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RC Baja Car Suspension

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R/C Baja Car Suspension

By

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MET 489
2017-2018

Contents

INTRODUCTION

Motivation:

An R/C Baja car must be created in order to compete in the 2018 R/C Baja Competition, and meet all the mandatory requirements for said competition. The car may be optimized to have strengths in any or all of the three styles of races: slalom, drag, and off-road. A team of two will be working together to complete this project and to abide by the ASME Competition Rules.

Function Statement:

A suspension must be designed and created so that parts can integrate without interfering with each other. Additionally, the car will be optimized so that it can drive even if flipped over. Steering must be optimized to efficiently maneuver through each of the courses during the competition.

Requirements:

The vehicle must be designed to meet each of the following requirements:

- Suspension must support up to 6 pounds upon a 2 foot drop without aid of a chassis
- Shock absorption system must be designed to damped the force of a 2 foot drop for at most a 6 pound car
- Suspension must have at least 1 inch of travel
- Steering system must articulate fully without interfering with any other parts
- Body of car must fit within the diameter of the wheels so that it may be driven if flipped upside down
- Steering must allow for a 5 foot turn diameter
- System must be fastened together with easily sourced fasteners

Engineering Merit:

The engineering merit for this project will come from designing a vehicle that will function properly and abide by all competition guidelines. Design parameters will be quantified and analyzed using the knowledge achieved through the courses taken at Central Washington University. For example, any fasteners used in the project had to be analyzed to determine if they were going to shear under any forces acting on the vehicle. Further merit can be found in the Analysis section.

Scope:

At the end of this school year, the goal is to have a fully-functioning, 1/10th scale RC Baja car. This proposal will focus on the design of the car's suspension with additional emphasis on the steering. The other member of the team will focus on the drivetrain, which will affect the design requirements of the suspension and steering. During Fall Quarter, the project will undergo design and analysis, as well as planning and budgeting, and end with a submitted proposal. Winter Quarter will consist of construction and redesign, and Spring Quarter will involve testing and presenting the project.

Success Criteria:

If the car is able to compete in the 2018 Baja Competition, and abides by all rules, then it will meet the success criteria. The car will race in the three events without any failures and finish the competition while still operational.

DESIGN & ANALYSIS

Approach:

Design began with research on the many different types of suspensions on stock R/C cars. Most used a system involving various arms, links, and shock towers, so this was the natural starting point for the design process. Analysis was done to determine the spring constant that would be needed in a shock-absorber (which can be found in Appendix A), but this data was rendered moot after the subsequent design overhaul. This overhaul included using a leaf-spring system rather than a shock tower system for the suspension.

Design Description:

With two other R/C cars being designed with the shock tower, the team decided that it would be more unique to use a leaf spring design rather than a shock tower system. This opened up a whole different world of calculations and design aspects to consider. After discussing ways to optimize our design, the final decision was made to try and create an R/C car that can be driven safely while upside-down as well as right-side-up. It was paramount to attempt to use as many spare parts as possible that the team could find in the Mechanical Engineering Department on CWU's campus. This would cut back on cost and allow measurements to be made more easily.

A typical suspension usually consists of an A-Arm design which connects the wheel hub or steering knuckle to the chassis of the vehicle. The vehicle being built here will not be using and A-Arm system, rather the leaf spring itself will act as the lower A-Arm component and connect the wheels to the chassis using a different configuration than the typical R/C car. The end of the leaf spring will connect to the wheel carrier which will also house the steering knuckles and drive shaft. Upper mounts will be added which will further support the wheel carriers in both the front and rear of the car.

The vehicle was originally supposed to have four-wheel drive, which altered the design in a big way. A belt would have run along the length of the chassis from front to rear axle. The differentials would be housed above the leaf springs on both ends of the vehicle, and each wheel would have a driveshaft. The steering system function was to weave its way between the belt drive in order to function properly. This gives only around one inch of clearance, so this design was interesting to finalize. Unfortunately, this design aspect became too much to try and fit due to parts being back ordered and being the incorrect size.

A servo will power the steering linkages connected through the belt drive. It will be mounted on the chassis of the vehicle and apply the force needed to turn the wheels left and right. Linkages will need to be pinned at different locations on the chassis to allow the inside wheel greater turning angles and achieve the required 5 foot turn radius.

Benchmark:

This type of design with a leaf-spring system has been used in previous years for the R/C Baja Competition. A benchmark will be established using one of these models. Other vehicles from online retailers can provide a benchmark as well, though since these are professionally made vehicles that benchmark is a high one to achieve for this project.

Suspension Analysis:

Analysis started with determining how much force would be applied to a single side if the RC car were to fall from a worst-scenario 2 feet. The car has an estimated maximum weight of 6 pounds. Using this data, a force was determined using energy equations and force equations using spring constants. This force will be applied to the leaf spring suspension, so using energy and force equations with spring constants was applicable. With a given maximum deflection of 1.5 inches, the force from a two foot drop was 192 pounds force. Since there are two sides (front and back) to the leaf spring suspension, each side will have a 96 pounds force impact after the two foot drop (see Figure 1 in Appendix A).

With this information, the length of the leaf spring suspension could be calculated. The leaf spring will consist of three layers of spring steel at 0.025 inches thick per layer and 1 inch wide. The spring's length was determined using cantilever beam deflection. The maximum deflection was the same as before at 1.5 inches. As a result, the length of the spring from the pinned point at the center to the wheel where the forces were applied is 3.66 inches. This equates to an overall length of 7.32 inches, and the team decided to round to an even 7.5 inches for added simplicity (see Figure 5 in Appendix A).

After finding appropriate material in the machine shops on CWU's campus, the leaf spring layers were to be made with spring steel that was 0.039 inches thick instead of the suspected 0.025 inches. This adjusted how many layers would be needed. After some tinkering with the calculations that were made in the same analysis as above (Figure 5 in Appendix A), the team could finalize the design with two layers of spring steel rather than three.

A suitable fastener had to be selected for the attaching the leaf spring to the chassis. The set screw had to be made of stainless steel and have a diameter wide enough to withstand the force from a 2-foot drop as determined above. Using the allowable stress determined with a safety factor of 2, dividing the load by the cross sectional area was the equation used. The diameter of the screw could be solved with this equation, and it was determined to be 0.087 inches (see Figure 6 in Appendix A). This represents the minimum diameter needed to achieve a safety factor of two, so the team decided on #6 machine screws, which meet the minimum requirement.

In the proposal for the drivetrain, it is stated that the car is required to achieve a top speed of 20 miles per hour. Given this, a maximum impact force could be calculated for a 6 pound vehicle hitting a wall and coming to a stop. Using the equation for force being equal to the mass multiplied by the change in velocity, a maximum force of 586 pounds force per wheel was determined (see Figure 7 in Appendix A).

The upper mounts had to be able to withstand any forces that the wheels have to go through. The team decided to make them out of ABS plastic with a rapid prototyping machine. As a result, the mounts are not as strong as they could be if made from a stronger material. Early spring quarter will likely consist of machining new mounts that can withstand the same forces as the leaf spring layers.

Steering Analysis:

The first step in designing the steering system was to find the angle for the steering arm. This was found using calculations from this proposal as well as the drivetrain proposal. The length of the suspension was found to be 7.5 inches from wheel to wheel, and from the drivetrain data the length from axle to axle will be 15 inches. With this data, the angle of the steering knuckle was determined using tangent functions to be 76 degrees (see Figure 8 in Appendix A). After finding this angle, it was used to equate the Ackerman angle, which represents the difference between the inside and outside wheel angles when making a turn. With a required 5-foot turn radius, these angles were determined using SolidWorks for assistance.

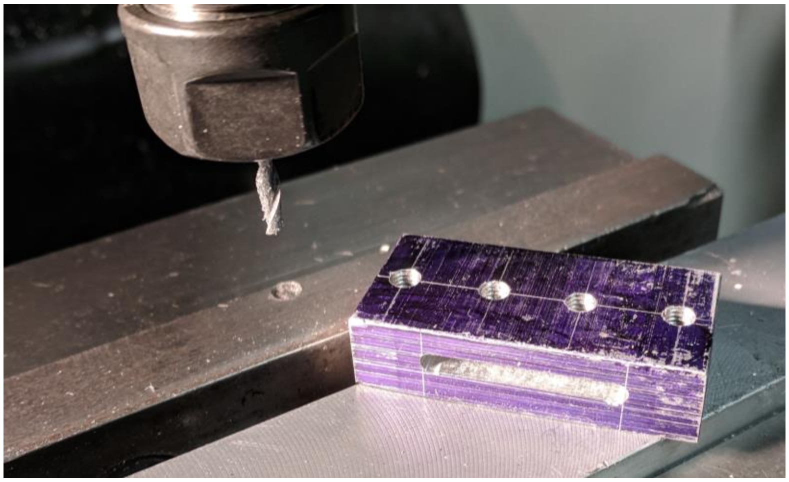
METHODS & CONSTRUCTION

Methods and Construction:

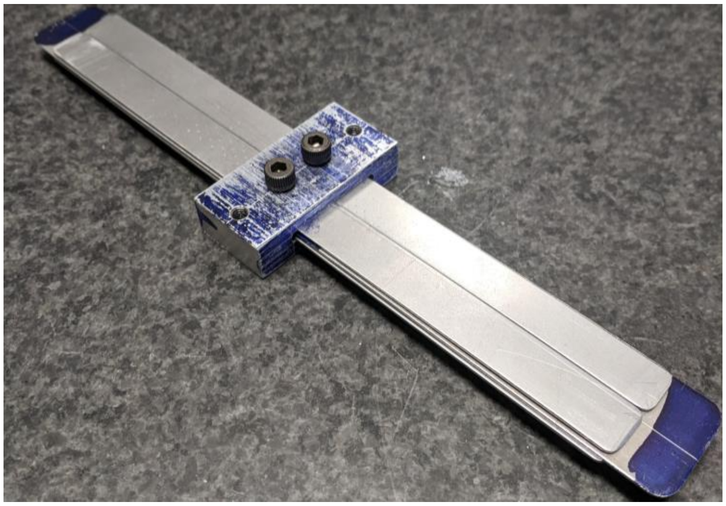
The project was designed and analyzed on the CWU campus. While working within the constraints of the University’s resources, the frame of the vehicle will be created using two different materials: three-dimensional printing plastic and aluminum. The steering components and wheel hubs will be made using SolidWorks and the available rapid prototyping machine, while the chassis and suspension will be made by shaping thin aluminum and steel materials.

The first step in construction will be designing the chassis to be long enough to keep the drive train belt taut. The other member of the team designed for a 15-inch belt, so the chassis was cut to 17 inches for some extra room at each end. In order to hold the motor safely on the chassis without it hanging off the edge, it was cut to be seven inches wide. Finally, 2x2 inch sections in the middle of each end were cut for locating the differential mounts and the leaf spring suspension.

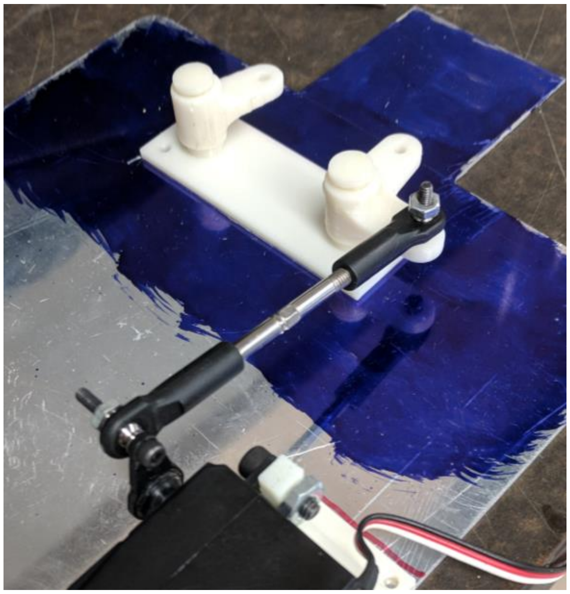
The next step will be constructing the suspension. A housing of 6061 Aluminum was machined using the facilities on campus at CWU. The housing is 1 inch wide by 2 inches long, and is a half-inch thick. Four holes were drilled into the material down the middle for use in mounting the leaf springs as well as mounting the housing to the chassis. The most difficult aspect of these parts was machining the thin, 1/8th inch thick slot in the middle for the leaf springs to fit through. Achieving this required the use of a 1/8th inch end mill, which will break at the slightest misstep. After meticulous machining at a mill, the slots turned out just fine, and were the perfect width to fit the entirety of the leaf spring system. An image of the leaf spring housing can be seen below.



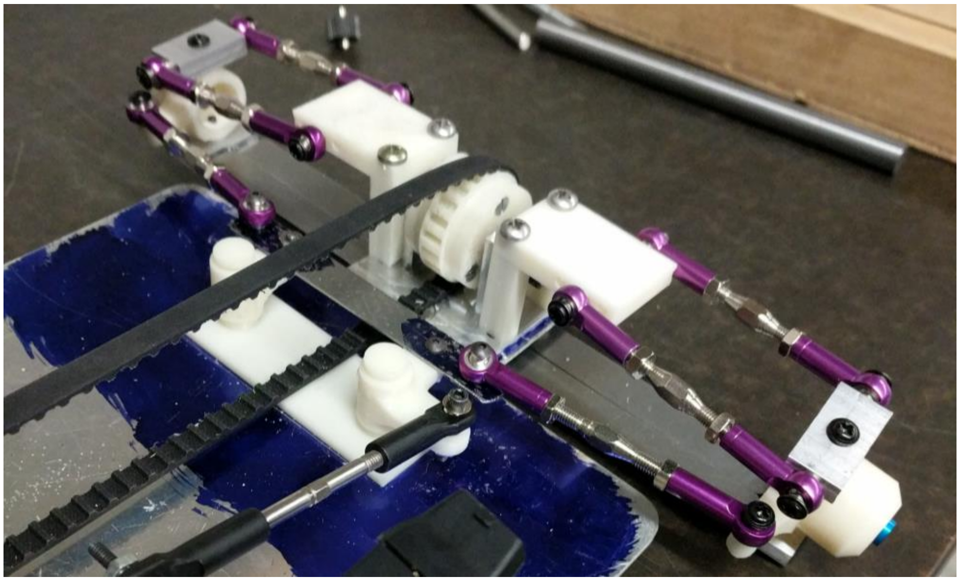
After making the housings, cutting the leaf spring layers was the next step. Cutting the spring steel to length was done using resources within Hogue Hall on campus grounds. Once the measuring and scratching sections in the sheet of steel was finished, a manual shear easily cut the thin layers. The sharp corners were rounded off and holes were drilled for the set screws. Each layer of the leaf spring system will be pinned together using 10-32 set screws, which were acquired from the resources on campus. The next image shows one of the leaf spring suspensions in its completed form, ready for mounting to the chassis.



With the suspension out of the way and ready for assembly, using the rapid prototype machine was the next step. Unlike RC cars made in previous which used store-bought steering mechanisms, the team decided to try and design a steering system that could fit in-between the drive train belt. Since there was only around 1 inch of clearance between the taut and slack belt sides, the steering took on a slim and efficient design. It consists of a mount with two circular posts. Each post will hold a rotating arm which will be connected using steering linkages and spring steel. The posts have a hole in the top where a pin will be press fit in order to keep the arms from falling off. Even if the team decides to remove the belt from the car entirely, the steering system will still be perfectly fine to use. Below is an image of the steering mount and arms, which are attached to the steering servo using a steering linkage.



The final task for this team member's half of the construction was to design the wheel carriers. The original thought for the design was to use a square-style steering knuckle that could easily maneuver the wheels. However, having 4-wheel drive in mind changed everything. The team was able to find viable wheel carriers with a mount for the steering linkages. They were not at the specified angle that was determined in the analysis, but the steering linkages can move freely to fit to the required angle. Mounts for the wheel carriers to attach to both the leaf spring suspension and the upper mounts were machined out of aluminum. The system in its entirety can be seen in the image below.



In spring quarter several things about the vehicle changed. The biggest change was switching from 4 wheel drive to 2 wheel drive. As a result, the belt was removed from the vehicle. This change occurred because the drive shafts that were back ordered came in and were too short for the width of the suspension. If the front wheels were going to be able to turn safely, there was no way that the drive shafts could have fit in the front. The rear suspension was cut down to a narrower width to fit the drive shafts, which can be seen in the image below. The last piece added was a spine along the bottom to support the thin chassis material, which was deforming under the weight of the various electronics attached to the car. The final image shows the completed car, with the shortened rear suspension, no belt, and all the electronics in place.

Device Operation:

The device will be operational when the suspension, steering, and drivetrain are combined into one vehicle. This was done for the most part by the end of winter quarter, however the team ran into some trouble with back-ordered parts that prevented the vehicle from being complete. This issue caused the team to re-think some aspects of the design. It has been decided that 4-wheel drive, along with designing for the car to be driven upside down was too difficult to make work, so at the beginning of spring quarter the car will be changed to only 2-wheel drive to make our original goal of driving upside down easier to achieve.

TESTING

Introduction:

There are several requirements that will be the subject of the tests on the RC car. As per the requirements, the car must survive a two foot drop, have a turn diameter of five feet, and have all parts integrated without any interference. Successful tests in these areas will determine if the suspension will perform as expected. The three tests will be done during the second and third weeks of April, and will not take longer than three or four hours combined to complete all tests, scheduling for which can be found in the Spring Gantt Chart. Testing the interference between parts should yield no interference and parts not within 0.01 inches of each other. During the drop test, the suspension should not deflect more than 1.5 inches. Finally, the car is predicted to make a turn to the left and right in a 5 foot diameter.

Method:

The first test will be determining if there is any interference between parts during all motions that the RC car can make. Very few resources will be required for this test, all that is needed is a pair of electronic calipers. Check the full range of motion for the steering and use the calipers to check the distance between parts that seem close to touching. Data will be recorded in a table that describes the parts, accounts the distance between said parts, and whether this distance passes or fails the requirement of 0.01 inches of space. The reasoning behind 0.01 inches is purely arbitrary. The designers figured that would be enough tolerance for the various parts and connections to adhere to for a successful car.

Testing the turn radius of the car is more involved than the first test. This test requires a large, open, and flat area to drive the vehicle unhindered in circles. One person will drive the car, while another will mark the location of a full turn diameter with tape. First, the driver will find and mark a starting location that will be used for the remainder of the test. Then, drive the car at a slow speed with the steering cranked all the way to the left or right. The second person will mark where the car meets its maximum turn diameter. Measure the distance with a tape measure, then repeat the process twice more. Repeat the procedure for the opposite turning direction, then all over again at a fast speed. A tape measure and eyeballed locations are not the most precise measuring tools, but it will provide accurate enough measurements for the purposes of this project. All data will be recorded in a table that clearly displays the speeds, and differentiates between right and left turns. Also, whether or not the turn diameter passed or failed the requirement.

The final test will be the drop test, which will be more difficult to precisely measure than the others. This test requires a camera or recording device that can capture the moment the car hits the ground with enough clarity to examine the results clearly. Taping a yardstick to a wall will allow the tester to drop the car from exactly two feet for each test. The yardstick can then be used to get an approximate value for the deflection, and should provide enough precision to determine whether the car passed or failed the drop test. Data for each trial will be recorded in a simple table, displaying the trial number, the approximate deflection, and whether that number is a pass or fail. At the risk of severely damaging the car, only three trials were performed for this portion of the testing.

Results:

After testing, the results showed that the car performed admirably when compared to the requirements. The parts did not interfere or come within 0.1 inches of each other. This was not a surprise because the team had spent a lot of time ensuring that there would not be any interference when constructing the car. During the turn diameter test, the car could turn to the left perfectly, and met the 5 foot mark. Turning to the right was a problem, and it could only make a turn with a 10 foot diameter. The problem is most certainly due to the angle of the steering arm being too obtuse. The drop test went off without any issues, and after the video footage was analyzed, the suspension only deflected less than an inch for each test, which met the required 1.5 inch maximum. For information on the tables and data tabulated over the course of testing, see Appendices G, H, and I.

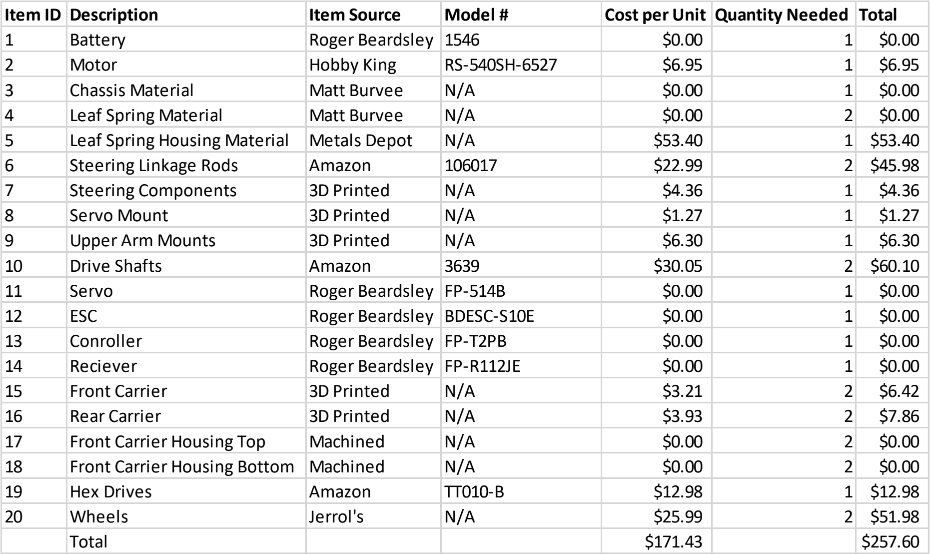
BUDGET, SCHEDULE, and PROJECT MANAGEMENT

Cost and Budget:

The budget will be managed by the members of the team building the R/C Car. For the purposes of this proposal, this section will focus on the components required to construct the suspension and steering apparatuses on the car.

