# Shell Eco-marathon
# Final Report
# MEEN 402 - 507

Texas A&M University

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# Executive Summary

A Mechanical Engineering senior design team represented Texas A&M University in the Shell Eco-marathon (SEM) competition for the first time this past April. The team competed in the Urban Concept category, which emphasizes the creation of a vehicle that is not only similar to a modern road-legal car, but is also very fuel efficient. The main, evaluated objective of the competition was to maximize fuel efficiency. In order to complete the vehicle in time, the team broke up into five subteams to divide up the necessary tasks. This report details the past work for each subteam.

For the body team, the past work has been the design and manufacturing of the exterior carbon fiber shell of the vehicle. The team first got the foam mold cut and prepped for the layup process. Then the team layed up the carbon fiber sheets to top and bottom molds. These portions were then joined together to complete an enveloping shell for the vehicle. After this, the door, windows, and windshield were cut out with poly-carbonate sheets installed for sealed visibility.

For the powertrain team, the majority of these first few months was been devoted to research and acquiring the necessary components to complete the engine and allow for testing. After this phase, the cooling system and fuel delivery system were constructed. Finally the wiring harness and various sensors were installed. Following this, the engine and all of its components were mounted onto the chassis and the drive chain connected the output gear of the engine was be attached to the rear axle. Finally the welded accelerator pedal was installed and connected to the throttle controller with a cable.

For the frame team, the first part of assembly began with modeling the construction process in separate phases numbered 1-10. This allowed for a smooth assembly process and a seamless transition from coping tubes to assembling them. Coping tubes was a trying process itself. Coping refers to applying the proper curvature of each tube end to ensure each construction section fits together properly. The final step after preparing our tubes was welding. The subteam completed the entire frame and then communicated with other subteams to verify

correct connection points for items such as the engine and door mounts.

For the steering team, the first task was to complete the steering system design and purchasing all needed components. Once the frame subteam completed the chassis, the steering team then carefully welded all the steering mounting points so as to keep the accuracy of the Ackerman steering calculations. Then the steering column was welded and attached to the carbon fiber layed-uped steering wheel. The tie-rods were put in place and attached to the welded steering knuckles on the front two wheel mounts. The brake system was then installed with purchased brake calipers, brake lines, and master cylinder. Finally the welded brake pedal was installed and connected to the master cylinder with the use of plungers.

For the electronics team, the first task was to design a wire diagram and order necessary components. The team then tested multiple components, such as the horn, wiper motor, and LED light strips to validate their use before installation. At the competition, the subteam wired and soldered the electronic system, using the wiring diagram as a guide throughout the process.

For the competition, the team created a detailed travel plan, describing transportation and lodging before, during, and after the event. This includes the rental of a mini-van and truck to tow and transport the team and vehicle out to Sonoma. At the competition, the team encountered some difficulties with technical inspection, passing only two of the 12 criteria the first time around. After a team meeting, the team created a 30 item action list, assigning certain tasks to the various subteams. The team then passed technical inspection and competed on the racetrack, completing two laps before an unforeseen technical error occurred. The team decided not to risk injury or damage to the car and did not race again. For this courageous decision and a detailed off-track application, the team won the competition's Safety Award, a cash prize of $3000.

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# Glossary Table

| | |
|---|---|
| *Ackerman* | An approximately ideal steering geometry |
| *BOM* | Bill of Materials |
| *Body* | Aerodynamic exterior of vehicle |
| *CAD* | Computer Aided Design |
| *cc* | Cubic centimeter |
| *CFD* | Computational Fluid Dynamics |
| $C_d$ | Drag Coefficient: Relates frontal area to drag force |
| *Chassis* | Structure that comprises the structure of the car |
| $C_L$ | Lift Coefficient: Relates frontal area to lift force |
| *CNC* | Computer Numerical Control |
| *CVT* | Continuously Variable Transmission |
| *CWSL* | Closed Wheel, Single Loft |
| *CWML* | Closed Wheel, Multi-Loft |
| *datum* | Reference value |
| *dB* | Decibel |
| *DR* | Design Review |
| *ECU* | Engine control unit |
| *FEA* | Finite Element Analysis |
| *FEDC* | Fischer Engineering Design Center |
| *FMECA* | Failure Mode Effect Consequence Analysis |
| *FOS* | Factor of Safety |
| *Frame* | See 'Chassis' |
| *FRC* | Flame Resistant Clothing |
| *HOQ* | House Of Quality |
| *hp* | Horsepower |
| *IC* | Internal Combustion (Engine) |
| *IIAE* | "Independent, Intuitive, Average" Evaluation |
| *kg* | Kilograms |
| *Loft* | A 3D solid defined by a series of cross sections |
| *m* | Meters |
| *MEEN* | Mechanical Engineering |
| *MIG* | Metal Inert Gas |
| *mm* | Millimeters |
| *MPG* | Miles per gallon |

| | |
|---|---|
| *mph* | Miles per hour |
| *N* | Newton |
| *OWML* | Open Wheel, Multi-Loft |
| *OWSL* | Open Wheel, Single Loft |
| *Req.* | Requirements |
| *RMP* | Risk Management Plan |
| *JSA* | Job Safety Analysis |
| *Rollbar* | Rounded chassis structure that protects the driver's head |
| *s* | Seconds |
| *SEM* | Shell Eco-marathon |
| *SNPS* | Solution Neutral Problem Statement |
| *Spec* | Specification |
| *Shell* | Royal Dutch Shell plc. |
| *TIG* | Tungsten-Electrode Inert Gas |
| *Urban Concept* | Competition category for passenger-style vehicles |
| *VRsensor* | Variable Reluctance Sensor |
| *W* | Watts |

# 1 Introduction

## 1.1 Shell Eco-marathon

The Shell Eco-marathon is a global energy efficiency competition sponsored by Royal Dutch Shell. The competition has two vehicle classes: Urban concept and prototype. UrbanConcept vehicles represent vehicles similar to commercially available vehicles, whereas prototype vehicles are designed purely to push the boundaries of energy efficiency. The competition was started in 1939 by a group of Shell scientists and has seen dramatically improved results since its founding. The purpose of this team was to create a UrbanConcept vehicle that would serve as a foundation for future teams from Texas A&M.

## 1.2 Team Structure

In order to meet the needs set forth by this competition, the team broke down into subteams. These subteams were selected by major sub assemblies or disciplines within the project. They are as follows: Body, Electronics, Frame, Powertrain, and Steering. This structure allowed team members to become technical experts within their team and optimize a design with respect to the vehicle.

## 1.3 Needs Analysis

Generally, the project needs were generated in two different ways and three different forms. Firstly, the two sources are the SEM official rules and the team itself with slight influences from Shanna Simmons and Dr. Jacobs [1]. The two forms of these needs could be termed as constraints and customer needs. Under this terminology, many of the requirements from SEM are constraints. SEM also supplied some customer needs in through the overall objectives for the competition. After carefully listing and studying the SEM constraints, the team members were able to add needs, including both constraints and customer needs. It was at this point that the Affinity Diagram helped to divide all of the constraints and needs into columns or categories, which largely corresponded to the sub-teams that were chosen. Some bias may have existed as the sub-teams were generally decided, but an overall category was created, mainly for the more customer type of needs. The Affinity Diagram is shown on the next page in Figure 1.

For clarity and efficiency when using other design tools, the SEM constraints and other needs were then divided to create Tables 2 and 3. If the SEM constraints were included in the Needs Document, they would all have an importance of 10, as failing any of them will result in disqualification from the competition. The constraints given by the rules define either a full specification including required values and units or state a binary constraint. For example, one constraint is a maximum turning radius of six meters, while another constraint is the requirement of a four-disc hydraulic brake system [1]. These SEM constraints are recorded in Table 2.

| **Overall** | **Powertrain** | **Electrical** | **Body** | **Steering** | **Frame** |
|---|---|---|---|---|---|
| Pass Technical Inspection | 4-stroke engine | Electrically started engine | No flexible aerodynamic appendages | 4 Wheels contact ground | Minimum driver weight |
| Human Safety | Direct Fuel Injection | Electronic Horn | Minimum radius of sharp points | Hydraulic brakes | Solid floor and bulkhead |
| Complete Race | Three Emergency Shut-offs | Running Lights | Vehicle fully covered | Parking brake | Minimum driver clearance |
| Realistic Urban Appearance | Gasoline Fueled | Red Brake Lights | Driver visibility | Steering wheel diameter | Seat with 5 harness straps |
| Innovative Design | High efficiency engine | Turn Signals and Hazards | Minimum ground clearance | Rim diameter | Rollbar load without deflection |
| Structural Integrity | Low transmission friction | Windshield wiper | Rear-view mirrors | Minimum track widths | Luggage storage space |
| Cost Effective | Low engine weight | Low energy consumption | Low aerodynamic drag | Maximum turning radius | Total vehicle dimensions |
| | | | Low body weight | Low rolling resistance | Minimum wheelbase |
| | | | Total vehicle dimensions | Easy to turn | Low frame weight |

Figure 1: Affinity Diagram

Table 2: Design Constraints from Shell Eco-marathon Rules

| **Powertrain Constraints** | Value | Units | Notes |
|---|---|---|---|
| Engine stroke | 4 | cycles | |
| Direct Fuel Injection | | | |
| 3 Emergency shut-offs | | | internal, external, dead man's |
| Gasoline Fueled | | | |
| **Electrical Constraints** | Value | Units | Notes |
| Electrically started | | | |
| Horn | 85 | dB | unobstructed |
| Running Lights | | | 2 headlights, 2 red rear |
| Brake Lights | | | 2 red rear |
| Turn Signals | | | 2 front, 2 rear, hazards |
| Windshield wiper | | | |
| **Body Constraints** | Value | Units | Notes |
| Flexible aerodynamic appendages | | | not allowed |
| Minimum radius of sharp points | 50 | mm | |
| Vehicle fully covered | | | wheels cutouts allowed |
| Driver visibility | | | 90° to both sides |
| Minimum ground clearance | 100 | mm | fully loaded |
| Rear-view Mirrors | 2500 | $mm^2$ | one each side |
| **Steering Constraints** | Value | Units | Notes |
| Wheels | 4 | | constant contact with the road |
| Hydraulic brakes | | | four-disc, two cylinders |
| Parking brake force | 50 | N | |
| Steering Wheel diameter | 250 | mm | |
| Rim diameter | 15-17 | in | |
| Minimum front track width | 1000 | mm | |
| Minimum rear track width | 800 | mm | |
| Maximum turning radius | 6000 | mm | |
| **Frame Constraints** | Value | Units | Notes |
| Minimum Driver weight | 70 | kg | with equipment |
| Solid floor and bulkhead | | | isolate driver |
| Minimum driver helmet clearance | 50 | mm | |
| Seat with 5 harness straps | | | 70 kg load |
| Rollbar load without deflection | 700 | N | all directions |
| Luggage storage space | | | 500 x 400 x 200mm |
| Total vehicle height | 1000-1300 | mm | |
| Total vehicle length | 2200-3500 | mm | |
| Total vehicle width | 1200-1300 | mm | |
| Minimum wheelbase | 1200 | mm | |

Each of the sub-teams must design to meet all of these constraints or specifications set directly by the SEM rules [1]. True customer needs in a more traditional form were set by Dr. Jacobs and the team members with the overarching objective of competing well in April. As these needs are unmentioned in the previous constraints, they closely follow the avenues of design left free to competitors. These needs are shown in Table 3. The importance values of these design needs were rated out of 10 based on how great of an effect each need is expected to have on the competitiveness of the car.

Table 3: Needs Table

| **Number** | **Need** | **Importance** |
|---:|---:|---:|
| 1 | High engine efficiency | 7 |
| 2 | Low transmission friction | 5 |
| 3 | Low rolling resistance | 8 |
| 4 | Low aerodynamic drag | 6 |
| 5 | Low electrical energy consumption | 5 |
| 6 | Easy to turn | 4 |
| 7 | Low weight | 9 |
| 8 | Human Safety | 10 |
| 9 | Pass Technical Inspection | 10 |
| 10 | Complete Race | 9 |
| 11 | Structural Integrity | 9 |
| 12 | Realistic Urban Appearance | 8 |
| 13 | Innovative Design | 6 |
| 14 | Cost Effective | 8 |

### 1.3.1 Powertrain Needs

The powertrain team is responsible for the propulsion of the car. This includes engine selection, transmission, and the necessary connections to power the wheels. SEM allows for teams to choose between internal combustion (IC), electric motor, or hydrogen fuel cells as their source of energy to accelerate the car. The initial thought was given to all of the alternatives. However, this being the university's first year at the competition, the team decided to go with a more familiar route, the IC engine. The team's faculty advisor, Dr.

Jacobs, is researching applications for improving the efficiency of IC engines and will provide some constructive feedback when the powertrain team selects an engine and tunes it.

The IC motor defined by competition standards has created some complications in motor selection. The SEM rules state the motor must be a four-stroke engine with direct injection. This is a hard combination to find in a factory motor so powertrain has been spending some time looking at different ways to achieve this through purchasing and modifying according to the purchased engine's shortcomings. The competition will take place at an average speed of around 15 miles per hour, so a motor with high horsepower is not necessary.

Based on the configuration of the other vehicle components within the frame, the engine is allocated a space and the selected engine must satisfy those dimensional restrictions. Also, the vehicle has no minimum weight requirement so the engine must be as light as possible. Currently, there is space within the frame set aside for a variety of motor dimensions so that the powertrain team can focus on optimizing power, efficiency, weight, and cost.

### 1.3.2 Aerodynamic Needs

The aerodynamics sub-team has one of the most critical roles in succeeding at the competition and the development of the SEM program at Texas A&M. This sub-team is responsible for designing the overall body style of the vehicle and optimizing the lift and drag coefficients ($C_L$ and $C_d$ respectively) through the use of SolidWorks and Altair aerodynamic software. Various nose, tail, and side profile shapes are being analyzed to understand how to most effectively design the body. Anybody designs analyzed have to meet the aerodynamic or body constraints listed in Table 2. The aero needs that allow for free design are included in Table 3. Having a lightweight body and components is the most important aspect the aero team can optimize to maximize the fuel efficiency of the vehicle. When designing a body for the vehicle, the second most important aspect after the weight is having a low coefficient of drag which also increases the fuel efficiency of the vehicle. Next, ease of access in the vehicle is important as the driver must be able to vacate the vehicle from being fully harnessed within 10 seconds.

### 1.3.3 Frame Needs

The frame sub-team is required to design the chassis for the vehicle. The roles of the chassis for an automobile are to provide structural stability, maintain rigidity/resist flexing under loads induced by road conditions, support the body panels and external components, and keep the driver safe from external intrusion [2]. This includes all structural support for the driver's cell, engine, steering to wheels, body and other vehicle components. This competition has no minimum weight associated with the vehicle, therefore it is necessary to create a lightweight yet sufficiently sturdy frame. Since this is the team's first year in competition, limited resources are available making a minimized cost an important factor as well. The frame team will focus on optimizing weight, structural integrity, and cost when moving in different directions throughout the project.

### 1.3.4 Steering Needs

The steering and wheels team is responsible for meeting dimensional requirements regarding the turning ratio, track width, wheelbase, and steering and linkage connections to the wheels. The competition requires 17-inch wheels [1]. The specific customer needs for the steering and wheels sub-team are shown in Table 2 as well as needs 3 and 6 in Table 3.

## 1.4 Needs Analysis

The final product will have to compete in the Shell Eco-marathon competition in April 2019. This competition requires the final product to be driven over a set distance on a track in an allotted time. The most successful design will be able to finish the road course while being as fuel efficient as possible. The weather conditions are variable and the track will be announced in March of 2019. Using data from last year's track, the team predicts the car will need to travel at a minimum speed of 15.8 mph. In order to finish the competition, the vehicle must be able to average approximately 40 mpg since the final design will be using one liter of fuel.

For the body, the main constraints include the vehicle dimensions outlined in Table 2. In addition, the driver must have full visibility in both directions. The main factors that are being taken into account while choosing between various body designs include a low coefficient of drag and ease of access to the inside of the body.

When designing the powertrain, the main restrictions include the engine being a four-stroke engine and having direct injection. In addition, the powertrain system must have three emergency shutoffs, be electrically started and be able to idle.

When determining the steering system, the most important factors include having a track width of at least 1000 mm for the front axle and 800 mm for the rear axle and the turning radius must be equal to 6 m or less. When determining the wheels that the vehicle to use, the constraint of a ground clearance of 100 mm is the main design factor.

The frame team has several requirements being used when designing. These include being able to support a maximum weight (including the driver) of 225 kg, and having a storage space of 500 x 400 x 200 mm, having a five-point harness for the driver and including a space of 880 mm x 700 mm for the driver's compartment.

# 2 Body

## 2.1 Introduction

The body subteam was responsible for creating the body of the vehicle. This includes the actual carbon fiber shell, the windows, the doors, interior panels, bulkhead and painting of the vehicle. The body team has a large impact on the efficiency of the vehicle as the weight of the overall body and its components play an important factor. In addition, the drag coefficient of the shell also plays a factor. The group completed exhaustive design and analysis of the body components, using SolidWorks and Altair Virtual Wind tunnel. The group then completed research on what materials to purchase and how to manufacture the body components before manufacturing the body.

## 2.2 Design Philosophy

The body team worked to find materials that would be easy to use as this is the first time the team has done any sort of carbon fiber layup before. In addition, the design of the body and its components were simplified to make production easier. The body team also had the largest portion of the budget, and thus cost-effectiveness played a large factor in material selection.

## 2.3 Design Process

The design philosophy for the body team was to create components that would be easy to manufacture, cost effective, and lightweight.

### 2.3.1 Body Material Selection

The shell of the vehicle is not load bearing, and must be both stiff and lightweight. The two materials which were chosen were 3k plain weave carbon fiber and 4oz fiberglass fabric. Although carbon fiber is 11% lighter then fiberglass and has a 12% larger elastic modulus, it is 6.3x more expensive then fiber glass, making it cost prohibitive. Due to this, fiber glass was initially chosen. However, due to a generous carbon fiber donation from L3 Technologies, carbon fiber was the final material chosen.

### 2.3.2 Body Design Selection

When starting the design of the body, hand-drawn sketches were used to design a body and show where other components of the vehicle such as the powertrain and steering systems would be placed. A general teardrop shape was used to minimize drag. Various models were then produced using SolidWorks. The most important aspect when creating these designs were making sure they met the dimensional requirements outlined in the Shell Eco-marathon rule. These requirements are shown in Table 2. In addition, the 90° visibility requirement must be met in order to compete. With these restrictions in mind, a body was designed that would be light, have a low coefficient of drag and maximize ease of access inside the vehicle. Eight total body concepts were created, with two major body designs being used. The first is an open wheel concept in which the front wheels are exposed and not covered by the body. The second is a closed wheel design in which the front wheels are enclosed by the body. The rear wheels of both of these designs are enclosed. The final design is shown below.

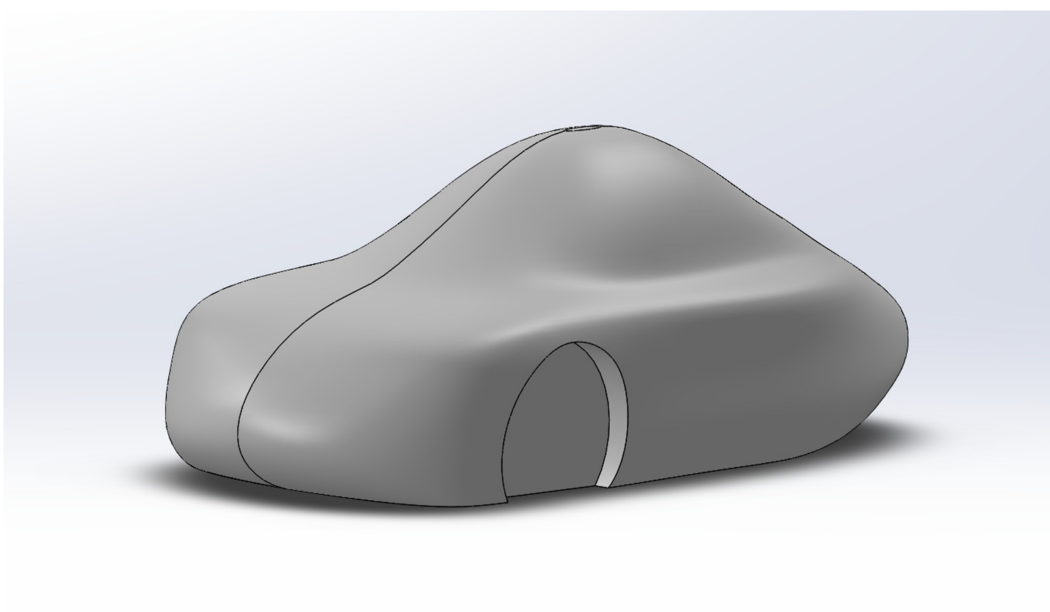

Figure 2: Final Body Design

### 2.3.3 Window Material Selection

The two materials which were chosen were Plexiglass (acrylic) and Lexan (polycarbonate). Polycarbonate is more impact resistant and harder to scratch, but Plexiglass is cheaper. Plexiglass was chosen as it is easier to thermoform. In order to thermoform Polycarbonate, it must be heated it at a lower temperature for 72 hours beforehand in order to prevent bubbles from forming.

## 2.4 Manufacturing

### 2.4.1 Creating the Mold

The first step in the manufacturing process was creating the mold that would be used for the carbon fiber layup. The first step was to create a styrofoam mold of the planned vehicle design. The team was very lucky to have PeterBilt sponsor the CNC cutting for the foam, however, due to dimensional limitations with the CNC machine, the design files had to be altered and saved in the proper formatting for the CNC machine. For future projects, it is recommended to design a body that would allow the team to create the foam mold in a single cut (instead of two). The new design included a 3-in base layer of foam that would be kept from the block, as it would be risky to cut with the CNC down to the base, as seen below.

