



MEMORANDUM

3/17/25

TO: Dan Castro, Professor, Mechanical Engineering
FROM: Maddy Reedy, ME 328 – 13
COPIES: Erin Maxwell, ME 328 – 13
Nathan Little, ME 328 – 13
SUBJECT: Final Design Report

Design Overview

We were given the task of designing and building a prototype for an entertaining, self-propelled vehicle that can hold one passenger. We were given several constraints to guide our design. One major constraint was on the materials to be used. The vehicle must be made primarily out of PVC pipe, with at least 50% of the design comprised of PVC pipe. The vehicle should also be built out of common, relatively cheap materials that most people could easily attain. Another constraint is that the vehicle must be able to fit through a standard doorway and thus be compact enough to be considered a “scooter”. The vehicle must also be able to be pushed or pulled without touching the passenger. Another constraint is that the design must be steerable in some way, either by the passenger or by the person propelling the vehicle. The vehicle must be durable enough to survive testing and in-class demonstrations. The manufacturing process must be repeatable by a third party, following our instructions. These design constraints informed our design process and helped us to create our own design considerations to further refine our design process.



Figure 1. Initial Design: Steering Stroller

After conducting brainstorming and sketching ideas that could meet these constraints, we decided the vehicle should be steerable by the passenger, pushed from behind, and would be a stroller-like design. By designing the vehicle to be steerable by the passenger, we intended to make the vehicle more fun and engaging to use. By having the vehicle be pushed from behind, the front of the vehicle is clear from obstacles, allowing the passenger to see the path they are travelling, thus allowing them to

steer better. The stroller-like design was inspired in part by the baby characters the Mario Kart games. This inspiration for and design element of the vehicle incorporated a playful aspect of the vehicle that we wanted to include. In this phase of the design process, we designed the vehicle for a youth passenger with a weight of roughly 150lbs. The aesthetics are primarily made for fans of the videogame Mario Kart. The vehicle was designed to be aimed at recreational riders, focusing on speed and agility. Our design considerations can be seen in our initial sketches in Figures 1, 2, and 3.

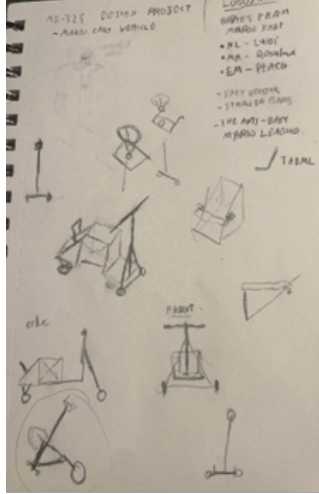


Figure 2. Initial Design: High Handlebar

Figure 3. Initial Design: Triangular Base Go-Kart

After our initial ideation, we started modeling our consolidated idea in SolidWorks software. By modeling the members of the PVC vehicle structure and approximating applied forces, we calculated how sturdy the vehicle needed to be to withstand the estimated forces being applied to it. From this

initial modeling, we determined the vehicle should be constructed from 1.5" PVC pipe. This modeling helped us transition into our prototype construction phase.

As we started the construction of our prototype, we first cut our pieces of PVC pipe and planned out how the joints would be arranged. Then we sewed loops at the ends of the canvas seat and glued all the PVC pieces together. Lastly, we attached the wheels to the vehicle through a small block of 2x4 wood and a $\frac{3}{4}$ " wood dowel.

While we designed the stroller vehicle to be easy to build and made from easily accessible supplies, a person trying to manufacture our design might have some difficulty working with the wheels. One of the first issues they may face is finding or buying three wheels of similar size. If the wheels are different than the ones used in our design then they would have to modify the wheel mounts. Another difficulty they might face is sewing the seat of the stroller. In our manufacturing process we used machine sewing, however the design uses simple stitches so hand sewing would also be possible for this process.



Figure 4. Final Vehicle Prototype

This vehicle is designed to propel its passenger across a distance, with the passenger steering the vehicle, while another person pushes the vehicle. The vehicle is capable of drifting motion as well as more subtle turns. This motion is accomplished using the steering wheel and column attached to a static wheel in combination with two freely rotating back wheels. The vehicle holds the weight of a single person by supporting the weight with the canvas seat, which is held up by the PVC structure of

the seat. The vehicle is propelled by force applied through a handle at the back of the seat. The details of the final prototype vehicle can be seen in Figure 4 above.

The user of the stroller should be careful with maneuvering the vehicle as it does not have any type of braking system. The only way to slow or stop the vehicle is by pulling the scooter from behind or by the passenger braking the vehicle with their feet. Another possible issue with operating the vehicle is if the drive shaft is not secured to the frame of the cart, the front wheel may come loose from the frame. To resolve this issue, make sure the driveshaft and frame are well secured before riding the stroller.

Drawings and Assembly

For assembly of this vehicle, begin by cutting 1.5" PVC pipe into needed lengths. Next, dry fit the PVC pieces into shape with the correct joints following the drawing provided in Attachment A. Sew the canvas seat by folding the short edges into a loop big enough to pull over the pipe. Carefully making sure the joints remain in the correct orientation, adhere the pieces together with PVC cement. We recommend assembling the large side support triangles first, then the front bumper triangle, then attaching the seat and handlebar. As you attach the seat, glue one side of the pipe, then slide the canvas seat over the pipe, then glue the other side. Once the body of the vehicle is fully assembled and adhered, start constructing the wheel mounts. Bore a $\frac{3}{4}$ " hole into 3 small blocks of 2x4, insert the wooden dowel and secure. Flip the blocks over and screw the wheels onto the blocks. Bore $\frac{3}{4}$ " holes into the PVC caps, then insert the dowel of the wheel mounts into the caps. Secure the steering wheel into the steering column with screws.

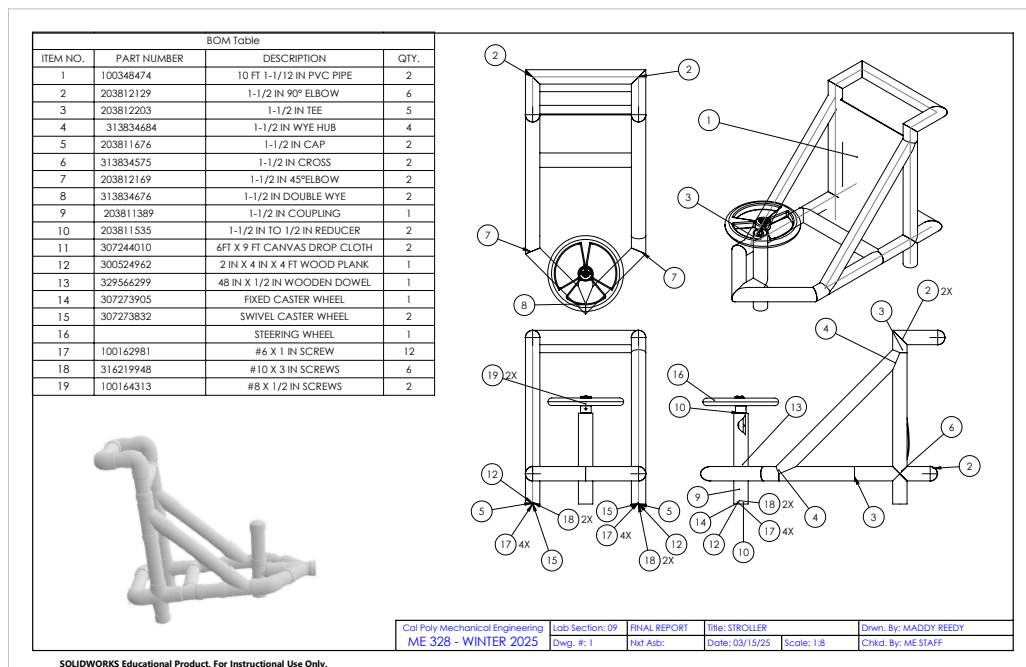


Figure 5. Stroller Assembly Drawing

To make the steering wheel, use SolidWorks software to design a part following the drawing provided in Attachment B. This design can be altered to fit the desired aesthetic of any vehicle. Print the steering wheel utilizing 3D printing.

