Honor Statement:

An essential feature of the University of Tennessee, Knoxville, is a commitment to maintaining an atmosphere of intellectual integrity and academic honesty. As a student of the university, I pledge that I will neither knowingly give nor receive any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity.

Project Expectations:

I have personally written all the code, compiled all the graphs, computed all the handwork, and written all the text in this project. I have accurately cited when I used information obtained anywhere except lecture notes, office hours, and Norton's Design Textbook.

Name: (Printed)

Will Buziak

Signature:

Date:

2/13/2022

Use this template to complete your project. Include any diagrams generated using Matlab. Show all work. Upon completion of this project:

1. Upload this report as a .docx document.
2. Upload the Excel answer sheet provided. **Make sure your answers are in the specified units and match the report.**
3. Upload your matlab code as a .m file.

Design a Bike Arm of length [L] inches so that it will not fail under static conditions. See Figures 1-3 for details.

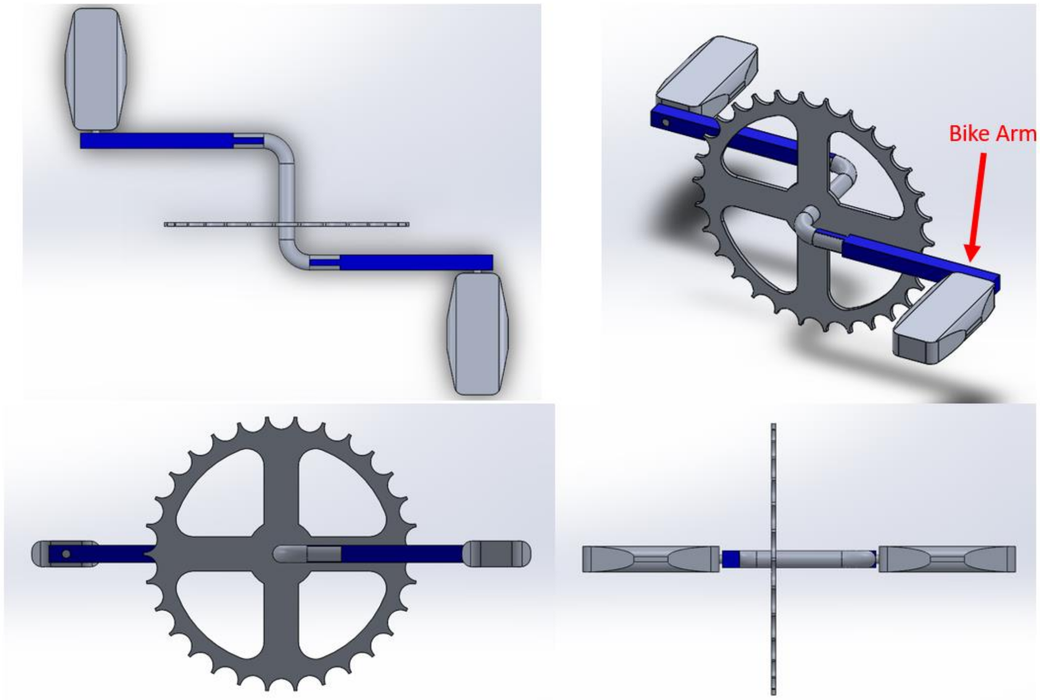


Figure 1 Bicycle Pedal Assembly with Bike Arm

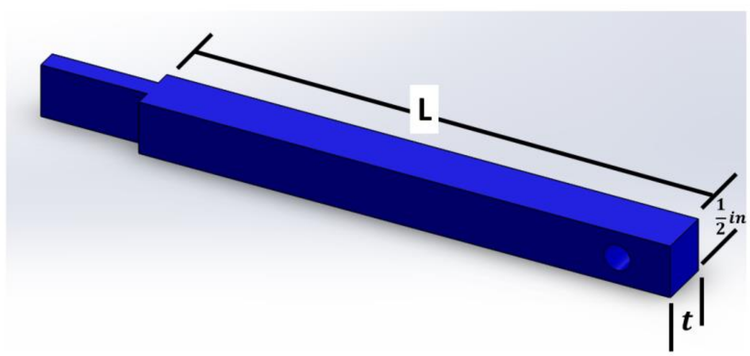


Figure 2 Isometric view of Bike Arm

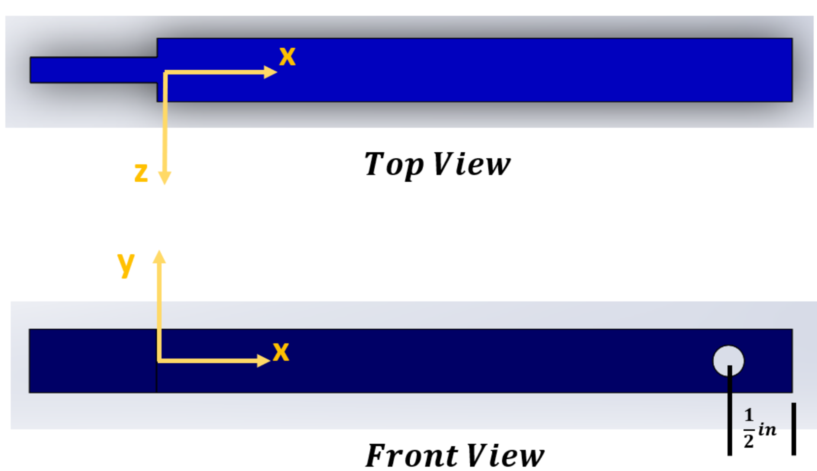


Figure 3 Front and Side views of Bike Arm with Coordinates Defined

Three scenarios are being considered. In all three scenarios, a person weighing [F] lbs is stepping on the pedal at a distance [a] inches from the centerline of the Bike Arm. The variables [L], [F], and [a] are unique for each student and are assigned in Canvas. Figures 4-6 illustrate the three scenarios.

