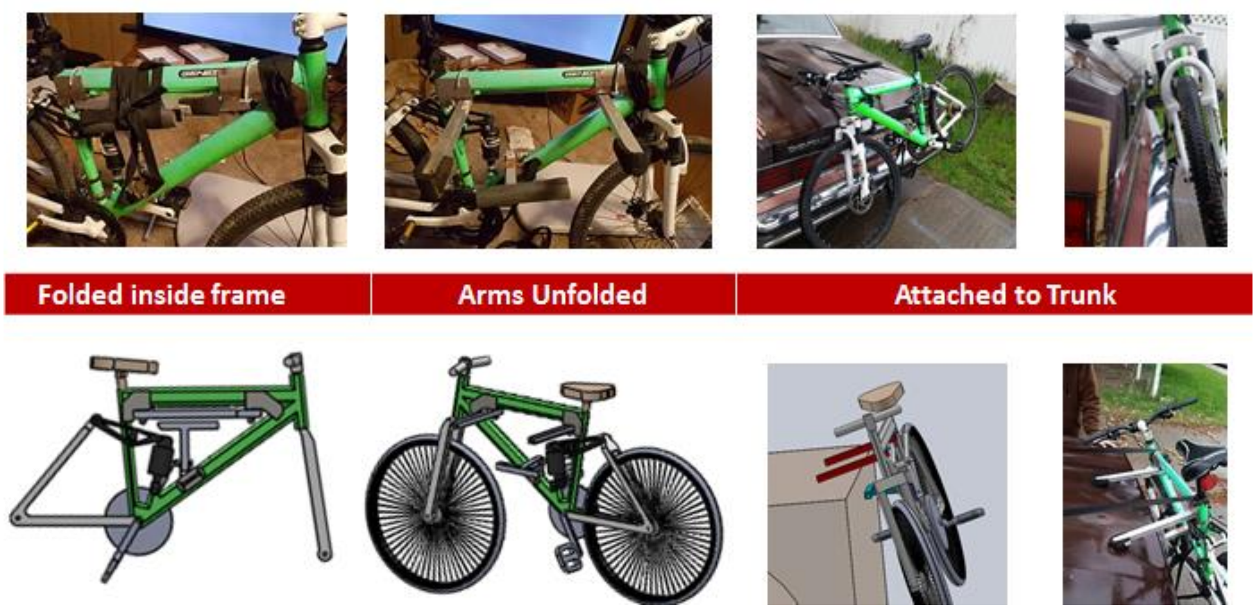
Built-in Bicycle Rack for Cars

By
Scott Hansberry



Contents

1: ABSTRACT

Transporting a bicycle after riding somewhere and then needing to be pickup can be problematic. Bicycles will not fit in most vehicles without removing components. There is also the risk of damaging the inside of the vehicle. Expecting everyone to have a bike rack for their vehicle is unrealistic because the bike rack could be considered unappealing visually, take up to much space in the trunk, or limit the vehicle owner’s access to the trunk. The solution to this problem is a bike rack that mounts onto your car and then mounts your bike onto the rack. Most people don’t drive around with a bike rack connected to their vehicle, it’s unappealing and they are unable to use their trunks due to the bicycle rack being too big and bulky to carry around while you’re riding your bike. A bicycle rack was designed to fits inside the bicycle frame and unfolds to attach to the vehicles trunk for transportation. The designed rack has three arms that fold inside the frame, two arms on the top of the frame that rotate out, and one arm on the bottom that folds down in the shape of a T. The rack also has six straps two on the top bar, two straps on the bottom, and one on the both sides left and right. After analysis of the weight of the bike and the length of the arms, the thickness required was calculated, for the arms to support the weight of the bike.

2: INTRODUCTION

Motivation

The motivation behind this project is the need to be able to transport a bicycle by car using a mounting rack built off the bicycle. When a bicyclist rides a bicycle somewhere but then gets picked up in a friend’s car or expectantly needs to transport their bike in a car the problem is that most people don’t drive around with a bike rack attached to their car for easy transportation of the bike. They typically need to stuff the bike in the trunk or awkwardly tie the bike to the outside of the car. This can results in damage to the bike and or the vehicle and could even result in a dangerous situation if not properly tied down and falls off into traffic. Bicyclists are usually forced to leave their bicycle since most people don’t drive around or leave a bike rack mounted on their car all the time. My solution to this problem would be to always have a bike rack with your bike although most car bike racks are too bulky and big to carry on your bike so to achieve this solution I designed a bike rack that unfolds out of the bicycles frame so that the bike can be easily attached to most standard cars for transportation and then the device can be folded inside the frame when riding the bicycle.

Function Statement

A device that is folded inside the frame of the bike to not effect performance during riding but can also be unfolded to mount the bike on a car for transporting the bike by vehicle.

Engineering Merit

The project includes structural design, stress analysis, optimization, and project management.

Requirements

- The device must be less than 5 lbs.
- The device must be able to mount to a car trunk without any need for special tools.
- The device must be able to support a bicycle weighting 50lb.
- The device needs to support the bicycle while mounted during city driving without failing or damaging the car.
- The device must fold inside of frame without interfering with the bikes performance.
- The device must be ergonomically friendly and simple to operate and attach.
- All parts and materials must cost less than $200.00.

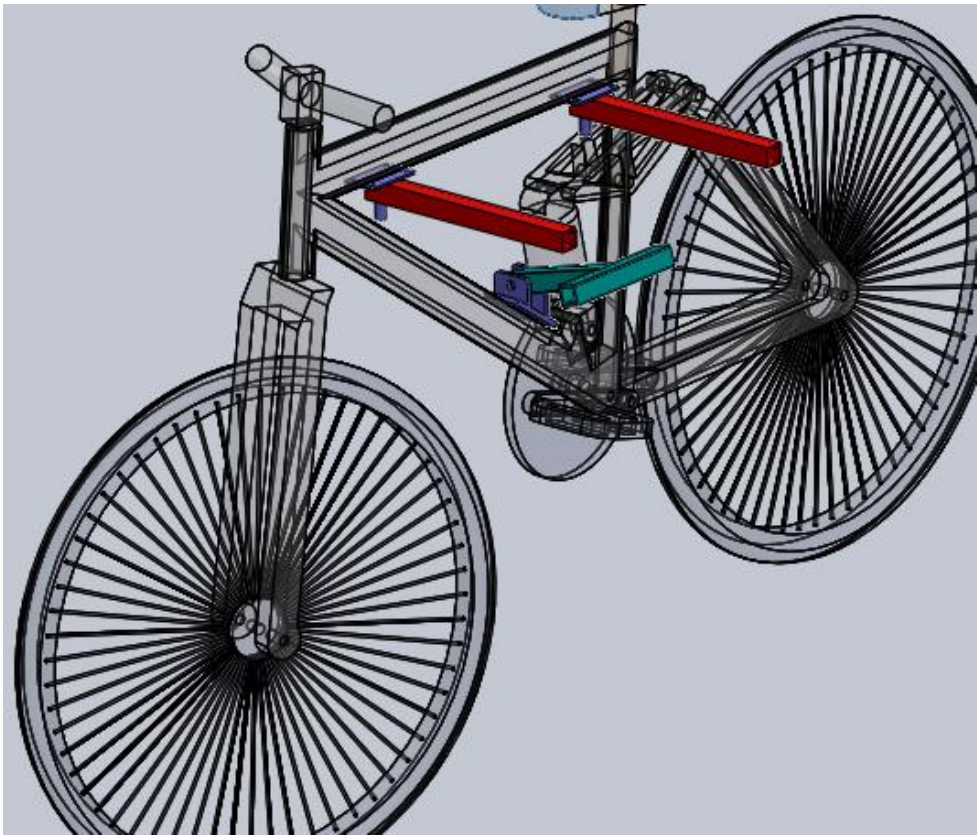
Scope

This project scope consists of designing the device to fit inside of the frame and also the top and bottom arms must be analyzed to insure they structurally support the weight of the bike without damaging the car. The brackets that hold the arms will be designed and build but will be overdesigned with stronger material then the arms. The 4 straps that hold the bike to the trunk will be bought as replacement straps for existing bike racks and will not be included in analysis since they were designed to hold the bike to the trunk already. The next step will be analysis the design and then optimize the device. Constructing the device and testing the device structurally.

Success Criteria

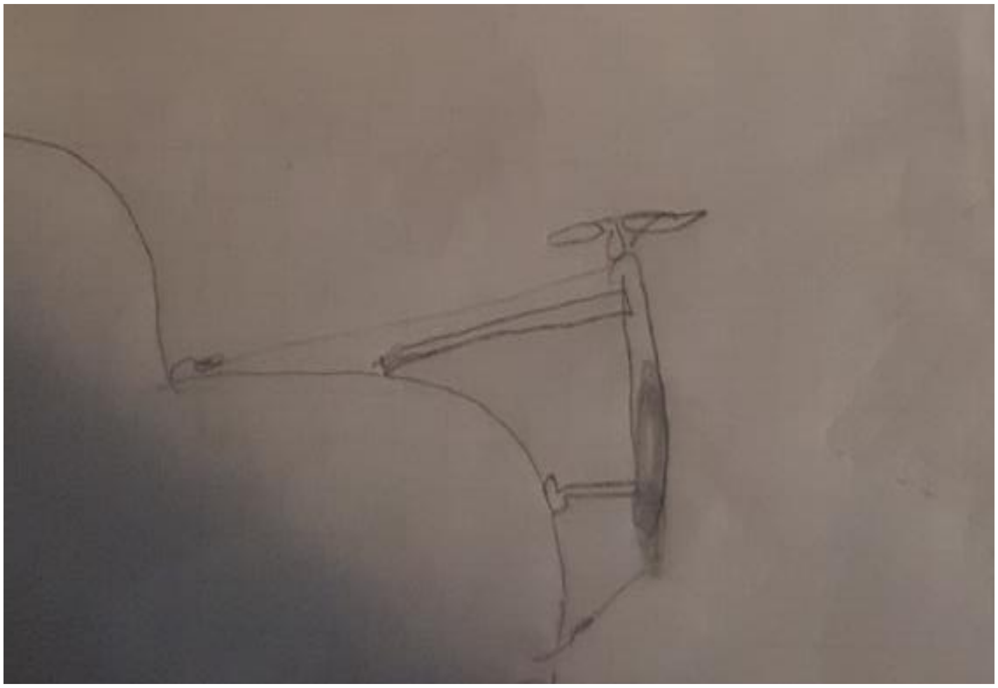
The success criteria for this project is if the device can fit inside the frame of the bicycle, fold out without interference and mount on the trunk and the device supports the weight of the bike without failing while the car is in transit.

2: DESIGN & ANALYSIS



Approach

After studying car racks on the internet I came up with my design of having two arms on the top and one support arm on the bottom with stability straps. The two arms on the top will help support the weight of the bike while the bottom arm supports the moment load transfer into the car. The securing straps will prevent movement and tie the bike down to the car. The arms will each fold up inside of the frame when the bike is not mounted on cars. To make sure there is enough clearance between the bike and the car the arm supports on the top were designed to be 12 inches while the bottom mount will be 7 inches long. The stability straps will hold the bike down and take some tension load while the arms will need to support the bikes weight with a safety factor of 6. The arms will be built out of aluminum tubing and the sizing will be determined using stress and beam analysis. Foam piping will cover the ends of the support arms to prevent them from scratching or damaging the car.



Description

The device needs to fit within the frame when not mounted onto the car. The dimensions of the frame are 22 inches for the top bar 17 inches for the vertical bar and 25.5 inches for the bottom diagonal bar as seen in Fig A-1. The bike rack arms will create enough clearance so that the bike frame or the bike pedal won't come in contact with the car when mounted. Weight and corrosion resistance are critical to this design, and the primary reason that aluminum was chosen as the structural component material. The sketch above and also Drawing 10 shows the bike mounted on the trunk and why the lengths of the arms are important for clearance. I plan on designing the bottom arm to be 7 inch long and the top two arms to be 12 inches.

Performance Predictions

The performance of the bike rack is predicted to support the weight of the bike with a safety factor of 6 while also deflecting less than 0.125 inches. The overall weight of the rack is very important and will be optimized throughout the material selection and design process. My calculations show the total weight to be less than 5 pounds and fold inside the frame while riding it. Because the bike will be exposed the rain and the elements, I plan to optimize the finishes for the frame and perform corrosion prevention testing. The devices will end up costing a total less than $200.

Analysis

When designing the length of the support arms, the first step was to measure the frame (Fig A-1) to determine my envelope size for the device when the arms are folded up inside the frame. The triangle shaped frame of 22inch on the top by 25 ½ diagonal and 17inch vertical. The lengths of the arms were designed to fit inside the frame at 12 inches for the top arms and 7 inches for the bottom arm as shown in Fig A-2.

Using the arm lengths of the bike free body diagrams were created of the bike rack as shown in Fig A-3. The straps are there to hold the bike in place and prevent any moments. The top strap would help decrease the force on B caused by the moment around A. The straps were eliminated from the analysis to insure that if the straps had slack or became loose all the weight would be on the support arms and I would rather overdesign them then under. Using Fig A-4 the sum of forces in the Y coordinate the equation $+F_y=0=F_{Ay}-50$ lb simplified to $F_{Ay}=50$ lb. Since there are 2 arms on the top the force could be divided in half since each arm would take half the weight but this would be assuming the bike is always level and assuming the car turned a corner hard or was on and incline all the weight could be put onto one of the arms so for safety reasons I calculated the force in the arm as if there was only one. The sum of the moment around A was then calculated to $+M_A=50*\cos(18)(13.416)-F_{bx}*\sin(35)*11.93$ which simplified to $F_{bx}=93.23$.

Using the $F_{ay}=50$ lb I calculated the force perpendicular to the arm as F_{aup} using the formula $50*\cos(10)=49.24$ lb as shown on Fig A-4. I next found the max moment of the top arm in Fig A-5 with the formula $M_{max}=F_{aup}*L$ so $M_{max}=49.24*12 = 590.9$ lb*in. Next we found the sectional modulus using the formula $S_x=M_{max}/(\sigma_{max})$, Fig A-6 shows that $M_{max}=590.9$ lb*in and the max stress of 45000 psi as defined by the given 6061 t6 material properties, solving this formula we found the $S_x=0.013$in. Using the calculated sectional modulus I made a table as seen in Fig A-7 showing different hollow square tube size and their sectional modulus and calculated their factor of safety using the formula $FOS=(S_x)/(\text{Required } S_x)$. Using the table from Fig A-7 I selected 1x1x0.125 since it has the smallest sectional modulus available while also being above the required FOS of 6 at 8.76.

