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R/C Baja Chassis and Suspension

Donovan Dueber
Central Washington University, dueberd@cwu.edu

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By

Donovan Dueber
Team member: Jason Schindler

Abstract

A team made up of two students have developed a unique design of a RC Baja Car to optimize functionality and performance. A Baja car is a remote controlled 1/10 scale car that is used for recreation or competition, usually meant for competing in the American Society of Mechanical Engineers (ASME) Baja car competition against various teams. The objective for the project was to create a unique suspension different from previous individual's projects by creating a two-type suspension. This was completed by having a coil suspension in the front which allows more travel in the suspension of the car and a leaf spring suspension in the rear which helps keep the rear tires in contact with the ground. The inspiration for this suspension came from researching and seeing how various RC cars have performed in the past. To integrate this concept, multiple analyses were conducted to help create the design of the RC car. The angle of the suspension arms and tolerances needed to be precise in order to produce a cohesive functional suspension between the front and rear of the car. Manufacturing machines such as a band saw, end mill, and a drill press were utilized to create the support for the suspension which connects the shocks to the a-arms. With the two-type suspension and allowable adjustments within the design, the RC Baja Car was able to withstand a drop of 1.5 feet.

Contents

1. INTRODUCTION

a. Description

The goal for this project is to compete in the ASME R/C Baja competition by demonstrating the ability to design, manufacture, and preform following the ASME Baja guidelines. Specifically, this report will cover the design, construction and testing of the chassis and suspension of the RC Baja car.

b. Motivation

This project was motivated by a need for a device that would compete in the ASME R/C Baja event. In addition, the need to apply students engineering skills to real world applications is key in progressing Mechanical Engineering student's skills. And to effectively apply these skills without spending too much money, a mini RC Baja car design and construction will test these skills that Mechanical Engineers have.

c. Function Statement

The chassis supports and holds all the physical parts comprising the RC Baja car. The suspension allows the car to go over bumps and absorb impacts the car will make with the ground. The RC Baja car must be able to sustain its own weight on all four wheels when placed on the ground. It must be able to navigate over smooth and rough terrain, including but not limited to asphalt, gravel, mud, stairs, large rocks, and jumps. Must be able to carry its own weight, be able to free roll in a straight line without steering input, ascend an incline of 45 degrees and be remote operated via radio signal.

d. Requirements

The requirements that will need to be completed in order for the project to be successful are listed as followed.

- The cost of parts for the Baja car should be limited to $600.
- The Baja Car must be able to withstand being dropped from 1.5 feet.
- The chassis will weigh no more than 8 pounds.
- The outside dimension not including the wheels must be no larger than 1/10 scale.
- Remotely operated.
- Suspension must handle at least 50 N of force.
- Suspension must be able travel 1.5 inches without interference.
- Be able to survive a collision with a wall going at least 7 mph.

e. Engineering Merit

All the knowledge that will be used for this project has been learned from classes that have been taken at the university. From the drawings completed on Solidworks to the calculations done to figure out a design that will complete what it needs to do.

f. Scope of Effort

As a team the whole R/C car will be completed, however for this particular project the focus will only be on the chassis and suspension. The suspension of the RC Baja car will be a shared responsibility with the other group member, so information will be referenced to other reports.

g. Success Criteria

Success in this endeavor would mean at least the meeting of each the function statement and requirement items. Completion (no DNF) for the competition of the ASME RC Baja event will result in a success. Exceeding expectations would mean placement in top 5 of each category of the competition.

2. DESIGN & ANALYSIS

a. Approach: Proposed Solution

The design for the suspension was conceived by doing research on different types of suspensions. Two different types were found, coil suspension and leaf spring suspension. Coil suspension is great for the ability to go over bumps, or take the impact coming off of a jump. Leaf spring suspension is going to be stiffer but allow for more power by keeping the wheels connected to the ground. The suspension that will support the car will be a mix of coil springs and leaf springs.

b. Design Description

The design that was came up with was to have coil suspension in the front and have a leaf suspension in the back. The coil suspension will allow more travel in the front which will absorb bumps and drops more than leaf spring suspension. The rear will have leaf springs, which will allow room for the driveshafts to drive the rear wheels. Leaf springs will have less overall travel than that of coil springs, however they will be stiffer, which will allow power transfer from the motor to the wheels to the ground to be more efficient.

c. Benchmark

Almost all other senior projects that competed in the ASME RC Baja competition in previous years used the same type of suspension in the front and back they all performed varyingly different. By having a mix of suspensions, the Baja car should do better going of bumps and jumps like the cars that had coil springs. Since the leaf springs will be in the back it will have a better power delivery since the leaf spring will be stiffer than a coil spring. Since the previous year's cars will not be available for direct comparison, presumed descriptions will be used to directly compare the performance of the finished product. The intent of the design, construction, and testing will be to at least meet the required design parameters, and then improve on them as much as possible.

d. Performance Predictions

The performance of the chassis and suspension is expected to be able to withstand being dropped from 1.5 feet. The suspension must handle at least 100 N of force when dropped on its tires. The coil suspension will be tested as the parts are designed, and the coil rate along with the dampening can be adjusted to best fit the given terrain that the car will travel on. For example, the spring rate will be higher when the car is driving on asphalt specifically, and lower spring rate for rougher terrain. The suspension should be able to travel 1.5 inches without interference. The chassis should support all the mechanisms of the car throughout all the events. The chassis should also not break or allow any pieces of the car to come off during any of the events.

e. Description of Analysis

During the design stage of this project, the components of the car will be assumed to a dimension that best fits the car's shell. Spring rates on both the coil and leaf spring will be determined by the weight of the car, the length of the control arm, and the geometry of the mounting point of the upper and lower control arm to the suspension tower on the chassis. The chassis size will be determined by the number of components it will need to support. The weight of the chassis can't be more than 8 pounds. Cost also becomes a factor because the car can't cost any more than $600 for everything that is included in it.

f. Scope of Testing and Evaluation

The scope of the testing and evaluation touches the aspect of structural integrity and longevity of the car; thus, the drop test being conducted. The scope also touches functionality and performance requirements, conducted in the speed test evaluation.

g. Analysis

i. Analysis 1

The material thickness of the chassis was calculated so that it could withstand a force of 100N when dropped. It was discovered the thickness must be at least 2.5mm. The thickness was chosen to be 6mm because this is a standard ¼ in. plate.

ii. Analysis 2

The impact force from a 1.5ft drop was calculated to find what the force per side of the car is when it hits the ground.

ii. Analysis 3

The RC Baja Car energy absorption requirement from being dropped at 1.5 feet was found this made it possible to find the minimum screw diameter. The energy needed to withstand the fall was found to be 16.28J.

ii. Analysis 4

The minimum allowable screw diameter to withstand impact and not fail at screws was found to be 0.028in, 1/16in was chosen because it is the closest standard size.

ii. Analysis 5

The buckling analysis on a suspension support was conducted. The critical stress was found to be 12,843 psi.

ii. Analysis 6

The maximum angular velocity of the wheels was discovered. The max angular velocity was calculated to be 216.37 rad/s.

ii. Analysis 7
Analysis was conducted to find the critical load of the chassis before buckling. It was found that the chassis can withstand 10kN of compression before it begins to buckle.

ii. Analysis 8
The geometry necessary to attach the shock to the shock tower and suspension arm was found. The angle towards the shock tower needs to be 26.4°. The angle towards the bottom of the shock needs to be 63.6°.

ii. Analysis 9
The k factor of the spring that the Baja car needs was found. The spring needed for the Baja car needs to have a k factor of 771*10^3 N/m.

ii. Analysis 10
The minimum allowable diameter for hinge pins was found. The minimum diameter that the hinge pins can be to withstand a force of 100N is 1.5mm. 2.5mm hinge pins will be used since they are a standard size for a Baja car.

ii. Analysis 11
Analysis of the RC car sustaining front impact due to object or wall at 20 mph was done. The force of the impact was found to be 1,707.4 lbf.

ii. Analysis 12
The bending stress on a-arm was analyzed. The bending stress on the a-arm was found to be 2,120 psi.

h. Device: Parts, Shapes, and Conformation
The intent of the design is to be functional. The shapes of each of the parts is to be as functional as possible. For example, the control arms house both the wheel hubs and the suspension. The variation between the rear and the front control arms are little to ensure that the construction of them is a streamlined as possible. The only parts that need to be machined are the control arms, the suspension tower/support and the chassis plate. The rest of the parts can either be 3D printed or made with hand tools. This allows the construction of these parts to be done more effectively. 3D printed parts have close geometry to the parts that interact with them, which allow little to no movement when assembled.

i. Device Assembly
The assembly of the car will be relatively easy. All the fasteners are going to be metric size, and most of them are going to be the same size. This allows a single tool to be used when building them. The components on the chassis can be removed from their mounting place, as well as the suspension components.

j. Technical Risk Analysis

The components that have the most difficulty to be removed and replaced like the chassis plate for example will have the highest safety factor. This also includes the parts that are the most expensive. The control arms are also parts that must have a high safety factor. This is because they are essential in keeping both the steering and the suspension components from failing.

k. Failure Mode Analysis

Analysis of the RC car sustaining front impact due to object or wall at 20 mph was done. Allowable bending stress was also found for the chassis. Design parameters were made around these forces that would cause the Baja car to fail.

l. Operation Limits and Safety

Due to COVID-19 access to the machine shop will be limited. Social Distancing is required at all times while on campus. Safety glasses and closed toed shoes are also required while being in the machine shop.

3. METHODS & CONSTRUCTION

a. Methods

The conception, analysis and design of this project will be done remote to the CWU campus. This means that limited resources are available, and lots of parts will be outsourced/purchased. Major components were fabricated onsite with supplementation of some parts being bought from outside retailers. The various retailers provided tools and parts that cohesively work with the designed and manufactured parts of the group. The parts being manufactured are the chassis plate, suspension tower, and the a arms. All other parts that are needed besides the chassis, suspension tower and a arms will be purchased or donated from Baja teams from the previous years. The first step in construction will be machining the chassis. The chassis will have to be machined into the desired shape from the donated material using a band saw. Once the chassis is made to the correct shape the holes for mounting everything to it need to be drilled in addition to the holes being drilled all edges will need to be filed down so they are no longer sharp. After that is complete the holes will need to be tapped so that the screws holding everything on the chassis will thread into the chassis. Next, the team will need to fill in the tapped holes that were already previously in the donated material by welding them and then grinding the filled holes and the extra screw length that is not needed smooth. Once that is complete the next step will be constructing the suspension tower this part will need to be measured and cut from the donated material then it will need to be machined into the right shape and have holes drilled at the bottom so that it can be bolted onto the chassis. After making the suspension tower, cutting the leaf springs was the next step. Cutting the spring steel to length was done using resources within Hogue on campus grounds. Once the measuring and scratching sections in the sheet of steel was finished, a manual shear cut the thin layers. The sharp corners were rounded off and holes were drilled so they will be able to be bolted onto the chassis. Once the leaf springs were finished the next step was to measure and cut the desired amount of material from the stock that was donated for the a arms then they must be cut to the desired geometry using a band saw and then machined so they will fit into the slots on the chassis plate. The last step was mounting the front suspension shocks to the suspension tower and the front a arms.

i. Process Decisions

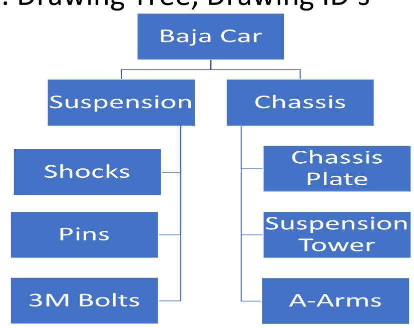
The suspension of the car is different between the front and the rear. The front will have coil spring suspension, which will allow more travel, along with softer reaction to compression under traveling. This will allow the car to absorb any terrain elevation or surface changes. The rear will have a leaf spring suspension, which will allow the rear of the car to be stiffer than the front. Being stiffer in the rear means that power delivery from the drivetrain will transfer better from the tires to the ground. The leaf springs will also allow the axles of the drivetrain to be connected from the differential to the hubs. This means that the suspension support in the rear will be centerline to the wheels, and control arms.

b. Construction

i. Description

This project was designed in increments. The majority of the parts were bought because of the worry of not having enough access to the labs due to COVID-19. However, the chassis and a few other components like the suspension tower and the four a arms were fabricated on campus with material that was donated to the team. The suspension of the car is more complicated than the chassis. The car has two different types of suspension the front will have shocks and the rear will have leaf springs. The reason for this is because the team wanted the car to have good traction and to always have the rear wheel as close to the ground as possible so that the car will be able to make solid contact with the ground and accelerate at a faster rate than it would if it had coil over shocks. The front suspension having shocks allows the car to survive impacts from going off jumps or hitting bumps at high speeds without having the front end get destroyed or flinging the front end of the car into the air causing the car to go out of control. The hubs connecting the wheels to the control arms are different between the front and the rear. The front has a spindle hub needed to operate the steering.

ii. Drawing Tree, Drawing ID’s



iii. Parts

The chassis which is the main support of the suspension was machined on campus with supplemental holes. Using Aluminum 6061, the material will be band sawed then end milled to get the desired profile. The suspension tower will be cut from donated stock then machined and holes will be drilled so that it can be mounted to the chassis and be able to support the front suspension.

iv. Manufacturing Issues

During a global pandemic, manufacturing of parts will be done in house at CWU. This means that members of the team are responsible for the correct construction of part geometry. By having individual team members manufacture parts themselves, this circumvents the process of outsourcing other labor to manufacture the parts themselves. This makes the designers of the parts responsible for creating the geometry needed for the parts individually. Parts that are going to be 3D printed, will be printed in house as well. However, test fitting parts like control arms, and motor mounts will be made first in cheaper, weaker material just to test fit the geometry of the design. This means that any needed revisions will be less expensive, so once the parts are finalized, they will be printed out of the original material that is structurally needed. Major issues could arise using the band saw and getting very precise and small radii. Another issue that could arise is the material could bend during the cutting process making it unusable. Slowly taking small cuts off each passthrough will be conducted to achieve desired results. Other issues such as not having enough access to the machine labs or manufactures not being able to complete the orders could also arise during the construction phase of the project.

v. Discussion of Assembly

The assembly of the car will be done in the machine lab at CWU. Fasteners will be sourced from local stores, using metric sizes only which will allow the assembly and disassembly of the car to be done with minimal tooling. The way the car will be assembled is by first machining the chassis to the shape needed, then drilling the holes for all of the suspension and whatever else may need to be mounted onto the chassis so that it will be secure. Next will be manufacturing the suspension towers and suspension support beams. Once that is done the a arms will need to be put onto the chassis. Lastly the shocks will be mounted from the suspension tower to the a arms and the leaf springs will be mounted to the rear part of the chassis.