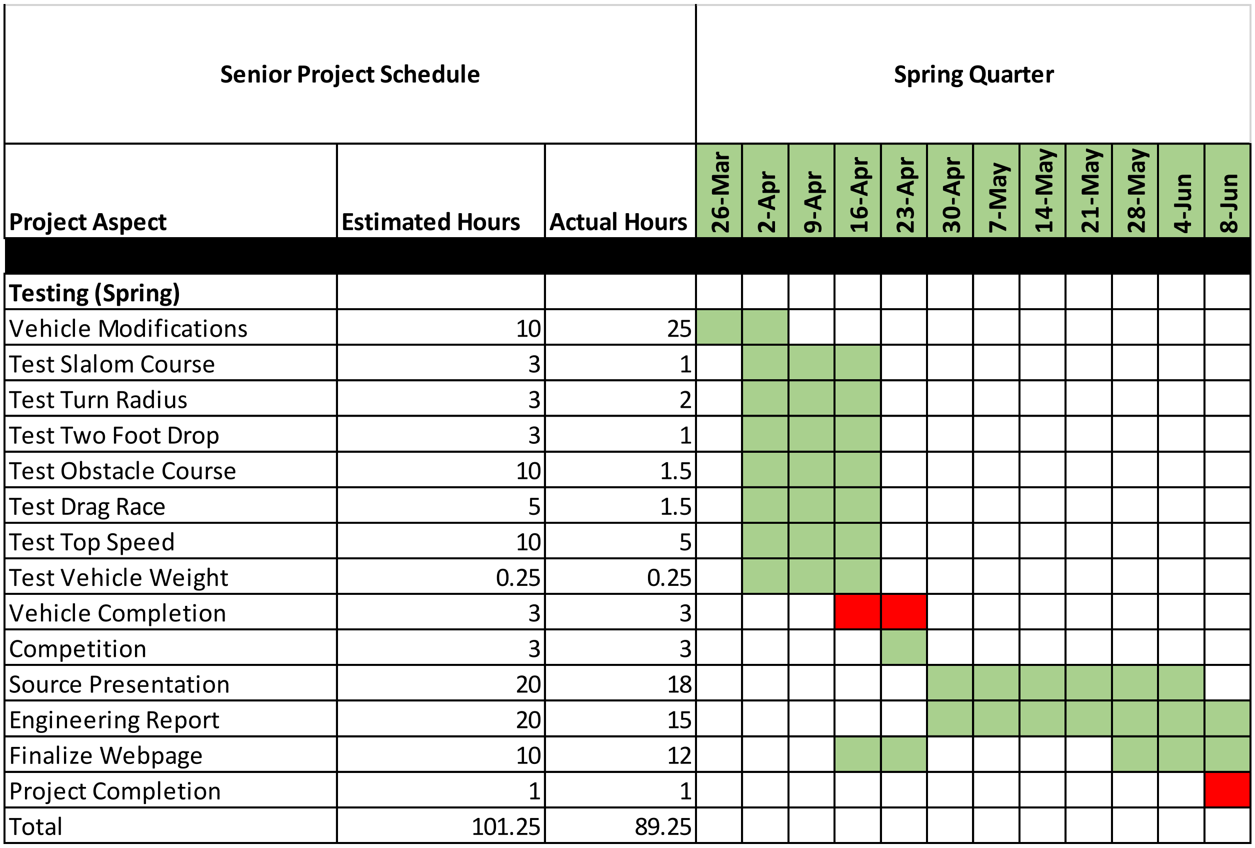
A majority of the parts and material have been found from scrap parts around CWU, which has saved a lot of money. Material for the leaf spring housing was the most expensive item ordered at $53.40. Most other parts can be rapidly prototyped rather than purchased. This has also been extremely helpful, as the team can design parts to fit specific dimensions for much cheaper. For example, the steering arms and mount were printed for around $4.36, rather than purchased at a sale price of double or even triple that cost. Continuing to use the 3D printer will drop costs significantly and will most definitely save the team from going over budget by the end of the year.

The proposed budget is a maximum of $500, making it $250 per team member. A parts list details the required materials below, and can also be found in Appendix C. The parts list below estimates a value of $257.60, which is just shy of the proposed budget. Some of the parts were split between members, including the steering linkage rods, the wheels, and the drive shafts. That means the actual cost so far has been around $204. These prices may change as the year progresses and parts are either added or not included.



Item ID	Description	Item Source	Model #	Cost per Unit	Quantity Needed	Total
1	Battery	Roger Beardsley	1546	$0.00	1	$0.00
2	Motor	Hobby King	RS-540SH-6527	$6.95	1	$6.95
3	Chassis Material	Matt Burvee	N/A	$0.00	1	$0.00
4	Leaf Spring Material	Matt Burvee	N/A	$0.00	2	$0.00
5	Leaf Spring Housing Material	Metals Depot	N/A	$53.40	1	$53.40
6	Steering Linkage Rods	Amazon	106017	$22.99	2	$45.98
7	Steering Components	3D Printed	N/A	$4.36	1	$4.36
8	Servo Mount	3D Printed	N/A	$1.27	1	$1.27
9	Upper Arm Mounts	3D Printed	N/A	$6.30	1	$6.30
10	Drive Shafts	Amazon	3639	$30.05	2	$60.10
11	Servo	Roger Beardsley	FP-514B	$0.00	1	$0.00
12	ESC	Roger Beardsley	BDESC-S10E	$0.00	1	$0.00
13	Conroller	Roger Beardsley	FP-T2PB	$0.00	1	$0.00
14	Reciever	Roger Beardsley	FP-R112JE	$0.00	1	$0.00
15	Front Carrier	3D Printed	N/A	$3.21	2	$6.42
16	Rear Carrier	3D Printed	N/A	$3.93	2	$7.86
17	Front Carrier Housing Top	Machined	N/A	$0.00	2	$0.00
18	Front Carrier Housing Bottom	Machined	N/A	$0.00	2	$0.00
19	Hex Drives	Amazon	TT010-B	$12.98	1	$12.98
20	Wheels	Jerrol's	N/A	$25.99	2	$51.98
	Total			$171.43		$257.60

Schedule:



Senior Project Schedule			Spring Quarter											
Project Aspect	**Estimated Hours**	**Actual Hours**	**26-Mar**	**2-Apr**	**9-Apr**	**16-Apr**	**23-Apr**	**30-Apr**	**7-May**	**14-May**	**21-May**	**28-May**	**4-Jun**	**8-Jun**
Testing (Spring)														
Vehicle Modifications	10	25	🟩	🟩										
Test Slalom Course	3	1		🟩	🟩	🟩								
Test Turn Radius	3	2		🟩	🟩	🟩								
Test Two Foot Drop	3	1		🟩	🟩	🟩								
Test Obstacle Course	10	1.5		🟩	🟩	🟩								
Test Drag Race	5	1.5		🟩	🟩	🟩								
Test Top Speed	10	5		🟩	🟩	🟩								
Test Vehicle Weight	0.25	0.25		🟩	🟩	🟩								
Vehicle Completion	3	3				🟥	🟥							
Competition	3	3					🟩							
Source Presentation	20	18						🟩	🟩	🟩	🟩	🟩	🟩	
Engineering Report	20	15						🟩	🟩	🟩	🟩	🟩	🟩	🟩
Finalize Webpage	10	12				🟩	🟩					🟩	🟩	🟩
Project Completion	1	1												🟥
Total	101.25	89.25												

The schedule for this project has been outlined using a Gantt Chart format. These charts are useful for providing an estimated timeline for when tasks will be accomplished, and how many hours will be spent on those tasks. The chart above outlines all of Spring quarter, which consisted of presenting this report as well as testing the RC Car. The chart shows completion times in number of hours, and lays out when tasks will be completed throughout the quarter (dark red squares indicate milestones). Milestones for Spring quarter completing the vehicle itself, and finalizing the design. This quarter consisted of approximately 101 hours of work, and by the end a total of 89 hours were spend on completing each of the tasks to the best of the team’s ability. Additional charts for Fall and Winter quarters can be found in Appendix E, along with another copy of the Spring chart.

Milestones:

These will mark the progression of the project. Publishing the website dedicated to the project and submitting the proposal are two examples of early milestones in the fall. During winter, assembling the device was the greatest milestone. In Appendix E, the milestones for the project can be located within the Gantt Charts by looking for the dark-red-colored project aspects.

Project Management:

Human resources and Physical resources are available for the duration of the project. The team members as well as the MET Faculty are valuable resources for any advice on design aspects, analysis, and any other questions regarding the project. Other faculty in the machine labs will be helpful during the construction phase of the project. Physical resources include the equipment available in the machining lab, foundry, and rapid prototyping lab. Any metal that needs to be cut can be done using the lathes, mills, and CNC machines in the machining lab. If a part needs to be welded at any point, the foundry lab can be used, and any parts that need to be 3D printed can be done using the rapid prototyping lab. Each of these labs can be found in the Hogue Technology Building on campus.

DISCUSSION

This type of project has been done in the past, so the team figured with reasonable certainty that it was a feasible project to be completed by the end of the year. With any luck, the project will be a success and will be able to compete fiercely in the competition against the other teams working on R/C cars. One of the most important things to complete the project will be sticking to the schedule and not getting too far behind. This could become an issue at any point, and it will take the combined effort of both teammates to keep the project on track. Another issue that could arise over the course of the year is scheduling lab times. The rapid prototyping lab is small, and some parts could take a while, so getting in there with enough time to get all the parts that need to be printed could cause some time constraints.

The design of the project began with looking at the most common types of R/C cars. The team had never done work like this, so there was a steep learning curve when figuring out the various parts and intricacies that come with vehicle design. The team decided on splitting the project into two areas: suspension and drivetrain. One would oversee designing the chassis, steering and suspension of the vehicle to keep it upright, while the other would develop the differential, belt drive, and gear reductions that would make the car move. This split seemed to evenly separate the work that needed to be done, and very much made this a two-person job.

First design ideas revolved around the idea of using a shock-tower system that is very common among R/C cars. There was a lot of information and designs to look through, but it seemed that whatever the team ended up doing, it wouldn’t be that unique. That point is when the team looked to a previous project where a leaf-spring system was used in the suspension rather than a shock tower. This was a new concept that was chosen to be the basis for the suspension on this project. Another key concept was going to be trying to figure out how to make the car four-wheel-drive. A whole new set of challenges came with trying to make the car a 4x4. Since both axles would need access to the drivetrain, the leaf-spring suspension idea freed up a lot of space for the differential housing at both ends.

The final design parameter that the team wanted to meet was being able to drive the car even if it flipped upside down. It was a decision made to challenge the team to try and find a way to fit all the necessary parts in a confined vertical space. All parts must fit within the diameter of the wheels so that nothing interferes with the ground if the car is ever flipped over.

At the end of winter quarter, after the due date for the car to be ready and moving, the drive shafts had still not arrived. Then over the weekend after that date they did, and the team was horrified to find that the dimensions given were incorrect, and they were far too short to work with the car. At that point, the executive decision to ditch the 4-wheel drive idea was made. The car would now be 2-wheel drive, which would be much easier to make work. Adjustments to the gear train are in the works, and the car will no longer require the belt along the chassis, which will free up a lot of room and allow the car to be more streamlined. It is extremely unfortunate that the critical parts that were needed to attach the wheels and complete the car were not only back ordered several weeks, but also ended up being a waste of money and time. The team will now be able to focus more on making sure the vehicle can run even if flipped upside down, which has been the most enjoyable aspect of this entire process.

CONCLUSION

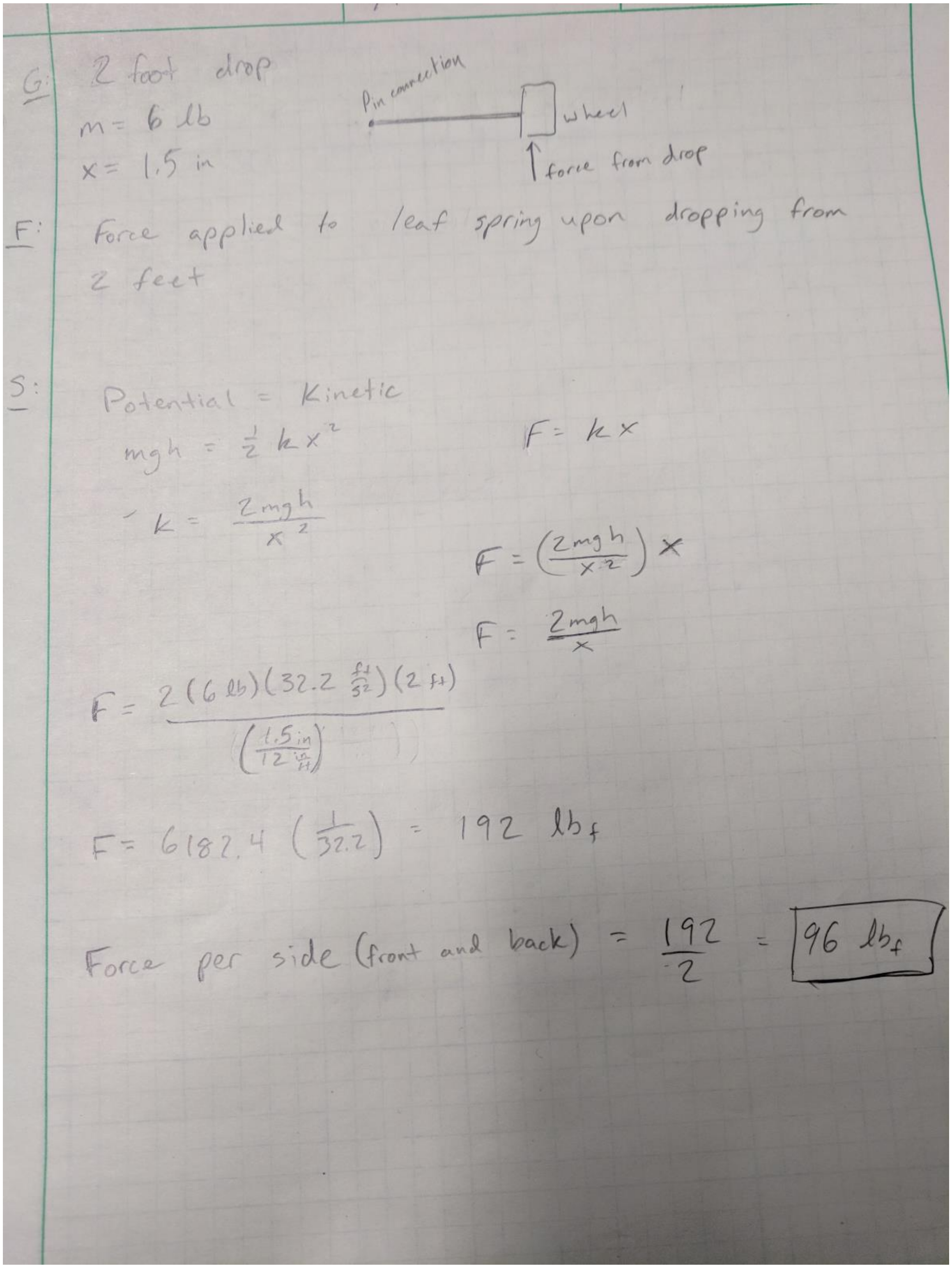
At the end of the year, the car turned out better than expected. The design team had set several requirements that the car met. For the suspension, it was required that there be no interference between parts and there could be no more than 1.5 inches of deflection. The car exceeded these expectations. Every part in the car articulated without hindrance, and there was never more than an inch of deflection in the leaf spring system. The steering was required to have a 5-foot turning diameter, and it only halfway succeeded. Turning to the left resulted in a quality turn that met the requirement but turning right did not have the same results. After all the struggles that the team went through with the project, they are proud of how the car turned out.

The schedule is laid out to be easily accomplished if the team is actively trying to meet the deadlines during the testing phase. However, there will be changes that have to be made due to the unfortunate falling behind that occurred at the end of winter quarter. The team will have to take the adversity in stride and work extra hard to get back on track. In doing so, the schedule will be returned to normal and the RC Car will be ready for the competition. The Faculty is there to answer the questions that will arise. Anything that hinders the project in any way should be addressed to them immediately so that the problems can be solved in an efficient manner, without missing any crucial deadlines due to back ordered parts. Finally, the team must learn to compromise in any future design decisions that are made during testing. There will most likely be parts that break or will need to be replaced during testing. How to solve or fix any problems or broken parts will need to be done collaboratively between the team members. This is a team effort first and foremost, and because of this all ideas should be taken into account when testing occurs. Redesigns will happen, and it is up to the team to find ways to make everybody happy so that the project is successful.

ACKNOWLEDGEMENTS

Thank you to Maverick Reddaway for being an excellent partner and always having a positive attitude even in the face of hardships. Tyler and Maverick would also like to thank Central Washington University for their assistance in making this project a reality. Without the efforts of the MET Faculty, this could not have been possible. Thank you to Matt Burvee and Ted Bramble for allowing full use of the machine shop and power lab, which were essential for completing this project. Finally, a special thanks to Professors Roger Beardsley, Craig Johnson, and Charles Pringle for answering all questions that the team had throughout the year.

APPENDIX A – Analyses



G: 2 foot drop

$m = 6\ lb$

$x = 1.5\ in$

F: Force applied to leaf spring upon dropping from 2 feet

S: Potential = Kinetic

$$mgh = \frac{1}{2} k x^2 \qquad F = kx$$

$$k = \frac{2mgh}{x^2}$$

$$F = \left(\frac{2mgh}{x^2}\right) x$$

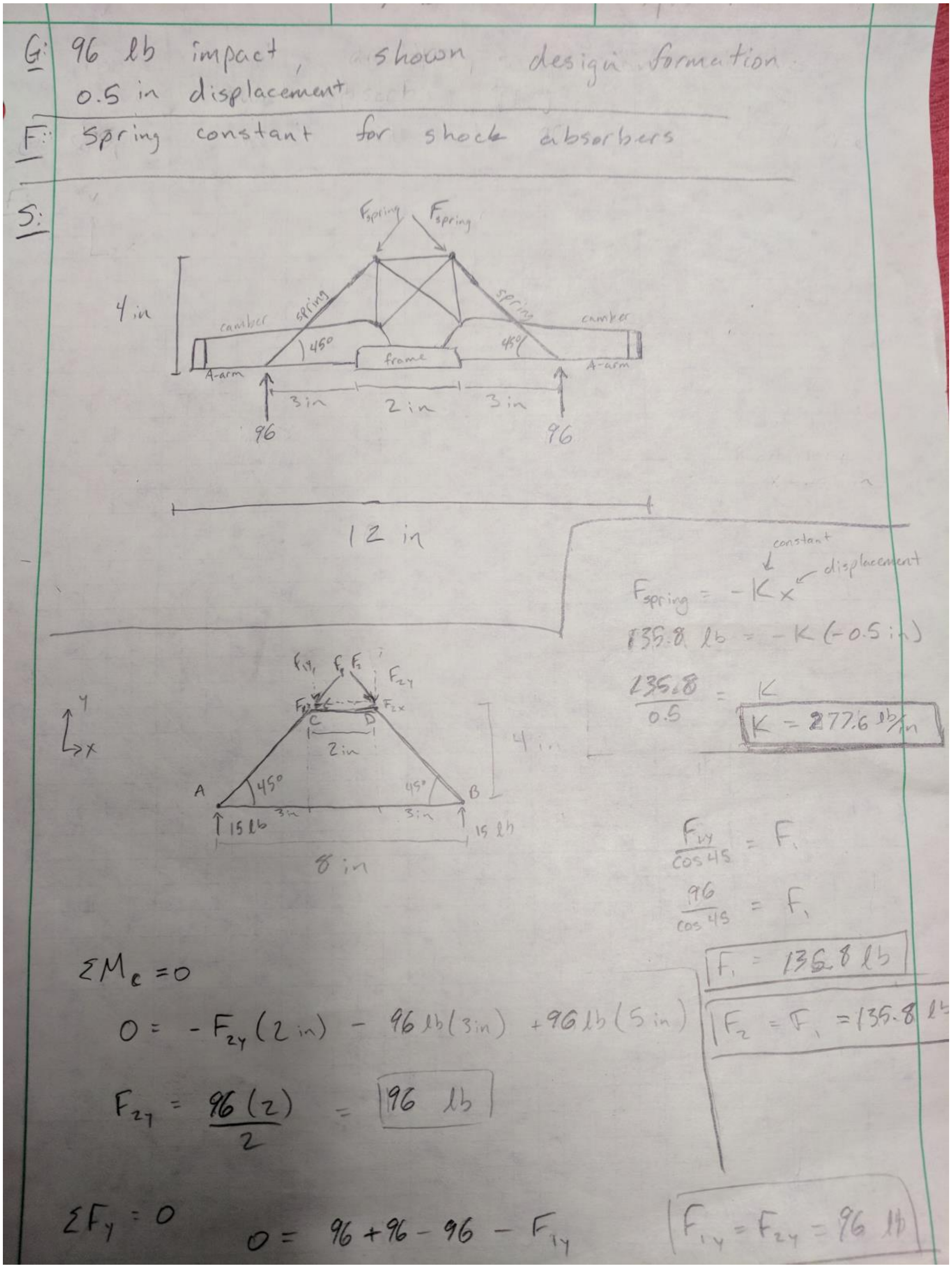
$$F = \frac{2mgh}{x}$$

$$F = \frac{2(6\ lb)(32.2\ \frac{ft}{s^2})(2\ ft)}{\left(\frac{1.5\ in}{12\ \frac{in}{ft}}\right)}$$

$$F = 6182.4 \left(\frac{1}{32.2}\right) = 192\ lb_f$$

$$\text{Force per side (front and back)} = \frac{192}{2} = \boxed{96\ lb_f}$$

Figure 1 - Impact force from 2 foot drop



G: 96 lb impact, shown design formation
0.5 in displacement

F: Spring constant for shock absorbers

S:

$F_{spring} = -Kx$ (K: constant; x: displacement)

$135.8 \text{ lb} = -K(-0.5 \text{ in})$

$\frac{135.8}{0.5} = K$

$\boxed{K = 277.6 \text{ lb/in}}$

$\frac{F_{1y}}{\cos 45} = F_1$

$\frac{96}{\cos 45} = F_1$

$\boxed{F_1 = 136.8 \text{ lb}}$

$\boxed{F_2 = F_1 = 135.8 \text{ l}}$

$\Sigma M_c = 0$

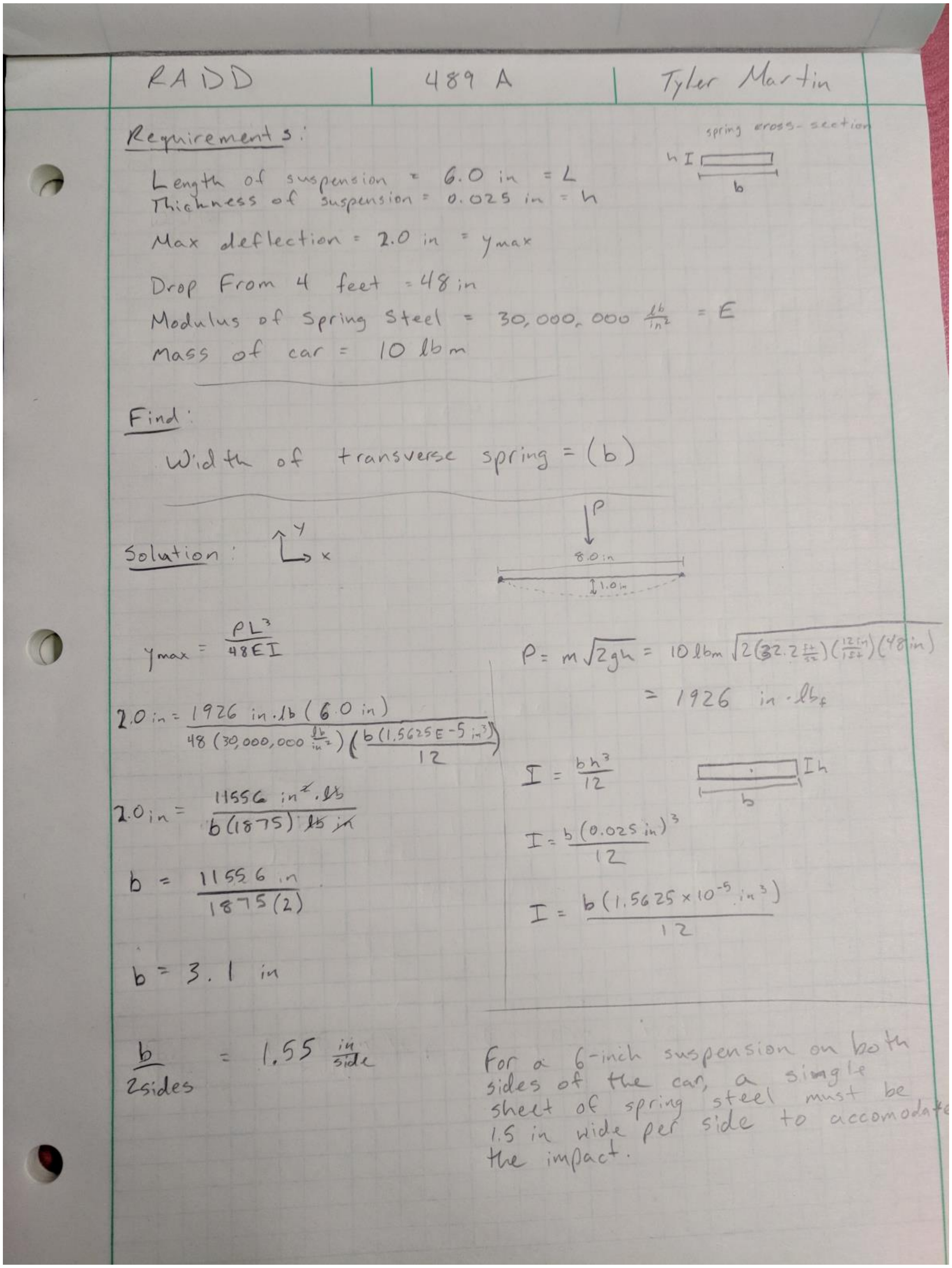
$0 = -F_{2y}(2 \text{ in}) - 96 \text{ lb}(3 \text{ in}) + 96 \text{ lb}(5 \text{ in})$