Next I calculated the shear bearing and allowable stress for the bolts in the top and bottom arms as send on Fig A-8 and continued onto Fig A-9. Using the forces in Fig A-4 I calculated the shear stress using formula F/A=AvgShear and found it to be 44.207 psi for the top and 737.84 psi for the bottom. Bearing stress was next calculated using formula F/(2t*d) to found to be 69.44 psi for the top arm and 372.92 psi for the bottom. The bolts were determined to be well below their specified limits.

Figure A-10 is a calculation of the length of tubing I will need to buy total. All the arms added together gave me a tube length size of 37inches and then I found the weight of the pipes by multiplying the length by the cross-sectional area to find my volume and multiplied that by the density of the aluminum to find the weight of 1.58lb.

Figure A-11 is similar to A-10 but is a calculation on the amount of steel plating needed to build the two top brackets and the single bottom bracket. This was calculated by finding the area of each bracket and the vertical sides for the bottom bracket which equaled 24.62. I then arranged the parts on a sheet to try and get the smallest sheet possible with all my parts still fitting inside the sheet and found that 5 x 5.33 is the smallest I could go without running out of material. The weight was then calculated the same as above in the last problem but with the density of steel instead of aluminum and was calculated to weight 1.85lbs. I then added the weight of the tubing and the weight of the plating to find the total weight of the device to be 3.43 lbs as seen the bottom of Fig A-10.

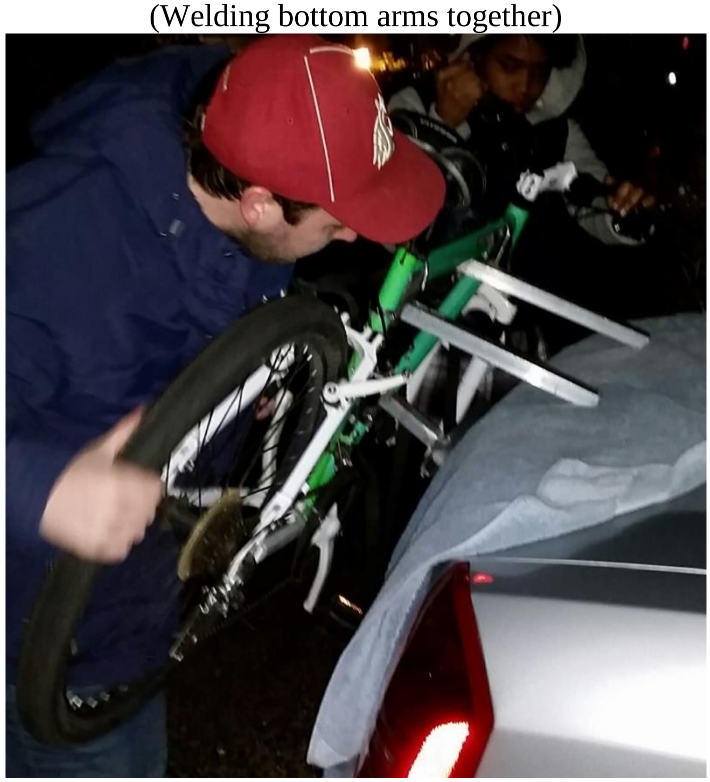
Max deflection was calculated in Fig A-12 for the upper arms since it's the longest and would show the most deflection and was calculated using beam analysis to be $S_{max}=0.04645$ inches using the formula $S_{max}=(P*L^3)/(3*E*I)$. The calculated deflection 0.04978 inches was 2.69 times less than the max deflection of 0.125 inches in the design requirements.

The Critical load was found for the bottom arm since it has the most compression force. Using the formula for critical load of $P_{cr}=(\pi^2*E*I)/(Le^2)$ I found K=2.1 since the top was free and the bottom pinned. Le=K*L=12.6in, E was given from material properties and the sectional modulus (I) was calculated back in Fig A-6. Solving for Pcr=35416.44 lb compared to the actual force of 93.23 lb you get a FOS of 379.9 much higher than the desired FOS of 6.

4: METHODS & CONSTRUCTION

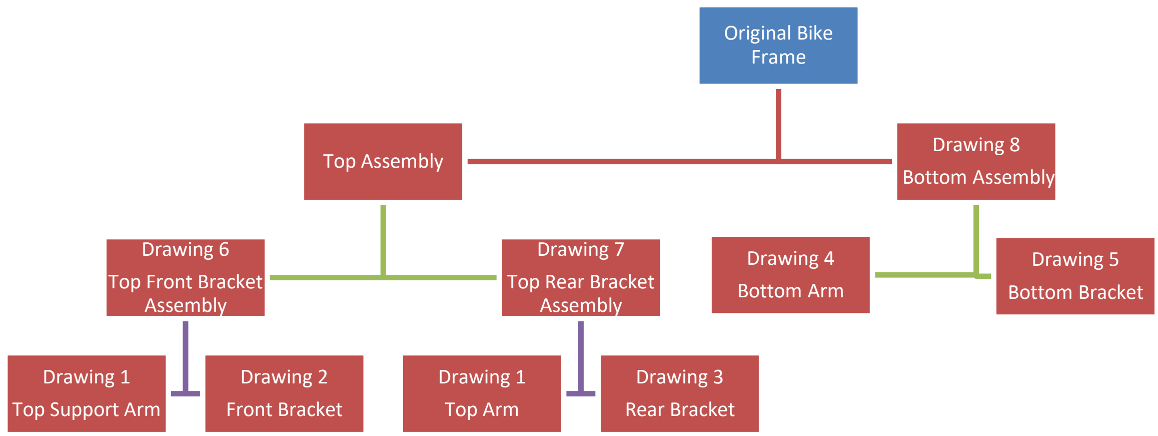
This project was conceived while working toward my mechanical engineering technology degree. The construction will mainly be at CWU labs along with all analysis and testing throughout the year. The device will be built in sections with the two top arms build and then the bottom arm built and also the bottom bracket and top 2 brackets built. The top two arms will be cut to length while the bottom will be cut to 6inch length and welded to the center of another tube cut to length of 6inch be welded to form a T shape. The top bracket will be constructed using a flat 1/8 inch plate of steel and welding a hex bolt off the center. The bottom bracket will be constructed off a flat 1/8 inch piece of steel and have two vertical 1/8 flat piece at 55 degrees welded on and then a hole drilled through booth vertical pieces. The brackets will be clamp on using U shape bolts. Foam tube will be placed over the tips of the top arms and over the top to the T of the bottom arm to prevent the arms from scratching or denting the car’s trunk. The 6 stability straps will be replacement straps for preexisting bicycle car racks and will be attached directly to the bike frame with 4 on the top bar with 2 going to the top of the trunk and 1 going to each side and 2 on the bottom bar going to the bottom of the car. The hardest part was welding the aluminum since I never did it before and did a lot of practice welds with scrapes to insure I didn’t mess up and melt through my piece. Once all the parts were constructed and assembled and bolted to the bike I test fitted it on a car to insure the pedal or anything else didn’t interfere with the car.

(Welding bottom arms together)



(Test fit to insure pedal doesn't hit car)

Drawing Tree



Device Operation

The top two arms will fold 90 degrees out and sit on top of the trunk to support the weight of the bike in the Y axis while the bottom arm will fold down and hold the bike against the trunk in the X axis. The bike will also have straps to support the tension load since the arms will only able to support the Y axis weight and prevent the bike from moving in the X direction.

Benchmark Comparison

This design is somewhat similar to a normal bike rack when mounted to the car except most standard bike racks can hold 2+ bikes were as mine can only support one bike. The picture below is of a typical bike rack you could purchase at the store. My design will be similar to this design as the bike rack will have 4 straps 2 on top and 2 on bottom. My design will be more compact as it will fit inside the frame unlike normal bike racks that are bulk and big and most couldn't fit be carried with you while you're riding your bike.

Performance vs Benchmark

The bike arms and brackets can be weighed and compared to existing bike racks. The bike clearance to the car can be measured and compared to existing bikes. Also the deflection in the arms can be measured and compared. The bike rack will also be tested while mounted on a moving vehicle to show that it is stable and doesn't damage the car surfaces.

Another bench mark test that is planned is to compare the time it takes to install and mount a bike to a conventional bike rake compared to the time required for the Built in Bike Mount.

5: TESTING METHOD

Test plan for accelerometer, mounting, and driving tests.

Introduction: (brief outline of what is to come)

- Requirements:
  - The device must be able to mount to a car trunk without any need for special tools.
  - The device needs to support the bicycle while mounted during city driving under 35mph without failing or damaging the car.
  - The device must be ergonomically friendly and simple to operate and attach.
  - The device must be able to support a bicycle weighting 50lb.
- Parameters of interest: The mounting of the bike onto the car, the accelerometer data from driving in town, Will the device support the weight of the bike while stopped and while driving in town.
- Predicted performance: The bike rack will support the bicycle while stationary and driving in town. It also will be ergonomically friendly

and simply to attach.

- Data acquisition: Excel sheet for accelerometer data
- Schedule: 4/23/2017

Method/Approach: (describe in detail)

- Resources (hard/soft/external, people, costs), Car, Smart phone with built in accelerometer, accelerometer app to record data (Physics Toolbox app on Galaxy S5)
- data capture/doc/processing: Using physics toolbox to record accelerometer data then export to excel sheet to calculate g forces
- test procedure overview: using accelerometer data calculated g force in city driving to a weight that bike would experience under those g forces
- Operational limitations: Since first testing on car doesn't want to exceed 35mph in case it fails and gets destroyed. The accelerometer app also is limited by the software and hardware.
- precision and accuracy discussion: the accelerometer data shows that the g forces are 4 decimal places and it records 3 directions every 60m/s
- data storage/manipulation/analysis: Galaxy s5 smartphone to record data then transfer to excel sheet for analysis
- data presentation: excel sheet

Test Procedure: (formal procedure)

- Summary/overview: Test drive with accelerometer to find max g force in city driving that the bike would experience, then mount bike on trunk and attach the weight to equal the g force the bike would experience. Then remove weight and test drive in city.
- Specify time, duration: Drove around town for 15min
- Place: Ellensburg Washington
- resources needed: Smartphone, Sedan type car, Bike with device attached to frame
- Specific actions to complete the test: Record max g force from city driving, mount bike onto car, place extra weight onto bike, drive car with bike attached, remove bike from car.
  - Step 1: Start recording g – forces using the physics toolbox app and place phone where it cannot move inside of car.
  - Step 2: Drive around town for 15min making sure to brake hard and hit bumps to experience most extreme cases
  - Step 3: After 15min turn stop recording and export file to excel sheet.
  - Step 4: Using excel calculate the max g force the car will experience the using that g force calculate the weight that bike would experience under that g force.
  - Step 5: Attach the bike to the trunk of the car and secure with straps
  - Step 6: Shake bike to make sure that it is secure and wont bounce or move.
  - Step 7: Apply the calculated g force weight to the bike and

repeat step 6

- Step 8: The car was then drove through town and every 3min the bike was checked to make sure it was still safely secured to the car.
- Step 9: The bike was removed from the car and inspected for damages

- risk, safety, evaluation readiness, other: Risk of bike damaging car or falling off and damaging other motorist.
- Discussion: The bike was easy to attach although a lot easier to do with two people then one since with two you can just hold the bike with the other person attaches all the straps.

Deliverables: (describe specific parameters and other outcomes)

- Parameter values: g – forces, pounds
- Calculated values: pounds
- Success criteria values: If bike rack can support weight of bike stationary and while driving in town. Also the bike doesn't damage the car and can be attached easily.
- Conclusion: The bike rack successfully supported the weight of the bike while stationary and in motion. It also didn't damage the car but did rip its foam so that needs to be replaced.

Report Appendix:

- Data forms

	A	B	C	D	E
1	time	gFx	gFy	gFz	TgF
2	0.005	-0.1202	-0.0501	1.0303	1.038
3	0.006	-0.119	-0.0486	1.0291	1.037
4	0.007	-0.1126	-0.043	1.0195	1.027
5	0.008	-0.1094	-0.0445	1.0193	1.026
6	0.017	-0.116	-0.0474	1.0105	1.018
7	0.018	-0.119	-0.0493	1.0086	1.017
8	0.022	-0.1214	-0.0511	0.9995	1.008
9	0.027	-0.1209	-0.0557	0.9951	1.004
10	0.041	-0.1178	-0.0562	0.9819	0.991
11	0.042	-0.1163	-0.0513	0.979	0.987
12	0.043	-0.1192	-0.0484	0.9687	0.977
13	0.048	-0.1138	-0.0535	1.0046	1.012
14	0.052	-0.1163	-0.0562	1.0017	1.01
15	0.057	-0.1207	-0.0489	0.998	1.007
16	0.062	-0.1187	-0.0476	1.0034	1.012
17	0.067	-0.1212	-0.0462	1.0034	1.012
18	0.072	-0.1175	-0.0489	1.0188	1.027
19	0.077	-0.1141	-0.0523	1.0144	1.022
20	0.087	-0.1165	-0.0476	1.009	1.017
21	0.088	-0.1151	-0.0476	1.0044	1.012
22	0.093	-0.1165	-0.0479	0.9951	1.003
23	0.108	-0.118	-0.052	1.0032	1.011
24	0.109	-0.1187	-0.0542	1.0029	1.011
25	0.11	-0.1175	-0.0542	0.98	0.988
26	0.113	-0.117	-0.0569	0.9853	0.994
27	0.116	-0.1146	-0.0533	0.9814	0.99
28	0.127	-0.1212	-0.0569	0.9748	0.984
29	0.131	-0.119	-0.0528	0.9819	0.991
30	0.132	-0.1209	-0.054	0.9844	0.993
31	0.136	-0.1182	-0.0528	0.9919	1
32	0.141	-0.1197	-0.0547	0.9976	1.006
33	0.146	-0.1187	-0.0496	1.0037	1.012
34	0.152	-0.1148	-0.0552	1.0034	1.011
35	0.158	-0.1134	-0.053	1.0012	1.009
36	0.161	-0.117	-0.0513	0.999	1.007
37	0.175	-0.1156	-0.0518	1.0015	1.009
38	0.177	-0.1212	-0.0523	1.0066	1.015
39	0.178	-0.1175	-0.0515	0.999	1.007