4. TESTING

a. Introduction

The aspect of suspension failure during a drop test will be analyzed. This is an important test to simulate due to possibilities during the ASME competition. The vehicle could hit obstacles or go off jumps during the competition so it is necessary to collect data and ensure that the vehicle will withstand the forces being applied. One other requirement the car must be able to make is to have the chassis weigh less than 8 pounds. This is so that the chassis doesn't weigh the car down and it will allow the car to preform better than a car with a heavier chassis.

b. Method/Approach

For the drop test, the car will be at a specific controlled height using a tape measure and then the wall will be marked with tape to have consistency when testing. One team member will hold the car level and the other one will record the test. Before the car is dropped all components of the car must be inspected to make sure everything is working prior to the drop. This test will test the suspension capabilities of the car and will determine if the car can withstand a 1.5ft drop which is one of the requirements it needs to meet. The deliverables of the test will be videos of suspension travel, as well as a height reading. The car will be dropped from a height of 1.5ft, and a recording on the ground will show how the suspension travel occurs. Before the car is fully assembled the chassis will be weighed to see if it meets the requirement of weighing less than 8 pounds. To find the weight of the chassis a scale will be used. During the front impact test, the device moved at a velocity of 15 mph, and hit an obstacle head on to simulate obstacles within the ASME competition. Ensuring that there is enough space for testing is important to limit the dangers of possible debris and proper precautions of protecting the walls or property if testing is conducted within the Hogue Technology building. Gathering a device such as a radar gun to ensure appropriate velocity is maintained would satisfy testing methods but also was not included due to supply chain lead times and cost. A visual inspection also took place after the vehicle sustained a front collision. The front impact test was conducted to confirm that the vehicle could sustain impact and maintain proper operation as intended.

c. Test Procedure

Testing always needs proper procedure and safety equipment. The possibility of pinching and debris will be the most concerning obstacles during testing. Proper eye wear will be worn during testing. Each test will have a controlled variable, such as a set height or mph. The tests will be conducted offsite and in a controlled area. Multiple trials will be conducted for each test and recorded or observed. For the first test which will be the drop test one team member will hold the car level at a measured height of 1.5 ft and the other team member will record. Prior to dropping the car a team member will inspect every part of the car to insure nothing is broken before being dropped. Once this is complete the team member holding the car will drop it so that all four tires of the car hit the ground at the same time. Once the car hits the ground the team members will inspect the car to see if anything is broken.

d. Deliverables

There will be multiple different tests completed for the RC Baja car. One deliverable from the tests completed will be that the car will survive a 1.5ft drop. This will be required because throughout the ASME Baja competition the car will need to survive drops from that height when it goes off of jumps. One other deliverable will be the weight of the chassis. The chassis will be weighted and must be under 8 pounds. This is to force the team to try to keep the car as light as possible in order for it to preform to its best ability. When all the testing is complete the data will be uploaded to Appendix G that is named Testing Report. The requirements it will meet will also be shared in this section.

5. BUDGET

a. Parts

Part suppliers included: RC Mart, Hobbywing, and Amazon for most of the components for the RC car. The material for the Aluminum originally was going to from Midwest Steel and Aluminum. Once the team had access to the machine shop donated material was able to be found and used for the chassis, suspension tower and the A-Arms. Some components such as the shocks and leaf springs were sourced from previous projects. The only components that had to be ordered were the screws, nuts and pins used to hold everything to the chassis. Those have not been ordered yet, the team is waiting for the chassis to be completed to avoid anything from needing anything to be returned they should be ordered in a week.

b. Outsourcing

No outsourcing was done other than part deliveries that were purchased online. This was because of the COVID pandemic. Due to the severity of the pandemic and since almost everything was closed during fall quarter everything that was manufactured was done in house in Hogue Hall by the team members. There were however a few 3-D printed items that needed to be reprinted throughout the manufacturing process. This was done by Professor Pringle since the team needed a higher quality 3-D printer than the one the team had.

c. Labor

Labor was calculated as if the group was paying two individuals; the number of students on the project, at a rate of $13.50 (minimum wage in Washington State) in 2020.

d. Estimated Total Project Cost

The total parts cost was estimated to about $444.70. Contingencies due to designing a suspension that is unique from previous Baja Car projects adds an element of calculations and designing. The overall list of parts and estimated labor hours changes occurred. The projected overall project goal is $600 or less, so the project was within the projected budget.

e. Funding Source

All the funding was self-sufficient through the team. Getting donations from ASCWU and outside companies was a goal for the team but was not possible mostly because of the global COVID-19 pandemic. Some parts were also donated from previous projects or integrated from parts already obtained.

6. Schedule

a. Design

The schedule can be found in Appendix E as figure E-1. This figure includes each step along the way of designing the entire project. It begins with the proposal, then outlines the construction and building of the R/C car and is finished with the testing of the car. The design schedule includes each part of the proposal and design processes. The duration that each aspect will occur has been estimated and started in figure E1 in Appendix E. How long each step will take has been estimated for each aspect, and this dictates which part of the design is more president. The approximation of how long each step will take has been estimated, and this will dictate which aspect of the design process that will be completed first. The longest part of the design will be the analysis portion. This is because multiple calculations are going to be needed to dictate the overall shape of the design of the chassis and suspension, and other aspects of the car. For fall quarter the proposal must be completed by the end of the quarter. For winter quarter the Baja car must be fully assembled before the quarter is finished. Lastly, by the end of spring quarter, the Baja car but be fully tested using various types of testing such as a drop test.

b. Construction

The construction schedule has had to be made around COVID-19 closures. The first two weeks of winter quarter the campus was closed, and no one had access to the tools and machines in the Hogue machine shop. Scheduling around campus being closed made the schedule tighter. The chassis and leaf springs were scheduled to be done the sixth week of class. The rest of the parts that need to be manufactured such as the a arms and suspension tower should be finished by week nine. One major hiccup during manufacturing was the horizontal band saw clamp was broken close. This made it not possible to cut the a arms out of aluminum and the team made a decision that the a arms would be 3-D printed until the horizontal band saw was fixed. Once all the parts were manufactured the RC Baja car was assembled and ready for the due date which is the last week of class.

c. Testing

The testing schedule has had to be made around COVID-19 closures. The first two weeks of spring quarter the campus was closed, and no one had access to campus or Hogue Hall. The first test that was conducted was the chassis weight test. This was done during the sixth week of winter quarter after the chassis was finished being manufactured. The next test that was completed was the drop test this was completed during the third week of spring quarter. Since the car failed the first drop test it was needed to be redone this was conducted week four of the quarter. The test to be completed after that was the front impact test, this was conducted during the fifth week of spring quarter. The final test that was conducted was the suspension loading test. This was done during the sixth week of spring quarter.

7. Project Management

a. Human Resources

MET Faculty- Professor Pringle and Professor Choi, Project Partner- Jason Schindler, and CWU student partners along with the Hogue machine shop technician Muir Hamilton are human resources for this project. These resources were essential in providing background knowledge, hands on help in the machine shop, helping set up equipment, giving guidance and providing feedback on the technical content of this report along with giving comments to what could be changed to make the project and report better overall.

b. Physical Resources

3D Printer (Hogue), CNC Mill, Bridgeport Mill, Drill Press, Deburr room, Hand tools, ruler, scribe, center punch and other machine shop basic tools are physical resources. These resources provided are essential in the construction of the car. There has been a large portion of purchased and donated parts in the car, however construction of some things is needed to complete the final car.

c. Soft Resources

Solidworks CAD, Microsoft Excel, Microsoft Word, zoom and Microsoft Teams have been used in the curation of this project. Solidworks has been used for the combination of purchased parts as well as custom made parts. Microsoft Excel has been used to plan the schedule of the entire project as well as create the Gantt Chart. Microsoft Word was used to create the project proposal. Microsoft Teams along with zoom was used to collaborate with others online and conduct meetings online throughout the pandemic.

d. Financial Resources

Personal finances, reused parts, and bulk material donations from the school are financial resources for this project.

8. DISCUSSION

a. Design

The initial design of the RC Baja car was to gather ideas and information from previous teams from the past and optimize the vehicle in the team's unique way. The team saw what was used effectively and where areas could improve from previous years RC Baja cars. The major design aspect that is unique to the Baja car this year is the suspension, it will support the car with a mix of coil springs and leaf springs. The coil suspension will be in the front, and the leaf spring will be in the back. The coil suspension will allow more travel in the front which will absorb bumps and drops more than leaf spring suspension. The rear will have leaf springs, which will allow room for the driveshafts to drive the rear wheels. Leaf springs will have less overall travel than that of coil springs, however they will be stiffer, which will allow power transfer from the motor to the wheels to the ground to be more efficient. Since coil suspension has been chosen for the front, the availability of changing the stiffness of the springs will allow how the car handles on different surfaces. For example, if the course that the car will travel on is hard packed, then a stiffer suspension will minimize body roll, which will give the car more responsive acceleration and steering input. However, if the course that the car will on is loose and uneven, then a loser suspension will optimize the car's performance. This is because as the car travels across bumps, the wheels will travel up and not be in contact with the ground. If the car's suspension is stiff, then it will cause the car's body to roll, and thus losing contact surface with the ground as it travels across bumpy ground. The Leaf spring suspension in the rear has been dictated by the design of the drivetrain. Since the front of the car has more travel than the rear, the power delivery from the motor to the tires to the ground will be more effective. In off road vehicles, nosedive is something that needs to be mitigated. Having the front suspension higher than that of the rear will allow the angle of attack of the chassis to be at its optimum position, which will eliminate the risk of nosedive. The chassis plate was projected to be a solid piece then the intent of optimizing it and make the part lighter was conducted. The problem became that if there were not any holes drilled into the chassis plate there would be no way to mount the suspension towers. In addition, this design change makes the chassis plate lighter which in returned made it easier to meet the requirement that the chassis plate must be less than 8 pounds.

b. Construction

The first thing that needed to be completed for manufacturing was cutting the donated material to the geometry needed for the chassis. This step was straight forward however an issue arose when the team realized there was no rulers that had millimeters. The design has everything in millimeters, to fix this problem a trip to the store was needed. One other issue that came about was the work stop for the band saw would move slightly every time it was locked in place. To fix this issue the help of a team member was needed. The team member held the work stop in the correct position when it was time for it to be locked in place. Once the team was able to measure everything precisely and have the work stop in the correct position it seemed to be smooth sailing the rest of the way until the team started to manufacture the a arms. This was the last part that needed to be made, the problem that arose was when the team went to cut the stock to the correct length the clamp on the horizontal band saw would not open. Several attempts were made to get the clamp to open so that the team could use it but even the lab assistant could not get it to move. When this happened, the team made a decision that printing them in ABS material with a 3-D printer was the best option so that the car would be complete by the due date.

c. Testing

The first test that needed to be completed was the drop test. This test requires the RC Baja car to survive a drop of 1.5 ft. The reason for this test needing to be completed was because during the ASME Baja competition the car will hit bumps or go off jumps that will be similar to dropping 1.5 ft or less. After completing the first drop test the RC Baja car failed the test. Both a-arms on the right side failed. After investigating the reason why, the team came to the conclusion that it was because of two factors. The first factor was the PLA 3-D printed material that was used to make the original a-arms was not strong enough and the second being the quality of the parts that were originally printed were very low. To fix these two problems the team decided to add some additional support around the area that broke and to print them in ABS and with a higher quality 3-D printer. This should fix both issues and the car should be able to survive at least a 1.5 ft drop and hopefully even a larger one even though it will not be required for the ASME Baja competition. After completing the second drop test it was clear the team's conclusion was correct. This time when the drop test was done the car was able to survive the fall and nothing broke or came off of the car. The next test that was completed was the front impact test. During this test the team was able to see how the car would survive if it were to run into a wall or barrier head on. This is important because during the ASME RC Baja competition the RC car could hit a wall, or a barrier head on and the car needs to be able to survive the impact so that it can finish the competition. After this test the car was able to survive hitting a wall head on going approximately 7.5 mph (half throttle). The next test that was conducted was the suspension loading test. This needed to be tested because the car had a requirement that the suspension must be able to support 100 N of force placed upon it. The last test that needed to be conducted was weighing the chassis. The chassis needed to weigh less than 8 lbs. after the team completed weighing the chassis , the chassis ended up weighing half the required weight at 4.25 lbs.

9. CONCLUSION(200)

The team will focus on the RC Baja Car project with focus on the drivetrain, chassis and suspension aspects of the vehicle. The goal for the project was to compete in the ASME Baja Car competition held at Central Washington University in the spring. The overall readiness to begin manufacturing was nearly ready in week 9 of fall quarter. Parts list, schedule, and project proposal had a few aspects needed to be finished and ready to begin the next phase of the project but was finished in time. All materials and parts were manufactured in winter quarter to streamline the senior project process. The two analyses that are of importance that contributes to the success of the project are: front impact test and drop test of the vehicle. These analyses both simulate possible outcomes or events that may take place in the ASME competition. The vehicle may have to sustain jumps and not fail, along with possible collision with obstacles and must not fail as well. With the suspension being a primary focus, the structural integrity and durability is prioritized to ensure the vehicle does not fail during operation.

10. ACKNOWLEDGEMENTS

Acknowledgements and overall appreciation for resources, feedback, and help goes to Jason Schindler, Professor Choi, and Professor Pringle for helping with the senior project. Their experience with many other senior projects allowed them to give helpful feedback and insight on how the project can be improved. The resources these individuals provided, created a seamless timeline for all elements of the project. There are many additional resources that have been essential to the success of the car. One of these is CWU's machine shop. This shop allowed the construction of multiple components and provided tools for the assembly process. Another resource that has been essential in the car's success is the aid of other students at CWU. These students have help with the design process from analysis of components, to decision making processes. Their support in the projects design and curation helped with both providing feedback on steps along the way, to insight.

References

Mott, Robert L., Edward Vavrek, Jyhwen Wang. Machine Elements in Mechanical Design.

Hibbeler, Russell C., and Kai Beng Yap. Statics and Mechanics of Materials. Pearson, 2019.