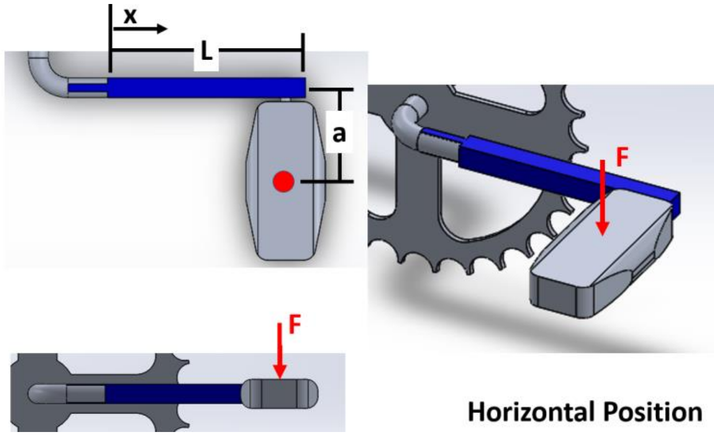


Figure 4 Horizontal Position

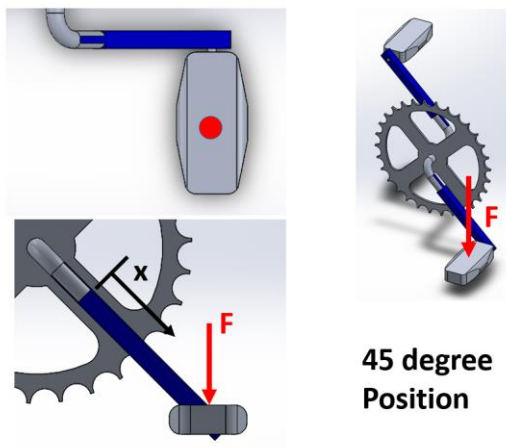


Figure 5 45-degree Position

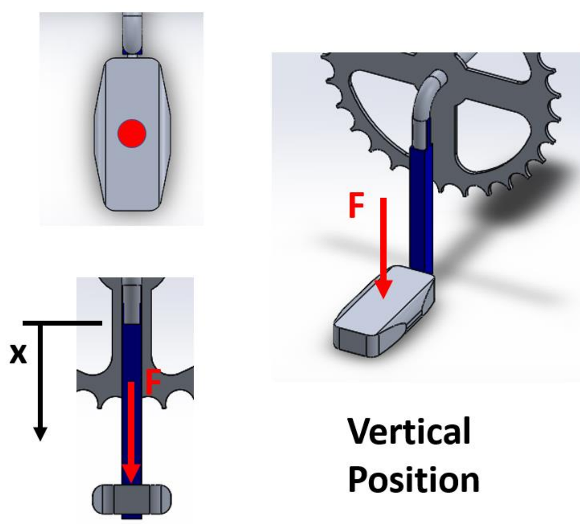


Figure 6 Vertical Position

1. Chosen Parameters:

For this project, I chose a thickness of 1.4 inches because I felt that it would be a good thickness that would give the bike arm enough thickness to have enough strength to hold the load. Although there was not officially an optimization condition to this project, due to Dr. Young's mention in class that the idea behind the project is to give a real-world simulation of a restrictive project to ensure that a given part will not fail under the expected loading conditions. With that said, the specified thickness will not create too much weight, therefore, still a respectable decision for most environments the bike arm will be expected to perform in.

	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Iteration 6
Material	Aluminum-3003	Carbon Steel-1050				
