Spring 2022

RC Baja Engineering Report

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R/C Baja: Suspension & Chassis

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ABSTRACT

The ASME RC Baja is a competition that tests engineering students' ability design, build, and test an RC car. The vehicle then competes against other engineering student's RC cars. The objective is to manufacture the most efficient and cost-effective RC Baja car.

During the first quarter of senior project, the student' engineering skill was applied to designing an RC car that will be able to compete in a competition at the end of spring quarter. The student was tasked with using all the information from the classes the student had taken previously at Central Washington University and design and build an RC car to the best of the student's ability. During the winter quarter the student was put to the test to manufacture the car that was designed in the previous quarter by using the 3D printers that prints in PLA plastic and using the CNC plasma cutter to cut out the aluminum sheet for the chassis plate. For this quarter the student will be doing all the testing to the car that were chosen back in fall quarter.

The student has completed all the tasks that were given and will be able to compete in the ASME RC Baja competition. The student completed three tests: suspension deflection, impact, and top speed. The first test the suspension deflected 12.5% less than the predicted 2 inches during the 1.5-foot drop test. The top speed achieved was 20 MPH and the deflection on impact was 10% more than predicted.

Keyword: RC Baja, ASME, Suspension.

Contents

1. INTRODUCTION

a. Description

The objective for this project is to compete in the ASME RC Baja competition. As a student you will be showing your ability to design and manufacture while following the ASME guidelines. The student will also have to make a report at the end of the year.

b. Motivation

This project is motivated to design a device that can be entered into the ASME RC Baja competition. Students will need to apply their engineering skills to real world problems and being able to build a device with certain guidelines that have been set by ASME.

c. Function Statement

The Chassis provides attachments for the parts of the car. The suspension provides stability of the car.

d. Requirements

The requirements according to ASME Baja rule include and requirements for the device to be successful.

- The suspension should not deflect more than 2 inches from being dropped from 1.5 ft
- The Rc cars total weight must be less than 10 pounds
- The Rc car must not be longer than 18 inches in total length
- The Rc car chassis must sit higher than 4 inches off the ground
- The Rc car must have 2 or more machined parts on it
- The RC car must be no wider than 10 inches
- The RC car will be able to withstand running into a wall at 20 MPH
- The RC car will have a top speed of 20 MPH

e. Engineering Merit

All the ideas and calculations going into the device will have been learned from life experiences and what the student has learned from CWU over the course of the last couple years. The things that will be used are Solid works and knowledge from the courses to complete the calculations.

f. Scope of Effort

For this project it will be a team project and will be completed in time for the RC competition. for this project the focus will be on the chassis and the suspension while the other team member will be working on the drivetrain and electronics.

g. Success Criteria

The RC car must be able to finish the drag race, the obstacle course, and the off-roading course and must meet all the requirements above.

2. DESIGN & ANALYSIS

a. Approach: Proposed Solution

The two different types of suspension that have been researched are a coil over suspension and a torsion spring coil over combo. the coil over spring will be good for going over bumps but the torsion spring and coil over spring will be a better combo because the designer will not have to worry about the spring being g the only thing that is being used. Below is a decision matrix that shows the most efficient design.

Criterion	Weight 1 to 3	Best Possible 3	Design # 1	Score x Wt	Design # 2	Score x Wt	Design # 3	Score x Wt	
Cost	2	6	2	4	2	4	2	4	
Weight	3	9	2	6	3	9	3	9	
Prediction precision	3	9	2	6	2	6	3	9	
Confidence in failure location	2	6	2	4	2	4	2	4	
Prismatic vs non prismatic	2	6	2	4	3	6	3	6	
Manufacturability	3	9	2	6	3	9	3	9	
Total	15	45		30		38		41	
NORMALIZE THE DATA (muliply by fraction, N)		2.22		66.67		84.44		91.11	Percent
								80.74	Average
								12.64	Std Dev.

Decide if Bias is Good or Bad

Good Bias: Standard Deviation is two or more digits — Good? Then you're done.

Poor Bias: Standard Deviation is one or less digits — Poor? Then change something!!!

You can change the criteria, weighting, or the projects themselves.

Weighting/Scoring Scale

1 Worst (too costly, low confidence, too big, etc.)

2 Median Values, or Unsure of actual value

3 Best (Low Cost, high confidence, etc.)

Criterion	
Cost	More mass is more cost
Weight	Light weight scores better on the success equation
Prediction precision	Are the engineers calculations sufficient and correct?
Confidence -failure loc	Confidence level in the indicated failure location
Prismatic vs non prismatic	Is the shape prismatic (retangle, square, etc) or is it irregullarly shaped to meet the engineering needs
Manufacturability	Is it simple to produce? Are there multiple process for a single component?

Comments:

Comment about why you scored each design as you did.

b. Design Description

The design that was thought up is a torsion spring coil spring combo the torsion spring will bring the least amount of deflection it will have the best ability for traveling over obstacles and have the best travel of the 2 different types. The springs on the back will be stiffer so the tires are back to the ground faster since that is where the power will be applied on the RC car.

c. Benchmark

All of the previous senior projects that have been previewed all of them have used the same design for their shocks with tall shock mounts and coil shocks the design that will be used is different from everyone else designs with a torsion spring and coil shock design. The RC car will be better at going over bumps than just having coil springs.

d. Performance Predictions

The performance of the chassis and the suspension is the suspension will be able to withstand a drop from 1.5 feet with less than 2 inches of deflection

e. Description of Analysis

The things that will be analyzed during the course of this quarter will be every part that will be put on the RC car from the chassis and suspension all the way down to the pins that will be holding the A-arms onto the chassis there will be an analysis being done for the total weight of the chassis and suspension and also, he deflection the suspension has total.

f. Scope of Testing and Evaluation

The scope of the testing and evaluation is about the structural integrity of the car and how long the car will last. This also is about the functionality and performance requirements by conducting drop test and speed tests.

g. Analysis

i. Analysis 1

See appendix A-1 to see full analysis. The analysis was done to fill the requirement to see how much energy there is when being applied to the chassis when being dropped from 1.5 feet. The analysis that was used were kinematic equations and also conversion equations to convert lb. of force to newtons and then newtons to kg. This analysis will be used to find how big of torsion springs will be needed to withstand the force when the RC car jumps off things because you don't want the car to bottom out the springs because that's when the springs will break when they are at full force so the spring that will be needed on the RC car are springs that their max force is about half the energy used. This analysis will not be shown on the final project but will affect the size of the torsion springs and coil springs that will be used.

ii. Analysis 2

See appendix A-2 to see full analysis. The analysis was calculation the K component of hooks law to figure out the Spring constant that fulfilled the requirement for the car being dropped 1.5 feet without 2 inches of deflection. The spring constant came out to be K=192x10^3 N/M. The problem with this analysis will be finding the coil spring and torsion spring that can hold up to a force that high.

iii. Analysis 3

See Appendix A-3 to see full analysis. The analysis that was done was calculating the thickness of the chassis plate with a 150 N force being applied at the end of the chassis plate the answer came out to be T= 2.55mm so that is the minimum thickness the chassis has to be without breaking. The requirement that was satisfied was the requirement of the length and the width requirement. The problem with using the minimum thickness is that there will not be enough plate to put threads on to mount up all the stuff on top so the thickness needs to be bigger than the minimum thickness.

iv. Analysis 4

See Appendix A-4 to see full analysis. The analysis that was done calculated the force that will be applied to the front bumper after hitting a wall going 20 MPH. the requirement that this fulfills will be the that the RC car will be able to withstand running into a wall at 20mph without breaking the front bumper the force that will be applied to the car's front bumper will be 405.02 N of force so the front bumper needs to be able to withstand 450 N of force just to be safe. v. Analysis 5

See appendix A-5 to see full analysis. The analysis that was done this week was the distance and angle the shock will be when fully compressed this analysis fulfills the requirement of being able to support the weight of the car when not being held by a student. This analysis fulfills the requirement of the car be able to ride more than 4 inches off the ground. the angles that were calculated were 30.96 degrees on the bottom and the top is 59.03 degrees this will be used when installing the shock onto the A-arm and onto the Shock tower. The angles and dimensions will be documented on drawing MSH_20-003 vi. Analysis 6

See appendix A-6 to see full Analysis. The analysis that was done was the specific distance the shock will be mounted on the shock mount from the centerline of the shock tower. The analysis fulfilled the requirement of being able to support the weight of the car and not bind up when the car jumps or hits a bump. This analysis fulfills the requirement of the car will ride 4 inches off the ground. The answer that was found is the shock will be mounted 3.5 inches from the centerline of the shock tower on the top of the shock tower. The dimensions on where the shock needs to be mounted will be documented in drawing MSH_20-003 vii. Analysis 7

See appendix A-7 to see full analysis. The analysis that was done was the minimum pin diameter for the a-arms with a 90 N shear force being applied. The analysis fulfills the requirement of being able to mount the a-arms to the chassis and the design requirement that the analysis fulfills would be being able to hold the weight of 10 lbs. from the car. The minimum diameter that was calculated was 1.9 mm which is 5/64 inches. The dimensions of the pin will be documented in drawing MSH_20-002 viii. Analysis 8

See appendix A-8 to see full analysis. The analysis that was done was the minimum screw diameter that would not strip out with a force of 90 N. The analysis fulfills the requirement of being able to mount up all the parts like the battery bracket, the motor mounts, and the shock towers. The design requirement that the analysis fulfills is that the components of the RC car will not move when a force is applied to the RC car. The Dimensions will be documented in drawing MSH_55-002 ix. Analysis 9

See appendix A-9 to see full analysis. The analysis that was done was the minimum shock tower height to be able so the tower doesn't break when a force is applied down. The analysis fulfills the requirement of being able to mount the shock to the tower at a height that will hold a force. The design requirement that the analysis fulfills is being able to travel over obstacles without bottoming out. This analysis took the stresses that were found in analysis 11 to see if the distance that the shock is mounted up if the arm will break. The dimensions will be documented in drawing MSH_20-003

x. Analysis 10

See appendix A-10 to see full analysis. The analysis that was done was the minimum A-arm length. The requirement the analysis fulfills is to have an a-arm long enough that your tires wont rub on the chassis when turning. The design requirement is the RC car will ride no less than 4 inches of the ground and being able to mount the tires to the a-arms. The dimensions will be documented in drawing MSH_20-004 xi. Analysis 11

See appendix A-11 to see full analysis. The analysis that was done was the stresses in the shock tower arms with a force being applied down on the arms from the shock tower. The requirement the analysis fulfills is to have a thick enough shock tower so the shock tower arms do not snap when under a load. The design requirement the analysis fulfills is the RC car will withstand a drop from 1.5 feet off the ground. The dimensions will be documented in drawing MSH_20-003

xii. Analysis 12

See Appendix A-12 to see full analysis. The analysis that was done was the Cross-sectional area of the shock tower this was needed to design the shock tower up so the student knew the minimum base and height dimensions of the shock tower arm. The requirement the analysis fulfills is to the right thickness and height of the shock tower arms. The design requirement the analysis fulfills is that the RC car will be able to withstand a drop from 1.5 feet off the ground without breaking. The dimensions will be documented in drawing MSH_20-003

h. Device: Parts, Shapes, and Conformation

The shape of the RC car will be a rectangular shaped chassis and there will also be a suspension shock mount that will be designed up for the front and back for the cool suspension to mount to the A-arms. There will also be holes that will be pre drilled into the chassis that will mount the motor, battery, and the controller module.

i. Device Assembly

The RC Baja car will be designed with 2 different types of suspensions torsion springs and coil springs. The chassis that will have specific spots drilled out for all the parts to be added on to the chassis.

j. Technical Risk Analysis

The design for the RC Baja car will be made for lightness and quality so the car can make it through all of the challenges. The beating that the car will be going through in the challenges are unknown so the values are estimated for the analysis. A lot of the parts will be bought but some of the parts will be fabricated so that could put the build off schedule.

k. Failure Mode Analysis

There will be a lot of failure analysis throughout the whole design process because the first design that will be chosen will not always be the best so there will be design changes that will. There is multiple analysis that will need to be done for the same part.

l. Operation Limits and Safety

The RC car should not be dropped or jumped higher than 1.5 feet off the ground because that is what the analysis will be done for is that height. One safety is when connecting the battery, the person needs to be careful to avoid injury.

3. METHODS & CONSTRUCTION

a. Methods: The RC Baja Chassis and suspension was conceived, analyzed, and designed at CWU-by-CWU students. Not all parts will be built at CWU some parts will be outsourced to be made. Also, some of the parts for the RC car will be bought online like the pins, nuts, bolts, and all the material for the chassis plate. There will also be parts built at CWU from stock material that is purchased most of the parts will be 3-D printed at Central Washington University in the MEC. The parts were chosen to be 3-D printed because the student used a decision matrix to weight out the options and the student found out that the parts would be cheaper and have a great amount of strength getting 3-D printed in PLA plastic material.

- Process Decisions:

  The A-arms analyzed in the decision matrix in appendix F-1. The methods of outsourcing, machined, or bought were compared on the basic cost, Decision precision, and manufacturability. After looking through the decisions matrix the best thing that the student could do would be outsource the parts to be built it will be cheaper and more precise being built. The part is being 3-D printed at Central Washington University and should be done on time even with all the other students going to the same place.

  The Shock tower analyzed in the decision matrix in appendix F-2. The methods of 3-D printing, machined, or bought were compared on the basic cost, Decision precision, and manufacturability. After looking through the decisions matrix the best thing that the student could do would be 3-D print the parts to be built it will be cheaper and more precise being built even though 3-D printing isn't going to have the most strength the student thinks that the 3-D printing will have enough strength to be able to withstand all the forces that will be applied on the RC car.

  The Different types of materials that can be used to make the Chassis plate this analysis is in the decision matrix in appendix F-3. The types of material are ABS Plastic, 6061 aluminum, and A-36 Steel these materials were compared on the basic cost, Decision precision, manufacturability, and weight. After looking through the decisions matrix the best Material that the student could use for the Chassis plate would be 6061 Aluminum Because it is light, easy to build with, very manufacturable, the only thing that is not good is it cost a lot of money for a shock sheet of 6061 aluminum. The student found a piece of aluminum that was $137 for a 21"x41"x ¼" sheet from Haskin's steel in Spokane that was purchased. The student is going to work with other students and the lab techs to CNC plasma cut out the chassis plate for the best precision cut out you can get because there is little to no human error involved which should produce the highest quality chassis plate. The chassis plate will have holes drilled through it to mount up all the other parts that the student has manufactured and all the parts that the student's partner has manufactured

The front bumper is the last part that is being manufactured for the RC car this part is going to be 3-D printed with the A-Arms and the Shock Towers this along with the other parts that are being 3-D printed had the same mindset about the manufacturing that 3-D print is the cheapest and also has enough strength for the application and will be able to hold up with all the forces applied.

b. Construction

- Description

  The device will not be built in this section. These sections are the suspension, chassis, drivetrain, and steering but specifically chassis and suspension seven parts will be built from stock material and or manufactured at the school and three parts will be bought. The student has decided to 3-D print the A-Arms, the Shock Towers, and the front bumper the material for the chassis has been bought and will be cut out on the CNC plasma cutter with the help of the lab techs. No other parts will need machined other than the chassis plate all the fasteners will be bought as is and will not need any modification to them

- Drawing Tree, Drawing ID's

  The full Drawing tree is posted in appendix B-1. The order the RC car will be assembled will be the chassis portion then the suspension portion. The chassis portion will be done first because the chassis has the most parts that will need to be assembled and the chassis needs to be done first because everything get mounted to the chassis plate like the a-arms will need to be mounted onto the chassis plate then the front bumper. Then, the suspension will be done by mounting the shocks to the shock tower then mounting the shock tower to the chassis plate and the shocks to the a-arms after this the student will get the parts from the student's partner and start assembling the partners parts to the chassis plate as well this should make a full and working RC car.

- Parts

The three different categories of parts for the suspension and chassis sub-assemblies are purchased parts, purchased parts with modifications, and machined/3D printed parts. All the purchased parts will be 55 drawings that are documented in appendix A the fasteners and the shocks the fasteners are a big bulk of the of the purchased parts, the purchased parts with modifications will be 20 drawings like the chassis plate. And the machined and 3/D printed items are 20 drawings also like the A-Arms, suspension towers and the front bumper. All the fasteners will be purchased parts from an online source and will not need to be machined since they will be bought at the right dimensions for the purpose they were bought for.

- Manufacturing issues

Potential risks and issues for this project will be not being able to get into the machining lab when the time is right for the students, another risk can be not shipping on time to the student will not be able to build the RC car in a timely manner, another risk could be the process taking longer than the students have anticipated it would take. All the 20 drawings are parts that will be built/ machined on campus and all the 55 drawings will be parts that will be bought online. The students will set aside 4 hours a week to make sure the students get enough time in the machine lab. The student will get stock material from an online source and will design the chassis plate and while that is happening the student will get all the other parts that need to be 3-d printed ready to get the parts printed. The student will use the CNC plasma cuter to cut the chassis plate for the most precise cuts and the least amount of human error.

- Discussion of assembly

The first part of the RC car that was assembled was the chassis plate this is the backbone of the RC car after the chassis plate was assembled the shock towers were then assembled onto the chassis plate after the shock towers came the front bumper which is mounted up right underneath the front shock tower which lead to do a little customizing of the holes that were printed into the front bumper when it was 3-D printed after this part was assembled the a-arms were mounted up onto the chassis plate and was pinned so they wont fall off the next thing will be the shocks which will be going on soon these parts will be from the shock tower to the a-arms to maximum travel. The final assembly will cost less than the student had calculated for which is always a good thing when doing a project

4. TESTING

a. Introduction: The RC Baja car will be tested to ensure that the design will be up to the standards that have been set for the students. The tests that will be done are the Drop test, the maximum speed test, the cornering test, and the collision test. Throughout the manufacturing process the student has not had any reason to change the tests that will be done so the student will stay with the same tests that were decided back in fall quarter.

b. Method/Approach: The tests that will be done in the end of winter quarter and spring quarter. The four tests are the drop test this test will be done by dropping the car from a specific height, The second test is the maximum speed test this test will be done by driving the car a specific distance and seeing how fast the car goes, the third test is the cornering test this test will be done by having a couple object to drive around, and the final test is the collision test this test will be done by running the car into something solid from a specific distance. The student did the first trial of the collision test and broke 3 a-arms the student put rubber on the front bumper and will be doing the last two trials to see if the rubber on the front bumper will dampen the energy front running into the wall at full speed.

c. Test Process:

The drop test will be done by one of the students picking up the RC Baja car and dropping the car from 1.5 feet off the ground and seeing if anything breaks or the car withstands the drop and the drops will be videoed to be able to calculate the deflection that cannot be more than 2 inches this will be done 3 times.

The maximum speed test will be done on campus the student will drive the RC car 50 meters and see what the top speed of the RC car will be to see if the car can reach a top speed of 25 MPH or more.

The cornering test will be done in Hogue there will be 3 objects that the students will have to drive the car around the objects and see if the car yaws less than 10-degrees around a 60-degree corner.
The collision test will be done in Hogue the car will be ran into a solid specimen from 30 feet away to see if the cars bumper will be able to withstand the impact from the car hitting the wall.

d. Deliverables: The deliverables will be documented in a table with all parts that were damaged or broken from the drop test the deflection will also be calculated in a separate table since the requirement says not more than 2 inches of deflection.

The max speed test will be documented in a table that will have the max speeds from 3 different attempts to see if the car can get to a speed of 25 MPH or faster.

The drop test will be documented in a table that will have the 3 different deflections of the chassis this will be from rest then to where it sits after the drop.

The collision test will be documented in a table that has all the parts that are broken or damaged this is to see if the car front bumper can withstand an impact at max speed.

The requirement for the collision test was that the car will be able to hit a wall at top speed and none of the parts will break. The predicted results are that the car will hit the wall and the car will still be able to drive after impact. The student has only done 1 trial for the test since after doing the first test 3 A-arms had snapped so those needed to be replaced and the last 2 trails will need to be done. The cars back 2 A-arms have a lot of play in them so the student will need to put shims on A-arms so that the play will go away. Another thing is that the student needs to put something on the front bumper for a little support and give.

5. BUDGET

a. Parts

Appendix-C shows the complete parts list of the parts that will either be built and or bought from other stores and how much the student estimated everything will cost. In Appendix D the student has a chart with the budget and how much everything is going to cos. The student has not run into any errors on the budget calculation the student is under the budget by a lot.

There were no extra funds that were used for errors that happened during the testing process. The only thing that was done was reprinting the A-arms and machining them so if this project was done again more parts should be printed in the beginning

b. Outsourcing

The outsourcing that will be done on the project will be the parts that are being bought and the 3-D printing of the A-arms and the Shock towers. The RC car will be built by Mathew and Matthew. The student figured it was going to cost around $100 but the student has all the parts that are being outsourced and the total cost was $14.00 which is way under the estimated budget.

c. Labor

For this project, outsourcing of labor is not accounted for in Appendix-D Because there will be no outsourcing labor done all the labor will be done by Mathew and Matthew to keep the price down. The student did have outsourced labor when the student had the chassis plate cut with the CNC plasma cutter, but the student did not have to pay for this job.

d. Estimated Total Project Cost

The total price for this project will roughly be around $8,350 dollars in total for all the parts being bought and the parts being manufactured here at CWU. With the total cost this is accounting the parts being bought, shipping cost, and tax will be included in the estimate. The total cost also takes into account the cost of the student's labor, but the student will not be getting paid for these services.

e. Funding Source

The funding source of this project will be supported by Mathew Morgan and Matthew Hart. The cost will be divided out by the responsible components of the car Mathew Morgan will pay for drivetrain and steering and Matthew Hart will be responsible for suspension and chassis. The students partner Mathew Morgan has calculated out the total to be $8,600 for the Drivetrain and Steering while the student calculated the total to be $8,350 total for the suspension and chassis

6. Schedule

a. Design: See Appendix E.1. as seen in appendix E there needs to be some catching up the analysis that are being done are out of order but are still getting done on time. The fall quarter is made up of an introduction into the project, Design and analysis, and method and construction. The introduction talks about the budget and the requirements of the vehicle. The design and analysis section are made up of 12 analyses and the method and construction is made up of the drawings that will be done throughout the fall quarter.

b. Construction: See Appendix E.1. For this section, the student will be manufacturing parts that will be assembled for a product of an RC Baja Car. The student has fallen behind on the schedule the student turned in the STL files to the school to get 3-D printed and the student does not have them back so this has put a hold on manufacturing the student might have to 3-D print the parts in Hogue to make sure that they get done on time. Once the parts are done from the MEC the student can start assembling the parts onto the chassis plate. The RC car was completed on time even with the long wait with the MEC printing the parts for the RC car. The student even had time to do some redesigns and get them printed at the MEC before everything was due. The student had also printed some parts at Hogue since it was way easier to do it in that building than having to walk all the way over to the MEC.

c. Testing: See Appendix E.1. The testing of the RC car will be done mostly in spring quarter before it is entered into the ASME RC Baja competition. The tests that the student did were the collision, top speed, drop, and a total weight test the student decided to do the collision test first which was not the best idea since the students A-Arms kept breaking when running into the wall once the student fixed the problem the other test was easy to complete. The student did some design changes throughout the quarter with the front bumper the first thing that was done was adding rubber to the front bumper for some more give instead of straight plastic and that did not work so the student redesigned the A-Arms and made them out of different material and this ended up working and the car survived the collision test. There is a little bit of testing that is being done in the fall quarter with the analysis section because the analysis tells you what the minimum requirements of dimension need to be to withstand a specific force that will be applied to the car.

7. Project Management

Section 7 will cover the project management of the project covering the risks that can occur during the whole time of the project. Some of the risks are when it comes to human resources if the student needs to ask a mentor a question about something sometimes the mentor is busy and the question cannot be asked, one for physical is the students can't always get into the machining lab to build parts for the car, another would be sometimes the Wi-Fi shuts down and the students' assignments can't be turned in. The risks that will be closely monitored during the project will be not going over budget and making sure that the parts the students have to buy online will be shipped and delivered on time to build the RC car. There are three main risks for this project one being if the students' mentors do not have enough time to get back to the student about a certain situation another risk could be the Wi-Fi not working and the student not being able to turn the assignment in and the last risk is the if any of the labs are shut down and the student can't finish up the project when it is due

.a. Human Resources: The engineers will supply a final design of the RC Baja Car and more specifically the Suspension and the Chassis. Some of the students' mentors were Brian Hart Sr., Mathew Morgan, Jack Huff, Professor Pringle, and Dr Choi. The associate risk of using these mentors is these people are all busy and can't always be there if the student has a question about the RC Baja project. This will be a problem if the student has a question during class or when the student is home working on the project.

b. Physical Resources: The physical resources will be the machining lab in Hogue on the CWU campus. The physical resource consists of drill presses, lathes, CNC machines, milling machines, and grinders. The risk for these resources is they are only available when the classroom isn't occupied by a class or a professor another risk is the student has to have a buddy to go into the lab so the student couldn't go in the lab by themselves the student will have to wait on another person to go which could take time if the other student has something going on. The students will put aside 1-2 hours a day to work in the machine shop.

c. Soft Resources: The soft resources for the RC Baja will be solid works, Microsoft word, Microsoft Excel, and Canvas. The risk that comes with using the software's listed above is that the software could crash and the student would not be able to submit the assignment on time, another risk is if the students Wi-Fi stops working the student cannot work on the given projects or assignments.

d. Financial Resources: The Financial resources will be provided by the students for the given tasks the students have chosen. The students will have to make a budget and will need to stay underbudget throughout the whole project. The biggest financial item will be the outsourced items that will need to be sent off to be made.

8. DISCUSSION

a. Design:

For fall quarter, the RC Baja design was designed by the students throughout the whole quarter. The beginning of the quarter the student designed 3 different designs that the student would pick one of the three designs to make the main design. The student then picked the main design throughout the quarter there was one change to the main design the student will not use torsion springs as a suspension because the student couldn't find any online that would be small enough to fit on the car this was the only change that was done to the main design. The student didn't not have any risks the project went smooth throughout the quarter. me

After the main design was chose the student started doing analyses that are documented in appendix A the analyses would give the students design parameters when making the drawings. The student had to do at least 12 analyses during the fall quarter the analysis would be able to show the student if the part that the analysis was being made for would fail or not when fulfilling a requirement that the student made another thing the analysis were doing is showing the student minimum diameter or minimum thickness of a specific material.

The next thing that was being done throughout the quarter was drawings the drawings are documented in appendix B the drawings are used for the student to make a sub assembly drawing which in return would be used to make a complete assembly drawing that will show if the RC car will work or not. The student had to do at least 10 drawings for the chassis and suspension the student didn't need to make any more drawings then the 10 that were required

The last thing is the student was updating the Report guide and the gantt chart throughout the whole quarter because that is a big portion of the fall quarter the gantt chart is a living document so it was updated every week throughout the quarter the living document helps a lot to keep the student on schedule with getting everything turned in when it needs to be turned in

b. Construction

For Winter quarter, the RC Baja Car will be manufactured by the students and assembled there are three different manufacturing processes machined, bought and modified to specific dimensions, and 3-D printed on campus.

The first method is machined this would be the section were the chassis plate is cut out with the CNC plasma cutter after the chassis plate is cut out the student will take the chassis plate to the machine lab and start placing where all the holes go on the chassis plate after this the student will drill press to make all the holes that are needed on the chassis plate to mount up all the drivetrain and suspension components.

The second method will be bought and modified for this section the student will by parts but will not need to modify them because the only parts that will be bought are fasteners and pins that will be bought to the specific diameters and lengths for the fit there are only 3 parts that will be bought those are nuts, bolts, and pins for the a-arms.

The final section is 3-D printed at the school for this section the student will get 7 parts 3D printed the first thing the student had to do was turn all the part files into STL files because that is the file the printers need to print the part. The parts that are being 3-D printed are the a-arms, the shock towers, and the front bumper these parts were turned in 2 weeks ago and are still being printed so hopefully they will be done by the end of the week

c. Testing

For Spring quarter, the RC Baja Car is put through a series of test to see the rigidity and strength of the parts that were designed in winter quarter the three different test that will be done are the drop test, the collision test, and the top speed test. The collision test was started but came to a halt after the first trial since three of the a-arms snapped during the test. The student changed the test procedure from hitting the wall at top speed to hitting the wall at different speeds to see at what speed the cars parts will start breaking the students partner calculated the top speed to be around 7 MPH so the student will drive the car into the wall at 3,5,7 MPH the student has already hit the wall at the top speed and that is when the parts broke so the hope is the parts won’t break at the lower speeds, but the student will change the front bumper to have more give when hitting the wall, the student is going to put some sort of foam on the front that will give a lot of give. The student has finished the second trial of the collision test and broke all 4 of the A-arms on the car the student has redesigned the A-arms to hopefully help from breaking the student has also printed the A-arms out of nylon carbon fiber this is the first time anyone has printed with carbon fiber, so the student doesn’t know how the carbon fiber is going to work. If the carbon fiber doesn’t work the student will try to make the bumper slide when the car has a front impact to dampen the force from the impact. The other tests have not yet been completed since it took so long for the parts that broke to get fixed, the parts are fixed now so the tests will resume as soon as possible. The student thinks that once the collision test is completed the other test will be able to be done easily since the test doesn’t put stress or strain on the car. The other two tests will be done in the up coming weeks and will hopefully be done in 2 weeks.

9. CONCLUSION

The design of the chassis components consists of chassis plate, A-Arms, Front bumper, and A-Arm pins this is the backbone of the RC car this is what all the components mount to The Chassis plate will be made out of rough stock that will be bought online the A-arms, and front bumper will be 3-d printed at Central Washington University and the A-arm pin will be bought online. For the Suspension this consists of Shock tower and the suspension shocks this will make the RC car sit off the ground and be able to travel over objects. The shock tower will be 3-d printed at Central Washington University and the shocks will be bought online with all of the fasteners that will be needed to complete the car.

The engineering merit used in this project is physics, Mechanical design, and Mechanics of materials all these classes have given the student a solid background on what to do for the design of the RC car. These classes have helped with finding the minimum thickness of the chassis plate and finding the minimum diameter of the A-arm pin that will be able to withstand a drop from 1.5 ft these classes also helped the student with finding the CSA of the shock tower arm and being able to find all the stresses in the shock tower arm.