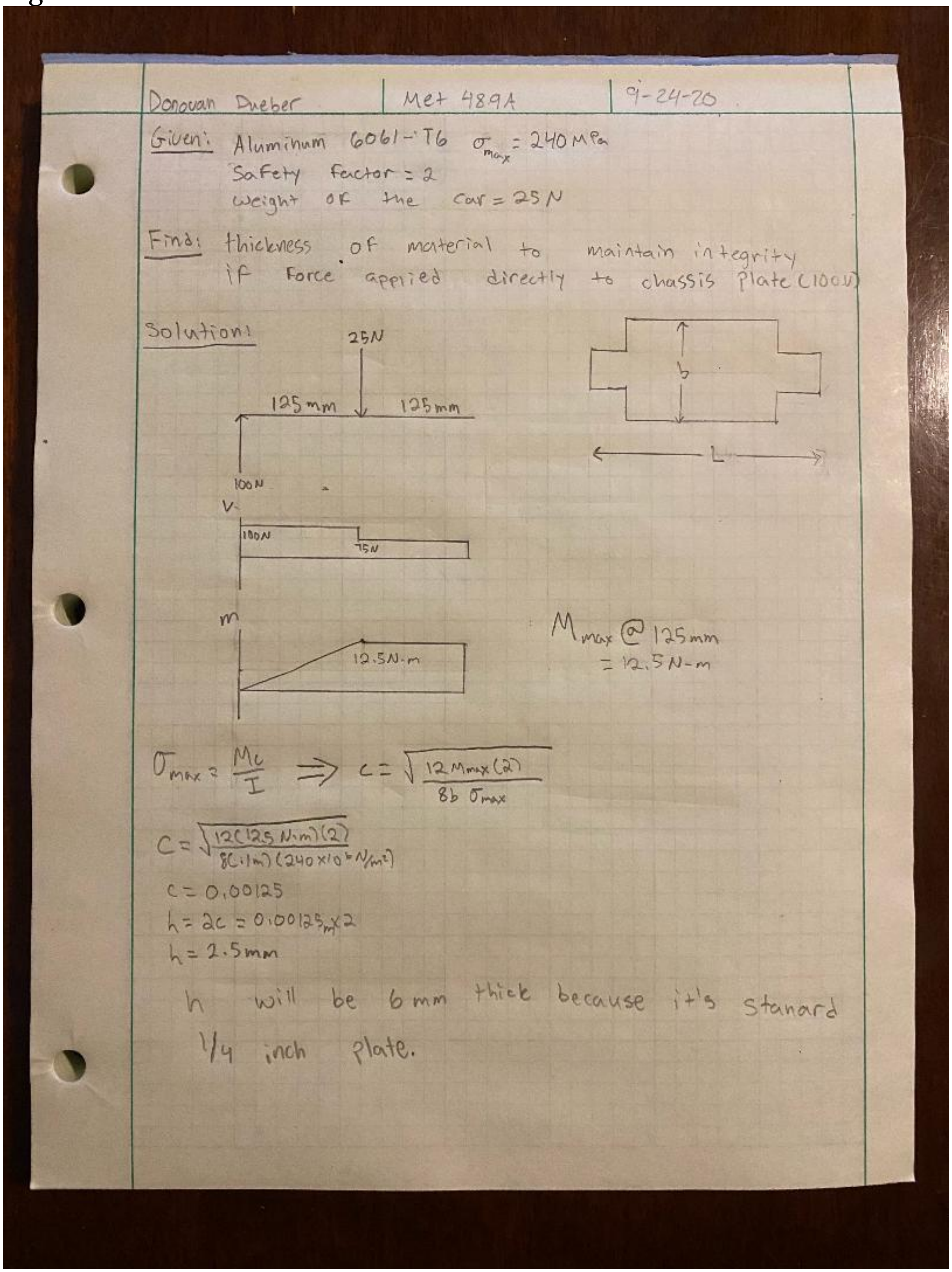
FxSolver, https://www.fxsolver.com/.

Engineering ToolBox, https://www.engineeringtoolbox.com/.

ASME RC Baja Competition Rules, https://www.cwu.edu/engineering/sites/cts.cwu.edu.engineering/files/documents/met_2015RC_BajaRules.pdf.

APPENDIX A – Analysis

Figure A-1 – Thickness of chassis



Donovan Dueber | Met 489A | 9-24-20

Given: Aluminum 6061-T6 $\sigma_{max} = 240$ MPa
Safety factor = 2
weight of the car = 25 N

Find: thickness of material to maintain integrity if force applied directly to chassis plate (100N)

Solution:

M_{max} @ 125 mm
= 12.5 N-m

$$\sigma_{max} = \frac{Mc}{I} \Rightarrow c = \sqrt{\frac{12 M_{max}(2)}{8b\,\sigma_{max}}}$$

$$c = \sqrt{\frac{12(12.5\ N\cdot m)(2)}{8(.1m)(240\times10^6\ N/m^2)}}$$

c = 0.00125
h = 2c = 0.00125 m × 2
h = 2.5 mm

h will be 6 mm thick because it's stanard 1/4 inch plate.

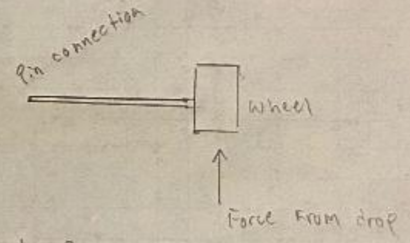
Figure A-2 – Impact force from 1.5ft drop

Donovan Dueber | Met 489A | 9-29-20

Given: 1.5 ft drop

$m = 8 lb$

$x = 1.5 in$



Find: Force applied to leaf spring upon dropping from 1.5ft

Solution: Potential = kinetic

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

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

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

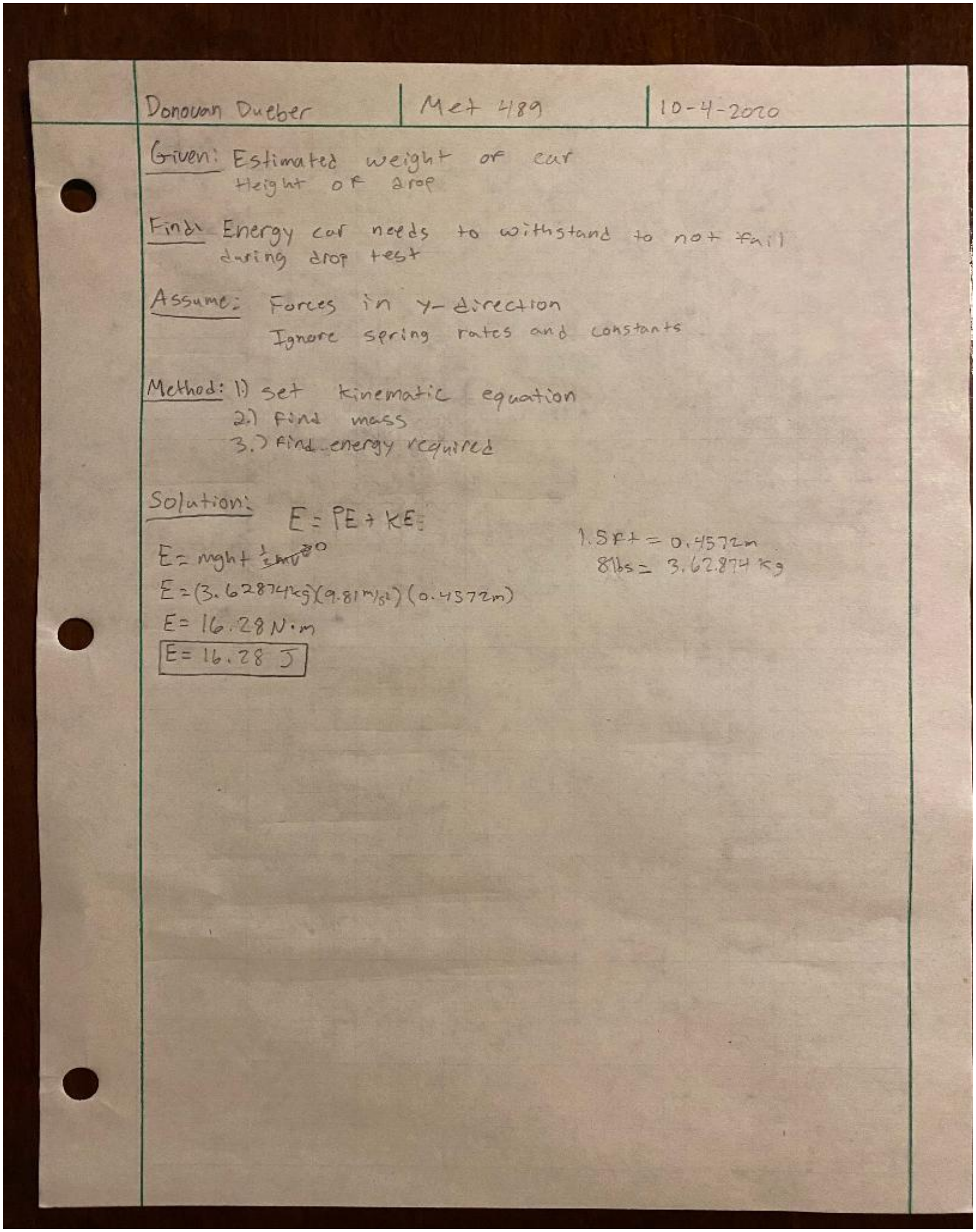
$F = \frac{2mgh}{x}$

$F = \dfrac{2(8lb)(32.2 ft/s^2)(1.5ft)}{\frac{1.5in}{12}}$

$F = \frac{772.8}{.125} = 6182.4\left(\frac{1}{32.2}\right) = 192 lbf$

Force per side $= \frac{192}{2} = \boxed{96 lbf}$

Figure A-3 – RC Baja Car energy absorption requirement from being dropped at 1.5 feet.



Donovan Dueber | Met 489 | 10-4-2020

Given: Estimated weight of car
Height of drop

Find: Energy car needs to withstand to not fail during drop test

Assume: Forces in y-direction
Ignore spring rates and constants

Method: 1.) set kinematic equation
2.) find mass
3.) find energy required

Solution: $E = PE + KE$

$1.5ft = 0.4572m$
$8lbs = 3.62874 kg$

$E = mgh + \cancel{\frac{1}{2}mv^2}^{0}$

$E = (3.62874kg)(9.81 m/s^2)(0.4572m)$

$E = 16.28 N \cdot m$

$\boxed{E = 16.28 J}$

Figure A-4 – Minimum allowable screw diameter to withstand impact and not fail at screws.

Donovan Dueber | Met 489 | 10-7-20

Given: Energy needed to withstand drop from 1.5 ft

Find: minimum allowable screw diameter

Assume: Material is Aluminum, homogeneous

Method: 1.) Find σ_{Allow}

2.) convert joules to lbf

3.) solve for diameter

Solution:

$$\sigma_{Allow} = \frac{\sigma_{yield}}{S.F.} = \frac{40{,}000\ psi}{2} = 20{,}000\ psi$$

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

$16.28\ J = 12.01\ lbf$

↑

found in previous analysis

$$20{,}000\ \frac{lb}{in^2} = \frac{12.01\ lbf}{\frac{\pi d^2}{4}}$$

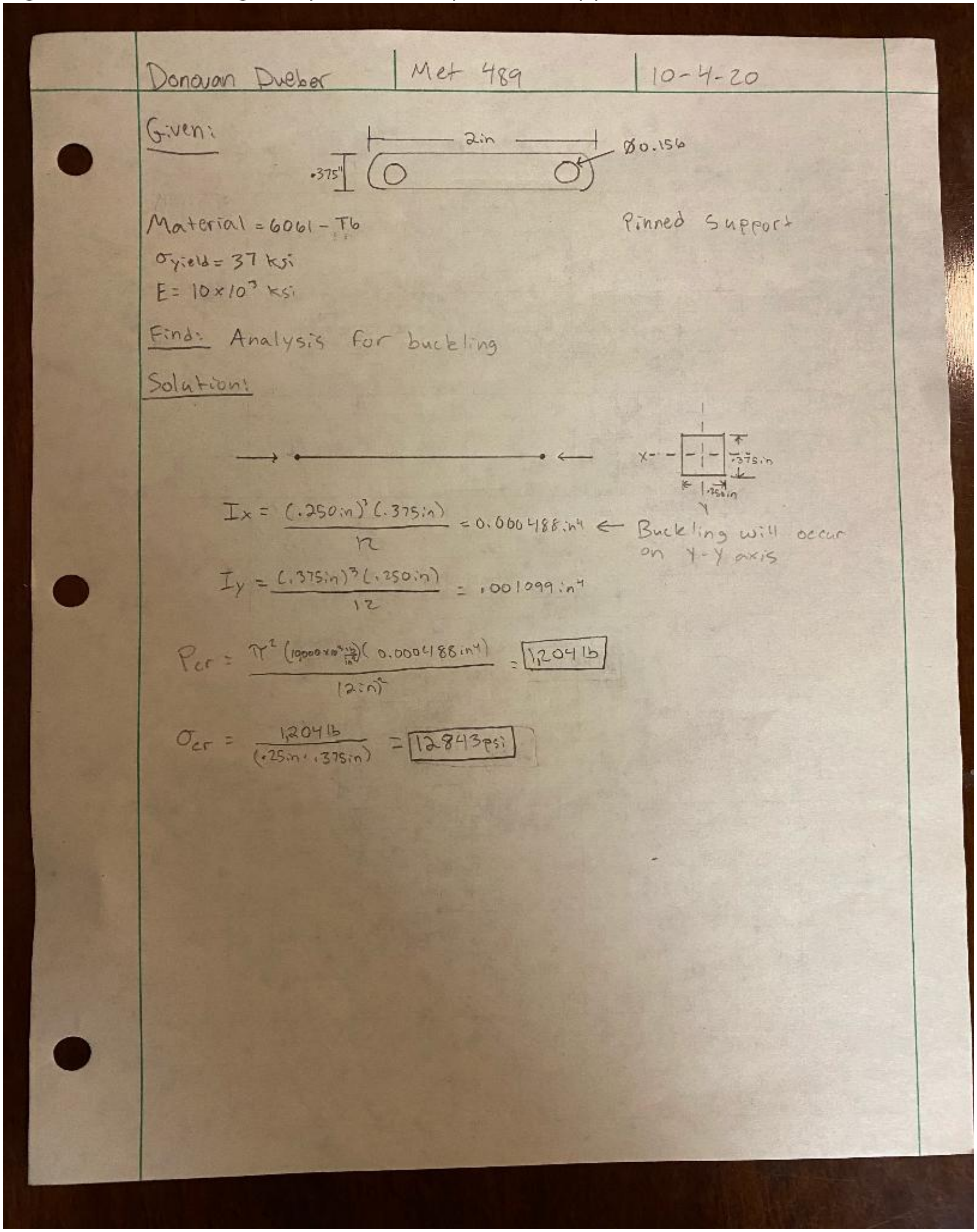
$$\frac{\pi d^2}{4}(20{,}000) = 12.01$$

$$d = \sqrt{\frac{12.01(4)}{\pi(20{,}000)}}$$

$$\boxed{d = 0.028\ in}$$

minimum screw diameter is 0.028 in, 1/16 screw diameter will be chosen because it is the closest standard size.