Condition	Cold rolled	Quench & temper @ 800 (Fahr.)				
S_y (kpsi)	27	115				
S_{ut} (kpsi)	29	158				
Thickness (in)	1.40	1.40				

$Material = Carbon\ Steel$ 1050 SAE Designation
Condition = Quenched & temper @ 800 deg. F.
$S_y =$ 27____________ kpsi
$S_{ut} =$ 29____________ kpsi
$Thickness =$ 1.40____________inch

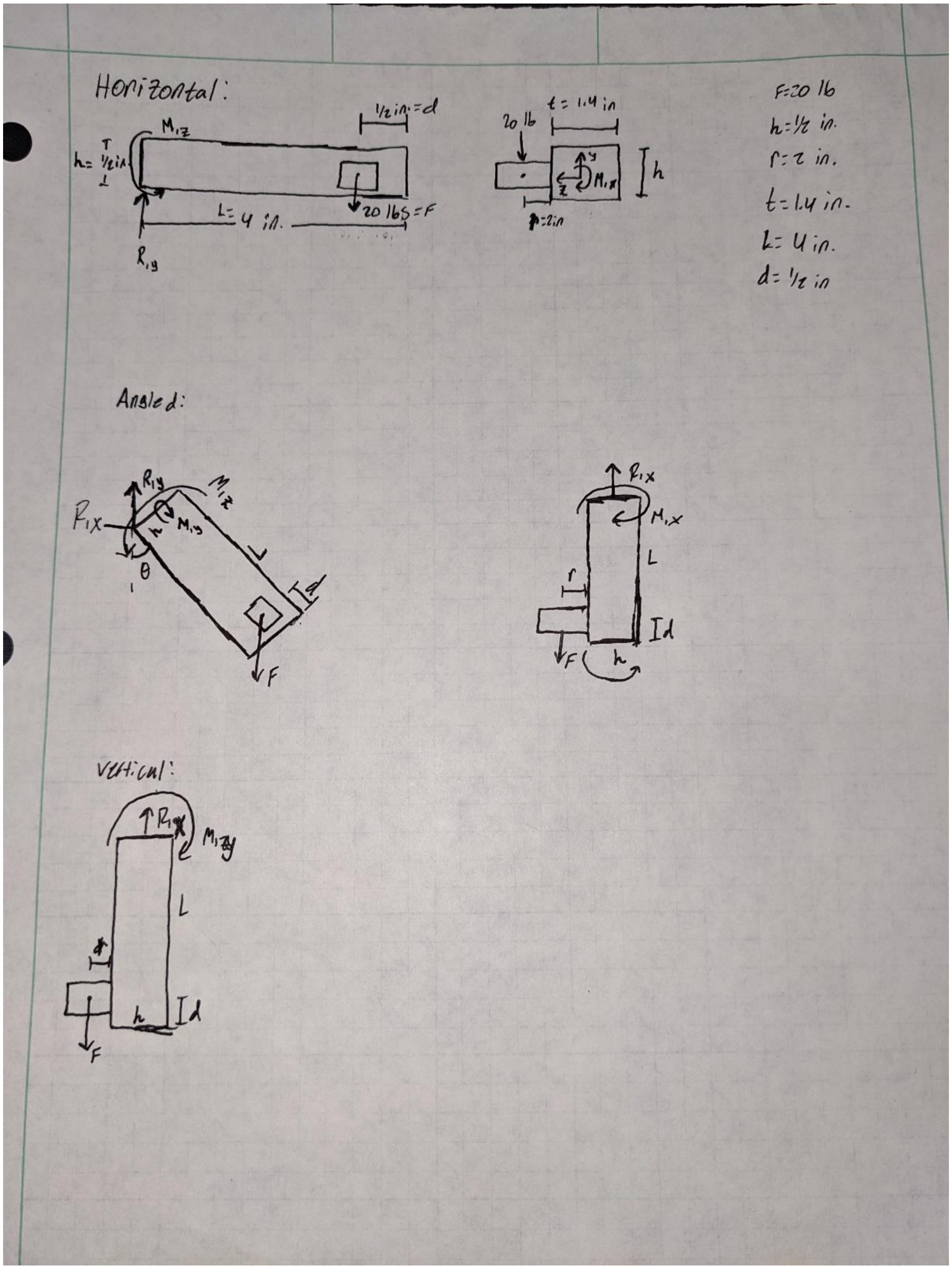
- Iteration one I chose to look at cold rolled Aluminum-3003 to identify a very lightweight, but potentially unsafe choice for a material due to it's much lower ultimate tensile strength. However, Aluminum-3003 is still a strong candidate due to it's relative strength to weight. Given a particular industry or purpose, Aluminum-3003 would be worth considering due to it's ductile properties.
- After Iteration 2 I was confident that Carbon Steel-1050 quenched & tempered @ 800(F) would be more than strong enough to hold the loads in all loading conditions.
- It is important to note that Carbon Steel-1050 is substantially heavier than aluminum