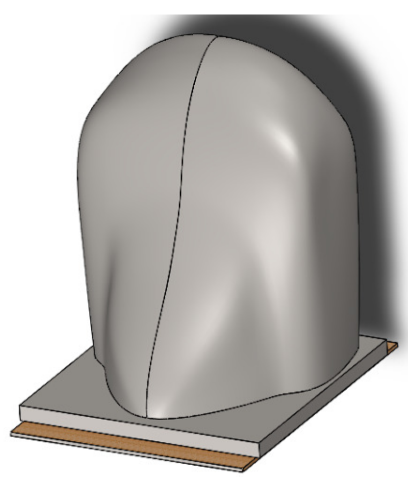

Figure 3: CNC Front SolidWorks Design

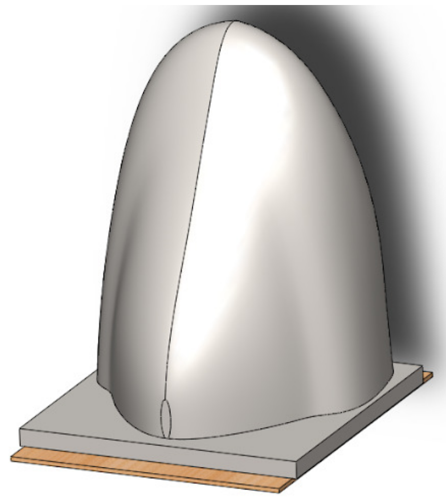

Figure 4: CNC Rear SolidWorks Design

In late January of 2019, two blocks of 2 $\frac{lb_f}{in^3}$ foam were purchased from StarRfoam in Arlington, TX. The dimensions of each block were 5.5 ft x 4.15 ft x 4.15 ft. The size was determined using the body model and foam size limitations. To hold the foam in place during the CNC process, a 4 ft x 5 ft x 1 inch plywood board was glued to the bottom of the foam block upon arrival to the Peterbilt facility. To ensure proper adhesion between the foam and wood, Gorilla Glue was used to connect the two pieces. The Gorilla Glue used was suitable for foam and wood. The CNC cutting process took about one week for each half, so the entire process took approximately two weeks. The final cutouts can be seen below

Figure 5: Raw Foam with Wood

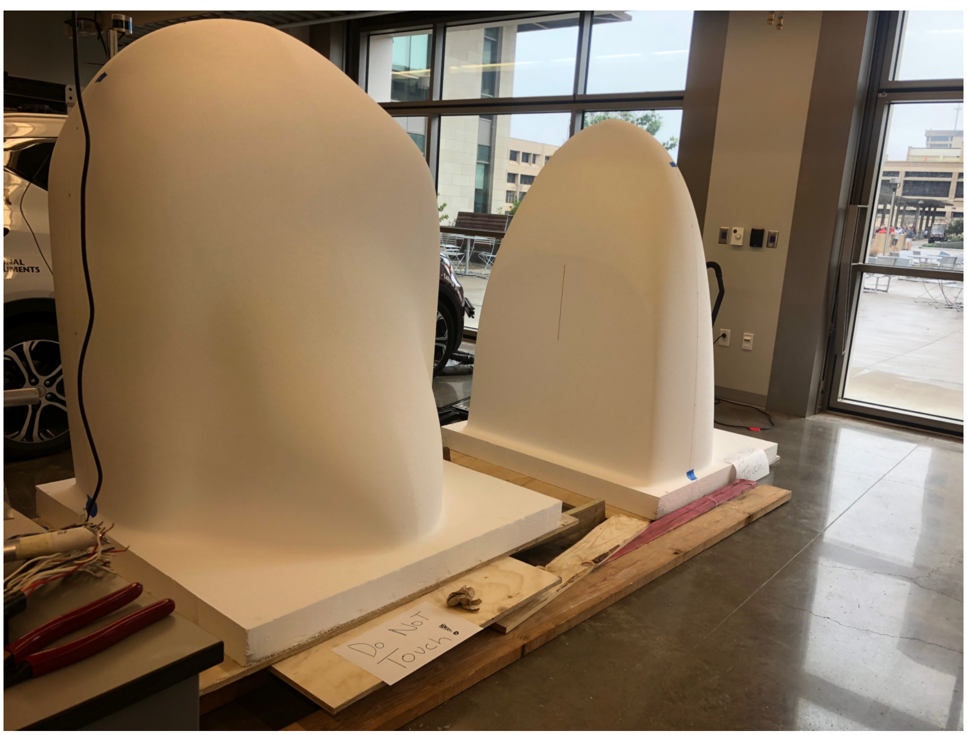


Figure 6: Foam Cutouts

Once the foam was CNC cut, it was taken back via U-Haul back to College Station. Each half of the vehicle was sanded to produce a smoother surface. Unfortunately, the surface was still too porous and needed additional work to create the foam into a mold. To make the mold, each piece of foam was cut off from its base-layer (that is not part of the car). Lines were drawn by using dimensions from the model. Since the hot-wire cutter stated it would be easiest to simply cut a horizontal line, each part needed to be angled slightly to ensure the line was horizontal. Once each half of the vehicle was cut using the FEDC's large hot wire cutter, each part was rotated horizontally and tilted at a slight angle using small foam pieces to ensure the cut line is horizontal. Once the front and back pieces were sliced horizontally, the bottom part of the front and back foam pieces were connected with Gorilla Glue. Each foam piece was propped onto the now-cut wood and foam block in order to elevate each part. A trash bag was used as a drip sheet underneath the seam in order to ensure no Gorilla Glue touched the ground. Since there was a slight misalignment from foam cutting, the same for the top pieces was done directly above the bottom-half pieces. This would ensure that the seams between all the parts align smoothly once the entire vehicle was assembled. The images shown below show the steps in this process.


Figure 7: Body Sanding

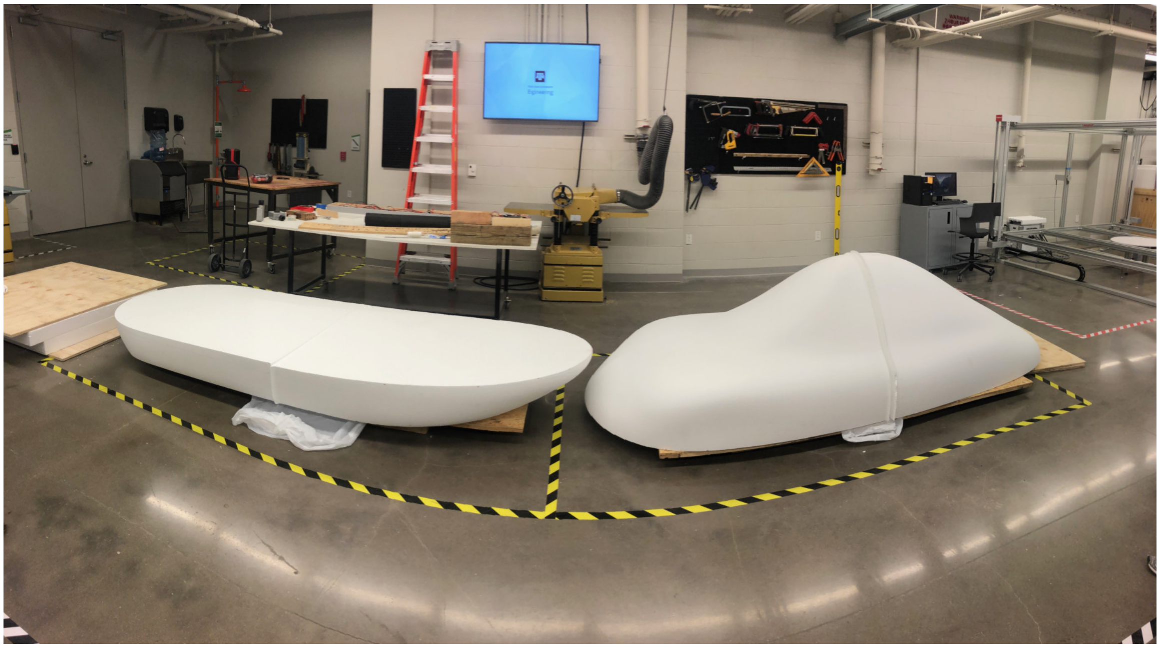

Figure 8: Glued Foam Molds

After the mold shapes were created by gluing the foam pieces together, the foam needed to be created into a mold for the carbon fiber layup. The team is very fortunate to have George Felix, from Poly-coat Systems, to assist us in this project by providing materials (epoxy, fiberglass, and other) and allowing us to do the next phase in his facility. Before the first visit, the team decided the orientation in which the fiberglass would be laid. This was determined using fiberglass cloth dimensions, vehicle dimensions, and intuition on which orientation would produce the least number of seams. Seams must be avoided to prevent air bubbles in the mold surface finishing. During our first visit to his facility, only the bottom mold was worked on. First, black pigmented epoxy was used to fill any imperfections in the body. Next, the fiberglass was laid over the part and excess material was trimmed from the edges. Three layers of epoxy were added in alternating colors after the fiberglass was laid. This is to give us a sense of depth when sanding the body with a power sander. This entire process was repeated for the top half in another trip about a week after the first. Images of this process can be found below.

Figure 9: Bottom Mold Fiberglass Lay

Figure 10: Top Mold Fiberglass Lay

Figure 11: Top Mold First Fiberglass & Epoxy Layer

Figure 12: Sanded Bottom Mold

Once both parts' epoxy was cured, each part was sanded with a power sander to improve surface finish. Because the power sander ate through some portions of the epoxy, and exposed foam, StyroShield was ordered to cover the entire body and protect the foam. StyroShield is a product specifically for protecting foam- so the foam could be used as a mold. This was then sanded yet again in order to produce a smooth outer surface for the layup surface.


Figure 13: StyroShield on Top Mold

After each mold was sanded for a smooth surface finish, the molds were ready for the carbon fiber layup. In order to prevent the epoxy from sticking to the mold surface, the surface was covered with PVA mold release. The mold release creates a thin, removable, coat that allows easy detachment of the carbon fiber components.

### 2.4.2 Body Layups

The carbon fiber layup process was very time intensive and required significant planning to prevent errors during the process. To lower the weight of the body, and to provide sufficient stiffness, a foam core laminate was used to stiffen the carbon fiber parts for a very minimal addition of weight. 1/8 inch thick DIVINIMAT foam was used as the core material for the majority of the body. This foam has ridges that allows it to conform to the shape of the part when used in thin strips. Each panel of DIVINIMAT was sliced into 3-block wide strips (with each strip being 42 inches long). The arrangement for the foam, shown below, was determined using good engineering judgment and intuition on areas most prone to flexing during static and dynamic conditions. For areas that require more support, such as the "backbone" of the vehicle, two trips were used side by side.

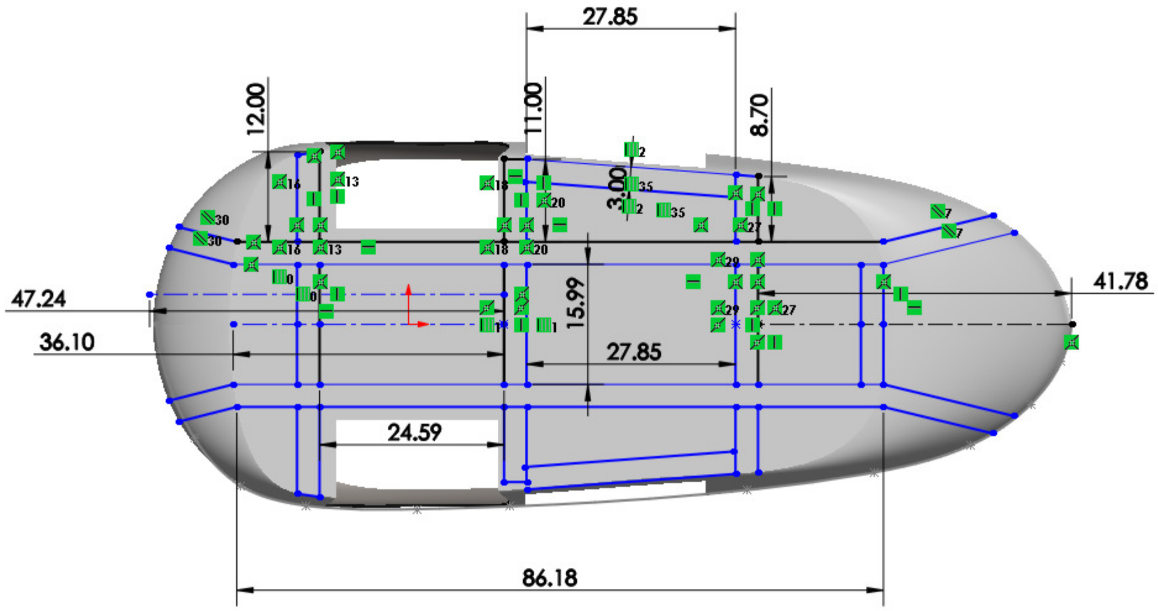


Figure 14: Foam Core Layout for Bottom

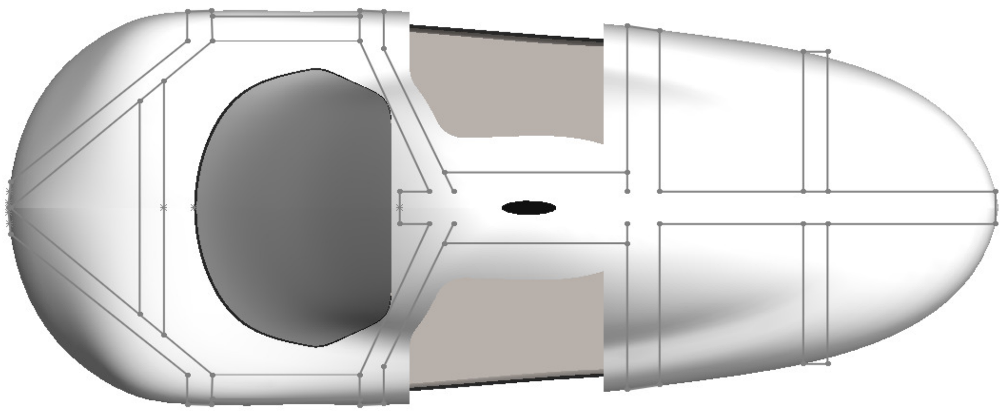

Figure 15: Foam Core Layout for Top

For ease of use, it was determined that the most effective method of doing the carbon fiber layup is by doing each layer using two strips of carbon fiber side by side (and along the length of the mold). The cross-section lengths were measured in SolidWorks at various locations along the body, and it was clear that the widest parts of the body would be covered by two strips of the 50 inch wide carbon fiber roll. The lengths of each strip was determined by measuring the arc length of the cross section of the body, to ensure that each strip of carbon fiber would cover end to end of the mold. Three layers were used for each half of the body, so a total of 12 strips of carbon fiber were needed (two for each layer, and three layers per part). A sight amount of overlap between the two parts for each layer was expected, which means that the middle section of the body had up to six layers due to this overlap.

To start the carbon-fiber layup process, the surface (with PVA) was slightly wetted with epoxy in order to provide a sticking surface for the first carbon fiber layer. The first strip of carbon fiber was laid (half of the first layer), and epoxy was dumped over it and spread with a squeegee. It is critical not to leave epoxy in the container once the resin has been added, and the cure time will be significantly accelerated. The epoxy should be mixed for a few minutes, then poured immediately over the entire surface. Once it has been poured, brushes and squeegees should be used to eve cover every surface of the carbon fiber. The squeegee should also be used to scrape away excess epoxy (by dragging it to the edges).

Proper safety attire must be work during this entire process (plastic gloves, long pants, and close toes shoes). Acetone should be used to clean squeegees from epoxy between each ”run” that is done. Acetone can also be used to clean hands from epoxy, but do not place items for a long duration in acetone. Once the first strip has been laid and filled with epoxy, the same should be done to the other side (using another carbon fiber strip). Once completed, the first layer has been done. Before this same process is repeated to add the second and third layers, the foam core will be placed immediately after the first layer of carbon fiber. Using the set-up shown previously, the foam core was cut and placed over the body in the areas shown. Prior to doing this, it would be beneficial to mark the location where the foam will start. Prior to starting the layup, a leveling stick, tape measure, and a meter stick was used to measure the distance the foam started from the tip of the car. These measurements were predetermined from the SolidWorks model. This was a difficult step, as the body is slightly curved. A small amount of epoxy was brushed onto the foam before applying it, in order to ensure the foam sticks. Once the foam was placed on the body, putty was used to chamfer the edges of the foam, and provide a better transition between the edge of the foam and the carbon fiber around it. This step of the carbon fiber layup process can be seen below.

Figure 16: Foam Core Layout for Bottom: Actual

Figure 17: Foam Core Layout for Top: Actual

Following the foam, two more layers of carbon fiber were added to complete the layup. The carbon fiber was then post-cured at 250 degrees Fahrenheit in order to strengthen the part further (this was also done at George's facility). Approximately 30-45 minutes was given between each layer of carbon fiber or foam layers, and this ensured the epoxy had "b-staged" by that time. When epoxy "b-stages", it becomes more tacky and adheres better to new layers. Typically, leaving more than 3-4 hours between layers should be avoided, as epoxy does not stick well to already-cured epoxy. In the future, if a bagging process is desired, the whole layup should be done in an hour or hour and a half, depending on the epoxy mix ratio.

After the layup process was fully completed, and a few days have gone by for the carbon fiber the fully cure, the next challenge was taking the mold and carbon fiber back to Texas A&M. Because the parts would not fit side-by side in the U-Haul, the parts were stacked like they would be if the vehicle was to be assembled. Thick bubble wrap was used between the two parts, and the mold and carbon fiber assembly were secured into the U-Haul via ties. The entire package was heavily wrapped in bubble wrap and other padding material. This was then transported to Texas A&M and unloaded into the build space.

### 2.4.3 Smaller Components

To begin work on the carbon fiber, the parts were removed from the molds, and the molds were kept in storage from there-on out. The first thing that was done to the carbon fiber was creation of connection tabs. These connection tabs, pictured below, would allow for relatively quick and easy assembling and disassembling of the body. These tabs work by pushing out against the opposite end, while providing a limit for the body's movement. For any process required carbon fiber-carbon fiber adhesion, the areas to be connected were sanded in order to provide a rough enough surface for the epoxy to adhere to. To create these tabs, 3x2 inch pieces of carbon fiber were cut from a flat sheet of carbon fiber. These tabs were sanded and epoxied to the edges of each half of the body. These tabs were held in place using clamps, and given 24 hours to fully cure and connect.

Figure 18: Clamping Tabs to Body

The next step in the manufacturing process was to create the doors. Since the body was split in half, the strategy to creating the door was to attach the two body parts together (using the newly added tabs) and doing a carbon-fiber layup of the seam where the body separates in the marked door location. The doors were first marked off, then the door seam was reinforced with duct tape on the outside, as seen below.


Figure 19: Taped-off door location

Figure 20: Door Carbon Fiber Layup

After this, the doors were cut out with the dremel, allowing each door to be cut out in a single part, while still having the main body assembly in two main parts. Once this was done, the windshield was taped off and cut out as well, along with the windows on each door. These cut-outs would be later be used to thermo-form the windows and windshield. The nest step was to cut out the wheel wells for all four wheels. Each of these cut-outs were taped off using the SolidWorks model measurements, and referenced onto the actual body with level indicators, tape measures, and good engineering judgment.

After the body holes were drilled, and before attaching the frame and the body together, the doors were attached to the frame. This was done by attaching the door to an arm that connects to the frame. The tip of this arm had a flat plate that would allow the arm to connect more easily to the door. To ensure proper alignment, the frame was placed inside the body, and the door was taped (on the outside) to the exact position on the body. By using the door window as an entry point for my hands, the arm was first JB welded into place, then reinforced with a carbon fiber layup. Three 1x1 ft were used to attach the arm securely to the door, then the door was given 24 hours to cure before it was operational.

Once the doors were created and attached to the frame, the next step was to attach the body to the frame. This must be done after attaching the doors to the frame to account for any misalignment while attaching the doors. Before creating the drill holes for connecting the body to frame, which was done with zip ties, the frame was fully assembled with wheels and placed into the body. This was to ensure the fitment is correct before creating permanent connection holes to the frame. After the body-frame fitment was verified (checking for wheel rubbing and clearance in particular), the next step was creating drill holes in the bottom half of the carbon fiber body that would connect easily to the frame. To ensure that the body is securely attached to the frame, 10-15 connection points were established. To do this, two holes were drilled about two inches apart for every attachment location. The attachment locations are all directly below one of the aluminum tube members. To ensure the body does not flex during static and dynamic loading, the body was secured to the frame along the length of the entire frame. Proper spacing is critical, as any body flex would cause the top half of the body and doors not to align correctly.

Once the body drill holes were completed and the doors had been attached to the frame, the next step was creating the windows and windshield. A 1/8 inch thick Acrylic sheet from home depot was purchased for the material to be thermo-formed. Upon purchasing this sheet, specifications for this product was found online, and they recommended heating the sheet between 1-10 minutes at 320 degrees Fahrenheit before thermo-forming. Multiple powder-coat facilities in College Station were contacted, and ultimately a manufacturing facility named Jackrabbit Manufacturing offered to lend us their oven free of charge. As seen in the image below, this oven was large enough to house the entire windshield in one part. In order to effectively thermo-form the windshield, a wooden jig was created to hold the windshield in place while the hot acrylic sheet was hand-pressed onto the carbon fiber part. This jig, also found in the image below underneath the carbon fiber part was created using 4x4's.

Figure 21: Thermo-forming Process

In preparation for the thermo-forming process, the acrylic sheet was cut roughly into the windshield and window sizes. Additionally, a thin 1/8 inch thick wooden sheet was purchased for placing the sheet on it during heating. Once at Jackrabbit Manufacturing, the windows were done first, in order to avoid risking the large sheet for the windshield. Each piece of Acrylic to be thermoformed was placed on the wooden sheet and heated for approximately four minutes. At the end of four minutes, the wooden sheet was pulled out and the acrylic sheet was picked up and placed over the carbon-fiber part. The acrylic sheet was then firmly pressed continuously in various locations over the surface of the carbon fiber. A slight amount of spring-back was observed, however it was not large enough to cause major fitment issues.

This was repeated twice again, for the other side window and the windshield. The side windows were flat enough to be done without a wooden jig, as the case with the windshield. Once each part was thermo-formed, and before removing the part from the carbon fiber piece, a red sharpie was used to mark the corners of the window in order to provide a reference when cutting out the windshield later. These parts were then taken to the FEDC and cut using an acrylic sheet cutting tool from Home depot. This was a very time intensive process, and it takes many sweeps with this tool to cut the windows/windshield out. It is important to handle the acrylic sheet very carefully, as they are prone to cracking. To speed the cutting process up, the windows and windshield were cut out using the dremel. This was done in the paint room with face masks.

Once this was completed, the next step was attaching the windows and windshield to the body and doors. To do this, small 2x1 inch tabs were cut and sanded in order to be spaced around the edges of where the window and windshield would sit. Once the windows were placed over these tabs, JB weld was placed in the tab and attached to the edge of where the window sits on the tab. Clamps were utilized to hold the tabs and windows firmly while the JB weld hardened. Once the JB weld had cured, the edge of the windows was covered with silicone sealant to prevent any water seepage. For the windshield, the windshield was held in place using hot glue, dispensed by a hot glue gun. This was used over JB weld initially due to the misalignment in the windshield from spring back during the thermo-forming process. Once held in place, the windshield-tabs connection was reinforced with JB weld. Because the gaps between the windshield and the body were fairly significant (1-2 inches), Flex Tape was used to provide a very strong barrier against water, while filling in this large gap. The Flex Tape is very difficult to cut with scissors, so it is recommended to use a sharp knife. The final assembly of the windshield, along with the Flex Tape, can be observed in the figure below.

