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Team H&H RC Baja: Chassis & Suspension

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By

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ABSTRACT

An RC car needed to be created to meet set requirements to compete in the annual American Society of Mechanical Engineers RC Baja Competition. Students of the Mechanical Engineering Department of Central Washington University developed an RC car that has working suspension/ chassis size to hold a all components of a working RC car with a floating rear end. This RC car needed to meet set requirements to compete in the annual American Society of Mechanical Engineers RC Baja Competition. The requirements relative to the suspension/chassis is that the RC car must not exceed a weight of 10lb, must not exceed 500 dollars in cost, survive a 1.5ft drop landing flat, and withstand a 506.72N force on the front end during the impact test. To achieve these requirements the team completed material matrices, 24 analysis calculations, and worked together to create a device that achieved both partners parameters. The devices main assembly was broken into sub-assemblies that required parts to be machined using processes such as milling, drilling, and plasma cutting. The principal engineer and Bill Hedlund combined all completed sub-assemblies to finalize the RC Car. After completing construction, tests were completed to decide if the car was ready to compete in the event. After completing the tests, results showed that the car has not exceeded a 10lb max weight, the total cost of the project is 418 dollars, the car sustained the 1.5ft drop and impact of 506.72N tests without the suspension deflecting .5 inches.

Keywords: Suspension, RC, Baja

Contents

1. INTRODUCTION

a. Description

The RC Baja car contest is a competition where teams of ASME Mechanical Engineering students demonstrate their ideas and manufacturing skills, presentation skills, and racing skills. The car must be able to turn, start, and stop whenever in use. To be qualified to compete the car must comply with all the set requirements. The project will consist of two-man teams who will work on different parts of the car. The overall outcome is to have a RC Baja that can compete in the ASME Baja event.

b. Motivation

This project was motivated by a need for a device that would be able to house multiple working parts that was sturdy and able to withstand many varying forces. Building an RC Baja car will help gaining knowledge of how real car chassis withstand these forces by learning suspension parts, front and rear bumpers, and different materials.

c. Function Statement

The RC Baja car chassis must be able to provide support for all the other components such as shocks, motor, battery, etc. The RC Baja car shocks must be able to stabilize the vehicles movements, enhance control when turning, braking, and accelerating.

d. Requirements

1. RC Baja car must be able to be operated at minimum of 50 feet.
2. The RC Baja car must not exceed 10 lbs.
3. The cost of the RC Baja project must not exceed 500 dollars.
4. The RC BAJA car must be able to go 25 mph.
5. The RC Baja car must be able withstand the 506.27N force from the impact test on the front end.
6. The RC Baja chassis must be able to withstand a 1.5ft drop test if landed upright.
7. Front/Rear Suspension tower must be able to withstand a 15lb force from the Suspension strut.
8. Rear Shock tower must be able to hold rear shock at an angle of between 30 and 60 degrees.

e. Engineering Merit

This project will require analysis using methods from statics, strength of materials, physics, etc. Statics will be used to determine loadings on components as well as maximum bending moments for structures that are like a beam. Strength of materials will be applied to determine the stresses in components due to loadings as well as thickness and types of materials used.

Physics will be used to determine the force of the car falling from 1.5ft and the amount of energy the car needs to withstand the drop test.

f. Scope of Effort

This portion of the RC Baja project will mainly focus on the suspension and chassis design of the RC car along with the analysis, methods, production, construction, and testing of all related parts. As well as using software such as solid works to design effective parts that can be used while performing tests.

g. Success Criteria

The success criteria of this project will be determined at the end of the school year at the final RC Baja competition. It will be successful if it completes the competition without any critical breakdowns, failures, and disqualifications while also placing in the top three positions.

2. DESIGN & ANALYSIS

a. Approach: Proposed Solution

The main problem for the suspension and chassis part of the RC Baja project is to create a chassis and suspension system that can withstand various stress, forces, and loads. This problem can be solved by comparing multiple design ideas of different forms of suspension and chassis systems. Multiple different ideas were disregarded while brainstorming designs because some ideas became unnecessary and excessive which helped lead to a final design. The decision matrix was also very helpful in comparing designs and leading to the better option. Figure F.1 in the appendix will show design matrix that was used to compare design ideas.

b. Design Description

The initial current design for the RC Baja car is simple. It consists of a simple flat chassis that would be able to house the battery, motor, shock towers, and other parts that are vital to operation. The shock towers on the front and back will connect the shocks to swing arms to help maintain tire-to-road contact. It also consists of front and rear bumps in case of impact. These sketches and designs are subject to change throughout the quarter but serve to be a foundation for more ideas and revisions. Please see scanned image of the sketch in APPENDIX B-1.

c. Benchmark

The benchmark car will be the Traxxas Unlimited Desert Racer trophy truck. This RC car has an inverted tub chassis that allows maintenance to be hassle free. The battery compartment has its own separate door, which makes battery replacement much easier. The RC Baja car that will be built for this project will use this trophy truck for inspiration to achieve the best possible chassis and suspension that can be built with the design requirements.

d. Performance Predictions

Performance predictions for the RC Baja Car include, being able to withstand a 10mph +-.05mphs impact to a wall without any critical damage that would affect the functionality of the car. The car will be able to withstand a 1.5ft +-.025ft drop test to the wheels without any critical damage to the chassis. The car will be able to travel up to speeds of 20mph +-1mph without losing or breaking of any components on car.

e. Description of Analysis

Some of the engineering merit areas that will be used for different types of analysis that will be performed throughout this project include statics, mechanic of materials, and physics. FBD from statics will be used to determine different loadings/forces and bending moments that will act on different components of the RC Baja Car. Strength of materials will be used to analyze various stresses on components due to loadings and help determine material and thickness for the RC Baja car. Basic physics and kinematic equations can be used to analyze certain values such as impact force and energy needed to withstand a 1.5ft drop.

f. Scope of Testing and Evaluation

The two components that will be designed and evaluated in this report include the suspension tower and Chassis of the RC Baja car. This testing will be conducted at Central Washington University using the various tools and machines that are available to students. Organized documentation will be kept over the progress and results of testing, construction, and design alterations will be made when and if needed upon testing results.

g. Analysis

All the analysis for the RC Baja car of the different components can be found in appendix A. There will be many different methods of analysis that will be used to determine parameters of components that correspond with the set requirements. Some of the parameters that will be gained from analyze will be chassis thickness, shock tower hole size, swing arm design, etc. These parameters will then be used to help make drawings of the components found in appendix B.

i. Analysis 1, Drop Test

Figure A.1 in appendix A shows the impact force and energy needed to withstand when being dropped from a 1.5ft height. The 10lb force was used because in the requirements it was stated that car should not exceed more than 10lb, so this was used to determine the max force. The 10lbf was converted into kg and then used to find the force using F=ma, this found force will help determine the minimum thickness of the suspension arms. Figure A.1 also shows the energy absorption of the suspension. After the sum of the energy was found the value came out to be 14.9 ft-lb that suspension must withstand from a 1.5ft drop. This design parameter will be documented in the swing arm DWG JFH-20-002.

ii. Analysis 2, Front Impact Test

Figure A.2 in appendix A shows the front impact force on the front of the car at 25 mph when driving into a wall. The 10lb force was used again in the analysis because in the requirements it was stated that the car should not exceed more than 10lb in weight, so this was used in the force equation once converted into mass. It can be assumed that it would take the car .1 seconds to go from 25mph to 0mph after contacting the wall. This time was used in finding the acceleration that was needed in F=ma equation. Once the mass and acceleration were found the equation was simple. The force on the front of the car came out to be 506.27N at a speed of 25 mph. This force will help determine the front bumpers design parameters which will be documented in the front bumpers DWG JFH-20-005.

iii. Analysis 3, Minimum Chassis Thickness

Figure A.3 shows the calculations for the minimum thickness of the chassis that would meet the requirement of the 120N force on the front end. The RC car was treated like a beam with a fixed end, there is a force in the middle of 44.48N which acts as the 10lb max weight of the car requirement and a 120N force on the front for the front-end requirement. Shear and moment diagrams were done for the forces acting on the car, which would then lead into the bending stress equation to solve for the section modulus. For the bending stress, 48.72Nm was found from the moment diagrams and used for M and 240MPA was used for stress max since it is the yielding stress value for Aluminum Plate 6061 steel. Solving this equation gave the value of 203 $X10^{-9}$ Nm^3 for section modulus. From Appendix 1, the Section modulus equation is $BH^2/6$ with H being the thickness for the chassis. Using this equation to solve for H, the analysis resulted in a design parameter of minimum required thickness of 2.8mm or .11 in. Since the minimum thickness is .11 inches it can be assumed that anything thicker should be acceptable, which is why the thickness for chassis will be .25 in. This thickness of .25 in seems more reasonable to work with when it's time to machine the part because it might be hard to find raw stock of aluminum that is .11 in or close to that value. This design parameter will be documented in the DWG for the chassis JFH-20-001.

IV. Analysis 4, Minimum Swing Arm Length

Figure A.4 shows the calculations for the minimum arm length for the swing arms, this design parameter will help in meeting the requirement of the Chassis withstanding a 1.5N drop if landed up right. In the analysis a triangle was designed that represented the shock tower height, shock, length, and the unknown swing arm length. It can be assumed that the shock tower height will be 3in tall when created and the shocks will be 4in long. Laws of sines were used to the angle the shock should stand at when mounted, which was 33.33 degrees. Laws of sines was used again to find the unknown minimum length of the swing arm, which was 2.23 in. A design factor of 2 will be used to make the swing arm 4 in. By making the swing arms 4 in long it will allow the shocks to be moved up and down the swing arm depending on which position works the best with the shock. This design parameter will be documented in the DWG for the swing arm JFH-20-002.

V. Analysis 5, Stresses in front Suspension Tower Arm

A problem the front shocks towers arm might experience during use can be fatigue due to constant force from the suspension struts. Figure A.5 shows the calculations for the stresses in the front shock tower arm, knowing these stress values will help in designing to meet the requirement of the front/rear suspension tower being able to withstand a 15lb force from the suspension strut. The benefit of designing for this requirement will be that the shock towers will not experience extreme fatigue from the assumed load. These stress values will also help find the minimum cross-sectional area that suspension tower arms should have in analysis #6. In the analysis, a free body diagram was made of the proposed suspension tower arm where the arm was treated like a beam. It can be assumed that the suspension strut will apply a force at a 14.28-degree angle since the suspension arm will sit at 47.61-degree angle and the shock itself will be at 33.33-degree angle, these values were found in analysis #4. Forces where then found in the x and y where Fy was 14.53lb. and Fx was 3.69lb. Shear and moment diagrams were then done to find shear max being 14.53 lb., normal stress max being 3.69 lb., and the moment being 14.53 lb. in since the arm length will be designed to be 1in. These stress values were found in this analysis and be used/documented in analysis #6 and in the DWG for the front suspension tower JFH-20-003.

VI. Analysis 6, Minimum Cross-Sectional Area of Front Suspension Tower Arms

The same problem and benefits of the design from analysis #5 can be applied to this analysis. Figure A.6 shows the calculations for the minimum cross-sectional area of the front suspension tower arms, this design parameter will help meet the requirement of the tower being able to withstand a 15lb force from the suspension strut. In the analysis the bending stress equation was used since one could find b and h in the moment of inertia equation, in this situation it can be assumed that the shock tower arms will be a square so b and h will be the same value. Once the equation is simplified down and set to solve for b, the moment value can be pulled from analysis #5 and plugged into the equation. The flexural strength for abs plastic is 11,000 psi, this value can be plugged into the denominator of the equation. Once the equation is solved, a b value of .2in is found. For the cross-sectional area design parameter, a standard size of .5in will be used for the base and height of the tower arm since this will apply a safety factor of 2.5. This parameter will be documented in the DWG for the front suspension tower JFH-20-003.

VII. Analysis 7, Minimum Height for Rear Shock Tower

A problem that the rear shock can experience is that shocks will not be mounted at a good angle due to the height of the shock tower. Figure A.7 shows the calculations for the minimum height for the rear shock tower, this design parameter will help in meeting the requirement of the rear shock tower being able to hold the rear shocks at an angle between 30 and 60 degrees. The benefits of designing the rear shock tower this way is that it will give the shocks enough of an angle to be efficient in stabilizing the vehicle when in use. In the analysis a 30-60-90 triangle was created that represents the rear shock tower height, swing arm length, and shock length. The desired shock length side BC is to be 4 inches and the designed swing arm length AC is 4 in as well. Law of sines was applied to find the length BA which represented the rear shock tower height. After solving for BA, the design parameter of minimum rear shock tower height came out to be 2.3 inches. For simplicity, when making parts the same height of the front shock tower will be used which is 2.6 inches. This design parameter will be documented in the DWG for the rear suspension tower JFH-20-004.

VIII. Analysis 8, Stresses in Rear Suspension Arm

Similar to the front shock towers, the rear shock towers will be exposed to fatigue due to the constant force applied by the suspension struts. Figure A.8 shows the calculations for the stresses found in the rear shock tower arm; these stresses are aimed at finding required values that will meet the requirement of the front/rear suspension tower being able to withstand against a 15lb force from the suspension strut. These stress values will also help find the minimum cross sectional are in the arms to withstand a 15lb force. The benefit of the designing the rear shock towers with this requirement is that it will minimize the amount of fatigue the shock tower will experience. In the analysis, a free body diagram was made of the proposed suspension tower arm where the arm was treated like a beam. The arm was designed to be 1.5 compared to the 1 in arms on the front tower since it will have to have more overhang on the rear to attach the shocks to the swing arms. Due to the requirement of the suspension arms on the rear having to sit at an angle of 30-60 degrees it will be assumed that the strut is causing a force at 30 degrees, which can be referenced in analysis #7. Forces were solved in the x and y where fy was 12.99lb and fx was 7.5lbs. Shear and moment diagrams were made with these values which ended up showing a shear max value of 12.99lb, normal stress value of 7.5lb, and a moment of 19.485lb in due to the 1.5 in arm length. These design parameters will be documented/used in analysis #9 which will help create a ASME Y14.5 drawing of the rear suspension tower JFH-20-004.

IX. Analysis 9, Minimum Cross-Sectional Area of Rear Suspension Tower Arms

The same problem and benefits of Analysis #8 can be applied to this analysis. Figure A.9 will show that analysis that calculates the minimum cross-sectional area of the rear suspension tower arms, this design parameter will help meet the requirement of the tower being able to withstand a 15lb force from the suspension strut. Like Analysis 6, the simplified bending stress equation can be applied because it allows to find b, which can serve as h as well since the shape of arms with be square. Once the bending stress equation is simplified, once can pull the moment for analysis 8 and the flexural strength of ABS plastic. Once this equation is solved with the known values, a minimum design parameter value of .22in is found for b and h of the arms. A value of .5 for the b and h will be used for the cross-sectional area of the arm because that is the same value of the front shock tower arms and will apply a safety factor of roughly 2. This design parameter will be documented in the DWG of the rear suspension tower JFH-20-004.

X. Analysis 10, K Constant needed to Withstand Force from Drop Test

A problem that the RC Baja car might experience is not being able to withstand the force from the drop test. Figure A.10 shows the calculations to find the design parameter of a K value of the shocks needed to hold up against a 10lbf from 1.5 ft drop. This design parameter will help in meeting the requirement of the car being able to withstand a 1.5 ft drop. The benefit of designing the RC Car with strong shocks is that it will allow it to withstand all sorts of different drop heights. In the analysis, the equation 1/2kx^2=mgh was used to solve for the K value. Once the equation was simplified to solve for the K value, one could plug in 10lbs for m (analysis#1), 1.5ft for h since it is the desired drop height in the requirement, 2 in converted to feet for x since this is the assumed compressed length of the shock, and 32.2ft/s^2 for g. This equation will give a k value of 1076lbf/ft which would equate to 89.3lbf/in. Using this k value to plug into the force equation of f=kx, one can get a force rating value of 172.8lbf. This 172.8lbf is greater than the 10lbf from the drop making the shocks able to withstand the drop test. This design parameter will be documented in the DWG of the shocks JFH-55-001.

XI. Analysis 11, Minimum Cross-Sectional Area of Front Bumper

A problem that the front bumper may experience while in use is breakage due to the force from the impact test. Figure A.11 shows the calculations for the minimum Cross-sectional area that front bumper must have to withstand this force, this design parameter will help in meeting the requirement of the front bumper surviving the 506.27N force from the impact test. The benefits of designing the front bumper this way is that it will protect the chassis and the entire car from strong forces on the front end. In the analysis, the area was found by using the stress = force/area equation. The force was already known from analysis #2, which was 506.72N or 116.81lbf. The yield stress of ABS plastic was 10,700 psi, so these values allowed the student to simplify the equation for a cross sectional area and find a value of .0106in^2. Next, from appendix 1 in Mott the area for a square is A=H^2 which allowed the student to find a h value of .1029in. The minimum cross-sectional area will be .0106in^2, however the student will use values of .5 for the base and height to machine easier and give a safety factor of roughly 5. This design parameter will be documented in the DWG for the front bumper JFH-20-005.

XII. Analysis 12, Check to see if Front Bumper will hold up against impact force

The same problems and benefits for analysis #11 can be applied to this analysis. Figure A.12 shows the analysis that checks to see if the design of the front bumper will hold up against the impact force and meet the requirement of the front bumper surviving of the 506.27N force from the impact test. First, the bumper was broken into two parts where the first part of the bumper was analyzed. Forces in the x were solved for and found a normal force of 113.18lb from part 2 of the bumper, this makes sense since part one of the bumper will be having this same force applied to it on the front (equal and opposite reactions). Second, a moment of the back of the first part of the bumper was done to find a moment value of 198.065lb ** in. Lastly, a stress max equation was to find the maximum stress the bumper would experience compared to the yield stress of ABS plastic. The max stress came out to be 482.42 psi while the yield strength of ABS plastic was 10,700 psi. This comparison shows how the front bumper should be able to withstand the 506.72 N force from the impact test. This design parameter will be documented in the DWG for the front bumper JFH-20-005.

h. Device: Parts, Shapes, and Conformation

The front suspension system design was based off the same front suspension system that a trophy truck has. This suspension system design was chosen because it is a very sturdy system that will also allow the wheels to turn at any angle. The rear suspension system was a team design that will allow the driveshaft to go right to the differential under the shock tower. The shocks will also be connected to only one rear swing arm rather than two that will be in the front of the chassis. The chassis design was made to be able to house all the necessary components to make the car run. The chassis also has one joint on the rear and two on the front, this will allow the swing arms to connect right to the chassis rather than designing or buying a part that would connect the swing arms to the chassis. A safety factor of three will be used when picking out shocks since the car will need as much spring force as it can get during the drop test and driving over different terrains. A tolerance of +- .5 in will be applied to the chassis dimensions since the car needs to be rather tight on size due to the requirements that were stated before.

i. Device Assembly

The overall assembly of for this project will be a remote control fully functional RC car with a sturdy chassis and suspension system specified by for the Baja style competition. The final assembly will be able to compete in the end of year competition, the ASME RC Baja event. The RC car must be able to drive multiple distance while housing all the necessary components of the RC car and be able to withstand impact forces from walls and being dropped. The RC Baja car assembly will be successful in this event as the assembly will feature great control from the electrical components, good handling from suspension and steering components, durability from chassis, and power from the transmission.

j. Technical Risk Analysis

The design is being optimized for lightness and power, this could end up making some components of the car not strong enough to withstand the drop test, impact test, and the ASME competition. The most abuse the car will take will be during the ASME event which is still far out making it hard to see if all the components of the car will be able to keep up. The manufacturing part of the car will also be difficult because a lot of the tools and equipment will require relearning or new learning since it will be new. This could make the project fall behind in schedule and cause the project to go over on the budget if mistakes or miscalculations are made.

k. Failure Mode Analysis

There are many factors that could cause failure in the RC car such as stress, strain, fatigue, and wear and tear over time. Since the chassis is going to be made from metal aluminum and the swing arms are going to be abs plastic, during the drop test the swing arms could brake because there is a possibility the plastic swing arms won't be as strong, this can be analyzed with the maximum shear stress, DET, or Goodman theory. Another example could be the constant wear and tear that will be applied to the tires during use of the RC car. The wheels will be exposed to constant fatigue since they are always in contact with the ground.

l. Operation Limits and Safety

The two big operation limits that should be recognized is when the impact test and drop test are being tested for. For best results, the drop test should not be tested more than three times before the time of testing or competition. This will prevent any wear or tear on the tire or shocks before they are tested. Secondly, the impact test should also not be tested more than three times before the time of testing or competition. This will prevent the chassis from any unnecessary damages and ensure that the chassis of the car is in good condition when final testing is conducted.

3. METHODS & CONSTRUCTION

a. Methods

The RC Baja car project was conceived, analyzed, and designed at Central Washington University within the Mechanical Engineering and Technology program. The team members of the project were able to come together and brainstorm to produce solutions for theoretical problems and problems defined by ASME RC Baja competition. This project requires the team to design/manufacture many RC car components and assembly them with other purchased parts. Each team member deigned their own unique problems and solutions, conducted analyses for design parameters, and manufacture parts for the solutions. The team will continue to analyze their components in winter quarter and test their components in spring quarter. The manufacturing of parts will occur within in Central Washington University with bought resources, given tooling, and with processes such as 3d printing, milling, lathing, plasma cutting, and CNC machining. Testing will be conducted by the team with utilizing some personal and borrowed instruments from the school.

i. Process Decisions

The two big decisions during the design portion of this project were the material for the swing arms and the body type/material of the chassis. At the beginning of the fall quarter, the initial idea was to 3D print the swing arms since the material and process were available to use through the school and a personal 3D printer was on hand. However, due to issues with the teammates personal 3D printer other materials have become an option. Making the swing arms out of aluminum and balsa wood have become an option since all the tooling is available to the students in the lab. Costs between these materials will have to be taken into consideration and will be used in a decision matrix posted in appendix F-2, this decision matrix will still need to be reviewed by the team to decide on the final material. Since there is another option for a material of the swing arms this would also open new manufacturing processes for the components. If the swing arms are no longer to be made from ABS Plastic, another manufacturing process would be to CNC for aluminum or Laser cutting for balsa wood in the Hogue Lab or out of class. A decision matrix will be done to compare 3D printing, CNC, and laser cutting that will be posted in appendix F-3. The other earlier main project decision was about the body style of the chassis, both group members came up with personal ideas of what the body of the car should look like. All the bodies that were designed had benefits and disadvantages that had to be discussed between the two members. To bring the number of ideas down to a minimal, the group members picked three designs that were the best among them all and used a decision matrix to finalize a design. To view this decision matrix, look at appendix F-1 in the proposal. Lastly, the students had to choose the best way to manufacture the final design of the chassis, it should be noted that the material for the chassis will be aluminum so all process will have to be able to work with aluminum. To do this a decision matrix was created comparing different processes of manufacturing which can be found in appendix F-4.

In winter quarter, the team has decided that material for the chassis will be made from aluminum and the process to create this chassis will be used on the plasma cutter since it offers the most precision and convince for this type of component. It should also be noted that the initial idea of 3d printing the swing arms is up for questions as of right now considering that printers have failed on the students twice now. The next option that is considered is to make them out of aluminum on the plasma cutter along with the chassis.

Winter Quarter Week 7:
Now in week 7 of winter quarter, the team has made tremendous progress on the creation of components and the methods used to create such components. The chassis was cut out using the plasma cutter with assistance of a lab tech, the chassis was cut out accurately to the drawing that was used to create the part. It Should be noted that the team experienced problems later due the breakage of a drill pit in the flange of the chassis. This required the team to mill out the drill bit and weld over it to create the full flange again. The team was able to grind down the weld and redrill the hole in the flange. The team has also stuck with the 3D printing idea of the swing arms due to the quick turnaround time the MEC was able to give in compensation due to multiple failed print jobs on other parts.

b. Construction

i. Description

The RC Baja car will consist of two main subgroups of assemblies, of which are the suspension/chassis and drivetrain/steering. The suspension engineer will be in control of the suspension/chassis subgroup and drivetrain engineer will oversee the drivetrain/steering subgroup. Most of this RC car will consist of purchased parts and manufactured parts created by the team members. The purchased parts will either be from the internet or from local hobby stores and are necessary to the completion of the car since some parts are beyond the team members manufacturing skills. The more design-oriented parts of this RC car are designed by the team and will be manufactured completely at Central Washington Facilities either with the 3D printers or use of facility equipment such as the lathe, mill, and CNC machine. Each team member will be responsible for the manufacturing of individual assemblies and parts.

ii. Drawing Tree, Drawing ID’s

A drawing tree of the suspension/chassis assemblies, subassemblies, and parts can be found in appendix B-1. The drawing tree shows the layout for the order of assemblies it will take to complete the suspension and chassis portion of the RC Car. The parts that make the assemblies were picked because they are what is needed to complete the assembly and are easy for the student to put together. There is no specific order of which assemblies should be completed first because all the assemblies act independent for the most part. The only connection between assemblies is when connecting the swing arms to shock tower assembly.

iii. Parts

A list regarding all the par numbers, quantity, part description, cost and disposition may be found on appendix C-1. The parts that have a prefix of 20 will be fully designed and manufactured by the team using equipment and tools found at Central Washington University labs. These parts will either be machined, or 3D printed to tolerance and certain parts will be tapped and threaded to match certain fasteners. Parts with a number 55 will be obtained by purchase and will require little to no modification, if modification is required for 55 part it will be done in the labs of Central Washington University. The team member designed parts will be designed in a way that they are compatible with purchased parts, so they mate and fasten together smoothly. The last grouping of parts will have a prefix of 10, this grouping will be subassemblies of a combination of machined and purchased parts. There will be no machining process for thus grouping since they will already have been machined or modified before they were put together into an assembly.

iv. Manufacturing Issues

Fall Quarter:

For winter quarter during construction there will be many potential issues that could arise while manufacturing parts. Some of these issues could be training for use of machines like the CNC, material availability, machines could break down and take a while to be up and running, and processes can take longer than anticipated for.

If a machine does require training, it will be up to the student to get help from classmates or professors to learn to work the equipment. If or when a machine breaks downs, the group members should discuss another way to manufacture parts until the machine is working again. When materials are not easily available the team members should discuss possible new materials or discuss with classmates that are using similar materials how they are dealing with the situation. Lastly, when a process is taking longer than anticipated for the students will either move on to a different process or stick with delay of time and work around it. Some of these manufacturing issues have simpler answers than other, however it will be up to the team members to work around these problems and still finish the project.

Winter Quarter:

The team is having trouble gathering the material for the chassis and the 3d printing time process. The team is trying to get around the issue of gathering the material for the chassis by working with the lab tech on ordering aluminum sheet metal that can be used for many students and at an affordable price rather than going over budget and spending money at a local machine shop. The team also was aware of the 3d printing time process, so the team ordered their parts early with 2 weeks in advance of when the parts needed to be complete.

However, the 3d printing lab in Samuelson is having issues printing the parts causing the parts to be completely redone over again twice now which will cost a couple days in time.

v. Discussion of Assembly

The first step of operation for the suspension/chassis side of the RC car was to create the CHASSIS-CAR (JFH-20-001). The chassis needed to be created first because it was the housing for all the components for the car. The CHASSIS-CAR was created using the plasma cutter in Hogue with the assistance of a lab tech and the material that was used was aluminum. The team realized that while the chassis would take a couple weeks to produce due to the material shipping that it would be a good idea to start the 3D printing of other components at the same time. These parts consisted of the ARM-SWING, FRONT (JFH-20-002), TOWER-SHOCK, FRONT (JFH-20-003), TOWER-SHOCK, REAR (JFH-20-004), SUPPORT-BUMPER, FRONT (JFH-20-005), and ARM-SWING, REAR (JFH-20-006) all if these components took about 3-5 weeks to get to the team due to the massive backorder and failed print jobs at the MEC in Samuelson. Once the team had to the CHASSIS-CAR and other 3D printed components, the assemblies from the drawing tree (Appendix B-1) ASSEMBLY-SUB,TOWER,SHOCK,FRONT (JFH-10-001) and ASSEMBLY-SUB,TOWER,SHOCK,REAR (JFH-10-002), and ASSEMBLY-SUB, CHASSIS (JFH-10-003) could be completed. These assemblies were relatively easy to put together since the components were all mated together using basic fasteners such as screws, nuts, washers, and pins. When comparing the RC Baja senior project car to the benchmark Traxxas truck one will see that the size of the senior project car will be bigger due to the long wheels sticking out of the back. When comparing cost, the senior project car will also cost more due to the added cost of the labor the team has added to the budget. The manufacturability for the senior project car will also be harder since it is not a massed produced car that is sold on shelves in stores on shelves and on the internet.

4. TESTING

a. Introduction

There will be three components of the RC Baja car that will be needed to be tested and reviewed during the yearlong senior project. These components being tested will mainly be the chassis and suspension side of the RC Car. These will include the chassis, shock towers, and front bumper. The chassis will have an integrity test and loading test to ensure that it will be able to withstand the forces and loads specified in the requirements. The shock towers will undergo forces based on loading from the suspension struts specified in the requirements. It will also have tested to ensure that it can mount properly to connect and operate all parts of the front and rear suspension system. The front bumper will undergo impact testing to ensure that it can withstand the required force on the front end which is stated in the requirements. All the data that is gathered from the testing will be used to improve all the components before the final competition at the end of the year.

Winter Quarter:
The team has that decided that a new test should implemented for the whole RC Baja car rather than just a component. This test will be a speed test to see how fast the car will go and to see if it meets requirements. During the construction of the RC car, the team has noticed that car might be heavier than intended and are curious to see how the car will hold up compared to initial thoughts in the fall.

Spring Quarter:
Testing has begun for the teams RC Baja car and the team has noticed some minor issues with the car. One of these issues being the rear swing arm, during the drop and impact test the rear swing arm sheared twice in the same location during two different trials. The team believes this has happened because the moment is too large on the back end for the PLA and ABS material the swing arm has been printed out of. The team is currently looking into ideas such as reinforcing the breakage location with aluminum and thickening the swing arm by .5 inches in hope to stop the breakage when dropped from 1.5ft.

b. Method/Approach

To summarize all the testing that needs to be done, the main tests that will be done will be force tests, loadings tests, mounting and integrity test. The three most important tests will be the chassis loading/integrity test, shock tower force tests, and front bumper impact test. All requirements stated in the introduction will be evaluated and reviewed. The integrity and loading test will be conducted by running the RC car at normal speed for a certain amount of time to see how it holds up. During this operation different number of weights will be added to the chassis to see how the car performs and components will be inspected for any yielding or stress. The shock tower force test be conducted by dropping the car from different heights, including the requirement height of 1.5 ft to ensure that the car can withstand many different forces from the heights The front and rear shock towers will be inspected after being exposed to different drop heights. The front bumper impact test will be conducted on a long stretch of road to allow the car to get to max speed. Once the car is at max speed it will be driven into the wall to see how it withstands the force. After the Collison, the front bumper and car will be inspected and disassembled from the car to look for any critical damage.

Winter Quarter:
The speed test of the RC Baja car as whole will be tested by simply stress testing the car and see how fast it will go. The goal of this test is not only to see how fast the car will go, but also to see if all components will function at high speeds and at the final weight the car will be.
Spring Quarter:
The drop test of the RC Baja car will be tested by dropping the car from 1.5ft and measuring the deflection of the chassis, front swing arms, and rear swing arms. The goal of this test is to see if the suspension system will be able to withstand the force from drop and return the car back to its original resting position before being dropped.

The impact rest of the RC Baja car will be tested by starting the car at varying distances and drive the car into the wall at the speed it achieves. The student will then use the velocity found using a phone app and calculate the force using F=ma with the known mass and calculated acceleration. The goal of this test is to see if the front bumper and integrity of the chassis will withstand the force from the front impact and be able to continue testing. In conclusion, the test ended up being successful with no issues with the written procedure and gave the student good data and insight for the future.

c. Test Process

Tests will occur at the Hogue building on campus or outdoors in the surrounding Area of Ellensburg. No tests should require equipment inside the Hogue building so there is no restriction to keep the tests inside of Hogue. For the drop and impact test, a flat street or flat surface should be sufficient to gather data. It should be noted that for the impact test that there should be enough road or space to allow the car to get to its max speed before contacting another surface. To test the shock towers, all that is needed is a clean/dry area that will allow the group members to put together and take apart the suspension systems. Basic measuring devices like a measuring tape will be used to gather data when needed. Timers will also be used for the drop and impact test. If weights needed to be added to get RC car to desired weight, they will be weighed beforehand. More information regarding testing will be posted in appendix G.

Winter Quarter:
The team has decided that the info for test process from Fall Quarter is sufficient info for all tests. The newly added speed test will only require a flat and long stretch area to conduct the test.

d. Deliverables

While testing is being conducted, data will be stored either into an excel spreadsheet or an engineering notebook. This data will then be transferred into an official document that will list why the test was conducted, requirements being tested, results, the test name, and an evaluation of the results. Photos will have to be taken during the testing to ensure references for data and will be attached in the appendix of this proposal. For data sheets from testing and images, visit appendix G.

