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The Tortuga Drivtrain and Chassis RC Baja

Roberto C. Vieyra Avalos
Central Washington University, beto20539@outlook.com

RC Baja Drive Train and Chassis SENIOR PROJECT

By

Roberto Vieyra

Team member(s):
Rogelio Arroyos

ABSTRACT

The students in charge of the project, seniors at Central Washington University were tasked with the design and manufacturing of the RC Baja to compete in the Slalom and Sprint event and the Baja event where the maneuverability and acceleration are demonstrated. The project was divided between Roberto, in charge of the drivetrain and chassis and Rogelio, in charge of the steering and suspension. There were also various requirements like velocity and deflection, ensuring the device reaches 30mph and keeping the deflection of components to a minimum and many others which can be seen in section D of the introduction.

The RC vehicle was designed using various engineering methods using subjects such as mechanical design, dynamics and mechanics of materials to ensure that the device was going to meet requirements. The main manufacturing method was 3D printing as the intention was to keep the weight as minimal as possible. Once all manufacturing and analysis was completed, various tests were performed to gather data on various aspects of the vehicle like acceleration and velocity.

The 3D printed components were required to not exceed a deflection of .1”. The vehicle was expected to achieve a velocity of 30mph, and the suspension was calculated to compress .5” while the turning radius which was expected to be 4’. In summary, with the testing, it was possible to determine that the vehicle would be meeting the various requirements like the velocity and showed that it would also withstand the drop test as was intended.

Keywords: drivetrain, chassis, RC, 3D printing, suspension

Contents

1. INTRODUCTION

a. Description

The RC Baja is an engineering design challenge that is held every year where engineering skills are tested by the American Society of Mechanical Engineers also known as ASME. The problem that will be confronted is the creation of an RC vehicle and the various testing that must be done such as the Slalom-and-Sprint event and the Baja race. It is also important to note whether the vehicle will hold out until the end as well as the design capability and ability to fix any issues that are noticed. The main focus for this report will be on the design, analysis, construction and testing of the drivetrain and chassis portion for the vehicle ensuring that the vehicle meets the requirements set.

b. Motivation

The motivation for choosing this project is to create an RC vehicle that is able to complete and fulfill the requirements proposed by ASME and to challenge the skills acquired.

c. Function Statement

The function of the RC drivetrain is able to provide locomotion. The drivetrain is designed to reach a maximum velocity of 30mph. The function of the chassis is to provide mounting points and provide support for all RC car components as well as being rigid enough to be able to withstand impacts at high velocities and drop tests.

d. Requirements

The RC Baja will need to satisfy the ASME Baja race requirements as well as the following requirements.

1. Must have ONE Propulsion Motor
2. Must have ONE Propulsion Battery Pack on the vehicle
3. Battery must be a 7.2-Volt 6-cell RC battery, or any 7.4-Volt 2-cell or 2S LiPo RC battery
4. Gears teeth will survive the stresses caused
5. Motor must Transmit a minimum of 50 W
6. Keep cost at $500 or less
7. Vehicle can reach a velocity of 30 mph
8. Differential must weigh less than 1lb
9. Chassis and drivetrain must withstand an impact at 30 mph
10. Chassis must not buckle due to force from a 30mph impact
11. Chassis must not exceed 5 lbf (2.27kg)
12. Adhesive will not fail due to force at 2ft drop
13. The Chassis will deflect at most .1in due to the force at a 2ft drop
14. Chassis must have a minimum of 1.5” of clearance from the ground and not hit during 2ft drop
15. Chassis must allow the usage of fasteners no greater than M3 or M4 hex fittings
16. Axle will deflect no more than .1in to withstand half of the materials yield strength

e. Engineering Merit

The RC Baja competition has various requirements and rules that were established by ASME and are used to determine what qualifies as a successful RC Baja. Analysis will be done throughout the design process of the vehicle using engineering methods learned in mechanics of material, statics and dynamics. More specifically, the use of dynamics in order to determine what the impact force will be when the vehicle is traveling at 30mph and the minimum cross-sectional area. This can then be followed by the use of mechanics of materials to determine what the buckling load for the chassis is and compare that value to the force at the impact to see if any buckling will occur. Another important engineering method used to design the drivetrain was the use of mechanical design to properly calculate the Train value and thus determine what size gears and how many teeth are needed to reach the desired velocity, in this case the maximum velocity was determined to be 30mph.

f. Scope of Effort

The scope of the project that will be discussed in the report is focused more on the chassis and drivetrain portion of the vehicle and to have a functioning RC vehicle at the end of the year. This will be accomplished by performing analysis on the chassis to determine the thickness and length dimensions as well as analysis on the drivetrain to reach a maximum desired velocity while also being able to withstand impacts at that speed.

g. Success Criteria

The success criteria for the project is whether the final product can meet the regulations [ASME Baja rules] and be able to compete in the two events, the Slalom-and-Sprint event and the Baja race. This in result relies on the design and calculations that will be done in order to build the final product.

h. Stakeholders

The stakeholders in the project are going to be Roberto Vieyra and Rogelio Arroyos attending CWU who are the ones responsible for the project. The end result of the project will all depend on the analysis and work that has been done as well as how carefully errors were handled throughout the processes.

2. DESIGN & ANALYSIS

a. Approach: Proposed Solution

The task that was chosen to undertake was the design of a functional drive train and chassis. One of the initial designs for the RC was to make it a low-profile compact vehicle, but because the RC had to be designed for the requirements the design was not implemented. The initial design of the drivetrain that was discussed was a simple toothed belt driven drivetrain which would require a timing belt, axles, wheels, bearings, correctly sized drive shaft and additional mounting hardware but in the end, it was decided that this was not feasible because of size restraints. The process can be seen in the decision matrix in Appendix F where the gear drivetrain design was chosen because of the change in drivetrain but because of the increase in size, the design will weigh more compared to the belt driven design. While the chassis would need to be made in order to support the weight of the motor and battery as well as provide mounting points for the components.

b. Design Description

The driving system that was chosen was a simple set of gears that would provide the required velocity which would require a pinion gear, spur gear, axles, wheels, bearings, correctly sized drive shaft and additional mounting hardware. The drivetrain will have a small pinion gear to a larger spur gear which means that it will produce more torque and acceleration. While the chassis would need to be made in order to support the weight of the motor and battery as well as provide mounting points for the components.

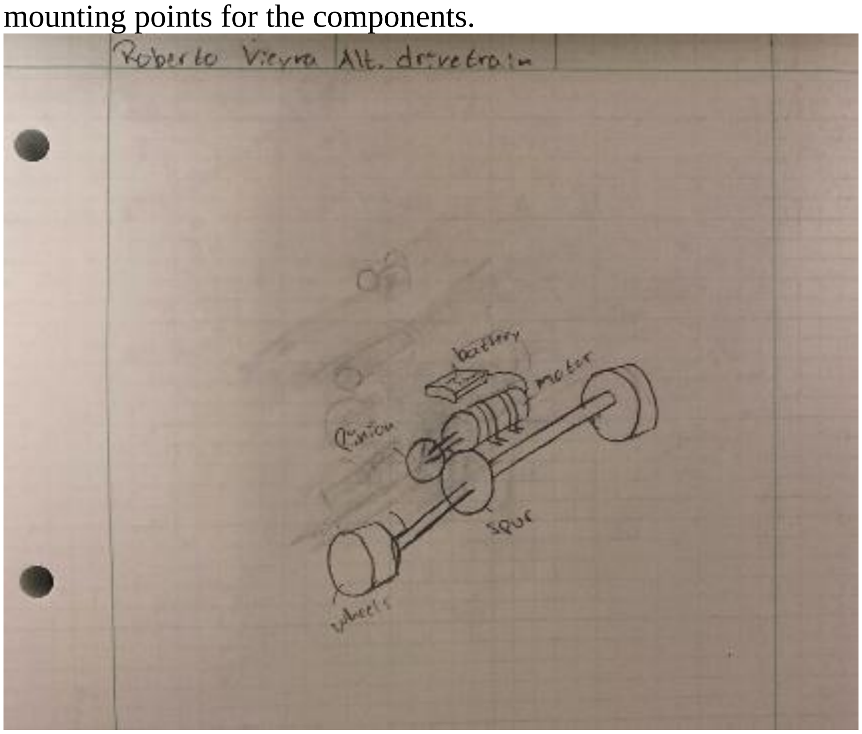


Figure 2.1 This is an image of the current drivetrain configuration. The motor is mounted to the chassis and attached to the battery. There are also two gears, one connected to the motor shaft and the other connected to the rear axle.

c. Benchmark

RC vehicles that can be bought through retail are typically affordable and accessible. Benchmarking against a Retail RC can provide insights into the cost-effectiveness of the project's solution and its potential for scalability. Taking a look at an H-King Rattler (RTR) 1/8 4WD Buggy V2 with Upgraded 80A ESC, which is similar to the model that is being designed however this model has decided to go with an all-wheel drive meaning that the retail rc will be better with offroad handling while the rc being designed in this project will have more torque and acceleration. A benchmark comparing the handling and acceleration of each could provide information on how well the student designed project performed and where some aspects performed better or worse than the retail model.

d. Performance Predictions

The predictions for this vehicle will be to reach a maximum velocity of 30mph based on the design of the drivetrain and the specifications of the motor and battery. Front and rear axles will deflect at most .1" and will have rattling caused by components down to a minimum.

e. Description of Analysis

For the drivetrain it will be important to use Statics when using a FBD to find the forces acting on the vehicle and find the deflection that is caused by the weight of the vehicle when it is dropped 2 feet. Statics will also be used to tell whether the vehicle will be able to withstand an impact at 30mph. Kinematics are used to solve for the axle rpm and can then be used to calculate the gear ratio. Mechanics of materials will be used to determine if the chassis will be able to support the full weight of the material. Mechanics of materials will also be used to determine the minimum thickness that is required to withstand the stresses from a drop of 2ft. Some additional analysis that will be required are for the axle and whether the material that the axle is made of can withstand the maximum loads. Analysis on the torque that the axles are experiencing and whether the material properties are able to withstand the stress will also be important.

f. Scope of Testing and Evaluation

The testing that will be performed on the vehicle will be impact testing to determine if the vehicle will withstand the forces when at a velocity of 30mph. This can be performed physically and on paper based on the material of the chassis. Deflection testing will also be performed to determine if the drive axles do not exceed the required amount of .1". Testing will also be performed on how the drivetrain performs and if the vehicle achieves 30mph and maintains the velocity by driving the rc in a large flat area.

g. Analysis

i. Analysis 1 – Pinion gear and Spur gear analysis

The analysis that is being done in this situation is the required rpm of the spur gear that is required for the vehicle to achieve a maximum velocity of 30mph which is one of the requirements (req-1.d.7). The first thing that was done was to convert the velocity from miles per hour to a unit that uses radians. In this instance the chosen unit was inches. After converting 30mph to 3171.09 rpm, the maximum rpm that the motor could produce was necessary. Since the motor was rated at a maximum rpm of 23400 at a voltage of 9.6v then that would mean that the Kv rating is 2437. 5Kv which can be seen in appendix A section A01. Taking this value and multiplying it by the voltage of the battery gives the actual maximum rpm, in this case that value was calculated to be 18037.5rpm. To find the train value of the drivetrain, the input rpm was divided by the output rpm of 1507.33. This came out to a gear ratio of 11.97:1 which looking at table 8-7 in Mott.

TABLE 8–7 Number of Pinion Teeth to Ensure No Interference

For a pinion meshing with a rack		For a 20°, full-depth pinion meshing with a gear		
Tooth form	Minimum number of teeth	Number of pinion teeth	Maximum number of gear teeth	Maximum ratio
$14\frac{1}{2}°$, involute, full-depth	32	17	1309	77.00
20°, involute, full-depth	18	16	101	6.31
25°, involute, full-depth	12	15	45	3.00
		14	26	1.85
		13	16	1.23

Figure 2.2 that can be found in page 321 of Machine Elements in Mechanical Design that describes possible pinion sizes based on tooth form.

According to the table for a 20°, full-depth pinion meshing with a gear, a pinion of 16 would not work since the maximum gear ratio possible is 6.31 which is less than the 11.97 that was previously calculated. To solve this issue the factoring method was used t determine that the drivetrain would require 2 sets of gears with a velocity ratio of 4:1 and 3:1 respectively. Following this it is now possible to find the number of teeth on each gear that is required to achieve this gear ratio. Through trial and error, it was calculated that for the configuration of this rc vehicle it is required to have a pinion spur gear with 16 teeth and a spur gear with 63 teeth. The other set will have bevel gears having 15 and 45 teeth respectively to achieve a Train value of 11.8125 which had a percent deviation of 1.56% ensuing the maximum velocity of 30mph was reached.

ii. Analysis 2- Minimum Frontal Cross-sectional Area of Chassis

This analysis was done in order to calculate the minimum dimensions that are required for the rc vehicle to be able to withstand the forces that would be experienced when the vehicle hits a wall while traveling at the maximum velocity of 30mph. This analysis can be seen in appendix A02 where an assumption for the current weight of the vehicle was made as this value is not currently known, an assumption of using the maximum allowable weight to determine what the minimum dimension needed to be at the maximum weight for the rc. Using 5lbs as the weight, the 30mph was converted to .00833 miles/s which was then used to find the acceleration. Another assumption made was that the time for the rc to stop was almost instantaneous and a time of .05s was used. This gave an acceleration of .166 miles per second squared and using the equation for force of F=ma the with a mass of 5lbm the force came out to be 4382.4 lbf which can be seen in appendix A02. This is the load that the front of the rc will experience when it hits the wall traveling at 30mph. Then using the materials ultimate tensile strength property, the dimensions for the cross-sectional area came out to be a square of $.4796in^2$. Although this value would work for withstanding the load of 4382.4lbf, the thickness was not large enough for mounting the motor and so a new length of 1.5"x .875" was used to evaluate the stress at this location. Using these values as the new dimensions the amount of stress at that location due to a force of 4382.4lbf the stress was calculated to be 1947.73psi. Comparing this with the material's ultimate tensile strength of 9137.38 psi, the stress caused from an impact at 30mph will not exceed the material properties meaning that the front of the chassis will hold out with a frontal area of 1.5"x .875". This ensures that the vehicle meets the impact requirement (1.d.9) which states that the vehicle will survive the impact force traveling at 20mph.

iii. Analysis 3 – Force from 2ft drop caused by vehicle weight on the chassis and wheels

The analysis that took place in appendix A03 was performed in order to determine the force caused by the vehicle's own weight from a 2ft drop and what the reaction at the wheels would be. Using the principle that the initial potential energy is the same as the final kinetic energy, the velocity was found by using the acceleration due to gravity and the height it was dropped. The velocity was calculated to be 135.76 in/s and was then used to calculate the acceleration of 383.97in/s ^{2} . Then using the equation F=ma the total force due to gravity acting on the RC was calculated to be 9.95lb of force. This would mean that each wheel would experience 2.486lbs at the point of impact from a 2ft drop. A calculation on the deflection experienced by the chassis was done to determine if the requirement was met and a deflection of .0078in was calculated and did meet requirement 13 in section d (req-1.d.13) of the introduction which states less than .1in of deflection for the chassis.

iv. Analysis 4 – Dimensions of Pinion and Spur gear

This portion of the analysis was focused on determining the needed dimensions to have a pair of gears with a train value of 12. One of the essential pieces of information was the number of teeth for each gear. This was determined in analysis 2 where the factoring method was used to determine that the drivetrain would require two sets of gears, one with t velocity ratio of 4:1 and the other with a ratio of 3:1. The spur gear has 63 teeth while the pinion gear has 16 teeth. In Appendix A04 it can be seen that the module had to be determined to be able to calculate other various dimensions required for the gear, one of them being the reference diameters for the gears. The module that was chosen was 0.8mm or a diametral pitch of 32in and with that it is possible to determine the reference diameter by multiplying the number of teeth by the diametral pitch. The spur gear had a reference diameter of 1.97in and the pinion gear had a reference diameter of .5in. Then the addendum is found simply by multiplying the module by one, so the addendum is essentially the module. The Addendum is the distance from the reference diameter to the tip of the teeth and to the root diameter. It is also important to calculate the center distance from where the gears should be placed. In this instance, the center distance was 1.234in. Knowing these pieces of information and that the pressure angle is 20, it is possible to model the gears. Through this analysis, the velocity requirement was met (req-1.d.7) which states that that the vehicle must be able to reach velocities of 30mph and with the current configuration of the drivetrain, the vehicle will be able to achieve this velocity. Then once the motor was switched to a 1980KV brushless motor, the gear ratio was changed from a 63/16 to 53/16 while the bevels stayed the same. The new train value was 9.7:1 which would allow the RC to reach 30mph.

v. Analysis 5 –Bolt Diameter for motor mount

The analysis in appendix A05 is focused on determining the minimum diameter bolt that will not fail for the motor mount to be fastened to the chassis. This analysis will also ensure that requirement 15 (req-1.d.15) is being met, which states that the fasteners must be no larger than M4 fasteners. Making the assumption that the bolt was made of SAE grade 1 steel, the yield strength of 36ksi was used to calculate the diameter based on the maximum shear force from the weight of the vehicle. Then to calculate the diameter the formula for shear stress was rearranged to $d = \sqrt{\left(\frac{4V}{\tau\pi}\right)}$. Plugging in the values that are known, the diameter is calculated to be .013298in. In order to be sure that these bolts would not fail, an analysis on an M4 bolt was done. Using the diameter of the M4 bolt, the area was calculated to be .0195 in^2 and using the shear stress from before of 5lbs. The new shear stress was calculated to be 256.702 psi. The yield strength of the material was rated at 36000 psi which meant that using the M4 bolts would be sufficient enough to not fail under load.

vi. Analysis 6 – Deflection and Stress caused by Suspension

This analysis is focused on determining what the reaction forces caused by the shock tower are and what the deflection is due to those forces. In appendix A06 it can be seen that the suspensions are set to be at a 45 angle which means the x and y components for these forces would be the same. Using a FBD, the reactions were calculated in order to determine the maximum shear and the maximum moment since these were values that needed to be determined in order to calculate the bending stress, the maximum shar force was determined to be 47.87lbs and the maximum moment was 30.16 lb-in. Then using the equation for normal stress due to bending. Calculating the moment of inertia to be .307in^4 and using the moment of 30.16 lb-in and a c of .4375in which is the maximum distance from the neutral axis to the outermost fiber of the beam. The bending stress was then calculated to be 42.97psi. Comparing this to the flexural strength of the material of 10732.8 psi, the chassis will be able to withstand the impact of the shocks. Lastly the deflection was calculated to be .00205in and was less than the required amount meeting requirement 13 (req-1.d.13) of less than .1in of deflection.

vii. Analysis 7– Actual motor power

The purpose of this analysis was to calculate the actual motor power based off of the estimated power calculated and then multiplied by motor efficiency, this also ensured requirement 5 was met (req-1.d.5) which states that the motor will transmit a minimum of 50 W. In appendix A07, initially the estimated motor power was first calculated by taking the input voltage of 7.4V and multiplying by the motors maximum current of 9.55 which was given by the specifications sheet.

RS-540SH

MABUCHI MOTOR

OUTPUT：5.0W～90W (APPROX)

カーボンブラシ | Carbon-brush motors | 碳精电刷

代表的用途 家電機器：バキュームクリーナー
工具：ドリル／ドライバー／
ガーデンツール／エアーコンプレッサー
玩具・模型：RCモデル

主要用途 家电机器：真空吸尘器
工具：电钻、螺丝刀、园艺工具、
空气压缩器
玩具、模型：RC遥控模型

Typical Applications Home Appliances：Vacuum Cleaner
Cordless Power Tools：Drill / Screwdriver / Cordless Garden Tool / Air Compressor
Toys and Models：Radio Control Model

WEIGHT：160g (APPROX)

MODEL		VOLTAGE		NO LOAD		AT MAXIMUM EFFICIENCY					STALL		
		OPERATING RANGE	NOMINAL	SPEED	CURRENT	SPEED	CURRENT	TORQUE		OUTPUT	TORQUE		CURRENT
				r/min	A	r/min	A	mN·m	g·cm	W	mN·m	g·cm	A
RS-540SH-7520	(*1)	4.8~7.2	7.2V CONSTANT	23400	2.40	19740	13.0	30.6	312	63.2	196	1998	70.0
RS-540SH-6527	(*1)	4.8~9.6	9.6V CONSTANT	23400	1.60	20040	9.55	31.0	316	64.9	216	2202	57.0

Figure 2.3 Image of RS-540SH specifications sheet

The estimated power was calculated to be 70.67W. Then the following step would be to calculate the motor's actual power by taking the maximum efficiency that it is rated at and multiplying by the estimated power.

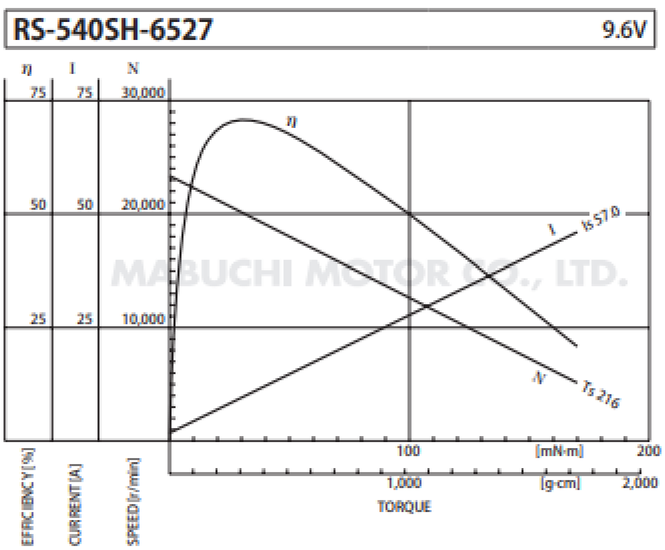


Figure 2.4 Image of motors maximum efficiency

Taking the best estimated value that can be seen on the graph, a motor efficiency of .71 was assumed. The actual power was calculated to be 50.13W which makes sense because the estimated value was calculated based on the assumption that the motor efficiency was .1 or 100% efficient. In real world applications this would not be the case and so motor efficiency was needed to calculate the actual value from the estimated.

vii. Analysis 8-Rear axle diameter and deflection

In appendix A08 the analysis is focused on calculating the minimum axle diameter for the designed to withstand a shear stress of half of the materials yield strength of 241MPa. The torque was first calculated by taking the power of the motor and multiplying by the constant 9.5488 then dividing by the RPM of the axle. Plugging in values, the torque was calculated to be .151Nm. Then by rewriting the formula for torsional shear of $\tau = \frac{Tc}{J}$ into $J = \frac{Tc}{\tau}$ the radius can be calculated by substituting J with $\frac{\pi r^4}{2}$ and assuming the material is aluminum 6061 –T6 evaluates to $9.274*10^{-4}$ in. Then the radius was doubled to get the minimum diameter for the axle which was .00185in. Then an axle diameter of .175in was used to calculate if the axle deflection met requirement 12 in section d of the introduction (req-1.d.16) which states that there must be less than .1in of deflection for the axle. The deflection was calculated to be .0704in at a length of 12in and a diameter of .472in or 12mm which was well within the required .1in of deflection. This would mean that the rear axle must be .472in to have a deflection less than .1in and be able to withstand 120.5Mpa of shear.

viii. Analysis 9- Angular and Actual Velocity

The analysis done in appendix A09 was done to determine what the actual velocity of the vehicle was going to be knowing the gear ratio that was determined. By taking the number of teeth on the spur and dividing by the number of teeth on the pinion, a train value of 11.956 was calculated. Then taking the motors maximum rpm of 18037.5rpm and dividing by the train value to calculate the axle rpm of 1508.59rpm. This was then multiplied by the circumference of the wheel and a velocity of 30.025mph was calculated. This met requirement 1.d.7 which states the RC can travel at 30mph. The angular velocity of the wheel was also calculated by multiplying the axle rpm by 2π and then dividing it by 60, this resulted in an angular velocity of 157.98 rad/s.

ix. Analysis 10-Forces on Pinion

The forces acting on the pinion were calculated in the analysis performed in appendix A10 in order to ensure that requirement 4 was being met (req-1.d.4) which states that the gear will handle the stress during operation. The pitch line speed of the teeth needed to be calculated in order to determine the tangential force. Plugging in the pitch diameter and the rpm of the motor into the pitch line speed equation, the pitch line speed was calculated to be 1710.41 ft/min. Then the tangential force was found by dividing the power of the motor by the pitch line speed and was calculated to be 1.30lbs. The radial force was found to be .472lbs by multiplying the tangential force by the tangent of the pressure angle and the normal force was found to be 1.381lbs by dividing the tangential force by the cosine of the pressure angle. With these forces, the stress caused will not exceed the materials yield strength of 13778.6psi and thus requirement 4 is met.

x. Analysis 11-Chassis Critical Load

This analysis was done in order to calculate the critical load of the chassis to determine if the force produced during the impact test will cause the chassis to buckle which can be seen in appendix A11. Here it was assumed that the width of the chassis was going to be the least dimension since that would be the location of failure so a width of 76.2mm was used and a thickness of 28.575mm for the cross section. It was determined that the chassis was a long column and so Euler's formula was used. Taking the material to be PLA +, the modulus of elasticity was determined to be 2.1GPa and the critical load was calculated to be 12,490lbs. Then taking a look at the calculated value in analysis 2 (appendix A02) which was the force due to an impact at 30mph which was calculated to be 4382.4lbf and so that would mean that the chassis will not buckle due to an impact at 30mph. This meets requirement 1.d.10 which states that the chassis must not buckle during the impact at 30mph.

xi. Analysis 12-Pinion Set Screw Dimension

The analysis performed in appendix A12 was done in order to determine what the minimum size set screw would be required to fasten the pinion gear and withstand the torque produced by the motor. The material of the set screw was assumed to an SAE Grade 1 Steel which meant it had a tensile strength of 60ksi. With a motor power of 50.13W and an rpm of 1507.33rpm, the torque was calculated to be .3176 N-m. Then using this value and plugging in to the equation $d = \sqrt{\left(\frac{4T}{D\pi S_u}\right)}$ the diameter came out to be .0221in or .562mm. Taking a look at standard sizes, a #0 set screw with a thread diameter of .060in will be sufficient to fasten the pinion to the motor shaft. This met requirement 1.d.15 which states that no greater than M4 fasteners will be used and since 4mm is .157in, the #0 set screw is within range.

h. Device: Parts, Shapes, and Conformation

The design for the parts of the drive train were designed based on the maximum velocity the RC vehicle is required to travel as well as the impacts that the chassis must resist. The shape and thickens of the chassis portion of the design were based on making sure that the weight of the battery and motor were able to be supported during the impact test. As for the material that was chosen, it was based on whether or not the stress caused by an impact from a 2ft drop would cause the chassis to break. The tolerances on the chassis and larger bodies of the vehicle like the axles were larger set to .1in because the role that they performed did not require close precision like the mating of the gears which was set to have a tolerance of .05in since they were going to be 3D printed. The ergonomics in the design include application of various requirements to ensure that the specific user needs were being met as well as making the vehicle as simple as possible since the initial intent for the project was to make an RC that was simple enough so others will be able to 3D print the vehicle while still meeting the requirements set in the introduction section previously. For example, requirement 1.d.11 which states that the chassis will not exceed a mass of 5 lbs. This was to ensure the cost would be kept to a minimum for anyone wanting to print the components. The kinematics involved during this project involve the performance of analysis to ensure that the vehicle would be able to reach the maximum velocity set by the team of 30mph. Safety factor of 2 was also applied to the weight of the vehicle during analysis since the weight is currently unknown. However, the team is assuming a weight of 5lbs and with the safety factor a weight of 10lbs is used during any analysis calculations.

i. Device Assembly

The RC will be constructed to perform in two events, the slalom and sprint event and the Baja event. RC design consists of a lightweight rear wheel drive, a single pair gear drivetrain assembly and a single point suspension. The reason for choosing a rear-wheel-drive vehicle was because of the better handling in dry condition which will be important in the Baja event that will test the rough terrain handling. As for the drivetrain, the small pinion gear to the larger spur gear configuration will allow the vehicle to have better acceleration which will aid in the slalom and sprint portion which requires not just handling but acceleration. The reason for the single point suspension was to have the force of the landing localize to one point and design the chassis to be able to withstand that load.

j. Technical Risk Analysis

One of the major technical risks is the stress caused by the single point suspension and whether or not the portion of the chassis that will be loaded during the 2ft drop will be able to withstand the load and will be a possible location where failure may occur. In order to keep the vehicle as lightweight as possible, simplistic drivetrain configuration was used which may not operate as efficiently as a more complex model.

k. Failure Mode Analysis

The types of loads that the RC vehicle will experience includes the force due to the weight of the vehicle being dropped. The maximum shear stress theory can be applied since this is one of the loads that was considered when selecting the material as it was important to know the materials bending strength to be able to calculate if the stress caused by the load from the drop would cause deformation. The axles of the vehicle will also be experiencing torsional load, and need to be made sure that they won't fail. Another potential failure mode that was addressed was an impact from the vehicle going 30mph and hitting a wall. The maximum normal stress theory, which is similar to the maximum shear stress theory was taken into consideration which states that failure will occur when the maximum principal stress reaches the material's ultimate strength for simple tension. As long as the stress calculated based on the force experienced at the maximum velocity does not exceed the maximum stress property of the material, then the material will be fine and not fail. An analysis on the chassis of the vehicle also needs to be made to determine how much deflection is caused by the vehicle weight. It is also important to determine if the chassis would fail under normal loading conditions.

l. Operation Limits and Safety

While operating the device it is important to take note of the following. The vehicle is designed to travel at a maximum velocity of 30mph and any use over that velocity may result in permanent damage to the battery and motor. Since the vehicle is a rear wheel drive, operation in dry conditions is recommended for an increase in handling. A safety factor of 2.0 was applied to the initial vehicle weight when performing failure load analysis. Careful handling will be required as the battery will be exposed as well as moving parts from the motor will be exposed.

3. METHODS & CONSTRUCTION

a. Methods

During the fall quarter, the RC Baja was designed with the intention of using the resources provided by CWU if necessary whether it be the use of the machine shop to make an axle couple if necessary or the use of the 3D printers if the personal printers don't print the parts with the required precision. For the chassis and drivetrain portion of the RC, the main form of manufacturing will be the use of 3D printing as most of the components were modeled in CAD and were planned to be printed out of PLA + after being analyzed.

As previously stated, the primary form of manufacturing is 3D printing because it was an affordable option and since it didn't require much hands on involvement, it allowed for the preparation of other parts and reduced the time spent on manufacturing. Another method implemented was the use of a soldering iron to heat up threaded inserts and placing them in the components. Additionally, the rear axle was also machined in a lathe out of aluminum using the CWU machine chop and the equipment provided.

i. Process Decisions

3D printing is going to be the main process in the construction of the RC vehicle chassis and drivetrain portion which will involve the printing of various major components including the chassis base and the gears for the drivetrain. This process was decided through a decision matrix to determine the best way to manufacture the parts which can be seen in appendix F03. The reason for this selection was because of the ease of use compared to other Manufacuring methods like laser cutting or a CNC machine. It was also determined that 3D printing would not necessarily be the fastest, but it will be the cheapest option.

Another decision matrix was performed to determine what other manufacturing method will be used if necessary. In appendix A04, the stamping process was the best out of the two others that were looked at. The reason for this decision was because with casting, it can be difficult to get a uniform part. Stamping is typically used with thinner materials while casting and welding are an additive process that can add unwanted weight. Stamping was also determined to be the least cost-effective choice.

The material that was chosen was PLA+, in appendix F02 a decision matrix was made to help facilitate this decision and the reason for this decision was because the RC was designed with the intention of keeping the weight to a minimum and using 3D printing will allow for the printing of components that are light weight and durable which can be seen in. The use of metals like aluminum 6061 would involve machining which can potentially be faster than 3D printing but the precision is up to the one performing the manufacturing and with a denser material, it would cause the weight of the vehicle to increase. It was also important that the material was strong enough to withstand a force of an impact traveling at 30mph which can be seen in appendix A02 where an analysis to determine the cross section for the impact based on the material. It was determined that going with PLA + would be sufficient enough with a cross section of 5" x 1.125". Going with PLA + was the best choice because it was a material that was able to be 3D printed and was a lightweight yet durable material which was one of the important properties that was desired.

One of the reasons that the project has stuck with 3D printing as the main form of manufacturing is because of how quickly it is possible to manufacture the components and then start fitting them to see if they fit properly. Because of this, some issues that were noticed with 3D printing were the parts not the same dimension as the modeled component by a fair margin however, this was solved by tuning the printer so that there is a balance between the accuracy of the inner feature dimensions and the outer dimensions of the component. When the hole dimensions were dialed to be accurate, the outer dimensions would be further off and vice versa.

The rear axle was first purchased with the intent of cutting it in half and creating a couple so that it could be extended and mounted. However, it was decided that an aluminum stock piece was going to be machined in a lathe then sanded as the finish. This would allow the team to machine the shaft to the length that was desired, and no couple was needed in this case.
Threaded inserts were also used since there was a need to fasten components to the chassis since there was a high chance that the RC would be taken apart multiple times, it would be very important that the metal fasteners don't eat away at the material over repeated assembling and disassembling

b. Construction

i. Description
The RC that was designed and constructed will be made by attaching components to the main body of the vehicle which is the chassis. Most of the components for the RC will be created inhouse and 3D printed which consists of the chassis, motor mount, battery mounts, rear and front shock towers, pinion and spur gear, upper and lower control arm for each wheel, servo mount and the gear box. The rest of the components will be purchased such as the servo, motor, battery, pinion and spur bevel gears, gear shafts, hardware, steering rack, axle, axle ends and wheels will be the purchased parts. The 3D printing of the chassis will be the first initial step in the process of assembling the RC which will then allow for the mounting of the shock tower and control arms followed by the wheels and wheel knuckles. Then the shocks, battery, electronics, motor and axle can be installed with the use of fasteners and other hardware.

ii. Drawing Tree, Drawing ID’s
The assembly of the RC will be performed by using fasteners to attach the 3D printed components to the chassis or other modeled parts like the shocks attaching to the shock tower or the motor mount being fastened to the chassis so the motor will not move. The chassis and drivetrain will consist of 2 sub-assemblies and one major assembly. One sub-assembly will be the drivetrain portion which first includes the motor mount which will be fastened to the chassis, followed by attaching the motor to the mount. The gears will then be attached, the pinion to the motor shaft mated to the spur gear which will have a shaft that leads to the differential at the rear of the chassis. The assembly was done in this order to determine what length shaft was needed to attach the set of spur gears to the differential which can be seen in the drawing tree in appendix B01. The other sub assembly will include the chassis and the battery with its mounts. The other major sub-assembly is the suspension portion which includes the front and rear shock tower, pillow block housing with bearing, upper and lower control arms and the axles which all will mount to the chassis.

iii. Parts

Fall: one of the process groups for this project that will be taking place will be an additive manufacturing process which is 3D printing. One example of this is the chassis (RCV-20-002) which will be one of the longest prints for the project and take the most material. If these components were to be machined, it would have been the most expensive along with the shock towers (RXA-20-001, RXA-20-002) thus 3D printing was the best option for parts construction while keeping cost to a minimum and component weights as low as possible. The second process group includes the purchased parts which can be seen in appendix C and includes the CNC machined shocks (RCV-55-001). The last process group will include the purchased parts that require any form of modification such as the axle (RCV-55-007) as a keyway will be needed to make sure the gear doesn't slip and freely rotate but matches with the keyway and drives the axle.

Winter: During the winter quarter some changes were made to the manufactured parts, like the rear axle (RCV-20-008). Previously, the group had decided that the rear axle was going to be purchased but the issue with this was that the axle that was going to be purchased was going to be too short and so it would've had to been cut then coupled together. Instead of doing this, the rear axle is now going to be machined out of aluminum. This makes it much easier to get the axle to the nominal size and no coupling would be required in this instance. Because of this, the gear box (RCV-20-009) would then require modification since the shaft diameter now changed. With this new restriction in place, the gear box was cut in half and threaded inserts were placed so that the two halves can be fastened together.

iv. Manufacturing Issues

Fall: Some potential risks that came up were the proper storage of the PLA + material that will be used to prevent the material from being contaminated and absorbing too much humidity. This issue can be solved by using a dehumidifier and periodically checking the humidity of the material. Another major risk was the capability of the 3D printer as it was initially planned to print out the gears in the differential. It was then decided to purchase the bevel gears since it turned out to not be feasible as the nozzles kept getting clogged with material due to the geometry of the bevel gear teeth.

Winter: During the initial manufacturing process, the 3D printed components were not as accurate dimensionally as the group had hoped for. It was noticed that the printed components were not exactly the same dimensions as the modeled parts. To mitigate this issue, the printer that was being used was calibrated so that the dimensions were much closer to the nominal values. Another issue that arose was during the manufacturing of the rear axle. Since it was a long shaft, in order to machine it properly the tail stock needed to be in place to give the shaft support. Initially this was not done and so when the axle was being machined, not much material was actually being removed and so this was quickly fixed by placing the tail stock and locking it in place.

v. Discussion of Assembly

While the device was being assembled, the first sub-assembly that was manufactured was the drivetrain (RCV-10-002) which can be seen in the drawing tree in appendix B01. Initially the smallest components were first manufactured as they were going to be taking the least material to manufacture and also the shortest time. By doing so, it was possible to further refine the manufacturing process which was 3D printing so that when the bigger components were being manufactured, they came out without any issues. Once this assembly was completed, the next sub-assembly that was manufactured and assembled was the chassis (RCV-10-003). This was a simple sub-assembly that only had a few components, which were the battery mounts and the chassis itself. The reason the assembly process occurred this way because the chassis was the biggest component that almost took 1kg of filament to manufacture and by printing the other components first it allowed the team a chance to correct any issues with the manufacturing process. There was also a need to use threaded inserts as the components were going to be constantly assembled and disassembled and it would be important that the fasteners don't eat away at the material. With the addition of threaded inserts to the various mounts, it allowed for the components to be fastened to the chassis without any issues. The benchmark the team was looking at was the H-King Rattler. Compared to this device, the manufactured RC was going to cost much more than the Rattler, one of the reasons was the expensive electronic equipment purchased like the battery charger. Another reason was the cost of the wheels and the fasteners that needed to be purchased for them. Maneuverability wise, the manufactured RC will have better acceleration than the retail version as well as having better handling since the manufactured RC will be a rear wheel drive while the retail version is an all-wheel drive.

4. TESTING

a. Introduction

This section of the proposal will introduce the process taken to perform testing on the RC to evaluate the overall function and its components. The main tests will involve a drop from higher than 2ft, a drag race competition where the acceleration will be heavily tested, and impact at the frontal section of the RC and an obstacle course. During the drop test, the deflection of the chassis will be monitored as it needs to meet requirement 1d-11. The acceleration will be tested simply by having the RC race down a track multiple times and take the average. As for the impact test, the main aspect that will be monitored is the amount of stress experienced by the chassis and the amount of deflection caused by the impact. An obstacle course will be made in order to test the RC’s maneuverability and ability to handle complex driving scenarios.

b. Method/Approach

Three of the main tests performed on the RC are the drop test, a deflection test and an acceleration test. During analysis for the impact test portion of the vehicle, it was calculated that with a frontal cross-sectional area of 2in x 1.125in the amount of stress caused by the impact will not cause any permanent deformation during the impact and will deflect less than .1in (req. 1d-11). This test will involve driving the vehicle into a wall traveling at the maximum velocity for multiple trials. The equipment needed will include sensors needed to measure the deflection during the impact and the amount of stress experienced, a slow-motion camera, large wall of choice and a speed sensor. Another major component in the vehicle is its ability to accelerate in a straight line. The current configuration of the drivetrain is set up to have a gear ratio of 6.31 which means at the cost of top speed, the RC will experience better acceleration. During the testing of the acceleration, multiple trials will be necessary to ensure consistency. This test will involve a drag race competing against other teams where all RC vehicles will line up and accelerate to the finish. There will also be a drop test from a height of 2ft and the deflection is something that will be measured. This test will involve the measurement of the distance that the chassis deflected using sensors and it will be necessary that the deflection is less than the required amount of .1in (req. 1d-11). A camera will be used to record the impact from the drop and with the use of sensors, the deflection must be checked and made sure that the deflection is within range. The test is done using a measuring stick to measure the initial height for each trial and then taking the average value of the results. Equipment needed will include the complete RC, a slow-motion camera and sensors for measuring deflection. Other testing will also be performed to make sure that the RC is running properly, a deviation test will be done to ensure that during the acceleration testing the RC doesn’t veer off. A steering angle test will also be performed which will require a jig to be set up under the wheels with increments marked, then the wheels will fully lock to the left and then to the right.

After having performed the velocity and deflection tests, there were a few changes to the initially proposed methods/approach seen above. One of the major changes was, instead of an impact test, a deflection test was performed since the team did not want to break the upper and lower control arms every time since they were made of PLA +. During the drop test, no sensors were purchased to determine the deflection or stress experienced since the budget for the project was already over the set amount of $500. Instead, the use of a slow-motion camera built into the team members smartphone was used to determine the initial position of the RC at rest and then the maximum deflection from the recording. Some procedural issues occurred when it was noticed that the chassis would sometimes hit the ground during the drop. To mitigate this the number of trials was increased from five to twelve thus allowing for a wider range of data to be collected. Another improvement can be too the clearance to help gather better data. Instead of an acceleration test where the RC was competing with others, a velocity test was performed instead of performing a separate acceleration test and was all combined into one. Since during the velocity test the total distance traveled was known, the final velocity was also known from the speedometer and the time it took the RC to travel the distance was also known. It was then possible to calculate the acceleration of the device, thus not requiring a separate test. Procedural issues here were due to the motor overheating and requiring some time to cool down, however a hard cut off time was set at 3min regardless of if the motor was cooled all the way down to have some consistency with each trial. Then in the deflection test using the Instron machine, there were no procedural issues experienced and it was possible to tabulate the data gathered given from the Intron loading the chassis at its center up to 40lbf.

c. Test Process

During the testing process for the acceleration of the vehicle, the velocity will also be recorded in a table to ensure that requirements were met like velocity (req.1.d.7). In order to do so, a large flat area will be required to ensure there is enough distance to allow the vehicle to achieve the maximum velocity and acceleration. After various trials an average acceleration will be determined which will require a drag race involving other competitors. The impact portion will involve the measurement of the amount of force and deflection of the chassis experiences which will be done using slow motion cameras to calculate the amount of force and then the deflection based off of that. This test will also ensure the deflection requirement is also being met (req.1.d.13) which stated that the deflection will be less than .1” from a 2ft drop. This portion will require that backup components be prepared as there is a chance that some components might break due to stress. During the drop test portion, this process will involve the RC being dropped from various distances gradually increasing to ensure that the deflection requirement (req.1.d.10) was also being met. Then the testing processes for the chassis deflection test performed on the Instron machine will be fairly simple, ensuring the requirement 12 was being met which stated that the adhesive will not fail due to the force from the 2ft drop. The main focus will be on how to set up the various parameters on the machine like setting the load to compression and also ensuring the correct units are being used, which can be seen in appendix G3.

d. Deliverables

During the gathering of the raw data for the testing processes, the data will be tabulated in a table for each test performed and a description will be added of how the test was performed. In order to keep the data as reliable as possible, each test will be performed as similarly as possible to reduce errors in data collection. There will also be photos and videos recorded during the testing to help validate the gathered data. As the RC will be tested for its top speed on a flat surface, then it will also be possible to determine if it will be able to withstand the impact at its maximum velocity. This will be done taking the force and then calculating the amount of stress the vehicle experienced and then comparing the results to the material properties of PLA + and the analysis that was performed. The steering will be tested using a jig that will be constructed, similar to what an alignment machine for full scale vehicles would do. The only difference here would be that the jig constructed will be on paper since it is a much smaller scale vehicle. The steering radius will then be measured using measuring tape, then a load will be applied to the RC so that it can travel a minimum of 1.5": Following this, the amount of deflection will be determined based on how the vehicle reacts to its own weight during a 2ft drop. To do so, a slow-motion camera will be used to record the raw data and determine that a deflection of .1" was being met.

The purpose of the drop test was not only to ensure that the chassis would be able to survive the impact, but also to ensure that the components would be meeting the deflection requirement which (req1.d.13) stated that the components would not deflect more than .1in and the adhesive that was used would not yield due to the force of the dropped device (req1.d.12) as well as requirement 1.d.14 which states that the clearance is enough to not hit the ground during testing. Which was not met since the intron machine would be a better representation of the deflection on the chassis due to some static load and there were times where the chassis would hit the ground. The predicted deflection for this test was .0314in which as determined by using the deflection equation for a simply supported beam which was similar to what was being experienced but the main difference was that the beam was not statically loaded and was experiencing some sort of impact caused by the potential energy of the vehicle. This caused the deflection values to be off from the predicted value which can be seen in appendix G1 where the actual deflection was at a maximum of 4.5cm. It is also important to mention that the deflection calculated was based on the load at the center of the chassis and was not the case. However, after applying the conservation of energy principles, it was possible to calculate a new set of predicted values which were far closer to the test data was gathered during the testing and can be seen in table 2 in appendix G.3. Some issues with this test were the fact that the RC weight was not evenly distributed and so it was noticed that the rear would be hitting the ground first causing the front to then slam down. To mitigate this the team made sure to drop the RC as evenly as possible and increased the number of trials to increase the accuracy of the results. It was also important that the adhesive that was used would not exceed the ultimate yield strength of the material which was 1200psi for E6000. Based on the assumption that the RC would weigh 10lbs, a stress was calculated to be 8.312psi based on the cross-sectional area and force due to the 2ft drop. The actual stress was 6.234psi since the force experienced was less than what was assumed and would mean the adhesive would have no issues. There were also issues with the 3D printed ball joints to give the steering better directional control and so they were switched out with ones made of 6061 aluminum because they were breaking due to the tensile strength of the plastic.

The calculated value of .0314in assumed that the chassis would be simply supported and statically loaded, which was not the case during the testing and so a better representation for this would be a test using the Instron machine.

The velocity test was the second test performed to determine what the maximum velocity of the vehicle was going to be. One of the important requirements was the vehicle being able to achieve a velocity of 30mph (req1.d.7), however this was not achieved. During the testing, some procedural issues that occurred were due to the RC having very slow acceleration and so a strip larger than 20ft was necessary to get up to speed. Thus, modifications were made to the procedure so that instead of marking up to 20ft, the distance was first marked at 5ft and then in 10ft increments up to 45ft. By doing so, this gave the RC more time to accelerate up a constant speed which would make it possible to assume a constant acceleration for calculations. Another major change was the removal of the trials going forward as it was noticed that the device had more trouble moving from rest. This could be due to the orientation that the motor spins as it was noticed that motor would overheat faster when traveling forward but would not overheat traveling in reverse. After the competition there may have been damage to the internal of the motor causing the drive forward to become even more inefficient. This, however, did not affect the motor when it was spinning in reverse, and it was possible to complete the testing. That being said, another issue was the motor overheating at the end of the 4^{th} trial and can be seen in the tabulated data as the velocity would then decrease in table G4 in appendix G. To mitigate this issue a break was taken after each trial to let the motor cooldown.

The main focus of the deflection test performed on the chassis using the Instron was to ensure that the adhesive used would not exceed the ultimate tensile strength of the material due to the load from the 2ft drop (req.1.d.12) and to ensure the deflection requirement (req.1.d.13) of less than .1in deflection was also being met. During the testing there were no procedural issues that occurred. However, there were discrepancies between the calculated and the tabulated data received from the Instron machine. The maximum deflection experienced was .104in which was .004in above the deflection requirement of .1in. This can be because during the initial calculation for the predicted value, it was assumed that the chassis was solid rather than at some percentage infill, thus the predicted value of .0314in was calculated. Then by multiplying the moment of inertia by 25% which was the infill, a new deflection of .127in was calculated. There were also holes on the chassis that may contribute to the deflection along with the fact that the chassis was split into two pieces and then joined together. These factors combined can cause the calculated deflection to be off from the actual data.

5. BUDGET

During the process of designing and performing analysis there were some risks that kept showing up. Cost was one of the major risks that was always at the fore front of things. It was important to determine early on what the main focus for the vehicle was which meant that more resources could be applied to make sure that the intended function was still the same at the end. This could be for example applying more resources to the suspension since the deflection of the chassis was something that the project was analyzing and designing for. Scheduling was also something that came up many times. When parts are purchased, it is completely out of anyone's hands, and it is important to anticipate this time frame so as not fall behind while waiting for the part to arrive and working on something that doesn't require the purchased part. Project management was also another risk that was relevant since it was completely up to the students to schedule and determine the planning and organization of the project and its resources. This issue was addressed by having weekly meetings and discuss if there are any issues or if the project is falling behind and where resources could be distributed.

a. Parts

During the fall quarter, the procurement of parts is not essential as most of the work being done is analysis but knowing the dimensions of certain parts is necessary. In appendix C the motor and battery are one of the components that needed to be decided on and purchased as most analysis was based on the specifications of the motor and battery. Other components were also procured, for example, the suspension for the chassis and the steering servo were also purchased since mounts needed to be created based off of the dimensions. Smaller components have not yet been purchased but a good idea of what type of hardware will be needed is required.

b. Outsourcing

One of the components that will potentially be outsourced is the axle couple that is planned to be used. This would require the process of having the piece manufactured elsewhere then delivered which could potentially cause delay if not delivered on time.

c. Labor

The labor that will take place includes the printing of various parts which include the chassis and the shock tower, as well as the spur and pinion gear and lastly the motor mount. Labor will also include the assembly of the whole vehicle which could cause issues if parts do not fit correctly and could cause delays in completion.

d. Estimated Total Project Cost

Some of the major sub totals include the purchase of parts, which will most likely be the highest since the components that will be purchased are ones that require precision which makes them more expensive. In appendix D, the first item listed in the budget is the total cost of the parts that will be purchased which is $145.18. Another major subtotal will be the 3D printing of the chassis and drivetrain portion of the RC. Most of these components will be printed out which includes the chassis frame, the spur gear and pinion gear as well as the front and rear shock towers. For the shock tower, the estimated cost was $5.4372 and was determined by taking the price of the spool and multiplying by the mass of the piece being printed in grams then dividing by 1000 to calculate cost. Printing this piece was not very expensive but considering the number of parts that will be printed and their sizes, there is a very high possibility for the costs of printing to reach the cost of the parts.

e. Funding Source

The funding for this project is supported by Roberto Vieyra and Rogelio Arroyos.

f. Winter Updates

5a: (Parts)- During the winter quarter, the majority of the purchased parts have been ordered and already delivered which can be seen in appendix C which has the parts list. The parts list has been updated so that it includes all of the purchased, manufactured and fasteners that have been purchased. This has brought the total to about $487 but because the current dog bones did not fit the knuckles, a new set had to be purchased or a workaround had to be determined. By adding ball bearings on either side of the knuckles this greatly reduced the play that was occurring before and so more bearings were decided to be purchased along with more fasteners, this took the current cost to $498 which then further increased to $523.04 later on.

5b: (Outsourcing)- During the winter quarter no outsourcing issues were relevant since this wasn't something that was utilized. This was the case since the team had planned on designing the RC so that it could be fully manufactured in-house.

5c:(Labor)- The majority of the labor cost during the winter quarter was mainly manufacturing of the components using fused deposition modeling. The time spent on manufacturing was mostly done by the 3D printer itself as all that was required was to convert the modeled component into a stl file so it can then be sliced and printed. In appendix D, the cost for this labor can be seen under the 3D printing section. The cost was estimated based on the weight of the component given through SolidWorks and then multiplied by the cost of 1kg of material that was purchased.

5d:(Estimated Prj. Cost)- The estimated cost for the winter is higher than the requirement that the team had set in section one D of the introduction. The estimated cost was about $500 during the fall quarter (req. 1.d.6), but because the price for some components were not accounted for like the charging station for the battery or the price for the fasteners that were going to be used, the cost increased. The current cost is $523.04 and so the team is really trying to ensure that the cost doesn't go over $600 by the end of the manufacturing process.

5e:(Funding)- The funding for the project has stayed the same with the main investors being Roberto Vieyra and Rogelio Arroyos who are the ones in charge of the project.

g. Spring Updates

5a: The cost of the project was estimated to be around $500 during the fall quarter when the project was just beginning. Then because of the knuckles and wheels that were purchased (see table C1) from RXA-55-006 to RXA-55-010 at a price of $86.39 thus causing the price to increase. The wheels on the other hand, RXV-0011 at a price of $72.34 It was also necessary to charge the battery after having it for some time and so a battery charger was purchased RXA-55-14 at a price of $62.55. After the velocity test, a new motor and ESC were purchased RCV-55-007 and RCV-55-008 at a price of $24.40 and $30.10. Totaling all of the purchased components in table C1, the cost was $737.51. Then with the addition of the labor cost and subtracting all of the unused components (see table C2) the actual cost of the project without any errors and extra components was $637.89. If the group knew this information back when the project was just starting, many of the unused components would not have been purchased like with the brushless motor and also alternatives should be looked into for the knuckles and wheels as well as a cheaper charger for the battery.

5c: The labor cost for this quarter was mainly due to 3D printed components that needed to be reprinted from failures during testing. After performing some tests, it was noticed that the pinion would be torn apart if the gears were not aligned correctly. This caused the team to 3D print quite a few pinions but since they were worth $.022586 the cost to replace them was negligible, which was about 15 and would only increase the cost by about $.34. A new motor mount needed to be printed for the new brushless motor costing $1.689. The labor costs during the testing portion were not large since most of the components that had to be 3D printed again were fairly small and did not require much filament. The majority of the price increase is due to the purchased components.

5d: The total cost of the project right now is sitting at $830.59 (see table D1) which is $330 larger than the estimated $500. The original $500 was just a general value that was found online but when components were being tested, that is where the price started to increase. The brushless motor did not have enough torque to get the RC moving from rest and would overheat quite often. With a new motor, a new ESC was also necessary to keep up with the amperage of the new motor. Very specific knuckles were required to make the wheels that were purchased work but because the knuckles were quite expensive just themselves, this was another huge boost to the cost. To prevent future mistakes in the testing, time was spent beforehand setting up a procedure that can be followed for each test to help mitigate any mistakes that could happen.

6. SCHEDULE

a. Design

Fall: During the creation of the RC vehicle there are many risks involved when it comes to the risks due to scheduling. During the fall quarter, the main focus was on performing analysis on the body of the vehicle to determine dimensions required. Some of them being the train value for a drivetrain or the required revolutions for the axle to travel at a maximum velocity of 30mph. In Appendix E in the fall schedule section, task 1a was estimated to take 3hrs but took 8hrs instead. This caused the group to fall slightly behind as another analysis was planned for that day but was rescheduled. The reason for the difference between the estimated and the actual was because at the time the project was still making final decisions on the proposed design which caused many revisions to the introduction of the proposal. This task was the only outlier while the other tasks lasted about the length of the estimated time. When there are uncertainties, it can cause the project to fall behind and it is important to make sure that not too much time is wasted and make those final decisions that were causing the delay

Winter: During the manufacturing of the device, there were a few changes that were made to the design to ensure other components fit properly or adding extra support in areas that needed them like with the rear axle. In appendix E, it can be seen in figure E03 where the documentation of the manufactured components was noted. Tasks 3o and 3n were two modifications made to the gearbox design. In order to fit the rear axle and add some shaft collars, it was necessary to split the gear box and then have them clamp down on the axle. The top half of the gearbox was modified so that the rear axle would have some support at the ends which were noticed to be less structurally stable. The motor was also changed from a brushed 2400kv motor to a 1980kv brushless motor which was noticed to help significantly. There were no issues with the motor overheating, but it was now important to boost the 24A rated ESC to a 45A ESC giving the RC better low-end power, so it is easier to start from rest.

b. Construction

Fall: In Appendix E, it can be seen during the winter schedule that the construction will involve the purchasing of many of the vehicle components. Final adjustments to the various components will also have to take place in order to start 3D printing parts. The chassis motor mounts are some components that will be printed out of PLA +. Scheduling risks will become readily evident since this section will require many components to come together. Some issues may arise with SolidWorks parts not opening and being corrupted as well as components not being delivered on time.

Winter: In appendix E, it can be seen that most components have been 3D printed, with the use of an Anycubic Kobra 2 which was provided by one of the project members. During the beginning of the manufacturing process, it was noticed that the components were not as accurate as was hoped for. However, the team managed to calibrate the 3D printer to be very close in tolerance to the inside features like the holes in a part, but the outside dimensions were still not perfect. It was decided that as long as the outside dimensions don't cause any interference, the internal features were going to be more important when printing. It was also decided that threaded inserts were going to be used and so the hole dimensions don't have to be quite as accurate since the threaded inserts will be heated up then pressed to melt the material around them. During the first initial prints, the team got slightly behind schedule while trying to calibrate the printer as it took some time but once it was calibrated the manufacturing started to speed up again and are currently back on track.

c. Testing

Fall: The testing portion of the RC will mainly take place in the spring quarter which can be seen in appendix E. In this section the RC vehicle will be put through various tests and determine if requirements were met. The impact on the chassis from the vehicle traveling at 30mph will be tested along with the impact from a 2ft drop. During this section, there is a possibility for the project to fall behind since these tests will be done in order to evaluate if the vehicle is able to withstand these forces and any failures will involve deformation of parts and replacements will be required.

Spring: During the spring quarter, the students were in charge of performing the various tests in order to ensure the device would meet some of the requirements set. One of the tests performed did cause some issues with the team falling slightly behind since it was necessary to purchase a new motor and ESC. In appendix E figure E06, the Gantt chart shows tasks 6b.i which is another velocity test that was performed. This was the case because during the initial velocity test, the maximum velocity experienced was 3.4mph and was due to the brushed motor overheating. Once the team purchased the new motor it was necessary to wait for the order and so some time was lost. However, as soon as the motor was in hand it was possible to get back on schedule since it was now possible to perform the velocity test again with the new motor. The time estimates for the tasks were fairly close in time with some lasting longer than estimated which was to be expected with the testing. One good example of this can be seen with task 6a (See figure E06) which lasted about 3hrs to the expected 1.5hrs. This was the case since it was possible to potentially break a component during testing which was what occurred during the drop test. Fortunately, a replacement was already at hand when one of the ball joints broke and was easily replaced during the testing making it possible to finish the same day just slightly delayed.

7. PROJECT MANAGEMENT

During the process of designing and performing analysis on the RC Baja, many risks were noticed as time went on. Some risks involved the 3D printing of certain components like the gears as it was something that could potentially change the course of the project as the drivetrain would need to be re-designed. This risk was mitigated by printing the gears earlier than other components to see how precise the printer was and if they fit together properly. Another important risk to take note of is the limited components for a 1/8 RC as it was sometimes difficult to find the correct dimensioned part as often times the seller would not give the dimension that was being looked at like with the axles that took a while to find because the diameter was not given. The way this was addressed was by looking online with specific search phrases and if that was not possible, other methods of acquiring the part will be required like the use of 3D printing of machining.

a. Human Resources

The main resource was the engineers performing the design and analysis for the RC Baja which includes Roberto working on the chassis and drivetrain, while Rogelio is working on the suspension and steering. The risk mitigation method used was the use of a Gantt chart to ensure that the time was being used wisely during the week.

b. Physical Resources

Some physical resources that will be required for the completion of the RC include a functional 3D printer with high precision as it will be used to print most components for the chassis and suspension and also to print the gears which require high precision. The risks that come along with this include the potential for the nozzle of the printer to jam and the part will be ruined and will have to restart. This can be mitigated by keeping a close eye on the printer during the process to ensure that nothing goes wrong and if it does stop it before anything else goes wrong. The printing will also take time so making sure the parts are printed ahead of time is essential. Other resources that will be used are a soldering iron to heat up the threaded insert that will go in to fasten the various components. Some risks involved with this could potentially be access to a soldering iron, which can be solved by purchasing one before it is required to be used, making sure that the iron heats up to the correct temperature. This issue is solved by making sure the specification of the soldering iron meets the temperature that is needed.

c. Soft Resources

The soft resources required to complete this project include the use of SolidWorks. This software is heavily used to design the components of the RC and then used to print them out using a 3D printer. The risks that were involved with using SolidWorks were that it was prone to crashing at times and so it was important that the model was constantly being saved so as not to lose the progress that was made. Cura slicer was also used to convert the part into G-code so that the printer can know where it is in space. The risks involved were the use of the program as it was new software being used and it could cause the project to fall behind if the parts were not printed correctly. To solve this issue, time was taken to learn, and a few practice pieces were used to get accustomed to the software.

d. Financial Resources

The sponsors for this project are the ones designing and performing the analysis for the RC Baja which includes Roberto and Rogelio. The equipment that will be used will be personal equipment like the 3D printer that will be used. If the project were to go over budget, a look at the proposed design will have to be looked at and determine where costs can be reduced weather that be the change in material to one that is cheaper or the reduction or removal of parts that are not entirely necessary.

8. DISCUSSION

a. Design

The overall design for the RC vehicle was re-designed a few times throughout the year because of various size constraints. One of the major changes was the front cross section for the chassis where it had to be changed after analysis 2 was performed (2.g.ii) where an analysis to determine the cross section for the front of the chassis so that it would survive an impact at 30 mph. It was determined that with the current cross section the chassis would have to large of a deflection and would not meet the deflection requirement (req-1.d.13). The dimensions were then readjusted to the values that were calculated and with the new dimension the chassis should survive the impact and also meet the deflection requirement (req-1.d.13). By changing this front cross section, the front shock tower had to also be re-designed as there was less space to mount the tower, but this was much easier to do since the issue was with the thickness of the shock tower. Another re-design that took place was after the adjustment to the train value. Once analysis 1 was completed and the dimensions for the gears were known a gear box had to be created and thus there was a need to extend the length of the chassis to accommodate the gearbox so it could fit with no interferences.

