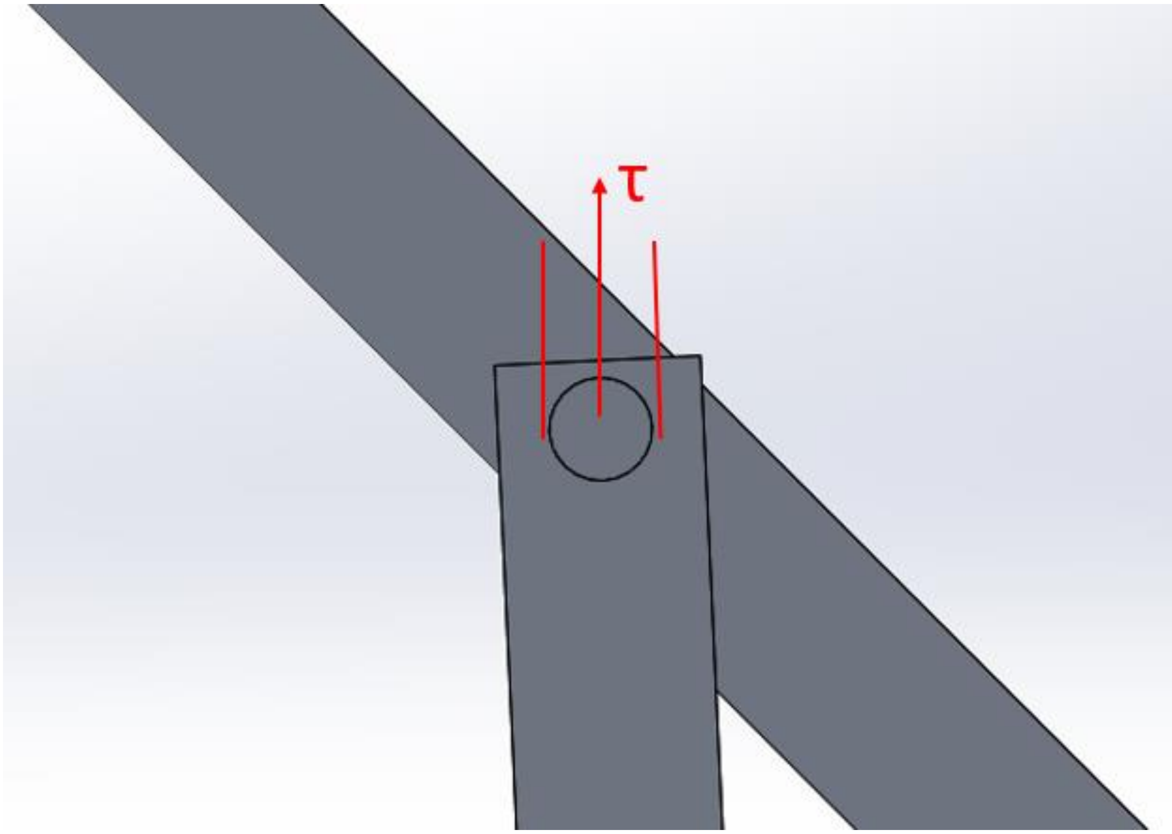

Figure 5: Shear and Tearout Stress at the Pin

Next, we analyzed the wheel axle as shown in Figure 6 for shearing and tearout stresses using a maximum load of 140 pounds. In the calculation in Appendix B, we found that the shear stress of the wheel axle is 316.90 psi and the tearout stress is 186.67 psi. We chose to use aluminum to manufacture the wheel axle because is a strong, lightweight, and inexpensive material with a yield strength of 77,875.95 psi.

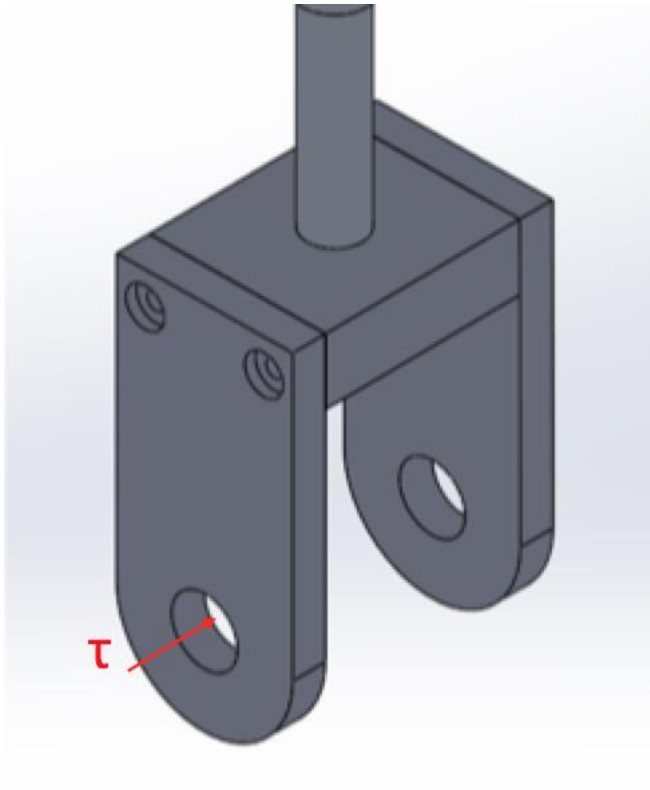

Figure 6: Shear and Tearout Stress at the Wheel Axle

Finally, we performed a stability analysis to ensure that the walker would not tip over with a load of 140 pounds. The analysis in Appendix C proves that the sum of the moments equals zero, therefore, the walker is stable.