Winter Quarter:
The team has decided that the info for the deliverables section from Fall quarter is sufficient information to fall into Winter Quarter.

Spring Quarter:

Drop Test:
The requirement associated with the drop test was that the RC Baja Car must be able to withstand the force from a 1.5ft drop if landed upright or parallel with the ground. The predicted results prior to conducting the test were that car would be to return to resting position and show no deflection after being dropped. This predicted result of the car not deflecting at all and returning to rest was calculated using Figure A.1 and A.10 in appendix A, these figures are analysis calculating the force the car would experience during the drop and spring force required return the car back to resting position. After conducting three different trials for the test the team noticed that the front suspension held up very good and did not deflect at returning the car to resting position. However, the rear swing arms did break twice during testing, the team believes that moment at the end of the swing arm was too great for the material causing it to shear. The swing arm did survive one drop when printed out of ABS and resulted in a deflection of .7in and the chassis of .8 inches, the rest of the data can be seen in in appendix G1.3. The biggest issues that the team encountered during the drop test was the breakage of the rear swing arm. This issue caused the team delay due to the printing of new parts and reconstruction. The team previously tried to resolve the issue by printing new swing arms out of ABS rather than PLA, the team is now looking into reinforcing the rear swing arm at the breakage location with aluminum.

Impact Test:
The requirement associated with the impact test is that the RC Baja car must be able withstand the 506.27N force from the impact test on the front end. The predicted results prior to conducting the test was that car would be able to withstand a 506.27N force on the front end at a speed of 25mph which can be see in appendix A figure A.2. After conducting three different trials the max speed the car was able to achieve was 7mph at 49 ft away from the wall that was being driven into. With this speed the car experienced a force of 146.3N, unfortunately the car did experience breakage at the rear swing arm. The student believes that force experienced in the last trial was too great for the swing arm and sheared at the same location during the drop test. This issue caused the team some delay since new swing arms had to printed and reassembled, the team also increased the thickness by .5 inches in hopes that new thickness would give strength to the hole locations and cause it not to shear.

Shock Tower Force Test:
The requirement associated with the shock tower force test is that the both the rear and front shock towers must be able to hold and withstand a load of 15lbs. The predicted results prior to conducting the test was that the front and rear shock towers would be able to hold the 15lb load. After conducting testing, the rear and front shock towers were both able to hold the 15lb load without breakage. Since the rear and front shock towers held the 15lb load the student can confirm that the RC car has met this requirement. All data and pictures relevant to the testing can be found in appendix G-3.

5. BUDGET

a. Parts

Fall quarter:

Other than the parts being designed and created by the RC Baja project team, there will be essential parts that will need to be bought to complete the overall assembly of the car. By getting these parts that will not be designed, it will help ensure the RC car will fulfill the requirements with complete functionality that it was intended for. So far there are at least 35 parts needing to be purchased are in the project parts list in appendix C-1.

Winter Quarter:

So far in winter quarter, the cost has been what the team has expected. There are some parts such as the battery and remote control that cost more than manufactured parts such as the shock towers from the MEC in Samuelson. A big cost change that has affected the team was not having to pay for the chassis. The team was estimating a couple hundred dollars for aluminum sheet metal, but a deal was worked out with the lab tech and cost the team nothing for the material. There has been no cost due to errors/mistakes because the team has not messed up or damaged a part to the point where it would have to be replaced. The total cost for the RC Baja is roughly 2,008.05 dollars, including labor cost.

Spring Quarter:

During spring quarter, the team experienced breakage in the rear swing arm that caused the team to reprint the part for a total of 3 times. The reprint of these parts did not end up costing the team any money since the parts did not take up a lot of the lab techs material, so nothing will have to be accounted for in the budget. The team thought that this would be a possibility while testing, so the team implemented a plan before testing of giving each test 1 week to complete the test. This week allowed the team to test, reprint if necessary, and continue testing while finishing on time. If the team were to do this project again in the future, this method would be implemented again due to its success.

b. Outsourcing

Fall Quarter:

At this stage in the project, the only outsourcing that will be needed will be the school's 3D printers and the use of the equipment in Hogue at Central Washington University. The parts that are designed will be manufactured by the project members. Since the school charges .50 cents per hour for abs/plastic material it can be assumed that the outsourcing cost should be no more than 20 dollars.

Winter Quarter:

A big issue that team is experiencing with outsourcing in winter quarter is the amount of turnaround time it takes to get the 3D printed parts from the MEC. So far, the team is experiencing about 2 weeks to obtain the parts once they have been ordered. The team is trying to get around this issue by ordering the parts early before manufacturing due dates. This plan has worked for both manufacturing deadlines but has been close to not being complete both times.

c. Labor

Labor costs will be based off the standard 3D printing rate here at Central Washington University and assumed labor of cost the team working on the project. The rate here at school is .50/hour for ABS plastic, so far, an estimated print time for abs parts is around 40 hours. This estimated labor cost for RC Baja will be around 20 dollars. The labor cost for working on the project will be 15/hour with an assumed work time of 100 hours. The labor cost will be around 1500 dollars.

Spring Quarter:
No new labor costs have been implemented in Spring quarter.

d. Estimated Total Project Cost

Fall Quarter:
At this point in the project the estimated total cost 1,704 dollars This cost includes the total cost of all the parts accounted for so far and 3D Printing costs at Central Washington University and manual labor cost by the team. This budget spreadsheet can be found in appendix D-1.

Winter Quarter:
The major cost subtotals still come from the labor cost of 15/hr and purchased parts such as remote control, battery, and shocks. One big contributing part to the subtotal that no longer contributes is the chassis due to the team not having to pay for it. There does not seem to be any issues with any of the previous sections in section 5 that the team can see now.

e. Funding Source

The funding source for this project will be covered by the members of the project. Expenses will be divided evenly between the two members and paid with their personal funds

6. Schedule

a. Design

Figure E.1 shows the schedule for the RC Baja project for fall quarter. The schedule for this project was estimated during the design phase before the start of any actual construction or ordering of components. The Gantt chart for fall is composed of proposal, website, analysis, and documentation tasks. The proposal tasks will all be related to the writing of the proposal and have descriptions for each section inside of the document. All the analysis tasks will be related to the construction of the RC Baja car and show how certain design parameters were found. The documentation tasks will show the DWG for each part that had to be created for the RC Baja project. Each task has an estimated hours, actual hours, completion, and schedule associated with the task. So far, each task is being completed to according to schedule and some tasks are taking longer hourly than estimated for in the chart.

b. Construction

Fall Quarter:

Some major tasks that can be found on Figure E.1 related to construction of the RC Baja car in the winter can be the documentation and analysis tasks. All the analysis and documentation task will guide the construction of the car in the winter because all the components and requirements will have been analyzed for when the construction begins. Some documentation tasks that can be related to construction of the RC Baja car can be Chassis and Shock tower drawings. These Drawings will be helpful in the winter because it will have the dimensions of the part listed.

Winter Quarter:

In Figure E.2, the winter Gannt chart can be found that shows all the part construction and documentation that was created in fall quarter. So far in winter quarter all the parts construction has been coming along according to schedule and the team has been working hard to keep the project on schedule. In comparison to scheduling, the team has experienced manufacturing issues that could have delayed the schedule. The 3D printers at the MEC in Samuelson has been experiencing printing issues that has led to multiple reprints of components. This issue has not delayed the schedule because the team started the print job early in case of this issue, when the parts did arrive the team had a couple days left before the first manufacturing due date.

c. Testing

Fall Quarter:

In appendix E Figure E.1 shows analysis task drop test and front impact test. These tasks on the fall Gannt chart can be related to testing of the device in spring quarter because in the spring the drop and front impact test will be conducted. Having these two-analysis done will be a big help when it comes to conduct the tests in the spring.

Spring Quarter:
In appendix E, Figure E.3 shows the device evaluation tasks that were completed in spring quarter. The tests that were completed were drop, impact, and shock tower force tests. All three of the tests were given a week to complete with 4 hours of test procedure preparation and post-test analysis. During the testing, the student experienced minor issues that set the student back a day or two, the problem was the failure of 3D printed parts. The student was successfully able to reprint the rear swing arm that continued to break during the drop and impact test with a .5 in thickness increase. This modification of the rear swing arm allowed the student to continue testing with no issues and still does not show any ware or fatigue. Since the 3D printer took 1 day to reprint the part the student was able to maintain the 1 week given time to complete each three tests. After testing was complete the student has recognized that the estimate time to complete all three tests, preparation, and post analysis was 12 hours. However, the actual total testing time was 20 hours, this is most likely because the student did not take fully into consideration the time it took outside of testing to prepare and analyze.

7. Project Management

Among all the types of resources there are many risks that can be associated with the RC Baja senior project. Some of these risks include availability of tools and equipment, software crashing, and finical problems. These risks can greatly affect the production of the project, but all these risks will be accounted for and have solutions so the project can be completed on time.

a. Human Resources

The following human resource groups that are present in this project will be principal engineers, supporting engineers, and mentors. The principal engineer of suspension and chassis side of the project will be Jack Huff. The other group member, Bill Hedlund will act as a supporting engineer for this portion of the project. The resume for Jack Huff can be found in Appendix H. The two mentors for this project will be Professor Pringle and Professor Choi. The professors will overview the progress of the RC Baja car project and support the team with guidance and will act as a resource for engineering knowledge. A risk with associate with human resources can be that the professors might not be available for help due to being out or some other reason. To deal with this risk the team will either send an email to ask a question or work around the problem and wait till later to for assistance.

b. Physical Resources

The physical resources to be used in this project will mostly come from Central Washington University engineering labs. A 3D printer will be used which can either be in Hogue or Samuelson. Tools such as taps, reamers, and grinders from the labs will be required to satisfy certain dimensions. Since this equipment is not personally owned, this means that the equipment might not always be available. This risk will affect the project because it could slow down the production rate. To deal with this risk the team will have to work with other groups in order to share all the equipment and be fair.

c. Soft Resources

The two biggest types of soft resources being used throughout the senior project will be Microsoft word and solid works. Microsoft word will be used for the creation of the proposal for the project and all other deliverables that might require the use of this software. Occasionally, Microsoft excel will also be used when needed to keep track of drawings, parts, or sets of data. Lastly, solid works is used to create 3D models, assemblies, and detailed drawings for the design portion of this project. The risks associated with these soft resources is that files might not save correctly or not at all. This risk will affect the project because it potentially could cause the student to lose all his work. The response to this risk is to save the file in multiple places and turn on autosave when available.

d. Financial Resources

All expenses will come of pocket from the group members of the RC Baja team. There will be no sponsors, grants, scholarships, or anything that represents financial assistance will be used for this project. The only anything that represents a donation will be the use of the lab's tools and equipment. A risk that could be associated with financial resources could be that team runs out of money. To deal with the problem the team will have to work to get more funds or outsource to family that could help fund the project.

8. DISCUSSION

a. Design

The RC Baja senior project at Central Washington University within the Mechanical Engineering and Technology program required a total of two team members to work together to complete the project. The two principal engineers that decided to take on this project was Jack Huff and Bill Hedlund. At the very beginning of the project, these two students decided that Jack Huff would oversee the suspension/Chassis side of the project while Bill Hedlund took care of the drivetrain/steering portion. There is no specific reason why the team members were assigned these roles, however it should be noted that Bill Hedlund did have some experience with RC cars prior to this project, so that would have influenced his decision to take on the drivetrain and steering portion of the project rather than the suspension and chassis side.

The first couple of weeks allowed the team members to get a good idea of what needed to be planned and completed in fall quarter to be successful. By the fourth week of class both team members understood what work needed to be done to be successful, which led to the first completions of analyses, proposal work, website work, and detail drawings. The final two weeks of fall quarter saw the last submissions for analyses, drawings, assembly drawing, final presentation, and the last bit of fall quarter proposal work. By the end of fall quarter, the RC Baja Car has a full design that will be ready to get started on in the upcoming winter quarter,

Notable successes of this project include great communication between the team, complete work on time, and be able to work independently inside and outside of class. The team was able to support each other and led to advanced knowledge and understanding of RC cars and good analysis/design skills.

For fall quarter, there were little to no hardships that were experienced during the design phase of the project. One hardship that Bill Hedlund could have experienced was that his original designs for certain parts did not always work out the way it was intended. This caused the principal engineer to go back several times and redesign some of the components. By redesigning the unsuccessful parts to make components work with each other, allowed them to become successful in the end of the quarter.

b. Construction

So far in winter quarter, the team has experienced a couple of project risks that need to be overcome. The first project risk being the production time for the 3d printed parts taking too long. The idea at the beginning of winter quarter was that the parts would be 3d printed at the Mec in Samuelson, it has come apparent to the team that the production times at the Mec take way too long due the amount of printing errors that parts experience due to machine or user error. This risk will be overcome by either changing where the parts are being printed or putting the order for the components in early with time to spare that way the parts are completed on time. Another project risk that the team is experiencing currently is manufacturing the holes for the swing arms on the chassis. When the chassis was created the team did not pay enough attention to how the holes being drilled through the side will be manufactured, this is a problem due to the length of the drill bit and the clearance that chassis provides when drilling. This risk is currently being overcome by using precise drilling with the drill press and using an extended drill bit provided by the lab tech that can reach the entire length of the desired hole depth.

As of right now, no changes to the design have occurred yet. This is because the team is seeing that all the components so far that are complete such as the CHASSIS- CAR, TOWER-SHOCK, FRONT, TOWER-SHOCK, REAR, AND SUPPORT-BUMPER, FRONT all seem to work together. The only change that can be speculate in the future of construction will be that some of the designed holes on the components might have to be increased to the next standard due to the worry of not finding desired dimension screw, pins, and bolts.

Lastly, when comparing the processes of manufacturing components based on unsuccessful and successful the team can say that the most successful processes was the plasma cutting of the chassis. The plasma cutting of the chassis was very simple and quick due to the help of lab tech and previous information of what to have done before using the plasma cutter. Showing up prepared and using the knowledge/help of the lab teach decreased the production time of chassis significantly. However, the most unsuccessful process so far is the process of 3d printing. The 3d printing of the TOWER-SHOCK, FRONT, TOWER-SHOCK, REAR, AND SUPPORT-BUMPER failed 3 times before the Mec was able to get these parts to the team. This process was unsuccessful because the printers in Samuelson clogged up multiple times over night and ran of PLA and in the process of printing. To make this successful, the team will either express their concerns to the workers at the Mec or find somewhere else to print such as Hogue labs.

c. Testing

Drop Test:
When the drop test began its testing, the student noticed a flaw that was easily changed. For supporting evidence, the student had planned on only doing a side view to show the deflection of the chassis and swing arms. The student decided that this was not sufficient supporting evidence and decided to get two more views, the front, and the back. These two additions of views gave the reader and tester a better angle to show how the front/rear swing arms and shocks reacted during the test. Other than this change to the procedure, the rest of the steps worked out good for the remainder of testing.

The team did experience some issues during the testing, this issue was the breakage of the rear swing arm during the drop. Twice the swing arm broke during testing, the team fixed this issue by changing the swing arm material from PLA plastic to ABS plastic. The team also reinforced the swing arm by attaching pieces of aluminum to the breakage spots on the swing arm. So far, the team has not noticed any problem with the modified rear swing arm. There was no issue with the related requirement because the team still thinks that the drop of 1.5ft is still reasonable for the RC Baja car.

Impact Test:
When the impact test began its testing, the student noticed that the three distances that were marked was too short for the car to be able to achieve speed worth recording. This was not a written procedure error but was a mistake on the student's part. The student solved this problem by simply increasing the distance the car would drive from to 19ft and 49ft. This increased starting distance allowed the car to gather good and recordable data for the testing. The rest of the procedural steps worked out for the remainder of testing.

The team did not experience any issues with the testing until the last trial, this issue was the breakage of the reinforced rear swing arm. On the last trial, during the impact the rear swing arm broke in the same location during the drop test. The aluminum reinforcement that the team implemented before decreased the amount of breakage, but still did not keep the part functional. The team has not increased the thickness of the rear swing arm by .5in in hopes that will help the rear swing arm from breaking.

Shock Tower Force Test:
When conducting the testing for the shock tower force test the student did notice any issues with the written procedure. Testing went smoothly since there was no breakage of parts and materials were easy to find and weigh to use as weights when conducting the testing. The student also noticed that the increased thickness of the rear swing arm performed a lot better than in the previous two tests conducted in spring.

9. CONCLUSION

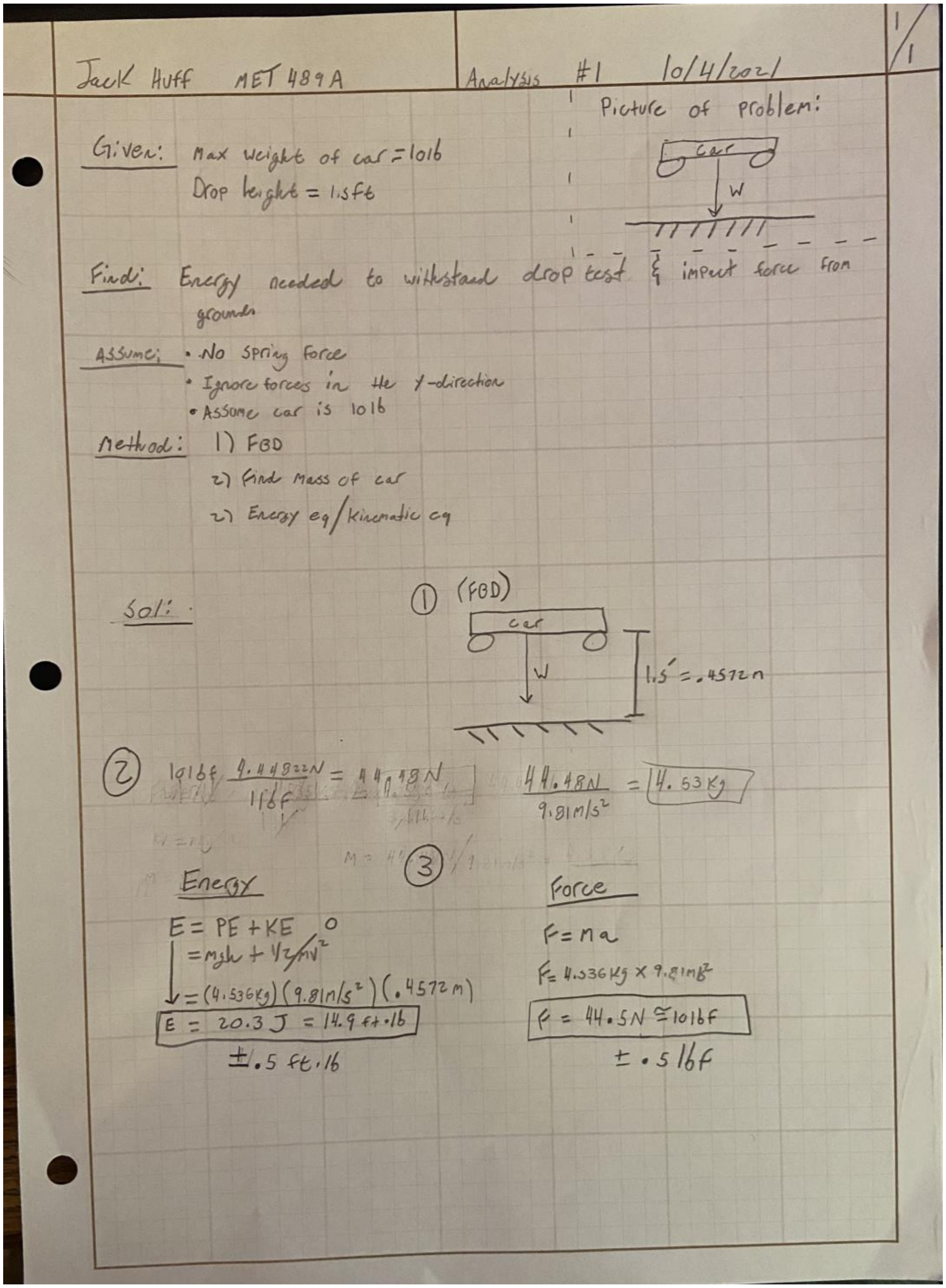
In conclusion, a model of the RC Baja car has been analyzed and designed that meets some of the created requirements of the principal engineers and of the final race at the end of the year. All current parts have been specified and budgeted for accession based off a detailed schedule and budget. The project meets most of the requirements for a successful project, since the car did fail during both the drop and impact test the student can conclude that the RC was not fully successful. The student was also able to have substantive engineering merit in both physics and statics, and follows the guidelines of the function statement, "The RC Baja car chassis must be able to provide support for all the other components such as shocks, motor, battery, etc. The RC Baja car shocks must be able to stabilize the vehicles movements, enhance control when turning, braking, and accelerating". Each component has been designed with at least one analysis and then made into a detail drawing that will lead to a successful construction process in the winter. At the end of fall quarter, the project is design ready due to many analyses of requirements, documentation of design parameters, and being ready for due to the necessary resources such as Hogue lab equipment and 3D printers being available to the team.

9. ACKNOWLEDGEMENTS

It should be acknowledged that Professor Choi, Professor Pringle, and lab tech Chris Berkshire have been a big help in guiding the RC Baja senior project in fall quarter, winter quarter, and spring quarter. All Professors mentioned have been able to give good advice and knowledge when the team has been stuck or needed in assistance in either the proposal, software such as SOLIDWORKS, and how to work all sorts of equipment and tools and the machine shop found in Hogue.

APPENDIX A - Analysis

Appendix A-1 – Analysis 1 Force and Energy From Drop



Jack Huff MET 489A | Analysis #1 10/4/2021 | 1/1

Picture of problem:

Given: Max weight of car = 10 lb
Drop height = 1.5 ft

Find: Energy needed to withstand drop test & impact force from ground

Assume:
- No spring force
- Ignore forces in the y-direction
- Assume car is 10 lb

Method:
1) FBD
2) Find mass of car
3) Energy eq / kinematic eq

Sol:

① (FBD)

② 10 lbf $\frac{4.44822\,N}{1\,lbf}$ = 44.48 N $\frac{44.48\,N}{9.81\,m/s^2}$ = 4.53 kg

③

Energy

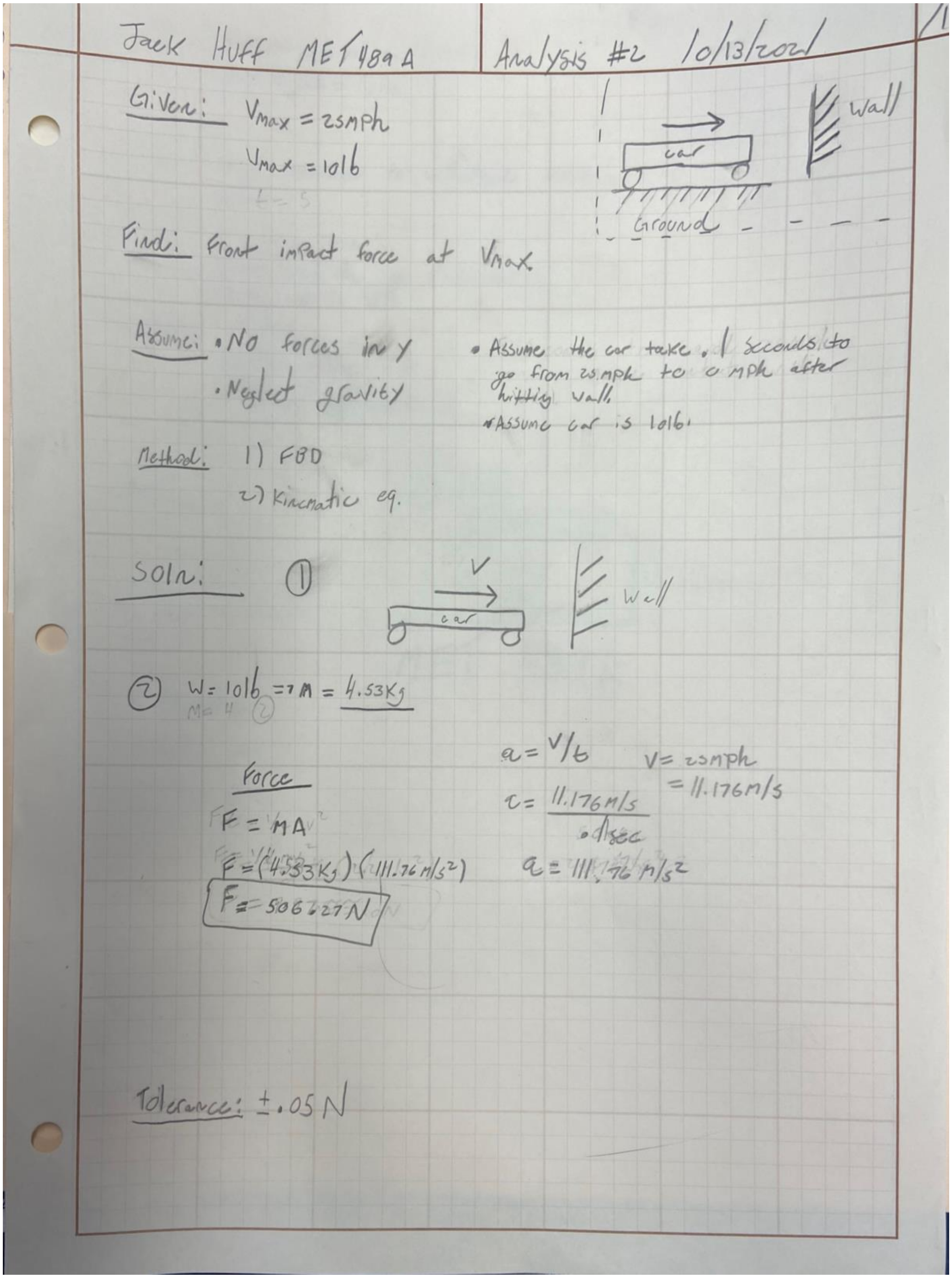
E = PE + KE
= mgh + ½mv² (KE = 0)
= (4.536 kg)(9.81 m/s²)(.4572 m)
E = 20.3 J = 14.9 ft·lb
± .5 ft·lb

Force

F = ma
F = 4.536 kg × 9.81 m/s²
F = 44.5 N ≅ 10 lbf
± .5 lbf

Figure A.1 Drop Test Analysis

Appendix A-2 – Analysis 2 Front Impact Force



Jack Huff ME 489 A | Analysis #2 | 10/13/2021

Given: $V_{max} = 25mph$

$V_{max} = 10lb$

Find: Front impact force at V_{max}

Assume: • No forces in y

• Neglect gravity

• Assume the car takes .1 seconds to go from 25 mph to 0 mph after hitting wall.

• Assume car is 10lb.

Method: 1) FBD

2) Kinematic eq.

Soln: ①

② $W = 10lb \Rightarrow m = \underline{4.53Kg}$

Force

$F = MA$

$F = (4.53Kg)(111.76 m/s^2)$

$F = 506.27N$

$a = V/t$ $V = 25mph = 11.176 m/s$

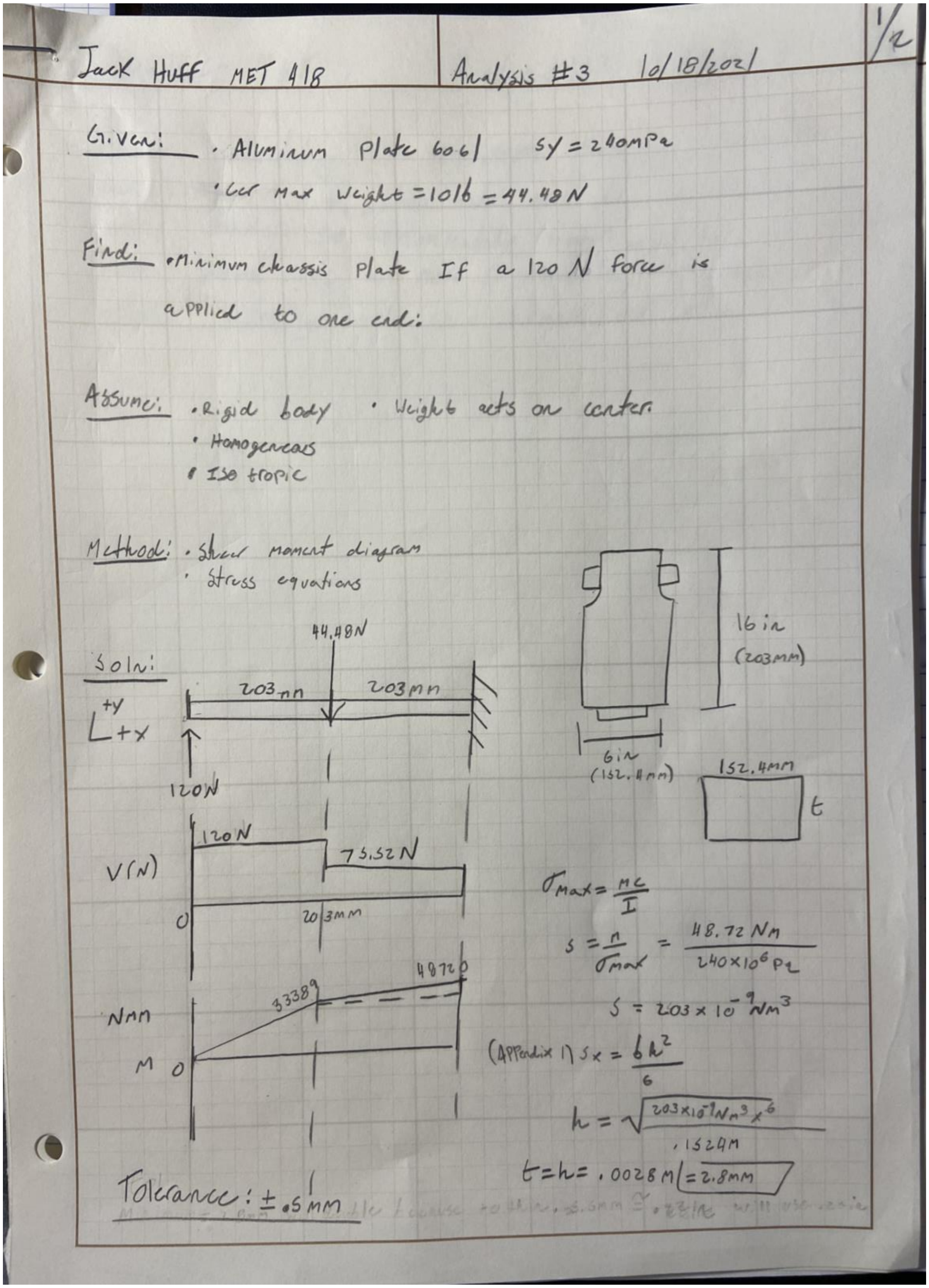
$a = \frac{11.176 m/s}{.1 sec}$

$a = 111.76 m/s^2$

Tolerance: $\pm .05 N$

Figure A.2 Front Impact Analysis

Appendix A-3 – Analysis 3 Minimum Chassis Thickness


Jack Huff MET 418 | Analysis #3 10/18/2021 | 1/2

Given: • Aluminum Plate 6061 Sy = 240MPa
• Car Max Weight = 10lb = 44.48N

Find: • Minimum chassis plate If a 120 N force is applied to one end:

Assume: • Rigid body • Weight acts on center
• Homogeneous
• Iso tropic

Method: • Shear moment diagram
• Stress equations

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

$S = \frac{M}{\sigma_{max}} = \frac{48.72\ Nm}{240\times10^{6}\ Pa}$

$S = 203 \times 10^{-9}\ Nm^3$

(Appendix 1) $S_x = \frac{bh^2}{6}$

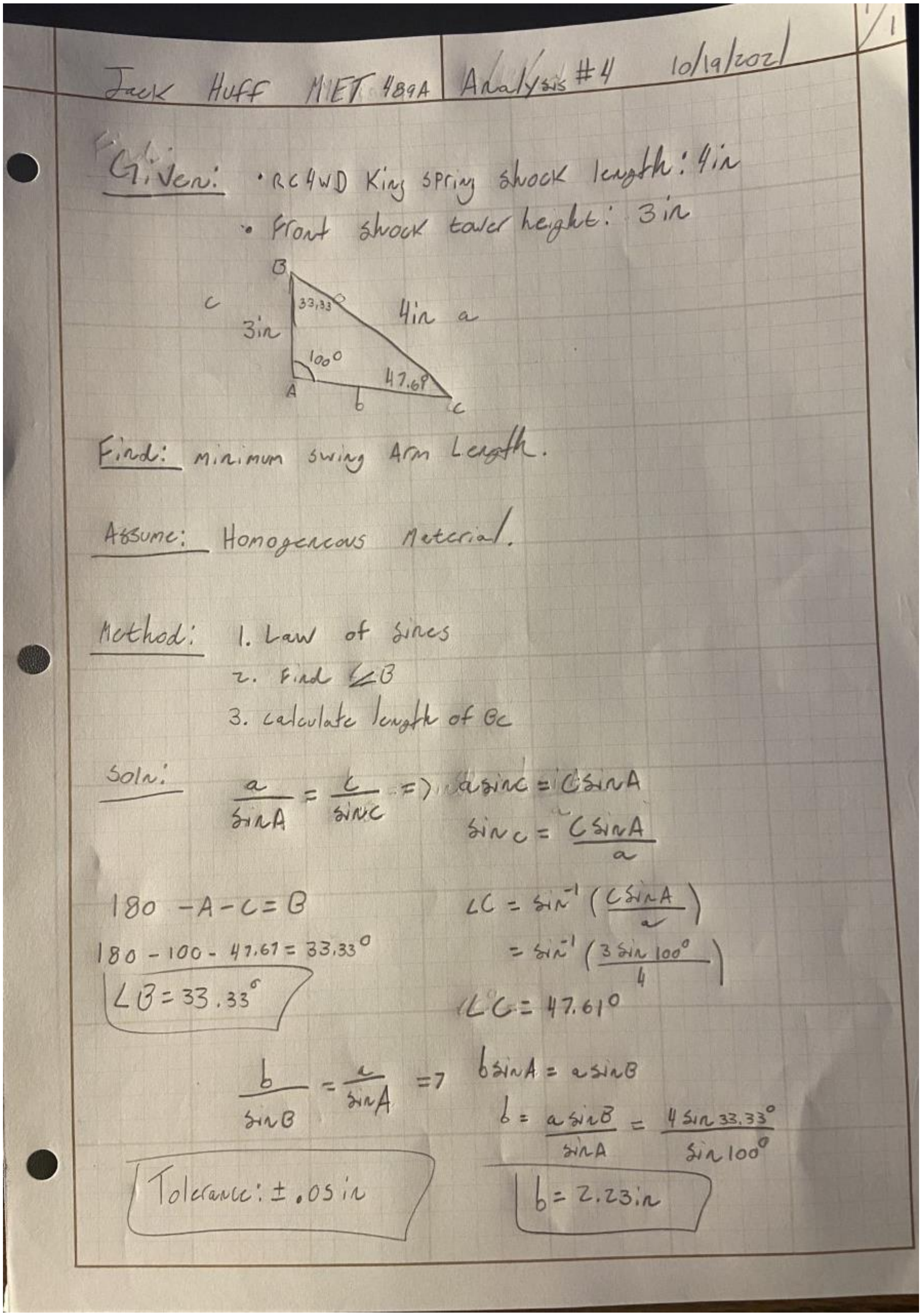
$h = \sqrt{\frac{203\times10^{-9}\ Nm^3 \times 6}{.1524\ m}}$

$t = h = .0028\ m = 2.8mm$

Tolerance: ± .5mm

Figure A.3 Chassis Analysis

Appendix A-4 Analysis 4 Minimum swing arm length



Jack Huff MET 489A | Analysis #4 | 10/19/2021 | 1/1

Given: • RC4WD King Spring shock length: 4in

• Front shock tower height: 3in

Find: Minimum swing Arm Length.