Some project risks that had to be overcome were the issues with the original pinion and spur gears being to big for the chassis, the chassis length being too big for the bed of the 3D printer. In order to solve these issues, it was decided to have a double reduction drivetrain and instead of having a train value of 11.967, two pairs of gears will be used with a gear ratio of 4:1 and 3:1 respectively. With these new gears, this solved the issue of the spur gear being too large. As for the chassis, it was decided to split the body into two separate pieces so that they could be printed in the 8.7” x 8.7” x 9.8” since the current length was just over 14”. With the chassis now in two pieces, inserts were created on one half of the chassis so that it could mate with the other and with adhesive joined together. This would solve the risk of not being able to print the chassis with the current 3D printed bed and a whole re-design would need to be however, this brought another potential risk of the adhesive not being strong enough and so an analysis had to be done to determine what adhesive was required.

Some successes during the design process were the design for the spur and pinion gears. Once they were printed out, the gears mated perfectly and had the correct center distance. However, one failure that occurred was the bevel gears not printing using the current 3D printer. It was observed that the nozzle would clog up when attempting to create the bevel gears no matter what orientation the model was. The issues with the printing could be due to the complex geometry of the bevel teeth as it was observed that the nozzle would not place the material in the correct location and would move on to the next tooth with material still in the nozzle. Another possibility is that the dimensions of the gears were too small for the printer and so the precision of the 3D printer was not capable of handling the tight tolerances. To solve this issue, it was collectively decided to instead purchase the two bevel gears based on the desired gear ratio which was calculated in analysis 1 (2.g.i).

During the winter quarter, there were some modifications made to the original design of the RC Baja vehicle. The chassis was split into two pieces so that it could be manufactured using the current 3D printers that were available which was an anycubic kobra 2, provided by one of the project team members. The issue here was that the chassis was far too large to fit in the build plate of the printer, and by splitting it in two it was then possible to get the chassis manufactured. Similarly, the gear box was split into two components since the rear axle needed to be placed inside of the gearbox and with a singular component that wouldn't have been possible. Another major design change was with the bore adapter (RCV-20-008) which was completely replaced by the rear axle (RCV-20-011) since it was going to be much easier to manufacture the axle that was needed instead of looking online and hoping to find the right one.

b. Construction

Moving on to the winter quarter, the team did not make any changes to the methods of construction and manufacturing that were stated above in section a of the discussion but did make some slight modification to components so they would fit better, like extending the length of the chassis (RCV-20-002). Performance creep was mitigated by ensuring that the requirements stayed the same throughout the project as to not add more work than needed. Another issue that was noticed throughout the process of manufacturing is the 3D printed pieces not being the same dimension as the modeled part. Going into manufacturing this was something that was considered and in order to solve or reduce this issue, either the modeled component needed to be dimensioned slightly larger or by further calibrating the 3D printer. After further calibration of the printer, it was noticed that as the hole dimensions were dialed in the outside dimensions of the component were further off from the nominal value. It was decided after deliberation that the hole dimensions were more important and that was the dimension that was going to be focused.

There were also some successes that occurred during the manufacturing process, for example there were no issues with the use of threaded inserts. After the printer was calibrated to be more accurate dimensioning holes, this made it much easier to insert the threaded inserts and then use a soldering iron to heat the inserts and gently push them through to sit flush with the outside wall of the component. Although the outside dimensions are not perfect, they are still very close to being in tolerance and the holes have a much better accuracy.

Following this, an additional manufacturing method was utilized in order to manufacture the rear axle (RCV-20-011) which was going to be made out of aluminum using a lathe. During this process, some manufacturing issues arose and multiple itirations of the axle had to be machined. Initially the axle was going to be machined 6mm throughout but as the machining process was underway, the tailstock was not utilized and so the axle did not come out concentric so it had to be scratched. The second time around, with the tailstock engaged it made the process much easier and it was possible to manufacture the rest of the axle without an issue. During the hole placement a punch wasn't used to guide the drill bit and so the hole come out slightly off center than the other side but it was possible to re-drill the whole and fix the one side that was off.

Another issue that occurred was that the fastener that was being used to fasten the axle ends with the rear axle was constantly coming undone due to vibrations and so with the addition of Loctite glue, this completely removed the issue. However, when the screw was being undone and with the additional strength of the Loctite, this caused the rear axle to twist and snap on one end and caused the M4 fastener to break. In order to salvage this piece, the end that was broken was grinded off so that a new hole could be drilled. This time by using a center punch to guide the drill bit, this made the placement of the holes much more accurate and now Loctite will be used at the end when everything is going to be assembled getting ready for the next phase, the testing phase.

There was another important construction process that occurred closer to the end of the manufacturing process of the project. There was a need to machine a slot for a square key on both the rear axle and the spur bevel gear. In order to do so, the axle and gear were thrown in a vertical end mill and with the use of a 1/8" bit it was possible to start machining these key slots on both components. It was going to be very important that no errors were made since it was going to cause major delays if something happened to the gear or the rear axle, especially since the gear would have to be re-ordered. However, no issues occurred during this machining process as small increments were being taken to ensure no major failures occurred.
With the majority of the components now manufactured it is possible to start assembling the sub-assemblies, like the chassis and drivetrain sub-assemblies as well as the front and rear shock tower sub-assemblies. After this, the team will be moving on to the testing phase where the fully assembled device will undergo various testing to ensure it will meet requirements as well as be functional.

c. Testing

During the testing process for the 2ft drop test, there were a few modifications made to the procedure. Initially the entire testing was going to be done without the assistance of a partner, however during some initial test runs it was noticed that by adding a partner to the process it made things much easier. For example, when one person was holding the RC device over the blue tape marked on the wall, the other would then start recording and then hold the tape measure in front of the RC so that a measurement could be taken. Another modification made was the number of trials that were performed. It was noticed that there were times where the bottom of the RC would hit the ground but there would also be times where it didn't. Then by adding more trials it was possible to get a wider variety of data points to mitigate this issue, as well as further increasing the clearance between the bottom of the chassis and the ground. There was also the risk of breaking components during the testing since most components were 3D printed. Surely enough, one of the ball joints for the steering ended up breaking since the threaded insert was pulled out of the material when the suspension hit the ground. It was determined that using the 3D printed ball joints would not be feasible for testing in general and so they were switched out for aluminum ball joints which worked much better. Taking a look at the initial requirement for this test which was the deflection of less than .1in for the components, the device did not pass since this test was not a great representation of the deflection that was calculated and a better representation for this would be a test using the Instron machine. However, after re-evaluating the analysis performed to determine the predicted deflection, a new equation using the conservation of energy was used to calculate the deflection and worked much better reflecting what was occurring during the test. It was also important that the adhesive did not exceed the ultimate tensile strength of the material of 1200psi which was also a requirement and through this test, it was ensured no issues with the adhesive would arise.

The second test that was performed was the maximum velocity test to ensure that the RC was going to be meeting the velocity requirement 1.d.7 of reaching 30mph. During the process, there were a few modifications made to the testing procedure to help facilitate better results. One of the major changes was the increase in distance to the originally planned of 20ft to 45ft. This change allowed the RC to slowly get up to speed rather than instantly starting and stopping since one of the issues with the motor was that it liked to overheat. With 20ft of space for the RC to travel, it was noticed that with a low acceleration it did not really allow the device to get up to a decent speed, but with the extension it was possible to now get the RC up to a somewhat constant acceleration. Another issue that arose was the motor overheating due to the repeated starts and stops. To mitigate this, the number of trials was limited to only 5 and with breaks in between. The maximum velocity observed was 3.4mph which was much less than the originally calculated of 30mph based on the circumference of the wheels and motor KV value. A trend can also be seen in the graph of the velocity (see figure G7) whereas the more trails that were performed, the lower the velocity became as the motor started to overheat. After doing further research a brushless and smaller KV motor would be used since they have more torque allowing the motor to run cooler and achieve a higher maximum velocity. After performing the second velocity test, the acceleration calculated was about ten times larger than with the brushed motor. The new maximum velocity experienced was 13.2mph (see figure G8) using the same span of distance of 40ft. In order to actually achieve the full maximum velocity, a distance of 141ft was calculated.

The third test performed was the deflection test on the Instron to ensure requirement 1.d.12 was being met which states that the chassis would not break at the location where the adhesive was applied since the component was too large to 3D print in one piece. There were no major issues with the procedure during this testing as with the other testing procedures. It was possible to load the chassis up to 40lbf on the Instron machine with no issues. One of the major risks for this test was the potential that the chassis would break during the testing from the load. In order to ensure this did not occur, analysis was performed beforehand to calculate the stress that the adhesive would experience. Based on the load from the 2ft drop the stress was determined to not exceed the ultimate yield strength of the adhesive and it was safe to load the chassis at 40lbf. There were no issues of the chassis breaking when fully loaded, but the deflection requirement (req.1.d.13) was not met by .004in but can be easily mitigated by reprinting the chassis.

The deliverables for the velocity test can be seen in appendix G2.4 where the acceleration was calculated for the 5 trials respectively, then the average acceleration was taken and used in kinematic equations. The average acceleration was .68ft/s^2 and it was determined through calculations (Figure G4) that the distance required to reach a velocity of 30mph was 1425ft or ¼ mile. This was due to the RC having a very small acceleration thus needing more time and space to reach the maximum velocity. It is also important to note that the acceleration was assumed to be constant. In the deflection test, the deliverables involve the tabulated data from the various deflections tests and the spring force calculated. With the table it was possible to determine that the clearance between the floor and chassis should be increased since there were times when the maximum deflection was the same as the clearance between the ground. It was also observed that because of the uneven distribution of weight, this caused the front section to slam down at times which can be seen in figure G2 where the spring force experienced at the front was larger than the rear. For the deflection test, the deliverables will mainly include the deflection data that was tabulated and ensuring the deflection requirement 1.d.13. The predicted value was about .0314in assuming a solid component then taking into account that the chassis was printed using a 25% infill, the deflection was now calculated to be .1259in. The deflection exceeded the requirement by about .004in at .104in and can be due to the fact that there are holes on the chassis and the analysis was conducted assuming a solid component rather than with some infill. Since the deflection was really close to the requirement, simply increasing the infill from 25% to 35% will be enough to pass the requirement.

9. CONCLUSION

a. Design

Throughout the year various designs and analysis were performed to accomplish one single goal, the completion of the RC Baja Drive Train and Chassis Senior Project along with the other half the Suspension and Steering. For the chassis and drivetrain portion, the chassis was designed to withstand an impact at a velocity of 30mph to meet the impact requirement (req-1.d.9). This was done by performing analysis 2 (2.g.ii) where the minimum cross-sectional area was determined based on the force from the impact at 30mph. Then taking this cross-sectional area and determining what the deflection would be, the deflection was well within range and met the deflection requirement (1.d.13) but with size restriction for other components a larger area was used that still met the impact requirement and the deflection at the same time. The critical load for the chassis was also determined in analysis 11 (2.g.xi) in order to verify if the force calculated in analysis 2 will not cause the chassis to buckle. With the current dimension for the cross-sectional area, the chassis was determined to not buckle under the load at the impact since the load calculated was less than the buckling load which meant that the chassis met the buckling requirement (req-1.d.10). For the drivetrain portion, an analysis was performed to ensure that the velocity requirement (req1.d.7) was met. In analysis 1 (2.g.1), the analysis focused on determining the diametral pitch and number of teeth and the center distance between the two along with other pertinent information involved in the design of gears. In the end a differential was used with two sets of gears, one set being a set of spur gears while the other is a set of bevel gears inside a gearbox with a velocity ratio of 4:1 and 3:1 respectively. This ensured that the velocity requirement was met (req-1.d.7) while still keeping the weight down to a minimum as to meet the weight requirement for the gearbox (req-1.d.8).

The RC Baja was designed with the intention to keep the weight of the vehicle to a minimum and with the intention of 3D printing as many components as possible. With the current design the chassis, shock towers, spur gears, bore adapter, gearbox, battery/motor mounts and control arms will all be 3D printed out of PLA +. Any other components like the axles, motor, battery and fasteners will be purchased. In order for the project to be successful, the RC will be able to travel at 27mph with a 10% deviation from the nominal value of 30mph. For the chassis, success criteria is to withstand an impact traveling at a velocity of 30mph and to withstand the stress caused by a 2ft drop and will also not buckle during impact and deflect less than .1in during the drop test. With the current design of the vehicle the estimated cost is going to be close to the budget requirement (req-1.d.6) of $500. With this analysis performed, the drivetrain and chassis portion for the RC Baja meets the requirements listed above and is within the estimated cost for the project.

b. Construction

The intended design for the drivetrain and chassis was to ensure that the vehicle would be able to reach the maximum velocity of 30mph that was set as one of the requirements (req1.d.7). For the chassis, it was really important that it was going to be able to withstand an impact at the maximum velocity as well as not buckling due to the force caused by the impact. All of this was made sure through analysis in the fall quarter which then lead to the manufacturing where all of the components were manufactured using additive manufacturing in the form of 3D printing with the exception of a few components.

Another form of manufacturing that was utilized was turning using a lathe to manufacture the rear axle. One of the major modifications made to the design of the vehicle was changing the initially intended bore adapter that would be fitted to the bevel gear so that it could be fastened to the axle into a full rear axle made of aluminum where the middle would be 8mm (the same as gear bore) and a slot would be machined to insert a square key between the axle and gear. Some issues that arose from this was that initially the tailstock was not used and so this made the turning process quite difficult and eventually the processes had to start over since the axle wasnt concentric throughout the entire length. The second attempt was much better with the addition of the tailstock as this added more support and it was possible to dig into the material without it being pushed away like before. Once these were manufactured a vertical endmill was required in order to machine the slots for the gear and rear axle. Unlike the turning processes, this time the team made sure everything was properly in place to ensure everything went smoothly since it would cause some delays if the gear or axle was ruined because of user error. Thankfully no issues arose during this process.

Other modifications made to the design where the chassis and gearbox were both split into two separate components. For the chassis, this was done because the build plate of the printer that was being used was not big enough to print the current dimension of the chassis. To solve this issue, the chassis was split into a rear and front section which will be fastened together using E6000 and industrial adhesive. The gearbox was split into two since the new rear axle had dimensions that wouldn't allow it to be fitted with the gearbox since the holes were 6mm, but the axle was 8mm at the center. By splitting the gearbox, this allowed the team to use the manufactured rear axle and it also made it possible to clamp the components down since the gearbox would be acting as a makeshift clamp once it is fastened down.

`With the majority of the components now manufactured it is possible to start assembling the sub-assemblies, like the chassis and drivetrain sub-assemblies as well as the front and rear shock tower sub-assemblies. After this, the team will be moving on to the testing phase where the fully assembled device will undergo various testing to ensure it will meet requirements as well as be functional.

With 3D printing, there were some issues with the components not being the nominal dimensions which was mitigated by further calibrating the printer. There were some issues with layer adhesion and layer shifts, but this was solved simply by reducing the printing speed as well as cleaning the build plate. Other than these issues, 3D printing was the most reliable With the majority of the components now manufactured it is possible to start assembling the sub-assemblies, like the chassis and drivetrain sub-assemblies as well as the front and rear shock tower sub-assemblies. After this, the team will be moving on to the testing phase where the fully assembled device will undergo various testing to ensure it will meet requirements as well as be functional.

c. Testing

The predicted results for the testing portion of the project correlated to the requirements that were set back in the fall quarter. For example, the predicted velocity for the device was 30mph however after preforming two separate velocity tests, it was noticed that the maximum velocity for the first test was 3.4mph while during the second test the velocity was 13.2mph. This was due to the new motor that was used during the second test being brushless at 1980KV and also the change in gear ratios from 12:1 to 10:1 in order to still achieve that 30mph with a slower motor. The predicted value for the deflection test using the intron was about .0078in which was not at all close to what was experienced at .104in. In order to get the results to be a better match the predicted value, the fact that the chassis was not 100% solid but rather had a 25% infill. Once this was accounted for a new predicted value of .125in was calculated. Now the error can be due to the fact that the chassis is two separate pieces joined with an adhesive which was at the location where the loading was applied. As for the drop test, the predicted value was initially calculated assuming the vehicle was going to experience a 3 point load which was not the case during testing, To mitigate this, a new predicted value was calculated by setting the potential energy due to the potential energy of the springs and was much closer to the actual results of 1.5in maximum deflection. To further improve this test which failed since the clearance from the chassis to the ground is 1.5in this meant that it was hitting during the drop. Oil can be added to the springs to further increase the stiffness and also changing the angle of the springs to further increase the clearance will help pass this test.

10. ACKNOWLEDGEMENTS

I am extremely grateful to Professors Charles Pringle and Dr. John (Jeunghwan) Choi for their assistance throughout the year in the development of the RC Baja vehicle. With their guidance it was possible to have someone more knowledgeable and experienced in the industry take a look at the proposal and have it revised where needed. Also, a special thank you to Professor Furman for the advice that was given in ways that the drivetrain could be improved, which definitely helped mitigate some issues that were being experienced with the 3D printer gears.

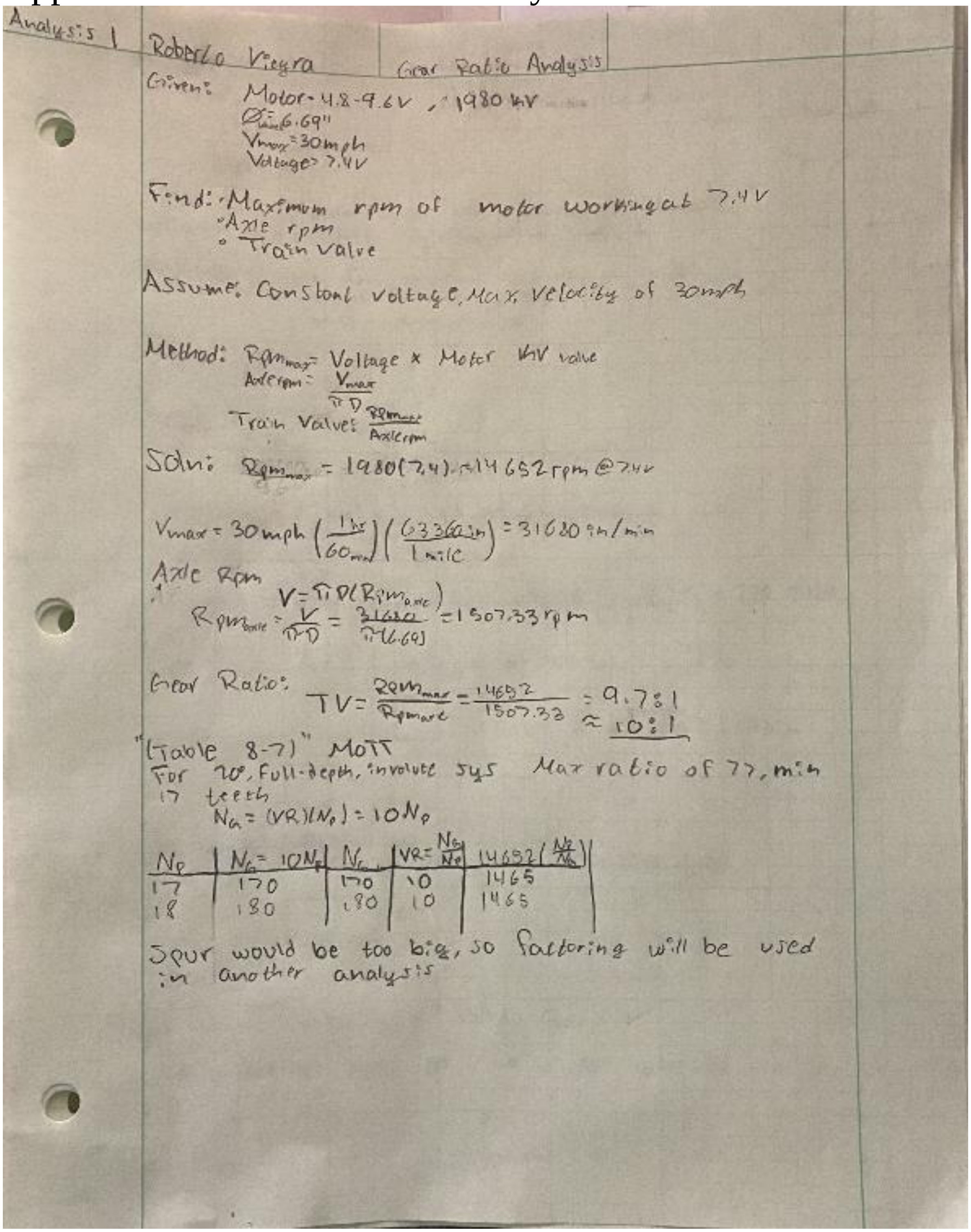
References

Mott, Robert, L. et al. Machine Elements in Mechanical Design. Available from: VitalSource Bookshelf, (6th Edition). Pearson Education (US), 2017.

Pla+. (n.d.-b). https://www.esun3d.com/uploads/eSUN_PLA+-Filament_TDS_V4.0.pdf

APPENDIX A - Analysis

Appendix A01 – Gear Ratio Analysis



Analysis 1 | Roberto Vieyra | Gear Ratio Analysis

Given: Motor - 4.8-9.6V, 1980 kV
$\varnothing_{tire}$ = 6.69"
V_{max} = 30 mph
Voltage = 7.4V

Find: · Maximum rpm of motor working at 7.4V
· Axle rpm
· Train value

Assume: Constant voltage, Max. velocity of 30 mph

Method: Rpm_{max} = Voltage × Motor kV value
Axle rpm = $\frac{V_{max}}{\pi D}$
Train Value: $\frac{Rpm_{max}}{Axle\,rpm}$

Soln: $Rpm_{max} = 1980(7.4) = 14652$ rpm @ 7.4V

$V_{max} = 30\text{ mph}\left(\frac{1\text{ hr}}{60\text{ min}}\right)\left(\frac{63360\text{ in}}{1\text{ mile}}\right) = 31680$ in/min

Axle Rpm
$V = \pi D (Rpm_{axle})$
$Rpm_{axle} = \frac{V}{\pi D} = \frac{31680}{\pi(6.69)} = 1507.33$ rpm

Gear Ratio: $TV = \frac{Rpm_{max}}{Rpm_{axle}} = \frac{14652}{1507.33} = 9.7:1 \approx \underline{10:1}$

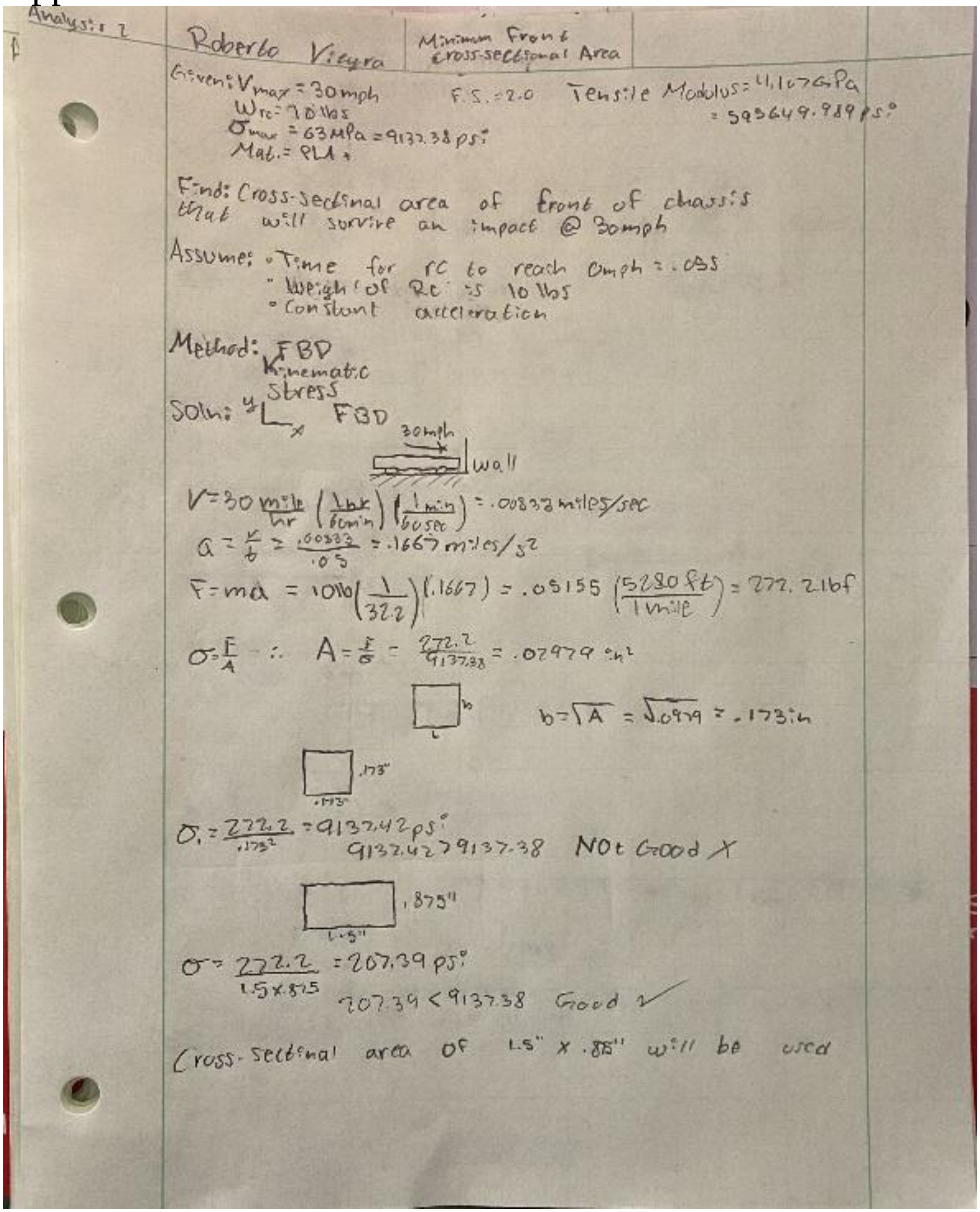
"(Table 8-7)" Mott
For 20°, full-depth, involute sys Max ratio of 77, min 17 teeth
$N_G = (VR)(N_P) = 10N_P$

N_P	$N_G = 10N_P$	N_G	$VR = \frac{N_G}{N_P}$	$14652\left(\frac{N_P}{N_G}\right)$
17	170	170	10	1465
18	180	180	10	1465

Spur would be too big, so factoring will be used in another analysis

Figure A02. Analysis of maximum axle rpm and gear teeth

Appendix A02 – Minimum Frontal Cross-sectional area



Analysis: 2

Roberto Vieyra — Minimum Front Cross-sectional Area

Given: $V_{max} = 30$ mph F.S. = 2.0 Tensile Modulus = 4.107 GPa = 595649.989 psi
$W_{rc} = 10$ lbs
$\sigma_{max} = 63$ MPa = 9137.38 psi
Mat. = PLA+

Find: Cross-sectional area of front of chassis that will survive an impact @ 30mph

Assume:
- Time for rc to reach 0mph = .05s
- Weight of RC is 10 lbs
- Constant acceleration

Method: FBD, Kinematic, Stress

Soln: FBD (30mph, wall)

$V = 30\frac{mile}{hr}\left(\frac{1hr}{60min}\right)\left(\frac{1min}{60sec}\right) = .00833$ miles/sec

$a = \frac{v}{t} = \frac{.00833}{.05} = .1667$ miles/s²

$F = ma = 10lb\left(\frac{1}{32.2}\right)(.1667) = .05155\left(\frac{5280ft}{1mile}\right) = 272.2lbf$

$\sigma = \frac{F}{A}$ ∴ $A = \frac{F}{\sigma} = \frac{272.2}{9137.38} = .02979\ in^2$

$b = \sqrt{A} = \sqrt{.0979} = .173in$

.173" × .173"

$\sigma_1 = \frac{272.2}{.173^2} = 9137.42$ psi
9137.42 > 9137.38 Not Good ✗

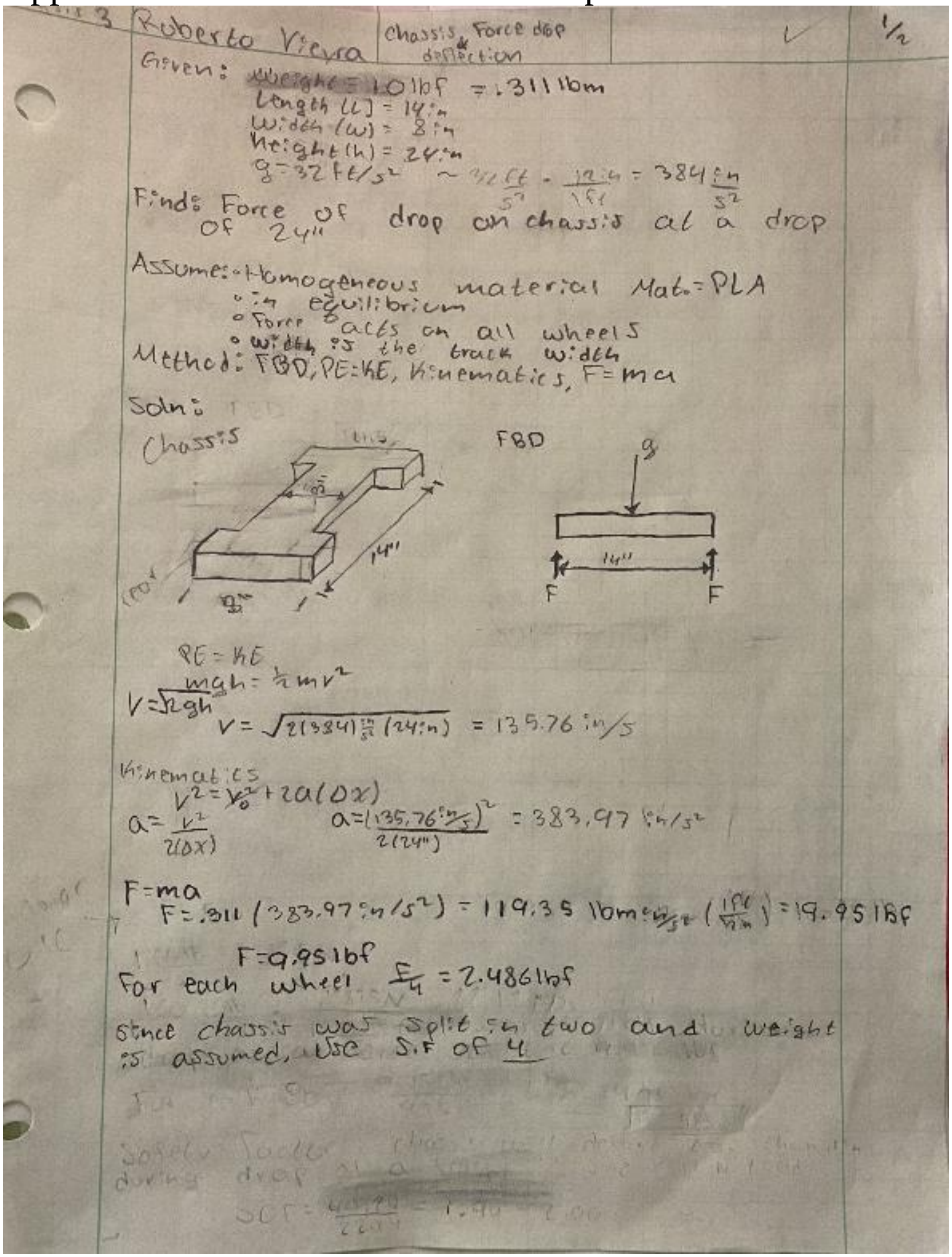
1.5" × .875"

$\sigma = \frac{272.2}{1.5 \times .875} = 207.39$ psi
207.39 < 9137.38 Good ✓

Cross-sectional area of 1.5" × .875" will be used

Figure A02. Analysis of the front chassis and the dimensions required to survive impact at 30mph

Appendix A03 – Chassis Force of drop and deflection



Roberto Vieira | Chassis Force drop & deflection | 1/2

Given: ~~weight = 10 lbf~~ = .311 lbm
Length (L) = 14 in
Width (w) = 8 in
Height (h) = 24 in
$g = 32\ ft/s^2 \sim 32\frac{ft}{s^2} \cdot \frac{12\ in}{1\ ft} = 384\frac{in}{s^2}$

Find: Force of drop on chassis at a drop of 24"

Assume: ◦ Homogeneous material Mat. = PLA
◦ in equilibrium
◦ Force acts on all wheels
◦ width is the track width

Method: FBD, PE=KE, Kinematics, F=ma

Soln:

$PE = KE$

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

$V = \sqrt{2gh}$ $\quad V = \sqrt{2(384)\frac{in}{s^2}(24\ in)} = 135.76\ in/s$

Kinematics

$V^2 = V_0^2 + 2a(\Delta x)$

$a = \frac{V^2}{2(\Delta x)}$ $\quad a = \frac{(135.76\ in/s)^2}{2(24")} = 383.97\ in/s^2$

$F = ma$

$F = .311(383.97\ in/s^2) = 119.35\ lbm\ in/s^2 \left(\frac{1\ ft}{12\ in}\right) = 19.95\ lbf$

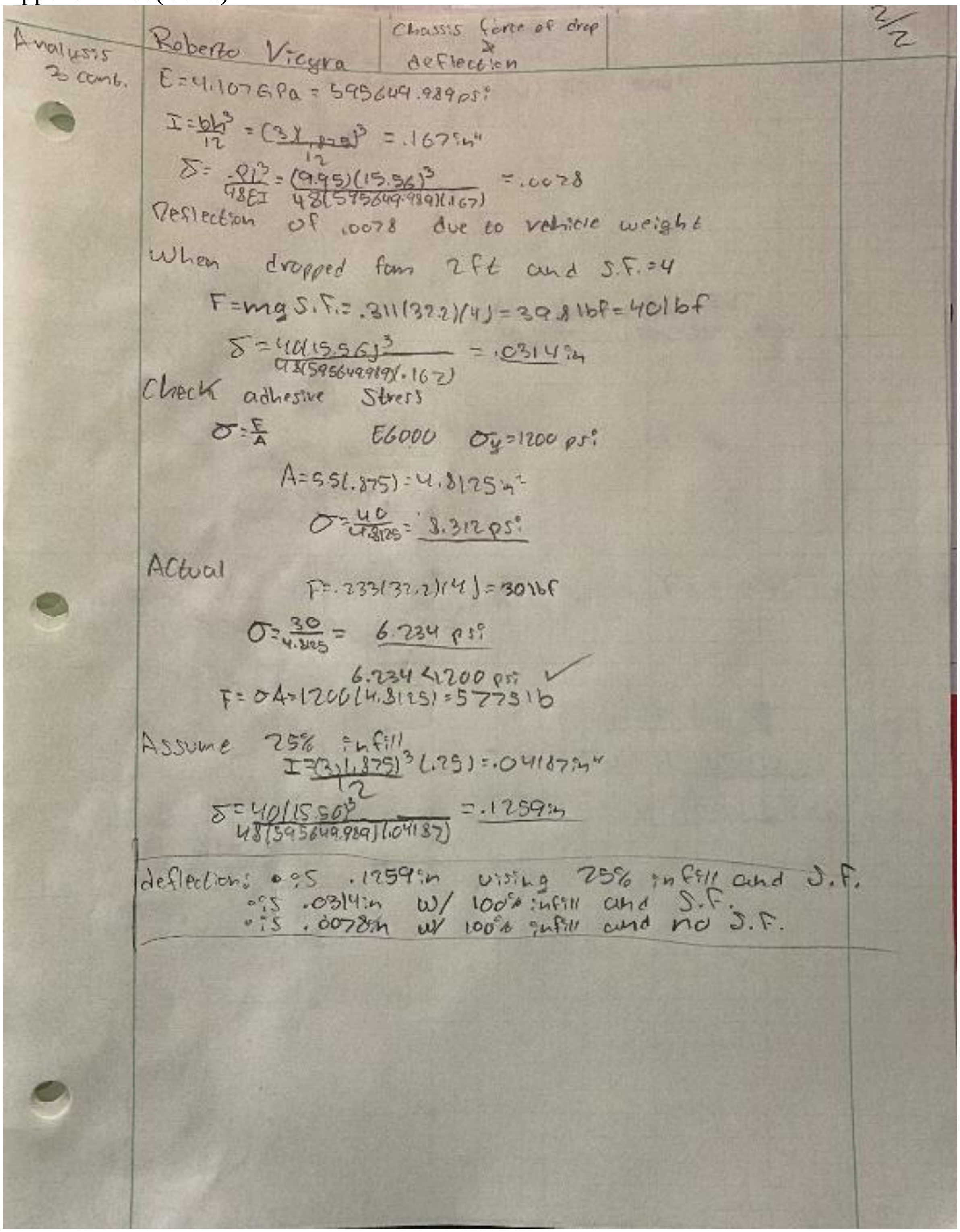
~~F = 9.95 lbf~~

For each wheel $\frac{F}{4} = 2.486\ lbf$

Since chassis was split in two and weight is assumed, use S.F of 4

Figure A03.1 Analysis performed on the chassis based on a 2ft drop

Appendix A03(Cont.)



Analysis 3 cont.

Roberto Vieyra | Chassis force of drop & deflection | 2/2

$E = 4.107\,GPa = 595649.989\,psi$

$I = \frac{bh^3}{12} = \frac{(3)(.875)^3}{12} = .167\,in^4$

$\delta = \frac{Pl^3}{48EI} = \frac{(9.95)(15.56)^3}{48(595649.989)(.167)} = .0078$

Deflection of .0078 due to vehicle weight

When dropped from 2ft and S.F.=4

$F = mg\,S.F. = .311(32.2)(4) = 39.8\,lbf = 40\,lbf$

$\delta = \frac{40(15.56)^3}{48(595649.989)(.167)} = .0314\,in$

Check adhesive stress

$\sigma = \frac{F}{A}$ E6000 $\sigma_y = 1200\,psi$

$A = 5.5(.875) = 4.8125\,in^2$

$\sigma = \frac{40}{4.8125} = 8.312\,psi$

Actual

$F = .233(32.2)(4) = 30\,lbf$

$\sigma = \frac{30}{4.8125} = 6.234\,psi$

$6.234 < 1200\,psi$ ✓

$F = \sigma A = 1200(4.8125) = 5775\,lb$

Assume 25% infill

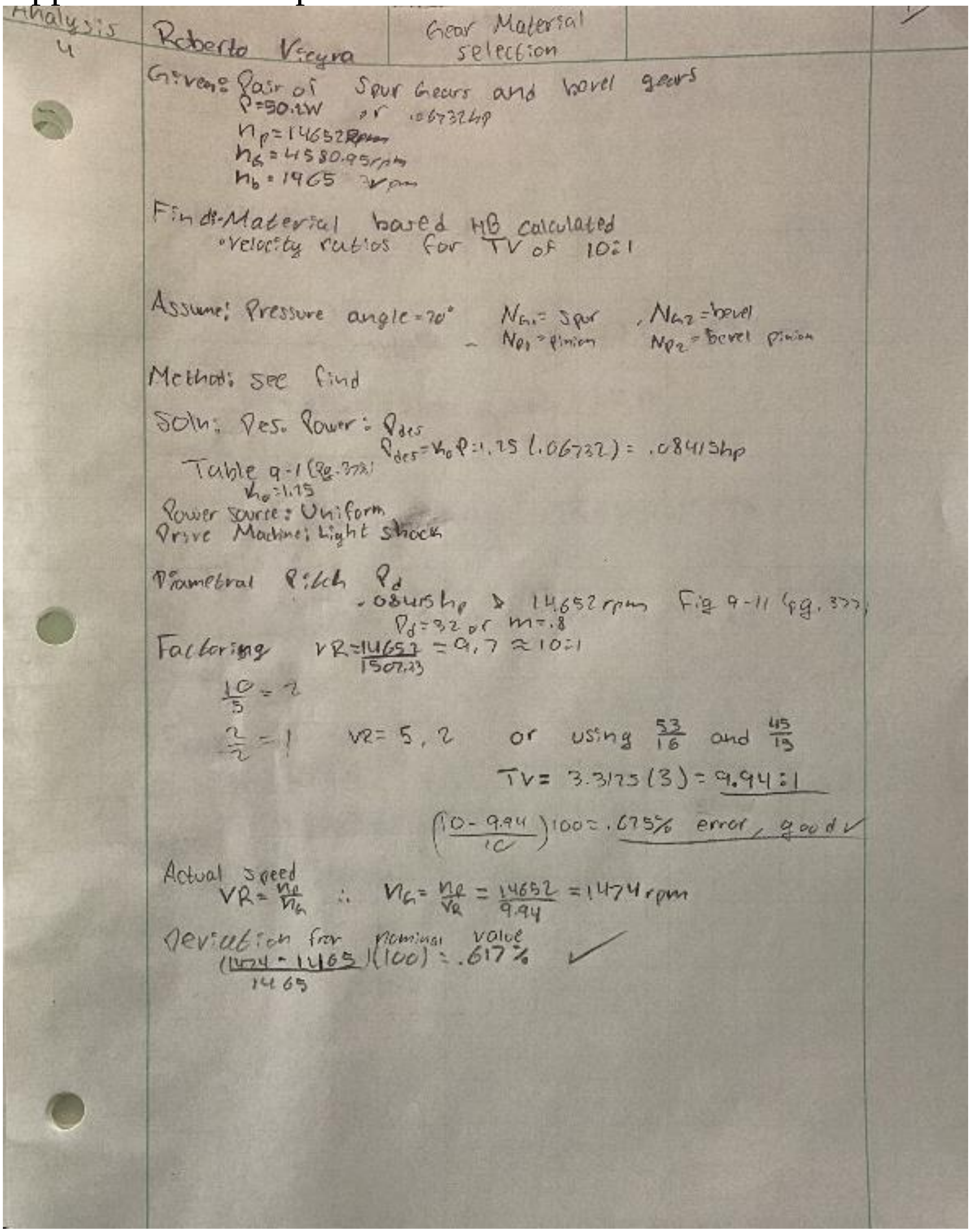
$I = \frac{(3)(.875)^3}{12}(.25) = .04187\,in^4$

$\delta = \frac{40(15.56)^3}{48(595649.989)(.04187)} = .1259\,in$

deflection: • is .1259in using 25% infill and S.F.
• is .0314in w/ 100% infill and S.F.
• is .0078in w/ 100% infill and no S.F.

Figure A03.2 The second page of the chassis force of drop analysis

Appendix A04 – Spur and Pinion Gear Dimensions



Analysis 4 | Roberto Vieyra | Gear Material selection

Given: Pair of Spur Gears and bevel gears
$P = 50.2W$ or $.06732hp$
$n_p = 14652 rpm$
$n_G = 4580.95 rpm$
$n_b = 1965 rpm$

Find: Material based HB calculated
• Velocity ratios for TV of 10:1

Assume: Pressure angle = 20° N_{G1} = Spur, N_{G2} = bevel
N_{P1} = pinion N_{P2} = bevel pinion

Method: see find

Soln: Des. Power: P_{des}
$P_{des} = K_o P = 1.25(.06732) = .08415hp$
Table 9-1 (pg. 372)
$K_o = 1.25$
Power Source: Uniform
Drive Machine: Light shock

Diametral Pitch P_d
.08415hp & 14652 rpm Fig 9-11 (pg. 377)
$P_d = 32$ or $m = .8$

Factoring $VR = \frac{14652}{1507.23} = 9.7 \approx 10:1$

$\frac{10}{5} = 2$

$\frac{2}{2} = 1$ VR = 5, 2 or using $\frac{53}{16}$ and $\frac{45}{15}$

$TV = 3.3125(3) = 9.94:1$

$\left(\frac{10 - 9.94}{10}\right)100 = .675\%$ error, good ✓

Actual speed
$VR = \frac{n_P}{n_G}$ ∴ $n_G = \frac{n_P}{VR} = \frac{14652}{9.94} = 1474 rpm$

Deviation from nominal value
$\frac{(1474 - 1465)}{1465}(100) = .617\%$ ✓

Figure A04.1 Analysis of spur gear dimensions and material selection

Appendix A04(Cont.)

Analysis 4 cont.	Roberto Vieyra	Gear Material Selection		2/4

Pitch Diameter

$D_{P1} = \frac{N_P}{P_d} = \frac{16}{32} = .5 in$ $\quad D_{P2} = \frac{15}{32} = .46875 in$

$D_{G1} = \frac{53}{32} = 1.66 in$ $\quad D_{G2} = \frac{45}{32} = 1.40625 in$

Center Distance for Spur

$C_{P1-G1} = \frac{16+53}{2(32)} = 1.078 in$

Pitch Line Speed

$v_t = \frac{\pi D_P n_P}{12} = \frac{\pi(.5)(14652)}{12} = 1917.94 ft/min$

Transmitted Load

$W_t = \frac{33000P}{v_t} = \frac{33000(.062322)}{1917.94} = 1.16 lb$

Face width

$\frac{8}{P_d} < F < \frac{16}{P_d}$

$\frac{8}{32} < F < \frac{16}{32}$ $\quad$ Nominal $\frac{12}{P_d} = \frac{12}{32} = .375 in$

$.25 < F < .5$ $\quad$ use $.375 in$

Elastic Coefficient

$C_p = 2300$ assume steel for bevels

Quality # Table 9-5

use A6

Dynamic Factor K_v

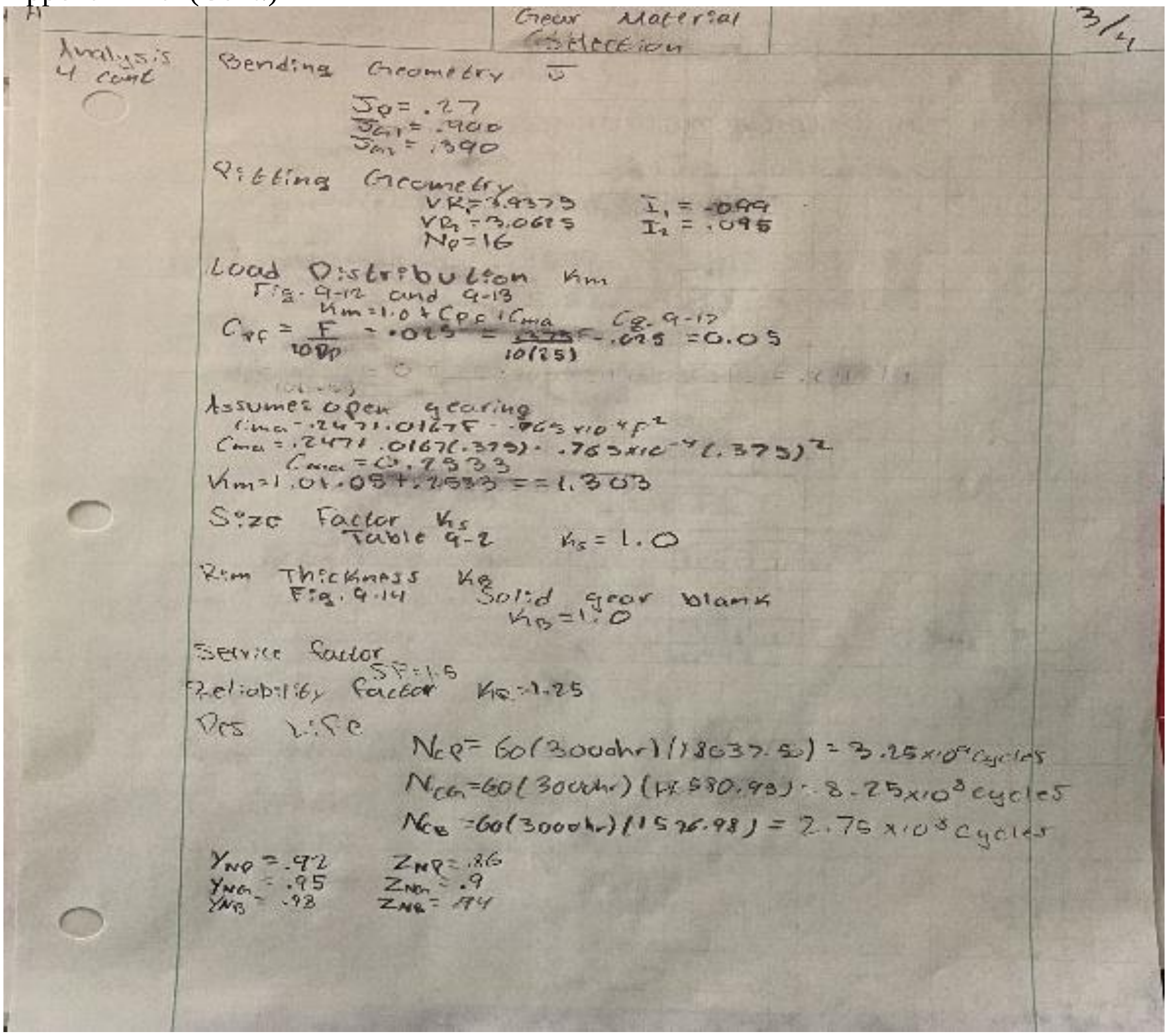
$B = .25(6-5)^{.667} = .25$

$C = 50 + 56(1-.25) = 92$

$K_v = \left(\frac{92}{92+\sqrt{1917.94}}\right)^{-.25} = 1.112$

Figure A04.2 Analysis of pinion gear dimensions and material selection

Appendix A04(Cont.)


Gear Material Selection 3/4

Analysis 4 cont

Bending Geometry J

$J_P = .27$
$J_{G1} = .900$
$J_{G2} = .390$

Pitting Geometry
$VR_1 = 3.9375$ $I_1 = .099$
$VR_2 = 3.0625$ $I_2 = .095$
$N_P = 16$

Load Distribution K_m
Fig. 9-12 and 9-13
$K_m = 1.0 + C_{pf} + C_{ma}$ Eq. 9-17
$C_{pf} = \frac{F}{10D_P} - .025 = \frac{.375}{10(.25)} - .025 = 0.05$

Assumes open gearing
$C_{ma} = .247 + .0167F - .765 \times 10^{-4} F^2$
$C_{ma} = .247 + .0167(.375) - .765 \times 10^{-4} (.375)^2$
$C_{ma} = 0.2533$
$K_m = 1.0 + .05 + .2533 = 1.303$

Size Factor K_s
Table 9-2 $K_s = 1.0$

Rim Thickness K_B
Fig. 9.14 Solid gear blank
$K_B = 1.0$

Service factor
SF = 1.5
Reliability factor $K_R = 1.25$

Des. Life
$N_{CP} = 60(3000hr)(18037.50) = 3.25 \times 10^9$ cycles
$N_{CG1} = 60(3000hr)(4580.93) = 8.25 \times 10^8$ cycles
$N_{CB} = 60(3000hr)(1526.98) = 2.75 \times 10^8$ cycles

$Y_{NP} = .92$ $Z_{NP} = .86$
$Y_{NG} = .95$ $Z_{NG} = .9$
$Y_{NB} = .98$ $Z_{NB} = .94$

Figure A04.3 Analysis of pinion gear dimensions and material selection

Appendix A04(Cont.)

Gear Material Selection

4/4

Analysis 4 Cont.

Bending Stress

$$S_{tP} = \frac{W_t P_d}{F J_P} K_o K_s K_m K_B K_v$$

$$= \frac{(.941 lb)(32)(1.25)(1.0)(1.303)(1.0)(1.112)}{(.375)(.27)}$$

$= 538.6$ psi (Same for both pinions)

$$S_{atP} \geq S_{tP} = \frac{538.6(1.5)(1.25)}{.92} = 1097.6 \text{ psi}$$

$$S_{tG_1} = S_{tP}(J_P / J_{G_1}) = 538.6(.27/.4) = 363.6 \text{ psi}$$

$$S_{atG_1} = 363(1.25)(1.5)/.95 = 717.63 \text{ psi}$$

$$S_{tG_2} = S_{tP}(J_P / J_{G_2}) = 538.6(.27/.39) = 372.87 \text{ psi}$$

$$S_{atG_1} = 372.87(1.25)(1.5)/.98 = 713.4 \text{ psi}$$

Contact Stress

$$S_c = C_P \sqrt{\frac{W_t K_o K_s K_m K_v}{F D_P I}} =$$

Elastic coefficient for Plastic (PLA+)

$$C_P = \sqrt{\frac{1}{\pi\left[\left(1 - v_P^2\right)/E_P\right] + \left[\left(1 - v_G^2\right)/E_G\right]}}$$

$$C_P = \sqrt{\frac{1}{\pi\left[\left(1 - .33^2\right)/517.785\times10^3\right] + \left[\left(1 - .33^2\right)/517.785\times10^3\right]}}$$

$= 304.1$

$$S_c = 304.1\sqrt{\frac{(.941)(1.25)(1.0)(1.303)(1.112)}{(.375)(1.5)(.099)}} = 3192.0 \text{ psi}$$

$$S_{acP} = 3192.0\frac{(1.5)(1.25)}{.86} = 6959.3 \text{ psi}$$ — controlling factor

$$S_{acG_1} = 3192.0\frac{(1.5)(1.25)}{.9} = 6650 \text{ psi}$$

$$S_{acG_2} = 3192.0\frac{(1.5)(1.25)}{.94} = 6367.02 \text{ psi}$$

Req. HB $= (S_{ac} - 29.1)/.322 = 6.96$ ksi $- 29.1/.322 = \underline{69}$

Mat Web: PLA Hardness = 87 ✓

Use PLA or PLA+ will work

Figure A04.4 Analysis of pinion gear dimensions and material selection

Appendix A05 – Bolt Diameter for motor mount

Analysis 5	Roberto Vieyra	bolt diameter for motor mount	1

Given: Weight = 5 lbs

Yeld stress = 36 ksi

Find: Min. bolt dia. for motor mount

Assume: Homogenous Mat., SAE grade1 Steel (p.693)

Method: Shear Stress

Soln:

$\sigma_y = 36\ ksi$

$\tau = \frac{V}{A}$ $A = \frac{\pi D^2}{4}$

$\tau = \frac{V}{\left(\frac{\pi D^2}{4}\right)}$ $\frac{\tau \pi D^2}{4} = V$ $D^2 = \sqrt{\frac{4V}{\tau \pi}}$

$D = \sqrt{\frac{4(5)}{(36\times10^3\ psi)(\pi)}} = \boxed{D.013298\ in}$

If using M4 bolts

$\varnothing = 4mm = 0.15748\ in$

$A = \frac{\pi (.15748)^2}{4} = .0195\ in^2$

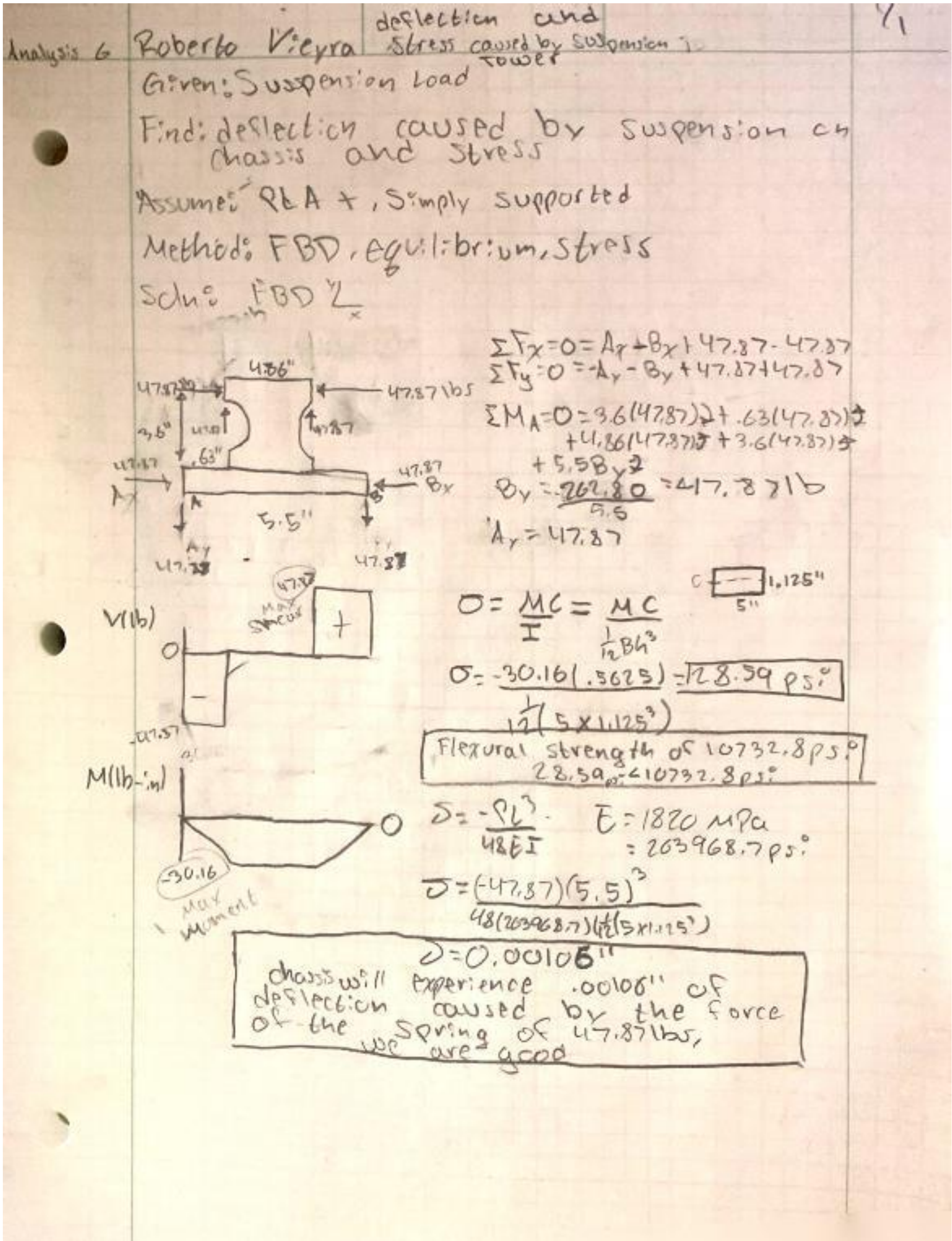
$\tau = \frac{5}{.0195} = 256.702\ psi$

36 000 < 256.702 psi

Using M4 bolt will work

Figure A05. Analysis performed to determine bolt diameter

Appendix A06 – Deflection and Stress caused by Suspension tower


Analysis 6 Roberto Vieyra deflection and Stress caused by Suspension tower 1/1

Given: Suspension Load

Find: deflection caused by suspension on chassis and Stress

Assume: QLA +, Simply supported

Method: FBD, equilibrium, stress

Soln: FBD

$\Sigma F_x = 0 = A_x + B_x + 47.87 - 47.87$

$\Sigma F_y = 0 = -A_y - B_y + 47.87 + 47.87$

$\Sigma M_A = 0 = 3.6(47.87) + .63(47.87) + 4.86(47.87) + 3.6(47.87) + 5.5 B_y$

$B_y = \frac{262.80}{5.5} = 47.87 \text{ lb}$

$A_y = 47.87$

$\sigma = \frac{Mc}{I} = \frac{Mc}{\frac{1}{12}bh^3}$

$\sigma = \frac{-30.16(.5625)}{\frac{1}{12}(5 \times 1.125^3)} = -28.59 \text{ psi}$

Flexural strength of 10732.8 psi
28.59 psi < 10732.8 psi

$\delta = \frac{-PL^3}{48EI}$ $E = 1820 \text{ MPa} = 263968.7 \text{ psi}$

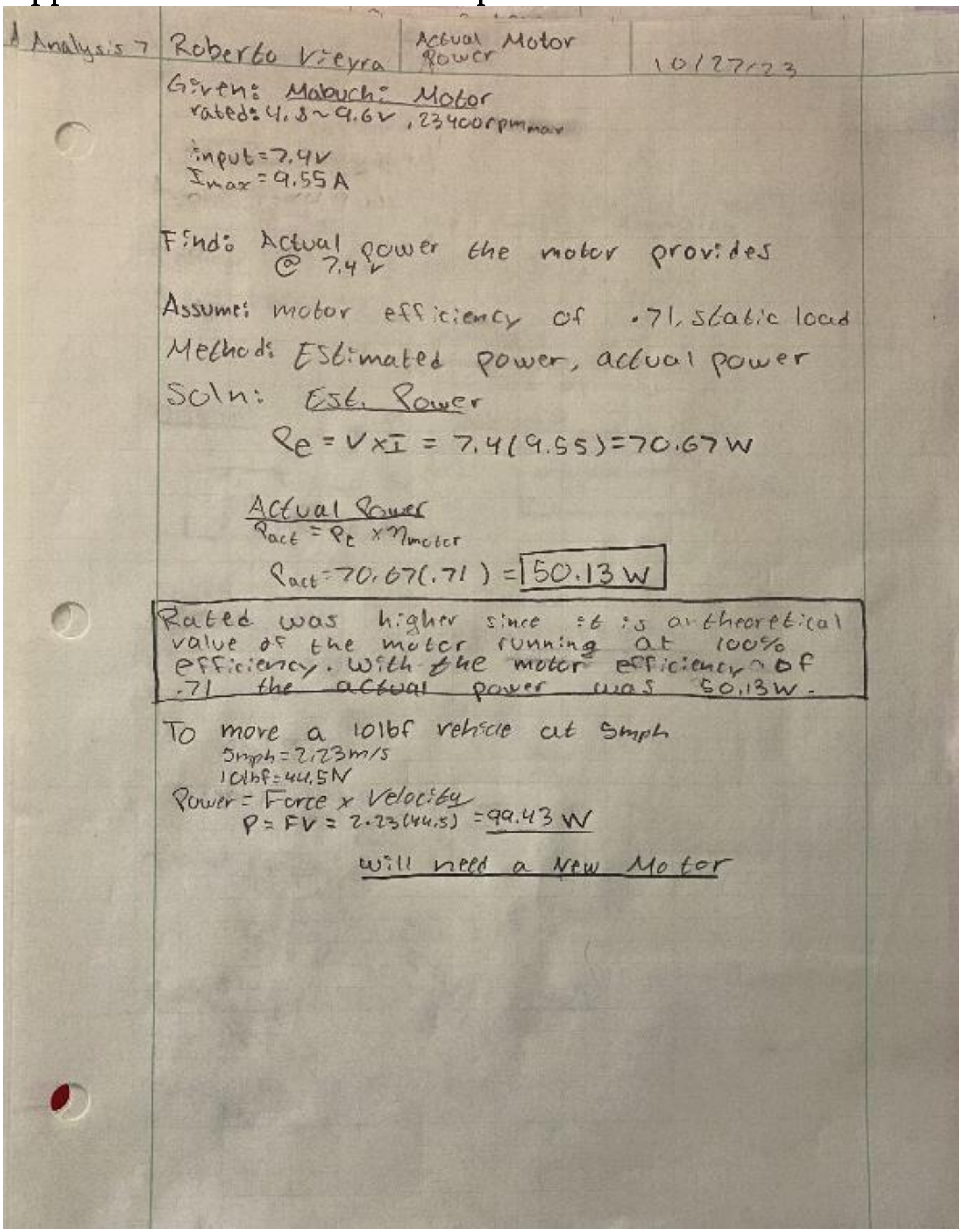
$\delta = \frac{(-47.87)(5.5)^3}{48(263968.7)(\frac{1}{12}(5 \times 1.125^3))}$

$\delta = 0.00106"$

chassis will experience .00106" of deflection caused by the force of the spring of 47.87 lbs, we are good

Figure A06. Analysis performed on chassis to determine deflection and stress from shocks

Appendix A07 –Actual motor power



Analysis 7 | Roberto Vieyra | Actual Motor Power | 10/27/23

Given: Mabuchi Motor
rated: 4.8~9.6V, 23400rpm$_{max}$

input = 7.4V
$I_{max} = 9.55A$

Find: Actual power the motor provides @ 7.4V

Assume: motor efficiency of .71, static load

Method: Estimated power, actual power

Soln: Est. Power

$P_e = V \times I = 7.4(9.55) = 70.67 W$

Actual Power

$P_{act} = P_t \times \eta_{motor}$

$P_{act} = 70.67(.71) = \boxed{50.13 W}$

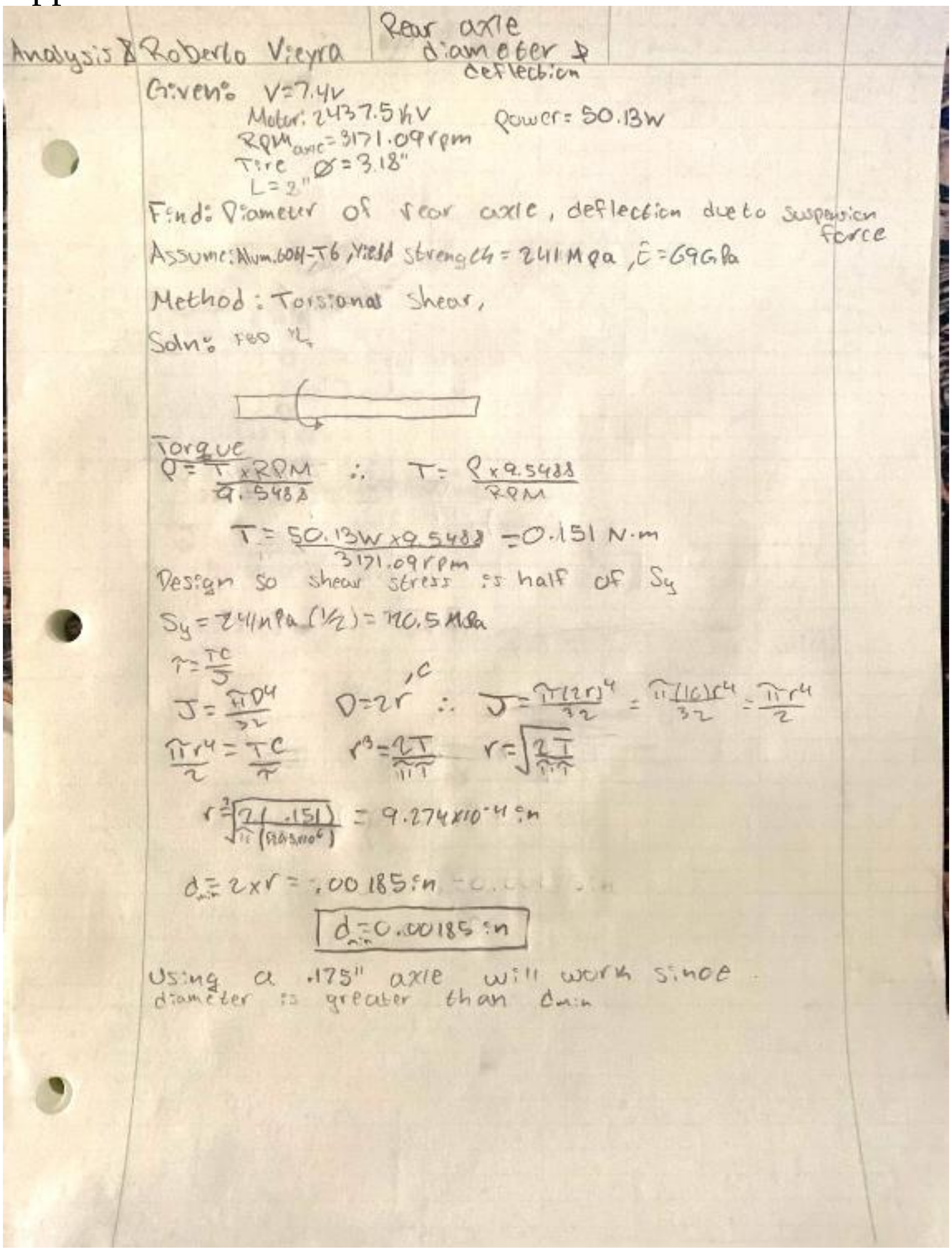
Rated was higher since it is a theoretical value of the motor running at 100% efficiency. With the motor efficiency of .71 the actual power was 50.13W.

