MEMORANDUM

10/13/2025

TO:	Andrew Davol, Professor, Mechanical Engineering
FROM:	Luke Romanini, Ari Dennis, Kevin Almontes ME 328 – 06
COPIES:	1
SUBJECT:	**Knee Scooter Design Report**

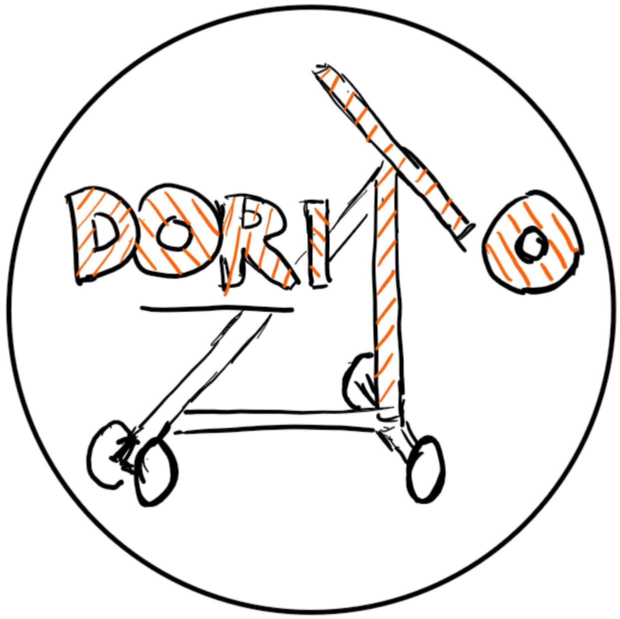

Figure 1: Team logo

Team name: Dorito

Memo Intro:

To design a knee scooter that adequately meets the needs of the customer, we must first establish what these customers' needs are. The device should not exceed 30 lbs. It should be about 36” long, 36” tall at the handlebars, and about 18” wide at its widest part.

The normal use load cases would be riding the scooter across various normal surfaces. One case would be using the scooter across a smooth floor, with no bumps. Another normal use case would be using the scooter on a rougher outdoor surface like asphalt that has some bumps to go over. The scooter may even be used on other types of terrain, such as across grass and dirt. An abuse case would be riding the scooter off a curb or trying to have two riders on it at the same time. When loaded at the seat, the seat should not deflect by more than 1”. If possible, adding a braking mechanism would be a very useful feature, but it may be very difficult to design and produce.

The knee scooter should be light enough for the customer to be able to maneuver it around, but since they are using it as a transportation device, they should not be picking it up frequently, so 30 lbs. is reasonable. This is also comparable to most knee scooters that are available to purchase, which tend to weigh just under 25 lbs. The 36” height is chosen to be a comfortable height for handlebars for any person, falling somewhere between their waist and their chest. The 36” length is comparable to other scooters on the market and is long enough to be stable and functional without being oversized. The 18” width would likely be the width of the front wheelbase, but it depends on the design. This would provide stability but not be so wide that it is difficult to maneuver.