Figure A-5 – Buckling analysis on a suspension support.



Donovan Dueber | Met 489 | 10-4-20

Given:

2in

Ø0.156

.375"

Material = 6061 - T6

Pinned Support

$\sigma_{yield} = 37$ ksi

$E = 10 \times 10^3$ ksi

Find: Analysis for buckling

Solution:

.375in

.250in

$$I_x = \frac{(.250in)^3(.375in)}{12} = 0.000488 in^4$$ ← Buckling will occur on y-y axis

$$I_y = \frac{(.375in)^3(.250in)}{12} = .001099 in^4$$

$$P_{cr} = \frac{\pi^2 \left(10000 \times 10^3 \frac{lb}{in^2}\right)(0.000488 in^4)}{(2in)^2} = \boxed{1,204 lb}$$

$$\sigma_{cr} = \frac{1,204 lb}{(.25in \cdot .375in)} = \boxed{12843 psi}$$

Figure A-6 – Finding the maximum angular velocity of the wheels.

Donovan Dueber | Met 489 | 10-14-20

Given: 3.25in wheel diameter
1 in. tire depth
20 mph max speed

Find: max angular velocity

Assume: neglect material and weight of wheel and tire

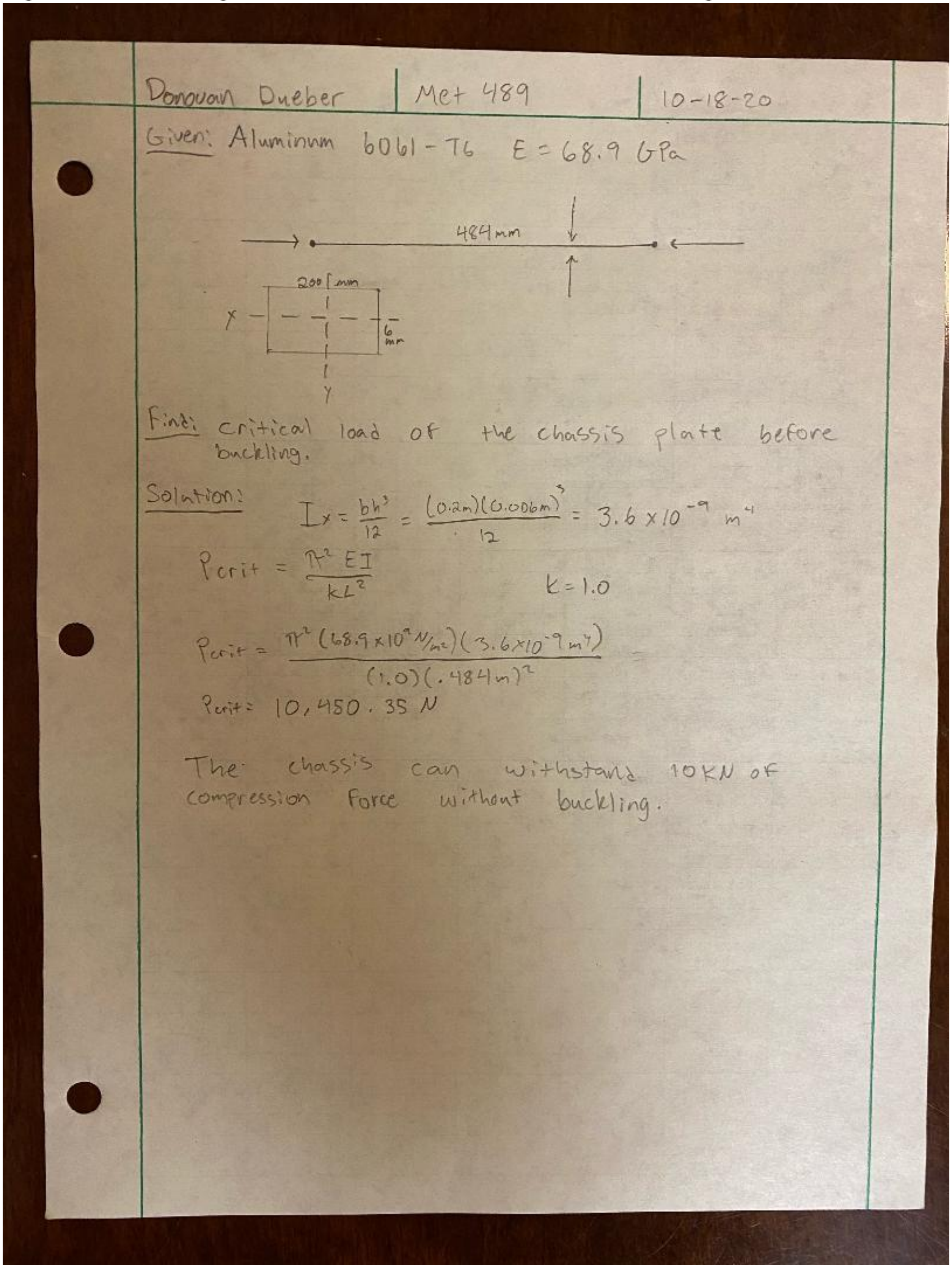
Method: 1.) convert miles/hour to feet/second
2.) find angular velocity

Solution:

$$\frac{20\,\text{mile}}{1\,\text{hr}} \times \frac{1\,\text{hr}}{3600\,\text{s}} \times \frac{5280\,\text{ft}}{1\,\text{mile}} = 29.3\,\text{ft/s}$$

$$\omega = \frac{v}{r} = \frac{29.3\,\text{ft/s}}{1.625\,\text{in}\left(\frac{1\,\text{ft}}{12\,\text{in}}\right)} = \boxed{216.37\,\text{rad/s}}$$

Figure A-7 – Finding critical load of the chassis before buckling.



Donovan Dueber | Met 489 | 10-18-20

Given: Aluminum 6061-T6 $E = 68.9$ GPa

Find: critical load of the chassis plate before buckling.

Solution:

$$I_x = \frac{bh^3}{12} = \frac{(0.2m)(0.006m)^3}{12} = 3.6 \times 10^{-9}\ m^4$$

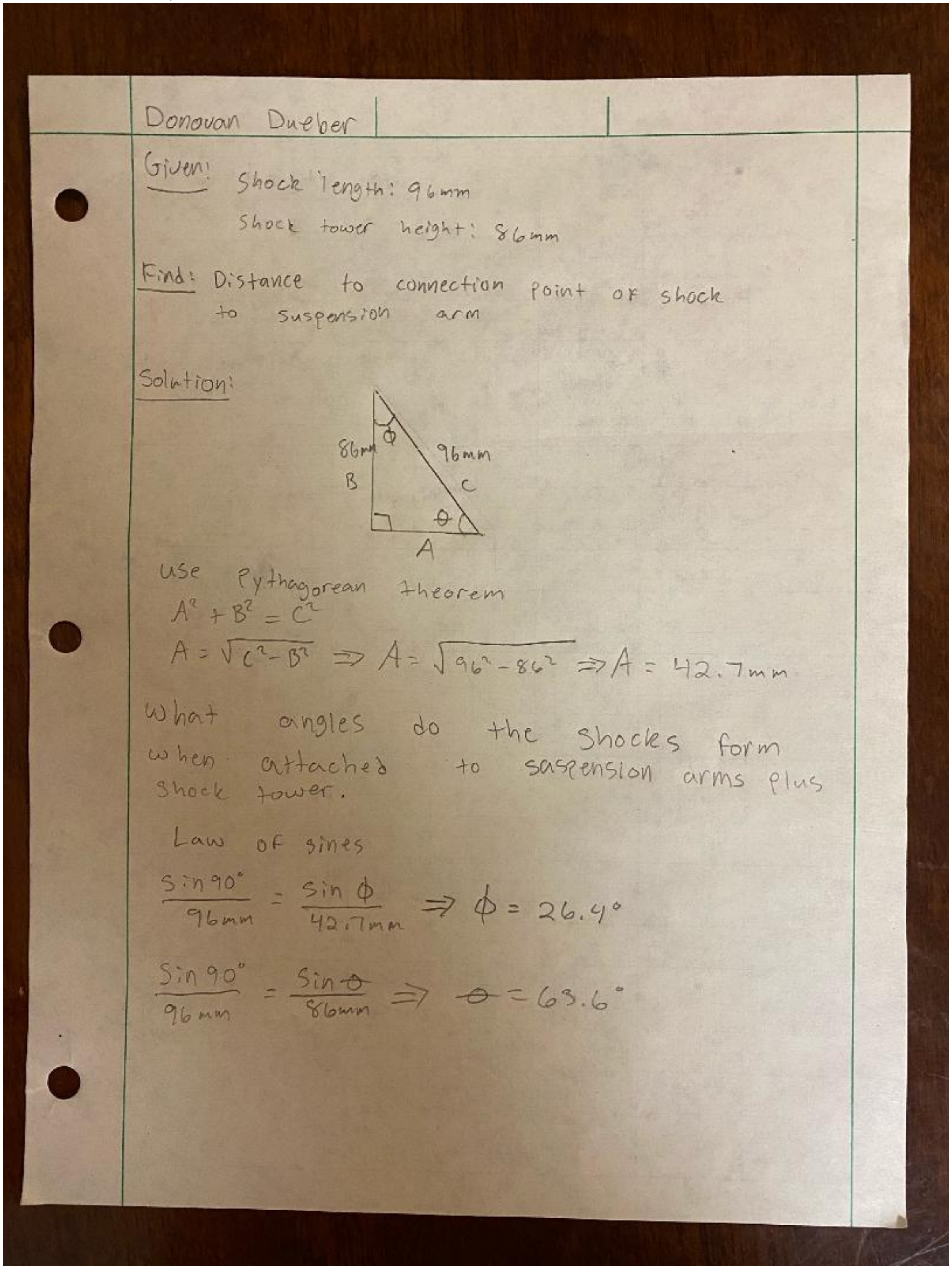
$$P_{crit} = \frac{\pi^2 EI}{kL^2} \qquad k = 1.0$$

$$P_{crit} = \frac{\pi^2 (68.9 \times 10^9\ N/m^2)(3.6 \times 10^{-9}\ m^4)}{(1.0)(.484m)^2}$$

$$P_{crit} = 10{,}450.35\ N$$

The chassis can withstand 10KN of compression force without buckling.

Figure A-8 – Finding the geometry necessary to attach the shock to the shock tower and suspension arm.



Donovan Dueber

Given: Shock length: 96mm

Shock tower height: 86mm

Find: Distance to connection point of shock to suspension arm

Solution:

use Pythagorean theorem

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

$A = \sqrt{C^2 - B^2} \Rightarrow A = \sqrt{96^2 - 86^2} \Rightarrow A = 42.7\text{mm}$

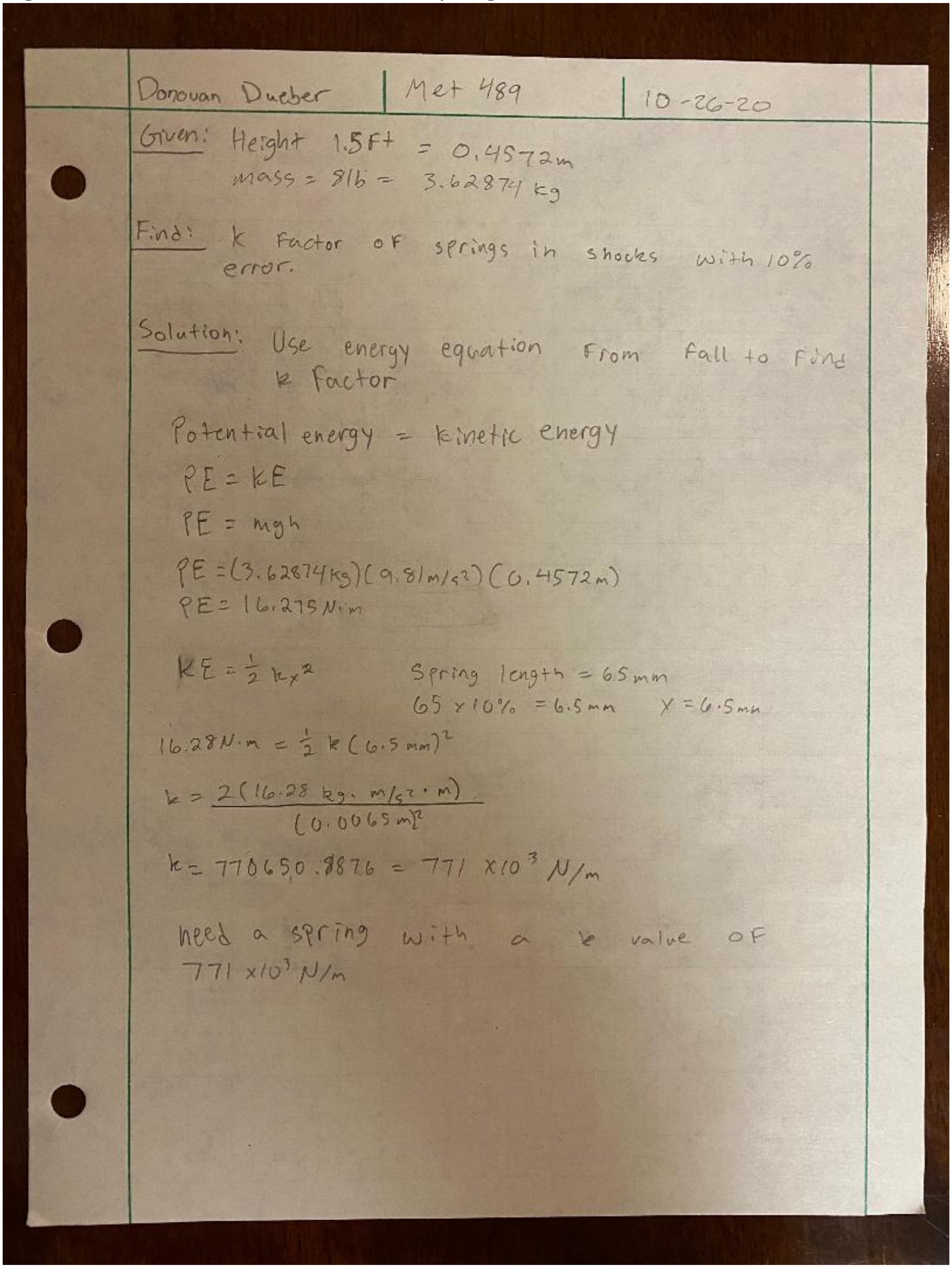
What angles do the shocks form when attached to suspension arms plus shock tower.