To move a 10lbf vehicle at 5mph
5mph = 2.23m/s
10lbf = 44.5N
Power = Force x Velocity
$P = FV = 2.23(44.5) = 99.43 W$

will need a New Motor

Figure A07. Analysis performed to determine actual motor power

Appendix A08 – Rear Axle diameter and deflection



Analysis & Roberto Vieyra | Rear axle diameter & deflection

Given: V=7.4V
Motor: 2437.5 kV Power = 50.13W
RPM_{axle} = 3171.09 rpm
Tire Ø = 3.18"
L = 3"

Find: Diameter of rear axle, deflection due to suspension force

Assume: Alum. 6061-T6, Yield strength = 241 MPa, E = 69 GPa

Method: Torsional shear,

Soln: FBD ½

Torque

$P = \frac{T \times RPM}{9.5488}$ ∴ $T = \frac{P \times 9.5488}{RPM}$

$T = \frac{50.13W \times 9.5488}{3171.09 rpm} = 0.151$ N·m

Design so shear stress is half of S_y

$S_y = 241 MPa (1/2) = 120.5 MPa$

$\tau = \frac{Tc}{J}$

$J = \frac{\pi D^4}{32}$ $D = 2r$ ∴ $J = \frac{\pi (2r)^4}{32} = \frac{\pi (16) r^4}{32} = \frac{\pi r^4}{2}$

$\frac{\pi r^4}{2} = \frac{Tc}{\tau}$ $r^3 = \frac{2T}{\pi \tau}$ $r = \sqrt[3]{\frac{2T}{\pi\tau}}$

$r = \sqrt[3]{\frac{2(.151)}{\pi (120.5 \times 10^6)}} = 9.274 \times 10^{-4}$ in

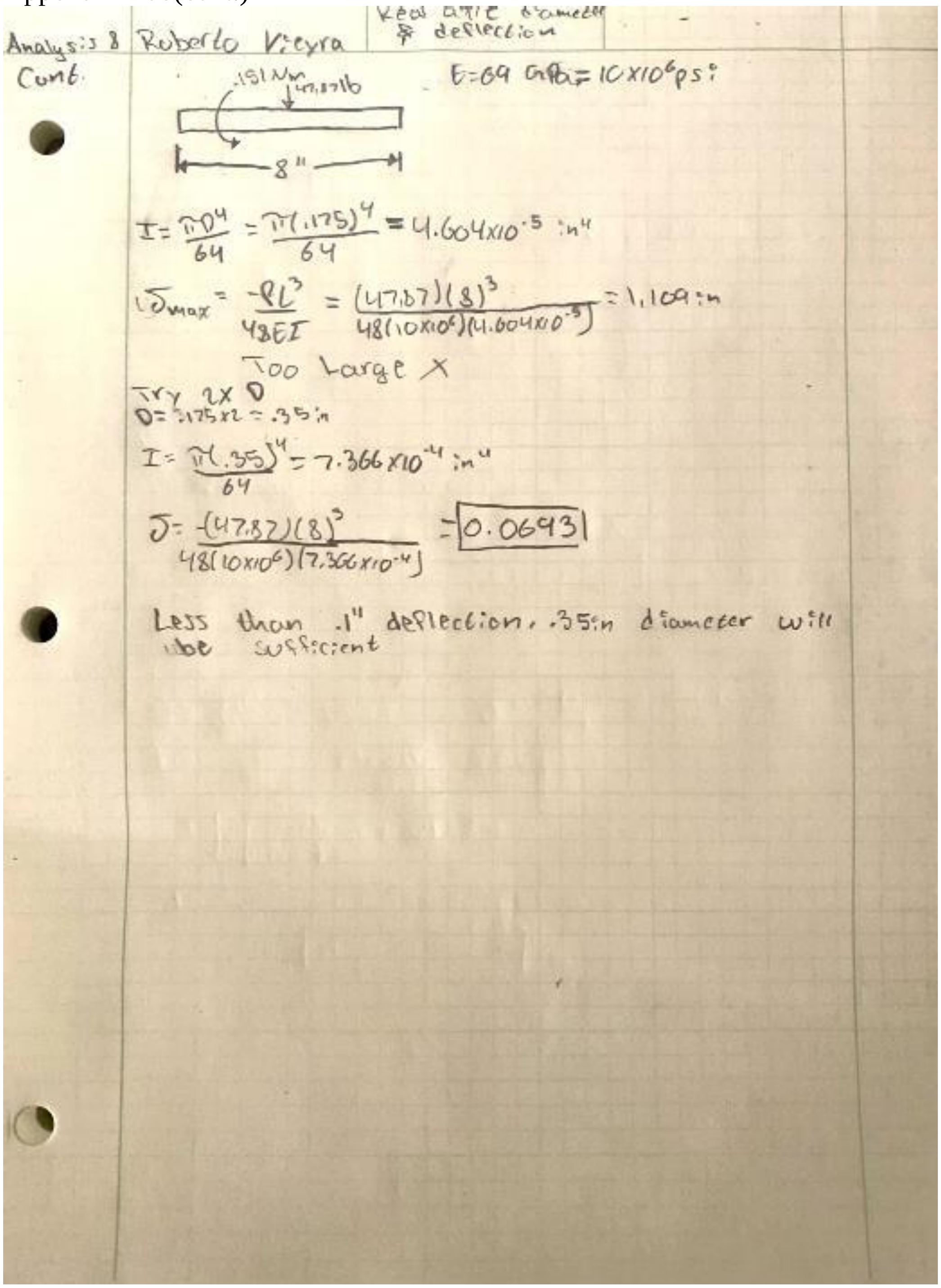
$d_{min} = 2 \times r = .00185$ in

$d_{min} = 0.00185$ in

Using a .175" axle will work since diameter is greater than d_{min}

Figure A08.1 Image of analysis to determine minimum axle diameter

Appendix A08(cont.)



Analysis 8 | Roberto Vieyra | Rear axle diameter & deflection

Cont.

$E = 69\ GPa = 10\times10^6\ psi$

$I = \frac{\pi D^4}{64} = \frac{\pi(.175)^4}{64} = 4.604\times10^{-5}\ in^4$

$\delta_{max} = \frac{-PL^3}{48EI} = \frac{(47.87)(8)^3}{48(10\times10^6)(4.604\times10^{-5})} = 1.109\ in$

Too Large X

Try 2X D

$D = .175\times2 = .35\ in$

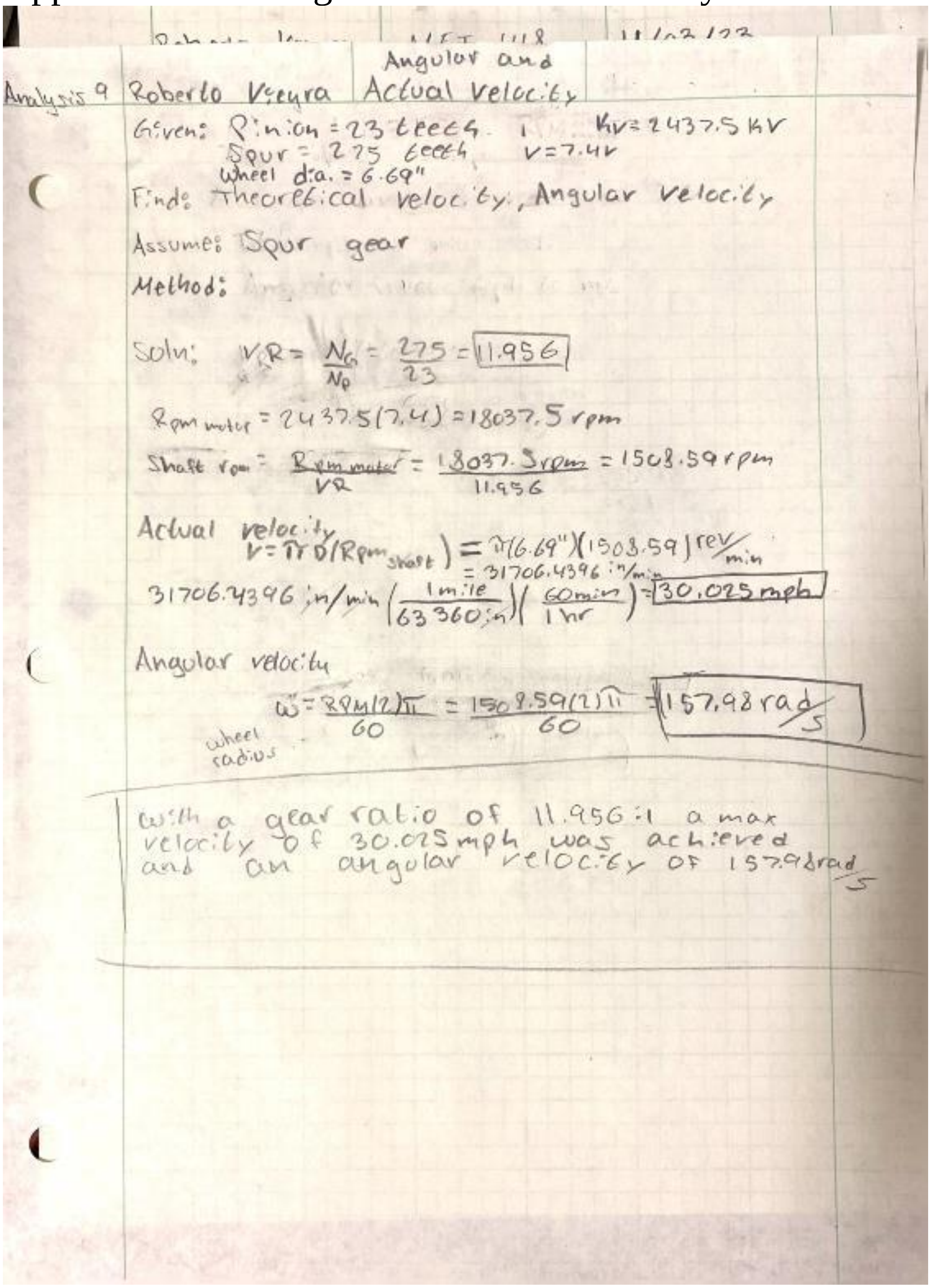
$I = \frac{\pi(.35)^4}{64} = 7.366\times10^{-4}\ in^4$

$\delta = \frac{-(47.87)(8)^3}{48(10\times10^6)(7.366\times10^{-4})} = \boxed{0.0693}$

Less than .1" deflection, .35in diameter will be sufficient

Figure A08.2 Image of analysis to determine deflection caused by the suspension forces

Appendix A09 –Angular and Actual Velocity



Analysis 9 | Roberto Vieyra | Angular and Actual Velocity

Given: Pinion = 23 teeth, Kv = 2437.5 KV
Spur = 275 teeth, V = 7.4V
Wheel dia. = 6.69"

Find: Theoretical velocity, Angular velocity

Assume: Spur gear

Method:

Soln: $VR = \frac{N_G}{N_P} = \frac{275}{23} = \boxed{11.956}$

$Rpm_{motor} = 2437.5(7.4) = 18037.5\ rpm$

$\text{Shaft rpm} = \frac{Rpm_{motor}}{VR} = \frac{18037.5\ rpm}{11.956} = 1508.59\ rpm$

Actual velocity

$V = \pi D (Rpm_{shaft}) = \pi(6.69")(1508.59)\ rev/min = 31706.4396\ in/min$

$31706.4396\ in/min \left(\frac{1\ mile}{63360\ in}\right)\left(\frac{60\ min}{1\ hr}\right) = \boxed{30.025\ mph}$

Angular velocity

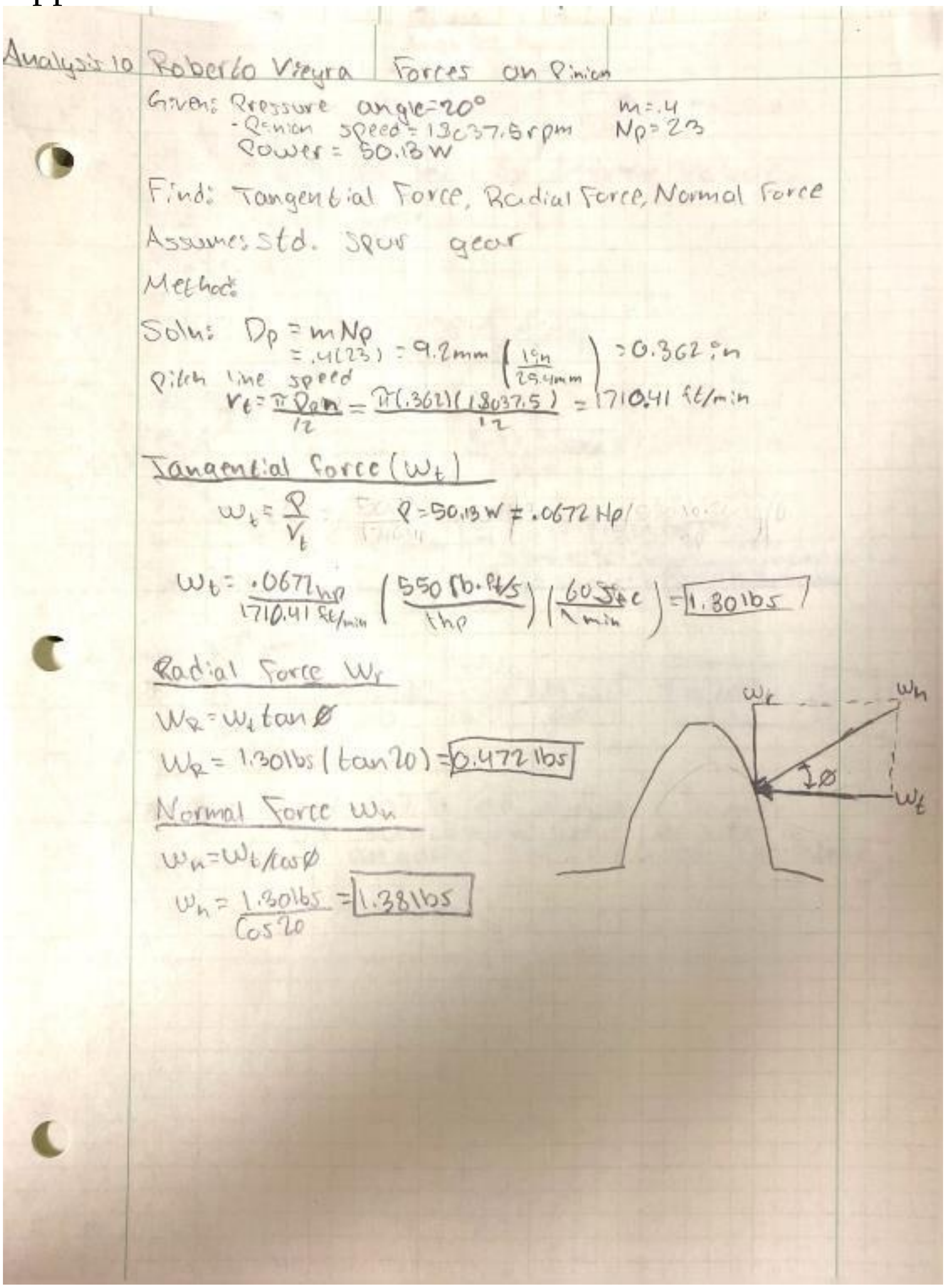
$\omega = \frac{RPM(2)\pi}{60} = \frac{1508.59(2)\pi}{60} = \boxed{157.98\ rad/s}$

wheel radius

With a gear ratio of 11.956:1 a max velocity of 30.025 mph was achieved and an angular velocity of 157.98 rad/s

Figure A09. Analysis done to determine RC’s actual velocity and maximum turning velocity

Appendix A10 –Forces on Pinion



Analysis 10 Roberto Vieyra | Forces on Pinion

Given: Pressure angle = 20°
- Pinion speed = 13037.5 rpm
Power = 50.13 W
m = .4
N_P = 23

Find: Tangential Force, Radial Force, Normal Force

Assumes std. spur gear

Method:

Soln: $D_P = m N_P$
$= .4(23) = 9.2mm \left(\frac{1 in}{25.4mm}\right) = 0.362 in$

pitch line speed
$V_t = \frac{\pi D_P n}{12} = \frac{\pi(.362)(18037.5)}{12} = 1710.41 \text{ ft/min}$

Tangential force (W_t)

$W_t = \frac{P}{V_t}$ $P = 50.13 W = .0672 Hp$

$W_t = \frac{.0672 hp}{1710.41 \text{ ft/min}} \left(\frac{550 \text{ lb} \cdot \text{ft/s}}{1hp}\right)\left(\frac{60 sec}{1 min}\right) = 1.30 lbs$

Radial Force W_r

$W_R = W_t \tan \phi$

$W_R = 1.30 lbs (\tan 20) = 0.472 lbs$

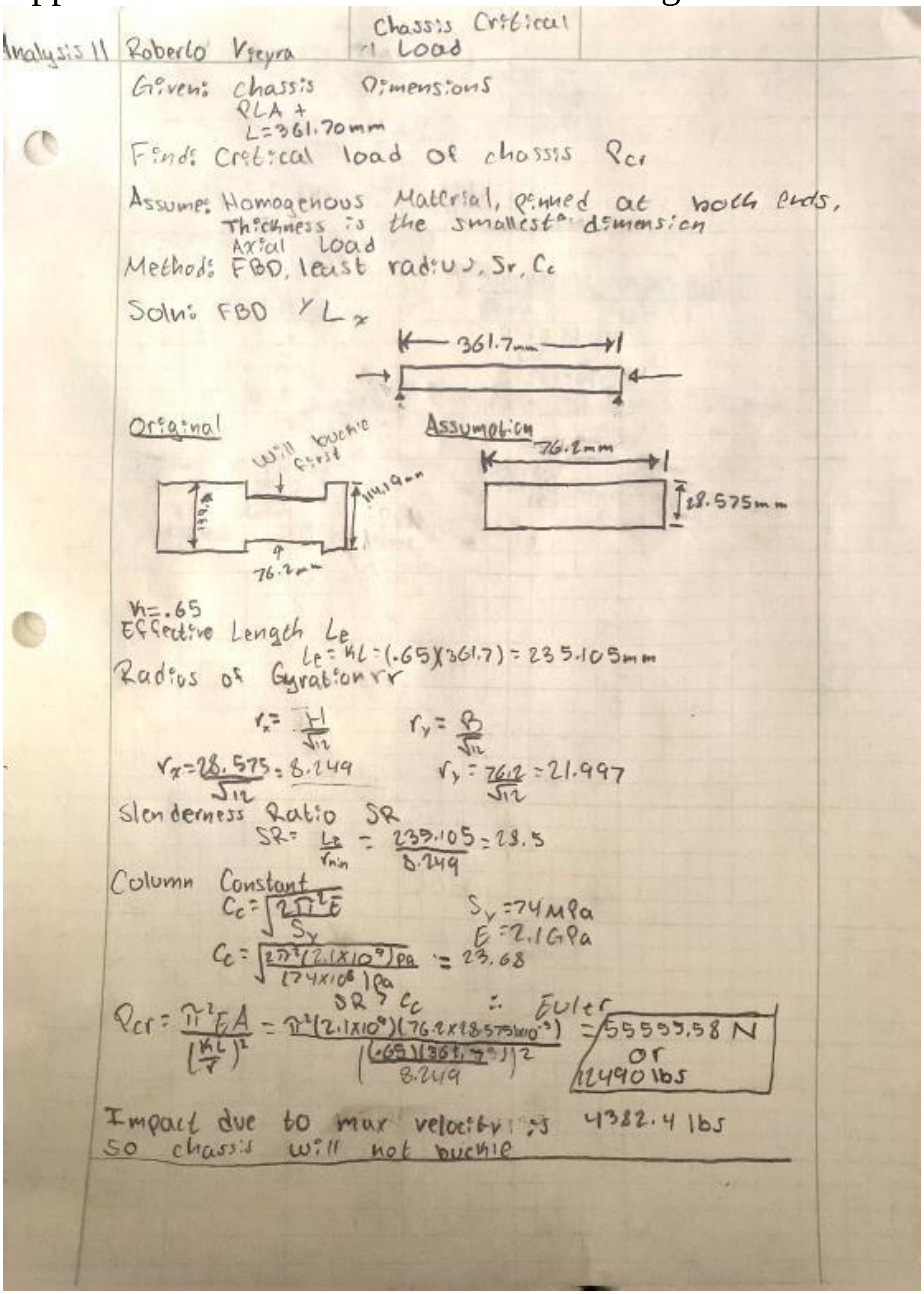
Normal Force W_n

$W_n = W_t / \cos \phi$

$W_n = \frac{1.30 lbs}{\cos 20} = 1.38 lbs$

Figure A10. Analysis performed to determine forces on pinion gear

Appendix A11 – Chassis Critical Buckling Load



Analysis 11 Roberto Vieyra Chassis Critical Load

Given: Chassis Dimensions
PLA +
L=361.70mm

Find: Critical load of chassis P_{cr}

Assume: Homogenous Material, pinned at both ends,
Thickness is the smallest dimension
Axial Load

Method: FBD, least radius, Sr, C_c

Soln: FBD

361.7mm

Original — will buckle first — 76.2mm

Assumption — 76.2mm — 28.575mm

k=.65

Effective Length L_e

$L_e = kL = (.65)(361.7) = 235.105mm$

Radius of Gyration r

$r_x = \frac{H}{\sqrt{12}}$ $r_y = \frac{B}{\sqrt{12}}$

$r_x = \frac{28.575}{\sqrt{12}} = 8.249$ $r_y = \frac{76.2}{\sqrt{12}} = 21.997$

Slenderness Ratio SR

$SR = \frac{L_e}{r_{min}} = \frac{235.105}{8.249} = 28.5$

Column Constant

$C_c = \sqrt{\frac{2\pi^2 E}{S_y}}$ $S_y = 74MPa$ $E = 2.1GPa$

$C_c = \sqrt{\frac{2\pi^2(2.1\times10^9)Pa}{(74\times10^6)Pa}} = 23.68$

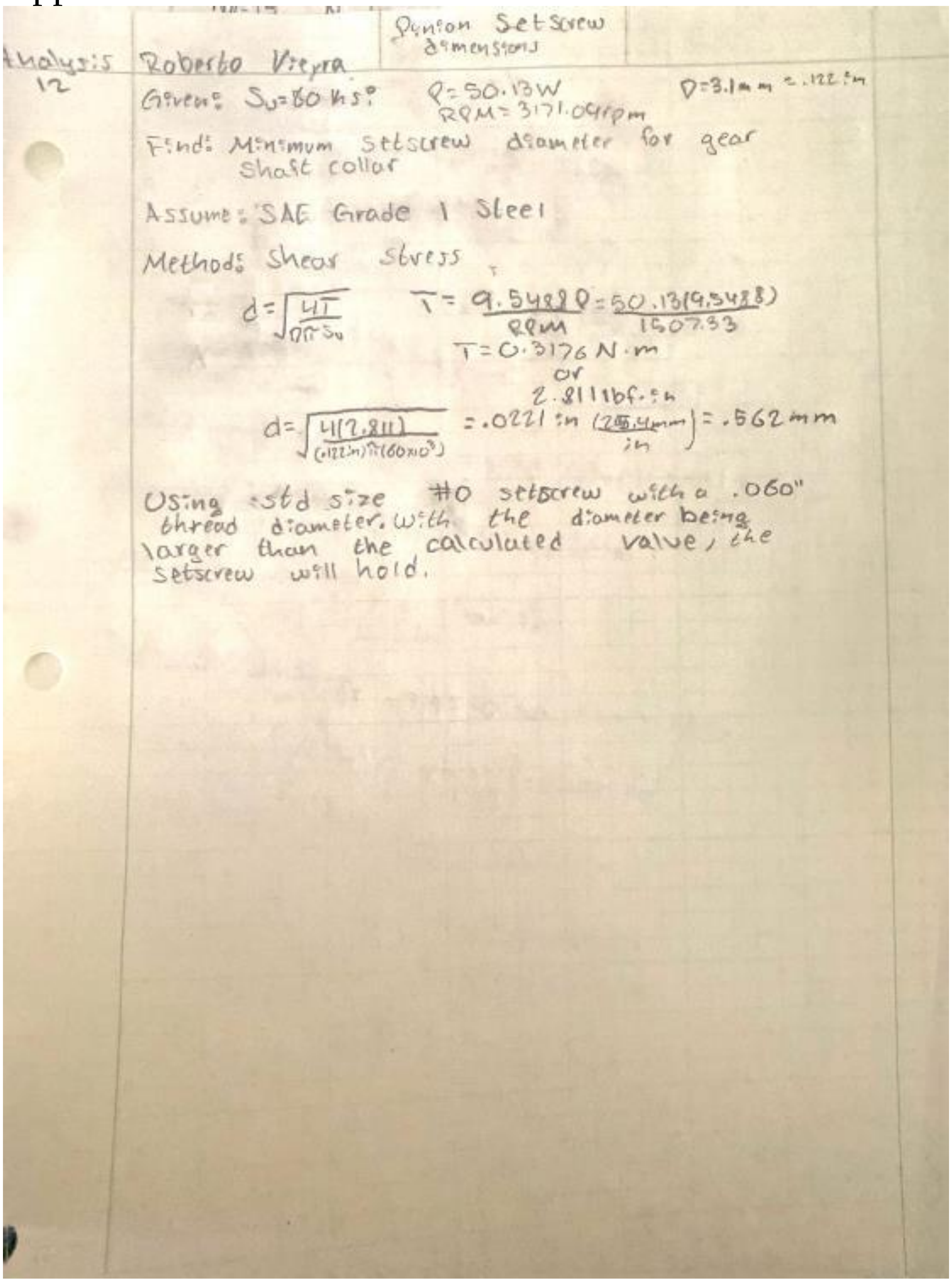
SR > C_c ∴ Euler

$P_{cr} = \frac{\pi^2 EA}{\left(\frac{KL}{r}\right)^2} = \frac{\pi^2(2.1\times10^9)(76.2\times28.575\times10^{-3})}{\left(\frac{(.65)(361.7)}{8.249}\right)^2} = 55555.58\ N$ or 12490 lbs

Impact due to max velocity is 4382.4 lbs
so chassis will not buckle

Figure A11. Analysis performed to determine chassis' critical load

Appendix A12– Pinion Set Screw Dimension



Pinion Setscrew dimensions

Analysis 12 — Roberto Vieyra

Given: $S_u = 80$ ksi $P = 50.13W$ $RPM = 3171.04rpm$ $D = 3.1mm = .122in$

Find: Minimum setscrew diameter for gear shaft collar

Assume: SAE Grade 1 Steel

Method: Shear stress

$$d = \sqrt{\frac{4T}{D\pi S_u}} \qquad T = \frac{9.5488P}{RPM} = \frac{50.13(9.5488)}{1507.33}$$

$$T = 0.3176\ N\cdot m$$

or

$$2.811\ lbf\cdot in$$

$$d = \sqrt{\frac{4(2.811)}{(.122in)\pi(60\times10^3)}} = .0221in\left(\frac{25.4mm}{in}\right) = .562mm$$

Using std size #0 setscrew with a .060" thread diameter. With the diameter being larger than the calculated value, the setscrew will hold.

Figure A12. Analysis performed to determine minimum set screw dimension

APPENDIX B - Drawings

Appendix B01 – Drawing Tree

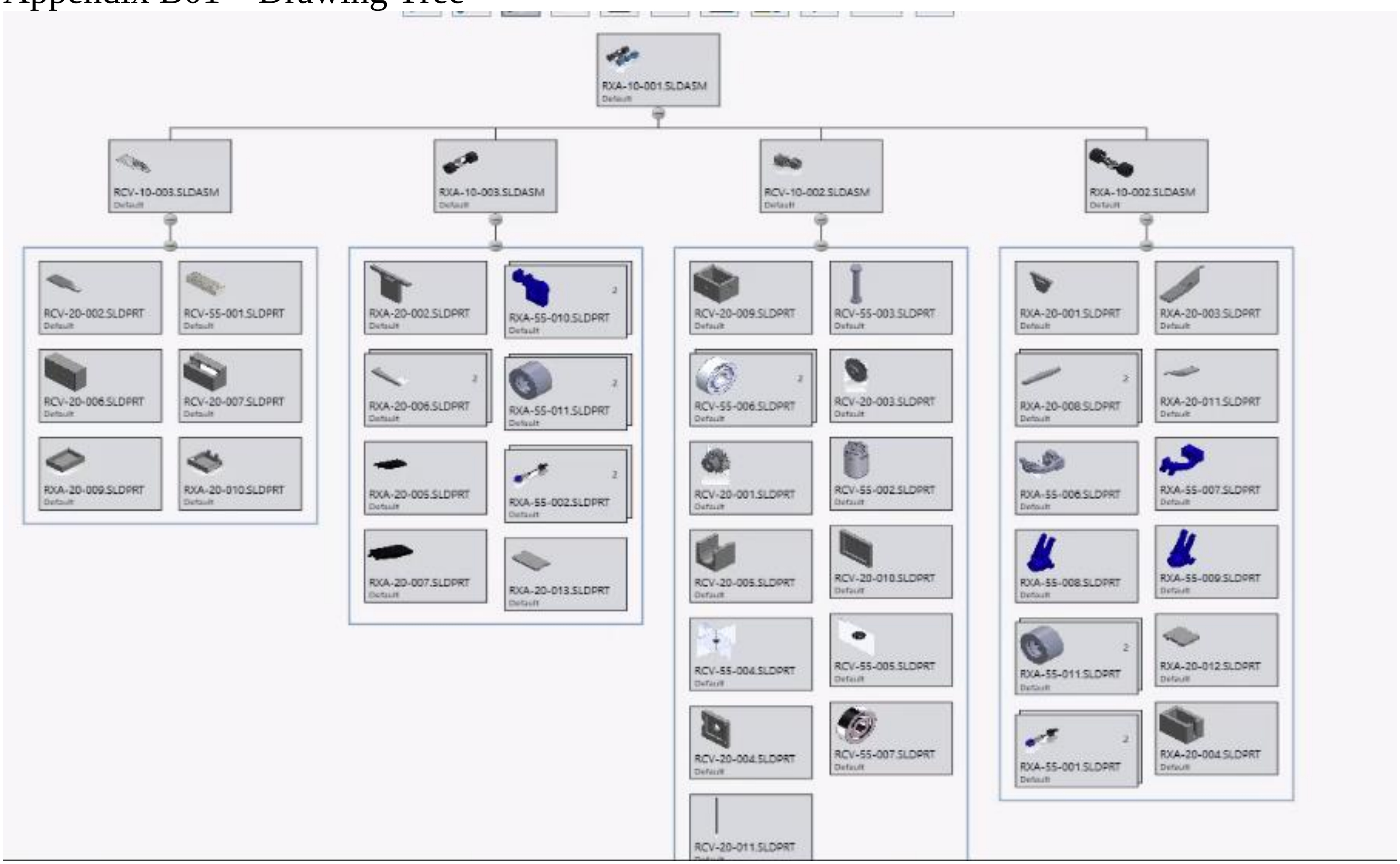


Figure B01. Drawing Tree

Appendix B02 – Drawing Index

Table B01. Drawing Index

Drawing Assignment Num.	Drawing #(s)	Date submitted
DWG 1	RCV-20-001	10/11/2023
DWG 2	RCV-20-002	10/18/2023
DWG 3 & 4	RCV-20-003, RCV-20-004	10/25/2023
DWG 5 & 6	RCV-20-005, RCV-20-006	11/01/2023
DWG 7 & 8	RCV-20-007, RCV-20-008	11/08/2023
DWG 9& 10	RCV-20-009, RCV-20-010	11/15/2023
Assembly DWG 1& 2	RCV-10-001, RCV-10-002	11/28/2023
Assembly DWG 3	RCV-10-003	01/05/2024
DWG 11	RCV-20-011	02/19/2024
DWG 12	RCV-20-012	01/31/2024
DWG 13 & 14	RCV-20-013, RCV-20-014	02/20/2024
DWG 15 & 16	RCV-20-015, RCV-20-016	02/21-2024

Appendix B03 – RCV-10-001 – RC Car Assembly

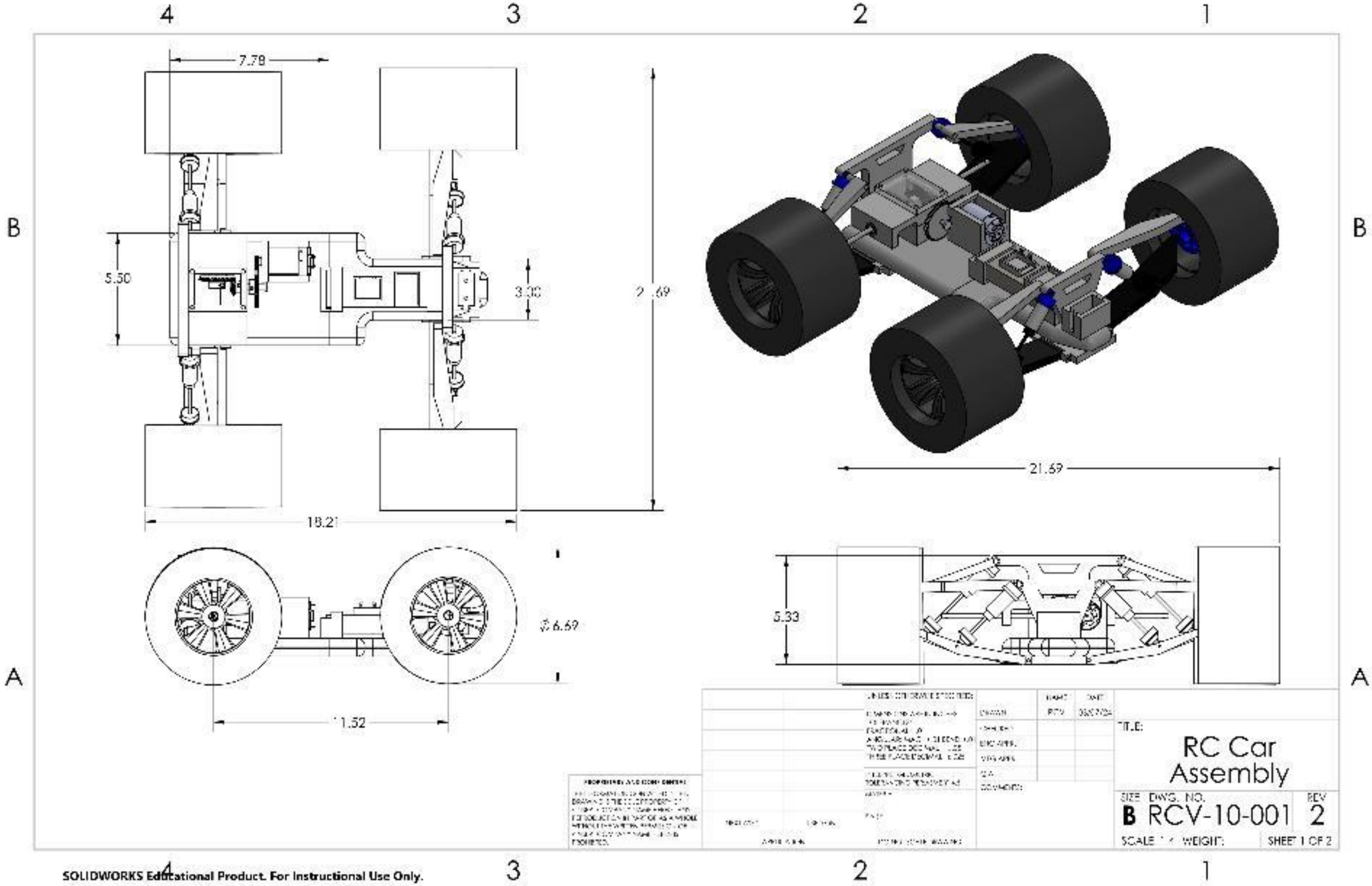
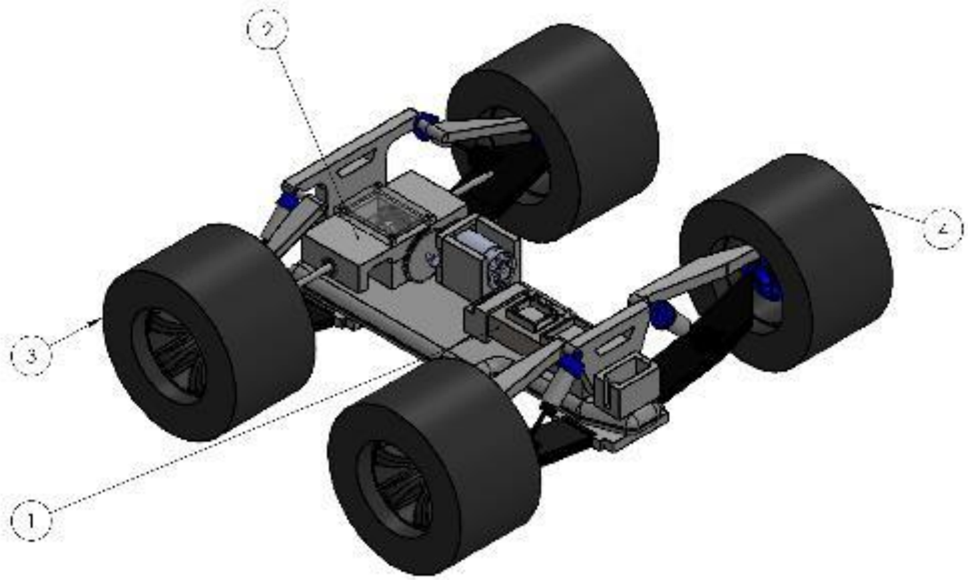


Figure B03. RC Car Assembly

Appendix B03(cont.)



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RCV-10-003	Chassis Assembly	1
2	RCV-10-002	Drivetrain Assembly	1
3	RXA-10-003	Rear Suspension Assembly	1
4	RXA-10-002	Front Suspension Assembly	1

TITLE: RC Car Assembly

SIZE B DWG. NO. RCV-10-001 REV 2

SCALE 1:4 WEIGHT: SHEET 2 OF 2

Figure B03.1 RC Car Assembly

Appendix B04 – RC-10-002- Drivetrain Sub-Assembly

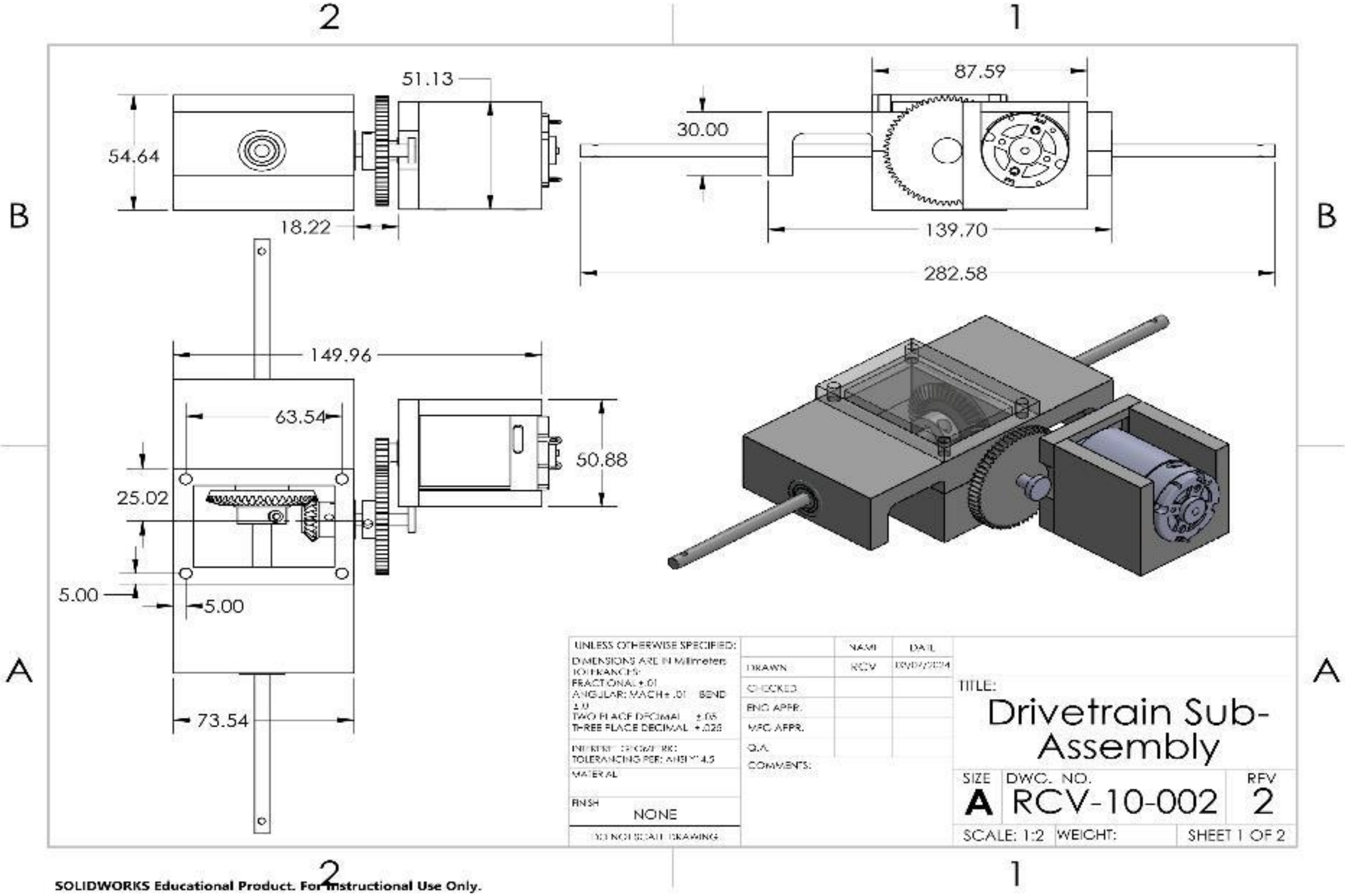
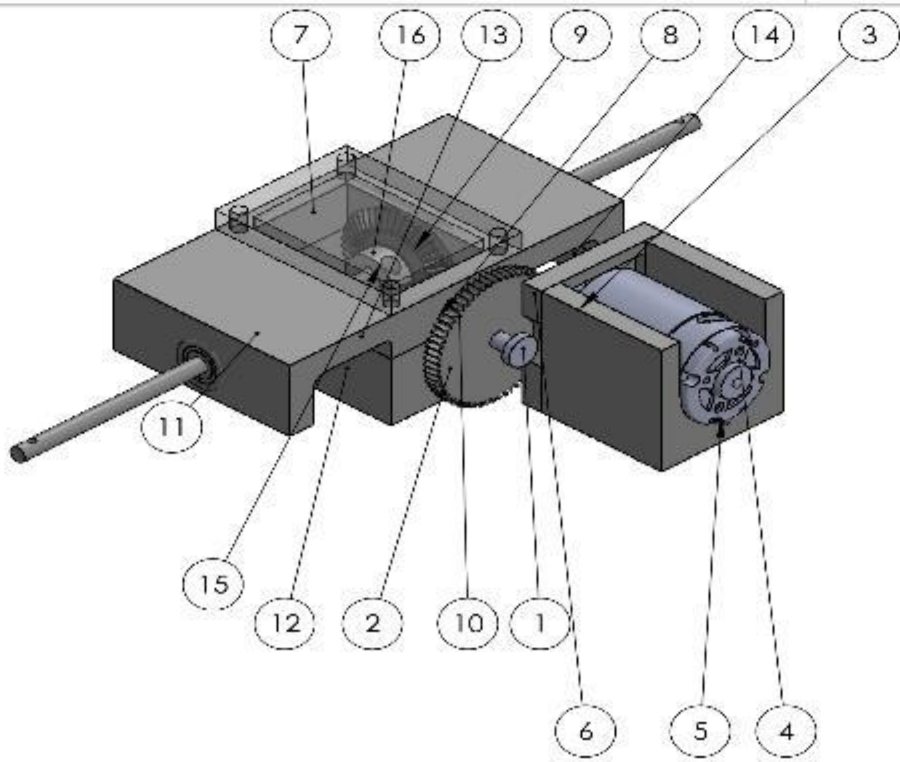


Figure B04. Drivetrain Sub-Assembly

Appendix B04(cont.)



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RCV-55-003	6mm Gear Axle	1
2	RCV-20-003	63T Spur Gear	1
3	RCV-20-001	15T Pinion Gear	1
4	RCV-55-002	Mabuchi Motor	1
5	RCV-20-005	Motor Mount	1
6	RCV-20-004	Motor Cover	1
7	RCV-20-010	Gearbox Cover	1
8	RCV-55-008	15T Bevel Gear	1
9	RCV-55-009	45T Bevel Gear	1
10	RCV-55-007	6mm Ballbearing	5
11	RCV-20-011	Rear Axle	1
12	RCV-20-015	Gearbox Bottom Half	1
13	RCV-20-016	Gearbox Top Half	1
14	RCV-20-018	Axle Support Clamp	1
15	RCV-20-012	Square Key	1
16	RCV-20-017	8mm Bore Shaft Collar	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN Millimeters
TOLERANCES:
FRACTIONAL ±.01
ANGULAR: MACH ± .01 BEND ±.01
TWO PLACE DECIMAL ±.05
THREE PLACE DECIMAL ±.025
INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5
MATERIAL
FINISH NONE
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	RCV	03/07/2024
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE: Drivetrain Sub-Assembly

SIZE A | DWG. NO. RCV-10-002 | REV 2

SCALE: 1:2 | WEIGHT: | SHEET 2 OF 2

Figure B04.1 Drivetrain Sub-Assembly

Appendix B05 – RC-10-003- Chassis Sub-Assembly

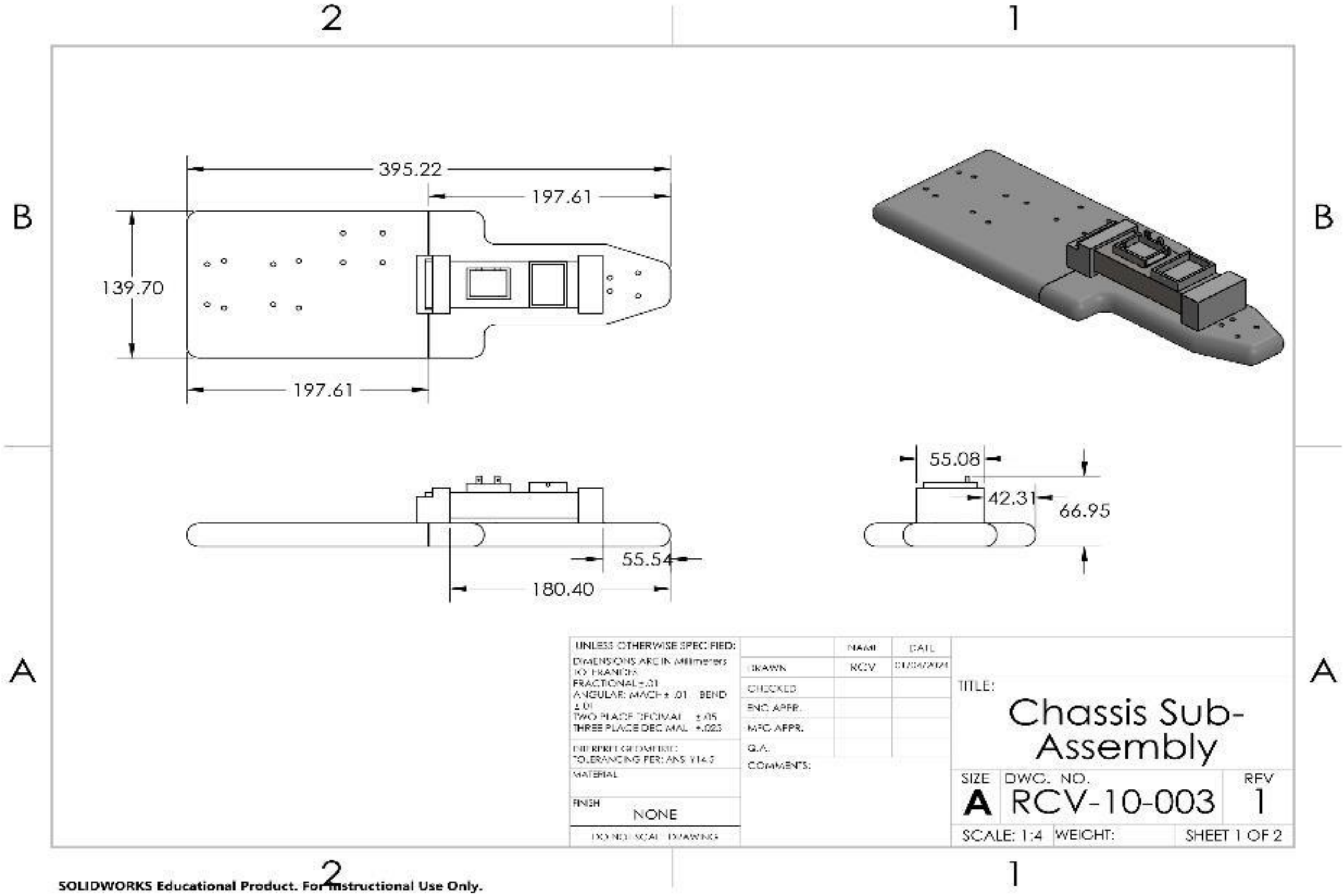
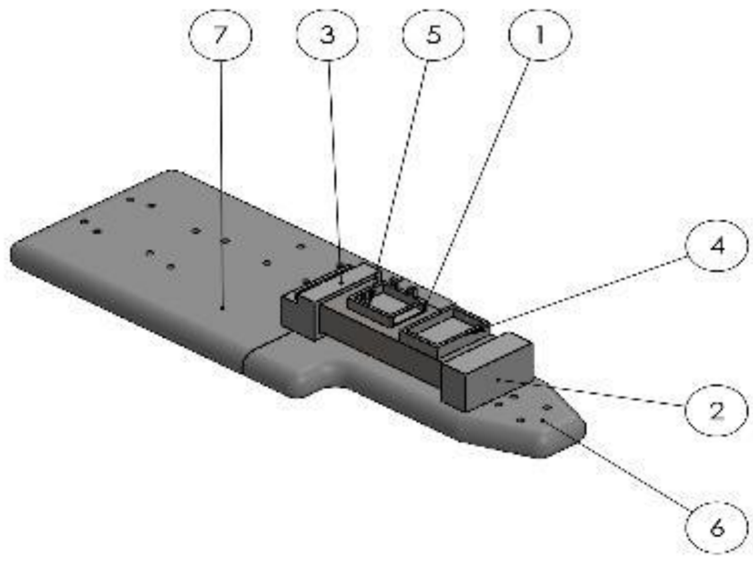


Figure B05- Chassis Sub-Assembly

Appendix B05(cont.)