$F_{2y} = \frac{96(2)}{2} = \boxed{96 \text{ lb}}$

$\Sigma F_y = 0 \qquad 0 = 96 + 96 - 96 - F_{1y}$

$\boxed{F_{1y} = F_{2y} = 96 \text{ lb}}$

Figure 2 - Spring Constant (unused design iteration)



RADD | 489 A | Tyler Martin

Requirements:

Length of suspension = 6.0 in = L
Thickness of suspension = 0.025 in = h

Max deflection = 2.0 in = y_{max}

Drop From 4 feet = 48 in

Modulus of Spring Steel = 30,000,000 $\frac{lb}{in^2}$ = E

Mass of car = 10 lbm

Find:

Width of transverse spring = (b)

Solution:

$$y_{max} = \frac{PL^3}{48EI}$$

$$2.0\ in = \frac{1926\ in \cdot lb\ (6.0\ in)}{48\ (30{,}000{,}000\ \frac{lb}{in^2})\left(\frac{b\,(1.5625E-5\ in^3)}{12}\right)}$$

$$2.0\ in = \frac{11556\ in^{\cancel{2}} \cdot \cancel{lb}}{b\,(1875)\ \cancel{lb}\ \cancel{in}}$$

$$b = \frac{1155.6\ in}{1875\,(2)}$$

$$b = 3.1\ in$$

$$P = m\sqrt{2gh} = 10\ lbm\sqrt{2\left(32.2\ \frac{ft}{s^2}\right)\left(\frac{12\ in}{1\ ft}\right)(48\ in)}$$

$$= 1926\ in \cdot lb_f$$

$$I = \frac{bh^3}{12}$$

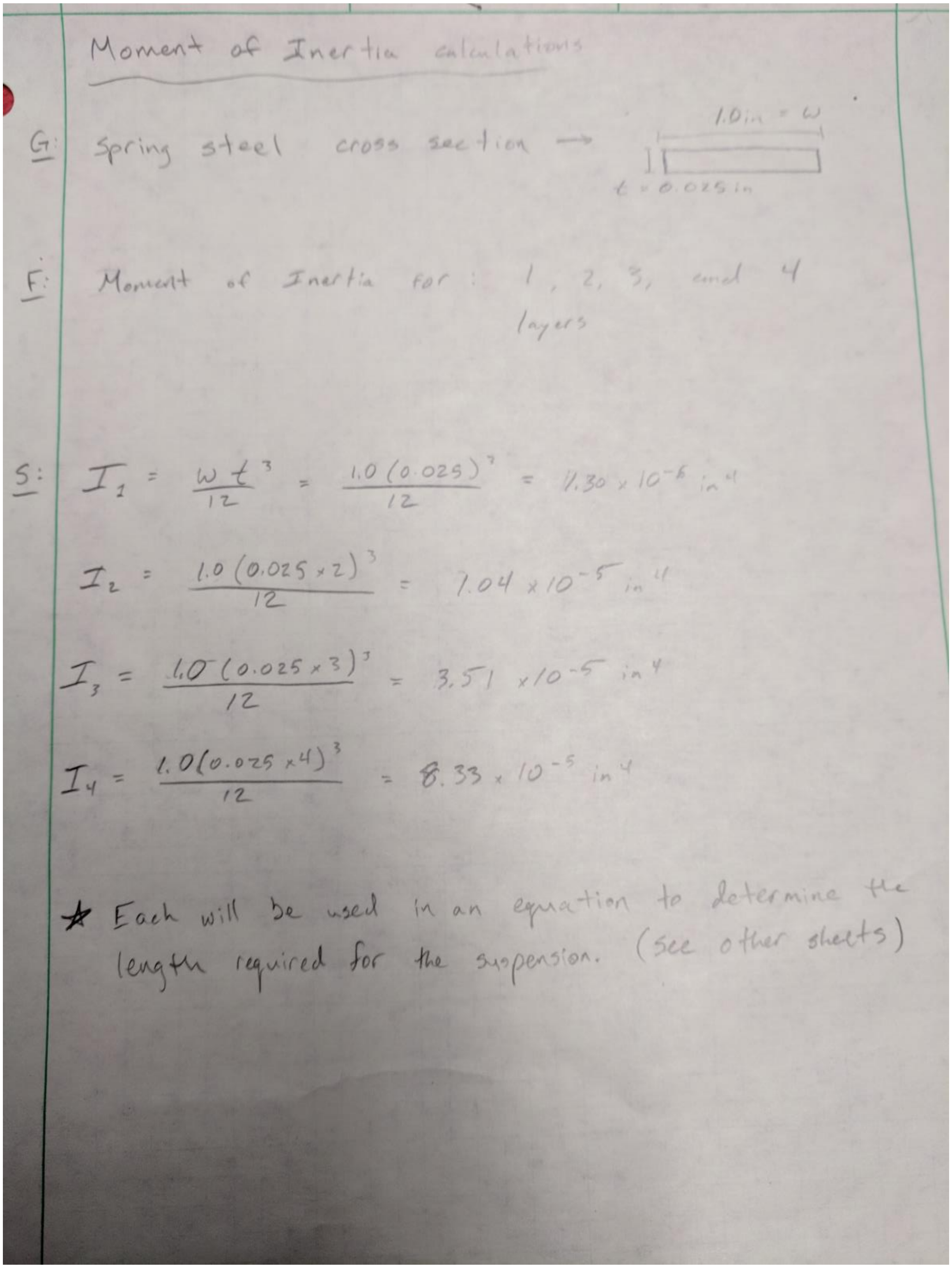
$$I = \frac{b\,(0.025\ in)^3}{12}$$

$$I = \frac{b\,(1.5625 \times 10^{-5}\ in^3)}{12}$$

$$\frac{b}{2\,sides} = 1.55\ \frac{in}{side}$$

For a 6-inch suspension on both sides of the car, a single sheet of spring steel must be 1.5 in wide per side to accomodat the impact.

Figure 3 - Width of suspension (used as benchmark for later design)



Moment of Inertia calculations

G: Spring steel cross section →

1.0in = w

t = 0.025 in

F: Moment of Inertia for: 1, 2, 3, and 4 layers

S: $I_1 = \frac{w t^3}{12} = \frac{1.0 (0.025)^3}{12} = 1.30 \times 10^{-6}$ in^4

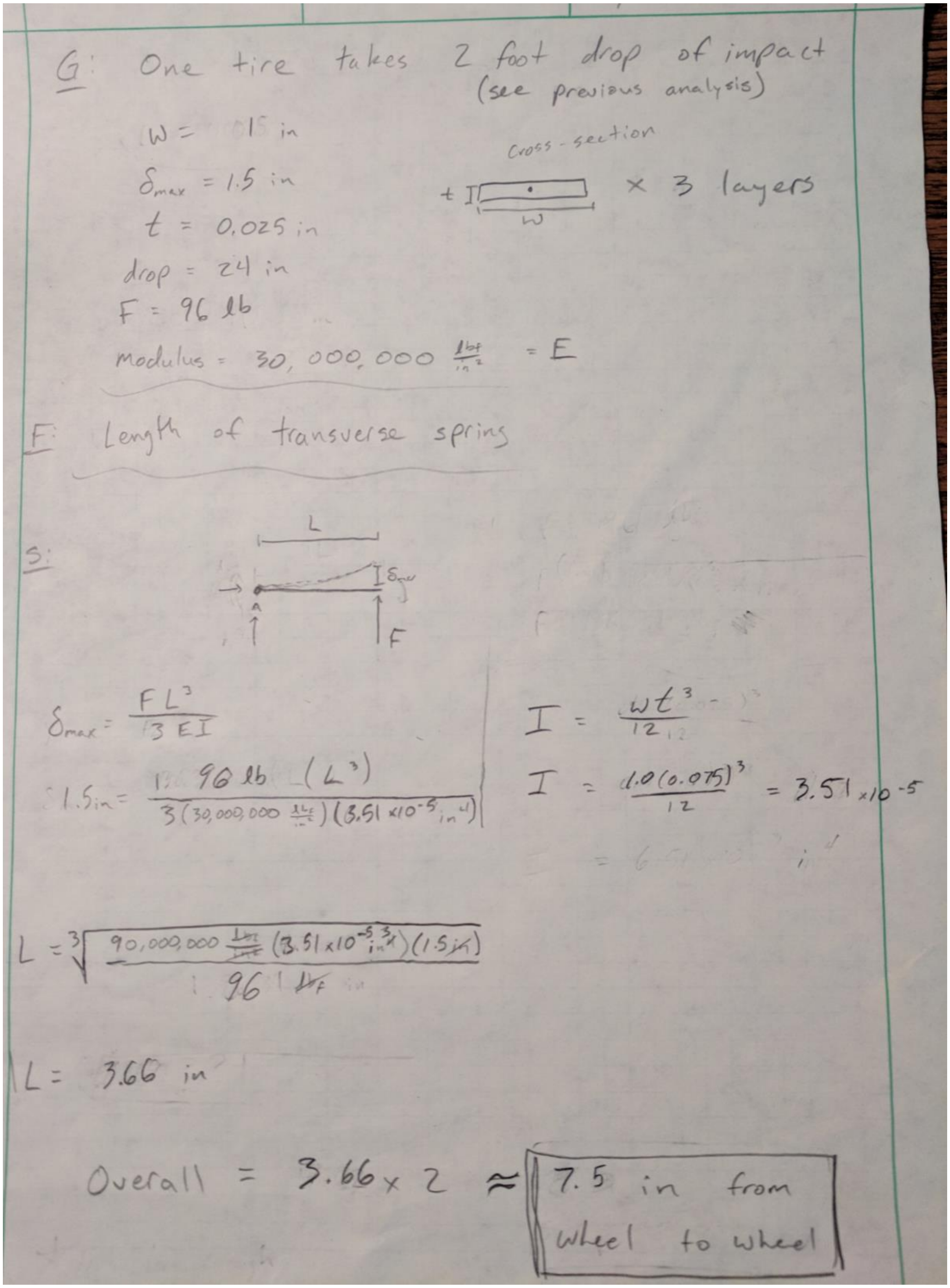
$I_2 = \frac{1.0 (0.025 \times 2)^3}{12} = 1.04 \times 10^{-5}$ in^4

$I_3 = \frac{1.0 (0.025 \times 3)^3}{12} = 3.51 \times 10^{-5}$ in^4

$I_4 = \frac{1.0 (0.025 \times 4)^3}{12} = 8.33 \times 10^{-5}$ in^4

★ Each will be used in an equation to determine the length required for the suspension. (see other sheets)

Figure 4 - Moment of Inertia of Leaf Spring



G: One tire takes 2 foot drop of impact (see previous analysis)

$w = 1$ in

$\delta_{max} = 1.5$ in

$t = 0.025$ in

drop = 24 in

$F = 96$ lb

modulus = 30, 000, 000 $\frac{lbf}{in^2}$ = E

Cross-section

× 3 layers

F: Length of transverse spring

S:

$$\delta_{max} = \frac{FL^3}{3EI}$$

$$1.5_{in} = \frac{96\ lb\ (L^3)}{3(30{,}000{,}000\ \frac{lbf}{in^2})(3.51\times10^{-5}\ in^4)}$$

$$I = \frac{wt^3}{12}$$

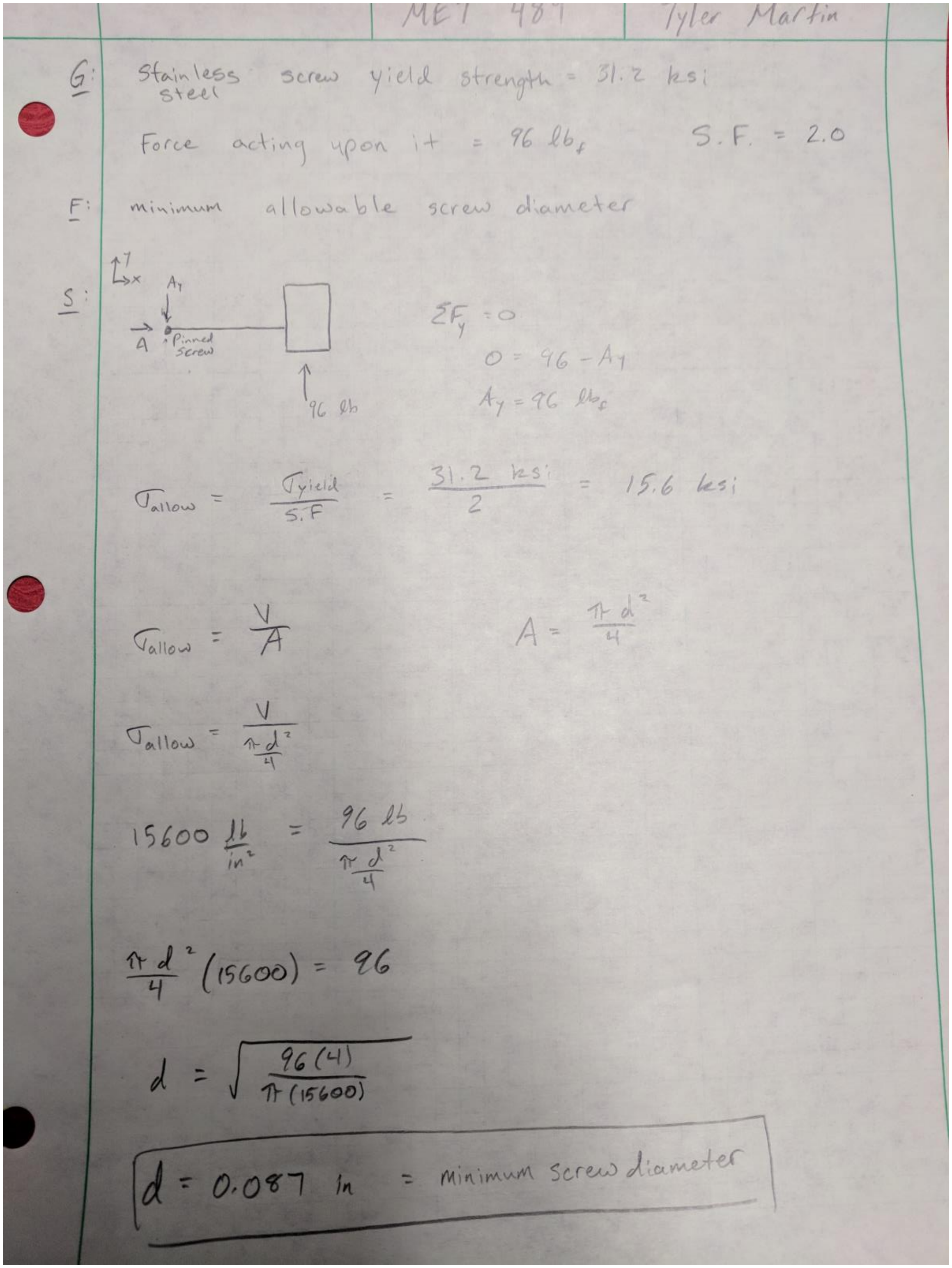
$$I = \frac{1.0(0.075)^3}{12} = 3.51\times10^{-5}$$

$$L = \sqrt[3]{\frac{90{,}000{,}000\ \cancel{\frac{lbf}{in^2}}\ (3.51\times10^{-5}\ in^{\cancel{4}\,3})(1.5\ \cancel{in})}{96\ \cancel{lbf}}}$$

$L = 3.66$ in

Overall = 3.66 × 2 ≈ $\boxed{\text{7.5 in from wheel to wheel}}$

Figure 5 - Length of full suspension



MET 489 | Tyler Martin

G: Stainless steel screw yield strength = 31.2 ksi

Force acting upon it = 96 lb_f S.F. = 2.0

F: minimum allowable screw diameter

S:

$$\Sigma F_y = 0$$

$$0 = 96 - A_y$$

$$A_y = 96\ lb_f$$

$$\sigma_{allow} = \frac{\sigma_{yield}}{S.F} = \frac{31.2\ ksi}{2} = 15.6\ ksi$$

$$\sigma_{allow} = \frac{V}{A} \qquad A = \frac{\pi d^2}{4}$$

$$\sigma_{allow} = \frac{V}{\frac{\pi d^2}{4}}$$

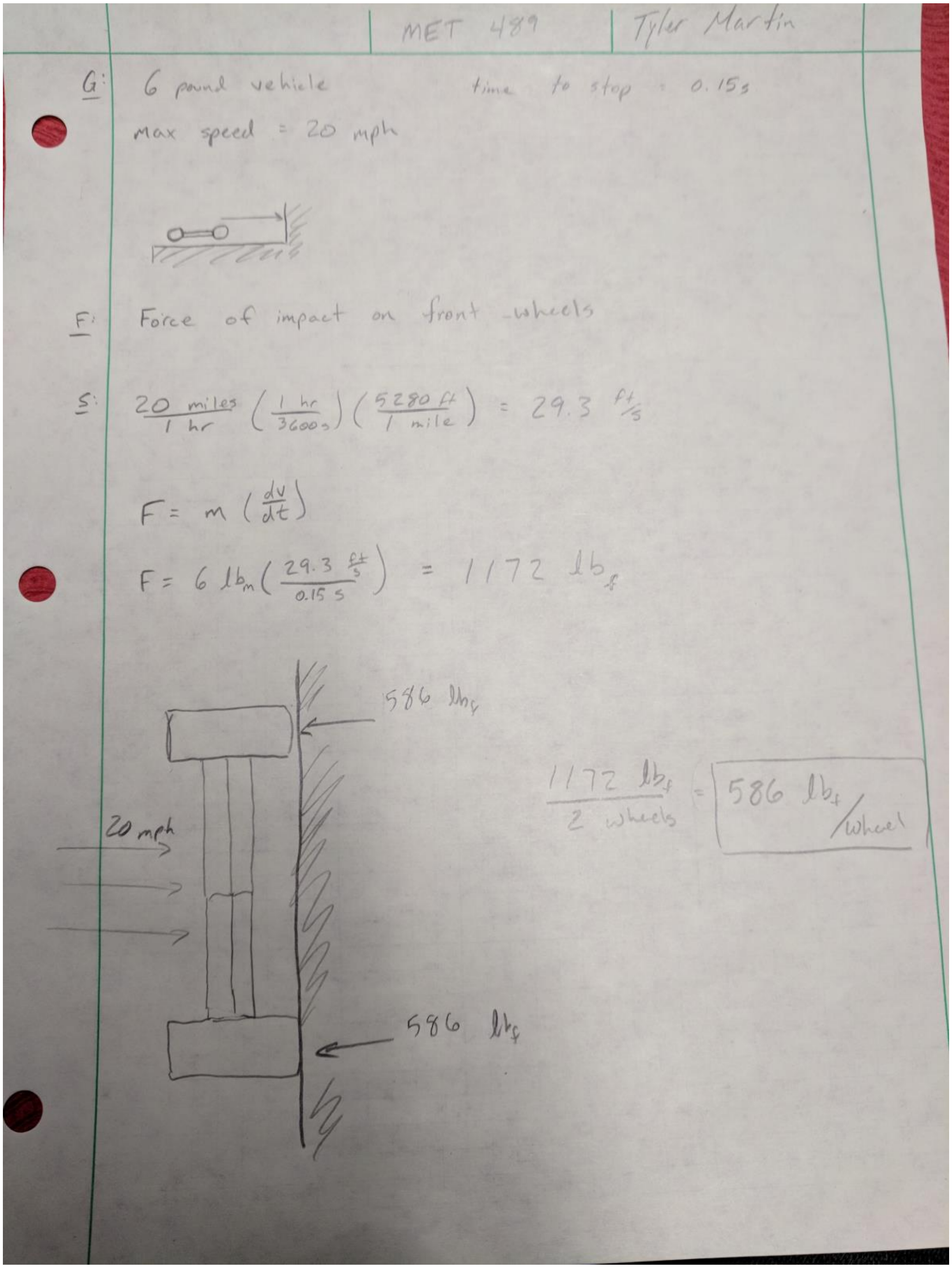
$$15600\ \frac{lb}{in^2} = \frac{96\ lb}{\frac{\pi d^2}{4}}$$

$$\frac{\pi d^2}{4}(15600) = 96$$

$$d = \sqrt{\frac{96(4)}{\pi(15600)}}$$

$$\boxed{d = 0.087\ in = \text{minimum screw diameter}}$$

Figure 6 - Minimum screw diameter for leaf spring



MET 489 Tyler Martin

G: 6 pound vehicle   time to stop = 0.15s

max speed = 20 mph

F: Force of impact on front wheels

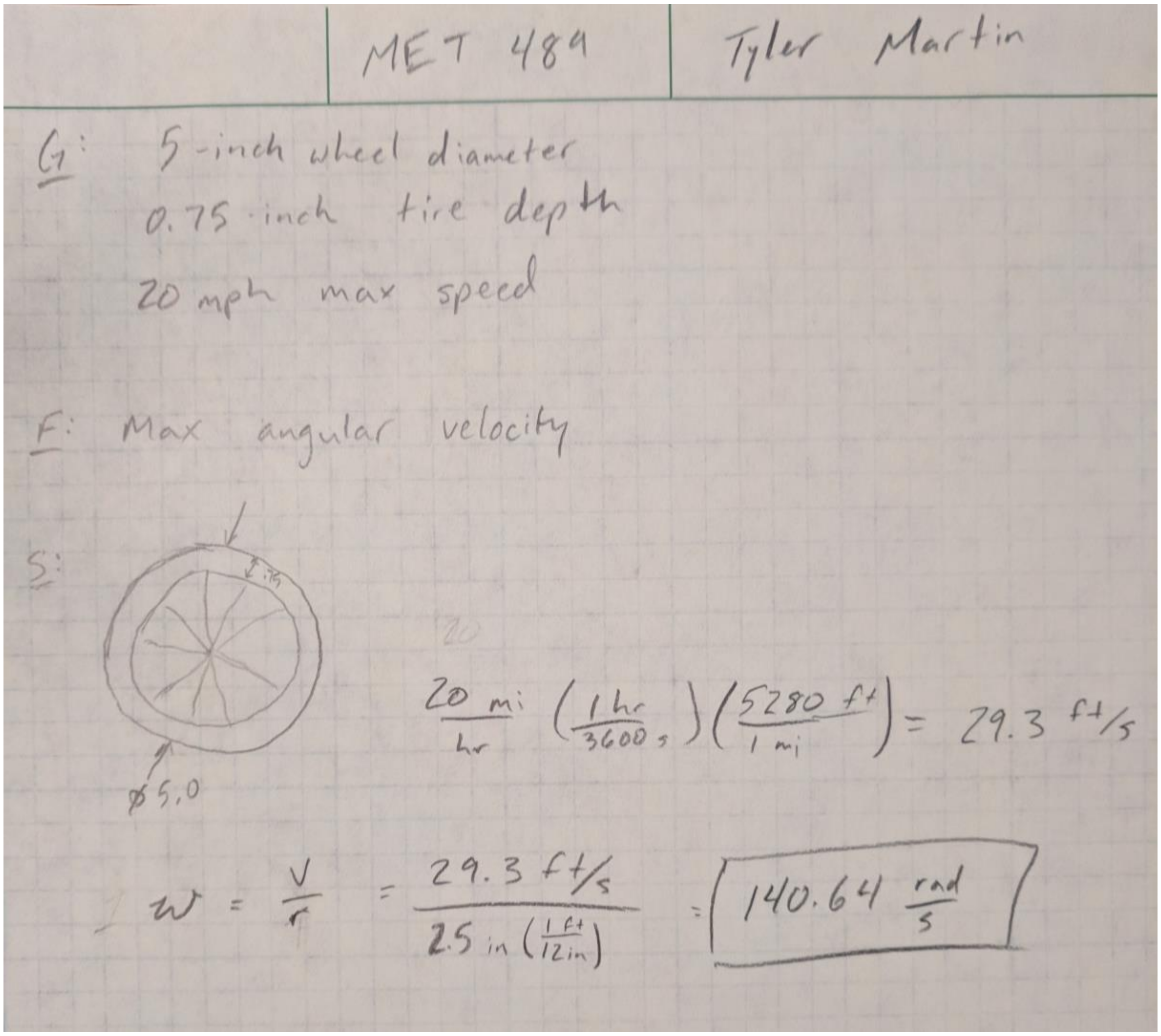
S: $\frac{20 \text{ miles}}{1 \text{ hr}}\left(\frac{1 \text{ hr}}{3600 s}\right)\left(\frac{5280 ft}{1 \text{ mile}}\right) = 29.3 \, ft/s$