2. Reaction Forces and Moments

Create a Free Body Diagram for each of the three scenarios. It is helpful to create the FBDs in terms of variables so that they will apply to any iteration. It is often helpful to do the first iteration by hand, then code it in Matlab to make sure that the code is correct. For that reason, it is ok to submit handwork for an iteration, but the final values recorded in the tables should be of the final iteration. Calculate the reaction loads that occur at x = 0.

	Horizontal	45 degrees	Down
R_{1_x} (lbs)	0	-10.51	-20

R_{1y} (lbs)	20	17.0	0
R_{1z} (lbs)	0	0	0
M_{1x} $(Torque)(in - lb)$	-54	46	0
M_{1y} $(in - lb)$	0	28.4	54
M_{1z} $(in - lb)$	-70	-59.6	0



- I chose to do two FBD's for the first two scenarios to give a better idea of the moments present in each situation.

- Scenario one has a reaction moment in the z from length L and force F and a reaction torque due to distance ‘r’ from the arm to the middle of the pedal plus half the thickness and F creating a “twist”.
- Scenario two is a little more complicated, due to the angle, F is split to Fx = Fcos(theta) and Fy = -Fsin(theta). This creates reaction moments in all three directions. Mx and Mz are caused by a similar occurrences as scenario 1 with a change in magnitude due to the split force. My is caused by the x component of the force and the distance d to the center of the pedal, producing a moment into the bike gear, with a reaction preventing it.

3. Individual Loading Diagrams

a. *Maximum Axial Load (about the x axis):*

- Axial loads produce a stress (P/A_cross) that is distributed evenly along the entire cross section.
- Due to the lack of geometry/material variations the axial load is the same throughout the part.
- Since we are only considering the axial load in each scenario, the x, y and z locations will all be zero as that is technically the “first” location at which the max stress exists along the cross section.
- The first scenario does not have an axial load, therefore, all values are zero.

	Horizontal	45 degrees	Down
$Value\ (lbs)$	0	10.51	-20
$x\ location\ (in)$	0	0	0
Max Stress (kpsi)	0	.015	.029
$y\ location\ (in)$	0	0	0
$z\ location\ (in)$	0	0	0

b. *Maximum Shear Load in the y direction:*

- Shear stress produces a max stress along the x axis in the center starting at x,y,z=0.
- Since there are only two equal and opposite shear forces present, the shear will be maximum at all points from the origin to the applied force.
- There is no shear present on the third scenario

	Horizontal	45 degrees	Down
$Value\ (lbs)$	20	17.02	0
$x\ location\ (in)$	0	0	0
Max Stress (kpsi)	.011	.010	0
$y\ location\ (in)$	0	0	0
$z\ location\ (in)$	0	0	0

c. *Maximum Moment about the x axis (Torque):*

- Torque is maximum around the outer radius of the object
- Third scenario does not have any torque applied