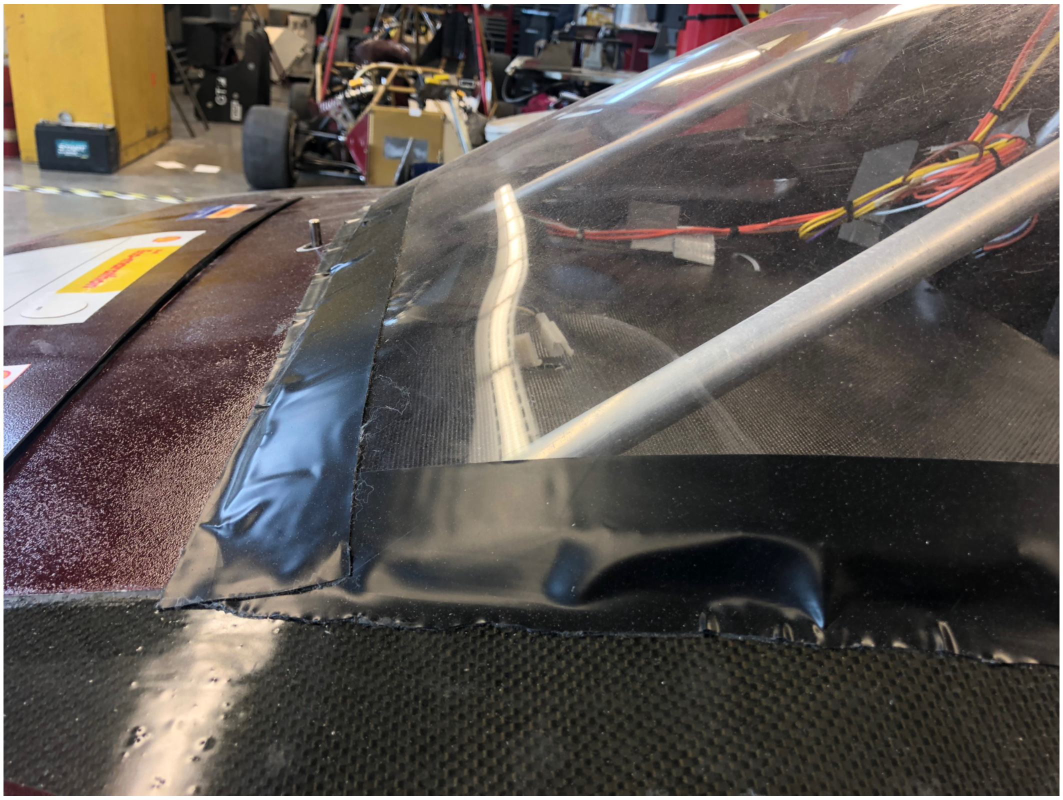

Figure 22: Windshield & Flex Tape

The next step in the manufacturing process was creating ventilation for the driver. Based on feedback from other teams, ventilation was advised due to the potentially high temperature buildup inside the driver's compartment. Small rectangular cutouts were made with the dremel, and each of these cutouts was covered with a thin mesh material. This mesh materials is typically found under the doors and windows section of Home Depot. This mesh was attached using a hot glue gun from inside the body, and an image of the final product can be seen below.


Figure 23: Ventilation

#### 2.4.4 Surface Finishing

Because the body did not have the glossy finish desired, the entire body was sanded with 80 grit sandpaper with a power sander from the FEDC. The majority of the body was be covered with a thin layer of epoxy to provide a glossy final finish, however, the midsection of the vehicle was painted in Maroon. To do this, multiple local paint companies were contacted for discounts and paint sponsorship. A local paint company, Anything Painted, agreed to provided maroon paint for free with the purchase of the primer for $60. To prepare for the paint process, the entire body was washed outside the FEDC using a hose, then the area to be painted was taped off with painter's tape. At this stage, epoxy was covered on the entire body (expect where it would be painted). The tape was removed once the epoxy had B-staged (or after 30-40 minutes). This prevents the tape from permanently sticking to the body. Once the tape was removed and the epoxy had hardened, there was a clear line separating the glossy part of the body and the section that would be painted, as seen in the image below.

Figure 24: Body Pre-Paint

The painted section was again taped of with tape, however, this time the tape went over the glossy area and exposed the dull-colored section. To protect the glossy section from paint, thin sheets of plastic were taped along these edges. Because the HVLP gun (High Volume Low Pressure Gun) produced a significant amount of air during use, it was important to ensure the plastic sheets were securely attached in various location to prevent exposure. This setup before the paint process started can be seen below.

Figure 25: Body Pre-Paint

The first step in the paint process was to prime the area to be painted. The primer solution was mixed and placed into the HVLP gun. A few practice sprays were done on the surrounding cardboard before applying the first layer of primer. A total of four layers were done, each about 30 minutes apart. The primer was allowed to sit for 15 hours before very carefully sanding with 320 GRIT, then 400 GRIT sandpaper. Once completed, the primed surface was very smooth, and this is critical for a smooth finish after painting. The sanded area was carefully cleaned by blowing air from the HVLP gun, and by using wet paper towels. Based on the vendor's recommendation, the medium sized nozzle was used. The nozzle was also cleaned thoroghly and immediately after use, as waiting too long makes it very difficult to clean the nozzle, even with paint thinner. It is important to clean the primed surface very well in order to prevent particulates from affecting the final paint finish. The HVLP gun was thoroughly cleaned with pain thinner before painting the maroon. The maroon solution was mixed and placed into the HVLP gun. A total of four layers were needed to completely cover the surface, with 45 minutes between each layer. It is highly recommended to apply multiple very thin layers over fewer thicker layers to prevent run-off a long drying times. Once painting was completed, the next step was to create hole cutouts for the electronics (headlights, taillights, turn signals).

### 2.4.5 Final Modifications

Small 1-inch holes were cut out in the rear and front end of the body to provide an exit location for the LED lights, as seen below. The lights were attached to the body using a hot glue gun, and the space in the hole was covered from the inside using Duct Tape.

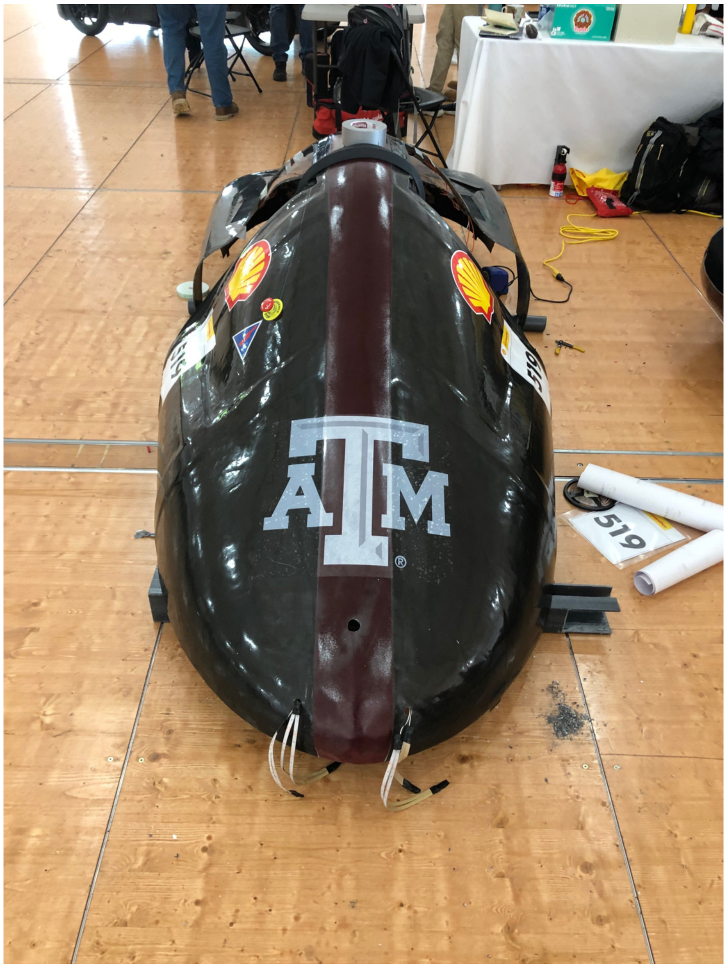


Figure 26: Light Cutouts

The remainder of the modification done on the body were done at Sonoma Raceway. These modifications included the storage compartment door, engine hatch, door brackets, and other smaller modifications. For the engine hatch, part of the body's rear side was cut out and secured with hinges on one end. Multiple tabs were attached on the inside of the hatch opening in order to stop this hatch from falling inside the body. Each of these tabs was JB welded and secured with clamps. One of the tabs near the opposite side from the hinges was covered with a piece of Velcro in order to hold the hatch down during operation. The completed assembly of the engine hatch can be seen below.


Figure 27: Engine Hatch

The next step was to create the opening for the storage compartment. This was to ensure the luggage could be accessed easily from outside the vehicle, as seen in the figure below. After the opening was cut out with a dremel, tabs were attached on the inside of the body, similar to what was done with the engine hatch. The difference, however, is that taps were also attached to the front end of the removable hatch. This removed the need for placing hinges on the front end. Similarly to the engine hatch, Velcro was attached to a tab in order to provide a detachable fastening mechanism.


Figure 28: Front Luggage

The final major modification to the body at Sonoma Raceway was the doors. The main issue with the doors is the misalignment while the door is closed. The doors swung downwards about 1-2 inches too far, so there where visible gaps that would allow water to enter the compartment. The solution to this was to cut 1 inch wide portions of an L bracket, and attach them to the top end of the doors. These brackets would then sit on small slots in the body once the doors are closed, as seen in the figure below. To open and close the doors, the doors must first be lifted upwards before being pushed in and out. To brackets were attached to each door, and these brackets were fastened using a bold and nut. Each of these bolts was then reinforced with JB weld to ensure the nut would remain firmly in place.

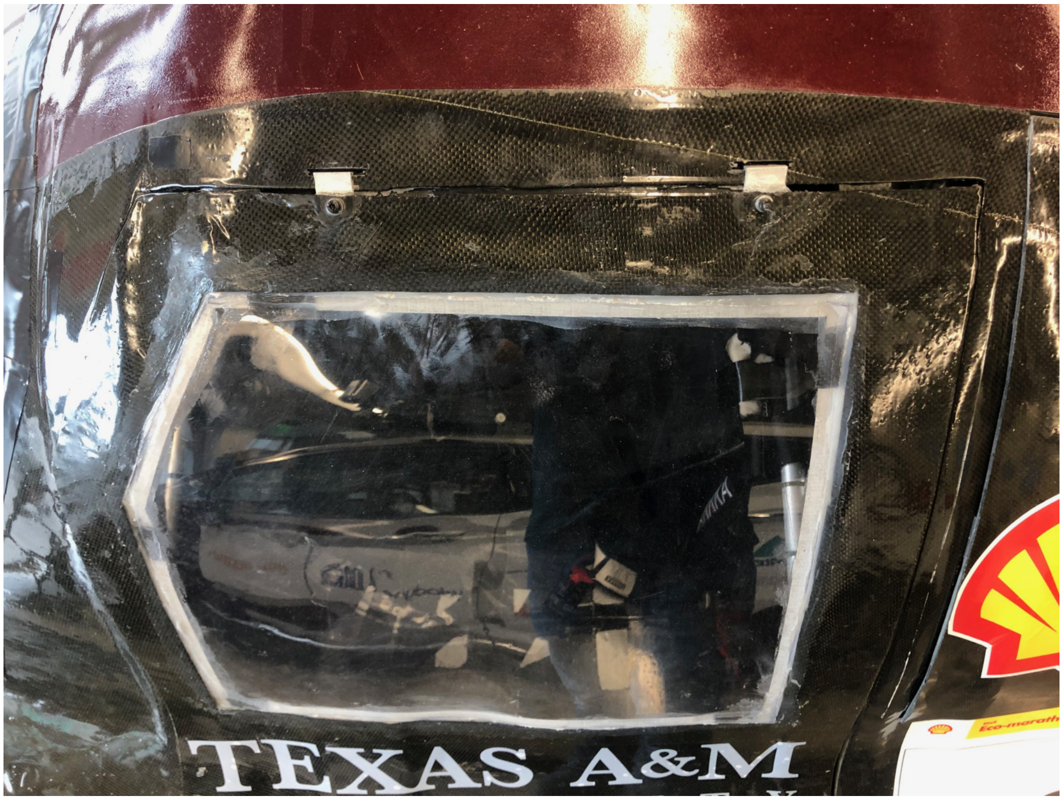


Figure 29: Door Brackets

Since there were still some small gaps present between the door and the body, a thick flat rubber sealant was taped along the edges of the door to prevent water from entering the driver's compartment.

To pass technical inspections, other small modifications were made to the body, such as the windshield wiper opening in the body, a large hole for the telemetry system on the rear-side of the vehicle, and door locks. The door locks were created using 0.5 x 2 inch tabs. To create this lock, a small slot was cut out of the doors for the lock to slide, and the sliding component was attached to a bolt that could be accessed from both inside and outside the vehicle. Once in the locked position, the sliding mechanism is help in space by a rectangular slot made using tabs.

## 2.5 Results

Through the efforts of the team, the body components were able to pass technical inspection. The body itself, while never tested in a wind tunnel, very closely matched the designed part and it is expected that the coefficient of drag also closely matched the simulations. The doors were functional and allowed the driver to egress the vehicle faster than any other UrbanConcept team. Additionally, the body served a secondary purpose of giving the car a 'coolness' factor that proved useful in attracting onlookers to the team. The interior paneling and sleekness of the car with the paint job is a fantastic recruiting tool, as it very easily catches the eye. Overall, the body team was successful in making a sleek, aerodynamic body for the vehicle that was stiff enough to mount and support components, while also being workable in competition.

# 3 Electronics

## 3.1 Introduction

The electronics subteam was responsible for the wiring and electronic components for the vehicle. These electronics are what differentiate the vehicle from a standard super mileage car and a vehicle that can compete in the Shell Eco-marathon Urban Concept category. Without these key components, such as the lights and accessories, the vehicle cannot pass technical inspection. As such, these components should not be neglected.

## 3.2 Design Philosophy

The design philosophy for the electronics team was to find effective, efficient, and inexpensive components for the vehicle. Components would be found that would satisfy the requirements set by the rules, then ranked on a balance of cost and electrical efficiency. Due to the constraints of the budget, bias was given to cost when a clear choice could not be made between cost and electrical efficiency.

## 3.3 Design Process

### 3.3.1 Component Selection

The constraints set by the rules and outlined in Table 2 delineated the components the car required. General intuition about the type of components was used, as the constraints were relatively simple. Further detail for each component follows.

#### 3.3.1.1 Battery

The battery voltage was selected by the 12V requirement from the ECU and starter motor. The size of the battery was selected by finding the power output required to start the engine multiple times while also running lights, wiper, horn, etc. This calculation showed that we needed a minimally-sized battery, so we chose a 4Ah replacement scooter battery. However, further communication with experts at Scoots revealed the 4-cell battery that was selected would likely not be able to produce enough amperage to properly start the engine. As such, a second battery was purchased to wire in parallel with the first. To follow the rules regarding having only one battery, a "black box" was put around the batteries so it would be an 8-cell.

#### 3.3.1.2 Horn

The horn used on the vehicle was taken from a used 50cc scooter, donated by another senior design project. This horn was used because it was lightweight, sufficiently loud at 105 dB, and free. The horn is operated via a button on the switchboard.

#### 3.3.1.3 Key

In order to make the electronics systems easy to use and deactivate, it was decided a starter key would be integrated. These keys work by taking a single input and connecting the first output when the key is in the first position, and both outputs when the key is in the spring-loaded second position. This allows the key to act on the starter without accidentally burning up the starter motor. The selected key is shown in Figure 30.

Figure 30: Starter Key

#### 3.3.1.4 Kill Switches

As required by the rules, the vehicle must have two twist-to-unlock push button kill switches as well as a "dead-man" switch. The kill switches were selected based on readily available switches that were similar to those used on heavy machinery. This was because of the familiarity the team had with such switches. The "dead-man" switch was selected to be a limit switch that could be mounted to the back of the steering wheel. This would allow for a very comfortable operation of the switch, while also being very clear when it is and is not activated. Finally, these components are quite inexpensive due to their simplicity.

#### 3.3.1.5 Lighting

Most of the electrical components required for the car were some type of light or indicator. Originally, the team decided to use individual LED lights to create the light arrays. These were purchased and validated. However, it was determined that these individual LED lights would be much more time-consuming to mount, and more prone to error due to each LED requiring soldering within the body. This decision proved to be very beneficial due to the amount of time before the body was available to the electronics team. In order to reduce the installation time of the LED lights, the team used light strips with adhesive. These rolls of LED lights (shown in Figure 31) were connected and set at a consistent distance. As such, the team only had to solder leads to the pads and glue the strips to the outside of the body. Additionally, the LED lights drew very low current and were extremely bright for their weight and draw. As such, they made for a good choice. Figure 32 shows the headlights mounted and turned on in the paddock. Also shown in Figure 31 is the orange flasher circuit selected to give the signal lights a flasher appearance. This circuit is a two-pin capacitor discharge circuit that causes the lights to flash when connected in series. This component was selected for its low cost and ease of implementation. The turn signals are operated by left and right switches on the switchboard, where turning both on activates the hazard function. The head and tail running lights are activated by a switch on the switchboard. The brake lights are activated by a spring loaded switch on the brake pedal.

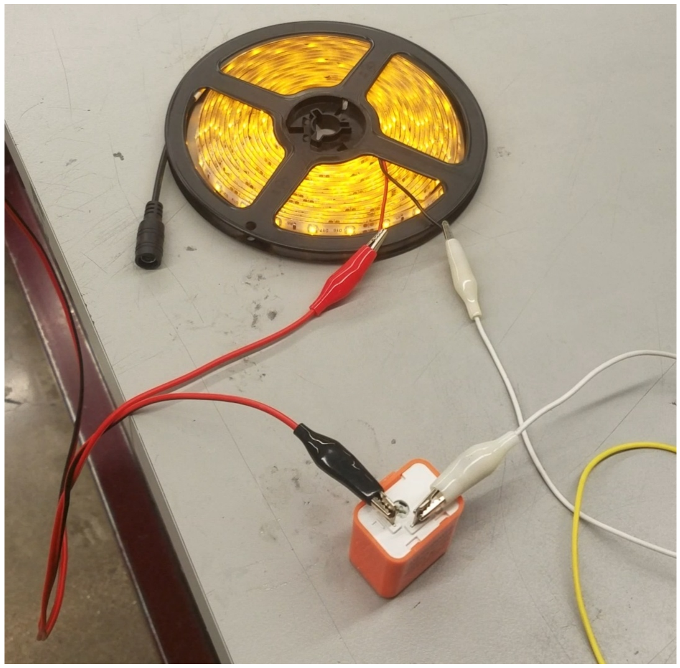

Figure 31: LED Strip Lights


Figure 32: Vehicle with Headlights on

#### 3.3.1.6 Tachometer

In order to aid the driver while running, a tachometer was selected. The main need when selecting the tachometer was a Hall-effect sensor instead of the spring damper used on many cycles and scooters. This is because a Hall-effect sensor is contactless and would therefore reduce efficiency less than a contact speedometer. Because a tachometer is a non-critical component and not required for the rules, the cheapest contactless tachometer with a digital display was selected. Mounting was designed by determining the distance from a magnet the Hall-effect sensor required. Then, a hole was added to the knuckle upright for the mounting of the tachometer Hall-effect sensor. The tachometer is turned on via grounding the first position of the key and automatically updates when the magnet is sensed.


Figure 33: Tachometer

#### 3.3.1.7 Windscreen Wiper

The rules require an effective windscreen wiper for wet-weather running, as we experienced. Due to the relative complexity of a windshield wiper system compared to lighting, the team opted to select a packaged wiper solution. The team selected a wiper that is used to replace vacuum windscreen wipers for a 12V motor assembly. As such, the kit included a arm assembly for a extremely reasonable price. The plug-and-play capability of this motor due to included oscillation control, made this an obvious choice to allow for quick installation and troubleshooting. The mounting of the motor was selected to allow for the best contact between the blade and the windscreen. The included mounting and waterproofing washers were used to mount the motor easily to the body. The windscreen wiper is controlled via a switch on the switchboard.

Figure 34: Windscreen Wiper

### 3.3.2 Wiring Harness

Integration of the electronic components with the engine wiring harness was necessary due to the limitation to one battery for the entire vehicle. As such, the battery would need to connect to the both the accessory and starter connections on the wiring harness, as well as the remaining components. As such, it was necessary to extensively study the wiring harness wiring diagram shown in Figure 35. This particular model operates by maintaining positive voltage on the starter relay, and the relay is activated when a switch grounds the relay. As such, the entire system had to be designed where the first position starter key grounds the electrical accessory components and ECU, while the second position starter key grounds the starter relay.