$F = m\left(\frac{dv}{dt}\right)$

$F = 6 \, lb_m\left(\frac{29.3 \, \frac{ft}{s}}{0.15 \, s}\right) = 1172 \, lb_f$

$\frac{1172 \, lb_f}{2 \text{ wheels}} = \boxed{586 \, lb_f/\text{wheel}}$

Figure 7 - Max Speed Impact Force



MET 484 | Tyler Martin

G: 5-inch wheel diameter

0.75 inch tire depth

20 mph max speed

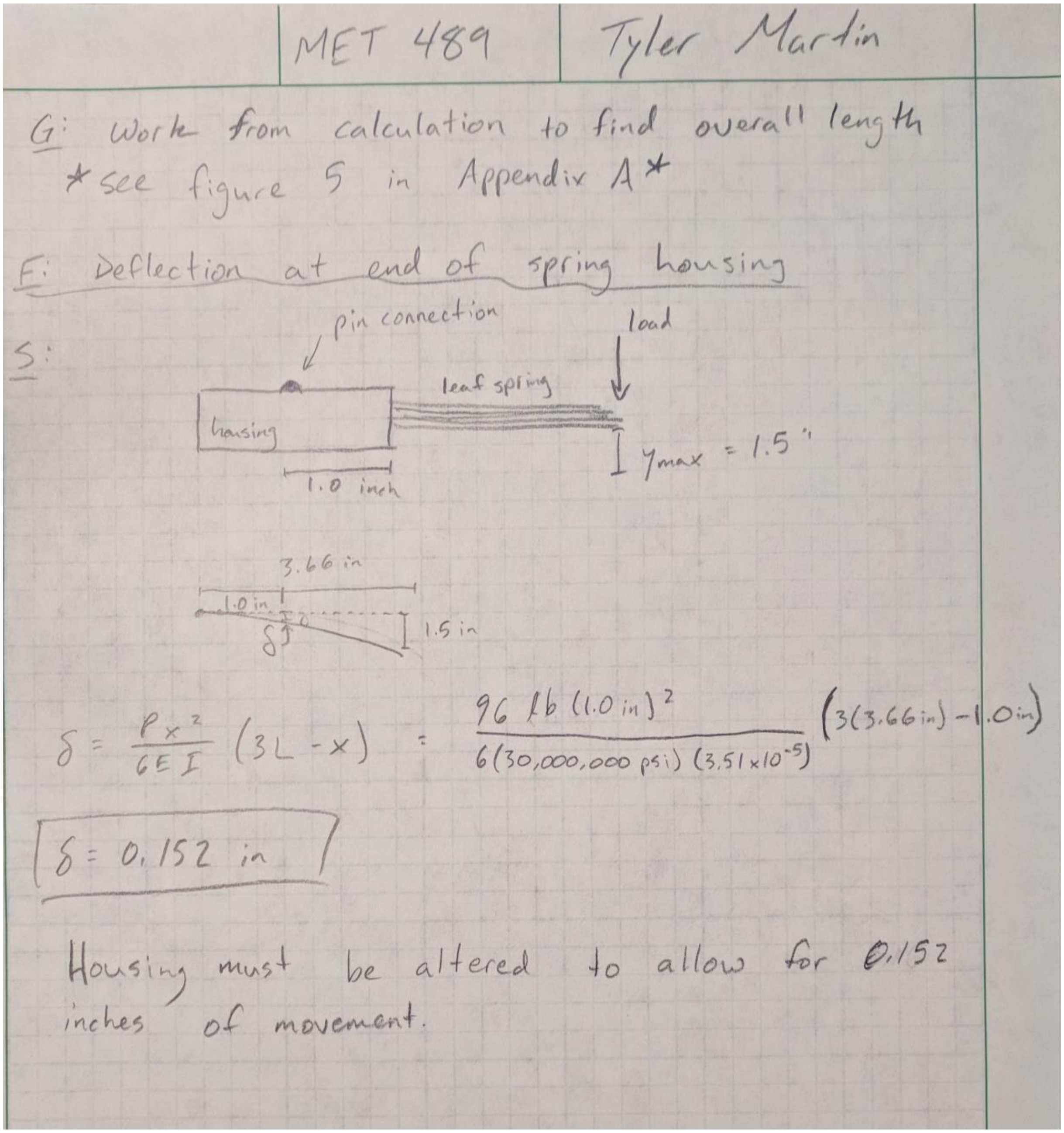
F: Max angular velocity

S:

$$\frac{20\ mi}{hr}\left(\frac{1\ hr}{3600\ s}\right)\left(\frac{5280\ ft}{1\ mi}\right) = 29.3\ ft/s$$

$$w = \frac{V}{r} = \frac{29.3\ ft/s}{2.5\ in\left(\frac{1\ ft}{12\ in}\right)} = \boxed{140.64\ \frac{rad}{s}}$$

Figure 8 - Angular Velocity of Tire



MET 489 Tyler Martin

G: Work from calculation to find overall length
see figure 5 in Appendix A

F: Deflection at end of spring housing

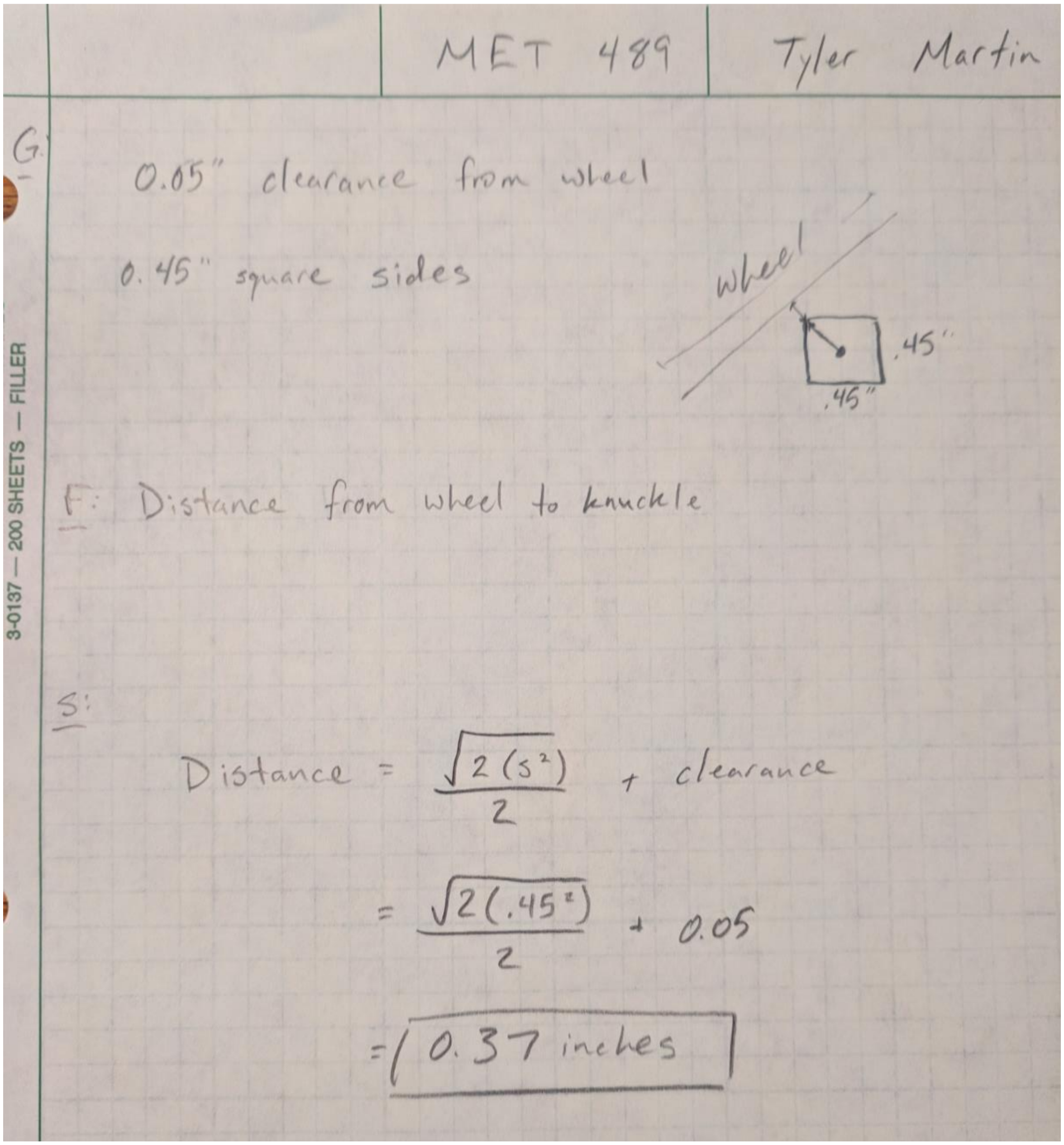
S:

$$\delta = \frac{Px^2}{6EI}(3L - x) = \frac{96\ lb\,(1.0\ in)^2}{6(30{,}000{,}000\ psi)(3.51 \times 10^{-5})}\left(3(3.66\,in) - 1.0\,in\right)$$

$$\boxed{\delta = 0.152\ in}$$

Housing must be altered to allow for 0.152 inches of movement.

Figure 9 - Displacement at Spring Housing



MET 489 | Tyler Martin

G: 0.05" clearance from wheel

0.45" square sides

F: Distance from wheel to knuckle

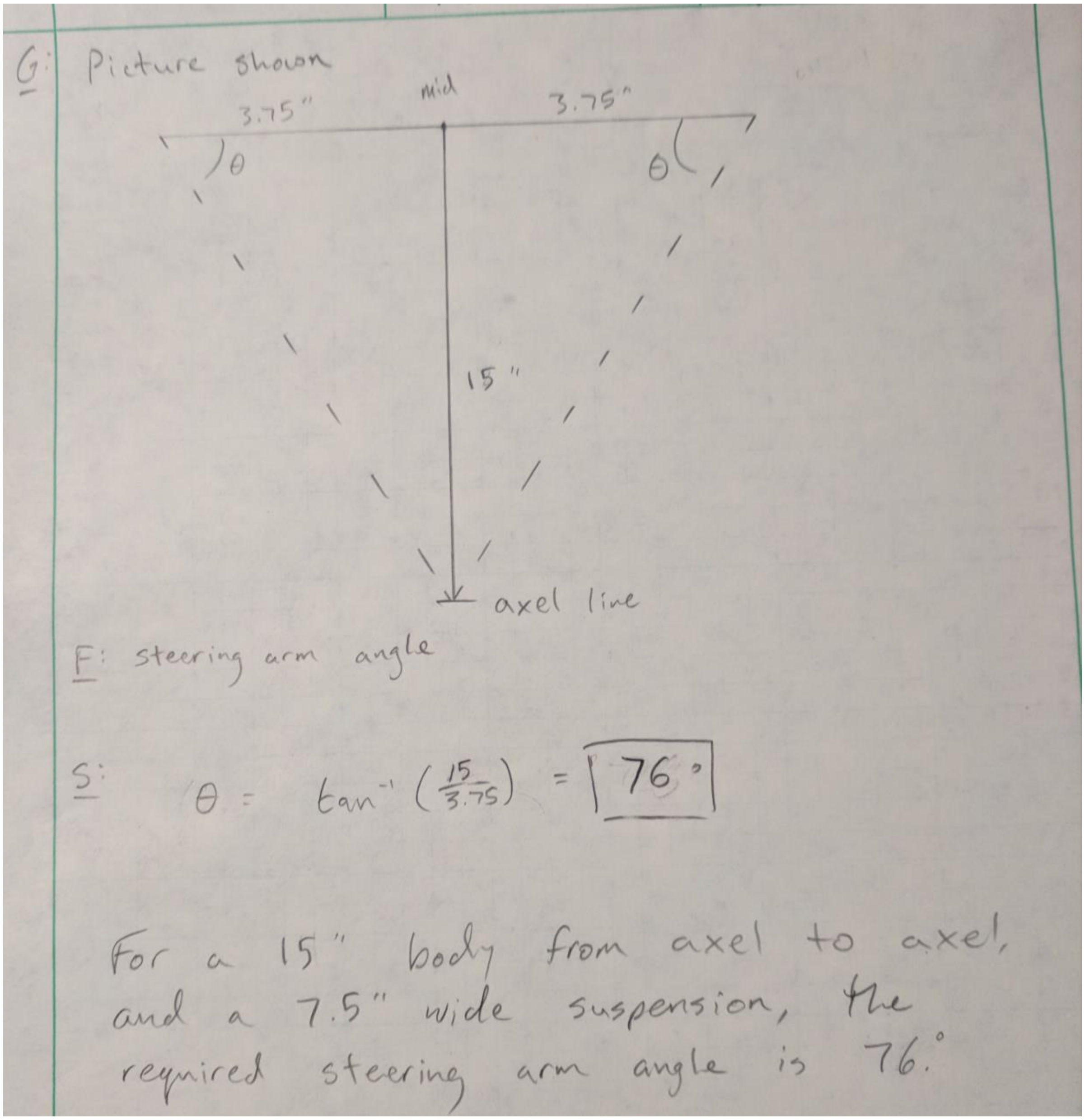
S:

$$\text{Distance} = \frac{\sqrt{2(s^2)}}{2} + \text{clearance}$$

$$= \frac{\sqrt{2(.45^2)}}{2} + 0.05$$

$$= \boxed{0.37 \text{ inches}}$$

Figure 10 - Steering Knuckle Clearance



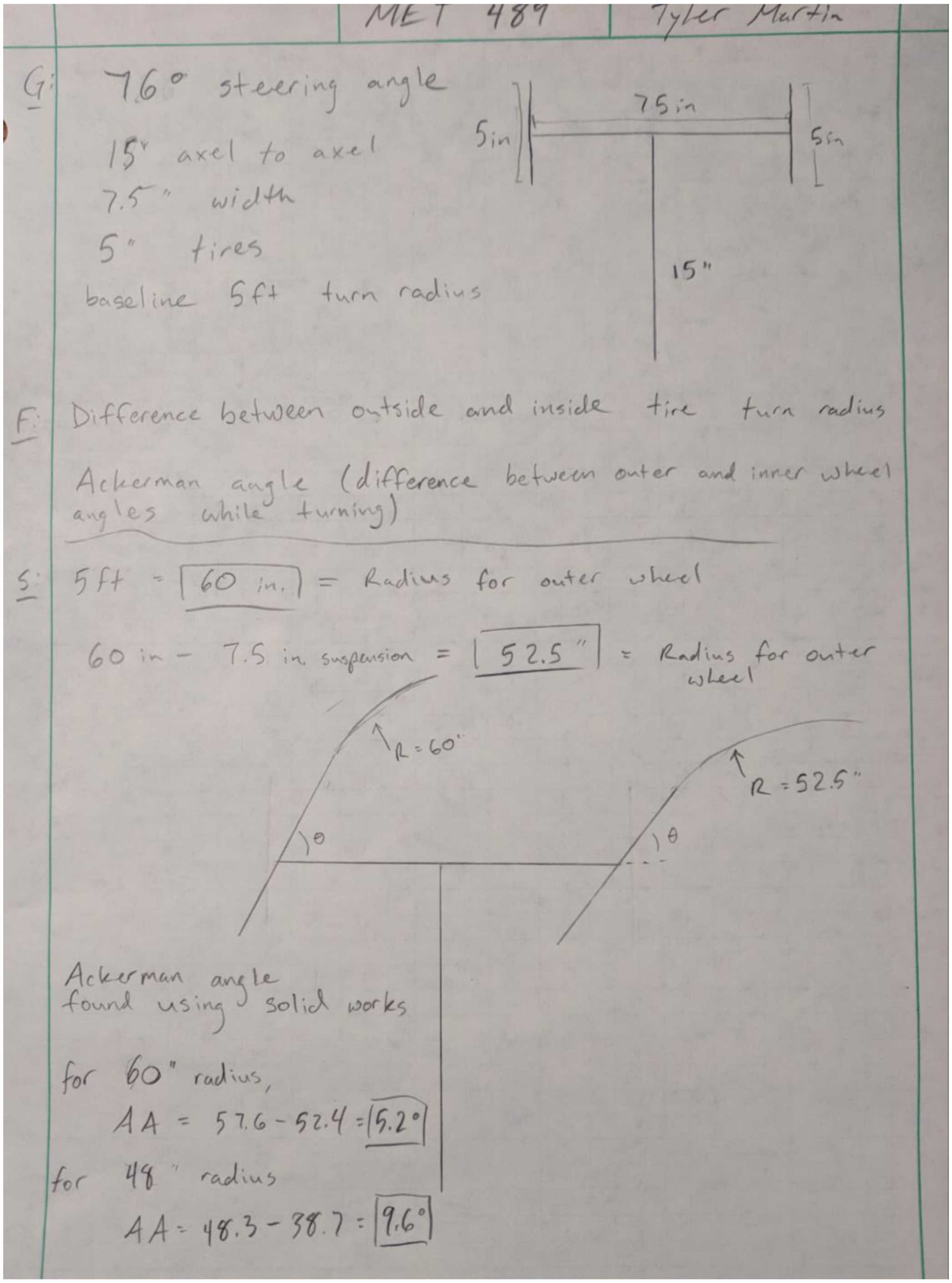
G: Picture shown

F: steering arm angle

S: $\theta = \tan^{-1}\left(\frac{15}{3.75}\right) = \boxed{76^\circ}$

For a 15" body from axel to axel, and a 7.5" wide suspension, the required steering arm angle is 76°

Figure 11 - Steering Knuckle Angle



MET 489 | Tyler Martin

G: 7.6° steering angle

15" axel to axel

7.5" width

5" tires

baseline 5ft turn radius

F: Difference between outside and inside tire turn radius

Ackerman angle (difference between outer and inner wheel angles while turning)

S: 5ft = $\boxed{60 \text{ in.}}$ = Radius for outer wheel

60 in − 7.5 in. suspension = $\boxed{52.5''}$ = Radius for outer wheel

Ackerman angle found using solid works

for 60" radius,

AA = 57.6 − 52.4 = $\boxed{5.2°}$

for 48" radius

AA = 48.3 − 38.7 = $\boxed{9.6°}$

Figure 12 - Ackermann Angle

Drawing Tree:

Baja Car Suspension

Chassis	Steering	Suspension
Chassis Pan	Steering Mount	Leaf Spring Housing
Servo	Steering Arm Left	Leaf Spring Layer
Servo Mount	Steering Arm Right	Front Middle Layer
Battery	Steering Arm Pin	Rear Middle Layer
Receiver	Steering Connection	Upper Arm Mount
	Front Wheel Hub	
	Rear Wheel Hub	
	Front Upper Housing	
	Front Lower Housing	