	Horizontal	45 degrees	Down
$Value\ (in\ lbs)$	48.6	45.9	0

$x\ location\ (in)$	0	0	0
Max Stress (kpsi)	.069	.066	0
$y\ location\ (in)$	.25	.25	0
$z\ location\ (in)$	.7	.7	0

d. *Maximum Moment about the y axis:*

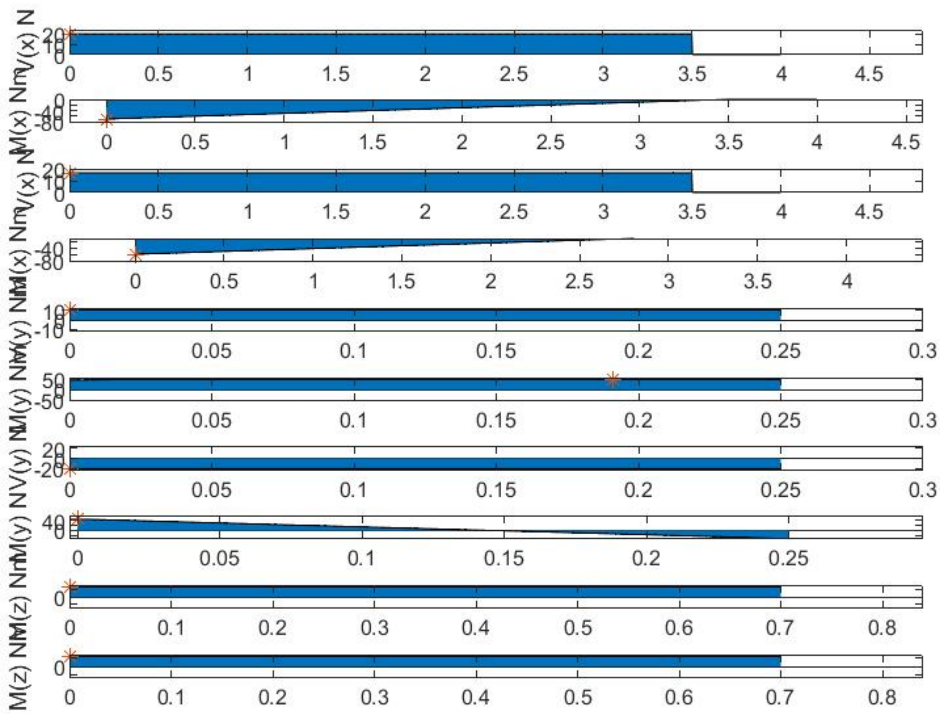
- In scenario 2 & 3, the distance between the pedal center and beam produce a y moment
- Max shear occurs along the outside edge along the z axis

	Horizontal	45 degrees	Down
$Value\ (in\ lbs)$	0	28.4	54
$x\ location\ (in)$	0	0	0
Max Stress (kpsi)	0	.016	.031
$y\ location\ (in)$	0	0	0
$z\ location\ (in)$	0	.7	.7