Assume: Homogeneous material.

Method: 1. Law of sines

2. Find ∠B

3. Calculate length of Bc

Soln:

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

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

$$\angle C = \sin^{-1}\left(\frac{c \sin A}{a}\right) = \sin^{-1}\left(\frac{3 \sin 100^\circ}{4}\right)$$

$$\angle C = 47.61^\circ$$

$$180 - A - C = B$$

$$180 - 100 - 47.67 = 33.33^\circ$$

$$\angle B = 33.33^\circ$$

$$\frac{b}{\sin B} = \frac{a}{\sin A} \Rightarrow b \sin A = a \sin B$$

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

Tolerance: ±.05 in

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

Figure A.4 Swing Arm Analysis

Appendix A-5 – Analysis 5 Stresses in Front Suspension Tower Arm

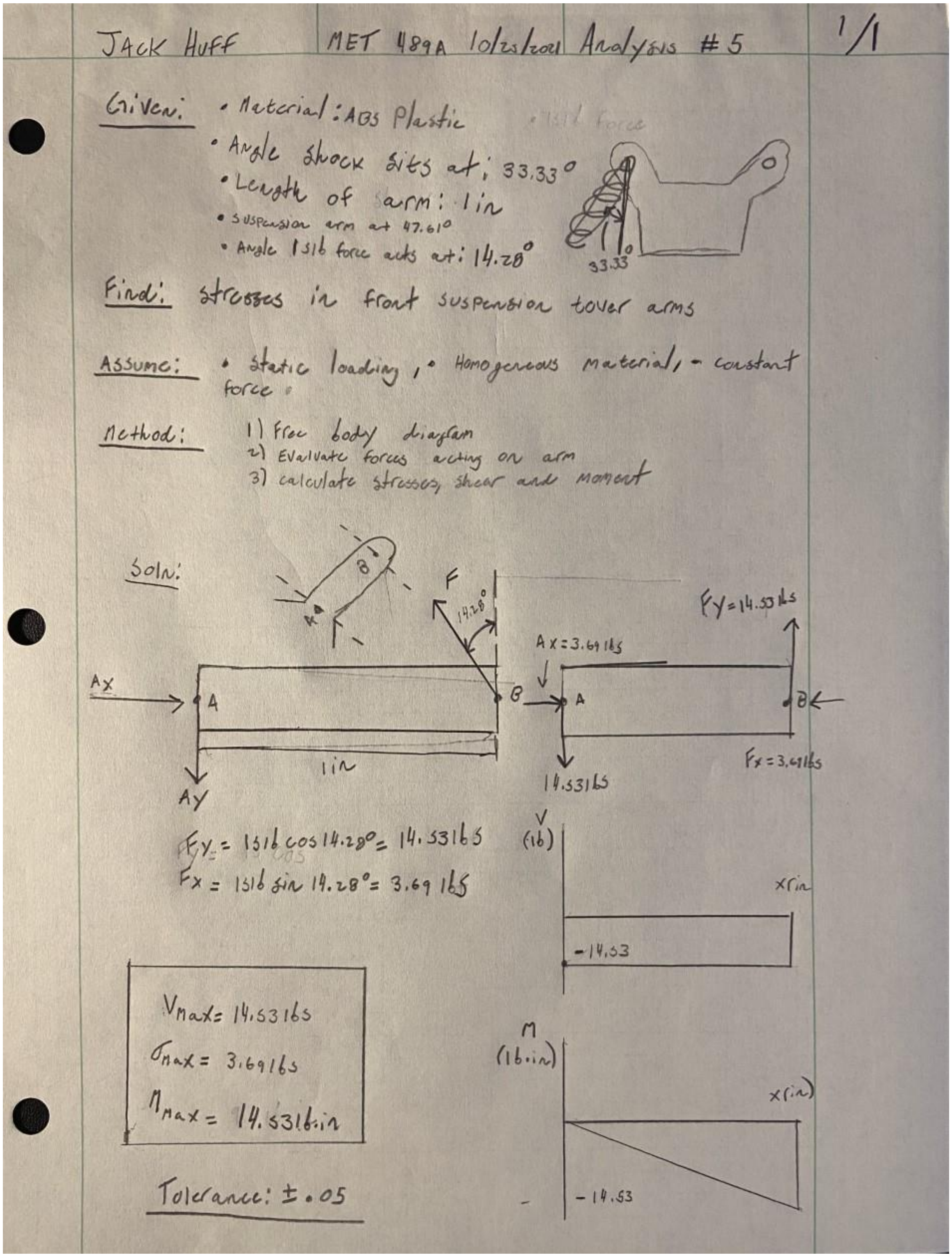


Figure A.5 Front Suspension Stress Analysis

Appendix A-6 – Analysis 6 CSA of Front Suspension Tower

Jack Huff | MET 489A 10/25/2021 | Analysis # 6 | 1/1

__Given:__ • stresses from analysis # 6, • Length of arm 1in, • Material: ABS plastic.

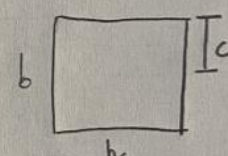
__Find:__ • CSA of front tower suspension.

__Assumptions:__ • Homogeneous material, • static loading, • constant force, • No Holes yet., • cross section will be square.

__Method:__ 1) Refer to bending moment from analysis #5
2) Bending Moment equation

__Soln:__

$$\sigma_B = \frac{Mc}{I} \qquad I = \frac{1}{12} bh^3 \qquad I = \frac{1}{12} b^4$$



$b = h$

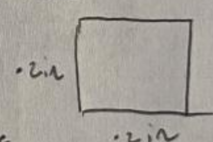
$$\sigma_B = \frac{M(\frac{1}{2}b)}{\frac{1}{12}b^4}$$

$$\sigma_B = \frac{12mb}{2b^4}$$

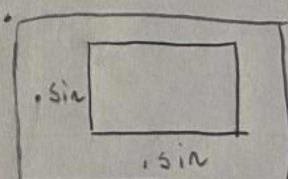
$$\sigma_B = \frac{6m}{b^3} \Rightarrow b = \sqrt[3]{\frac{6m}{\sigma_B}} = \sqrt[3]{\frac{6(14.5316 \cdot in)}{11{,}000\ Psi}}$$

$b = .19 \cong .2in$

* Flexural strength of ABS = 11,000 Psi



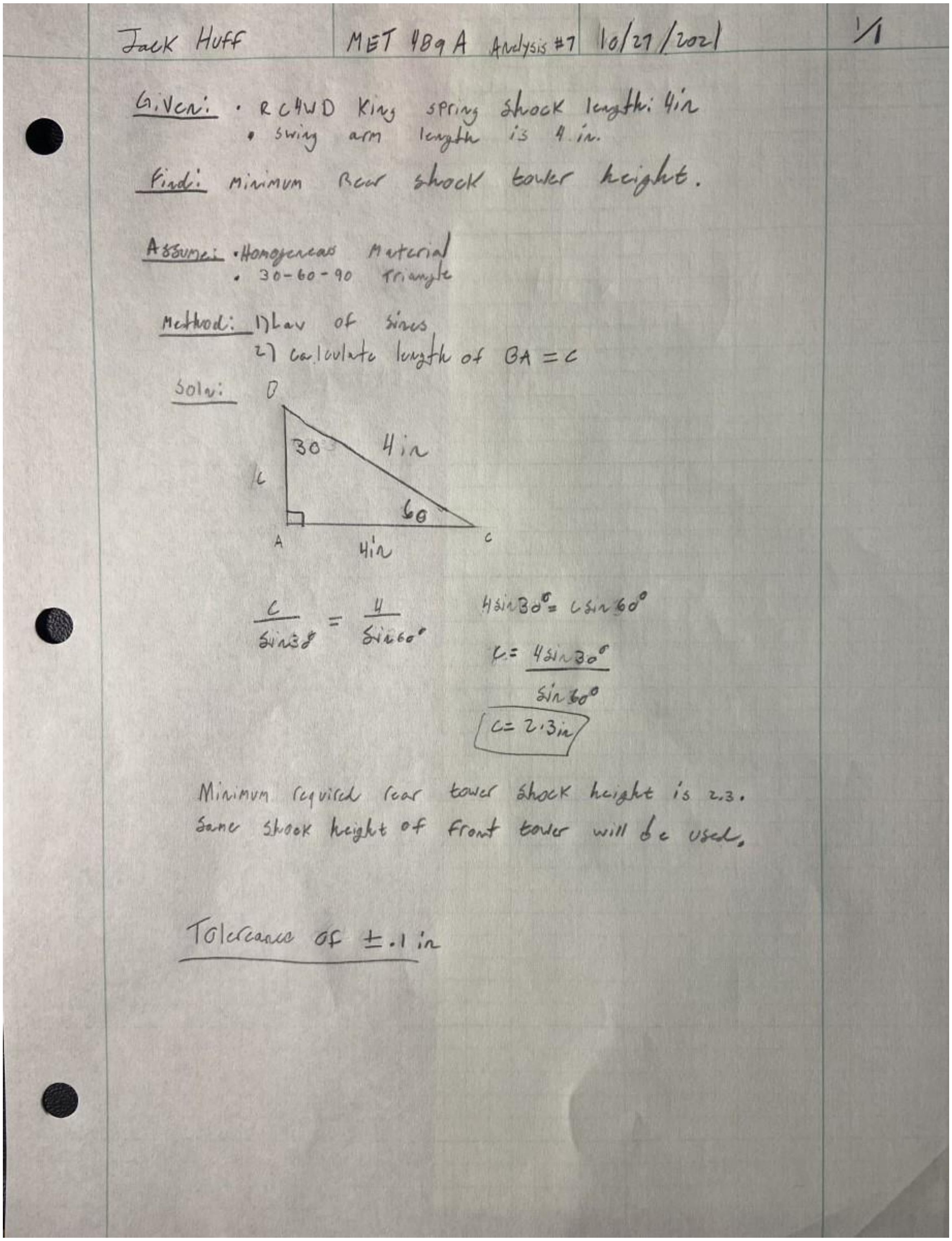
A standard size of .5in will be used for a saftey factor of 2.5.



__Tolerance: ± .01in__

Figure A.6 Front Suspension CSA Analysis

Appendix A-7 Analysis 7 Minimum Height in Rear Shock Tower


Jack Huff | MET 489 A Analysis #7 | 10/27/2021 | 1/1

Given: • RC4WD King spring shock length: 4in
• swing arm length is 4 in.

Find: minimum Rear shock tower height.

Assume: • Homogeneous Material
• 30-60-90 Triangle

Method: 1) Law of sines
2) calculate length of BA = c

Solve:

$$\frac{c}{\sin 30} = \frac{4}{\sin 60°}$$

$$4\sin 30° = c\sin 60°$$

$$c = \frac{4\sin 30°}{\sin 60°}$$

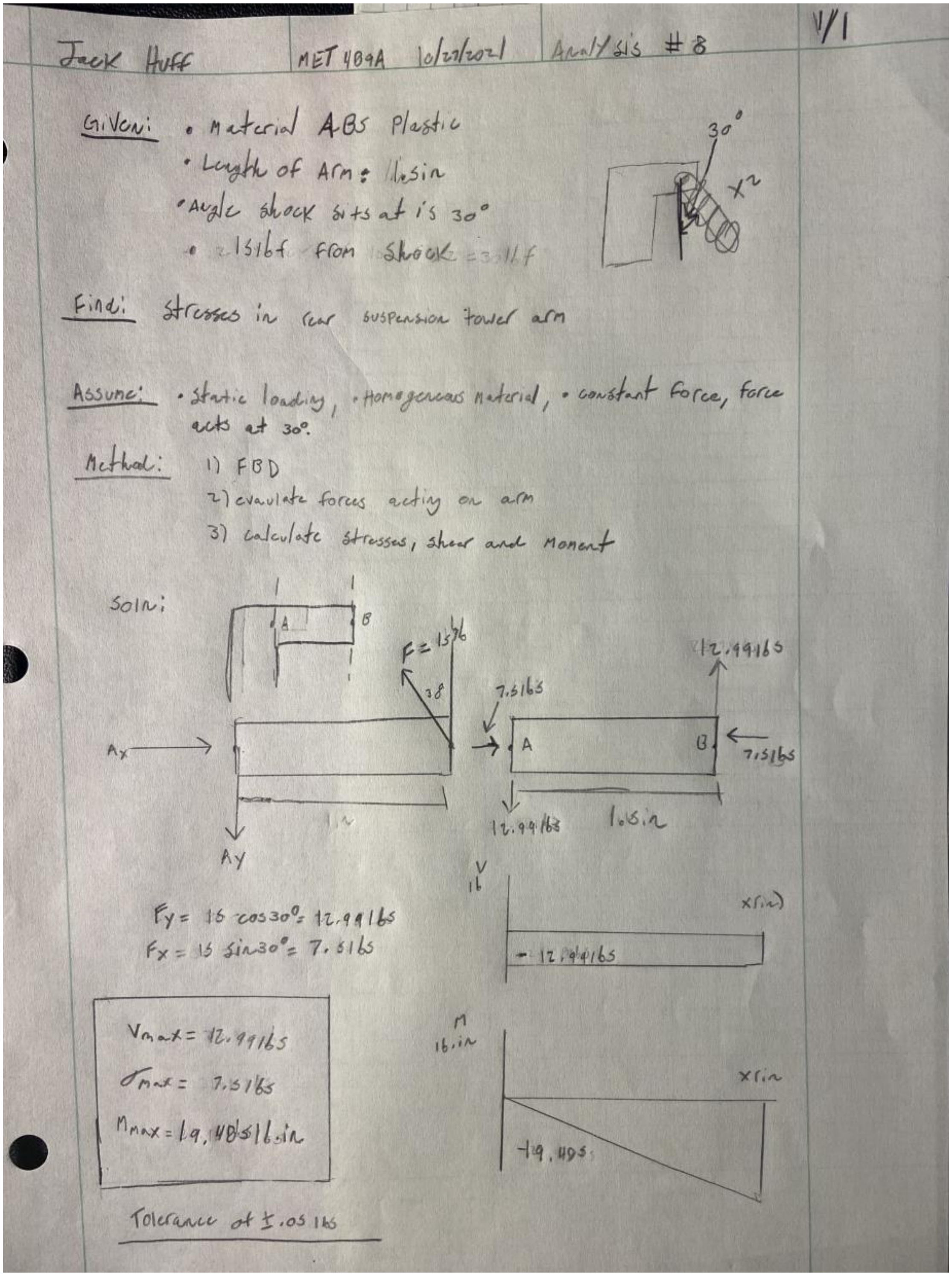
$$c = 2.3\text{in}$$

Minimum required rear tower shock height is 2.3.
Same shock height of front tower will be used.

Tolerance of ±.1 in

Figure A.7 Minimum Height Analysis

Appendix A-8- Analysis 8 Stresses in Rear Suspension Tower Arm


Jack Huff | MET 484A | 10/27/2021 | Analysis #8 | 1/1

Given: • material ABS Plastic
• Length of Arm: 1.65in
• Angle shock sits at is 30°
• 15lbf from shock

Find: stresses in rear suspension tower arm

Assume: • static loading, • Homogeneous material, • constant force, force acts at 30°.

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

Soln:

$F_y = 15 \cos 30° = 12.99$ lbs

$F_x = 15 \sin 30° = 7.5$ lbs

$V_{max} = 12.99$ lbs

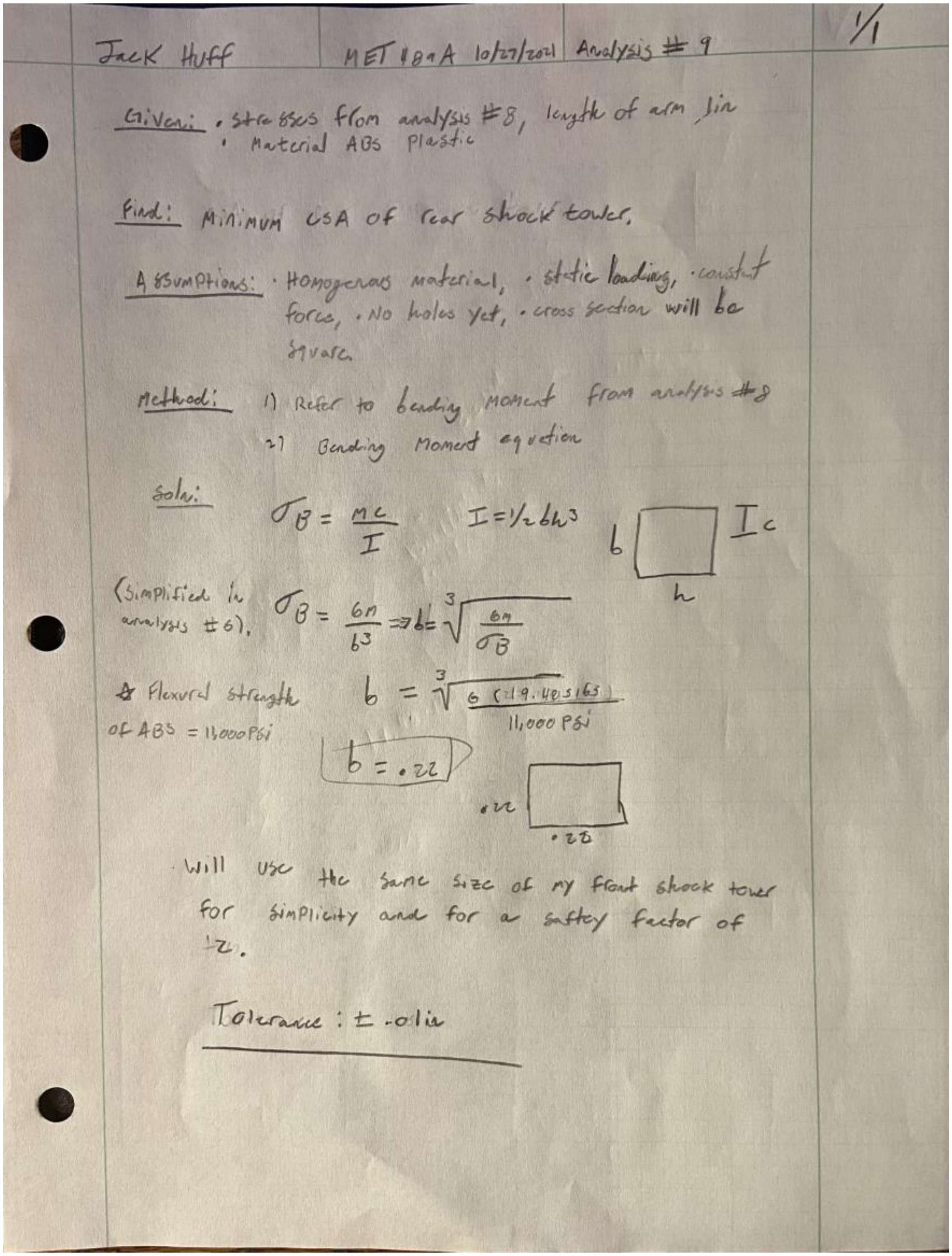
$\sigma_{max} = 7.5$ lbs

$M_{max} = 19.485$ lb·in

Tolerance of ±.05 lbs

Figure A.8 Rear Suspension Stress Analysis

Appendix A-9 Analysis 9 Cross Sectional Area in Rear Suspension Tower Arm



Jack Huff MET 189A 10/27/2021 Analysis # 9 1/1

Given: • stresses from analysis #8, length of arm 1in
• Material ABS plastic

Find: Minimum CSA of rear shock tower.

Assumptions: • Homogeneous material, • static loading, • constant force, • No holes yet, • cross section will be square.

Method: 1) Refer to bending moment from analysis #8
2) Bending Moment equation

Soln:

$$\sigma_B = \frac{Mc}{I} \qquad I = 1/12\, bh^3$$

(Simplified in analysis #6).

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

* Flexural strength of ABS = 11,000 Psi

$$b = \sqrt[3]{\frac{6\,(19.405\,165)}{11{,}000\text{ Psi}}}$$

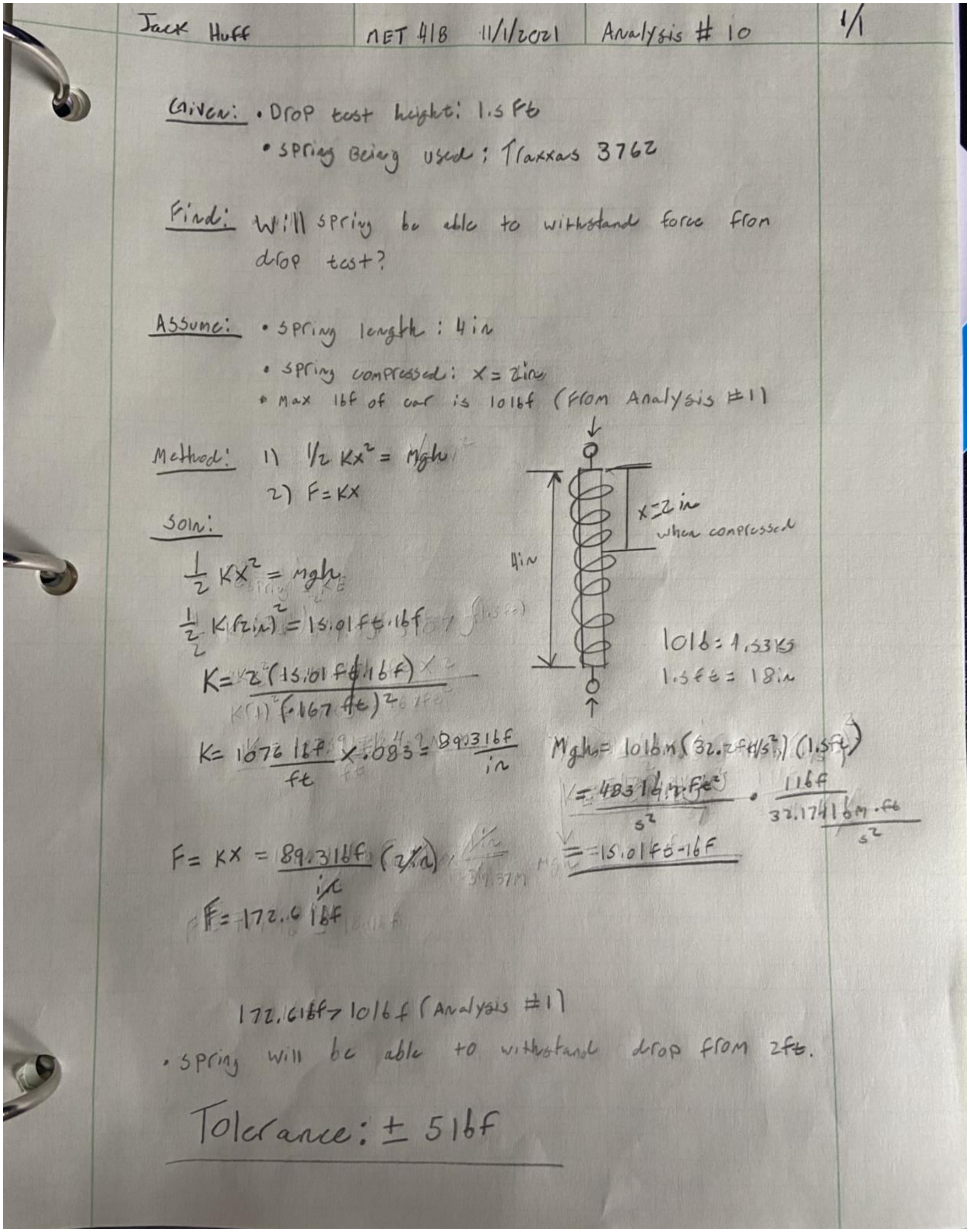
$$\boxed{b = .22}$$

• Will use the same size of my front shock tower for simplicity and for a saftey factor of 2.

Tolerance: ± .01 in

Figure A.9 CSA of Rear Suspension Tower Arm

Appendix A-10 Analysis 10 Spring Force



Jack Huff | MET 418 | 11/1/2021 | Analysis # 10 | 1/1

Given: • Drop test height: 1.5 ft
• Spring being used: Traxxas 3762

Find: Will spring be able to withstand force from drop test?

Assume: • Spring length: 4 in
• Spring compressed: $x = 2$ in
• Max lbf of car is 10 lbf (from Analysis #1)

Method: 1) $\frac{1}{2}Kx^2 = mgh$
2) $F = Kx$

Soln:

$\frac{1}{2}Kx^2 = mgh$

$\frac{1}{2}K(2\,in)^2 = 15.01\ ft\cdot lbf$

$K = \frac{2(15.01\ ft\cdot lbf)}{(.167\ ft)^2}$

$K = 1076\ \frac{lbf}{ft} \times .083 = 89.31\ \frac{lbf}{in}$

4 in

$x = 2$ in when compressed

10 lb = 4.53 kg

1.5 ft = 18 in

$Mgh = 10\ lbm(32.2\ ft/s^2)(1.5\ ft)$

$= 483\ \frac{lbm\cdot ft^2}{s^2} \cdot \frac{1\ lbf}{32.174\ \frac{lbm\cdot ft}{s^2}}$

$= 15.01\ ft\cdot lbf$

$F = Kx = 89.31\ \frac{lbf}{in}(2\,in)$

$F = 172.6$ lbf

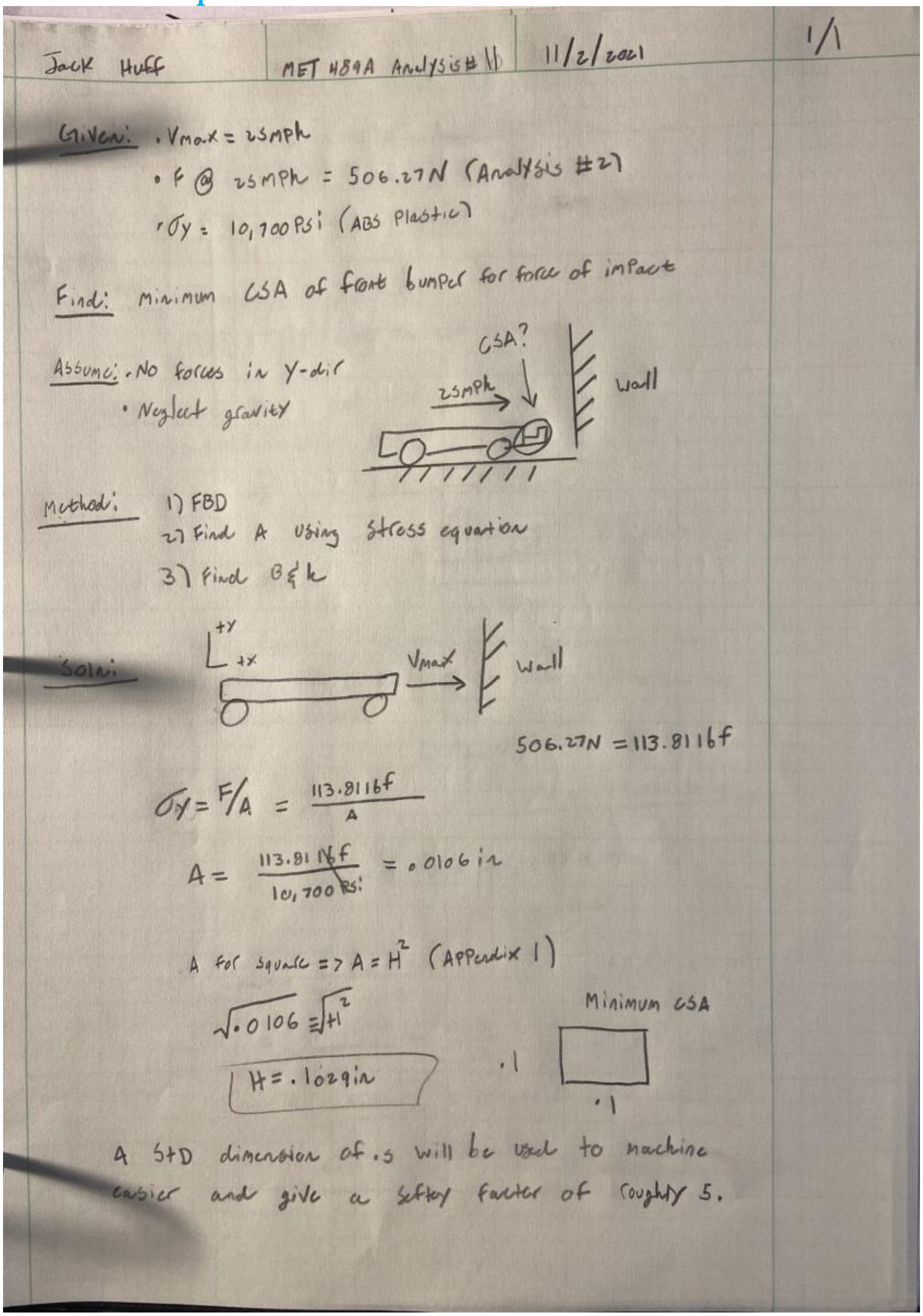
172.6 lbf > 10 lbf (Analysis #1)

• Spring will be able to withstand drop from 2 ft.