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RCV-55-001	Lipo Battery	1
2	RCV-20-006	Right Side Battery Mount	1
3	RCV-20-007	Left Side Battery Mount	1
4	RXA-20-009	Receiver Mount	1
5	RXA-20-010	UBEC Mount	1
6	RCV-20-013	Chassis Front Section	1
7	RCV-20-014		1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN Millimeters
TOLERANCES:
FRACTIONAL ±.01
ANGULAR: MACH ± .01 BEND ±.01
TWO PLACE DECIMAL ±.05
THREE PLACE DECIMAL ±.025

INTERPRET GEOMETRIC TOLERANCING PER: ANSI Y14.5
MATERIAL
FINISH NONE
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	RCV	01/04/2024
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: Chassis Sub-Assembly

SIZE A | DWG. NO. RCV-10-003 | REV 1

SCALE: 1:4 WEIGHT: SHEET 2 OF 2

Figure B05- Chassis Sub-Assembly

Appendix B06 – RCV-20-001 – Spur Gear

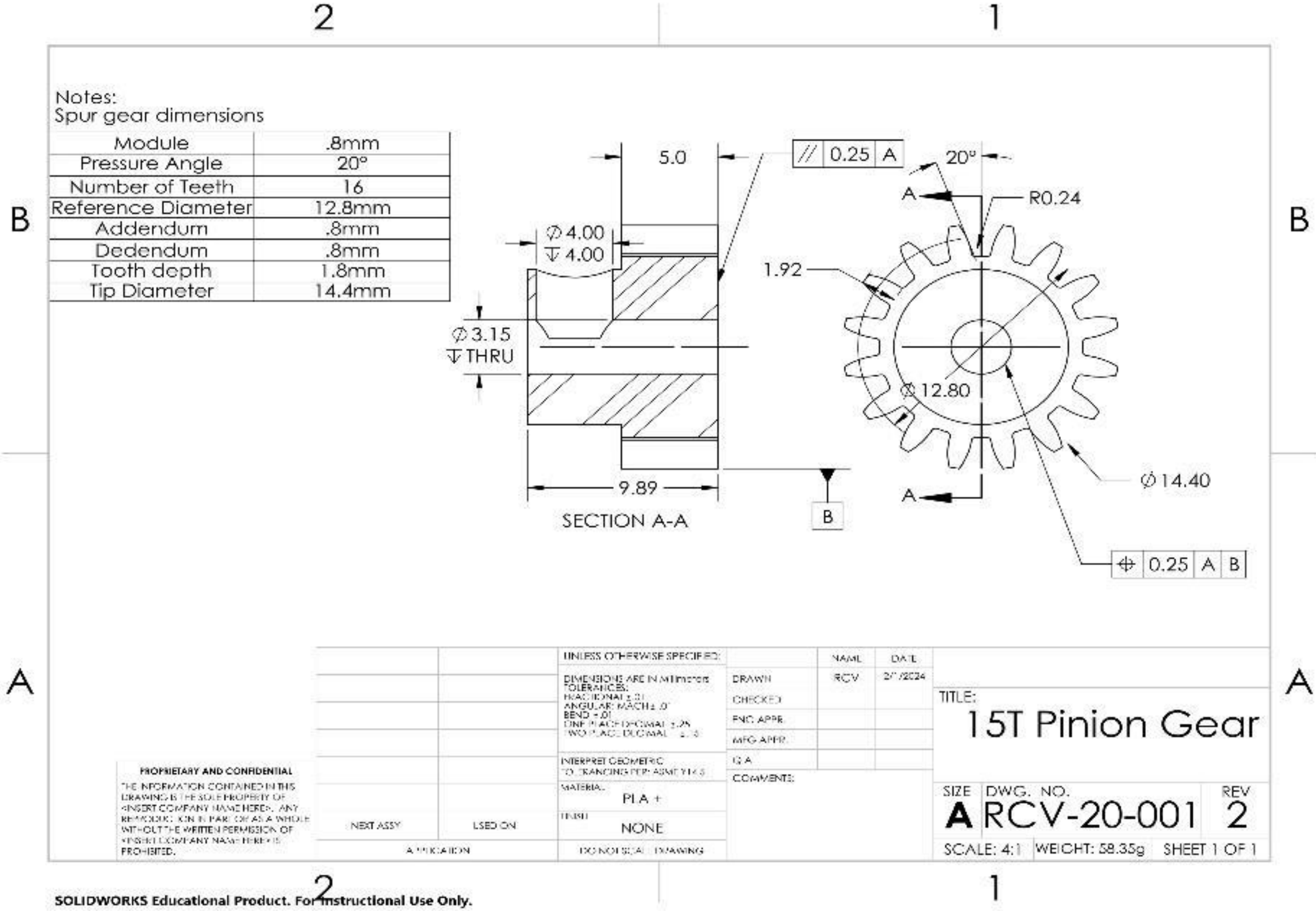


Figure B06. Drawing of Pinion Gear

Appendix B07 – RCV-20-002 – Chassis

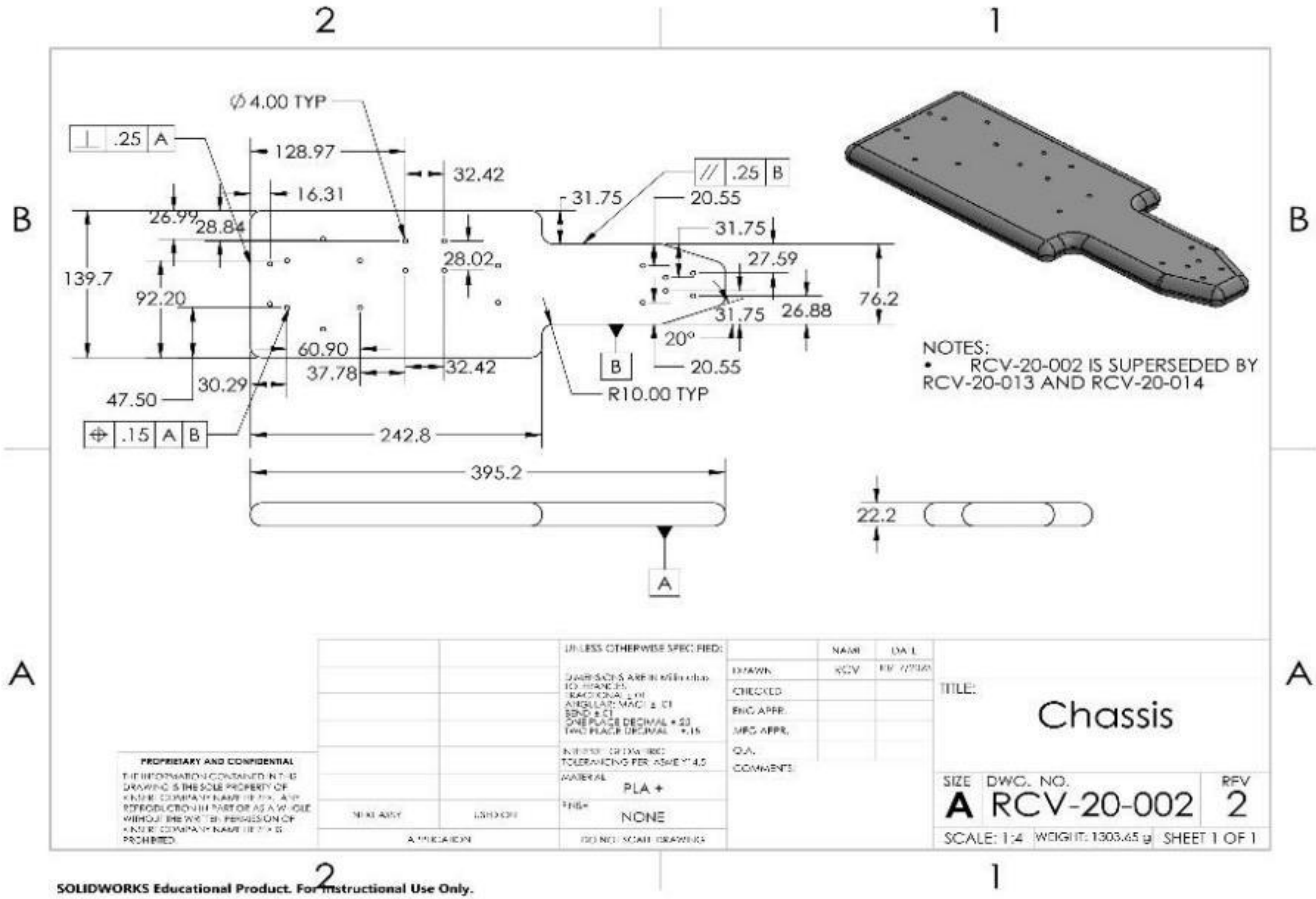


Figure B07. Drawing of Chassis

Appendix B08 – RCV-20-003 – Spur Gear

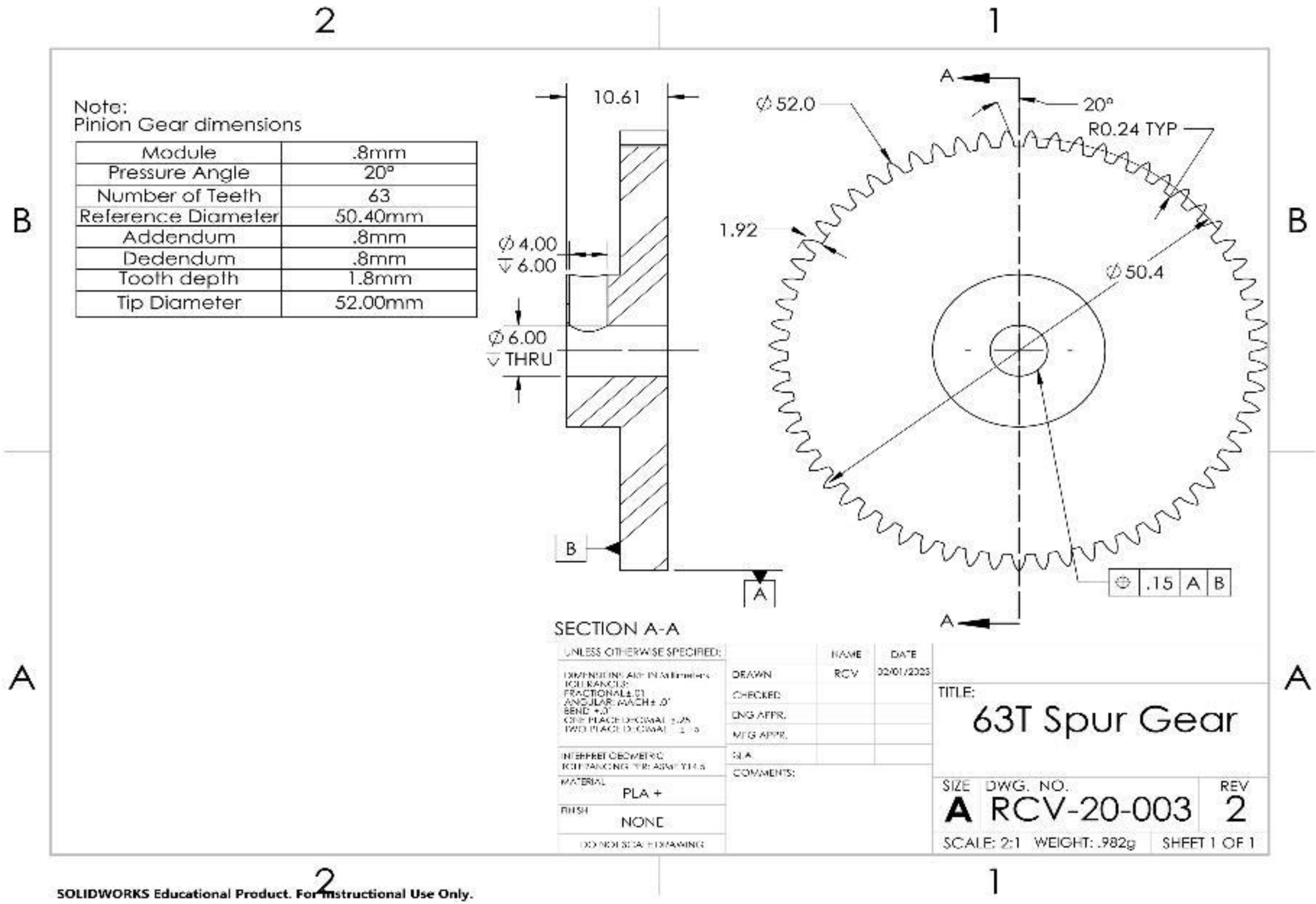


Figure B08. Drawing of 63T Spur Gear

Appendix B09 – RCV-20-004 – Motor Cover

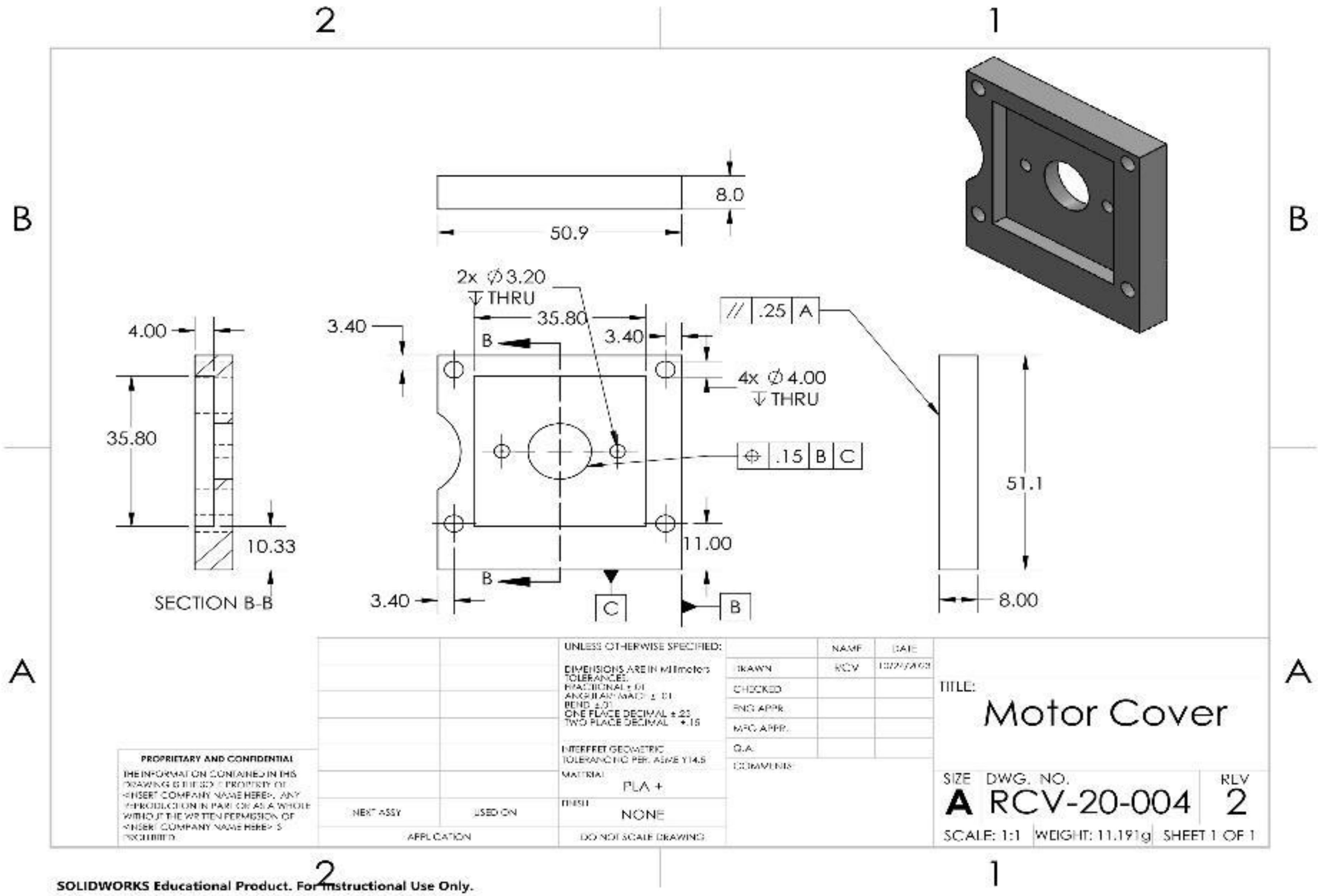


Figure B09. Drawing of motor cover for motor mount

Appendix B10 – RCV-20-005 – Motor Mount

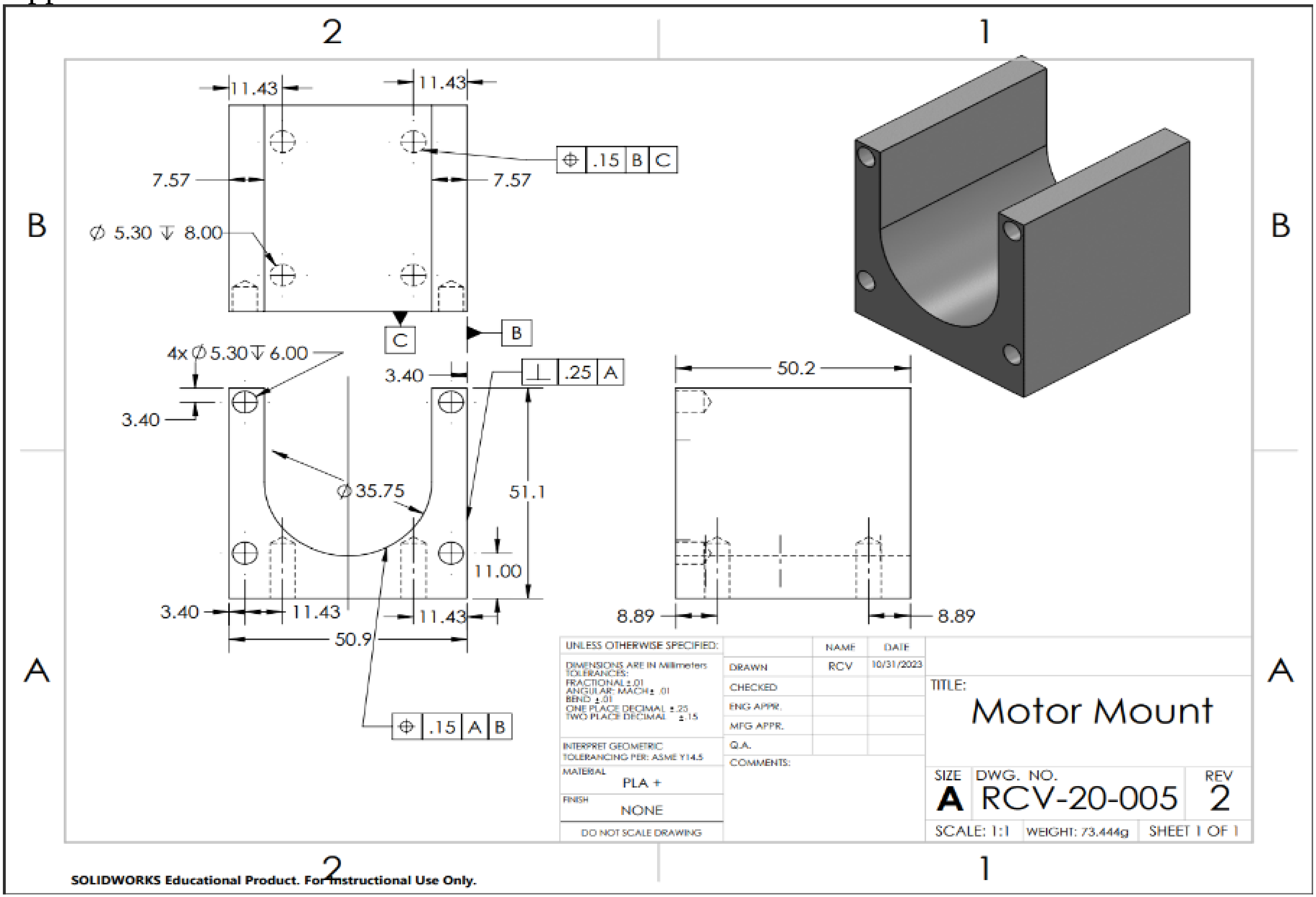


Figure B10. Drawing of motor mount

Appendix B11 – RCV-20-006 –Right side Battery Mount

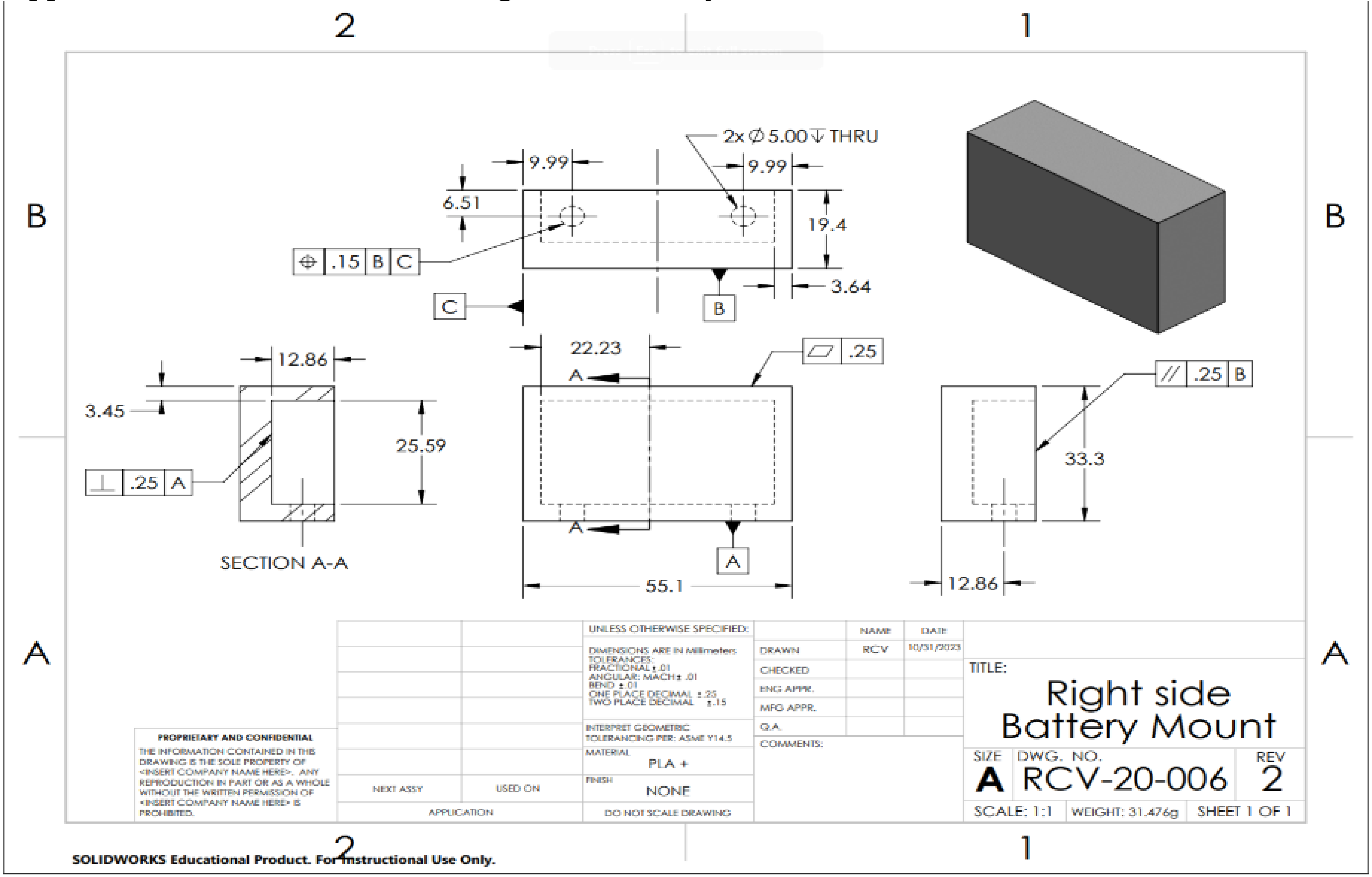


Figure B11. Drawing of right hand side battery mount

Appendix B12– RCV-20-007 –Left Side Battery Mount

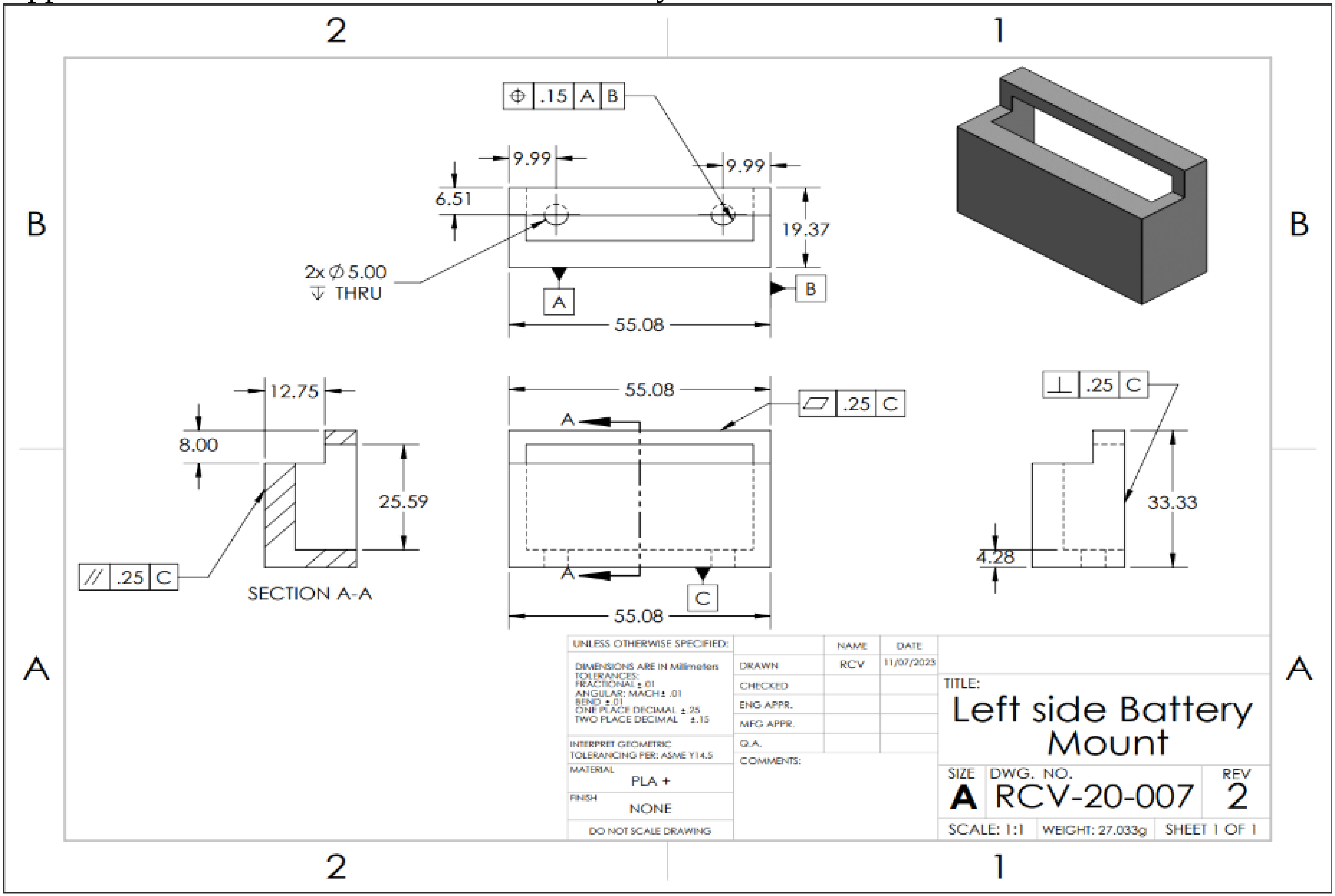


Figure B12. Drawing of left hand side battery mount

Appendix B13– RCV-20-008 –Gear Bore Reducer

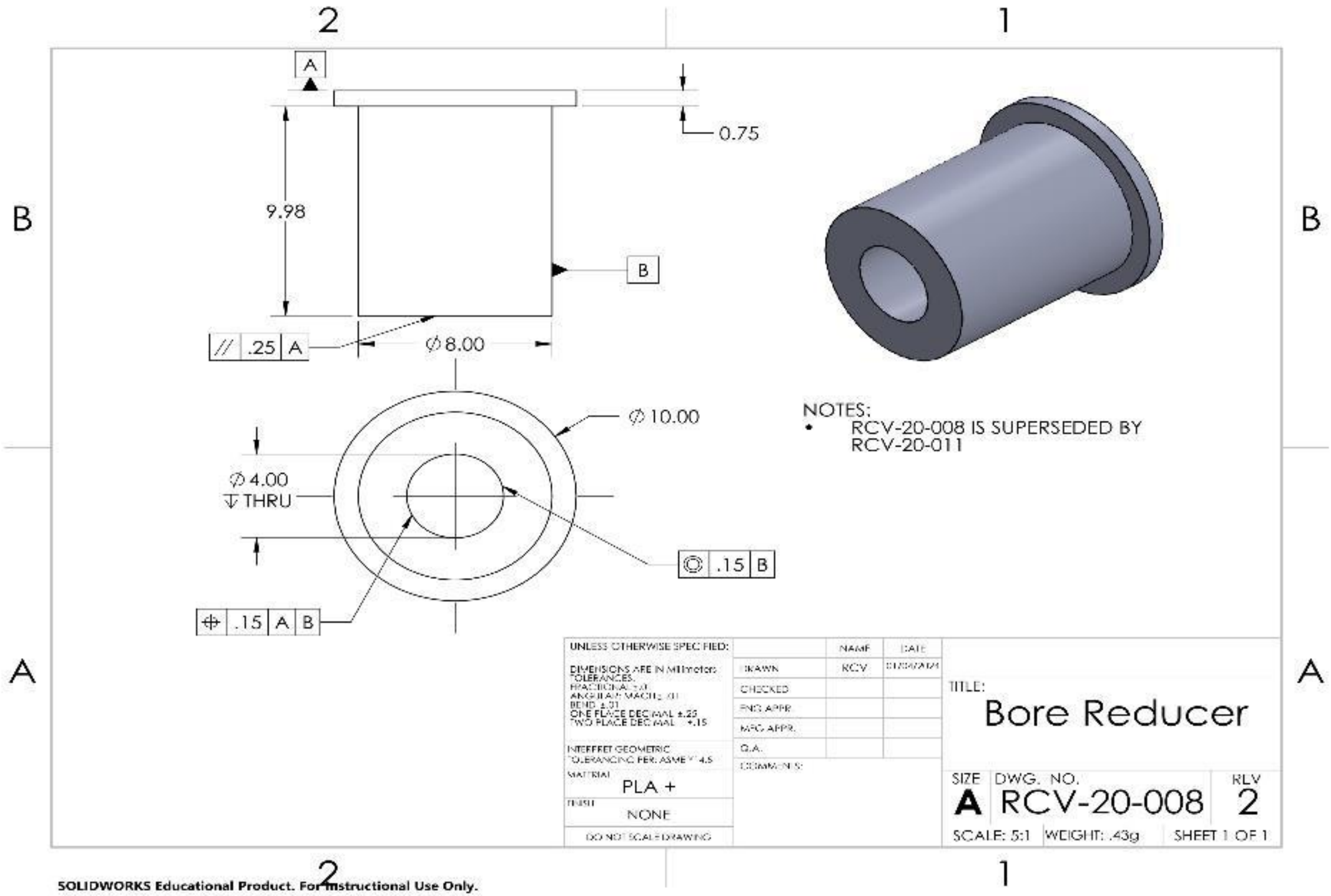


Figure B13. Drawing of bore reducer for gear

Appendix B14– RCV-20-009 – Gearbox

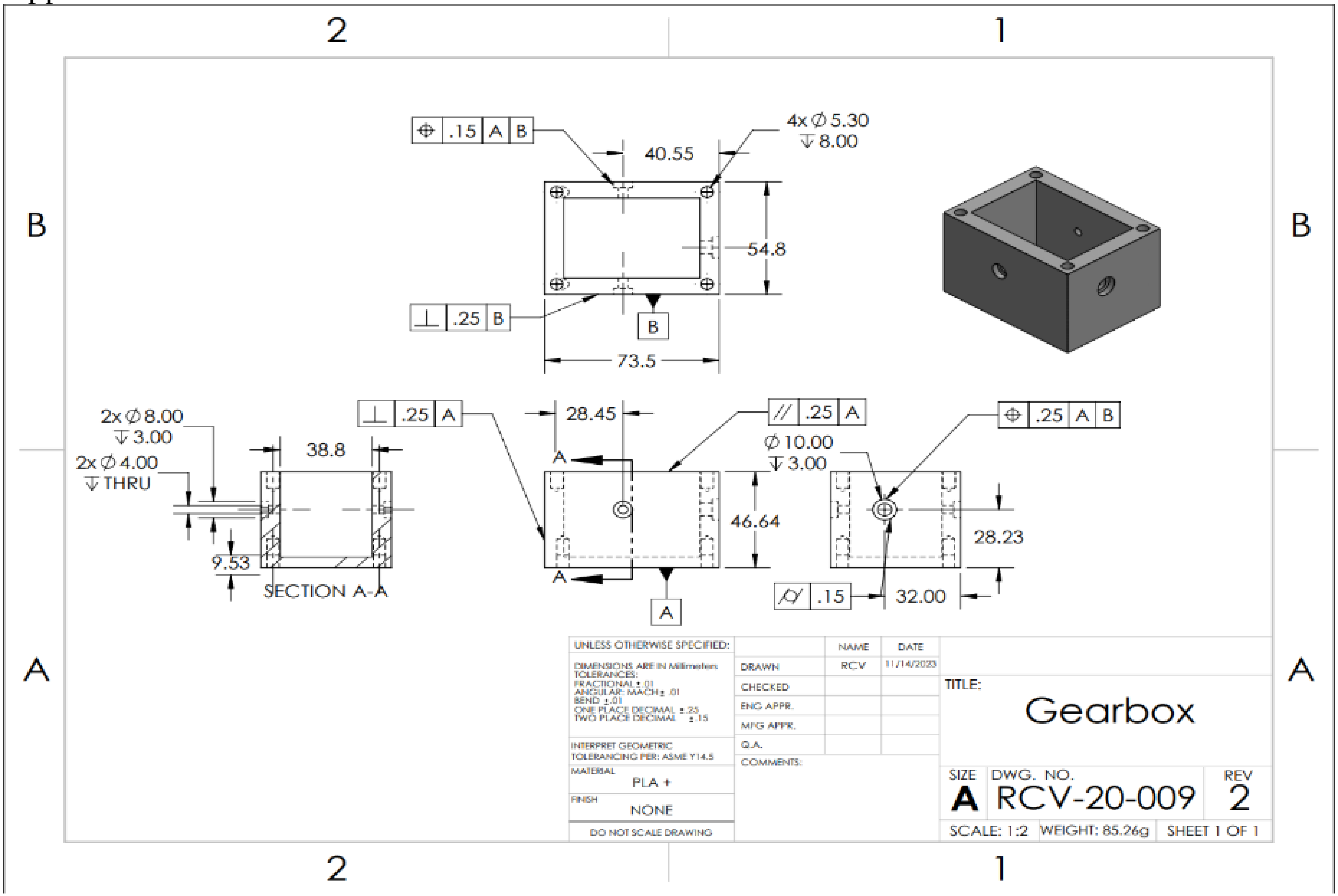


Figure B14. Drawing of bevel gear gearbox

Appendix B15– RCV-20-010 – Gearbox Cover

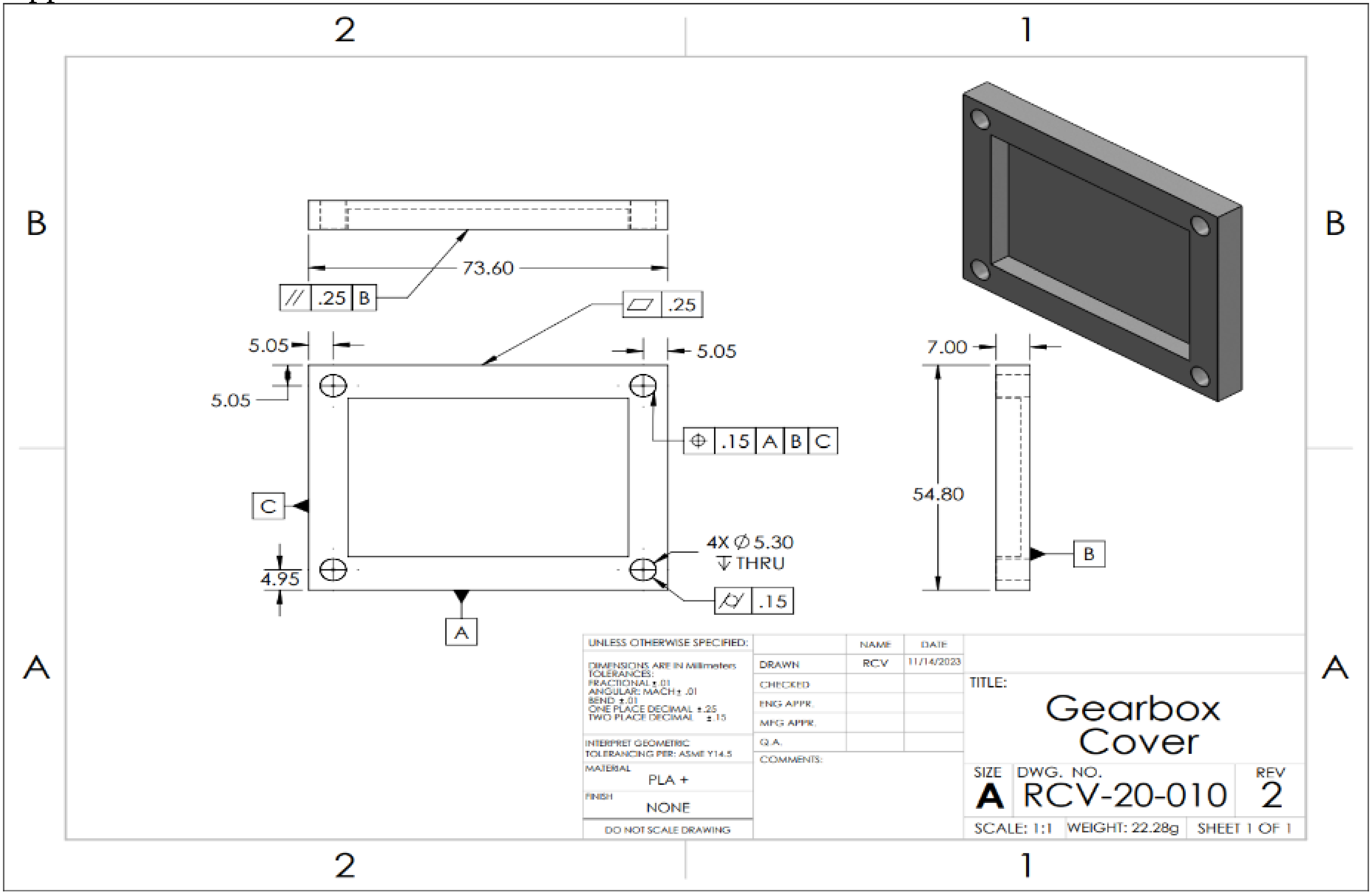


Figure B15. Drawing of Gearbox cover

Appendix B16– RCV-20-011 – Rear Axle

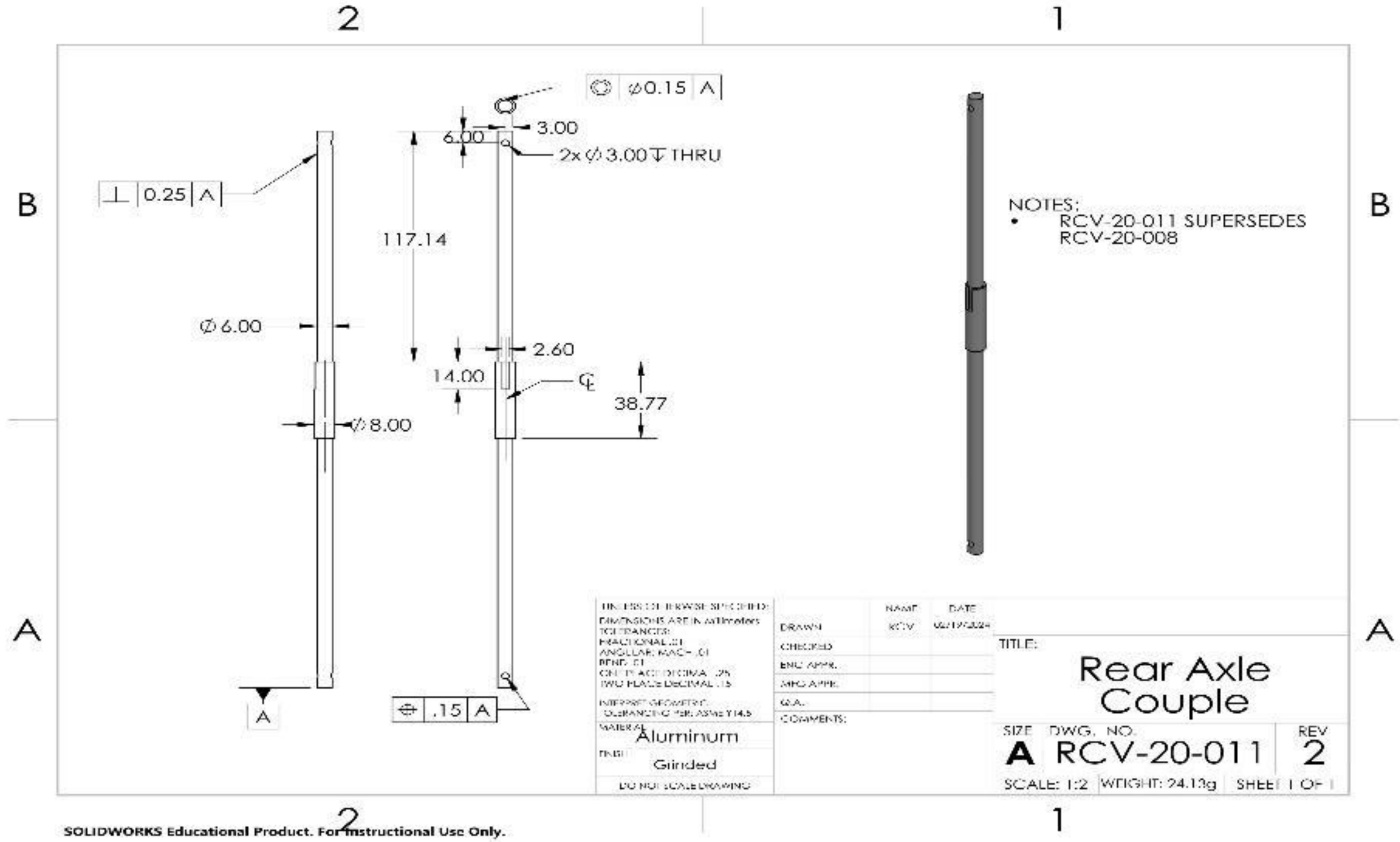


Figure B16. Drawing of Rear Axle

Appendix B17– RCV-20-012 – Rear Axle Square Key

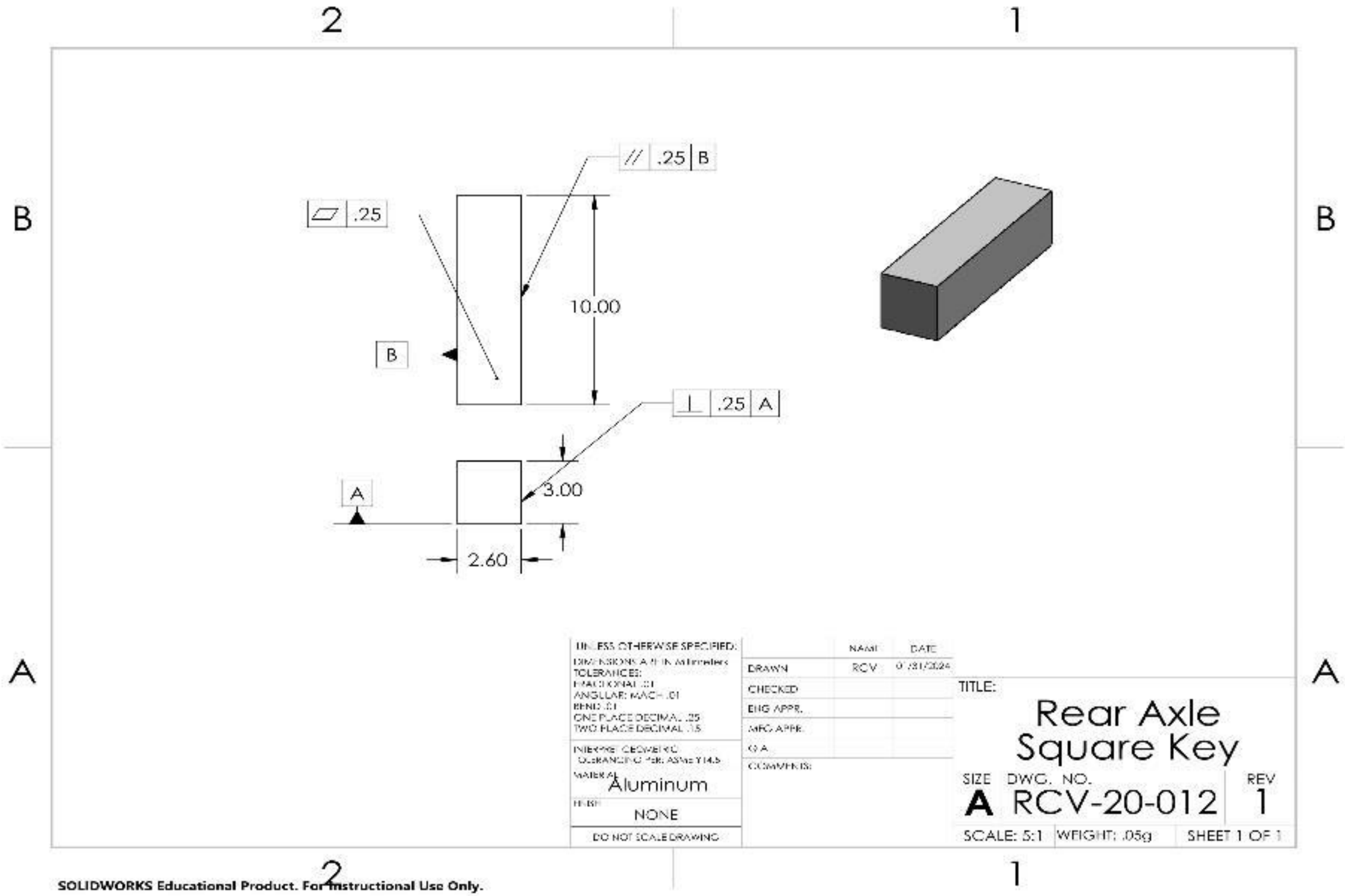


Figure B17. Drawing of Rear Axle Key

Appendix B18– RCV-20-013 –Front Chassis Section

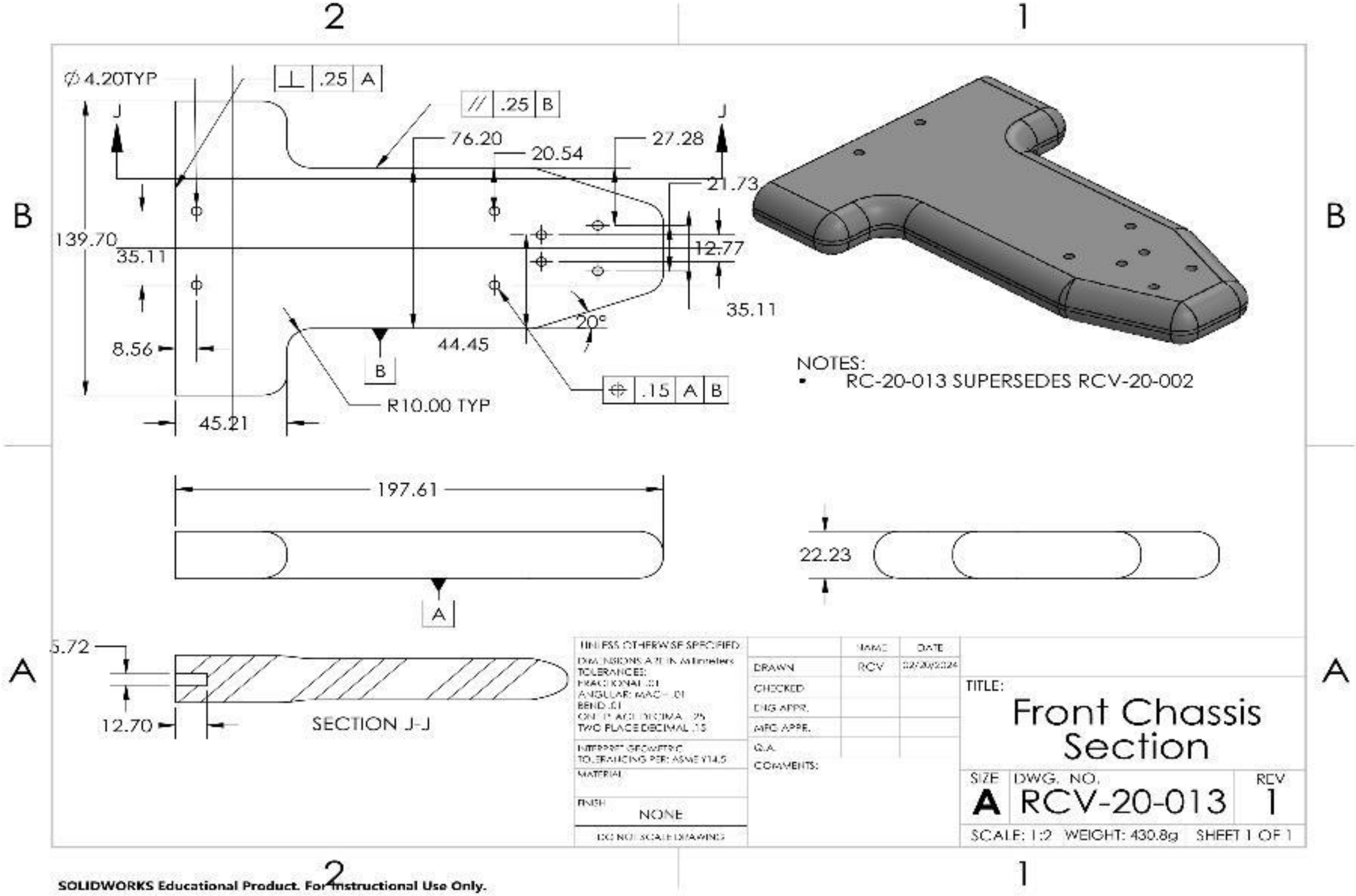


Figure B18. Drawing of Front Chassis Section

Appendix B19– RCV-20-014 –Rear Chassis Section

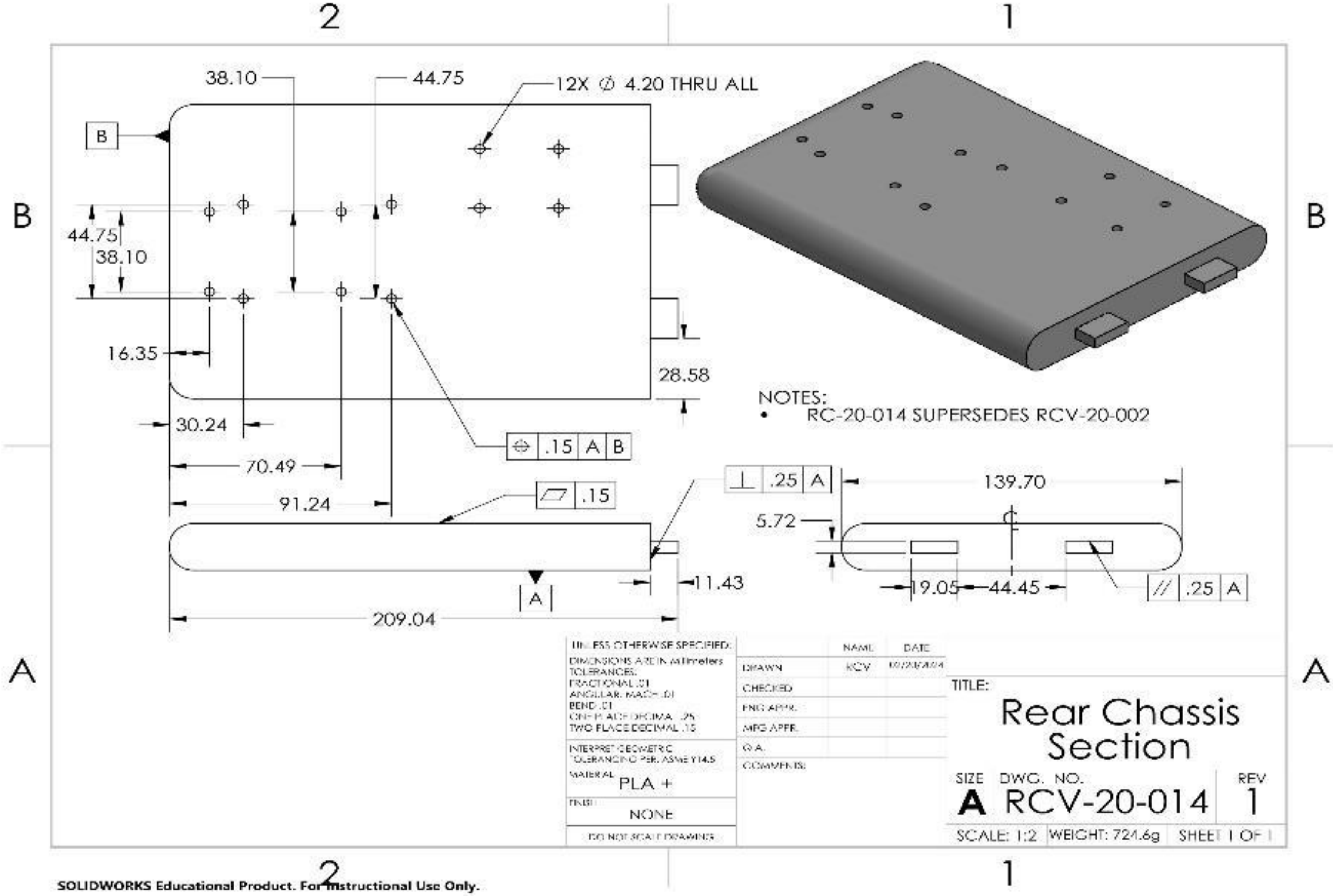


Figure B19. Drawing of Rear Chassis Section

Appendix B20– RCV-20-015 –Gearbox Bottom Half

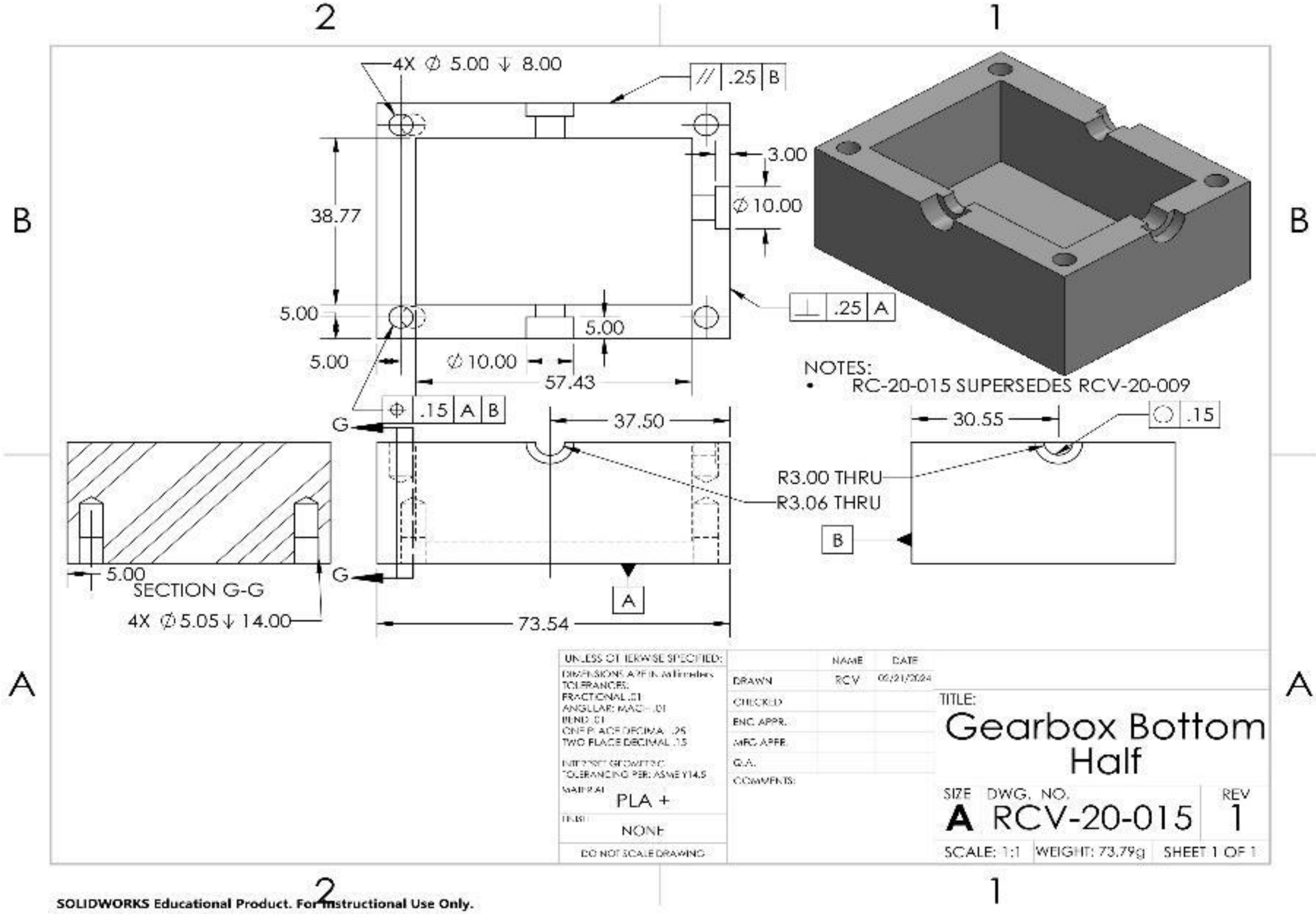


Figure B20. Drawing of the Gearbox’s Bottom Half

Appendix B21– RCV-20-016 –Gearbox Top Half

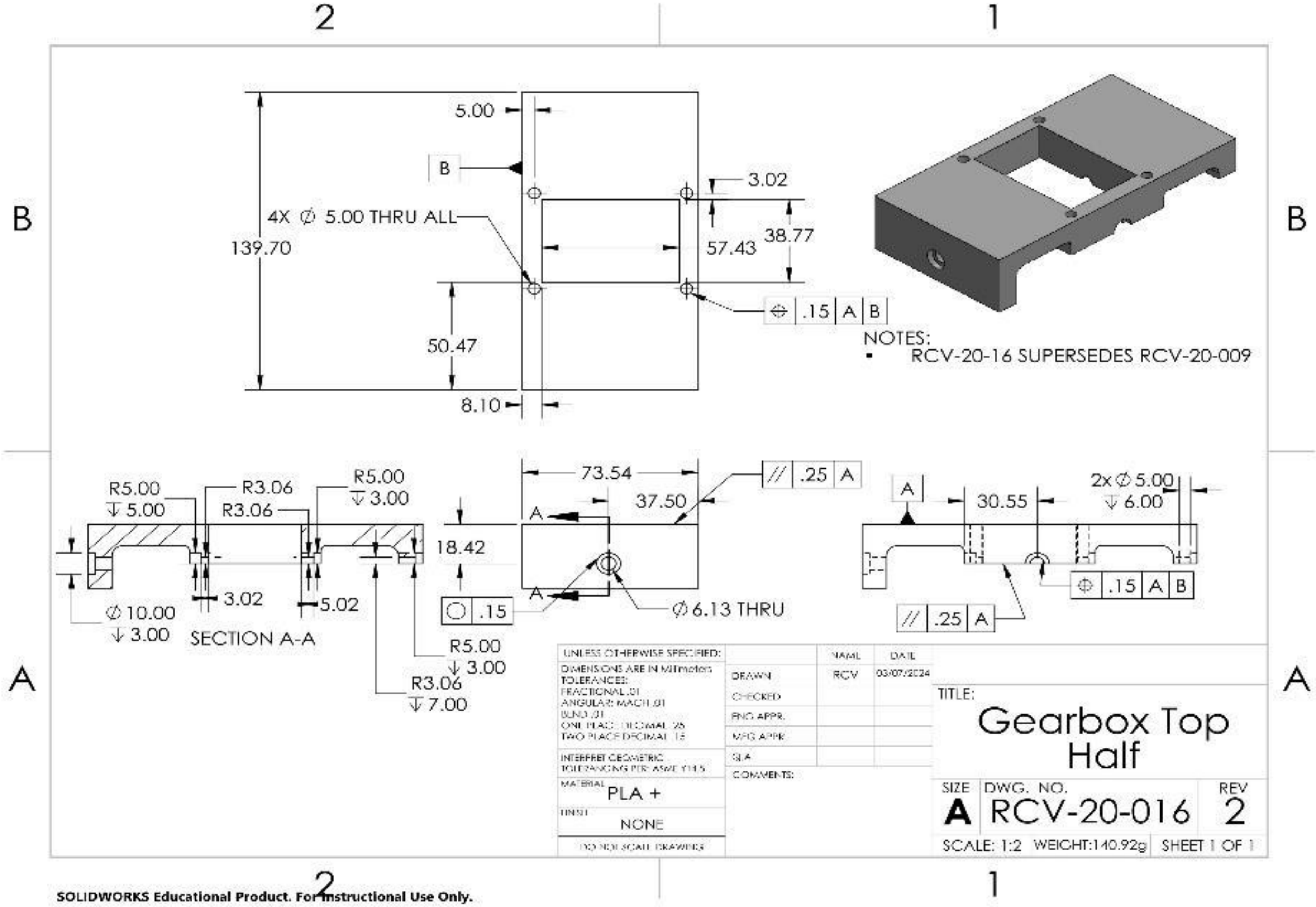


Figure B21. Drawing of Gearbox’s Top Half

Appendix B22– RCV-20-017 –8mm Bore Shaft Collar

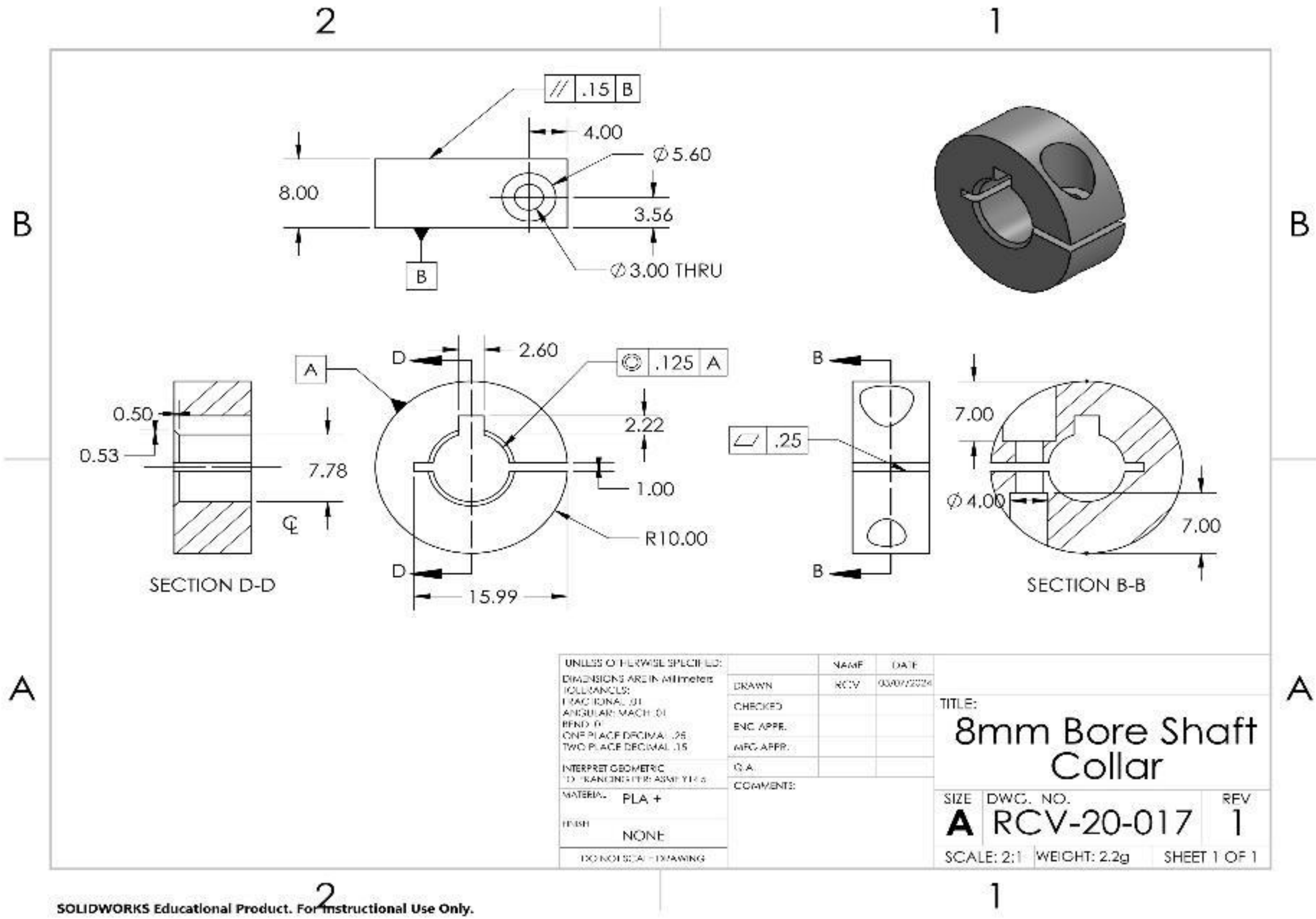


Figure B22. Drawing of 8mm Bore Shaft Collar

Appendix B23– RCV-20-018 –Axle Support Clamp

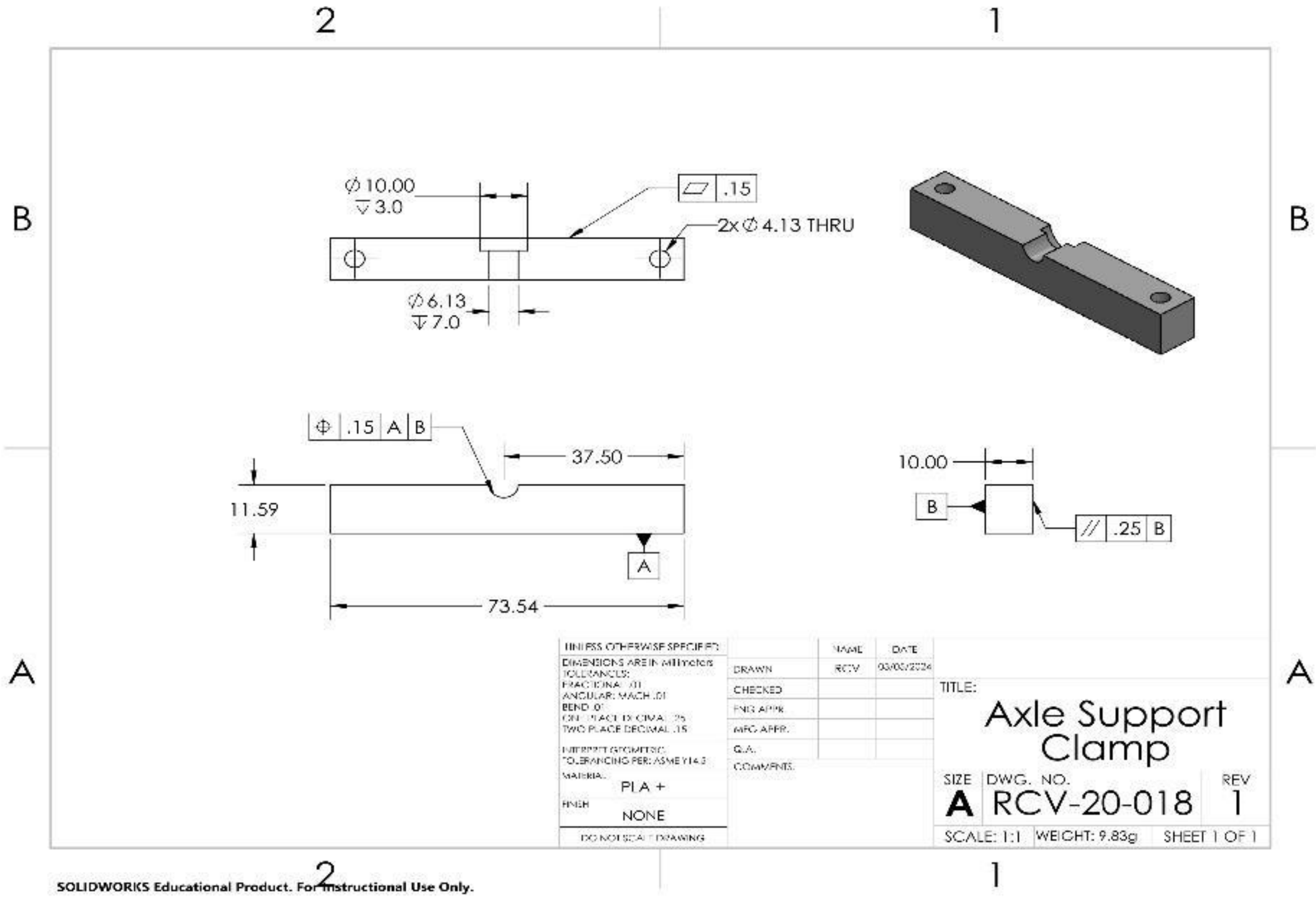


Figure B23. Drawing of Axle Support Clamp

Appendix B24– RCV-55-001 – 7.4 Lipo Battery

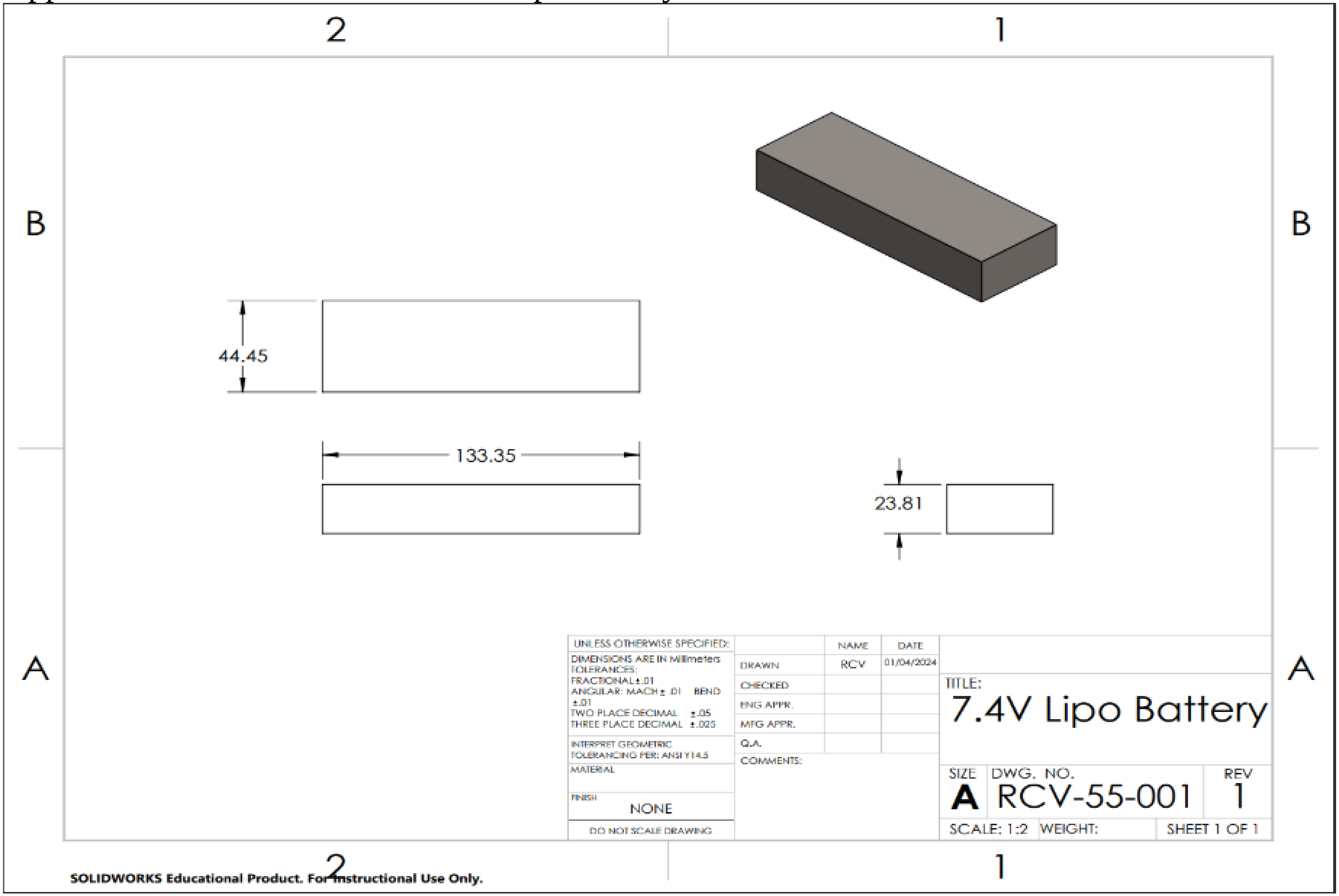