Law of sines

$$\frac{\sin 90^\circ}{96\text{mm}} = \frac{\sin \phi}{42.7\text{mm}} \Rightarrow \phi = 26.4^\circ$$

$$\frac{\sin 90^\circ}{96\text{mm}} = \frac{\sin \theta}{86\text{mm}} \Rightarrow \theta = 63.6^\circ$$

Figure A-9 – Finds the k factor of the spring.



Donovan Dueber | Met 489 | 10-26-20

Given: Height 1.5 ft = 0.4572 m

mass = 8 lb = 3.62874 kg

Find: k factor of springs in shocks with 10% error.

Solution: Use energy equation from fall to find k factor

Potential energy = kinetic energy

$PE = KE$

$PE = mgh$

$PE = (3.62874\,kg)(9.81\,m/s^2)(0.4572\,m)$

$PE = 16.275\,N{\cdot}m$

$KE = \frac{1}{2}kx^2$ Spring length = 65 mm

65 × 10% = 6.5 mm $x = 6.5\,mm$

$16.28\,N{\cdot}m = \frac{1}{2}k(6.5\,mm)^2$

$$k = \frac{2(16.28\,kg{\cdot}m/s^2{\cdot}m)}{(0.0065\,m)^2}$$

$k = 770650.8876 = 771 \times 10^3\,N/m$

need a spring with a k value of $771 \times 10^3\,N/m$

Figure A-10 – Minimum allowable diameter for hinge pins.

Donovan Dueber | Met 489 | 10-28-20

Given: $F = 100\,N$

Aluminum 6061

Safety Factor = 2

$$\tau_{max} = \frac{S_y}{2} = \frac{240\ mPa}{2} = 120\ mPa$$

Find: Diameter of pins required to withstand 100N of force

Solution:

$$\tau = \frac{F(2)}{A} \rightarrow A = \frac{F(2)}{\tau} \rightarrow \frac{\pi}{4} D^2 = \frac{F(2)}{\tau}$$

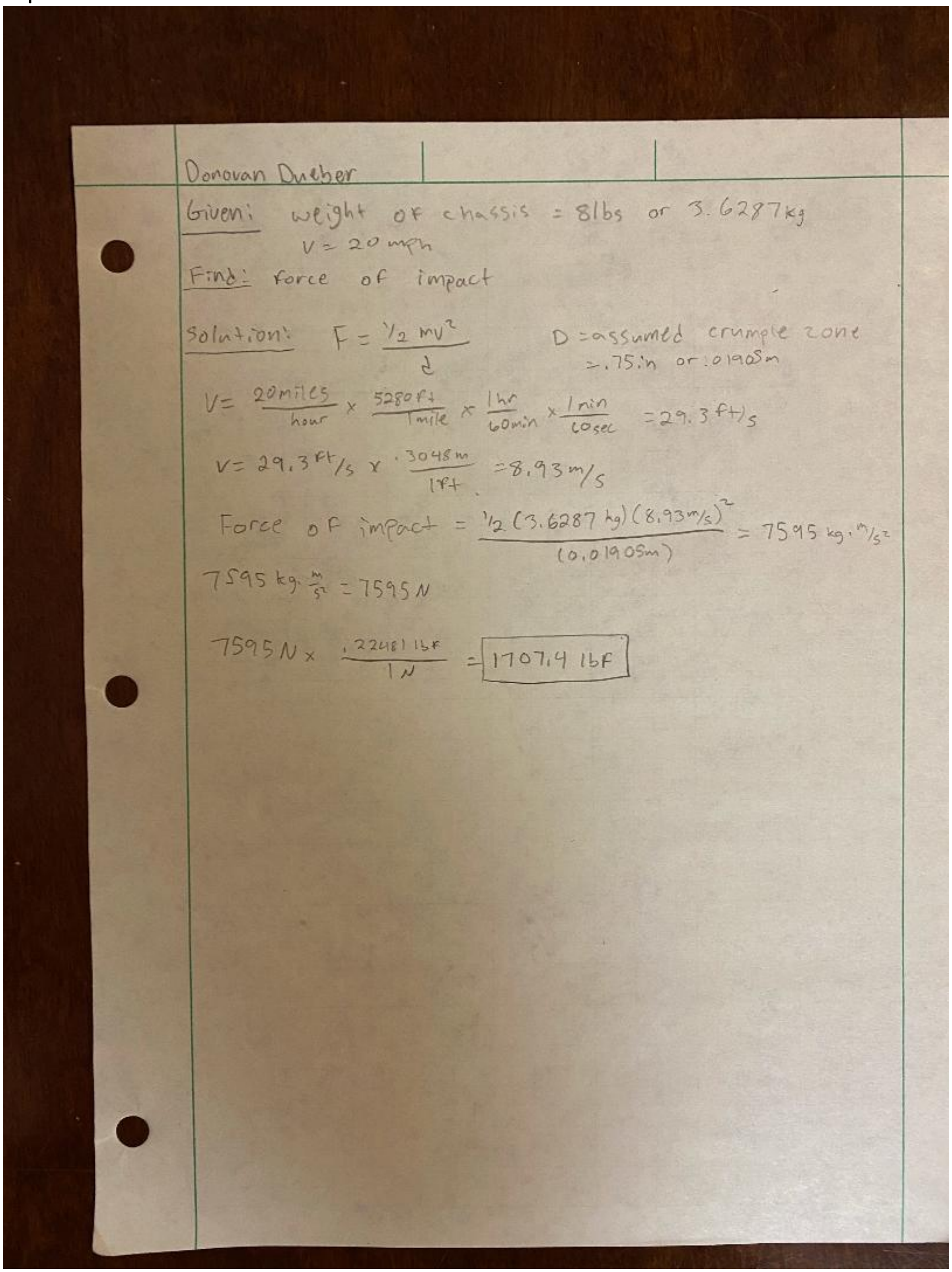
$$D = \sqrt{\frac{4F(2)}{\pi\tau}}$$

$$D = \sqrt{\frac{8(100N)}{\pi(120 \times 10^6\ N/m^2)}}$$

$D = 0.0015m$ or $1.5mm$

Will use 2.5mm pins since they are standard size for a RC car.

Figure A-11 – Analysis of RC car sustaining front impact due to object or wall at 20 mph.


Donovan Dueber

Given: weight of chassis = 8 lbs or 3.6287 kg

$V = 20$ mph

Find: force of impact

Solution: $F = \dfrac{\frac{1}{2} m v^2}{d}$ D = assumed crumple zone = .75 in or .01905 m

$V = \dfrac{20 \text{ miles}}{\text{hour}} \times \dfrac{5280 \text{ ft}}{1 \text{ mile}} \times \dfrac{1 \text{ hr}}{60 \text{ min}} \times \dfrac{1 \text{ min}}{60 \text{ sec}} = 29.3 \text{ ft/s}$

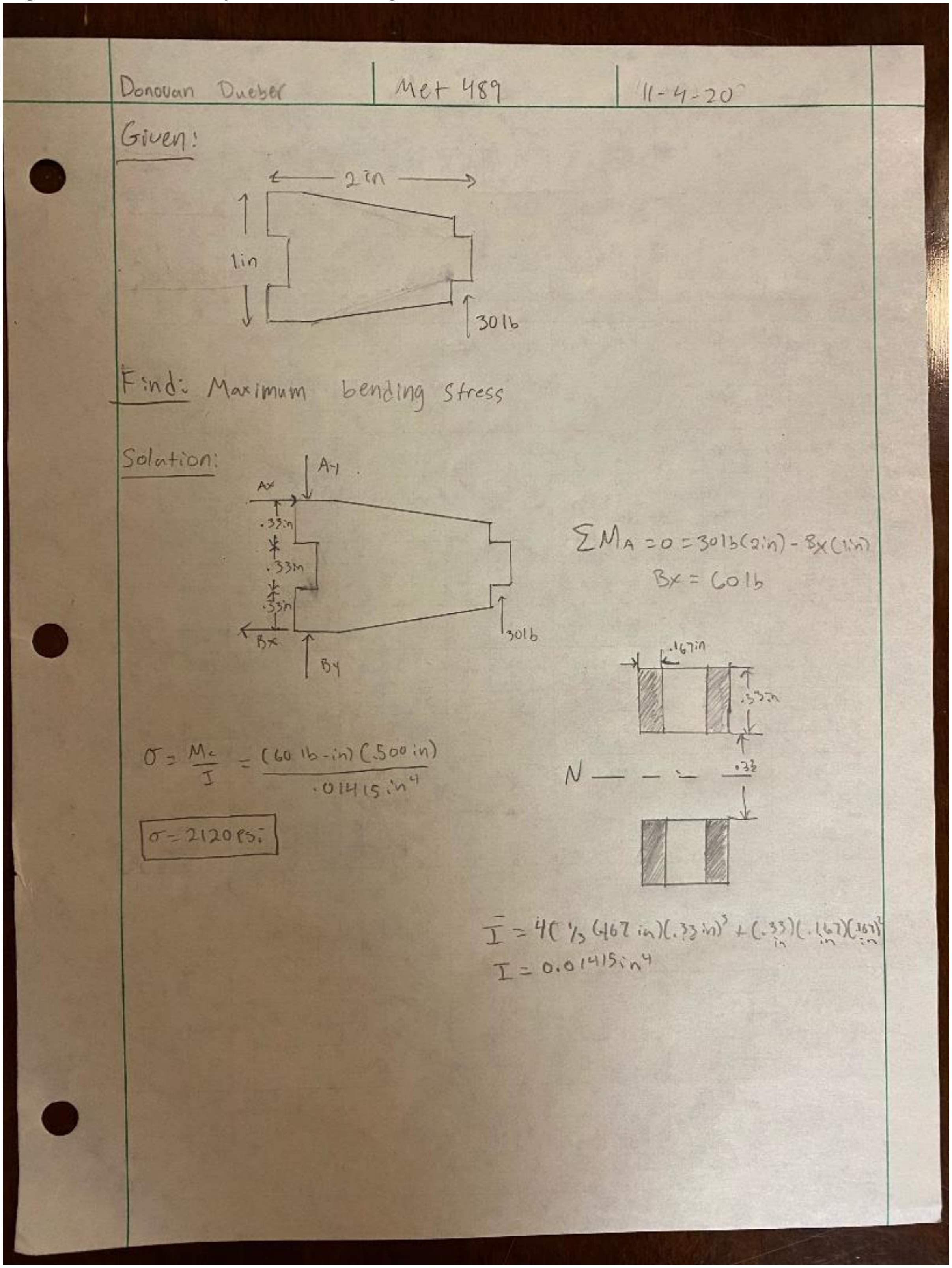
$V = 29.3 \text{ ft/s} \times \dfrac{.3048 \text{ m}}{1 \text{ ft}} = 8.93 \text{ m/s}$

$\text{Force of impact} = \dfrac{\frac{1}{2}(3.6287 \text{ kg})(8.93 \text{ m/s})^2}{(0.01905 \text{ m})} = 7595 \text{ kg} \cdot \text{m/s}^2$

$7595 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2} = 7595 \text{ N}$

$7595 \text{ N} \times \dfrac{.22481 \text{ lbf}}{1 \text{ N}} = \boxed{1707.4 \text{ lbf}}$

Figure A-12 – Analysis of bending stress on a-arm.