Tolerance: ± 5 lbf

Figure A.10 Spring Force Analysis

Appendix A-11 Analysis 11 Minimum Cross-Sectional Area of Front Bumper



Jack Huff | MET 484A Analysis # 11 | 11/2/2021 | 1/1

Given: • V_{max} = 25mph
• F @ 25mph = 506.27N (Analysis #2)
• σ_y = 10,700 Psi (ABS Plastic)

Find: minimum CSA of front bumper for force of impact

Assume: • No forces in y-dir
• Neglect gravity

Method: 1) FBD
2) Find A using stress equation
3) Find B & h

Soln:

506.27N = 113.81 lbf

$\sigma_y = F/A = \frac{113.81\,lbf}{A}$

$A = \frac{113.81\,lbf}{10,700\,Psi} = .0106\,in$

A for square => $A = H^2$ (Appendix 1)

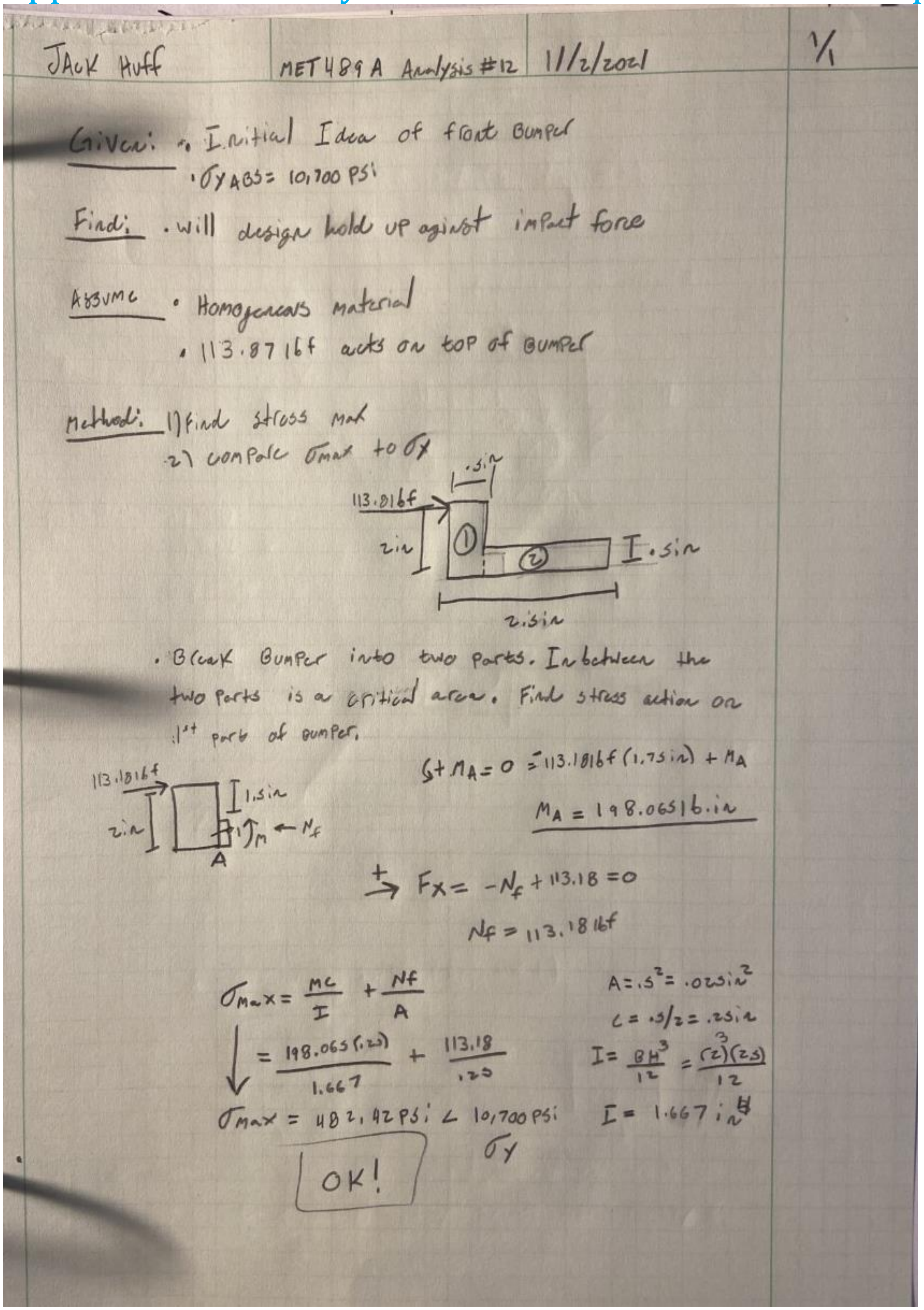
$\sqrt{.0106} = \sqrt{H^2}$

H = .1029 in

A STD dimension of .5 will be used to machine easier and give a saftey factor of roughly 5.

Figure A.11 CSA of Front Bumper

Appendix A-12 Analysis 12 Stress Check in Front Bumper



Jack Huff | MET489A Analysis #12 | 11/2/2021 | 1/1

Given: • Initial Idea of front bumper
• $\sigma_{Y\,ABS} = 10{,}700$ psi

Find: • will design hold up against impact force

Assume • Homogeneous material
• 113.87 lbf acts on top of bumper

Method: 1) find stress max
2) compare σ_{max} to σ_Y

• Break bumper into two parts. In between the two parts is a critical area. Find stress action on 1st part of bumper.

$$\circlearrowleft + M_A = 0 = -113.18\text{lbf}(1.75\text{in}) + M_A$$

$$M_A = 198.065\ \text{lb.in}$$

$$\xrightarrow{+} F_x = -N_f + 113.18 = 0$$

$$N_f = 113.18\ \text{lbf}$$

$$\sigma_{max} = \frac{Mc}{I} + \frac{N_f}{A} = \frac{198.065(.25)}{1.667} + \frac{113.18}{.25}$$

$A = .5^2 = .025\text{in}^2$

$c = .5/2 = .25\text{in}$

$I = \frac{BH^3}{12} = \frac{(2)^3(2.5)}{12}$

$I = 1.667\ \text{in}^4$

$\sigma_{max} = 482.42\ \text{psi} < 10{,}700\ \text{psi}$ (σ_Y)

OK!

Figure A.12 Stresses in Front Bumper

APPENDIX B – Drawings

Appendix B-1 – Drawing Tree

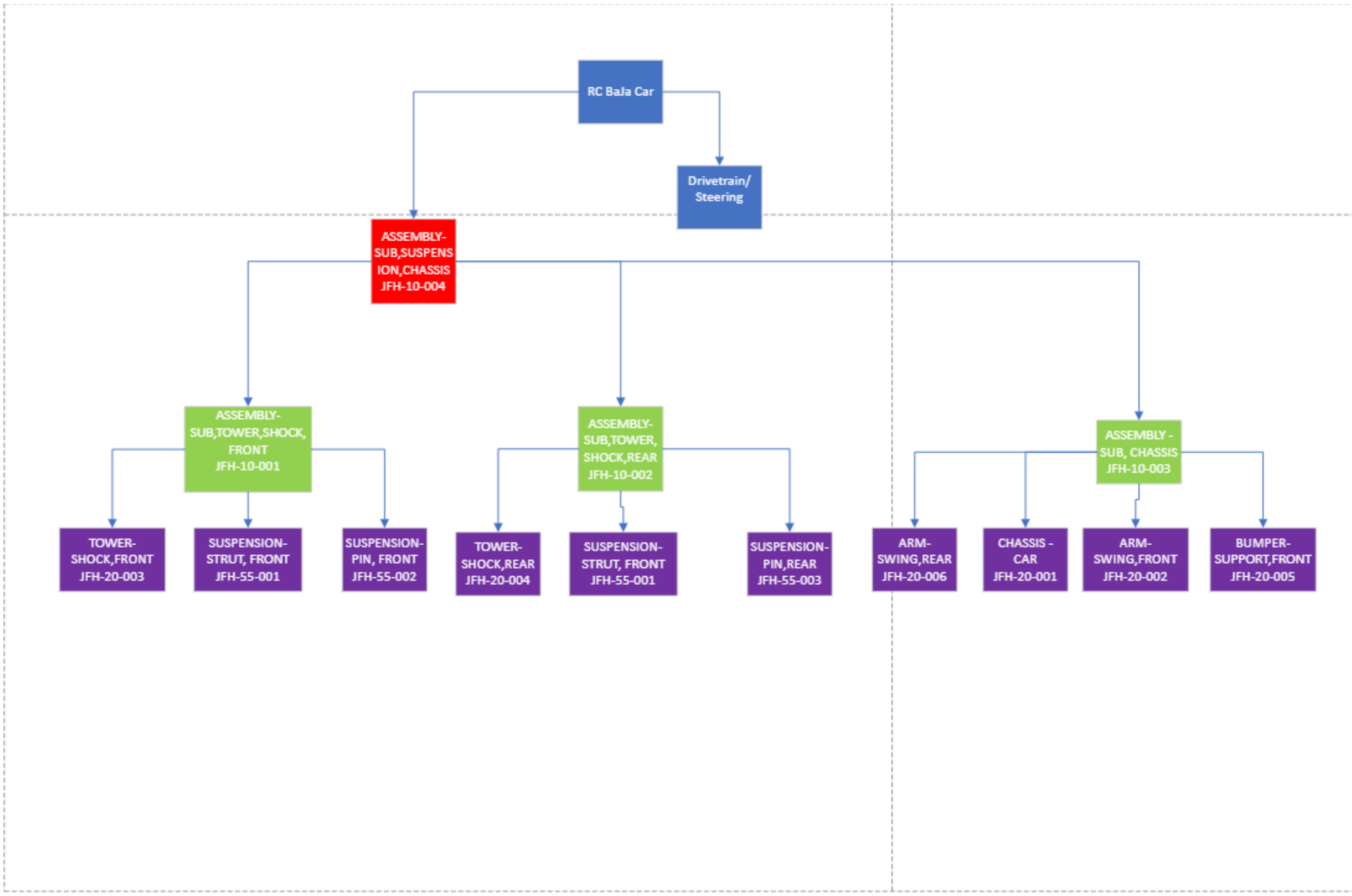


Figure B.1 Drawing Tree

Appendix B-2- ASSEMBLY- VEHICLE, RC BAJA

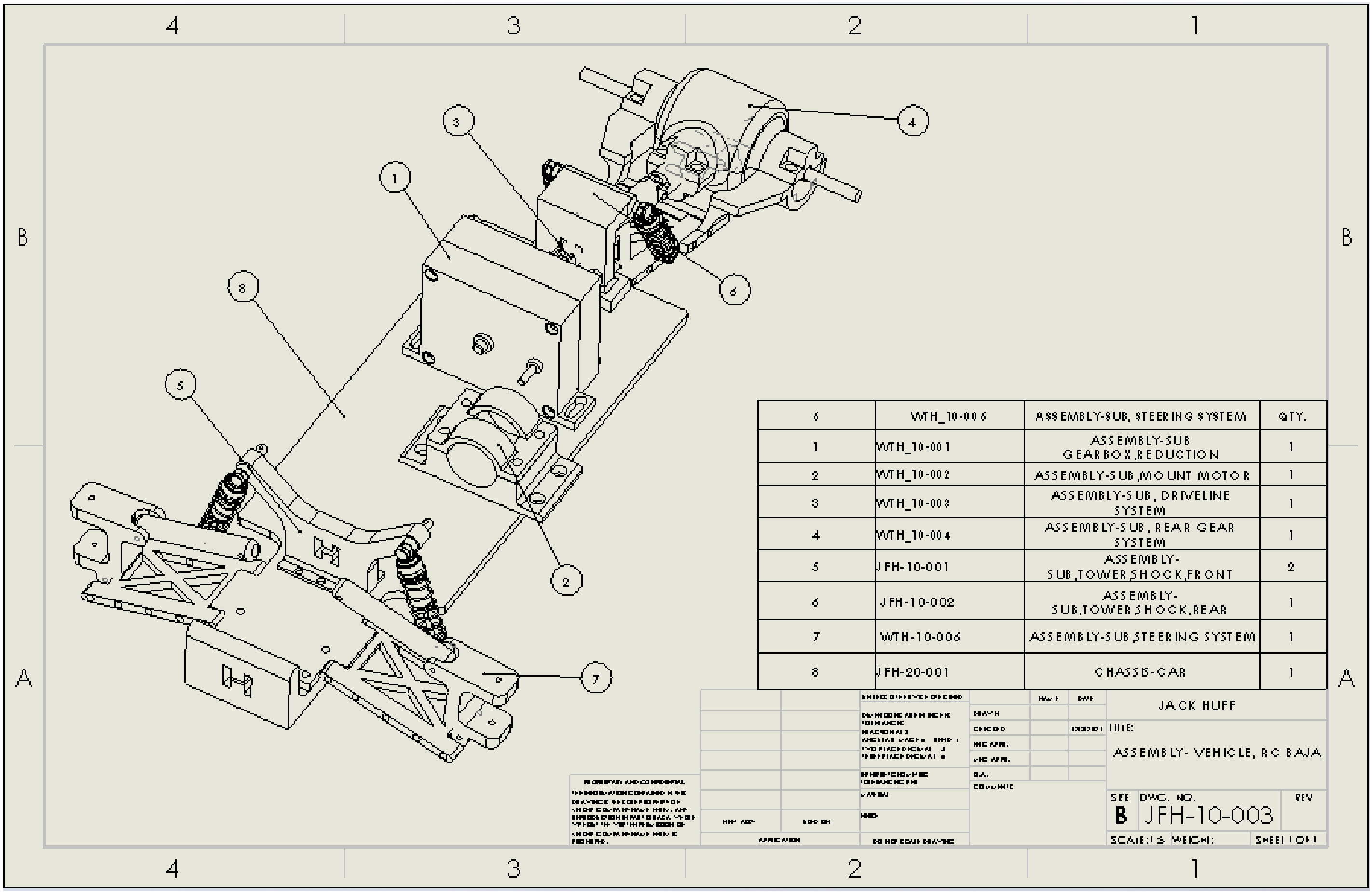
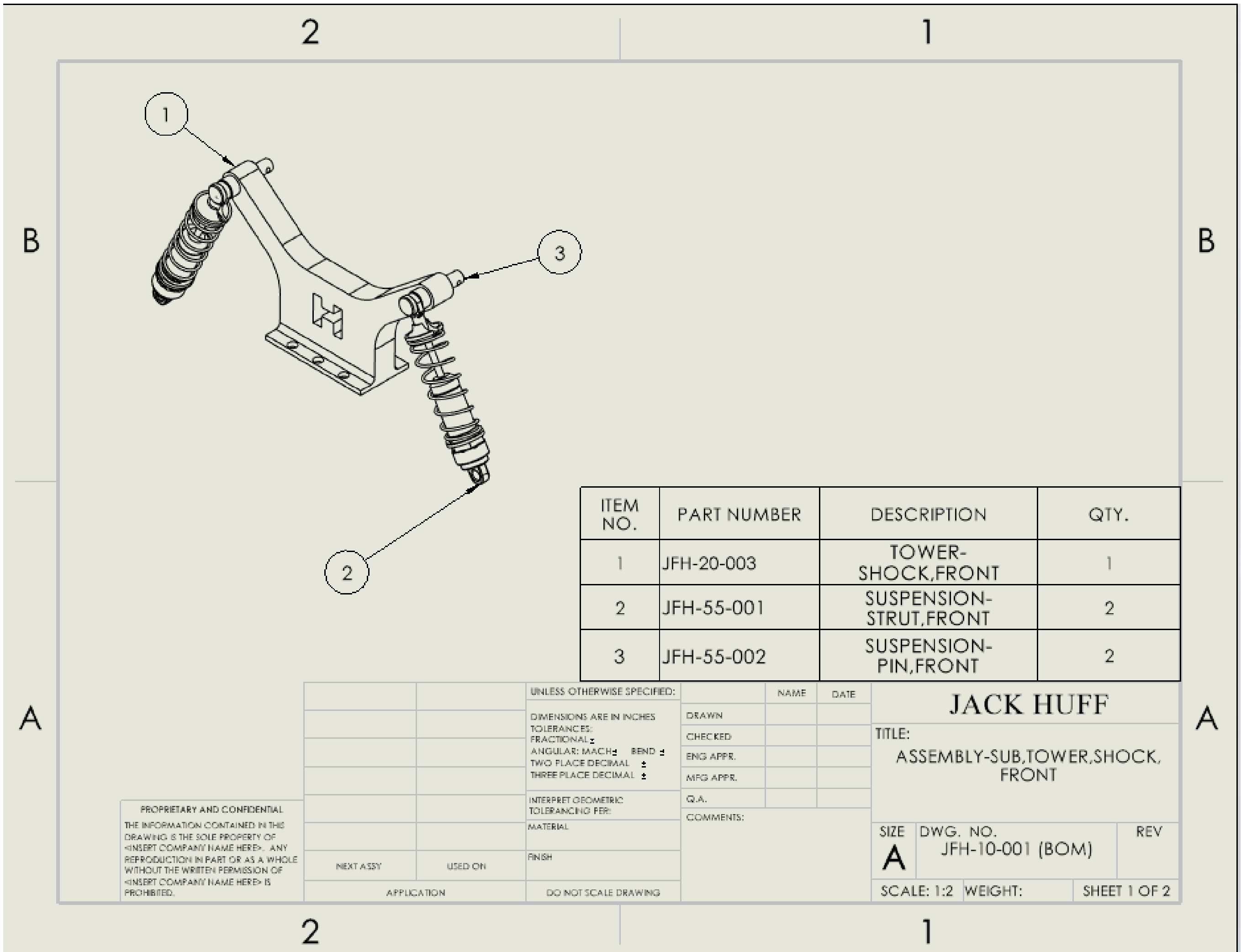


Figure B.2 DWG of Full Assembly

Appendix B-3 – ASSEMBLY SUSPENSION-SUPPORT, FRONT (BOM)



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	JFH-20-003	TOWER-SHOCK,FRONT	1
2	JFH-55-001	SUSPENSION-STRUT,FRONT	2
3	JFH-55-002	SUSPENSION-PIN,FRONT	2

Figure B.3 BOM of Front Suspension Assembly

Appendix B-4 ASSEMBLY SUSPENSION-SUPPORT, FRONT

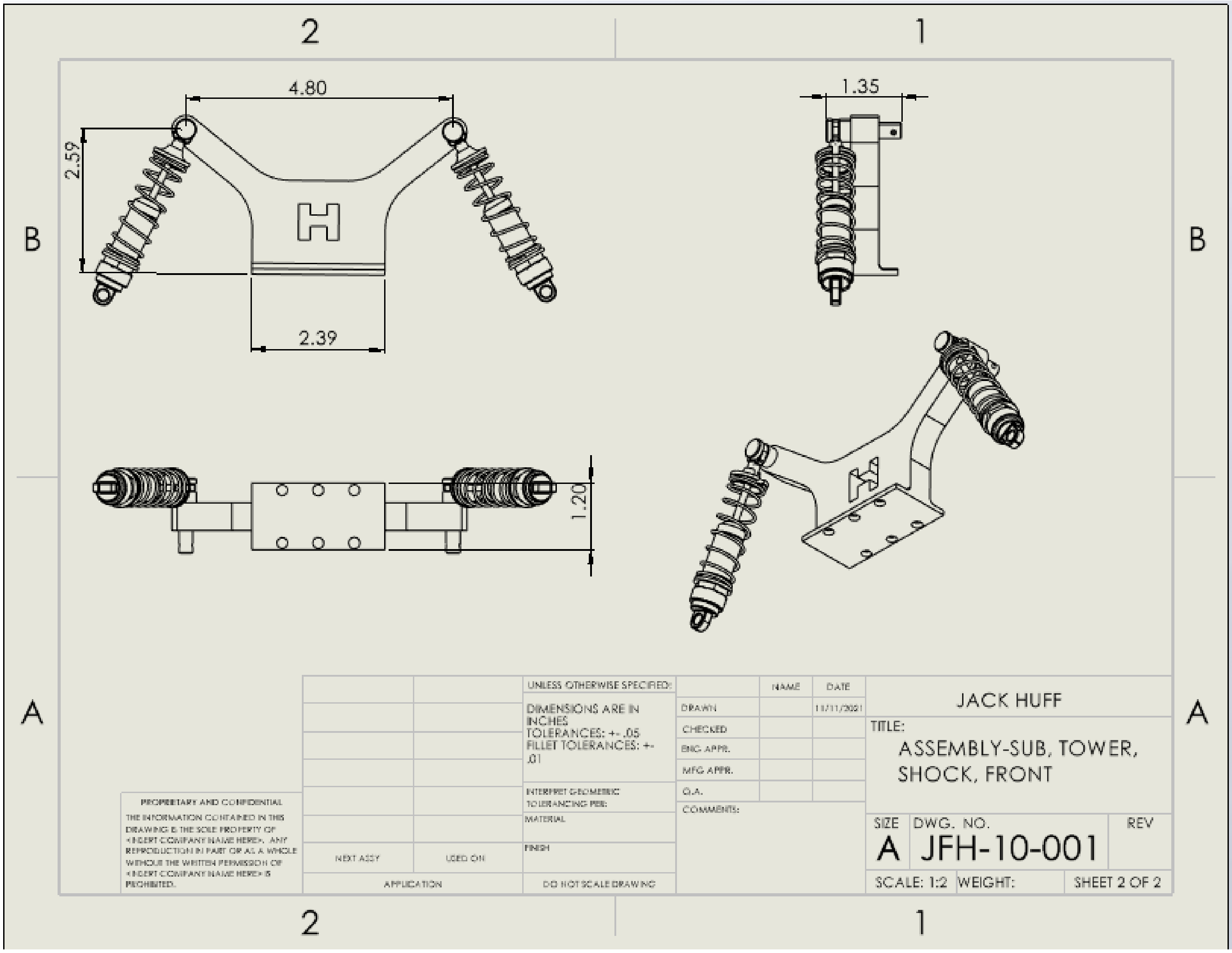


Figure B.4 DWG of Front Suspension Assembly

Appendix B-5 ASSEMBLY SUSPENSION-SUPPORT, REAR (BOM)