Figure B24. Purchased 7.4V Lipo Battery 2S 50C 5200mAh

Appendix B25– RCV-55-002 – Mabuchi 540-6527 Brushed Motor

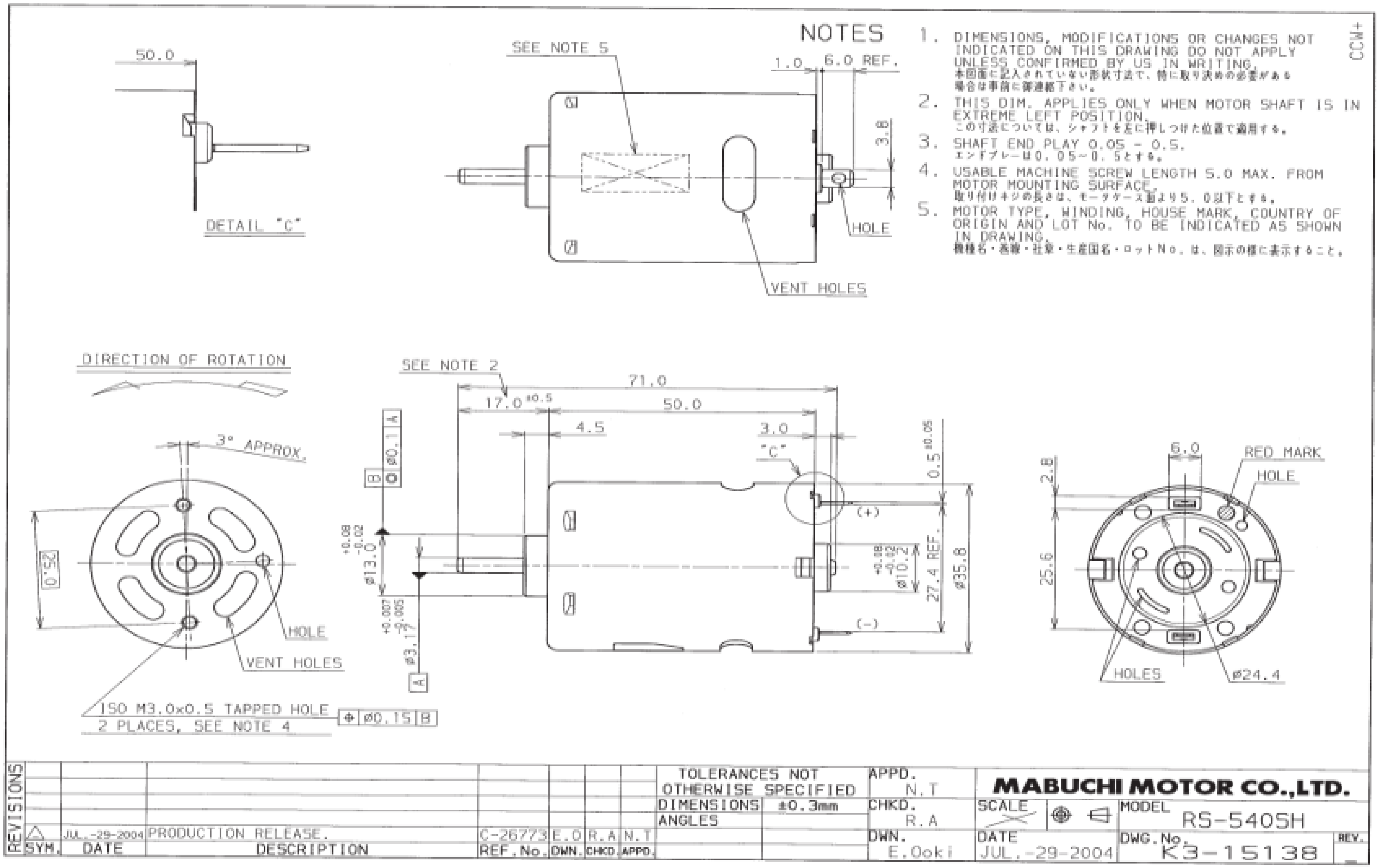


Figure B25. Purchased MABUCHI 540-6527 Brushed Motor 90W

Appendix B26– RCV-55-003 – 6mm Gear Axle

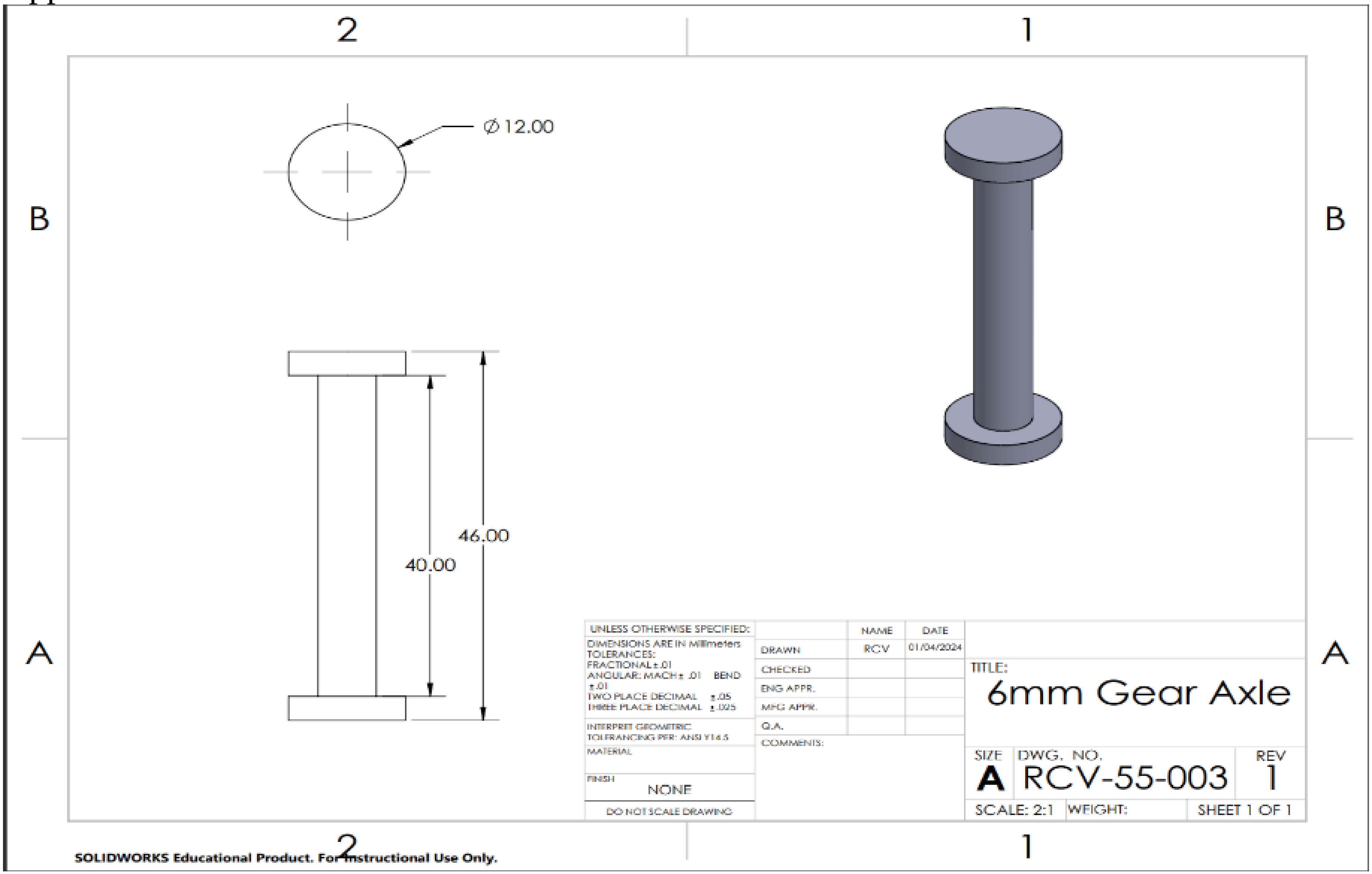


Figure B26. Purchased 6mm gear axle

Appendix B27– RCV-55-004 – 15T Bevel Gear

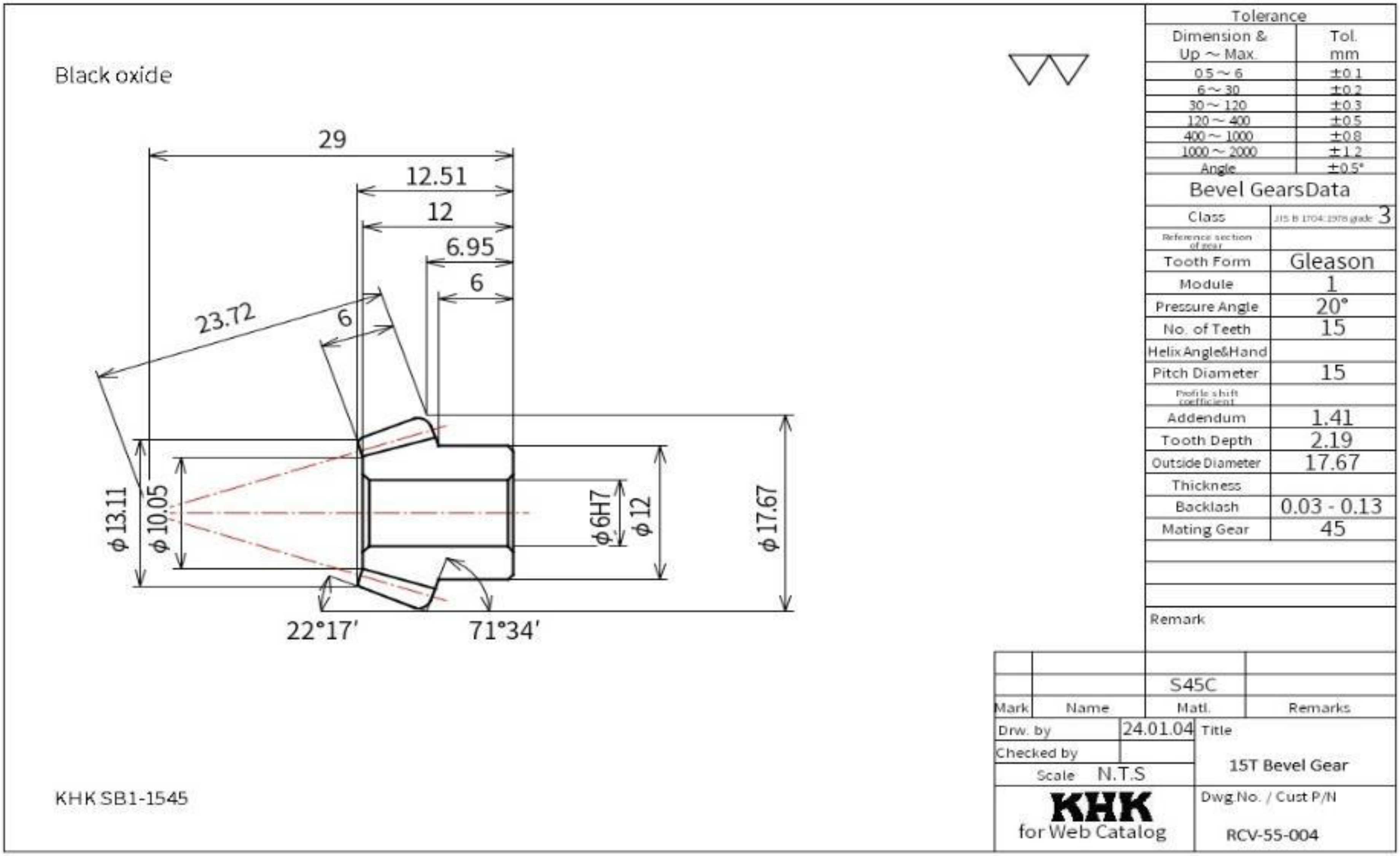


Figure B27. Purchased 15T Bevel Gear

Appendix B28– RCV-20-005 –45T Bevel Gear

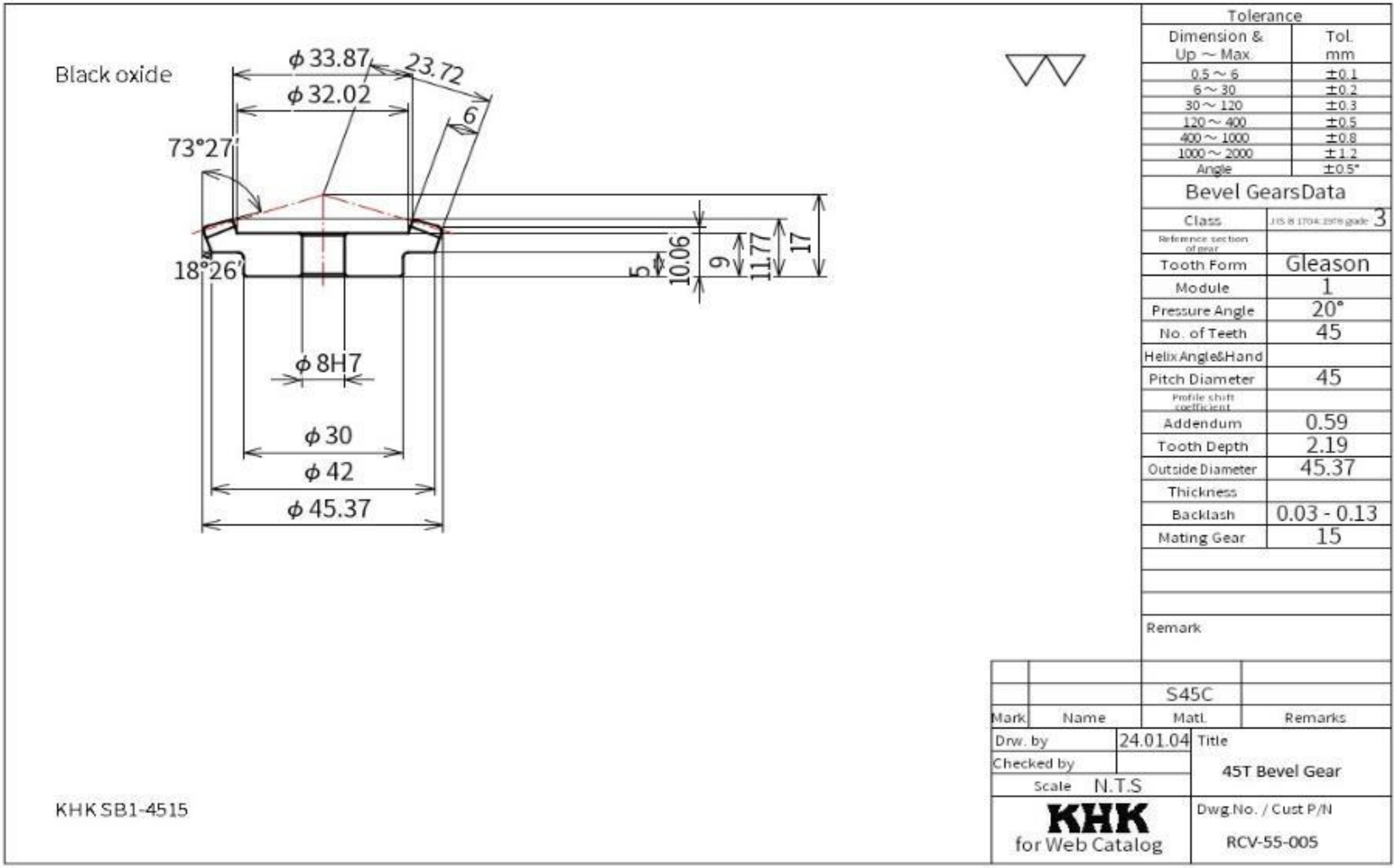


Fig B28. Drawing of 45T bevel gear

Appendix B29- RCV-55-006 – 4mm Ball Bearing

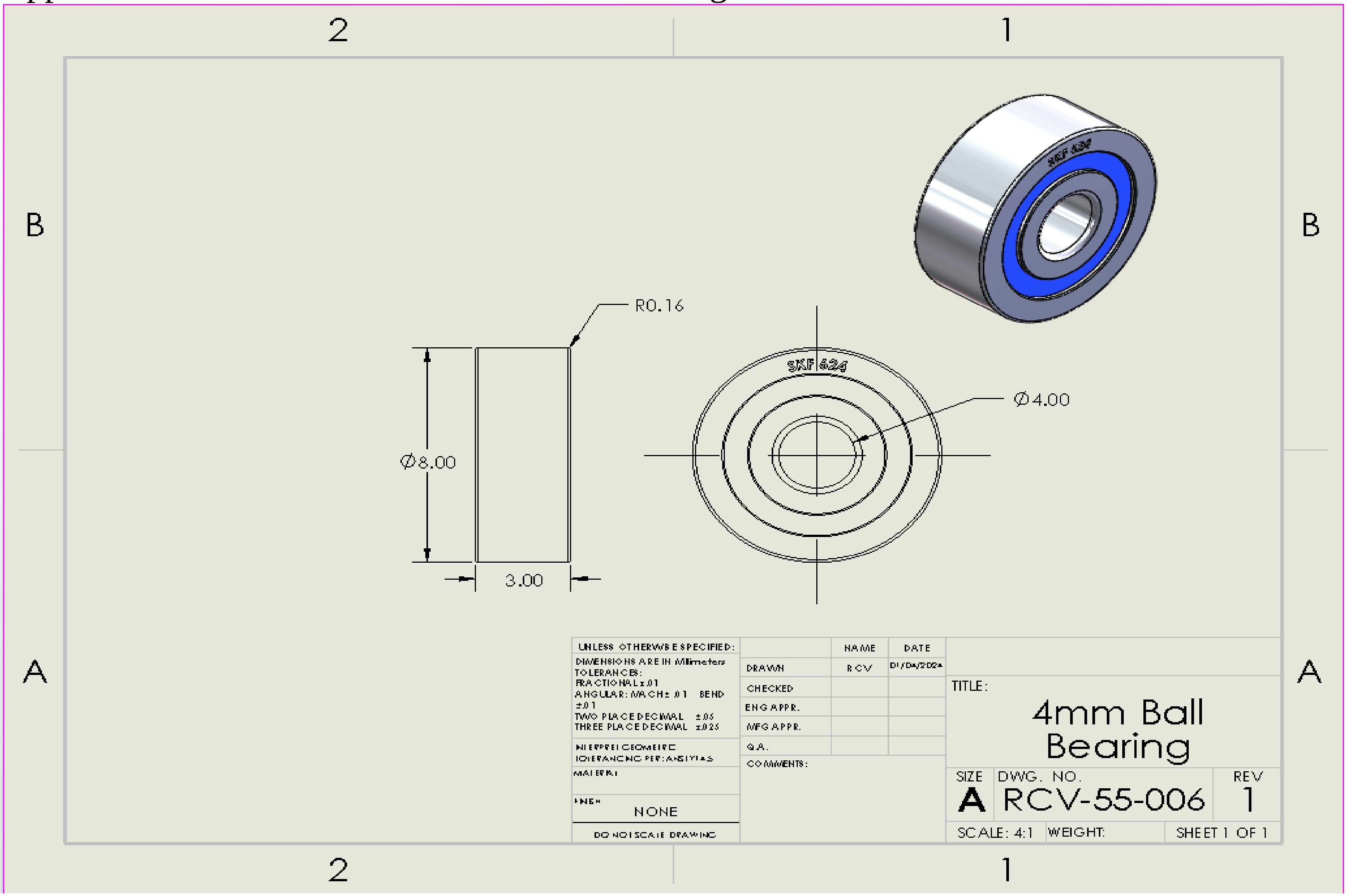


Figure B29. Purchased 4mm Ball Bearing

Appendix B30– RCV-55-007 –6mm Ball Bearing

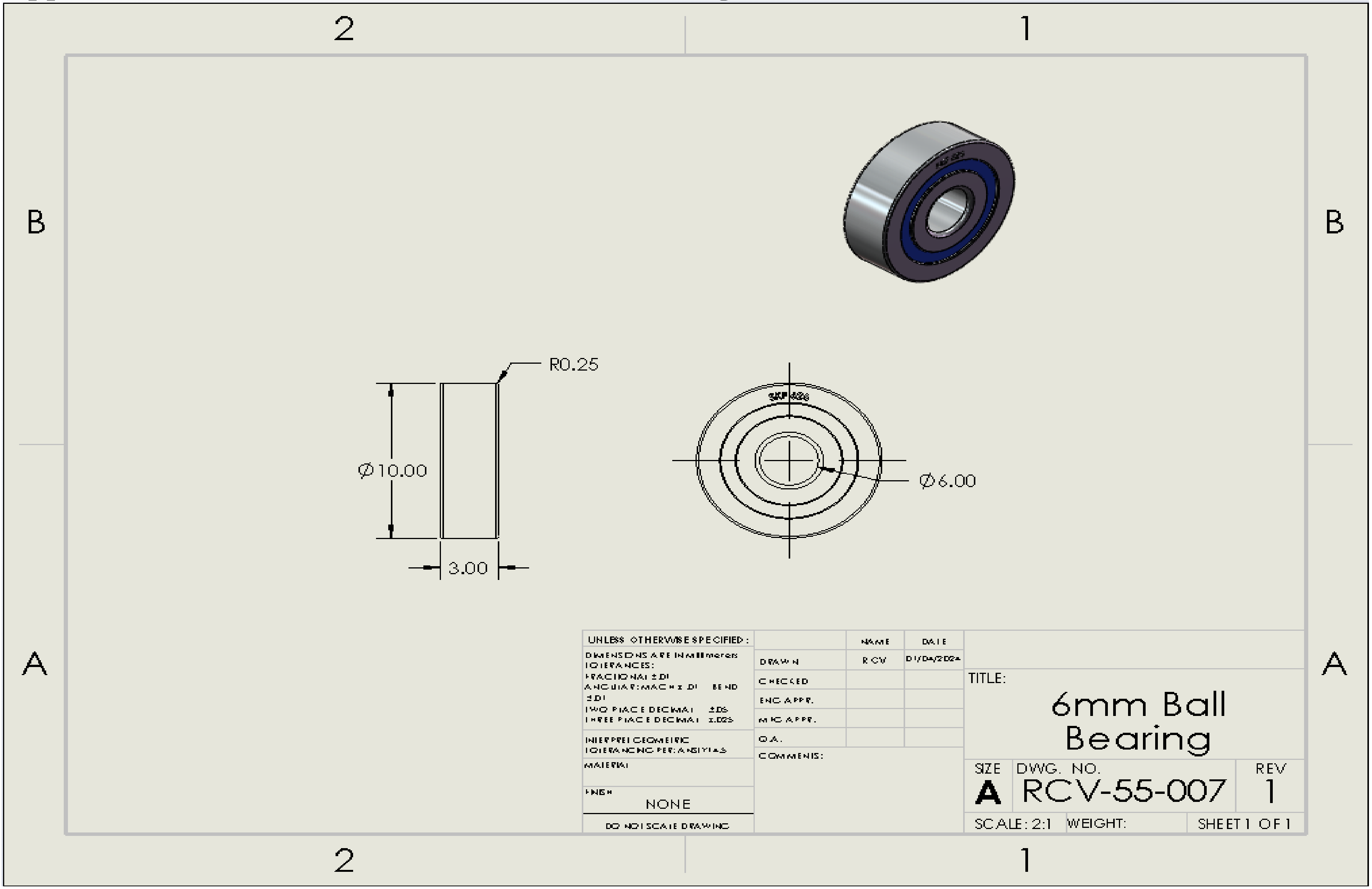


Figure B30.Purchased 6mm Ball Bearing

Appendix B31 – <RXA-10-002> - Front Shock Tower Sub-Assembly

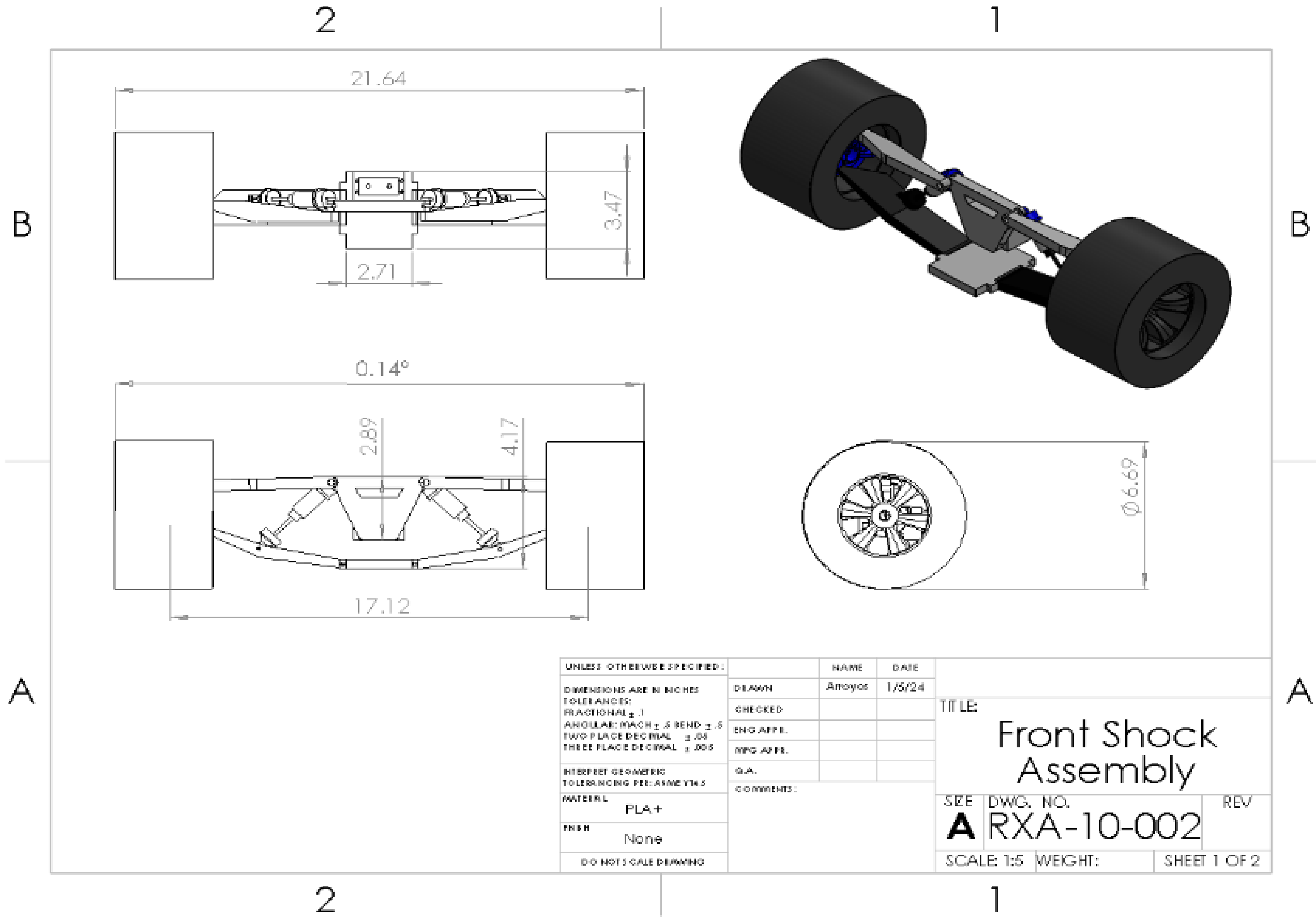


Figure B31. Front Shock Tower Sub-Assembly

Appendix B31(Cont)

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RXA-20-001	Front Shock Tower	1
2	RXA-20-003	Front Lower Left Control Arm	1
3	RXA-20-008	Front Upper Control Arm	2
4	RXA-20-011	Front Lower Right Control Arm	1
5	RXA-55-006	Front Right C- Channel	1
6	RXA-55-007	Front Left C- Channel	2
7	RXA-55-008	Front Left Knuckle	2
8	RXA-55-009	Front Right Knuckle	2
9	RXA-55-011	1/8 RC Monster truck tires	2
10	RXA-20-012	Rear Lower Control Arm Mount	1
11	RXA-55-001	Front Shock	2
12	RXA-20-004	Servo Motor Mount	1

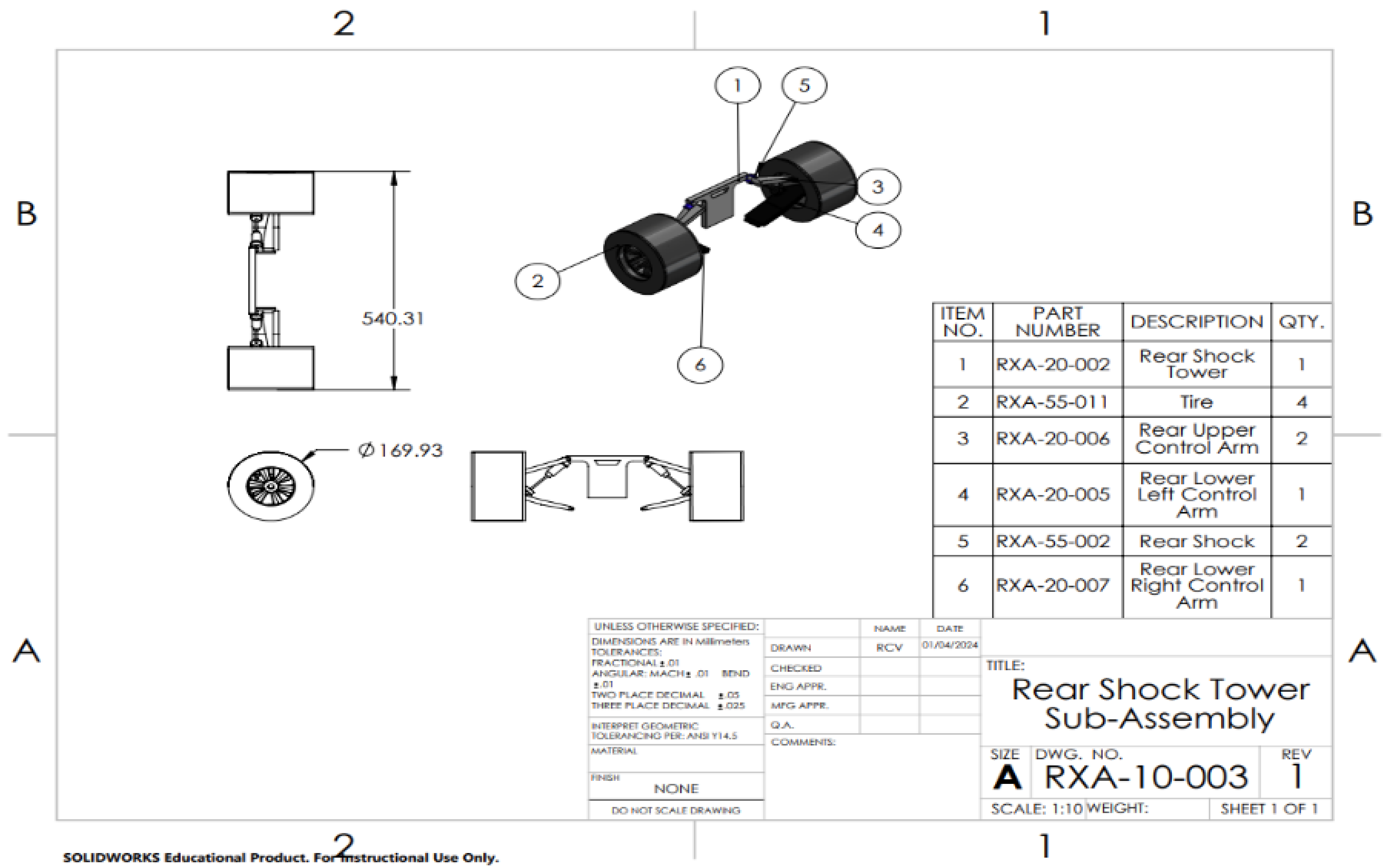
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± .1
ANGULAR: MACH ± .5 BEND ± .5
TWO PLACE DECIMAL ± .05
THREE PLACE DECIMAL ± .005
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
MATERIAL: PLA+
FINISH: None
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	Arroyo	1/5/24
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: Front Shock Assembly
SIZE A DWG. NO. RXA-10-002 REV
SCALE: 1:5 WEIGHT: SHEET 2 OF 2

Figure B31.1. Bill of materials for Front Shock Tower Sub-Assembly

Appendix B32– <RXA-10-003> - Rear Shock Tower Sub-Assembly



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	RXA-20-002	Rear Shock Tower	1
2	RXA-55-011	Tire	4
3	RXA-20-006	Rear Upper Control Arm	2
4	RXA-20-005	Rear Lower Left Control Arm	1
5	RXA-55-002	Rear Shock	2
6	RXA-20-007	Rear Lower Right Control Arm	1

Figure B32. Rear Shock Tower Sub-Assembly

Appendix B33 – <RXA-20-001> - Front shock tower

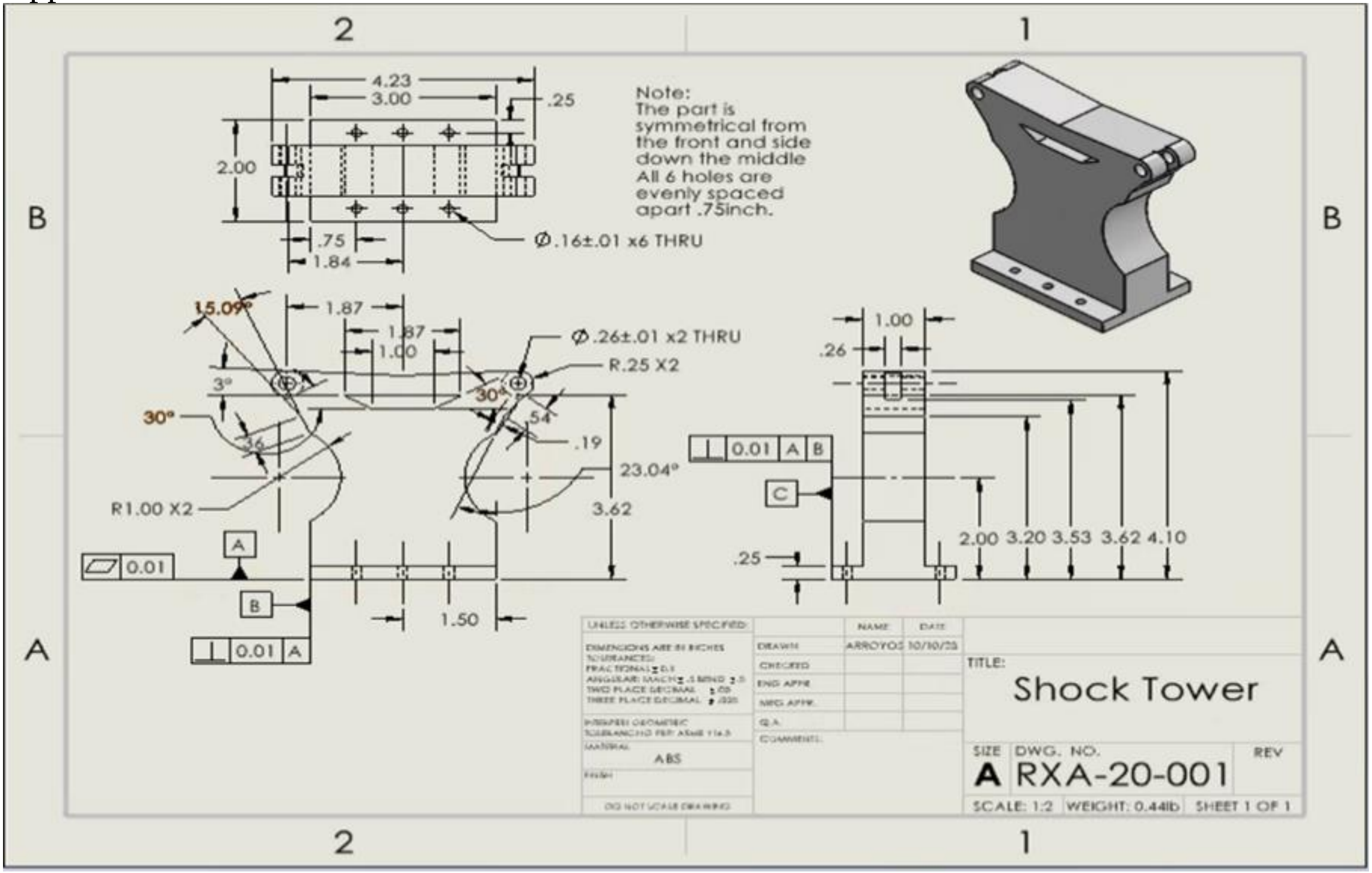


Figure B33- Receiver mount drawing

Appendix B34– <RXA-20-002> - Rear shock tower

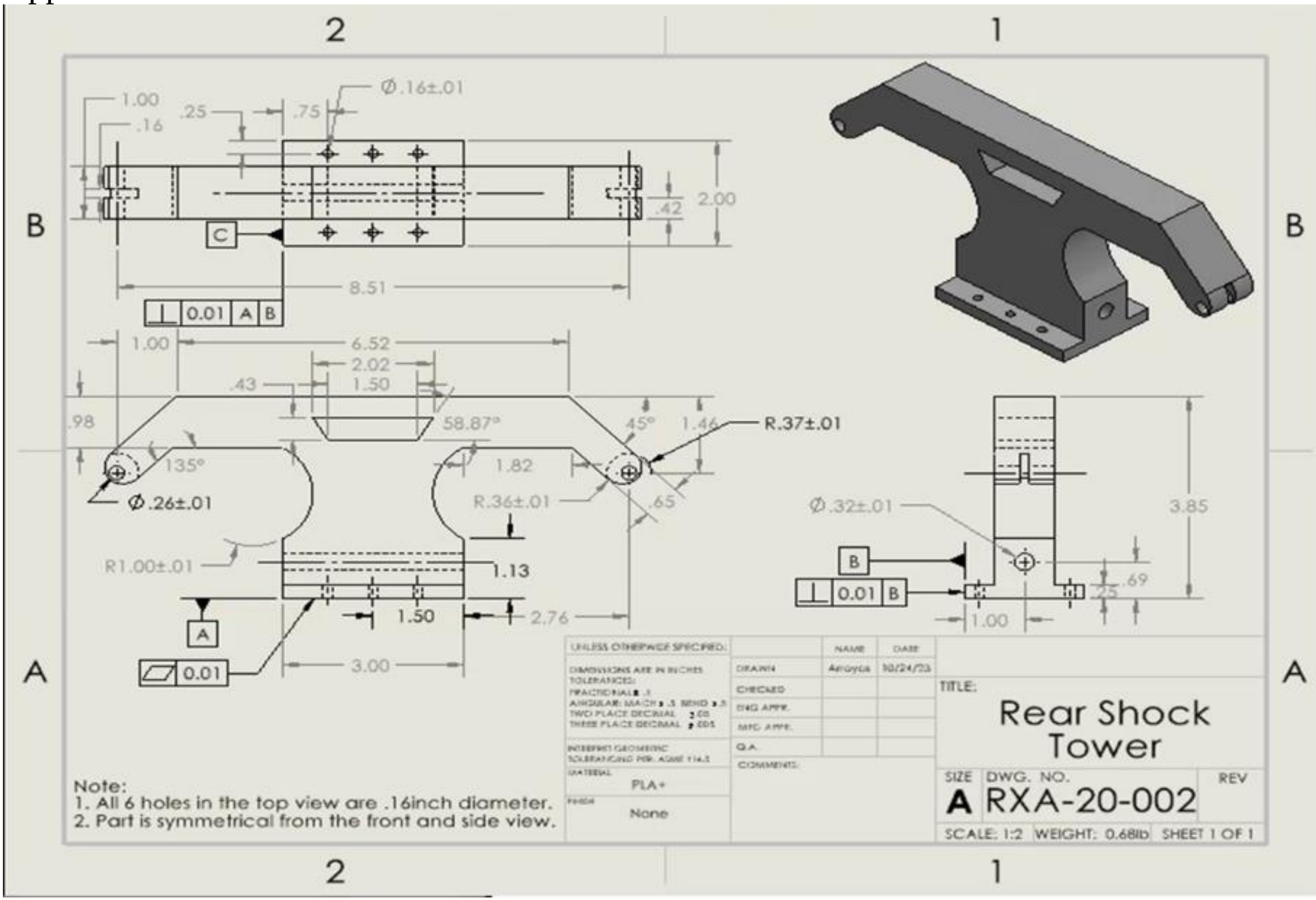


Figure B34- Drawing of the rear shock tower.

Appendix B35– <RXA-20-003> - Lower control arm

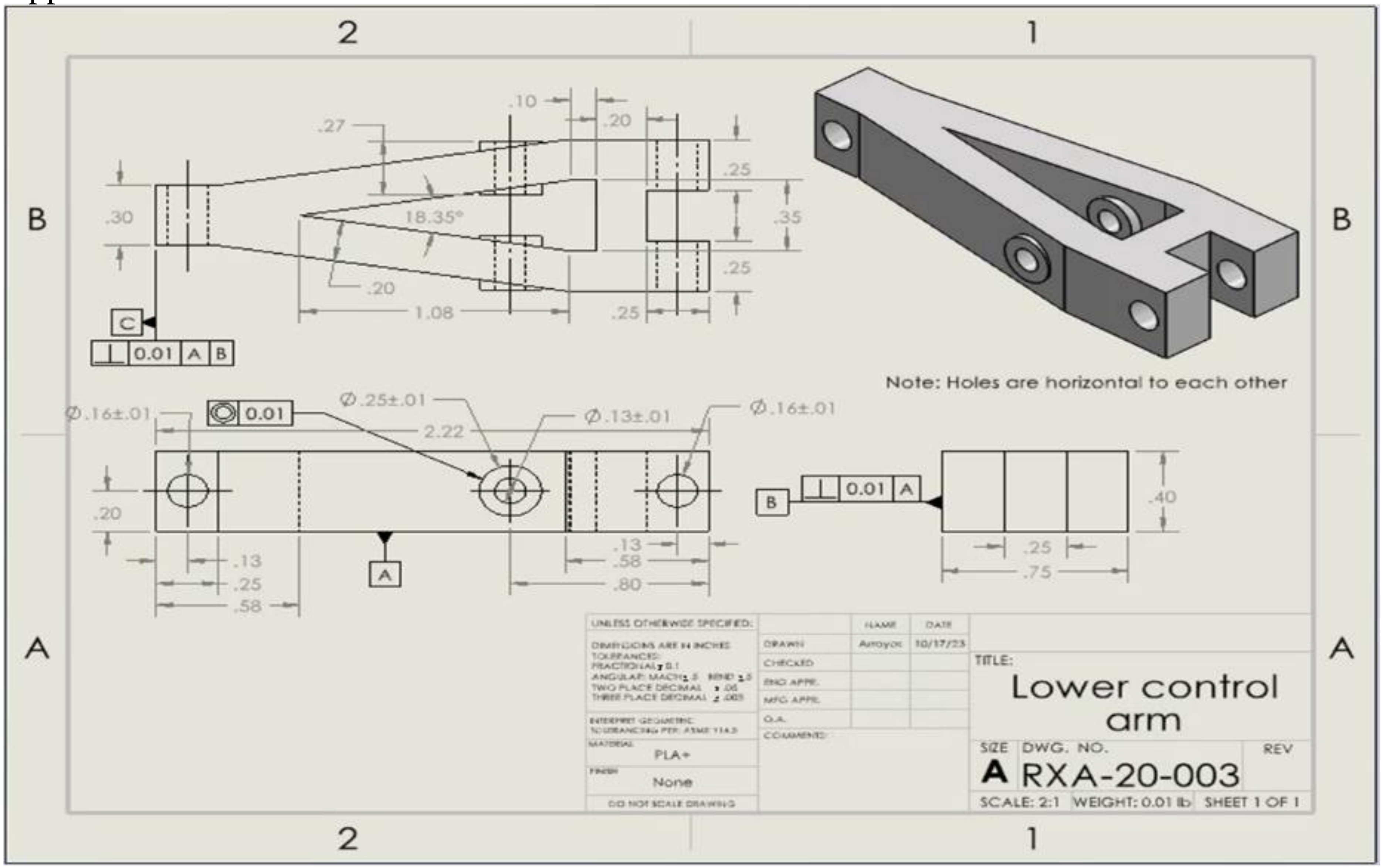


Figure B35- Drawing of the lower control arm.

Appendix B36– <RXA-20-004> - Servo Motor Mount

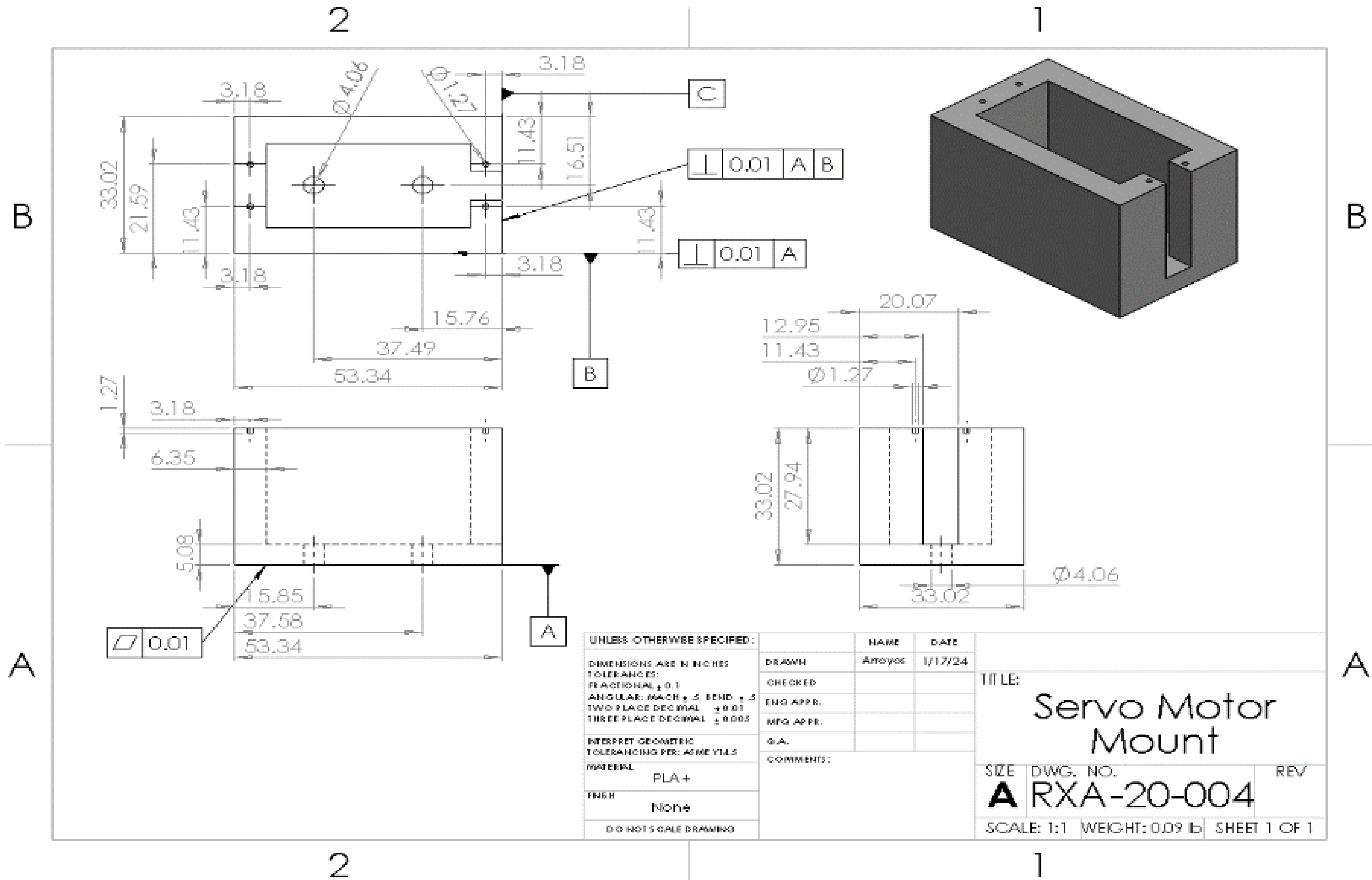


Figure B36- Servo Motor Mount drawing.

Appendix B37 – <RXA-20-005> - Rear left lower control arm

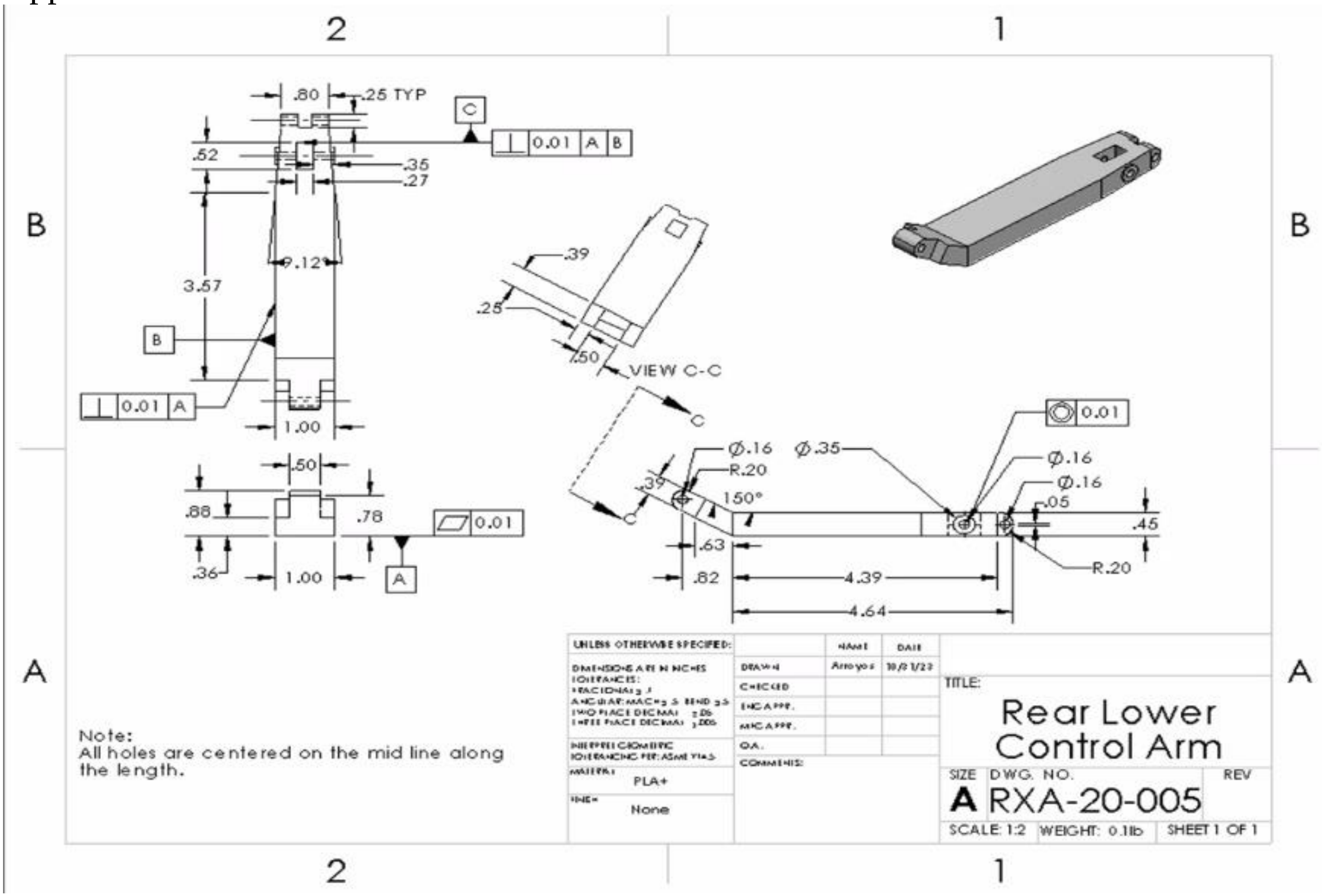


Figure B37- Rear left lower control arm drawing.

Appendix B38– <RXA-20-006> - Rear upper control arm

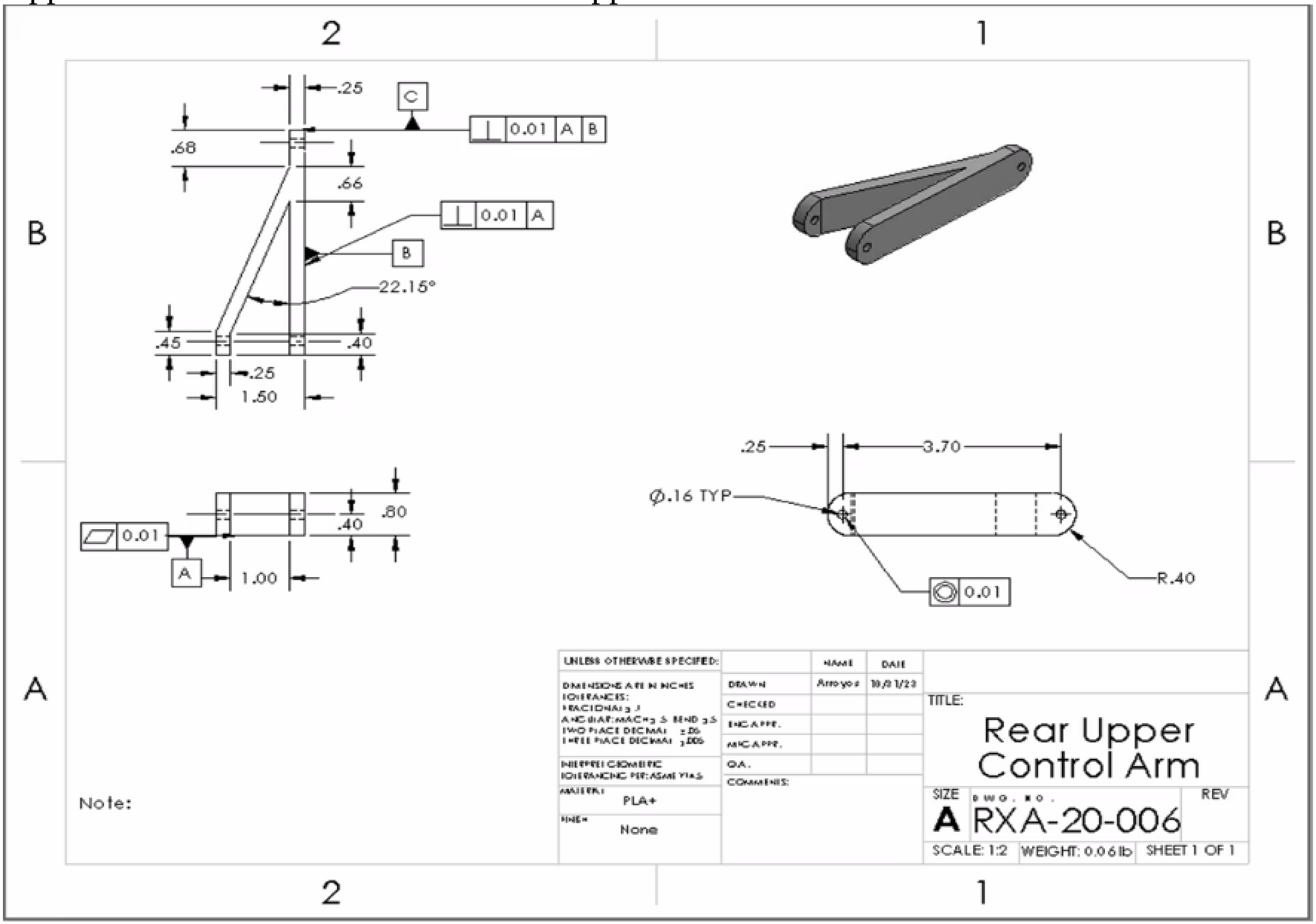


Figure B36- Rear upper control arm drawing.