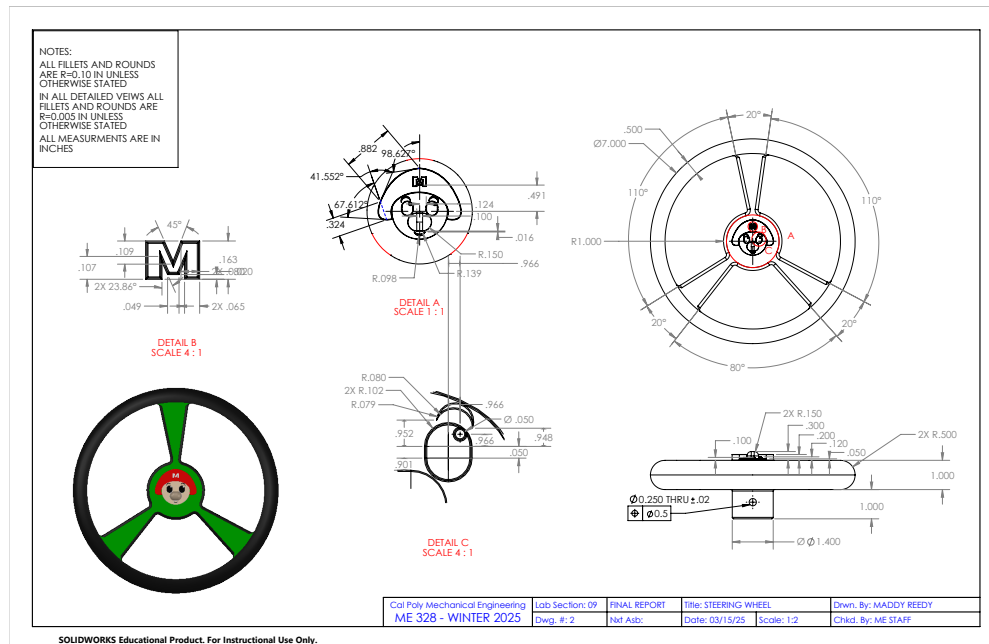


Figure 6. Part Drawing – Steering Wheel

Calculation and Modeling:

To ensure a reasonable factor of safety, we modelled our forces as being applied solely at the center of members. These forces would be distributed across the beams; for the passenger they would be distributed by the cloth seat (which we did not directly model) and as for the force applied by the one pushing the vehicle it would be distributed to the two points where their hands contact the cart instead of the center of the beam. By modelling it in this way, we exaggerated the effects of the forces, proving that the design could withstand greater forces than would be applied on the vehicle.

We tested our prototype under three different load cases to see how the vehicle would handle under various conditions. The first load case is a stationary test with the weight of the passenger sitting in the cart. This is to make sure that the vehicle does not break, change shape, or hurt the passenger in any way. The second load case was to have a passenger in the cart while it was moving and being pushed from the handles. This is to see how the vehicle works while doing its intended purpose and to make sure that there are no problems. The third load case, which is also referred to as the abuse case, is when we tested for what would happen if the user abused the vehicle by jumping off curbs or crashing it. These are situations which we can expect the user to end up in eventually, so we want to guarantee that the vehicle will survive without harming the passenger. The hand calculations for the first two load cases provided in Attachment C. We used these to verify that our FEA model was working properly and

then started mainly using the FEA model to make minor changes while verifying with quick hand calculations when necessary.

The areas in which we expect higher deflection, and the highest stresses, are the center of the two bars which the seat is attached to and in the middle of the handlebar when it is being used to push the cart. Of these three places we expect the maximum stress and deflection to be in the bar where the bottom of the seat attaches. This is because it is more likely that the passenger's weight is not evenly distributed and that they will be sitting closer to that bar and thus putting more force into it. We also expected and saw a large amount of stress on the connections between the wheels and the frame. These stresses were hard to calculate as such we tested them on the full size prototype and designed one that could withstand the forces exerted by the vehicle.

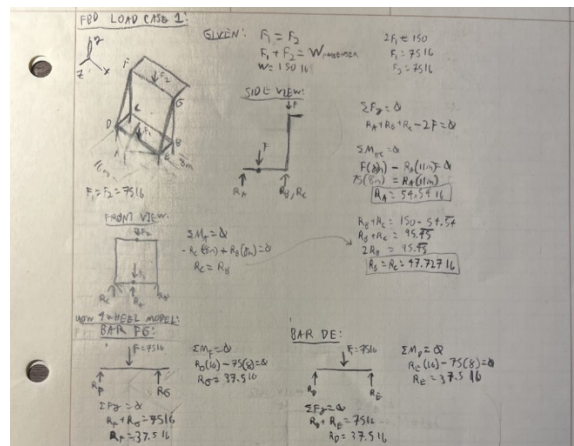


Figure 7. Hand calculation FBD for sketch design under stationary conditions

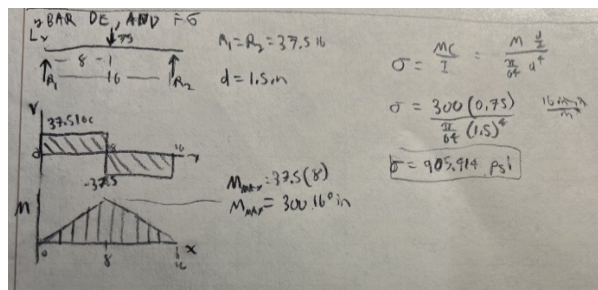


Figure 8. Hand calculation for stresses under stationary conditions

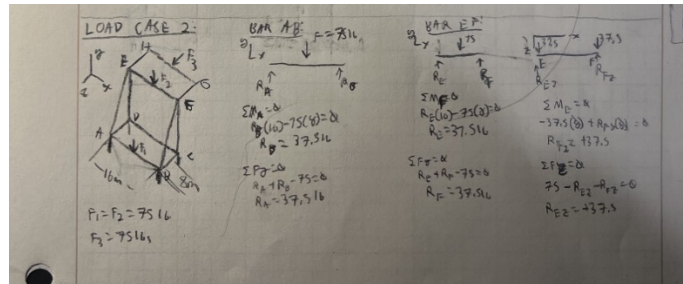


Figure 9. Hand calculation FBD of design under moving conditions

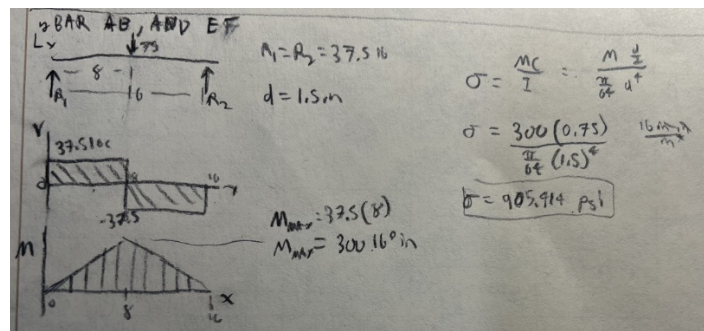


Figure 10. Hand calculation of stresses for moving conditions

Besides, the main bars in which our forces were being applied our only other areas with high stresses were the wheels and drive shaft. To test these, we did in person tests with various materials that we were debating using and decided on the wooden dowl that we used after verifying that it could withstand much more force and stress than it would be under while in the vehicle.

The initial hand calculations and final FEA results vary quite a bit as we initially were planning on testing with a passenger weight that was only 150lbs split across the top and bottom bars where the seat would connect. But by the final design we had decided to bring in a factor of safety and increase the weight split across both beams to 400lbs to guarantee that the design would not exceed critical stresses. The FEA modeling is shown below in Figures 11 and 12.

In our FEA non-moving model (figure 11) had a deflection of 0.1389 in. with a 200 lb. load in the center of the top support bar as well as the center of the bottom support bar. In our motion FEA model (figure 12), we had a deflection of 0.528 in. with the same forces as the non-moving model as well as an additional 200 lb. force on the handlebar to act as a very strong pushing force. While our maximum deflection was already quite low this the highest deflection begins when its moving, it still only peaks at 0.528 inches. Even with this minimal deflection, we expect the simulation deflection to be greater than the constructed product. We believe this due to the fabric, the fabric will be draped over the top support bar and the lower support bar and sewed into place. With the way the fabric will be draped the weight of the person riding.