Donovan Dueber | Met 489 | 11-4-20

Given:

Find: Maximum bending stress

Solution:

$\Sigma M_A = 0 = 30\,lb(2\,in) - Bx(1\,in)$

$Bx = 60\,lb$

$\sigma = \frac{Mc}{I} = \frac{(60\ lb\text{-}in)(.500\ in)}{.01415\ in^4}$

$\boxed{\sigma = 2120\ psi}$

$\bar{I} = 4(\tfrac{1}{3}(.167\ in)(.33\ in)^3 + (.33)(.167)(.167)^2)$

$I = 0.01415\ in^4$

APPENDIX B - Drawings

Appendix B – Drawing Tree

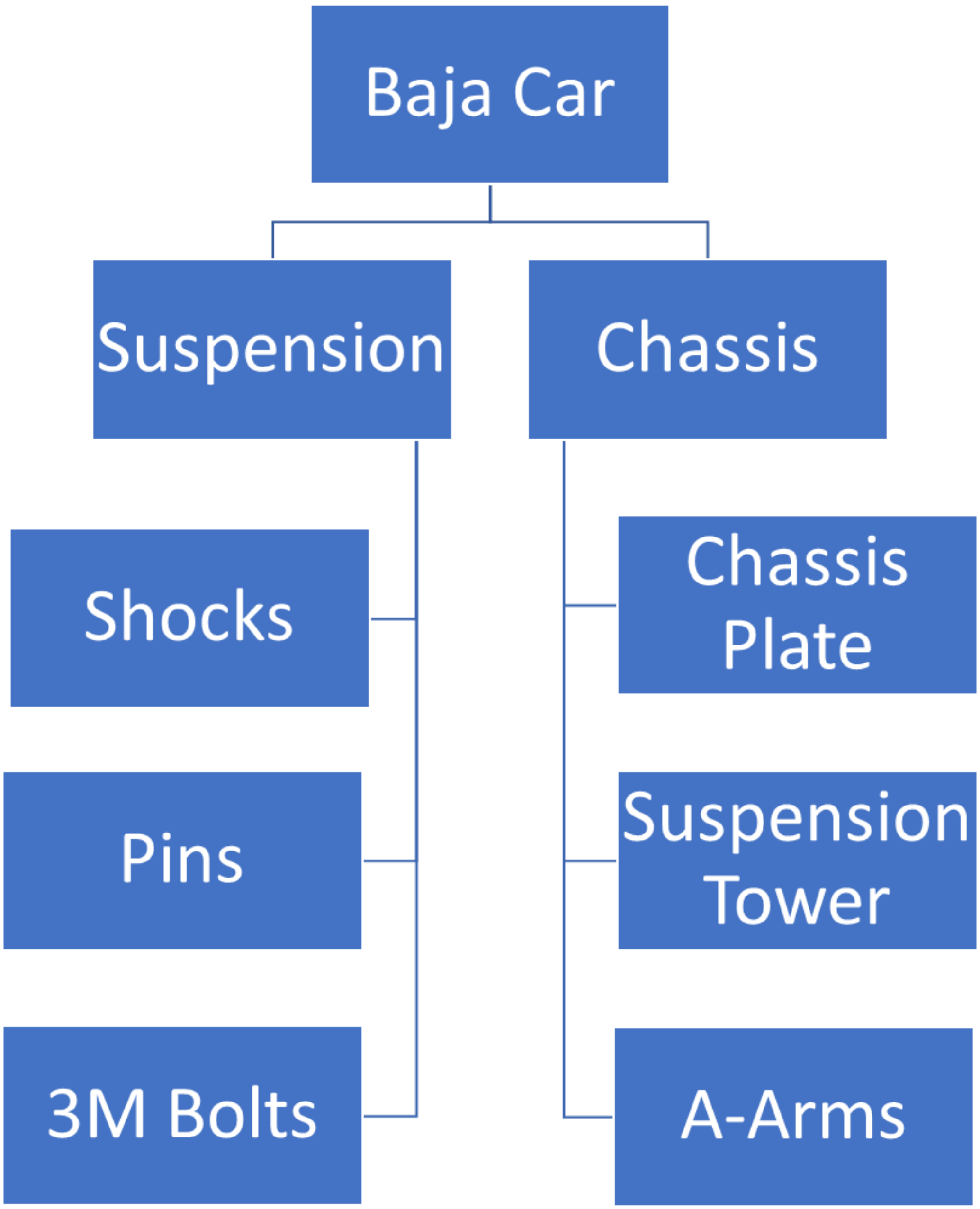
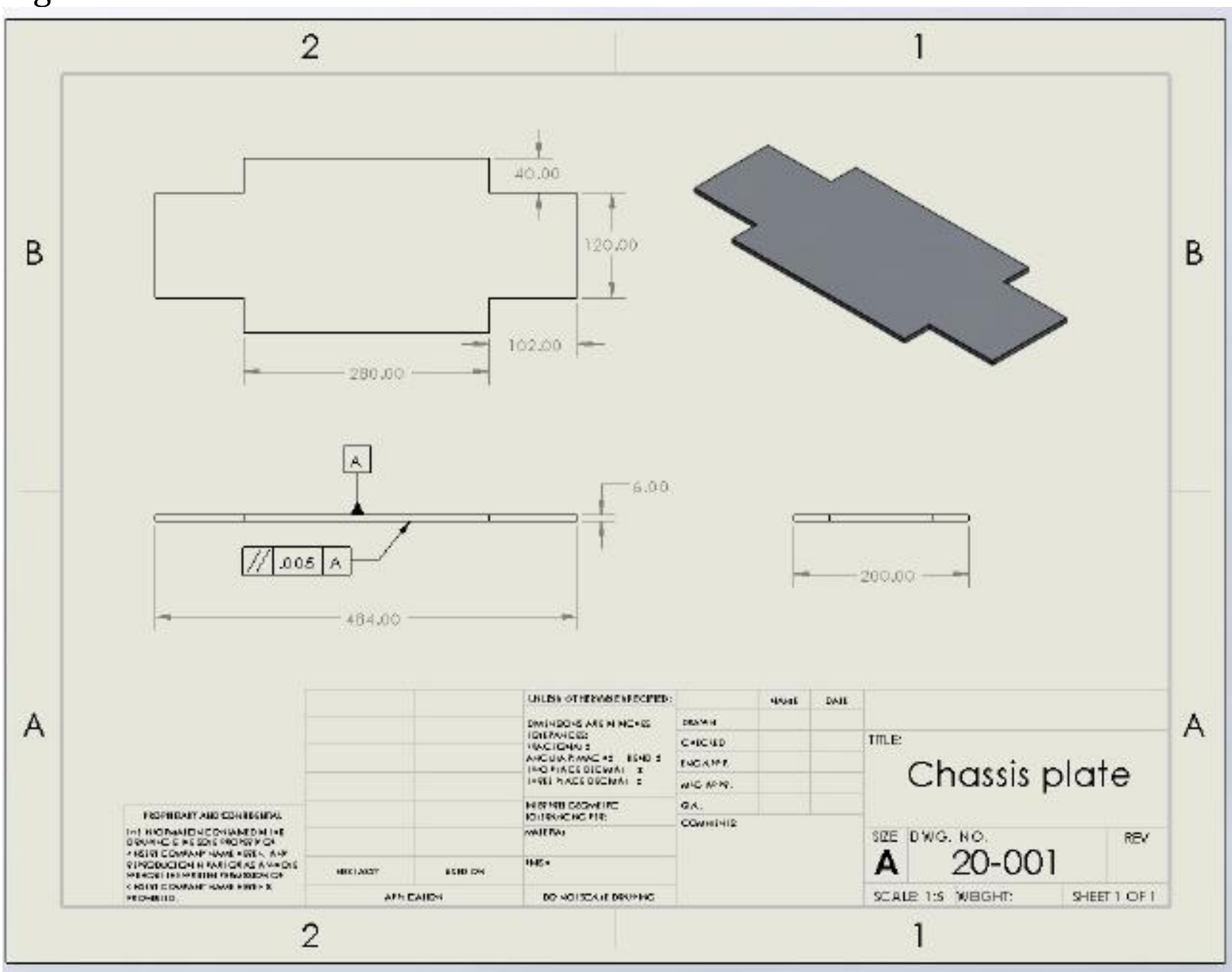
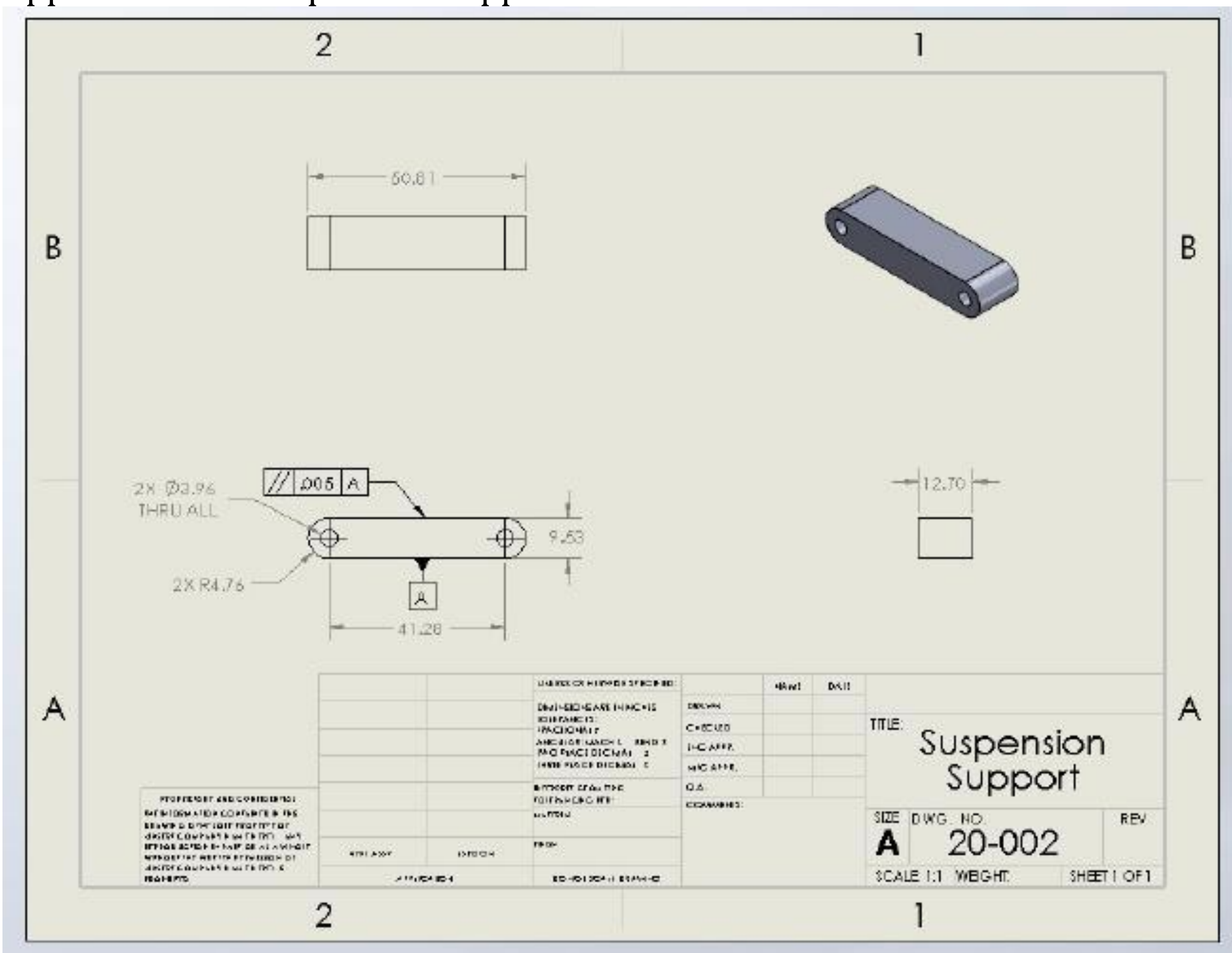