	G	H	I	J	K
3		gFx	gFy	gFz	TgF
4	Average	-0.1474	-0.0349	0.992901	1.006295864
5	Min	-0.5345	-0.2707	0.7239	0.77
6	Max	0.0701	0.3897	1.4146	1.464
9	weight of bike at 1 g force			60	
10	Weight at 1.464			87.84	
11	Difference			27.84	

test drive

Ready

- Gantt chart with test day details
- procedure checklist

Overall Weight Test

Introduction: (brief outline of what is to come)

- Requirements: The device must be less than 5 lbs.
- Parameters of interest: Weight
- Predicted performance: The predicted weight of this device is 3.2lbs in SolidWorks plus the straps so an estimated total weight of 3.5lbs.
- Data acquisition: Measured weight using a bathroom scale and used an excel sheet to record and calculate the differences.
- Schedule: Should take an hour and will be performed on 5/1/2017

Method/Approach: (describe in detail)

- Resources : Need bathroom scale, bike, bike rack
- data capture/doc/processing: Excel sheet
- test procedure overview: Using bathroom scale to find weight of device
- operational limitations: Scale only reads to one decimal place so the accuracy is limited. Scale has a max weight of 500lbs

- precision and accuracy discussion: Scale only reads to one decimal place so the accuracy is limited
- data storage/manipulation/analysis: Excel sheet to record and calculate weights
- data presentation: Excel table

Test Procedure: (formal procedure)

- Summary/overview: Using bathroom scale to find weight of device
- Specify time, duration: The bathroom scale is digital and once you're still it blinks a couple times and then the weight stays on the screen after your still for about 3-5 seconds.
- Place: Kitchen since its big enough for the bike and has a hard floor for the scale
- resources needed: Bathroom Scale
- Specific actions to complete the test,
    - Step 1: Weight myself to find my overall weight
    - Step 2: Weight myself while holding the bike in the air
    - Step 3: Attached bicycle rack device to bike and weigh the bike the same as step 2
    - Step 4: Repeated the last 3 steps 2 more times and record all data into an excel sheet.
    - Step 5: Using excel formulas the bike weight was found by subtracting the weight found in step 1 from step 2 then the weight of the device was found by subtracting step 3 from the calculated weight of the bike.
- Risk, safety: Overall a safe and risk free test just be carefully lifting the bike so you don't injure your back.
- Once the test is done the overall weight can be calculated using excel and compared with the predicted overall weight.

Deliverables: (describe specific parameters and other outcomes)

- Parameter values: Weight in Pounds
- calculated values: Weight of bike and Weight of device
- success criteria values: Weight of device is under 5lbs
- conclusion: The weight of the device was 3.6lbs, 3.9lb, and 3.8lbs so the test was a success and the device passed the requirement of being under 5lbs

Report Appendix:

- Data forms

Testsing of Device total weight			
Test #	1	2	3
Bike Weight	38.6	38.6	38.7
My Weight	206.2	206.4	206.3
Bike + My weight	248.4	248.9	248.8
Device + Bike weight	42.2	42.5	42.5
Device Weight	3.6	3.9	3.8

- Gantt chart with test day details
- procedure checklist

Test Design for Deflection of support arm

4/5/17

Introduction:

- Requirements: The support arms cannot deflect more than 0.25 inches when mounted
- Parameters of interest: Deflection at the end of support arm. Amount of weight added.
- Predicted performance: Calculated deflection of 0.086 inches with 60lbs of weight
- Data acquisition: Measured deflection with a ruler or tape measure
- Schedule: Testing shouldn't take longer than a 1 hour and will be performed on Friday 4/7/2017

Method/Approach:

- Resources: Table Vice to clamp bracket, measuring tape to measure deflection, Weights up to 100lbs, either a hook or rope to secure weights to arm.
- Data capture/doc/processing: I will record the measured deflection for different weights in an excel spreadsheet.
- Operational limitations: Limitation by amount of weight I can attach safely to the arm.
- Precision and accuracy discussion: Since the test will be measured with a tape measure by eye the accuracy will be affected but with multiple weights I should be able to see a pattern.
- Data storage/manipulation/analysis: Using the deflection formula I can analysis the deflection at different weights on an excel file and then compare it to the measured values.
- Data presentation: Using excel charts and maybe even graphs

Test Procedure: (formal procedure)

- Summary/overview: A test of the arms deflection using a known weight.
- Specify time, duration: Since the deflection should be seen immediately after applying the weights. After weights are added a wait time of 5 seconds is used before measuring the deflection.

- Place: Central Washington University Hogue building
- Resources needed: Table Vice, tape measure, weights
- Specific actions to complete the test
  - Step 1: Since the front arm is the longest it will have the most deflection and will be used for this test. First remove the front top bracket from the bike Frame.
  - Step 2: Clamp the bracket into the vice so that the arm can stick straight out parallel to the floor.
  - Step 3: Measure the distance from the floor to the bottom edge of the arm and record as the initial height.
  - Step 4: Place weights on the end of the arm starting with 20lb
  - Step 5: After waiting 5 seconds measure the distance from the floor to bottom edge of the arm and subtract the initial height from this height to find your deflection for 20lbs.
  - Step 6: Repeat step 4 and 5 but with an additional 20lbs
  - Step 7: Repeat step 6 multiple times until your overall weight equals 100lbs.
- Risk, safety, evaluation: Safety and risk include dropping the weights on your foot. Hurting your back by lifting with your back and not your legs and knees.
- Once the test is done I can compare the measured values with the calculated values and see how they compare and if my prediction was correct or if I need to reassess my project.

Deliverables:

- Parameter values: Weights added in Pounds
- Calculated values: Deflection in Inches
- Success criteria values: Deflection at 60lbs is .25 or less
- Conclusion: Did the deflection at 60lbs deflect less then .25inches and how did my calculated values match my measured values.

Report Appendix:

- Data forms: Excel Table and Graphs
- Gantt chart with test day details: Friday is planned day to test
- Procedure checklist: Will be added into testing method inside the project report document.

6: BUDGET/SCHEDULE/PROJECT MANAGEMENT

The project will be managed by following the proposed schedule and keeping a tight budget. Some risks include falling behind the schedule and also manufacturing problems including welding aluminum as I have no prior experience with welding aluminum. Also any redesigns or alterations especially towards the end of the project could cause major delays. Another risk is the bike rack can't be tested for stability on a moving car until it is fully built which could make it difficult to make changes within the allotted schedule time.

Cost and Budget

The cost of this project is completely funded by and all parts will be manufactured by me using the CWU shop and also my father's garage. The bicycle for the project has already been purchased and is ready for modifications. A complete parts list is shown in Appendix C showing the total price for all parts of the project to cost $138.01

Labor costs for construction of this device are estimated to take 29 hours Rates are estimated at $25 per hour and the total labor cost for the project would be 29*25=$725 although the labor and construction are estimated to take longer than normal since it the first time making these parts and also first time welding aluminum so problems were expected and delays were calculated into the estimated hours to construct. Once the construction process is tweaked and more familiar I'm sure I could cut the construction time in half. The total cost of parts for this project is estimated to be $138.01. The project total cost including labor and parts would be $138.01+$725=863.01 although the price would go down with construction time speed up with more experiences.

Schedule

Below contains the full schedule for this project in the form of a Gantt chart starting at the proposal and including constructed the bike rack, testing the bike rack and finally analysis the results with the calculated predictions. As the project continues I will fill in the actual hours spent on each task and at the end of the project I can compare my estimation with actual and see how efficient I was and how accurate I was with my projected time spent. My total project was estimated to take 162 hours to complete the construction will only take 29 hours. Although with many redesign and adjustments the actually time took 57 hours. The biggest time waste was trying to get all the brackets squared and parallel to the frame.

Built-in Bicycle Mounting Rack for Cars
By: Scott Hansberry

TASK: ID	Description	Duration Est. (hrs)	Actual (hrs)	November	Dec	January	February	March	April	May	June
1	Proposal*										
1a	Outline	2	3								
1b	Intro	4	3								
1c	Methods	3	5								
1d	Analysis	15	18								
1e	Discussion	4	3								
1f	Parts and Budget	2	4								
1g	Drawings	10	15								
1h	Schedule	3	1								
1i	Summary & Appx	8	5								
	subtotal:	51	57								
2	Analyses										
2a	Structural	2	5								
2b	Stress	6	4								
2c	Bending	2	1								
2d	Buckling	1	5								
2e	Bolts	2	1								
	subtotal:	13	16								
3	Documentation										
3a	Drawing 1 Top Arm	3	4								
3b	Drawing 2 Top Bracket Front	6	12								
3c	Drawing 3 Top Bracket Rear	7	14.5								
3d	Drawing 4 Bottom Arm	2	2								
3e	Drawing 5 Bottom Bracket	3	4.5								
3f	Drawing 6 Top Assemble Front	2	3								
3g	Drawing 7 Top Asssemble Rear	2	3								
3h	Drawing 8 Bottom Assemble	2	2								
3i	Drawing 9 Complete Assembly	6	10								
3j	Drawing 10 Hex Bolt	2	2								
3k	Drawing 11 Hex Nut	2	2								
3l	Drawing 12 Bike Mounted on Trunk	1	1								
3m	Drawing 13 Exploded Top Front	2	3								
3n	Drawing 14 Exploded Top Rear	2	3								
3o	Drawing 15 Exploeded Bottom	2	2								
	subtotal:	44	68								
					#		5			5	#
4	Proposal Mods										
4a	Project Bike Rack Schedule	1	3								
4b	Project Bike Rack Part Inv.	3	4								
4c	Crit Des Review*	1	3								
	subtotal:	5	10								
7	Part Construction										
7a	Reasearch Materials and Prices	5	8								
7b	Buy Material	3	5								
7c	Create Traveler for Brackets	1	2								
7d	Cut Brackets	2	5								
7e	Weld Brackets	3	3								
7f	Grind welds down	2	1								
7g	Create Traveler for Arms	1	1								
7h	Cut Arms	1	1								
7i	Weld Arms	1	3								
7j	Grind welds down	1	2								
7k	Drill Arms	1	1								
7l	Drill Brackets	2	2								
7m	Update Website	1	0								
7n	Update Report	5	5								
	subtotal:	29	39								
9	Device Construct										
9a	Top Front Arm + Bracket	2	5								
9b	Top Rear Arm + Bracket	2	5								
9c	Bottom Arm + Bracket	2	2								
9d	All 3 Brackets + Frame	3	5								
9e	Take Dev Pictures	1	1								
9f	Update Website	2	0								
	subtotal:	12	18								
10	Device Evaluation										
10a	List Parameters	1	0								
10b	Design Test&Scope	2	0								
10c	Obtain resources	1	0								
10d	Make test sheets	3	0								
10e	Plan analyses	4	0								
10f	Mount Bike	1	0								
10g	Test Plan	10	0								
10h	Perform Evaluation	4	0								
10i	Take Testing Pics	2	0								
10h	Update Website	2	0								
	subtotal:	30	0								
11	495 Deliverables										
11a	Get Report Guide	2	0								
11b	Make Rep Outline	1	0								
11c	Write Report	10	0								
11d	Make Slide Outline	3	0								
11e	Create Presentation	1	0								
11f	Make CD Deliv. List	2	0								
11e	Write 495 CD parts	2	0								
11f	Update Website	1	0								
11g	Project CD*	2	0								
	subtotal:	24	0								
	Total Est. Hours=	208	208	=Total Actual Hrs							
Labor$	100	20800									

Note: Deliverables*

- Draft Proposal
- Analyses Mod
- Document Mods
- Final Proposal
- Part Construction
- Device Construct
- Device Evaluation
- 495 Deliverables

Project Management Risks

The main risk I see is welding the bottom arm being that its aluminum and it may take longer than the estimated time period to complete. Another risk is getting busy with work and other classes and start falling behind schedule and failing to catch up. I predict the testing and proposal will take the most time. This projects budget is low enough to fit well within my budget even if I end up going over my limit of 200 dollars it shouldn't be a big problem or risk.

7: DISCUSSION

The project has taken many changes during the design stages. I optimized the arms to be as long as possible while still be able to fold up and fit inside the frame when the bike is being ridden. My original design as seen in Fig A-14 had the top arms curve down at the ends to give more clearance but had to change to straight so they would fit inside of the frame. Any changes I made to the geography of the parts even small changes in SolidWorks forced me to redesign almost the entire part and then have to redefine the mates for the assemble files. This caused extra time and frustration being spent on the drawings and designing the parts in SolidWorks. Also any changes I make to the parts I have to chance or update my analysis so that it will match up with my designs. Plans to do a FEA using Autodesk Simulation Mechanical of the arms failed because the program keep freezing and I had to restart it from scratch after several hour of no success I finally gave up on the FEA and will try and do some next quarter during MET 495B. With the maturity of the design as shown in the drawings and original sketches, I'm very excited with a final design and can't wait to start the build and test process.

8: CONCLUSION

This project could help to motivate people to bike more cutting down on pollution and getting people to exercise more and be healthier. With our fast paced society having a simple built in bike rack allow people more freedom to ride their bike in unpredictable situations without the worry of how to get it from place to place when needing it transported by a car. For example, I like to ride my bike to work but when I get off its late and dark out and I would rather get a ride home with a coworker but then if I do that I have to leave my bike at work and then figure out a way to get it the next day. My device would solve this kind of problems for bicyclist everywhere and with a few modifications this device could be retrofitted to different bike frames as long as the arms sit fit inside the frame.

This project will be deemed a success if the bike rake can fold inside the frame when not mounted to the car and not affect the performance of the bike. Also the bike rack must be able to unfold and mount on a trunk easily while supporting the weight of the bike. The device must also weight under 5 lb which should be easy to accomplice since the total weight of the arms and brackets was calculated to be 3.43 lb and the deflection is calculated as 0.0491 inch well below the required max deflection of 0.125 inch. To achieve this project I need to staying on track and keep to a tight schedule.

ACKNOWLEDGEMENTS

I would like to thank Dr. Craig Johnson, Professor Pringle, and Professor Beardsley for their time and help by providing constructive feedback, resources, and helping this project along the way. Also would like the thank Central Washington University for teaching me and letting me use the machines in the machining shop and the welding shop and also for letting me use the computer lab to do all my SolidWorks drawing.