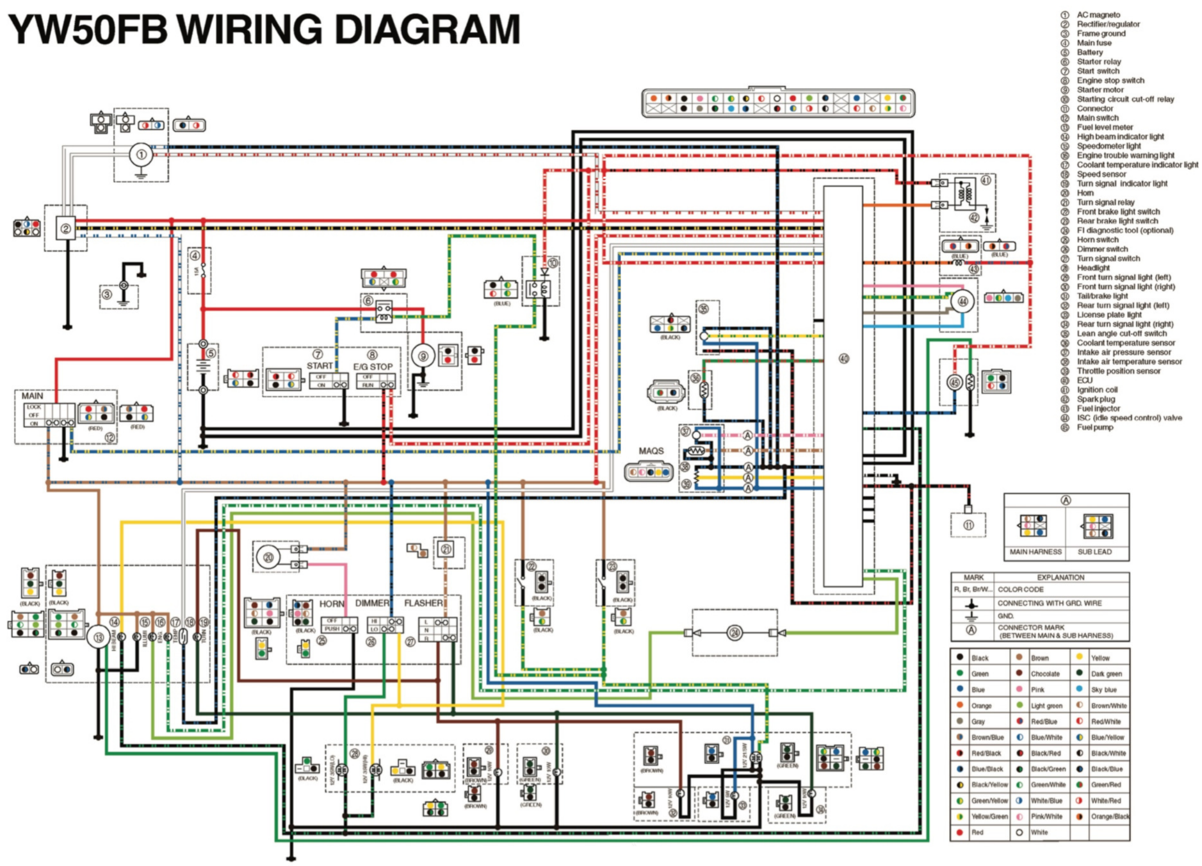


Figure 35: YW50 Engine Wiring Diagram

### 3.3.3 Component Integration

Keeping the wiring harness in mind, the electrical systems were designed in order to be inoperable without the key being in the first position. As such, all accessory components, such as the horn, lights, tachometer and ECU were grounded through the first output of the starter key. Therefore, without the key in the first position, the vehicle's electrical components would be inoperable. Additionally, the starter switch is grounded through the second output of the starter key, allowing the starter to be operated by torquing the key, similar to most production vehicles. Further details on the wiring of each electrical component can be found in Figures 36 and 37. Additionally, all of the electronic components that were wired to the top of the body were connected through a 10-pin plug. This would allow for the easy attachment and removal of the top of the vehicle.

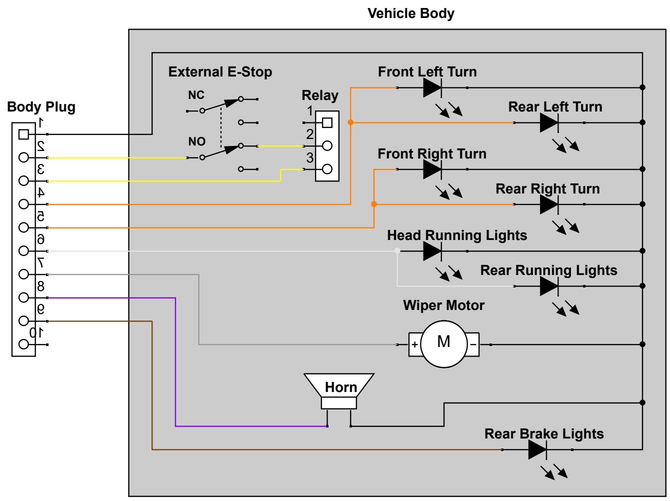


Figure 36: Upper Body Wiring Diagram

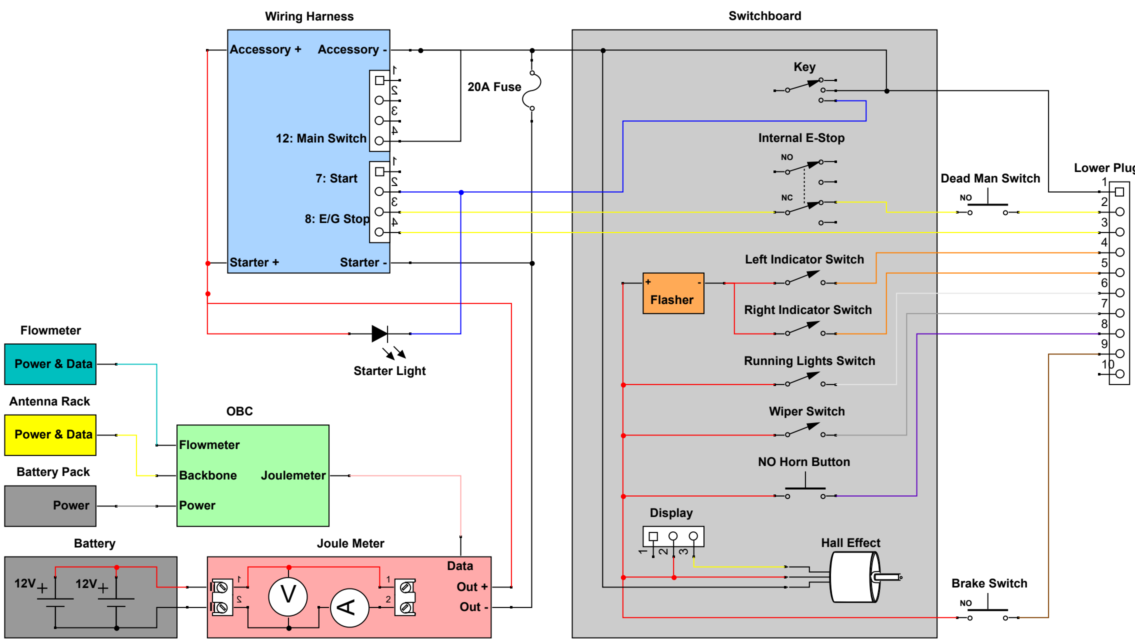


Figure 37: YW50 Engine Wiring Diagram

## 3.4 Manufacturing

### 3.4.1 Lights

The installation of the lights was done in two steps: soldering, and mounting. This was decided to help save time by allowing the team to solder the wires and connections before having access to the body. Unfortunately, this proved to be more work for the team in the long run.

Soldering LED strip lights involves cutting the rubber shielding that extends over the entire strip from the solder pads. This leaves behind a thin, papery set of connections with which to wire two leads. We connected all of the sets of LED lights and maintained polarity on the connections. This was crucial as LED lights act as diodes and are current direction dependent. Once the leads were soldered, the connections were sealed with hot glue, to keep the solder beads from shorting due to the pads bending. Finally, the longer wires that ran inside the body were soldered to the leads. As an aside, the LED lights were tested throughout the process for continuity using a power supply.

To mount the lights, holes were drilled in the body to feed wires through. The LED strips were then attached with double-sided tape, electrical tape, and hot glue. This proved to be the troublesome part for the lights as the solder connections were ripping apart the LED strips due to fatigue. As such, multiple sets of LED lights had to be redone or replace in order to function properly.

### 3.4.2 Horn

During the validation of the horn, it was found to be much louder than the 85 dB requirement. Because it would be inside the car with the driver, we decided it would not be ideal to have the horn be that loud. As such, a box of corrugated plastic was made with insulation inside of it to direct the sound through the holes in the body, rather than the interior of the car. This box was wired with leads coming out of it so the box could be glued to the interior of the body and soldered once attached.

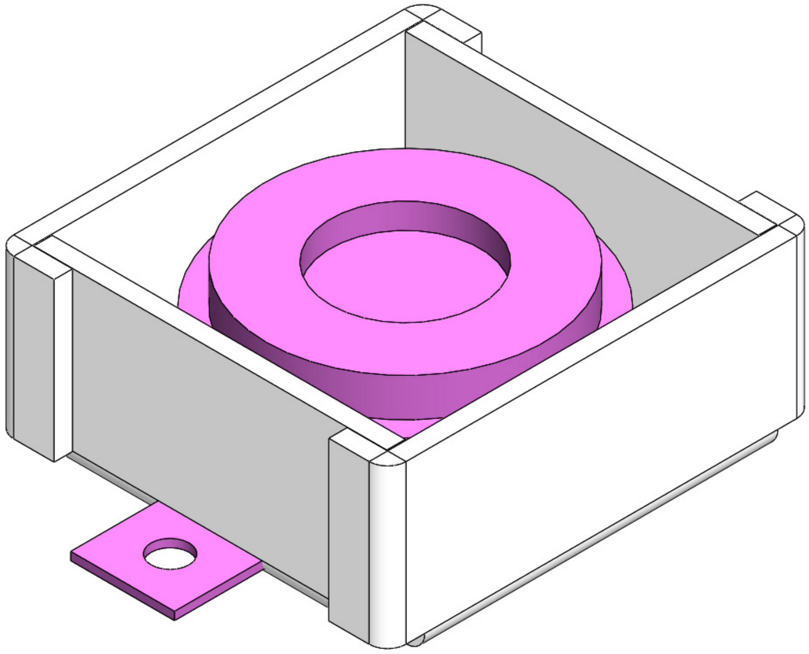

Figure 38: Horn Insulator Box

#### 3.4.3 Telemetry

The telemetry system was incorporated at competition with the electronic subsystem. It was wired as shown in Figure 37. Modifications made to include the telemetry system included adding an additional relay on the kill switch loop, including the joule meter between the battery and the remainder of the car, and adding mounting points for the CPU and backbone.

### 3.5 Results

At competition, the electronics subsystem performed as necessary to pass technical inspection. The lights and horn consistently worked throughout the week, but were sometimes affected by loose connections at the main plug. Due to a loose connection on the tachometer magnet, it was crushed during testing and was never able to be fixed before competition. The windscreen wiper spring was overextended, and now has too little pressure to effectively wipe the windshield. The key was a fantastic incorporation and adds a lot to the coolness factor for the car. Moving forward, the spring will likely need replacement as well as the wiring for the radiator fan, which has now become disconnected. In general, more time should be devoted to the electronics subteam to create more robust designs.

# 4 Frame

## 4.1 Introduction

The frame subteam was responsible for the fabrication of the chassis for the vehicle, as well as mounting points for the other subsystems of the vehicle. This entailed cutting and shaping the necessary aluminum tubing and welding them together. Since the competition has no minimum weight associated with the vehicle, the frame was created to be as lightweight and sturdy as possible to improve efficiency of the vehicle and safety of the driver.

## 4.2 Design Philosophy

The design philosophy for the frame team was to have as lightweight a chassis a possible. The team also aimed for a frame that was stiff and easy to manufacture. An important factor kept in mind was the strength of the frame to ensure driver safety. Comfort of the driver as well as competition rules were also used while designing. Some important changes were made to heighten the focus on ease of manufacture and integration with the other subteams' major components.

## 4.3 Design Process

The frame team began the frame design by accounting for all of the key dimensions required by the SEM rules [1]. Within the allowable ranges to pass technical inspection, smaller lengths were chosen in most cases in order to minimize weight. Many of these were joint decisions with the steering, body, and powertrain subteams. For example, the steering team set the wheelbase and the front and rear trackwidths, while the powertrain team provided necessary dimensions for mounting the engine. Especially careful coordination with the body team was needed to meet external dimensions such as vehicle height, width, and length, as well as the internal dimensions for the driver's compartment and door opening. After the refocusing on ease of manufacture and integration, the frame design was divided into simple phases. These phases were largely made up of in-plane welding which also decreased the number of complex coping required for manufacturing. The specific grouping of tubes and ordering of the phases also lessened the need for complex jigs even for the more geometrically complicated portions of the frame. The division of the phases can be seen in Figures 39-42 below.

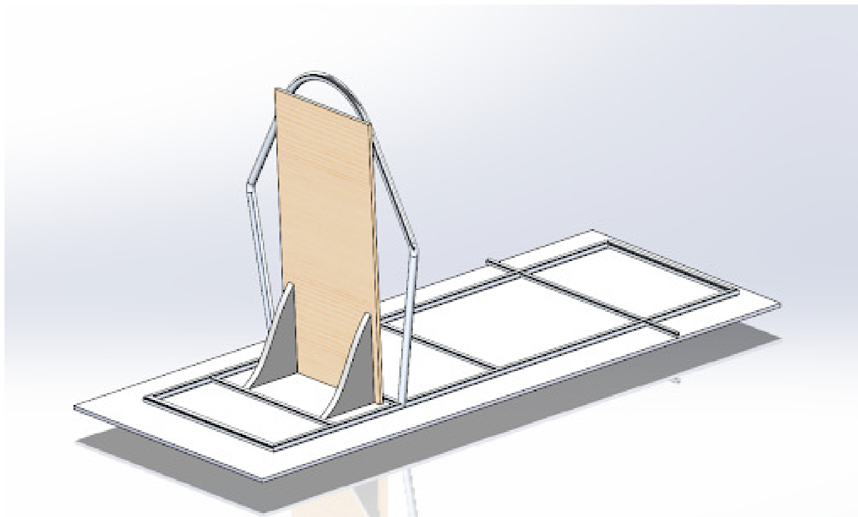

Figure 39: Frame Phases 1-3

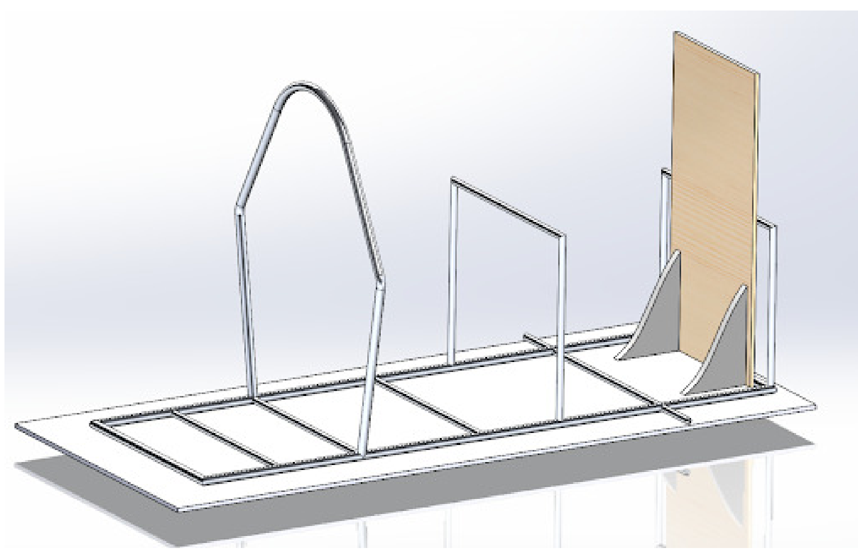

Figure 40: Frame Phases 1-5

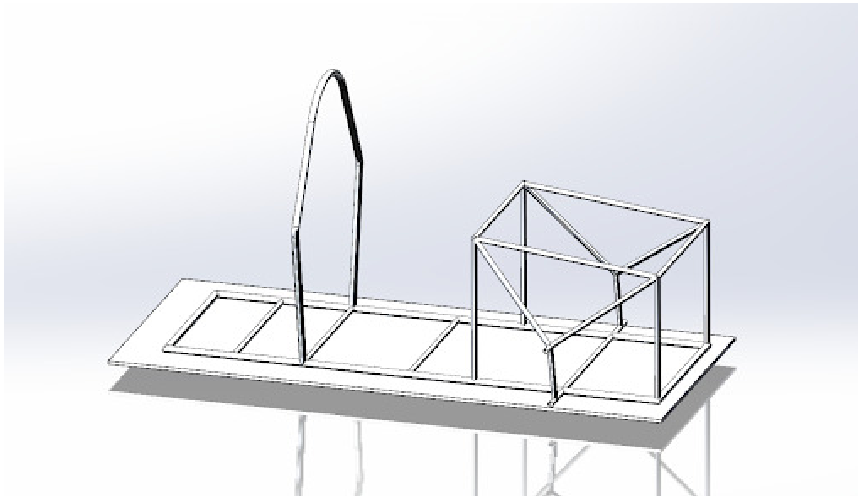

Figure 41: Frame Phases 1-7

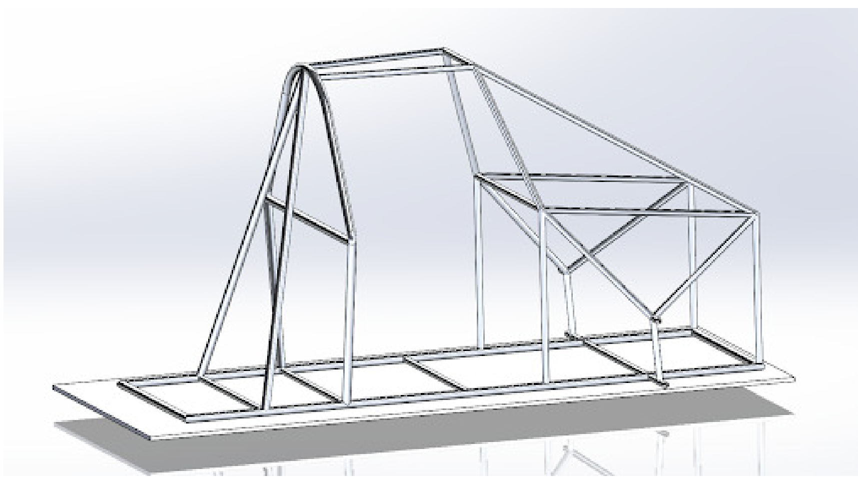

Figure 42: Frame Phases 1-9

#### 4.3.1 Material Options

Initial research showed that aluminum and steel each had their benefits as material choices for the frame's tubes. Aluminum was chosen for its strength to weight ratio and sufficient stiffness for the predicted loads on the frame. Ultimately, several unforeseen and unappreciated advantages of steel would likely lead to a choice of steel for future frames. The key advantages were those in hardness and weldability. However, Aluminum proved to perform very well for constructing a fully enclosing frame without adding a significant amount of weight. Had the frame been done with steel, the driver cell would have had less members for protection to meet the same target for the frame weight. Carbon fiber tubing and a monocoque were options that were also ruled out do to their complexity and lack of available data. Should these materials be pursued in the future, sufficient data for strengths of different carbon fiber matrix configurations should be available or completed through experimentation. Carbon fiber would eliminate the stress of welding all-together with the exception of metal sleeved reinforcements at the joints (if using carbon fiber tubing).

## 4.4 Manufacturing

Manufacturing of the frame was divided into three main tasks: cutting, coping, and welding the tubes. Cutting was done to each tube to get them to a length that was close to the tubes from the SolidWorks model to allow for coping. Coping is the process of cutting and shaping the tubes to fit with each other the same way as in the model. This involved taking profiles from the model tubes and unwrapping them to make a flat sheet that gave an outline of the contour. Then drawings are used to create coping templates on a 1:1 scale and are printed out. All of the coping templates are located in informal drawings in the appendix. The templates were cut to shape and wrapped around the corresponding aluminum tubes. This allowed the team members to cut and grind the tubes to be prepared for welding. Once a full phase was ready to be welded, the tubes could be clamped or held in place relative to the rest of the frame in order to determine if any adjustments were needed.

The simplistic and boxlike frame allowed for welding to be done in multiple phases, most of which were not entirely dependent on the completion of others. The simplicity also allowed for an easy manufacturing plan without the need for a complex jig. The frame was constructed by using key dimensions between members and a right angle plane that was located for each construction phase. The use of these phases allowed for simultaneous coping and welding of different sections of the frame, such that some people could weld one part while others coped another. Certain phases could even be finished out of order without impeding later welding. In total the frame was split into 10 phases. These phases consisted of the base, hoop structures, connection tubes, and engine mount. Figures 43-47 below show the actual construction of the frame. They show that some phases were joined out of order in order to coordinate with team members' schedules as many additional hands were necessary for certain portions.

Figure 43: Frame Phases 1-2 Constructed

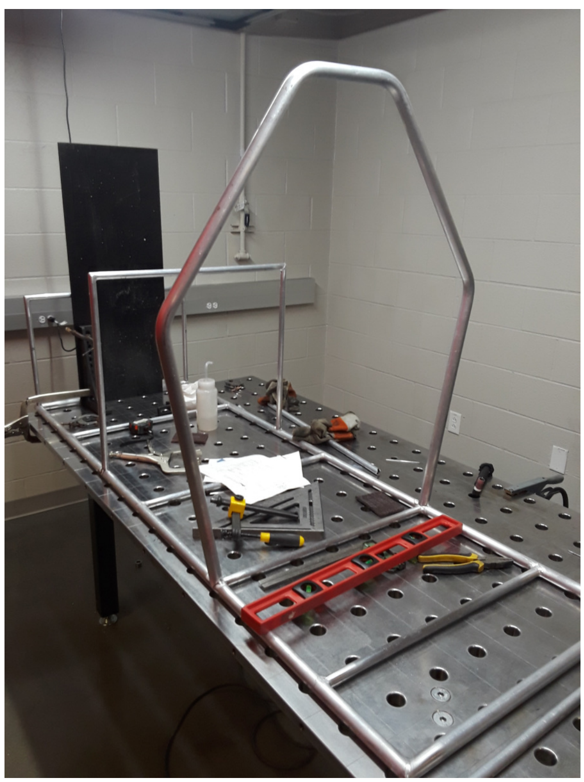

Figure 44: Frame Phases 1-5 Constructed

Figure 45: Frame Phases 1-6 Constructed

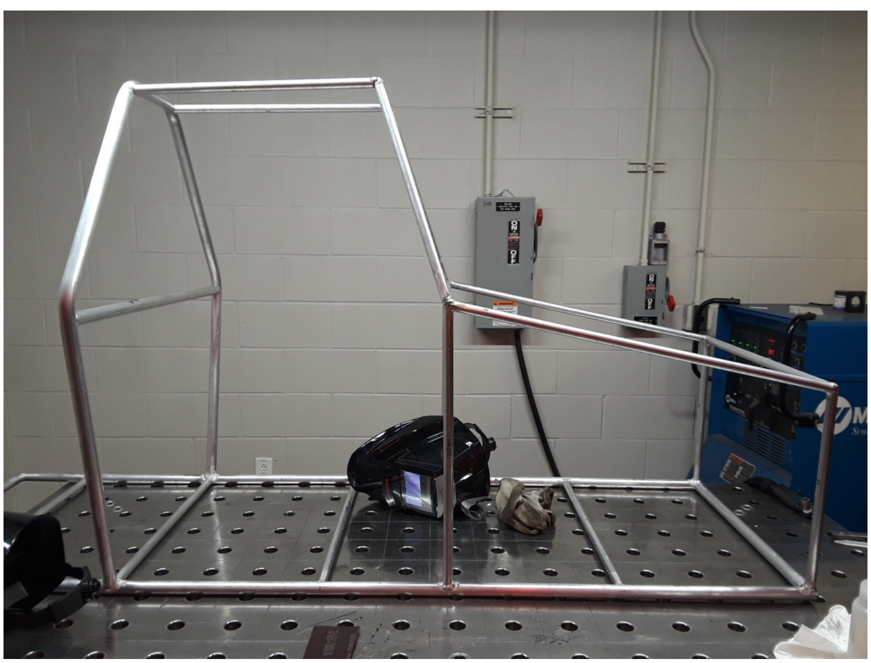

Figure 46: Frame Phases 1-6,8 Constructed

Figure 47: Frame Phases 1-10 Constructed

The method of welding was TIG, done in the FEDC. Prior the welding the frame, team members spent time practicing aluminum TIG welding since no team members had previous experience. Welding of the frame was preformed with multiple small jigs that held the tubes in appropriate positions and locations. Dimensions from the model were printed in drawings that showed the necessary locations for each phase's tubes. After the tubes necessary for a phase were all coped and fitting well, they were then welded together with the jigs holding them in the correct place. Finally, various tabs and gussets were added in critical locations such as the integration points for the knuckles and rear axle.