APPENDIX B – Sketches, Assembly drawings, Sub-assembly drawings, Part drawings

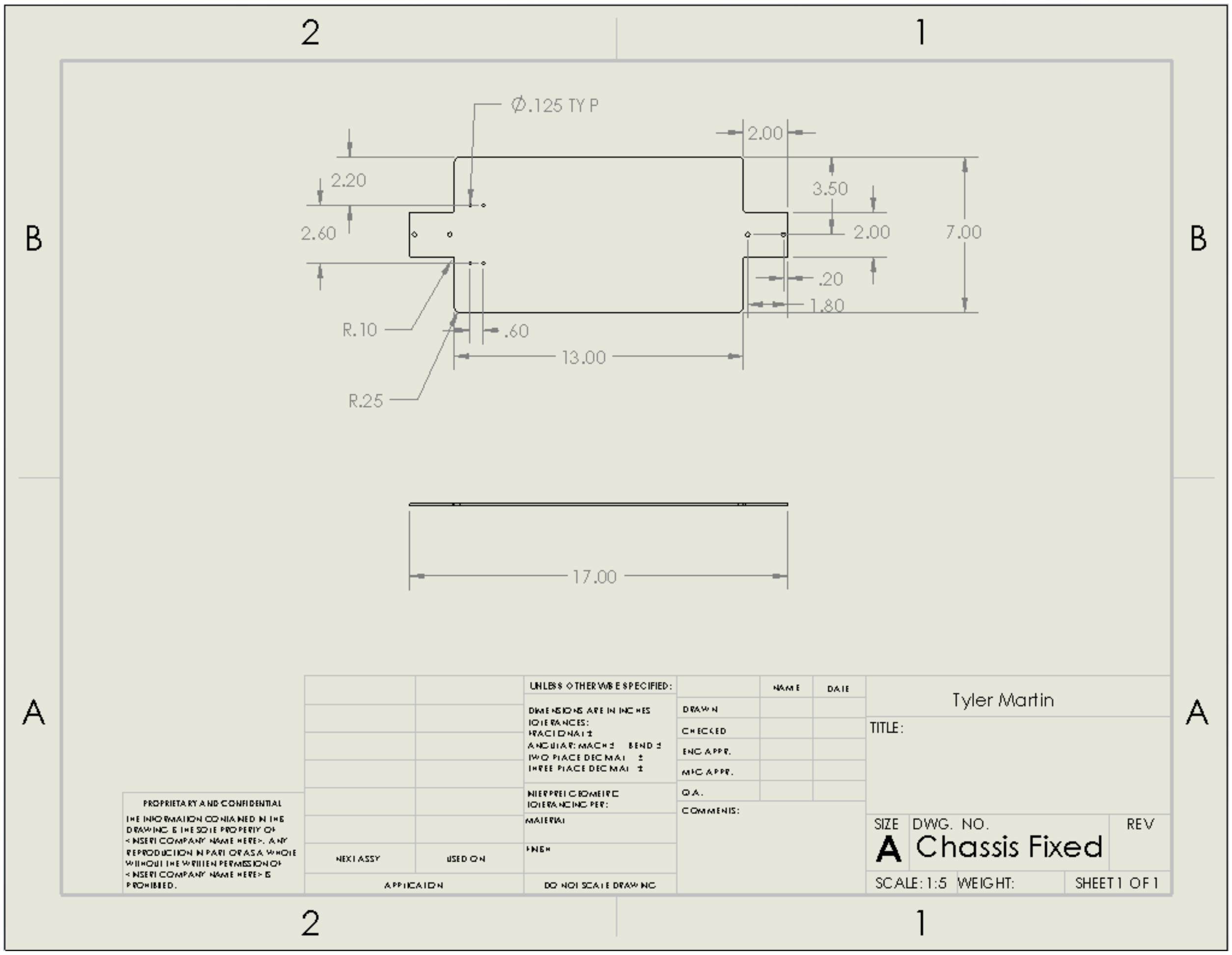


Figure 1 - Chassis Pan

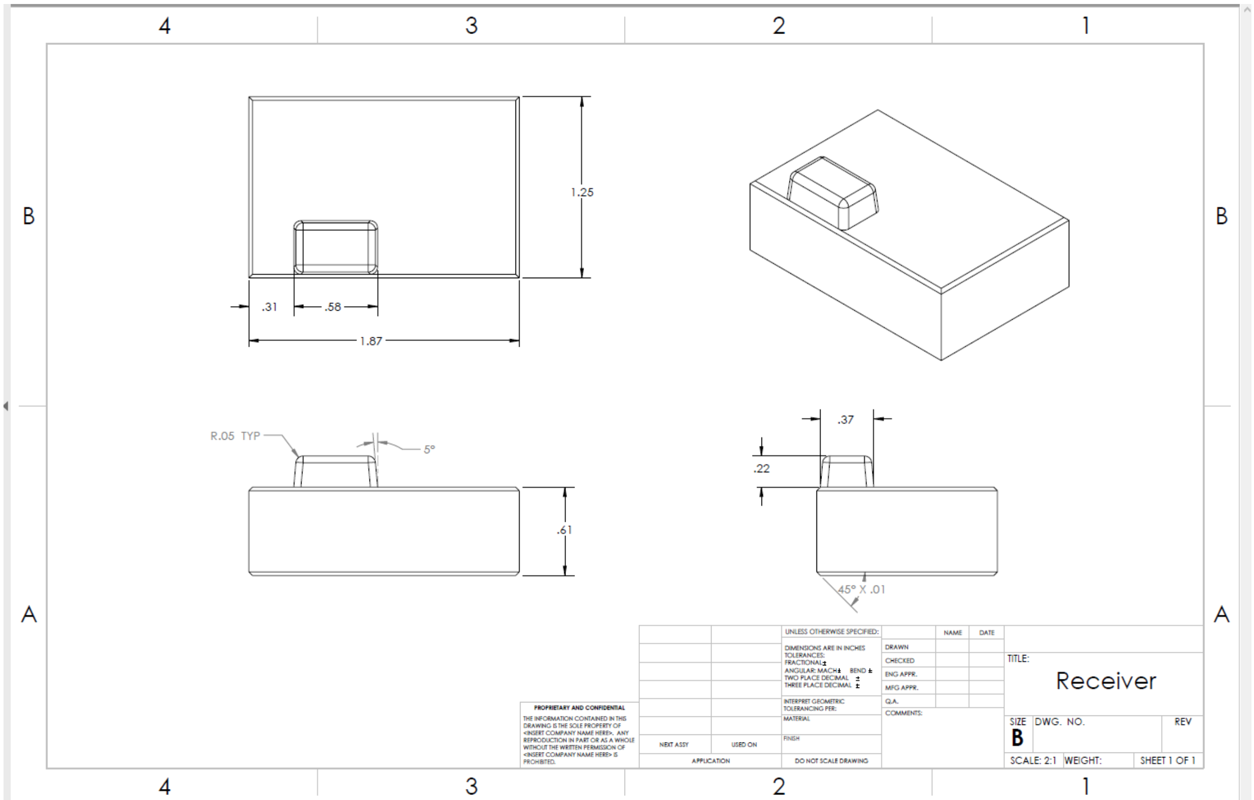


Figure 2 - Remote Receiver

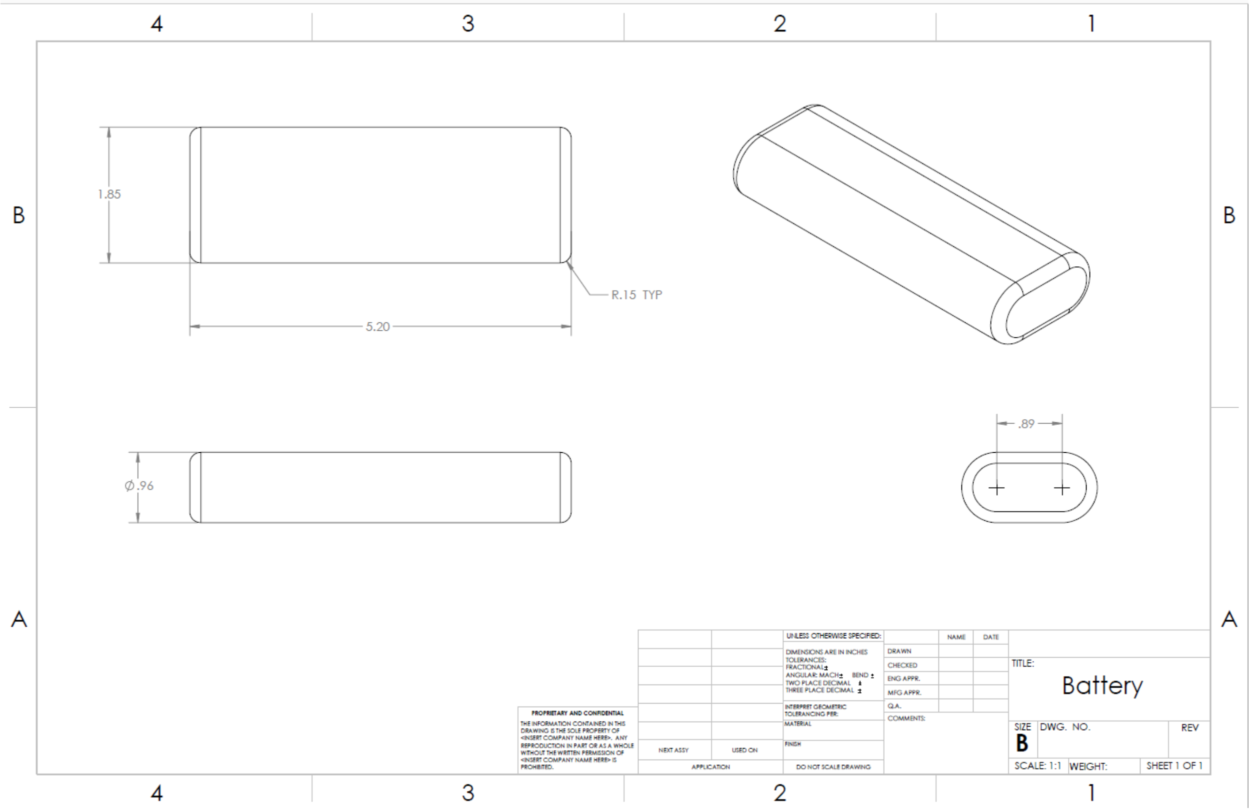


Figure 3 - Battery

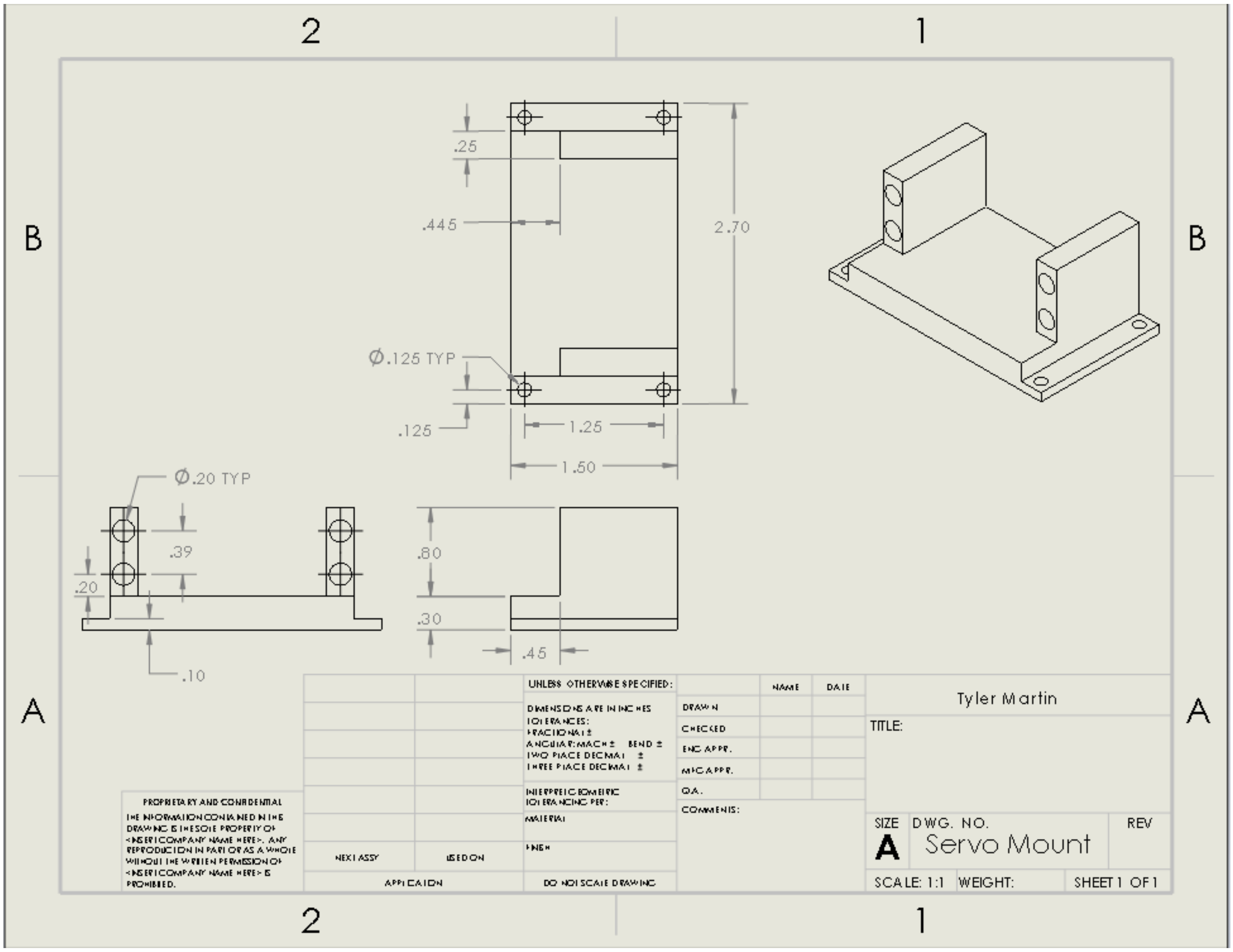


Figure 4 - Servo Mount

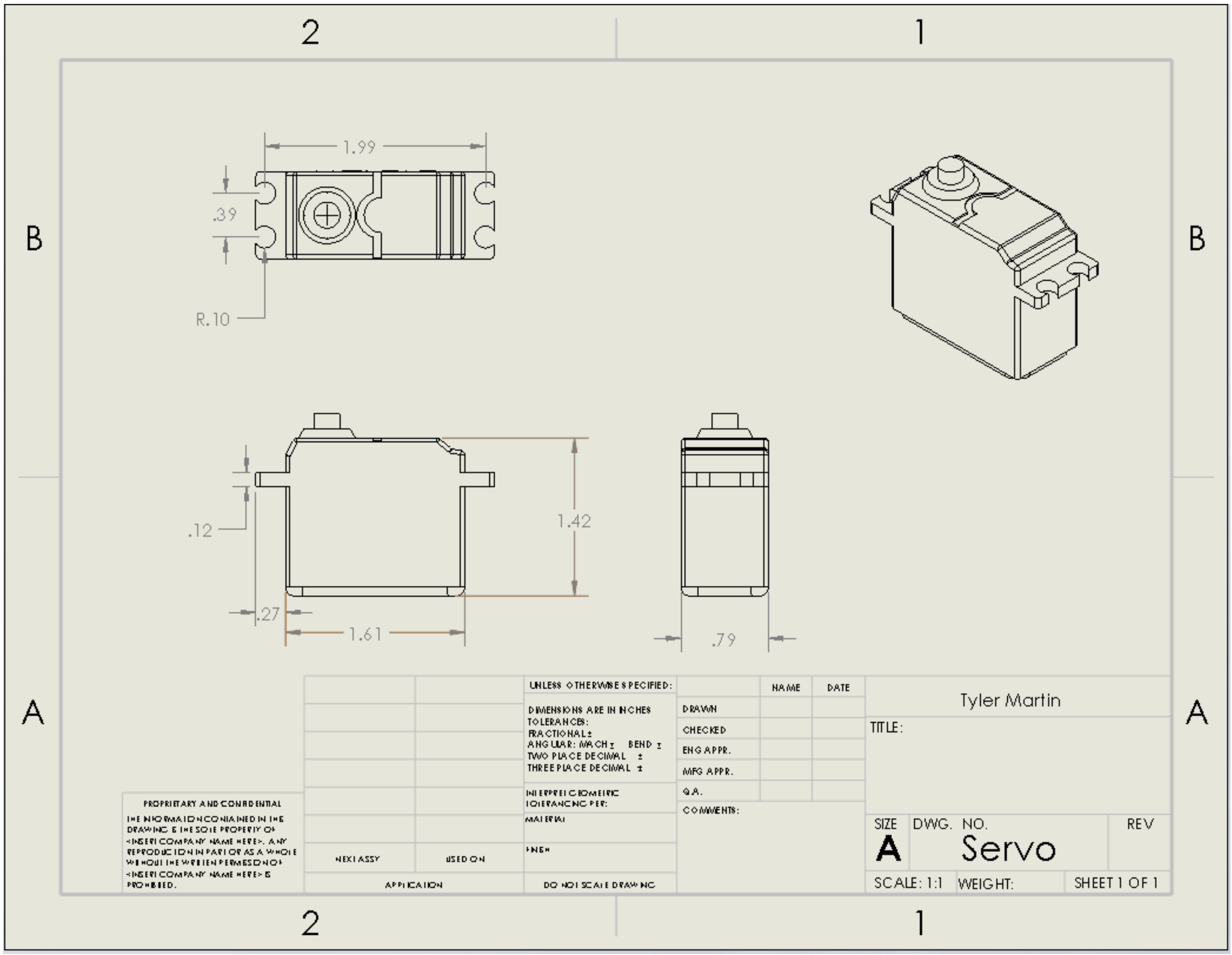


Figure 5 - Servo

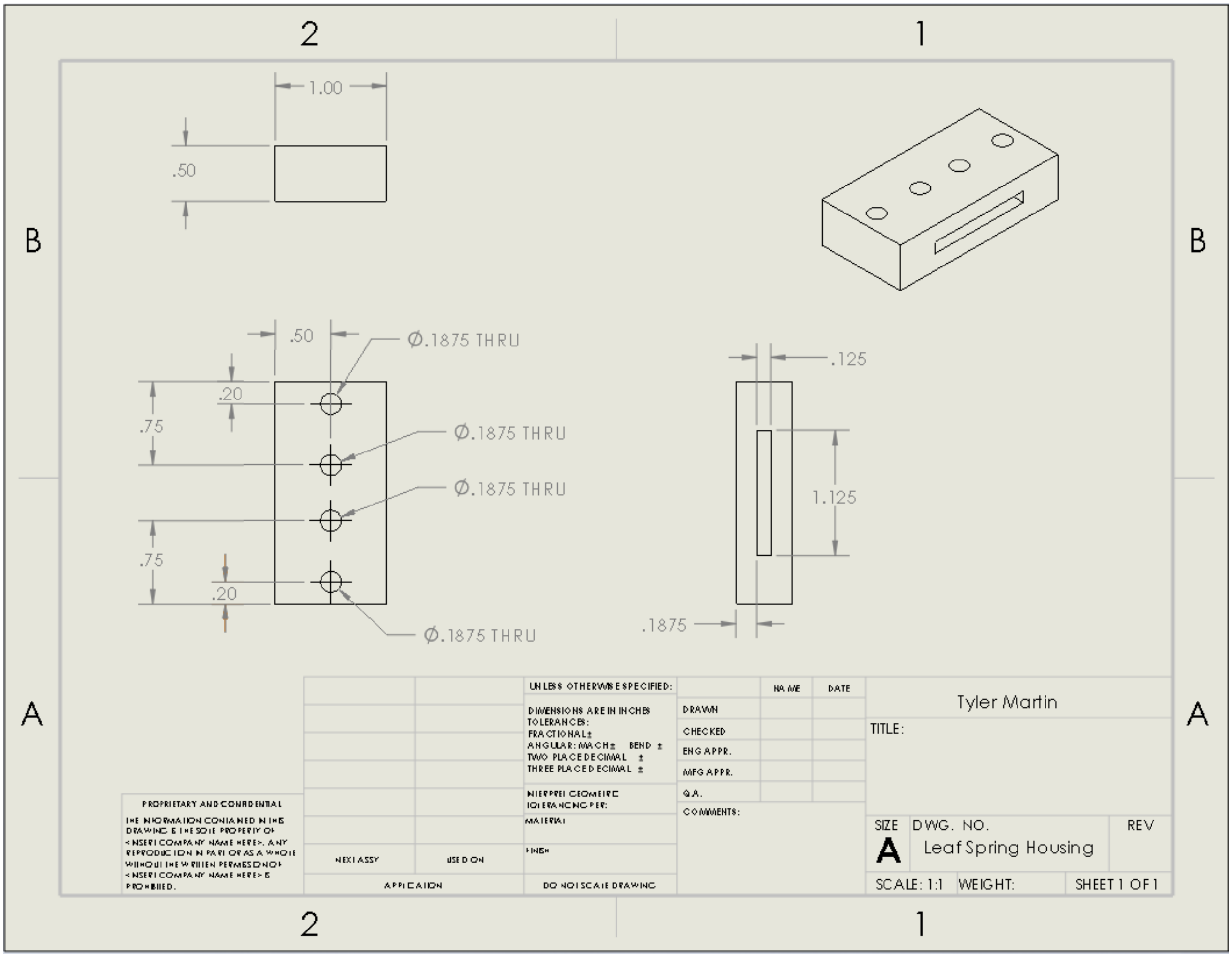


Figure 6 - Leaf Spring Housing