APPENDIX A – Analysis

Fig A-1 Dimensions of frame

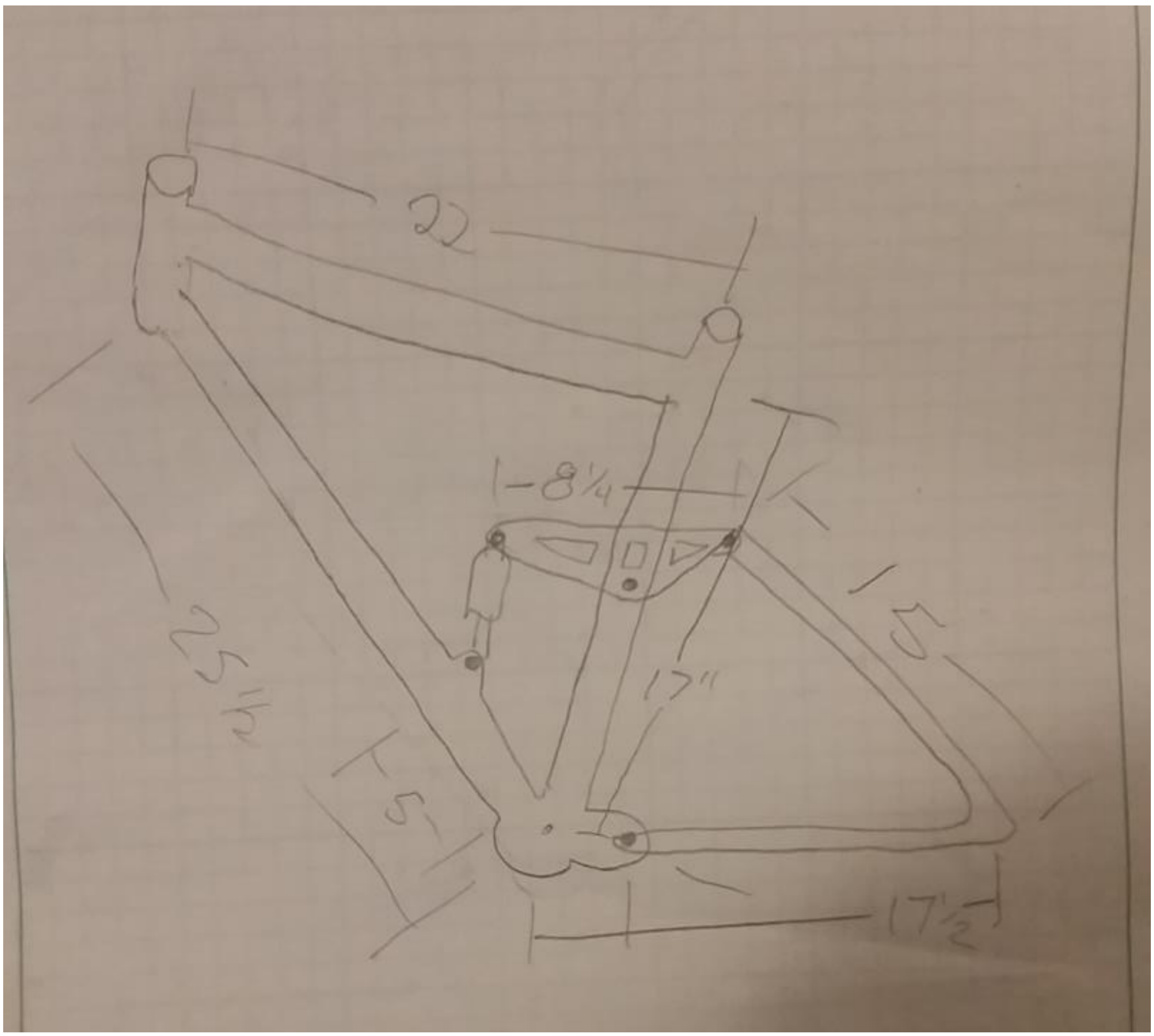


Fig A-2 Dimensions of Top and Bottom Arms

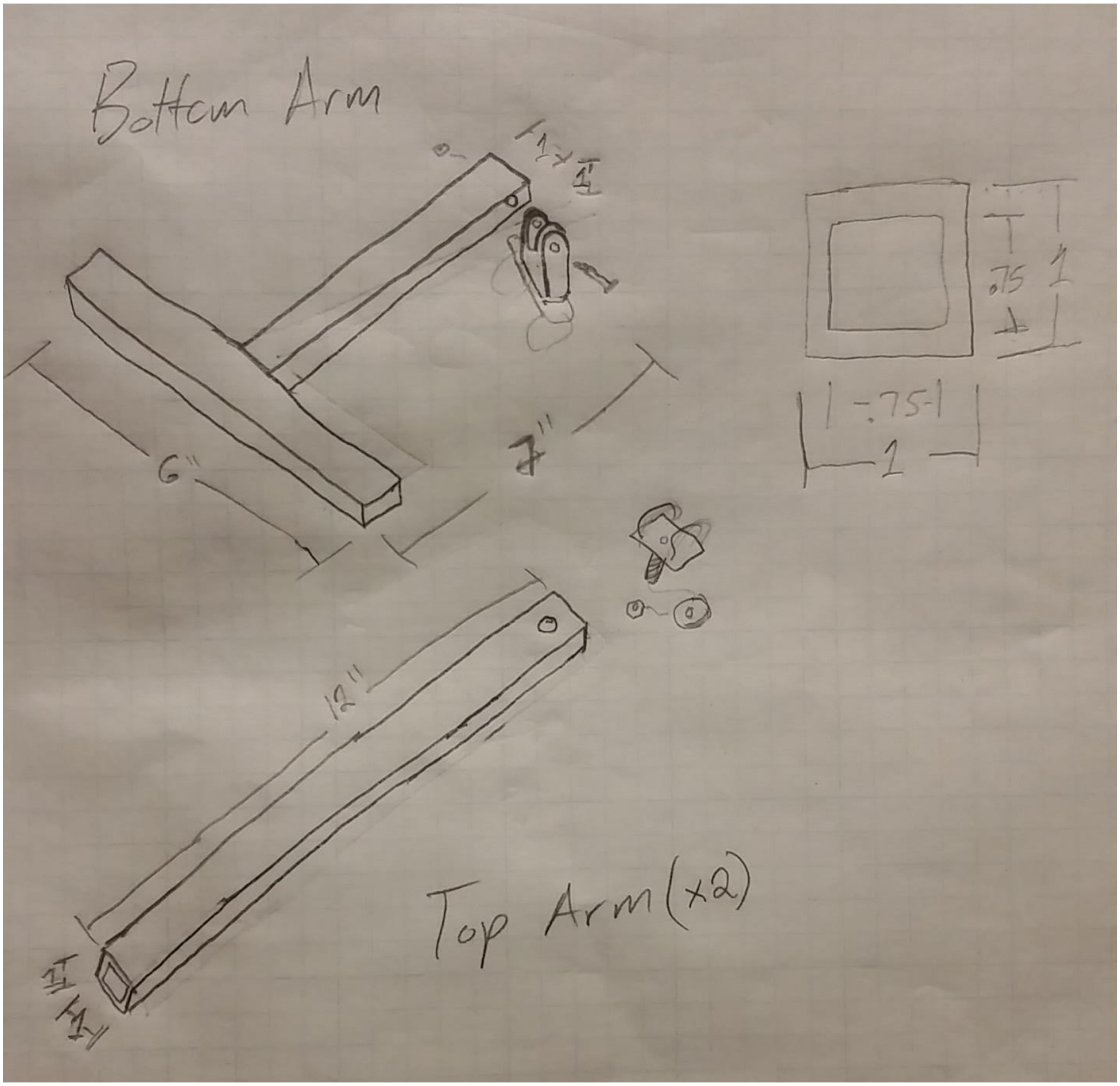


Fig A-3 FBD with straps

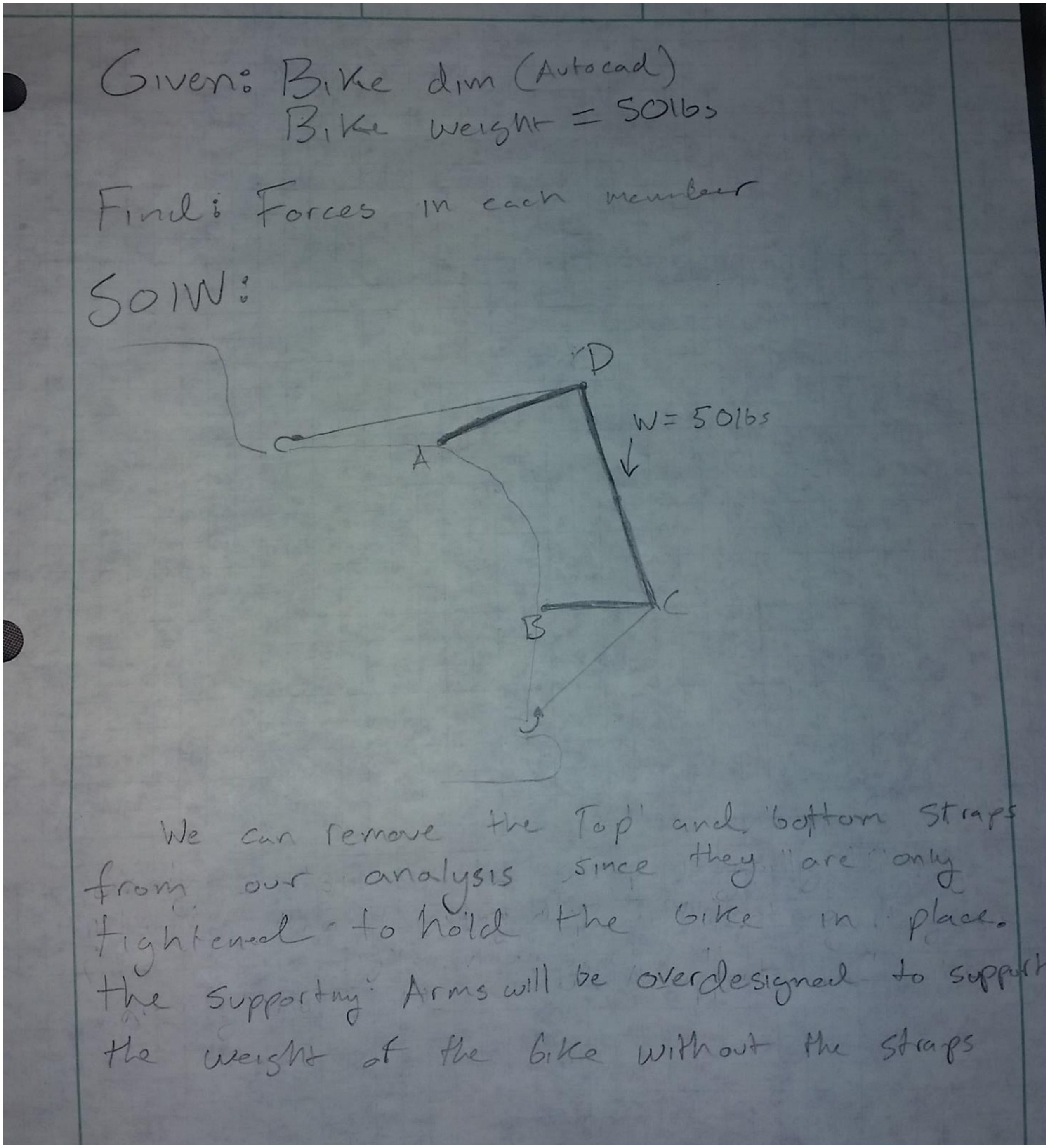


Fig A-5 FBD forces

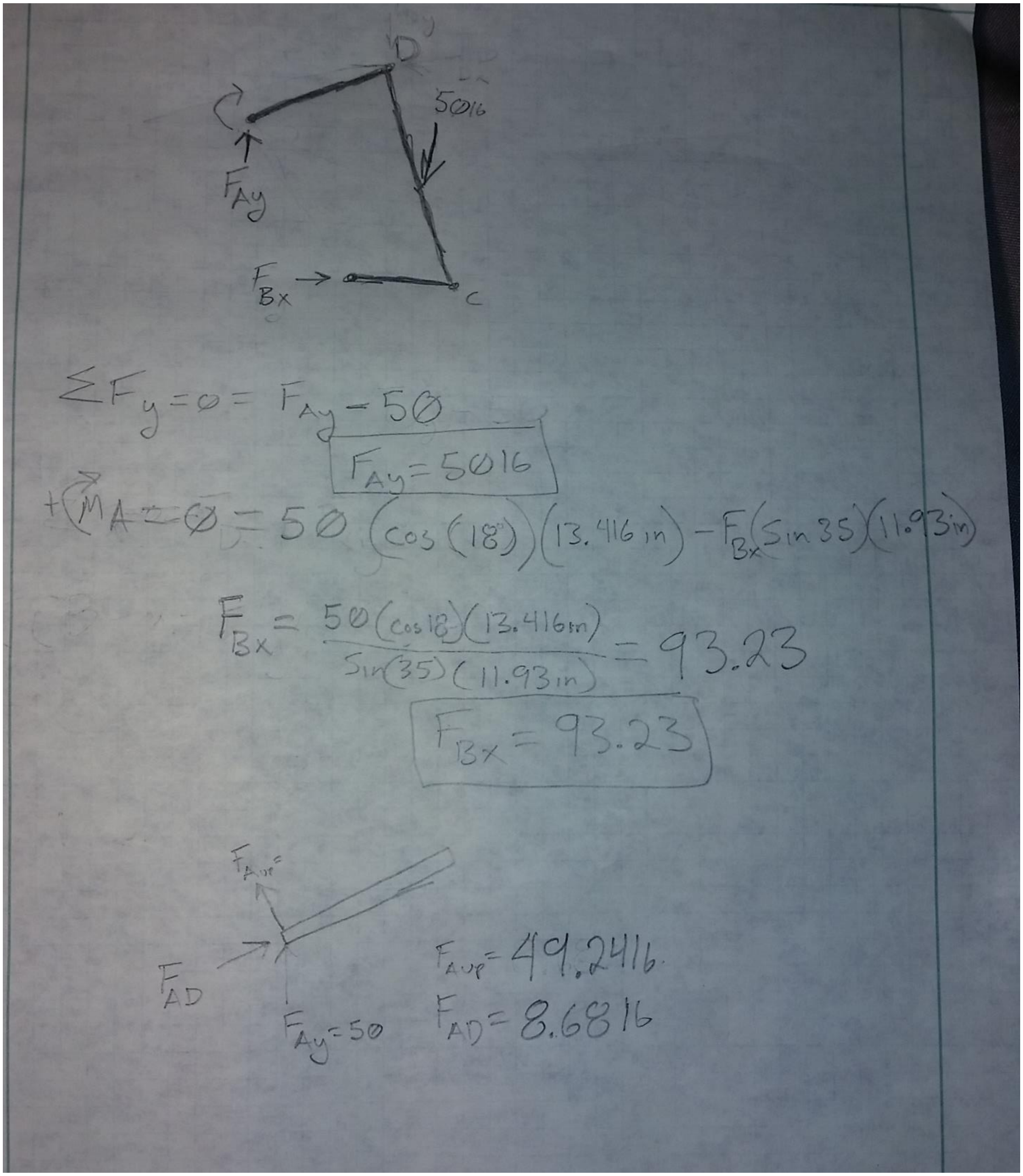


Fig A-5 Max Moment

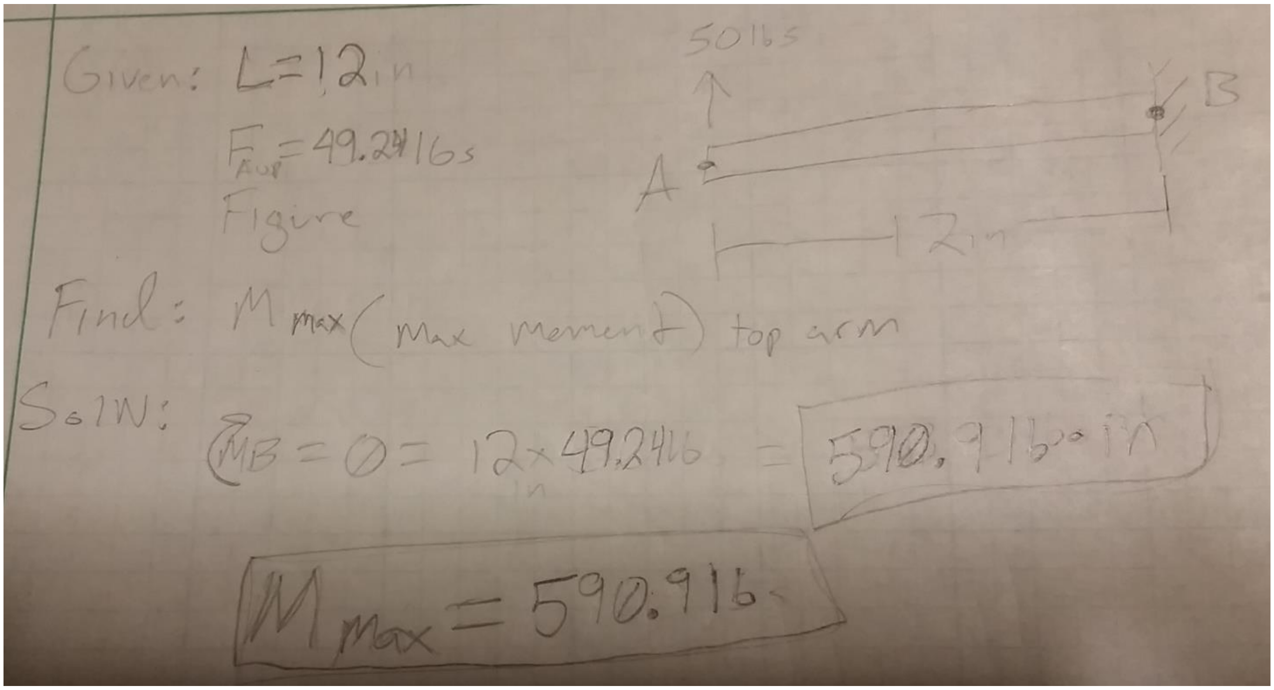


Fig A-6 Sectional Modulus

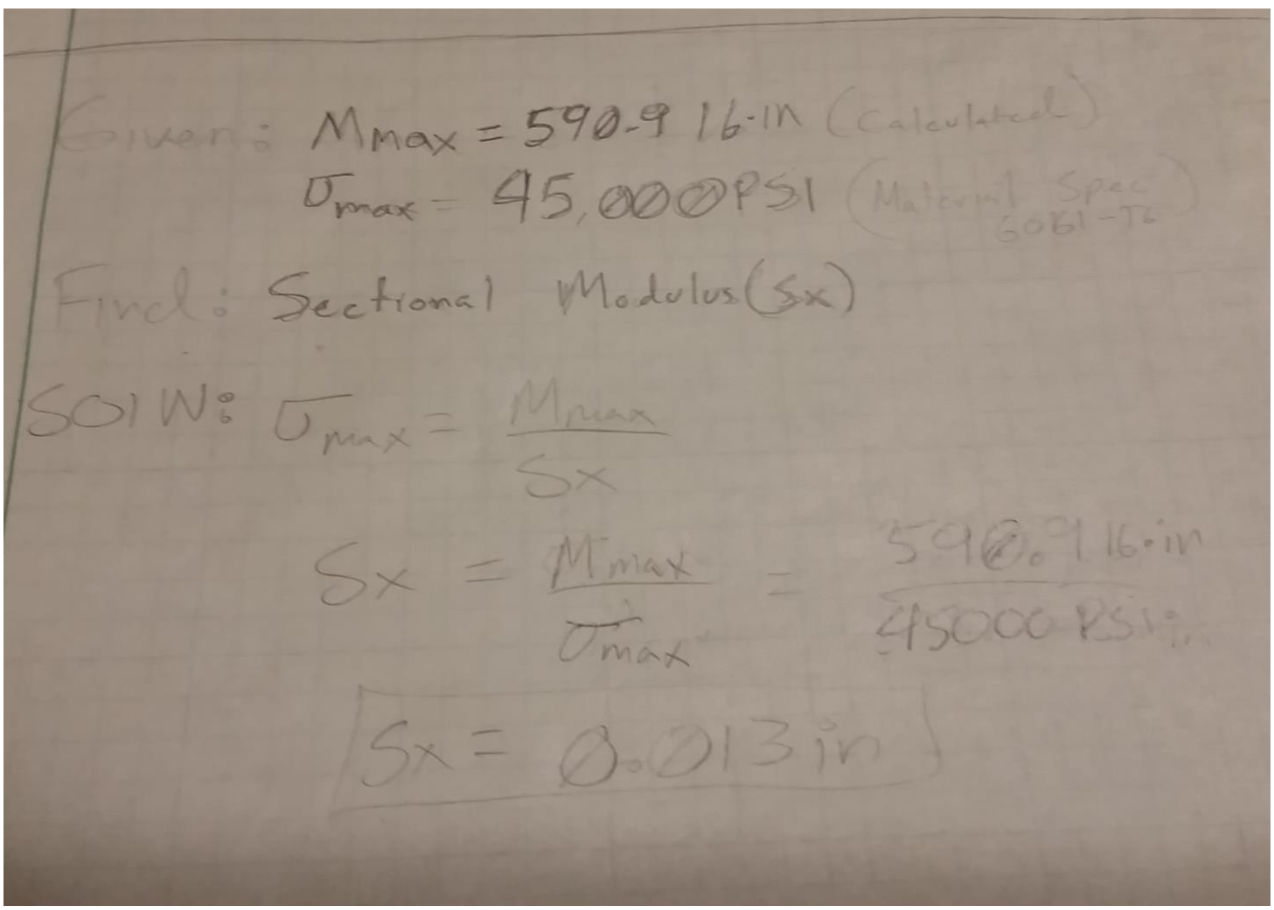
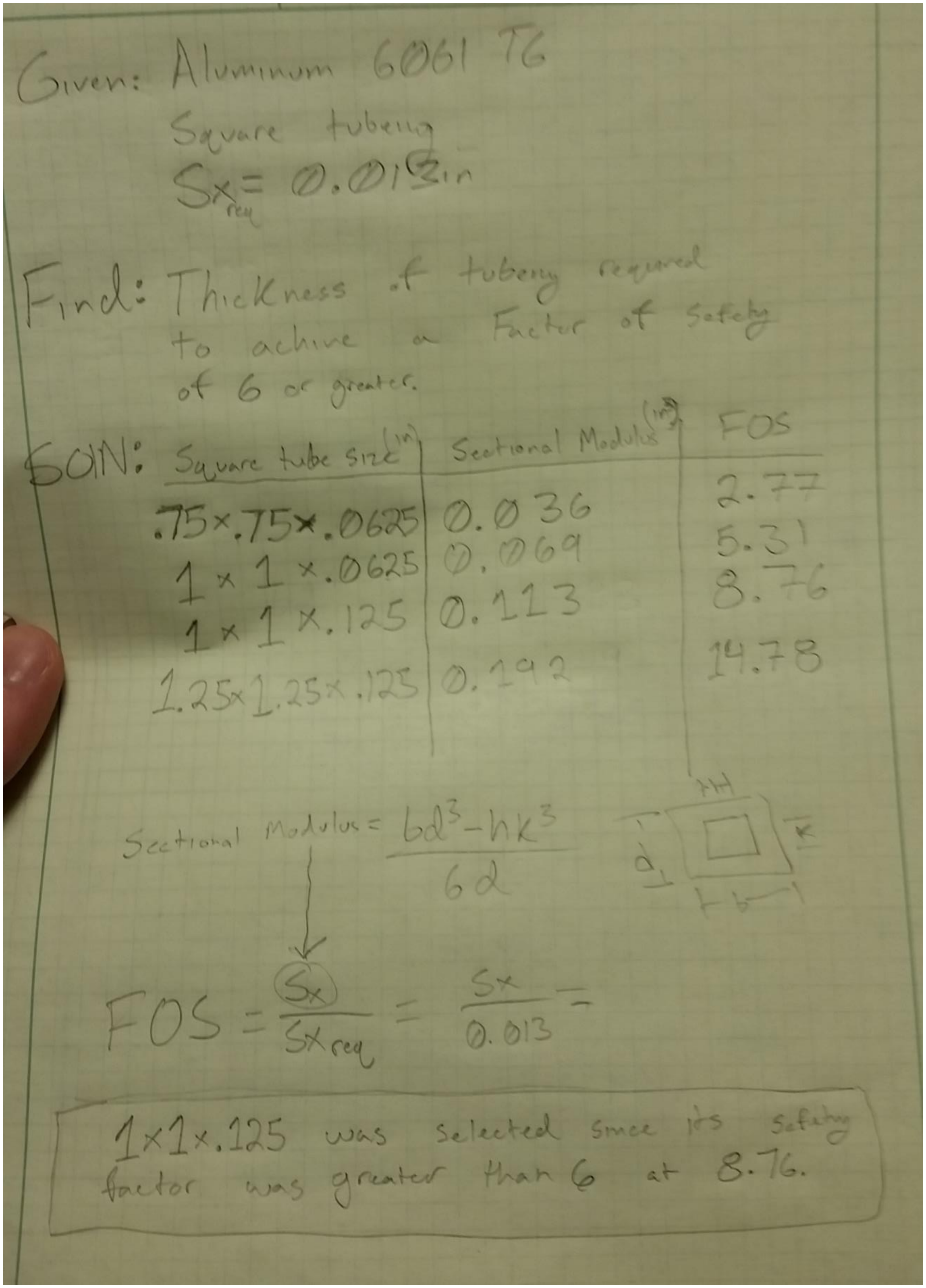


Fig A-7 Size Tubing Selection



Given: Aluminum 6061 T6

Square tubing

$S_{x_{req}} = 0.013 \text{ in}$