For the RC Baja project, the RC car the chassis will be the backbone of the car that will mount all the components from the student's team members drawings and the suspension will make the RC car travel from point A to B while being able to go over objects. The car will also be able to travel at a max speed of 20 MPH and hit something solid and be able to withstand the force applied to the car

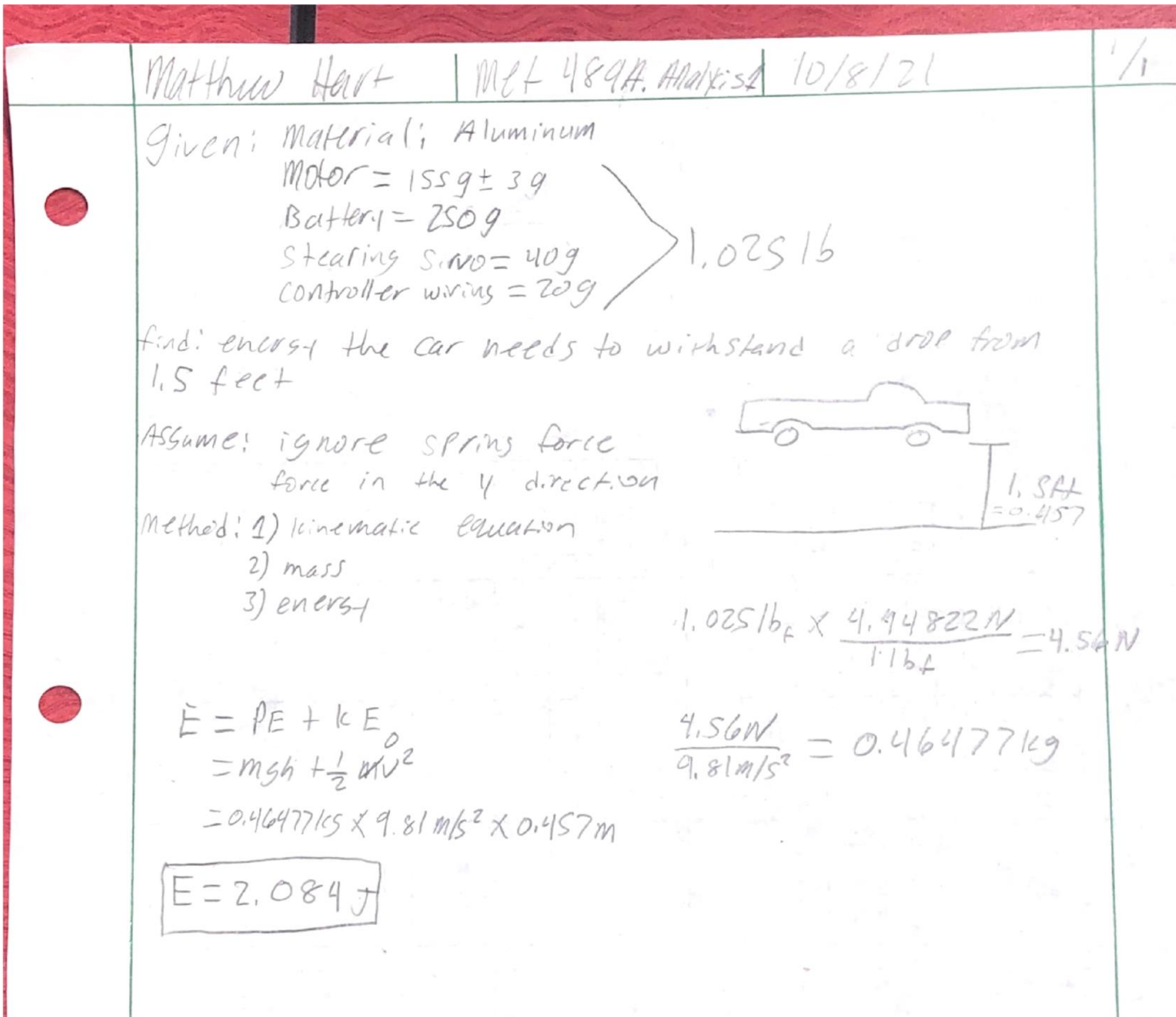
10. ACKNOWLEDGEMENTS

Many Resources were used during the duration of this quarter to make the senior project the best the project could be the main resource that was used during the quarter was the students partner Mathew Morgan during the quarter Mathew Morgan and the student talked about the different aspects. Another resource during this quarter was professor Pringle and Dr. Choi these resources were used when the students needed any answers on what needed to be done for the specific item or any questions at all. The final resources were the student’s dad who was there to have ideas bounced off and if the resource thought it would be a good idea.

References

APPENDIX A - Analysis

Appendix A-1 –Energy Analysis


Matthew Hart | Met 489A Analysis 1 | 10/8/21 | 1/1

Given: Material: Aluminum

Motor = 155g ± 3g
Battery = 250g
Stearing Servo = 40g
Controller wiring = 20g

→ 1.025 lb

Find: energy the car needs to withstand a drop from 1.5 feet

Assume: ignore spring force
force in the y direction

Method: 1) kinematic equation
2) mass
3) energy

$1.025\,lb_f \times \frac{4.44822N}{1\,lb_f} = 4.56N$

$\frac{4.56N}{9.81m/s^2} = 0.46477kg$

$E = PE + KE_0$
$= mgh + \frac{1}{2}mv^2$
$= 0.46477kg \times 9.81\,m/s^2 \times 0.457m$

$E = 2.084J$

Appendix A-2 –Drop test force

Matthew Hart | ME 489.001 | 10/14/21 | 1/1

given: 2.5 ft vertical drop 2.5 ft = 0.762m

Mass 10lb = 4.53592 kg

Shock stroke = 25mm

use 75% of stroke

find: K factor of spring

Assume: homogenius material

method: conservation energy hooks law

Sol.

$PE = KE$

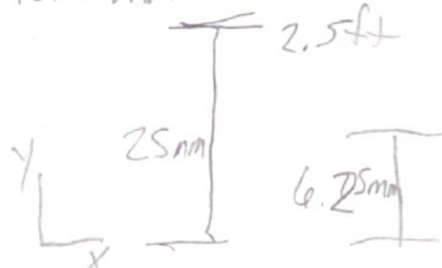
$PE = mgh$

$PE = 4.53592\,kg \times 9.81\,m/s^2 \times 0.762\,m$

$= 33.91\,J$

$U = \frac{1}{2} kx^2$ $0.75 \times 25 = 18.75\,mm$

$U = PE = KE$ $x = 18.75\,mm$

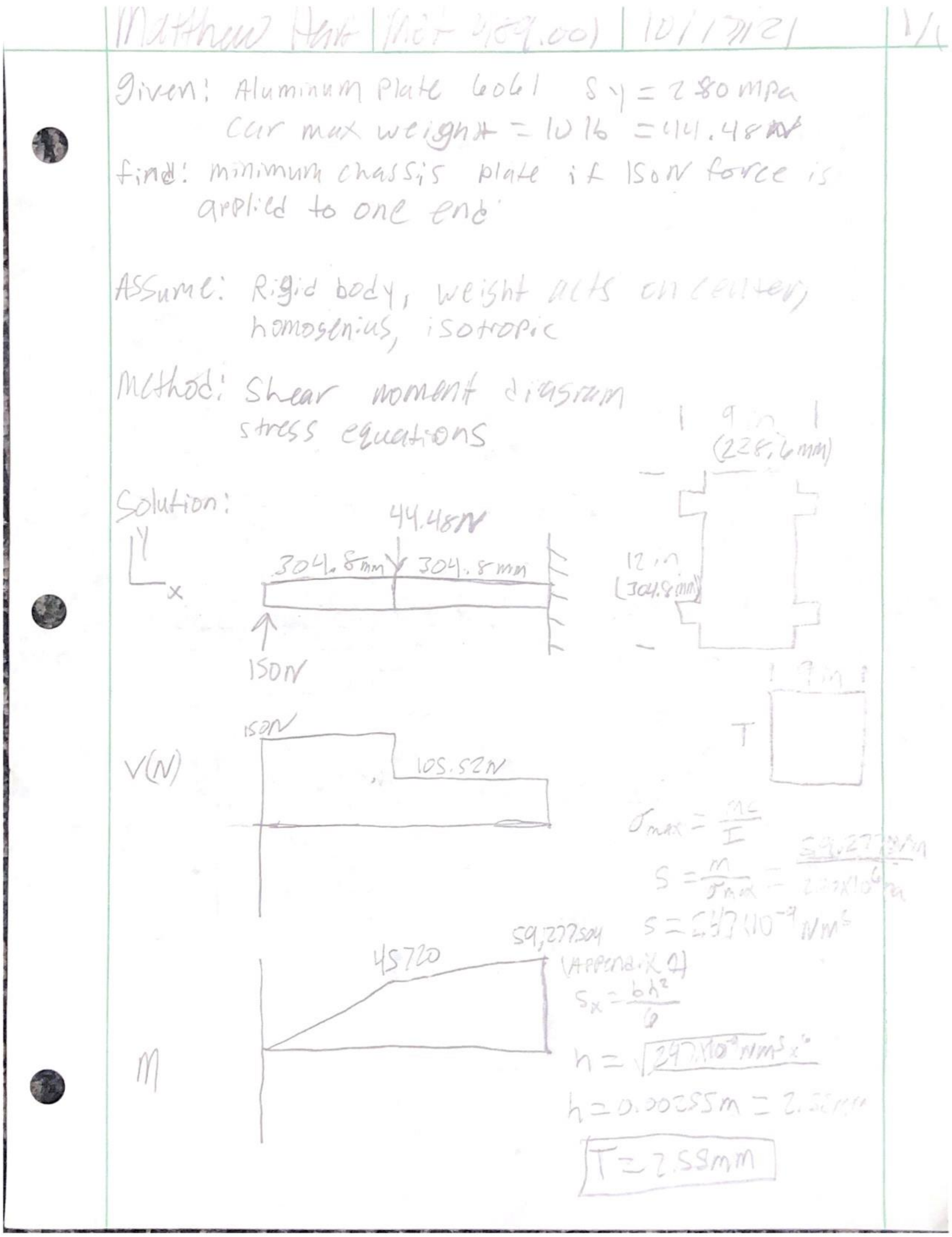


$\frac{2U}{x^2} = k$

$k = \frac{2(33.91\,N/m)}{0.01875^2\,m} = 192 \times 10^3\,N/m$

$k = 192 \times 10^3\,N/m$

Appendix A-3 – Chassis thickness


Matthew Hart | MET 469.00 | 10/17/21 | 1/1

Given: Aluminum Plate 6061 $S_y = 280$ MPa
Car max weight = 10 lb = 44.48 N

find: minimum chassis plate if 150N force is applied to one end

Assume: Rigid body, weight acts on center, homogenius, isotropic

Method: Shear moment diagram
stress equations

Solution:

$\sigma_{max} = \frac{Mc}{I}$

$S = \frac{M}{\sigma_{max}} = \frac{59.277 Nm}{280 \times 10^6 Pa}$

$S = 2.47 \times 10^{-7} Nm^3$

(Appendix 4)

$S_x = \frac{bh^2}{6}$

$h = \sqrt{2.47 \times 10^{-7} Nm^3 \times 6}$

$h = 0.00255 m = 2.55 mm$

T = 2.55mm

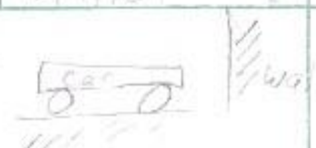
"

Appendix A-4 Front Bumper force analysis

Matthew Hart | MET 489.001 | 10/19/21 | 1/1

given: $v_{max} = 20\,mph$

$W_{max} = 10\,lb$



find: front impact force at v_{max}

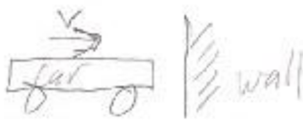
Assume: no force in y, the car take 0.1 second to go from 20mph to 0mph after hitting wall, neglect gravity, car is 10 lbs

method: 1) FBD

2) kinematic eq.

Sol.

FBD:



kinematic: $W = 10\,lb = 4.53\,kg$

$A = V/t$ $\quad V = 20\,mph = 8.9408\,m/s$

$A = \dfrac{8.9408\,m/s}{0.1\,sec}$

$A = 89.408\,m/s^2$

Force

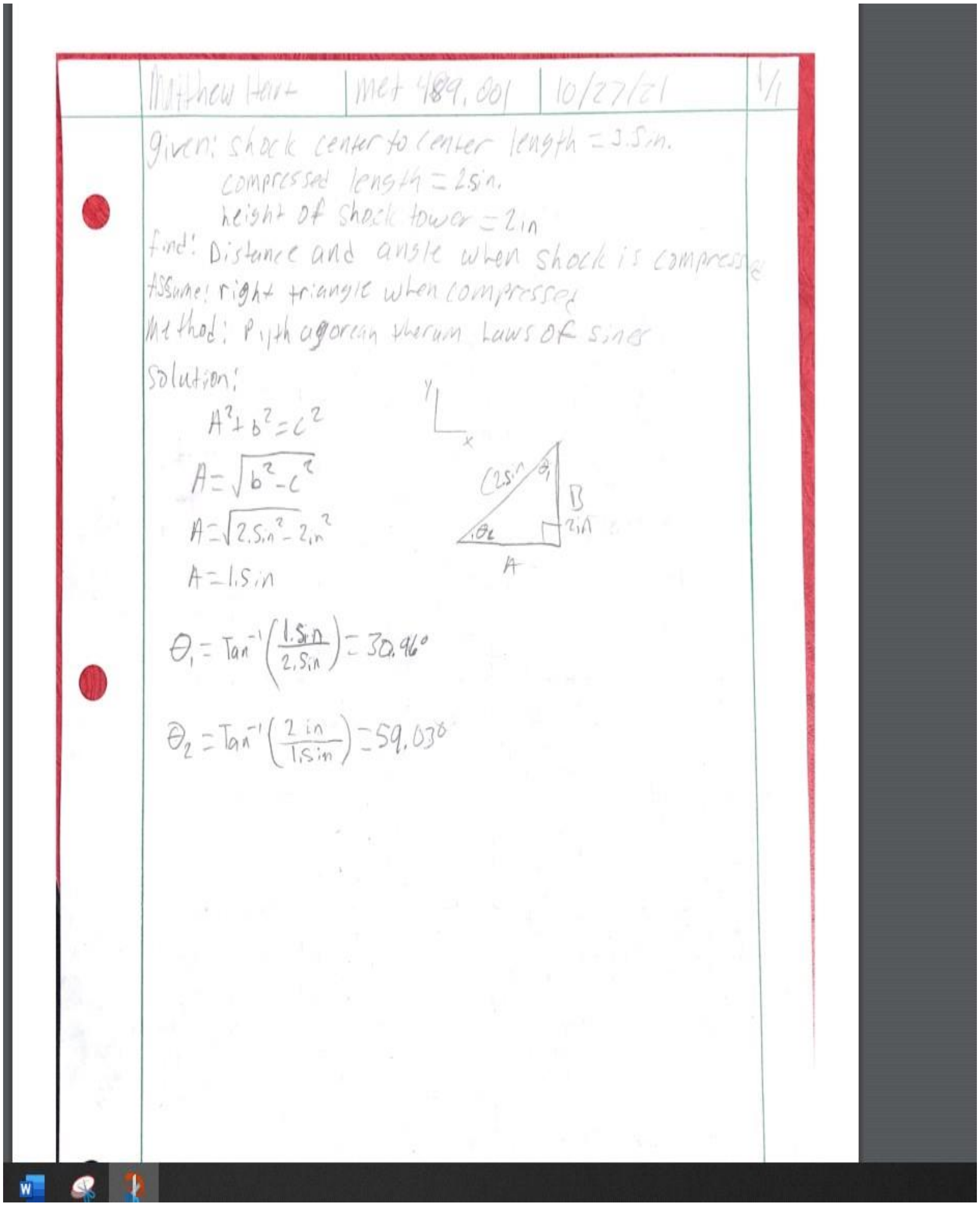
$F = mA$

$F = (4.53\,kg)(89.408\,m/s^2)$

$\boxed{F = 405.02\,N}$

Tolerance $= \pm 0.05\,N$

Appendix A-5- Distance and angle analysis of shock



Matthew Hart | met 489.001 | 10/27/21 | 1/1

given: shock center to center length = 3.5in.

compressed length = 2.5in.

height of shock tower = 2in

find: Distance and angle when shock is compressed

Assume: right triangle when compressed

Method: Pythagorean therum Laws of sines

Solution:

$A^2 + b^2 = c^2$

$A = \sqrt{b^2 - c^2}$

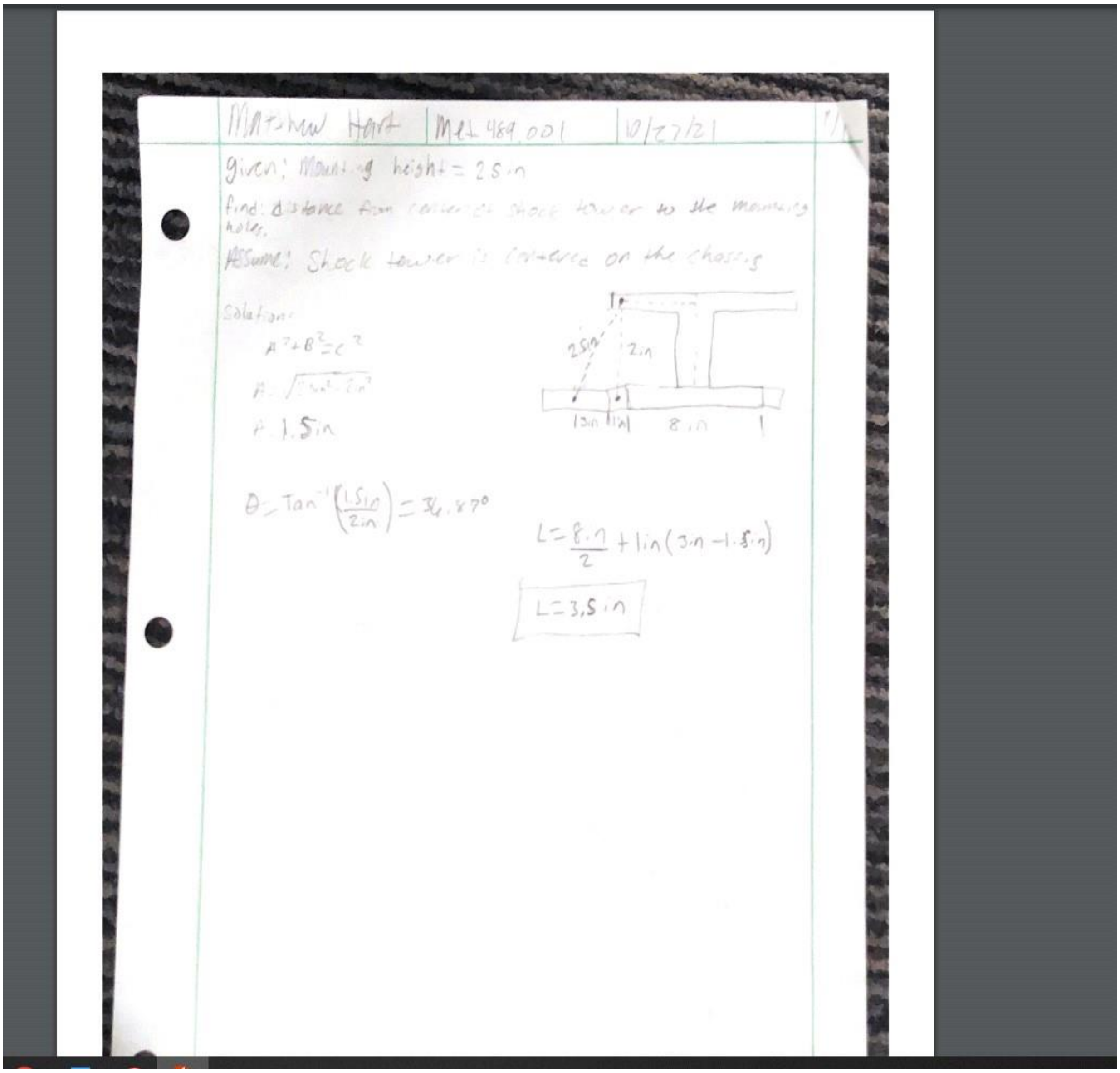
$A = \sqrt{2.5in^2 - 2in^2}$

$A = 1.5in$

$\theta_1 = Tan^{-1}\left(\frac{1.5in}{2.5in}\right) = 30.96°$

$\theta_2 = Tan^{-1}\left(\frac{2in}{1.5in}\right) = 59.03°$

Appendix A-6- Shock tower distance analysis



Matthew Hart | MET 489.001 | 10/27/21

given: Mounting height = 2.5 in

find: distance from centered shock tower to the mounting holes.

Assume: Shock tower is centered on the chassis

Solution:

$A^2 + B^2 = C^2$

$A = \sqrt{2.5in^2 - 2in^2}$

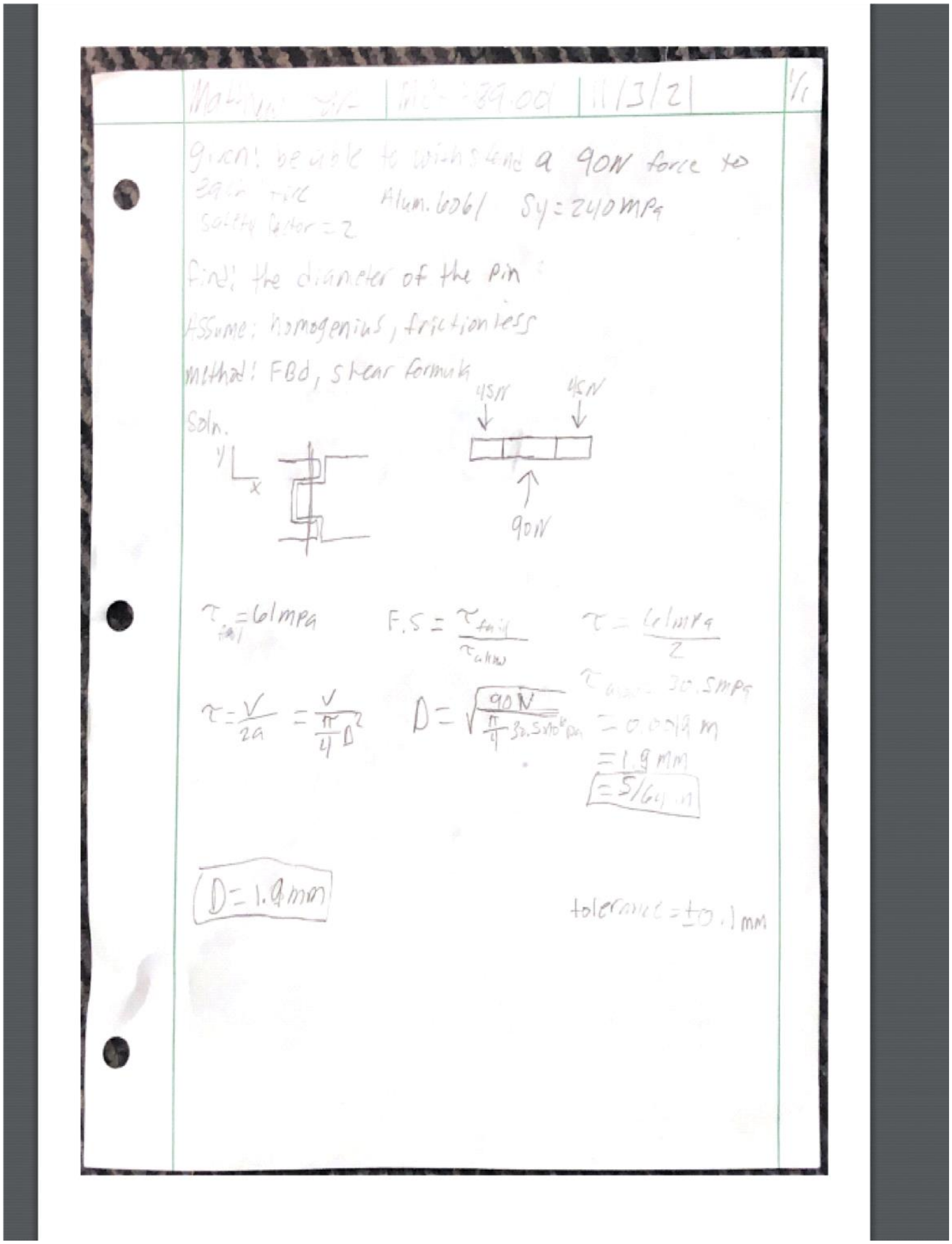
$A = 1.5in$

$\theta = Tan^{-1}\left(\frac{1.5in}{2in}\right) = 36.87°$

$L = \frac{8in}{2} + 1in(3in - 1.5in)$

$L = 3.5in$

Appendix A-7- Minimum Pin Diameter Appendix



11/3/21 1/1

Given: be able to withstand a 90N force to each tire
Alum. 6061 $S_y = 240$ MPa
Safety factor = 2

Find: the diameter of the pin

Assume: homogenius, frictionless

Method: FBd, shear formula

Soln.

45N 45N
90N

$\tau_{fail} = 61$ MPa $\quad F.S = \frac{\tau_{fail}}{\tau_{allow}} \quad \tau = \frac{61 \text{ MPa}}{2}$

$\tau_{allow} = 30.5$ MPa

$\tau = \frac{V}{2A} = \frac{V}{\frac{\pi}{4}D^2} \quad D = \sqrt{\frac{90 N}{\frac{\pi}{4} 30.5 \times 10^6 \text{ Pa}}} = 0.0019$ m

$= 1.9$ mm

$= 5/64$ in

D = 1.9 mm

tolerance = ±0.1 mm

Appendix A-8- Minimum Screw Diameter

Matthew Hart | MET 489.001 | 11/3/21 | 1/1

given: the force to withstand a drop from 1.5ft

$F = 90N$ Safety factor = 2 $\tau_{fail} = 61MPa$

Alum. 6061

find: the minimum diameter screw

Assume: homogeneous, frictionless

Method: shear formula

Soln.

$\tau_{fail} = 61MPa$ $\tau_{allow} = \frac{\tau_{fail}}{2} = \frac{61}{2} = 30.5MPa$

$\tau_{allow} = 30.5\ MPa$

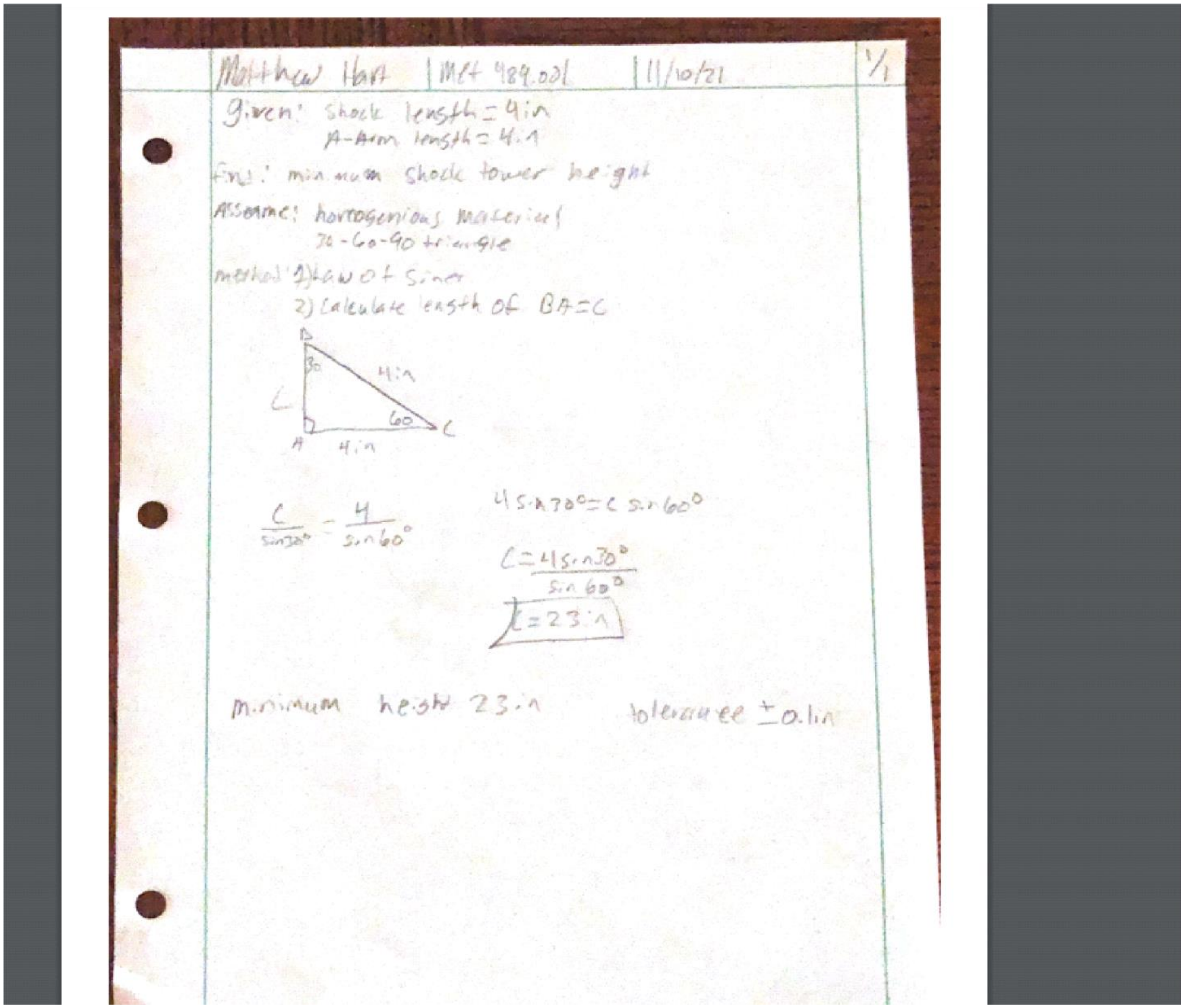
$\tau = \frac{V}{A} = \frac{V}{\frac{\pi}{4}d^2} = d = \sqrt{\frac{V}{\tau_{allow}\frac{\pi}{4}}} = \sqrt{\frac{90N}{30.5\times10^6 Pa\ \frac{\pi}{4}}}$