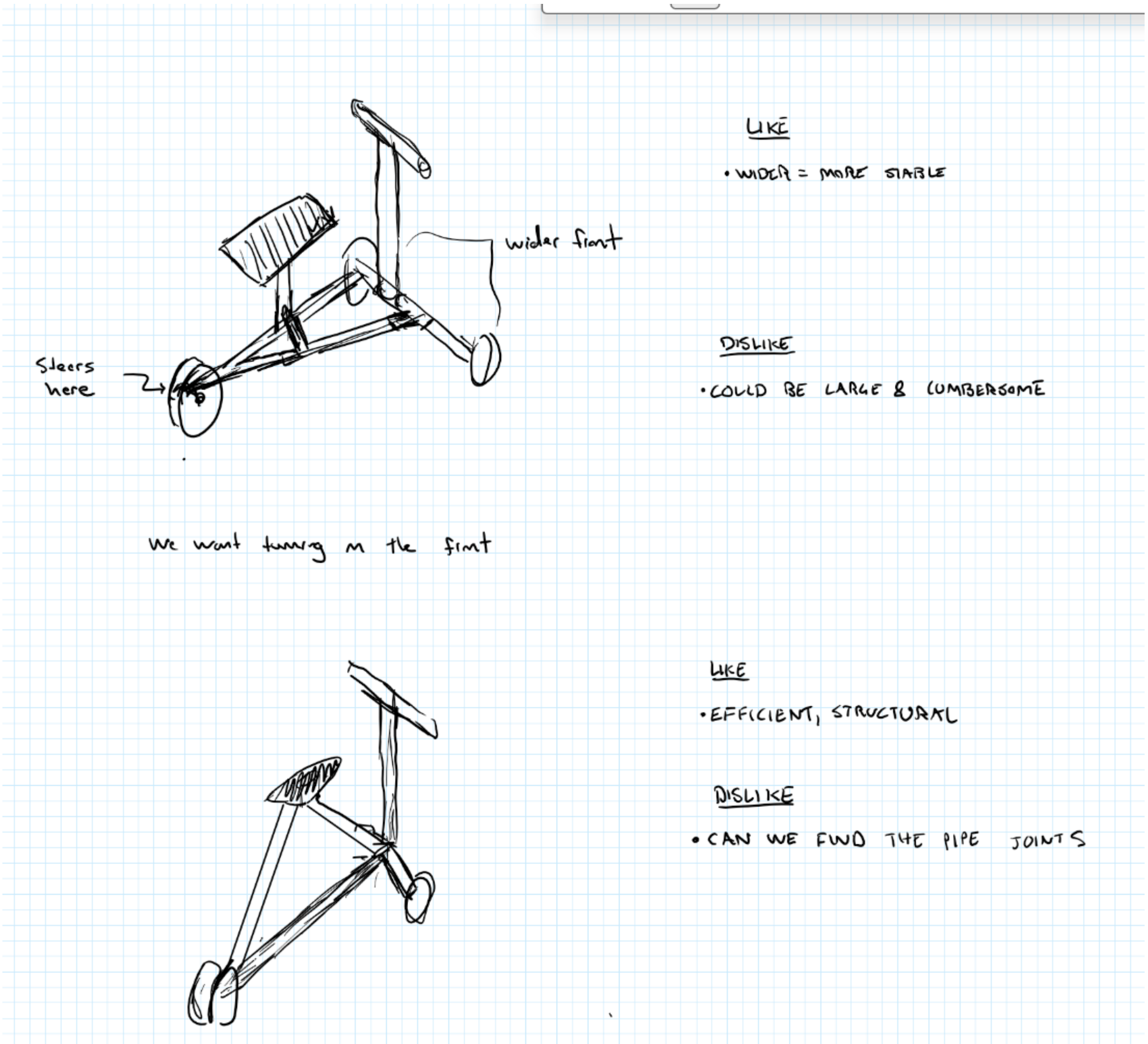

Figure 2: Brainstormed ideas

The first drawing is a very stable design, but the width of the base may get in the way when the user tries to push the scooter. There also is not much in the design that would help to limit deflection when there is a load on the seat.

The second drawing may not have as much horizontal stability, but the triangular design should help limit the deflection when there is load on the seat. It may also be difficult to connect the PVC at the joints.