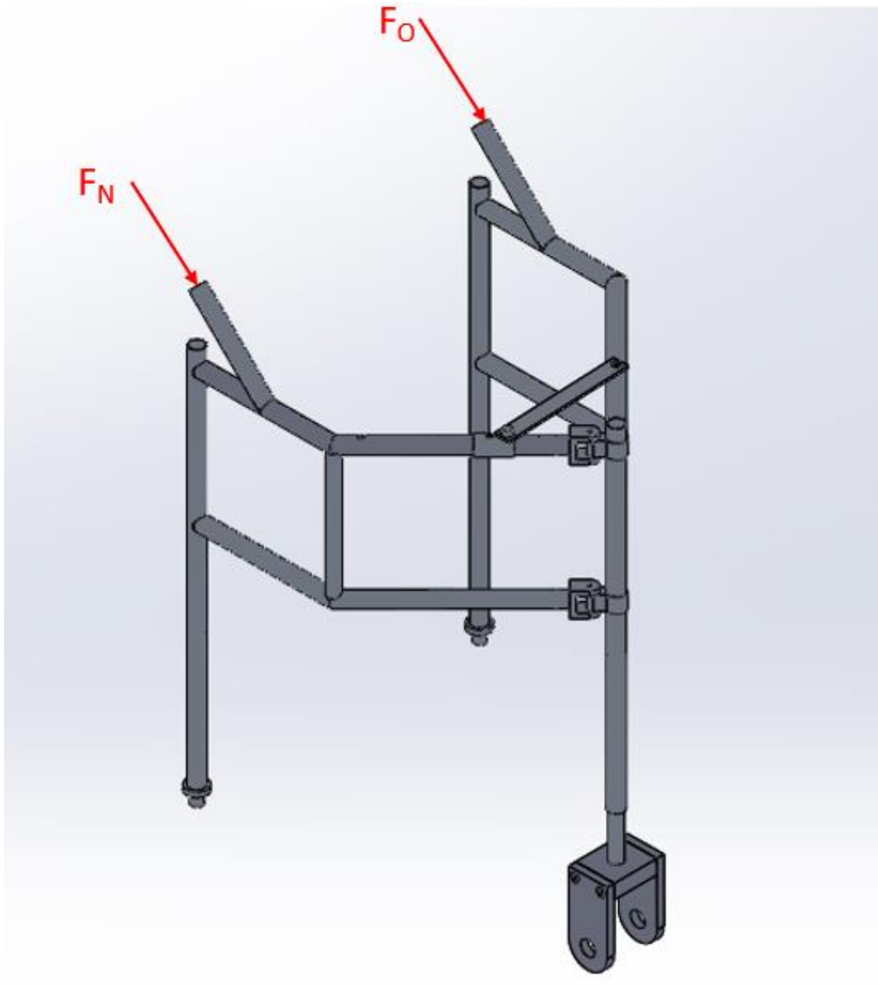

Figure 7: Applied Force

In conclusion, we determined that steel and aluminum provided strength and stability for the three-wheeled walker design and compiled a list of materials providing strength and stability in existing four-wheeled walker designs.

5. Design Selection

After extensive research and analysis of our design concepts, we determined key features that were vital to the success of an improved pediatric walker. Utilizing a design matrix, we evaluated these features to choose our final design.

5.1 Design Matrix

The factors used to select a design were determined based on research of existing posterior pediatric walkers, interviews with a family and physical therapist who have experience with posterior pediatric walkers, and an analysis of the existing issues. From this research, we were able to determine functional requirements as well as bonus features for the device which can be seen in the Background Section of this report.

Table 3: Design Matrix

Features	Weight	Design 1: Four Wheels	Results	Design 2: Tilted Handles & Four Wheels	Results	Design 3: Three Wheels	Results	Design 4: Three Wheels & Tilted Handles	Results
Maneuverability	8	3	24	5	40	7	56	10	80
Ease of Collapsibility	10	1	10	1	10	8	80	8	80
Operating Size	6	8	48	8	48	10	60	10	60
Adjustability	9	7	63	7	63	10	90	10	90
Weight	4	2	8	2	8	7	28	7	28
Aesthetically Appealing	4	2	8	2	8	5	20	5	20
Comfort	3	6	18	8	24	6	18	10	30
Stowed Size	6	2	12	2	12	6	36	8	48
		Final Score	191	Final Score	213	Final Score	388	Final Score	436

The functional requirements and bonus features were divided into eight simple features that were used in a design matrix shown in Figure 8. Each feature was assigned a weight from one to ten based on the integrity of the design, one being least integral to the design and ten being most integral to the design. This matrix was then used to evaluate each of our initial design concepts to determine which design best fulfilled all of the features in the matrix. This was done by evaluating each design with respect to each feature by assigning each design a score corresponding with how well it fulfills the goal of each feature. A score of one was assigned for designs that least fulfilled the feature being evaluated and a score of ten was assigned for designs that fully fulfilled the feature being evaluated.

5.2 Weighting of Features

The eight features that were used to evaluate each design were maneuverability, ease of collapsibility, operating size, adjustability, weight, aesthetic appeal, user comfort, and stowed size. Ease of collapsibility was weighted the highest of all the features with a weight of ten because through our research and interviews, we found that transportation was one of the biggest issues with existing devices. These devices take up a significant amount of space in the operating position, therefore it is necessary for the device to have the ability to collapse and be stored. Through our research and interviews, we found that collapsing the existing devices is a tedious process that requires force to properly collapse, prolonging the process of transportation.

Adjustability also had a significant weighting of nine. This feature focuses on the device's ability to grow with the child. These devices are designed to be small because they are intended for a child to use, however, they often have a very short life with one user because of how quickly the child grows. Most devices offer options for height adjustments, however, the adjustability range is limited and does not allow the child to use the walker for a long period of time. Another issue is that even if the height adjustability is satisfactory, the user may grow out of the device with regards to width.

Maneuverability held the next highest weighting with a weight of eight. The main purpose of these devices is to mobilize children with a walking disability and aid them in learning to walk properly, so it is extremely important that the device helps the user to move. Through our research, we found that the wheels on many devices limited the user's ability to move backwards, which often resulted in children getting trapped in corners. We also found that not all devices had multi-directional wheels, making it difficult for users to travel in any direction other than forward. We found these to be limiting and inconducive to the way a child would be interacting with other children or maneuvering through their own home.

Operating and stowed size of the device was assigned a weighting of six. This is because issues regarding size of the device are also addressed through other features. For example, the stowed size of the device is very closely related to ease of collapsibility. One of the issues with existing devices is that even when the device is collapsed properly, the stowed size is not much easier to store or transport than when it is in the full operating position. Rather than decreasing the overall size, the size is distributed in different directions. Therefore, it is important that the stowed size truly consumes a smaller area than when it is in the operating position. The operating size of the device is also closely related to the maneuverability of the device. Through our research, we found that the bulkiness of the device often limits the user, especially when navigating through narrow spaces such as doorways. Therefore, it is important for the device to also be as small as possible in the operating position, while still fully supporting the user.

Weight, aesthetic appeal, and user comfort were all weighted similarly, with weight and aesthetic appeal having a weight of four and user comfort having a weight of three. Weight of the device is very closely related to other features, such as the size because it is likely that the larger the device is, the heavier it will be. It also closely related with the ease of collapsibility because if it is a heavy device, it will be difficult to collapse and transport. However, another importance that the weight has with the device is that it needs to be light enough for the user to move, but heavy enough to not tip over. Aesthetic appeal is also an important feature of the device because it can impact the way the user interacts with others. The bulkiness of the device can often be intimidating to other children, therefore impacting the user socially. Still, it is important that the device supports the user and improves mobility and posture. It is important that the user is as comfortable as possible with the maximum mobility and proper posture while walking.