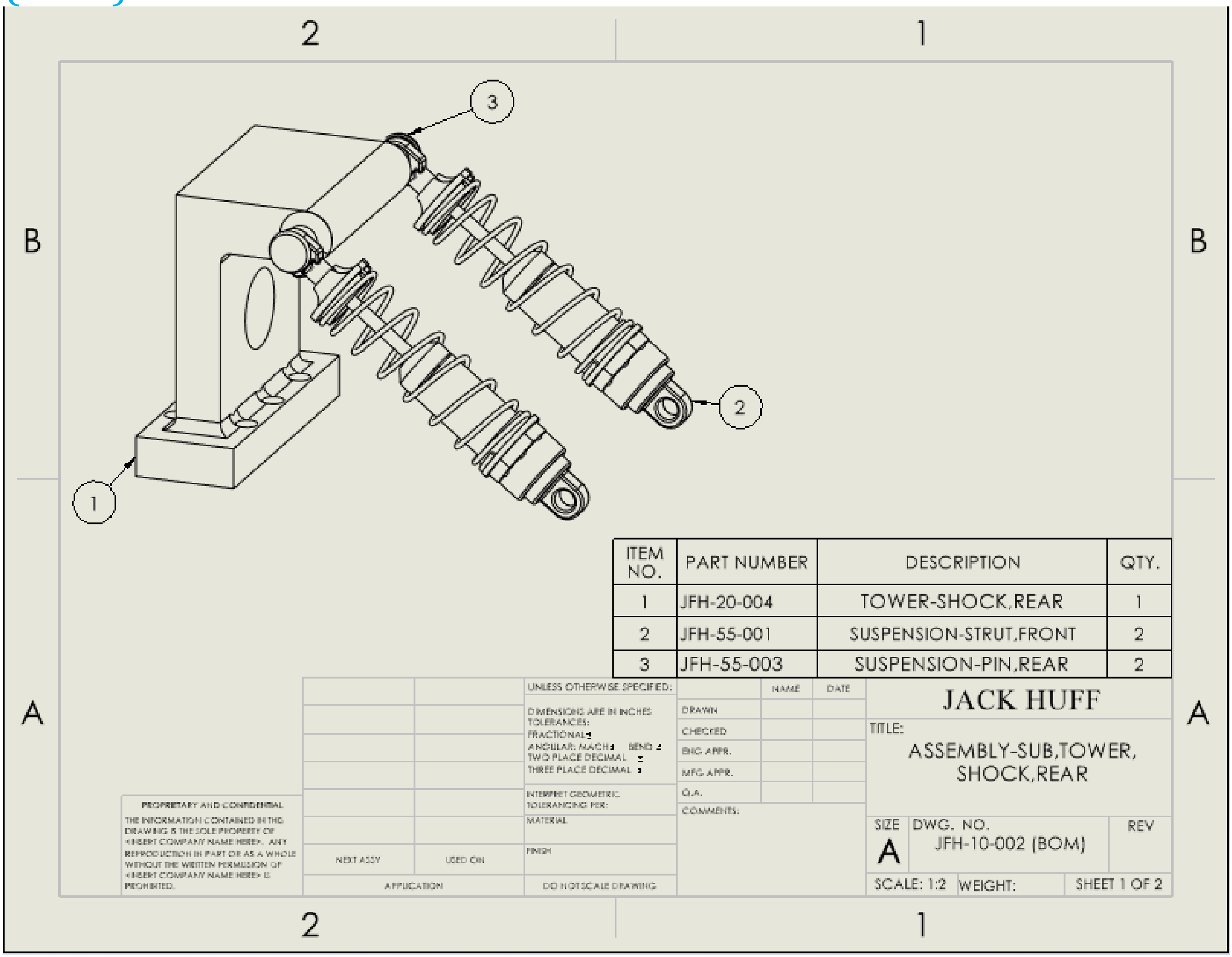


Figure B.5 BOM of Rear Shock Tower Assembly

Appendix B-6 ASSEMBLY SUSPENSION-SUPPORT, REAR

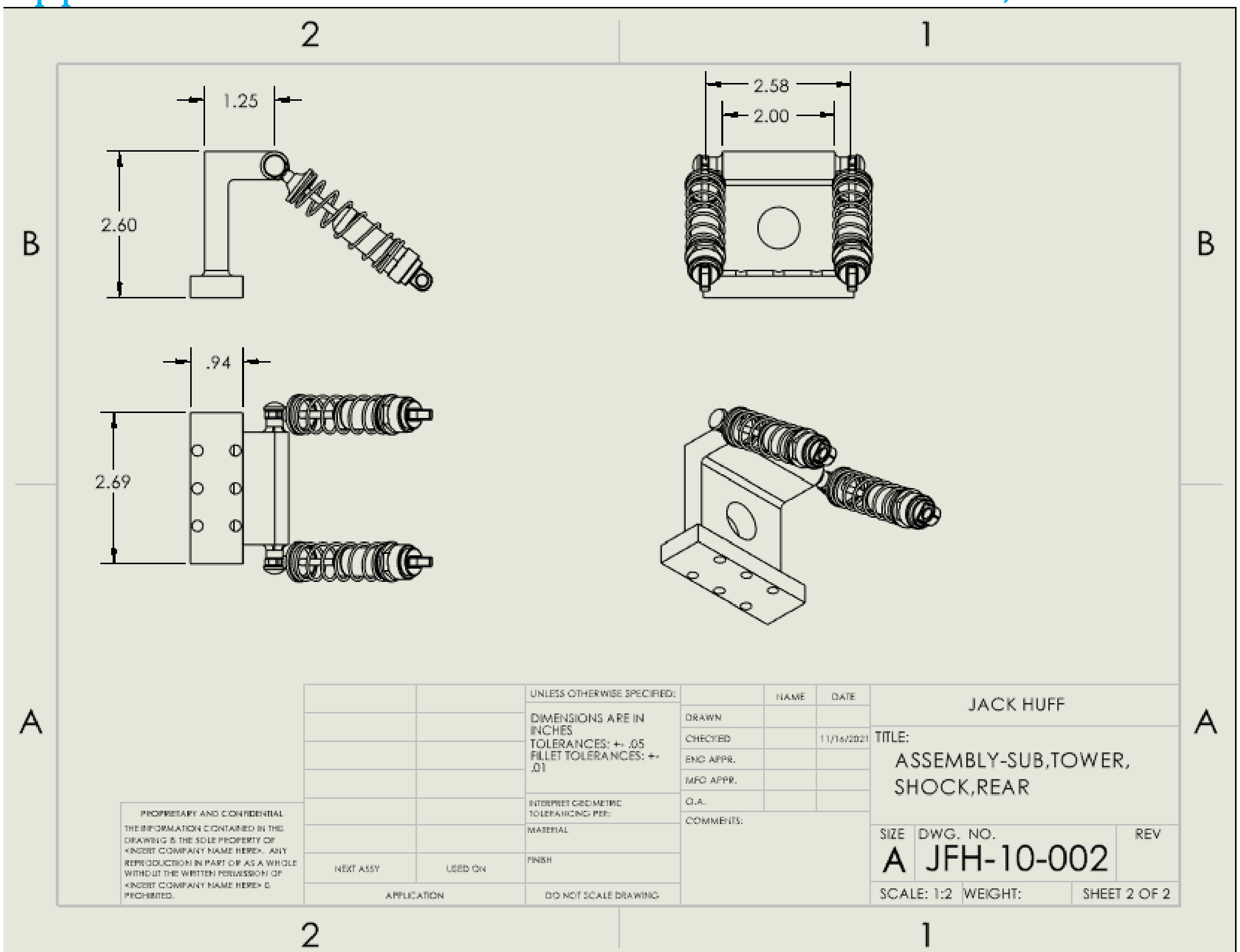


Figure B.6 DWG of Rear Tower Assembly

Appendix B-7 – CHASSIS-CAR

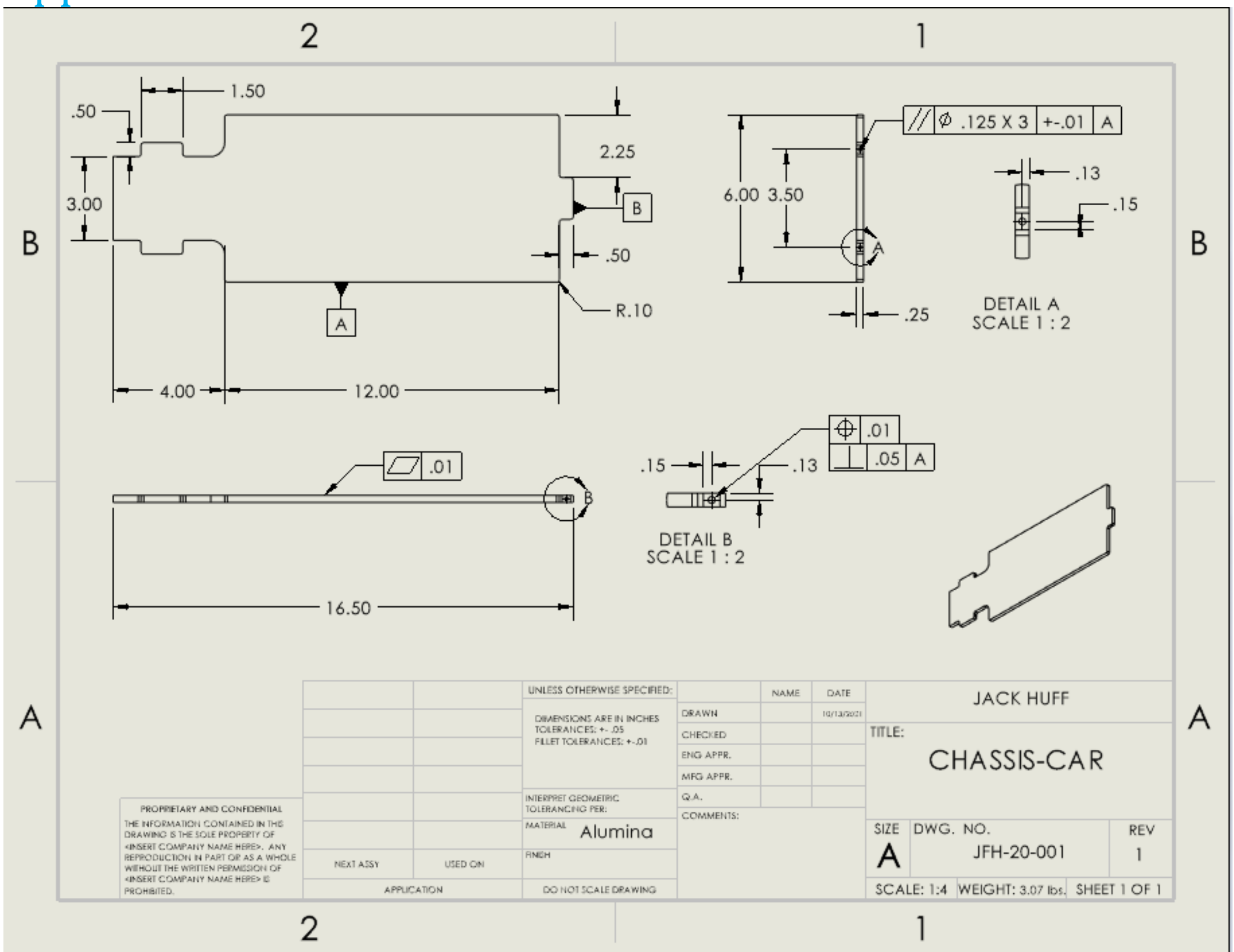


Figure B.7 Drawing of Chassis

Appendix B-8 – ARM-SWING, FRONT

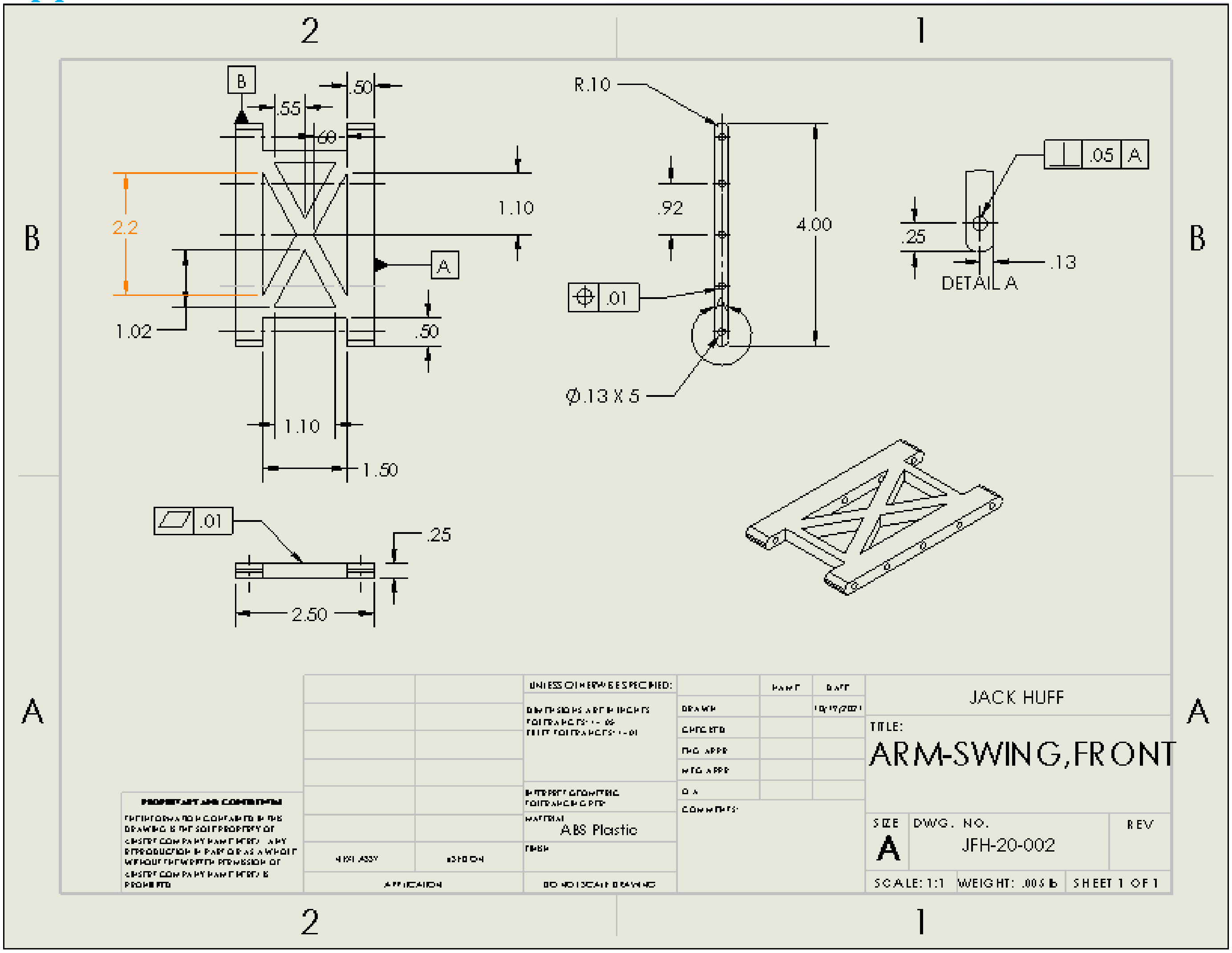


Figure B.8 Drawing of Front Swing Arm

Appendix B-9 - TOWER-SHOCK, FRONT

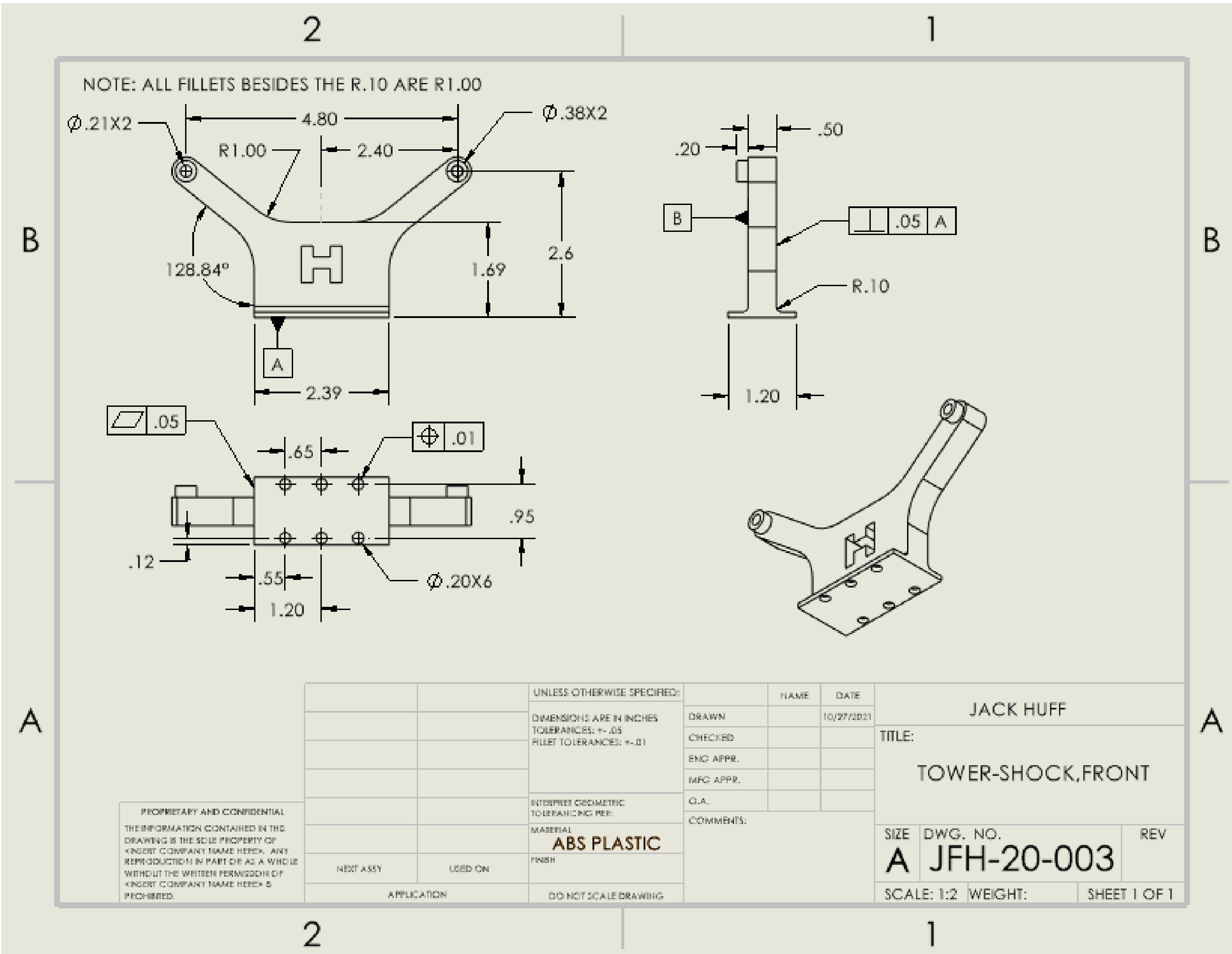


Figure B.9 Drawing of Front Shock Tower

Appendix B-10 – TOWER-SHOCK, REAR

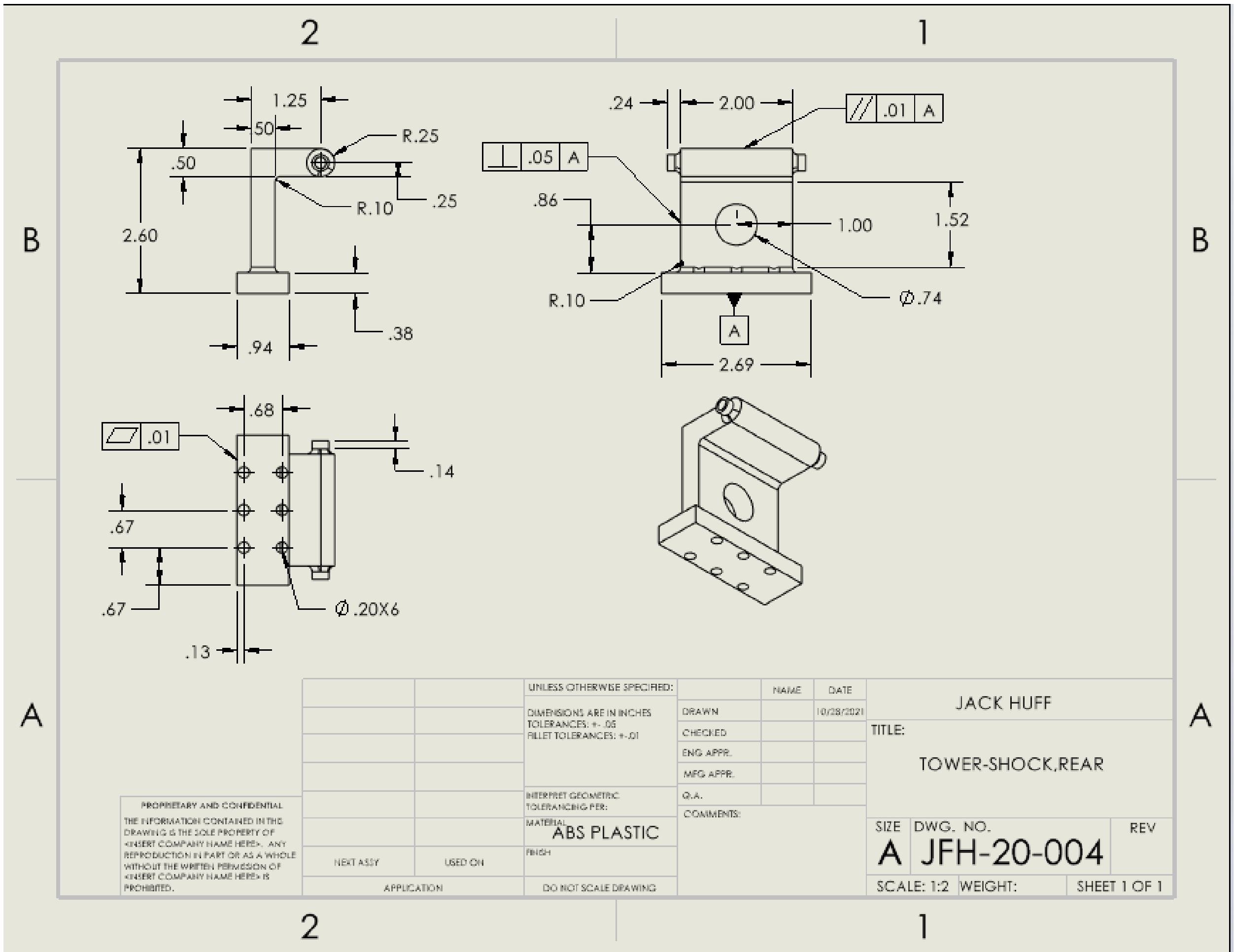


Figure B.10 Drawing of Rear Shock Tower

Appendix B-11 – SUPPORT-BUMPER, FRONT

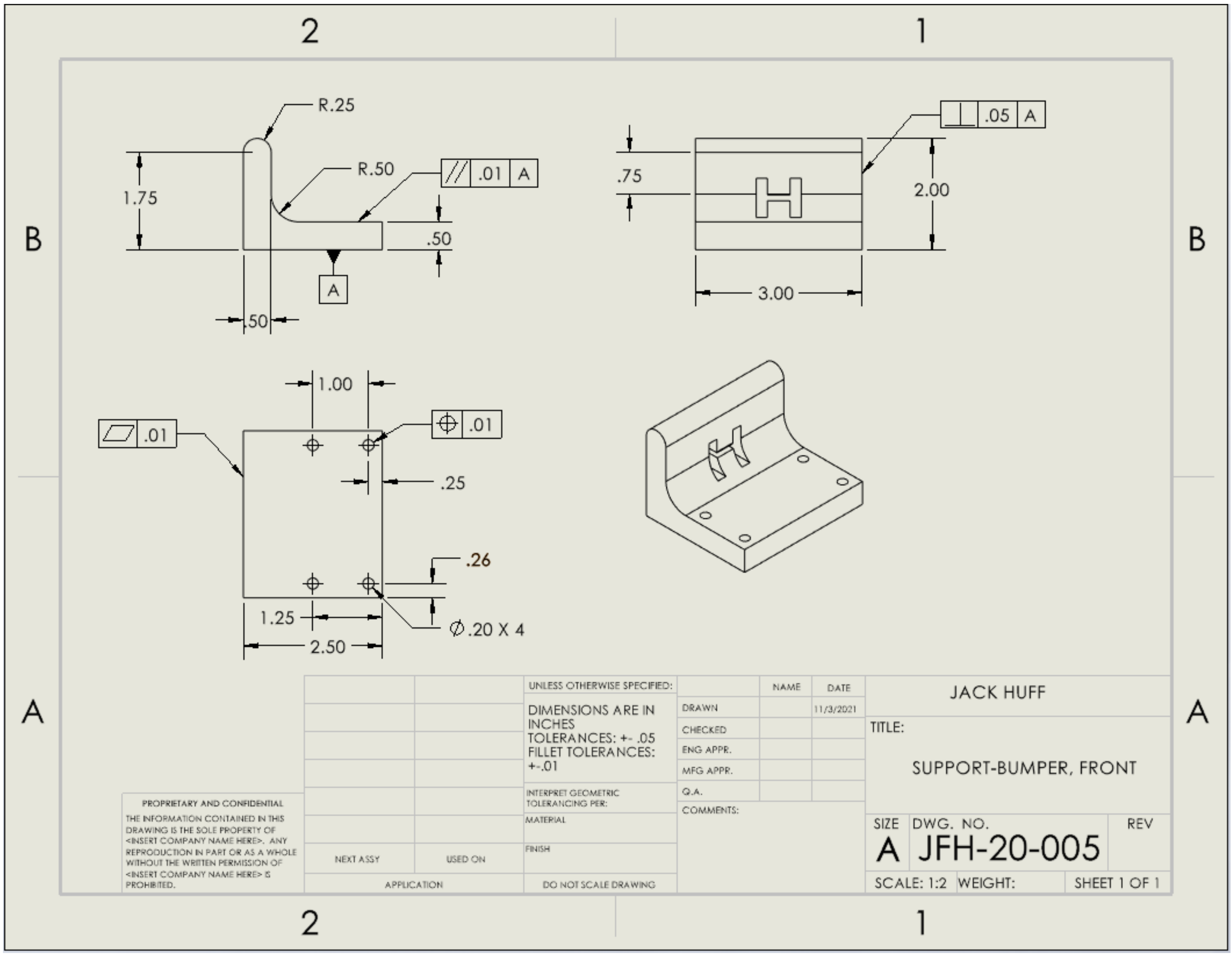


Figure B.11 DWG of Front Bumper

Appendix B-12-ARM – SWING, REAR

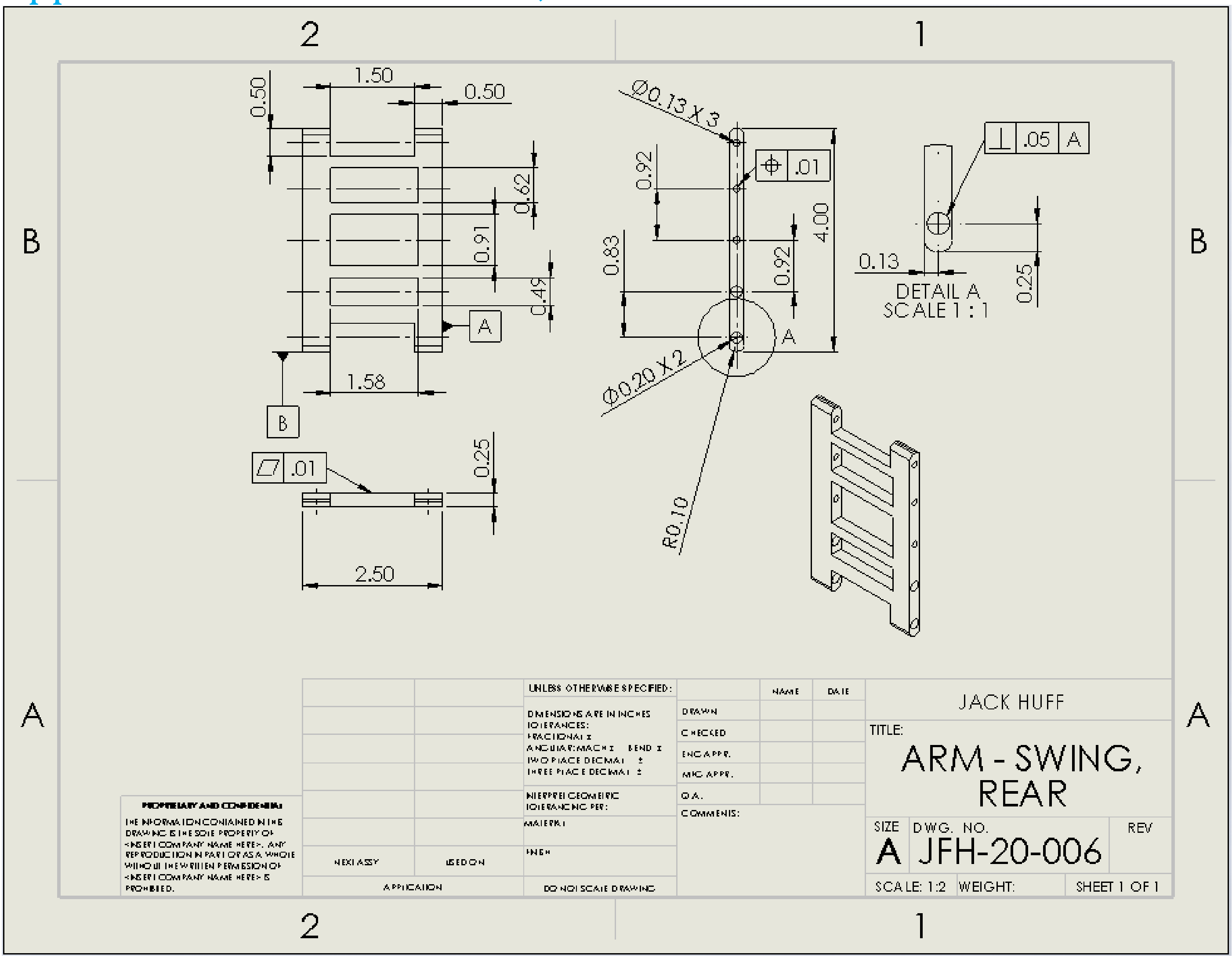


Figure B.12 DWG of Rear Swing Arm

Appendix B-13 – STRUT-SUSPENSION, FRONT

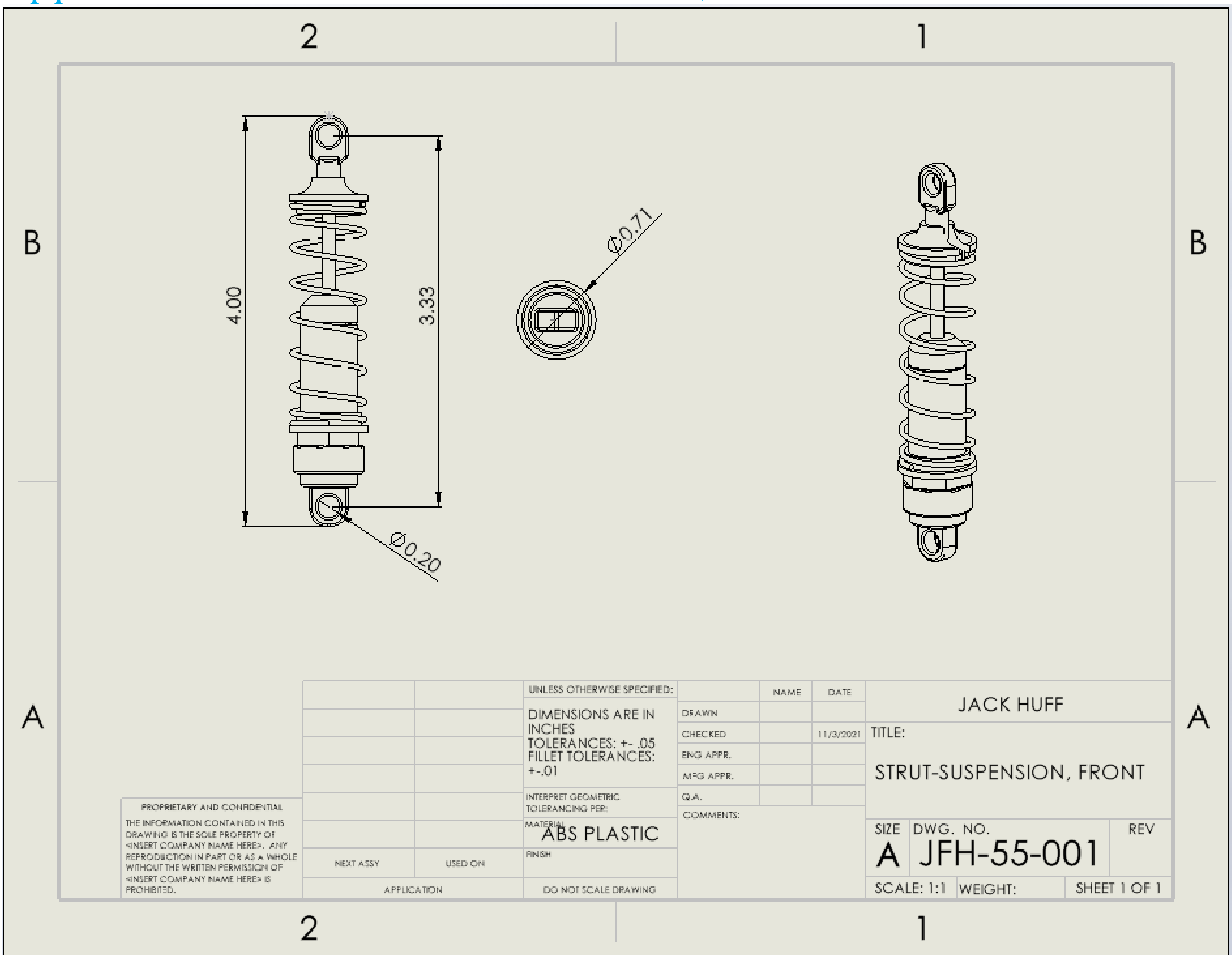


Figure B.13 DWG of Strut

Appendix B-14 – SUSPENSION-PIN, FRONT

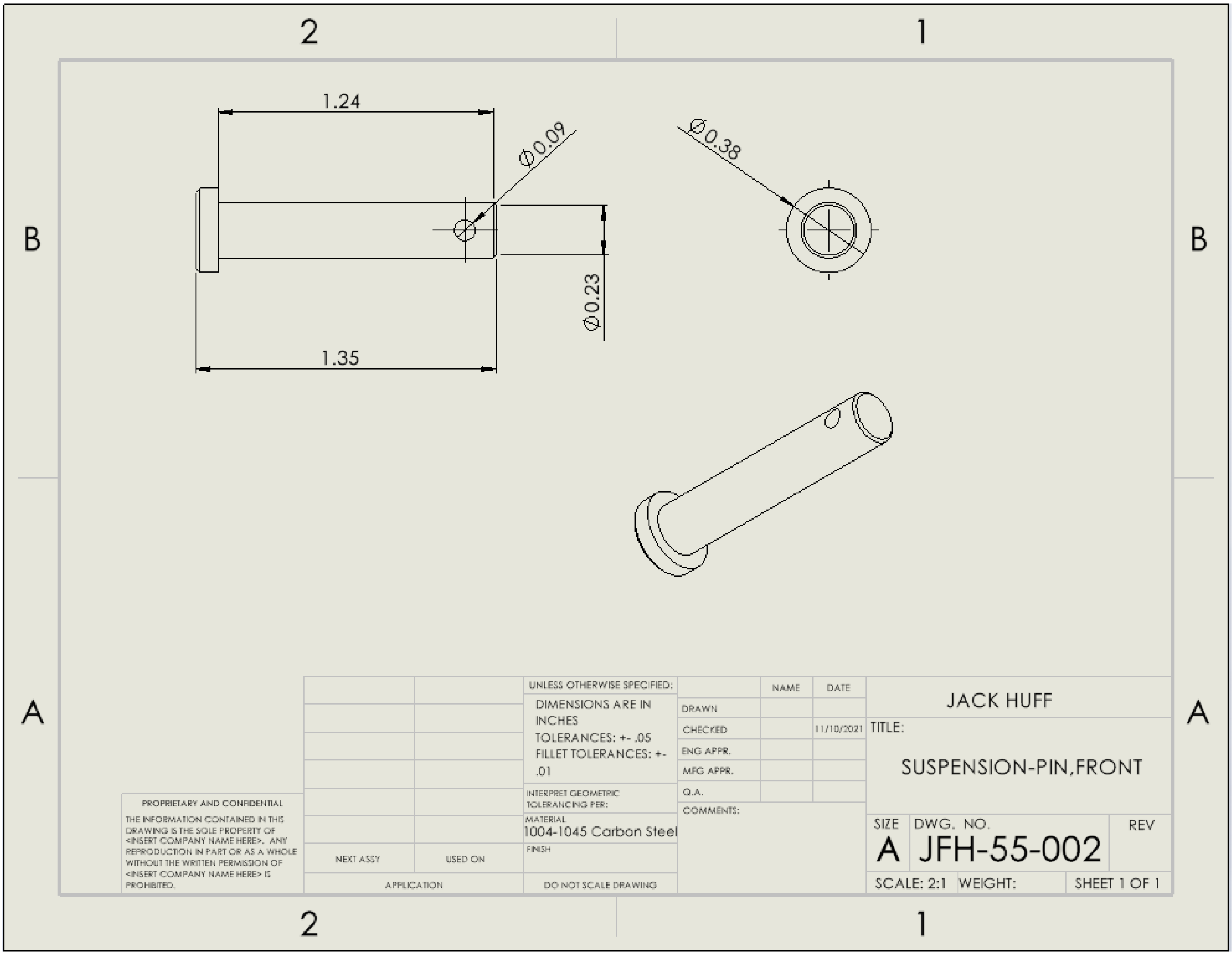


Figure B.14 DWG of Front Pin

Appendix B-15– SUSPENSION-PIN, REAR

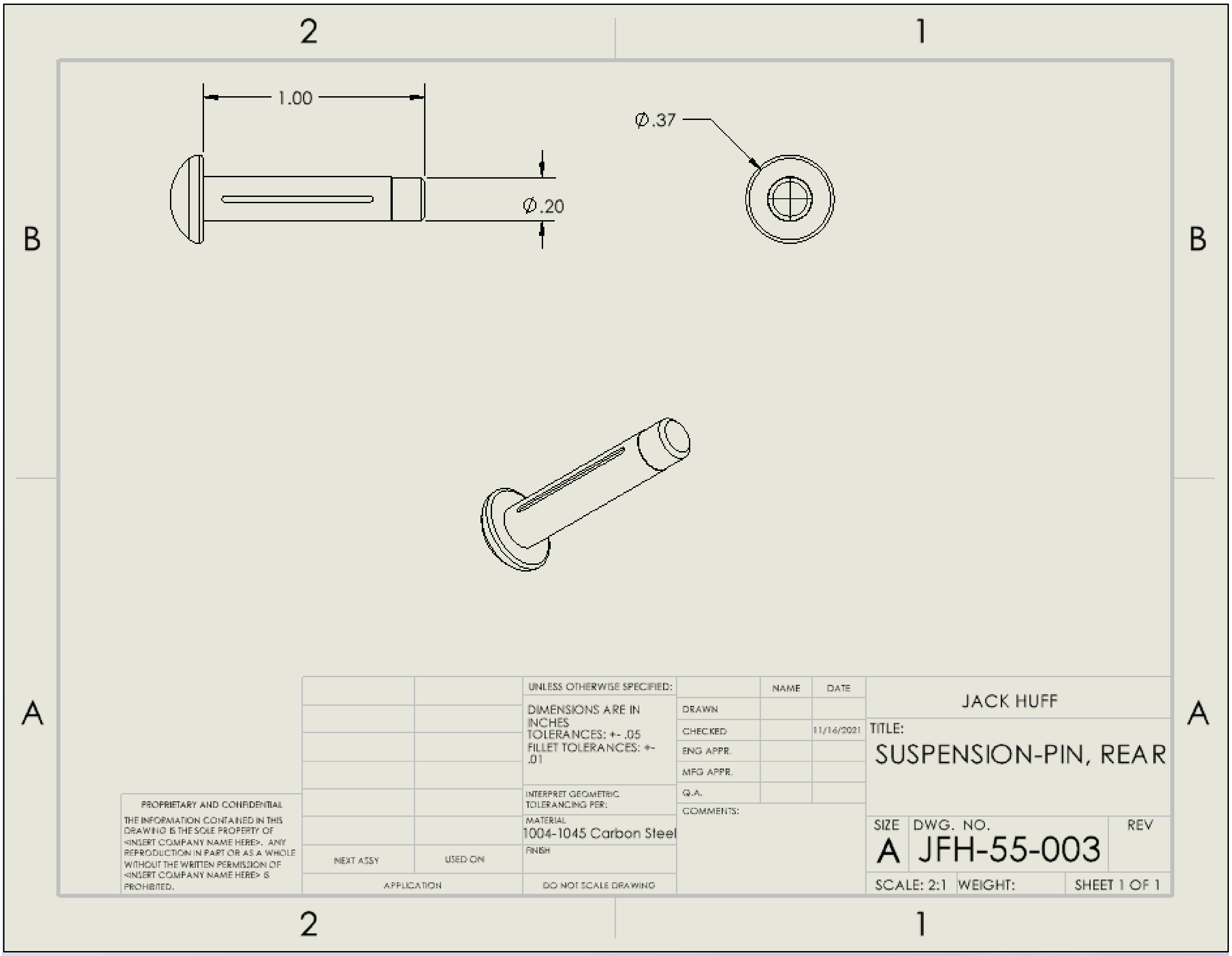


Figure B.15 DWG of Rear Pin

Appendix B-16 – MOUNT-MOTOR, LOWER

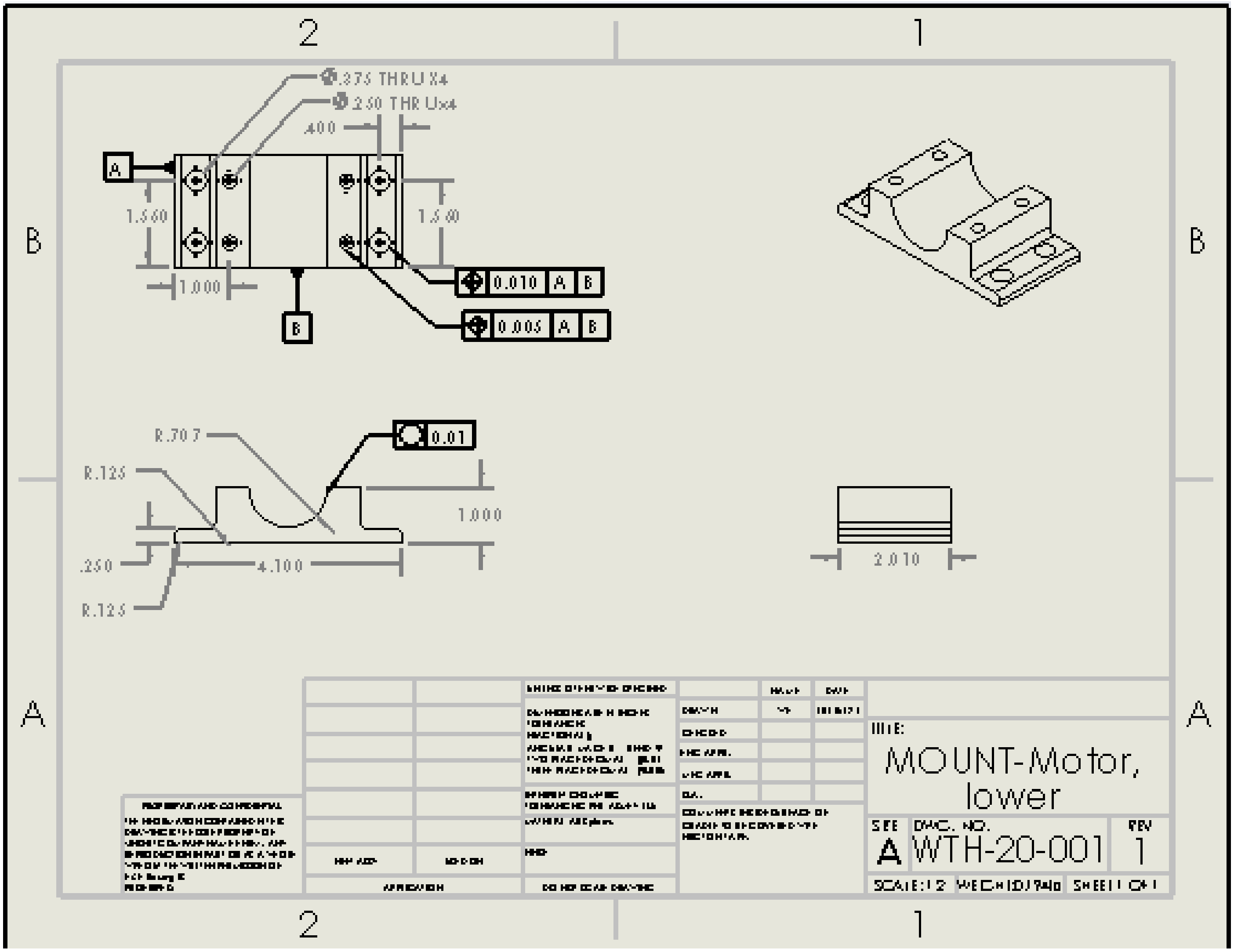


Figure B.16 Lower motor mount drawing WTH20-001

Appendix B-17-HOUSING-LOWER, REAR

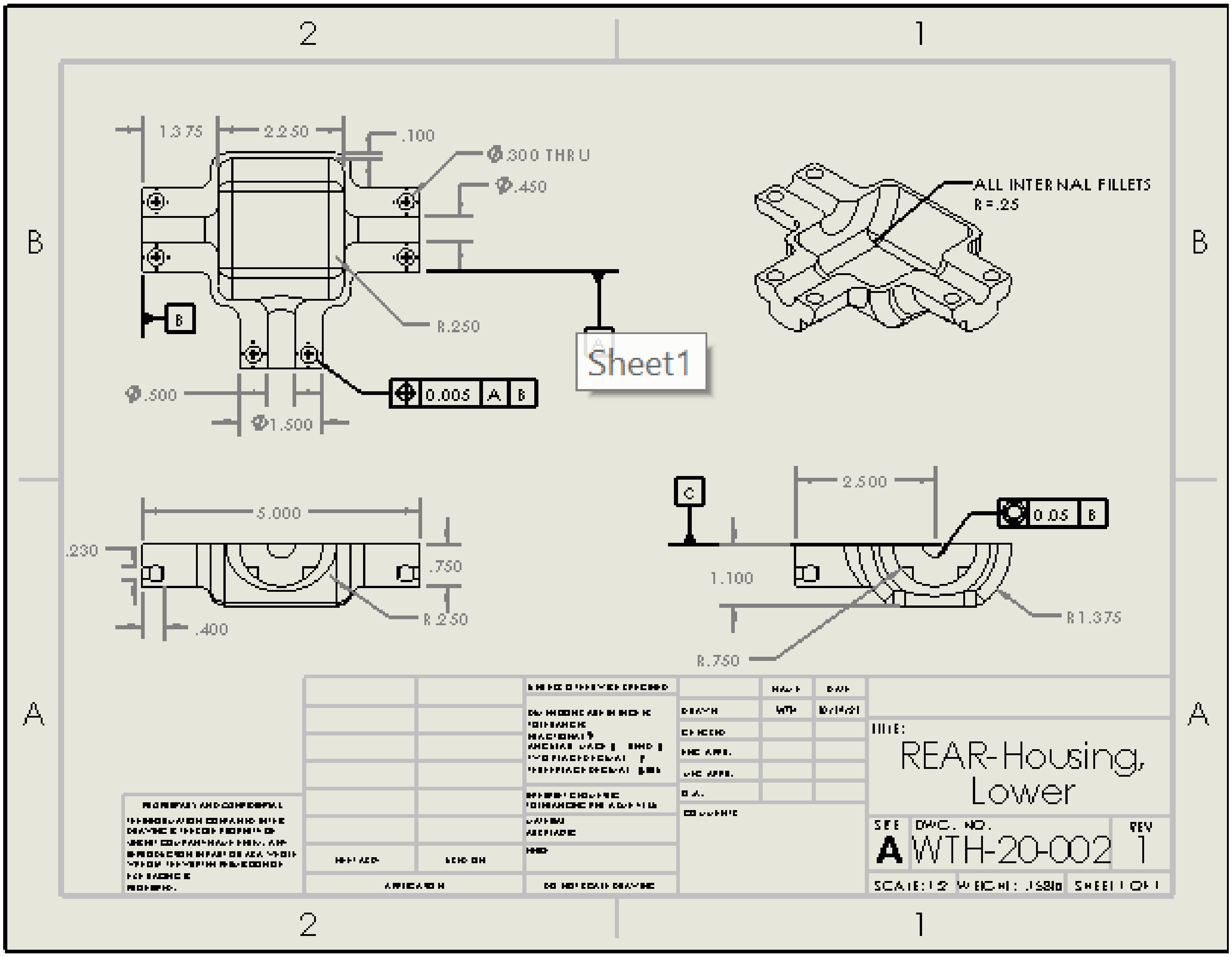


Figure B.17 Lower Rear Gear Housing

Appendix B-18–MOUNT-MOTOR, UPPER

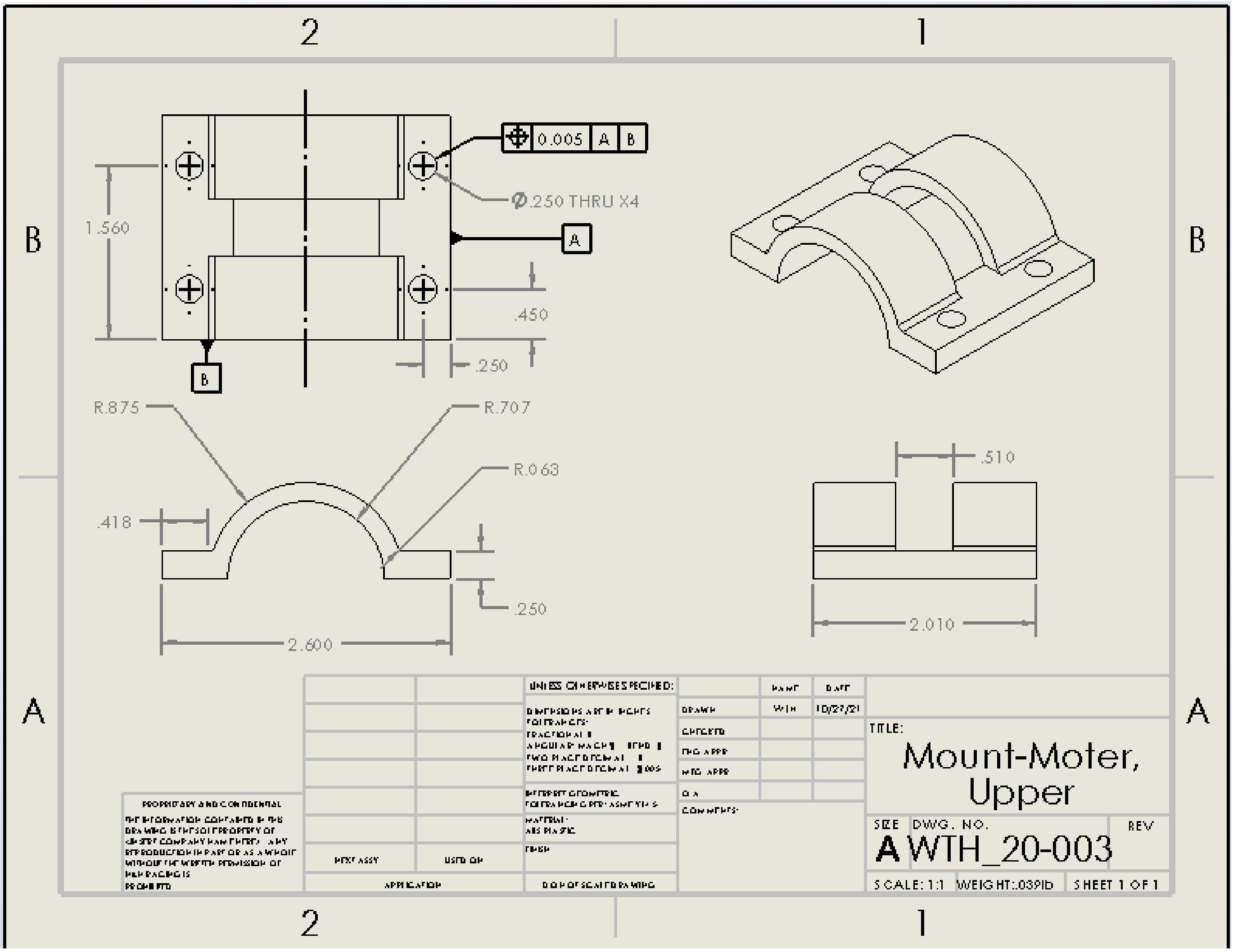


Figure B.18 Upper Motor Mount Half

Appendix B-19 – HOUSING-UPPER, REAR

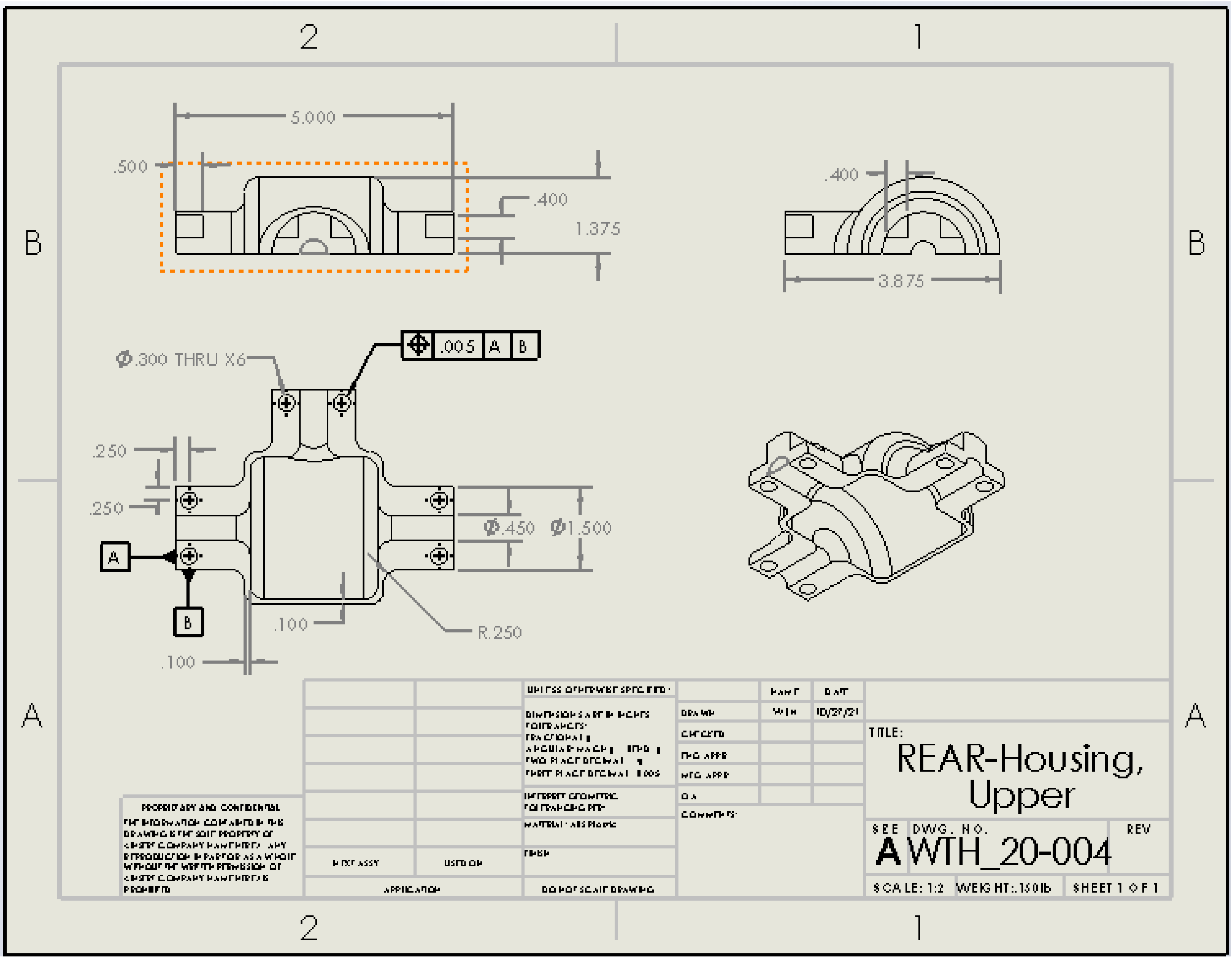


Figure B.19 upper rear gear case

Appendix B-20 – TIE ROD, FRONT

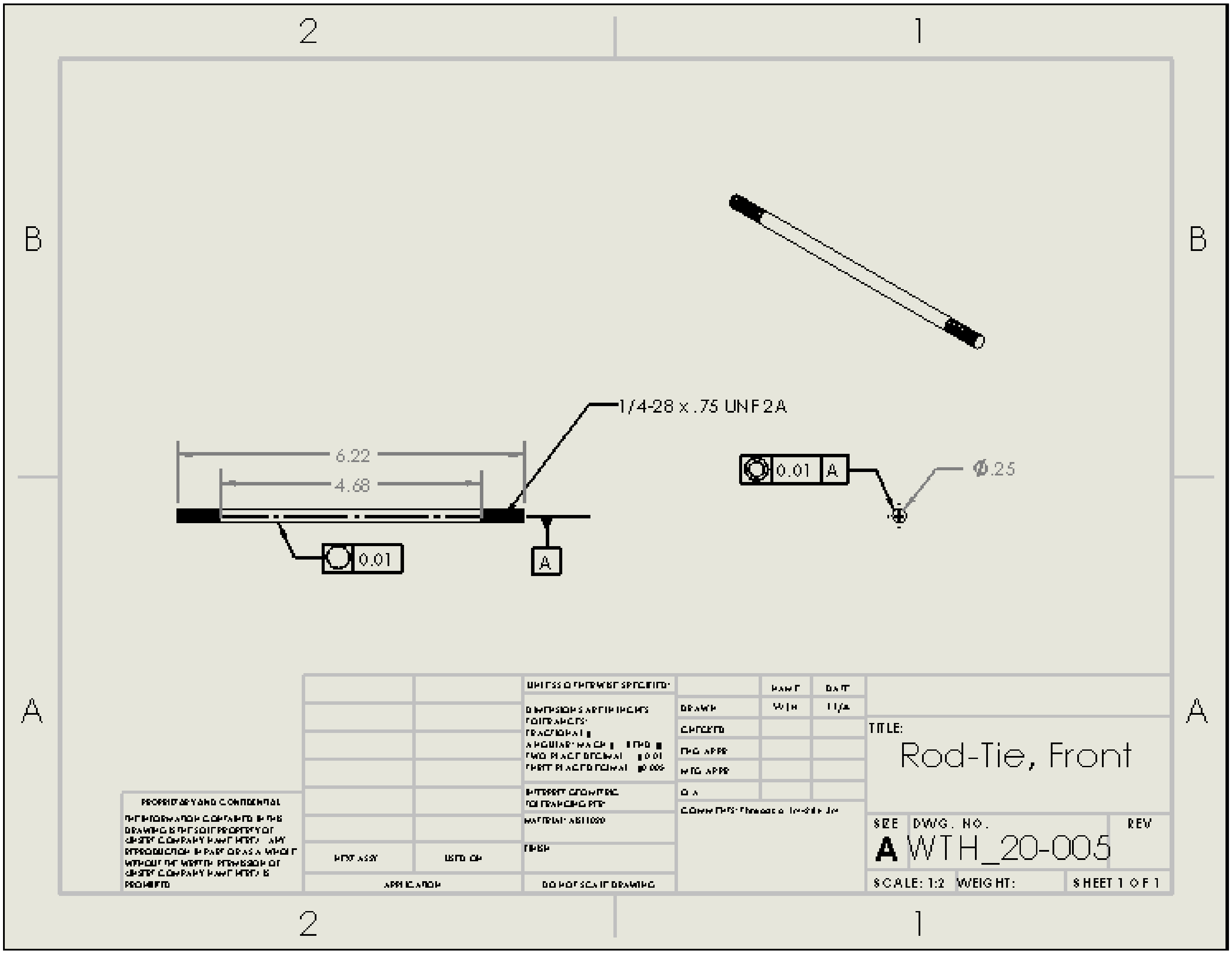


Figure B.20 Front tie rods

Appendix B-21 – ARM-CONTROL, UPPER

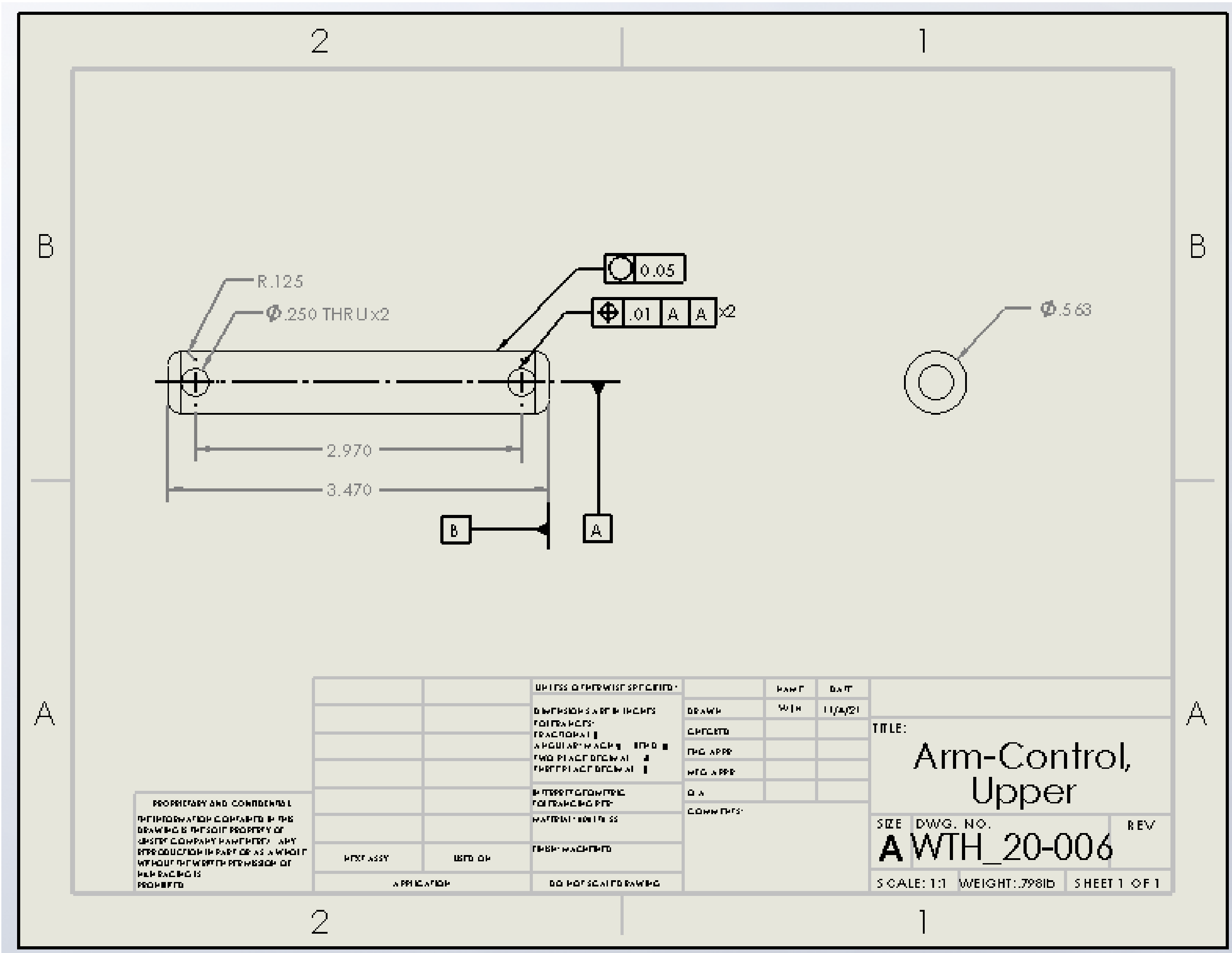


Figure B.21 Upper control arm

Appendix B-22 – CASING-TRANSMISSION, FRONT

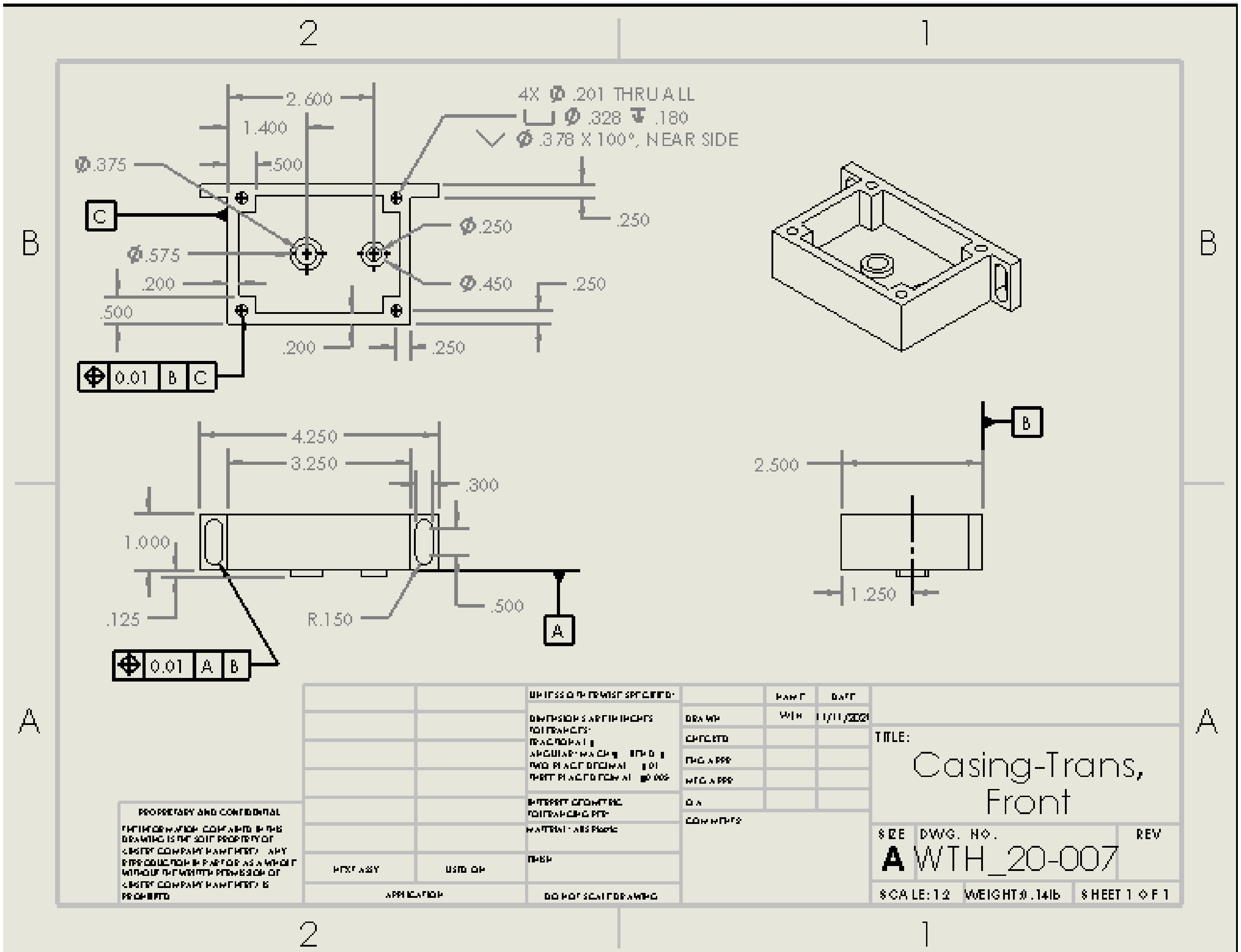


Figure B.22 WTH_20-007 Front Transmission Casing

Appendix B-23 – CASING-TRANSMISSION, REAR

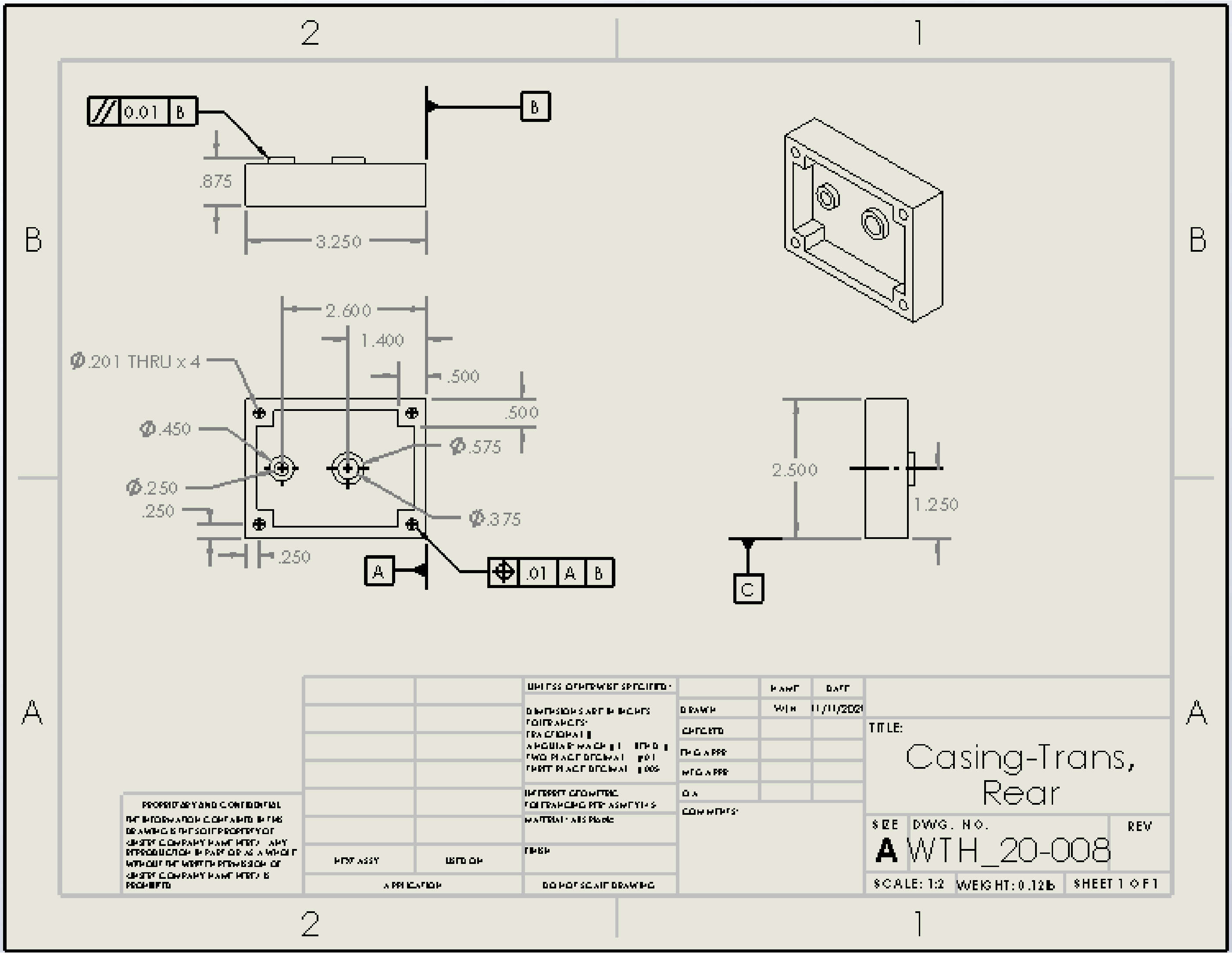


Figure B.23 Rear Transmission Casing

Appendix B-24 - SHAFT, DRIVELINE

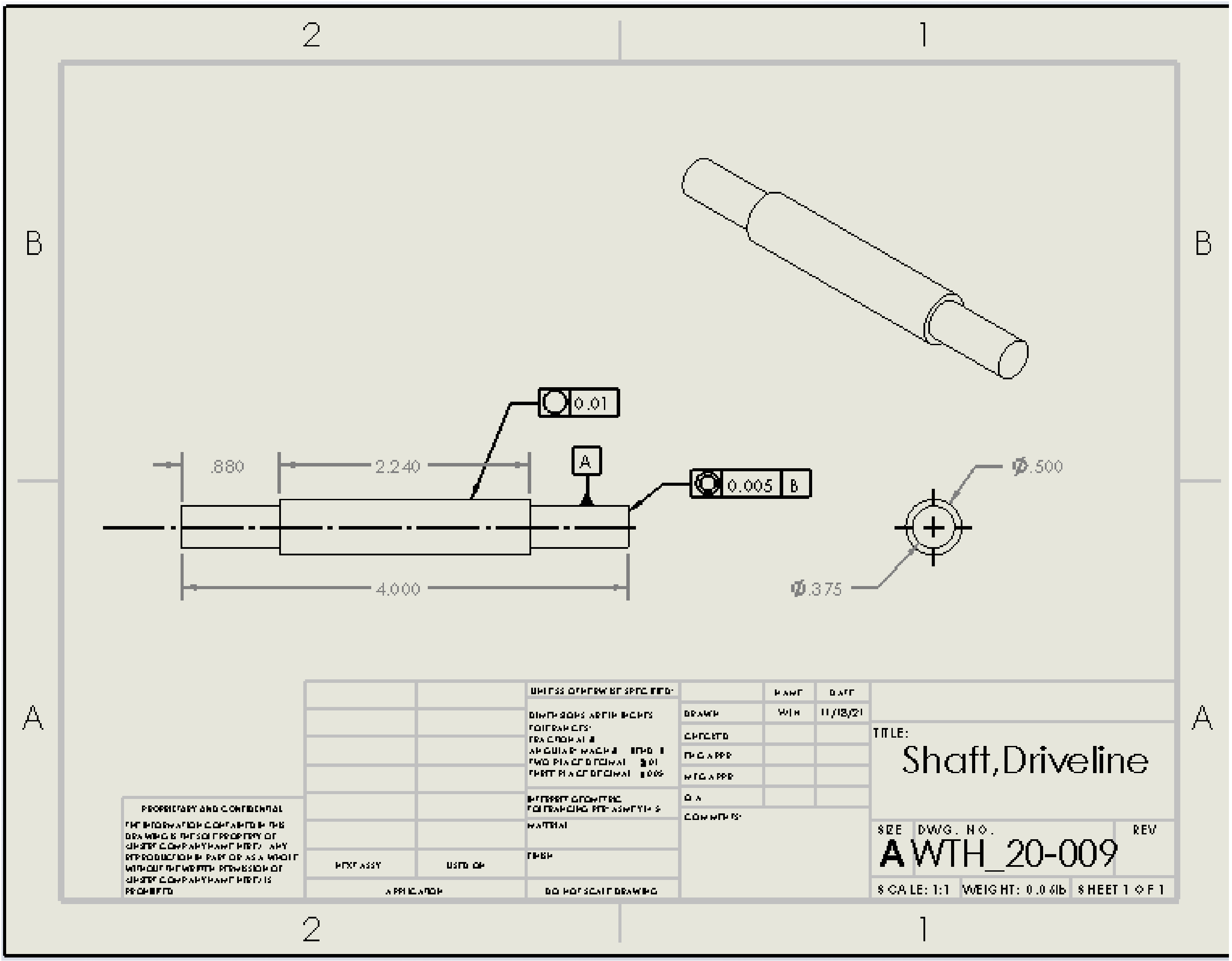


Figure B.24 Driveshaft

Appendix B-25 –KNUCKLE-STEERING, FRONT

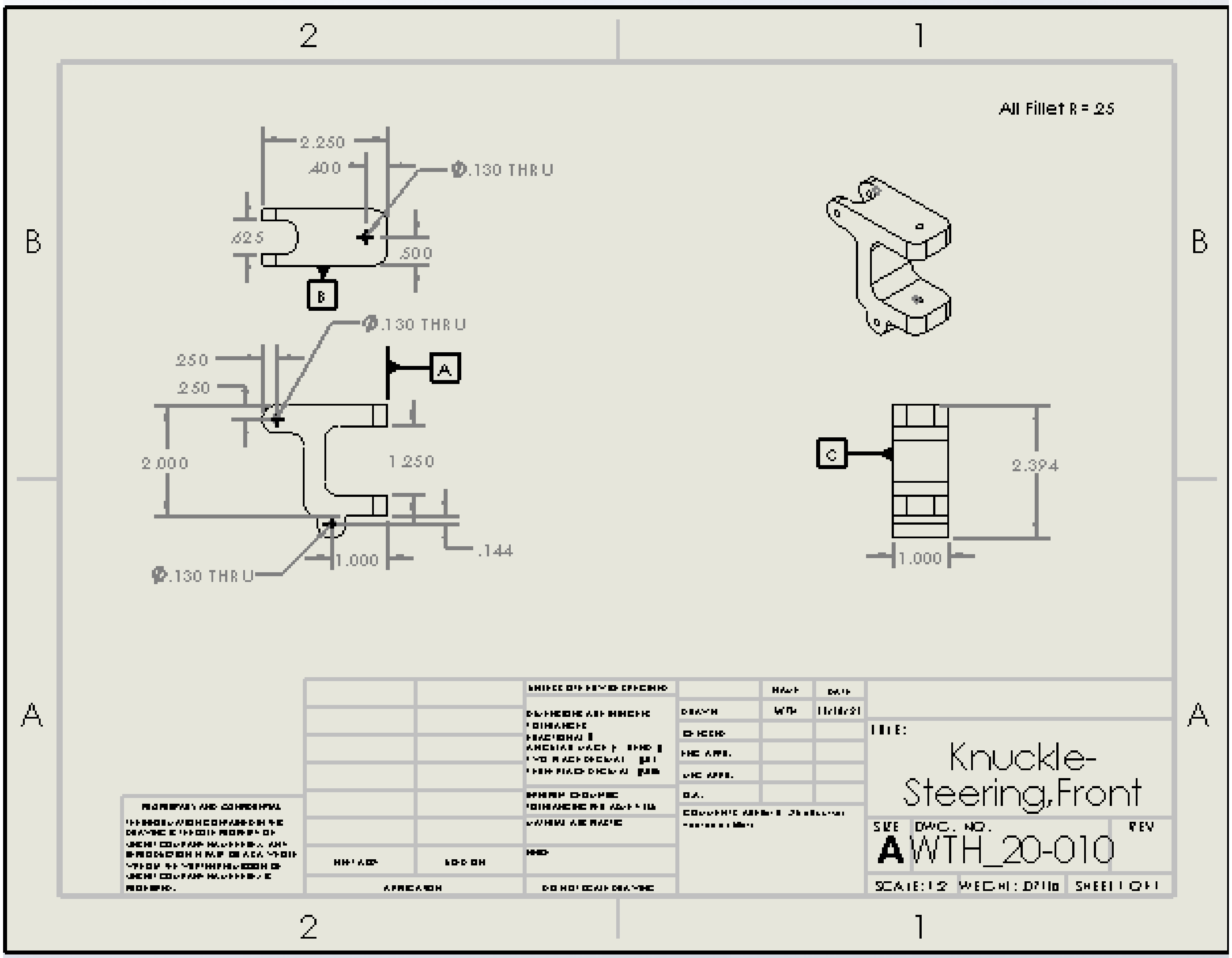


Figure B.25 Front Steering Knuckle

Appendix B-26 – GEAR, PINION – REDUCTION, BOX

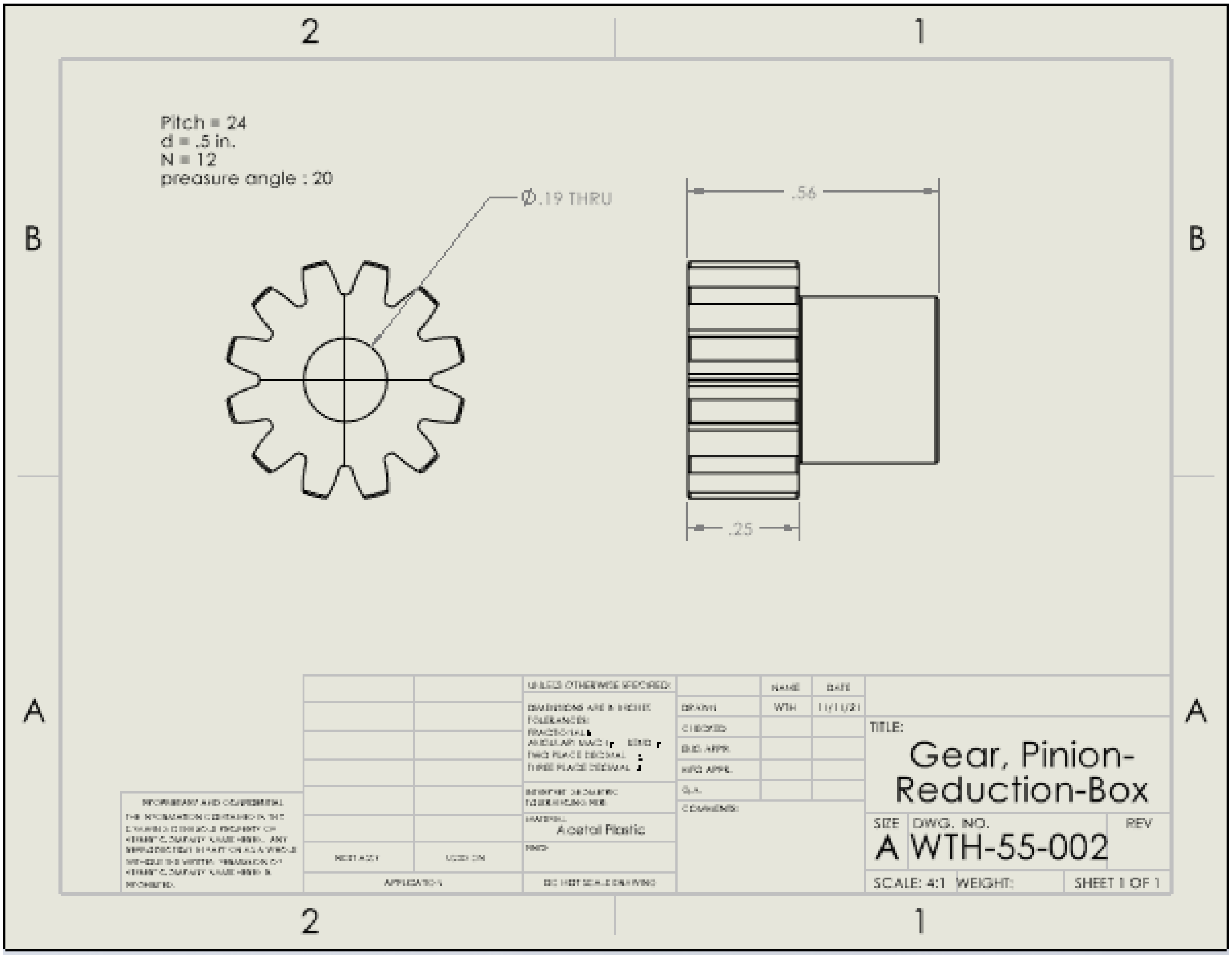


Figure B.26 Gear Pinion Reduction Box

Appendix B-27 – GEAR-REDUCTION, GEAR BOX

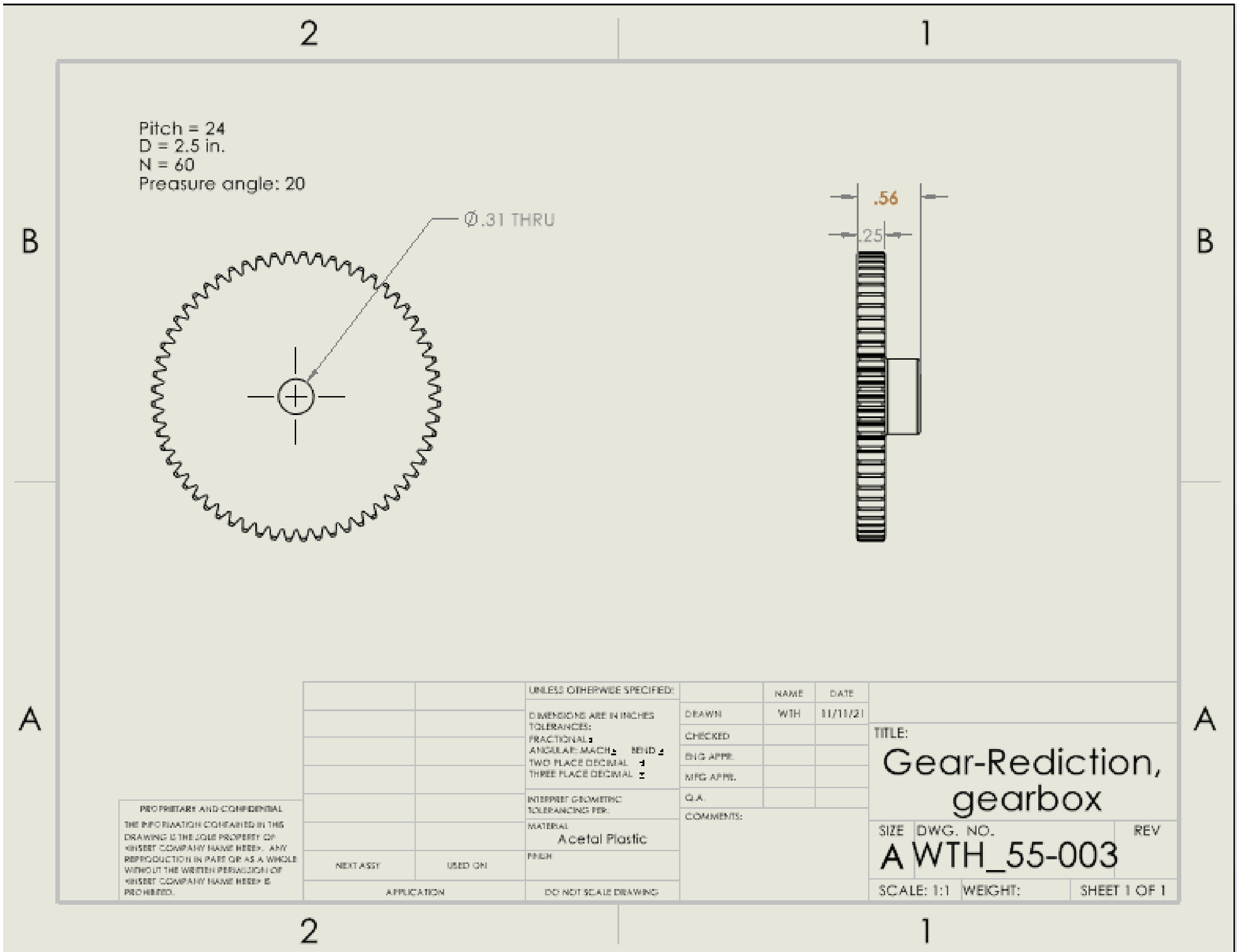


Figure B.27 Gear Reduction Gear Box

Appendix B-28 – SHAFT -REDUCTION, DRIVEN

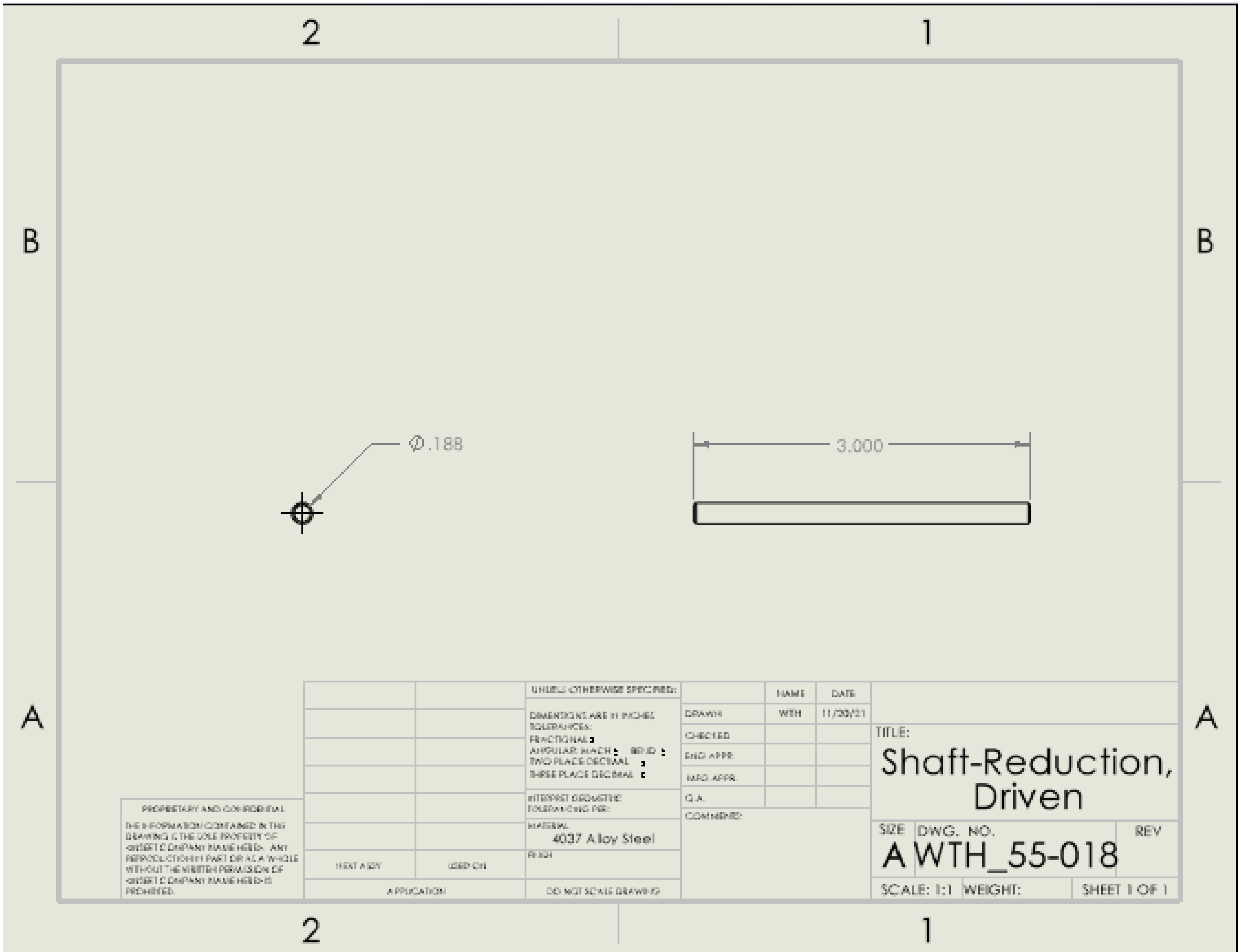


Figure B.28 Shaft Reduction, Driven

Appendix B-29 – SHAFT – REDUCTION, PINION

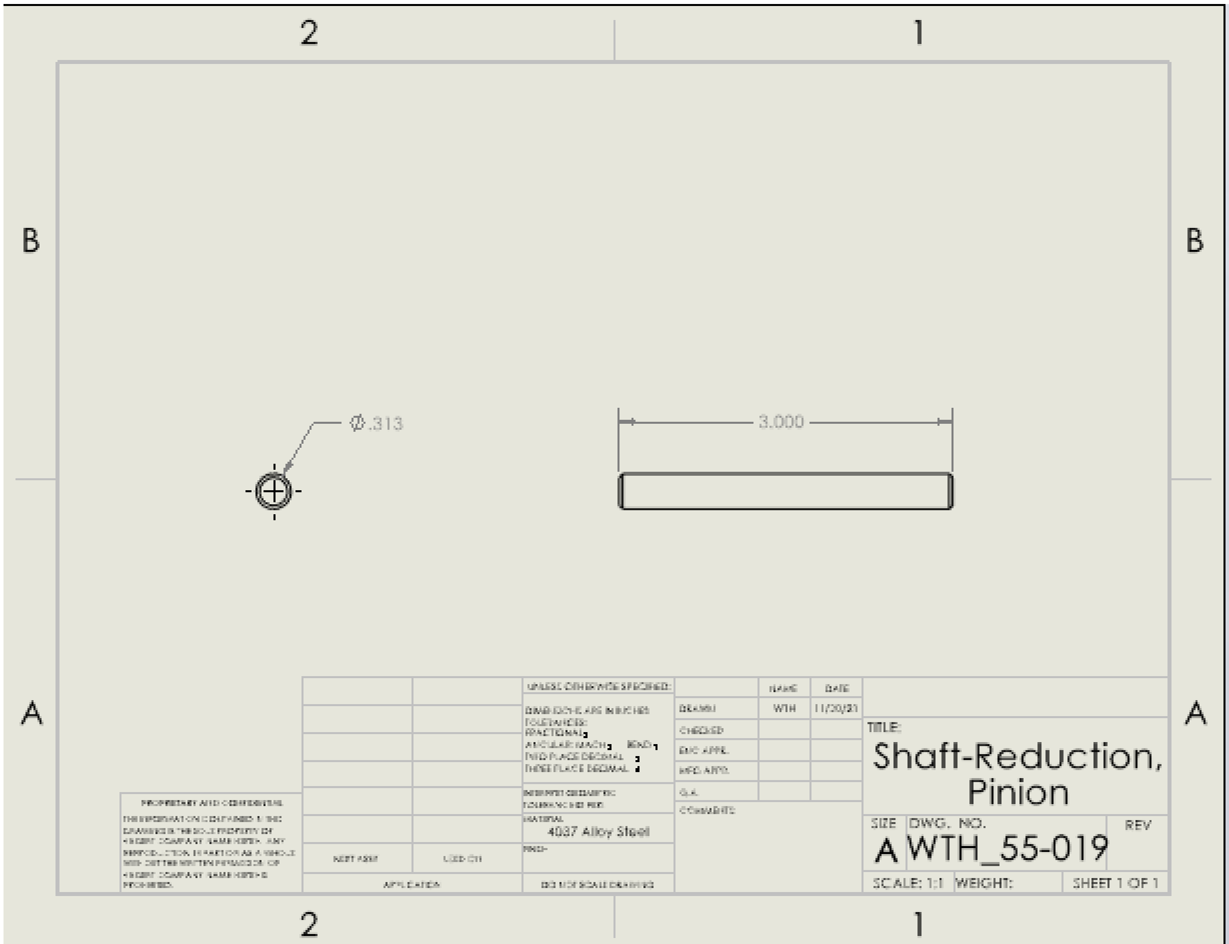


Figure B.29 Shaft Reduction Pinion

APPENDIX C – Parts List and Costs

Table C.1 Parts and Cost Lists for Suspension/Chassis

Part number	Qty.	Part Description	Source	Unit Cost	Actual cost
JFH_20-001	1	CHASSIS-CAR	mfg	$200.00	$0.00
JFH_20-002	2	ARM-SWING,FRONT	School Print	$4.00	$3.00
JFH_20-003	1	TOWER-SHOCK,FRONT	School Print	$4.00	$3.00
JFH_20-004	1	TOWER-SHOCK,REAR	School print	$4.00	$3.00
JFH-20-005	1	BUMPER-SUPPORT,FRONT	School Print	$5.00	$3.00
JFH-20-006	1	ARM-SWING,REAR	School Print	$3.00	$3.00
JFH-55-001	1	SUSPENSION-STRUT,FRONT	amazon	$50.00	$40.00
JFH-55-002	0	SUSPENSION-PIN,FRONT	Mcmaster Carr	$5.00	$0.00
JFH-55-003	0	SUSPENSION-PIN,REAR	Mcmaster Carr	$5.00	$0.00
Total	8				$55.00

Table C.2 Parts and Cost Lists for Drivetrain/Steering

Part number	Qty.	Part Description	Source	Unit Cost	Actual cost
WTH_20-001	1	Mount-Motor, Lower	School Print	$6.00	$6.00
WTH_20-002	1	Housing-Rear, Lower	School Print	$2.00	$2.00
WTH_20-003	1	Moount-Motor, upper	School Print	$5.00	$5.00
WTH_20-004	1	Housing-Rear, Upper	School Print	$3.00	$3.00
WTH_20-005	2	Rod-Tie, Front	mfg	$15.00	$30.00
WTH_20-006	2	Arm-Control, Upper	mfg	$15.00	$30.00
WTH_20-007	1	Casing-Transmission, Front	School Print	$2.00	$2.00
WTH_20-008	1	Casing-Transmission, Rear	School Print	$2.00	$2.00
WTH_20-009	1	Shaft, Driveline	mfg	$15.00	$15.00
WTH_20-010	2	Knuckle-Steering, Front	School Print	$3.00	$6.00
WTH_20-015	1	Carrier, Axle,Rear	School Print	$5.00	$5.00
WTH_55-002	2	Gear, Pinion-Reduction-Box	Mcmaster Carr	$3.00	$6.00
WTH_55-003	1	Gear, Reduction-Gearbox	McMaster Carr	$9.57	$9.57
WTH_55-004	1	Motor-speed controller	HobbyWing	$110.95	$110.95
WTH_55-005	1	Bevel- Pinion	Mcmaster Carr	$8.87	$8.87
WTH_55-006	1	Bevel- driven	Mcmaster Carr	$10.24	$10.24
WTH_55-010	2	U-joints	Mcmaster Carr	$38.50	$77.00
WTH_55-018	1	Shaft-Reduction, Driven	Mcmaster Carr	$12.99	$12.99