## 4.5 Results

The two main goals for the frame were met, including weighing 11kg or less and supporting 700N with minimal deflection of the roll hoop. The frame was sufficiently strong to hold the driver and other components. Other nondestructive testing would be needed to further validate and find limits of the frame strength. The frame met design dimensions within 0.325 inch maximum error due to small warping of frame base. This was most likely caused from extensive welding without adequate cooling times towards the end of manufacturing.

The lower hardness of aluminum compared to steel led to damage to the frame assembly in several locations. The bolts attaching the steering knuckles began to wear down their mounting tubes, which created an unintended camber angle by the end of competition. Similar wear also occurred on the aluminum plates supporting the steel steering column. The main issue with these components was the insufficient hardness for the repeated relative motions they experienced. Redesigning these joints to account for this effect would greatly improve the frame.

The weight of the door was more than expected and put a significant amount of torque on the door tabs and tube holding the door in place. The main tube that was holding the door was sized incorrectly for the force it experienced and began to crimp/bend where it was connected to the tabs on the frame. Using a square piece of aluminum for the upper arm with the addition of bearings at the tab mounting location would have kept the door upright (as long as the tabs were strong enough). In addition, the bottom link for the door was placed on a part of the floorboard that was susceptible to flexing. This failed to provide a secondary support to keep the door in plane.

A misunderstanding between several subteams led to the incorrect evaluation of the maximum torque output by powertrain. This necessitated the placement of more support members for the engine mounting.

# 5 Powertrain

## 5.1 Introduction

The powertrain subteam was essentially responsible for the propulsion system of the vehicle. This included the engine, transmission, and fuel delivery system. This is a vital component of the vehicle in both allowing it to move and achieving high fuel efficiency. The team did not have the time and resources to design and build an entire engine, but completed research and analysis to determine the optimal option. The group, however, did have to design the fuel delivery system since electric fuel pumps are not allowed by the competition.

## 5.2 Design Philosophy

Since many of the components needed by the team were going to be purchased, the primary goal of the team was to be as cost-effective as possible. Additionally, the team wanted to pick components that were simple and commercially available. This was done to ensure that the team could have all the working components together in time for competition, since without them, the car would not run.

## 5.3 Design Process

The team needed to first understand the rule requirements pertaining to the powertrain components before purchasing and assembling them to put in the car. The rules are very specific as they relate to the engine which limits the freedom of the team to choose the best one. Two of the main regulations are that the engine must be a 4-stroke engine and is required to be fuel injected. Additionally, the team wanted to keep the displacement volume of the engine as small as possible for the sake of fuel efficiency. The difficulty arises from finding a small enough engine that is fuel injected since most small engines are carbureted.

### 5.3.1 Engine Options

Based off the requirements, the team researched the potential engines that were available and could be used for the competition. Table Table 4 shows the engines the team considered after research. Some of the engine options in the table are listed as having a carburetor which would require extra work to be modified using a conversion kit, if chosen.

Table 4: Potential Engine Options Based off Research

| | **157QMJ (GY6)** | **QMB139** | **Honda Clone** | **Yamaha Zuma 50F** |
|---|---|---|---|---|
| **Vd (cc)** | 149.6 | 48 | 48 | 49 |
| **Engine Type** | 4 stroke | 4 stroke | 4 stroke | 4 stroke |
| **Cylinders** | 1 | 1 | 1 | 1 |
| **Bore (mm)** | 57.4 | 39 | 38.8 | 38 |
| **Stroke (mm)** | 57.8 | 41.4 | 41.4 | 43.6 |
| **Rc** | 8.8:1 | 10.5:1 | 7.2:1 | 12.0:1 |
| **Max Power (hp/RPM)** | 8.6/7000 | 2.95/7500 | 2.68/7500 | 3.7/6500 |
| **Max Torque (Nm/RPM)** | Couldn't Find | Couldn't Find | 3/7500 | 4.07/6500 |
| **Fuel Delivery** | Carburetor | Carburetor | Carburetor | Fuel Injected |

### 5.3.2 Power Calculations

The team also needed to make sure there was sufficient power from the engine in order to move the car. In order to do so, the team assumed certain parameters which are outlined in Table 5 below. Using those parameters, the power required to move the car to the velocities needed in the competition were calculated and are outlined in Table 6. In the table, the force of the drag is the summation of air resistance, brake resistance, and an inclination. Lastly, an 8 second acceleration to 20 miles per hour is used which is approximately what mopeds are able to achieve. From these calculations, it was determined that about 2.4 hp would be needed to achieve the max speed the car would need to operate at in order to complete the competition.

Table 5: Parameters for Engine Power Calculations

| **Parameter** | **Symbol** | **Value** | **Units** |
|---|---|---|---|
| Total Weight | m | 230 | kg |
| Coefficient of Rolling Resistance | Crr | 0.004 | - |
| Coefficient of Brake and Steering Resistance | Cbsr | 0.002 | - |
| Percent Grade | Pg | 0.02 | dec. |
| Coefficient of Drag | Cd | 0.2 | - |
| Air Density | $\rho$ | 1.225 | kg/m^3 |
| Frontal Area of Car | A | 1 | m^2 |
| Gravity | g | 9.81 | m/s^2 |

Table 6: Engine Power Calculations

| | | | |
|---|---|---|---|
| **Velocity** | m/s | **7** | 11 |
| | mph | 15.659 | 24.606 |
| **Force of Drag** | N | 44.262 | 53.082 |
| **Power for constant velocity** | W | 309.831 | 583.897 |
| | hp | 0.4155 | 0.783 |
| **Time** | s | 6.263 | 9.8426 |
| **Power for acceleration** | W | 586.74 | 922.02 |
| | hp | 0.7868 | 1.236 |
| **Total Power Required** | hp | 1.202 | 2.019 |

#### 5.3.3 Engine Selection

Ultimately, the team decided to go with the engine from the Yamaha Zuma 50F. This was done primarily because it was already a fuel-injected engine which saved the time, money, and complexity of attempting to install a conversion kit. It was also deemed that the engine was powerful enough to move the car according to its listed horsepower and weight of the scooter was comparable to the weight of the Shell Eco-marathon car. Instead of buying an entire scooter, the team found a used engine online. Unfortunately, many of the parts needed to start the engine were missing upon arrival and so the team had to find corresponding parts that would work.

Figure 48: Engine Selected - Yamaha Zuma 50f

#### 5.3.4 Fuel Delivery System

Since an electric fuel pump can not be used according to the competition rules, a pressurization system had to be designed that could push fuel into the fuel injector. According to the rules, the pressure tank had to be a transparent volume so the team decided to use a large soda bottle which was consistent with what other competitors were doing. Additionally, a pressure gauge, pressure regulator, and a safety relief valve were needed as part of the system for safety to ensure the system is never pressurized over 5 bar. Lastly, the system could only be pressurized by means of an air pump and so a schrader valve was needed at one end.

#### 5.3.5 Accelerator Pedal

To control the engine, the powertrain team designed an accelerator pedal with SolidWorks. They based their design off the standard operation of scooter accelerator handles. This involved designing pieces to be cut out of aluminum sheet and welded together for the actual pedal assembly and 3D printed parts for connecting the throttle cable. By pressing down the accelerator pedal, the throttle cable would be pulled, turning the throttle body, finally resulting in more air flowing into the engine, increasing combustion.

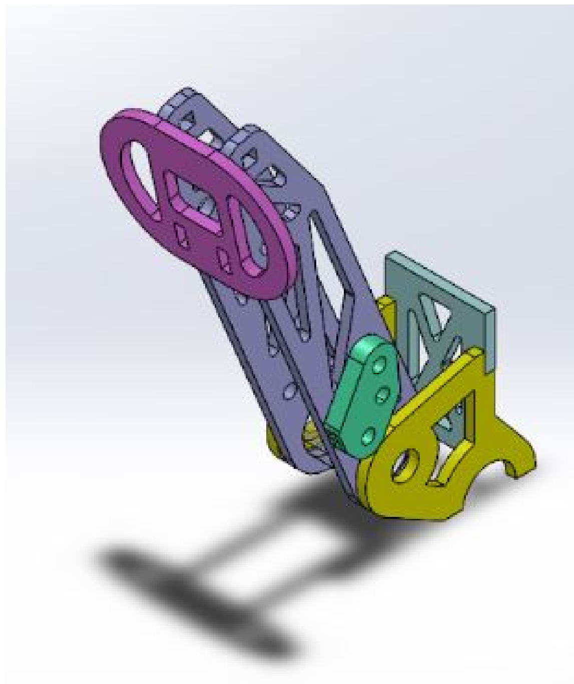

Figure 49: SolidWorks Design of Accelerator Pedal

## 5.4 Manufacturing

Due to the nature of the engine components, the powertrain team did not comprise of a great deal of manufacturing. However, there were vital components that had to be custom made in order to fulfill competition requirements and get the engine running. These included the fuel delivery system, the radiator, and the output shaft of the engine.

### 5.4.1 Fuel Delivery System

The fuel delivery system required the manufacture of a pressure tank. To do this, a hose barb was epoxied through the cap of a soda bottle and attached using pneumatic tubing. Then the rest of the competition required components, such as pressure regulator and gauge, were installed in the order designated by the rule book.

Figure 50: Fuel Delivery System according to SEM rules

### 5.4.2 Accelerator Pedal

The accelerator pedal required the team to submit a manufacturing request to the FEDC to water cut aluminum sheet to the specifications of the SolidWorks file. The pedal was assembled and welded into place by members of the frame team. Then the throttle cable mounts for both ends of the cable were 3D printed using another manufacturing request. Finally the throttle cable mounts were bolted into place and the cable connected to the pedal and throttle body.

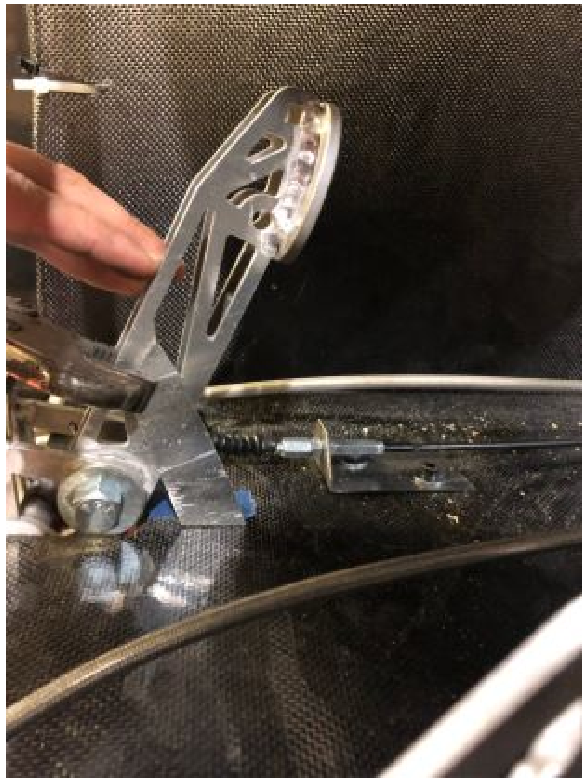

Figure 51: Accelerator Pedal and Throttle Cable

#### 5.4.3 Radiator Assembly

The radiator required a fan to be mounted in order to properly cool the engine. As such, a computer fan was attached to the radiator in order to ensure airflow and was wired through the wiring harness.

#### 5.4.4 Output Shaft

The output shaft of the engine required a custom manufactured part from a Zuma rear wheel hub. This is because of the complex spline cut on the output shaft of the engine. As such, a hub was machined down to a flat surface and a shaft with the spline cut using a mill. With this done, a matching hole pattern between the sprocket and the hub were drilled and the sprocket was bolted to the hub with spacers. A chain then connected this sprocket-hub assembly to the rear axle sprocket to power the car.

Figure 52: Custom Rear Sprocket Assembly

## 5.5 Results

The engine components were able to pass technical inspection the third time through. Additionally, the engine was able to power the car and get it to move on the track. The team was not able to calculate the exact mileage for the car but approximately 150 miles per gallon were expected. One issue that the team originally faced in technical inspection was the relief valve being 5 psi too high. This required a on-site modification to get it to the 5 bar limit. The team also faced some issues with air bubbles in the fuel line due to the varying heights of the tubing. Lastly, using one four cell battery caused the battery to drain rapidly which in turn resulted in the fuel injector not working properly.

# 6 Steering

## 6.1 Introduction

The steering subteam was responsible for the subsystems that dealt with the rolling aspects of the car, the brakes, and the steering mechanism for the vehicle. In order to have an effective vehicle, accurate and precise turning is necessary during operation, and this comes down the design on the various components for which this team is responsible.

## 6.2 Design Philosophy

Due to the complexity of the steering systems, the team focused on designing a system that would be easy to manufacture, effective in competition, and relatively inexpensive. Components were selected that would fulfill the requirements of the rules, provide low rolling resistance, and were readily accessible. The steering team sought to maintain Ackerman steering, have no suspension, and have $+5°$ of caster.

## 6.3 Design Process

### 6.3.1 Geometry

To begin the design process, a initial geometry was created in order to fulfill the basic requirements set by the rules. These include the front and rear track widths, the wheelbase, and the turning radius. In order to maintain Ackerman steering, the knuckles and tie rods were aligned with the lines connecting the center of the uprights with the middle of the rear axle, as shown in Figure 53. Additionally, the required minimum angles of turn for each wheel were calculated using a 5500 mm radius, which is less than the minimum turning radius of 6000 mm. This was done by aligning each knuckle with lines connecting the common center of rotation. Essentially, Ackerman steering allows all four wheels to have the same center of rotation, which maximizes traction and minimizes drag. Those calculations for this particular vehicle required the inner wheel to be set to $-12.51°$ and the outer wheel to be set to $15.04°$. With the angles calculated, it was possible to design a mounting system in order to achieve these geometries.

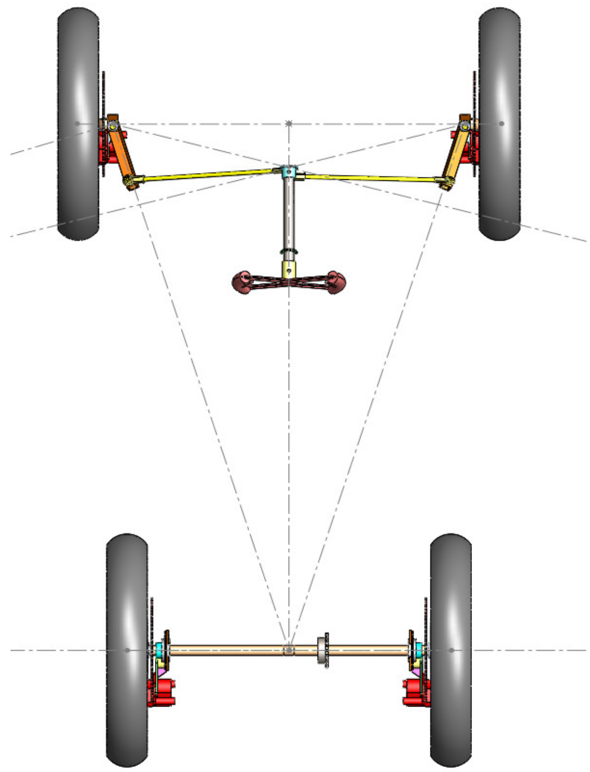

Figure 53: Steering Geometry

### 6.3.2 Steering Type

Many types of steering systems were considered when designing the car. These included power steering, rack and pinion, and go kart steering. While each has it's benefits, a go kart steering system was selected. This was because of the low cost and relative ease of design and manufacture for such as system. Designing the tie rods and knuckles concurrently allowed for greater control over the steering parameters and therefore go kart steering was thought to be the best choice. for the vehicle

### 6.3.3 Component Selection

#### 6.3.3.1 Axle Bearings

The rear axle bearings were selected by finding press fit go kart bearings. These types of bearings were selected because their intended use case is very similar to our needs, as well as their availability at a low cost. Choosing go kart rear axle bearings allowed the team to have a 1 inch OD rear axle, and by finding a kit that came with brackets, simplified the mounting process.

#### 6.3.3.2 Brake Calipers

The brake calipers were selected by finding the cheapest set of hydraulic brakes available. The team already had four calipers from Kawasaki Ninja EX250s, but it was determined the master cylinder that had been selected would not have enough volume to properly actuate the brakes. As such, smaller and lighter brake calipers were desired. Additionally, by purchasing a set of four brakes, the mounting system could be the same for the pairs of front and rear wheels. In order to verify the calipers would work with the design, the master cylinder actuation volume was compared to the brake calipers. Since the displacement was an acceptable amount (1 mm), the brakes would be able to be actuated. Additionally, the force on the pedal required to keep the vehicle stopped at an inclined was also calculated (54 N). With these calculations, it was possible to select the brake calipers currently on the vehicle.

Figure 54: Brake Caliper

#### 6.3.3.3 Brake Lines

The brake lines were selected by considering the length and relative motion of the brake lines. Because of the attachment points on the brake calipers, M8 banjo brake lines were selected. Additionally, the team opted for threaded steel brake lines to help prevent kinking and bends when routing and running the car.

Figure 55: Brake Lines

#### 6.3.3.4 Brake Fluid

Given the specifications of the selected brake calipers, the team is using DOT3 brake fluid in the hydraulic lines.

#### 6.3.3.5 Brake Rotors

In order to minimize cost, the brake rotors were reused from the Kawasaki Ninja EX250 front wheel assemblies. These rotors are stronger than required, already balanced, and already have a mounting system to the selected hub.

#### 6.3.3.6 Master Cylinder

The rules require the vehicle to have either a dual-circuit master cylinder, or two separate master cylinder that can actuate the brakes in an X-pattern. In order to have enough actuation volume to properly actuate the brake calipers, a double master cylinder system was selected. Additionally, these systems are readily available and therefore simplified the design process.

Figure 56: Master Cylinder

#### 6.3.3.7 Return Spring

In order to aid the pedals to return to a set stopping point, return springs were set inside. The selected springs are meant for go karts, and therefore fit very nicely within the vehicle's design. The spring constant was not considered when selecting this component.

Figure 57: Pedal Return Spring

#### 6.3.3.8 Chain and Sprocket

In order to select a drive chain and sprocket assembly, the chain was first chosen based on it's specified maximum loading. Using this calculation, a wide variety of chain sizes were allowable. After consultation with the powertrain team, a 1:1 drive ratio was determined to be ideal. Because of this ratio, #40 roller chain allows for increments of 0.5 inches when adding links due to its pitch. This simplified the engine mounting process and therefore was a good choice for the drive chain. The sprocket was selected to accept both a #40 roller chain while also having a 1 inch bore. 20 tooth sprockets were selected because of their sufficient outer diameter to easily mount to the engine.

#### 6.3.3.9 Tie Rod Ends

The tie rod ends were selected based on the maximum deflection required in the system. By using the steering column and knuckle geometries, it was possible to determine the maximum angle between the tie rod end and the mounting bolt. This limited the number of options available, and a low-cost option was selected. The selected tie rod ends did not have left and right threads (which many do to allow for greater control over the tie rod lengths), but this was deemed not necessary to simplify manufacturing. Moreover, due to the thread pitch, the team already could control the lengths of the tie rods to 1.15 mm increments.

Figure 58: Tie Rod Ends

#### 6.3.3.10 Wheels

The wheels were by far the hardest components to select. This was because of the complex and unusual requirements on their geometry. While custom built spoke wheels would have been the ideal solution, the team was severely limited on budget. As such, the most readily-available wheels that fit the requirements were selected. This was done because the more widely manufactured the wheel was, the more likely it would be for the team to be able to find a low-cost option to purchase or replace the wheels. Keeping this in mind, the team was able to determine that Kawasaki Ninja EX250 front wheels fulfill the requirements set by the rules by having 16 inch rims and 100 mm wide tires. The team was able to find a full set of rims and tires on eBay for much less than all alternatives. Wheels were selected that also included the brake rotor to save cost.

Figure 59: Kawasaki Ninja EX250 Front Wheel

#### 6.3.4 Knuckles

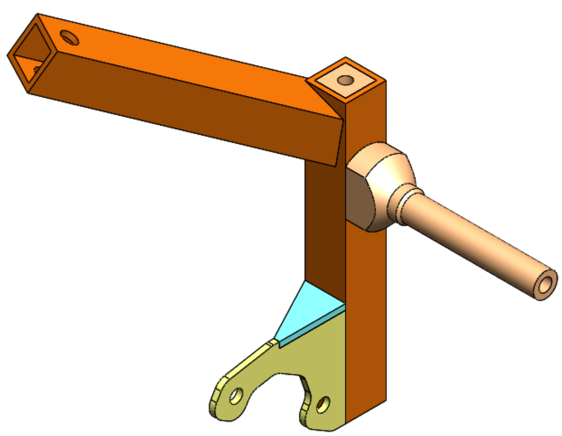

Figure 60: Steering Knuckle

##### 6.3.4.1 Arm

The knuckle arm is defined as the piece that extends to meet the tie rod at the proper angle to achieve Ackerman steering. The arm length was determined from a balance of weight and steering geometry requirements. The tab on the steering column that drives the tie rods should be long enough to maintain linearity, but short enough to minimize steering back torque. Moreover, the knuckle arms should be short enough to minimize weight, but long enough to maintain precision. The eventual lengths were selected as a balance of all these parameters as well as percentage of Ackerman achieved and compartmental leg room within the vehicle. Additionally, the arms were angled towards the steering column in order to minimize the angle of incidence between the tie rod ends and the knuckle arms. This increased the efficacy of the tie rods. The arms were designed out of 1” X 1” X 11 GA A513 Square Steel Tube to meet strength requirements while also being easier to cope and weld.