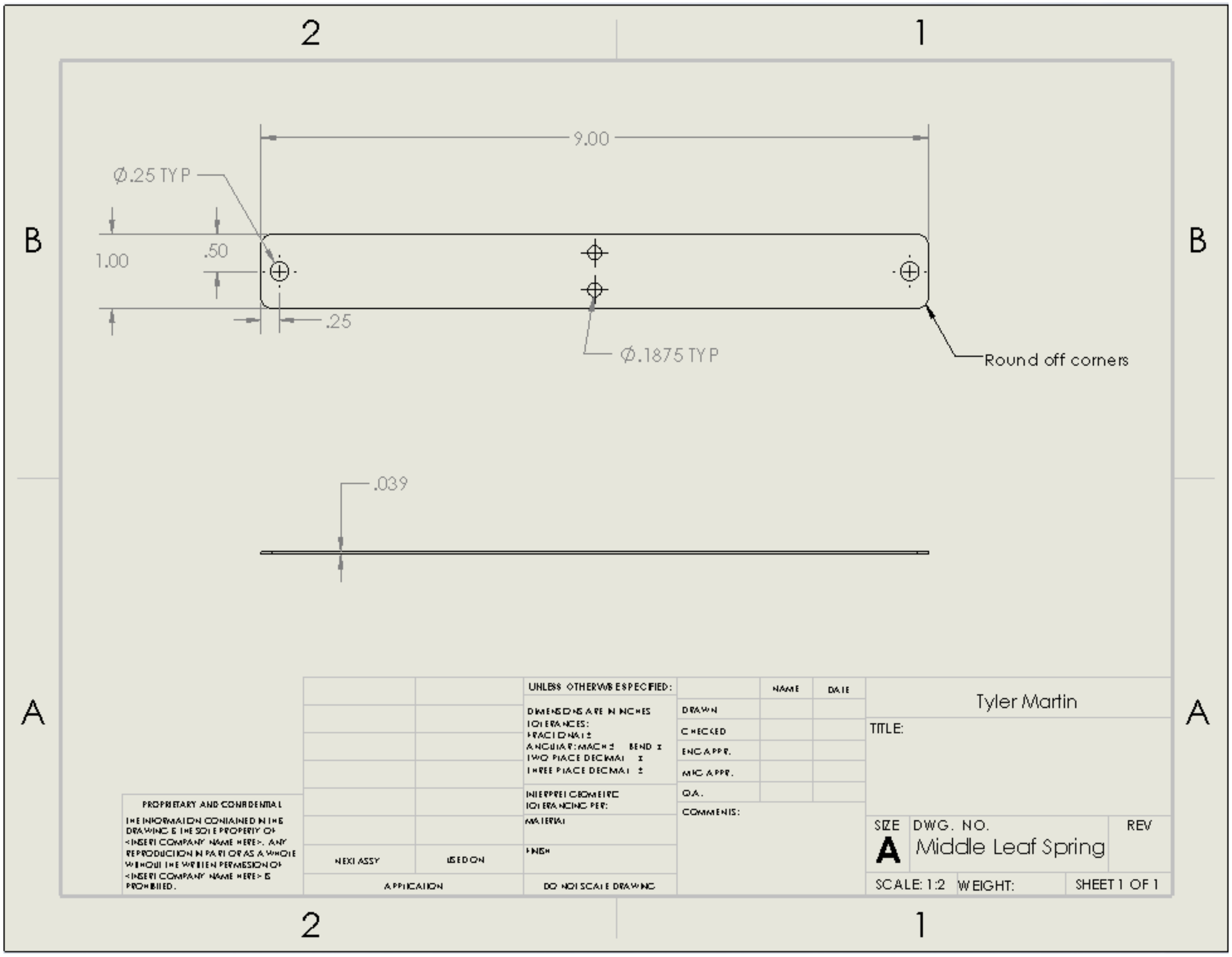


Figure 7 – Front Middle Leaf Spring

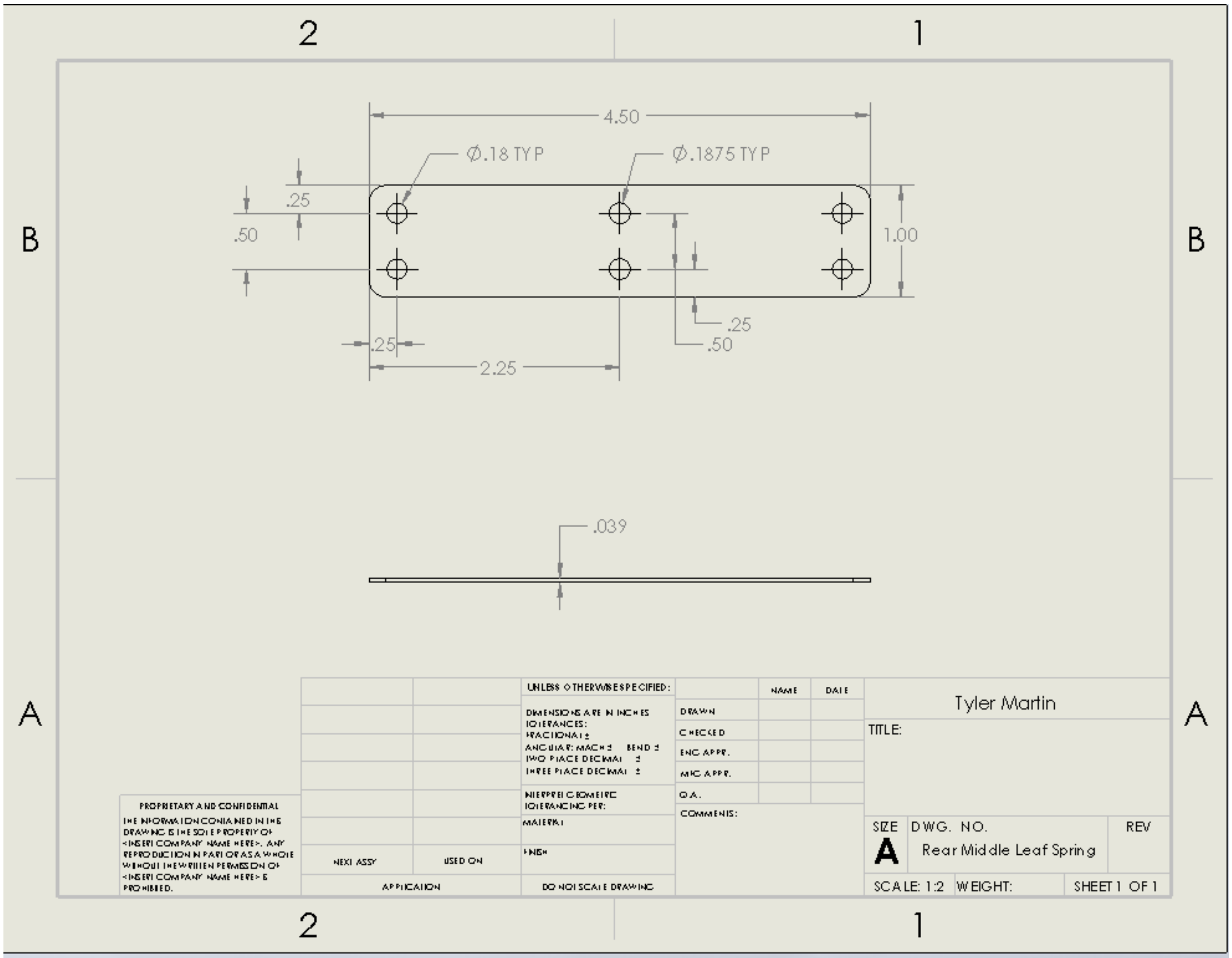


Figure 8 - Rear Middle Leaf Spring

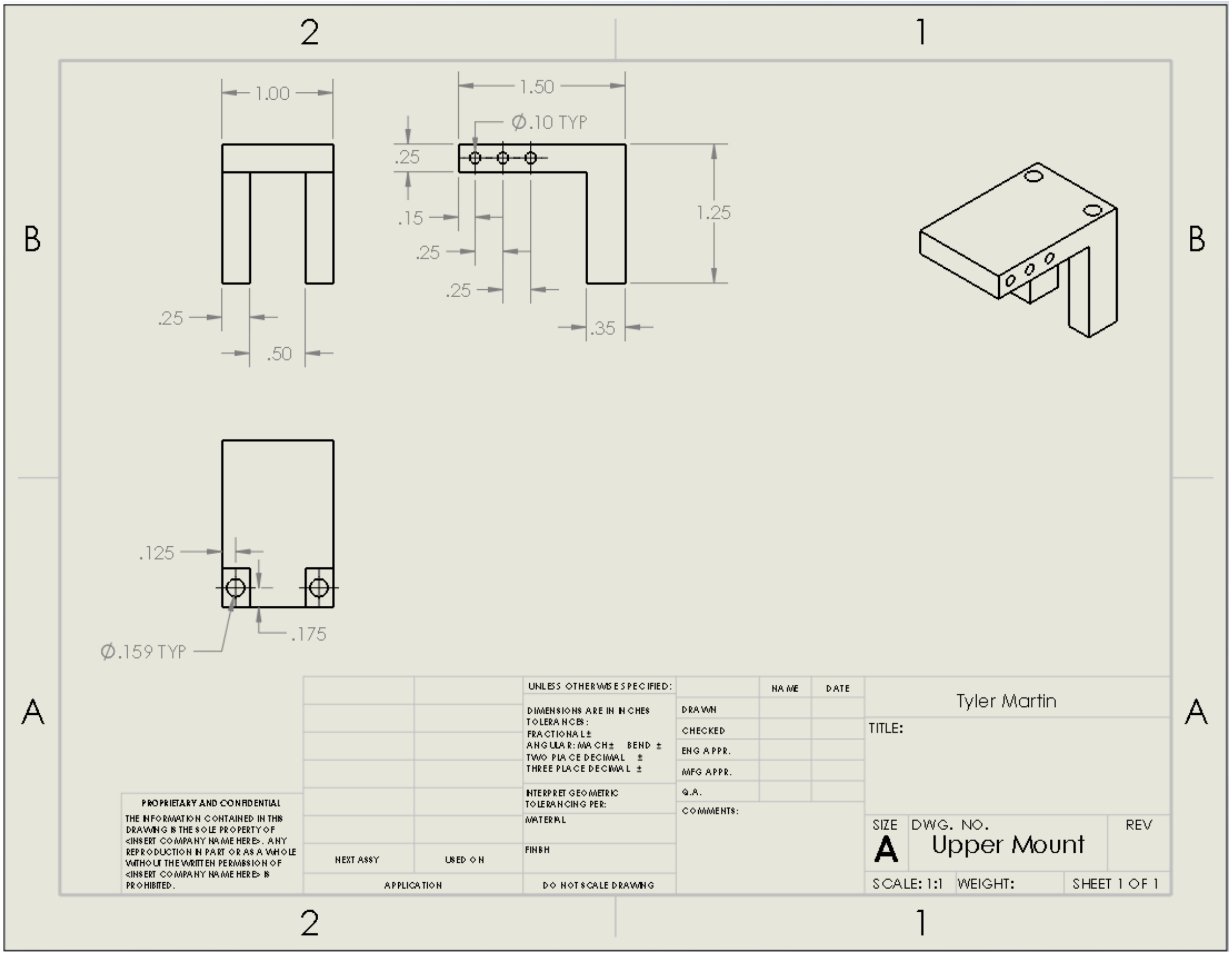


Figure 9 - Upper Arm Mount

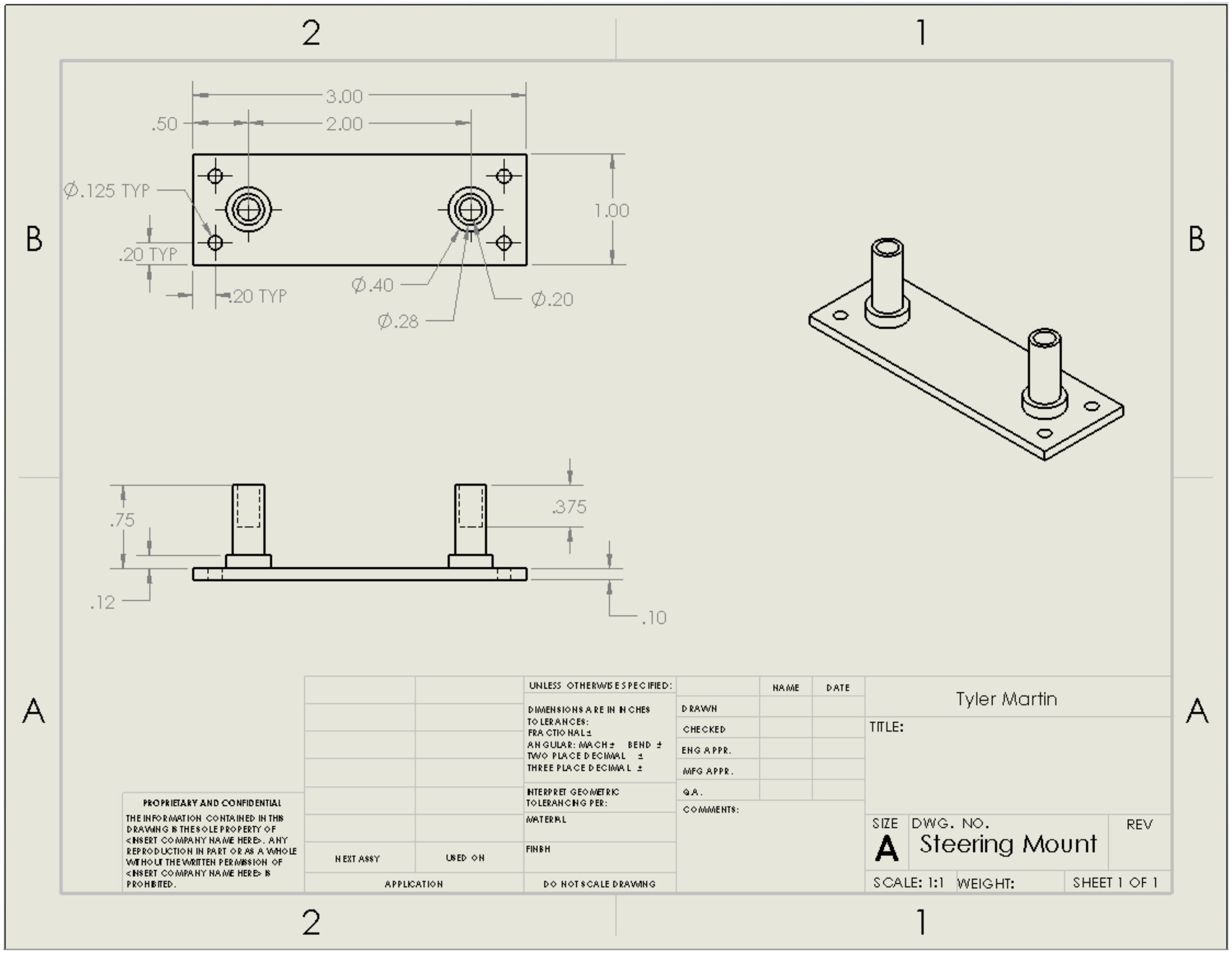


Figure 10 - Steering Mount

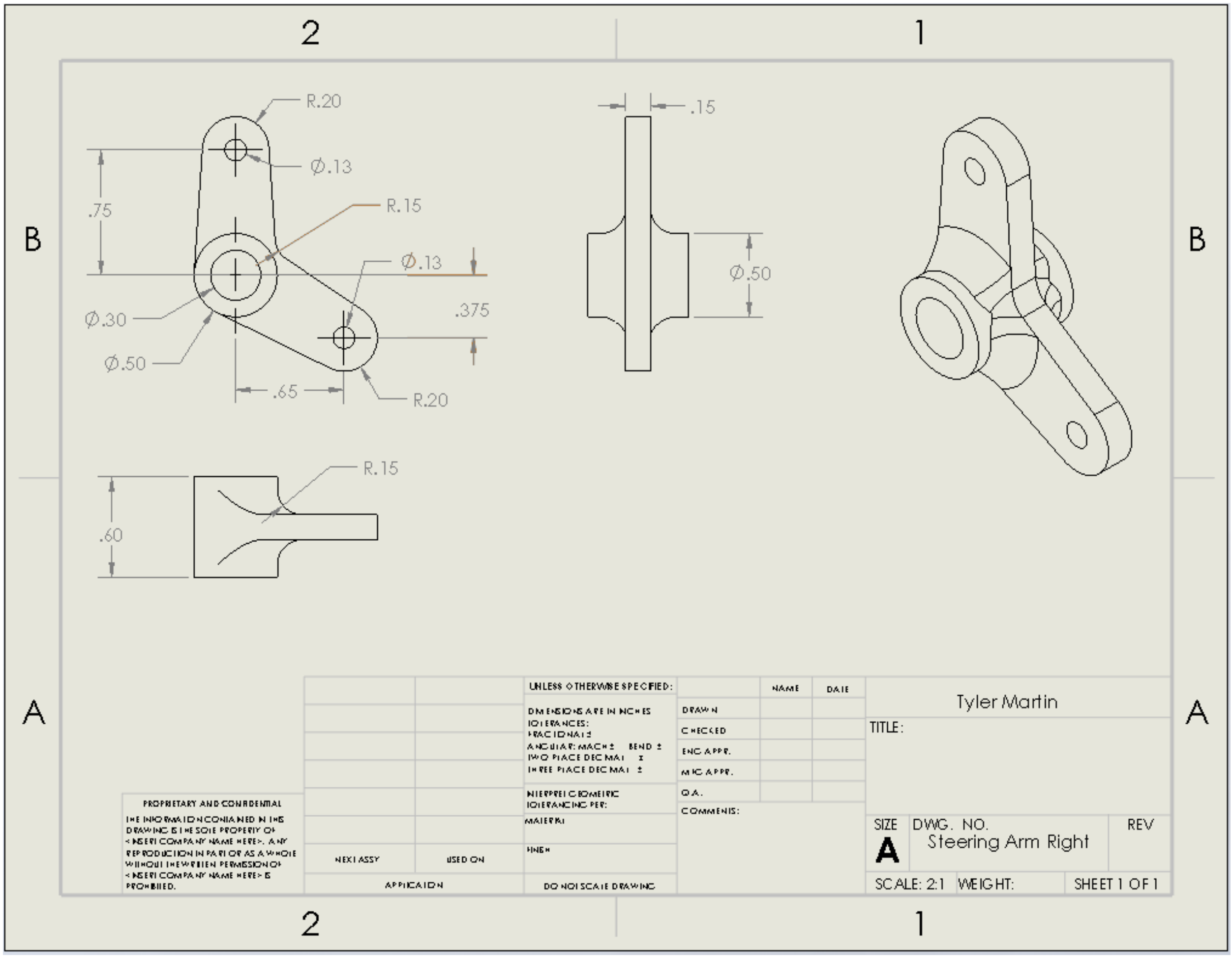


Figure 11 - Steering Arm Right

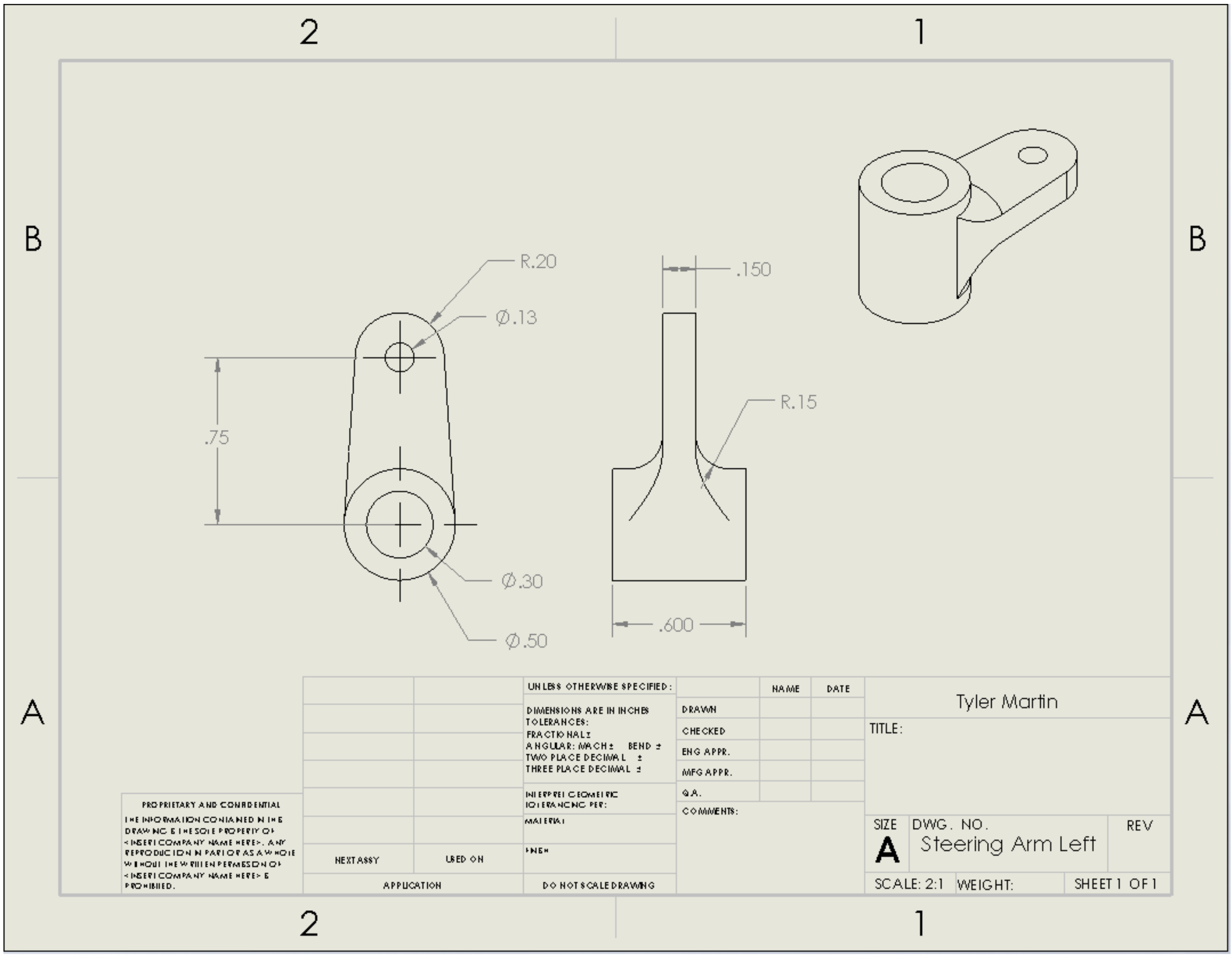


Figure 12 - Steering Arm Left

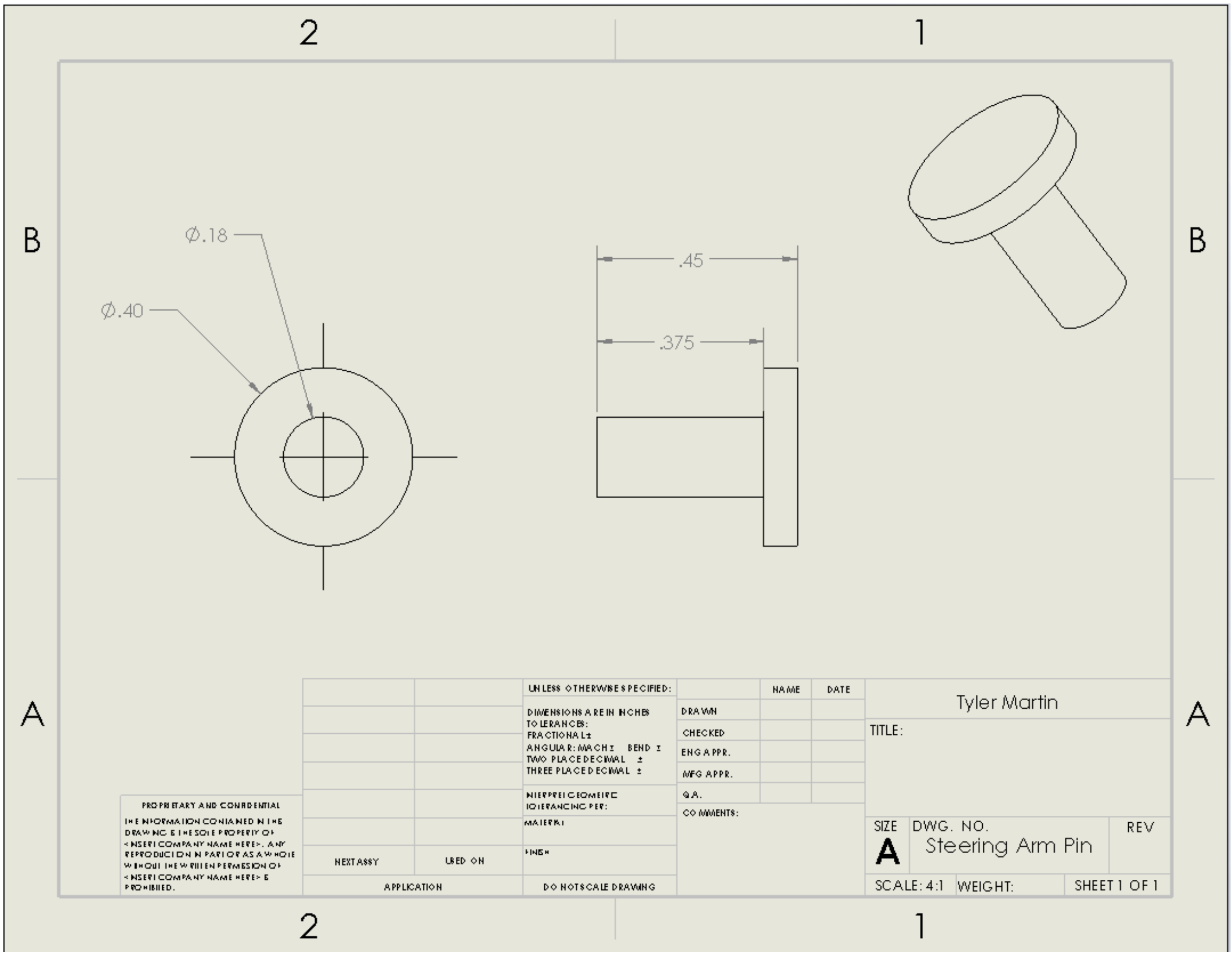