Find: Thickness of tubing required to achive a Factor of Safety of 6 or greater.

SOLN:

Square tube size (in)	Sectional Modulus (in³)	FOS
.75×.75×.0625	0.036	2.77
1×1×.0625	0.069	5.31
1×1×.125	0.113	8.76
1.25×1.25×.125	0.192	14.78

$$\text{Sectional Modulus} = \frac{bd^3 - hk^3}{6d}$$

$$FOS = \frac{S_x}{S_{x_{req}}} = \frac{S_x}{0.013} =$$

1×1×.125 was selected since it's safety factor was greater than 6 at 8.76.

Fig A-8 Average shear stress and bearing stress and allowable stress in top bolt

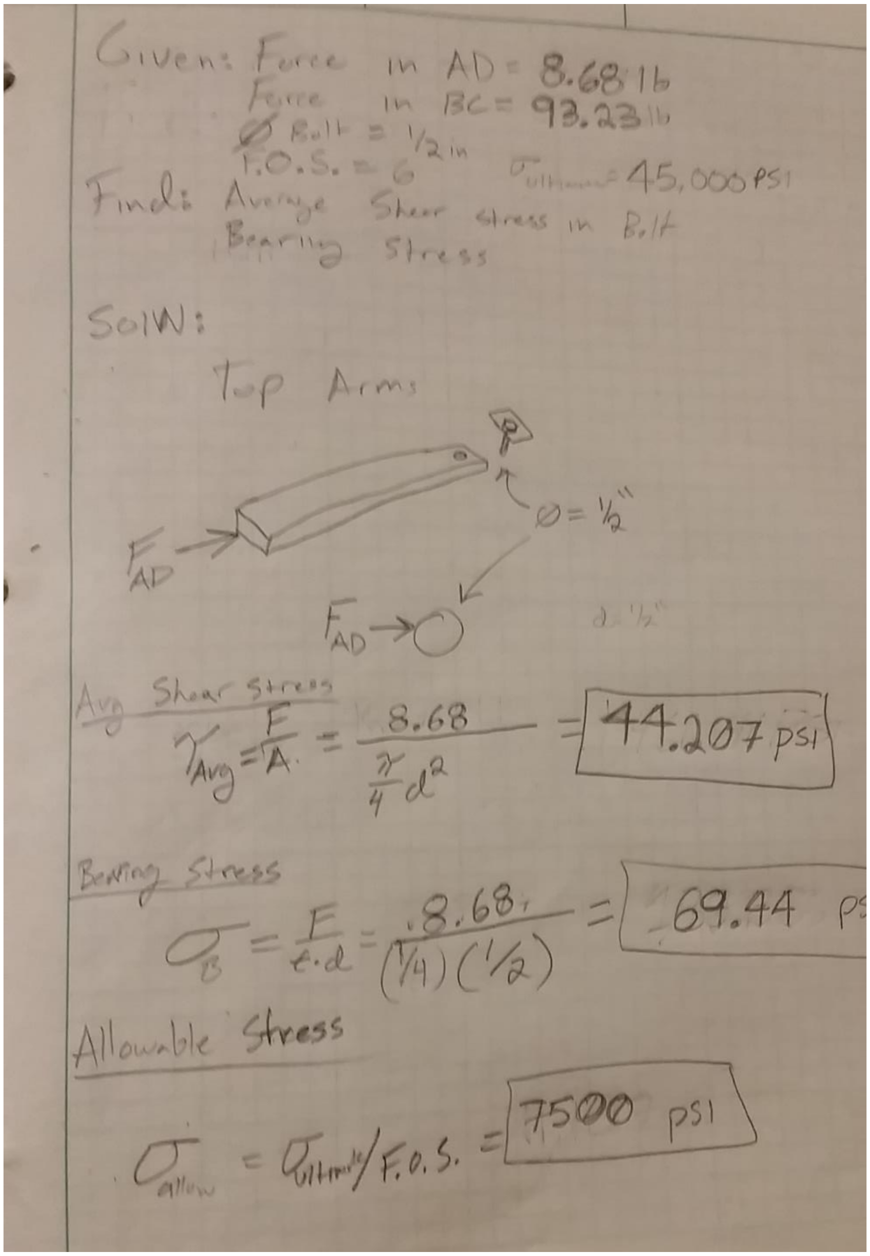


Fig A-9 Average Shear stress, bearing stress, and allowable stress in bottom bolts