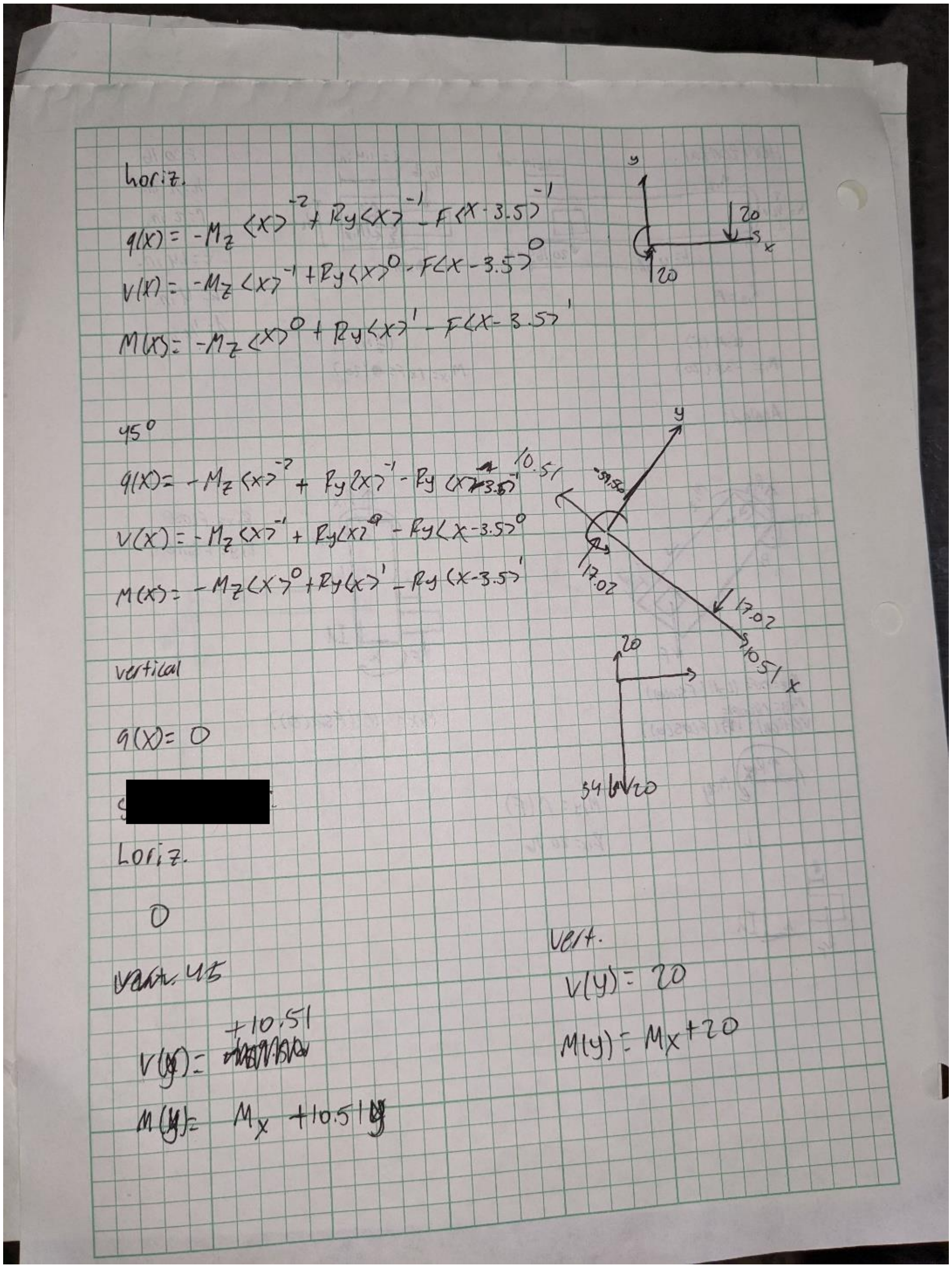
e. *Maximum Moment about the z axis:*

- In the first two scenarios, the downward y force generates a (-) bending moment, however, in the final scenario, that bending moment is positive.
- Bending moment creates a stress that is maximum about the y axis largest at the two ends.

	Horizontal	45 degrees	Down
$Value\ (in\ lbs)$	-70	-59.6	0
$x\ location\ (in)$	0	0	0
Max Stress (kpsi)	.014	.012	0
$y\ location\ (in)$	.25	.25	0
$z\ location\ (in)$	0	0	0



Matlab generated loading diagrams



- The scratch work begins with loading diagram for shear forces acting in the y direction for each scenario, which was then coded and after some scratch for the singularities for axial loads I was able to finish the rest of the singularity functions in matlab symbolically.

4. Superimposed Stress diagram:

We now need to check the total stress at every point along the beam. There are several methods for doing this. If we were working the problem by hand, it is best to find the locations on the x-axis that have the highest loads. We would then find the points in each of those cross sections that have the highest stresses and calculate effect of all the loads on the stress at those locations.

Since we are using Matlab, we can check the stress for a point on the cross section throughout the whole beam. Displayed graphically, we can quickly see the highest stress for each location of the cross section. Consider nine possible points on the cross section as described by Figure 7.