WTH_55-019	1	Shaft-Reduction, Pinion	Mcmaster Carr	$12.27	$12.27
WTH_55-021	2	3/16 dia transmissionm shaft	Mcmaster Carr	$3.34	$6.68
WTH_55_022	2	5/16 dia transmission shaft	Mcmaster Carr	$2.74	$5.48
Total	28				$366.05

APPENDIX D – Budget

Table D.1 Budge Spreadsheet

Item	Qty	Description	Cost
Total Parts	35	All parts needed	$418.05
Manufactured Parts	19	Parts that were 3D printed or made out of school	$90.00
Labor cost	1	Manual labor by project members	$1,500.00
		Total Cost	$2,008.05

APPENDIX E – Schedule

Appendix E-1 – Fall Gantt Chart

1	PROPOSAL/REPORT WRITING								
1a	Intro (1a-g)	2	3	100%	X				
1b	Intro section 2 (a-g)	2	2	100%				X	
1c	Intro Section 2 (H-I)	2	2	100%				X	X
1d	Analysis	3						X	X
1e	Methods	4							
1f	Testing	6							
1g	Budget	2							
1h	Schedule	3							
1	Project Management	3							
i	Discussion	3							
1j	Conclusion	2							
1k	appendix	2							
	subtotal:	34	7						
2	WEBSITE								
2a	Project web page outline	2	3	100%	X				
2b	Design sketches	2	2	100%	X				
2c	introduction	2	1				X	X	
2d	Analysis	4	1				X	X	
2e	Finalize Design	4					X	X	
	subtotal:	14	7						
3	ANALYSIS								
3a	Introduction	1	1			X	X	X	
3b	Drop Test	1	1			X			
3c	Front Impact Test	1	1					X	X
3d	Plate thickness	1							
3e	Chassis critcal load	1							
3f	Suspension Arm Impact	1							
3g	K facotr of spring	1							
3h	Front shock mount height	1							
3i	Rear shock mount height	1							
3j	Shock towler hole location	1							

Figure E.1

	subtotal:	14	7	
3	ANALYSIS			
3a	Introduction	1	1	X X X
3b	Drop Test	1	1	X
3c	Front Impact Test	1	1	X X
3d	Plate thickness	1		
3e	Chassis critcal load	1		
3f	Suspension Arm Impact	1		
3g	K facotr of spring	1		
3h	Front shock mount height	1		
3i	Rear shock mount height	1		
3j	Shock towler hole location	1		
3k	Shock angle mount	1		
3l	Min pin diameter	1		
3m	wheel size	1		
	subtotal:	13	3	
4	DOCUMENTATION			
4a	Chassis Drawing	2	2	X X
4b	Front shock tower	2		
4c	Rear Shock tower	2		
4d				
4e				
4f				
4g				
4h				
4i				
4j				

Figure E.1.2

Appendix E-2 – Winter Gannt Chart

TASK:	Description	Duration Est.	Actual	%Comp.	September	October	November	Dec	January	February	March	April	May	June
	subtotal:	13	20											
4	DOCUMENTATION													
4a	Chassis Drawing	2	2	100%		X X								
4b	Suspension Arm Drawing	2	1	100%		X X								
4c	Front Shock Tower Drawing	2	2	100%		X								
4d	Rear Shock Tower Drawing	2	2	100%		X								
4e	Suspension Strut Drawing	1	1	100%			X							
4f	Front Bumper Drawing	1	1	100%			X							
4g	Front Shock Tower Pins	1	1	100%			X							
4h	Front Shock Tower Sub Assembly	1	1	100%			X							
4i	Rear Shock Tower Pins	1	1	100%			X							
4j	Rear Shock Tower Sub Assembly	1	1	100%			X							
4K	Full Assembly	2	2	100%			X	X X	X					
	subtotal:	16	15											
5	PART CONSTRUCTION													
5a	Front shock tower	10	15	100%					X X					
5b	Rear shock tower	10	2	100%					X X					
5c	Shocks	3	2						X X X					
5d	Chassis	1	2						X X					
5e	Swing Arms	10	10						X					
5f	Front Bumper	10	15						X X					
5g														
5h														
5i														

Figure E.2

Appendix E-3 Spring Gantt Chart

TASK:	Description	Est.	Actual	%Comp.	Septembe	October	November	Dec	January	February	March	April	May	June
6e	swing arm assembly	2	4	100%						X X				
	subtotal:	19	53											
7	DEVICE EVALUATION													
7a	Drop Test	2	4	100%								X		
7b	Impact Test	2	2	100%								X X		
7c	Shock Tower Force Test	2	2	100%									X X	
7d	Test Procedure Preperation	3	6	100%								X X X X	X X X	
7e	Post Test Analysis	3	6	100%								X X X X	X X X	
	subtotal:	12	20											
8	489 DELIVERABLES													
8a	Final Presentation	1	1											X
8b	Source Poster	1	2										X	X
8c	Website	5	15										X	X X
8d	Written Report	5	5										X	X X
8e	Test Report	2	2										X	X X
8f	Jump Drive	1	1											X
8e														
8f														
8g														
	subtotal:	15	26											
	Total Est. Hours=	167	195		=Total Actual Hrs									

Figure E.3

APPENDIX F – Expertise and Resources

Appendix F-1 Decision Matrix for Body

Table F.1 Decision Matrix for Style of Body

Criterion	Weight	Best Possible	Design #		Design #		Design #		
	1 to 3	3	1	Score x Wt	2	Score x Wt	3	Score x Wt	
Cost	3	9	3	9	2	6	3	9	
Weight	3	9	2	6	2	6	3	9	
Prediction precision	2	6	2	4	2	4	2	4	
Confidence in failure location	2	6	2	4	2	4	3	6	
Prismatic vs non prismatic	3	9	2	6	2	6	3	9	
Manufacturability	2	6							
Total	15	45		29		26		37	
NORMALIZE THE DATA (muliply by fraction, N)		2.22		64.44		57.78		82.22	Percent
								68.15	Average
								12.64	Std Dev.

Appendix F-2 – Decision Matrix for Material of Swing Arms

Table F.2 Decision Matrix for Material of Swing Arms