In the table below, the weights assigned to each feature were then multiplied by the score of each design in that category. These products were then summed for each design to determine the overall score of that design. These overall scores were then compared with maximum possible score of 500 to determine how well they satisfied the features. Therefore, the design scoring closest to 500 best satisfied all of the features in the matrix.

5.3 Final Design

The design matrix showed that Design 4 satisfied all of the features, with three wheels and tilted handles. The design received a score of ten for maneuverability because the device coming to a single wheel in the back reduces the bulkiness of the device, allowing the user to navigate through narrow spaces while still allowing them to move freely by having multi-directional wheels that swivel in the front and a stationary back wheel that allows for movement in the forwards and backwards directions.

A score of eight was given for ease of collapsibility. This is because we recognize that the ease of transitioning the device from the operating to stowed position, or vice versa, can also dependent on time constraints and environment. However, we believe the mechanism used to collapse this design is much simpler, requiring only one person, and also consumes less space in the stowed position.

The design received a score of ten for operating size. These reasons are very similar to those stated when discussing maneuverability, because the single back wheel allows the device to be narrower towards the back, resulting in a smaller and less bulky overall size.

A score of ten was also given for adjustability because of the devices ability to accommodate the user as they grow.

The design received a score of ten in the weight category because it is made of aluminum and steel, which is very similar to other designs, however since this device has one less wheel and leg than other designs, it is lighter. It is light enough for a child to be able to easily maneuver and move freely, however, heavy enough to stay grounded and not be easily tipped.

A score of 5 was given for aesthetic appeal. This is because although the size of the device is decreased, it will still be surrounding the user and is something that their peers will not be familiar with. However, we have worked to incorporate different colors and add-on features to give the device characteristics similar to that of a toy so that the user and other children might associate the device with playing rather than a medical device.

The design received a score of ten for comfort. This is because the tilted handles allow the user to keep their hands at a more natural position, rather than having to grip the device with their arm perpendicular to the handle. The tilted handles also encourage the user to have proper posture by preventing them from running ahead of the device and dragging it behind them.

Lastly, the design received a score of eight for stowed size. This is because we recognize that although it will take up less space than most other devices, it will still require that a portion of space be dedicated to transporting or storing the device. However, the device will collapse by a hinge at the back leg and latch when the two front legs meet. This greatly decreases the amount of size of the device and ensures that the device will stay in the stowed position during transportation.

6.0 Detailed Design Description

After utilizing the design matrix, we selected Design 4 because it satisfied the design features and functional requirements. The most drastic modification that we made was to the structure of the existing device by designing a three-wheeled walker rather than using four wheels. We chose to create a three wheeled device for a couple of reasons. First, this made the walker much less bulky as it closely wraps around the user instead of being a large rectangular shape. Second, this design choice greatly increases the ease of collapsibility. The existing designs require multiple steps to collapse the device, however our design collapses using a single button clip that locks into either the operating or stowed position, which folds the device in half at the back leg. Additionally, the three wheels of the device are not all the same. We chose to make the front wheels small and on a swivel allowing the user to maneuver the walker more easily in narrow or crowded spaces. The back wheel is wider to provide stability and does not swivel. This was important for the overall functionality of the device as it provided added stability and support as well as some limits to how much the front wheels could swivel.

We chose to make our walker adjustable between the heights of 26.5 and 36.5 inches to accommodate the average height of a user between the ages of two and eight. The width of our design remained the same as the existing device at fifteen and eight inches wide in the operating and stowed position respectively. We also decided to angle the handles at 45 degrees. This angle was chosen because it is a comfortable position for a user to grip the device but also helps to improve the users posture. This angle encourages the user to push the device ahead of them, instead of pulling it behind them, forcing them to stand up straighter.

To improve the ease of collapsibility of the device, we incorporated a slider mechanism that is attached to the top right frame of the walker at one end and slides along the top left frame on the other end. This slider works to fold the walker in half at the hinge on the back leg by moving along the top frame and locking into place by button clip at the operating and stowed positions. We used geometry to determine the location of the button clip holes. These holes needed to be the perfect distance to allow the walker to lock into the fully open position, maintaining the correct distance between the handles, but also lock into the stowed position without the two front poles intersecting. Therefore, the distance between these holes had to be calculated to ensure that the locations were correct to achieved the intended positions.

Because the device is intended for a small child, it is important that the material is strong enough to support their weight. However, it is equally important that the device is light enough that the child is able to maneuver the walker. We chose to use aluminum for the frame of our device because this material is both strong and light. We decided to use steel for the pin at which the device hinges around because this piece must be strong and is small enough that the weight of steel will not affect the overall weight of the walker. The hub of the back wheel will also be made from steel to provide stability.

7. Manufacturing

The manufacturing of our selected design was a multistep process that included exploring the different options for machining the various components of the walker, considering the method of assembly, and acquiring the necessary materials. A few components that we paid very close attention to from a manufacturing standpoint were the hinges, the sliding mechanism that allowed the walker to collapse, the caster for the rear wheel, and the connections for the front swiveling wheels. The method of assembly also played a large role in our manufacturing decisions.

Since our analyses determined that aluminum was a sufficient material for the walker, we purchased aluminum tubing to manufacture the structure of the device. Solid aluminum stock was purchased to manufacture the hinges, rear wheel caster, front wheel connections, and sliding mechanism components and steel stock was purchased for the hub of the back wheel. However, aside from these materials, the walker utilized pins at the hinges and sliding mechanism along with button clips for the adjustable height and width in the stowed and operating positions.

Some of the most challenging pieces to manufacture were the sliding mechanism that moves along the top of walker to lock the walker into the operating and stowed positions, and the hinges at the back leg of the walker allowing it to collapse. The sliding mechanism had to allow for the attachment of the slider while still moving smoothly and securely along the top of the walker. This was done by attaching the slider to the sliding mechanism with a very small screw that did not interfere with its smooth and secure movement. The hinges were connected to the structure in a similar way, as the open mouth hinge needed to fit around the back leg smoothly and securely, however these pieces did not move and were held in place by their connections to the walker's structure. Both pieces of the hinge also had a hole for the pin, these holes needed to line up perfectly on both pieces of the hinge and be the correct dimension for the hinges to pivot tightly about the pin.

Since the walker had two front swiveling wheels and a single non-swiveling rear wheel that remained stable, it was important that wheel connectors for the front wheels allowed them to swivel and that the back wheel caster was strong enough to keep the back wheel grounded and stable. The rear wheel caster and hub was machined from steel so that it would be a heavier material so that the user would not be able to easily lift the rear wheel. The caster was made of three pieces, a top in which the back leg was secured into, and two identical side pieces that were screwed into the top. This simplified the assembly of the rear wheel and strengthened the caster. The front wheel connectors needed to be able to attach to the swiveling wheels but also to the front legs of the walker. The swiveling wheels that were purchased had stem coming from the caster for attachment, however, the wheel stem the front leg had differing diameters so the connecting piece needed to accommodate both diameters without hindering the front wheels ability to swivel.