#### 6.3.4.2 Brake Caliper Mount

The brake calipers are designed to be through mounted to the upright, similar to many motorcycles. As such, the caliper is to be mounted on the rotor side of the upright, and connected via threaded bolt. The knuckles were designed such that the wheel-sided face of the upright was the proper distance from the face of the brake rotor. As such, the brake caliper mount was easily designed as a piece of 10 GA. HRA36 that was water jet to the exact specifications of the brake caliper. This allowed for extremely easy installation of the front brake caliper. Furthermore, a gusset was added in order to reduce any twisting motion caused by the torque on the brake caliper.

#### 6.3.4.3 Retention

In order to retain the knuckle assemblies, threaded blocks were inserted into the top and bottom of the upright. Because of the direction of the stresses on the knuckle to the frame, the retaining bolts would not see extremely large stresses. Their main purpose is to maintain the angles of the steering knuckles. Originally, the inserts were intended to be two separate blocks of steel that would be welded around the top. However, because of the difficulty in threading hardened steel (post weld or risking ruining the threads), a single aluminum block was press fit inside of the square tubing. This block was then threaded and bolted to the frame. Vertical thrust bearings were inserted between the bolt and the frame in order to reduce steering friction and wear on the surfaces.

#### 6.3.4.4 Spindle

The spindle was designed to support the cantilevered weight of the car while also fitting inside the bearings of the wheel hub. Because the inner diameter of the wheel is only 15 mm, A36 steel was the only option for the spindle. Using the cross-sectional profile of the wheel hub, the spindle was designed to allow the upright to ride as close to the wheel as possible while also maintaining a proper distance for the brake caliper mount. FEA was performed throughout this process to verify the strength of the design. A threaded hole was added to retain the wheel from the outside using a nut and washer.

#### 6.3.4.5 Tachometer Mount

In order for the tachometer to work properly, it was necessary for it to be able to detect a magnet attached to the wheel using its Hall-effect sensor. With the geometry of the wheel and the knuckle, it was determined that mounting the magnet inside of the main wheel hub would be the most ideal location to reduce the possibility of imbalance while also being easy to mount the tachometer. The tachometer mount then became just a through-hole on the knuckle where the sensor could be inserted and bolted from either side.

#### 6.3.4.6 Upright

The upright was also designed out of 1” X 1” X 11 GA A513 Square Steel Tube. This material is currently over-engineered for the stresses seen by the car, but the efficacy of welds and the possibility of the tube buckling was a major concern. As such, the upright as designed is capable of handling all the cantilevered load from the spindle under dynamic loads independently of the aluminum block that is press fit inside. This sized material was selected as a balance of size and strength in order to minimize weight while also being capable of turning within the frame.

### 6.3.5 Rear Axle Hangers

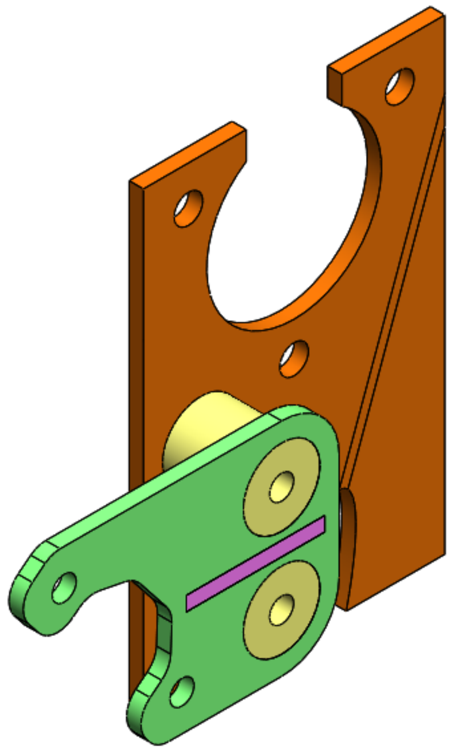

Figure 61: Rear Axle Hangers

#### 6.3.5.1 Bearing Hangers

The selected axle bearings included a set of retainers that allow the bearings to self-align and only require three bolts to attach. In order to incorporate these retainers, an aluminum hanger was designed that would match the hole pattern of the retainers. This upright hanger was also tested for the weight and turning loads that the bearings would experience to verify its strength. The part was designed to be water jet cut from 3/16 inch 6061 Al plate and then welded to the frame.

#### 6.3.5.2 Brake Caliper Mount

Because the frame was not as wide as the front track width, the rear bearing hangers were significantly further from the brake rotor than the front knuckle. As such, standoffs were made to extend the rear brake caliper mount towards the brake rotor. A similar design was used that would hold the brake calipers at the correct angle relative to the rotor. The standoff length was selected to place the rotor inside the calipers, and the mount itself was water jet from 3/16 inch 6061 Al plate. The standoffs were designed to be threaded to the upright to ease the assembly process.

### 6.3.6 Rear Axle

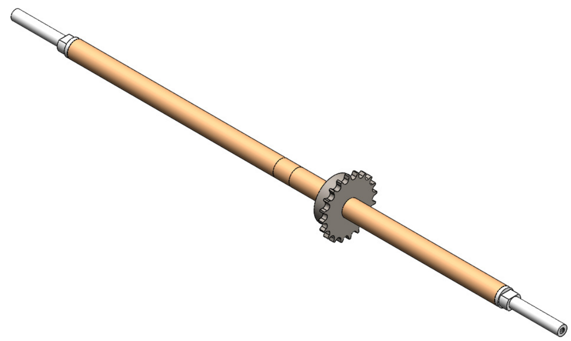

Figure 62: Rear Axle Assembly

#### 6.3.6.1 Axle Tips

The rear axle tips were one of the more challenging part to design. This was mostly due to the question of power delivery to the wheel. Drawing on past experience, the method eventually chosen was what is called a "double-D" keyway. Essentially, this is a round bar that is flattened on either side to create a self-centering keyed shaft. The axle tips were designed out of A36 steel round to be machined down to the inner diameter of the wheel bore. A step up on the inside of the tip as well as threads for a bolt were added to retain the wheel. On the axle shaft side of the tips, the ends were machined to the inner diameter of the shaft to aid in welding on the tips.

#### 6.3.6.2 Column

The steering column was designed from the same 1 inch OD A36 as the rear axle in order to save cost. The length was calculated by determining the distance from the drivers hands to the optimal connecting point for the tie rods to maintain Ackerman steering as closely as possible. The stopper was designed to limit the angle of the steering column in order to keep the wheels from colliding with the body via over rotation.

#### 6.3.6.3 Hub Keyway

The hub keyway was designed to accept the axle tip and provide power to the wheel. Because the hubs are aluminum, the keyway was also designed to be aluminum. The width of the keyway was selected to be 5/8 inch to aid in manufacturing while also keeping the tip from plunging too far into the hub.

#### 6.3.6.4 Shaft

Originally, the shaft was designed in Aluminum. However, when performing stress analysis, it was determined that due to the bending and torsional stresses seen by the axle, and the 1 inch OD limit on its size, a steel rear axle would be lighter and stronger. Therefore, thin-walled 1" OD x .065" wall x .870" ID A36 tubing was used to make the rear axle.

#### 6.3.6.5 Sprocket Keyway

The sprocket keyway was designed as a piece of 11 GA A36 to the width of the keyway slot. It was determined the shear stress of the keyway was sufficiently less than the stress caused by the applied torque from the engine.

### 6.3.7 Steering Column

The overall design of the steering column was developed over many iterations by looking at steering columns of go karts and other competition vehicles that use a similar steering system. The attachment points were designed as a simplified version of a quick disconnect steering wheel system.

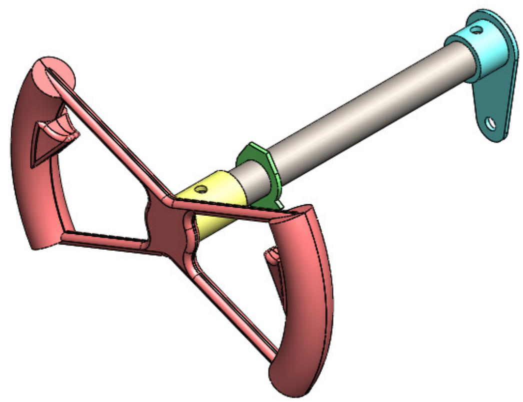

Figure 63: Steering Column

#### 6.3.7.1 Steering Hanger

The steering hanger was designed in a way that would allow easy assembly around the steering column. As such, a pair of round hangers were designed to accept the steering column and be sandwiched between the steering wheel and the steering stopper.

#### 6.3.7.2 Steering Tab

The steering tab is a piece of A36 sheet attached to the rear of the steering column that is responsible for pushing and pulling the tie rods. In addition to the geometries of the knuckles and lengths of the tie rods, the length of this tab was also considered when optimizing the Ackerman geometry. This tab was designed using 11 GA A36 and is to be welded to a sleeve that fits over the steering column with a through hole allowing a bolt to attach these parts. This allows for easy assembly and maintenance.

#### 6.3.7.3 Steering Wheel

The steering wheel was designed to be the minimum size required by the rules as well as strong enough to hold the forces required to steering the vehicle. As such, a carbon fiber with steel insert wheel was designed that could connect to the steering column via bolts. The steering torque was calculated using the forces seen by the wheels during a minimum radius turn at maximum speed. It was determined the selected steel plate would be able to withstand the forces, and the foam insert and carbon fiber just add volume and rigidity.

The foam insert was designed with the goal of driver comfort in mind. As such, the cutout for the dead man switch was placed behind the left fingers and thumb rests were added.

#### 6.3.8 Brake Pedal

The brake pedal assembly had one the most degrees of freedom of any of the systems on the vehicle. As such, a number of design iterations were performed while studying other teams and go kart designs. The leg angle of the driver was considered when initializing the placement of the pedal. Because of the size of the frame, two-footed steering was assumed, and the brake pedal was placed in such a way that it would be comfortable to use the left foot to operate.

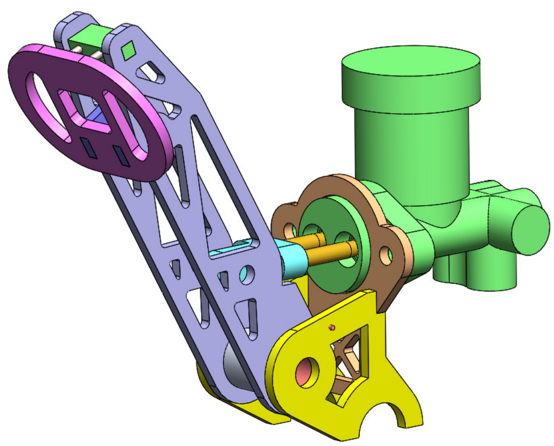

Figure 64: Brake Pedal

##### 6.3.8.1 Brake Light Switch

As required by the rules, the vehicle must have functioning brake lights. As such, it was decided the simplest way to achieve this was through a switch mounted inside of the brake pedal. The face of the brake pedal is capable of pivoting approximately 15 degrees in order to activate this switch. Small springs taken from a mechanical pencil are used in order to return the pedal face to its normal position and deactivate the switch. A small limit switch was mounted in such a way that the pedal face would activate it when the pedal was depressed with a 10 N force. A 3D printed mount was used to hold the opposite sides of the springs and exactly position the limit switch inside of the pedal assembly.

#### 6.3.8.2 Master Cylinder Gussets

In order to withstand the torque applied by the driver's foot, gussets with round bottoms that could be welded to the frame tube were added. Similar to the pedal arm, the gusset mass was minimized by reducing the thickness of the members and checking with FEA simulations.

#### 6.3.8.3 Master Cylinder Mount

The master cylinder mount was likely the simplest part to design as the mounting holes on the master cylinder show the intended mounting system. As such, a aluminum plate was designed to center and house the master cylinder and hold it in place while a pedal was designed to actuate the cylinders. the height of the master cylinder from the frame was minimized in order to minimize the torque on the welds at its base.

#### 6.3.8.4 Pedal Arm

The pedal arm was designed in such a way that it would allow for comfortable actuation via a foot, could apply a reasonable force to the cylinders, withstand the internal forces, all while minimizing mass. The length of the pedal was determined by calculated the necessary forces on the cylinders and using the lever multiplier with a standard foot force of 200 N. Additionally, the face of the pedal was designed to be flat to the driver's foot. Because of the size of the pedal arms, efforts to minimize mass here were very useful. This was done by running series of FEA simulations in SolidWorks and gradually reducing the width of internal cross members within the pedal arms. Finally, the pedal arms were designed around the mounting point for the pedal considering the pedal return spring, the plunger mount, the pivot for the pedal face, and the brake light switch mount.

#### 6.3.8.5 Pedal Face

The pedal face was designed to meet the minimum area requirements set by the rules while also being ergonomic to press. The face was designed to pivot about a point that allows a switch to be activated while depressed that would activate the brake lights. Centering holes were added to help the springs for the face stay in place to ensure the brake lights would not stay activated.

#### 6.3.8.6 Plunger mount

Inside of the pedal assembly is a mount that holds both plungers for the master cylinder. This part equally transfers the force from the foot to the master cylinders themselves. The positioning of this part on the pedal was done by simulating the motion of the pedal and ensuring the plungers would clear the holes inside the master cylinders and be able to properly actuate.

#### 6.3.8.7 Return Spring

In order to help the pedal return to a natural position and not sustain force on the brakes, a return spring was added to the brake pedal design. This return spring was selected from a go kart brake set and therefore had an acceptable spring coefficient. The mounting of the spring was accounted for by adding a slot in the sleeve and gussets that would accept the spring.

### 6.3.9 Seat

#### 6.3.9.1 Bend Supports

In order to support the corrugated plastic insert for the seat, bent aluminum sheet was added to the interior of the design. These parts would allow the bends to be far more accurate while also strengthening the seat. Aluminum flat bar was chosen for its ability to hold a bend while also being extremely lightweight and inexpensive. The locations of these supports were chosen to maximize the stiffness of the seat and support critical bends.

#### 6.3.9.2 Foam Insert

The foam insert, and therefore the shape of the seat itself, was designed using a commercially available seat. Using the listed dimensions, an adjusted seat was created that would fit the driver's specifications. Specifically, this was in regards to the height and width of the driver. With this information, a similar and easier to manufacture seat model was created.

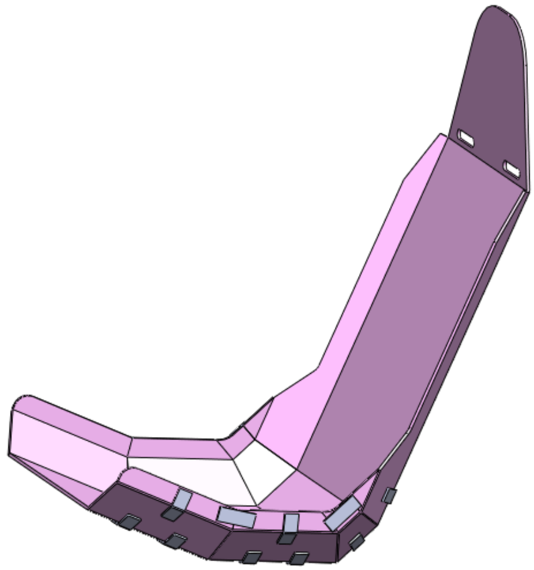

Figure 65: Custom Seat Design

## 6.4 Manufacturing

The manufacturing of the steering systems was kept in mind during the design process. This by no means implies the manufacturing process was completed quickly. Due to the precision of many of the parts, the critical component was not skill, but time needed to manufacture.

Figure 66: Assembled Steering System

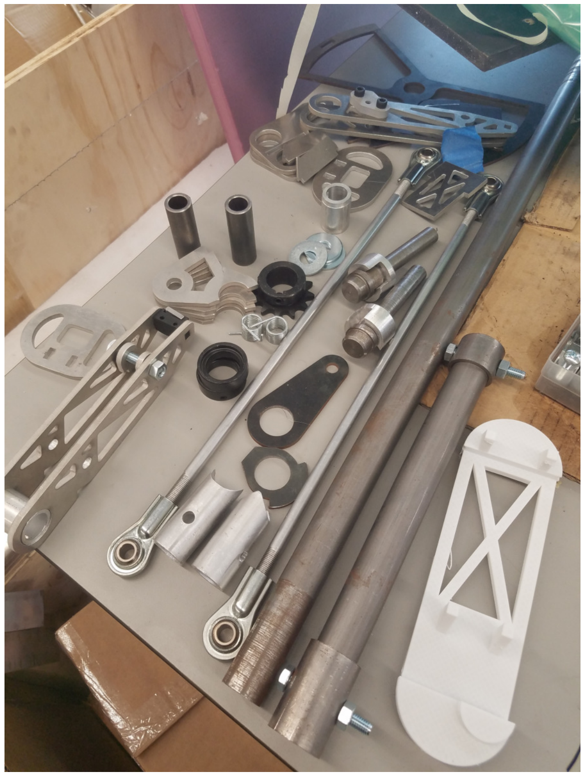

Figure 67: Manufactured Steering Parts

### 6.4.1 Axle Hangers

The axle hangers were made of two sets of water jet parts and four machined standoffs. The standoffs were cut to approximate length from pieces of 1 inch 6061 bar and then put in the lathe to face off. The lathe was used to cut the standoffs to exact length and to pre-drill the M8x1.25 tap hole with a 7.2 mm bit. While in the chuck, the holes were then tapped. Once these standoffs were complete and the other parts were water jet cut, the standoffs were welded to the plate with the gusset in place. Both the standoffs and the gusset had a hole or slot to aid with positioning. From this point, the final step to mount the rear brakes was to bolt on the calipers and then bolt on the standoffs to the bearing hangers.

### 6.4.2 Brake Pedal

The brake pedal was designed using almost entirely water jet parts. This greatly simplified manufacturing. A spacer to retain the return spring and mounting bolt was cut from 1” OD x 1/8" thick 6061. The lathe was used to cut this spacer to length and a mill was used to cut the slot meant for the return spring. With this done, the pedal pivots were welded to the pedal face with a bolt in place to help align the holes. With this weld complete, the 3D printed spring centering piece was glued to the pedal face. The spacer was welded to the pedal arms with the 3D printed brake switch mount in place. The gussets were welded to the master cylinder mount using clamps and maintaining right angles. The hole for the stationary side of the spring was drilled out after verifying the spacing. In the final stage, the gussets and master cylinder mount were welded to the frame. With this in place, it was possible to bolt the pedal in place with the return spring, bolt the plungers in place, bolt the master cylinders in place, and bolt the pedal face with the pencil springs in place.

#### 6.4.3 Brake Rotors

The original design planned to use the unaltered brake rotors from the Kawasaki wheels. However, the maximum acceptable width of the brake rotors for the given calipers was not considered. The team ran into issues when it was realized that the brake calipers accept a 3 mm brake rotor, while the Kawasaki Ninjas have 4.9 mm rotors. As such, the rotors had to be taken down approximately 40%. This was done using a surface grinder, which was an extremely tedious process as it can only take 0.0015 inch per pass at five minutes per pass. The lathe and mill were considered, but each gave inconsistent results in taking off such a small amount off a hard, cantilevered material. This resulted in only being able to clamp from the interior diameter and attempting to push on the outer diameter, which deflected the material. As such, the lathe produced a part that was thinner at the middle than at the edges due to the stiffening of the material as the tool got closer to the clamping point. The mill would have similar issues. Additionally, the surface grinder has a much more even surface finish which would not cause any issues with the brake caliper.

Finally, because the calipers are not designed for these rotors, there was an issue with collision between the bolt heads on the rotors and the caliper face. To correct for this without destroying the calipers, the face of each caliper was milled to remove approximately 2 mm of material to give the bolt head clearance, as shown in Figure 68.

Figure 68: Caliper Clearance Machined

#### 6.4.4 Brake System

Once the calipers were capable of being fitted to the rotors and the master cylinder had brake fluid inside of it, it was possible to connect the brake lines to bleed the brakes. The brake lies were connected in an X-pattern using the double banjo bolts and the copper crush washers.

Brake bleeding was an extremely tedious process, especially when using a double connection double cylinder setup. The most effective method of bleeding the brakes was to open up the bleeder valve on the cross connected calipers in addition to the master cylinder. Then, with the opened calipers in a bucket hanging below the master cylinder, brake fluid was poured into the master cylinder bleeder port until fluid freely flowed out of the calipers. At this point, the bleeder valve was closed off and the master cylinder topped off before the bleeder port was bolted shut. The calipers were placed on a brake rotor. Fluid was added to the master cylinder. Then, using the plungers and ensuring the master cylinder reservoir was cracked open, the cylinders were cycled until a braking force was felt on the calipers. The reservoir was closed and the process repeated for the other circuit. Once this process was complete, the brakes were mounted to the vehicle.

### 6.4.5 Keyway

The rear keyway was made from blanks cut from a large block of 6061 Aluminum. They were turned down to the proper diameter and a 15 mm drill was used to bore out the center hole. Then, they were taken to the mill where the slot was slowly milled from the center line. The inner bearings of the rear wheels were removed using retaining ring pliers and a punch. These keyway inserts were then welded inside the bore of the wheel hub to be the female end of the double-d keyway design. However, upon assembly, the rear wheelbase was approximately 9 mm too narrow, so a sheet of aluminum was cut to the same keyway and then welded on top of the original piece in order to hold the wheels further apart.

### 6.4.6 Knuckles

The steering knuckles were a difficult part to manufacture due to the relative complexity of the welds. The uprights, and arms were rough cut using a band saw then ground down to the proper height. Coping diagrams for the arm were created by converting the part to an extremely thin piece of sheet metal that followed the contour of the square tube, flattened, and printed out. This made it much simpler to use a grinding wheel to cope the arms to accept the uprights at the proper angle while welding.

The spindles, being made of 2 inch A36, were very tedious to turn down. Very slowly (180 rpm with fluid), 0.100 inch passes were taken off of the spindle until the desired diameters were achieved, as shown in Figure 69. Then, the edges were chamfered by hand. The M8x1.25 tap was drilled with a 7.2 mm drill, and then tapped by hand. Finally, the opposite face was faced off and then cut to length. Moving to the mill, parallels were used to place the round piece in place. The spindled was squared off on two sides to be 1 inch wide.

Figure 69: Spindle in Lathe

The uprights were simple pieces of square tubing that were cut to length. However, to bolt to the frame, a piece of 1" x 1" 6061 Aluminum was cut and hydraulically pressed into the uprights. This piece was then drilled and tapped with a 7.2 mm bit and M8x1.25 tap respectively.

With the upright complete, the arms and spindle were clamped in place and welded to the knuckle. Lastly, the water jet cut brake mounts were welded to the knuckle by laying the parts flat on the table. A complete knuckle assembly is shown in Figure 70.