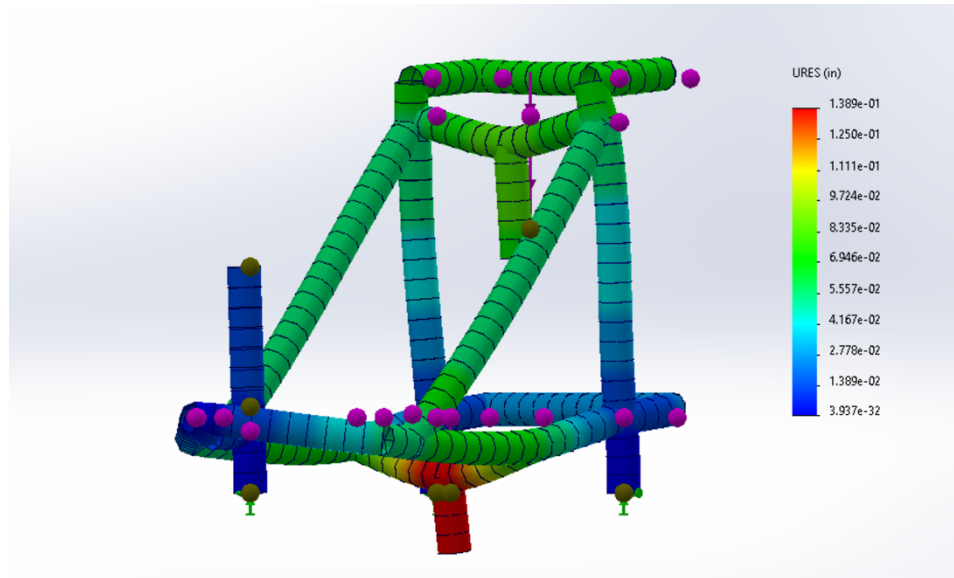


Figure 11. Static Stoller FEA

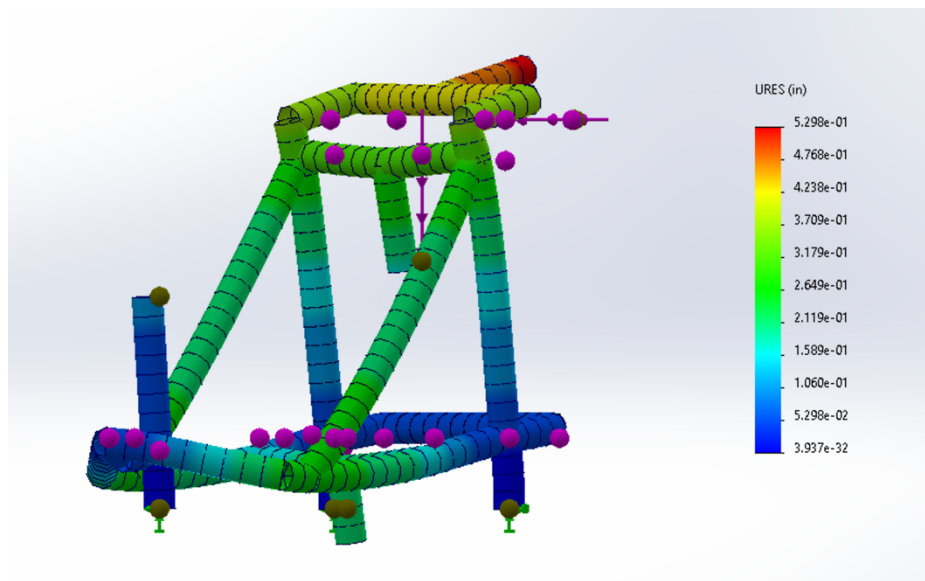


Figure 12. Motion Stoller FEA

Deflection Measurements and Other Testing Results

In the prototype we had no noticeable deflection after performing multiple tests with not only our team members but other people of a variety of sizes found around the shop. We used a level that we lined up against our top support bar and measured how much it changed after a person sat in it. We noticed no change in the level when people ranging from roughly 120 lbs. to 175 lbs. sat in our stroller. This lines up with our hypothesis that the canvas seat would allow for a more even weight distribution across our PVC top and bottom support bars. On top of this our FEA simulation was tested for essentially a 200 lbs. person, which was purposely a heavier weight than any of our group members. This allowed us to have more versatility in who can ride our stroller as well as allow us to overestimate the deflection for possible scenarios. We compiled our test data into Table 1 below.

Table 1. Deflection Measurement Table

Test Type	Load (lbs)	Critical Points	Deflection (in)
FEA - Static Model	200 top bar 200 bottom bar	Center of top and bottom support bar	0.1389
FEA – Motion Model	200 top bar 200 bottom bar 200 handlebar	Center of top and bottom support bar	0.528
Physical Test	120-175	Top support bar (measured with level)	0 (no noticeable deflection)

Recommendations for Improvements

One improvement that we would recommend is to design a better wheel mounting system than what we ultimately ended up using. While our final design worked, there is a lot of stress going into the wheel attachments and they are not as securely fastened to the frame as they should be. In abuse load cases or in prolonged use, the wheel attachments could fail. By utilizing a flat PVC cap, instead of a rounded one, the connection between the wooden block and the PVC structure would be much more stable. This would vastly improve the stability and weight capacity of the overall design.

Another improvement that could be made to our design is with connection between the steering column and the main frame of the stroller. Currently it is secured together with PVC cement, which worked throughout our initial testing. However, after prolonged use, the bond of the PVC cement failed, and the joint slipped out of place. To improve this issue, we would secure it with a fastener that applies pressure on both sides of the failing joint. This would hold the steering column into the frame, so it doesn't pop out like it did in our abuse loading test.

Some other improvements we recommend would be on the aesthetic side of the vehicle. To more properly fit the inspiration of the Mario Kart strollers, we would build a canopy out of the excess



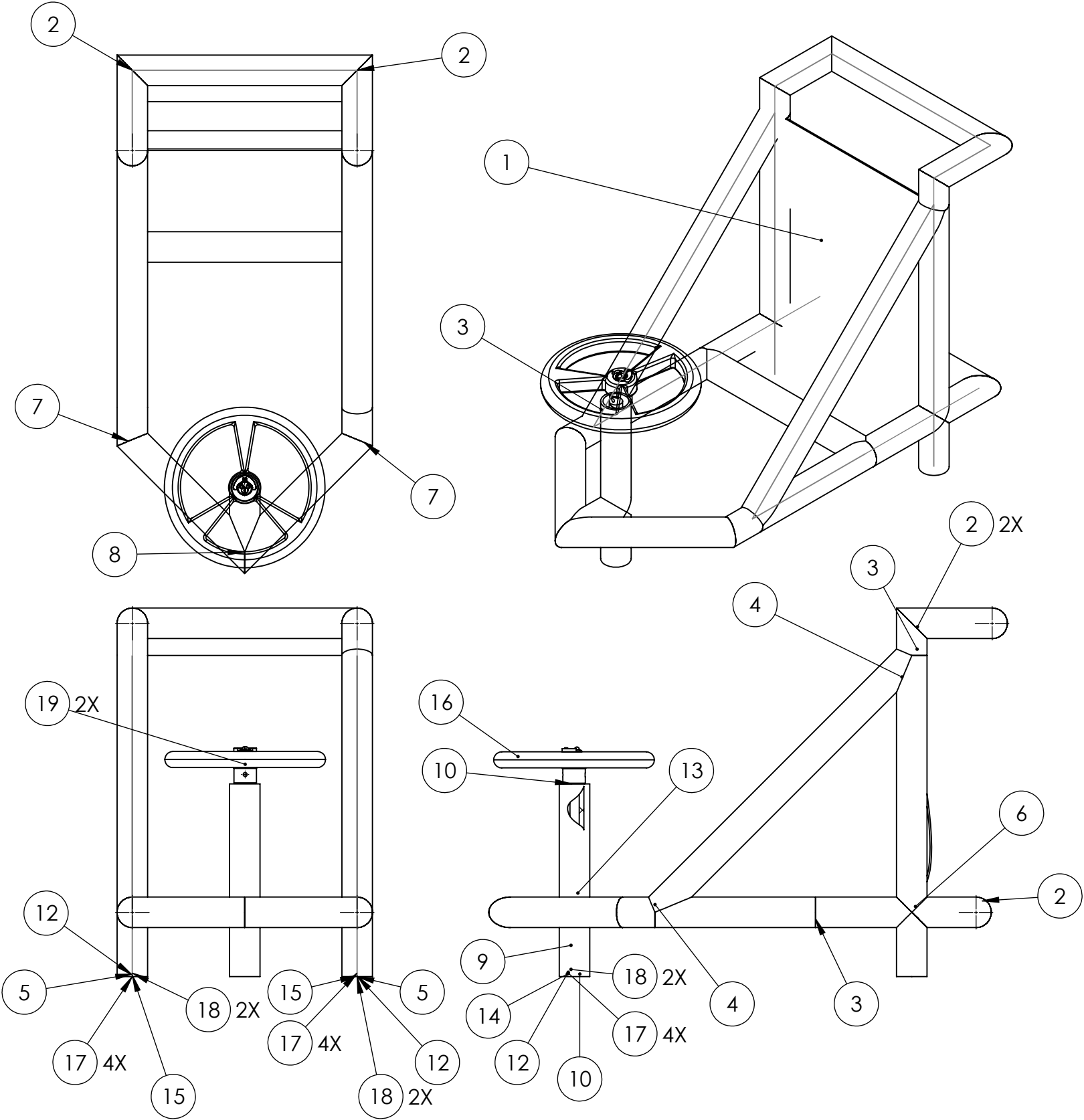
drop cloth. This would improve the look of the vehicle as well as guard the passenger from the sun. We also recommend decorating and painting the cart with colors to fit your personal preferences and styles.