The majority of the walker was assembled through welding. Therefore, the way the components were manufactured needed to be able to accommodate strong and successful welds. The components being welded needed to have sufficient surface area to apply the welding beads and for the welds to form properly. If there was not sufficient surface for welding, the coverage of the weld could compromise the dimensions and functionality of the piece being welded. This required modification of certain pieces to ensure that the components could be welded successfully without compromising the dimensions or function of the pieces being welded.

Although all of these things were considered before and during the manufacturing process, there were still some challenges we faced in assembling the final product. Since the dimensions of the front wheels differed from the rear wheel, the tubing cut for the front and back legs were different lengths. This was calculated prior to manufacturing, but the measurements that were taken for these calculations were not precise enough to provide a level walker. The back leg was slightly longer, meaning that when all of the legs were on the lowest height, the walker was tilted downward. To correct this, we disassembled the back leg, marked the sliding back pole at the point where the walker would be level, and trimmed the piece to the correct length. Our original design also had the slider on the top of the walker. However, upon assembly, we realized that although the slider did not interfere with the button clip on the sliding mechanism they were very close together, making the button clip difficult to use. This was corrected by attaching the slider to the bottom of the sliding mechanism rather than the top, making it much easier to operate the sliding mechanism without compromising the function. The tops of the legs were also exposed after being manufactured, and because they were cut, the edges were a sharp. We ordered caps for each of the legs so that the user would not be injured by the edges. The pin that we had initially purchased to attach the slider to the walker structure was too large, leaving it hanging down off of the structure. This was corrected by ordering a different sized pin that would hold the slider up against the structure while still allowing it to move. One of the larger issues we encountered in manufacturing was the attachment of the front wheels, wheel connector, and front legs. The wheel connector was designed with a lip where the piece wheel stem ended and the connector fit into the front legs, however, the weld was larger than this lip and covered some of the front pole sliding leg. The size of this weld prevented the sliding leg to reach the shortest button clip, therefore the walker could only adjust to four heights rather than five since the last button clip was inaccessible. We also manufactured our walker with relatively large tolerances. After assembly, we recognized that these tolerances allowed provided slight movement in areas where it was not intended.

8.0 Conclusion and Recommendations

After testing our final device, we found that the posterior pediatric walker satisfied four of our six functional requirements. Through our calculations and analysis, our final design can support a 70 pounds user. The wheels on our final device are able to rotate 360 degrees about the y axis. By utilizing aluminum and minimal steel, we were able to create a device weighing only 5 pounds 8.5 ounces. The device measures 8X17X26.5 inches in the stowed position and 15.5X17X28.5 inches in the operating position, which satisfies our volume requirements. To improve the performance, appearance, and safety of the device we developed the following recommendations. We intended for our device to be adjustable between 14 and 30 inches, however through interviews with the physical therapist we determined that this large of a range was not necessary. We reduced the adjustability to 26.5 inches to 36.5 inches as these were more appropriate heights for the intended user. Our front wheels also are able to rotate 360 degrees about the y and z axis. Finally, we were not able incorporate a braking mechanism, however this could be useful to the overall functionality of the device in the future. To improve the performance, appearance, and safety of the device we developed the following recommendations.

The first recommendation is to add hinges at points A, B, C, and D of Figure X. Our 3 wheeled design with the hinge at the back leg greatly reduces the size of both the operating and stowed position of the device. Still, the volume can be further reduced by adding hinges at each corner allowing the device to fold in half eliminating the diamond shape in the stowed position.

The next recommendation is to add an additional button clip hole to the slider mechanism. By incorporating another hole, the device would have more width adjustability in addition to the height adjustability. Further, it would accommodate a larger user by offering the user another option for a comfortable position.

The front wheels of the walker have a very small surface area that makes contact with the ground. Although this provides mobility, it could decrease the stability of the walker on different terrains. Therefore, another recommendation is to increase the surface area of the front wheels to increase the stability of the walker. Although our analysis proved that the walker is stable, adding more surface area will increase the safety of the device.

Although the purpose of the front wheels swiveling is to provide the user with freedom and mobility, since they rotate at 360 degrees, it allows for the front wheels to be facing opposite directions. To prevent this, we recommend that the rotation of the front wheels be limited to 180 degrees. By limiting the rotation of the wheels along the z axis, it will improve maneuverability while providing more stability.

The next recommendation is to include a locking mechanism for the wheels. The wheels of a stroller can lock in place when the user does not want the stroller to roll away. The walker could utilize the same type of mechanism so that it will stay in place when not in use.

The final recommendation is to cap the areas that hinge because they require grease in order to operate smoothly. This cap would protect the child from the grease and from getting pinched at the hinges.

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Appendix A

Shearing of Pin

$\tau_{shear}=\frac{P}{A}$;
where "P" is the maximum load applied by the user and "A" is the cross-sectional area of the pin

P= 2(70lbs) = 140 lbs.

$A = \pi \left(\frac{0.375}{2}\right)^2$ = 0.1104 inches

$\tau_{shear}=\frac{140\ lbs}{0.1104\ in.} = 1{,}267.58\ psi$

σ_{steel}= 50,763.20 psi

$\sigma_{steel} \times \sqrt{3}$ = 87,924.44 psi

$\tau_{sheer} < \sigma_{steel}$

Appendix B

Tear-out of Steel Pin

$\tau_{\text{tear-out}} = \frac{P}{A}$

A = [2(0.1)(0.25)]= 0.05 in.

$\tau_{\text{tear-out}} = \frac{140\ lbs.}{0.05\ in.}$ = 2,800 psi

$\tau_{\text{tear-out}} < \sigma_{\text{steel}}$

Appendix C

Shearing of Wheel Axle

$\tau_{shear} = \frac{P}{A}$;

where "P" is the maximum load applied by the user "A" is the cross-sectional area of the axle

P= 2(70lbs) = 140 lbs.