Appendix B39 – <RXA-20-007> - Rear Lower Right Control Arm

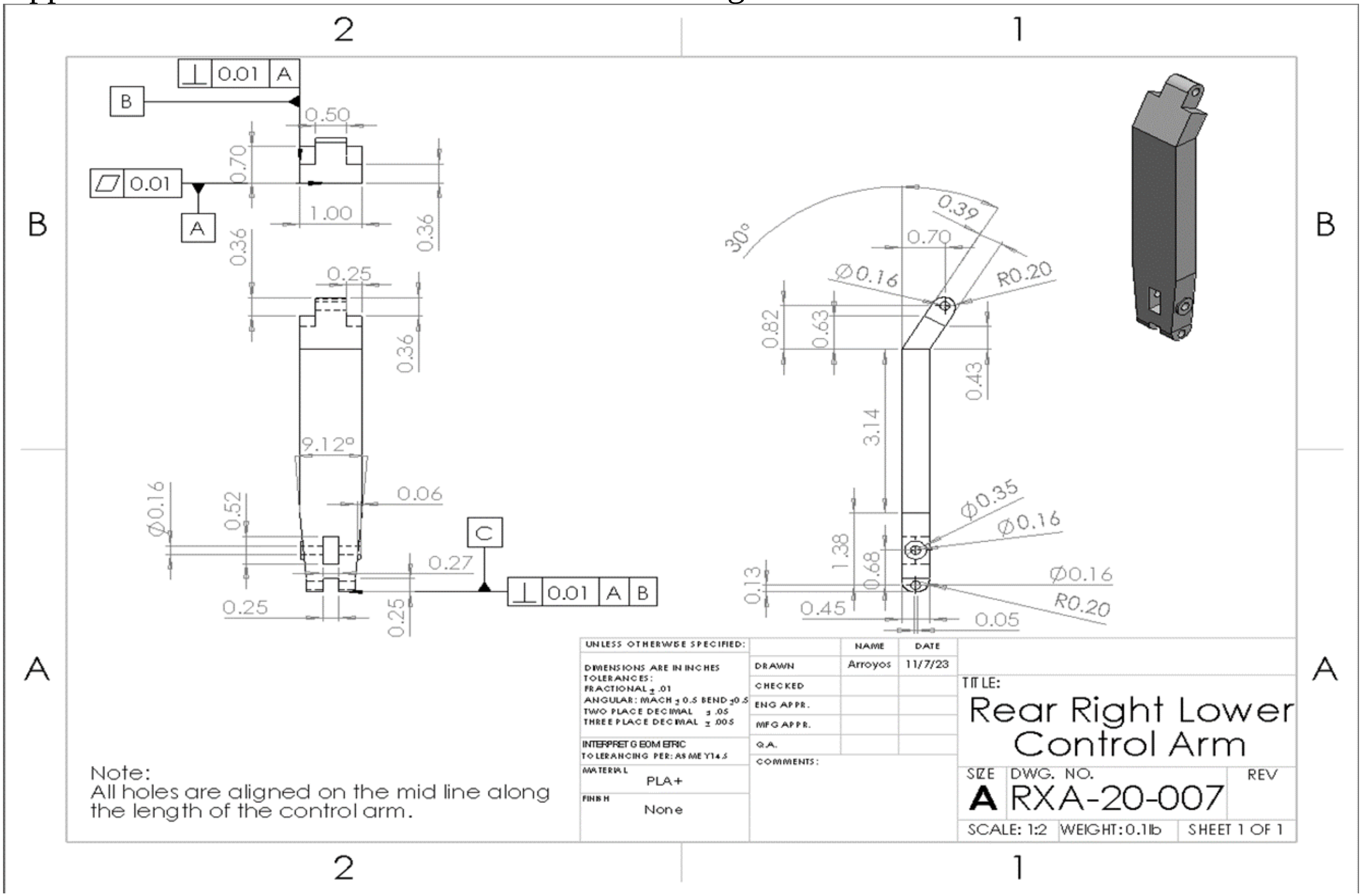


Figure B39- Rear right lower control arm drawing

Appendix B40 – <RXA-20-008> -Front Upper Left Control Arm

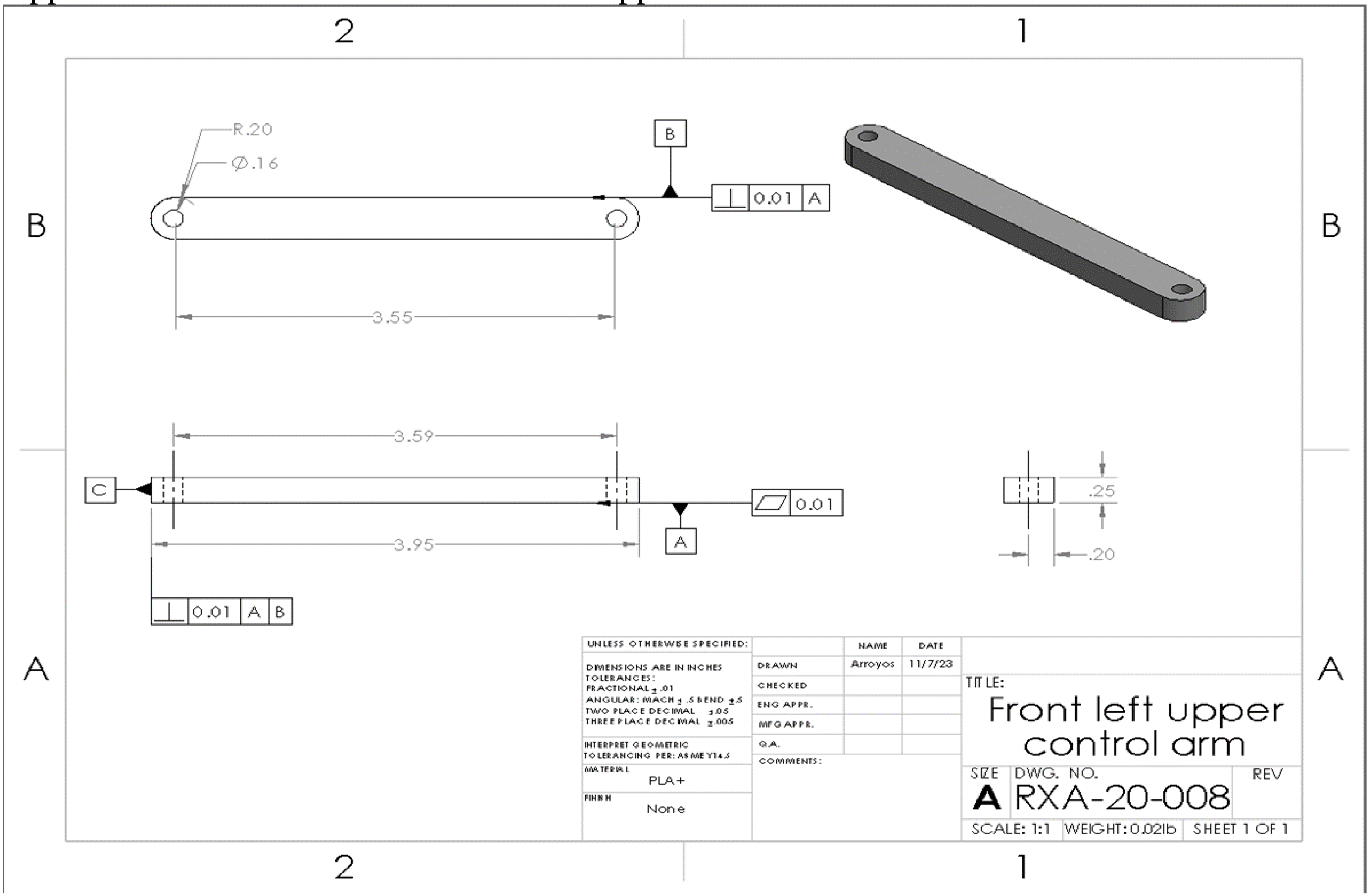


Figure B40- Front left upper control arm drawing.

Appendix B41 – <RXA-20-009> -Receiver Mount

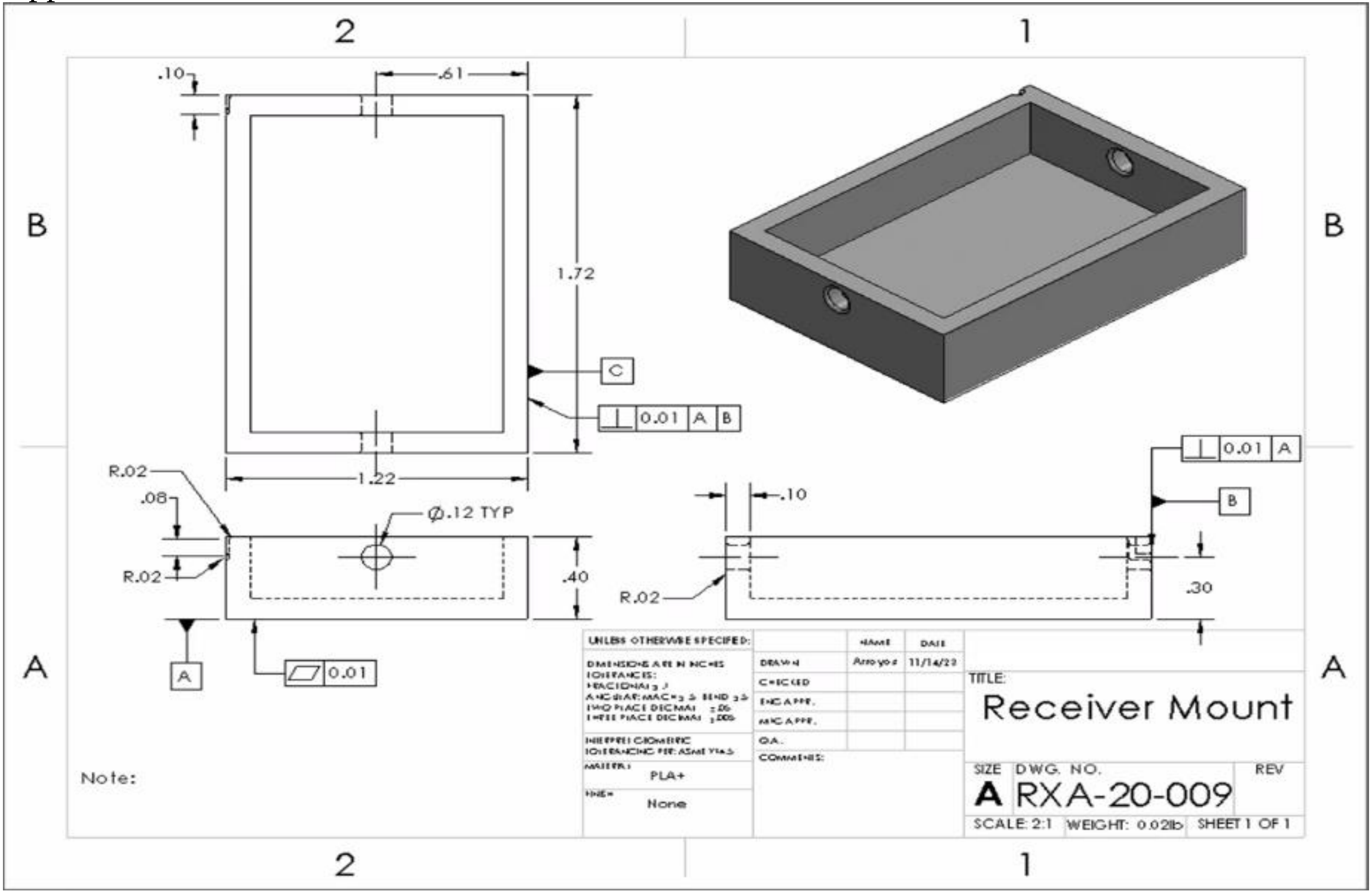


Figure B41- Receiver mount drawing.