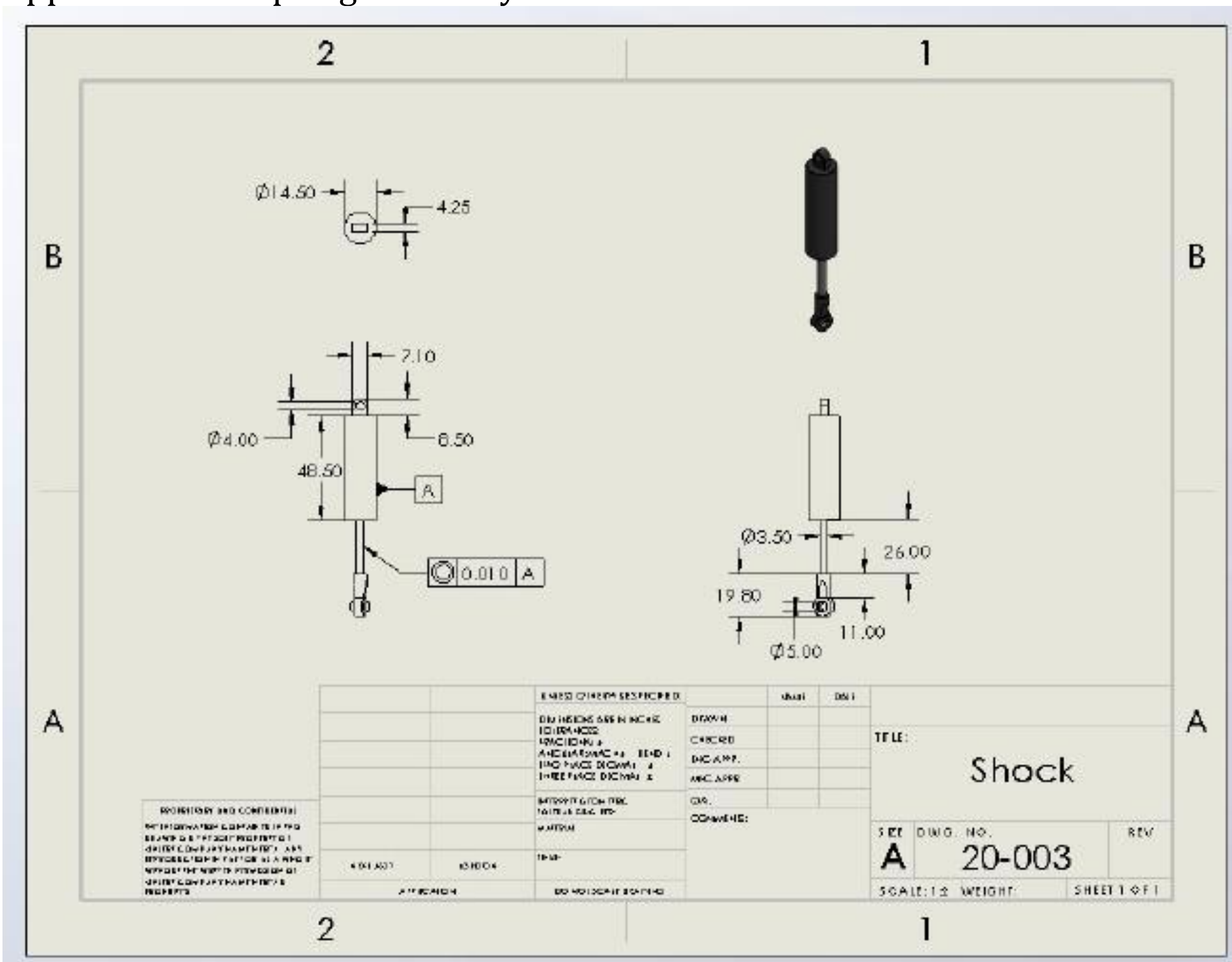
Figure B-2 – Chassis Plate



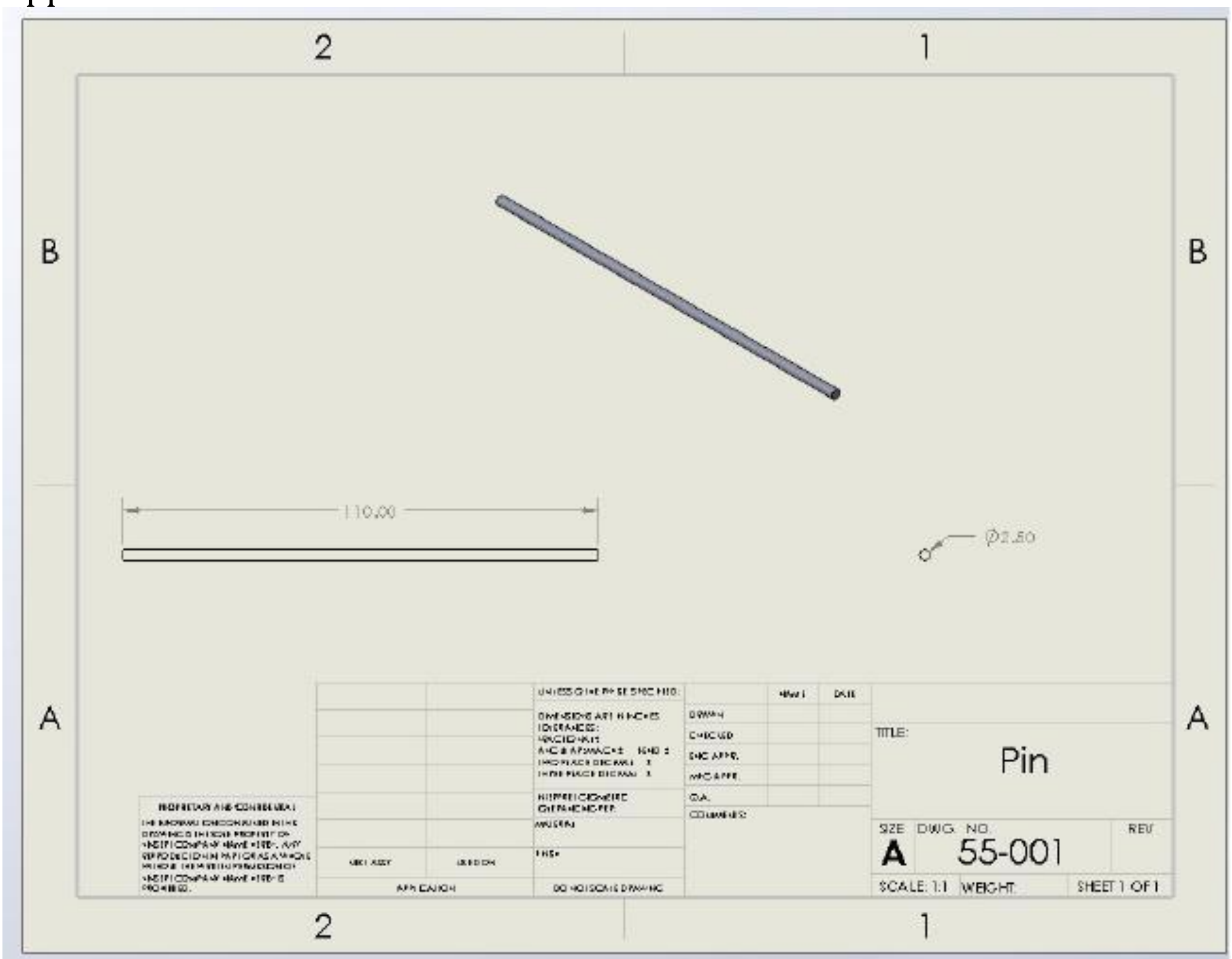
Appendix B-3 – Suspension Support



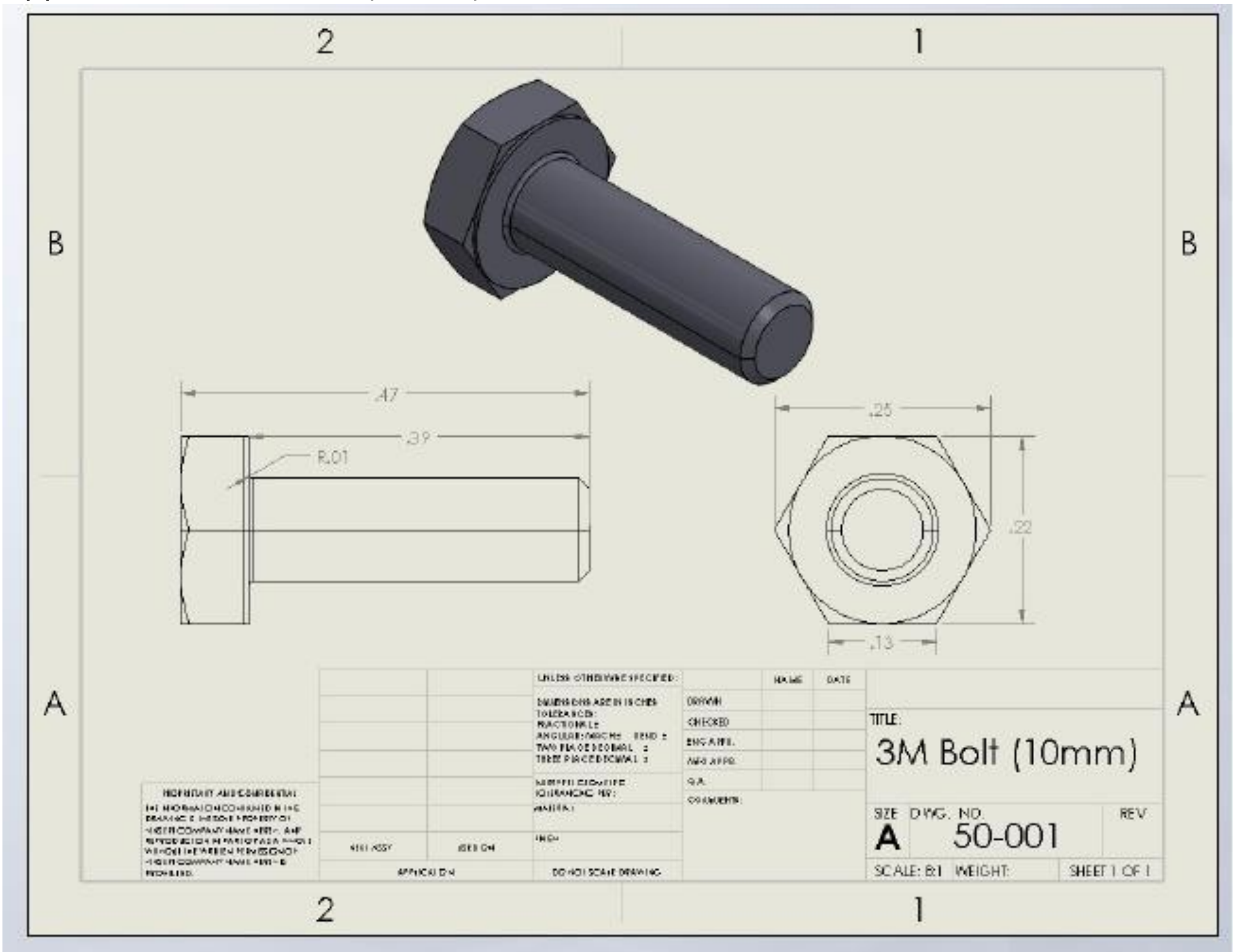
Appendix B-4 – Spring Assembly



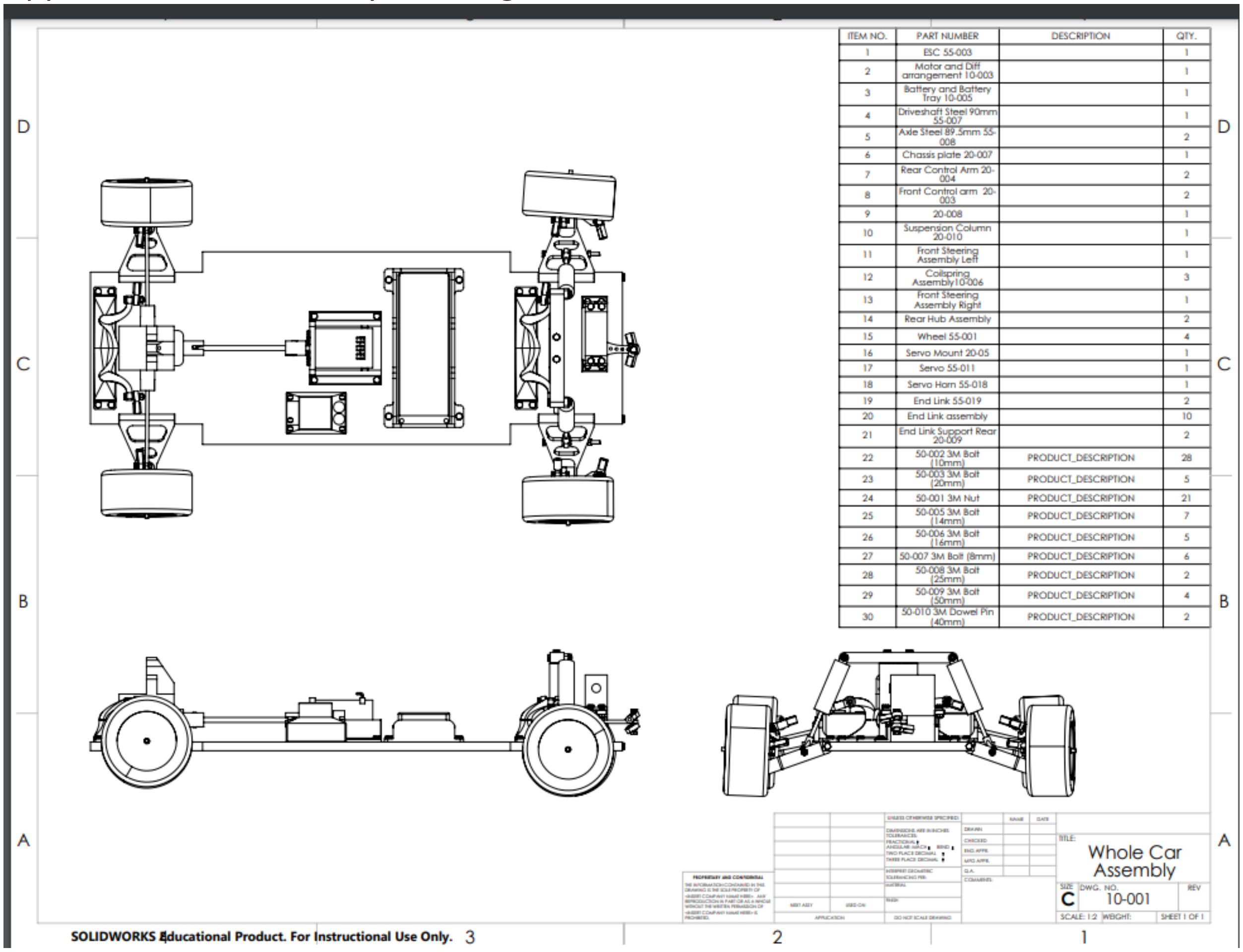
Appendix B-5 – Pin



Appendix B-6 – 3M Bolt (10mm)



Appendix B-7 – Assembly Drawing



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	ESC 55-003		1
2	Motor and Diff arrangement 10-003		1
3	Battery and Battery Tray 10-005		1
4	Driveshaft Steel 90mm 55-007		1
5	Axle Steel 89.5mm 55-008		2
6	Chassis plate 20-007		1
7	Rear Control Arm 20-004		2
8	Front Control arm 20-003		2
9	20-008		1
10	Suspension Column 20-010		1
11	Front Steering Assembly Left		1
12	Coilspring Assembly10-006		3
13	Front Steering Assembly Right		1
14	Rear Hub Assembly		2
15	Wheel 55-001		4
16	Servo Mount 20-05		1
17	Servo 55-011		1
18	Servo Horn 55-018		1
19	End Link 55-019		2
20	End Link assembly		10
21	End Link Support Rear 20-009		2
22	50-002 3M Bolt (10mm)	PRODUCT_DESCRIPTION	28
23	50-003 3M Bolt (20mm)	PRODUCT_DESCRIPTION	5
24	50-001 3M Nut	PRODUCT_DESCRIPTION	21
25	50-005 3M Bolt (14mm)	PRODUCT_DESCRIPTION	7
26	50-006 3M Bolt (16mm)	PRODUCT_DESCRIPTION	5
27	50-007 3M Bolt (8mm)	PRODUCT_DESCRIPTION	6
28	50-008 3M Bolt (25mm)	PRODUCT_DESCRIPTION	2
29	50-009 3M Bolt (50mm)	PRODUCT_DESCRIPTION	4
30	50-010 3M Dowel Pin (40mm)	PRODUCT_DESCRIPTION	2

APPENDIX C – Parts List and Costs

Part Number	Qty	Part Description	Source	Cost	Total
CB2063	2	Battery	RC Mart	$49.99	$99.98
8277-13	1	Front Tires (Pack of 2)	RC Mart	$27.16	$27.16
8267-13	1	Rear Tires (Pack of 2)	RC Mart	$22.28	$22.28
3416-00	1	Body	RC Mart	$28.90	$28.90
XS-TA29008BK	1	Shocks (Pack of 2)	RC Mart	$11.90	$11.90
CLS5830HV-V2	1	Servo	RC Mart	$36.90	$36.90
30401059	1	Motor	Hobbywing	$79.99	$79.99
30113301	1	ESC.	Hobbywing	$109.99	$109.99
N/A	1	Wheel Axle Hubs	Amazon	$11.83	$11.83
6061ASHT250	1	6061 Aluminum Plate	Midwest Steel and Aluminum	$15.86	$15.86

APPENDIX D – Budget

Item	Qty	Description	Cost
CB2063	2	Battery	$49.99
8277-13	1	Front Tires (Pack of 2)	$27.16
8267-13	1	Rear Tires (Pack of 2)	$22.28
3416-00	1	Body	$28.90
XS-TA29008BK	1	Shocks (Pack of 2)	$11.90
CLS5830HV-V2	1	Servo	$36.90
30401059	1	Motor	$79.99
30113301	1	ESC.	$109.99
N/A	1	Wheel Axle Hubs	$11.83
6061ASHT250	1	6061 Aluminum Plate	$15.86