Figure 13 - Steering Arm Pin

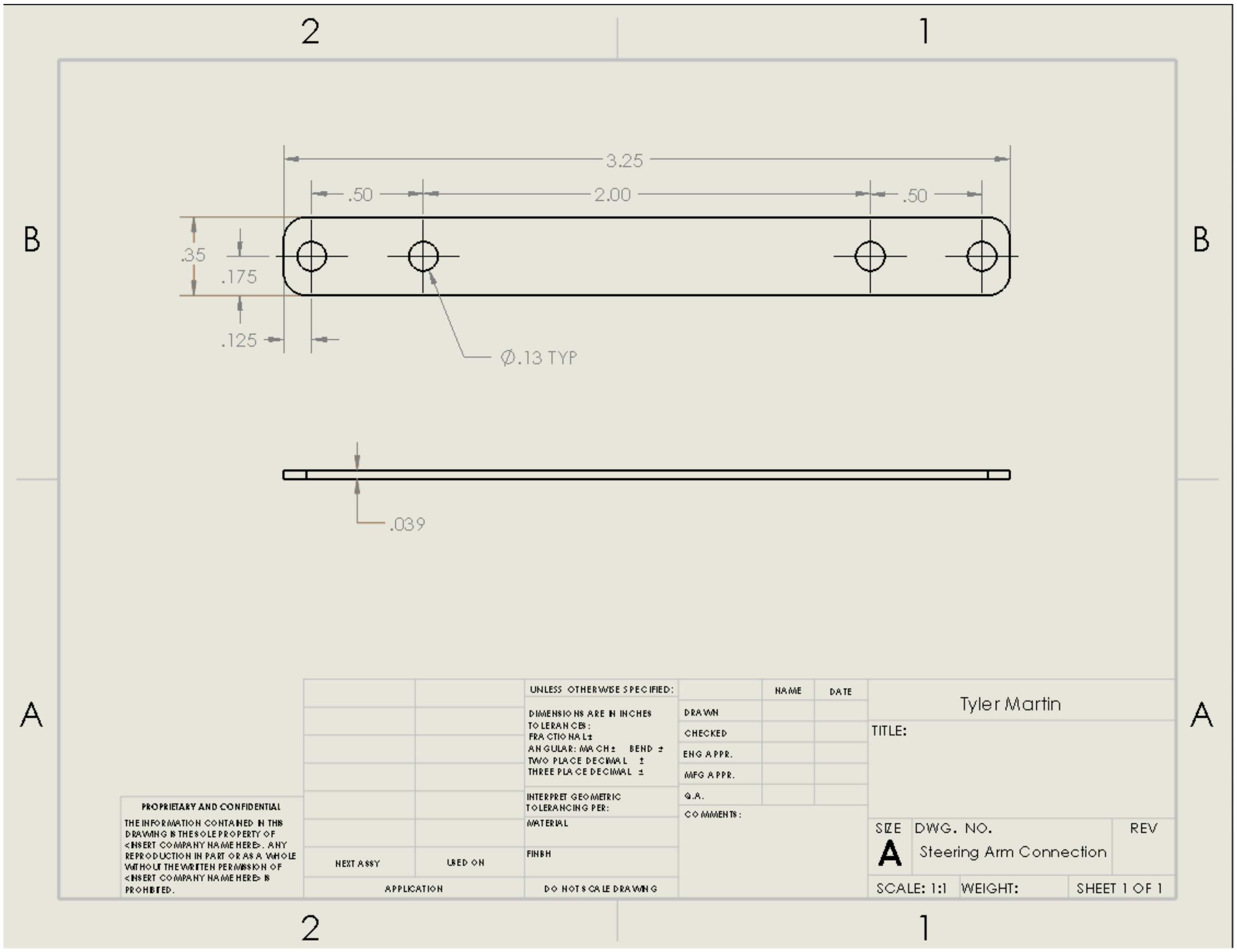


Figure 14 - Steering Connection

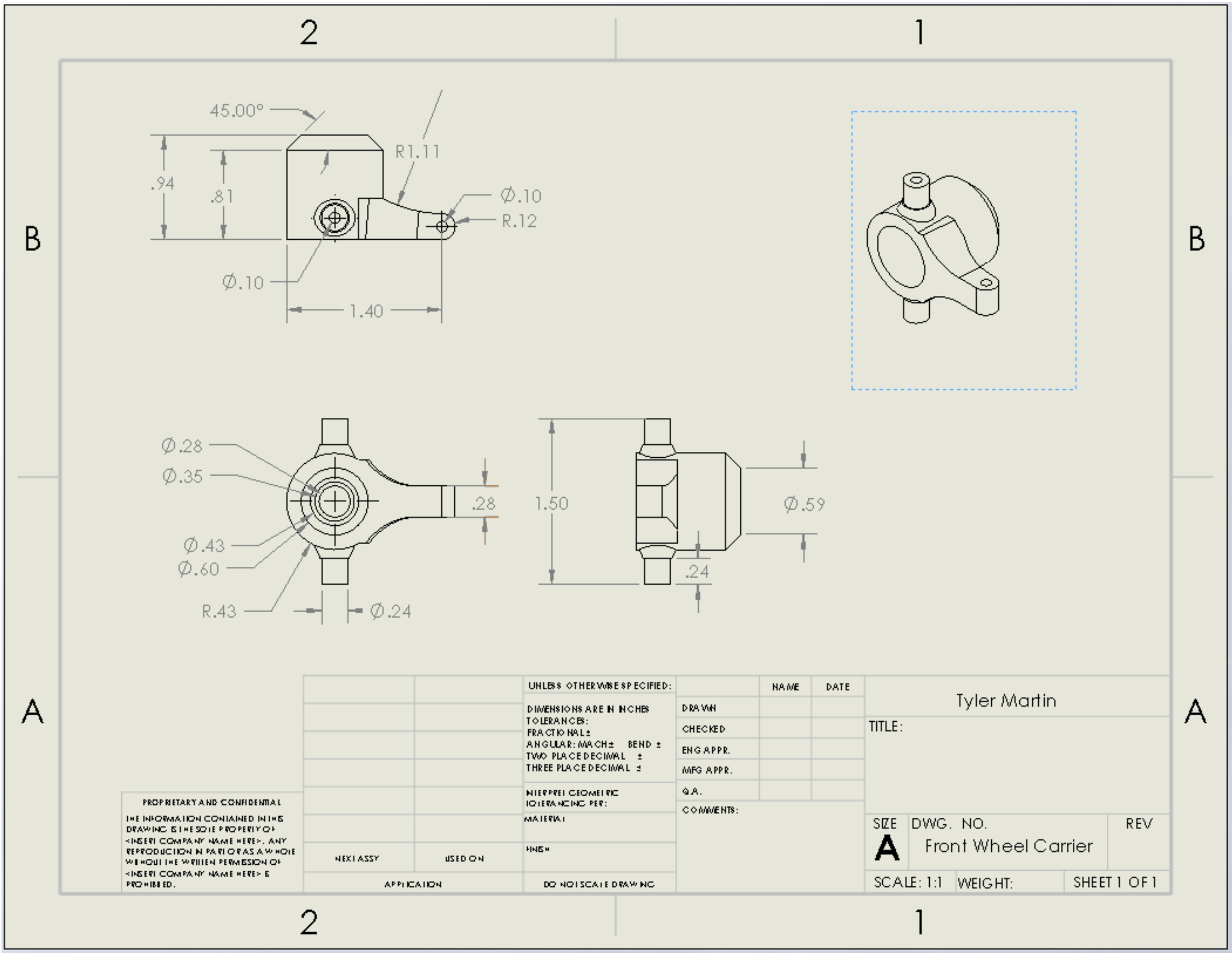


Figure 15 - Front Wheel Carrier

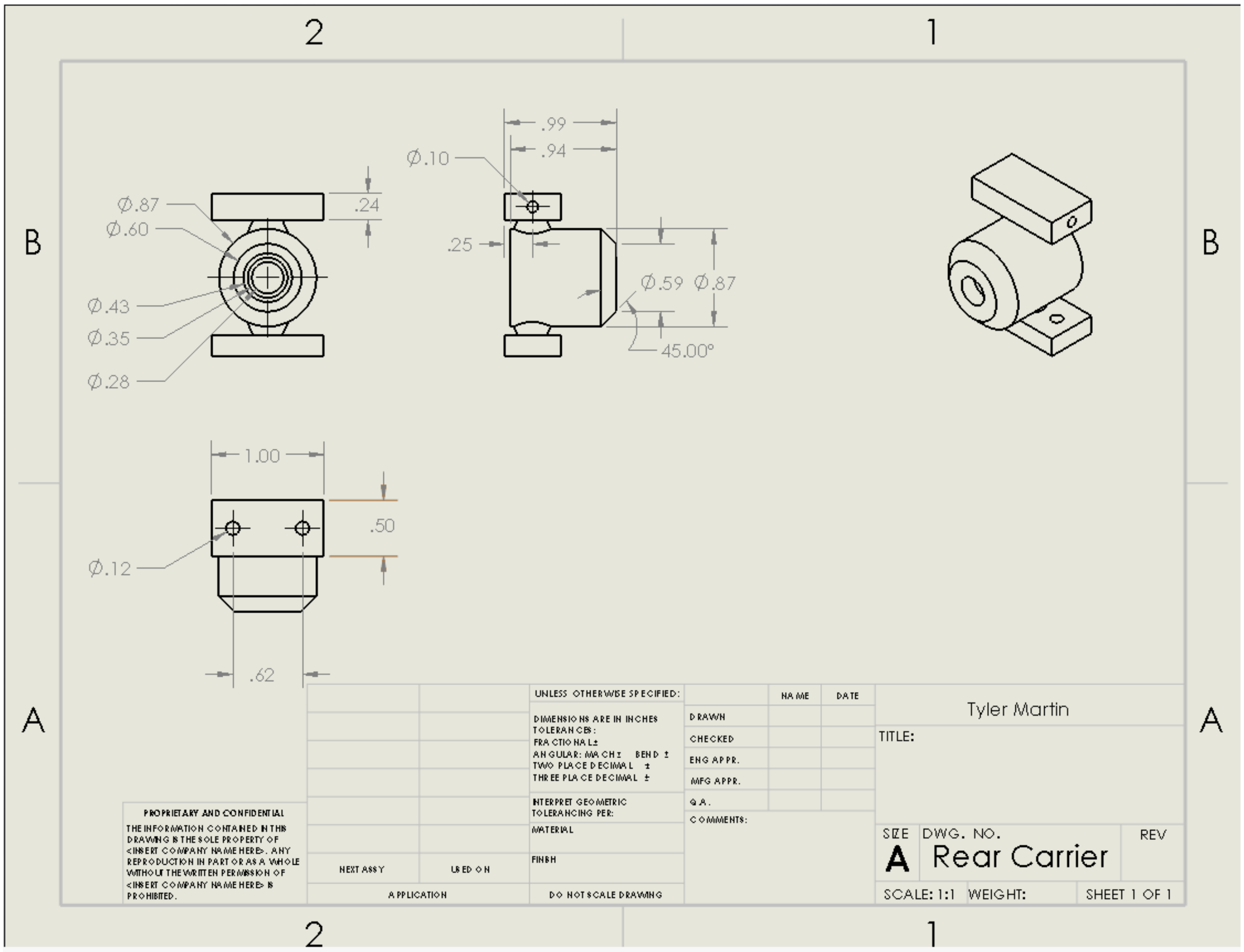


Figure 16 - Rear Wheel Carrier

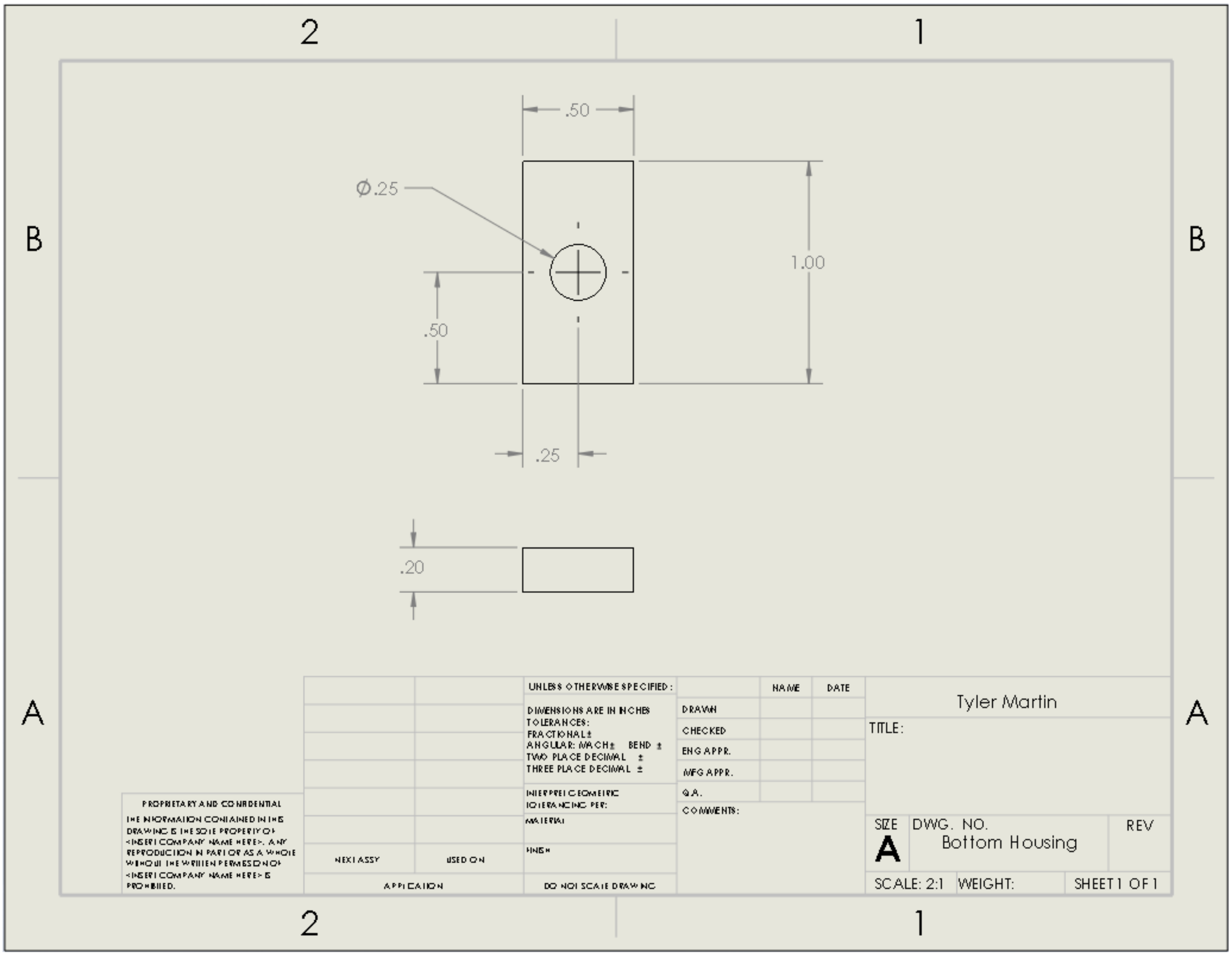


Figure 17 - Front Lower Housing

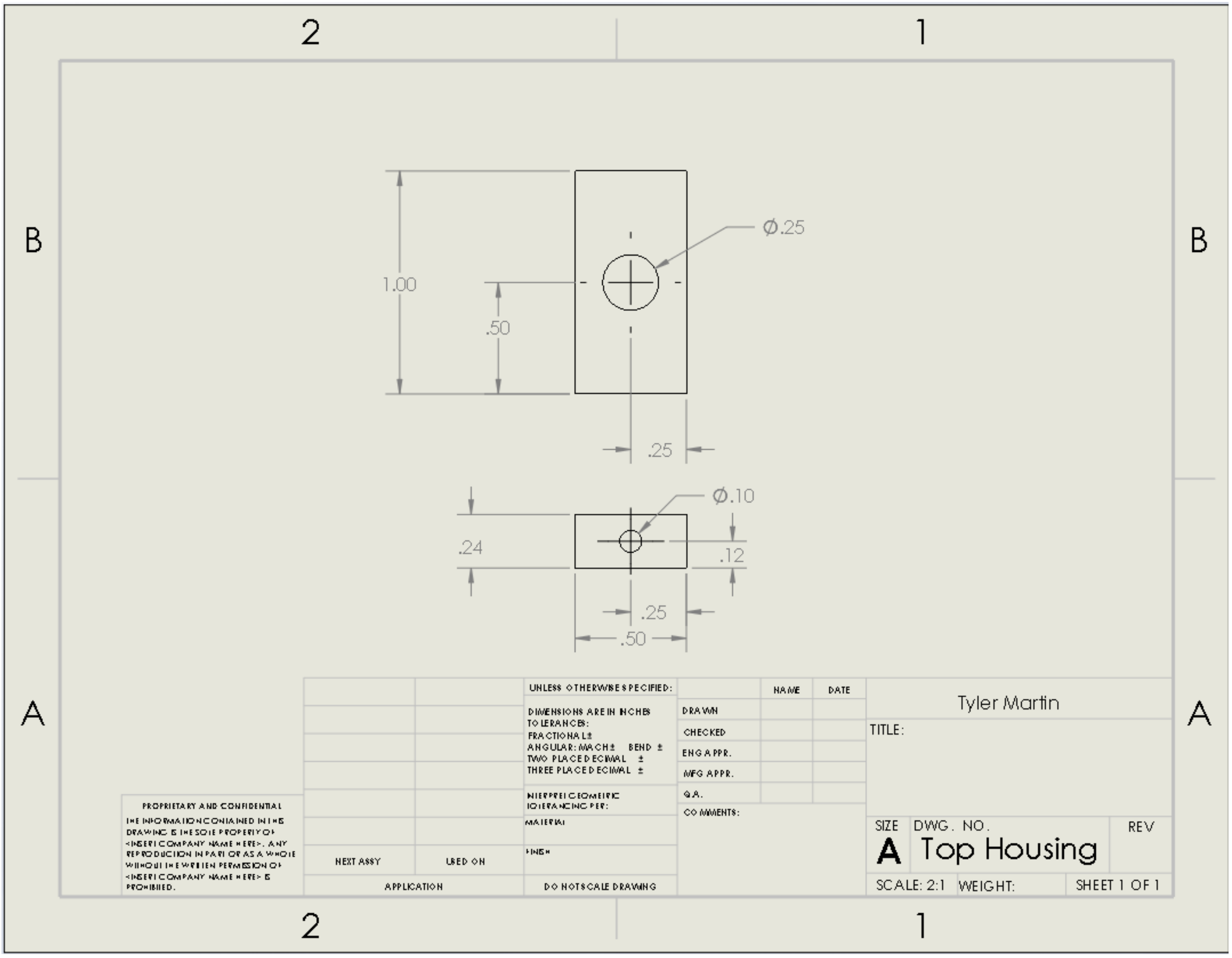


Figure 18 - Front Upper Housing

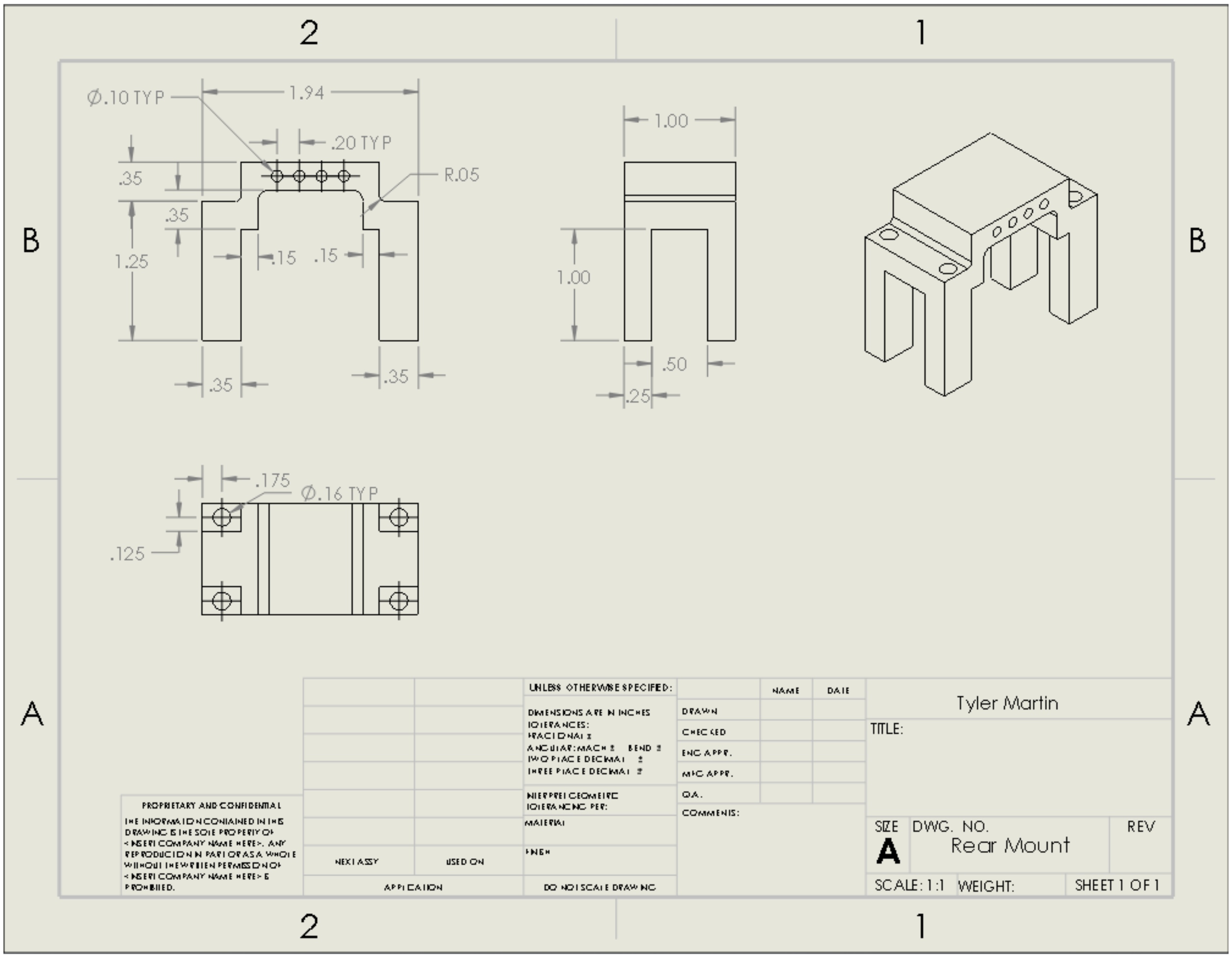
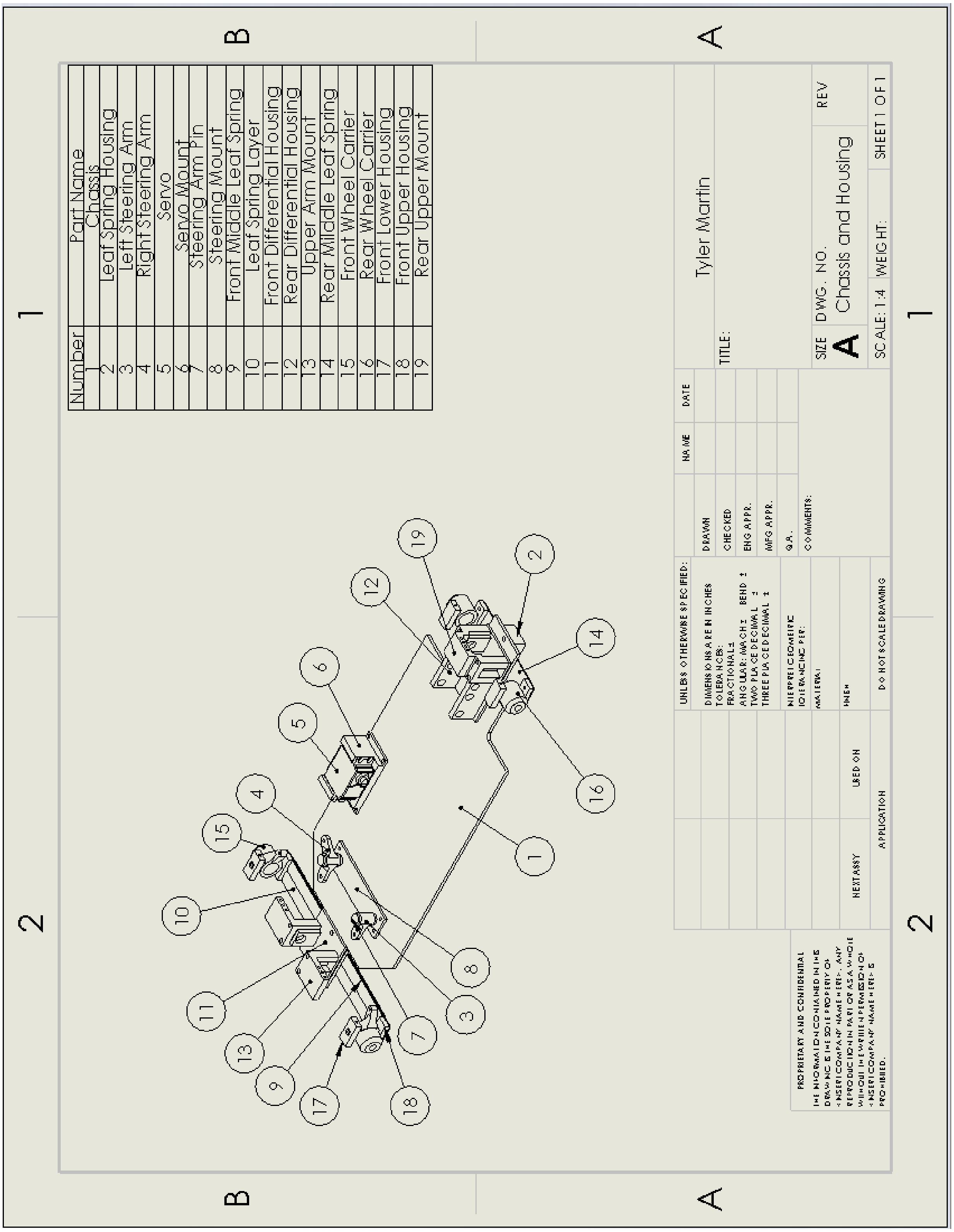