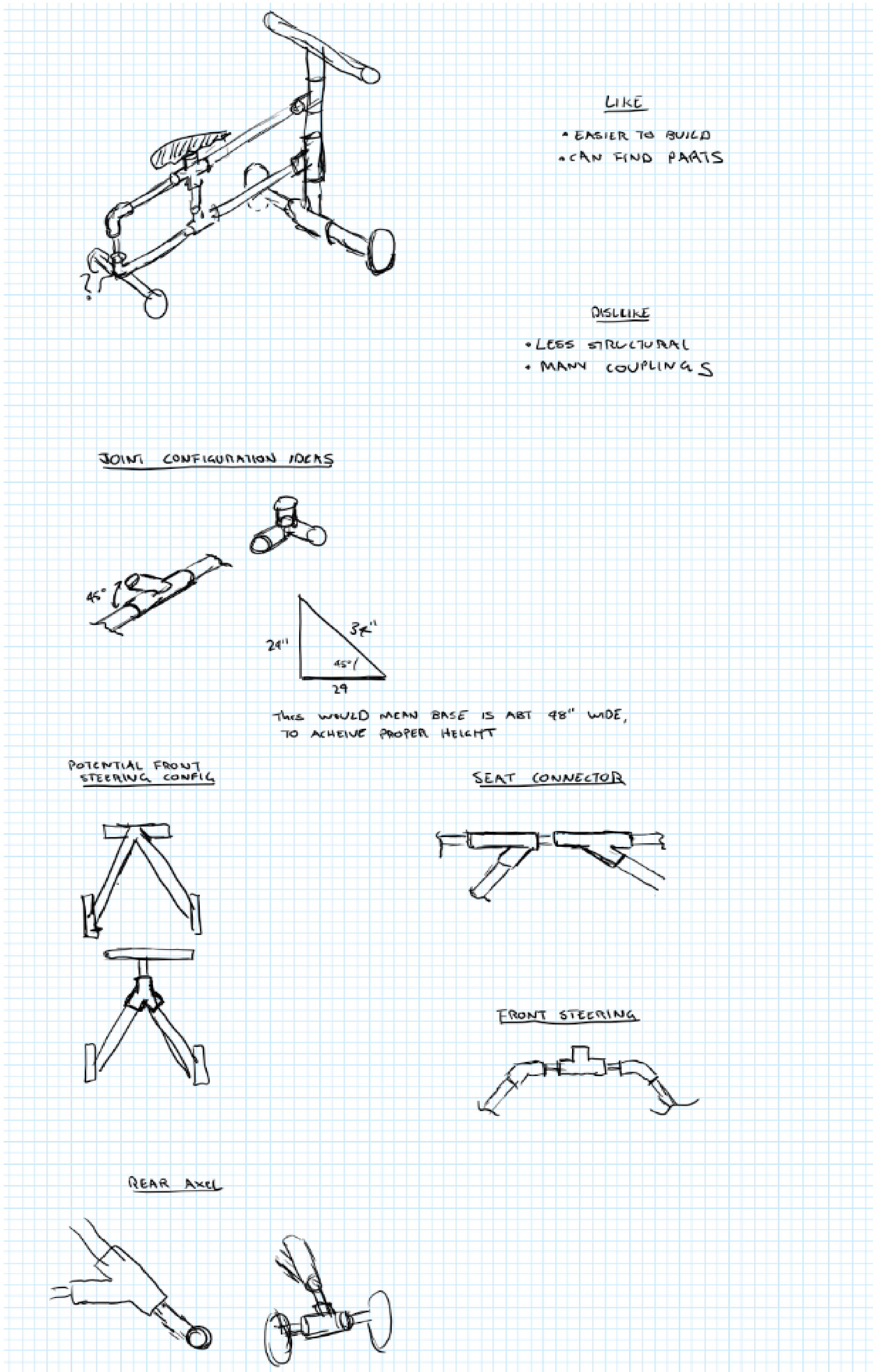

Figure 3: Brainstormed ideas with consideration for pipe fittings

This design is linear and could be easier to design, but it has a lot of PVCconnections and looks like it may not hold up very well when the seat is loaded. The couplings would be easy to find, and it would be easy to assemble.

Cost Analysis Table

Size	Type	Price
1”	Stright Pipe	$0.85/ft
1-1/2”	Stright Pipe	$1.28/ft
2”	Stright Pipe	$1.77/ft
3”	Stright Pipe	$5.48/ft
1”	Elbow	$1.48
1”	Tee	$1.97
1-1/2”	Elbow	$2.85
1-1/2”	Tee	$4.17
2”	Elbow	$4.42
2”	Tee	$4.95
3”	Elbow	$5.27
3”	Tee	$8.45
1-1/2”	Wye	$5.42

Design Factors:

We chose a design factor of 2.5. The scooter is made of PVC, which is a well-known material, but the strength at the connections between the pieces of PVC is more difficult to determine. It will be used in an ordinary environment with stable temperatures. The loads applied can be estimated, but with a moving person using the scooter on terrain that can change, the stresses cannot be perfectly determined. Ultimately, this is an ordinary material in an environment with stresses that can be estimated, but the environment and forces are not constant. Based on the Juvinall-Marshek Factor of Safety chapter, a safety factor of 2.5 seems appropriate due to these conditions.

Hand Calculations to Verify FEA:

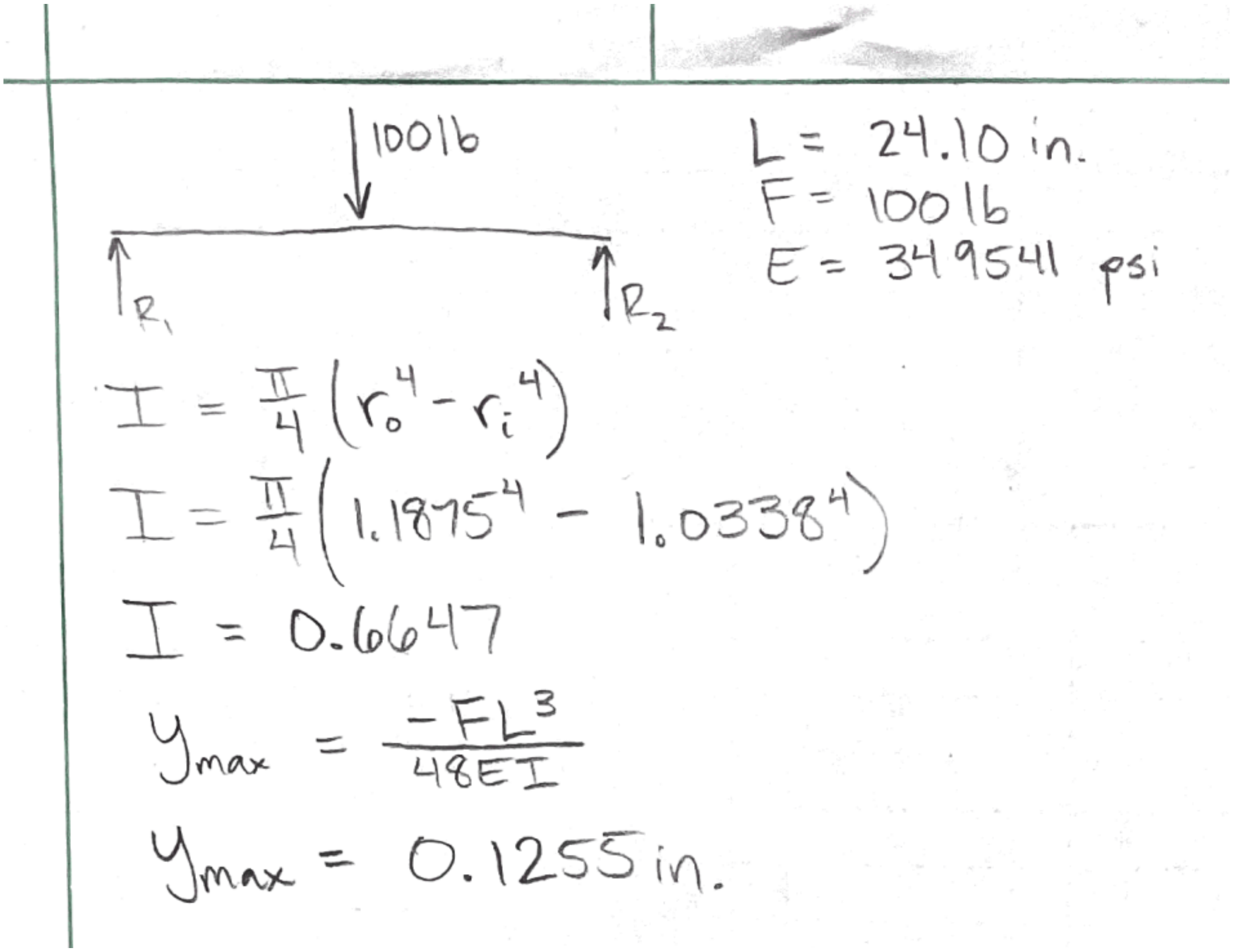

Figure 4: Hand verification based on 100 lb load and pinned ends

FEA Plots:

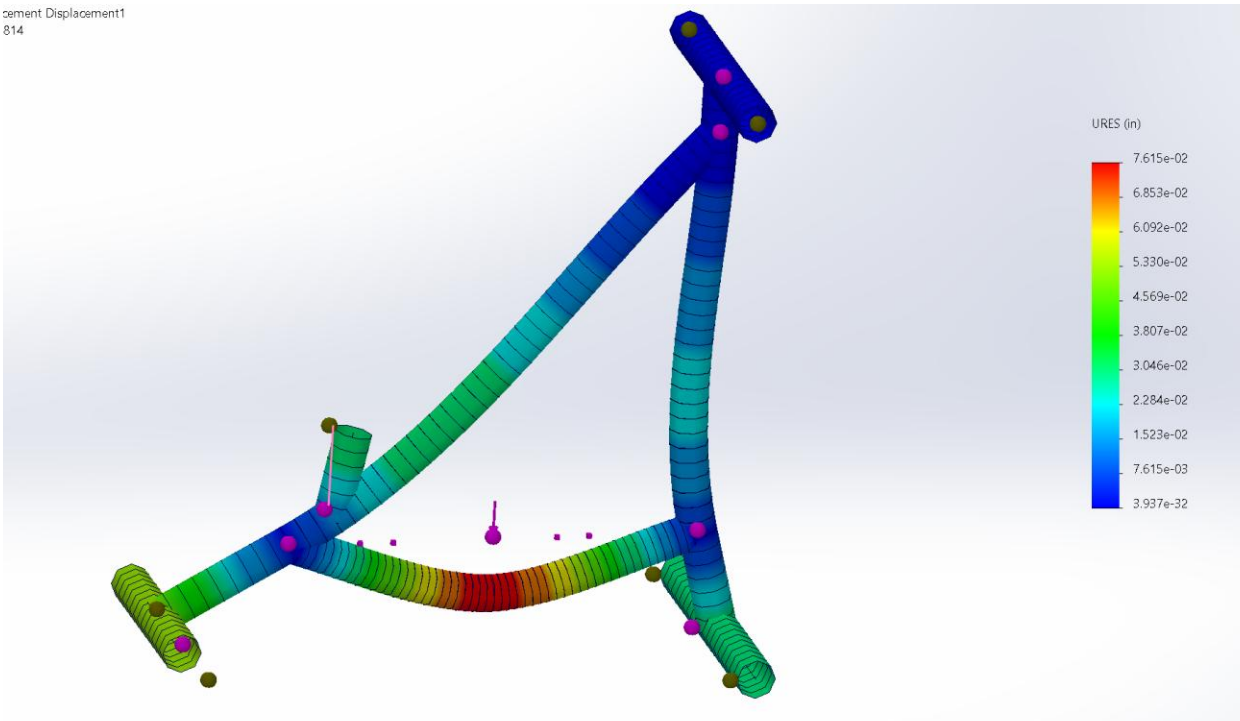

Figure 5: FEA Model with 100 lb load to verify accurate FEA

This deflection result makes sense because it is on a similar order of magnitude as the hand calculations, but it is smaller. This is because in our design, the bar is not simply supported with pins on the ends, which is how it was calculated by hand. Instead, it behaves like something in between being pinned on the ends and being fixed, so a slightly smaller deflection than what we calculated makes sense.

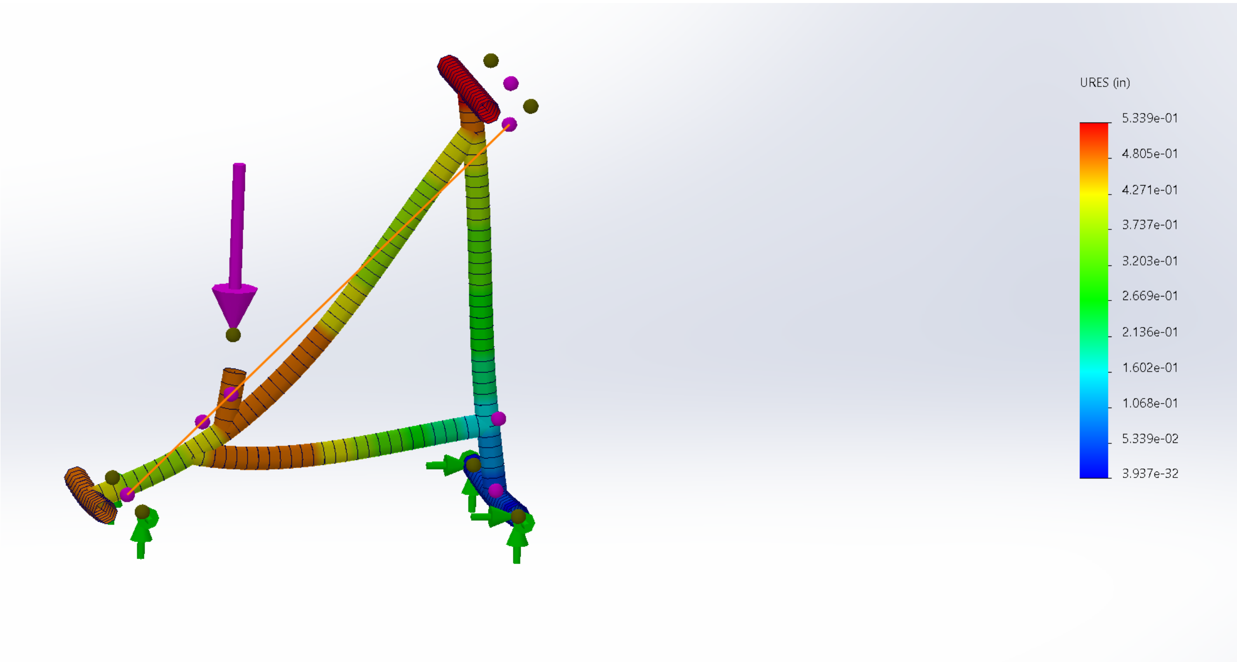

Figure 6: Deflection when 200 lbs is loaded onto the seat

The maximum deflection with 200 lbs loaded onto the seat is 0.53 inches, which is smaller than the maximum deflection of 1 inch that we wanted to allow in this case. This means that the design does meet our stiffness criteria.