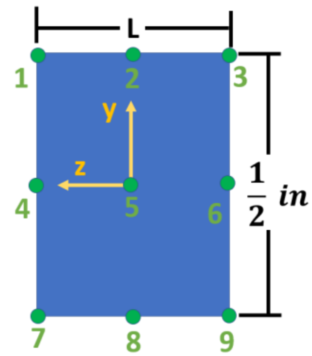
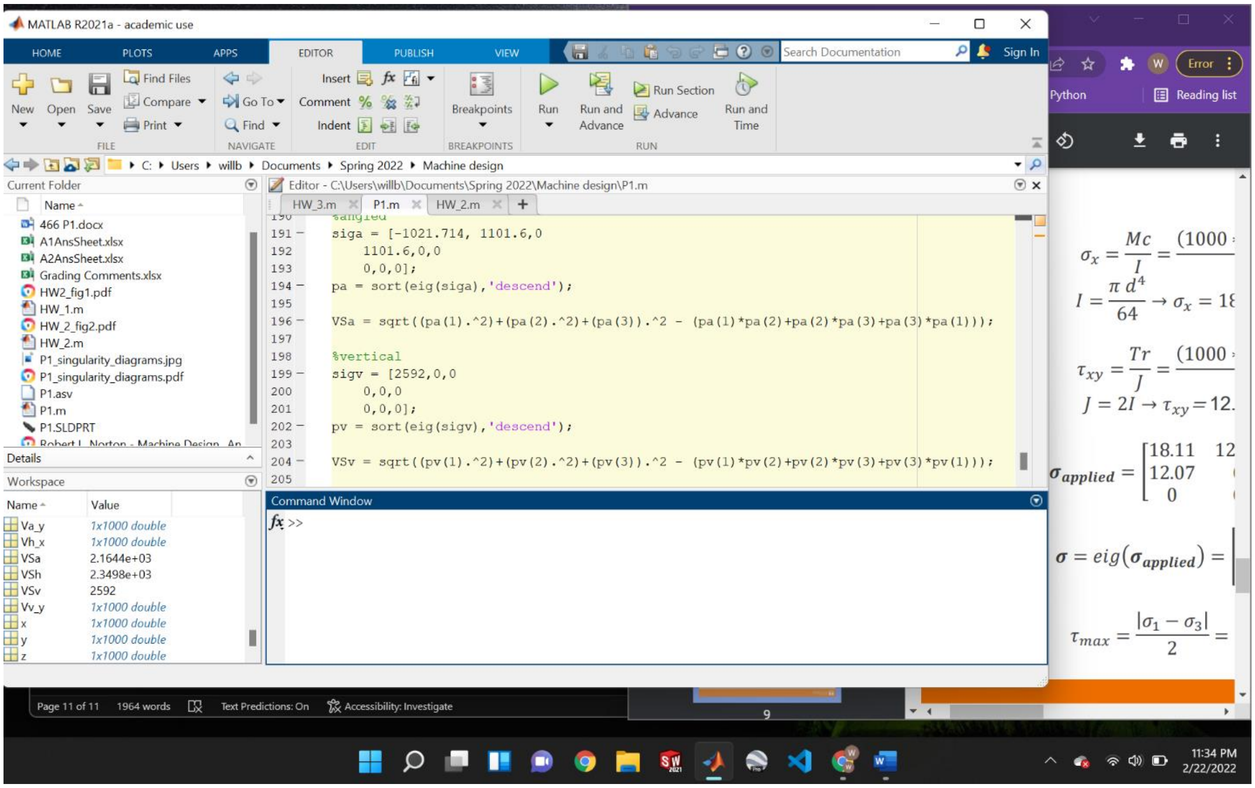


Figure 7 Cross Section of Bike Arm with Points Defined

$$\acute{\sigma} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - (\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_1\sigma_3)}$$

	Horizontal	45 degrees	Down
Max von Mises Stress (kpsi)	2.35	2.16	2.59
x $location$ (in)	0	0	0
y $location$ (in)	.25	.25	0
z $location$ (in)	0	.7	.7

- Potential points of error could lay in needing to use My for the “down” orientation to find sig_x, there was no x or z moments in that orientation which would produce a von mises stress of zero. This seemed unlikely to me since there is still
- Another possible point of error is each von mises stress could be wrong, due to an error in the setup of each sigma value. It was to my understanding based on the examples found in modules under combined loading I was to calculate sig_x through Mc/I and Tao_xy as Tr/J. I understood T as torque but was confused as to how to apply M. I chose to use the z moment, but this fell apart as I reached the “down” orientation through the error discussed above.



5. Conclusions

It is vitally important to consider the context in which the bike arm will be used. If this is a mountain bike arm, or perhaps, in an attempt to not sound crass, a bike for a heavier rider. This could be a useful to ensure that it will not fail. However, this material will not be desirable for a competitive or lightweight criterion.

Maximum von Mises stress on the Bike Arm = 2.59 kpsi