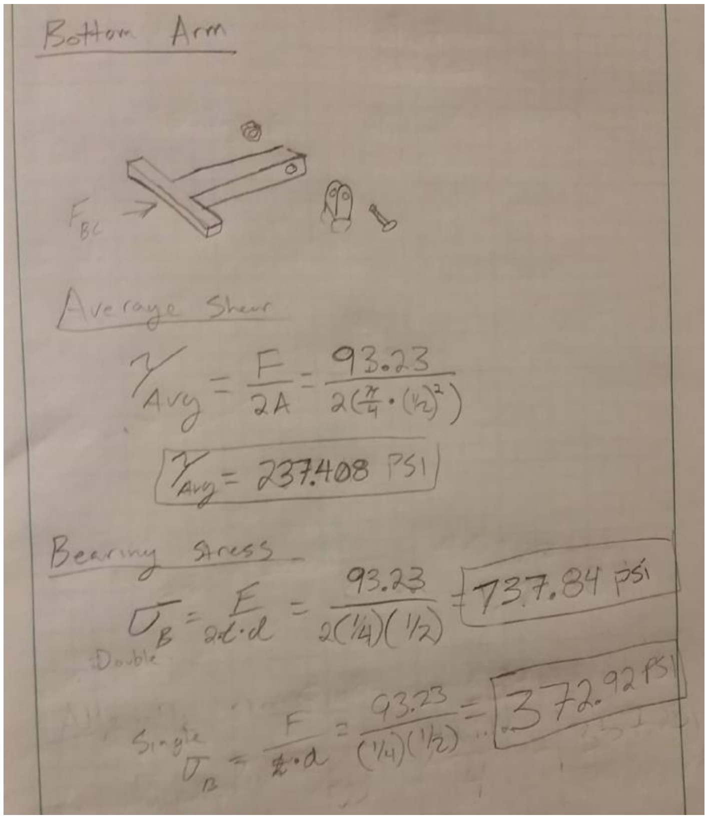


Fig A-10 Steel Plate Amount and Weight

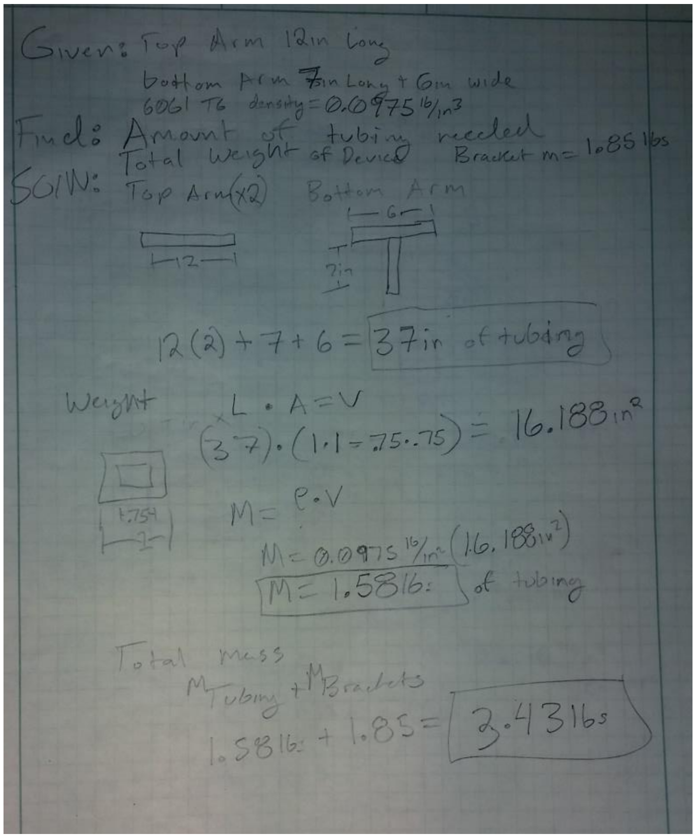


Fig A-11 Tubing Amount and Weight

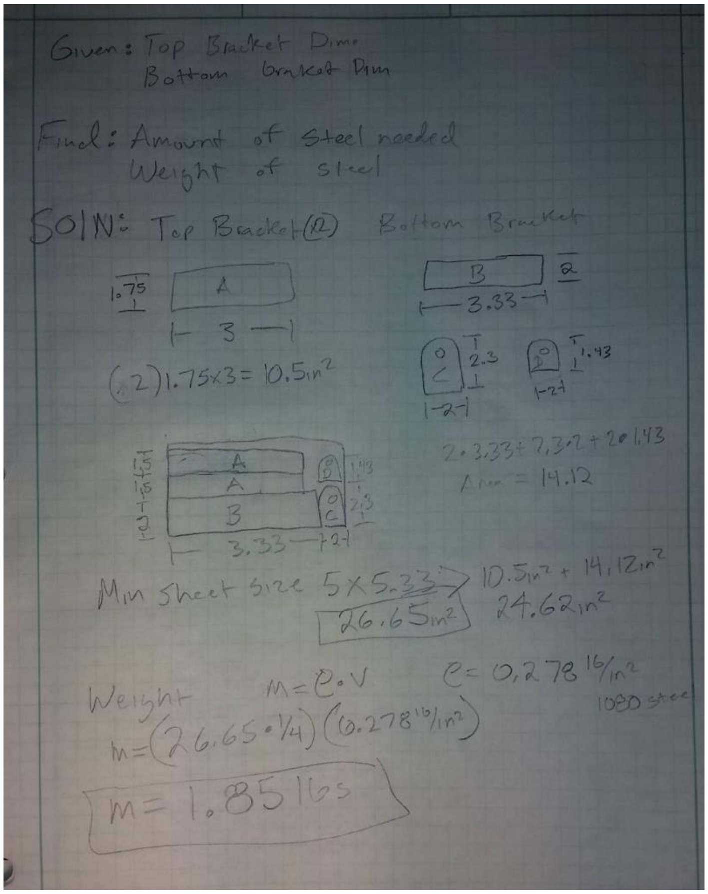


Fig A-12 Max Deflection

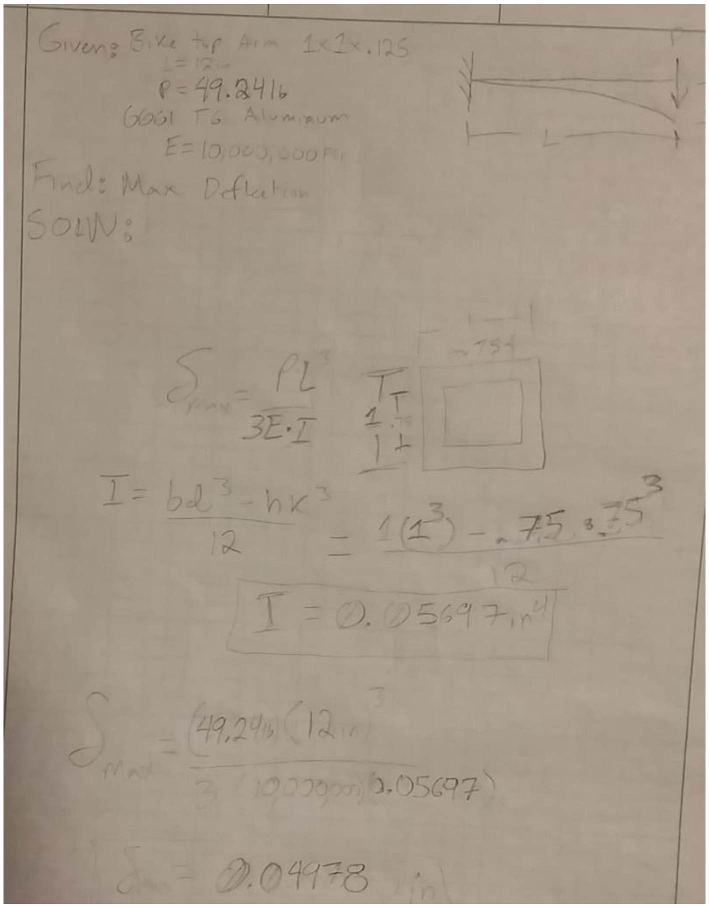
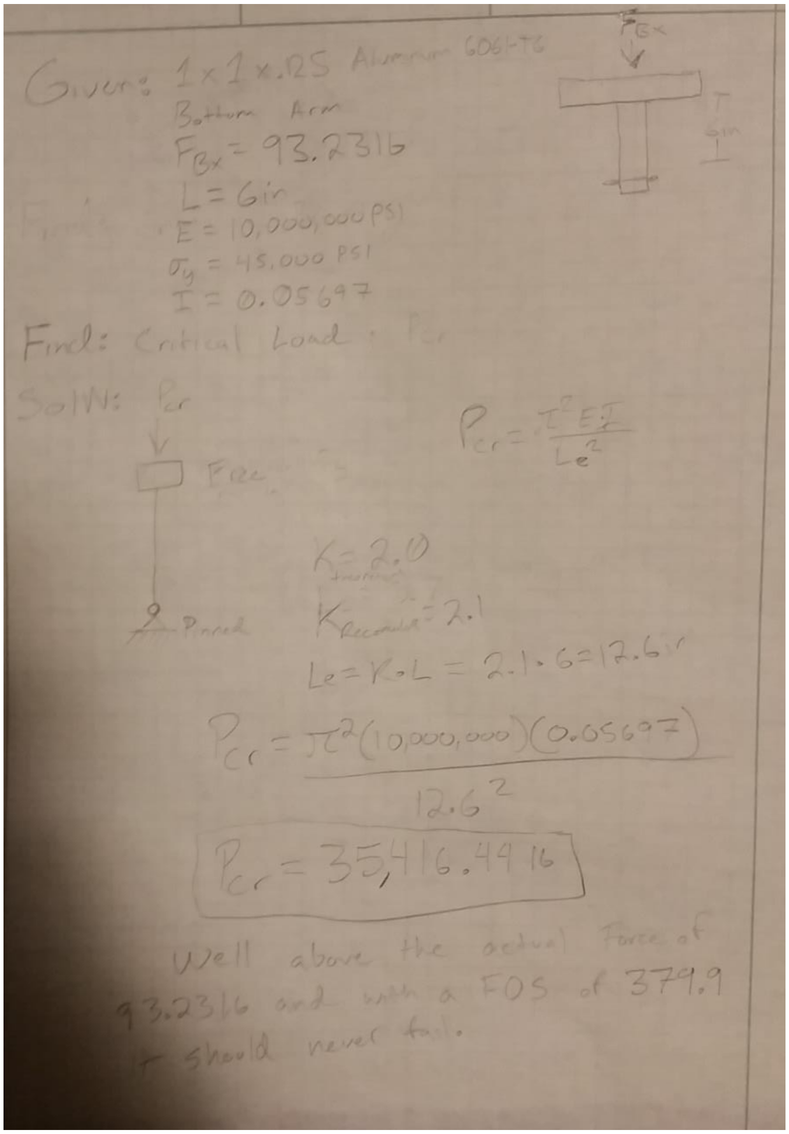


Fig A-13 Critical load on bottom arm


Given: 1x1x.125 Aluminum 6061-T6
Bottom Arm
$F_{Bx} = 93.23 lb$
$L = 6 in$
$E = 10,000,000 psi$
$\sigma_y = 45,000 psi$
$I = 0.05697$

Find: Critical Load: P_{cr}

Soln: P_{cr}

Free

Pinned

$$P_{cr} = \frac{\pi^2 E I}{Le^2}$$

$K = 2.0$

$K_{Recommended} = 2.1$

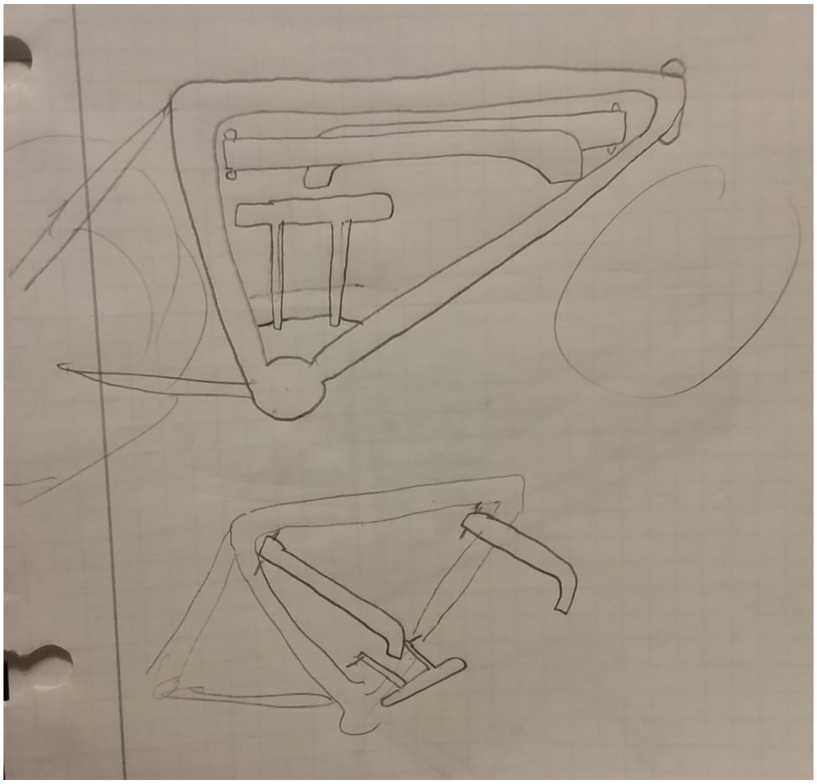
$Le = K \cdot L = 2.1 \cdot 6 = 12.6 in$

$$P_{cr} = \frac{\pi^2 (10,000,000)(0.05697)}{12.6^2}$$

$$P_{cr} = 35,416.44 lb$$

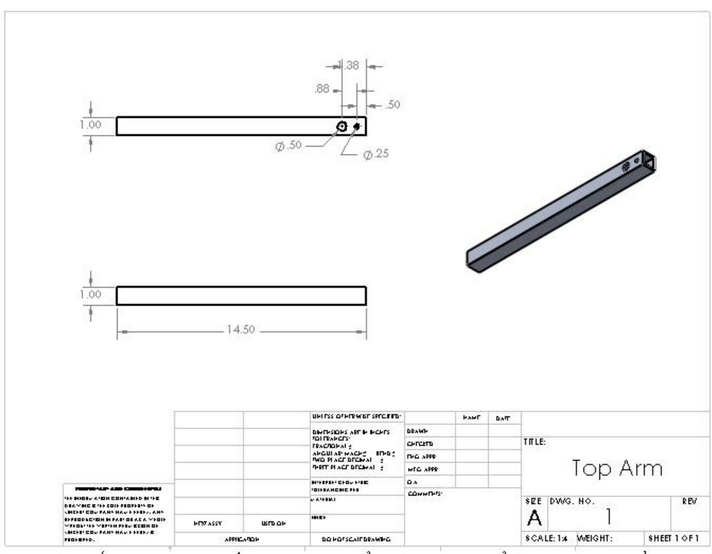
Well above the actual force of 93.23 lb and with a FOS of 379.9 it should never fail.