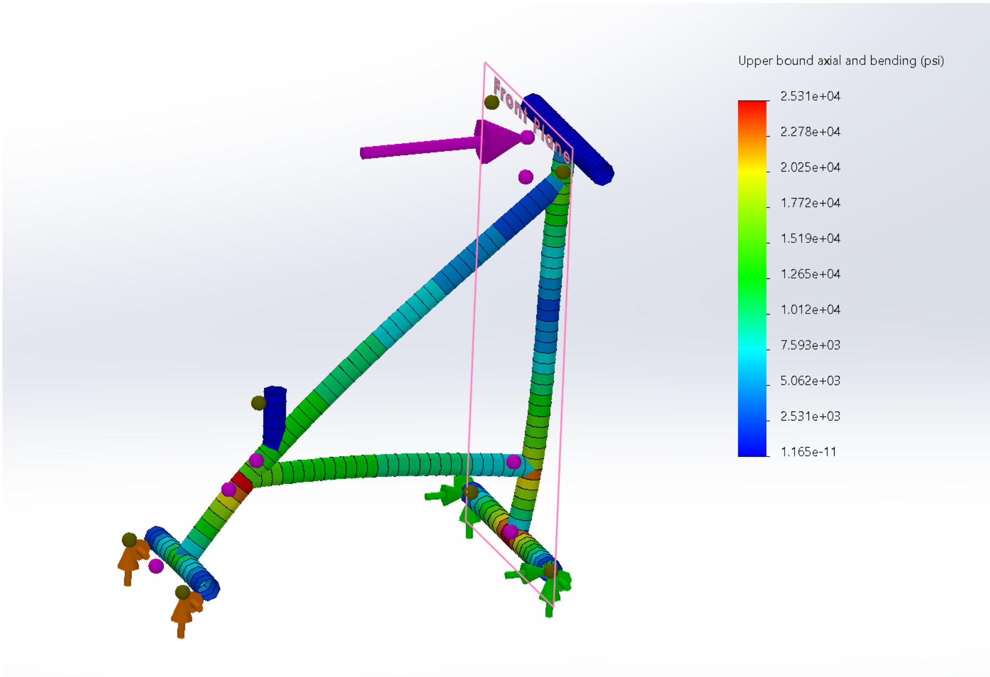

Figure 7: Stress with 6G into handlebars, 1200 lb load

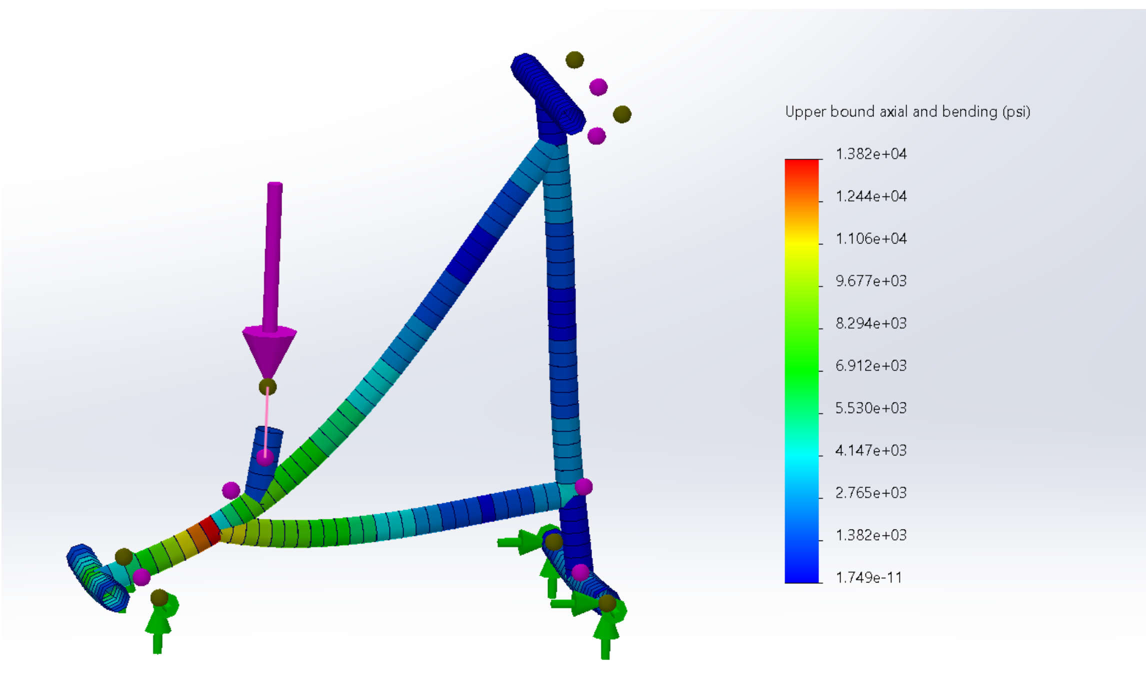

Figure 8: Stress with 5G (1000lb) load on the seat

Since PVC has an allowable stress of about 20kspi, these models show that the scooter would not break under the vertical strength case, but it likely would break in the forward crash case. In retrospect, a 6G forward load is a high-strength case, and the scooter may not be subjected to such a crash. In the event of this crash, however, it would probably fail since the actual maximum stress is about 25 kpsi and the allowable is only 20 kpsi.