Criterion	Weight	Best Possible	Material #		Material #		Material #		
	1 to 3	3	ABS Plastic	Score x Wt	Aluminum	Score x Wt	Wood	Score x Wt	
Cost	3	9	3	9	1	3	2	6	
Weight	3	9	3	9	2	6	2	6	
Prediction precision	2	6	3	6	2	4	1	2	
Confidence in failure location	2	6	2	4	2	4	2	4	
Prismatic vs non prismatic	3	9	2	6	2	6	2	6	
Manufacturability	3	9	3	9	2	6	3	9	
Total	16	48		43		29		33	
NORMALIZE THE DATA (muliply by fraction, N)		2.08		89.58		60.42		68.75	Percent
								72.92	Average
								15.02	Std Dev.

Appendix F-3 Decision Matrix for Process to Make Swing Arms

Table F.3 Decision Matrix for process to Make Swing Arms

Criterion	Weight	Best Possible	3D Printing		CNC		Laser Cut		
	1 to 3	3	1	Score x Wt	2	Score x Wt	3	Score x Wt	
Cost	3	9	2	6	3	9	3	9	
Availiabilty	3	9	3	9	2	6	2	6	
Prediction precision	3	9	3	9	2	6	2	6	
User ability	3	9	3	9	2	6	2	6	
Production Rate	3	9	1	3	3	9	3	9	
Manufacturability	3	9	3	9	2	6	2	6	
Total	18	54		45		42		42	
NORMALIZE THE DATA (muliply by fraction, N)		1.85		83.33		77.78		77.78	Percent
								79.63	Average
								3.21	Std Dev.

Appendix F-4 Decision Matrix for Process to Make Chassis

Table F.4 Decision Matrix for process to Make Chassis

Criterion	Weight	Best Possible	CNC		Power Tools		BandSaw		
	1 to 3	3	1	Score x Wt	2	Score x Wt	2	Score x Wt	
Cost	3	9	3	9	3	9	3	9	
Availiability	3	9	2	6	2	6	2	6	
Prediction precision	2	6	3	6	1	2	2	4	
User Ability	3	9	2	6	2	6	3	9	
Production Rate	3	9	3	9	1	3	2	6	
Manufacturability	3	9	3	9	2	6	2	6	
Total	17	51		45		32		40	
NORMALIZE THE DATA (muliply by fraction, N)		1.96		88.24		62.75		78.43	Percent
								76.47	Average
								12.86	Std Dev.

APPENDIX G – Testing Report

Introduction:

During the testing of the RC Baja car, drop, impact and top speed results from testing will be found during spring quarter 2022. The requirements related to each of the three tests is as follows:

Requirements:

- The RC Baja chassis must be able to withstand a 1.5ft drop test if landed upright.

- The RC Baja car must be able withstand the 506.27N force from the impact test on the front end.

- The RC Baja front and rear shocks must be able to withstand a 15lb load without failure.

Predicted Performance:

- The predicted performance for the drop test of the RC Baja car was that the shocks will sustain the force from the drop as high of 2 feet. The calculations that were done to find this predicted performance is based off Figure A.1 and A.10 in appendix A. These figures show the calculations off the energy needed to withstand drop and impact from ground and the calculations for a spring that would have the energy to sustain this force.

- The predicted performance for the impact test of the RC Baja car was that the front end would sustain a force of 506.27N at a predicted max speed of 25mph. This calculation can be found in Figure A.2 in appendix A.

- The Predicted performance for the front and rear shocks is that the shocks will be able to hold the 15lb load. The calculation for this predicted result can be found in Figure A.5, A.6, A.7, and A.8 in appendix A.

Data Acquisition:

- Data during the three tests will be all be stored in excel sheets regarding the respected test.
- Data gathering will be done by measuring deflection of the chassis, front swing arm, and rear swing arm by taking the different of where the car rests before and after the car is dropped.
- Data for the impact test will be gathered by using a speedometer app on the student's phone and using that velocity to calculate several other values that will lead to the student's final force value.
- The shock tower force test data will be gathered by weighing several objects and placing the objects on the swing arms which will apply the force to the shock towers.

Schedule:

The schedule for the testing is related to the due dates that the student was required to follow during the spring quarter of the senior project course. Each test was allotted a week to finish while compensating for the any issues that might have occurred. Some complications did occur with breakage of parts, but the week allotted time allowed the student to finish all testing all on time. More details can be found on the Spring Gannt chart in appendix E.3.

Method/Approach:

Resources:

During the testing process there were some resources that were needed to complete each test. Each Test had to have a laptop on hand that had the excel sheet pulled up, some sort of recording device such as a phone was needed to record devices or take pictures. All other resources were used from equipment that could be found in the machine shop such as tape, rulers, safety glasses, and stools. There were no added costs to the team's budget while gathering testing resources.