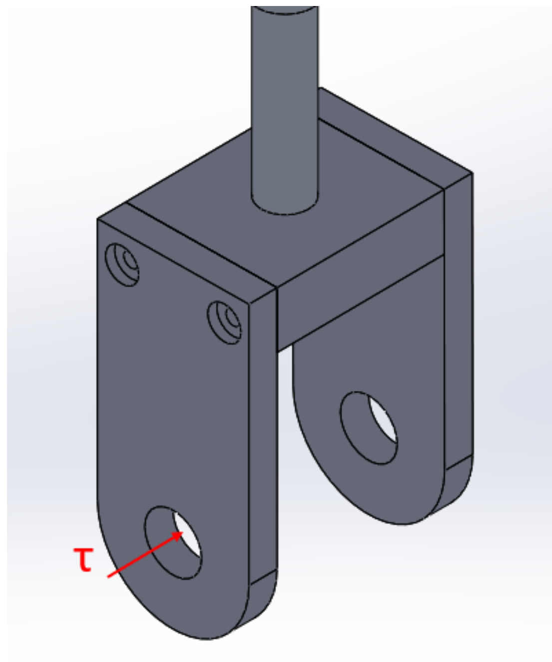
$A = \pi \left(\frac{0.75}{2}\right)^2$ = 0.4418 inches

$\tau_{shear} = \frac{140\ lbs}{0.4418\ in.} = 316.90\ psi$

$\sigma_{aluminum}$= 44,961.70 psi

$\sigma_{aluminum} \times \sqrt{3}$ = 77,875.95 psi

$\tau_{sheer} < \sigma_{aluminum}$



Appendix D

Tear-out of Wheel Axle

$\tau_{tear\text{-}out} = \frac{P}{A}$

A = [2(0.1)(0.375)]= 0.75 in.

$\tau_{tear\text{-}out} = \frac{140\ lbs.}{0.75\ in.}$ = 186.67 psi

$\tau_{tear\text{-}out} < \sigma_{aluminum}$

Appendix E

Stability Analysis

$\sum M_{AX} = F_A(0) + F_N(0) + F_H(0) + F_B(7.07) + F_I(14.78) + F_c(14.78) + F_o(14.78)\cos(45) = 0$
$\sum M_{Ay} = F_A(0) + F_N(3.54)\sin(45) + F_H(07) + F_B(14.07) + F_I(7) + F_c(0) + F_o(3.54)\sin(45) = 0$
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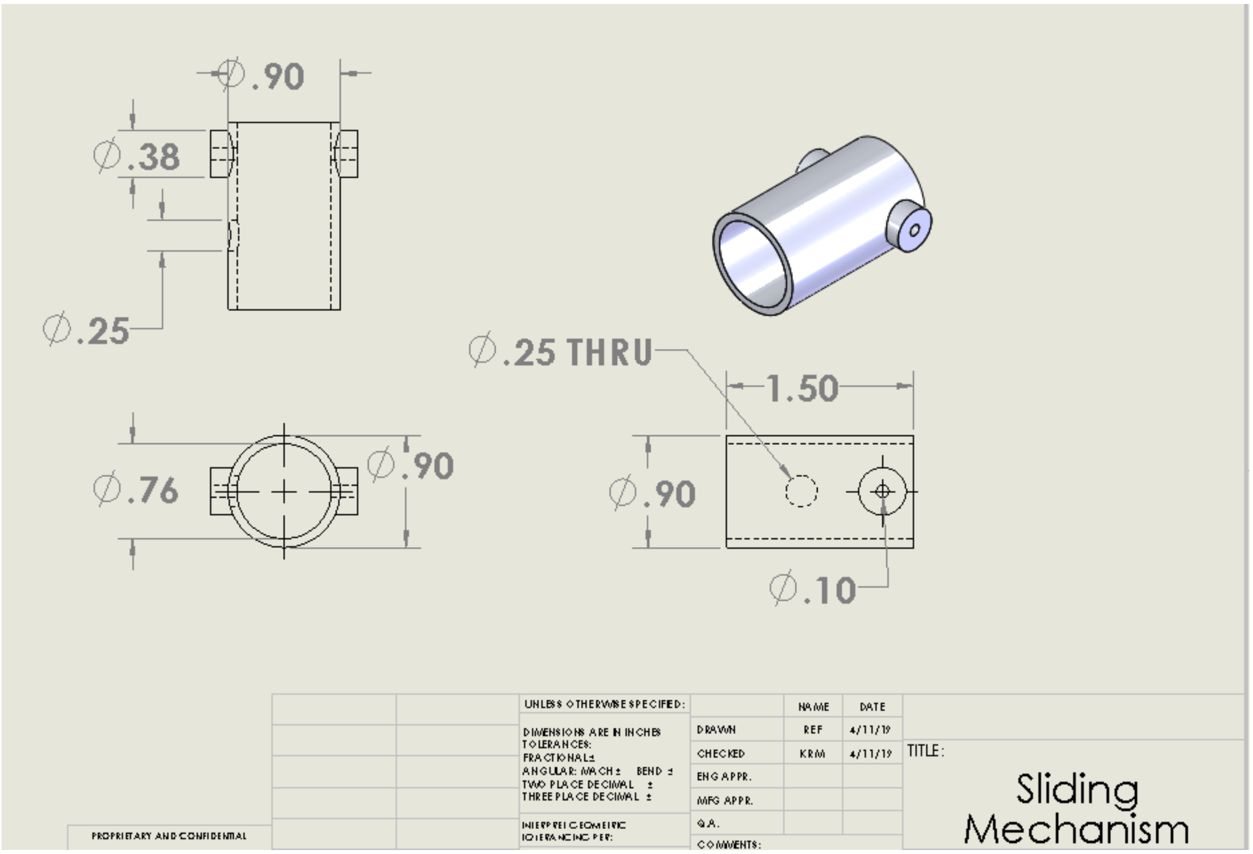
$\sum M_{BX} = F_A(7.07) + F_N(7.07)\sin(45) + F_H(7.07) + F_B(0) + F_I(7.07) + F_c(7.07) + F_o(7.07)\sin(45) = 0$
$\sum M_{By} = F_A(14.78) + F_N(10.53)\sin(45) + F_H(7.07) + F_B(0) + F_I(7.07) + F_c(14.78) + F_o(10.53)\sin(45) = 0$
$\sum M_{Bz} = F_A(0) + F_N(24.61)\cos(45) + F_H(0) + F_B(0) + F_I(0) + F_c(0) + F_o(24.61)\cos(45) = 0$

$\sum M_{CX} = F_A(14.78) + F_N\cos(45) + F_H(14.78) + F_B(7.07) + F_I(0) + F_c(0) + F_o(0) = 0$
$\sum M_{CY} = F_A(0) + F_N(3.54)\sin(45) + F_H(7) + F_B(14.07) + F_I(7) + F_c(0) + F_o(3.54)\sin(45) = 0$
$\sum M_{Cz} = F_A(0) + F_N(24.61)\cos(45) + F_H(0) + F_B(0) + F_I(0) + F_c(0) + F_o(24.61)\cos(45) = 0$