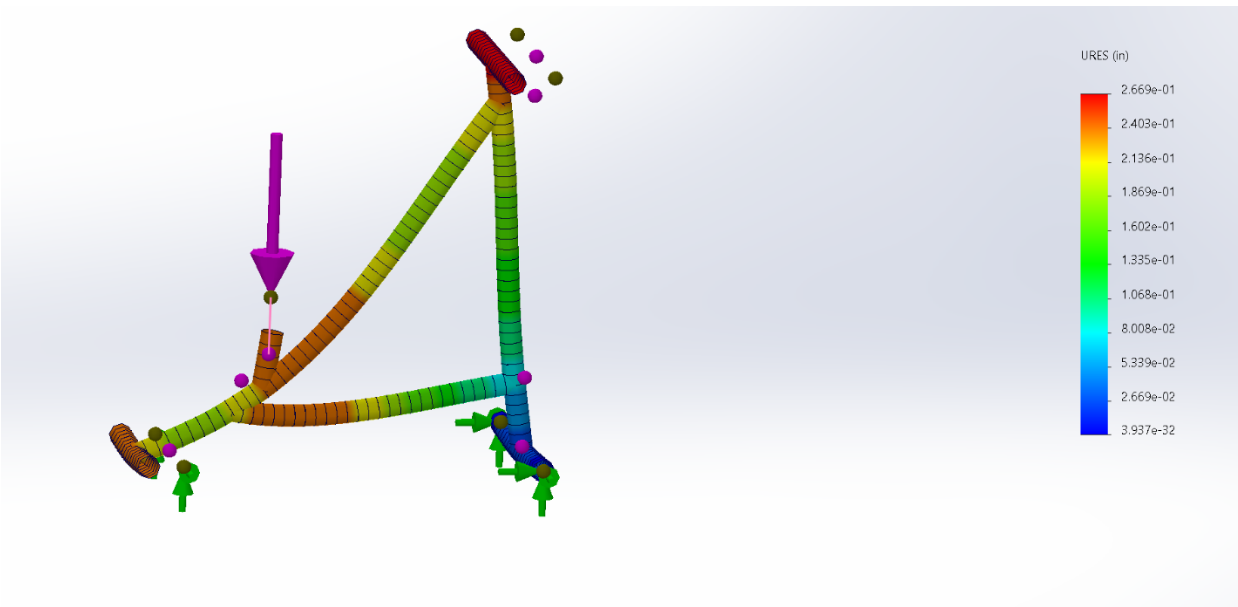

Figure 9: Deflection with 100 lb loaded onto the seat

The maximum deflection in this model occurs at the handlebars, with a max deflection of 0.267 inches. However, the model predicts a deflection of 0.23 inches on the horizontal support of the scooter frame with 100 lb loaded onto the seat. We measured this same location on test day, and it only experienced a deflection of 0.131 inches.

Parts List:

- 1" Tee: 2
- 1 ½" tee: 2
- 1 ½" wye 45: 3
- 1" PVC pipe: 5 feet
- 1 1/2" PVC pipe: 7 feet
- PVC primer and glue
- 4 wheels
- 1/2-inch thread rod: 3 ft
- Old bike seat