Figure 19 - Rear Upper Mount



Number	Part Name
1	Chassis
2	Leaf Spring Housing
3	Left Steering Arm
4	Right Steering Arm
5	Servo
6	Servo Mount
7	Steering Arm Pin
8	Steering Mount
9	Front Middle Leaf Spring
10	Leaf Spring Layer
11	Front Differential Housing
12	Rear Differential Housing
13	Upper Arm Mount
14	Rear Middle Leaf Spring
15	Front Wheel Carrier
16	Rear Wheel Carrier
17	Front Lower Housing
18	Front Upper Housing
19	Rear Upper Mount

Figure 20 - Assembly

APPENDIX C – Parts List and Costs

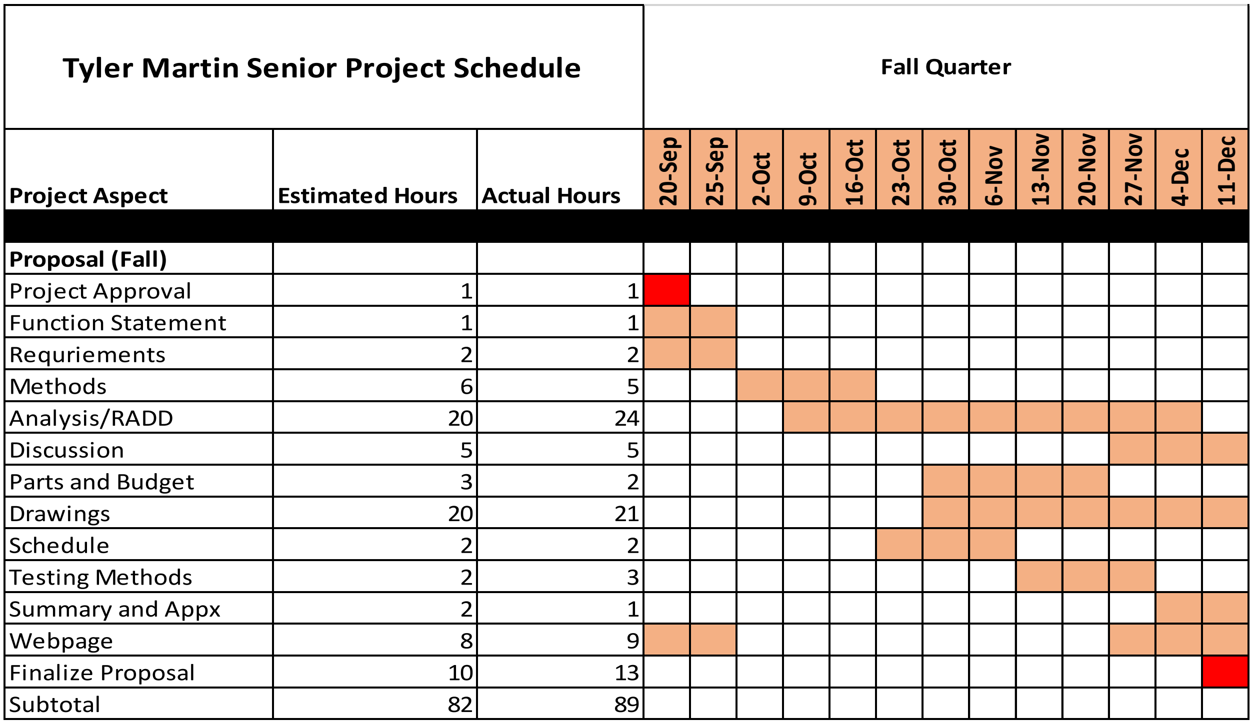
Item ID	Description	Item Source	Model #	Cost per Unit	Quantity Needed	Total
1	Battery	Roger Beardsley	1546	$0.00	1	$0.00
2	Motor	Hobby King	RS-540SH-6527	$6.95	1	$6.95
3	Chassis Material	Matt Burvee	N/A	$0.00	1	$0.00
4	Leaf Spring Material	Matt Burvee	N/A	$0.00	2	$0.00
5	Leaf Spring Housing Material	Metals Depot	N/A	$53.40	1	$53.40
6	Steering Linkage Rods	Amazon	106017	$22.99	2	$45.98
7	Steering Components	3D Printed	N/A	$4.36	1	$4.36
8	Servo Mount	3D Printed	N/A	$1.27	1	$1.27
9	Upper Arm Mounts	3D Printed	N/A	$6.30	1	$6.30
10	Drive Shafts	Amazon	3639	$30.05	2	$60.10
11	Servo	Roger Beardsley	FP-514B	$0.00	1	$0.00
12	ESC	Roger Beardsley	BDESC-S10E	$0.00	1	$0.00
13	Conroller	Roger Beardsley	FP-T2PB	$0.00	1	$0.00
14	Reciever	Roger Beardsley	FP-R112JE	$0.00	1	$0.00
15	Front Carrier	3D Printed	N/A	$3.21	2	$6.42
16	Rear Carrier	3D Printed	N/A	$3.93	2	$7.86
17	Front Carrier Housing Top	Machined	N/A	$0.00	2	$0.00
18	Front Carrier Housing Bottom	Machined	N/A	$0.00	2	$0.00
19	Hex Drives	Amazon	TT010-B	$12.98	1	$12.98
20	Wheels	Jerrol's	N/A	$25.99	2	$51.98
	Total			$171.43		$257.60

Several items have been split between team members. These include the steering linkage rods, the wheels, and the drive shafts. Because of this, the total becomes about $204. Since the quantity needed should be listed, the current cost reflects that.

APPENDIX D – Budget

The budget has been laid out to be $500 for the whole car, making it $250 dollars per team member for the drivetrain and the suspension. Further details can be found in the Budget section of the report.

APPENDIX E – Schedule



Tyler Martin Senior Project Schedule			Fall Quarter												
Project Aspect	**Estimated Hours**	**Actual Hours**	**20-Sep**	**25-Sep**	**2-Oct**	**9-Oct**	**16-Oct**	**23-Oct**	**30-Oct**	**6-Nov**	**13-Nov**	**20-Nov**	**27-Nov**	**4-Dec**	**11-Dec**
Proposal (Fall)															
Project Approval	1	1	🟥												
Function Statement	1	1	🟧	🟧											
Requriements	2	2	🟧	🟧											
Methods	6	5			🟧	🟧	🟧								
Analysis/RADD	20	24				🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	
Discussion	5	5											🟧	🟧	🟧
Parts and Budget	3	2							🟧	🟧	🟧	🟧			
Drawings	20	21							🟧	🟧	🟧	🟧	🟧	🟧	🟧
Schedule	2	2						🟧	🟧	🟧					
Testing Methods	2	3									🟧	🟧	🟧		
Summary and Appx	2	1												🟧	🟧
Webpage	8	9	🟧	🟧									🟧	🟧	🟧
Finalize Proposal	10	13													🟥
Subtotal	82	89													

Senior Project Schedule				Winter Quarter										
Task#	**Project Aspect**	**Estimated Hours**	**Actual Hours**	**3-Jan**	**8-Jan**	**15-Jan**	**22-Jan**	**29-Jan**	**5-Feb**	**12-Feb**	**19-Feb**	**26-Feb**	**5-Mar**	**12-Mar**
	Construction (Winter)													
2.01	Order Material	2	1	🟥	🟥	🟥								
2.02	Order Fasteners	0.5	0.5	🟨	🟨	🟨								
2.03	Order Wheels	0.5	0.5		🟨	🟨								
2.04	Order Wheel Components	1	0.5		🟨	🟨	🟨							
2.05	Cut Chassis	4	3				🟨	🟨						
2.06	Drill Press Holes in Chassis	1.5	2				🟨	🟨				🟨		
2.07	3D Print Front Wheel Hub	2	2.5				🟨	🟨	🟨	🟨	🟨	🟨		
2.08	3D Print Rear Wheel Hub	2	2.5				🟨	🟨	🟨	🟨	🟨	🟨		
2.09	3D Print Upper Arm Mounts	4	3				🟨	🟨	🟨	🟨	🟨	🟨		
2.1	3D Print Steering Arms	3	3.5				🟨	🟨	🟨	🟨	🟨	🟨		
2.11	3D Print Steering Mount	2.5	3				🟨	🟨	🟨	🟨	🟨	🟨		
2.12	3D Print Servo Mount	3	2.5				🟨	🟨	🟨	🟨	🟨	🟨		
2.13	Ream Holes in 3D Parts (if needed)	2	1				🟨	🟨	🟨	🟨	🟨	🟨		
2.14	Cut Leaf Spring Layers	1.5	2				🟨	🟨	🟨					
2.15	Round Edges of Layers	0.5	0.5				🟨	🟨	🟨	🟨	🟨	🟨		
2.16	Cut Holes in Leaf Spring Layers	0.5	1				🟨	🟨	🟨	🟨	🟨	🟨		
2.17	Cut Leaf Spring Housings	1	1.5							🟨	🟨	🟨		
2.18	Drill Holes in Leaf Spring Housing	0.5	1								🟨	🟨		
2.19	Cut Slots in Leaf Spring Housing	2	3								🟨	🟨		
2.2	Dremmel Any Holes to Fit	2	2.5								🟨	🟨		
2.21	Assemble Suspension	10	9										🟥	🟥
2.22	Assemble Steering	10	8										🟥	🟥
2.23	Assembly with DriveTrain	10	15											🟥
2.24	Modifications	30	25					🟨	🟨	🟨	🟨	🟨	🟨	🟨
2.25	Document All Progression	5	5	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
2.26	Update Webpage	3	3				🟨	🟨					🟨	🟨
2.27	Finalize Design	2	2											🟥
	Total	106	104											

Senior Project Schedule			Spring Quarter											
Project Aspect	**Estimated Hours**	**Actual Hours**	**26-Mar**	**2-Apr**	**9-Apr**	**16-Apr**	**23-Apr**	**30-Apr**	**7-May**	**14-May**	**21-May**	**28-May**	**4-Jun**	**8-Jun**
Testing (Spring)														
Vehicle Modifications	10	25	🟩	🟩										
Test Slalom Course	3	1		🟩	🟩	🟩								
Test Turn Radius	3	2		🟩	🟩	🟩								
Test Two Foot Drop	3	1		🟩	🟩	🟩								
Test Obstacle Course	10	1.5		🟩	🟩	🟩								
Test Drag Race	5	1.5		🟩	🟩	🟩								
Test Top Speed	10	5		🟩	🟩	🟩								
Test Vehicle Weight	0.25	0.25		🟩	🟩	🟩								
Vehicle Completion	3	3				🟥	🟥							
Competition	3	3					🟩							
Source Presentation	20	18						🟩	🟩	🟩	🟩	🟩	🟩	
Engineering Report	20	15						🟩	🟩	🟩	🟩	🟩	🟩	🟩
Finalize Webpage	10	12				🟩	🟩					🟩	🟩	🟩
Project Completion	1	1												🟥
Total	101.25	89.25												

APPENDIX F – Expertise and Resources

- Beardsley, R.
- Burvee, M.
- Bramble, T.
- Johnson, C.
- Mott, Robert L., Machine Elements in Mechanical Design. 5th Edition.
- Pringle, C.

APPENDIX G – Testing Data

Test 1:

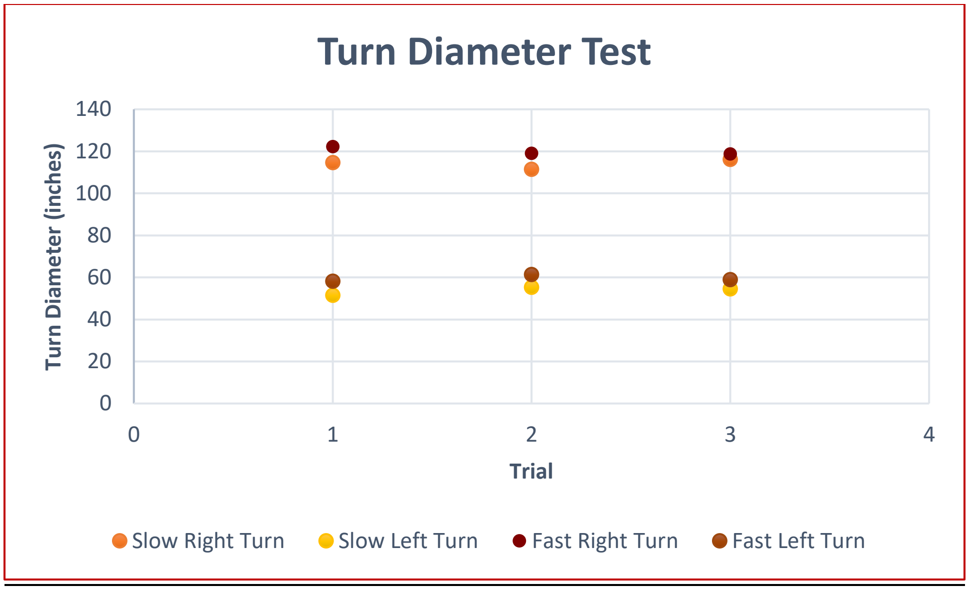
RC Car Part Interference

Part Being Tested	Distance of Clearance (in)	Interference? (PASS or FAIL)
Left Wheel Hub	.45	PASS
Right Wheel Hub	.45	PASS
Right Steering Arm	.06	PASS
Left Steering Arm	.07	PASS
Servo Steering Arm	.33	PASS
Rear Wheel and Motor	.08	PASS

Test 2:

RC Car Turn Diameter

Pass Parameter		**Right Turn**				**Left Turn**		
≥60 in (5 ft)	Speed	Attempt	Inches	Feet		Attempt	Inches	Feet
	Slow	**Trial 1**	114.625	9.552		**Trial 1**	51.5	4.292
	Slow	**Trial 2**	111.5	9.292		**Trial 2**	55.375	4.615
	Slow	**Trial 3**	116.25	9.688		**Trial 3**	54.5	4.542
	Slow	**Average**	114.125	9.510		**Average**	53.79167	4.483
	Slow	**Pass/Fail**	FAIL			**Pass/Fail**	PASS	
	Speed	Attempt	Inches	Feet		Attempt	Inches	Feet
	Fast	**Trial 1**	122.25	10.188		**Trial 1**	58.25	4.854
	Fast	**Trial 2**	119.125	9.927		**Trial 2**	61.375	5.115
	Fast	**Trial 3**	118.75	9.896		**Trial 3**	59	4.917
	Fast	**Average**	120.042	10.003		**Average**	59.542	4.962
	Fast	**Pass/Fail**	FAIL			**Pass/Fail**	PASS	



Test 3:

RC Car Drop Test		
Trial	**Approximate Deflection (inches)**	**>1.5 inches? (PASS or FAIL)**
1	0.55	PASS
2	0.75	PASS

APPENDIX H – Evaluation Sheets

The tables used when conducting the tests can be found below.

RC Car Part Interference		
Part Being Tested	**Distance of Clearance (in)**	**Interference? (PASS or FAIL)**

RC Car Turn Diameter								
Pass Parameter		**Right Turn**				**Left Turn**		
≥60 in (5 ft)	Speed	Attempt	Inches	Feet		Attempt	Inches	Feet
	Slow	**Trial 1**				**Trial 1**		
	Slow	**Trial 2**				**Trial 2**		
	Slow	**Trial 3**				**Trial 3**		
	Slow	**Average**				**Average**		
	Slow	**Pass/Fail**				**Pass/Fail**		
	Speed	Attempt	Inches	Feet		Attempt	Inches	Feet
	Fast	**Trial 1**				**Trial 1**		
	Fast	**Trial 2**				**Trial 2**		
	Fast	**Trial 3**				**Trial 3**		
	Fast	**Average**				**Average**		
	Fast	**Pass/Fail**				**Pass/Fail**		

RC Car Drop Test		
Trial	**Approximate Deflection (inches)**	**>1.5 inches? (PASS or FAIL)**
1		
2		
3		

APPENDIX I – Testing Report

The following will outline each test procedure. All tests can be done in the Hogue building on CWU's campus. The tests should take no longer than one hour each.

Test 1: Part Interference

1. Gather all essential materials, including a set of electronic calipers, and the RC car.
2. Determine all locations for the test to occur. This should include all links attached to the steering system, and the wheel components.
3. Record each location in the table, then prepare for testing.
4. Move the steering to its maximum distance to the right and left, and check the distances between links.
5. Determine whether the parts pass or fail the required 0.1 inches of space. Record the result in the table.

Note: this test is very straightforward, and the components included are at the discretion of the tester. Not all parts will be checked for interference if it is obvious they will not interfere anywhere.

Test 2: Turn Diameter

1. Gather all essential materials, including a tape measure, masking tape, and a camera if necessary.
2. Find an open area, about 20x20 feet, that has a flat and even surface.
3. Determine the starting location that will be used for each trial, mark that spot with tape.
4. One person will drive the car with the steering maximized to the right. The other will use tape to mark the spot of one full diameter turn.
5. The driver will start by driving with the throttle only pulled halfway. This will be the “slow” speed for the car.
6. Mark the location of the diameter, then measure that distance with a tape measure and record the result.
7. Repeat steps 5-6 with the slow speed for an additional two trials.
8. Repeat steps 4-6 turning to the left at the slow speed.
9. Repeat steps 4-8 with the throttle fully pressed, this will be indicated as the “fast” speed in the table.

Test 3: Two Foot Drop

1. Gather all essential equipment, including a yardstick, tape, and a quality camera.
2. Find a blank wall that will allow the car to be visualized and recorded clearly.
3. Tape the yardstick upright along the wall.
4. Set up the camera so that the numbers on the stick can be clearly seen.
5. Raise the RC car to the two foot mark on the yardstick and position it in front of the camera so that the full drop can be recorded.
6. Begin recording then release the car.
7. Repeat this process twice more, taking individual videos for each trial.
8. Examine the footage in order to determine the distance deflected for each trial.
9. Record the approximate value of the deflection in the table.
10. Determine whether or not the suspension passed or failed staying within the required deflection distance of 1.5 inches.

APPENDIX J – Resume

TYLER MARTIN

1175 GORE ROAD
SELAH, WASHINGTON 98942
5099307586
TYLERMARTINTJM@GMAIL.COM

EDUCATION

CENTRAL WASHINGTON UNIVERSITY
ELLENSBURG, WA
Current Mechanical Engineering Major
September 2015-Present

- Student Alumni Association Senator

YAKIMA VALLEY COLLEGE
YAKIMA WA
Associates Degree
June 2015

- President's List - Fall 2014
- Dean's List - Winter 2015
- Dean's List - Spring 2015

UNIVERSITY OF WASHINGTON
SEATTLE WA
Completed coursework towards Associates Degree
June 2014

- Recipient of PACCAR’s Paul Pigott Scholarship

SELAH HIGH SCHOOL
SELAH WA
High School Diploma – Top five percent of class
June 2013

- Senior Council Member
- National Honors Society Secretary
- Varsity Track and Cross-Country Athlete

WORK EXPERIENCE

TRIUMPH INTEGRATED SYSTEMS – YAKIMA
YAKIMA WA
Manufacturing Engineering Intern
June 2017 – September 2017

- Extensive experience with solid modeling software
- Lead design engineer for work-holding fixture

CENTRAL WASHINGTON UNIVERSITY
ELLENSBURG WA
Student employee
November 2016 – June 2017

- Student Alumni Association Senator, office and computer support, event planning and working

ALLAN BROTHERS FRUIT
NACHES WA
Receiving Lead
June 2013 – August 2016

- Data entry and fruit testing
- Receiving fruit shipments
- Training other receiving team members

SELAH HIGH SCHOOL
SELAH WA
Volunteer
September 2014 - December 2014

- Helping with instruction of the calculus class
- Grading tests and other assignments

ADDITIONAL SKILLS

- Fast learner and detail oriented
- Works well with others
- Exemplary problem solving skills
- Great with computers and other technology