Appendix B42– <RXA-20-010> -ESC Mount

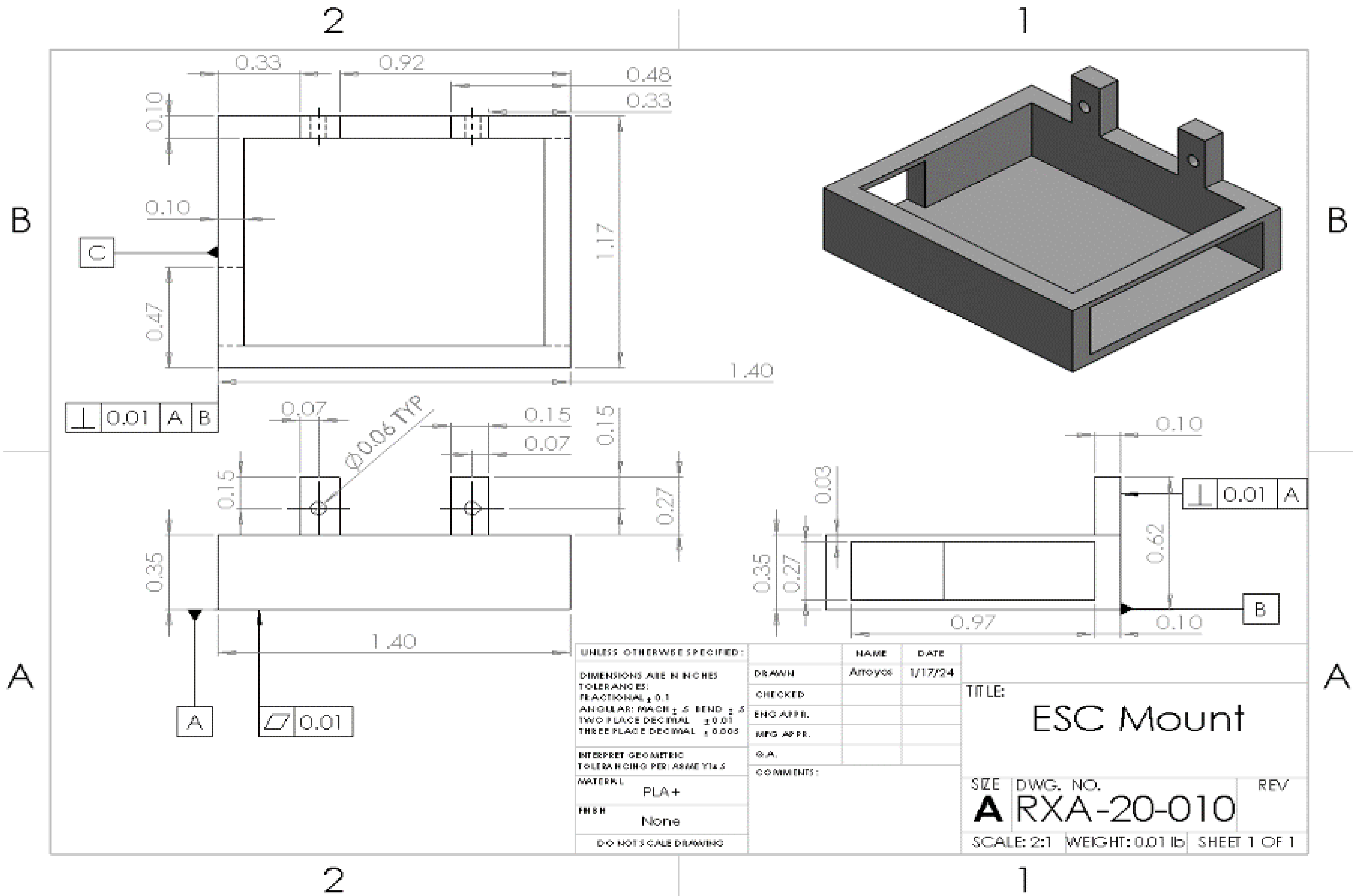


Figure B42- ESC mount

Appendix B43 – RXA-20-011-Front Lower Right Control Arm

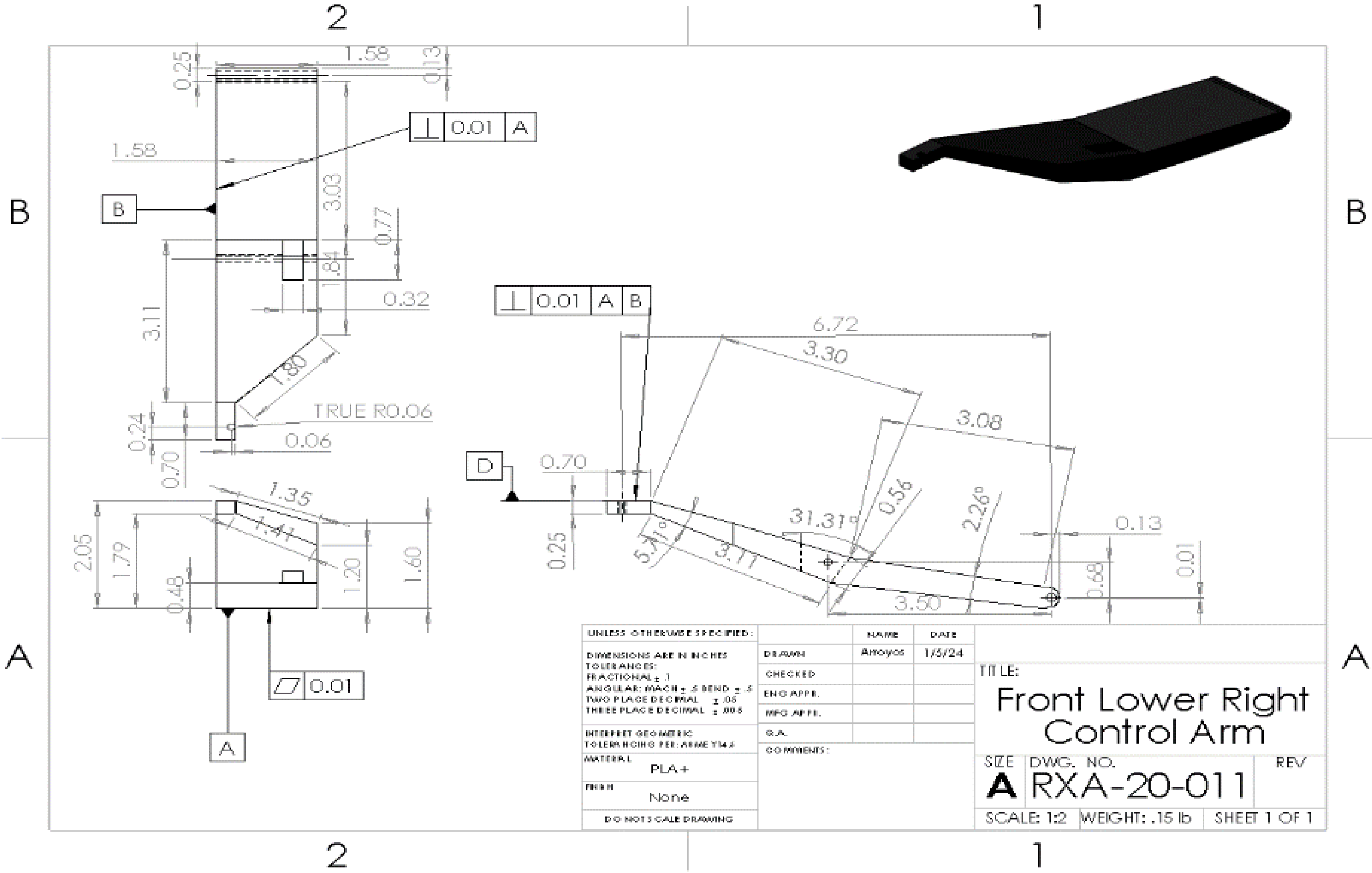


Figure B43. Front Lower Right Control Arm

Appendix B44 – RXA-20-012-Front Lower Control Arm Mount

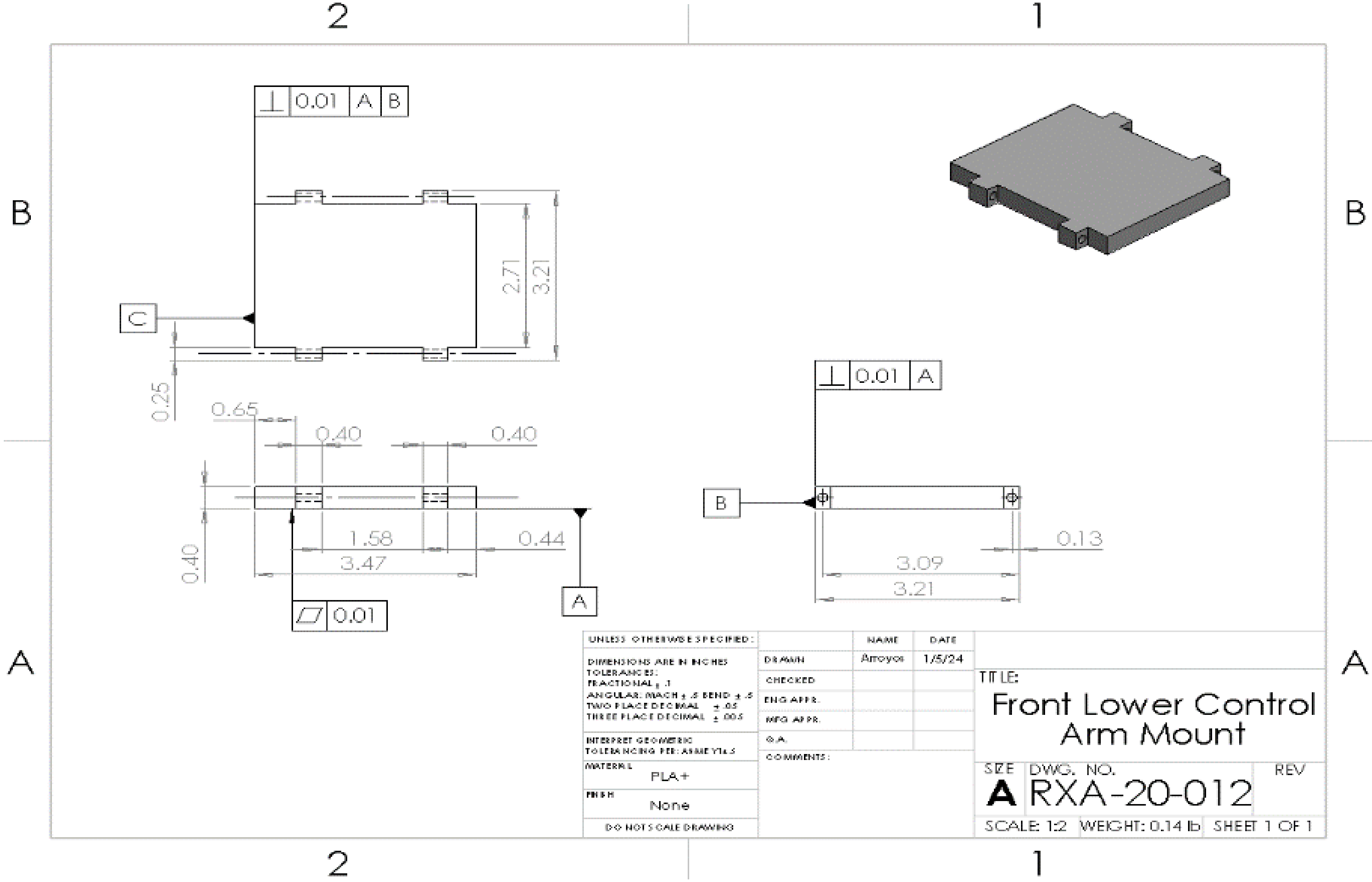


Figure B44. Front Lower control Arm

Appendix B45 – RXA-20-013-Rear Lower Control Arm Mount

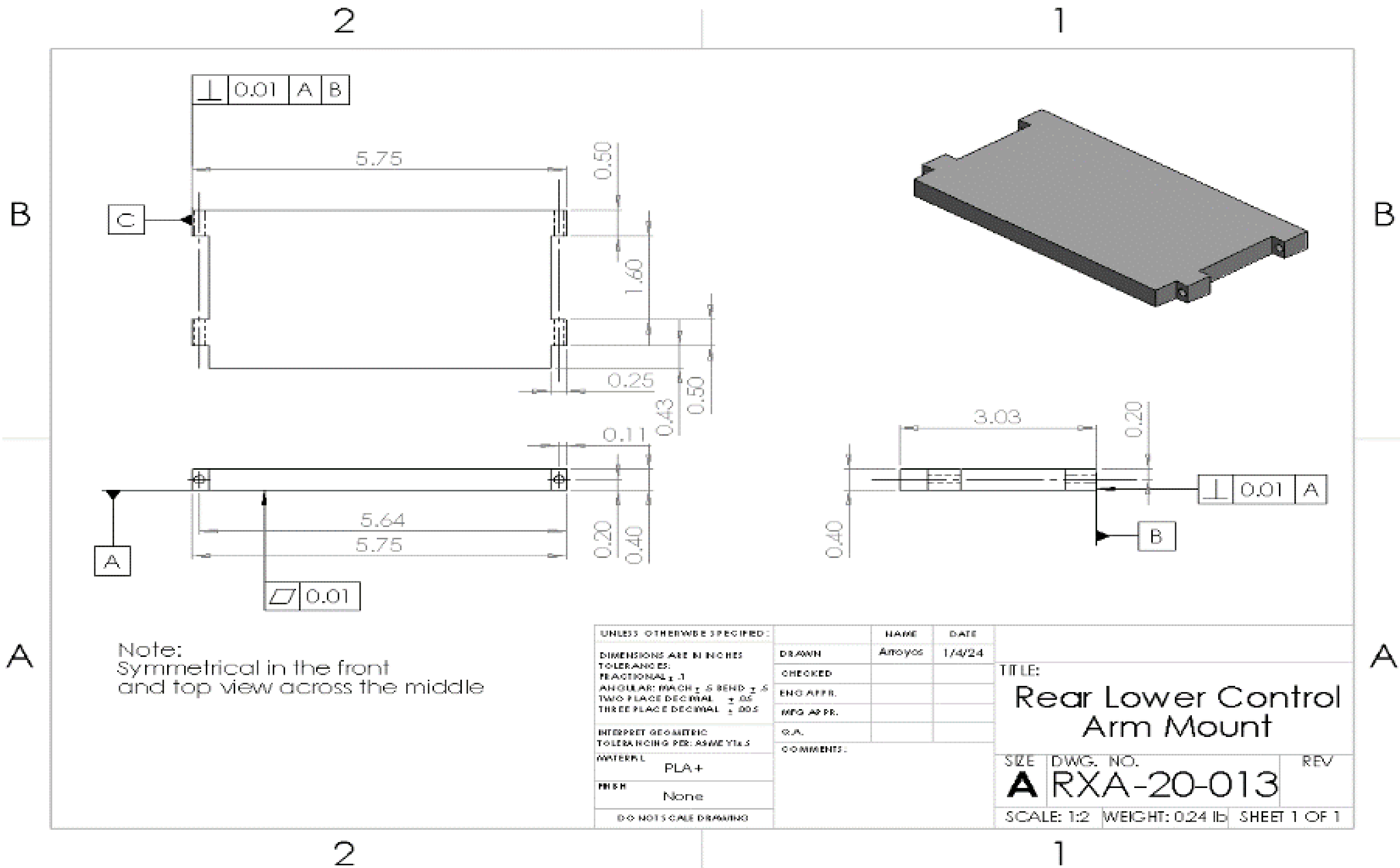


Figure B45. Rear Lower Control Arm mount

Appendix B46 – RXA-20-014-Right Steering Rod

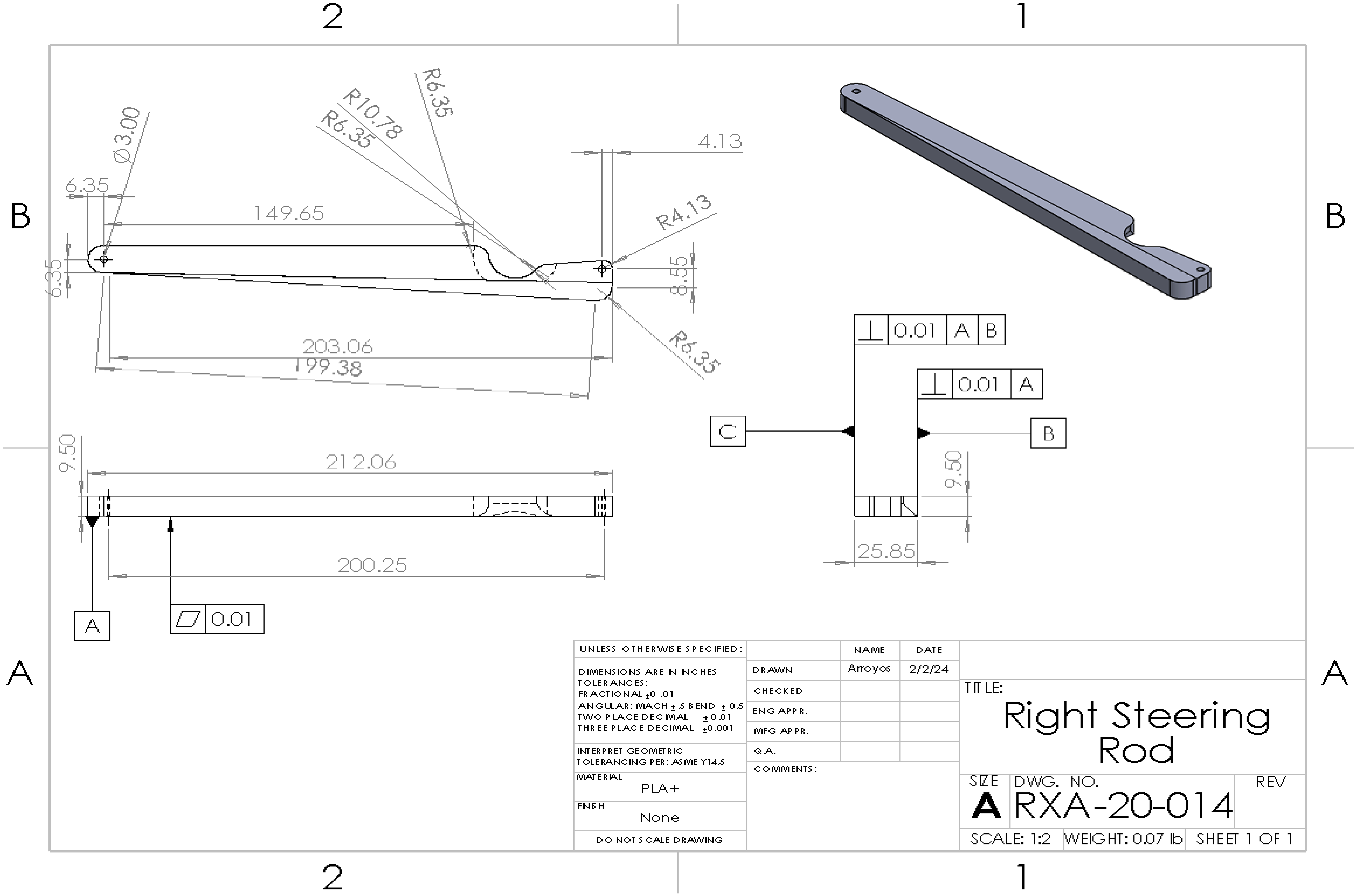


Figure B46. Right steering rod

Appendix B47 – RXA-20-015- Left Steering Rod

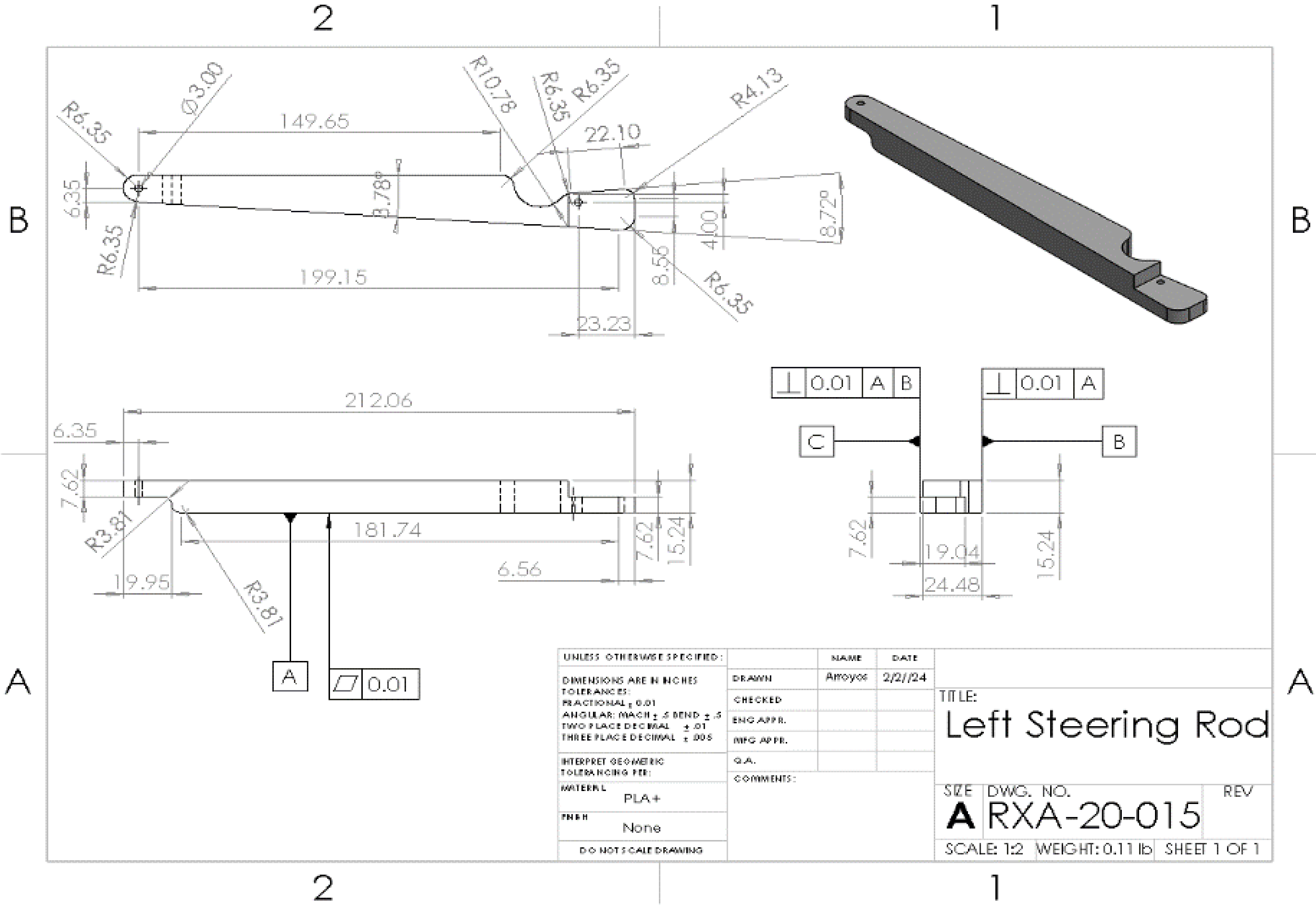


Figure B47. Left steering rod

Appendix B48 – RXA-55-001-Front Shocks

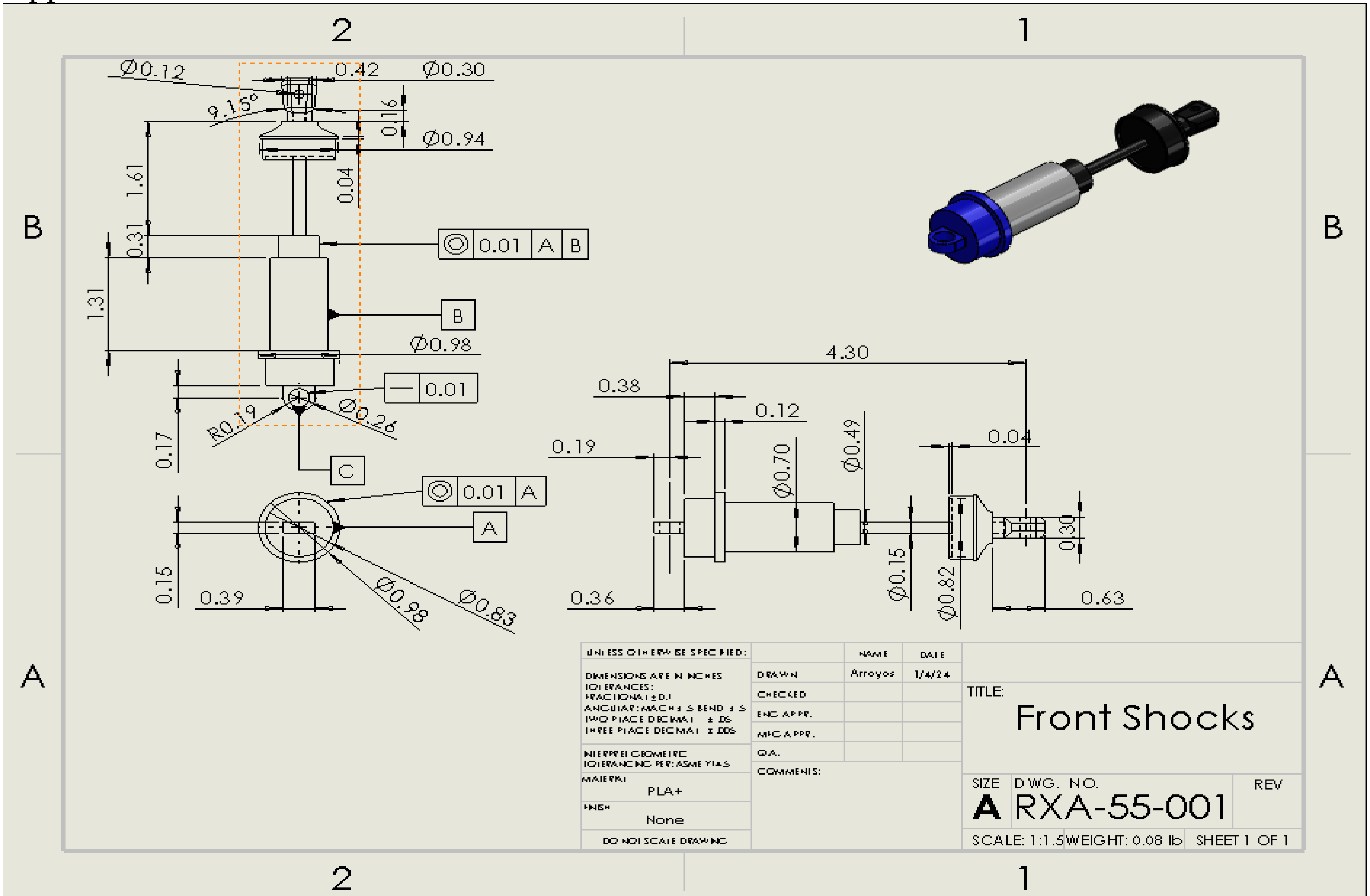


Figure B48. Purchased Front Shocks

Appendix B49 – RXA-55-002-Rear Shocks

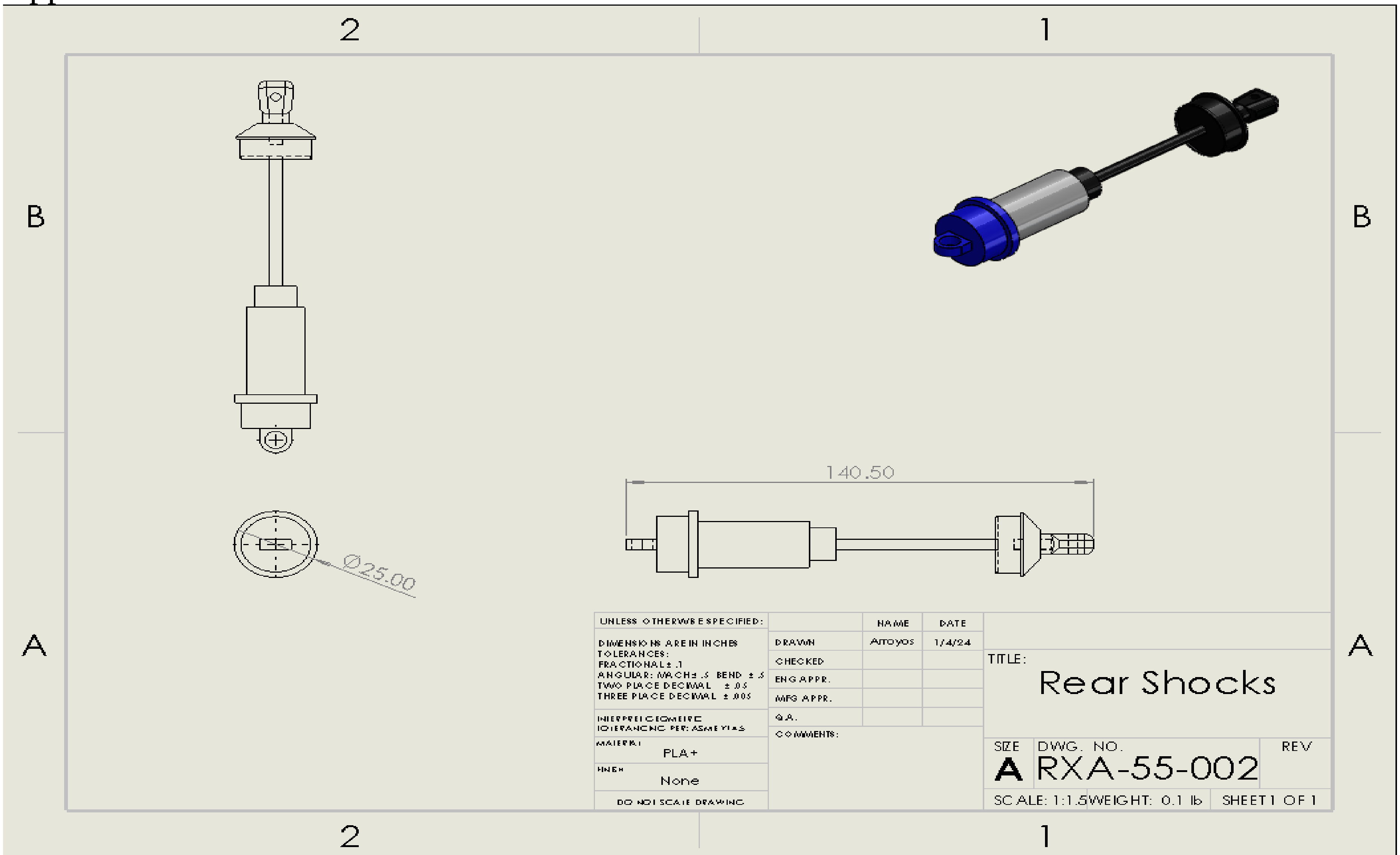


Figure B49. Purchased Rear Shocks

Appendix B50 – RXA-55-003-reciever

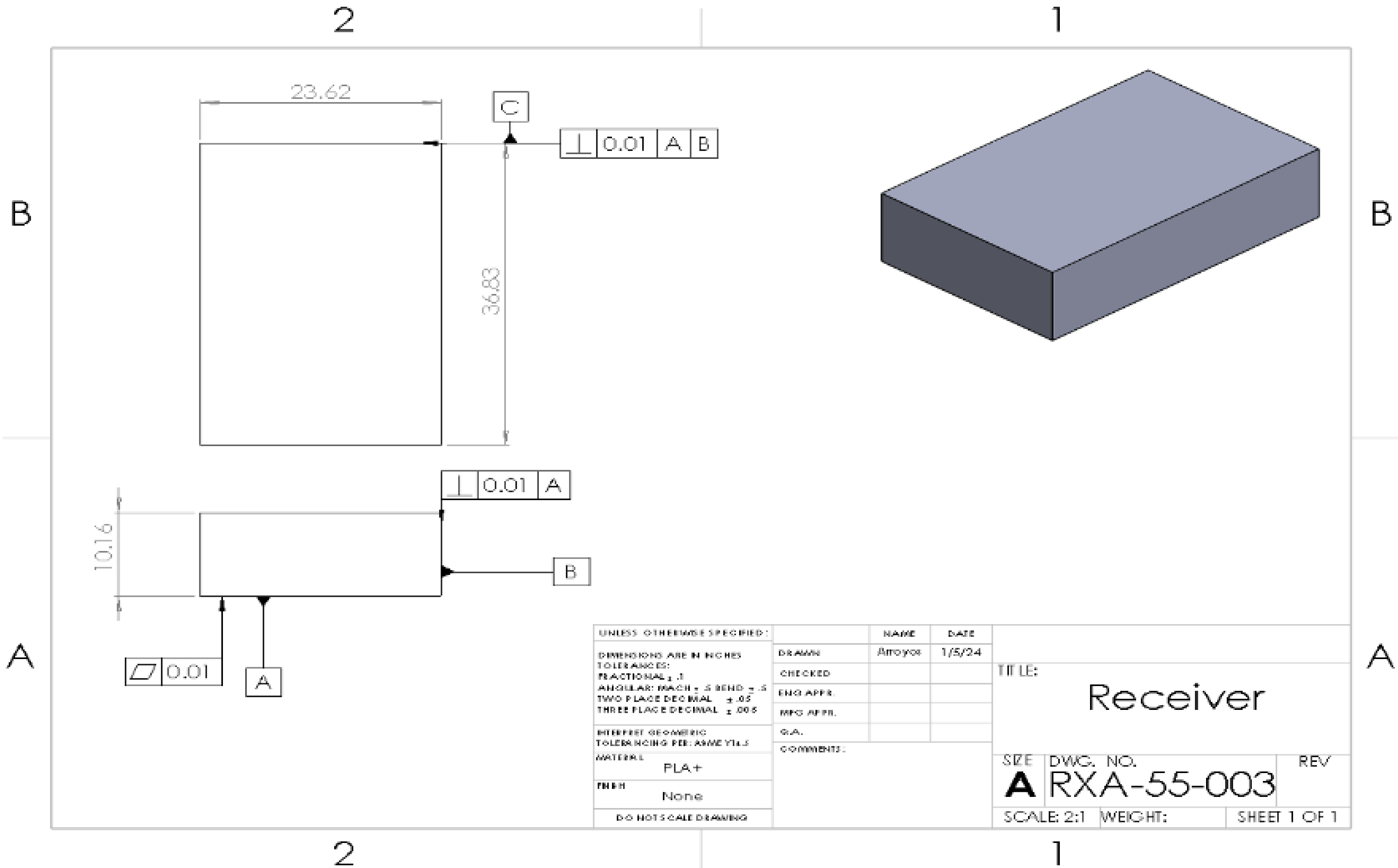


Figure B50. Purchased Receiver

Appendix B51 – RXA-55-004-UEBC

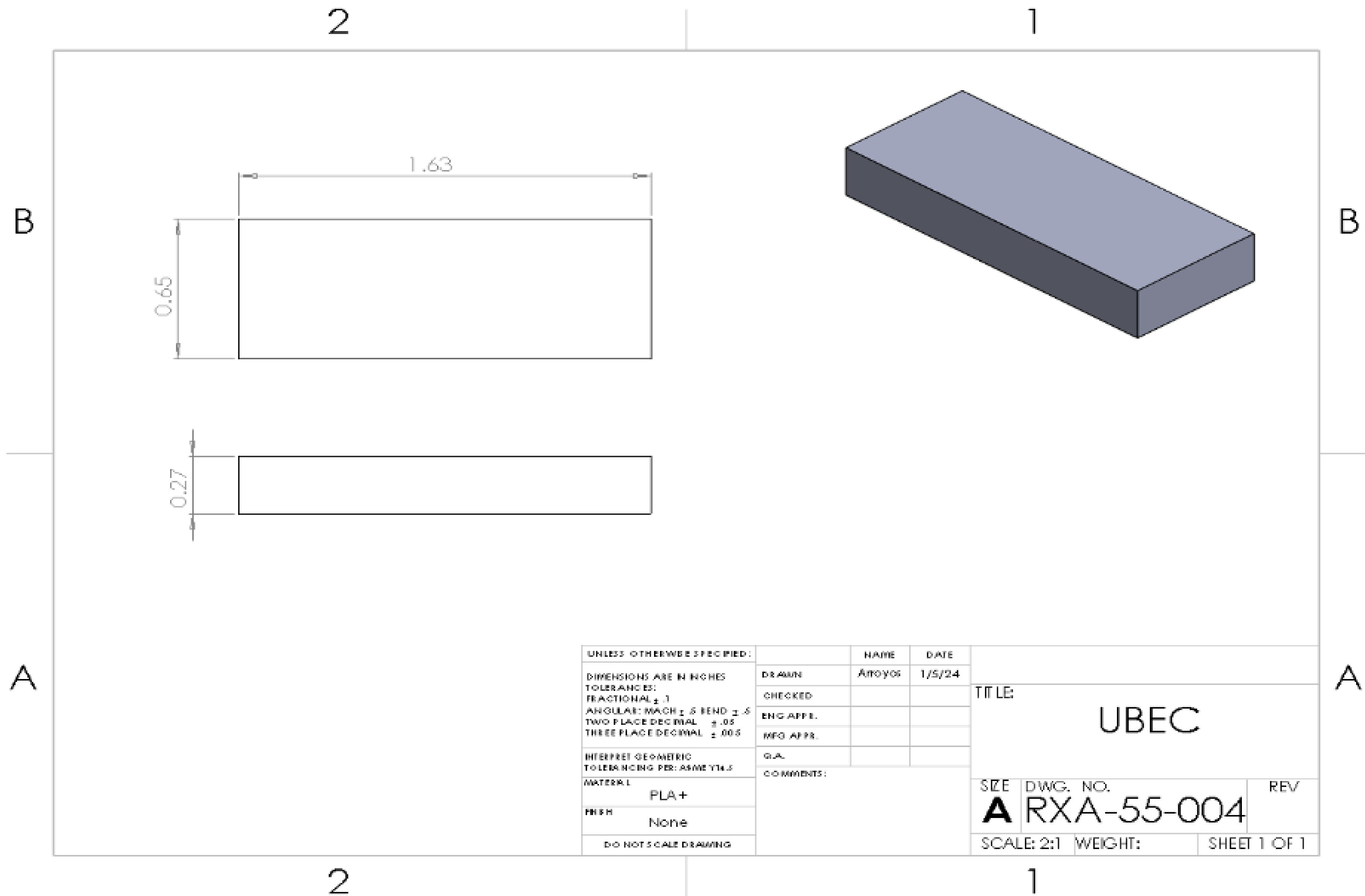


Figure B51. Purchased UBEC

Appendix B52 – RXA-55-005- NestNiche RC servo

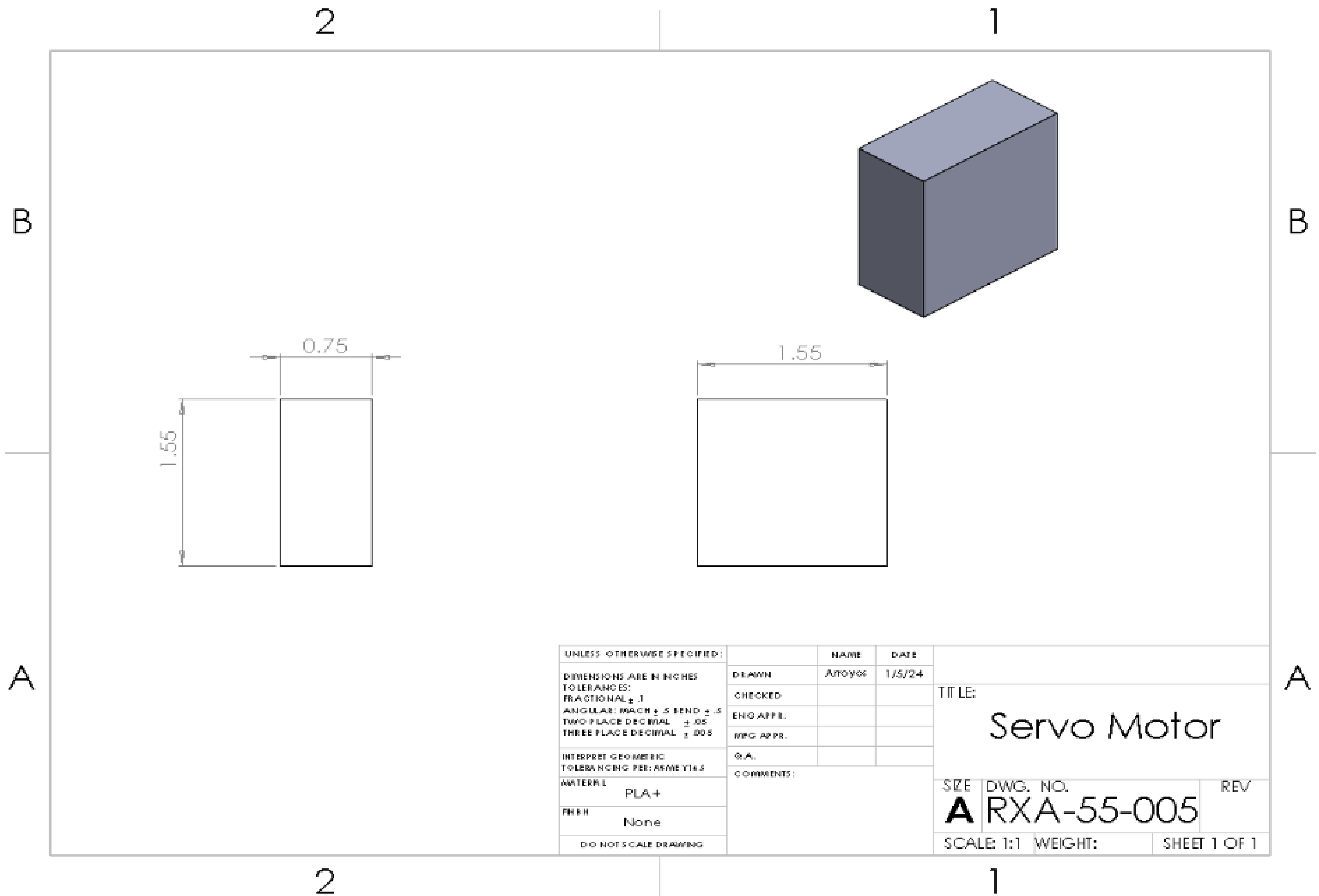


Figure B52. Purchased RC Servo Motor

Appendix B53 – RXA-55-006-Front Right C-Channel

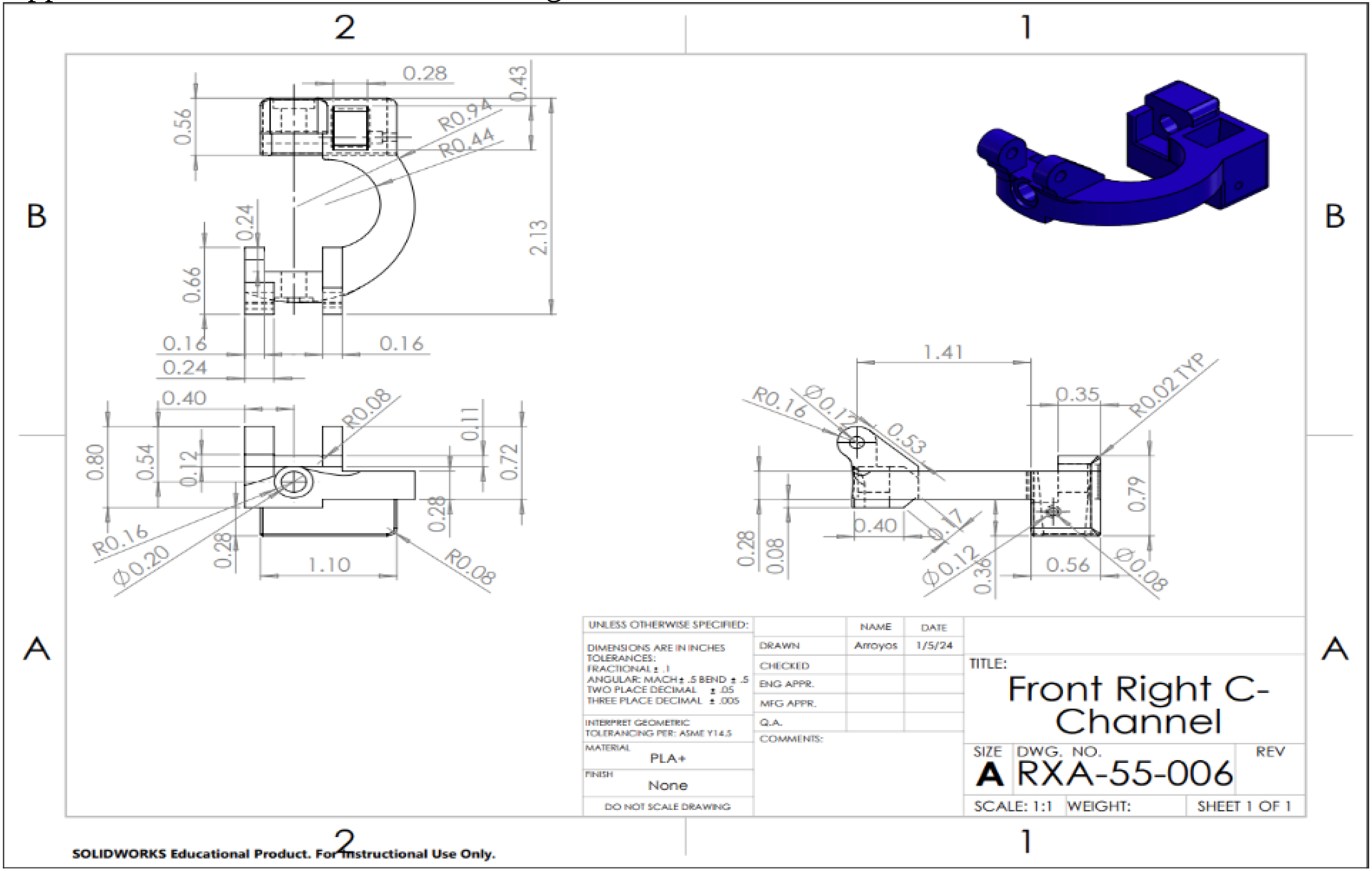


Figure B53. Purchased Front Right C-Channel

Appendix B54– RXA-55-007-Front Left C-Channel

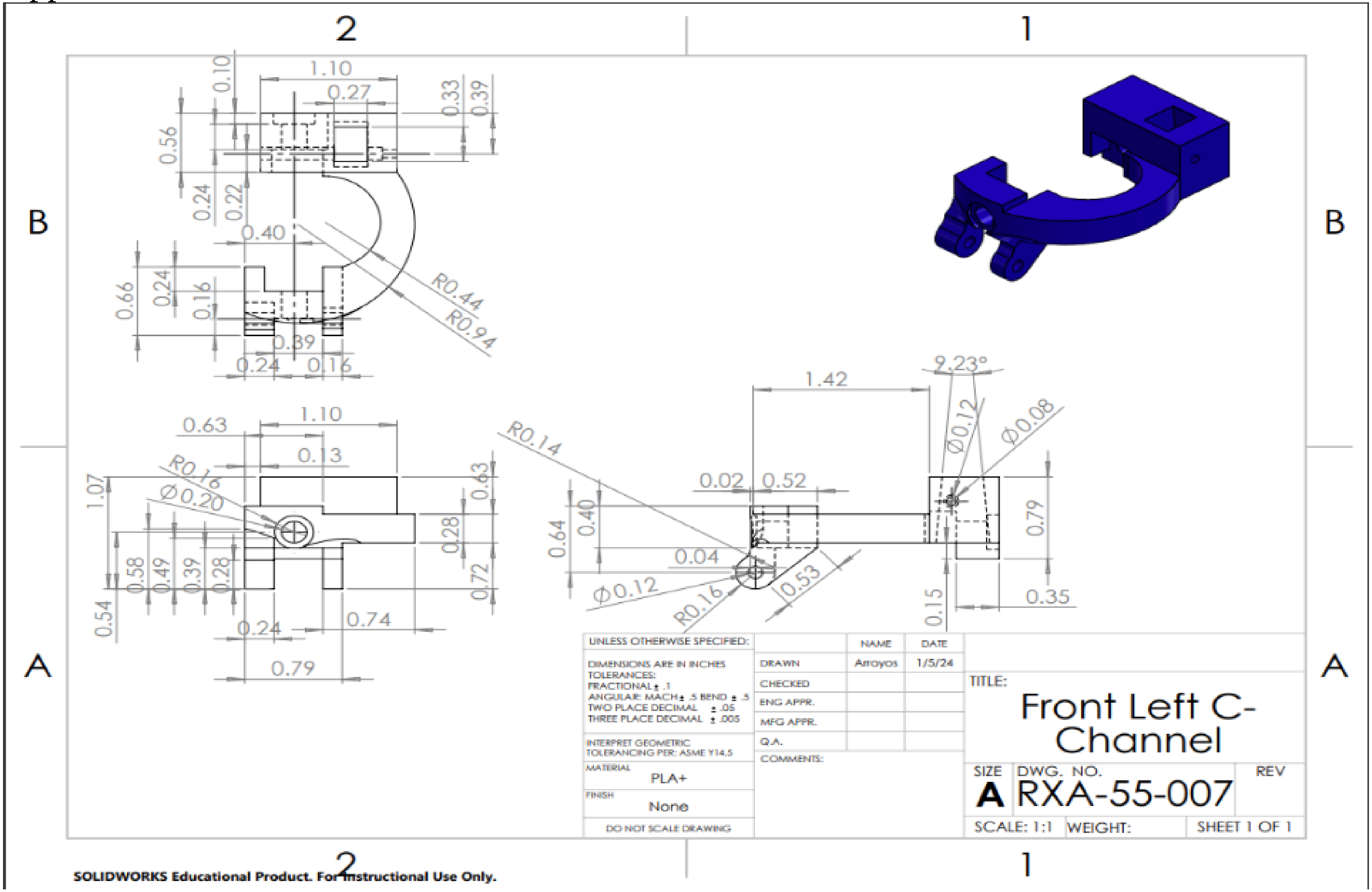


Figure B54. Purchased Front Left C-Channel

Appendix B55 – RXA-55-008 -Front Left Knuckle

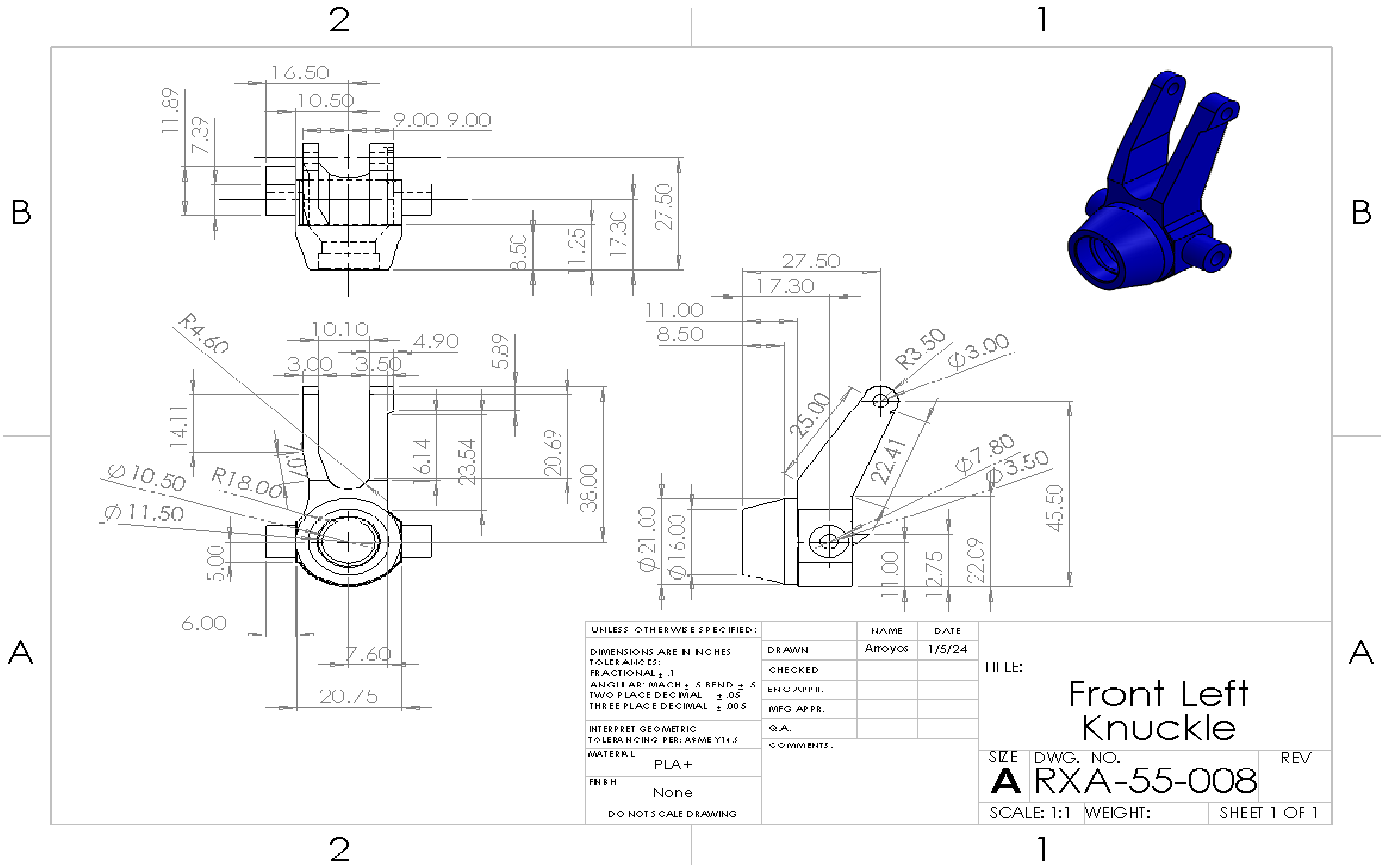


Figure B55. Purchased Front Left Knuckle

Appendix B56 – RXA-55-009-Front Right Knuckle

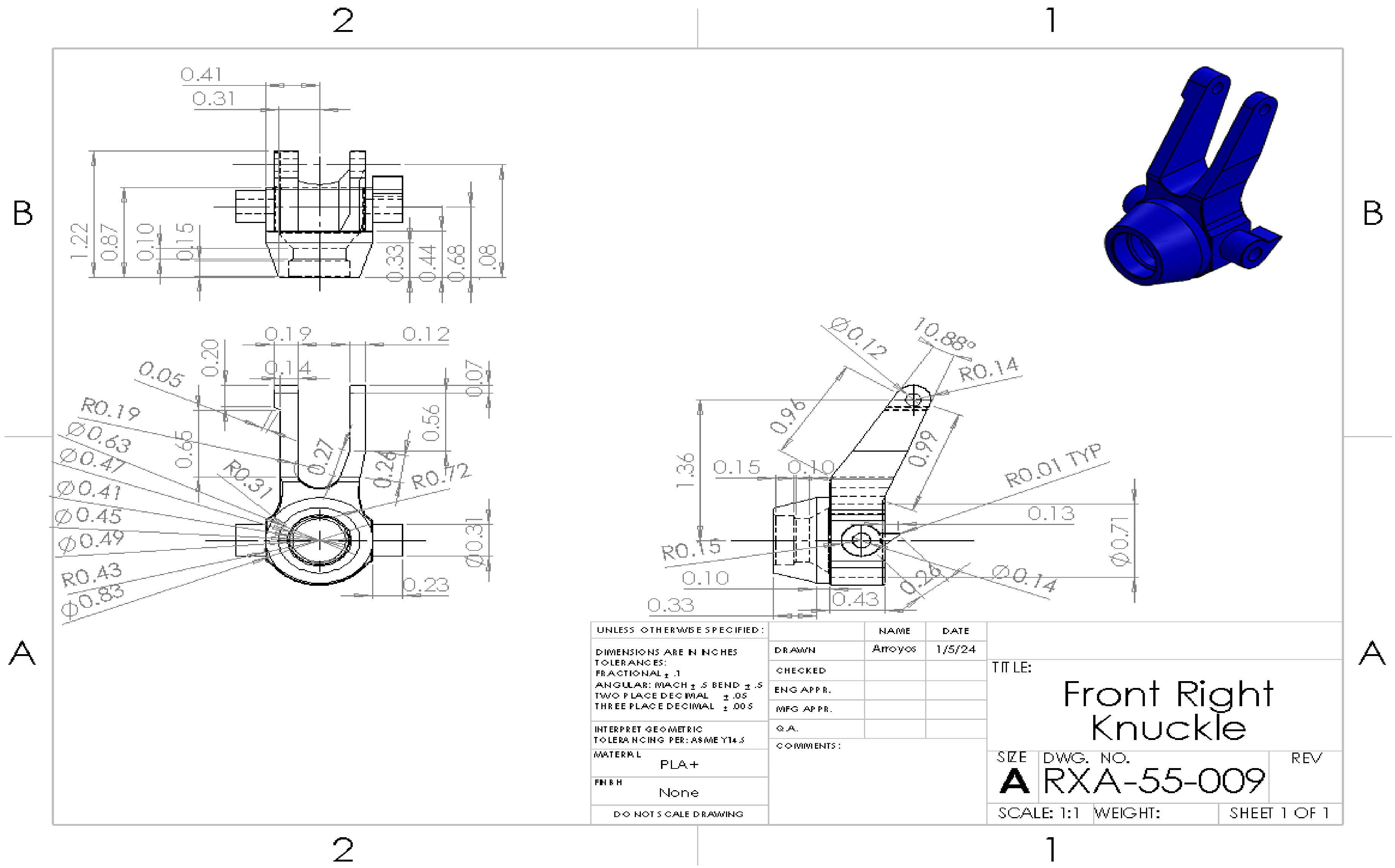


Figure B56. Purchased Front Right Knuckle

Appendix B57 – RXA-55-010-Rear Knuckle

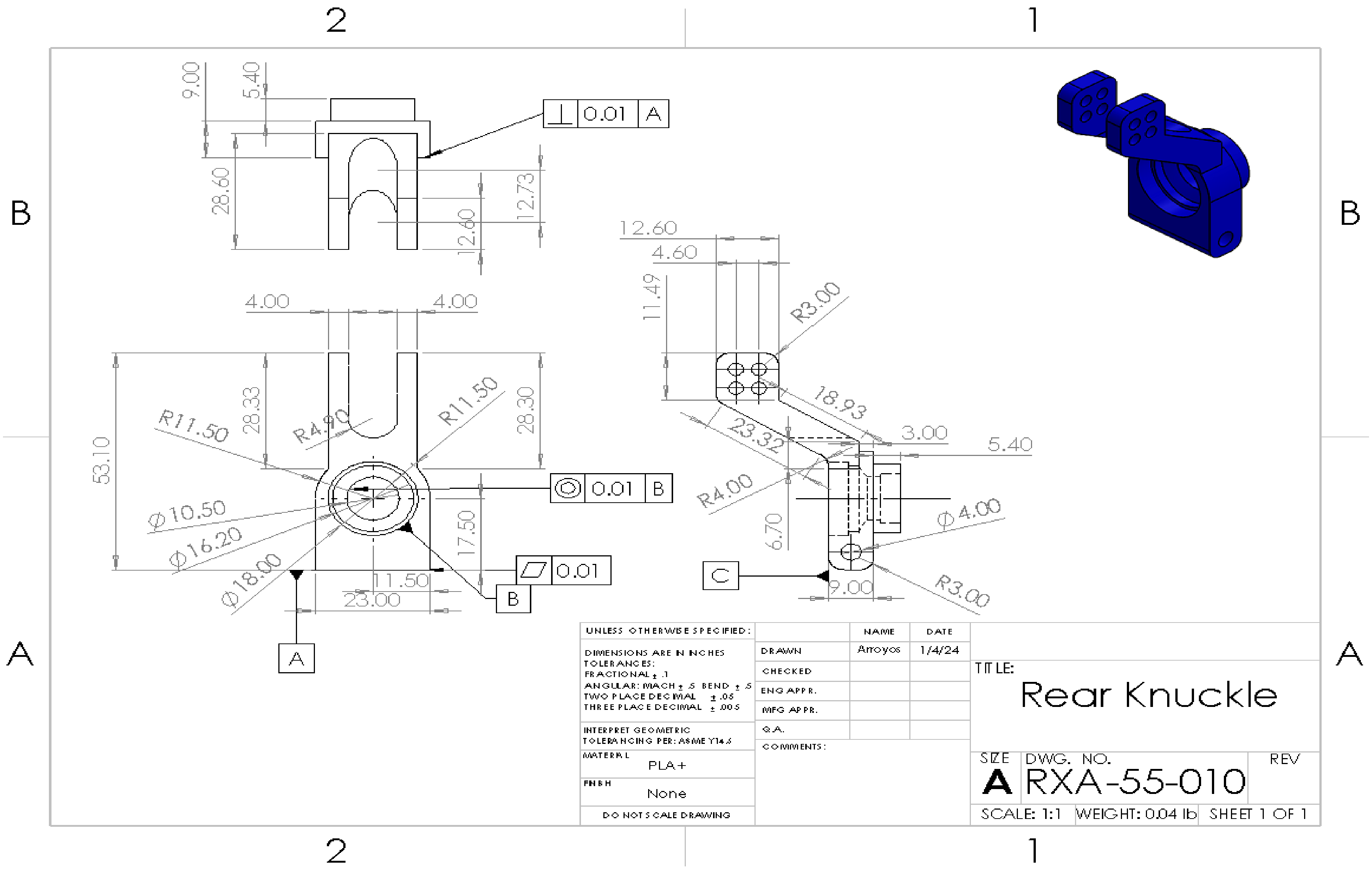


Figure B57. Purchased Rear knuckle

Appendix B58 – RXA-55-011-Tire

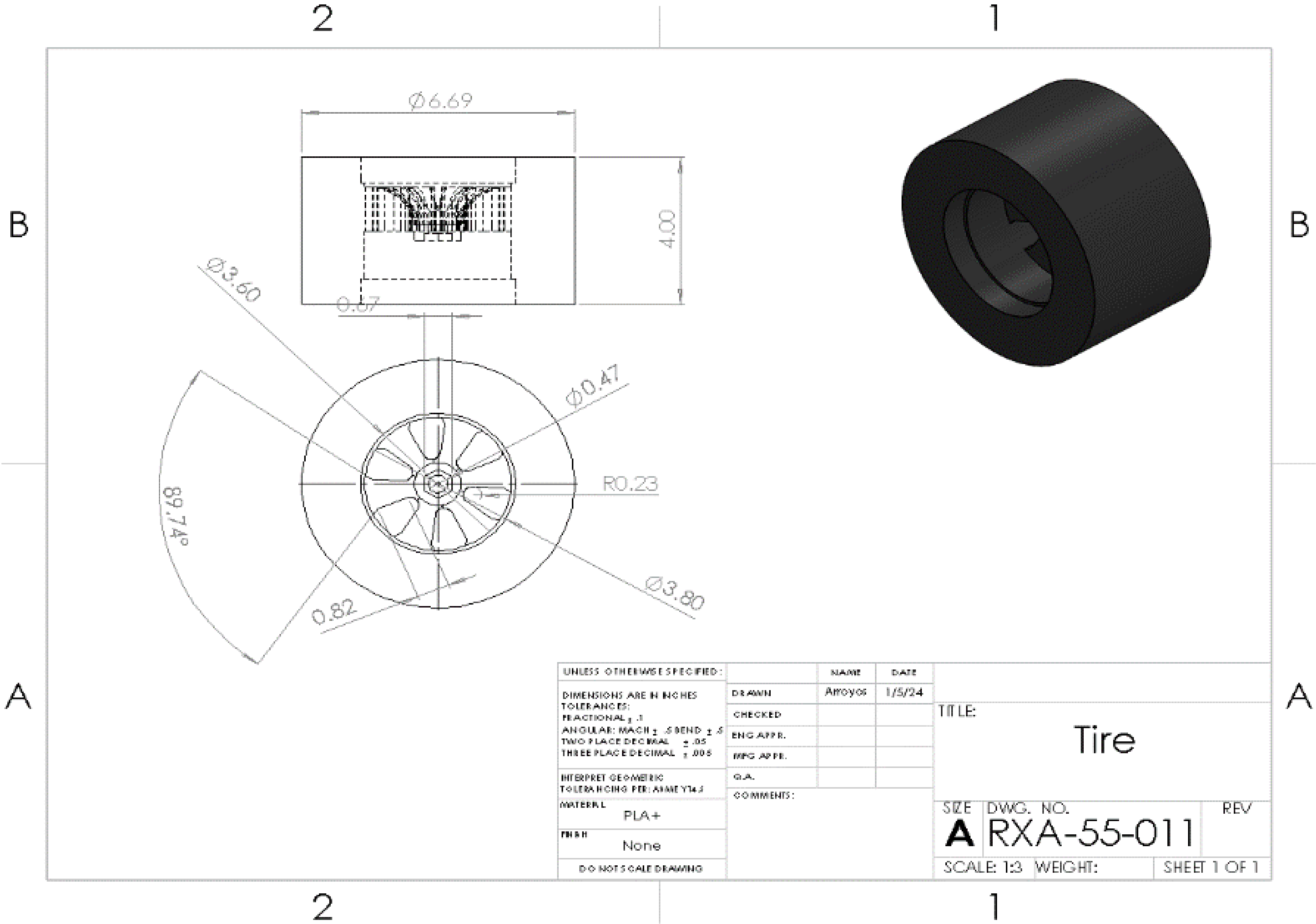


Figure B58. Purchased Tire

Appendix B59– RXA-55-012-ESC

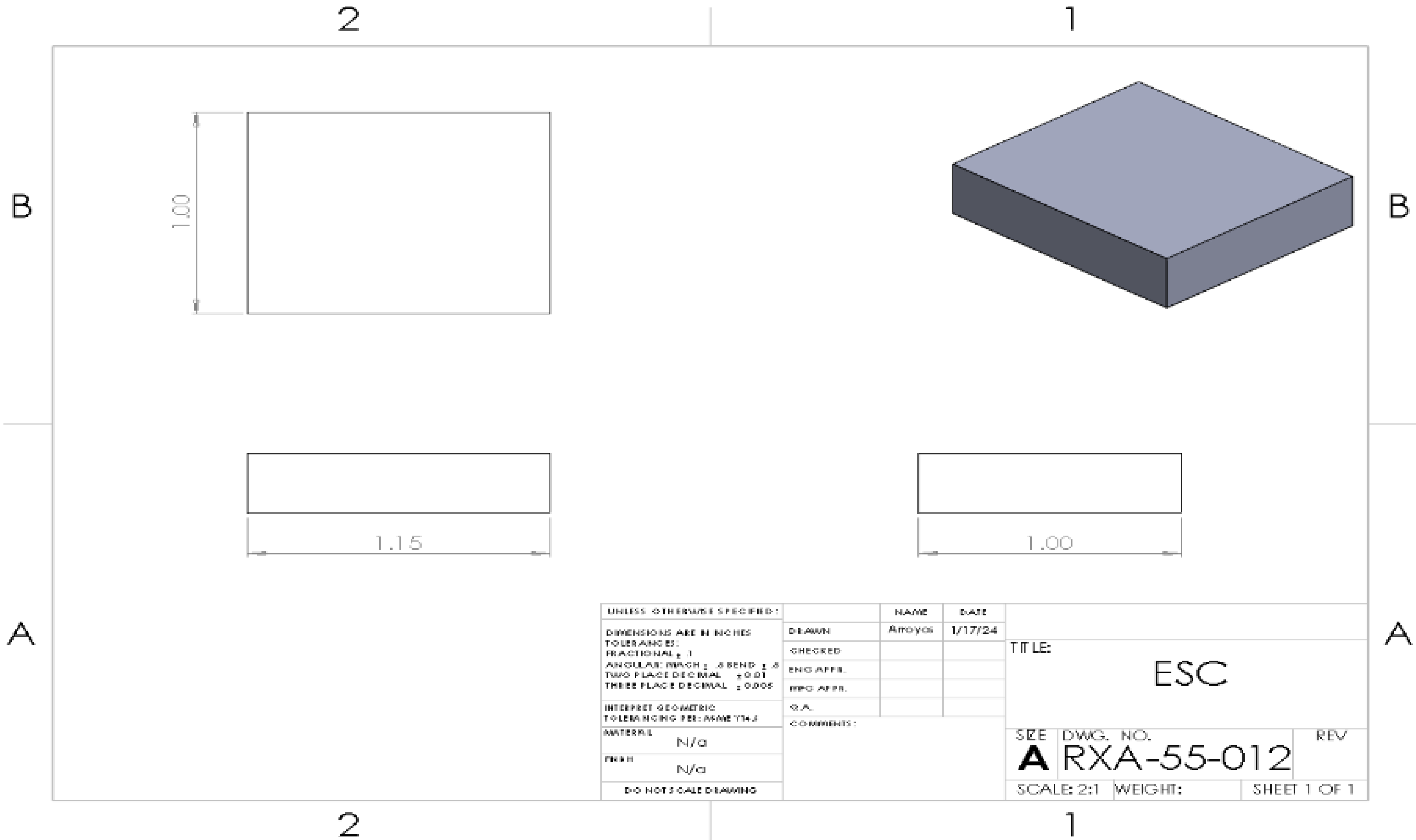


Figure B59. Purchased ESC

APPENDIX C – Parts List and Costs

Table C1. Parts List

Part Number	Qty	Part Description	Source	Cost	Disposition
RCV-20-001	1	Pinion Gear	Modeled	$0.022586	3D Printed
RCV-20-002	1	Chassis	Modeled	$29.98	3D Printed
RCV-20-003	1	Spur Gear	Modeled	$1.342	3D Printed
RCV-20-004	1	Motor Cover	Modeled	$0.257	3D Printed
RCV-20-005	1	Motor Mount	Modeled	$1.689	3D Printed.
RCV-20-006	1	Right Side Battery Mount	Modeled	$.7238	3D Printed.
RCV-20-007	1	Left Side Battery Mount	Modeled	$0.622	3D Printed.
RCV-20-008	1	Bore Reducer	Modeled	$.00989	3D Printed.
RCV-20-009	1	Gearbox	Modeled	$1.961	3D Printed.
RCV-20-010	1	Gearbox Cover	Modeled	$0.513	3D Printed.
RCV-20-011	1	Rear Axle	Modeled	$.0527	Machined: Lathe
RCV-20-012	1	Rear Axle Square Key	Modeled	$.00115	Machined: Grinder
RCV-20-013	1	Front Chassis Section	Modeled	$9.91	3D Printed
RCV-20-014	1	Rear Chassis Section	Modeled	$16.67	3D Printed
RCV-20-015	1	Gearbox Bottom Half	Modeled	$1.70	3D Printed
RCV-20-016	1	Gearbox Top Half	Modeled	$3.24	3D Printed
RCV-20-017	1	8mm Bore Shaft Collar	Modeled	$.056	3D Printed

RCV-20-018	1	Axle Support Clamp	Modeled	$0.2261	3D Printed
RXA-20-001	1	Front Shock Tower	Modeled	$1.66819	3D Printed
RXA-20-002	1	Rear Shock Tower	Modeled	$2.478	3D Printed
RXA-20-003	1	Left lower control arm	Modeled	$1.324	3D Printed
RXA-20-004	1	Servo mount	Modeled	$1.119	3D Printed
RXA-20-005	1	Rear lower control arm	Modeled	$1.324	3D Printed
RXA-20-006	1	Rear upper control arm	Modeled	$0.427	3D Printed
RXA-20-007	1	Rear right lower control arm	Modeled	$0.427	3D Printed
RXA-20-008	2	Front upper control arm	Modeled	$0.70449	3D Printed
RXA-20-009	1	Receiver Mount	Modeled	$0.172	3D Printed
RXA-20-010	1	UBEC Mount	Modeled	$0.09085	3D Printed
RXA-20-011	1	Front Lower Right Control Arm	Modeled	$1.324	3D Printed
RXA-20-012	1	Front Lower Control Arm Mount	Modeled	$1.4996	3D Printed
RXA-20-013	1	Rear Lower Control Arm Mount	Modeled	$2.5047	3D Printed
RCV-50-001	1	4pc 6mm Shaft Collar	Amazon Seller: AOWEITAL	$7.99	12/23/23
RCV-50-002	1	450 Pc M3 & M4 Threaded Insert Set	Amazon Seller: Generic	$12.99	12/23/23
RCV-50-003	1	5Pc 4mm Shaft Collar	Amazon Seller: Uxcell	$10.36	Ordered 1/3/24
RXA-50-001	1	450 Pc M3 & M4 SS Fastner	Amazon Seller: Taiss	$9.99	Ordered 1/3/24
RXA-50-002	1	4 pc Axle end M4 fasteners	AMAZON SELLER: Hobbypark	$8.97	Ordered 1/17/24
RXA-50-003	1	100pc M3 Bolts	AMAZON SELLER: iexcell	$10.45	Ordered 1/22/24
RXA-50-004	1	100 pc M4 Bolts	AMAZON SELLER: iexcell	$10.67	Ordered 1/17/24
RXA-50-005	1	10 pc Ball joint ends	AMAZON SELLER: Vgoodhobby	$12.95	Ordered 1/21/24

RCV-55-001	1	7.4V Lipo Battery 2S 50C 5200mAh	Amazon Seller: ZEEE POWER	$32.38	Ordered 10/13/23
RCV-55-002	2	MABUCHI 540-6527 Brushed Motor 90W	HOBBYKING.com	$17.86	Ordered 10/13/23
RCV-55-003	1	12pc 6mm Gear Axle	Amazon Seller: YongXuan	$8.99	Ordered 1/03/24
RCV-55-004	1	15T Bevel Gear	KHKGEARS.com	$17.62	Ordered 12/29/23
RCV-55-005	1	45T Bevel Gear	KHKGEARS.com	$34.60	Ordered 12/29/23
RCV-55-006	1	6mm Ball Bearing	Amazon Seller: uxcell	$8.49	Ordered 12/23/23
RCV-55-007	1	HobbyKing Sensorless Brushless Car ESC 45A W/ Reverse (2~3S)	HOBBYKING.com	$24.40	Ordered 1/3/24
RCV-55-008	1	Turnigy XK2845-1980KV Brushless Inrunner	HOBBYKING.com	$30.10	Ordered 5/01/24
RXA-55-001	1	Front Shocks for 1:8 RC	Amazon seller: ARRAROWN	$28.13	Ordered 10/11/23
RXA-55-002	1	Rear Shocks for 1;8 RC			
RXA-55-003	1	HOTRC CT-6A 6 Channel 2.4ghz RC Transmitter and Receiver	Amazon Seller: Havcybin Tech	$39.96	Ordered 10/16/23
RXA-55-004	1	2Pc RC UEBC 3 AMPS 6.0-25.5v input/5v/6v/ Adjustable Output BEC	Amazon Seller: JINOARC	$9.71	Ordered 10/16/23
RXA-55-005	1	NestNiche RC servo, 30kg RC Steering Servo with Winch Spool Kit	HOBBYKING.com	$17.14	Ordered 10/13/23
RXA-55-006	1	Front Right C-Channel	Amazon Seller: RCAWD	$86.39	Ordered 10/13/23
RXA-55-007	1	Front Left C-Channel			
RXA-55-008	1	Front Left Knuckle			

RXA-55-009	1	Front Right Knuckle			
RXA-55-010	1	Rear knuckles			
RXA-55-0011	1	Acekeeps 4=pack 1/8 Monster truck tires	Amazon Seller: ACEKEEPS HOBBIES	$72.34	Ordered 10/13/23
RXA-55-012	1	Vgoohobby RC 30A Brushed ESC	AMAZON SELLER: Vgoodhobby	$12.84	Ordered 11/18/23
RXA-55-013	1	T Plug to JST	AMAZON SELLER: FLY RC	$8.63	Ordered 1/21/24
RXA-55-014	1	Battery Charger kit	AMASON SELLER: Haisito Store	$62.55	Ordered 1/21/24
RXA-55-015	1	Wheel hub 17mm-12mm adapters	AMAZON SELLER: GTHELE $14.03	$14.03	Ordered 1/21/24
RXA-55-016	1	Drive shaft axles for1/8 Arrma vendetta 4x4 3s BLX	AMAZON SELLER: RCMYou $51.83	$51.83	Ordered 2/3/24
RXA-55-017	1	GoolRC GA-4H-TX 4CH Receiver and Transmitter	AMAZON SELLER: Xinzhemaoyi	$27.00	Ordered 2/7/24
RXA-55-018	1	Ichiias 60A ESC Brushed	AMAZON SELLER: Blurte432	$20.05	Ordered 2/7/24
RXA-55-019	1	Radiolink Cool 90A ESC	AMAZON SELLER: RadioLink Direct	$30.34	Ordered 3/1/24
RXA-55-020	1	Dkky RCCar Motor Heatsink Dual Fan	AMAZON SELLER: DKKY DKKY Racing	$8.12	Ordered 3/7/24

Total Cost	$737.51
Total Parts	33
Total Purchased Parts	36

Note:

- Total cost takes into account the extra items that were purchased and are also listed above which include Motor (1), Battery (1), UBEC (1)
- Total of parts does not include fasteners and subassemblies.
- Parts that were ordered but weren’t used in the final version of the RC are in the following table:

Table C2- Unused Parts

Part Number	QTY	Part Description	Source	Cost	Disposition
RCV-20-002	1	Chassis	Modeled	$29.98	3D Printed

RCV-20-009	1	Gearbox	Modeled	$1.961	3D Printed
RXA-55-003	1	HOTRC CT-6A 6 Channel 2.4ghz RC Transmitter and Receiver	AMAZON SELLER: Havcybin Tech	$39.96	Ordered 10/16/23
RXA-55-004	1	2Pc RC UBEC 3 AMPS 6.0-25.5v input / 5v/6v/ Adjustable Output BEC	AMAZON SELLER: JINOARC	$9.71	Ordered 10/16/23
RXA-55-012	1	Vgoohobby RC 30A Brushed ESC	AMAZON SELLER: Vgoodhobby	$12.84	Ordered 11/18/23
RXA-55-018	1	Ichiias 60A ESC Brushed	AMAZON SELLER: Blurte432	$20.05	Ordered 2/7/24
RCV-55-002	2	MABUCHI 540-6527 Brushed Motor 90W	HOBBYKING.com	$17.86	Ordered 10/13/23
RXA-55-019	1	Radiolink Cool 90A ESC	AMAZON SELLER: RadioLink Direct	$30.34	Ordered 3/1/24
RCV-20-001	13	Pinion gear (broken)	Modeled		
			Total Cost	$162.7	

APPENDIX D – Budget

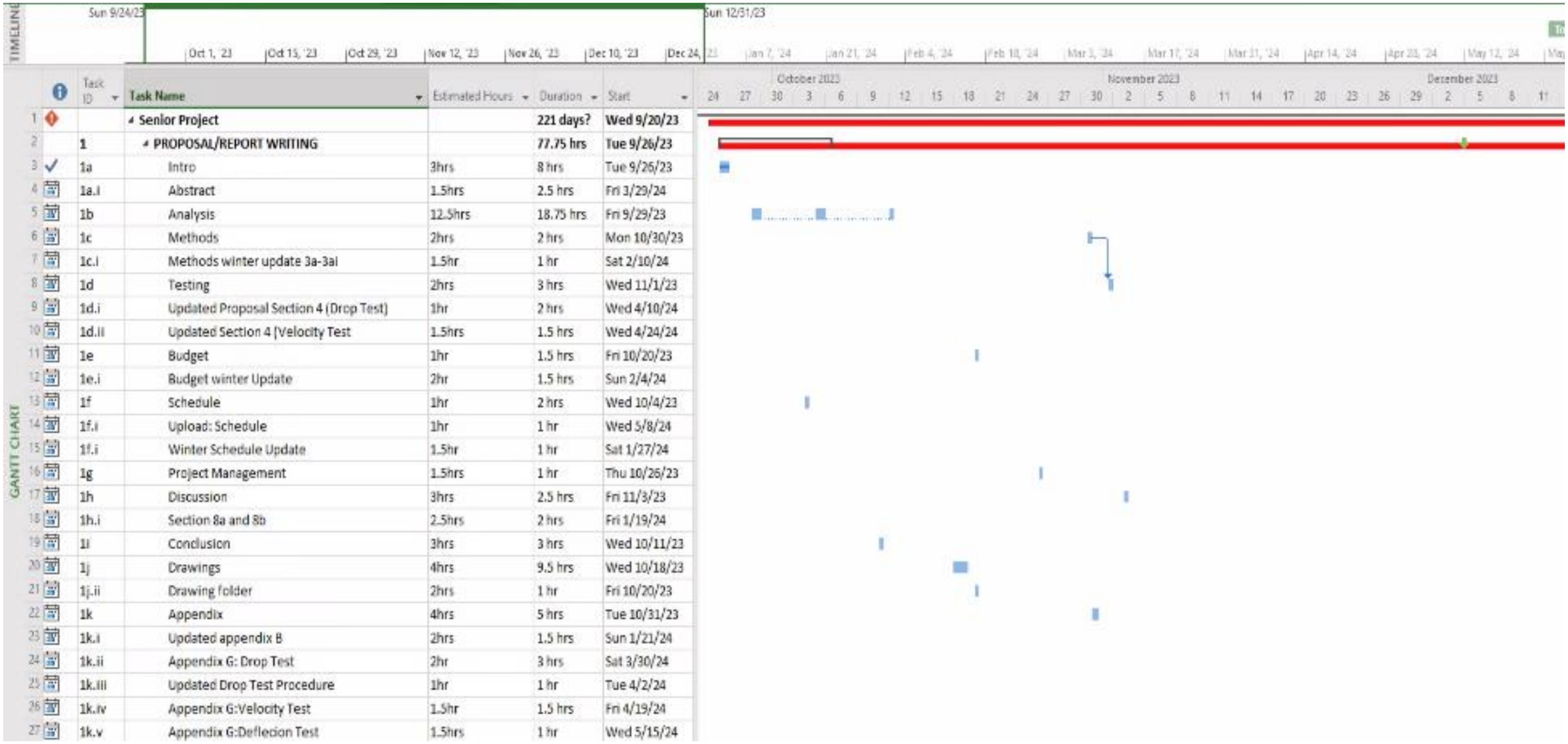
Table D1. Project Budget.

Item	Qty	Description	Cost
Part list and Cost	1	Parts list of components that will be purchased	$745.51
Unused Parts	1	List and cost of purchased components not used	$162.7
3D Printed	33	3D printed components	$85.16
-Total		$830.59	
-Actual Cost		$637.89	

Note:

- Actual cost is determined if the unused cost was neglected
- The cost for the 3D printed parts are calculated based off the cost amount per 1kg of spool material multiplied by the mass of the part then divided by 1000.
- Spool cost per 1kg: $23

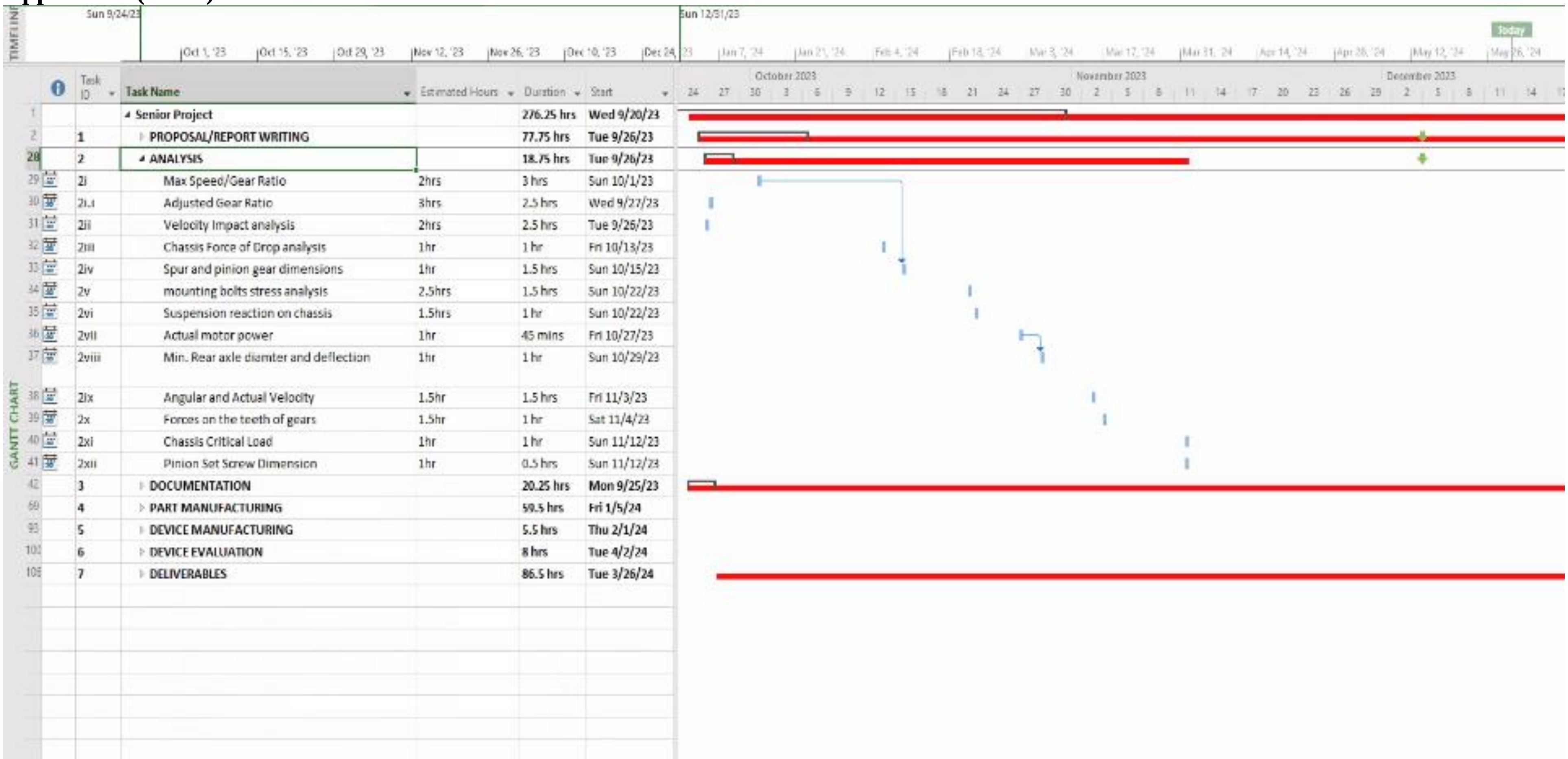
APPENDIX E – Schedule



	Task ID	Task Name	Estimated Hours	Duration	Start
1		Senior Project		221 days?	Wed 9/20/23
2	1	PROPOSAL/REPORT WRITING		77.75 hrs	Tue 9/26/23
3	1a	Intro	3hrs	8 hrs	Tue 9/26/23
4	1a.i	Abstract	1.5hrs	2.5 hrs	Fri 3/29/24
5	1b	Analysis	12.5hrs	18.75 hrs	Fri 9/29/23
6	1c	Methods	2hrs	2 hrs	Mon 10/30/23
7	1c.i	Methods winter update 3a-3ai	1.5hr	1 hr	Sat 2/10/24
8	1d	Testing	2hrs	3 hrs	Wed 11/1/23
9	1d.i	Updated Proposal Section 4 (Drop Test)	1hr	2 hrs	Wed 4/10/24
10	1d.ii	Updated Section 4 (Velocity Test	1.5hrs	1.5 hrs	Wed 4/24/24
11	1e	Budget	1hr	1.5 hrs	Fri 10/20/23
12	1e.i	Budget winter Update	2hr	1.5 hrs	Sun 2/4/24
13	1f	Schedule	1hr	2 hrs	Wed 10/4/23
14	1f.i	Upload: Schedule	1hr	1 hr	Wed 5/8/24
15	1f.i	Winter Schedule Update	1.5hr	1 hr	Sat 1/27/24
16	1g	Project Management	1.5hrs	1 hr	Thu 10/26/23
17	1h	Discussion	3hrs	2.5 hrs	Fri 11/3/23
18	1h.i	Section 8a and 8b	2.5hrs	2 hrs	Fri 1/19/24
19	1i	Conclusion	3hrs	3 hrs	Wed 10/11/23
20	1j	Drawings	4hrs	9.5 hrs	Wed 10/18/23
21	1j.ii	Drawing folder	2hrs	1 hr	Fri 10/20/23
22	1k	Appendix	4hrs	5 hrs	Tue 10/31/23
23	1k.i	Updated appendix B	2hrs	1.5 hrs	Sun 1/21/24
24	1k.ii	Appendix G: Drop Test	2hr	3 hrs	Sat 3/30/24
25	1k.iii	Updated Drop Test Procedure	1hr	1 hr	Tue 4/2/24
26	1k.iv	Appendix G:Velocity Test	1.5hr	1.5 hrs	Fri 4/19/24
27	1k.v	Appendix G:Deflecion Test	1.5hrs	1 hr	Wed 5/15/24

Figure E01. Fall Schedule

Appendix E(Cont.)



Task ID	Task Name	Estimated Hours	Duration	Start
	Senior Project		276.25 hrs	Wed 9/20/23
1	PROPOSAL/REPORT WRITING		77.75 hrs	Tue 9/26/23
2	ANALYSIS		18.75 hrs	Tue 9/26/23
2i	Max Speed/Gear Ratio	2hrs	3 hrs	Sun 10/1/23
2i.i	Adjusted Gear Ratio	3hrs	2.5 hrs	Wed 9/27/23
2ii	Velocity Impact analysis	2hrs	2.5 hrs	Tue 9/26/23
2iii	Chassis Force of Drop analysis	1hr	1 hr	Fri 10/13/23
2iv	Spur and pinion gear dimensions	1hr	1.5 hrs	Sun 10/15/23
2v	mounting bolts stress analysis	2.5hrs	1.5 hrs	Sun 10/22/23
2vi	Suspension reaction on chassis	1.5hrs	1 hr	Sun 10/22/23
2vii	Actual motor power	1hr	45 mins	Fri 10/27/23
2viii	Min. Rear axle diamter and deflection	1hr	1 hr	Sun 10/29/23
2ix	Angular and Actual Velocity	1.5hr	1.5 hrs	Fri 11/3/23
2x	Forces on the teeth of gears	1.5hr	1 hr	Sat 11/4/23
2xi	Chassis Critical Load	1hr	1 hr	Sun 11/12/23
2xii	Pinion Set Screw Dimension	1hr	0.5 hrs	Sun 11/12/23
3	DOCUMENTATION		20.25 hrs	Mon 9/25/23
4	PART MANUFACTURING		59.5 hrs	Fri 1/5/24
5	DEVICE MANUFACTURING		5.5 hrs	Thu 2/1/24
6	DEVICE EVALUATION		8 hrs	Tue 4/2/24
7	DELIVERABLES		86.5 hrs	Tue 3/26/24

Figure E02. Fall schedule(cont.)

Appendix E(Cont.)

	Task ID	Task Name	Estimated Hours	Duration	Start
1		Senior Project		276.25 hrs	Wed 9/20/23
2	1	PROPOSAL/REPORT WRITING		77.75 hrs	Tue 9/26/23
28	2	ANALYSIS		18.75 hrs	Tue 9/26/23
42	3	DOCUMENTATION		20.25 hrs	Mon 9/25/23
43	3a	Spur Gear	1hr	1 hr	Sat 1/27/24
44	3a.I	Modified Spur Gear	.5hr	0.5 hrs	Wed 1/31/24
45	3b	Pinion Gear	.5hr	0.5 hrs	Fri 10/13/23
46	3c	Chassis	1.5hr	1 hr	Wed 10/18/23
47	3c.I	Modified Chassis	1.5hr	1 hr	Tue 10/24/23
48	3c.II	Chassis Front Section	1hr	0.75 hrs	Tue 2/20/24
49	3c.III	Chassis Rear Section	20hrs	0.75 hrs	Tue 2/20/24
50	3d	Motor Cover	1hr	0.5 hrs	Tue 10/24/23
51	3d.I	Modified Motor Cover	.5hr	0.5 hrs	Mon 1/29/24
52	3e	Motor Mount	1hr	1 hr	Thu 9/28/23
53	3f	Right Side Battery Mount	.5hr	0.5 hrs	Thu 9/28/23
54	3g	Left Side Battery Mount	.5hr	0.5 hrs	Fri 10/20/23
55	3h	Pillow Block Housing	1.5hr	1 hr	Mon 9/25/23
56	3i	4mm Bore Adapter	.5hr	0.5 hrs	Wed 10/11/23
57	3j	Gearbox	1hr	2 hrs	Tue 11/14/23
58	3j.I	Adjusted Gearbox	1.5hrs	1 hr	Wed 11/15/23
59	3j.II	Gearbox Lower Half	1hr	1 hr	Thu 2/22/24
60	3j.III	Gearbox Upper Half	1hr	0.75 hrs	Thu 2/22/24
61	3k	GearBox Cover	.5hr	0.5 hrs	Sat 11/18/23
62	3k.i	Modified Rear axle	1hr	1 hr	Tue 2/6/24
63	3l	Rear axle	1hr	1.25 hrs	Tue 1/30/24
64	3m	Square Key	.5hrs	0.5 hrs	Wed 1/31/24
65	3n	Gear box bottom half	.5hr	0.5 hrs	Wed 2/21/24
66	3o	Gear box top half	1hr	1.5 hrs	Thu 3/7/24
67	3p	8mm bore shaft collar	.5hr	0.25 hrs	Thu 3/7/24
68	3q	Axle support clamp	.5hr	0.5 hrs	Tue 3/5/24

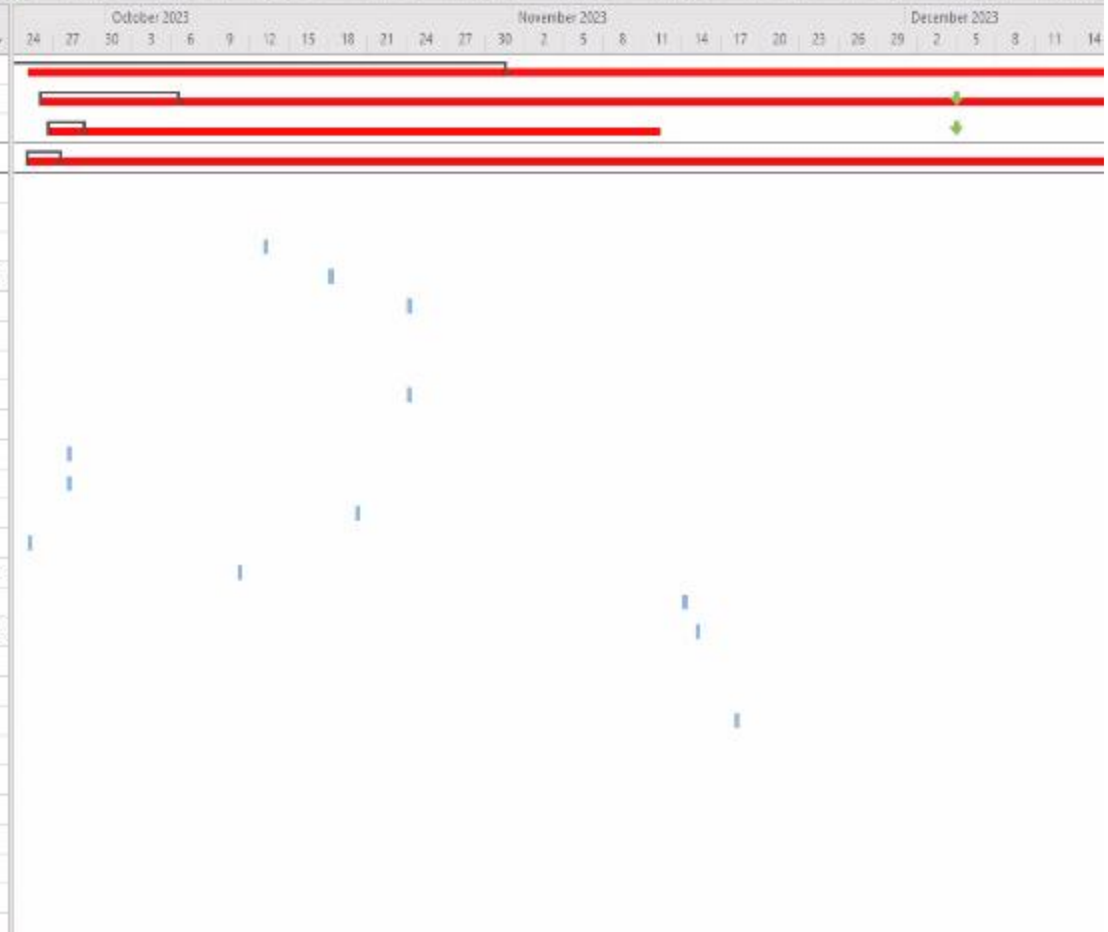
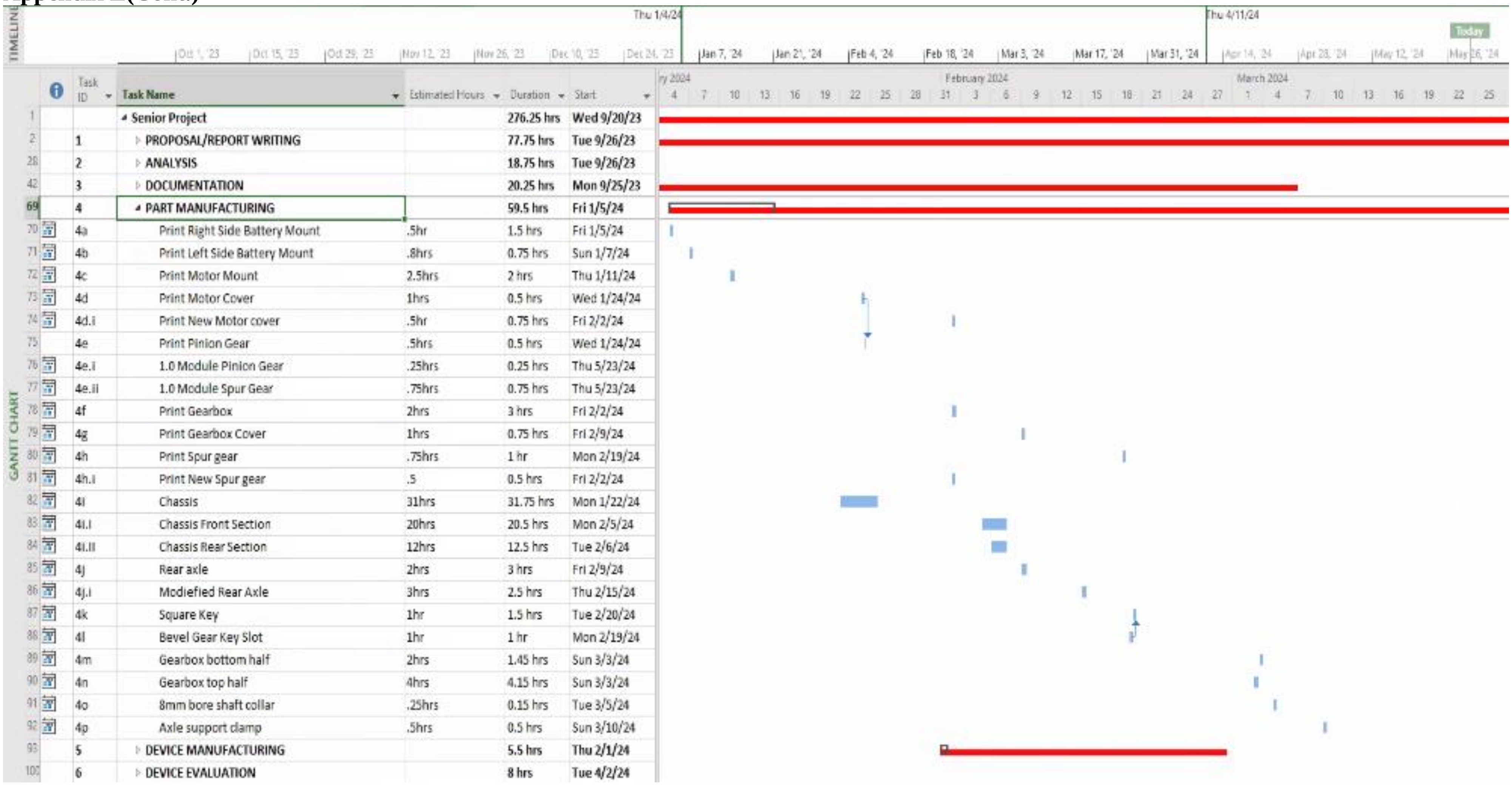


Figure E03. Fall schedule(cont.)

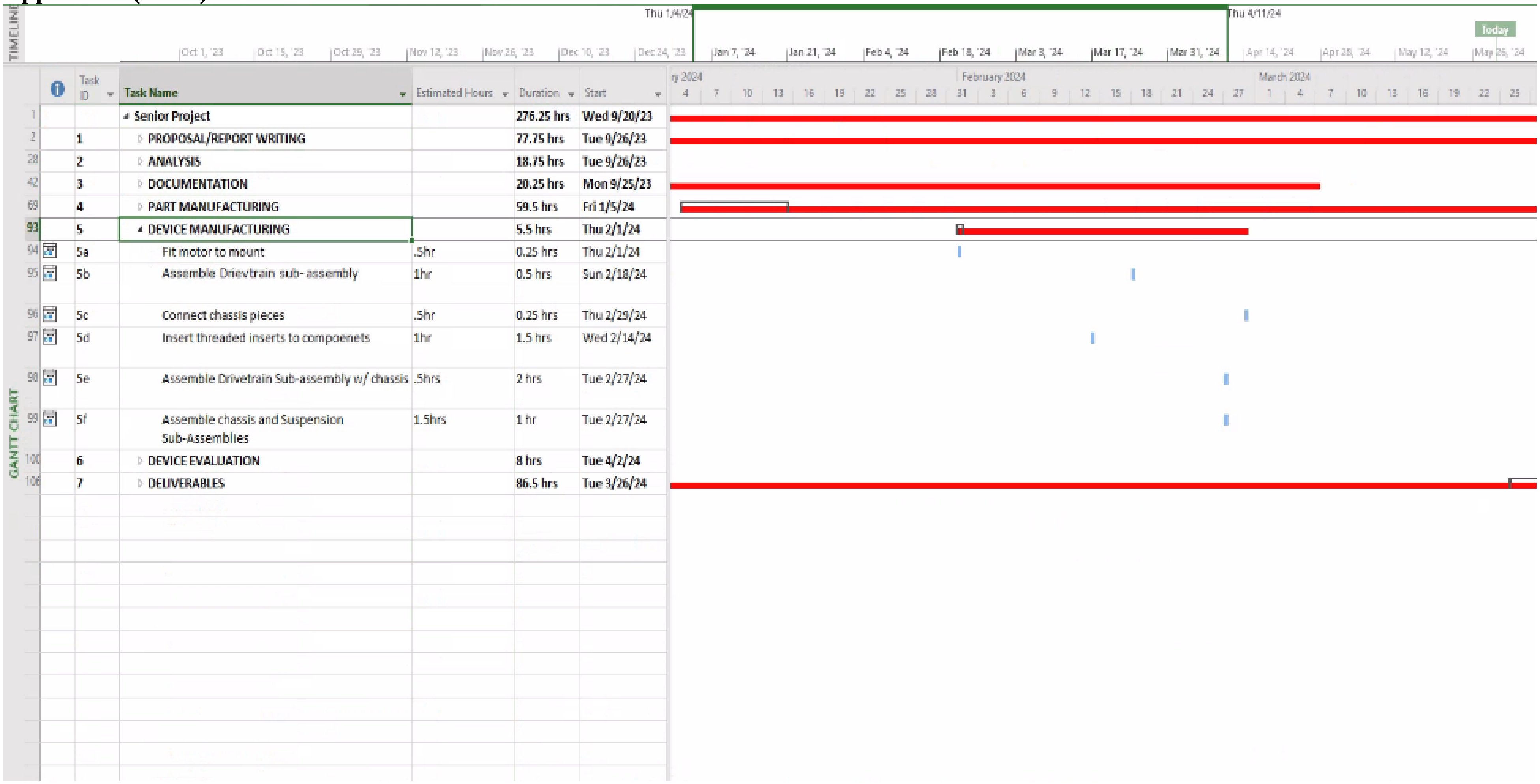
Appendix E(Cont.)



	Task ID	Task Name	Estimated Hours	Duration	Start
1		Senior Project		276.25 hrs	Wed 9/20/23
2	1	PROPOSAL/REPORT WRITING		77.75 hrs	Tue 9/26/23
28	2	ANALYSIS		18.75 hrs	Tue 9/26/23
42	3	DOCUMENTATION		20.25 hrs	Mon 9/25/23
69	4	PART MANUFACTURING		59.5 hrs	Fri 1/5/24
70	4a	Print Right Side Battery Mount	.5hr	1.5 hrs	Fri 1/5/24
71	4b	Print Left Side Battery Mount	.8hrs	0.75 hrs	Sun 1/7/24
72	4c	Print Motor Mount	2.5hrs	2 hrs	Thu 1/11/24
73	4d	Print Motor Cover	1hrs	0.5 hrs	Wed 1/24/24
74	4d.i	Print New Motor cover	.5hr	0.75 hrs	Fri 2/2/24
75	4e	Print Pinion Gear	.5hrs	0.5 hrs	Wed 1/24/24
76	4e.i	1.0 Module Pinion Gear	.25hrs	0.25 hrs	Thu 5/23/24
77	4e.ii	1.0 Module Spur Gear	.75hrs	0.75 hrs	Thu 5/23/24
78	4f	Print Gearbox	2hrs	3 hrs	Fri 2/2/24
79	4g	Print Gearbox Cover	1hrs	0.75 hrs	Fri 2/9/24
80	4h	Print Spur gear	.75hrs	1 hr	Mon 2/19/24
81	4h.i	Print New Spur gear	.5	0.5 hrs	Fri 2/2/24
82	4i	Chassis	31hrs	31.75 hrs	Mon 1/22/24
83	4i.i	Chassis Front Section	20hrs	20.5 hrs	Mon 2/5/24
84	4i.ii	Chassis Rear Section	12hrs	12.5 hrs	Tue 2/6/24
85	4j	Rear axle	2hrs	3 hrs	Fri 2/9/24
86	4j.i	Modiefied Rear Axle	3hrs	2.5 hrs	Thu 2/15/24
87	4k	Square Key	1hr	1.5 hrs	Tue 2/20/24
88	4l	Bevel Gear Key Slot	1hr	1 hr	Mon 2/19/24
89	4m	Gearbox bottom half	2hrs	1.45 hrs	Sun 3/3/24
90	4n	Gearbox top half	4hrs	4.15 hrs	Sun 3/3/24
91	4o	8mm bore shaft collar	.25hrs	0.15 hrs	Tue 3/5/24
92	4p	Axle support clamp	.5hrs	0.5 hrs	Sun 3/10/24
93	5	DEVICE MANUFACTURING		5.5 hrs	Thu 2/1/24
100	6	DEVICE EVALUATION		8 hrs	Tue 4/2/24

Figure E04. Winter Schedule

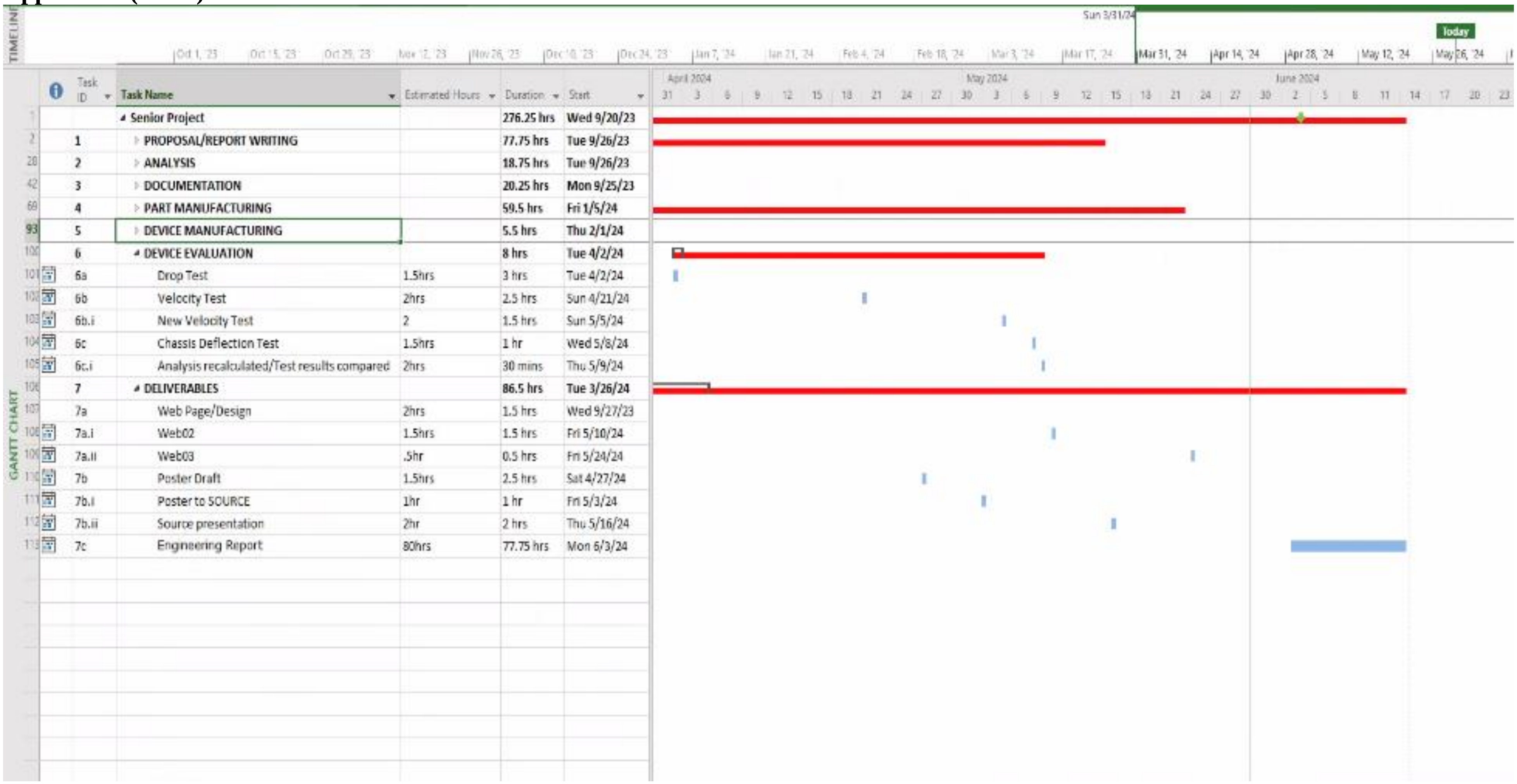
Appendix E(Cont.)



	Task ID	Task Name	Estimated Hours	Duration	Start
1		Senior Project		276.25 hrs	Wed 9/20/23
2	1	PROPOSAL/REPORT WRITING		77.75 hrs	Tue 9/26/23
28	2	ANALYSIS		18.75 hrs	Tue 9/26/23
42	3	DOCUMENTATION		20.25 hrs	Mon 9/25/23
69	4	PART MANUFACTURING		59.5 hrs	Fri 1/5/24
93	5	DEVICE MANUFACTURING		5.5 hrs	Thu 2/1/24
94	5a	Fit motor to mount	.5hr	0.25 hrs	Thu 2/1/24
95	5b	Assemble Drievtrain sub-assembly	1hr	0.5 hrs	Sun 2/18/24
96	5c	Connect chassis pieces	.5hr	0.25 hrs	Thu 2/29/24
97	5d	Insert threaded inserts to compoenets	1hr	1.5 hrs	Wed 2/14/24
98	5e	Assemble Drivetrain Sub-assembly w/ chassis	.5hrs	2 hrs	Tue 2/27/24
99	5f	Assemble chassis and Suspension Sub-Assemblies	1.5hrs	1 hr	Tue 2/27/24
100	6	DEVICE EVALUATION		8 hrs	Tue 4/2/24
106	7	DELIVERABLES		86.5 hrs	Tue 3/26/24

Figure E05. Winter Schedule (cont.)