Figure 70: Mounted Knuckle

#### 6.4.7 Rear Axle

The rear axle was rough cut using a band saw and put in the lathe to face off and more precisely cut the length. Slight chamfer was also added to aid in welding.

The rear axle tips were manufactured in a way very similar to the front spindle. Slow cutting with fluid was used to get the part to the correct diameters. The M8x1.25 tap was drilled with a 7.2 mm drill, and then tapped by hand. The opposite face was cut to length for insertion into the axle. Lastly, the keyway face was milled by clamping the piece with parallels.

With the tips completed, they were welded in place by vertically clamping the tips into place. Unfortunately, the inserted end was not long enough to center one end of the axle, so the axis of rotation was 0.035 inches off from center. This was corrected using the hydraulic press and the available fixturing. The welds were then taken back down to the original diameter in the lathe to allow the bearings to fit on the axle, as shown in Figure 71. Due to imperfections on the tube, one bearing had to be hydraulically pressed onto the axle, whereas the other had a running fit. Once the bearing was pressed into place, the sprocket, bearing retainers, and set screws could be added, as shown in Figure 72. The final step was to insert the key into the sprocket and weld it into place.

Figure 71: Axle Tip Welded and Machined

Figure 72: Axle Assembled

#### 6.4.8 Seat

The seat insert was made from a piece of corrugated plastic that was scored and bent using the flat pattern of the seat. The bend supports were made using strips of flat aluminum bar that were cut into 2 inch segments. A brake press was used to manually bend them to the correct angles. With the plastic scored, the bend supports were glued into place, as shown in Figure 73. Also shown is the foam that will be placed between the layers of carbon fiber.

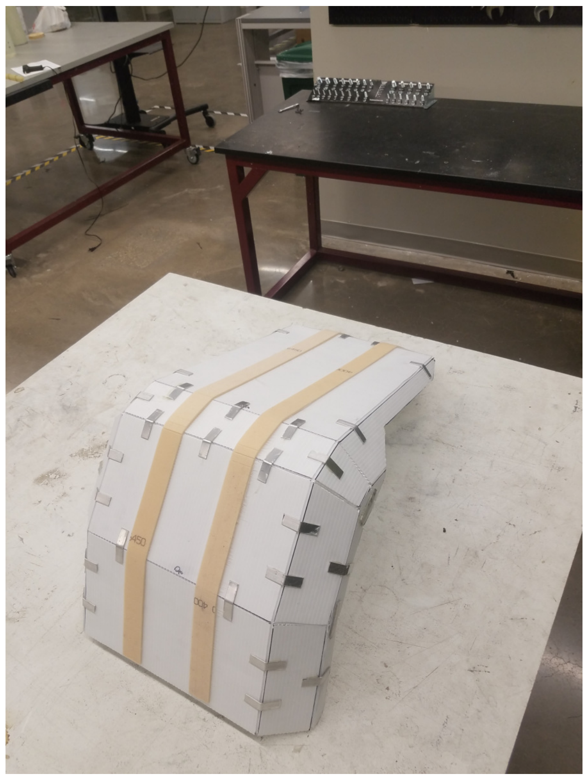

Figure 73: Seat Insert with Bend Supports

With the insert completed, two layers of carbon fiber with the foam in the middle were laid out on the back side of the seat. The fiber was cut to size and relief cuts were made beforehand in order to keep the area clean. Small amounts of epoxy were put on the seat to hold the fiber in place, but most of it went on top of the first layer. When adding the second layer, it was very important to press the corners into the bend supports to prevent gaps or pockets of epoxy. The back two layers were completed and trimmed, and the process was repeated without the foam insertion for the front two layers, shown completed in Figure 74.

The entire seat was then sanded down to get rid of burrs.

Figure 74: Seat after Layup

With the structure of the seat done, holes were then cut for the seat belt straps. Upholstery foam was cut to the dimensions of the seat, and a piece of fabric cover was placed over it to protect the foam. 3D printed grommets were made and then glued to the foam seat in order to keep the fabric and foam together. Finally, the seat belt was strung through the seat and bolted.

While at competition, the judge that looked at the seat belts was not satisfied that he could not see the actual attachment point through the seat, despite it being a solid connection. As such, the seat had to be butchered apart to give clear line of sight of the mounting points.

#### 6.4.9 Steering Column

The steering column was cut to length using a band saw and then faced off using a lathe. A mill was used to drill out the mounting holes for the steering tab and the steering wheel. The steering stopper had to be welded at a set distance from the front, so it was lightly press fit onto the column and welded into place.

Figure 75: Welding Jig to hold Steering Hangers

#### 6.4.10 Steering Hanger

The steering hanger was made from four water jet cut pieces of 3/16 inch 6061 Aluminum and a spacer machined to help with alignment during welding. The spacer was machined to a rectangular prism from a 0.75" x 0.75" pieces of 6061 Aluminum block. Then, it was turned on its end and an end mill was used to slowly take out the curved surface that would eventually be welded to the frame.

The spacer was welded between the circular hangers, and the steering stopper tabs were welded to one face of the hangers. With this completed, the entire assembly was welded to the frame using a rig to hold it parallel to the wheel well tubes, as shown in Figure 75.

#### 6.4.11 Steering Wheel

The steering wheel was manufactured using pieces of foam take from the Haverty's dumpster, a water jet pieces of 10 GA A36, and carbon fiber. The foam was CNC'd using the shop bot because it has evacuation. When the foam was complete, it was cut and glued to the metal insert. Strips of carbon fiber were then wrapped around the steering wheel after being soaked in epoxy. Because of the number of strips, there were a great number of loose ends that made the steering wheel extremely dangerous to hold. As such, despite sanding, it was wrapped with friction tape to protect those who handle it. Additionally, the hold for the "dead-man" switch was cut using a dremel and the wired switch was glued into the wheel.

### 6.4.12 Tie Rods

The tie rods were manufactured from 3/8 inch 6061 Aluminum rods. They were rough cut using the vertical band saw and fine cut using the lathe. While clamped in the lathe, the ends were also threaded with a 3/8-24 die. The tie rod ends were then screwed onto the ends of the rods to meet the length as specified in the design.

## 6.5 Results

### 6.5.1 Technical Inspection

During technical inspection, the steering systems passed all geometrical requirements. The judges were happy with the brake system, rotors, and lines as it was well routed and made use of threaded steel lines. The brakes, when first tested were unable to hold the weight of the car at an incline. It was determined this was because of a brake pad being misaligned in one caliper and a nut being stuck in another. The only other issue that arose during inspection was the slop in the steering column that became progressively worse throughout the week. The judges were satisfied, but it is likely to continue to deteriorate with time. As such, the steering and braking systems passed technical inspection.

### 6.5.2 Ongoing Issues

With further testing, however, it became clear that the wheels were becoming cambered, which was not part of the design. This was especially apparent in the right wheel. The main issue is the rotation of the retaining bolt would slowly grind away at the mounting point of the frame. This was exacerbated in the right wheel by the bolt not being inserted all the way. This caused the threaded part of the bolt to be exposed to the frame, accelerating the rate at which material was chipped away. With less material, the bolts shifted, allowing the wheel to camber outward.

A similar issue was experienced by the steering column. Turning the steel steering column would chip away at the aluminum journals in the column hangers. Without bearings, these joints became more and more loose, eventually to the point were the control of the wheels is no longer precise or accurate and requires correction before driving.

### 6.5.3 Point of Failure

The points of failure in the car were both found on the rear axle. Both the sprocket keyway and the main axle tube had failures. The main factor in both of these failures was an incorrect consideration of the output torque of the engine. When running simulations, the nominal max engine torque of 3 ft-lbs was used to generate loadings and calculate the factor of safety. However, this value was not the output torque of the transmission, but rather the torque of the engine. As such, the CVT can increase that torque by up to seven times, depending on the tuning of the variator. As such, despite having a high factor of 3.1, this was not sufficient to withstand the much higher than expected torque from the engine.

The keyway, while also experiencing higher than expected load, should have been able to withstand the additional stress. However, because the weld was approximately 0.75 inches from the sprocket, the key bent and stretched, rather than sheared. This allowed the key to fail at a lower stress than would have otherwise been allowable.

Additionally, there was unaccounted for loading during the event. While on the track, our driver did not stop in the stopping zone as is required. At the completion of the second lap, the track marshal ran out on the track to ensure our vehicle stopped, forcing the car to stop as quickly as possible. The stopping force that was applied was not accounted for during the design, which could have been a factor in the failure of the rear axle.

# 7 Risk Analysis

Managing risk played a large role in the overall development of the vehicle. We began our risk assessment early in the design phase to clearly distinguish aspects of the design that required more of our attention. This was done through the use of the FMECA table displayed in Table 12, which utilizes a semi-quantitative approach as a means to assign priority numbers to critical components of the car. Our risk analysis began in [3] but has considerably changed accounting for new predictions with the help of different risk modelling tools. From [3], the risk management plan developed by the team consists of JSA's by subteam, FMECA, FMA, Fault Tree Analysis, and Event Tree Analysis. Currently, the team is on track with our RMP as we have completed three of the five risk management tools listed above. This consisted of job safety analyses found in Table 9 in Appendix Appendix D which summarizes critical activities involved with manufacturing the car, FMECA and fault tree analyses which are discussed more in detail below.

The FMECA analysis begins by first assigning a severeness factor to a given potential failure. This number is from one to ten where one represents a nearly negligible effect and ten represents an effect that can cause total failure to the vehicle or immediately jeopardize our objective of finishing the competition. Next, we are to assign a likelihood factor from one to ten where the value is directly proportional to the probability of the potential failure event. The last constant needed is the detection factor which the likelihood that we are to detect anything wrong with the potential failure event. A detection factor of one means the issue will be clear and noticed immediately and a factor of ten means there is a more random process associated with detection. All of these factors are then multiplied in the FMECA table to generate a Risk Priority Number (RPN). We then sort the potential failure events from largest to smallest RPN values which helps identify aspects of our design that need improvement. this could be done by designing redundancy electronics for failed electrical systems or generating a checklist to inspect key systems with high RPN values. Some of the highest RPN values listed in Table Table 12 are a misinterpretation of the rules, depressurization of the fuel, and disengagement of the chain. Because of our risk analysis with the FMECA strategy we were able to generate solutions to reduce the risk of the high RPN events. For these potential events the operational changes made to address these issues are as follows respectively; we placed high priority during the design and currently in the manufacturing phase to double and triple check compliance with the SEM rules, we have generated a checklist in verifying the integrity of the fuel pressurization system before the race as well as a method for testing fatigue on the seals to maintain adequate pressurization, and finally we have re-designed the engine mounting structure so that the chain we are using has the precise amount of slack needed to maintain adequate tension to prevent disengagement. These are only a few solutions to the potential issues called out the FMECA table and a full list of solutions to all of the potential failures we have currently predicted are listed in Table Table 13. This Failure Modes Analysis table is more of a blend between the JSA and FMECA results in that it provides solutions to remedy the potential failures with high RPN's. Through the use of these two risk modeling tools, we were able to identify weak points in our design and make changes accordingly.

The team has also completed a fault tree analysis as a means to identify potential solutions to prevent potential system failures. This is similar to what Table Table 13 does except what the FMA table has solutions listed by a general approach to solving an issue. Using fault trees allows the team to fully break down each component in terms of its subcomponents to identify even further what the weak points are in systems used for our design. Our fault trees by subteam can be found in Appendix Appendix D.

Focuses were initially largely placed on meeting the SEM rule requirements for critical dimensions and sustainable loads, however, we were able to shift our attention to one step further and begin setting higher standards of safety for our vehicle that would satisfy real-world application hazards. This competition is after all supposed to represent a vehicle that can be driven in society. This was a great opportunity to extend our safety analysis to include impact and collision modeling for front, rear, and side as well as the design of crumple spaces to minimize the impulse felt by the driver. This was primarily done by accounting for more FEA for impacts on the vehicle from multiple angles of attack.

# 8 Project Management

## 8.1 Budgeting

Budgeting was a major concern for the team due to limited financing. Despite a donation of approximately $8,000 from Shell recruiting to support the team, the Mechanical Engineering Department took their standard 50% cut of senior design sponsor budgets for overhead. This is standard overhead and maintenance fee to help pay for the student worker in purchasing, the 3D printing lab, etc. It is important to note that this is typical for sponsored projects, as which this project was incorrectly listed. Therefore, in order to maximize possible funds for the team, it is important that all donations are sent to the department as donations to the team, rather than sponsorship for a senior design project. As a result of this frustrating confusion, the team was only given $4,000 to work with, an amount quoted as "being impossible to [build a competitive vehicle]." Being a new team concerned with getting on the track, it was vital that components were selected that would both be successful and cost-effective.

Major decisions had to be made with insecurity of the budget. This was because the budget was developing as the year progressed. As such, it was extremely important that up-to-date information was available to the whole team in order to better make financial decisions. Through the efforts of the team, the budget was eventually reigned in, and a summary of the final team budget can be seen in Table 7. A line-by-line breakdown of the current budget can be found in Table 14 of Appendix E.

Table 7: Budget Summary

| **Budget** | **Allocation** |
|---|---|
| Powertrain | $1,380.00 |
| Body | $1,614.47 |
| Frame | $534.62 |
| Steering | $751.44 |
| Electronics | $206.74 |
| Safety | $464.83 |
| Travel | $3,830.00 |
| **Subtotal** | **$8,782.10** |
| | |
| **Funding** | **Amount** |
| Shell Stipends | -$5,500.00 |
| Funds Raised | -$3,500.00 |
| **Subtotal** | **-$9,000.00** |
| | |
| **Total** | **-$217.90** |

## 8.2 Cost Tracking

In addition to updates of the budget, it was also important that the team maintain an accurate count of the funds currently available to the team. Due to financial limitations of the department, it is currently impossible for the team to verify account finances, further making this a vital need. As such, a balance sheet was kept in order to track the running balance. All purchases were updated as they were made. The final recorded balance of the account is $406.10.

## 8.3 Sponsorship

To supplant the funds allowed by the department, it was necessary for the team to seek out sponsorships for financial and material donations. A focus on aerospace companies was given in order to secure carbon fiber. Motorcycle, go kart, and mechanics were contacted for mechanical parts. Lastly, auto makers and general engineering companies were contacted for funding and services. As a result, the team was able to raise $3,500 in financial sponsorship and over $12,000 of material and service sponsorship.

### 8.4 Cost Model

In order to estimate the cost of manufacturing a single vehicle, the team considered the costs of all raw materials as well as manufacturing services such as welding and machining. Taking into account all the physical work done by the team, it would cost approximately $43,035 to professionally recreate the vehicle. sA line-by-line breakdown of each cost estimate is shown in Table 15 of Appendix E.

## 9 Competition

### 9.1 Travel

In order to actually get to Sonoma, a lot of planning had to be put forth. For starters, the team decided that they would be camping at the raceway as opposed to staying in a hotel or renting an Airbnb. This was because camping on the raceway was not only free, but allowed the team to be within a short walk of all of its gear, from personal gear such as new shirts to the actual car in the paddocks area. Once this had been decided, the team then moved forward and picked the dates of travel to and from the event. Because the event was from April 3rd to the 6th, the team decided to leave in the early morning of April 1st and take two days to drive to Sonoma with a pit stop in Flagstaff, AZ. This resulted in a 16 hour day to Flagstaff followed by a 14 hour drive to Sonoma. The team had to wake up early on the 2nd as well as they had to get to Sonoma before 7 PM in order to check into the campsite on time.

Following the competition and to return back to College Station, the team decided to leave Sonoma immediately following the awards ceremony on the 6th and drive back as far as possible before stopping at a hotel in Bakersfield. The team did this to ensure they got a good nights rest in a bed before the long journey back home. The next day, the team woke up early again and drove to Lubbock, TX where they had rented another Airbnb there for one last night before completing the journey home the next day.

To set up this journey, the team had to acquire two vehicles, a rented minivan via Enterprise and a Ford F250 acquired from College Station Ford. To get the van, a team member used his contact to get a cheaper deal on it. Then, he communicated with the MEEN department business office on the first floor of the MEOB to set up a travel account about a month or two before the competition. With this account, the van could then be rented under A&M's name, which was key. As a result of that, the van was covered under A&M's insurance and any TAMU student could drive the vehicle worry free. It also made the van cheaper by a significant margin. Once this van was acquired, the team then used a contact via UV (the FSAE advisor) at the local Ford dealership in an effort to rent a truck for a low cost. After meeting with Mike at College Station Ford in person, he agreed to give the team a 2019 F250 for free and has promised to give next year's team the same luxury if wanted. Just email Mike at College Station Ford explaining that the Shell Eco-marathon team is looking to get a truck for next year's competition. The only contingency is that the drivers of the truck have to put the truck on their own insurance if anything happens to it. To do this, since the truck is not being rented and simply loaned, the drivers will have to have a written consent from their insurance companies stating that if their driver damages the vehicle, they will pay for it. For more information regarding this, again, just contact Mike and he will give more details. On another note, it is important to state that both vehicles were acquired a couple of days before the team left so that they could pack everything up (the actual car, trailer, tools, etc) the day before, meet at a house in the early AM on the 1st and leave immediately.

With both vehicles planned out, the next thing up was paying for gas and lodging on the trip. For gas, the team used their travel account from the MEEN business office to acquire a travel card which would pull money directly from their account to pay for gas. The team only had one card, however, so the truck was given it. Consider getting two next year, one for each team. As for lodging, the team worked with the MEEN business office to pay for all of the hotels and houses and such. Next year's team can always cancel these arrangements and get refunded if their plans change as ours did. Just use the travel card if possible to pay for any hotels and such along the way.

To ensure safety, travelers should never push themselves during this type of journey since it is 60+ hours of driving, making it inherently dangerous. Drivers need plenty of sleep and frequent rotation, so passengers should take naps. It is also safer to stop and change plans if need be. It is not worth it to try and drive straight from one location to the next if a uncomfortable situation were to arise.

## 9.2 Inspection and Testing

The team was extremely busy modifying the car during the competition due to challenges passing the technical and safety inspection. This is by no means a small feat and required three days of working from 6 AM to 10:30 PM straight. This is due to the fact that there were a lot of issues that were found on our car that did not meet their rules and specifications. Some of them were listed in the rules explicitly such as the car's lack of a parking brake. However, a majority of the issues found were never listed anywhere in the rules and had to be dealt with on site. There was no way to prepare for this, it just had to get done there. Some of the big such issues were the huge changes in the telemetry system at the competition compared to what was given in the rules, light requirements, and many more. Below is a complete list of what was not in the rules that we had to correct or was misinterpreted by the team:

- Accessible from the outside: In the rules, there is mention of the engine being accessible from outside of the vehicle. During the team's discussion, it was decided that removing the top half of the body would be sufficient to satisfy these rules, in addition to the need to access the luggage. However, it was made clear that the luggage needs to be accessible without tools, and the engine should be very easily accessible immediately before getting on the track. This is because the fuel must be completely depressurized until moments before racing. As such, there is no time to take the top half of the body off before the start of the race. As such, the design should include hatches so that the screen of the joule meter is visible or accessible from outside the car, the engine pressurization is accessible, and the luggage is accessible.

- Safety Harness: The judges did not like the way our harness routed through the seat, despite it being very secure to the frame and compliant with the rules. As such, future seat designs should be shorter than the shoulders, or have sufficient gaps for the harness to clearly be attached to the frame.

- Ballast: The ballast must not only be securely fastened to the chassis of the car, but it also must have a red tag (provided by Shell) that must be broken to remove the ballast. As such, the weights used must be able to be securely fastened while also matching with holes in the frame so that a tie can be put through the ballast and the frame.

- Bulkhead: The bulkhead should be completely sealed. The initial removable body design was not well received by the judges. The top portion of the body ideally needed to be fixed to the bulkhead.

- Steering Precision: Because of wearing issues, the steering had become loose before inspection. The judge very much harped on us for having loose bolts and other connections that weren't road worthy. As such, it is important that the steering system has no slop in it and allows the driver to precisely steer.

- Chain Guard: The chain guard must encase the chain and be stiff enough to protect participants in the case of a chain failure. It must cover all sides but the bottom of the chain and must be rigid enough to deflect loose bits of metal.

## 9.3 Results

After working for three hard days in the paddocks, the team was able to successfully pass technical inspection. There were still issues that normally would have needed to be resolved, but the judges were able to let them slide. These were having two batteries in the car (we would have needed a 'black box' around the batteries to make it one) and the ballast weight tag was improperly secured (not looped through frame and weights). However, with limited time, we were able to get the car through to the track for the last time slot. We were checked in, given our fuel, and pressurized the system. We rolled the car up to the start line, successfully started, and were able to get the car rolling by having the driver rock back and forth and throttling the accelerator pedal. After the second lap, the car had a much harder time getting going again from the stopping zone. It is expected that sometime during that stop and starting again the axle was bent to its most extreme point. Sometime during the third lap, the keyway sheared on the axle, and the engine was no longer engaged with the axle. The car required towing to get off the track and we pushed it back to the paddocks.

Because of the custom manufactured nature of the rear axle, the team would have needed access to a lathe and a mill in order to fix the part. As such, it was unreasonable to think we would be able to get back on the track. Additionally, multiple judges and participants tried to convince us to try and fix the axle we had to make it work. However, the team understood that would likely cause further failure, and we knew we could not fix the axle in a way that we would be confident in the safety of our team. As such, we made the decision to be content with the amazing progress that we had made that year and to leave a foundation for the future Texas A&M teams.

It was because of this "courageous decision" in addition to our thorough safety analysis that we were awarded the Safety Off-Track Award. Our simulated loadings and factors of safety far exceed the requirements and expectations of the competition. We were confident our car would protect our driver even in the case of collisions or rollover. We focused on proper use of tools and PPE throughout the competition, and overall, this set us apart from other teams.

In all, the team is extremely pleased with the results of the work done this past year and it is hoped that future teams can take this and run.

# 10 Recommendations

## 10.1 Body

The most important recommendation is to create the body next time using vacuum bagging methods and going with an overall smaller design. Having to make two foam cut-outs while making the mold made body manufacturing much more logistically challenging. By creating a design that was within the dimensions of the CNC, the foam vehicle body could be cut into one part. A smaller body would be easier to move around and would require much less materials, in addition to being lighter. Vacuum bagging would also be a very good idea, as it would significantly reduce the overall weight of the body. It is expected that the body would have weighed 50 lbs, instead of 70 lbs, if it were vacuum bagged. Another important recommendation is to create a female mold for the carbon fiber layup of the body, not a male mold as the 2019 team had done. A female mold would require an additional step creating a fiberglass mold from the original foam mold. The benefit of creating the body from a female mold is a much smoother final surface, which also leads to a much better paint surface. Since foam reinforcement is necessary to provide rigidity, the bulge from the foam would not be visible from the outside (as it is in the 2019 vehicle). For the windows and windshield, it is recommended to use poly-carbonate instead of acrylic due to its ability to withstand much higher forces. The downside the poly-carbonate is that it is harder to thermo-form and is prone to severe bubbling while heating. From a project management perspective, it is highly recommended to start the body manufacturing process in early October at the latest. The 2019 team officially started the foam CNC process in late January, and this made completing all the other steps for body manufacturing very time sensitive. The main issue is that doing work on the body usually required at least 2-3 people at all times, as mobility (such as moving the body from one place to another in the FEDC) was very labor intensive.