$= 1.9mm$

minimum diameter = 1.9mm

tolerance = ± 0.1mm

Appendix A-9- Minimum Shock tower Height



Matthew Hart | MET 489.001 | 11/10/21 | 1/1

given: Shock length = 4in
A-Arm length = 4in

find: minimum shock tower height

Assume: homogenious material
30-60-90 triangle

method: 1) Law of Sines
2) Calculate length of BA = C

$$\frac{C}{\sin 30^\circ} = \frac{4}{\sin 60^\circ}$$

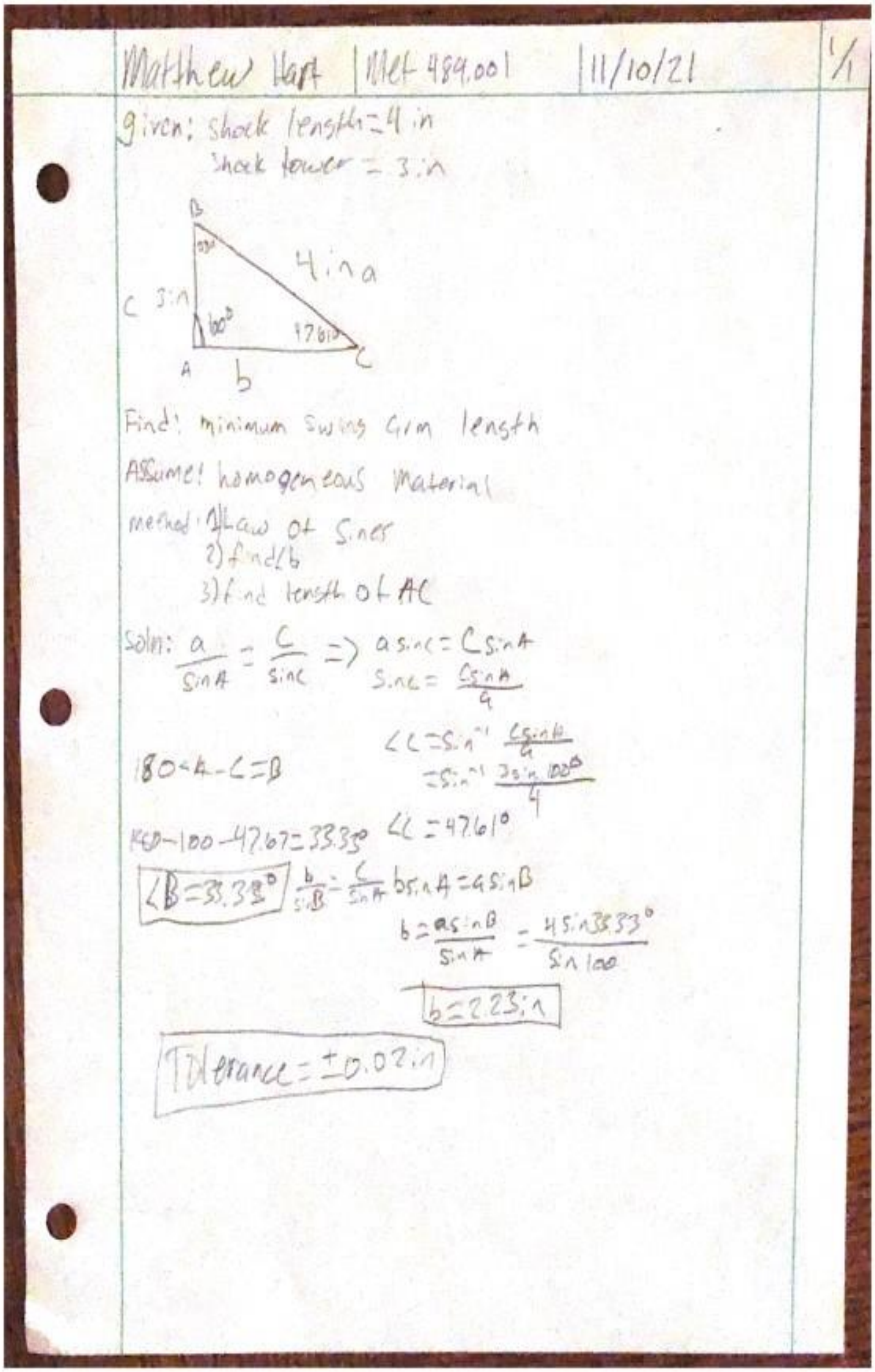
$$4 \sin 30^\circ = C \sin 60^\circ$$

$$C = \frac{4 \sin 30^\circ}{\sin 60^\circ}$$

C = 2.3 in

minimum height 2.3 in tolerance ±0.1in

Appendix A-10- Minimum Swing Arm Length



Matthew Hart | MET 489.001 | 11/10/21 | 1/1

given: shock length = 4 in
shock tower = 3 in

Find: minimum swing arm length

Assume: homogeneous material

method: 1) Law of Sines
2) find ∠b
3) find length of AC

soln: $\frac{a}{\sin A} = \frac{c}{\sin C} \Rightarrow a \sin C = c \sin A$

$\sin C = \frac{c \sin A}{4}$

$\angle C = \sin^{-1} \frac{c \sin A}{4}$

$= \sin^{-1} \frac{3 \sin 100°}{4}$

$180 - A - C = B$

$\angle C = 47.61°$

$180 - 100 - 47.67 = 33.33°$

$\boxed{\angle B = 33.33°}$ $\frac{b}{\sin B} = \frac{c}{\sin A}$ $b \sin A = a \sin B$

$b = \frac{a \sin B}{\sin A} = \frac{4 \sin 33.33°}{\sin 100}$

$\boxed{b = 2.23 \text{ in}}$

$\boxed{\text{Tolerance} = \pm 0.02 \text{ in}}$

Appendix A-11: Stress in Suspension Arms

Matthew Hart | Met 489.001 | 11/18/21 | 1/1

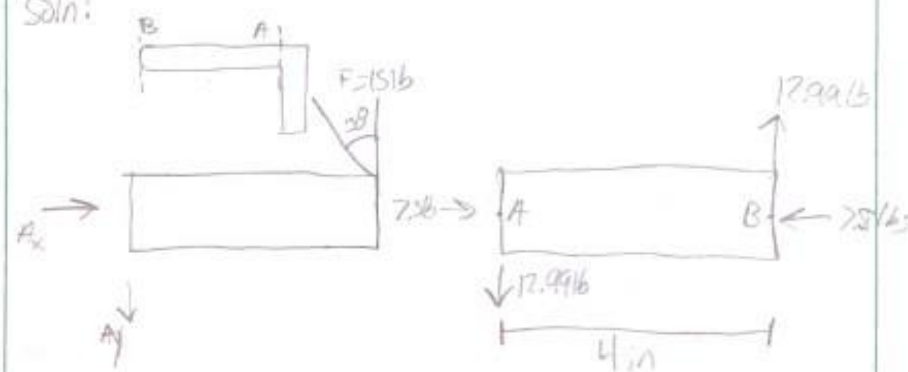
Given: material: ABS Plastic
length of arm: 4 inches
angle Shock sits at is 30°
15 lb force from Shock

Find: Stresses in suspension arms

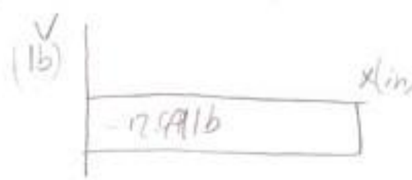
Assume: Static loading, homogenious material, constant force
force acts at 30°

Method: 1) FBD
2) evaluate forces acting on arm
3) Calculate stresses, shear, and moment

Soln:



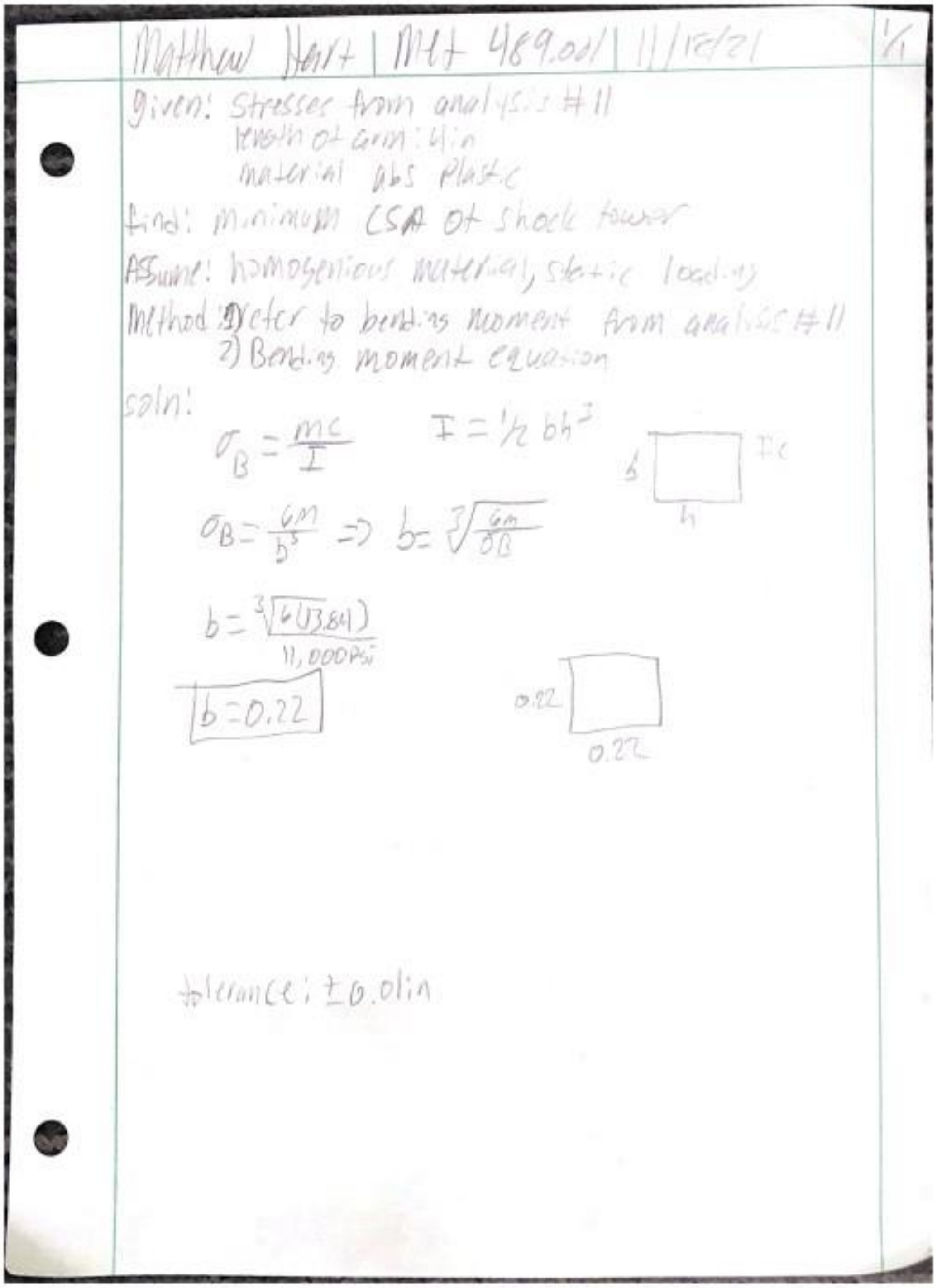
$F_y = 4\cos 30° = 3.46$ lbs
$F_x = 4\sin 30° = 2$ lbs



$V_{max} = 3.46$ lbs
$\sigma_{max} = 2$ lbs
$M_{max} = 13.84$ lb·in

tolerance ± 0.01 lbs

Appendix A-12: Minimum Cross-Sectional Area



Matthew Hart | MET 489.001 | 11/12/21 1/1

Given: Stresses from analysis #11
length of arm: 4 in
material abs plastic

Find: minimum CSA of shock tower

Assume: homogenious material, static loading

Method: 1) refer to bending moment from analysis #11
2) Bending moment equation

soln:

$$\sigma_B = \frac{mc}{I} \qquad I = \tfrac{1}{12} bh^3$$

$$\sigma_B = \frac{6m}{b^3} \Rightarrow b = \sqrt[3]{\frac{6m}{\sigma_B}}$$

$$b = \sqrt[3]{\frac{6(13.84)}{11{,}000\,psi}}$$

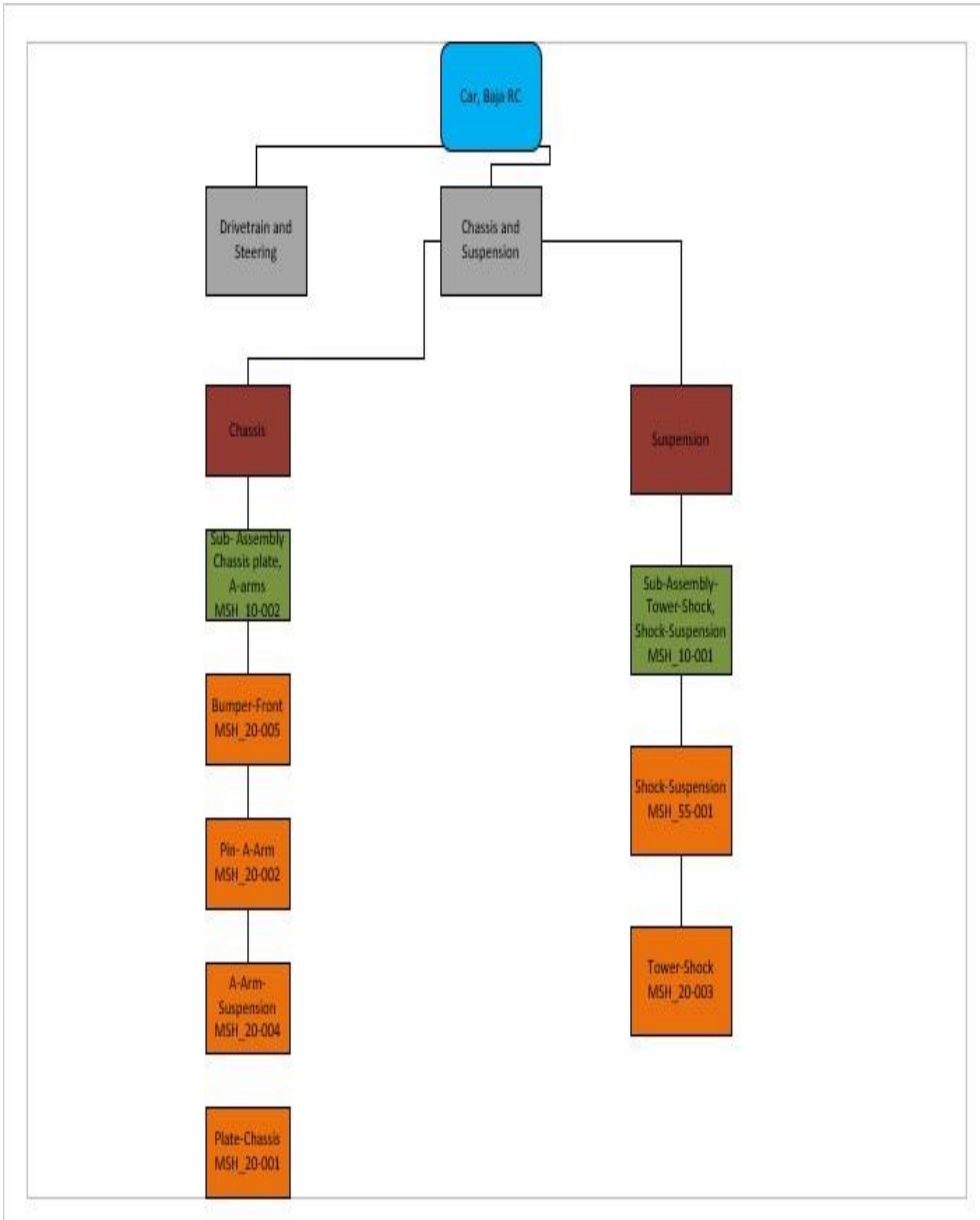
$$\boxed{b = 0.22}$$

0.22 × 0.22

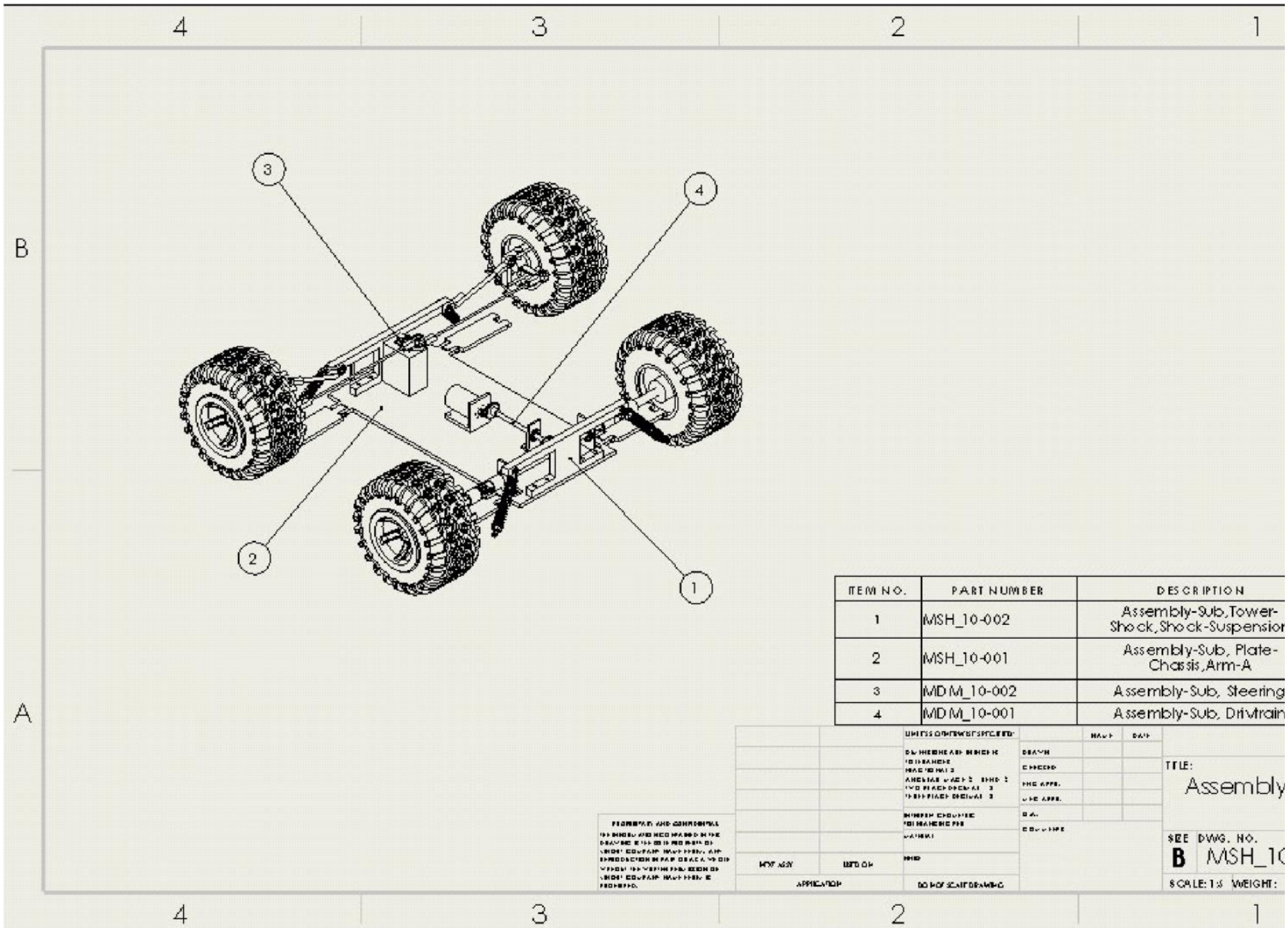
tolerance: ±0.01in

APPENDIX B – Drawing

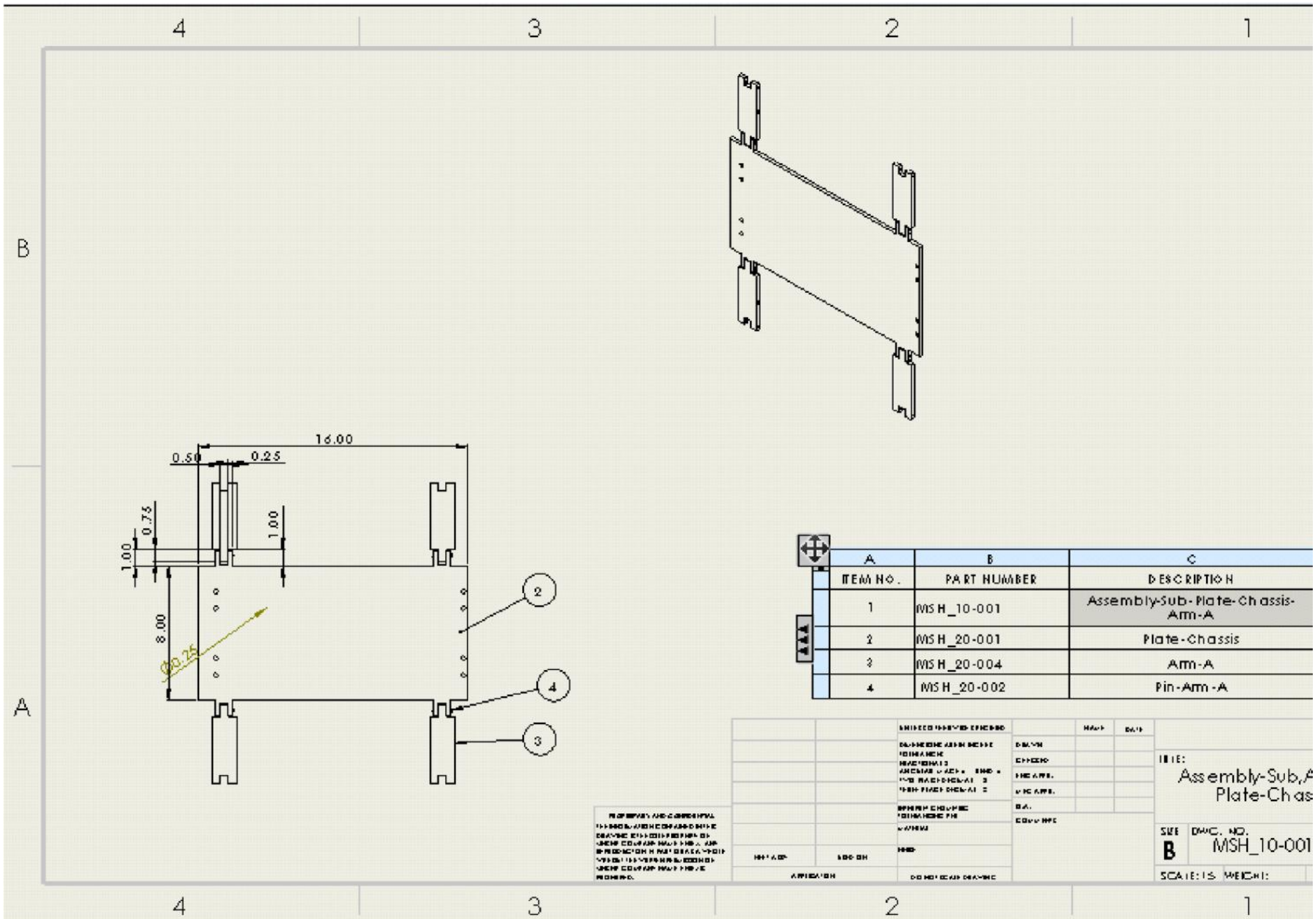
Appendix B-1: Drawing Tree



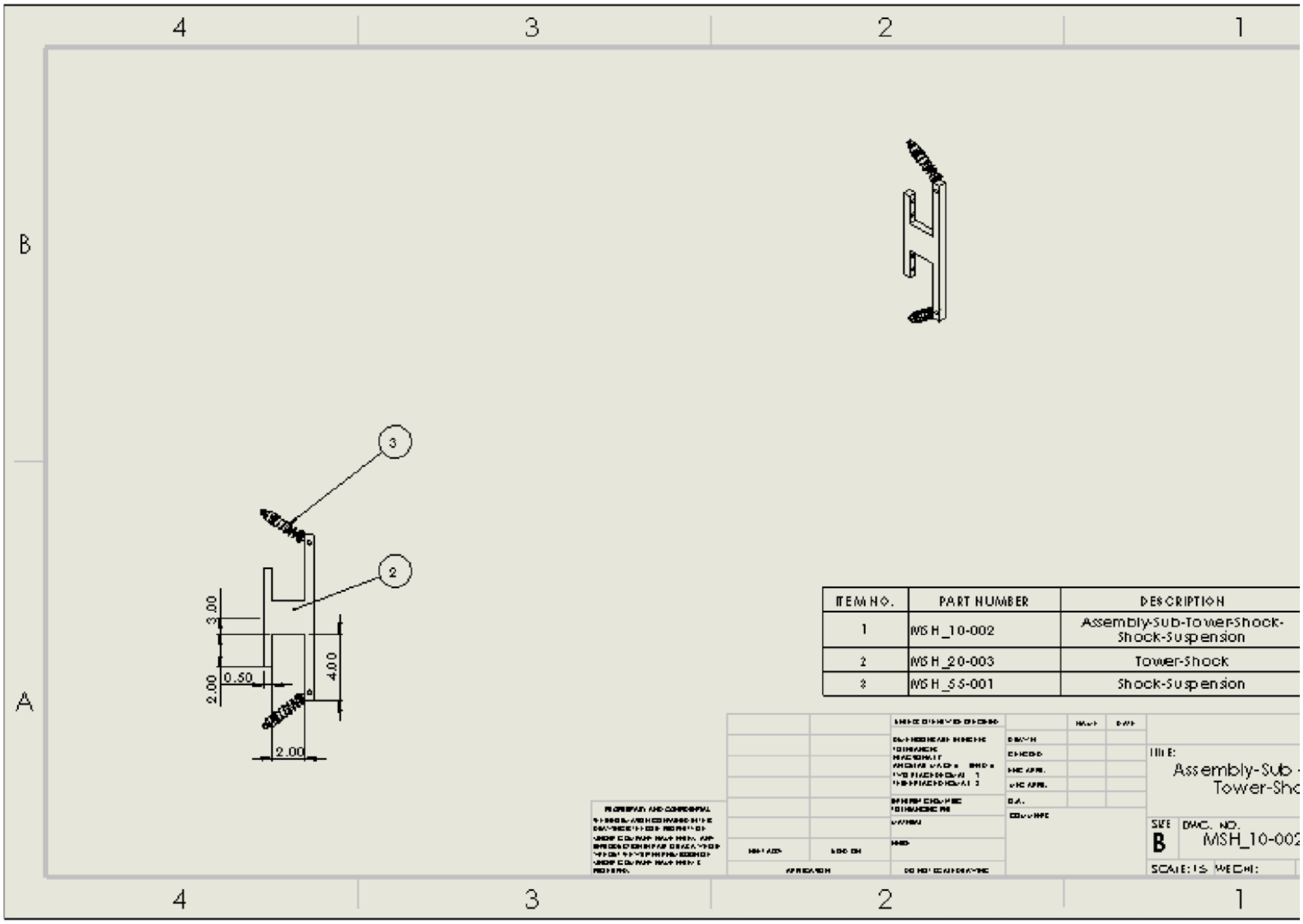
Appendix B-2: Assembly, Car-RC



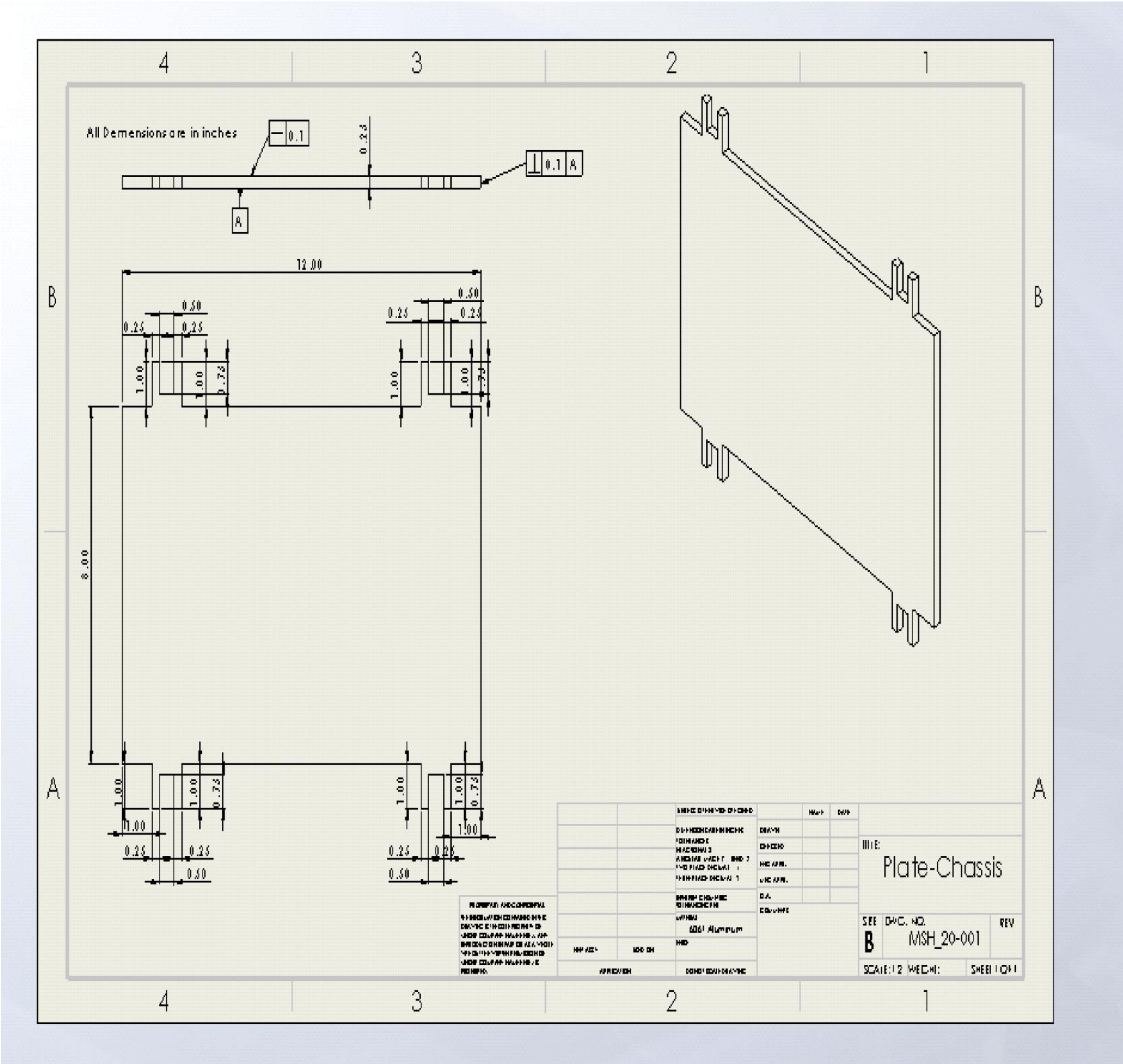
Appendix B-3 sub-assembly, Chassis



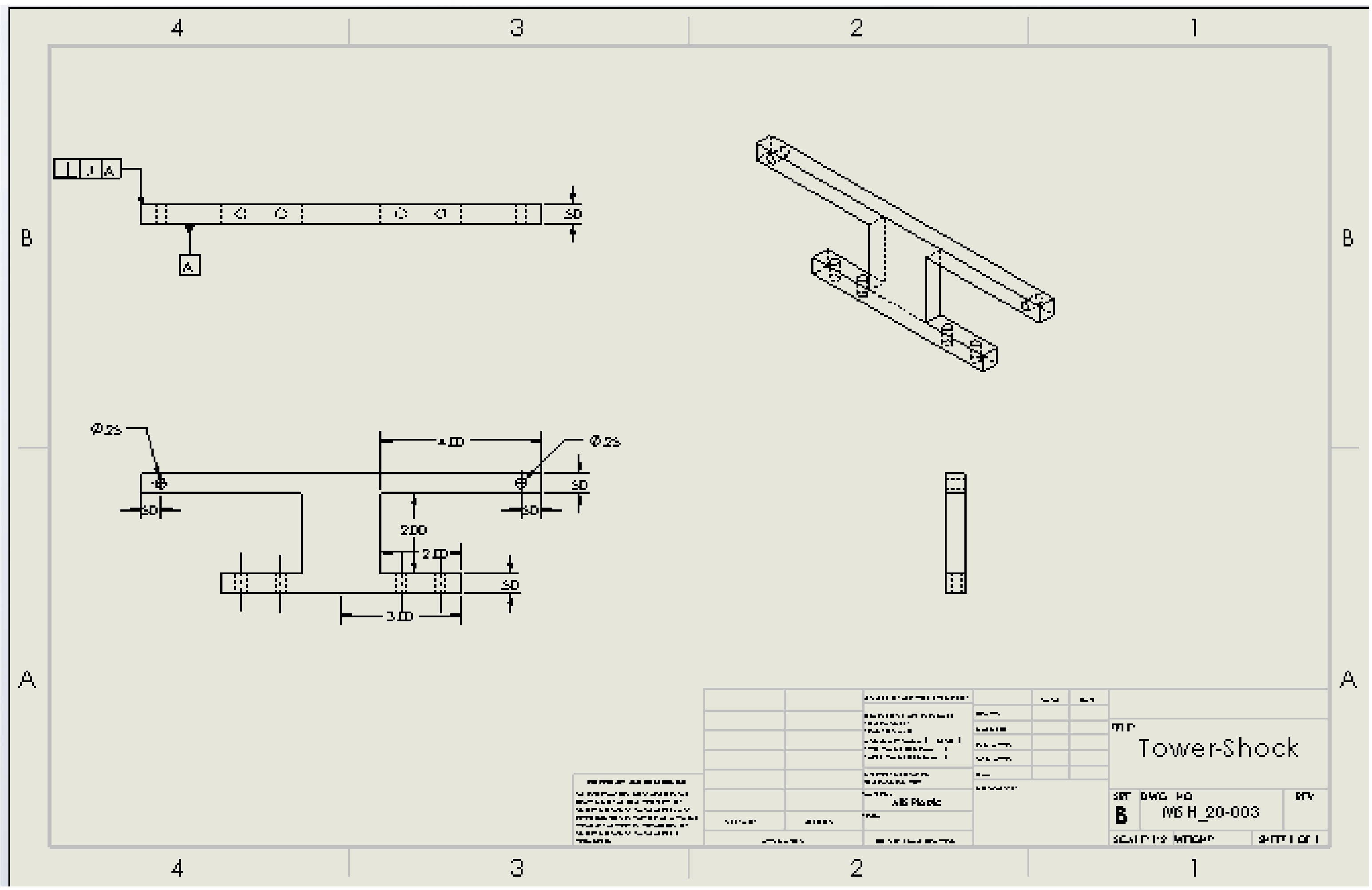
Appendix B-4 Sub-Assembly, Suspension



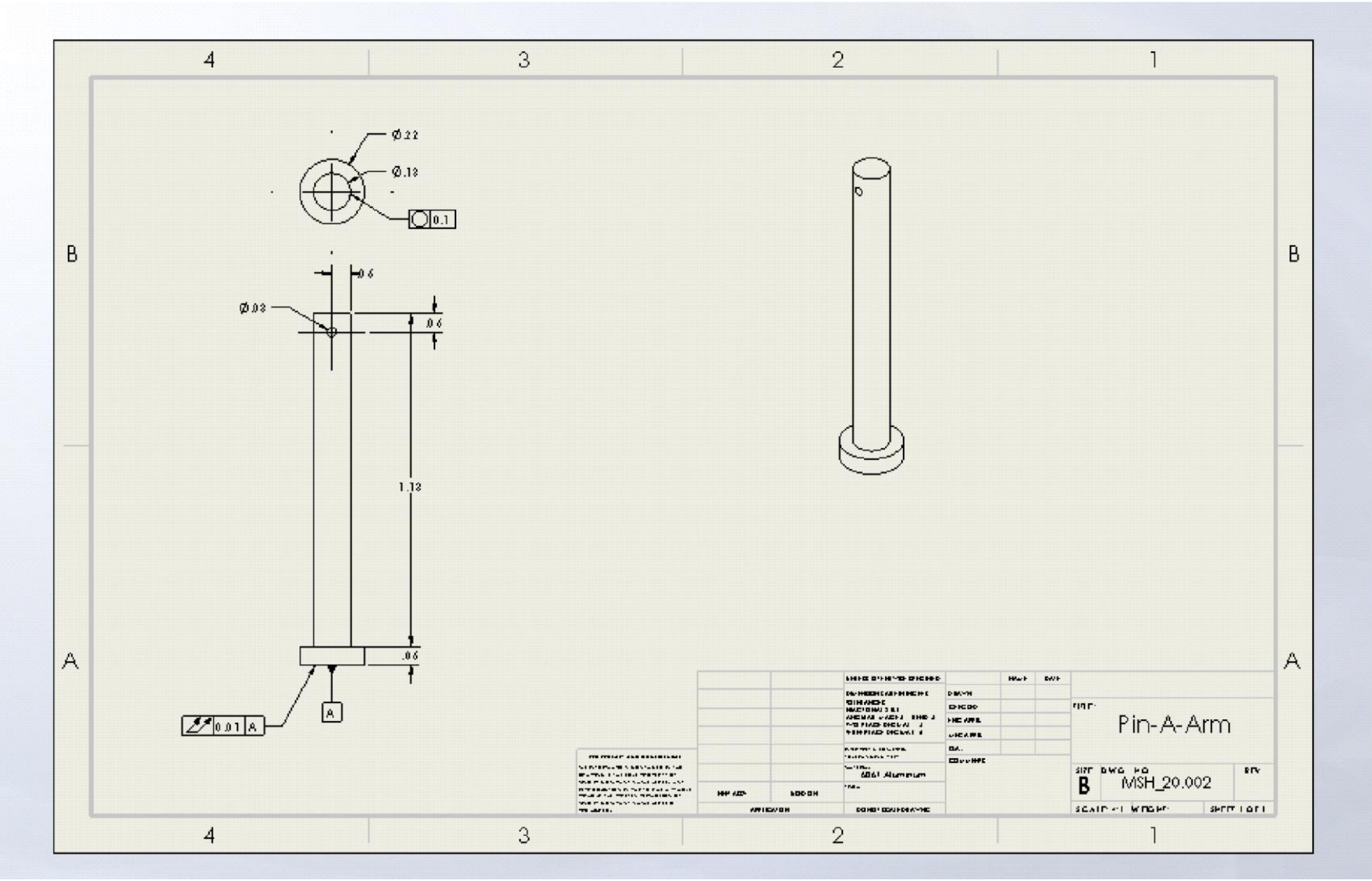
Appendix B-5 Plate Chassis



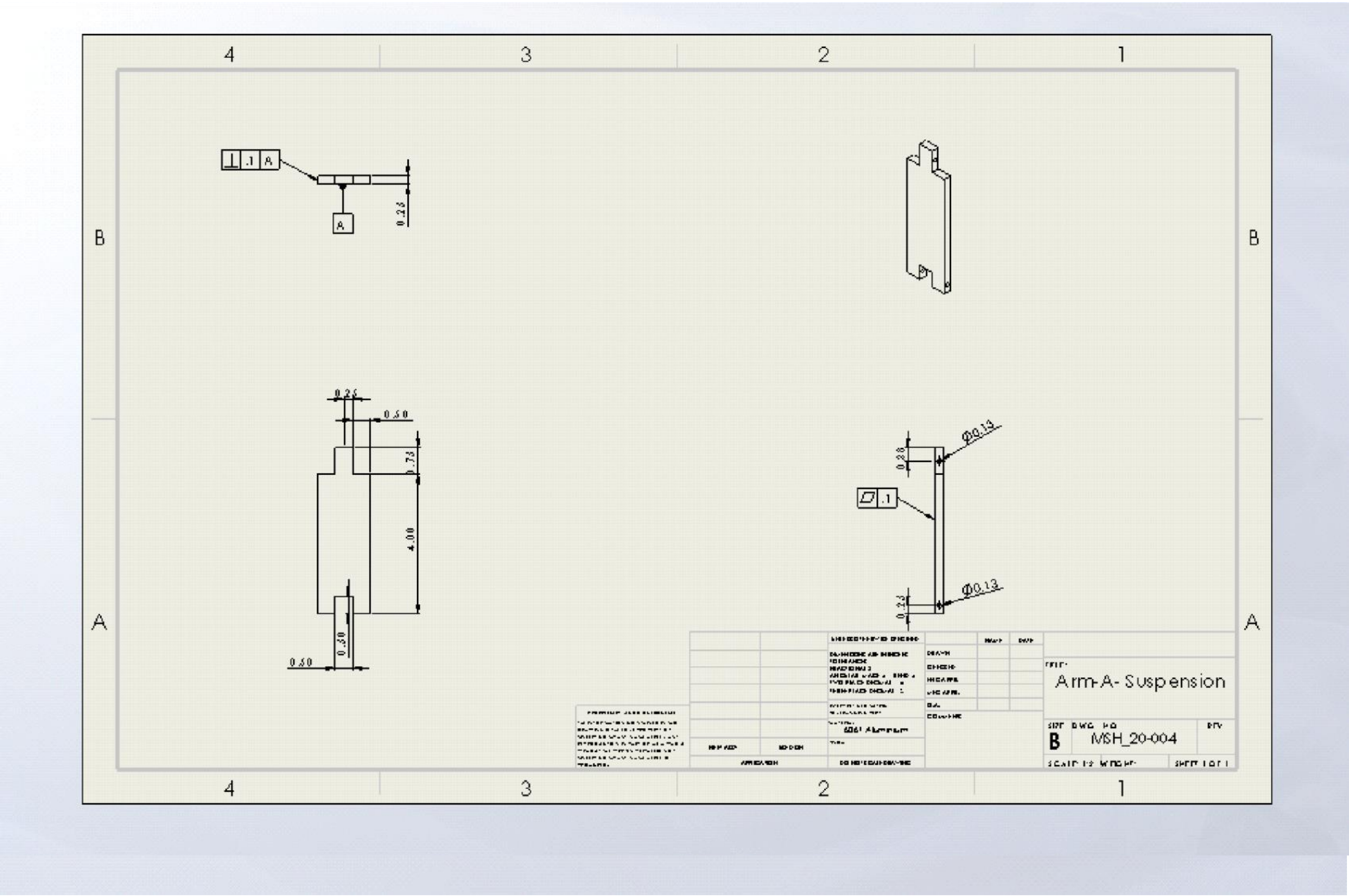
Appendix B-6 Tower Shocks



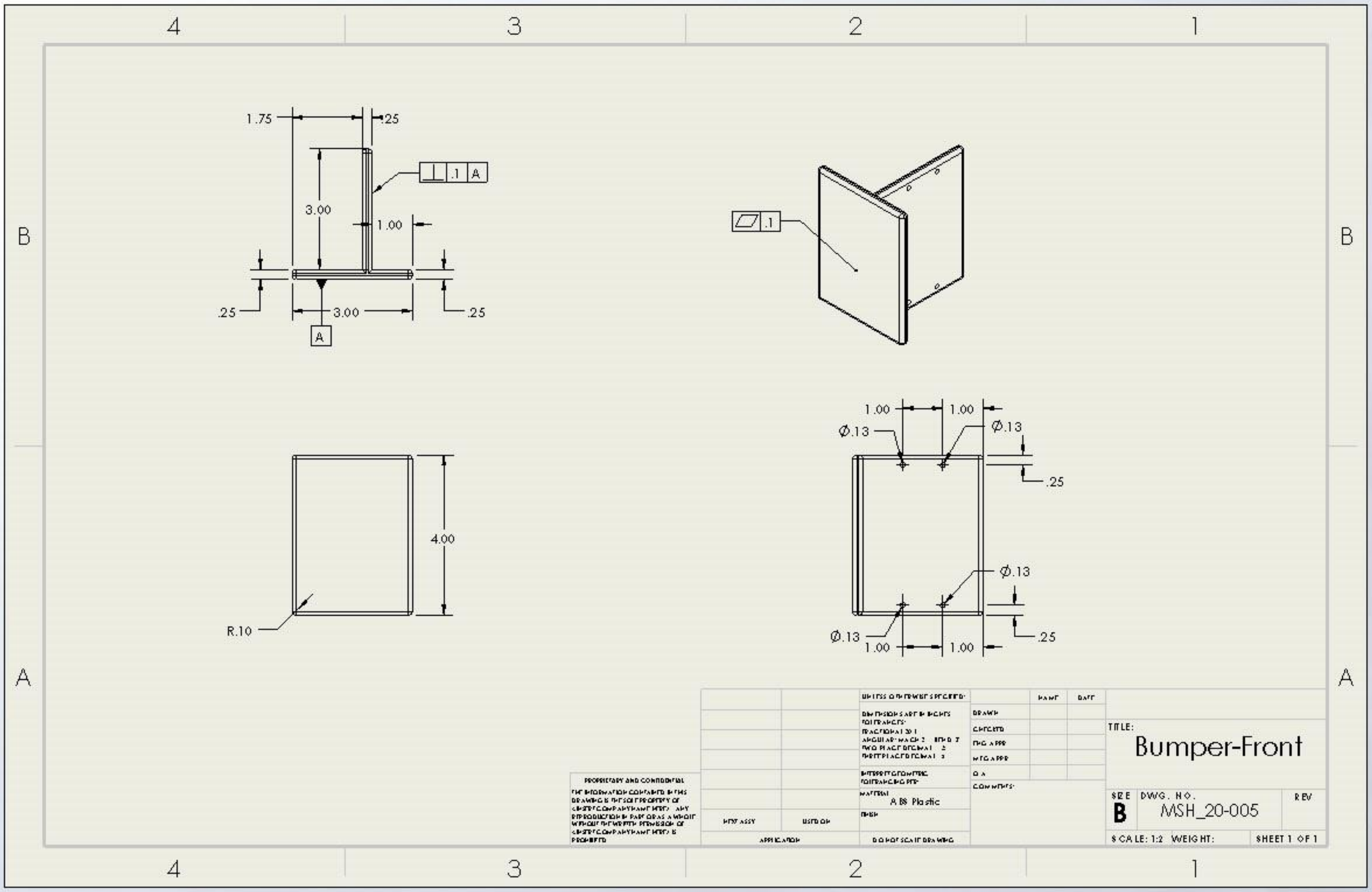
Appendix B-7 Pins



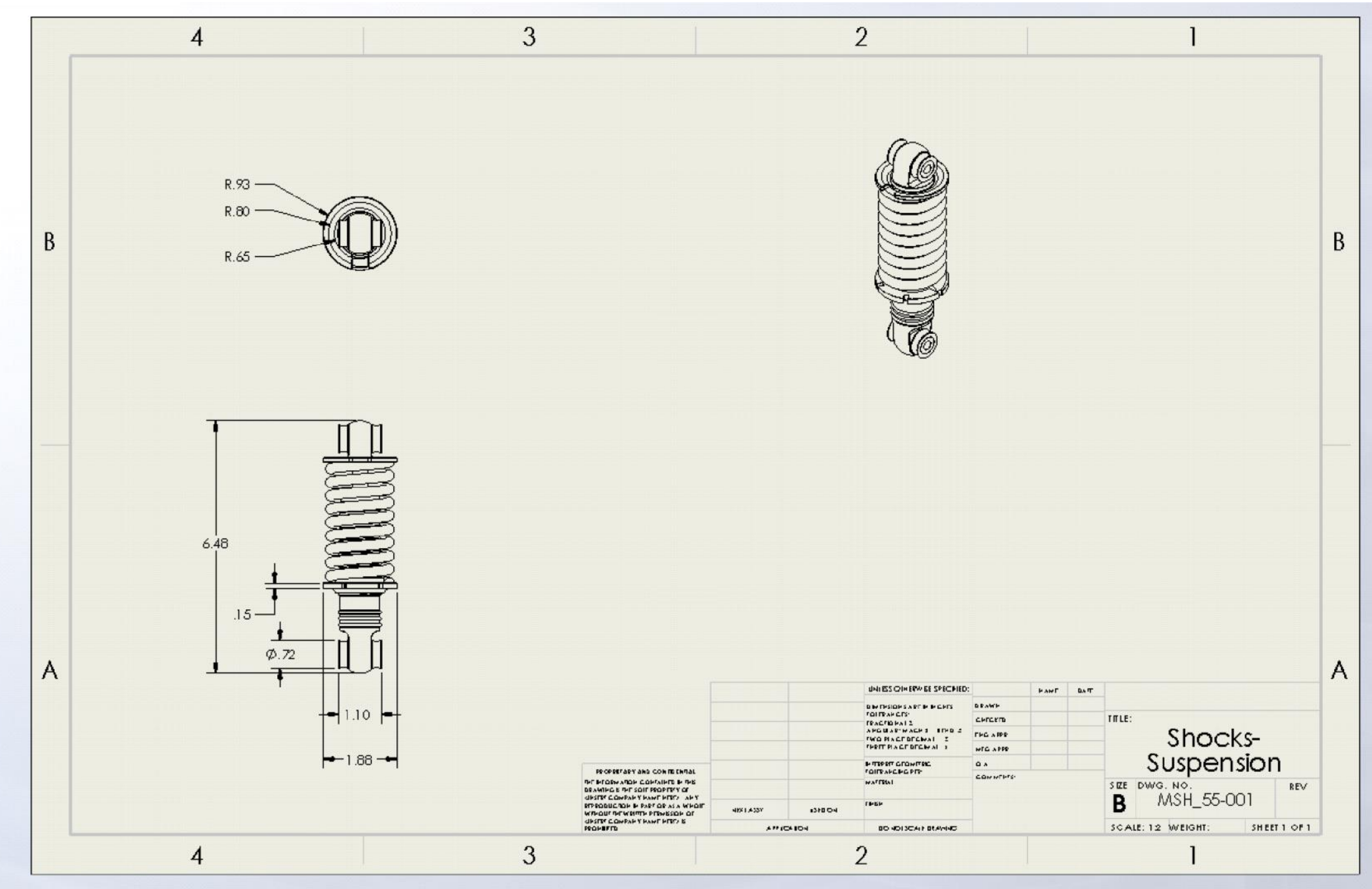
Appendix B-8 Arms-A



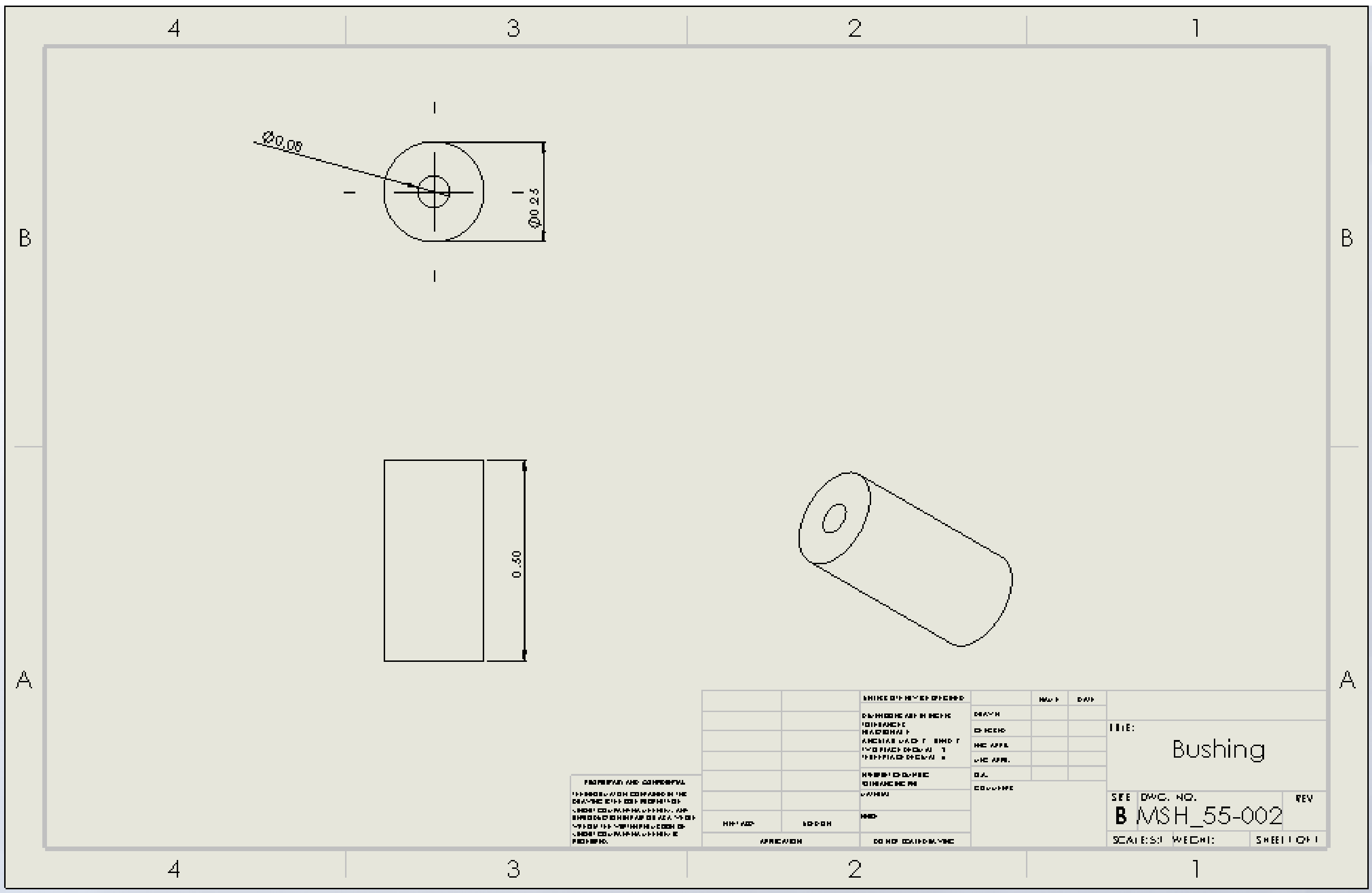
Appendix B-9 Bumper Front



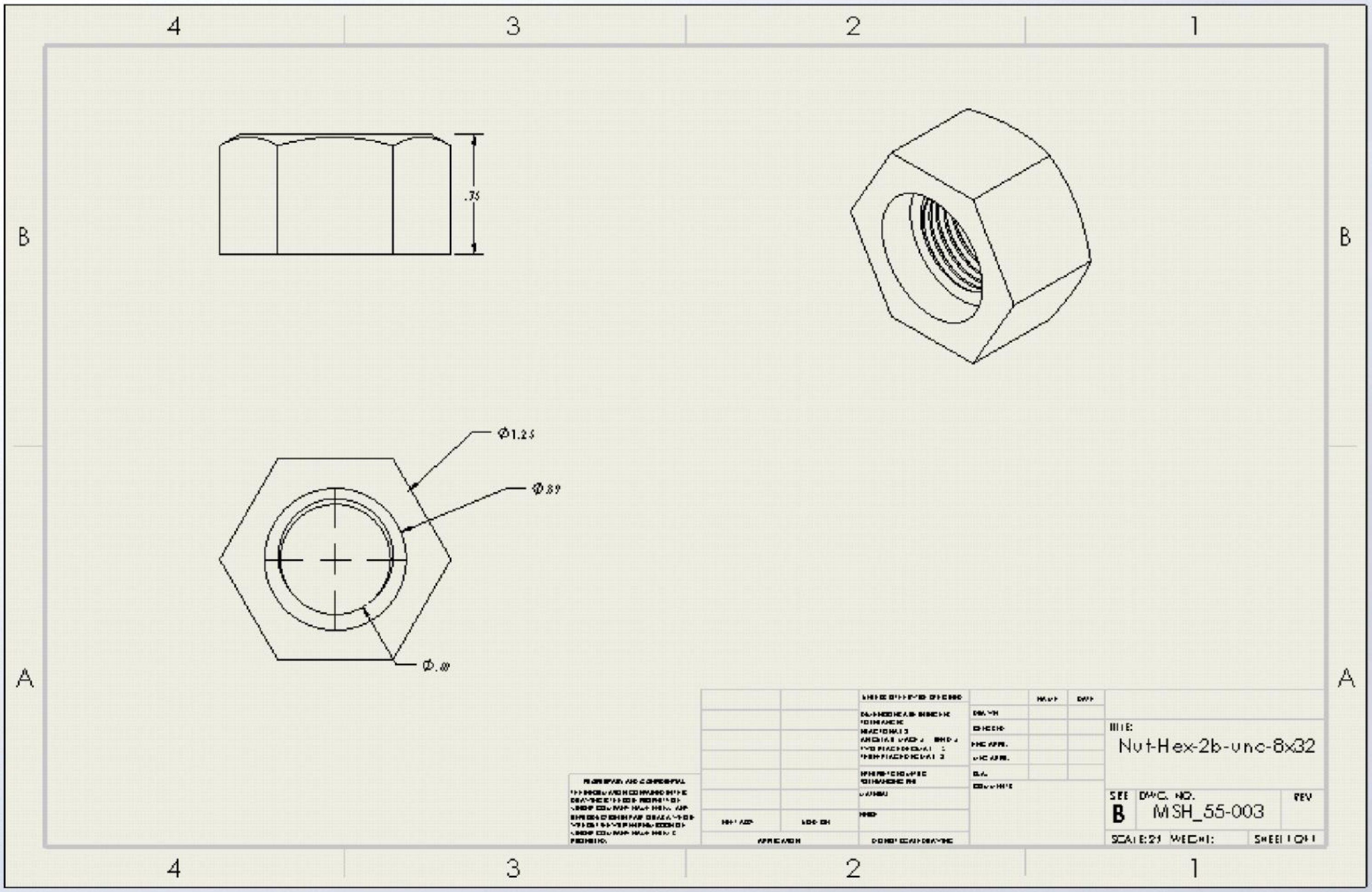
Appendix B-10 Shocks



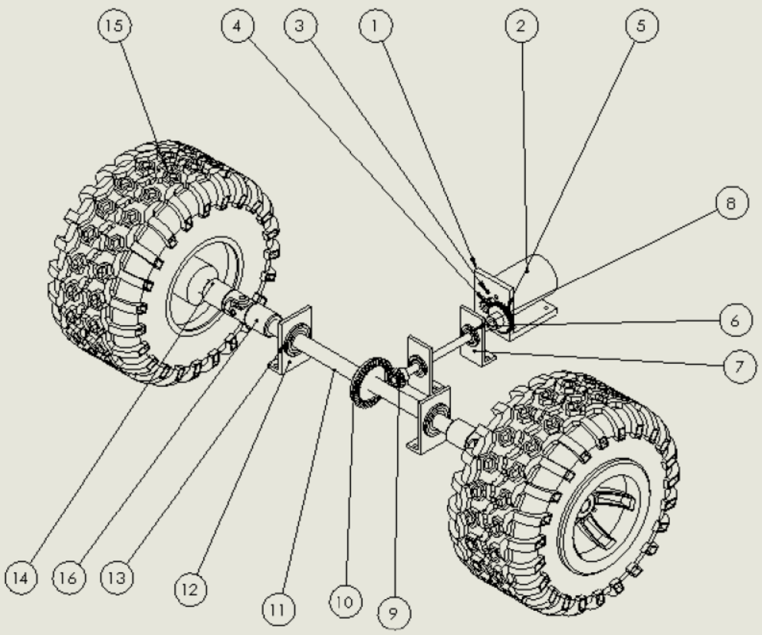
Appendix B-11 Bushing



Appendix B-12: Nut-Hex-2b-unc-8x32



Appendix B-13: Assembly-Sub,Drivetrain (Mathew Morgan)



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MDM_20-001	Motor Mount	1
2	MDM_55-009	Motor	1
3	MDM_50-001	Button Head Hex Drive Screw	6
4	MDM_55-001	Transmission Pinion Gear	1
5	MDM_55-002	Transmission Spur Gear	1
6	MDM_20-002	Driveshaft	1
7	MDM_20-008	Driveshaft Support	2
8	MDM_55-012	Permanently Lubricated Ball Bearing	2
9	MDM_55-005	Differential Driver Miter Gear	1
10	MDM_55-006	Differential Driven Miter Gear	1
11	MDM_20-003	Rear Axle	1
12	MDM_20-009	Rear Axle Support	2
13	MDM_55-013	Permanently Lubricated Ball Bearing	2
14	MDM_20-015	Rear Axle Extension	2
15	MDM_20-004	Tires	2
16	MDM_55-010	Single U-Joint	2

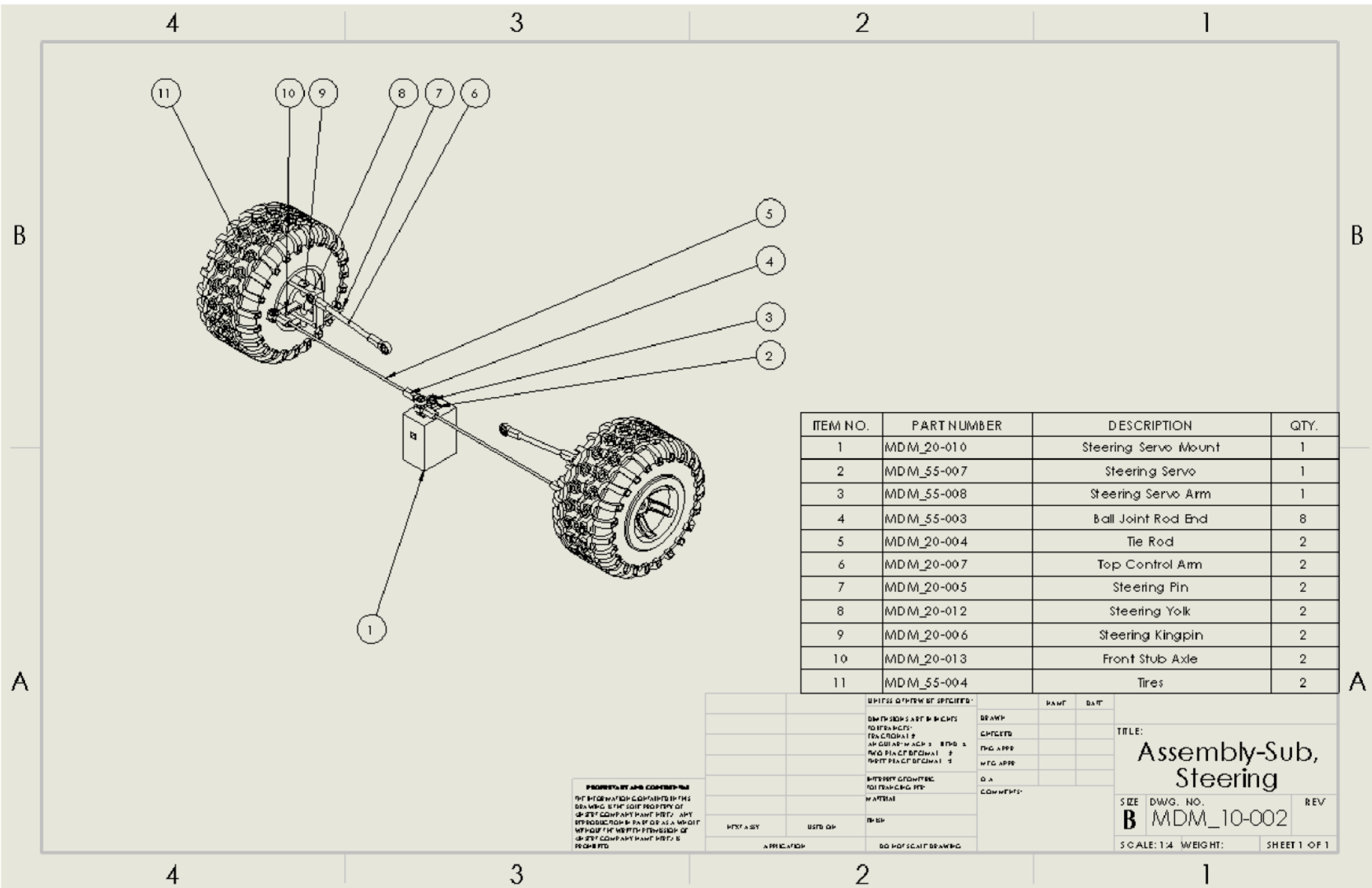
UNLESS OTHERWISE SPECIFIED:

TITLE: Assembly-Sub, Drivetrain

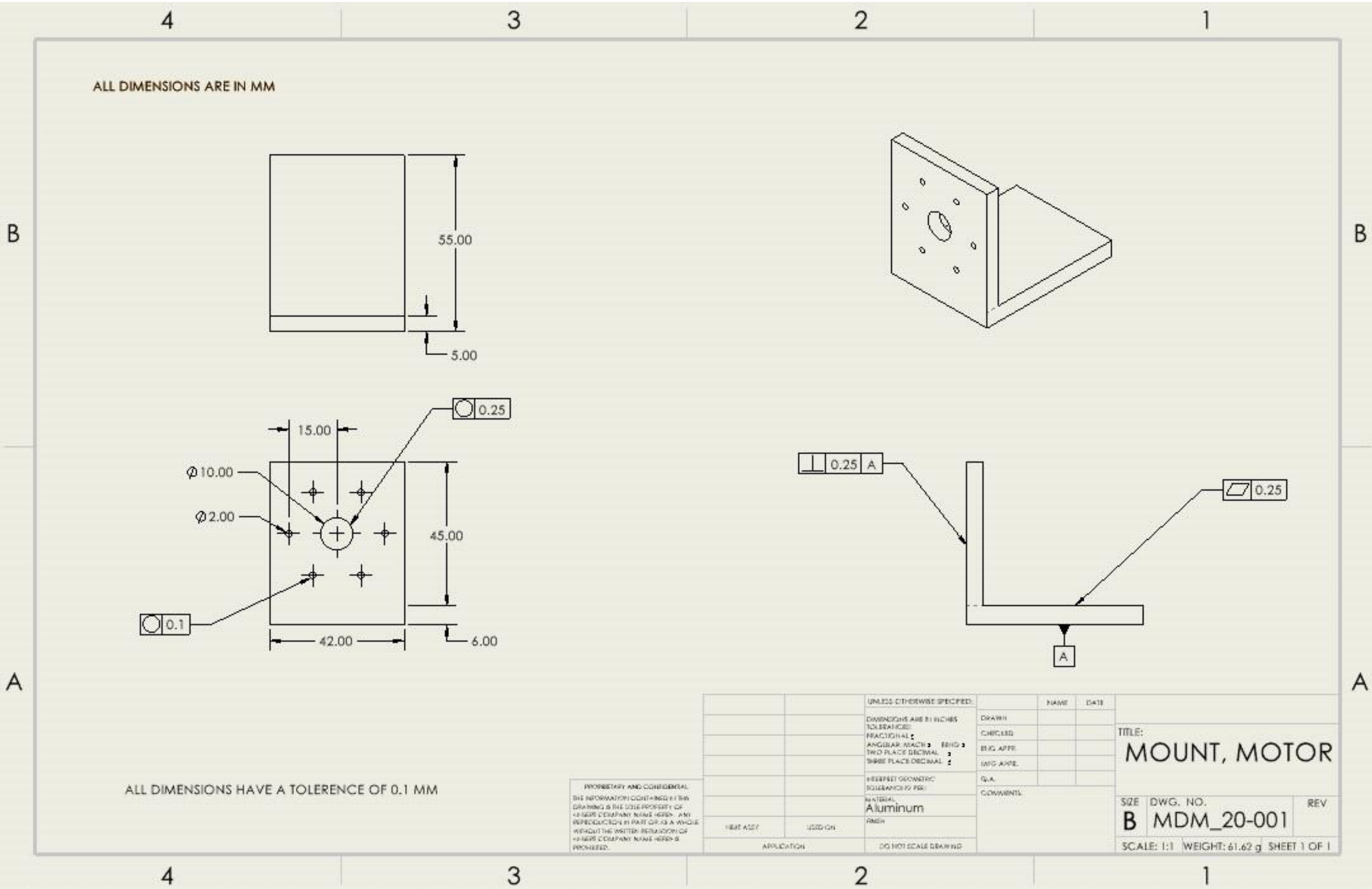
SIZE B DWG. NO. MDM_10-001 REV

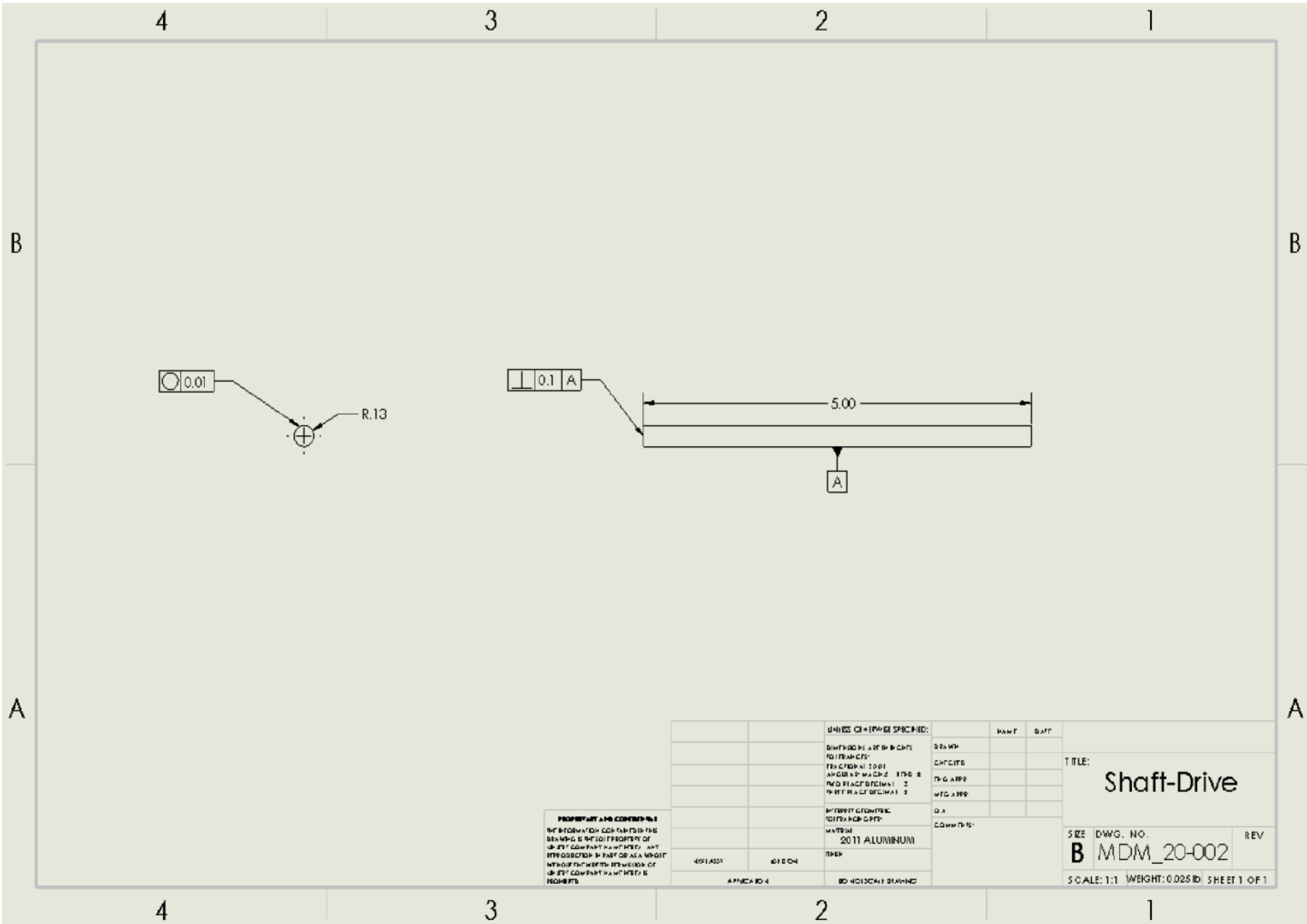
SCALE: 1:3 WEIGHT: SHEET 1 OF 1

Appendix B-14: Assembly-Sub, Steering (Mathew Morgan)