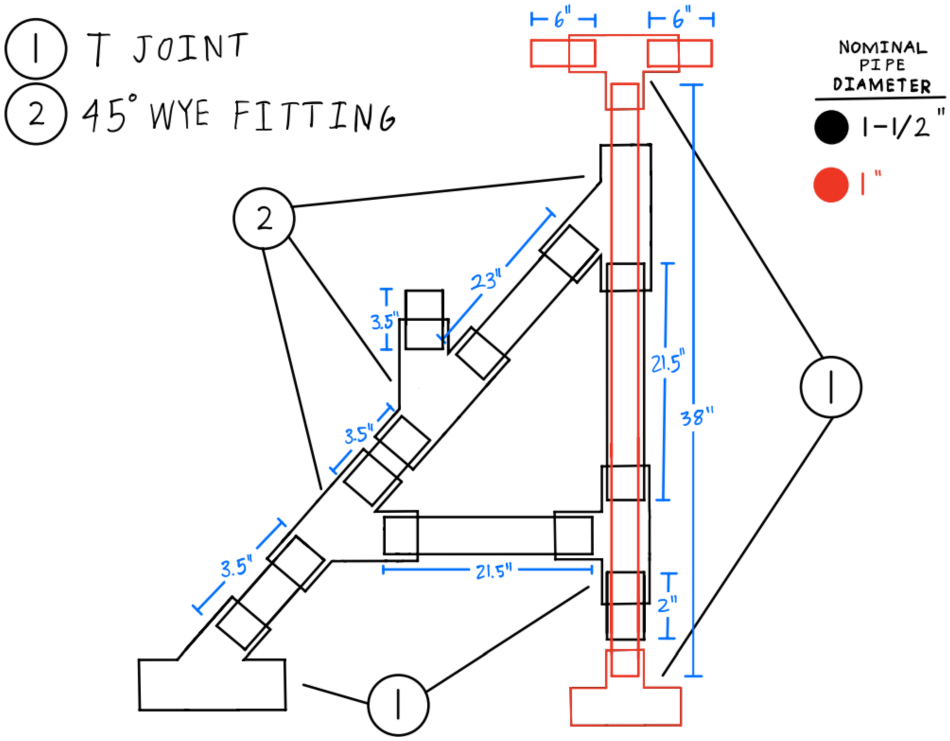

Figure 10: Instruction manual schematic

Instructions:

From the 1 ½" PVC pipe, cut two pieces to 21.5", two pieces to 3.5", one piece to 2" (above front axle), and one piece to 23". These will be used to assemble the main frame.

From the 1" PVC pipe, cut one 38" piece and two 6" pieces (handlebars).

Assemble the 1 ½" PVC portion of the scooter as seen in the diagram above and use PVC primer and glue to glue all the connections. Glue one tee onto the 38" piece of PVC and put it vertically through the inside of the 1 ½" PVC. Then glue the other tee onto the end. Connect and glue the 6" pieces onto the top tee (these are the handlebars).

Cut two 12" pieces of thread rod. Place them through each tee on the bottom of the scooter. Place the wheels on the rod, screw a nut on the outside of each wheel, and wrap the thread rod in duct tape on the outside so that the nuts cannot spin off.

Place the bike seat into the 3.5" piece that is sticking up vertically in the middle of the scooter.

Test Day Reflection:

Figure 11: Our Scooter

The scooter felt very sturdy, and it did not deflect very much at all when it was ridden. It was strong enough and stiff enough to feel comfortable riding, but the biggest issue was the steering and front axle. The front axle was a little bit narrow, so we could only turn the scooter if it was moving at a controlled pace. If we were rolling any faster than a comfortable walking pace, it would tip over when we tried to turn. Additionally, the handlebars didn't spin concentrically inside the frame. There was some wiggle room. They functioned fine, but they did move around slightly which made the scooter feel a little harder to control. Overall, it was very comfortable to ride, it felt both strong and stiff, and the seat was at a comfortable height.

Two other designs:

Figure 12: Classmate Design 1

In the design in the figure above, the team used a scooter wheel at the back so that the scooter could pivot about the fixed front two wheels. This is how the scooter would turn. I like this because in many of the scooters, the steering was not precise and inaccurate because the load on the handlebars would cause the handlebars to deflect so the users input i.e. Turning the handlebars left or right, is not what steering output was. Also, when you don't need a front steering that pivots, you can design a stronger front handlebar system. In the design you can see the team used 3 vertical members and two rigid connections on the center vertical member, which is stronger than what was used in many teams' designs. Another cool feature of the steering is that the back wheel locks and unlocks with a lever on the front handlebar so you can choose when you want to go straight and turn. I like that the place where the person places their knee and hence most of their weight is above a "column" opposed to being in a midsection of a horizontal member, this allows for a stronger and stiffer scooter. One feature that could use improvement is the height of the knee pad, it is way too high for the average person. The scooter was also weak at resisting horizontal moment, so additional features to address this problem, such as thicker pipe, could improve the design.

Figure 13: Classmate Design 2

In this knee scooter the thicker pipe allowed for an overall relatively strong scooter, unfortunately this does make the scooter more expensive. The simplicity of the design is nice as it will make it easy to reproduce, the knee pad is at a good height, and we like that they made the wheels wide because it makes for a stable scooter. The axel design is fine, it works and is simple. The biggest problem with this scooter is that they did not glue the PVC together, so it was not as strong as it should have been given the thickness of the PVC that was used. The one thing we might change to this is that the person can exert a relatively large moment on the handlebars due to the frame being about halfway down the front steering column, which could break the scooter and/or lead to poor handling.