Attachments

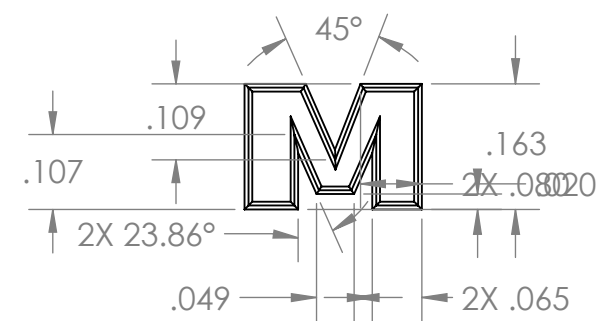
1. Stroller Assembly Drawing
2. Part Drawing – Steering Wheel
3. Load Case Hand Calculations

BOM Table			
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	100348474	10 FT 1-1/2 IN PVC PIPE	2
2	203812129	1-1/2 IN 90° ELBOW	6
3	203812203	1-1/2 IN TEE	5
4	313834684	1-1/2 IN WYE HUB	4
5	203811676	1-1/2 IN CAP	2
6	313834575	1-1/2 IN CROSS	2
7	203812169	1-1/2 IN 45° ELBOW	2
8	313834676	1-1/2 IN DOUBLE WYE	2
9	203811389	1-1/2 IN COUPLING	1
10	203811535	1-1/2 IN TO 1/2 IN REDUCER	2
11	307244010	6FT X 9 FT CANVAS DROP CLOTH	2
12	300524962	2 IN X 4 IN X 4 FT WOOD PLANK	1
13	329566299	48 IN X 1/2 IN WOODEN DOWEL	1
14	307273905	FIXED CASTER WHEEL	1
15	307273832	SWIVEL CASTER WHEEL	2
16		STEERING WHEEL	1
17	100162981	#6 X 1 IN SCREW	12
18	316219948	#10 X 3 IN SCREWS	6
19	100164313	#8 X 1/2 IN SCREWS	2

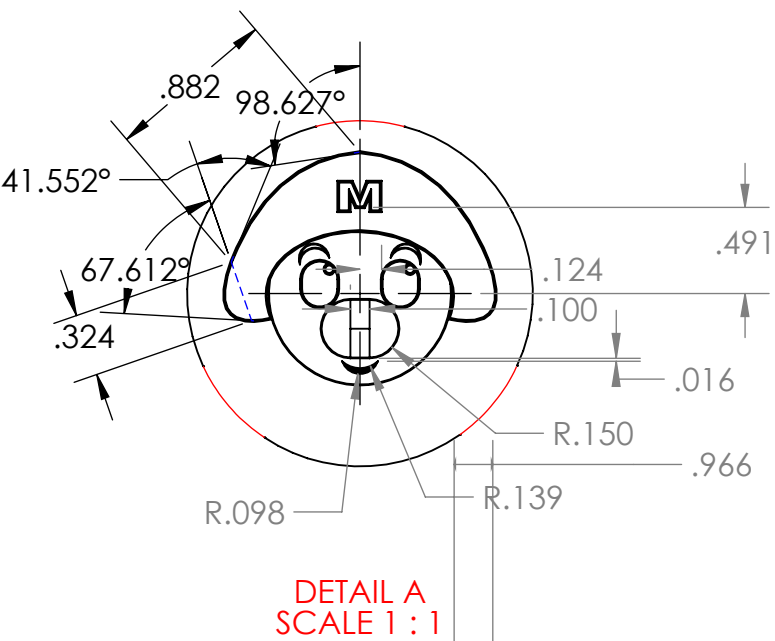
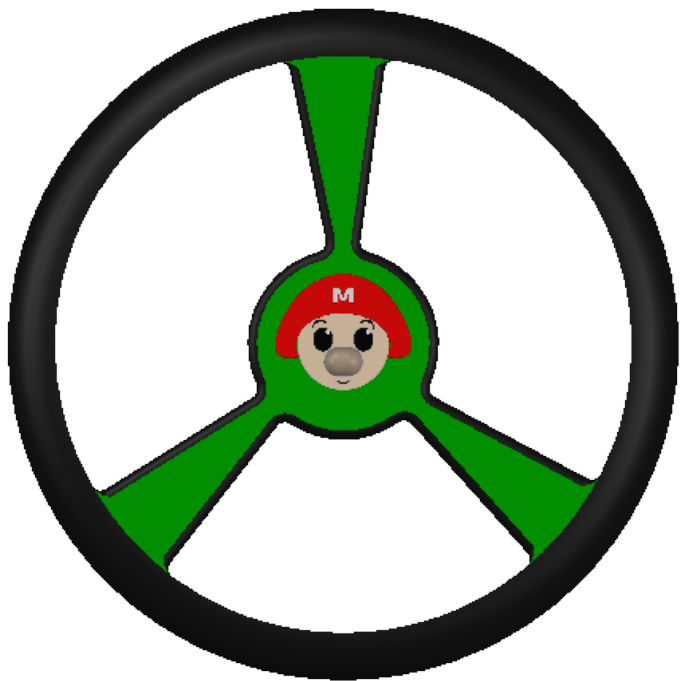


Cal Poly Mechanical Engineering ME 328 - WINTER 2025	Lab Section: 09	FINAL REPORT	Title: STROLLER		Drwn. By: MADDY REEDY
	Dwg. #: 1	Nxt Asb:	Date: 03/15/25	Scale: 1:8	Chkd. By: ME STAFF

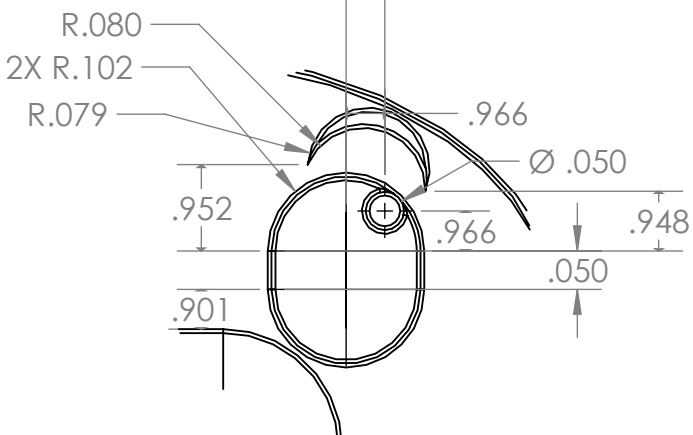
NOTES:
ALL FILLETS AND ROUNDS
ARE R=0.10 IN UNLESS
OTHERWISE STATED
IN ALL DETAILED VEIWS ALL
FILLETS AND ROUNDS ARE
R=0.005 IN UNLESS
OTHERWISE STATED
ALL MEASURMENTS ARE IN
INCHES