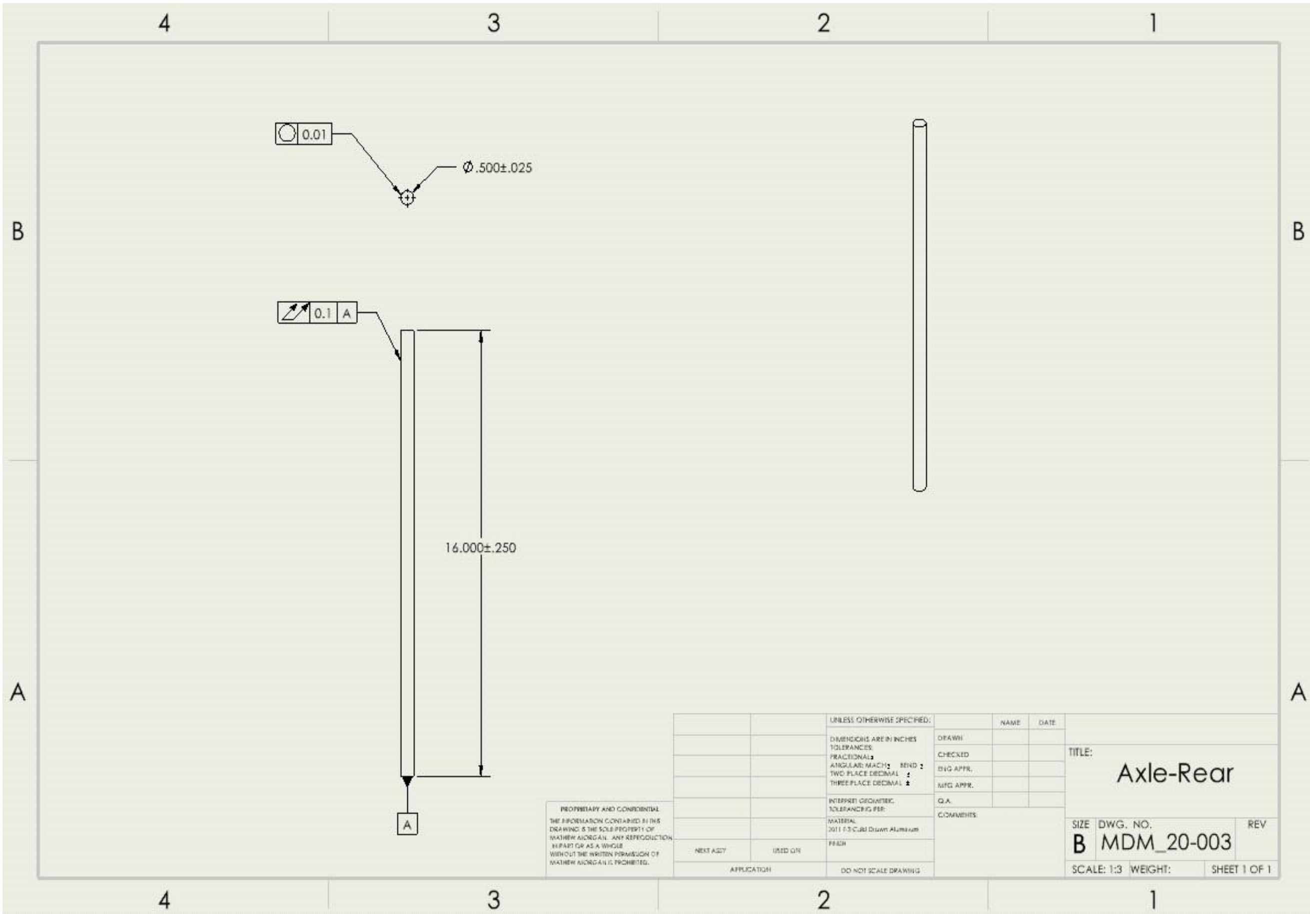


Appendix B-15 – Mount, Motor

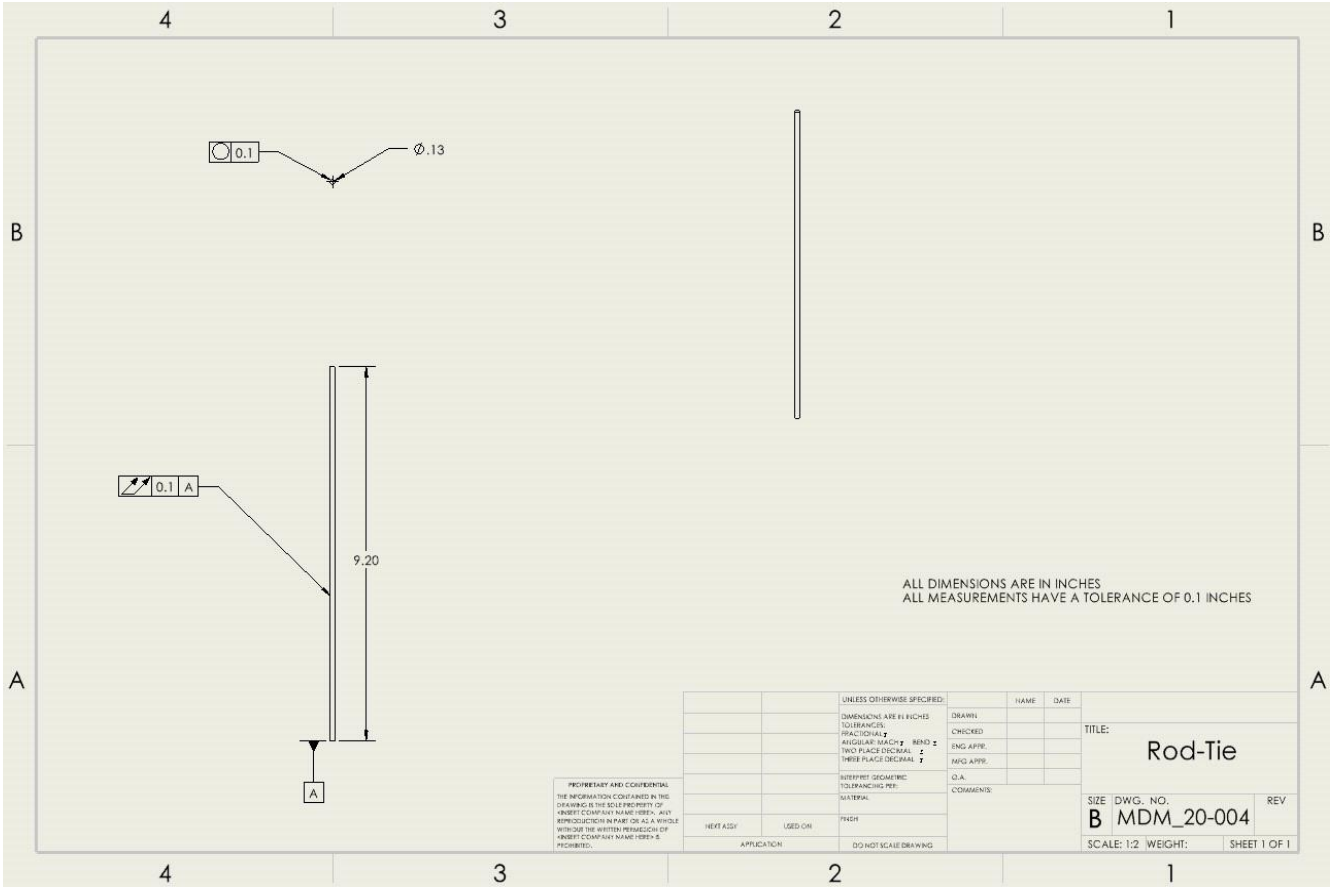




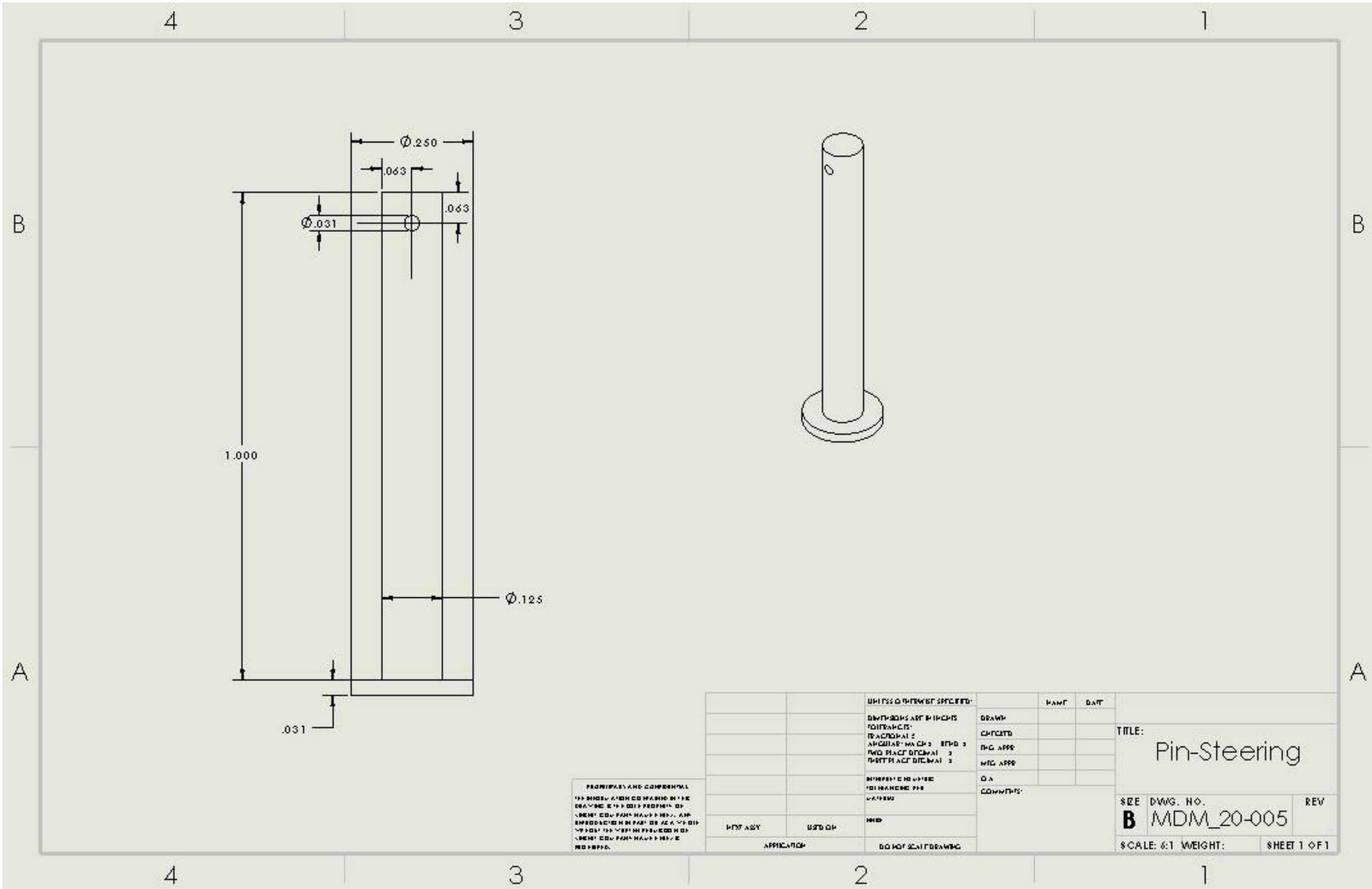
Appendix B-16 – Shaft-Drive



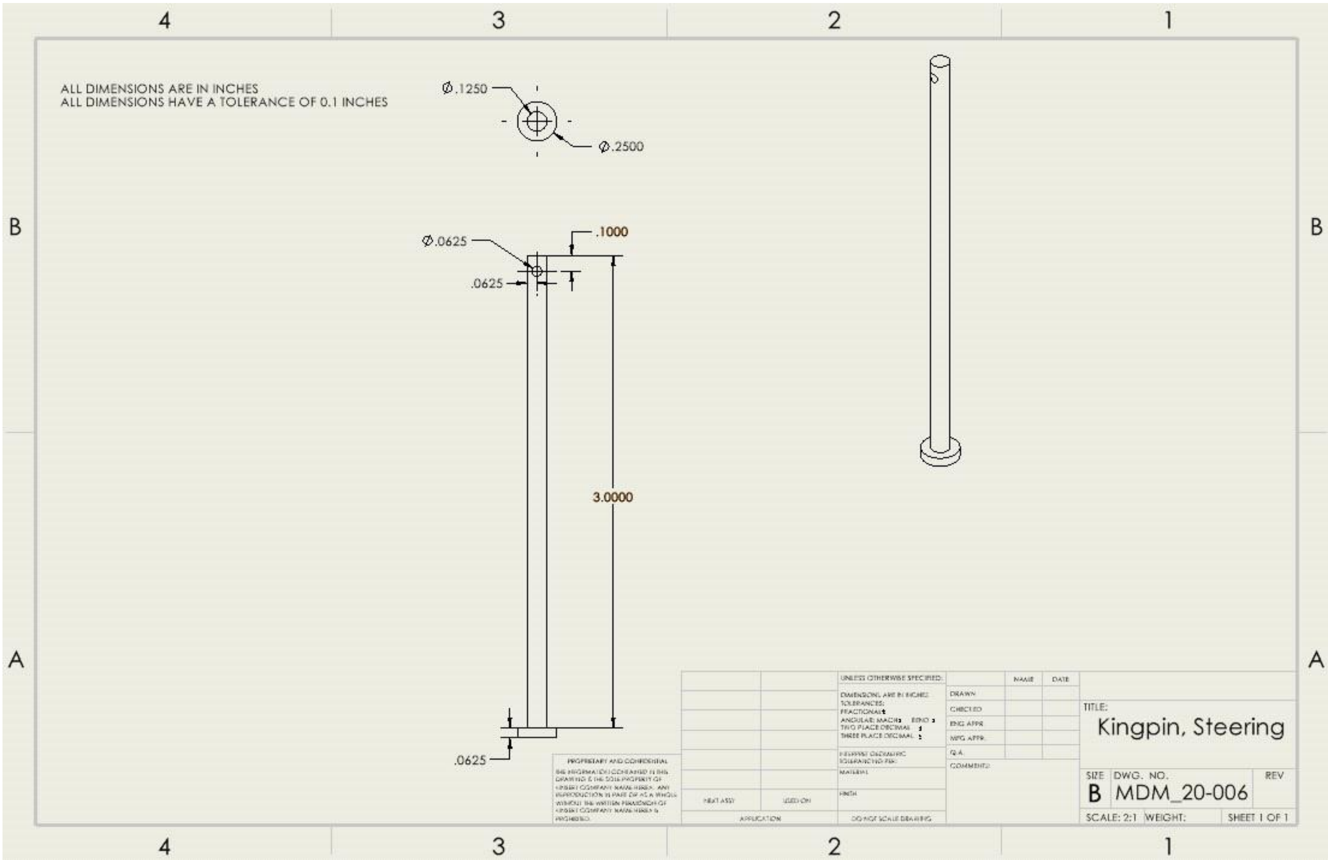
Appendix B-17 – Axle-Rear



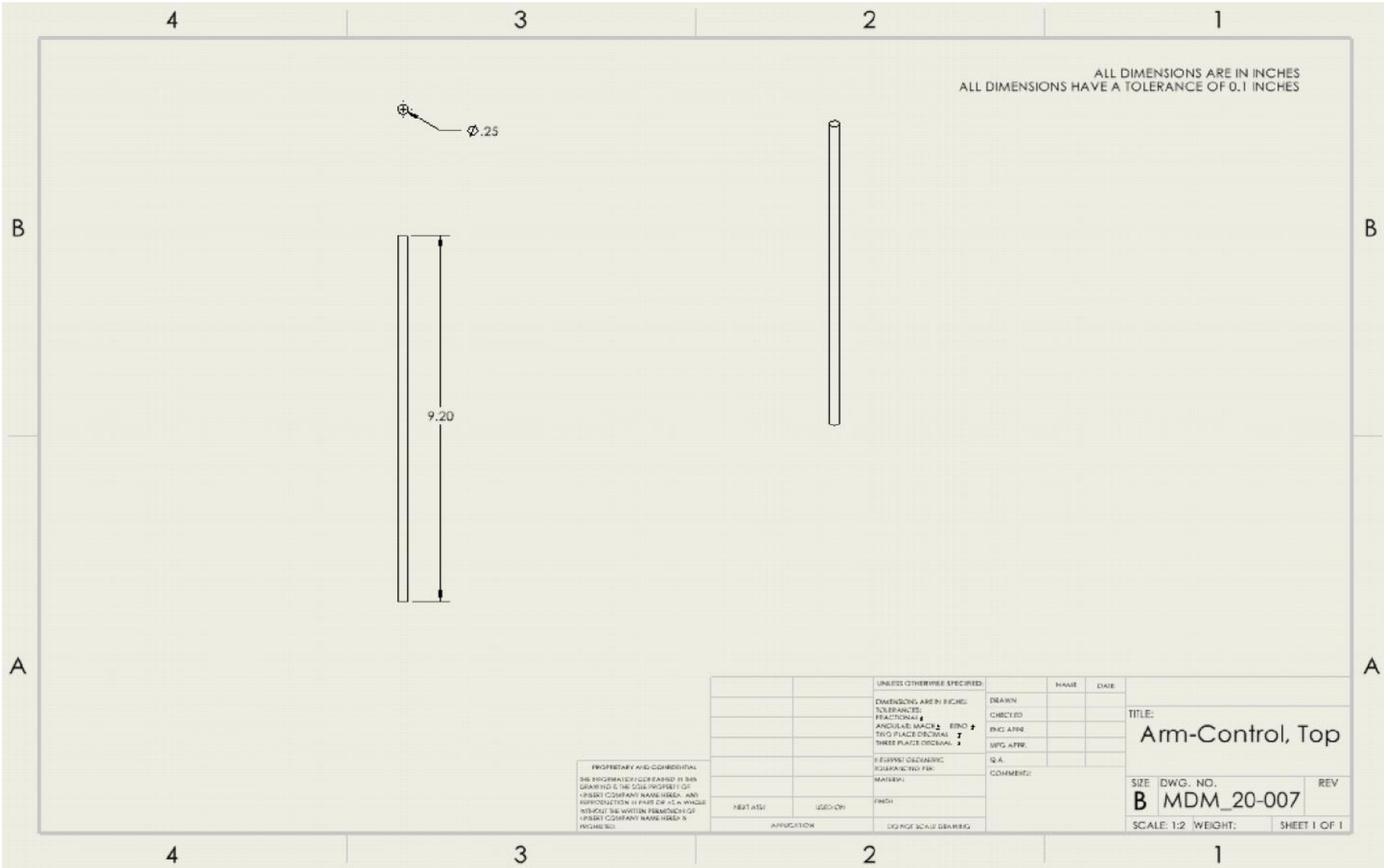
Appendix B-18 – Rod-Tie



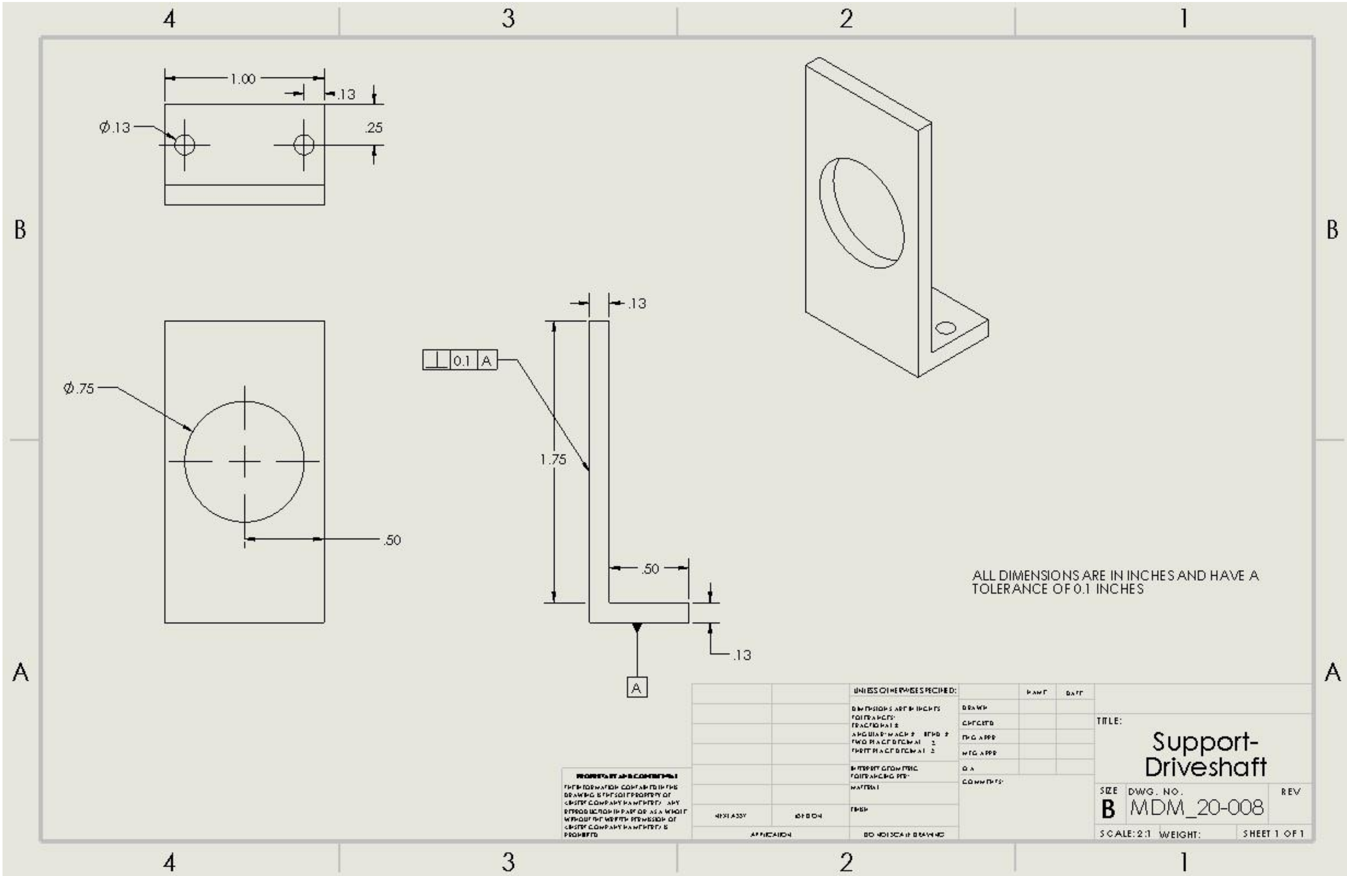
Appendix B-19 – Pin-Steering



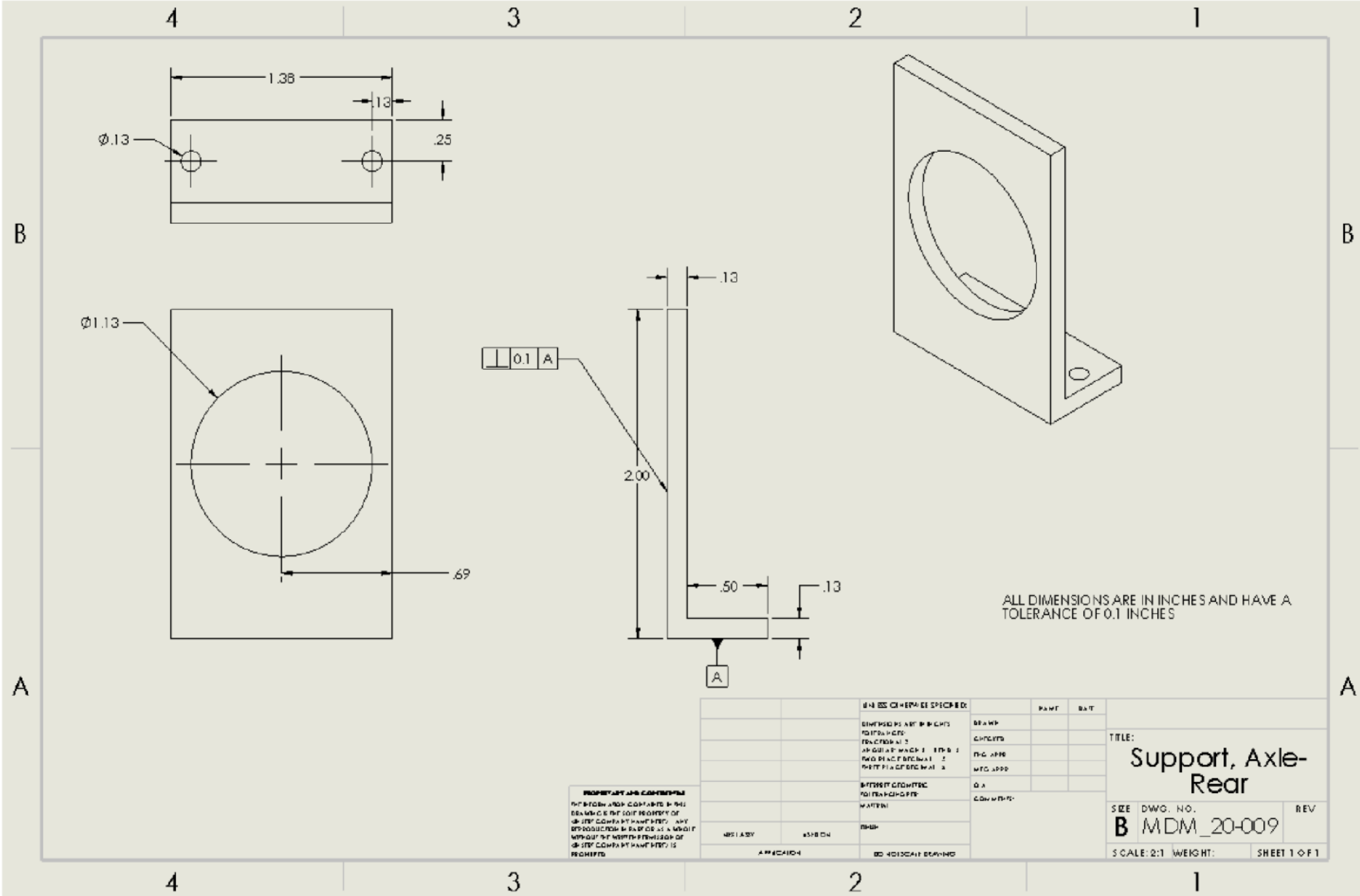
Appendix B-20 – Kingpin, Steering


ALL DIMENSIONS ARE IN INCHES
ALL DIMENSIONS HAVE A TOLERANCE OF 0.1 INCHES
Ø.25
9.20
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL
ANGULAR: MACH BEND
TWO PLACE DECIMAL
THREE PLACE DECIMAL
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
TITLE:
Arm-Control, Top
SIZE
B
DWG. NO.
MDM_20-007
REV
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