APPENDIX E - Schedule

Figure E-1 – Gantt Chart

1	SCHEDULE FOR SENIOR PROJECT:					
2						
3	PROJECT TITLE: RC Baja					
4	Principal Investigator: Donovan Dueber					
5			Duration			
6	TASK:	Description	Est.	Actua	%Cor	Septemb October November Dec January February March April May June
7	ID		(hrs)	(hrs)		
8		Fall				
9	1	Proposal*				
10	1a	Outline	0.25	0.25	100	
11	1b	Intro	1	1.5	100	
12	1c	Methods	1	1.5	100	
13	1d	Analysis	1	1	100	
14	1e	Discussion	1	1	100	
15	1f	Parts and Budget	2	2	100	
16	1g	Construction	1	1	100	
17	1h	Schedule	1	1	100	
18	1i	Summary & Appx	0.5	0.5	100	
19		subtotal:	8.75	9.75		
20						
21	2	Analyses				
22	2a	Analysis 1	1	0.5	100	
23	2b	Analysis 2	1	1	100	
24	2c	Analysis 3,4,5,6	4	3.5	100	
25	2d	Analysis 7,8,9,10	4	4	100	
26	2e	Analysis 11,12	2	2	100	
27		subtotal:	12	11		
29	3	Winter				
30	3a	Construction	1	1	100	
31	3b	Methods	1.5	1	100	
32	3c	Discussion	1	1	100	
33	3d	Schedule	1	1	100	
34	3e	Budget	1	1	100	
35	3f	Construction 2	1	1	100	
36	3g	Methods 2	1	1	100	
37	3h	Testing	1	1	100	
38	3i	Discussion 2	1	1	100	
39	3j	Website	0.5	1	100	
40	3k	Website 2	1	1	100	
41	3l	MDR	1	1	100	
42						
43		subtotal:	12	12		
44						
45	4	Part Construction				
46	4a	Purchase shock/leaf sprir	0.5	0.5	100	
47	4b	Make Chassis/A Arms	8	9	100	
48	4c	Make Suspension Suppo	2	2	100	
49		subtotal:	10.5	11.5		
51	7	Spring				
52	7a	Abstract and Test Proced	2	2.5	100	
53	7b	TDR 1&2	4	4	100	
54	7c	TES 1&2	2	3	100	
55	7d	Web 1&2	2	2	100	
56	7e	Discussion 1&2	3	3	100	
57	7f	Test Report	3	3	100	
58	7g	Budget	1	1	100	
59	7h	Schedule	1	1	100	
60	7i	FE Response	1	1	100	
61		subtotal:	19	20.5		
62						
63	9	Spring				
64	9a	Presentation	0.5	0.5	100	
65	9b	Report Upload	2	2	100	
66	9c	Scholar Works	0.5			
67	9d	Jump Drive	1			
68	9e	Clean Up	1			
69	9f	Work Survey	0.5			
70		subtotal:	5.5	2.5		

APPENDIX F – Expertise and Resources

Expertise

Expertise came from Jason Schindler, Professor Choi, and Professor Pringle. The expertise these individuals provided, were essential in providing background knowledge and providing feedback on the technical content of this report.

Resources

Resources for this project include the 3D Printer in Hogue, Machine shop that is also in Hogue. The computer lab that allowed access to Solidworks CAD, Microsoft Excel, Microsoft Word, and Microsoft Teams.

APPENDIX G – Testing Report

1. Drop Test Report

Introduction:

The design requirement that will be tested is as follows. The car must be able to survive a 1.5ft drop. This requirement can be found in section 1d. The parameters of this test are either pass/fail based on its criteria. These are found by taking visual observations of both before the test and after the test is completed. The schedule for when this testing will occur can be found in Appendix E.

Method/Approach:

The test will be conducted so that it tests the cars ability to be able to survive a drop and continue on with the competition. The data that will be captured are videos of the testing occurring so that it can be reviewed for completion. The procedure of the test is to place blue tape on the wall at the set height, then setting up the camera to record the testing, and then dropping the car level so that all four wheels hit the ground at the same time. The accuracy of this test is how well the video can show the testing that has occurred. The data that has been recorded can be found in Appendix G3.

Test Procedure:

This procedure documents the process of recording the results after dropping a RC Baja car from 1.5ft. The RC Baja car was made from a team of two students that are seniors at Central Washington University. The RC car was made for a Senior Capstone Project that the students need to graduate from the university. The following is the test information and procedure.

Time: This test can be conducted once the finished components are constructed and assembled on the car. The overall estimated time it will take to complete this test is less than 30 minutes long.

Place: Outside in an empty parking lot, this will provide a hard, level surface that the car can be dropped from.

Risk: The car must be turned off and free from anything that may help with the fall in any way. Individuals that are testing must be wearing closed toed shoes, as a risk of dropping the device on themselves is possible. Safety glasses are also required just in case of a failure of a part, and debris is thrown.

Required equipment includes:

- Fully assembled RC Car
- Device to take photos and record
- Platform that will hold the device for photos and while recording the testing.
- Measuring tape (standard units)
- Printed testing procedure
- Safety glasses
- Partner to help assist.

The testing procedure is as follows:

1. Collect required equipment.
2. Go outside to an empty parking lot.
3. Place all equipment on the ground.
4. Setup the platform for the device that will be used to record the testing.
5. Visually inspect each component of the RC car.
6. Have one individual measure the height from the ground to 1.5 feet of elevation.

a. Continue to hold that measurement so that another individual can continue the procedure.

7. Start recording on device.
8. Holding the RC Car flat to the ground, elevate the car to the measurement that the other is indicating.
9. After reaching this height, release the car so that it travels towards the ground without rotating, and have it land on all four of its wheels at the same time.
10. After the car has settled on the ground, walk over to the device used for recording, and stop the recording.
11. Playback the recording just taken and confirm that all 4 wheels of the car reach the ground at the same time.

a. If the car’s wheels land at the same time, continue with the test procedure.

b. If the car’s wheels did not land at the same time, then repeat steps 6-11

12. Repeat step 5.

Deliverables:

- □ Pass or fail on having damage to any component on the car.
- □ Car is able to drive off after the drop test is conducted.
- □ Video of correct drop test (all for tires of the car hit the ground at the same time.).

2. Front Impact Test Report

Introduction:

The design requirement that will be tested is as follows. The car must be able to survive a front impact collision with a wall going approximately 7.5 mph. This requirement can be found in section 1d. The parameters of this test are either pass/fail based on its criteria. These are found by taking visual observations of both before the test and after the test is completed. The schedule for when this testing will occur can be found in Appendix E.

Method/Approach:

The test will be conducted so that it tests the cars ability to be able to survive a front impact with a wall and continue on with the competition. The data that will be captured are videos of the testing occurring so that it can be reviewed for completion. The procedure of the test is to set up the camera to record the testing and then, place the RC Baja car in front of a wall and at half throttle (approximately 7.5 mph) drive into the wall head on. The accuracy of this test is how well the car hitting the wall head on and also how well the video can show the testing that has occurred. The data that has been recorded can be found in Appendix G3.

Test Procedure:

This procedure documents the process of recording the results after driving the RC Baja car into a wall head on. The RC Baja car was made from a team of two students that are seniors at Central Washington University. The RC car was made for a Senior Capstone Project that the students need to graduate from the university. The following is the test information and procedure.

Time: This test can be conducted once the finished components are constructed and assembled on the car. The overall estimated time it will take to complete this test is less than 30 minutes long.

Place: Inside Hogue Hall, this will provide a hard, level surface that the car can be driven on and plenty of walls for the car to be driven into.

Risk: Individuals that are testing must be wearing closed toed shoes, as a risk of driving the device in to themselves is possible. Safety glasses are also required just in case of a failure of a part, and debris is thrown.

Required equipment includes:

- Fully assembled RC Car

- Device to take photos and record

- Platform that will hold the device for photos and while recording the testing.

- Printed testing procedure

- Safety glasses

- Partner to help assist.

The testing procedure is as follows:

1. Collect required equipment.

2. Go inside Hogue Hall.

3. Place all equipment on the ground.

4. Setup the platform for the device that will be used to record the testing.

5. Visually inspect each component of the RC car.

6. Have one individual place the car in front of a wall.

7. Start recording on device.

8. Using the remote for the RC Car hold the throttle at half of its full capacity (Approximately 7.5 mph) and drive the RC Baja car into the wall.

9. After the RC car has crashed into the wall try making the car reverse away from the wall and drive off.

10. After attempting to have the car back away from the wall, walk over to the device used for recording, and stop the recording.

11. Playback the recording just taken and confirm that the car hits the wall head on and not at an angle.

a. If the car hits the wall head on, continue with the test procedure.

b. If the car doesn't hit the wall head on, then repeat steps 6-11

12. Repeat step 5.

Deliverables:

□ Pass or fail on having damage to any component on the car.

□ Car is able to drive off after the front impact test is conducted.

□ Video of correct front impact test (The car hits the wall directly head on.).

3. Suspension Load Test Report

Introduction:

The design requirement that will be tested is as follows. The suspension must be able to handle at least 50 N of force placed upon it (Approximately 11 lbs.). This requirement can be found in section 1d. The parameters of this test are either pass/fail based on its criteria. These are found by taking visual observations of both before the test and after the test is completed. The schedule for when this testing will occur can be found in Appendix E.

Method/Approach:

The test will be conducted so that it tests the suspensions ability to be able to handle a force of 50 N (Approximately 11 lbs.). The data that will be captured are pictures of the testing occurring so that it can be reviewed for completion. The procedure of the test is to set up the camera to take pictures of the testing and then, place the 15 lb. weights evenly on the front and rear suspension of the car. The reason 15 lb. weights were chosen is because it is the closest the team could get to 11 lbs. without being under it. The accuracy of this test is how well the weight is evenly distributed on the front and rear suspension and also how well the pictures can show the testing that has occurred. The data that has been recorded can be found in Appendix G3.

Test Procedure:

This procedure documents the process of recording the results after loading the RC Baja car's suspension with 50 N (Approximately 11 lbs.) of force. The RC Baja car was made from a team of two students that are seniors at Central Washington University. The RC car was made for a Senior Capstone Project that the students need to graduate from the university. The following is the test information and procedure.

Time: This test can be conducted once the finished components are constructed and assembled on the car. The overall estimated time it will take to complete this test is less than 20 minutes long.

Place: Inside Hogue Hall in the casting lab, this will provide a hard, level surface that the car can be placed on so the team can place the weights on the car evenly.

Risk: The car must be turned off and free from anything that may help with supporting the force placed on the suspension in any way. Individuals that are testing must be wearing closed toed shoes, as a risk of dropping the device on themselves is possible. Safety glasses are also required just in case of a failure of a part, and debris is thrown.

Required equipment includes:

- Fully assembled RC Car
- Device to take photos
- Printed testing procedure
- Safety glasses
- Partner to help assist.
- Scale
- Weights

The testing procedure is as follows:

1. Collect required equipment.
2. Go inside Hogue Hall in the casting lab.
3. Place all equipment on the ground.
4. Setup the scale for measuring the weights that will be used to load the suspension during the testing.
5. Visually inspect each component of the RC car's suspension.
6. Have one individual place the car on the scale.
7. Using the weights that were weighed previously load the cars suspension with 11 lbs. distributed evenly on the front and rear suspension.
8. After the RC cars suspension has been loaded wait 10 seconds.
9. After waiting the 10 seconds remove the weights on the car's suspension.
10. Repeat step 5.

Deliverables:

□ Pass or fail on having damage to any component of the suspension.

□ Car is able to drive after the Suspension Load test is conducted.

□ Pictures of correct Suspension Load test (The weights are put directly on the suspension.).

4. Chassis Weigh Test Report

Introduction:

The design requirement that will be tested is as follows. The cars chassis must weigh less than 8 lbs. This requirement can be found in section 1d. The parameters of this test are either pass/fail based on its criteria. These are found by reading the scale after the chassis is placed on it. The schedule for when this testing will occur can be found in Appendix E.

Method/Approach:

The test will be conducted so that it tests if the cars chassis weighs less than 8 lbs. The data that will be captured are pictures of the testing occurring so that it can be reviewed for completion. The procedure of the test is to set up the camera to take pictures of the testing and then, place the RC Baja cars chassis on the scale and read the weight displayed. The accuracy of this test is how accurate the scale being used is and also how well the pictures can show the testing that has occurred. The data that has been recorded can be found in Appendix G3.

Test Procedure:

This procedure documents the process of recording the results after weighing the chassis of the RC Baja car. The RC Baja car was made from a team of two students that are seniors at Central Washington University. The RC car was made for a Senior Capstone Project that the students need to graduate from the university. The following is the test information and procedure.

Time: This test can be conducted once the chassis is finished being manufactured. The overall estimated time it will take to complete this test is less than 15 minutes long.

Place: Inside Hogue Hall, this will provide a hard, level surface that the cars chassis can be weighed on a scale.

Risk: Individuals that are testing must be wearing closed toed shoes, as a risk of dropping the chassis on to themselves is possible. Safety glasses are also required just in case debris comes off of the chassis.

Required equipment includes:

- Fully manufactured RC Car chassis

- Device to take photos
- Scale
- Printed testing procedure
- Safety glasses
- Partner to help assist.

The testing procedure is as follows:

1. Collect required equipment.
2. Go inside Hogue Hall.
3. Place all equipment on the ground.
4. Place the RC car’s chassis on the scale
5. Read the weight the scale presents.
6. Take a picture of the chassis on the scale and of the weight the scale is showing.

Deliverables:

□ The RC Baja cars chassis weighs less than 8 pounds.

□ Picture of the chassis weighing less than 8 pounds.

APPENDIX H – Resume

Donovan Dueber

2420 N AIRPORT RD APT 5208 | (253)820-6100 | donovandueber@yahoo.com

Objective

To obtain a full-time engineering position.

Education

BETHEL HIGH SCHOOL

Graduated

2012-2016

CENTRAL WASHINGTON UNIVERSITY

Major: Mechanical Engineering Technology

2016 - present

Awards

PERFECT ATTENDANCE AWARDS
TEAM CAPTAIN FOR BETHEL VARSITY BASEBALL

Experience

VOLUNTEER TEACHER | HIGH POINT CHURCH
Taught 4 & 5-year-old Sunday school.

LIFEGUARD | WILDWAVES THEME PARK | JUNE-SEPTEMBER 2016
Watched guests, help with any questions/problems guests had, cleaned pools.

WAREHOUSE WORKER | LOGIC STAFFING | JUNE- SEPTEMBER 2017
Worked at various warehouses, would do any work they needed done.

STAFF | BURGER KING | JUNE-DECEMBER 2018
Worked in the kitchen, drive-thru and front counter. I would clean, take orders, and make food.

INTERN | BUYKEN METAL PRODUCTS | JUNE-SEPTEMBER 2020
Drilled, tapped and countersunk holes, operated various CNC machines, deburred parts, spot welded, operated 250 ton stamp press, picked parts,