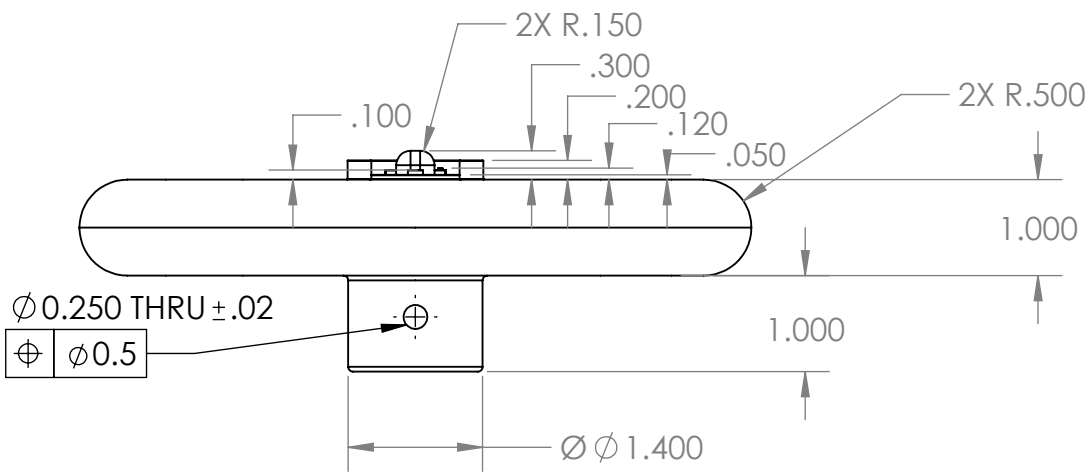
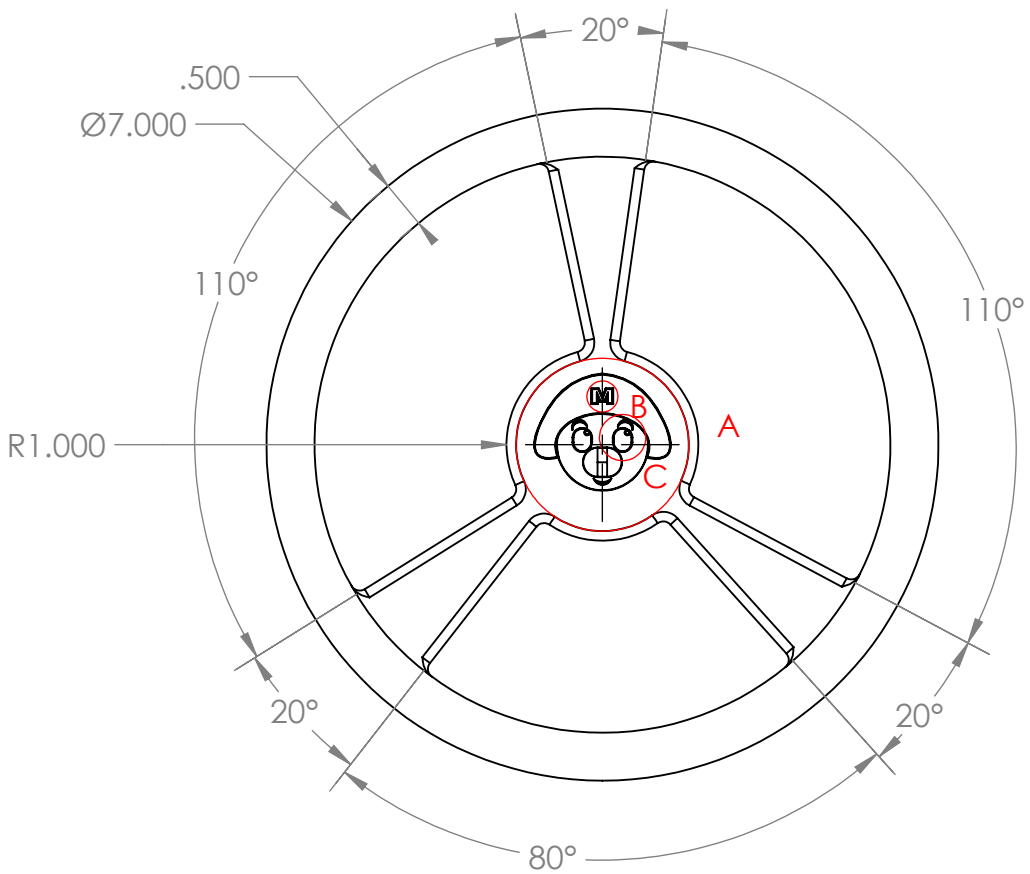
DETAIL B
SCALE 4 : 1



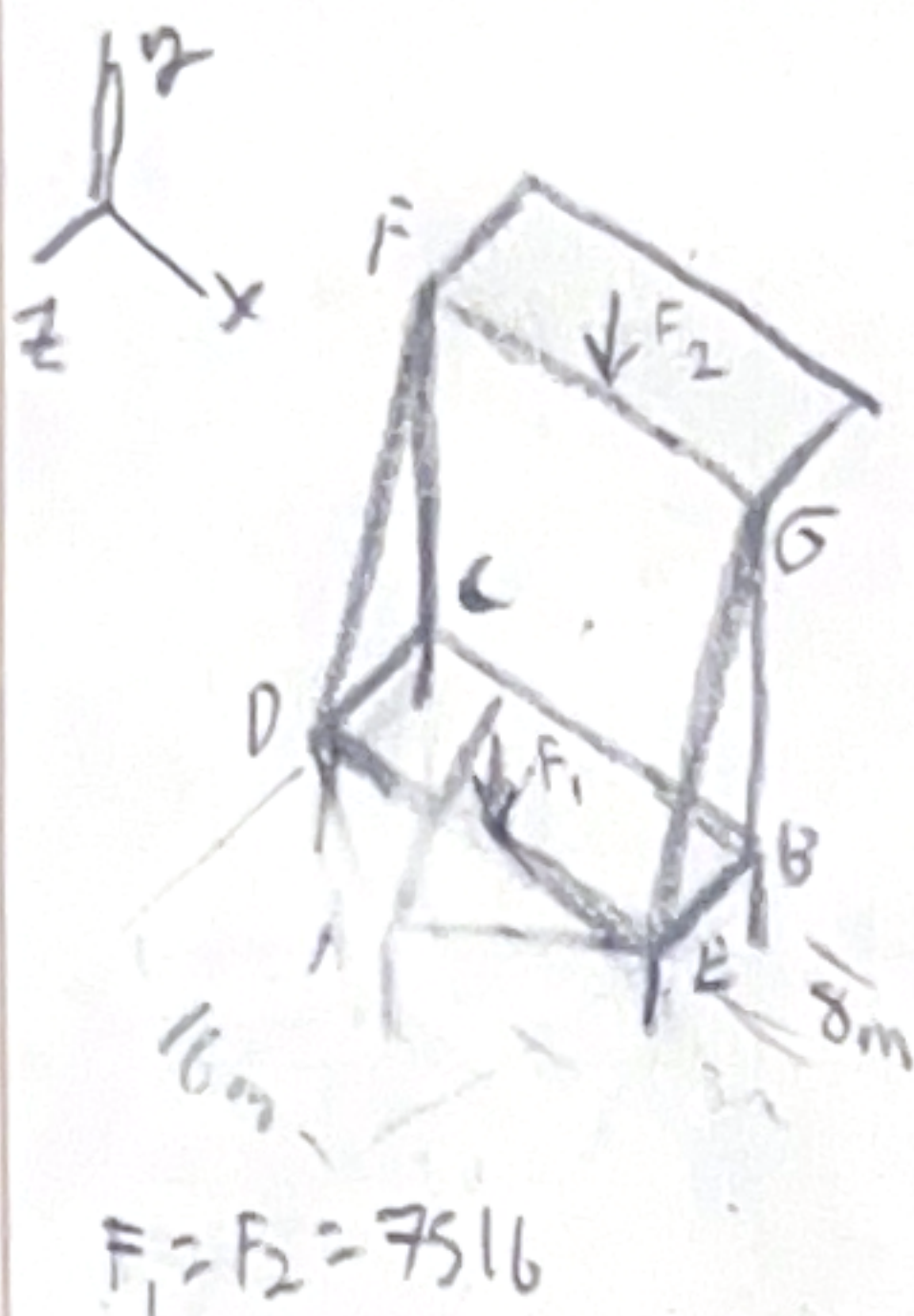
DETAIL A
SCALE 1 : 1



DETAIL C
SCALE 4 : 1



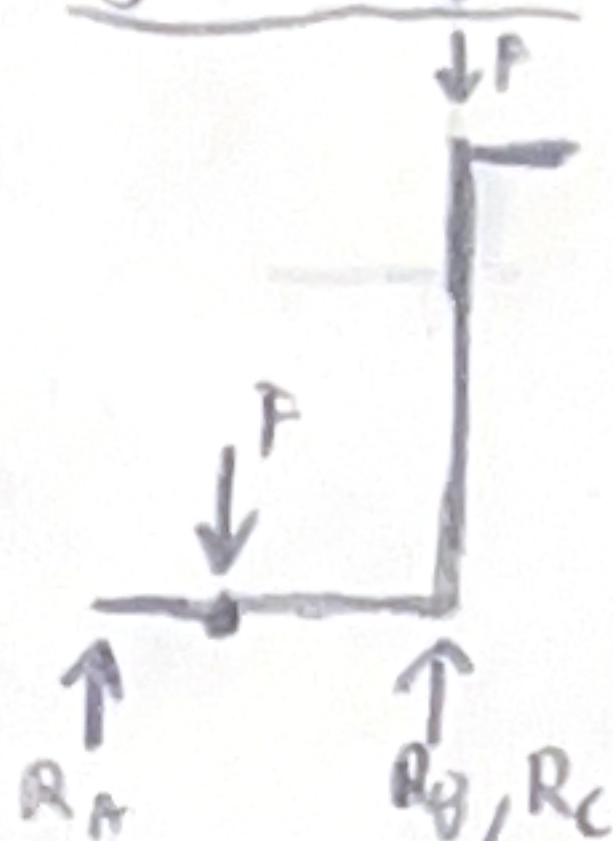
FBD LOAD CASE 1:



GIVEN: $F_1 = F_2$
 $F_1 + F_2 = W_{\text{PASSENGER}}$
 $W = 150 \text{ kN}$

$2F_1 = 150$
 $F_1 = 75 \text{ kN}$
 $F_2 = 75 \text{ kN}$

SIDE VIEW:

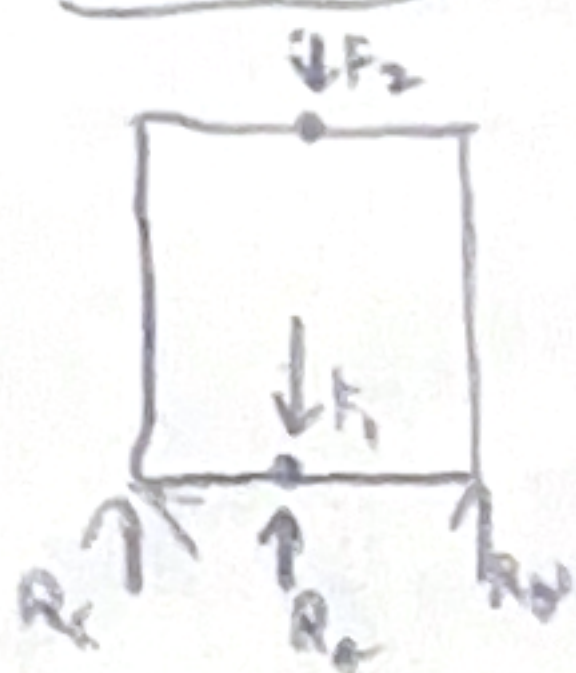


$\sum F_y = 0$
 $R_A + R_B + R_C - 2F = 0$

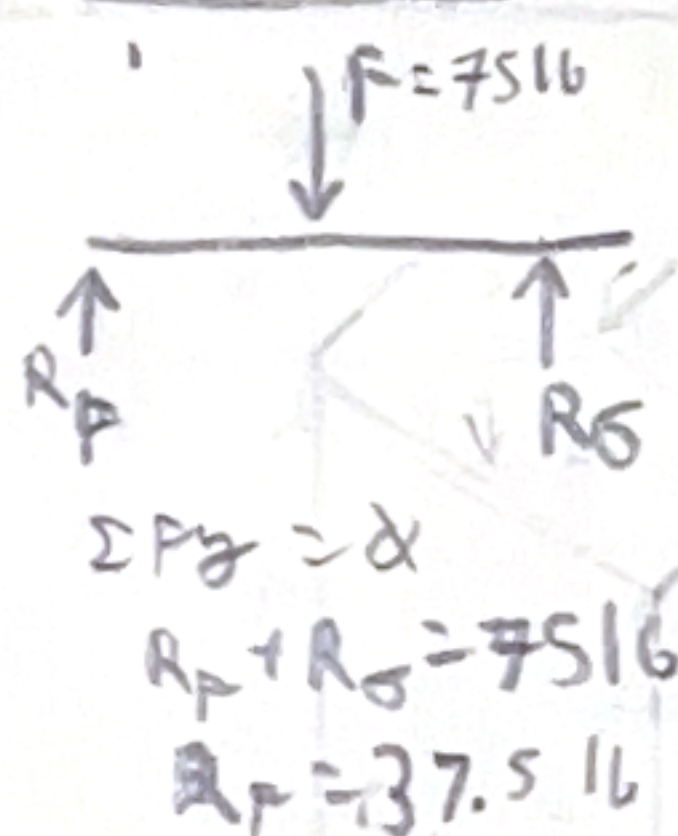
$\sum M_{RC} = 0$
 $F(8m) - R_A(16m) = 0$
 $75(8m) = R_A(16m)$
 $R_A = 54.54 \text{ kN}$

$R_B + R_C = 150 - 54.54$
 $R_B + R_C = 95.45$
 $2R_B = 95.45$
 $R_B = R_C = 47.727 \text{ kN}$

FRONT VIEW:

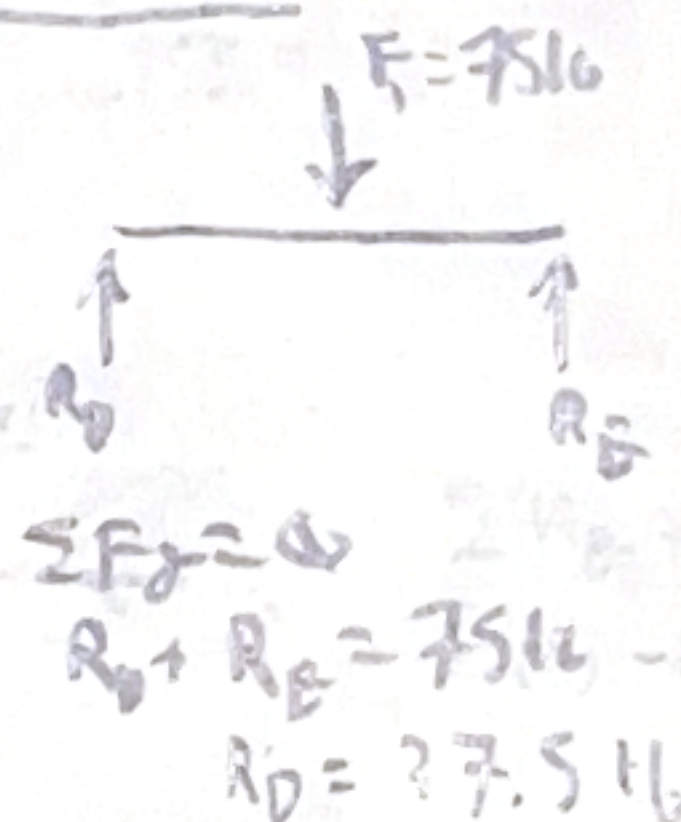


$\sum M_A = 0$
 $-R_C(8m) + R_B(8m) = 0$
 $R_C = R_B$

NOW 4 WHEEL MODEL:
BAR FG:

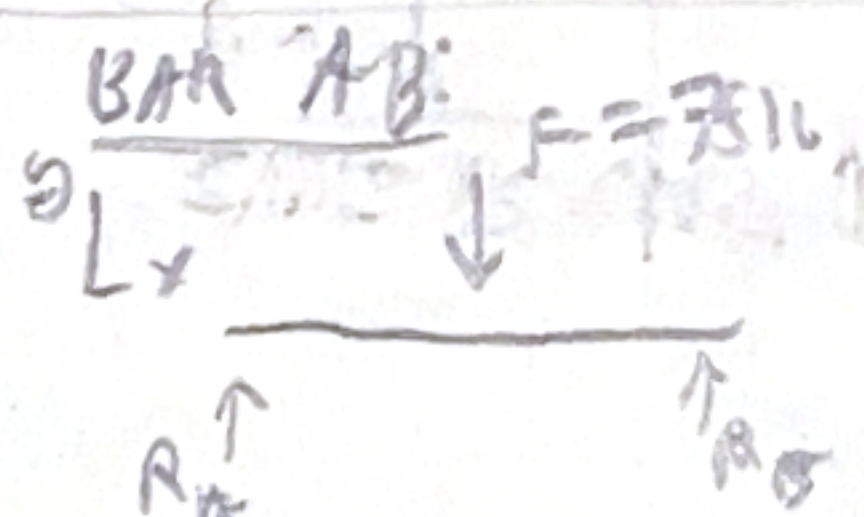
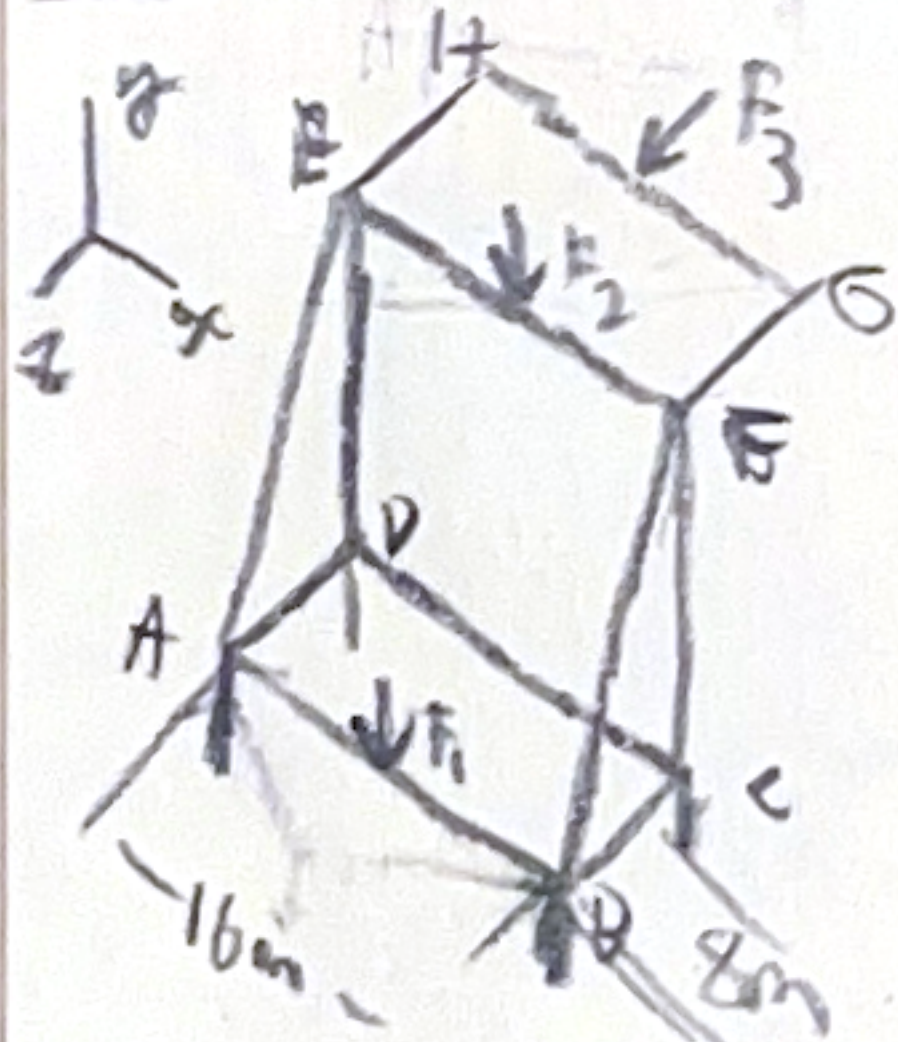
$\sum M_F = 0$
 $R_B(16) - 75(8) = 0$
 $R_B = 37.5 \text{ kN}$