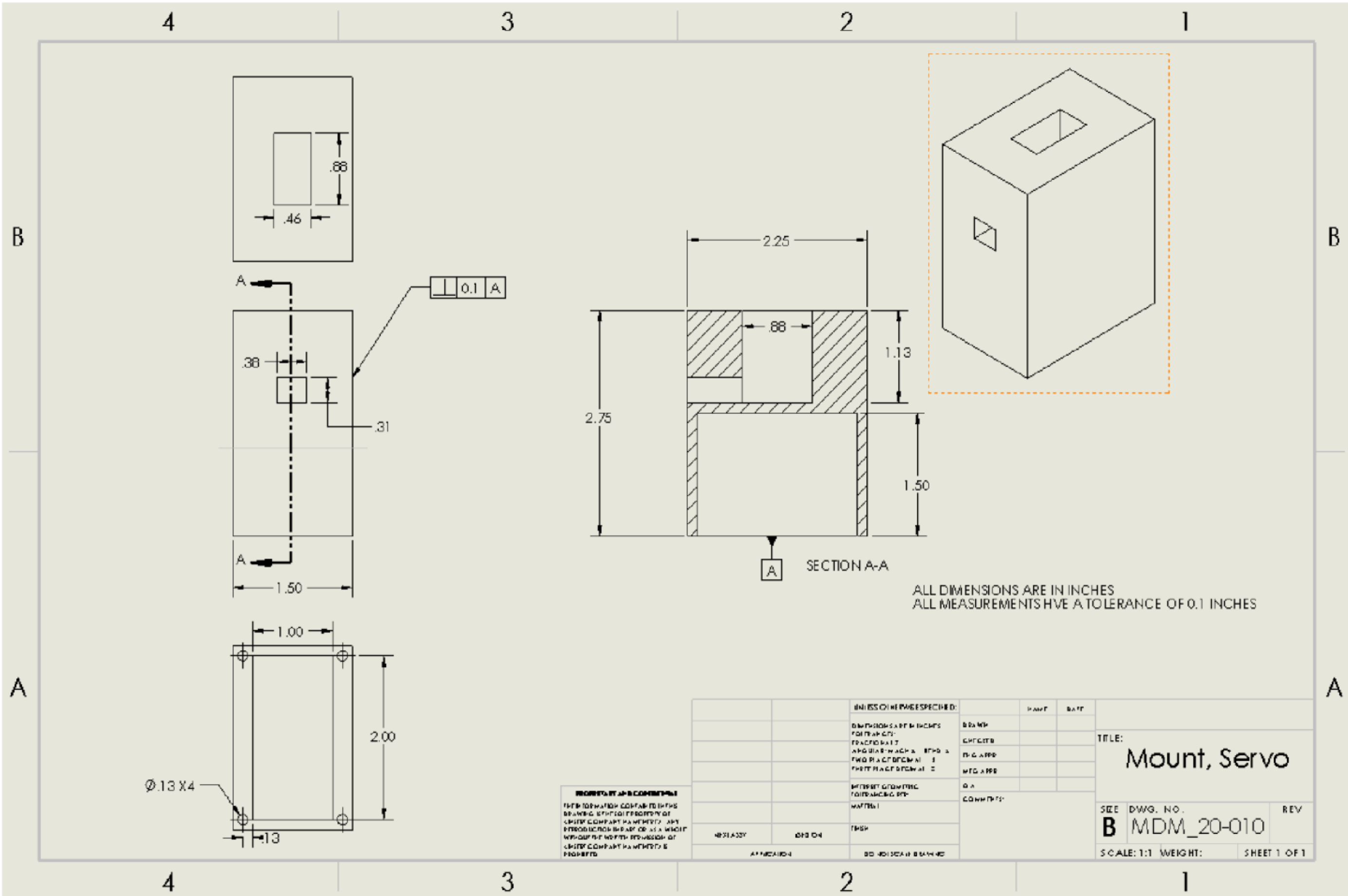
Appendix B-21 – Arm-Control, Top



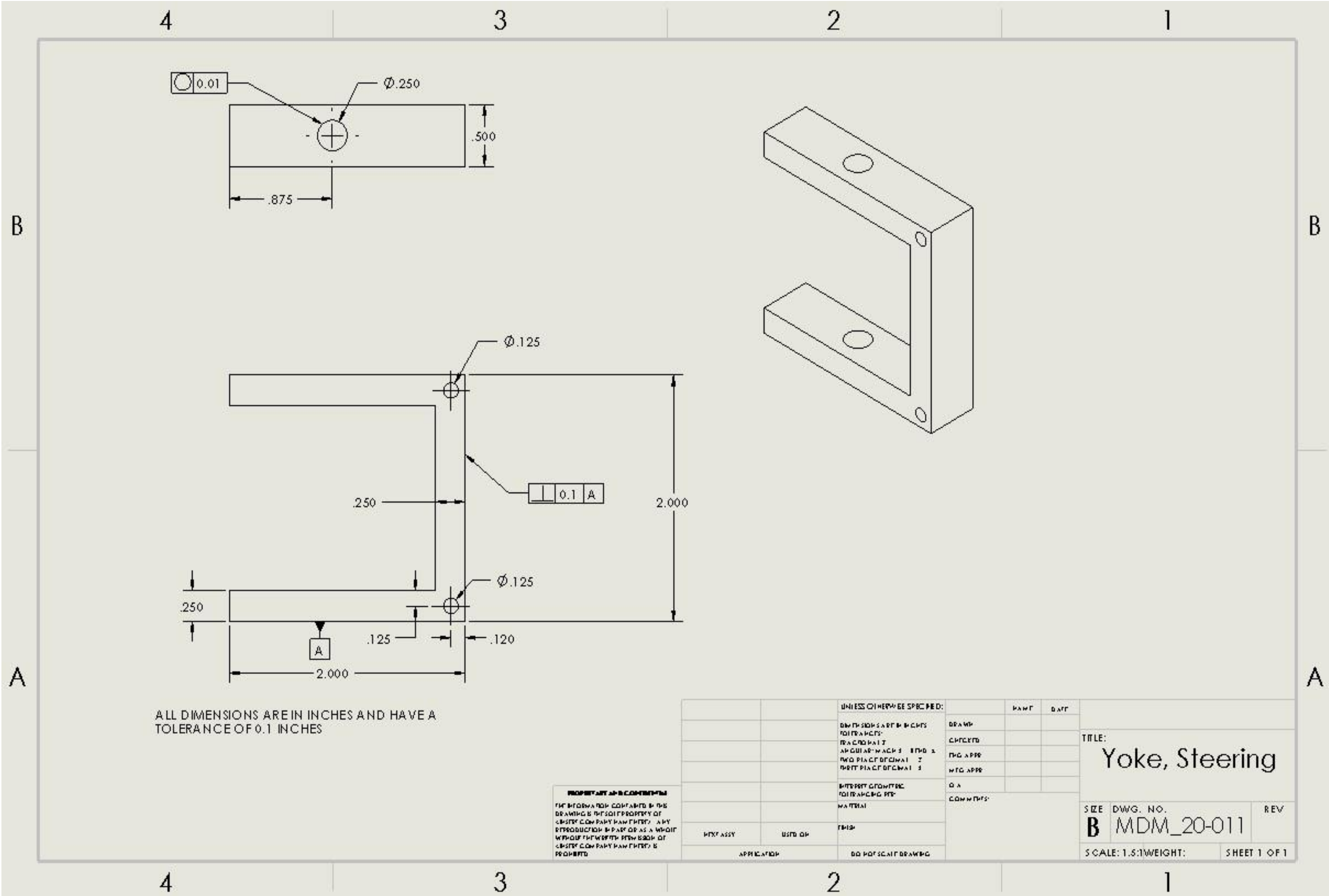
Appendix B-22 – Support-Driveshaft



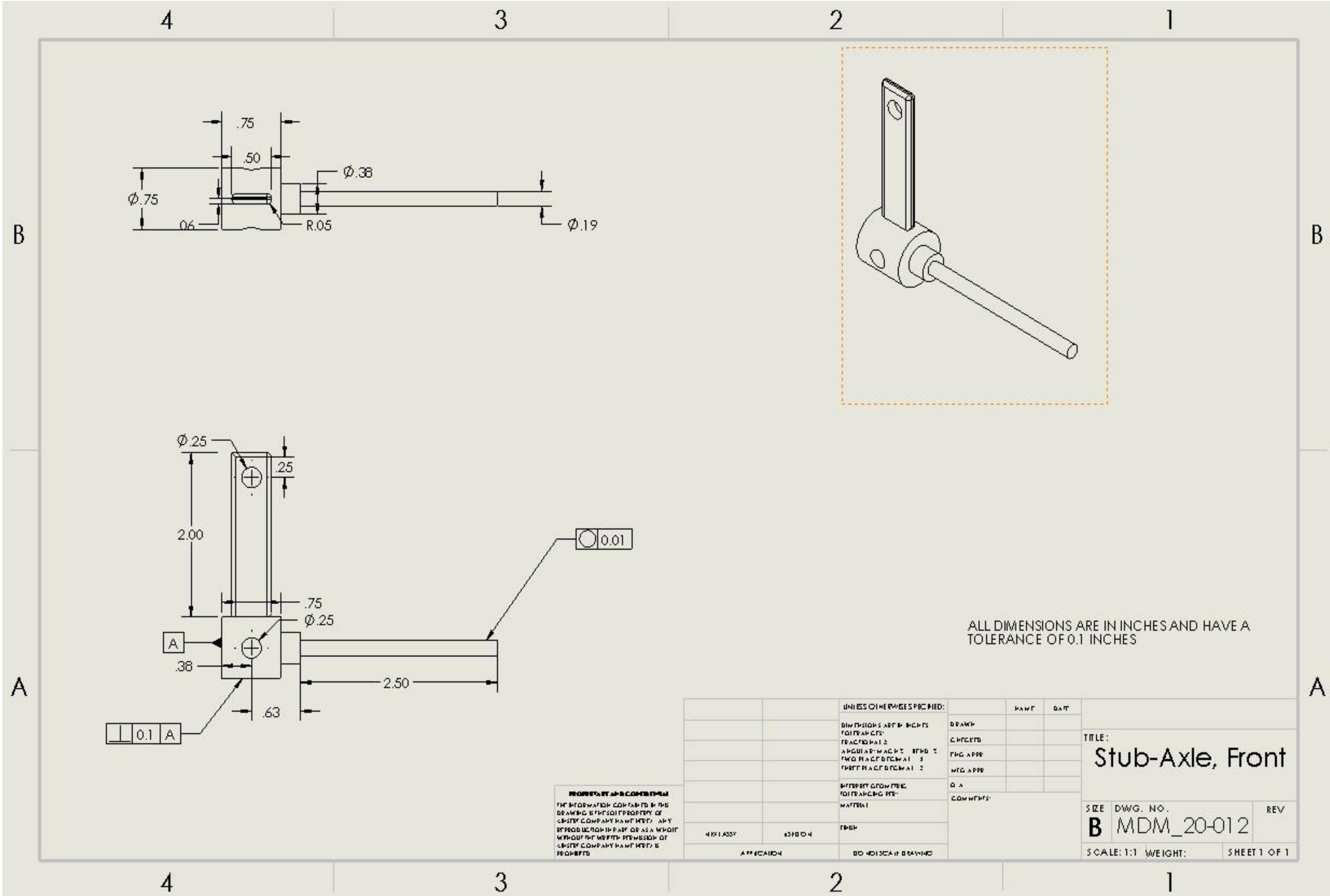
Appendix B-23 – Support, Axle-Rear



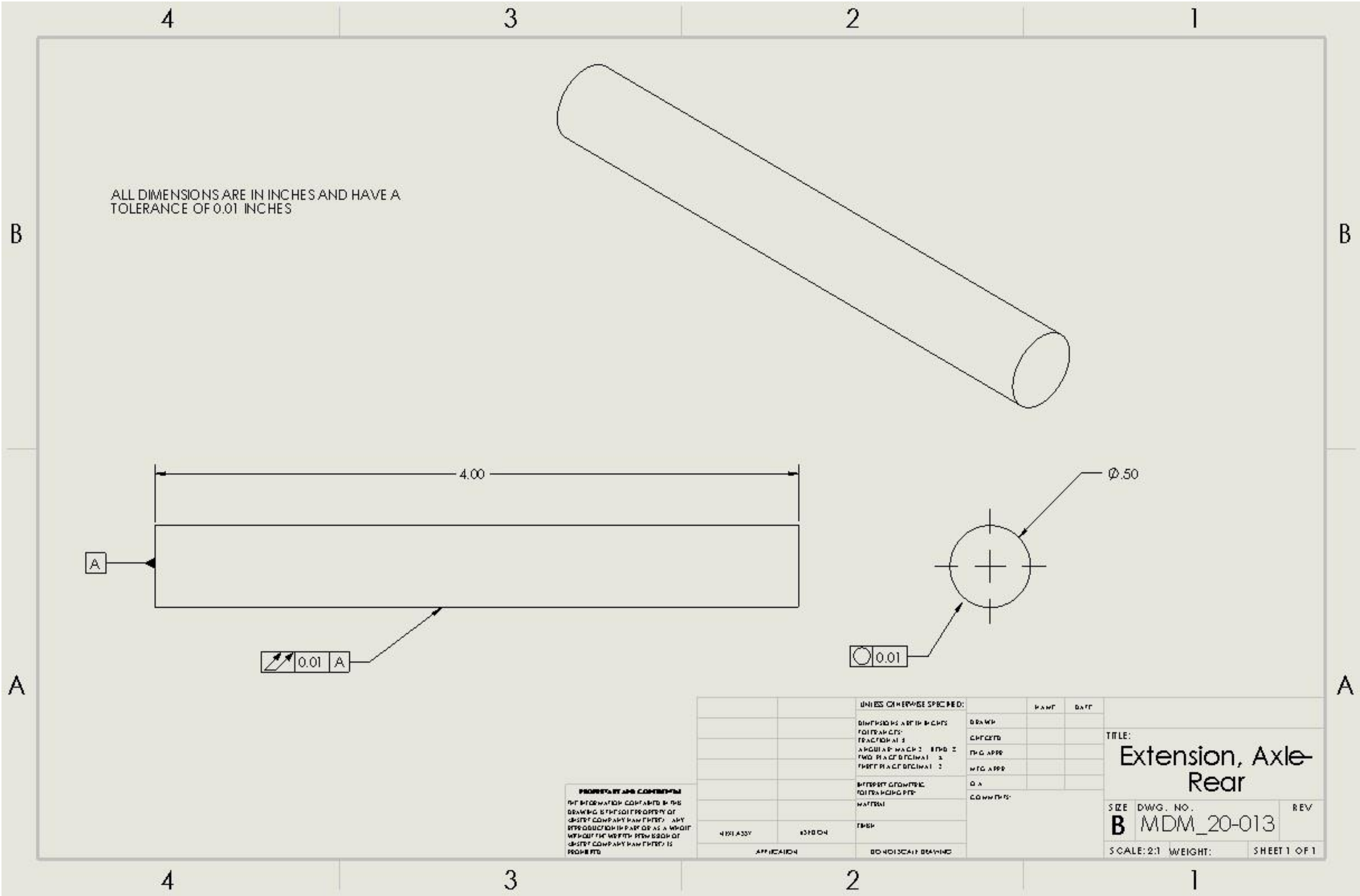
Appendix B-24 – Mount-Servo



Appendix B-25 – Yoke-Steering



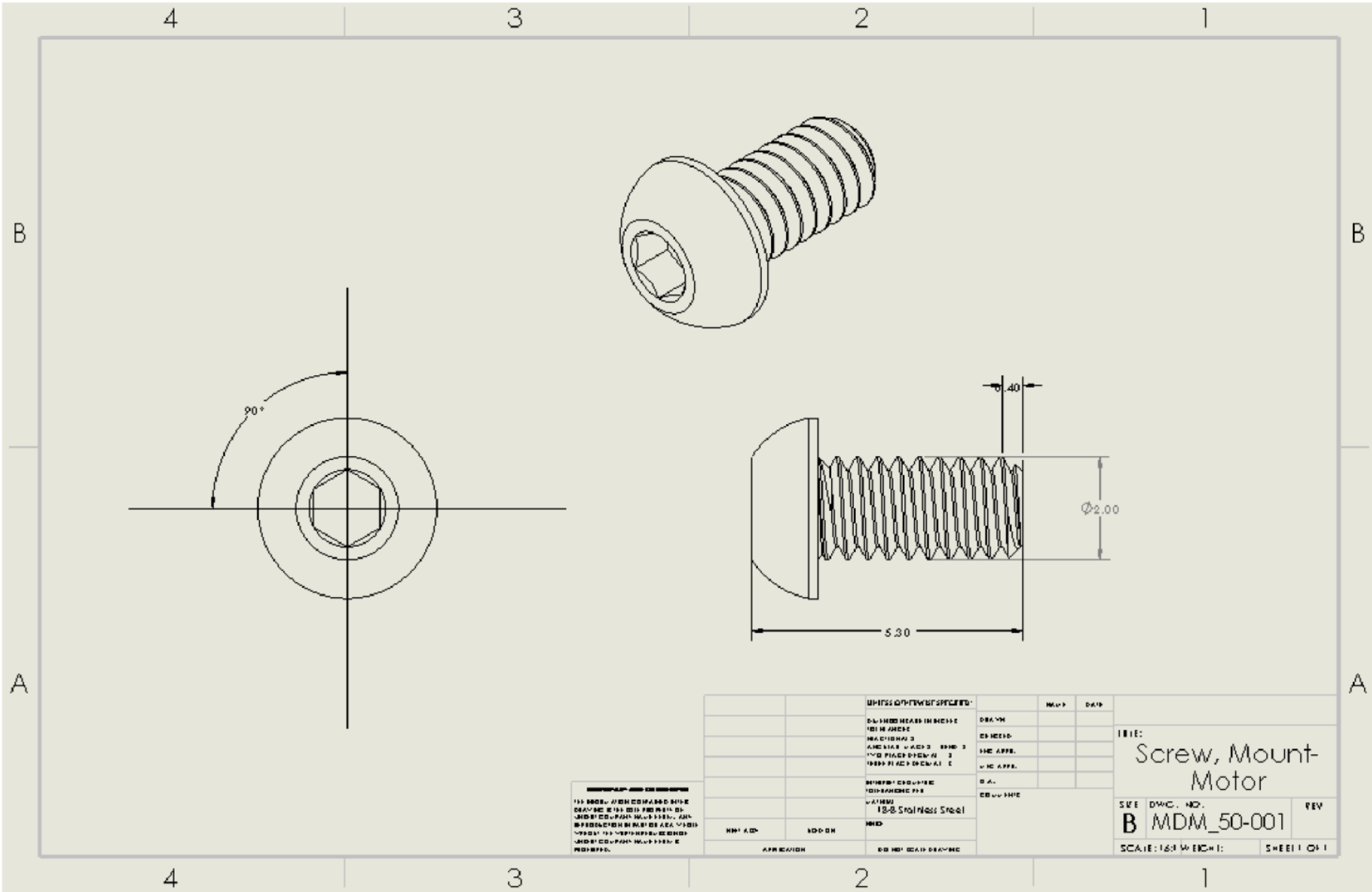
Appendix B-26 – Stub-Axle, Front



Appendix B-27 –

Extension, Axle-Rear

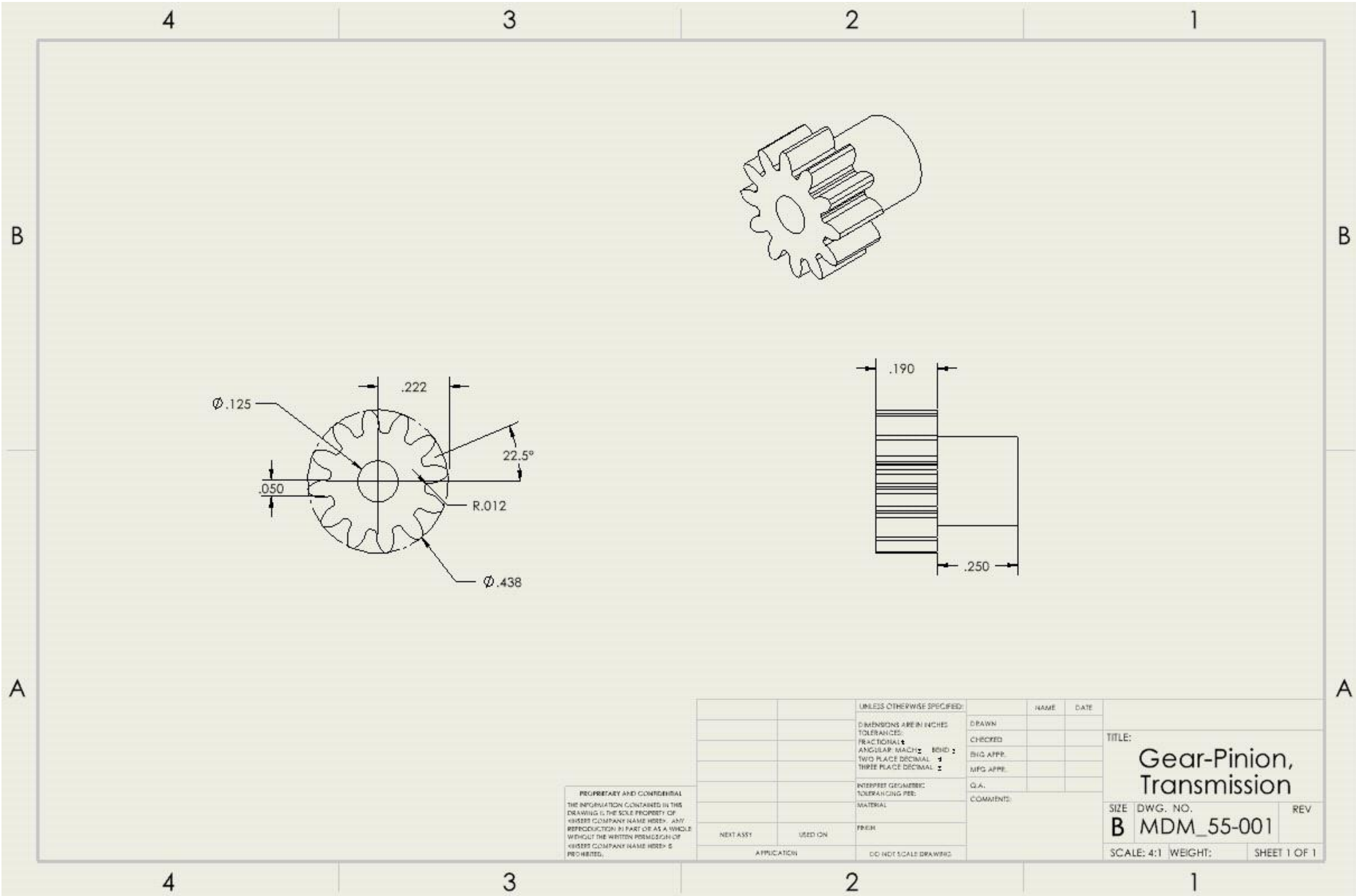
Appendix B-28 –



Appendix B-29 –

Screw, Mount-Motor

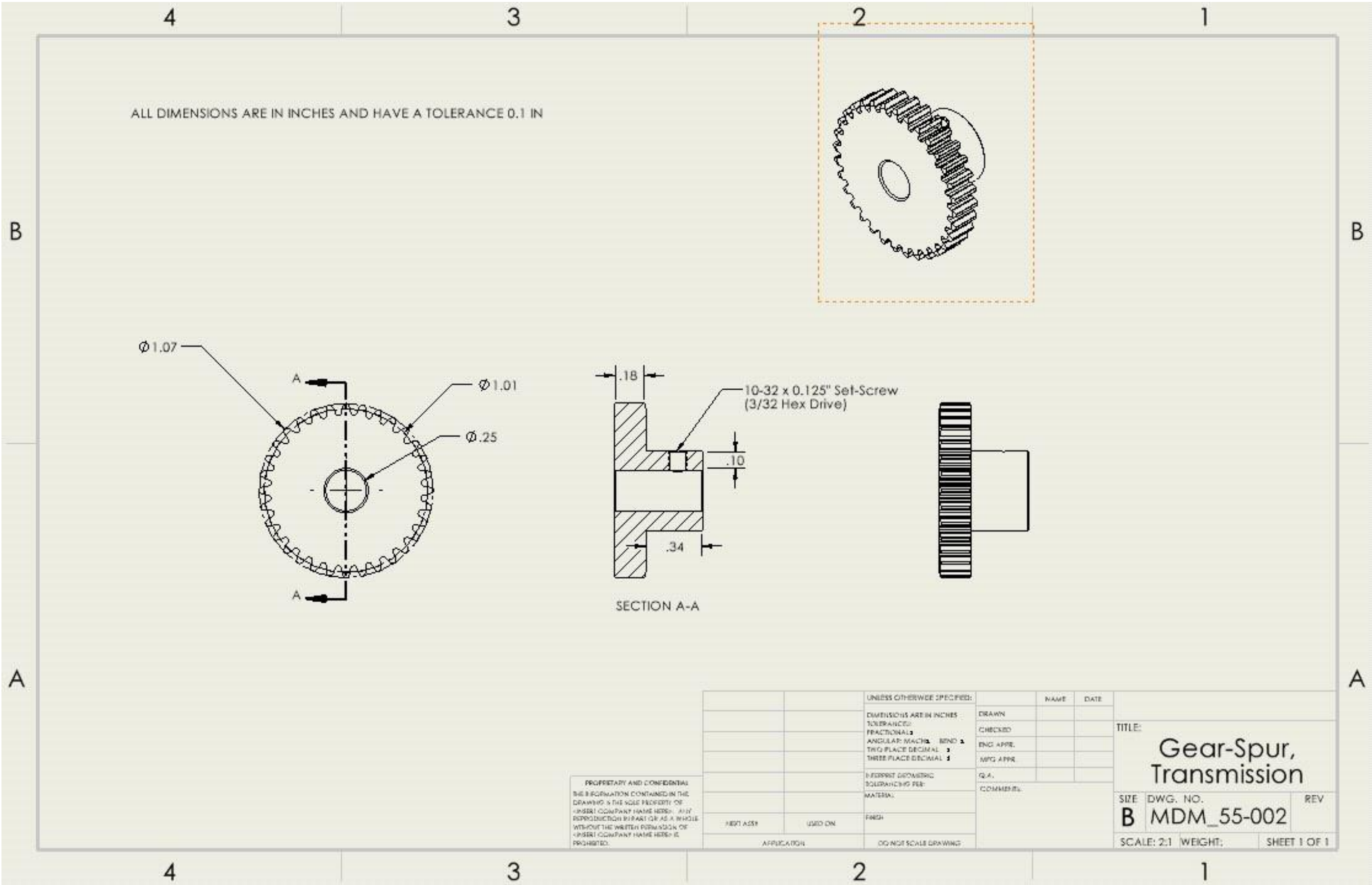
Appendix B-30 –



Appendix B-31 –

Gear-Pinion, Transmission

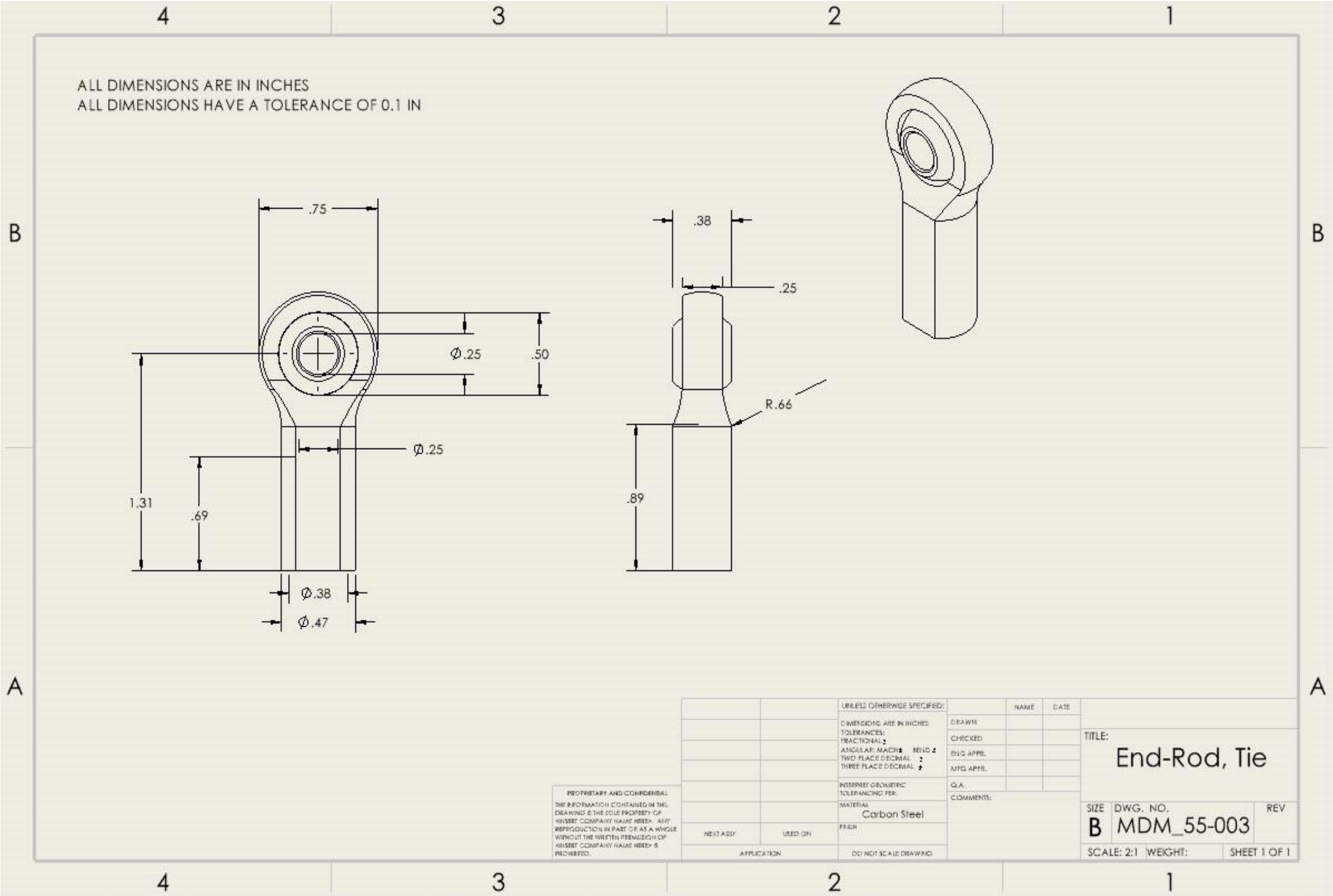
Appendix B-32 –



Appendix B-33 –

Gear-Spur, Transmission

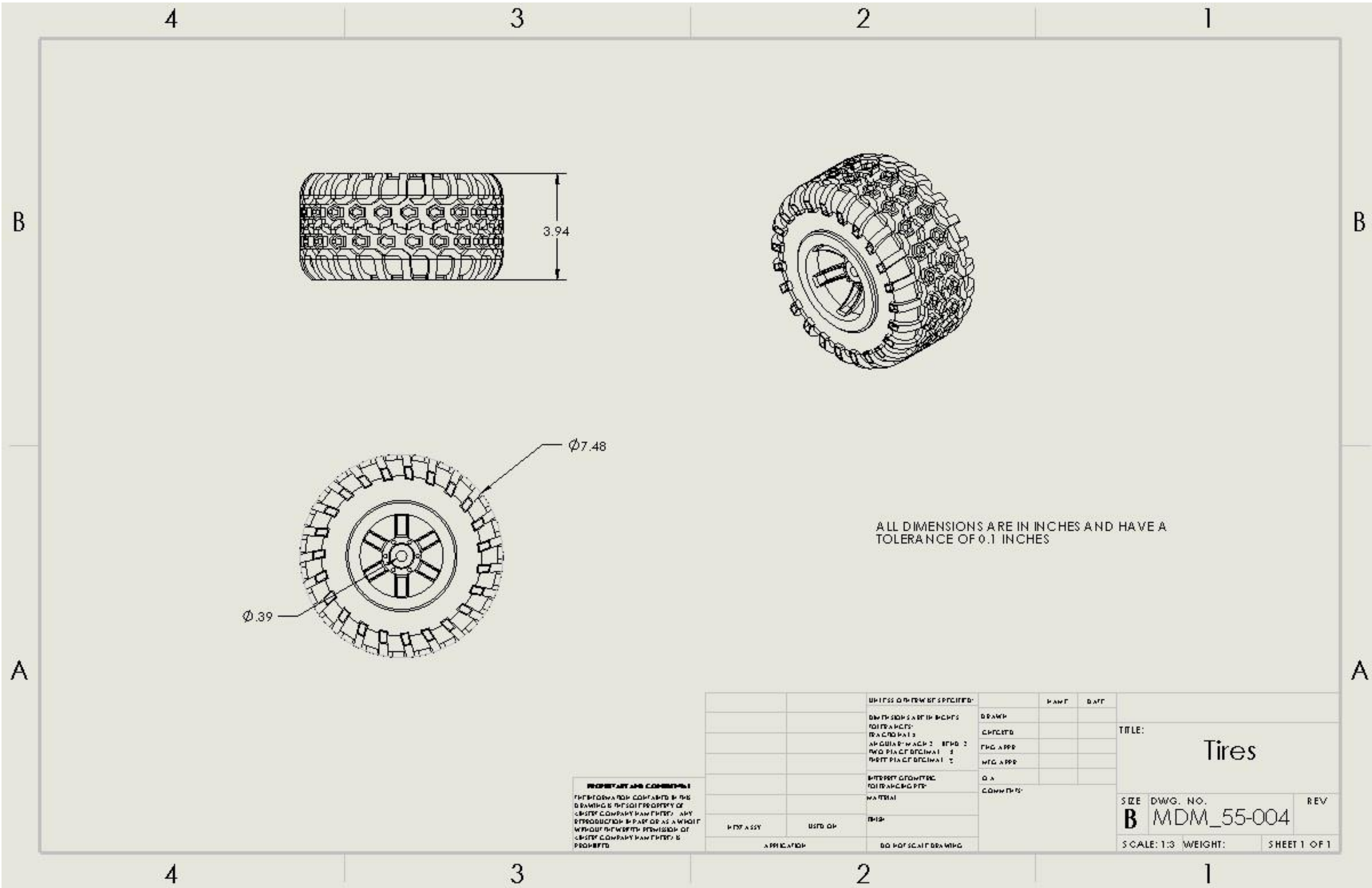
Appendix B-34 –



Appendix B-35 –

End-Rod, Tie

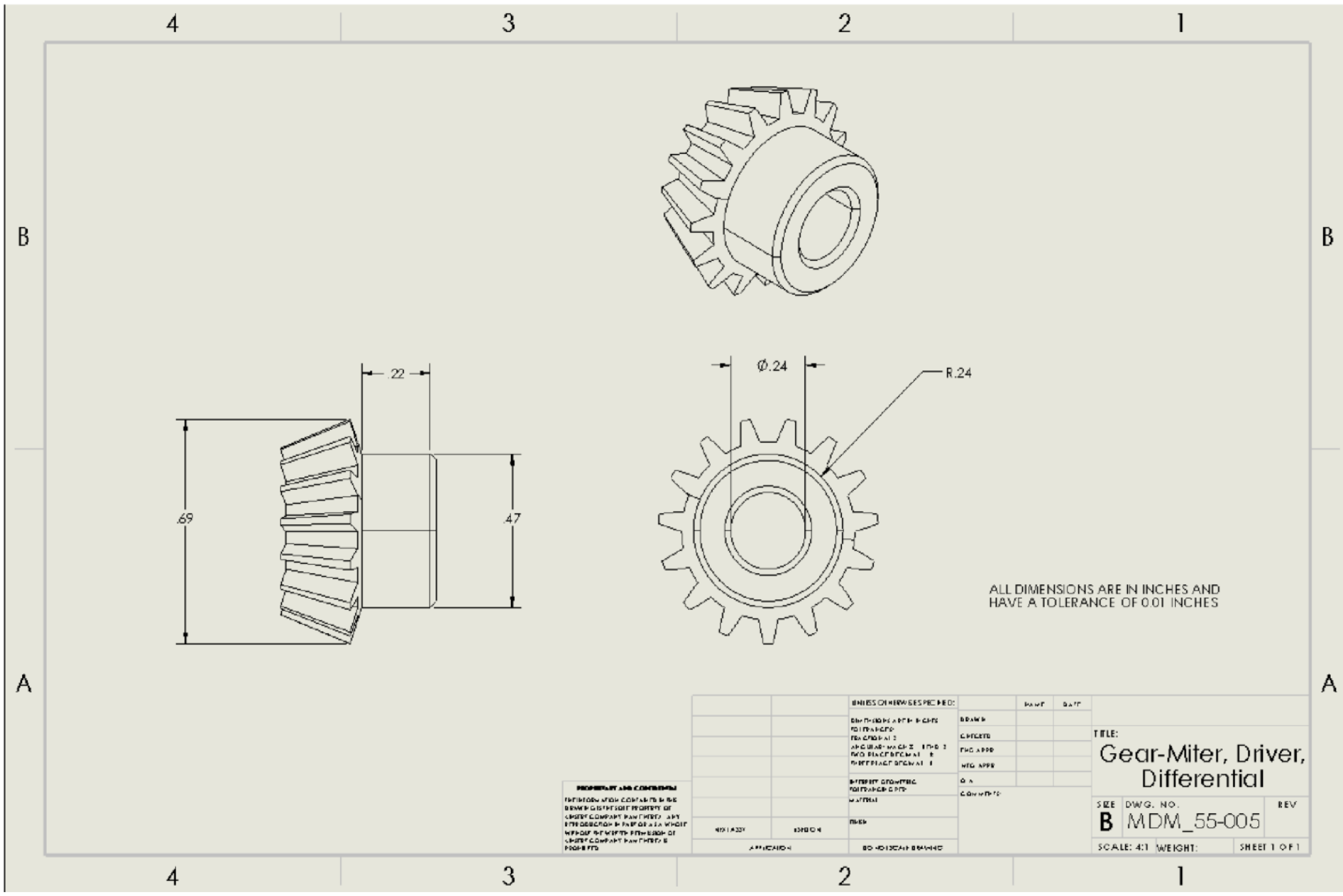
Appendix B-36 –



Appendix B-37 –

Tires

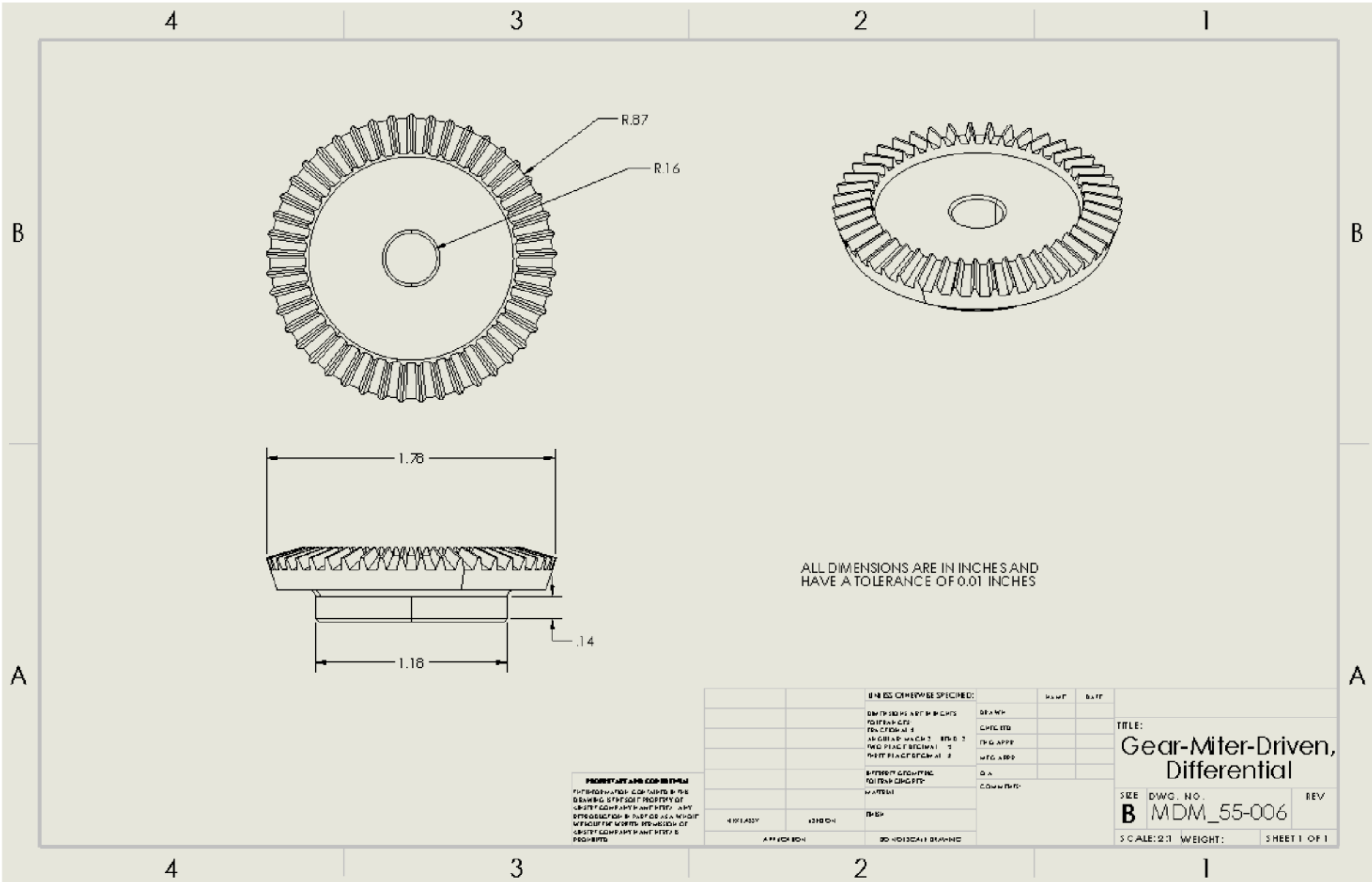
Appendix B-38 –



Appendix B-39 –

Gear-Miter-Driver, Differential

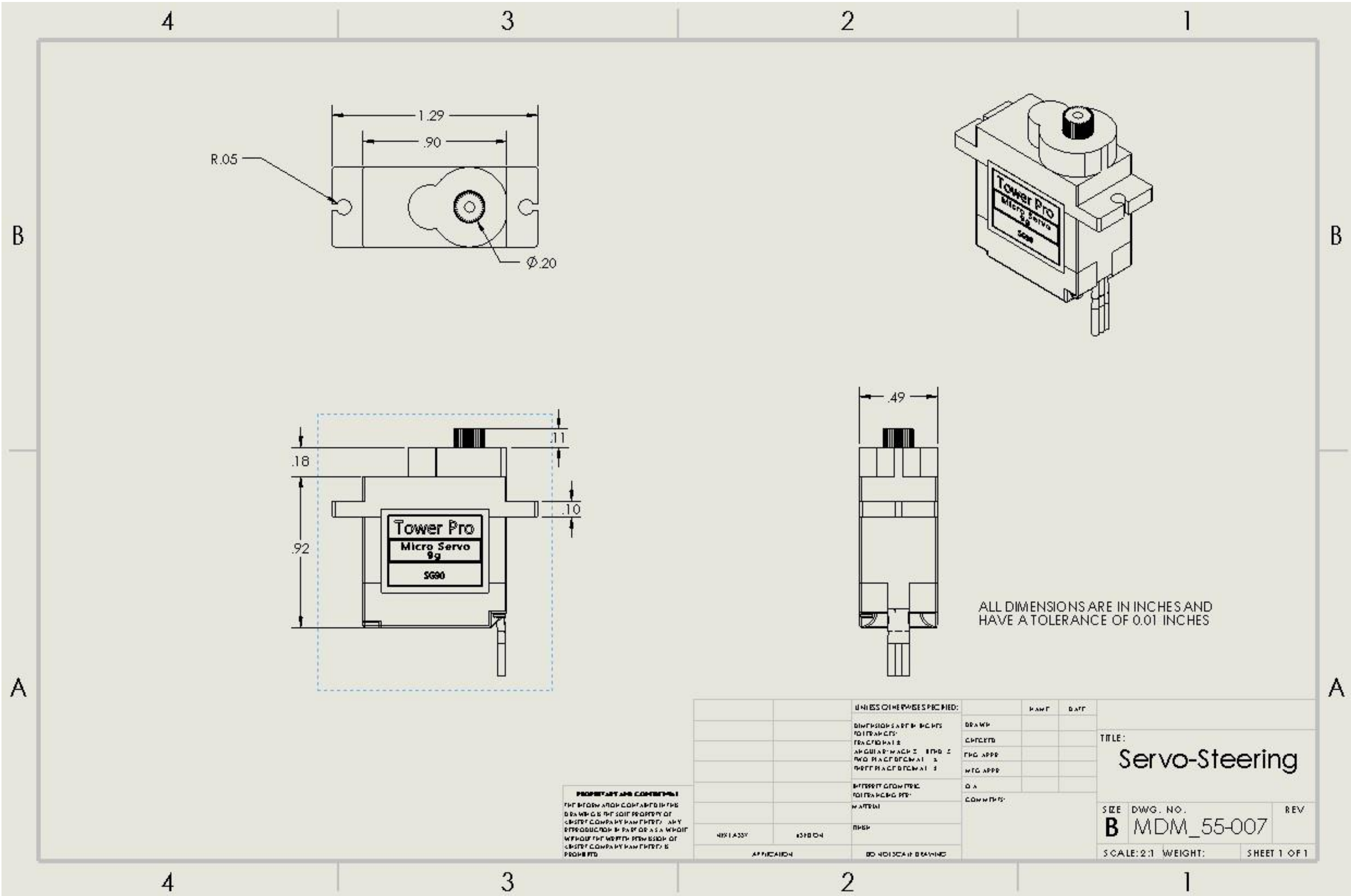
Appendix B-40 –



Appendix B-41 –

Gear-Miter-Driven, Differential

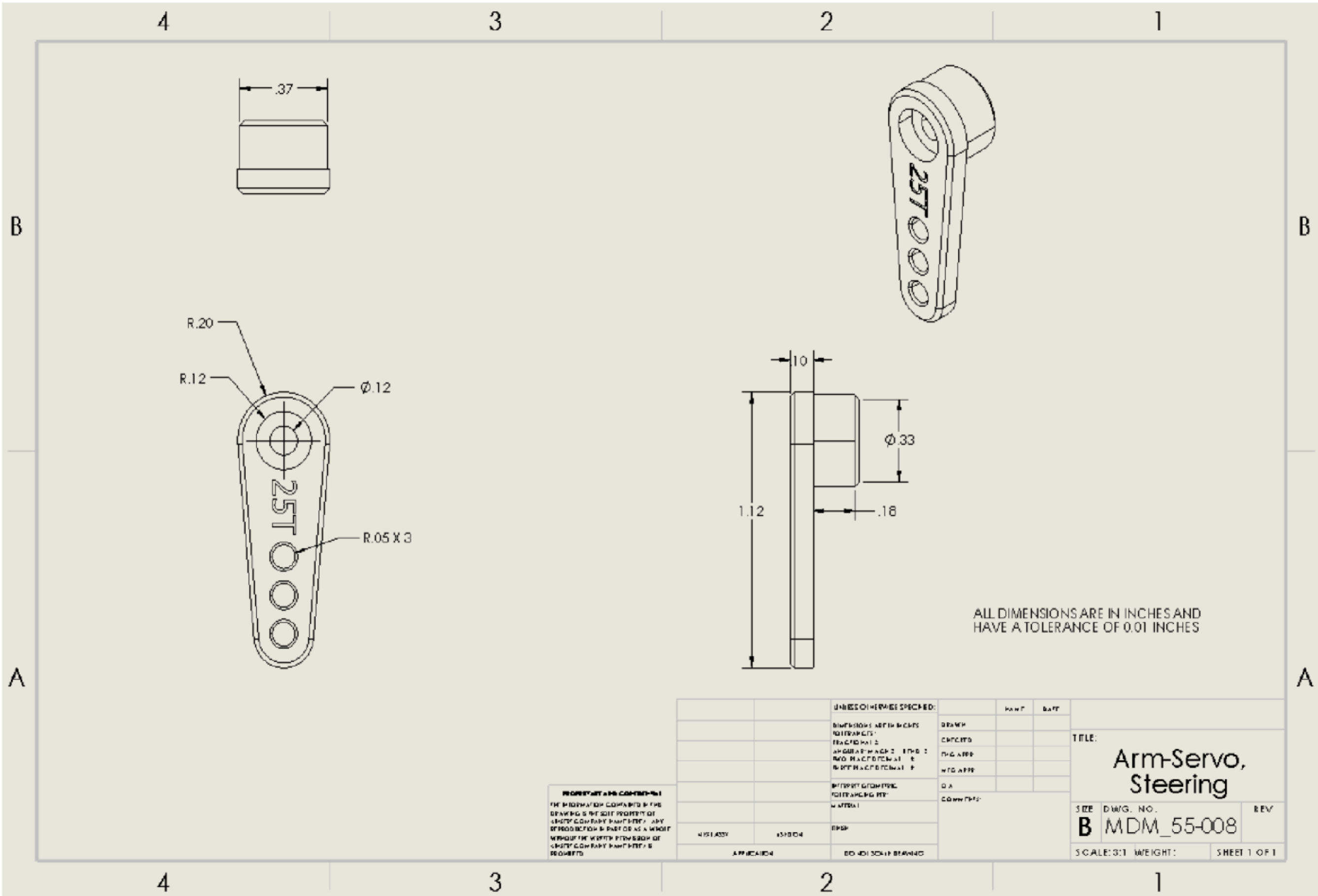
Appendix B-42 –



Appendix B-43 –

Servo-Steering

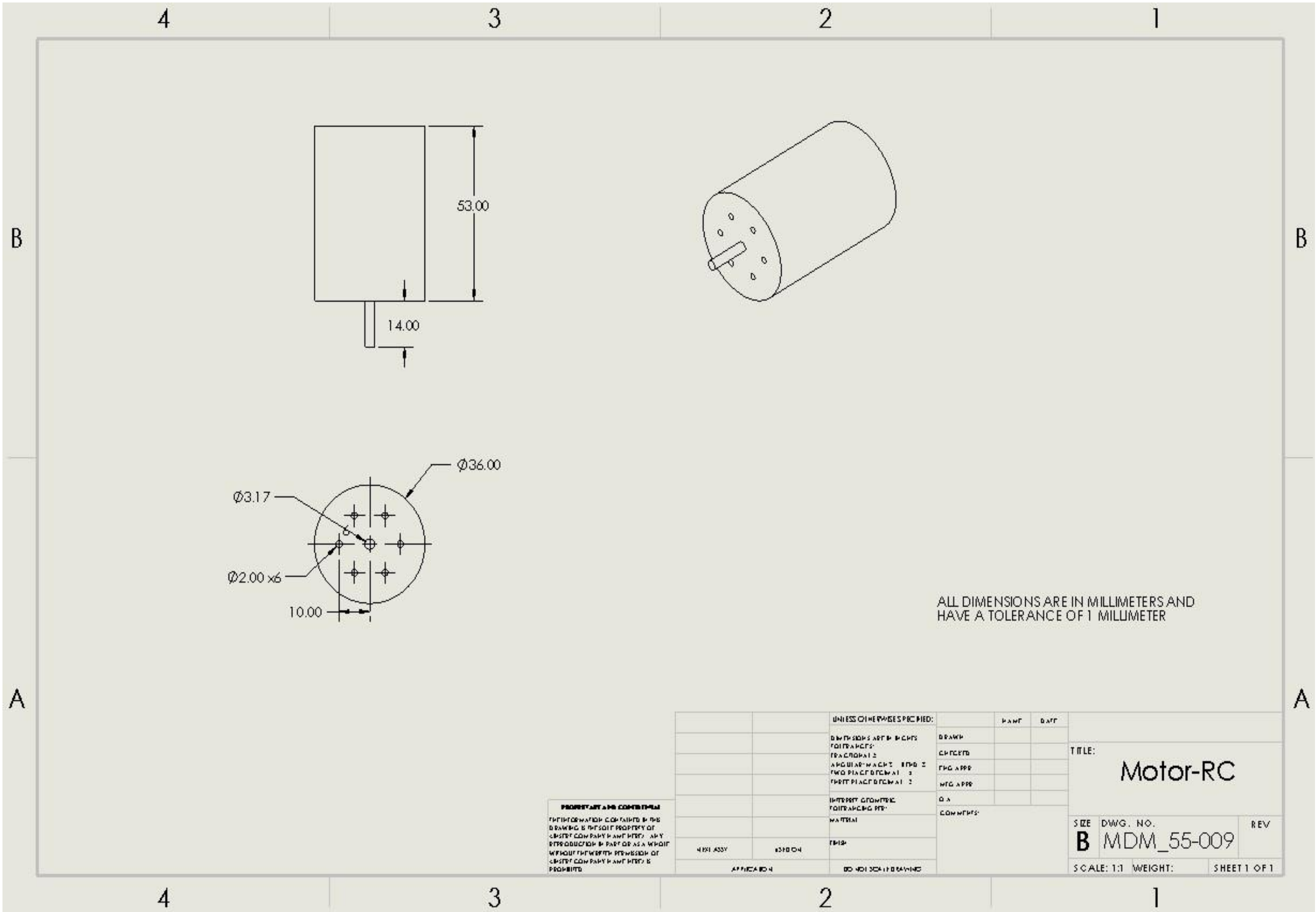
Appendix B-44 –



Appendix B-45 –

Arm-Servo, Steering

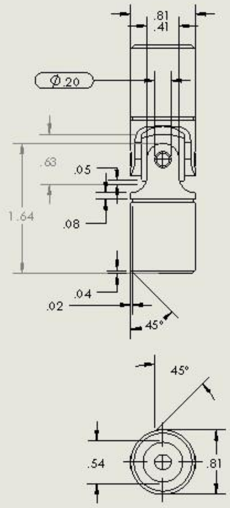
Appendix B-46 –

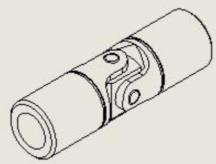


Appendix B-47 –

Motor-RC

Appendix B-48 –





ALL DIMENSIONS ARE IN INCHES AND
HAVE A TOLERANCE OF 0.01 INCHES

UNLESS OTHERWISE SPECIFIED:

MATERIAL: Zinc

NEXT ASSY | USED ON | APPLICATION | DO NOT SCALE DRAWING

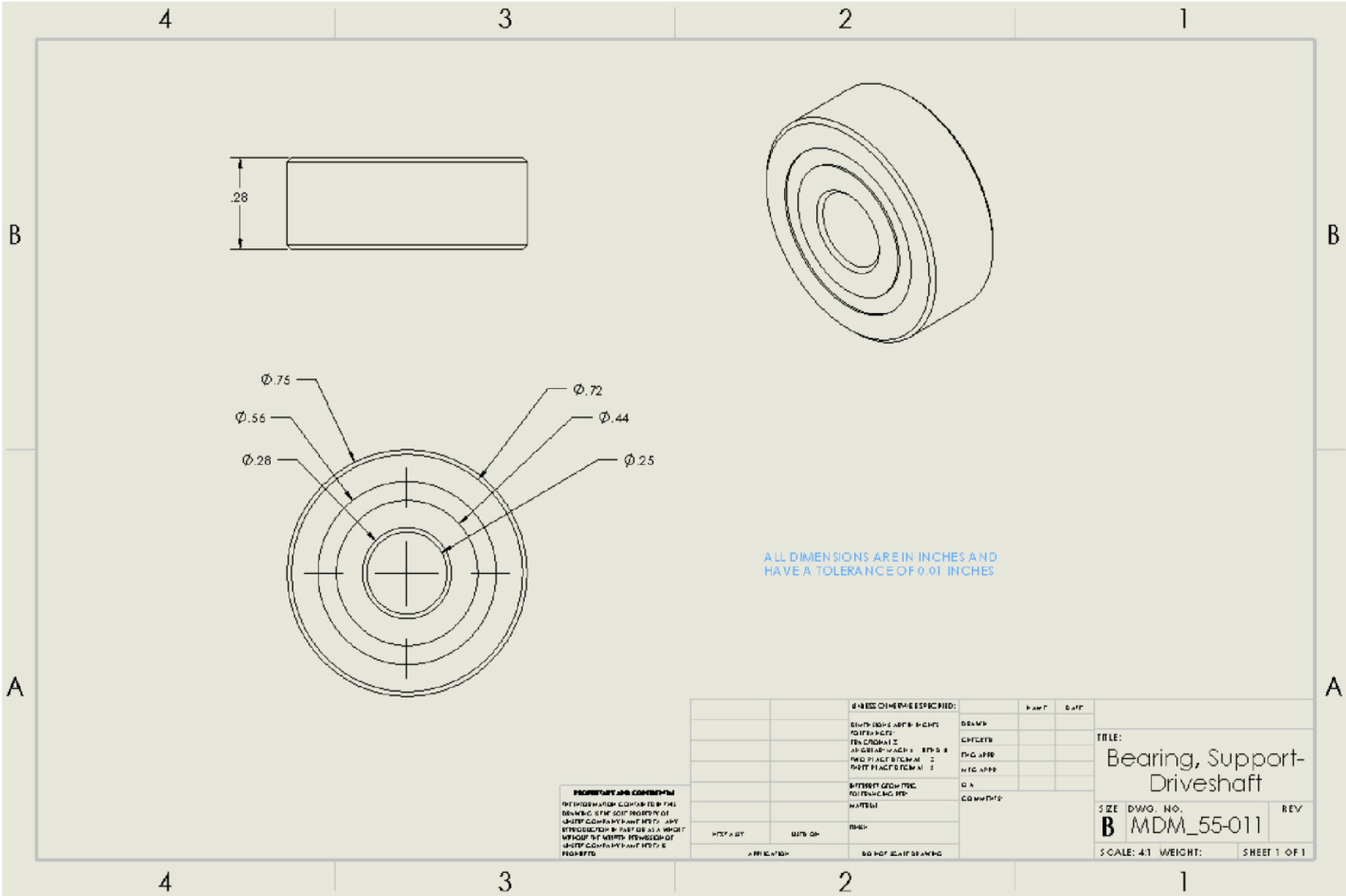
DRAWN | CHECKED | ENG APPR | MFG APPR | Q.A. | COMMENTS:

TITLE: Joint-U, Axle-Rear

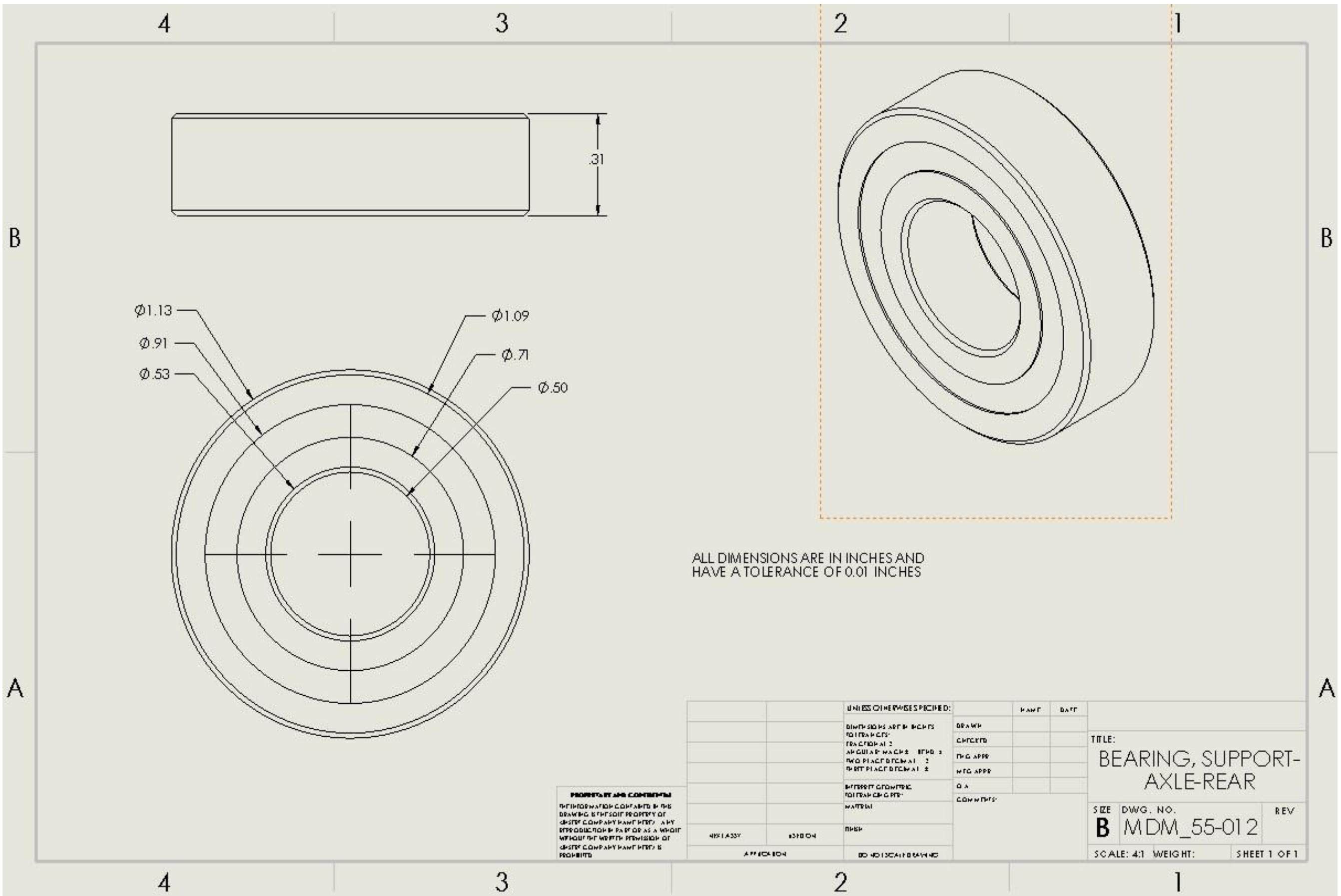
SIZE: B | DWG. NO. MDM_55-010 | REV

SCALE: 1:1 | WEIGHT: | SHEET 1 OF 1

Appendix B-38 – Joint-U, Axle-Rear



Appendix B-39 – Bearing, Support-Driveshaft



Appendix B-40 – Bearing, Support-Axle-Rear

APPENDIX C – Parts List and Costs

Table C-1: Parts list and cost

Part Number	Qty	Part Description	Source	Cost	Disposition
20-001	1	6061 Aluminum Chassis	Onlinemetals.com	$20	Needs ordered
20-002	4	6061 Aluminum pin	Onlinemetals.com	$20	Needs ordered
20-003	2	ABS Plastic Shock mount	CWU	50C/hr	Needs ordered
20-004	4	ABS plastic A-arm	CWU	50C/hr	Needs ordered
55-001	20	¼ in screws	Home Depot	20C/screw	Needs Ordered

Table C-2: Partners Part list and cost

Part Number	Qty	Part Description	Source	Cost	Disposition
MDM_20-001	1	Motor Mount	Onlinemetals.com	$12.16	Shipped
MDM_20-002	1	Driveshaft	Onlinemetals.com	$4.45	Shipped
MDM_20-003	1	Rear Axle	Onlinemetals.com	$9.05	Shipped
MDM_20-004	2	Tie Rods	Onlinemetals.com	A part of driveshaft cost	Shipping
MDM_20-005	4	Steering Pin	Onlinemetals.com	A part of driveshaft cost	Shipping

MDM_20-006	2	Steering Kingpin	Onlinemetals.com	A part of driveshaft cost	Shipping
MDM_20-007	4	Top Control Arm	CWU	$2.00	Needs to be picked up
MDM_20-008	2	Driveshaft Support	Onlinemetals.com	A part of Steering Yoke cost	Shipping
MDM_20-009	2	Rear Axle Support	Onlinemetals.com	A part of Steering Yoke cost	Shipping
MDM_20-010	1	Servo Mount	CWU	$4.00	Needs to be printed
MDM_20-011	2	Steering Yoke	Onlinemetals.com	$38.59	Shipping
MDM_20-012	2	Front Stub Axle	CWU	$4.00	Needs to be printed
MDM_20-013	2	Axle Extensions	Onlinemetals.com	A part of rear axle cost	Shipped
MDM_50-001	6	Motor Mount Screw	McMaster Carr	$8.33	Needs to be ordered

MDM_55-001	1	Transmission Pinion Gear	Axialracing.com	$6.99	Shipped
MDM_55-002	1	Transmission Spur Gear	us.misumi-ec.com	$39.93	Shipped
MDM_55-003	12	Tie Rod Ends	McMaster Carr	$60.36	Shipping
MDM_55-004	4	Tires	Hand me downs	Free	Received

MDM_55-005	1	Differential Driver Miter Gear	us.misumi-ec.com	$17.60	Shipped
MDM_55-006	1	Differential Driven Miter Gear	us.misumi-ec.com	$36.27	Shipping
MDM_55-007	1	Steering Servo	Amazon.com	$26.65	Shipped
MDM_55-008	1	Steering Servo Arm	Amazon.com	Came with servo	Shipped
MDM_55-009	1	RC Motor	AMainHobbies.com	$104.99	Shipping
MDM_55-010	2	Rear Axle U-Joint	McMaster Carr	$40.61	Needs to be ordered
MDM_55-011	2	Driveshaft Support Bearing	McMaster Carr	$29.12	Shipping
MDM_55-012	2	Rear Axle Support Bearing	McMaster Carr	$32.04	Shipping
Parts				$477.14	
Shipping				$83.15	
Total=	61			$560.29	

APPENDIX D – Budget

Table D-1: Project Budget

Item	Qty	Description	Cost
Purchased Parts	5	Parts that will be purchased	$250
Manufactured Parts	8	Parts that will be printed and also built in the machine chop	$100
Labor Cost	400	Cost of the labor of the student	$8,000
		Total Budget=	$8,350

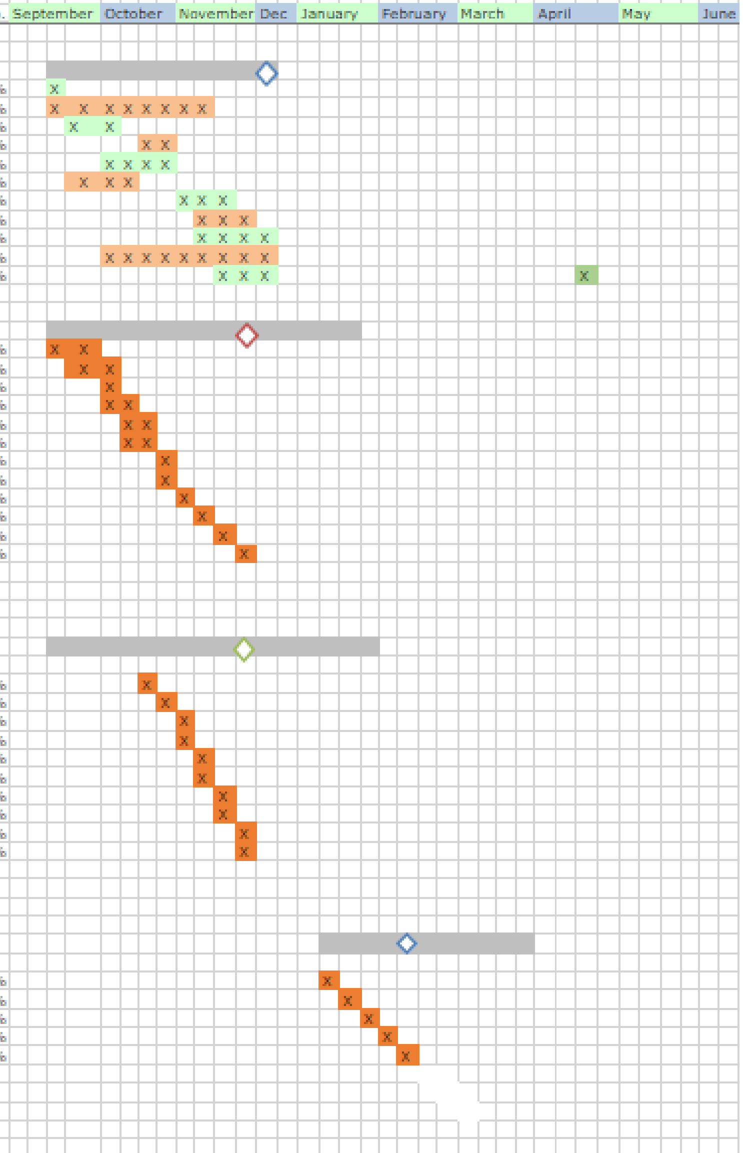
APPENDIX E – Schedule

EXAMPLE SCHEDULE FOR SENIOR PROJECT:

PROJE RC Baja

Principal Investigator.:_______________ Matthew Hart

TASK: ID	Description	Duration Est. (hrs)	Actua (hrs)	%Comp.
1	PROPOSAL/REPORT WRITING			
1a	Intro	1	1	100%
1b	Analysis	2	2	100%
1c	Methods	3	3	100%
1e	Testing	3	2	100%
1f	Budget	1	1	100%
1g	Schedule	3	3	100%
1h	Project Management	2	1	100%
1i	Discussion	3	3	100%
1j	Conclusion	2	1	100%
1k	Drawings	8	10	100%
1l	Appendix	2	2	100%
	subtotal:	30	29	
2	ANALYSIS			
2a	Suspension Analysis(Deflection)	1	1	100%
2b	Suspension Analysis(Stress)	2	1	100%
2c	Front Bumper Analysis	1	1	100%
2d	Chassis Minimum Thickness	1	1	100%
2e	Shocktower Angle Analysis	2	2	100%
2f	Shocktower Analysis	2	2	100%
2g	A-arm Pin Analysis	1	1	100%
2h	Screw Diameter For Mounting	1	1	100%
2i	Minimum Shock Tower Height	2	1	100%
2j	Minimum A-Arm Length	2	1	100%
2k	Shock tower Stress Analysis	1	1	100%
2l	Shock tower CSA	2	1	100%
		18	10	
	subtotal:			
3				
3a	DOCUMENTATION			
3b	Chassis	1	1	100%
3c	Pin-Chassis	1	1	100%
3d	Tower-Shock	1	1	100%
3e	A-arm	1	1	100%
3f	Bumper-Front	1	1	100%
3g	Shock-Suspension	1	1	100%
3h	Bolt- Mounting	1	1	100%
3i	Nut-Hex-2b-unc-8x32	1	1	100%
3j	Assembly-sub-tower-shock,shock	1	1	100%
3k	Assembly-sub-plate-chassis,A-arm	1	1	100%
3l				
3m				
		10	10	
	subtotal:			
4				
4a	PART CONSTRUCTION			
4b	Chassis	2	1	100%
4c	Pin, Chassis	2	1	100%
4d	Tower, Shock	2	1	100%
4e	A-arm	2	1	100%
4f	Bumper, Front	2	1	100%
4g				
4h				
4i				
		10	5	
	subtotal:			



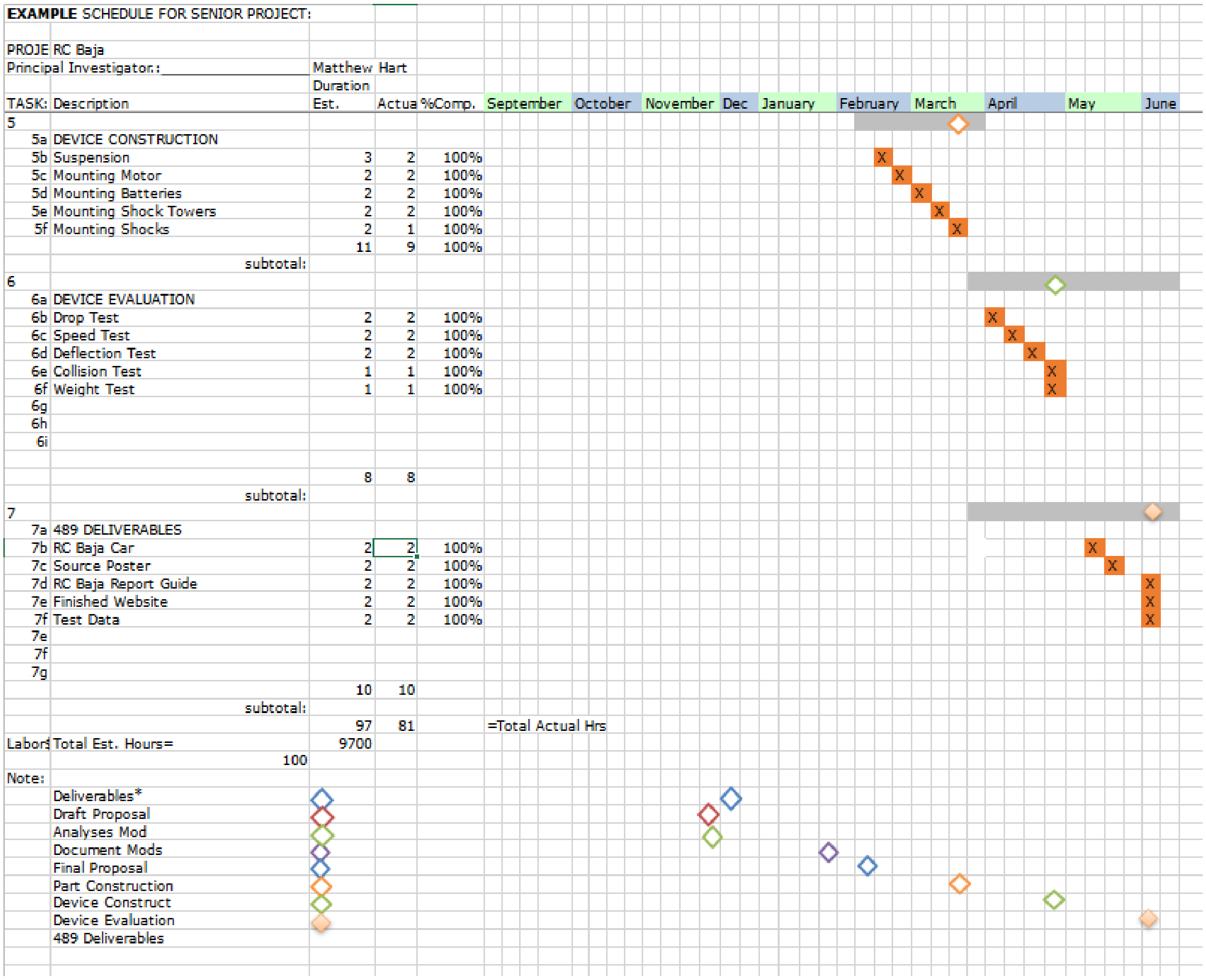


Figure E1. Project Gantt Chart.

APPENDIX F – Expertise and Resources

Criterion	Weight 1 to 3	Best Possible 3	Design # 1	Score x Wt	Design # 2	Score x Wt	Design # 2	Score x Wt
Cost	2	6	2	4	2	4	2	4
Weight	3	9	2	6	3	9	3	9
Prediction precision	3	9	2	6	2	6	3	9
Confidence in failure location	2	6	2	4	2	4	2	4
Prismatic vs non prismatic	2	6	2	4	3	6	3	6
Manufacturability	3	9	2	6	3	9	3	9
Total	15	45		30		38		41
NORMALIZE THE DATA (muliply by fraction, N)		2.22		66.67		84.44		91.11 Percent
								80.74 Average
								12.64 Std Dev.

Decide if Bias is Good or Bad

Good Bias: Standard Deviation is two or more digits — Good? Then you're done.

Poor Bias: Standard Deviation is one or less digits — Poor? Then change something!!!

You can change the criteria, weighting, or the projects themselves…

Weighting/Scoring Scale

1 Worst (too costly, low confidence, too big, etc.)

2 Median Values, or Unsure of actual value

3 Best (Low Cost, high confidence, etc.)

Criterion

Cost: More mass is more cost

Weight: Light weight scores better on the success equation

Prediction precision: Are the engineers calculations sufficient and correct?

Confidence -failure loc: Confidence level in the indicated failure location

Prismatic vs non prismatic: Is the shape prismatic (retangle, square, etc) or is it irregullarly shaped to meet the engineering needs

Manufacturability: Is it simple to produce? Are there multiple process for a single component?

Comments:

Comment about why you scored each design as you did.

"

Criterion	Weight 1 to 3	Best Possible 3	Design # 3-d Printed	Score x Wt	Design # Machined	Score x Wt	Design # Bought	Score x Wt
Cost	3	9	3	9	2	6	3	9
Prediction precision	1	3	2	2	1	1	1	1
Manufacturability	2	6	2	4	1	2	1	2
Total	6	18		15		9		12
NORMALIZE THE DATA (muliply by fraction, N)		5.56		83.33		50.00		66.67 Percent
								66.67 Average
								16.67 Std Dev.

Decide if Bias is Good or Bad

Good Bias: Standard Deviation is two or more digits — Good? Then you're done.

Poor Bias: Standard Deviation is one or less digits — Poor? Then change something!!!

You can change the criteria, weighting, or the projects themselves…

Weighting/Scoring Scale

1 Worst (too costly, low confidence, too big, etc.)

2 Median Values, or Unsure of actual value

3 Best (Low Cost, high confidence, etc.)

Criterion

Cost: More mass is more cost

Weight: Light weight scores better on the success equation

Prediction precision: Are the engineers calculations sufficient and correct?

Confidence -failure loc: Confidence level in the indicated failure location

Prismatic vs non prismatic: Is the shape prismatic (retangle, square, etc) or is it irregullarly shaped to meet the engineering needs

Manufacturability: Is it simple to produce? Are there multiple process for a single component?

Comments:

For the Shock Tower outsourcing looks like it will be the best option for the cost needs to be low and the presicion of demensions and the manufactorablitity needs to be good since the student

Appendix F-1- Tower-Shock

Criterion	Weight 1 to 3	Best Possible 3	Design # ABS Plastic	Score x Wt	Design # 6061 Alum.	Score x Wt	Design # A-36 steel	Score x Wt
Cost	3	9	2	6	3	9	3	9
Weight	3	9	1	3	3	9	2	6
Prediction precision	2	6	2	4	3	6	2	4
Manufacturability	1	3	3	3	3	3	2	2
Total	9	27		16		27		21

NORMALIZE THE DATA (muliply by fraction, N) 3.70 | 59.26 | 100.00 | 77.78 Percent

79.01 Average

20.40 Std Dev.

Decide if Bias is Good or Bad

Good Bias: Standard Deviation is two or more digits — Good? Then you're done.

Poor Bias: Standard Deviation is one or less digits — Poor? Then change something!!!

You can change the criteria, weighting, or the projects themselves...

Weighting/Scoring Scale

1 Worst (too costly, low confidence, too big, etc.)

2 Median Values, or Unsure of actual value

3 Best (Low Cost, high confidence, etc.)

Criterion

Cost	More mass is more cost
Weight	Light weight scores better on the success equation
Prediction precision	Are the engineers calculations sufficient and correct?
Confidence -failure loc	Confidence level in the indicated failure location
Prismatic vs non prismatic	Is the shape prismatic (retangle, square, etc) or is it irregullarly shaped to meet the engineering needs
Manufacturability	Is it simple to produce? Are there multiple process for a single component?

Comments:

For the chassis plate 6061 Aluminum will be the best all around option for the RC Baja because its is sturdy and can be precise and can be manufactored easily the one thing wrong is

Prediction precision	1	3	2	2	1	1	1	1
Manufacturability	2	6	2	4	1	2	1	2
Total	6	18		15		9		12

NORMALIZE THE DATA (muliply by fraction, N) 5.56 | 83.33 | 50.00 | 66.67 Percent

66.67 Average

16.67 Std Dev.

Decide if Bias is Good or Bad

Good Bias: Standard Deviation is two or more digits — Good? Then you're done.

Poor Bias: Standard Deviation is one or less digits — Poor? Then change something!!!

You can change the criteria, weighting, or the projects themselves...

Weighting/Scoring Scale

1 Worst (too costly, low confidence, too big, etc.)

2 Median Values, or Unsure of actual value

3 Best (Low Cost, high confidence, etc.)

Criterion

Cost	More mass is more cost
Weight	Light weight scores better on the success equation
Prediction precision	Are the engineers calculations sufficient and correct?
Confidence -failure loc	Confidence level in the indicated failure location
Prismatic vs non prismatic	Is the shape prismatic (retangle, square, etc) or is it irregullarly shaped to meet the engineering needs
Manufacturability	Is it simple to produce? Are there multiple process for a single component?

Comments:

For the A-Arms outsourcing looks like it will be the best option for the cost needs to be low and the presicion of demensions and the manufactorablitity needs to be good since the student needs 4 of t

Appendix F-2- A-Arm Appendix F-3- Material

APPENDIX G – Testing Report

Appendix G1 (Collision Test)

Introduction: For this test the student will be testing the rigidity of the RC car and all the parts on the car, when the car is running into a wall at top speed. The car will be able to withstand the impact when running into the wall.

Method/Approach: This test will be done outside the fluke lab of Hogue on the campus of Central Washington University the student will not need any extra resources to complete the test. This test will not cost the students any money unless it breaks parts on the RC car. The results will be given in a chart with how many parts break in each of the three test that will be conducted.

Test Procedure: The risks that are involved with this test is when running the car into the wall a piece off the car can come off and hit the student so wear safety glasses when completing this test. For this test the student will first grab the car, the remote speed controller and a tape measure and walk outside the fluke lab. second, the student will need to measure out 20 m from the wall outside the fluke lab. Third, set the car on the ground at the 20 m mark. Finally, run the car at top speed not the wall red these steps for 2 more trials to get the most efficient data.

Deliverables: The results from the test are that none of the parts on the RC car broke the car was very sound and was engineered well. This was a really good test to run on the car to see how the parts were going to hold up when ran into a wall. The student thinks that more tests should ran on the car to make sure all is well.

Appendix G1.1 – Procedure Checklist

- Charged the RC car battery
- Put charged batteries in the controller
- Made sure Hogue had painter’s tape
- Got a camera from the MEC
- Made sure the weather was fine to do the test

Appendix G1.2 – Data Forms

Number of Trials	Number of parts broken	Speed of impact
Trial 1		
Trial 2		
Trial 3		

Appendix G1.3 – Raw Data

Number of Trials	Number of Parts Broken	Speed of Impact
Trail 1	3	6.5
Trail 2	4	6.5
Trial 3	0	6.5

Appendix G1.4 – Evaluation Sheet

Appendix G1.5 – Schedule (Testing)

Appendix G2 (Top Speed)

Introduction: For this test the student will be testing the top speed of the RC car. This test will show if all the suspension and chassis parts will work to the max potential when the car is traveling at the cars top speed.

Method/Approach: This test will be done out on the patio of the Hogue building on the Central Washington University campus the student will mark out 25 feet and start from one end and drive the car at top speed then the student will use the times and calculate the top speed of the car between those two points

Test Procedure: The risks that are involved with this test is when running the car into the wall a piece off the car can come off and hit the student so wear safety glasses when completing this test. For this test the student will first grab the car, the remote speed controller and a tape measure and walk outside the fluke lab. second, the student will need to measure out 20 m from the wall outside the fluke lab. Third, set the car on the ground at the 20 m mark. Finally, run the car at top speed not the wall red these steps for 2 more trials to get the most efficient data.

Deliverables: The results from the test are that none of the parts on the RC car broke the car was very sound and was engineered well. This was a really good test to run on the car to see how the parts were going to hold up when ran into a wall. The student thinks that more tests should ran on the car to make sure all is well.

Appendix G2.1 – Procedure Checklist

Appendix G2.2 – Data Forms

Trial Number	Time (sec)	Speed (ft/s)	Speed (MPH)
1			
2			
3			

Appendix G2.3 – Raw Data

Number of Trials	Time (Sec)	Speed (ft/s)	Speed (MPH)
1	0.63	11.1	7.57
2	0.74	9.46	6.46
3	0.80	8.75	5.96

Appendix G2.4 – Evaluation Sheet

Appendix G2.5 – Schedule (Testing)

Appendix G3 (Drop Test)

Introduction: For this test the student will be testing the rigidity of the RC car and all the parts on the car, when the car is running into a wall at top speed. The car will be able to withstand the impact when running into the wall.

Method/Approach: This test will be done outside the fluke lab of Hogue on the campus of Central Washington University the student will not need any extra resources to complete the test. This test will not cost the students any money unless it breaks parts on the RC car. The results will be given in a chart with how many parts break in each of the three test that will be conducted.

Test Procedure: The risks that are involved with this test is when running the car into the wall a piece off the car can come off and hit the student so wear safety glasses when completing this test. For this test the student will first grab the car, the remote speed controller and a tape measure and walk outside the fluke lab. second, the student will need to measure out 20 m from the wall outside the fluke lab. Third, set the car on the ground at the 20 m mark. Finally, run the car at top speed not the wall red these steps for 2 more trials to get the most efficient data.

Deliverables: The results from the test are that none of the parts on the RC car broke the car was very sound and was engineered well. This was a really good test to run on the car to see how the parts were going to hold up when ran into a wall. The student thinks that more tests should ran on the car to make sure all is well.

Appendix G3.1 – Procedure Checklist

Appendix G3.2 – Data Forms

Number of Trials	Before Drop Height (in)	After Drop Height (in)	Deflection (in)
1			
2			

3			

Appendix G3.3 – Raw Data

Number of Trials	Before Drop Height (in)	After Drop Height (in)	Deflection (in)
1	2.75	2.25	0.50
2	2.75	2.27	0.48
3	2.75	2.22	0.53

Appendix G3.4 – Evaluation Sheet

Appendix G3.5 – Schedule (Testing)

APPENDIX H – Resume

Matthew Hart

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Objective: To get a job at Boeing in Washington in the Mechanical engineering field building airplane parts. EDUCATION:

Bachelor of Science in Mechanical Engineering

Central Washington University, Ellensburg, WA

CERTIFICATIONS:

First Aid/ CPR

Concealed Pistol License

WORK EXPERIENCE:
Construction Laborer, Lanzce G. Douglass, Ellensburg, WA

Swept buildings to keep the clean for trades to come in and work ran power equipment.

June 2022.

Fishing Boat, F/V Mary Margrett, Naknek, Ak
Catching sockeye salmon in nets and selling them to canaries also ran hydraulics on the boat.

Fishing Boat, C/V Freedom, Westport, WA
Taking people out into the ocean to catch all types of fish.

Fishing Boat, F/V Ocean Dream, Gig Harbor, WA
Fished for squid down in California ran Hydraulics on the boat.

Worker, J and G land, Grayland, WA
Ran forklifts I have ran machines for picking I and ran track carts.

VOLUNTEER EXPERIENCE

Ocosta booster club crab feed (2013-2017)
Salmon feeding for Ocosta school district (2013-2017)

Skills

Microsoft Office AutoCAD

Solid works

Rhino