Appendix F



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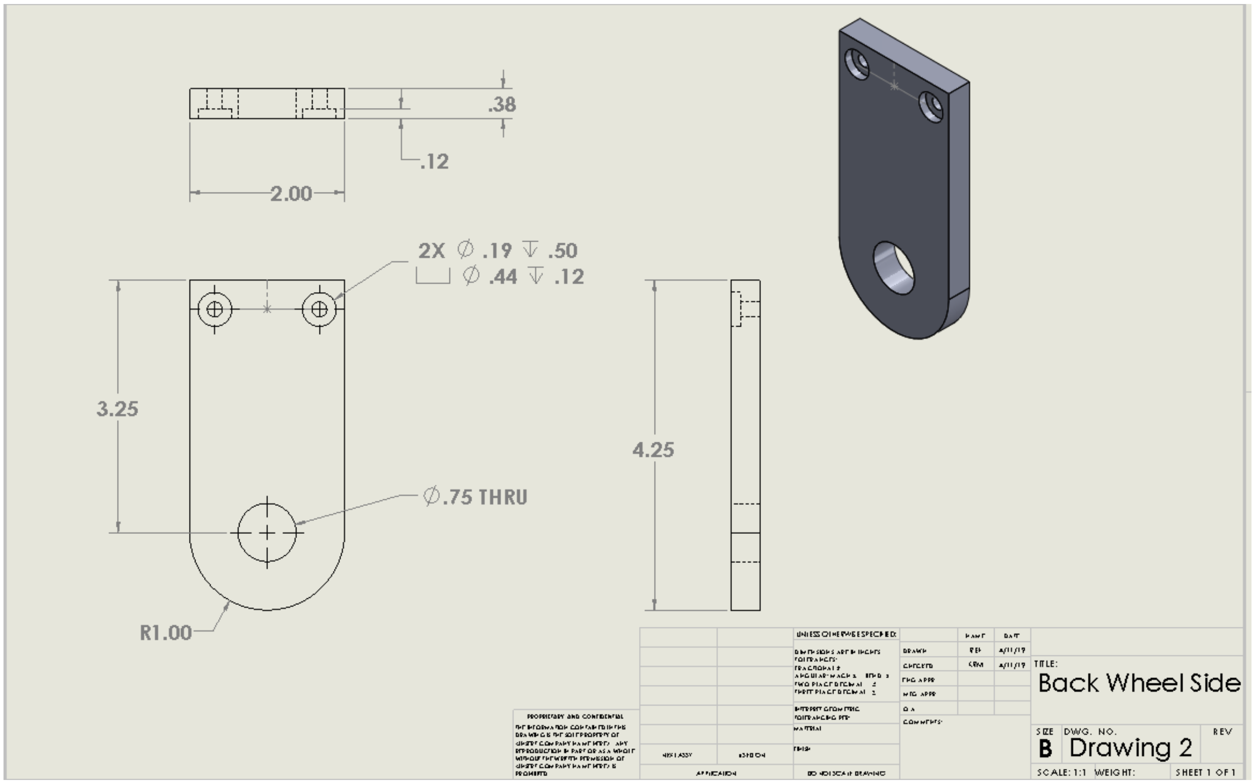
TITLE:
Sliding Mechanism

Appendix G



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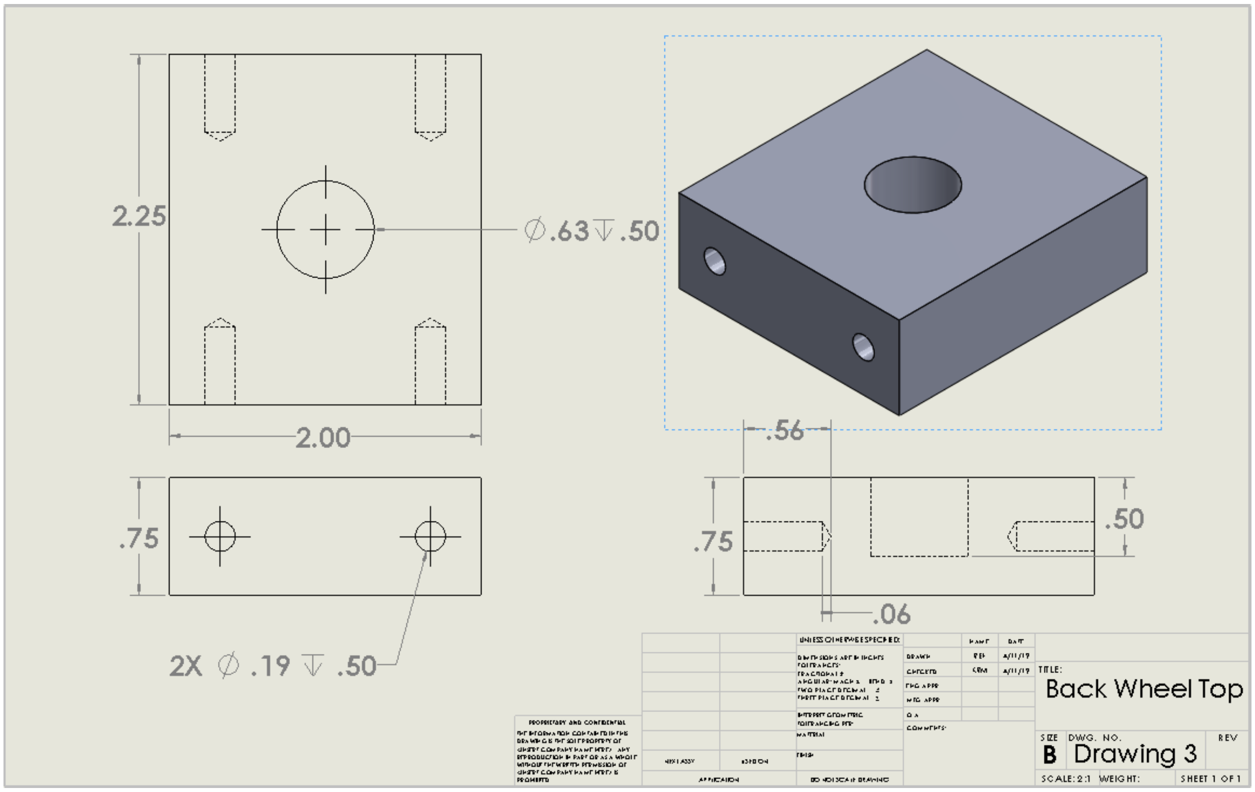
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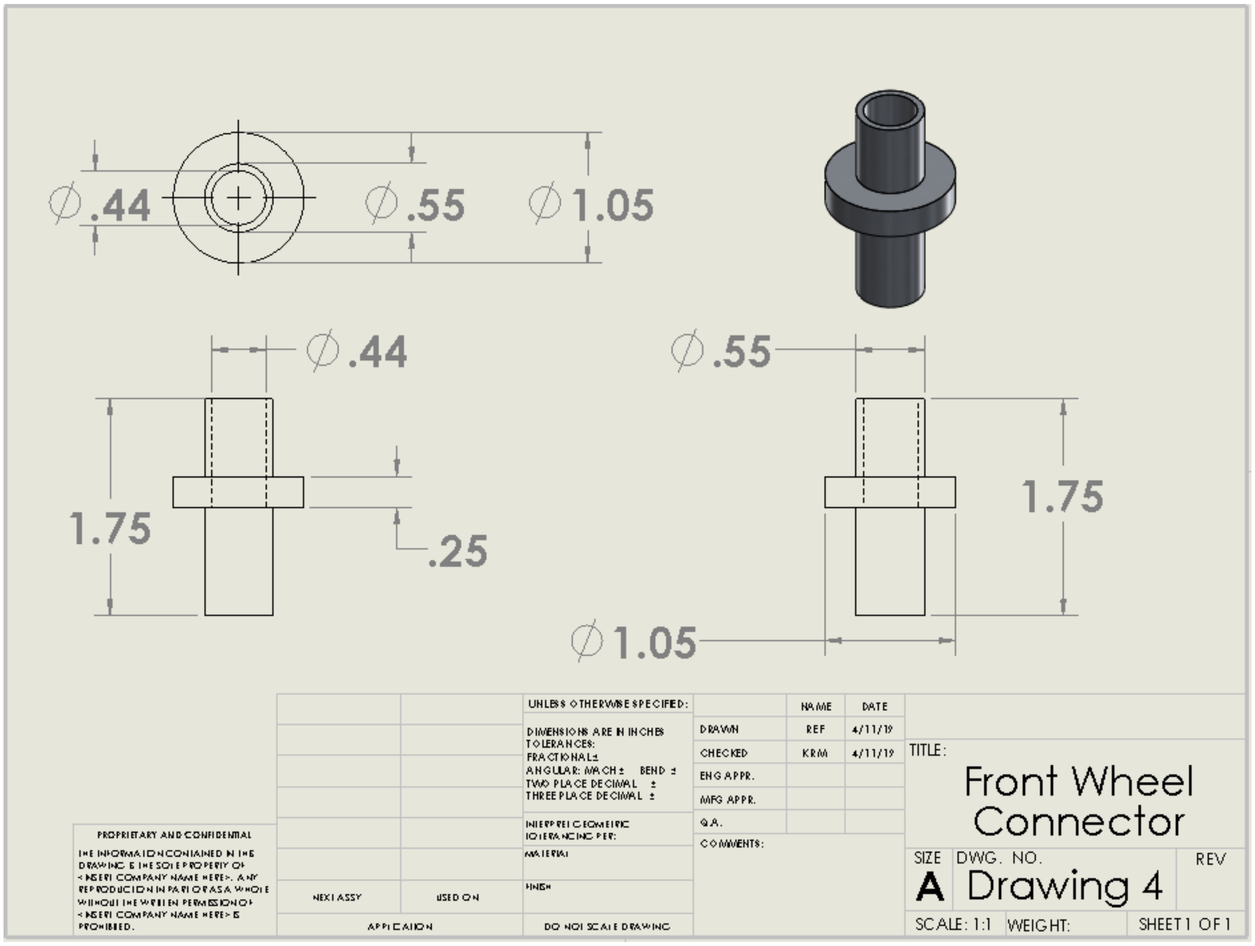
Appendix I