Fig A-14 Original Design

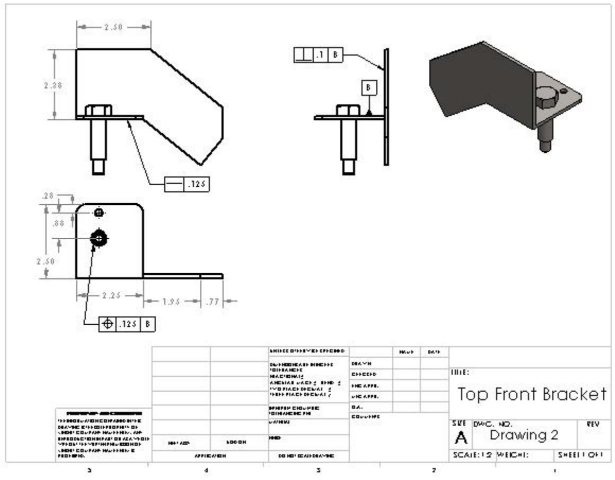


APPENDIX B – Drawings

Drawing 1 – Top Arm

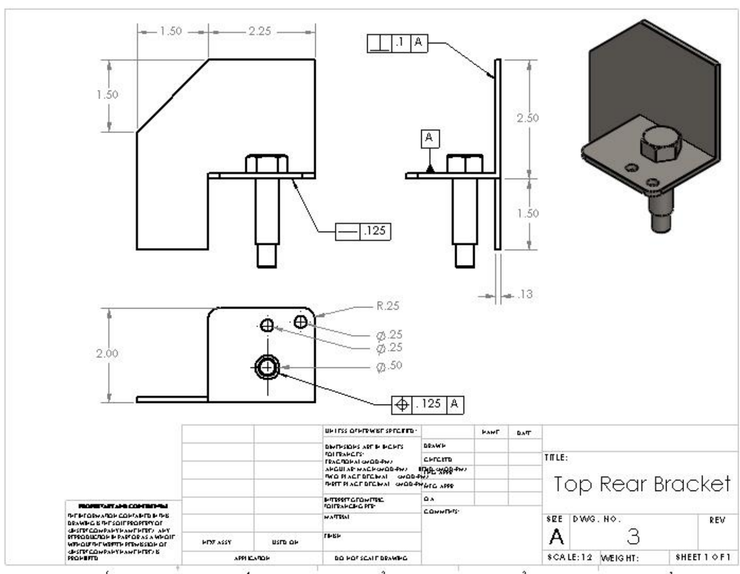


Drawing 2 – Top Front Bracket

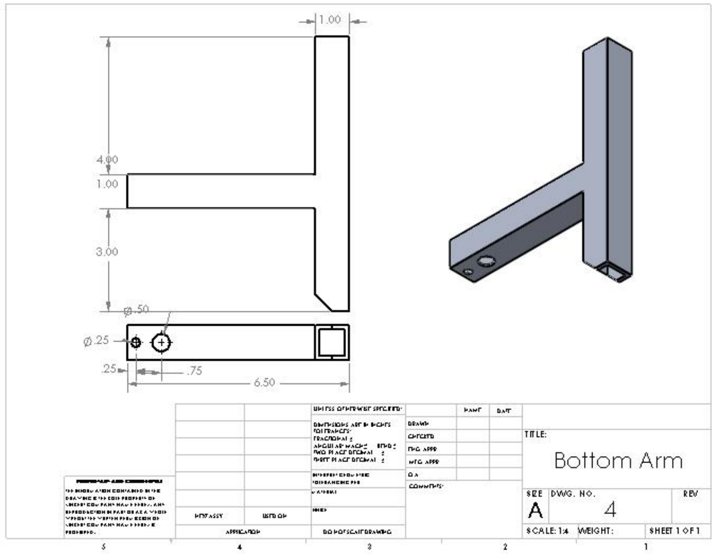


⊕ .125 A

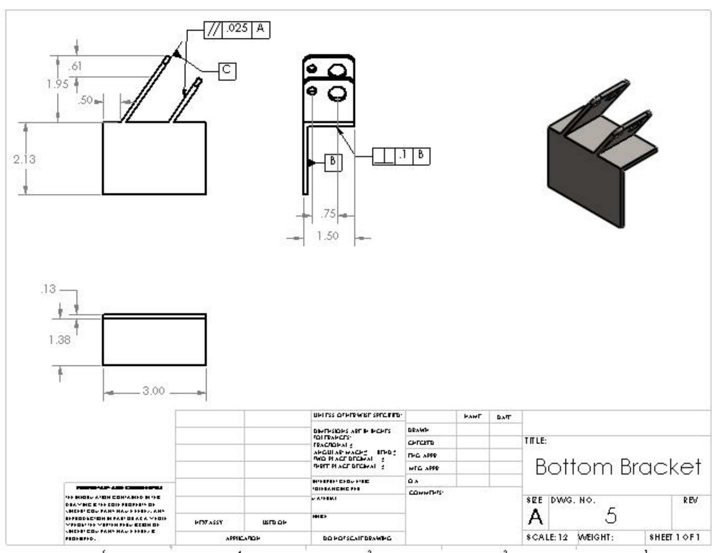
Drawing 3 – Top Rear Bracket



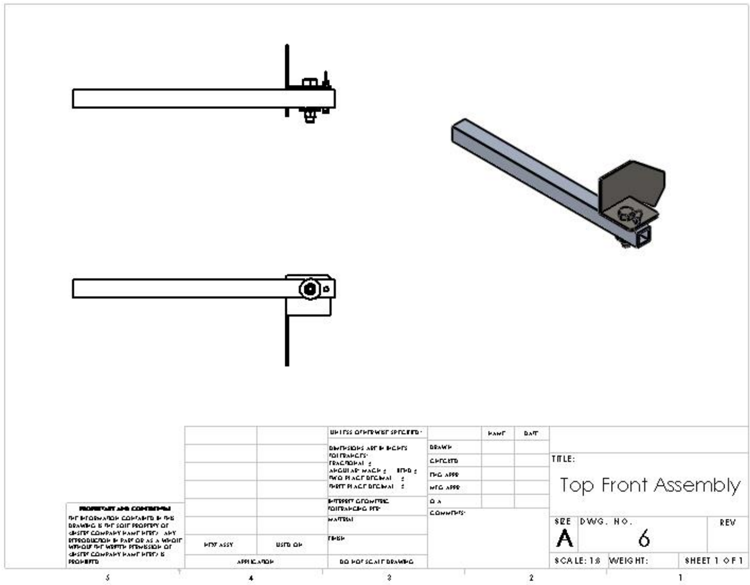
Drawing 4 – Bottom Arm



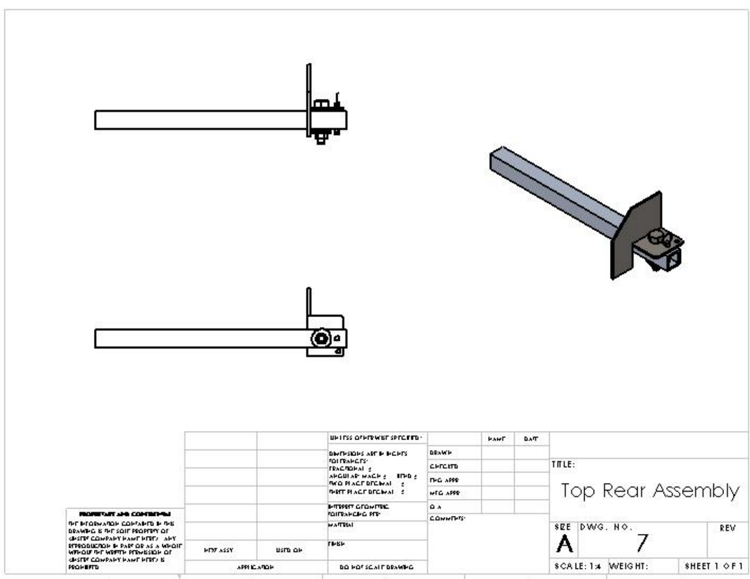
Drawing 5 – Bottom Bracket



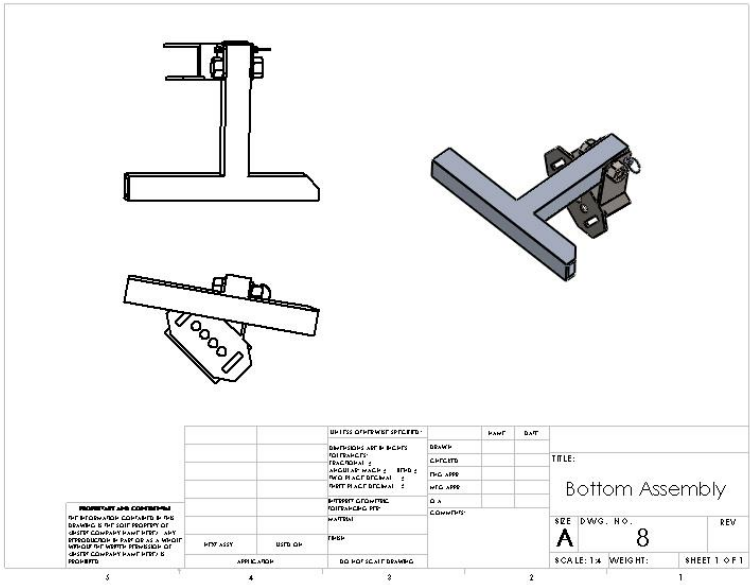
Drawing 6 – Top Front Assembly



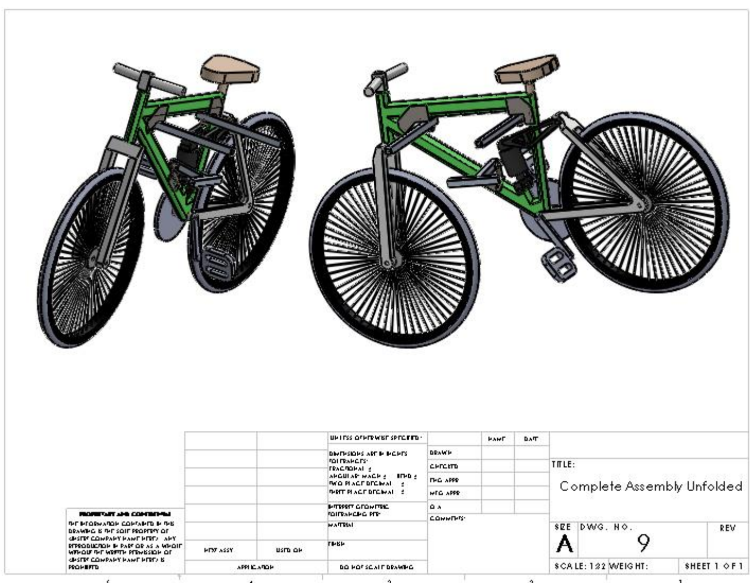
Drawing 7 – Top Rear Assembly



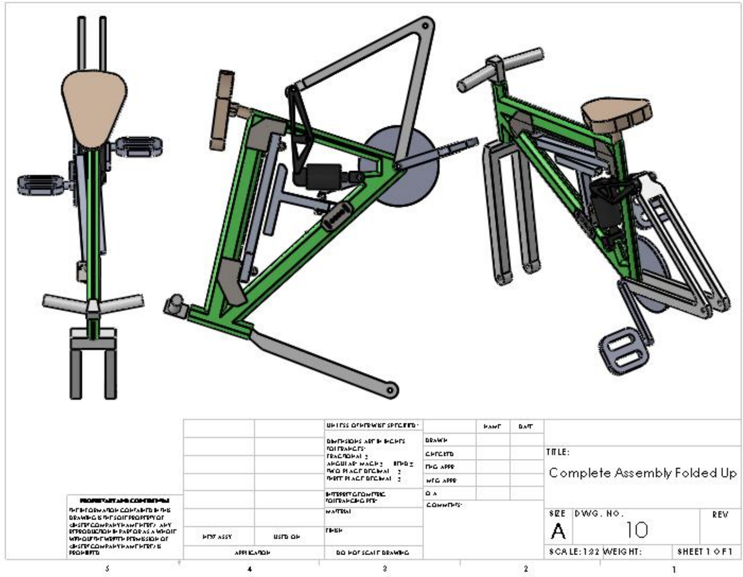
Drawing 8 – Bottom Assembly



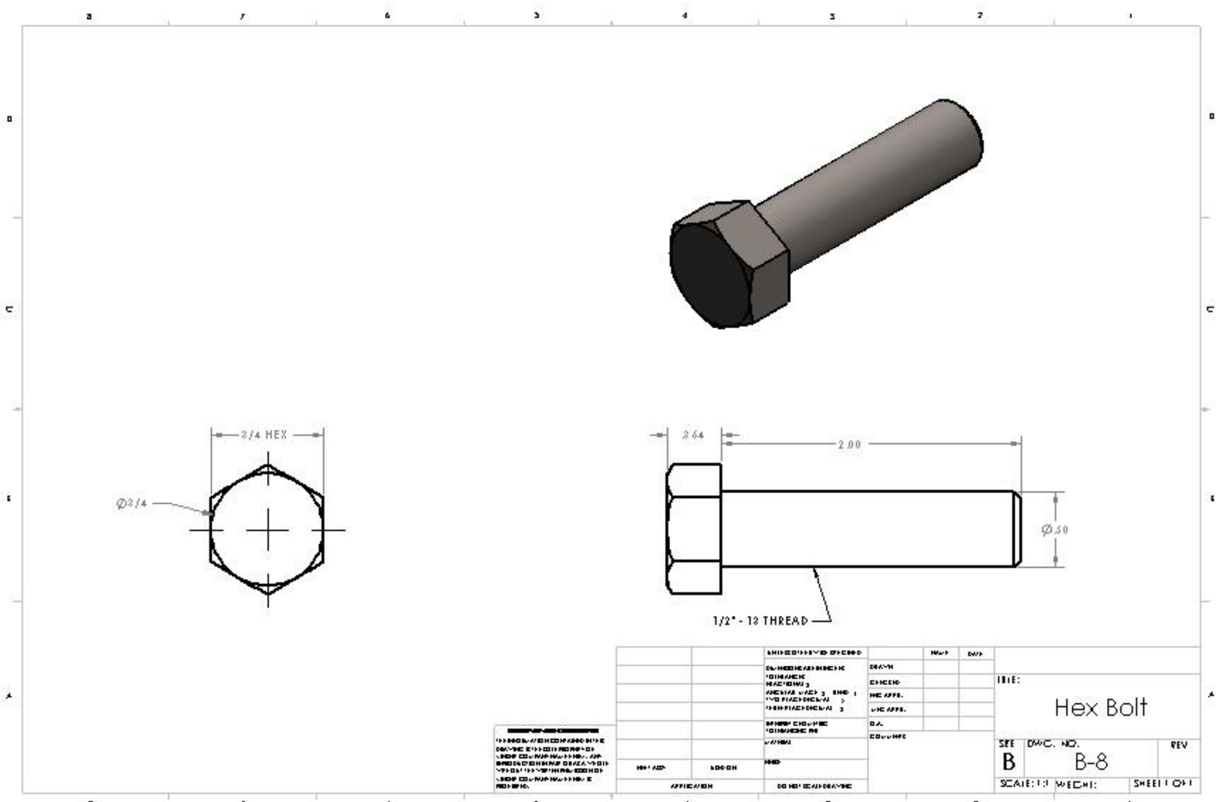
Drawing 9 – Assembly Complete Unfolded



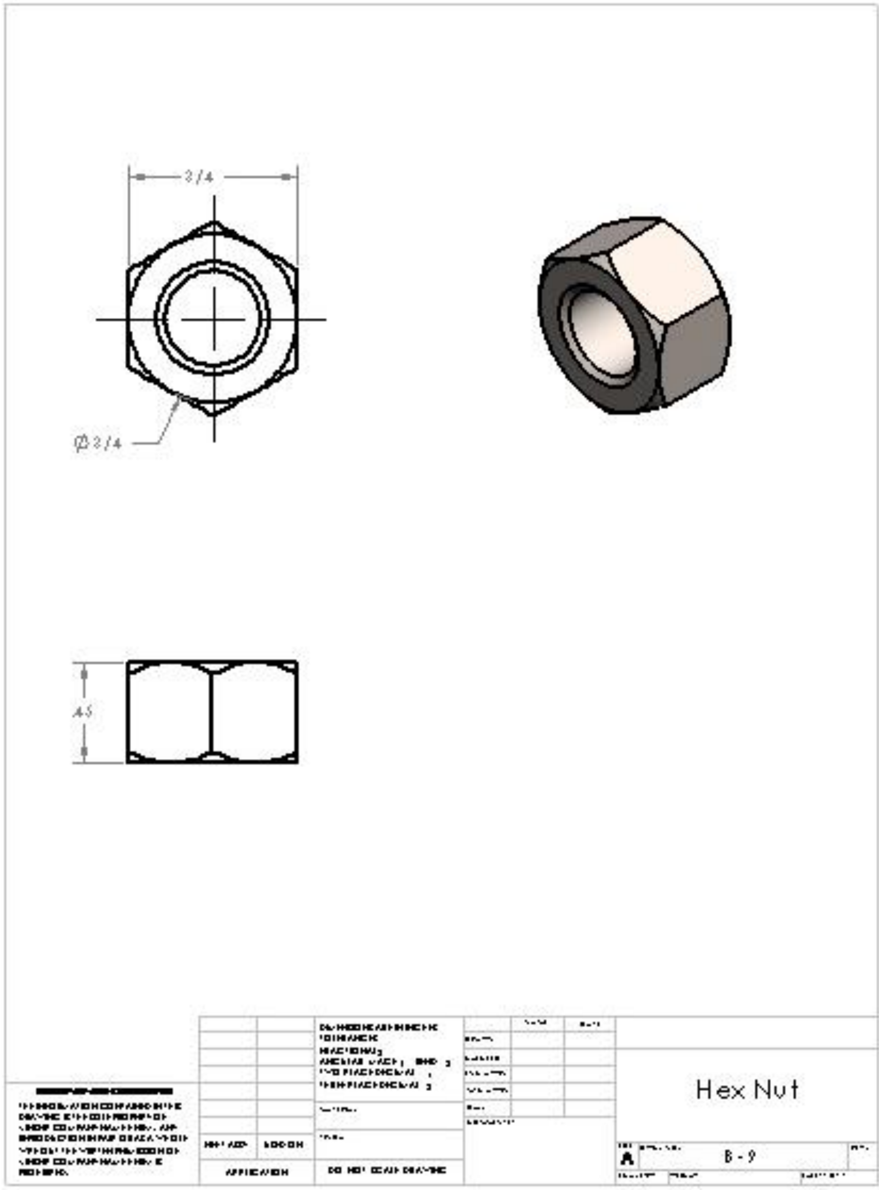
Drawing 10 – Assembly Complete Folded up



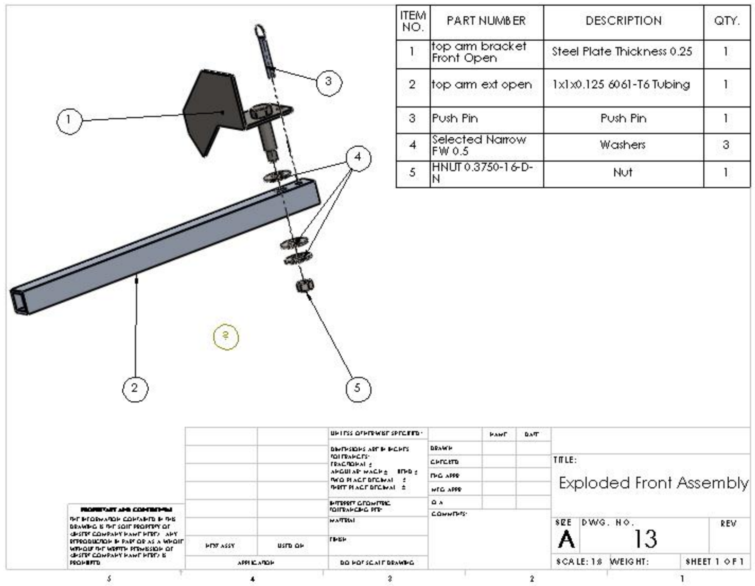
Drawing 11 - Hex Bolt



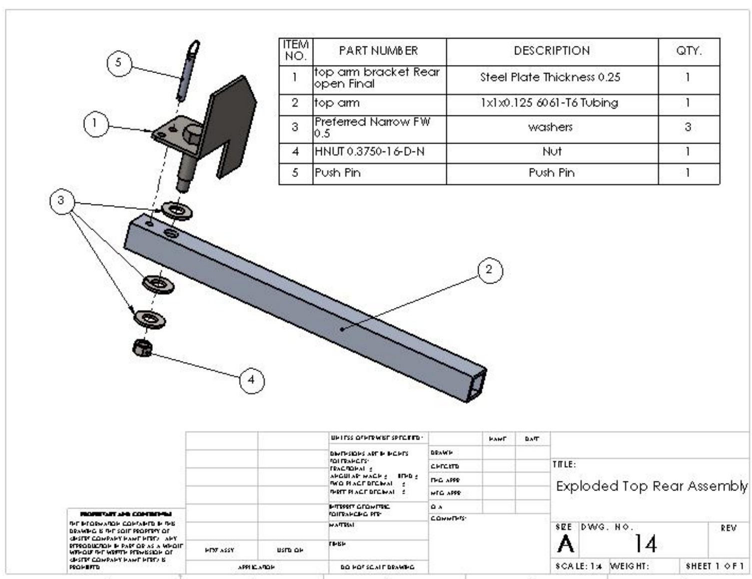
Drawing 12 – Hex Nut



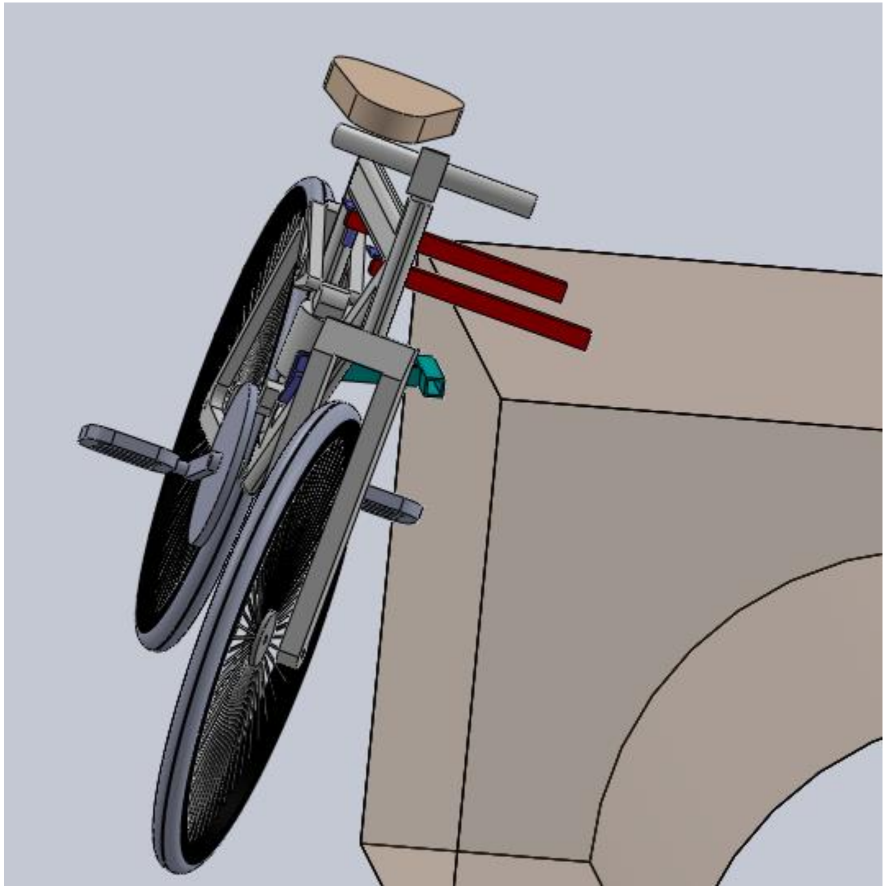
Drawing 13 – Exploded Top Front



Drawing 14 – Exploded Top Rear



Drawing 15 – Bike Mounted on Trunk



APPENDIX C – Parts List and Costs

Part Identification	Part Description	Source	Cost	Disposition
6061 aluminum	1x1x.125 tubing 48inch long	http://www.metalsdepot.com/	$32.56	
Straps	Saris bones 3 complete replacement strap kit	http://www.outsideoutfitters.com/	$29.99	
Shoulder Bolts	½ diameter x3	Local Hardware store	$3.24	
½ x 2inch bolt	½ x 2inch bolt	Local Hardware store	$1.09	
Washers	½ diameter x4	Cost Total:	$55.23	
Foam tubing	1 in. x 6 ft. Foam Pipe Insulation	Local hardware store	$1.99	
Steel Plate	A36 1/8" thick 6"x12	http://www.ebay.com/	11.00	
		TOTAL COST=	124.10	

APPENDIX F – Expertise and Resources

Central Washington University resources include access to computer lab, machine shop, and professor knowledge and insight.