BAR DE:

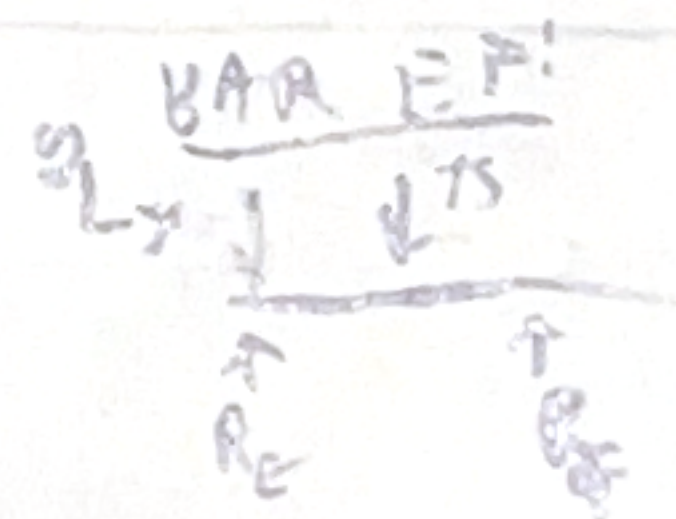


$\sum M_D = 0$
 $R_E(16) - 75(8) = 0$
 $R_E = 37.5 \text{ kN}$

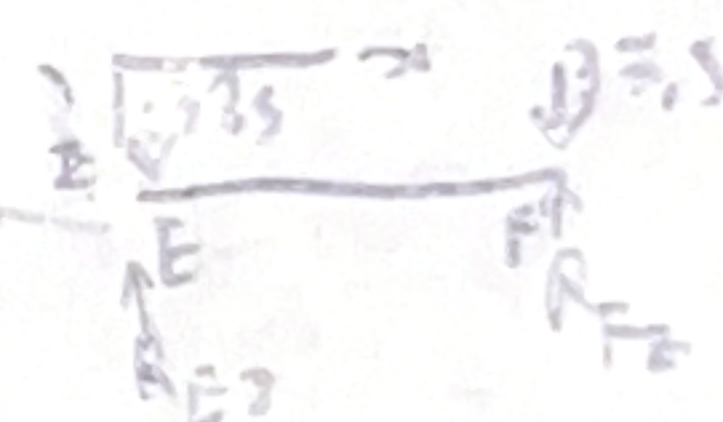
LOAD CASE 2:



$\sum F_y = 0$
 $R_A + R_B - 75 = 0$
 $R_A = 37.5 \text{ kN}$



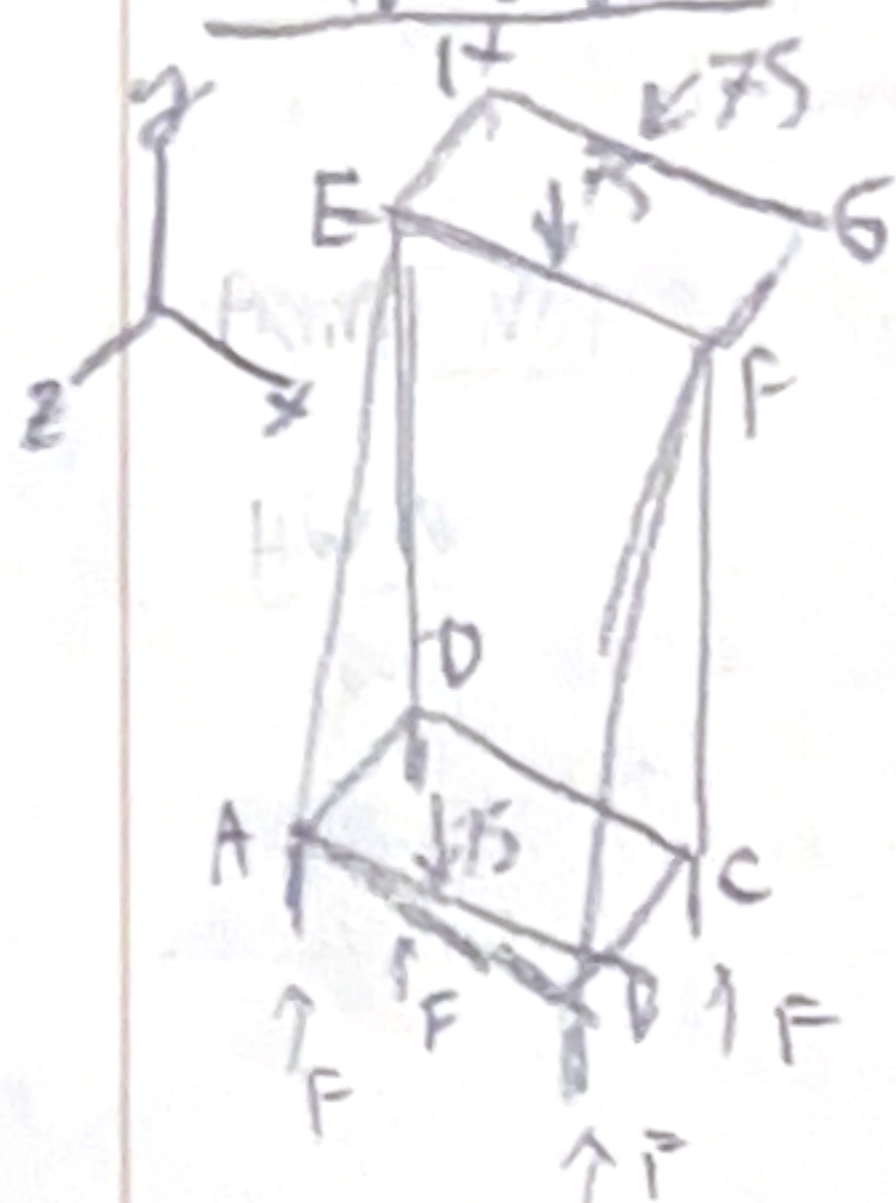
$\sum F_y = 0$
 $R_E + R_F - 75 = 0$
 $R_E = 37.5 \text{ kN}$



$\sum F_y = 0$
 $75 - R_{E2} - R_{F2} = 0$
 $R_{E2} = 37.5 \text{ kN}$

8 people on WL
- 4th place

LOAD CASE 3:

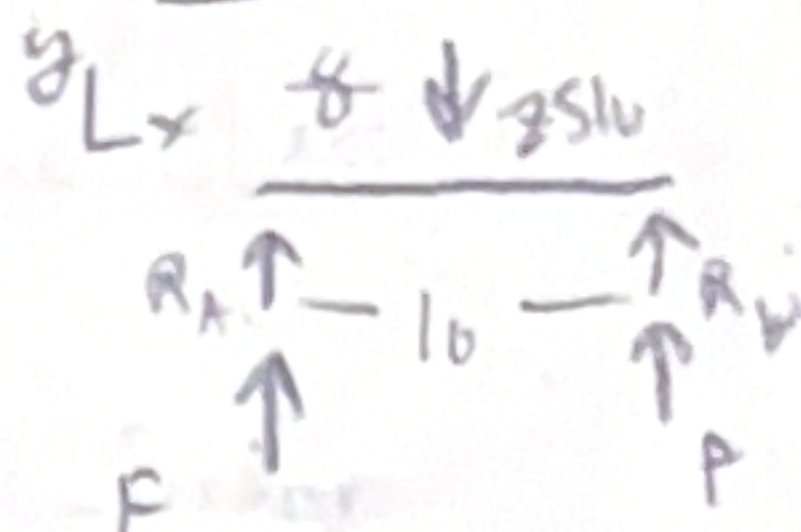


4 small bottom
arrows are
impact as it
lands after
hitting a curb

SA

Assume $P = 75 \text{ lb}$

BAR AB:



$$\sum M_A = 0$$

$$R_B(16) + 75(16) - 75(8) = 0$$

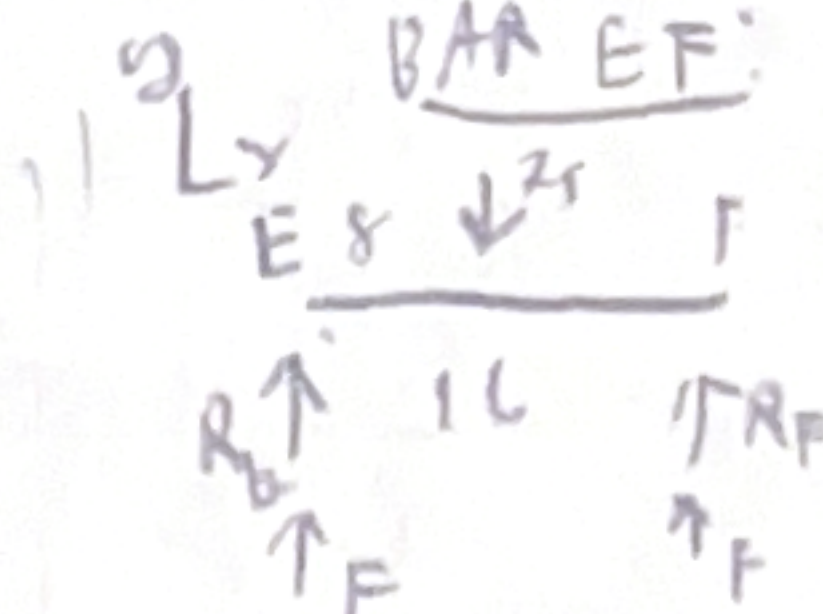
$$R_B = -37.5 \text{ lb}$$

$$\sum F_y = 0$$

$$150 - 75 - 37.5 + R_A = 0$$

$$R_A = -37.5 \text{ lb}$$

BAR EF:



$$\sum M_E = 0$$

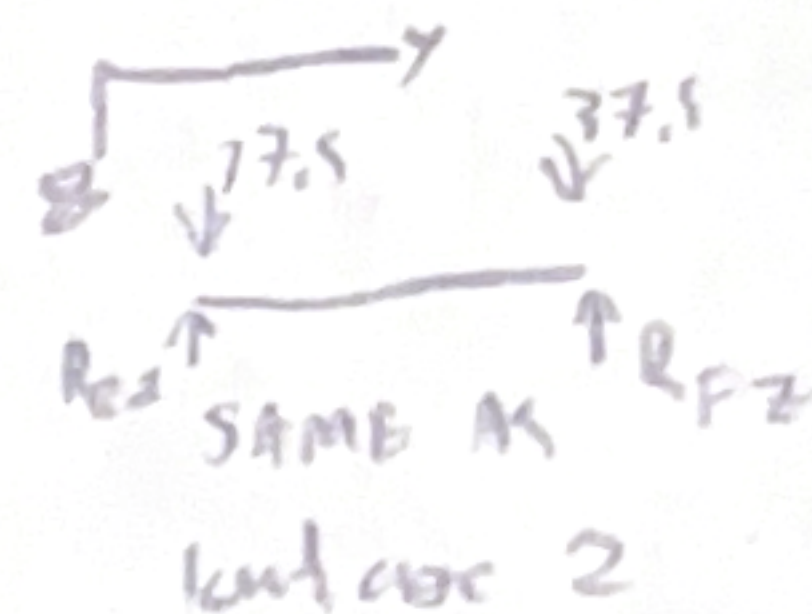
$$R_F(16) + 75(16) - 75(8) = 0$$

$$R_F = -37.5 \text{ lb}$$

$$\sum F_y = 0$$

$$150 - 75 + R_F + R_E = 0$$

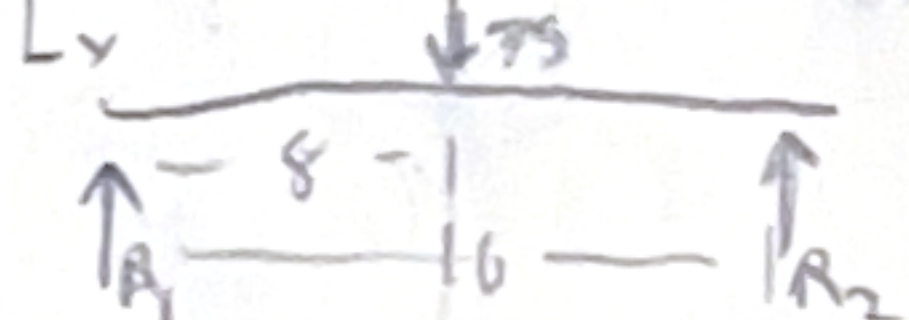
$$R_E = -37.5 \text{ lb}$$



$$R_E = -37.5$$

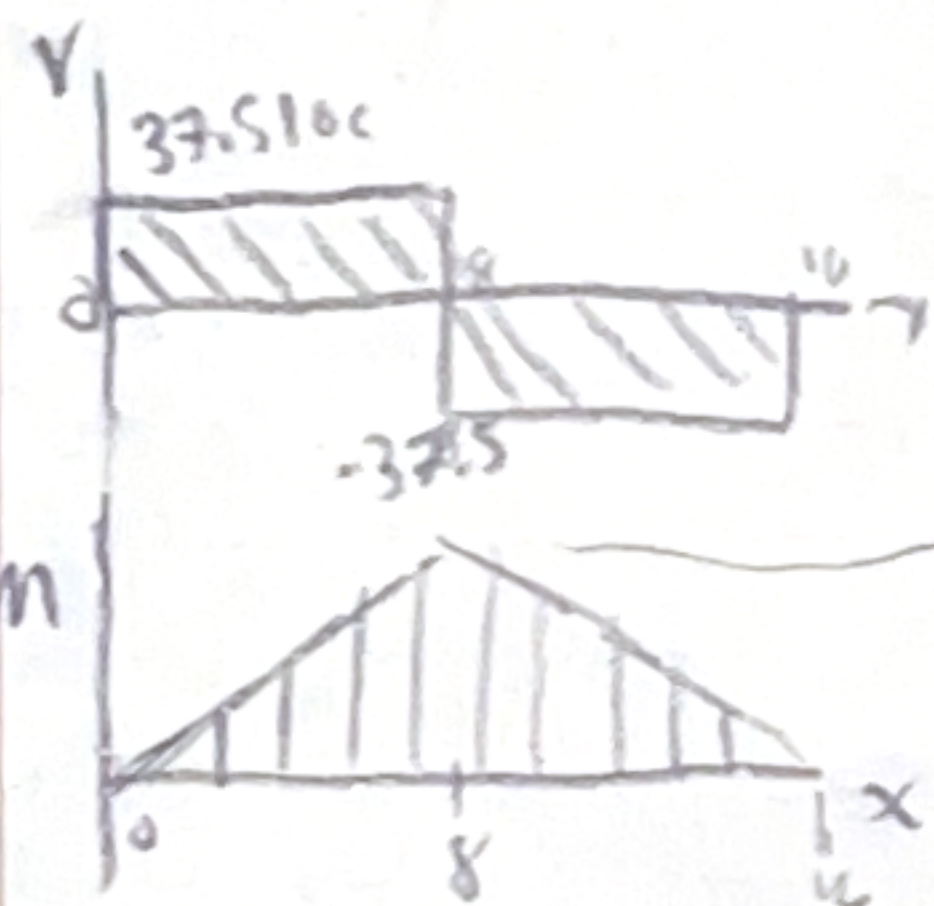
$$R_F = -37.5$$

BAR AB, AND EF



$$R_1 = R_2 = 37.5 \text{ lb}$$

$$d = 1.5 \text{ m}$$



$$M_{max} = 37.5(8)$$

$$M_{max} = 300.16 \text{ in}$$

$$\sigma = \frac{Mc}{I} = \frac{M \frac{d}{2}}{\frac{\pi}{64} d^4}$$

$$\sigma = \frac{300(0.75)}{\frac{\pi}{64} (1.5)^4} \quad \frac{16 \text{ mm}}{m}$$

$$\sigma = 905.914 \text{ psi}$$