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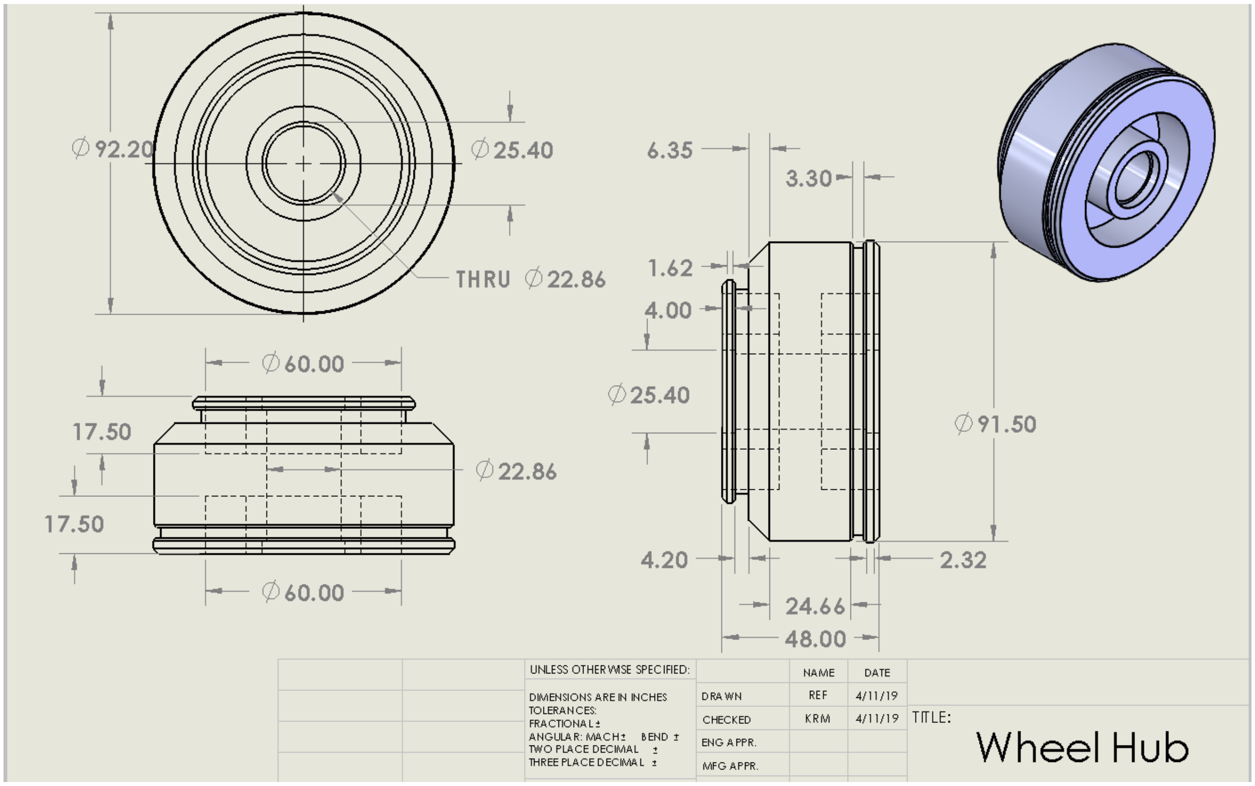
Appendix J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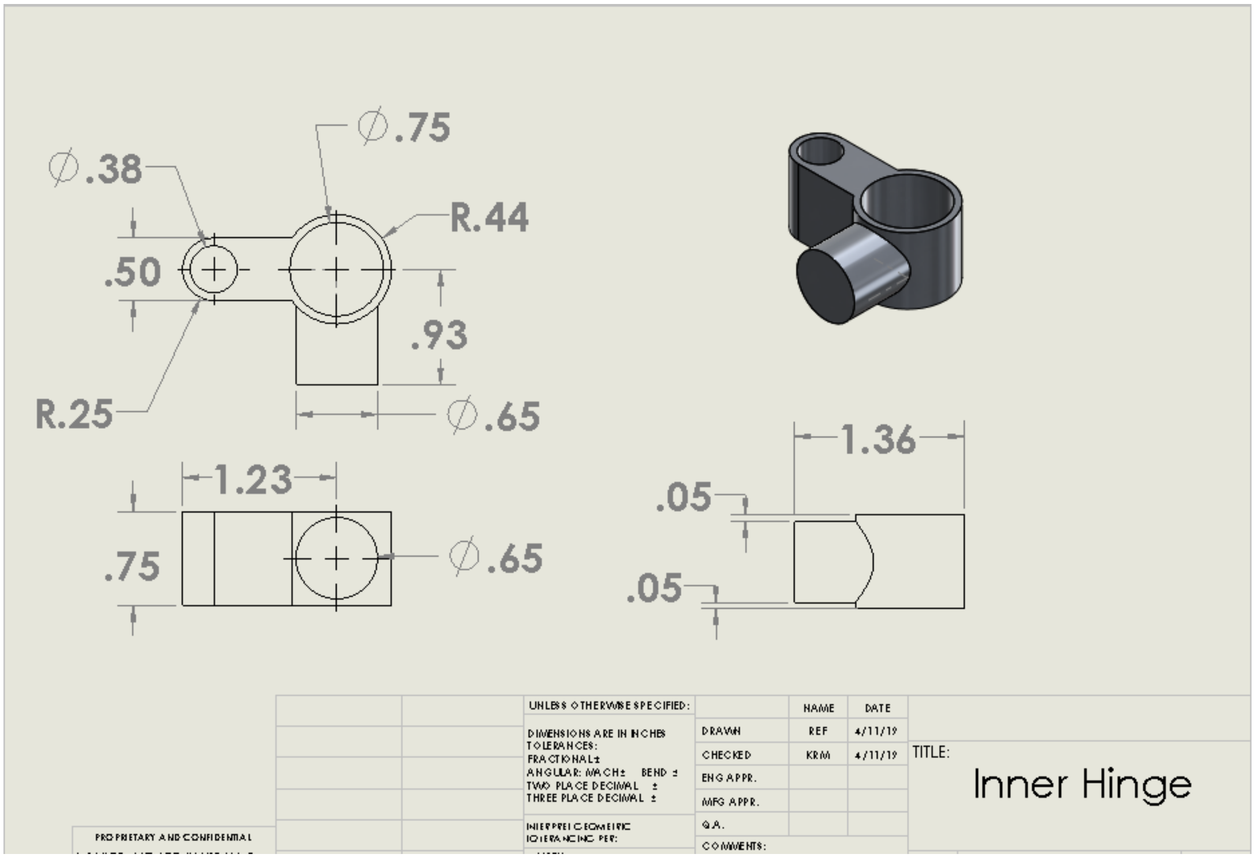
Appendix K