APPENDIX G – Evaluation sheet (Testing)

APPENDIX H – Testing Report

APPENDIX I – Testing Data

APPENDIX J – Resume

Scott Hansberry

801 E 18th AVE #23, Ellensburg WA
(253) 217-3555
Hansbesc@cwu.edu

Education

Central Washington University 2009 – In progress

- Degree – Mechanical Engineering Technology – Spring 2016

Green River Community College 2008 - 2009

- Degree – Associate in Arts – June 2009

Whatcom County Community College 2006 - 2008

- Worked towards AA degree.

Kentwood High school

- Graduated Senior year – June 2006

Skills

• SolidWorks and AutoCAD • Customer Service and Cash Register	• Mechanically gifted • High Technical and Math Skills

Work History

Kabob House September 2015 to Current
Duties: Manage kitchen staff, prep and cook food, and open and close restaurant.
Supervisor: Husain
(509) 901-1627

Quality Inn September 2014 to May 2015
Duties: Maintenance throughout hotel, pool, and landscaping.
Supervisor: Thonna Bodi
(509) 925-9800

Automobile Rebuilding Summers, 2010 thru 2014
Worked for father's side business rebuilding cars for re-sale. Work and skills obtained include engine removal/rebuilding, brake work, welding, complete auto body painting and detailing as well as regular maintenance. Main focus for 2014 was two 1967 Mustangs, but have also worked on various makes and models of automobiles.

King County Parks July thru October 2008
Duties: Parks Maintenance, landscaping, mowing, and cleanup.
Supervisor: Kirsten Chapmen

(206) 423-6374

Fed Ex July thru September 2007

Duties: Sort and load packages for deliveries.
Supervisor: Geoff Dunning
(253) 508-5124

Pizza Hut May thru September 2006

Duties: Cooking, customer service, cash register, telephone duties.
Supervisor: Matt Springer
(425) 227-9999