Data capture/documentation/processing:

Data capture was done by the student with the help of a phone. The data capture only required the student to use a phone to record and visually see what happened during testing. The data was then taken and put into an excel testing sheet.

Test Procedure Overview:

The testing procedures that can be found in the following page of the report consist of three different tests, drop test, impact test, and shock tower force test. The drop test was a measure of deflection before and after dropping, the impact test a measure of force the car could withstand at its top speed, and the shock tower force test measured the amount of load the shock towers could support. All three tests were down in Hogue Hall in the Fluke Lab and machine shop.

Operational Limitations:

Operational limitations came from the car's rear transmission housing. The gears in the rear transmission housing did not always mate properly, which would cause the car not to work properly. The limitation was solved during the first round of testing which allowed the team to finish all testing that required the car to drive.

Precision and Accuracy Discussion:

During the testing, the precision and accuracy of timing the RC car had a chance to vary. To minimize the possibility of error, the student used a phone to carefully record everything that was tested. Using the phone, allowed the student to review material in normal time or slow time to reduce the chance of error. This method of recording testing allowed the student to have both precise and accurate data among all three tests.

Data Storage/Analysis/Manipulation/Presentation:

Data will be recorded in an excel data sheet regarding each respected test. The data will then be analyzed and manipulated with different equations if needed to find other values to get to data the student is looking for. Once all data for each test is completed, the student will then present all data with its excel sheet in addition to many written observations and pictures while conducting testing.

Appendix G-1 Drop Test

Test Procedure:

- Summary/overview:
    - This procedure documents the process of dropping the RC car at 1.5 ft and processing the outcomes of what happens to the RC car. These RC cars have been designed and constructed over the previous fall and winter quarters for the senior project in the Mechanical Engineering and Technology program. The following is the test information and procedure.

Figure G.1 Overview

- Time:
    - The test was conducted on 4/3/2022 from 11am to 1pm in the Hogue Fluke Lab. There will be half an hour of gathering equipment and setting up, half an hour of conducting the drop test, half an hour of inspecting the RC car and analyzing results, and half hour an of clean up.

- Place:
    - Fluke Lab, Hogue Hall, Central Washington University, Ellensburg WA

- Required Equipment:
    - Web Camera/Phone Camera
    - Stand for camera if deemed necessary
    - USB cable if camera needs it
    - Tape
    - Ruler, Meter Stick, Etc.
    - Flat Ground
    - Flat Wall
    - Completed RC Car
    - Notebook/Laptop

- Data Sheet
- Pencil/Pin
- Magnifying glass if deemed necessary
- Stool
- Writing surface
- Excel or similar
- Safety Glasses

- Risk:
  - All equipment must be gathered ahead of time. Risk to successful completion to this test is not having a completed RC car ready to be tested. Safety glasses will be always required while conducting testing inside Hogue Hall. Additional testing partners are not required but could be used for extra observing.

- Test Procedure is as follow:

1) Collect Equipment:
   a. Web cam/Phone camera, recording device
   b. RC car, Camera Stand, Tape, Measuring Stick, Notebook/Laptop, Data Sheet, Stool.
2) Go to Fluke Lab in Hogue Hall.
3) Place all equipment in organized pile on ground where testing will be conducted.
4) Use measuring stick to measure a height of 1.5 ft on flat wall being used.

Figure G.1 Step 4

5) Use tape to mark 1.5 ft distance on flat wall.

Figure G.1 Step 5

6) Set up recording device on stand if necessary (Ok to use partner to record testing if available). The device needs to record the whole car, recommended no farther than 1-2 ft back.

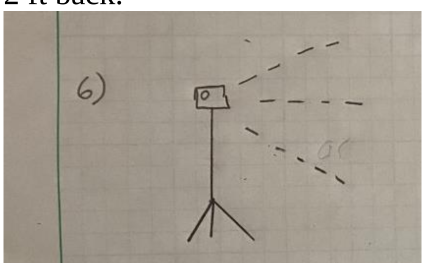


Figure G.1 Step 6

7) Setup Data sheet on either laptop (Via Excel or similar) or notebook.
   a. Recommended to set up data sheet of test 1-3
   b. Each test will explain what happened to car with a supporting picture.

Figure G.1 Step 7

Drop Test						Initial d for chassis (in):
	Test 1	Test 2	Test			Initial d for Rear Swing Arm (in):
Height Dropped:	1.5ft	1.5ft	1.5 ft			Initial d for Front Swing Arms (in):
Deflection (in):						
Written observations:						
Picture:						

8) Make sure RC car is at completed condition before conducting drop test.
9) Measure the initial distance of the chassis, front/rear swing arms from the ground the car is resting on. Use the middle holes on the swing arms to measure from when finding those measurements. Make notes of these initial values in data sheet.
10) Ensure recording is setup properly, start recording or have partner start recording.

11) Hold RC at 1.5 ft mark on wall.
12) Drop RC car onto floor. Try best to have car land flat, recommended to hold car parallel to floor.

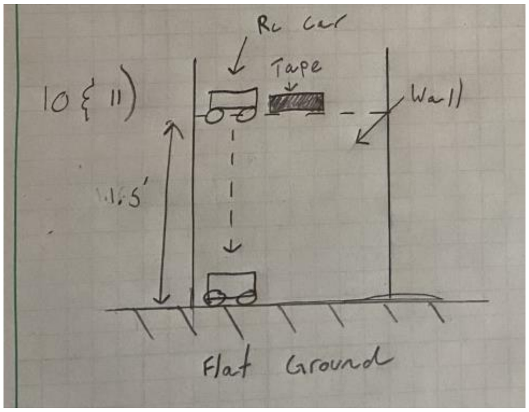


Figure G.1 Step 10 and 11

13) Analyzing results
    a. Look for breakage
    b. Loose screws
    c. Take measurement deflection of chassis and swing arms compared to the ground (These values will be used to compare to the initial values that were collected before conducting test).
    d. Take supporting picture of RC car
14) Record results on excel via already created data sheets
15) Repeat steps 9-13 two more times
16) Return all equipment to its original location if taken from Hogue Hall or elsewhere.
17) Save data sheet if on laptop
18) Testing is concluded.

- Discussion:
    - The test went as planned according to the written test procedure. The test procedure was able to guide the test and did not present any issues to the student. However, the results from the testing did cause some issues for the student. The first test that was conducted ended up breaking the rear swing arm, this slowed down the student since new swing arms had to be printed. After two days, the student was able to further conduct testing with three brand new swing arm printed out of ABS. The second trial went well with the rear swing arm not breaking, but the swing arm did break on the third and final trial. The student was able to gather good data and will be able to use what was learned for the future.

- Deliverables:
    - The Drop Test was a measure of the deflection of the chassis, front swing arms, and rear swing arm. After testing was completed, the student notices that the chassis and front swing arms were able to withstand the drop test with minimal deflection of calculating values. However, the rear swing arm did not pass the drop test because the swing arm broke twice, thus not being able to withstand the load. In conclusion, the success criteria were that all three measured parts would be able to lift the car back up to its natural resting state or within half an inch. 2 out of 3 measured parts of the RC Car met this criterion.

Appendix G1.1 – Procedure Checklist

1. RC Baja car is completed.
2. Test Procedure has been read.
3. Items from Test Procedure are acquired.
4. Data form has been created.
5. Camera is setup.
6. Drop distance is measured and marked.
7. Student feels competent and ready to conduct test.

Appendix G1.2 – Data Forms

Table G.1 Blank Example Data Form

Drop Test						Initial d for chassis (in):
	Test 1	Test 2	Test			Initial d for Rear Swing Arm (in):
Height Dropped:	1.5ft	1.5ft	1.5 ft			Initial d for Front Swing Arms (in):
Deflection (in):						
Written observations:						
Picture:						

Appendix G1.3 – Raw Data

Table G.2 Raw Data Form

Drop Test						Initial d for chassis (in):	3
	Test 1	Test 2	Test			Initial d for Rear Swing Arm (in):	2.5
Height Dropped:	1.5ft	1.5ft	1.5 ft			Initial d for Front Swing Arms (in):	2
Deflection Chassis (in):	N/A	0.8	1.2				
Deflection Rear Swing Arm(in):	Broke	0.7	Broke				
Deflection Front Swing Arms (in):	0	0	0				
Written observations:	The rear swing arm sheared at the connection with the transmission housing. This could be because the rear swing arm made connecton with the ground when dropped. New swing arm will be printed out of ABS rather than PLA.	The rear swing arm took the drop test better than the first attempt and did not shear at all. The chassis deflected a total of .8 inches, rear swing arm deflected .7 in, and the front swing arms did not deflect at all.	Unfortunately, the rear swing arm did break shortly after the test was finished. Before the rear swing arm broke, the chassis deflected 1.2 inches and the front swing arms did not deflect at all again. The team is looking into refenforcing the rear swing arm break point with aluminum.				

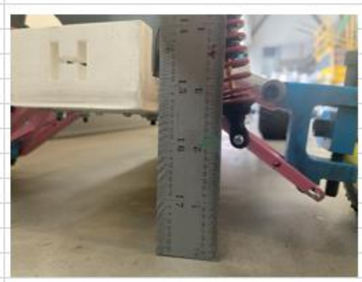
Table G.3 Data Form Pictures

Picture:







Appendix G1.4 – Evaluation Sheet

It should be noted that only a simple equation was needed to calculate the deflection. An Evaluation sheet showing how to compute multiple values was not needed since only one value was being recorded.

Evaluation Sheet:	Initial d-Measured d = deflection

Figure G.6 Deflection Equation

Appendix G1.5 – Schedule (Testing)

TASK:	Description	Duration Est.	Actual	%Comp.	Septemb	October	November	Dec	January	February	March	April	May	June
5	PART CONSTRUCTION													
5a	Front shock tower	10	15	100%					X X					
5b	Rear shock tower	10	2	100%					X X					
5c	Shocks	3	2						X X X					
5d	Chassis	1	2						X X	X				
5e	Swing Arms	10	10						X	X X				
5f	Front Bumper	10	15						X X					
	subtotal:	44	46											
6	DEVICE CONSTRUCTION													
6a	Chassis/Full Assmebly	5	37	100%						X X X X	X X X X	X		
6b	Front Shock tower Assembly	5	3	100%						X X				
6c	Rear Shock Tower Assembly	5	3	100%						X X				
6d	Front Bumper Assembly	2	1	100%						X X				
6e	swing arm assembly	2	4	100%						X X				
	subtotal:	19	48											
7	DEVICE EVALUATION													
7a	Drop Test	2	4	100%								X		
7b	Impact Test	2												
7c	Speed Test	2												

Figure G.4 Gannt Chart

Appendix G-2 Impact Test

Test Procedure:

- Summary/overview:
    - This procedure documents the process of driving the RC Baja car at max speed into a perpendicular surface and processing the outcomes of what happens to the RC car. These RC cars have been designed and constructed over the previous fall and winter quarters for the senior project in the Mechanical Engineering and Technology program. The following is the test information and procedure.

Figure G.2 Overview

- Time:
    - The test was conducted on 4/19/2022 from 8am to 10am in the Hogue Fluke Lab. There will be half an hour of gathering equipment and setting up, half an hour of conducting the impact, half an hour of inspecting the RC car and analyzing results, and half hour an of clean up.

- Place:
    - Fluke Lab, Hogue Hall, Central Washington University, Ellensburg WA

- Required Equipment:
    - Web Camera/Phone Camera
    - Stand for camera if deemed necessary
    - USB cable if camera needs it
    - Tape
    - Ruler, Meter Stick, Etc.
    - Flat Ground
    - Flat Wall
    - Completed RC Car
    - Notebook/Laptop
    - Data Sheet
    - Pencil/Pin
    - Magnifying glass if deemed necessary

- Stool
- Writing surface
- Excel or similar
- Safety Glasses
- Speed App
- Scale

- Risk:
  - All equipment must be gathered ahead of time. Risk to successful completion to this test is not having a completed RC car ready to be tested. Safety glasses will be always required while conducting testing inside Hogue Hall. Additional testing partners are not required but could be used for extra observing.

- Test Procedure is as follows:

1) Take note of mass and weight of car prior to testing

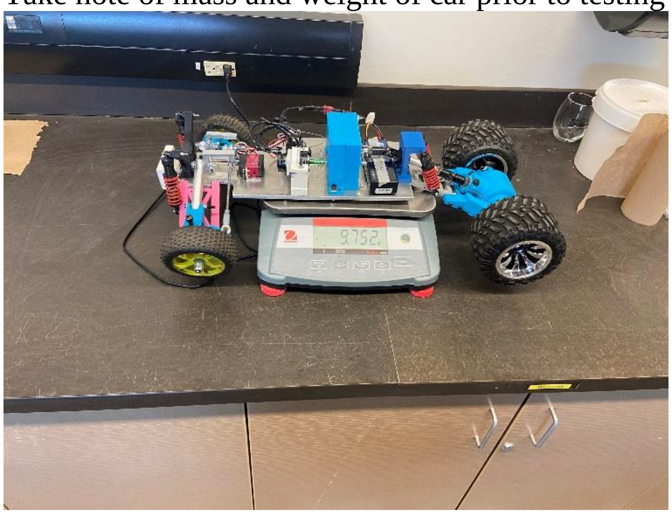


Figure G.2 Step 1

2) Collect Equipment:
   a. Web cam/Phone camera, recording device
   b. RC car, Camera Stand, Tape, Measuring Stick, Notebook/Laptop, Data Sheet, Stool, Etc.
3) Go to Fluke Lab in Hogue Hall.
4) Place all equipment in organized pile on ground where testing will be conducted.
5) Pick wall or perpendicular flat object car will drive into.
6) Mark off starting distance for car. Each starting distance will depend on how far the student thinks it will take to reach desired speed for each test. Take note of marked location.


Figure G.2 Step 6

7) Pull up speed app on phone.
8) Secure Phone on car for safety of device (Tape or zip ties).

9) Place car at marked location facing wall or perpendicular object to be driven into.


Figure G.2 Step 9

10) ensure car is secure and undamaged before testing.
11) Drive car into wall from marked location at desired testing speed.


Figure G.2 Step 11

12) Analyzing Results:
    a. Look for breakage
    b. Loose screws
    c. Shift of parts
    d. Analyzing damage to front bumper
    e. Speed car was at before impact

13) Record results on excel via already created data sheets

Table G.2 Blank Data

Impact Test			
	Test 1	Test 2	Test 3
Weight (lb):			
Mass (kg):			
Initial Distace (ft):			
Top Velocity (m/s):			
deceleration (m/s^2)			
Force (N):			
Force (lb-lf):			
Written observations:			
Pictures:			

14) Repeat steps 9-13 two more times at different speeds. Increase distance if no breakage and decrease distance if breakage.
15) Return all equipment to its original location if taken from Hogue Hall or elsewhere.
16) Finish calculations on data sheet to find the force the car experienced.
17) Save data sheet if on laptop
18) Testing is concluded.

- Discussion:
  During the impact test the student was able to successfully complete the testing with no issues. The test procedure that the student made previously was able to guide the student throughout the whole test with no need to make changes to the test procedures. The student was able to complete all three trials of the impact test with no breakage of parts until the end of the third trial where the rear swing arm broke in the same location when conducting the drop test. The team has already printed new rear swing arms with an improved thickness of .5 inches in hopes to strengthen the location of where the breakage is occurring.

- Deliverables:
  The impact test was a measure of the force that the front bumper and integrity of the chassis could take at varying speeds. After testing was completed, the student has recognized that at speed of 7.4MPH the car experienced a force of 146.3N which cause that rear swing arm to break. However, the front bumper and chassis did not experience

any breakage or bending of any sort. In conclusion the success criteria was that the front bumper nor the chassis would not break at a speed of 25mph. It can be inferred that with the results of the testing that front bumper and integrity of the chassis would not meet this criterion.

Appendix G2.1 – Procedure Checklist

1. RC Baja car is completed.
2. Test Procedure has been read.
3. Items from Test Procedure are acquired.
4. Data form has been created.
5. Camera is setup.
6. Distances to drive from into wall are setup and marked.
7. Student feels competent and ready to conduct test.

Appendix G2.2 – Data Forms

Table G2.1 Blank Example Data Form

Impact Test					Gravity:	9.81m/s^2
	Test 1	Test 2	Test 3			
Weight (lb):						
Mass (kg):						
Initial Distace (ft):						
Top Velocity (m/s):						
deceleration (m/s^2)						
Force (N):						
Force (lb-lf):						
Written observations:						
Pictures:						

Appendix G2.3 – Raw Data

Table G2.2 Raw Data Form

	Impact Test		
	Test 1	Test 2	Test 3
Weight (lb):	9.752	9.752	9.752
Mass (kg):	4.423	4.423	4.423
Initial Distace (ft):	19	19	41
Top Velocity (MPH):	3.4	4.3	7.4
Top Velocity (m/s):	1.5	1.9	3.3
Impact Time (s):	0.1	0.1	0.1
Declaration (m/s^2)	15.2	19.2	33.1
Force (N):	67.2	85.0	146.3
Force (lb-lf):	15.1	19.1	32.9
Written observations:	At a distance of 19 feet the car was able to reach a speed of 3.4 mph according to the speedometer app. The RC car was able to withstand the force generarted from this speed with no damages. The next trial will be at the same distance.	At the second trial at the same speed the car was able to reach a faster speed of 4.3mph. This speed generated an increased force of 85 N, the car was again able to withstand this force with no breakage.	The final trial the student started the car at 41 feet awat from the wall. The car was able to reach a speed of 7.4 mph becore hitting the wall. The speed generated a top force of 146.3 N. The car did exerpeince some breakage at the rear swing at the same location during the drop test. The student is unclear if it was from the impact test or just normal fatigue that broke the swingarm since the student noticed while cleaning up.

Gravity: 9.81m/s^2

Pictures:

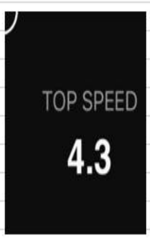
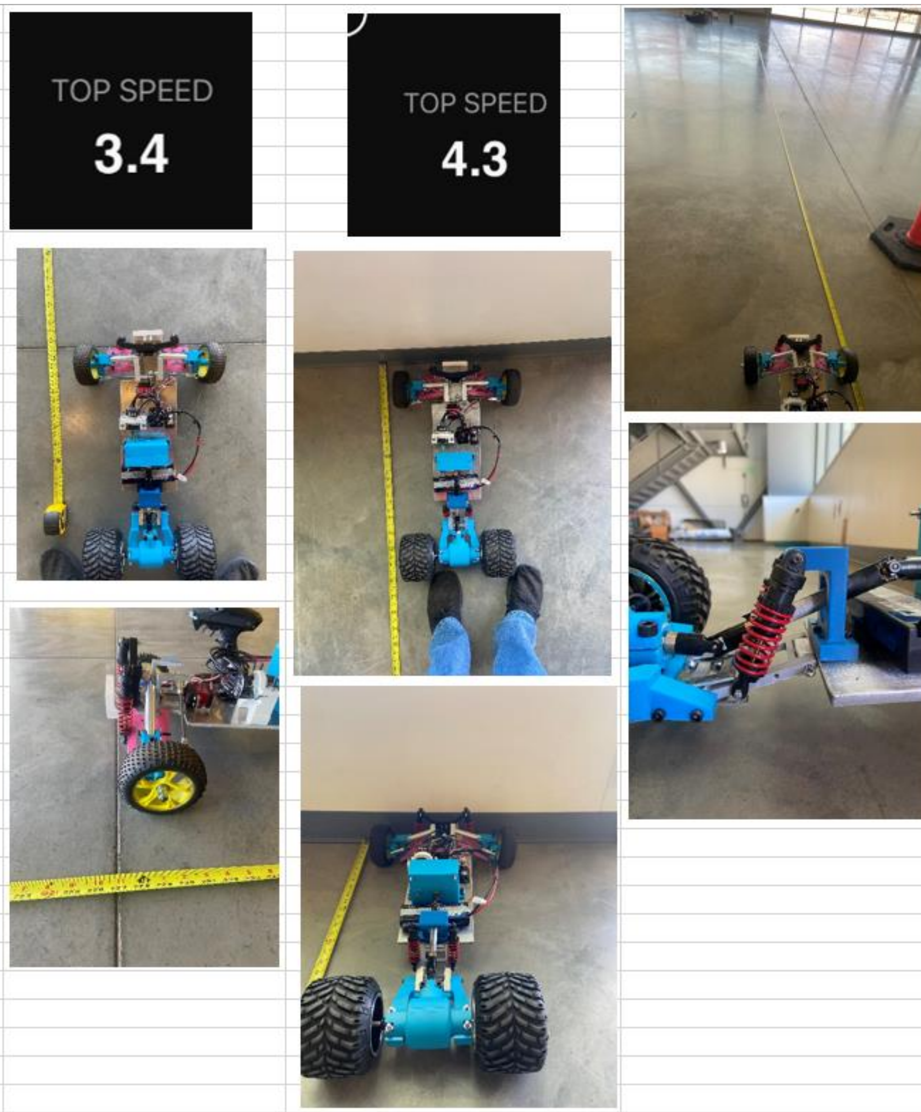


Table G2.2 Data Forms Pictures

Pictures:



Appendix G2.4 – Evaluation Sheet

It should be noted that only two equations were needed to calculate the declaration and force.

Force	F=Ma
Declaration	a=v/t

Figure G2.3 Main Equations used

Appendix G2.5 – Schedule (Testing)

TASK:	Description	Est.	Actual	%Comp.	Septemb	October	November	Dec	January	February	March	April	May	June
4K	Full Assembly	2	2	100%			X	X X	X					
	subtotal:	16	15											
5	PART CONSTRUCTION													
5a	Front shock tower	10	15	100%					X X					
5b	Rear shock tower	10	2	100%					X X					
5c	Shocks	3	2						X X X					
5d	Chassis	1	2						X X	X				
5e	Swing Arms	10	10						X	X X				
5f	Front Bumper	10	15						X X					
	subtotal:	44	46											
6	DEVICE CONSTRUCTION													
6a	Chassis/Full Assmebly	5	39	100%						X X X X	X X X X	X X		
6b	Front Shock tower Assembly	5	3	100%						X X				
6c	Rear Shock Tower Assembly	5	3	100%						X X				
6d	Front Bumper Assembly	2	1	100%						X X				
6e	swing arm assembly	2	4	100%						X X				
	subtotal:	19	50											
7	DEVICE EVALUATION													
7a	Drop Test	2	4	100%								X		
7b	Impact Test	2	2	100%								X X		
7c	Speed Test	2												
7d														
7e														
7f														
7g														
7h														
7i														

Figure G2.4 Gannt Chart

Appendix G-3 Shock Tower Force Test

Test Procedure:

- Summary/overview:
    - This procedure documents the process of applying weight to both the rear and front shock towers to see the amount of force the towers can take and meet the requirement of withstanding a 15lb load. These RC cars have been designed and constructed over the previous fall and winter quarters for the senior project in the Mechanical Engineering and Technology program. The following is the test information and procedure.

Figure G.3 Overview

- Time:
    - The test was conducted on 5/5/2022 from 8am to 10am in the Hogue Machine Shop. There will be half an hour of gathering equipment and setting up, half an hour of conducting the impact, half an hour of inspecting the RC car and analyzing results, and half hour an of clean up.

- Place:
    - Fluke Lab, Hogue Hall, Central Washington University, Ellensburg WA

- Required Equipment:
    - Web Camera/Phone Camera
    - Stand for camera if deemed necessary
    - USB cable if camera needs it
    - Flat Ground or Surface
    - Completed RC Car
    - Notebook/Laptop
    - Data Sheet
    - Pencil/Pin
    - Magnifying glass if deemed necessary

- Stool
- Writing surface
- Excel or similar
- Safety Glasses
- Scale
- Weights

- Risk:
  - All equipment must be gathered ahead of time. Risk to successful completion to this test is not having a completed RC car ready to be tested. Safety glasses will be always required while conducting testing inside Hogue Hall. Additional testing partners are not required but could be used for extra observing.

Test Procedure is as follows:

1) Collect Equipment:
   a. Web cam/Phone camera, recording device
   b. RC car, Camera Stand, weights, scale, Notebook/Laptop, Data Sheet, Stool, Etc.
2) Go to Fluke Lab in Hogue Hall.
3) Place all equipment in organized pile on ground or surface where testing will be conducted.
4) Measure weights that will be used when applying a load with a scale. Take notes of weights.

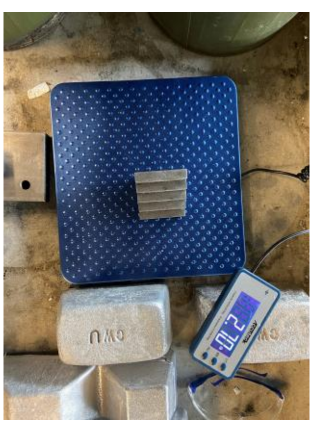


Figure G.3 step 4

5) Take off parts of car that will not be needed for testing such as wheels, hubs, rear transmission hub. These parts will add unneeded weight when testing.
6) Turn car on its backside so weight can be properly applied.

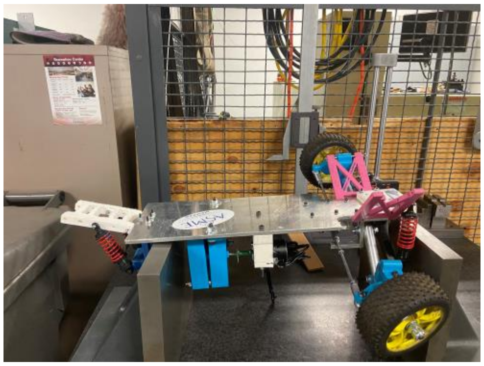


Figure G.3 Step 6

7) Apply minimal and same weight to front and rear shock towers by laying weight on swing arms.

Figure G.3 Step 7

8) Analyzing Results:
    a. Look for breakage
    b. Loose screws
    c. Shift of parts
    d. Analyzing damage to swing arms and shock towers
9) Record results on excel via already created data sheets.

Table G.3 Blank Data Form

	Front Shock Tower Force Test				Rear Shock Tower Force Test		
	Test 1	Test 2	Test 3		Test 1	Test 2	Test 3
Weight (lb):							
Mass (kg):							
Acceleration (m/s^2):	9.81	9.81	9.81		9.81	9.81	9.81
Force (N):							
Force (lb-lf):							
Written observations:							
Pictures:							

10) Repeat steps 7-9 three more times gradually increasing weight up to a max of 15lbs.
11) Return all equipment to its original location if taken from Hogue Hall or elsewhere.
12) Finish calculations on data sheet to find the force the car experienced.
13) Save data sheet if on laptop

14) Testing is concluded.

- Discussion:
  During the shock tower force test the student was able to successfully complete the testing with no issues. The test procedure that the student made previously was able to guide the student throughout the whole test with no need to make changes to the test procedures. The student was able to complete all six trials of the shock tower force test with no breakage of parts. No modifications will have to be made to rear and front shock towers.

- Deliverables:
  The shock tower force test was a measure of the force that the rear and front shock tower could take. After testing was completed, that both front and rear swing arms could hold a load of 15.7 lbs., meeting the requirement of holding 15 lbs. In conclusion the success criteria were that both shock towers could hold a load of 15lbs. It can be stated that with the results of the testing that the shock towers would meet this criterion.

Appendix G3.1 – Procedure Checklist

1. RC Baja car is completed.
2. Test Procedure has been read.
3. Items from Test Procedure are acquired.
4. Data form has been created.
5. Camera is setup.
6. Car is setup and ready to be tested.
7. Student feels competent and ready to conduct test.

Appendix G3.2 – Data Forms

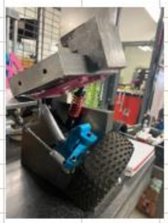
Table G3.1 Blank Example Data Form

	Front Shock Tower Force Test				Rear Shock Tower Force Test		
	Test 1	Test 2	Test 3		Test 1	Test 2	Test 3
Weight (lb):							
Mass (kg):							
Acceleration (m/s^2):	9.81	9.81	9.81		9.81	9.81	9.81
Force (N):							
Force (lb-lf):							
Written observations:							
Pictures:							

Appendix G3.3 – Raw Data

Table G3.2 Raw Data

	Front Shock Tower Force Test				Rear Shock Tower Force Test		
	Test 1	Test 2	Test 3		Test 1	Test 2	Test 3
Weight (lb):	6.5	9.2	15.7		4.35	9.2	15.7
Mass (kg):	2.9	4.2	7.12		1.97	4.2	7.12
Acceleration (m/s^2):	9.81	9.81	9.81		9.81	9.81	9.81
Force (N):	28.9	40.9	69.9		19.4	40.9	69.9
Force (lb-lf):	6.50	9.20	15.71		4.35	9.20	15.71
Written observations:	The front shock tower was able to hold the weight with no issues.	The front shock Tower was able to hold the increased weight with no	The Front Shock Tower was able to meet the 15lb requirment with no breakage.		The rear shock tower was able to hold the weight with no issues.	The rear shock Tower was able to hold the increased weight with no issues	The Rear Shock Tower was able to meet the 15lb requirment with no breakage.



Appendix G3.4 – Evaluation Sheet

Force:	F=Ma

Figure G3.3 Main Equation used

Appendix G3.5 – Schedule (Testing)

TASK:	Description	Est.	Actual	%Comp.	September	October	November	Dec	January	February	March	April	May	June
4K	Full Assembly	2	2	100%			X	X X	X					
	subtotal:	16	15											
5	PART CONSTRUCTION													
5a	Front shock tower	10	15	100%					X X					
5b	Rear shock tower	10	2	100%					X X					
5c	Shocks	3	2						X X X					
5d	Chassis	1	2						X X	X				
5e	Swing Arms	10	10						X	X X				
5f	Front Bumper	10	15						X X					
	subtotal:	44	46											
6	DEVICE CONSTRUCTION													
6a	Chassis/Full Assmebly	5	42	100%						X X X X	X X X X	X X X X	X	
6b	Front Shock tower Assembly	5	3	100%						X X				
6c	Rear Shock Tower Assembly	5	3	100%						X X				
6d	Front Bumper Assembly	2	1	100%						X X				
6e	swing arm assembly	2	4	100%						X X				
	subtotal:	19	53											
7	DEVICE EVALUATION													
7a	Drop Test	2	4	100%								X		
7b	Impact Test	2	2	100%								X X		
7c	Shock Tower Force Test	2	2	100%									X X	
7d														
7e														
7f														
7g														
7h														
7i														
	subtotal:	6	8											
8	489 DELIVERABLES													
8a	Final Presentation													
8b														
8c														
8d														
8e														
8f														
8e														
8f														
8g														
	subtotal:	0	0											

Figure 3.4 Gannt Chart

APPENDIX H – Resume

John (Jack) Huff IV
Kent, WA | Jackhuff115@gmail.com | 425-495-3991

OBJECTIVE

Highly driven soon to be engineering graduate seeking a full-time position in mechanical engineering where I can lend my knowledge and skills to help your company be the best it can be.

EDUCATION
Bachelor of Science in Mechanical Engineering Technology
June 2022
Central Washington University - Ellensburg, WA
GPA: 3.72
Dean's List, Central Washington University
Sept. 2018 – Current

Relevant Coursework
Basic Electricity
Machining
Computer Aided Design and Drafting
Statics
Three-Dimensional Modeling
Thermodynamics
Technical Writing
Technical Dynamics

SKILLS

Microsoft Excel, Microsoft Word, Microsoft PowerPoint, Auto CAD, Solid Works, 3DPrinting, Java programming (basic)

EXPERIENCE

Engineering Inter, NorthStar Casteel – Seattle, WA June – August 2021

- Spent many hours in the foundry making sand molds
- Helped design new floor plans for Vancouver plant
- Designed new Dollie to help move heavy equipment

Picker, Amazon- Kent, WA June – Sept. 2020

- Displayed a high level of initiative and independence
- Efficiently stocked inventory utilizing technology in a warehouse
- First person enlisted for many tasks due to high level of versatility on the job
- Trained 5 new employees

Multiple Roles, Sansonina Ristorante Italiano - Renton, WA June 2019 – Jan.2020

- Served as a busser, host and waiter's assistant in a find dining restaurant
- Utilized strong customer services and interpersonal skills to ensure good guest experience

Multiple Roles, Grazie Ristorante - Tukwila, WA Sept. 2017 – Jan. 2019

- Prioritized tasks in order to best serve the customers in a fast-paced environment
- Memorized food and wine menus, educating guests on their options

Food Server, KFC - Renton, WA Aug. 2016 - 2017

- Displayed strong leadership skills while working as a part of a team of up to 5 team members

Job Shadow Program, Boeing Facility - Renton, WA March 2017

COMMUNITY INVOLVEMENT

Volunteer, Northwest Harvest - Kent, WA March 2017 - May 2018
Volunteer, Kent Parks & Recreation - Kent, WA February 2018