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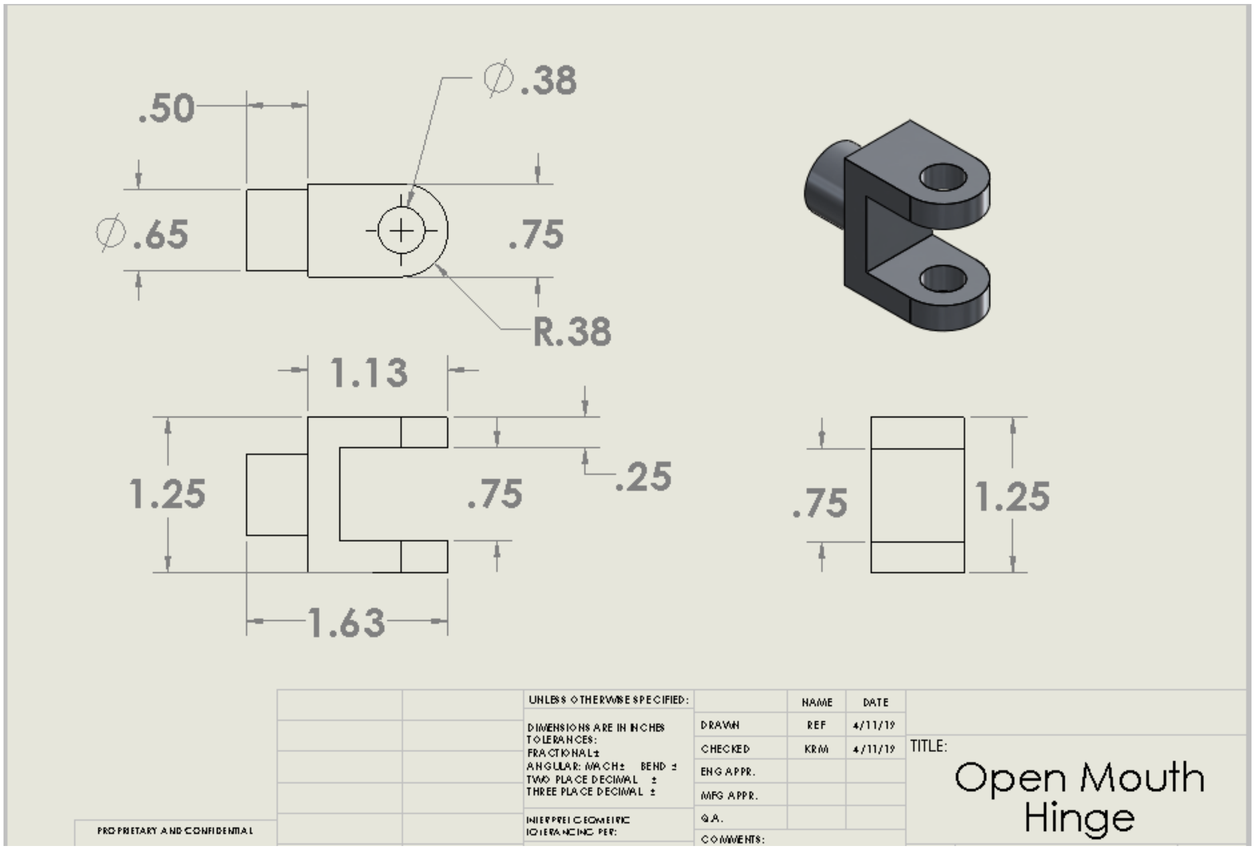
Appendix L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