Appendix E(Cont.)



Task ID	Task Name	Estimated Hours	Duration	Start
	Senior Project		276.25 hrs	Wed 9/20/23
1	PROPOSAL/REPORT WRITING		77.75 hrs	Tue 9/26/23
2	ANALYSIS		18.75 hrs	Tue 9/26/23
3	DOCUMENTATION		20.25 hrs	Mon 9/25/23
4	PART MANUFACTURING		59.5 hrs	Fri 1/5/24
5	DEVICE MANUFACTURING		5.5 hrs	Thu 2/1/24
6	DEVICE EVALUATION		8 hrs	Tue 4/2/24
6a	Drop Test	1.5hrs	3 hrs	Tue 4/2/24
6b	Velocity Test	2hrs	2.5 hrs	Sun 4/21/24
6b.i	New Velocity Test	2	1.5 hrs	Sun 5/5/24
6c	Chassis Deflection Test	1.5hrs	1 hr	Wed 5/8/24
6c.i	Analysis recalculated/Test results compared	2hrs	30 mins	Thu 5/9/24
7	DELIVERABLES		86.5 hrs	Tue 3/26/24
7a	Web Page/Design	2hrs	1.5 hrs	Wed 9/27/23
7a.i	Web02	1.5hrs	1.5 hrs	Fri 5/10/24
7a.ii	Web03	.5hr	0.5 hrs	Fri 5/24/24
7b	Poster Draft	1.5hrs	2.5 hrs	Sat 4/27/24
7b.i	Poster to SOURCE	1hr	1 hr	Fri 5/3/24
7b.ii	Source presentation	2hr	2 hrs	Thu 5/16/24
7c	Engineering Report	80hrs	77.75 hrs	Mon 6/3/24

Figure E06. Spring Schedule

APPENDIX F – Expertise and Resources

Criterion	Weight 1 to 3	Best Possible 3	Gear Drivetrain Design	Score x Wt	Belt Drivetrain Design	Score x Wt	Off Road Design	Score x Wt	
Criterion1	1	3	3	3	2	2	1	1	
Criterion2	3	9	2	6	3	9	1	3	
Criterion3	2	6	2	4	1	2	1	2	
Criterion4	2	6	2	4	2	4	1	2	
Criterion5	3	9	2	6	1	3	1	3	
Criterion6	2	6	3	6	3	6	1	2	
Total	13	39		29		26		13	
NORMALIZE THE DATA (muliply by fraction, N)		2.56		74.4		66.7		33.3	Percent

Decide if Bias is Good or Bad	Good Bias:	Standard Deviation is two or more digits	Good? Then done.	58.1	Average
	Poor Bias:	Standard Deviation is one or less digits	Poor? Change something!!!	22	Std Dev.
		You can change the criteria, weighting, or the projects themselves...			

Weighting/Scoring Scale	
1	Worst (too costly, low confidence, too big, etc.)
2	Median Values, or Unsure of actual value
3	Best (Low Cost, high confidence, etc.)

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

Comments:

The gear drivetrain design scored the highest out of the three because it showed the best possibilities of being produced with minimal cost and manufacturability. The off road design scored the least because of its size it would cost more to produce. As for belt drivetrain desing it was similar to the alt gear drivetrain , but it has additional components that would affect cost of manufacturing and create a complication of space availability in the drivetrain.

Figure F01. Image of design decision matrix

Criterion	Weight 1 to 3	Best Possible 3	PLA	Score x Wt	PLA +	Score x Wt	Aluminum 6061	Score x Wt	
Cost	1	3	2	2	2	2	1	1	
Prediction Precision	2	6	2	4	3	6	2	4	
Yield Strength	3	9	1	3	2	6	3	9	
Density	3	9	1	3	3	9	1	3	
Manufacturability	1	3	2	2	2	2	3	3	
Total	10	30		14		25		20	
NORMALIZE THE DATA (muliply by fraction, N)		3.33		46.7		83.3		66.7	Percent

Decide if Bias is Good or Bad	Good Bias:	Standard Deviation is two or more digits	Good? Then done.	65.6 Average
	Poor Bias:	Standard Deviation is one or less digits	Poor? Change something!!!	18 Std Dev.
		You can change the criteria, weighting, or the projects themselves...		

Weighting/Scoring Scale	
1	Worst (too costly, low confidence, too big, etc.)
2	Median Values, or Unsure of actual value
3	Best (Low Cost, high confidence, etc.)

Criterion	
Cost	More mass is more cost
Prediction precision	Are the engineers calculations sufficient and correct?
Density	Desnity value of the material
Yield Strength	Materials maximum stress before deformation
Manufacturability	Is it simple to produce? Are there multiple process for a single component?

Comments:

Cost : this was not very important as the cost was not something analysis was performed on

Prediction Precision: Analysis was performed to determine possible failure modes

Yield Strength: Very important since it determines the materials maximum stress before dformation

Density: Important since it will determine what the material weight

Figure F02. Image of Material decision matrix

Criterion	Weight	Best Possible	3-D Printing	Score x Wt	CNC Machine	Score x Wt	Laser Cutting	Score x Wt
	1 to 3	3						
Cost	3	9	3	9	1	3	2	6
Weight	3	9	3	9	1	3	2	6
Predicition Precision	2	6	3	6	2	4	2	4
Confidence Failure Loc	1	3	1	1	2	2	2	2
Prismatic vs non Prismatic	2	6	3	6	3	6	3	6
Manufacturability	3	9	3	9	1	3	1	3
Total	14	42		40		21		27
NORMALIZE THE DATA (muliply by fraction, N)		2.38		95.2		50.0		64.3 Percent

Decide if Bias is Good or Bad	Good Bias:	Standard Deviation is two or more digits	Good? Then done.	69.8 Average
	Poor Bias:	Standard Deviation is one or less digits	Poor? Change something!!!	23 Std Dev.
		You can change the criteria, weighting, or the projects themselves...		

Weighting/Scoring Scale

1	Worst (too costly, low confidence, too big, etc.)
2	Median Values, or Unsure of actual value
3	Best (Low Cost, high confidence, etc.)

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

Comments:

Cost: 3D printing is the least cost consuming form of manufacturing, while CNC machining is the highest and laser machining is in between.

Weight: 3D printing is the lightest form of manufacturing because it is made of plastic, while the other forms of manufacturing are meant for metals which are heavier.

Prediction Precision: The calculcations are done the same way but with different values of material properties. They all have suitable properties, but 3d printing is much more available.

Confidence Failure Loc: CNC machining and laser cutting are much better decisions for an application where stronger properties are required to withstand the loads, but a 3d printing method would have much more predictable failure locations due to imperfections..

Prismatic vs non Prismatic: The shape would be the same for all, simple squares.

Manufacturability: Manufacturing with 3D printing is simpler than using bigger machines to cut away material, while in contrast the printer adds material.

Figure F03. Image of Process decision matrix for manufacturing process

Criterion	Weight	Best Possible						
	1 to 3	3	Casting	Score x Wt	Welding	Score x Wt	Stamping	Score x Wt
Cost	3	9	1	3	2	6	3	9
Weight	3	9	1	3	2	6	3	9
Predicition Precision	2	6	1	2	2	4	3	6
Confidence Failure Loc	3	9	1	3	1	3	2	6
Prismatic vs non Prismatic	2	6	3	6	2	4	1	2
Manufacturability	3	9	1	3	2	6	2	6
Total	16	48		20		29		38
NORMALIZE THE DATA (muliply by fraction, N)		2.08		41.7		60.4		79.2 Percent

Decide if Bias is Good or Bad	Good Bias: Standard Deviation is two or more digits	Good? Then done.	60.4 Average
	Poor Bias: Standard Deviation is one or less digits	Poor? Change something!	19 Std Dev.
	You can change the criteria, weighting, or the projects themselves...		

Weighting/Scoring Scale	
1	Worst (too costly, low confidence, too big, etc.)
2	Median Values, or Unsure of actual value
3	Best (Low Cost, high confidence, etc.)

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

Comments:

Cost: Stamping is the least costly form of manufacturing in comparison to welding and casting just due to the processes needed to form a final product.

Weight: Stamping is usually done with thinner materials to form a shape, while welding and casting are additive forms of manufacturing through the use fusion.

Predicition Precision: Casting is inconsistent and welding would be hard to determine if a weld deforms the part, but when stamping it is measured and pressed with a jig.

Confidence Failure Loc: Casting would be hard to get a uniform part with correct dimensions and welding make the material more brittle, While stamping is more consistant.

Prismatic vs non Prismatic: For solid shapes the use of casting and welding are more desireable, but stamping is done with flat sheets, which is not as desireable for this project application.

Manufacturability: Welding and Casting are more available to students than stamping, but stamping is much more feasible because it doesn't require as much skill and setup.

Figure F04. Image of Process decision matrix for suspension and steering

APPENDIX G – Testing Report

Appendix G1-2ft Drop Test

Introduction

The RC device was required to withstand a drop from a 2ft distance while not deflecting more than .1" which can be seen in requirement 13. In appendix A03 an analysis was conducted to calculate the deflection of the chassis due to the force experienced during the 2ft drop. The calculated deflection was determined to be .00224" which was less than the requirement and should withstand the impact. Another important requirement was to ensure that the adhesive used would not exceed the ultimate tensile strength of the material of 1200psi (1d.12). The data will be collected with the use of a slow-motion camera and with the use of tape to mark the initial starting position, then with a ruler the deflection will be determined.

Method/Approach

During the testing, some resources utilized was the tape used to determine the initial location of the testing as well as the use of the slow-motion camera that will be used to record the RC during the drop so that the data can be gathered based on the measuring tool that was used, in this case it was a tape measure. The expense for this test includes the purchase of the tape and slow-motion camera while the measurement tool was provided by the CWU machine shop. The accuracy of the data will only be as accurate as the slow-motion capture rate and resolution as well as how accurate each trial run is from the previous one. In order to perform this test, a large flat area will be used to ensure all wheels hit the ground at the same time. The data will be recorded in a table then graphed to compare the force and the deflection caused during the 2ft drop.

Test Procedure

Image of Testing Setup:

Figure G1. Image of testing set up where all the required materials are shown from the RC device to the measuring tool and writing utensils

Summary: The main focus will be to determine the amount of deflection caused to the entire vehicle and ensure the adhesive utilized to join the chassis won't fail. To do so, the RC will be dropped from 2ft off the ground and will be marked with tape. Then with the use of a device with the capability of slow-motion, the testing procedures will be recorded and with a tape measure, the deflection will be measured. Then the force can be calculated based on the weight and the amount of deflection that the device experienced.

Time: The test was conducted 04/02/2024 from 10:00am to 1:00pm outside of Hogue Hall. There was 20min to set up and collect the required equipment needed for the testing. After each trial run, there was 10min to retrieve the data and clean up.

Place: Hogue Hall, Central Washington University campus in Ellensburg, WA

Required Equipment:

- Marker
- Blue Tape
- Tape Measure
- Slow-Motion Device (Ie. Smartphone, iPhone)
- RC Device

- Writing Utensil
- Safety Glasses
- Paper
- Hanging Scale

Risk:
This test will put stress on various components which may cause them to fail and break. In order to mitigate this issue as much as possible, many extras were printed for the components so that if one did break a replacement was already at hand. Weather will also be a risk, since the testing will take place outside there can be a chance that it rains which will cause issues since the RC is not waterproof and may cause damage.

The test procedure is as follows:

1. Bring the purchased equipment to the testing cite: Rc, blue tape, camera with slow-mo, tape measure, paper and writing utensil, hanging scale from room 127 in Hogue Hall. See figure G1.
2. Arrive outside of Hogue Hall near the loading dock outside the machine shop.
3. Place equipment on the floor near the building wall
4. Set up the camera 4ft away from the wall sitting horizontal on the ground.
5. Place 2 inches of blue tape at the front of the chassis and draw a cross at the center. (This will be used to compare deflections at different states from the normal state)
6. Have someone ready to hold the measuring tape against the wall measuring over 4ft
7. Measure 2ft on the wall and mark it with the blue tape (starting position)
8. Start recording.
9. Hold measuring tape in front of RC
10. Bring the Rc over to the 2ft mark on the wall with the blue tape.
11. Drop the Rc with the front facing the camera.
12. Stop recording.
13. Look at the footage for the most deflection.
14. Record deflection measurement on the table.
15. Repeat steps 8-14 five times.
16. Repeat steps 8-15 once but with the Rc rotated 90deg about its Z-axis. (Total of 12 runs)
17. Measure the force due to its own weight using scale(mg)
18. Record Calculated Values on Table
19. Make a graph with the Force vs Deflection
20. Calculate stress due to the force from the drop
21. Clean up the testing area.
22. Remove tape from walls.
23. Compare the deflection prediction to the gathered data.

Discussion: The testing for this progressed with some procedural issues like with the clearance between the chassis and the ground hitting the ground. This was mitigated by adding more trials from the original 5 trials to 12 trials. Another challenge was the 3D printed ball joints breaking due to the impact during one of the trials. This was solved by simply swapping the 3D printed component for an aluminum one.

Deliverables

The main deliverable for this testing section is the table where the deflection was tabulated. With this, it was observed that the maximum deflection experienced was about the same as the clearance between the chassis and the ground. It would be best to then increase the clearance thus a better set of results could be obtained. It can also be seen that the front would slam at times if the device did not lad evenly on the ground which can be seen in the table (appendix G1.4) where the front section experienced a larger spring force at times due to the rear being heavier.

Appendix G1.1 – Procedure Checklist

Collect Materials:

- Marker
- Blue Tape
- Tape Measure
- Slow-Motion Device (Ie. Smartphone, iPhone)
- RC Device
- Writing Utensil
- Safety Glasses
- Paper
- Hanging Scale

Set up testing location

Measure 2ft height on wall

Star recording

Stop recording

Notate results in table

Appendix G1.2 – Data Forms

Table G1- 2ft drop test data table

Front equilibrium point:			K=
Front	End Point (cm)	Displacement (cm)	Predicted Displacement (cm)
1			
2			
3			
4			
5			
6			
Side equilibrium point:			

Side	End Point (cm)	Displacement (cm)	
1			
2			
3			
4			
5			
6			

Weight of Vehicle:
Distance dropped:
Adhesive Stress:

Appendix G1.3 – Raw Data

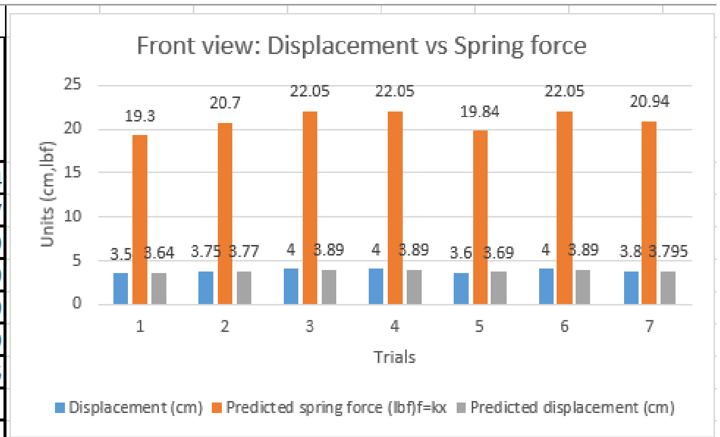
Table G2- 2ft drop test data table

Front equilibrium point: 6.5cm			K=14lb/in
Front	End Point (cm)	Displacement (cm)	Predicted Displacement (cm)
1	3.0	3.5	3.64
2	2.75	3.75	3.77
3	2.5	4.0	3.89
4	2.5	4.0	3.89
5	2.9	3.6	3.69
6	2.5	4.0	3.89
AVG		3.8	3.795
Side equilibrium point: 6.0 cm			
Side	End Point (cm)	Displacement (cm)	Predicted Displacement (cm)
1	3.8	2.7	3.19
2	4.0	2.5	3.07
3	3.25	3.25	3.5
4	3.75	2.75	3.22
5	3.9	2.6	3.13
6	4.5	2.0	2.75
AVG		2.6	3.14

Weight of Vehicle: 7lbs/31.14N
Distance dropped: 2ft
Adhesive Stress: 6.234psi

Appendix G1.4 – Evaluation Sheet

Front equilibrium point: 6.5cm				k=14lb/in
Front	End Point (cm)	Displacement (cm)	Predicted spring force (lbf)f=kx	Predicted displacement (cm)
1	3	3.5	19.3	3.64
2	2.75	3.75	20.7	3.77
3	2.5	4	22.05	3.89
4	2.5	4	22.05	3.89
5	2.9	3.6	19.84	3.69
6	2.5	4	22.05	3.89
AVG	2.69	3.8	20.94	3.795
Side equilibrium point: 6.0 cm				
Side	End Point (cm)	Displacement (cm)	Predicted spring force (lbf)f=kx	Predicted displacement (cm)
1	3.8	2.7	14.88	3.19
2	4	2.5	13.78	3.07
3	3.25	3.25	17.91	3.5
4	3.75	2.75	15.16	3.22
5	3.9	2.6	14.32	3.13
6	4.5	2	11.02	2.75
AVG	3.87	2.63	14.5	3.14



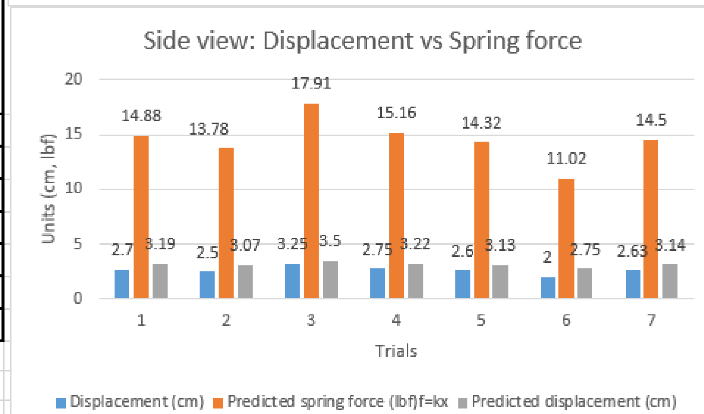


Figure G2. Evaluation Sheet

Appendix G1.5 – Schedule (Testing)

	6	**DEVICE EVALUATION**		**57 days?**	**Tue 3/26/24**	**Fri 6/7/24**
	6a	Drop Test	1.5hrs	3 hrs	Tue 4/2/24	Tue 4/2/24

Figure G3. Schedule of drop test

Appendix G2-Maximum Velocity Test

Introduction

During this testing section, the main focus is on ensuring that the device will be meeting the velocity requirement (req-1.d.7) which states that the RC will be able to reach a velocity of 30mph. In Appendix A01 an analysis was performed to determine the gear ratio required in order to achieve a top speed of 30mph. In the analysis it was determined that in order to achieve a velocity of 30mph the RC would need a train value of 9:1 with a wheel diameter of 6.9”. Data will be collected by timing the device through various trails and with a speedometer the velocity will be determined.

Method/Approach

During the testing procedure, some important materials include a device with a stopwatch and a large area with open space. Just driving the device normally, it was noticed that the acceleration was not the best and so for this test a large area where the RC could reach its maximum velocity was going to be important. Then with a device that has a speedometer like a smartphone, the top speed will be measured by strapping the smartphone to the device for the trails. Then this data will be tabulated, and it will be possible to calculate the acceleration. The expense for this test will include the purchase of the stopwatch and speedometer if none are available, however this can be easily solved since a majority of smartphones have both capabilities. The accuracy will depend on the measuring tool used; in this case the tool was a speedometer on a smartphone. Since a large area is required, either the fluke lab will be used in Hogue or the track at CWU will be used. Because of this, it will be important that it is not too windy as that may hinder the device's performance due to air resistance. The data will then be recorded on a table to compare the acceleration and velocity experienced.

Test Procedure

Figure G4. Image of required testing equipment

Summary: This procedure details the process of timing the device through various trails to determine the maximum velocity. The device was designed by the students in charge of this report and was designed to achieve a velocity of 30mph. In order to do so, a large flat area will be required with multiple trail runs being conducted.

Time: The test was performed 04/20/2024 from 11:00am to 1:00pm. There were 15min of set up and each trial was performed with 2 min intervals to give the device time to rest.

Place: outside of the fluke lab in Hogue Hall or the track in Central Washington University campus in Ellensburg, WA

Required Equipment:

- Writing utensil
- Paper
- Speedometer (phone)
- RC Car
- Large flat area
- Safety glasses
- Stopwatch
- Blue tape

Risk: During the velocity test, it was observed beforehand that the acceleration of the device is not very large and so this might cause issues with the RC not reaching its maximum velocity. To mitigate this, various runs will be performed and then the acceleration will be calculated. Then it will be possible to determine the distance required for the RC to reach the maximum velocity.

The test procedure is as follows

1. Arrive at testing location: Fluke Lab outside of the machine shop in Hogue
2. Bring required equipment to testing: Safety glasses, stopwatch, writing utensil, paper, speedometer, RC device, Blue tape
3. Measure a 5ft distance and mark it with blue tape
4. From the 5ft mark, measure a 10ft distance and mark it with blue tape (make sure the starting position is also marked with blue tape, i.e.0ft) up to 45ft
5. Place the front wheels of the RC on the blue tape with the rear wheels being at the front
6. The person with the stopwatch will count down from three and then the run will begin
7. Once the timekeeper says three, the RC handler will slowly accelerate until they reach the 5ft mark
8. Once at 5ft, full throttle the device and travel as fast as possible
9. Timekeeper will time how long it took the RC to travel the 45ft distance
10. Record data in table
11. Take 5min break for motor
12. Repeat steps 5-11 4 times (total of 5 trials)
13. Clean up testing cite
14. Compare predicted result to the actual data

Discussion: During the testing for the velocity, it was observed that the motor being used would overheat quite drastically due to the fact that more torque was required but the motor was already receiving the maximum current thus causing the overheating. To mitigate this issue, breaks had to be taken to allow the motor to cool down, however this was not enough, and the velocity just kept decreasing (see table G4). Once a new 1980kV brushless motor was purchased, the velocity was now 13.2mph rather than 3.4mph and no further issues of overheating were experienced. To further increase the velocity, metal gears would be used to help with any issues of teeth being ripped apart at high velocities

Deliverables

The deliverables for this section will include the data that was gathered during the velocity test. It was determined that a new motor would need to be used since the old one was noticed to overheat quite often. Another potential change is with the gear ratio, increasing it from 12:1 to 10:1 giving the device more acceleration and top speed.

Appendix G2.1 – Procedure Checklist

Collect Materials:

- Writing utensil
- Paper
- Speedometer (phone)
- RC Car
- Large flat area
- Safety glasses
- Stopwatch
- Blue tape

Appendix G2.2 – Data Forms

Table G3- Maximum velocity table

Forward	Velocity (mph)	Time (s)

1		
2		
3		
4		
5		
Average		

Distance Traveled:

Appendix G2.3 – Raw Data

Table G4- Maximum velocity table data

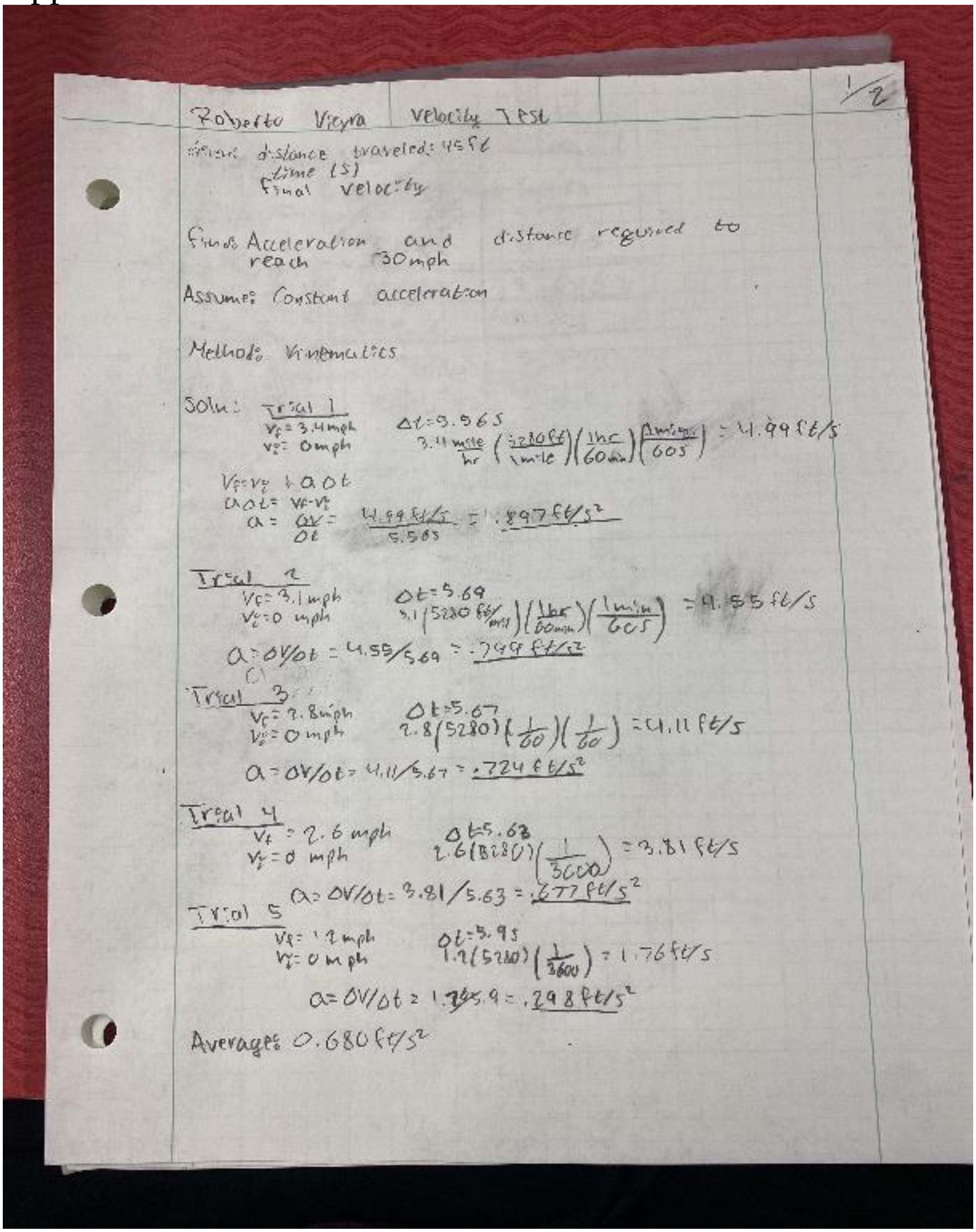
Forward	Velocity (mph)	Time (s)
1	3.4	5.56
2	3.1	5.69
3	2.8	5.67
4	2.6	5.63
5	1.2	5.90
Average	2.62	5.69

Distance Traveled: 40ft

Table G5-Second Velocity test data

Forward	Velocity (mph)	Time (s)
1	11.8	3.14
2	12.8	2.9
3	12.9	2.86
4	12.9	2.7
5	13.2	2.65
Average	12.72	2.85

Appendix G2.4 – Evaluation Sheet


Roberto Vieyra | Velocity Test | 1/2

distance traveled: 45 ft
time (s)
final velocity

Find Acceleration and distance required to reach 30 mph

Assume: Constant acceleration

Method: Kinematics

Soln: Trial 1
$V_f = 3.4$ mph $\Delta t = 5.56$ s
$V_i = 0$ mph $3.1 \frac{mile}{hr}\left(\frac{5280 ft}{1 mile}\right)\left(\frac{1 hr}{60 min}\right)\left(\frac{1 min}{60 s}\right) = 4.99$ ft/s
$V_f = V_i + a\Delta t$
$a\Delta t = V_f - V_i$
$a = \frac{\Delta V}{\Delta t} = \frac{4.99 ft/s}{5.56 s} = .897$ ft/s²

Trial 2
$V_f = 3.1$ mph $\Delta t = 5.69$
$V_i = 0$ mph $3.1\left(5280 \frac{ft}{mi}\right)\left(\frac{1 hr}{60 min}\right)\left(\frac{1 min}{60 s}\right) = 4.55$ ft/s
$a = \Delta V/\Delta t = 4.55/5.69 = .799$ ft/s²

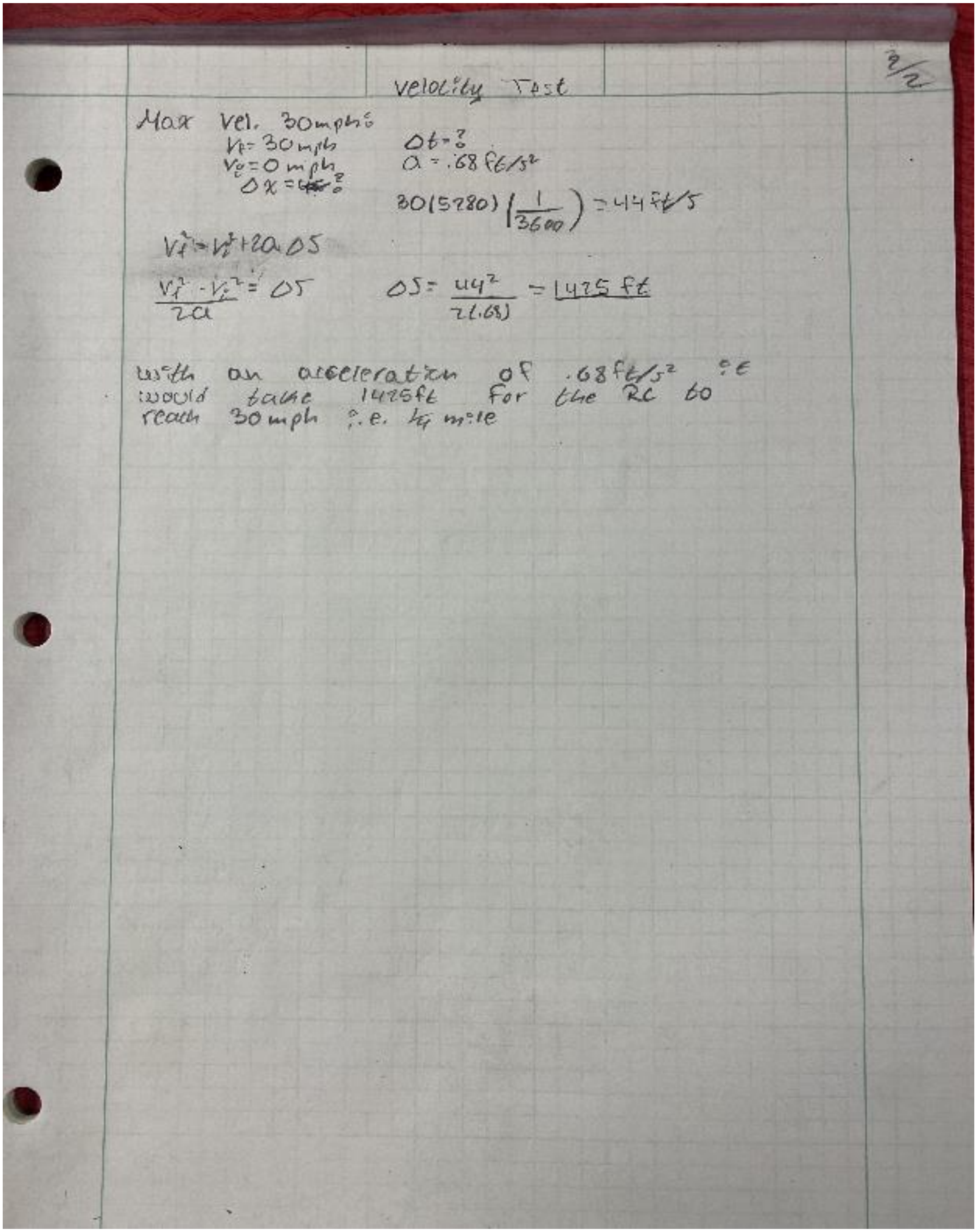
Trial 3
$V_f = 2.8$ mph $\Delta t = 5.67$
$V_i = 0$ mph $2.8(5280)\left(\frac{1}{60}\right)\left(\frac{1}{60}\right) = 4.11$ ft/s
$a = \Delta V/\Delta t = 4.11/5.67 = .724$ ft/s²

Trial 4
$V_f = 2.6$ mph $\Delta t = 5.63$
$V_i = 0$ mph $2.6(5280)\left(\frac{1}{3600}\right) = 3.81$ ft/s
$a = \Delta V/\Delta t = 3.81/5.63 = .677$ ft/s²

Trial 5
$V_f = 1.2$ mph $\Delta t = 5.9$ s
$V_i = 0$ mph $1.2(5280)\left(\frac{1}{3600}\right) = 1.76$ ft/s
$a = \Delta V/\Delta t = 1.76/5.9 = .298$ ft/s²

Average: 0.680 ft/s²

Figure G5. Green sheet analysis of acceleration calculations



2/2

Velocity Test

Max Vel. 30mph?

$V_f = 30$ mph

$V_i = 0$ mph

$\Delta x = ?$

$\Delta t = ?$

$a = .68\ ft/s^2$

$30(5280)\left(\frac{1}{3600}\right) = 44\ ft/s$

$V_f^2 = V_i^2 + 2a\Delta S$

$\frac{V_f^2 - V_i^2}{2a} = \Delta S$

$\Delta S = \frac{44^2}{2(.68)} = 1425\ ft$

With an acceleration of .68 ft/s^2 it would take 1425ft for the RC to reach 30 mph i.e. ¼ mile

Figure G6. Green sheet analysis for the distance required to travel 30mph

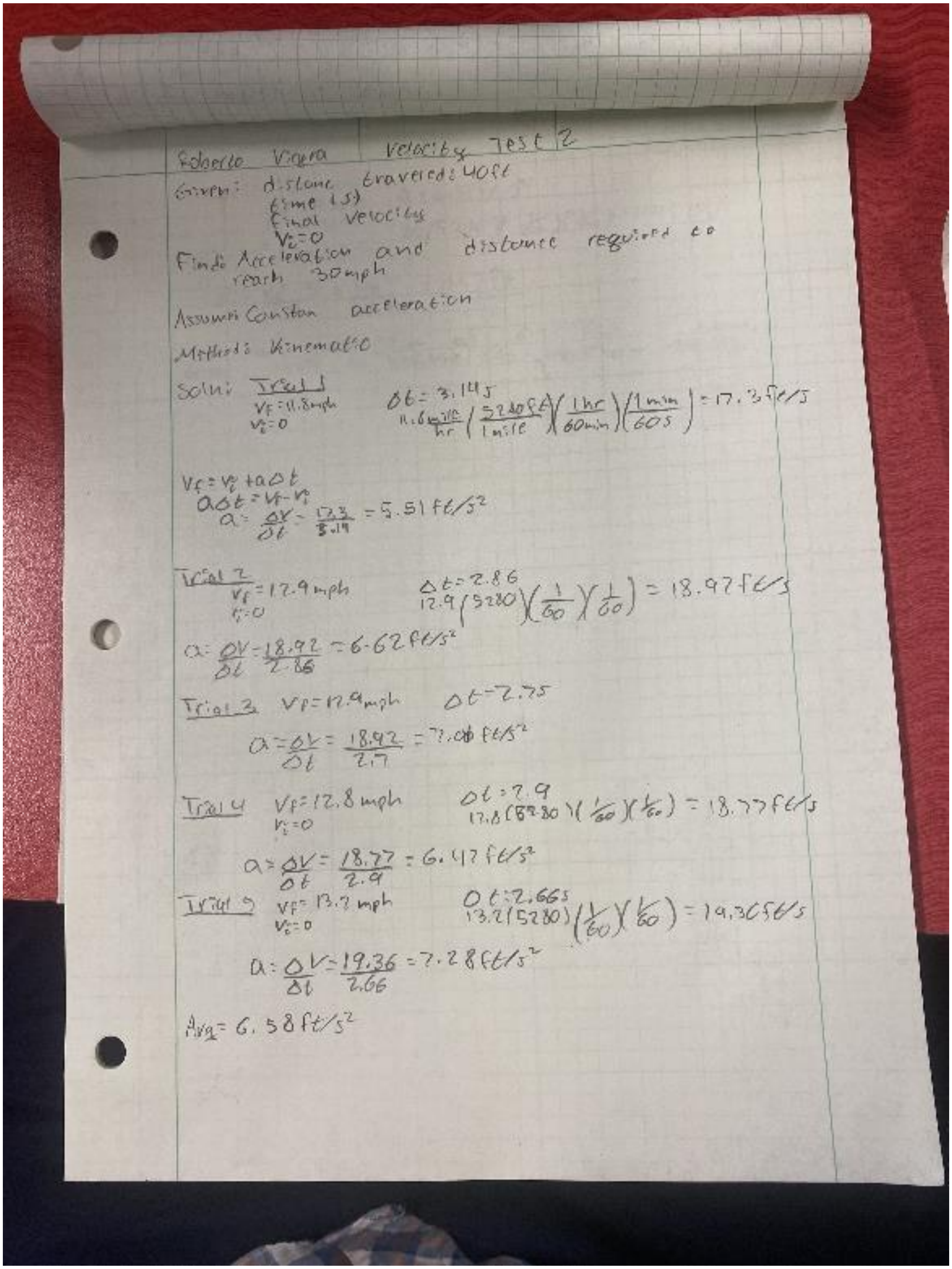


Figure G7. Second Velocity test of acceleration calculations

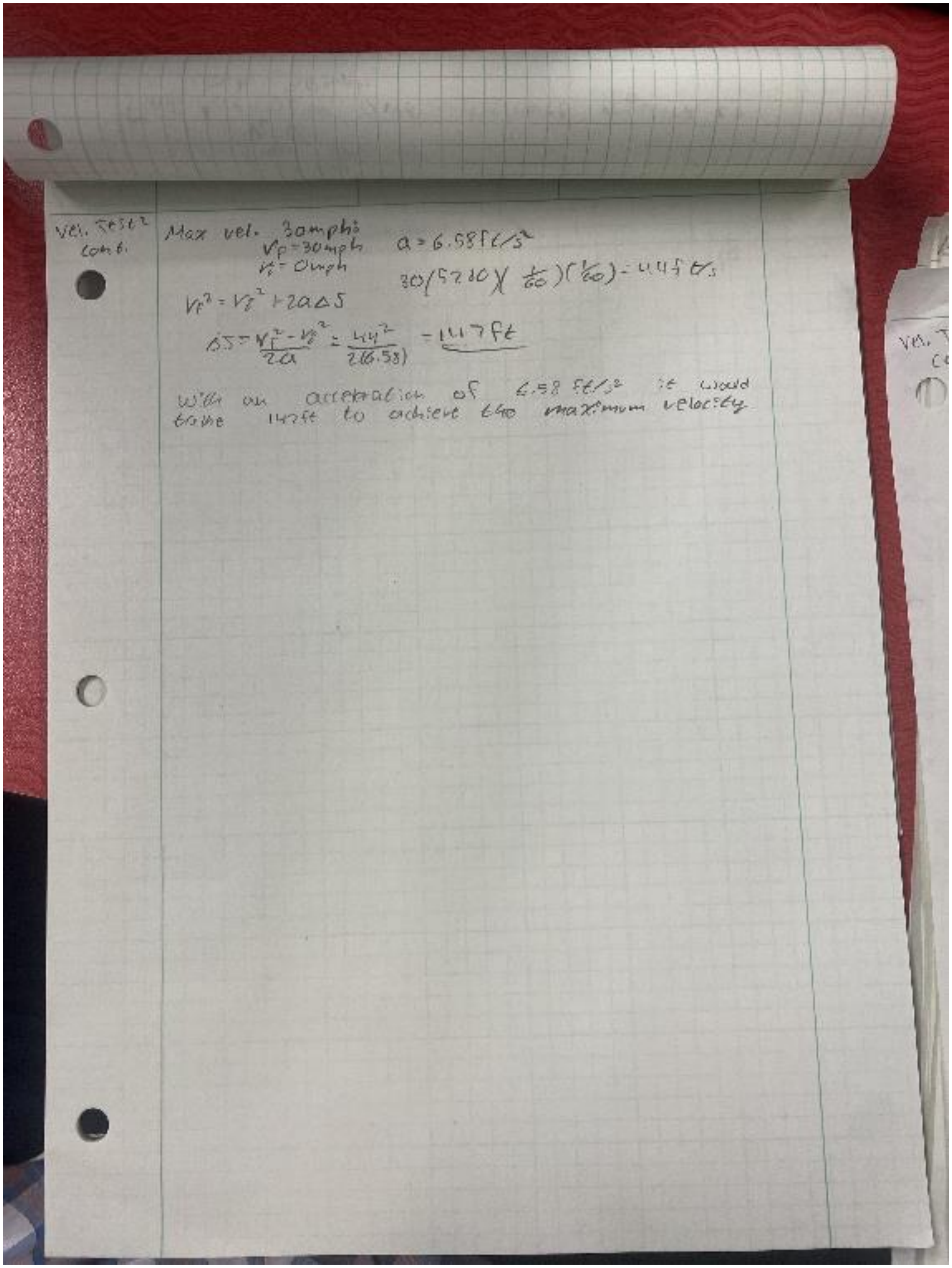


Figure G8. Second velocity test calculation where the distance was calculated

Velocity (Mph)	Time (s)	Distance (ft)
3.4	5.56	40
3.1	5.63	40
2.8	5.69	40
2.6	5.72	40
1.2	5.9	40

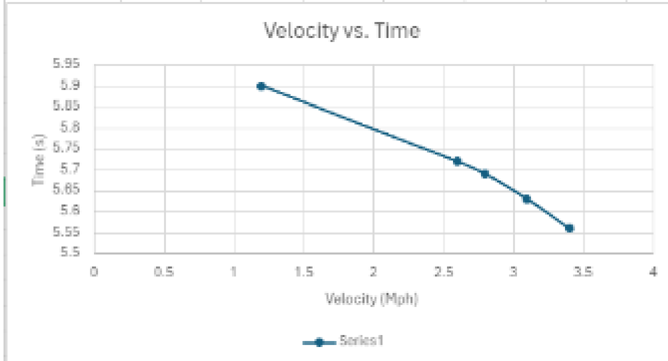


Figure G9. Graph of the velocity vs time results

Velocity (Mph)	Time (s)	Distance (ft)
11.8	3.14	40
12.8	2.9	40
12.9	2.86	40
12.9	2.7	40
13.2	2.65	40

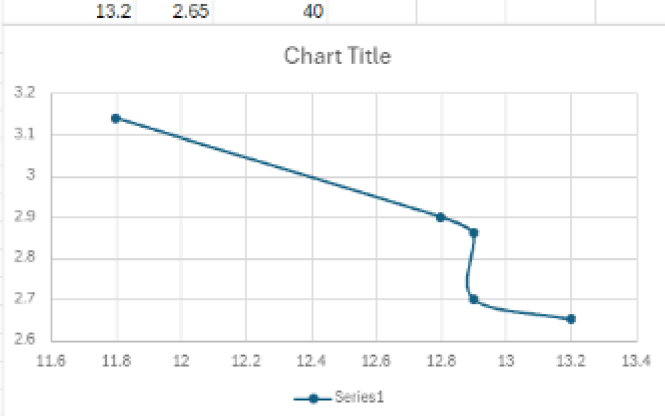


Figure G10. Second velocity test data

Appendix G2.5 – Schedule (Testing)

6b	Velocity Test	2hrs	2.5 hrs	Sun 4/21/24	Sun 4/21/24

Figure G11. Schedule of velocity test

Appendix G3- Chassis deflection Test

Introduction

The main focus for this test is to ensure the deflection requirement req.1d-13 which states that the chassis will not deflect more than .1in due to the force caused during the 2ft drop. This test will put the chassis through a simulated load on the Instron machine which will determine the deflection due to a three-point load. Analysis was performed in appendix A03 where the maximum deflection was calculated assuming the chassis would be simply supported experiencing 40lbf.

Method/Approach

During the testing for this component, some of the important pieces of equipment was going to be the Instron machine available in Hogues's materials lab and the chassis that is going to be loaded. Once all of the components were stripped from the chassis, it was then possible to place it on the Instron with two supports on each side simulating a 3-point load. With the chassis in place the Instron was set to load up to 40lbf and once the chassis was fully loaded the testing was over. Then the data was downloaded and opened in excel so that a graph can be made, and the data analyzed.

Test Procedure

Summary: This procedure will document the process of testing for the deflection requirement for the RC. The students performed an analysis to determine the cross-sectional area required to not exceed a deflection of .1in due to the force from the 2ft drop. This test will use the Instron machine as the main tool for testing.

Time: The test was performed on 05/08/2024 from 8:00am – 10:00am. Testing takes about 30min and the set up and clean up portions each taking about 15min each.

Place: Testing took place in Hogue Hall room 127 (Materials Lab), Central Washinton University, Ellensburg WA

Required Equipment:

- RC Baja chassis
- Thumb drive
- Instron Machine-Model 34SC-5
- Safety Glasses
- Cell phone (to record/images)

Risk/Safety: The major risk for this test was the possibility of the chassis fully breaking during the loading since it was split in two pieces and then joined together with an adhesive. To mitigate this risk, analysis was performed to ensure the adhesive would not fail.

Testing procedure is as follows:

1. Arrive at testing location: Hogue Hall room 127
2. Bring required testing equipment: thumb drive, RC Baja chassis, safety glasses cell phone
3. Set up the Instron Machine
    a. Ensure computer is logged in
    b. Turn on the Intron machine using the switch on the back side of the machine, located on the right side
        i. The side closest to the machine
    c. Place flash drive in the computer, located under the Instron

d. Select Blue Hill Application from the home screen
e. Ask Professor Pringle or Professor Capovilla to help long in as it required ADMIN access

4. Setting up test
    a. Once logged in to the Blue Hill application, select the quick test option
    b. Set the units to the corresponding ones for the test, in this case they will be lbf and inches (see figure G8 in orange)
    c. The testing direction will also be set to compression rather than stretch
    d. Set the speed to .125 in/min which will allow for flaws and stress concentration to be noticeable (see in figure G12 in blue)

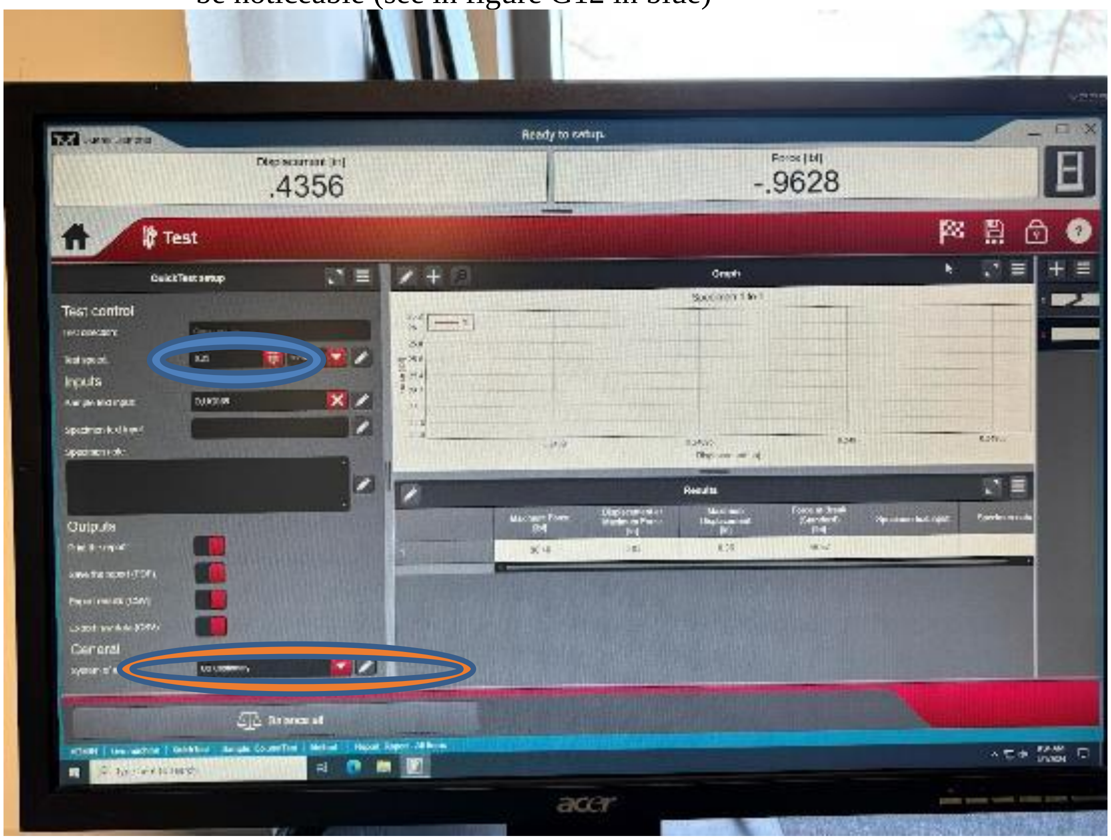


Figure G12. Instron test set up

5. Set up Instron Machine Testing Fixture
    a. This test will utilize the three-point load fixture (see figure G9)

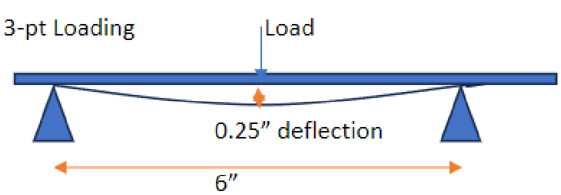


Figure G13. Image of three-point load set up

    b. Remove the pins from the currently placed supports (see figure G13) this will be done to both sides and replaced with the supports needed for the three-point loading

c. Lay the chassis as close to the center of the test fixture
d. Lower the center point load to the chassis using the up and down arrows on the front panel of Instron (see figure 14)

Figure G14. Front panel of Instron Machine

6. Starting the Test
    a. Make sure the estop is off (big red button in figure G14)
    b. Start the test by pressing the start test button on the computer
7. Once the chassis reaches the load during analysis (40lbs), remove the chassis from the fixture
8. Download the data from the Instron software onto the flash drive
    a. Click the save icon in the upper right-hand corner of the computer screen
9. Click the finish button
    a. Button on the upper right-hand corner of the screen that looks like a finish flag
10. Clean up testing area

Discussion: The deflection test was important to ensure that there were going to be no issues during the drop test as well as to ensure the adhesive used to join the two halves of the chassis. With the Instron machine, it was possible to place the chassis as if it were 3-point loaded at the center of the chassis which was also the location where the adhesive was placed. There were no issues during this testing phase as everything was done by the Instron machine and the only set up was the placing of the chassis on the machine.

Deliverables

During this section the deliverables was to ensure that the chassis would be meeting requirement 1d-13 which states that the chassis will not deflect more than .1in due to the force from the 2ft drop. The predicted value was about .0314in assuming a solid component then taking into account that the chassis was printed using a 25% infill, the deflection was now calculated to be .1259in. The deflection exceeded the requirement by about .004in at .104in and can be due to the fact that there are holes on the chassis and the analysis was conducted assuming a solid component rather than with some infill. Since the deflection was really close to the requirement, simply increasing the infill will be enough to pass the requirement.

Appendix G3.1 – Procedure Checklist

- Collect Materials:
- Writing Utensil
- Paper
- Camera (Phone)
- RC Device
- Flash drive
- Safety glasses

Appendix G3.2 – Data Forms

Table G6- Instron Deflection data

Time (s)	Displacement (in)	Force (lbf)

Appendix G3.3 – Raw Data

12.04	0.099405512	37.85632
12.06	0.099586614	37.92376
12.08	0.099744094	37.9912
12.1	0.09988189	38.05864
12.12	0.100019685	38.1036
12.14	0.100177165	38.14856
12.16	0.10034252	38.216
12.18	0.100511811	38.28344
12.2	0.100688976	38.35088
12.22	0.10088189	38.41832
12.24	0.101070866	38.50824
12.26	0.10123622	38.57568
12.28	0.101405512	38.64312
12.3	0.101590551	38.71056
12.32	0.101767717	38.80048
12.34	0.101917323	38.86792
12.36	0.102059055	38.91288
12.38	0.102216535	38.98032
12.4	0.102374016	39.02528
12.42	0.10253937	39.09272
12.44	0.102704724	39.13768
12.46	0.10288189	39.20512
12.48	0.103062992	39.29504
12.5	0.103224409	39.36248
12.52	0.103377953	39.42992
12.54	0.103559055	39.49736
12.56	0.103751969	39.5648
12.58	0.103909449	39.63224
12.6	0.104051181	39.69968
12.62	0.104208661	39.76712
12.64	0.104370079	39.81208
12.66	0.104527559	39.87952
12.68	0.104692913	39.92448
12.7	0.104870079	39.99192
12.701	0.104877953	39.99192

Figure G15. Image of Intron test results

The maximum deflection that was experienced was

Appendix G3.4 – Evaluation Sheet

0.74	0.005244094	0
0.76	0.005409449	0
0.78	0.005551181	0
0.8	0.005688976	0
0.82	0.005850394	0.02248
0.84	0.006011811	0.02248
0.86	0.006173228	0.04496
0.88	0.006346457	0.04496
0.9	0.006535433	0.06744
0.92	0.006720472	0.1124
0.94	0.006889764	0.13488
0.96	0.007062992	0.17984
0.98	0.007255906	0.2248
1	0.007440945	0.24728
1.02	0.007586614	0.31472
1.04	0.007728346	0.35968
1.06	0.00788189	0.40464
1.08	0.00803937	0.4496
1.1	0.008204724	0.49456
1.12	0.008377953	0.562
1.14	0.008562992	0.60696
1.16	0.008748031	0.6744
1.18	0.008913386	0.74184

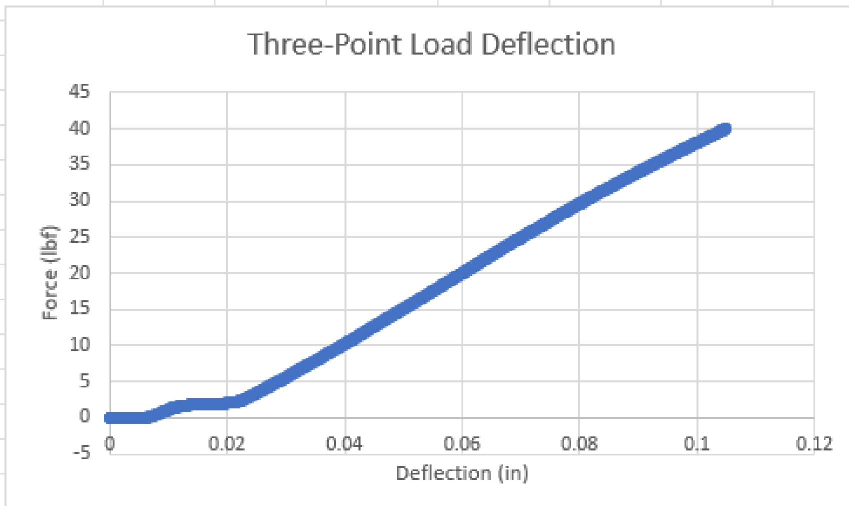
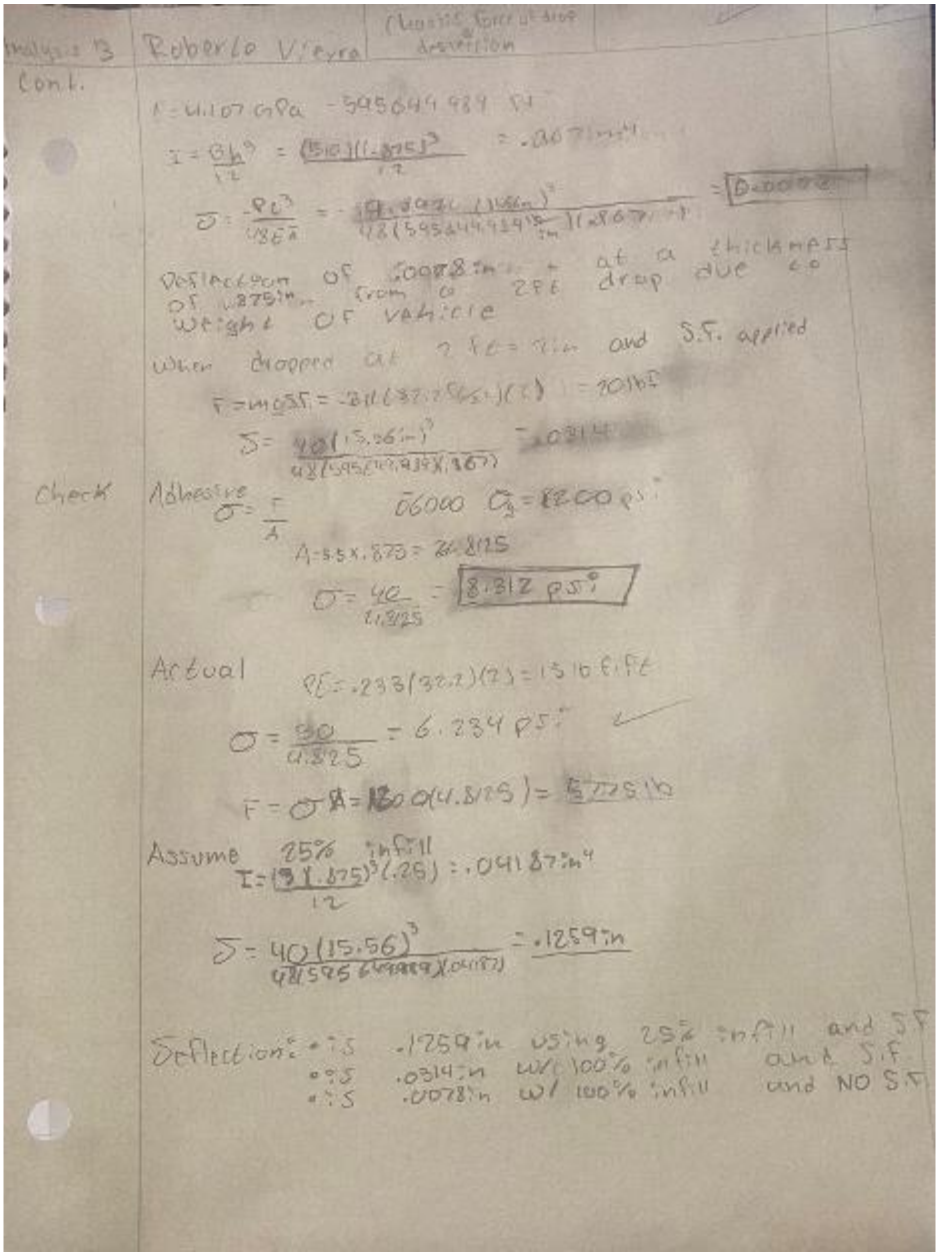


Figure G16. Deflection vs Force graph of tabulated results



Analysis 3 | Roberto Vieyra | Chassis force of drop deflection

Cont.

E = 4.107 GPa = 595649.989 psi

$I = \frac{bh^3}{12} = \frac{(5.10)(1.875)^3}{12} = .2071 in^4$

$\delta = \frac{PL^3}{48EI}$

Deflection of .0078 in at a thickness of .875 in from a 2 ft drop due to weight of vehicle

When dropped at 2 ft = 24 in and S.F. applied

F = mgS.F. = .233(32.2 ft/s²)(2) = 20 lbf

$\delta = \frac{40(15.56 in)^3}{48(595649.989)(.2071)} = .0314$

Check Adhesive $\sigma = \frac{F}{A}$ 06000 σ_y = 8200 psi

A = 5.5 × .875 = 4.8125

$\sigma = \frac{40}{4.8125}$ = 8.312 psi

Actual PE = .233(32.2)(2) = 15.0 ft lbf

$\sigma = \frac{30}{4.8125}$ = 6.234 psi

F = σA = 1800(4.8125) = 8662.5 lb

Assume 25% infill

$I = \frac{(5)(.875)^3(.25)}{12} = .04187 in^4$

$\delta = \frac{40(15.56)^3}{48(595649.989)(.04187)} = .1259 in$

Deflection:
- .1259 in using 25% infill and S.F.
- .0314 in w/ 100% infill and S.F.
- .0078 in w/ 100% infill and NO S.F.

Figure G17. Green sheet analysis where deflection was calculated

Appendix G3.5 – Schedule (Testing)

101	6c	Chassis Deflection Test	1.5hrs	1 hr	Wed 5/8/24
102	6c.i	Analysis recalculated/Test results compared	2hrs	30 mins	Thu 5/9/24

Figure G18. Schedule of Instron Deflection Test

APPENDIX H – Resume

Roberto C. Vieyra Avalos

1520 E Adelia St

WA, Pasco 99301

beto20539@outlook.com

Career Objective: In search of a position where it will be possible to further expand my career in Mechanical Engineering. A strong set of skills were developed through various years of study relating to mechanical design as well as manufacturing and machining.

Summary of Qualifications: I am interested in a position where I am able to apply the skills that I have acquired through various courses and build a solid professional foundation. Experienced working with SolidWorks and have taken and passed the CSWA certification.

Experience:

MET 355 CAD/CAM Manufacturing **FALL 2022**

- The knowledge relating to 3D modeling software like SolidWorks was used in conjunction with computer numeric controlled (CNC) equipment to incorporate these two subjects allowing for complex components to be manufactured. During the duration of the course, the professor guided the students through various CNC operations to manufacture a hammer from raw stock material.

MET 489 Senior Project **FALL 2023**

- Experience was built during the duration of the course where many mechanical design aspects were utilized in the design of the senior project which involved the design/analysis, manufacturing and testing for a 1/8 scale RC where the drivetrain and chassis was designed.

Education:

Central Washington University **SPRING 2024**

Currently a Senior at Central Washington University BS, Mechanical Engineering. CWU, 400 E University Way WA 2023

Chiawana High School

Highschool diploma **JUNE 2020**

Technical Skills:

Hard-Skills: SolidWorks, AutoCAD, Word, Excel

Soft-Skills: Adaptable, Flexible, Punctual, Meeting deadlines

Certificates + Training:

Certified SOLIDWORKS Associate in Mechanical Design (CSWA) **SPRING 2022**

Deans Honor Roll **FALL 2020-2024**

Foreign Languages:

Fluent in: Spanish, English

Figure H1. Image of current resume