From a design perspective, the most important recommendation is to analyze how the body will be manufactured before the design is finalized. Depending on the final design chosen, it may be very difficult to manufacture the body if this is not accounted for. For example, it is important to ensure there is no negative-draft when planning the layout of the mold, as it would make it very difficult to de-mold the carbon fiber part from the mold. When preparing to decide what foam to use, we recommend looking at other foam options, or even higher density EPS foam than the one used by the 2019 team. The foam used for the 2019 car was very porous, which made it difficult to make a smooth surface. Any small bumps on the layup-surface will clearly show in the final component.

For logistics, it would be very beneficial for a group member to have a truck or SUV with towing capabilities. Although this is not always in the group's control, not having a vehicle with towing capabilities would make it very difficult to transport body components from place to place, especially if the body is being worked on in a facility external to Texas A&M University. We also recommend trying to obtain a sponsorship from U-Haul due to the likely hood of how often they will be used. Although the 2019 was unsuccessful in doing so, next year's team may attempt to do so with motivation from the 2019 team's successes.

Lastly, the final recommendation is to heavily utilize available knowledge that could help in making the body easier. The body is a very time and money intensive part of the project that could fail because of a single mistake. Using what is recommended in this report, information from vendors (much of what the team has learned was from vendors of carbon fiber), and other professional contacts, such as George from Polycoat Systems.

## 10.2 Electronics

The largest recommendation in regards to the electronics is to not put it off due to the simplicity of the requirements. Because of the attitude of the sub team, it was not placed as a priority and therefore was put off until days before actually racing. This was also in part due to needing access to the body for long stretches of time. Irregardless, the electronics in the vehicle are likely going to have the best options moving forward to increase the competitive edge of A&M. There are many opportunities to automate the acceleration, start, and kill processes using an electronic gas pedal. Additionally, a properly working telemetry system will give extremely useful information for the team.

In regards to systems currently on the car, it is recommended that a significant amount of time is spent studying the wiring diagrams to fully understand the voltages and flows of energy within the system. This will help with intuition in regards to understanding and changing the wiring for the components.

Finally, it is recommended that stronger component connections are used, in particular for the plug and LED lights. Both had issues of poor vibration resistance and had to be fixed multiple times before competition.

## 10.3 Frame

With respect to the current frame, the main recommendations are aimed at solving the issues mentioned previously. The upper door arms could be improved through using a square/flat piece of aluminum and increased stiffness of the tabs, along with using bearings where the arm meets the tabs to allow it to be in flush contact on both sides while still being able to rotate. Alternative options include redesigning the doors to becoming gull wing style. Coordinating with the steering subteam, the steering column needs additional support at its forward end as well as an improved junction with the frame near the steering wheel. Also alongside the steering subteam, the interface between the steering knuckles and the frame must be redesigned for improved durability.

In regards to the design of a new frame at some point in the future, a steel frame would at least partially eliminate all of these mentioned issues of the current frame. It would also be much easier to weld. Smaller parts such as the plates and tabs used to mount the doors, rear axle and brakes, and steering column would be heavier as steel, but would gain exceptionally helpful stiffness and hardness. Since weight is the largest concern for reducing rolling resistance, the benefits of steel can be accomplished through reinforcement plates or surfaces on the aluminum. Changing the frame from aluminum to steel should be done without sacrificing the current target weight and without compromising driver safety standards set by this year's frame.

Throughout the manufacturing process, the frame team gained knowledge and experience through advice from others and on their own. When creating coping templates, a common mistake was neglecting the K-factor, which must be 1.0 for the method used on this year's car. This method involved cutting each tube longitudinally to allow it to be flattened as a sheet metal part. This flattening leaves a level edge at the longer length between the inside and outside surfaces. This provides a template that can be strictly followed before removing more material towards the interior. For thinner, steel tubes, the coping process may be faster in this step. There are slightly more intensive methods for creating coping templates, but these were avoided as they allow less room for error when coping as they provide a looser fit. For aluminum and possibly steel given necessary tool speed adjustment, the preferred method for coping the tubing required only the vertical band saw and angle grinder with appropriate attachment. With regards to welding, team members who plan on welding the frame are recommended to either have previous experience with the material used for the frame or begin practicing during the first semester. This years team had no previous experience and began welding at the beginning of the second semester. This lead to the frame being finished latter than expected and resulted in insufficient time for testing and validating. Additionally effort should be taken to work with the FEDC and ensure there are no impediments and being proactive about obtaining materials necessary for welding to limit delays.

## 10.4 Powertrain

The biggest recommendation for the future as it relates to powertrain would be to get an entire scooter instead of just buying the components. Purchasing components individually added up in cost relatively quickly and it was difficult to integrate everything. If an entire scooter is purchased, the engine can be tested right away and all the parts will already be available. The team can then spend more time trying to tune the engine. Additionally, it would be beneficial to find an air cooled engine opposed to a liquid cooled so that a radiator and coolant system are not necessary. This will likely also mean that the engine is not fuel injected but conversion kits are relatively cheap and easy to install. Finally, look into using a clutch system rather than a CVT. Have the ability to completely disengage the axle from the engine or transmission so that it can freely roll. This can be beneficial because it will allow coasting while driving on the track.

## 10.5 Steering

### 10.5.1 Wheelbase and Track Widths

With the current vehicle geometry, in order to meet the turning radius requirement, the inner wheel must turn $-12.51°$ and the outer wheel must turn $15.04°$. This created issues when steering at competition due to the larger angle and open-wheeled body. On the current design, the wheelbase can be effectively reduced to 1150 mm, which reduces the angles required to $11.05°$ for the inner wheel and $13.29°$ for the outer. This, in addition to smaller diameter wheels could allow the body to encapsulate both the front and rear wheels, making the vehicle even more aerodynamic. Additionally, mounting the front uprights closer to the center of the wheel would allow even tighter turning, which is preferred.

### 10.5.2 Spoke Wheels

An issue faced with the mounting and turning of the wheels was the cantilevered nature of the spindle. Because the motorcycle wheels are designed to be supported on both ends, the hub is rather deep. This caused a good deal of headache when designing the front knuckles. Additionally, the wheels are much heavier and have a higher moment of inertia than is necessary. In order to overcome these challenges, it is recommended that spoke wheels with custom hubs are designed. This would allow greater control over the turning mechanism for the wheel and smaller uprights. This would also aid in the design on a suspension geometry, if so desired.

### 10.5.3 Steering Column

As mentioned in Section 6.5.2 regarding ongoing issues, the steering column has increasing amounts of play in its rotation due to loss of material in the steering hangers. It is suggested that bearings are added to the steering column system in order to prevent this loss of material. Additionally, having support at the end of the steering column can help prevent such extreme motion in the future.

### 10.5.4 Steering Style

The current setup for the steering tie rods forces the drivers legs to go beneath the tie rods, reducing the leg space and maneuverability during egress. Additionally, the angled steering tab and tie rods makes the steering nonlinear and deviate from Ackerman. Lastly, the additional length from the tie rods and the knuckles adds weight to the car. Therefore, a suggested solution would be a steering column that extends to the floorboard and tie rods that actuate beneath the drivers legs. This would help stiffen the steering system, allow for rack and pinion steering if desired, and overall help linearize the steering system. This could also has the benefit of allowing greater precision in the steering mechanism.

### 10.5.5 Knuckle

Due to the knuckle mounting system, there is material loss on the frame where the bolts rub. It is recommended that to fix this issue, bearings are added to help prevent this metal to metal rubbing and chipping of the frame material.

As mentioned previously, the knuckle can also be designed to be much smaller and lower stress-bearing if it is placed closer to the center of rotation of the wheel. This would help reduce the moment on the spindle and reduce the risk of failure due to bumps at speed.

### 10.5.6 Brake Connections

During the brake bleeding process, the team experienced issues with the crush washers not sealing properly. Thankfully, there were multiple sets of rubber gasket washers that were used in their place, but there weren't enough for all the connections. The most prone to leaking were the double banjo bolts at the master cylinder. As such, it is recommended that all brake washers are replaced with rubber gasket washers to allow for easier sealing and multiple uses.

### 10.5.7 Brake Rotors

The brake rotors as installed on the vehicle are much stronger and heavier than is ideal for the competition. Because they were repurposed motorcycle rotors, they were much larger in diameter than the calipers typically accept. If possible, smaller rotors can be purchased and mounted to the rear axle, which would allow the calipers to be mounted to the frame, under the rotors, rather than horizontally to the uprights. Additionally, Smaller rotors would be able to fit inside the front wheel rim if a hub redesign is successful. This would help lighten the steering system while also allowing less relative motion between the rotors and the calipers, which would reduce rolling friction.

### 10.5.8 Rear Axle

When manufacturing the rear axle, if a similar design is used, it is recommended that a longer insert is used for the axle tips. A longer, tapered tip would help with centering and welding the end. Additionally, a thicker shaft will likely be required to withstand the torque from the engine. Higher performance bearings can also be found that would reduce rolling resistance. Lastly, the weld on the keyway should be much closer to the key itself to help prevent failure in tension rather than shear.

## 10.6 Sponsorship

Due to the limited funds for the team, it was extremely necessary to secure funding from outside resources. It is recommended to find either local companies, or former students when contacting companies for resources. Additionally, reach out to possible vendors about sponsoring fundamental components and materials. It was found that both having images of the car as well as a specific list of items was extremely useful in convincing companies to help. As soon as a plan of action is created and materials are known, begin contacting early, as companies have vastly different response times when it comes to supporting student teams.

## 10.7 Miscellaneous

As a side note, it may be possible to get a year long personal MatLab license by leveraging participation on the team.

# 11 Conclusions

Being a first-year team, there was very little expectation that we would be able to build a car that would pass technical inspection, let alone run on the track. Very early on, our expectations for ourselves were set on completing a run. As such, extensive thought and work was put in to the design and planning on this car. Multiple disciplines were considered in the design, and it proved vital to the final design. Countless hours were put in to the precise manufacturing of parts for the vehicle, and overall, the design was achieved.

The team was able to meet and overcome administrative challenges. There was little support from the department, because we had not proven ourselves yet. Because of this, the team had to be persistent in our efforts to secure a foothold for ourselves and ensure that the resources we needed to compete were made available to us.

The team managed to exceed expectations and take a functioning vehicle to competition, where most teams fail to pass technical inspection their first year. With a tremendous push, we were able to get our vehicle through technical inspection and running on the track. Despite all of the time spent on the car, we were also able to find time to put ourselves in the safety off-track award, which we were awarded.

Finally, the team is at the stage where we are preparing to hand off our knowledge to next year's team. Through this report and documentation, we hope that future teams are more prepared than we to face the challenges of competition and represent A&M on a national or even global scale.

In short, there were many challenges faced by this team as this project is not standard by any means. Our mentor Dr. Jacobs, put it very nicely early on by telling us, "[we] will likely work harder than any other senior design team...but [we] will learn more about engineering than anyone else." Having been through this experience, we would choose to do it again.

## 12 Acknowledgements

Dr. Jacobs - We have greatly appreciated all the time and direction you have given to the project. You gave excellent insight to the design of the vehicle and we appreciate your experience. Without your help, we likely never would have been able to navigate the administration.

Namita Anil Kumar - Thank you so much for being such a wonderful studio instructor and putting up with our project (and team) for an entire year.

And thank you to our sponsors:

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# A Bill of Materials

Table 8: Bill of Materials

| ITEM NO. | PART NO. | CONFIG. | QTY. | DRAWING NO. |
|---|---|---|---|---|
| 1 | DriverFloor | Default | 1 | 123 |
| 2 | Bulkhead | Default | 1 | 113 |
| 3 | Cockpit Panels | Default | 1 | 114 |
| 4 | WW_sides | Default | 1 | 189 |
| 5 | WW_front | Default | 1 | 188 |
| 6 | WW_top | Default | 1 | 190 |
| 7 | DriverFloor | Pedal | 1 | 123 |
| 8 | Steering Assem | Default | 1 | 24 |
| 8.1 | Wheel Assem | Rear | 1 | 29 |
| 8.1.1 | EX250Rim | Default | 1 | 127 |
| 8.1.2 | Tire | Default | 1 | 186 |
| 8.1.3 | BrakeRotor | Default | 1 | 112 |
| 8.1.4 | Bearing | Default | 1 | 101 |
| 8.1.5 | Keyway | Default | 1 | 142 |
| 8.1.6 | KeySpacer | Default | 1 | 141 |
| 8.2 | RearAxleBearing_assem | Default | 1 | 19 |
| 8.2.1 | RearBearing | Default | 1 | 166 |
| 8.2.2 | BearingFlange | Default | 1 | 102 |
| 8.2.3 | BearingFlange | Default | 1 | 102 |
| 8.3 | Steering Column_assem | Default | 1 | 23 |
| 8.3.1 | Steering Tab | Default | 1 | 179 |
| 8.3.2 | SteeringWheelBase | Default | 1 | 180 |
| 8.3.3 | SteeringWheelInsert | Default | 1 | 181 |
| 8.3.4 | SteeringWheelInsert | Front | 1 | 181 |
| 8.3.5 | Collar 1x1 | Default | 1 | 115 |
| 8.3.6 | Collar 1x2 | Default | 1 | 116 |
| 8.3.7 | column_assem | Default | 1 | 6 |
| 8.3.7.1 | Steering Column | Default | 1 | 175 |
| 8.3.7.2 | Steering Stopper | Default | 1 | 177 |
| 8.4 | FrontWheel_Left | Default | 1 | 11 |
| 8.5 | FrontWheel_Right | Default | 1 | 12 |

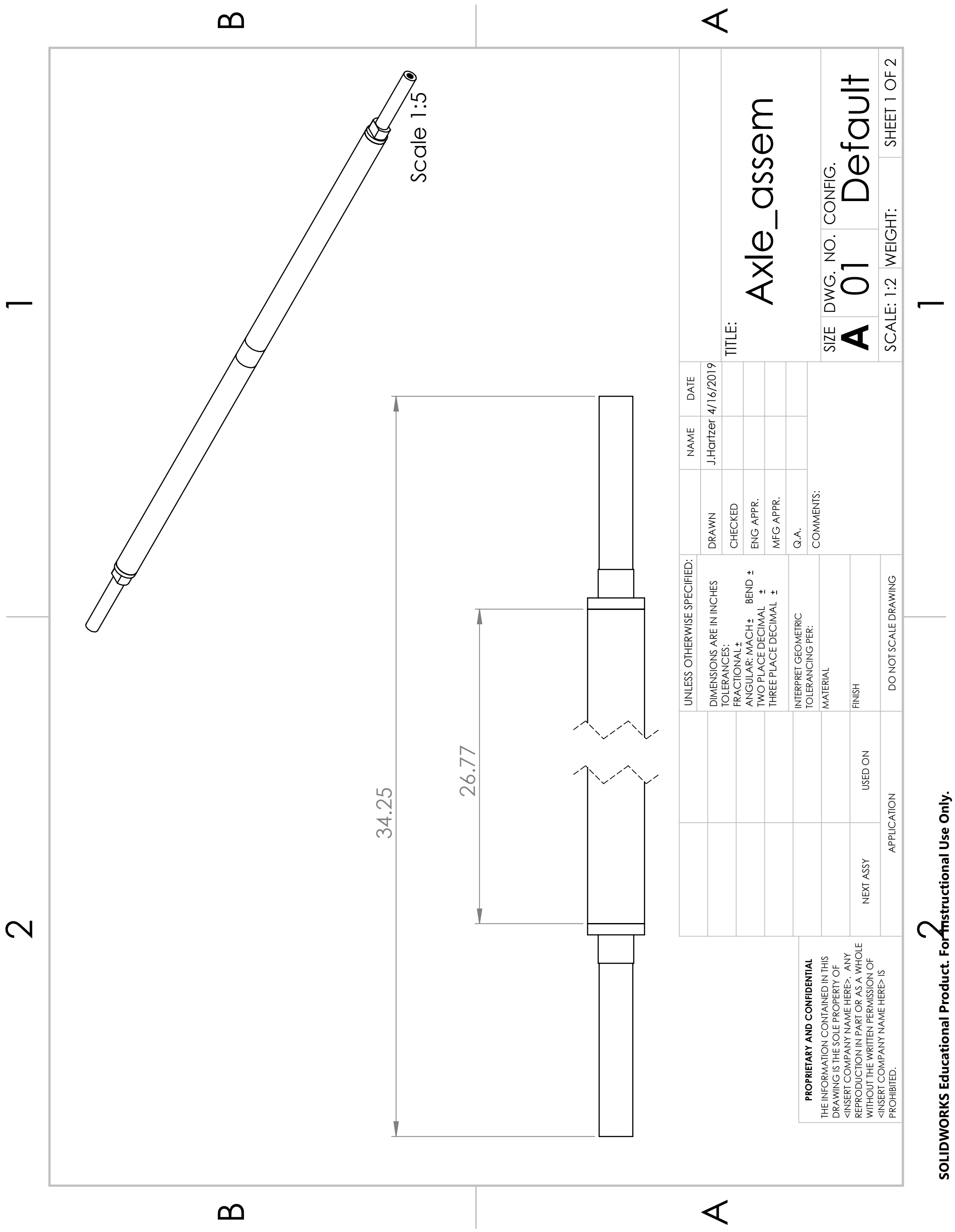
| | | | | |
|---|---|---|---|---|
| 8.5.1 | Wheel Assem | Front | 1 | 28 |
| 8.5.1.1 | EX250Rim | Default | 1 | 127 |
| 8.5.1.2 | Tire | Default | 1 | 186 |
| 8.5.1.3 | BrakeRotor | Default | 1 | 112 |
| 8.5.1.4 | Bearing | Default | 2 | 101 |
| 8.5.1.5 | DustSeal | Default | 1 | 124 |
| 8.5.2 | Knuckle_right | Default | 1 | 16 |
| 8.5.2.1 | Knucke_Axle | Default | 1 | 143 |
| 8.5.2.2 | Knucke_Joint | Default | 1 | 144 |
| 8.5.2.3 | Knuckle_Insert | Default | 1 | 147 |
| 8.5.2.4 | knucke_joint_right | Default | 1 | 146 |
| 8.5.2.5 | BrakeMountFront | Default | 1 | 107 |
| 8.5.2.6 | BrakeMountFront_gusse t | Default | 1 | 108 |
| 8.6 | Thrust Bearing | Default | 2 | 182 |
| 8.7 | Bolt 8x50 | Default | 4 | 105 |
| 8.8 | KnuckleBoltSleeve | Default | 2 | 148 |
| 8.9 | BrakeCaliper | Default | 4 | 106 |
| 8.1 | Retaining Washer | Default | 4 | 168 |
| 8.11 | Axle_assem | Default | 1 | 1 |
| 8.11.1 | Rear Axle | Default | 1 | 164 |
| 8.11.2 | RearAxleTip | Default | 2 | 165 |
| 8.11.3 | Axle_sprocket | Default | 1 | 100 |
| 8.12 | RearHangar | Right | 1 | 21 |
| 8.12.1 | BearingHanger | Default | 1 | 103 |
| 8.12.2 | BrakeMountRear_asse m | Right | 1 | 5 |
| 8.12.2.1 | BrakeMountRear | Default | 1 | 109 |
| 8.12.2.2 | BrakeMountRear_gusse t | Default | 1 | 110 |
| 8.12.2.3 | BrakeMountRear_riser | Default | 2 | 111 |
| 8.13 | RearHangar | Left | 1 | 20 |
| 8.13.1 | BearingHanger | Default | 1 | 103 |
| 8.13.2 | BrakeMountRear_asse m | Left | 1 | 4 |
| 8.13.2.1 | BrakeMountRear | Default | 1 | 109 |
| 8.13.2.2 | BrakeMountRear_gusse t | Default | 1 | 110 |
| 8.13.2.3 | BrakeMountRear_riser | Default | 2 | 111 |

| | | | | |
|---|---|---|---|---|
| 8.14 | Wheel Assem | Rear | 1 | 29 |
| 8.14.1 | EX250Rim | Default | 1 | 127 |
| 8.14.2 | Tire | Default | 1 | 186 |
| 8.14.3 | BrakeRotor | Default | 1 | 112 |
| 8.14.4 | Bearing | Default | 1 | 101 |
| 8.14.5 | Keyway | Default | 1 | 142 |
| 8.14.6 | KeySpacer | Default | 1 | 141 |
| 8.15 | RearAxleBearing_assem | Default | 1 | 19 |
| 8.15.1 | RearBearing | Default | 1 | 166 |
| 8.15.2 | BearingFlange | Default | 1 | 102 |
| 8.15.3 | BearingFlange | Default | 1 | 102 |
| 9 | Frame_assem | Default | 1 | 10 |
| 9.1 | RearGusset | Default | 2 | 167 |
| 9.2 | Frame it6.4 | Default | 1 | 128 |
| 9.3 | Steering Hanger | Default | 1 | 25 |
| 9.3.1 | Steering Hanger | Default | 2 | 176 |
| 9.3.2 | Steering Stopper_tab | Default | 2 | 178 |
| 9.3.3 | HangerSpacer | Default | 1 | 136 |
| 9.4 | DoorTabs | Default | 4 | 120 |
| 10 | Mirror_assem | Default | 2 | 18 |
| 10.1 | MirrorFrameMount | Default | 1 | 155 |
| 10.2 | MirrorMount | Default | 1 | 156 |
| 10.3 | Mirror | Default | 1 | 154 |
| 11 | Brake_assem | Default | 1 | 3 |
| 11.1 | master cylinder | Default | 1 | 151 |
| 11.2 | MC Mount | Default | 1 | 152 |
| 11.3 | Return Spring | Default | 1 | 169 |
| 11.4 | MC Mount Gusset | Default | 2 | 153 |
| 11.5 | Plunger | Default | 2 | 162 |
| 11.6 | PlungerMount | Default | 1 | 163 |
| 11.7 | PedalSleeve | Default | 1 | 160 |
| 11.8 | Pedal_Lever | Default | 2 | 158 |
| 11.9 | Pedal | Default | 1 | 157 |
| 11.1 | PedalPivot | Default | 2 | 159 |

| | | | | |
|---|---|---|---|---|
| 11.11 | SpringHolder | Default | 1 | 172 |
| 11.12 | Pencil Spring | Default | 2 | 161 |
| 11.13 | SpringCentering | Default | 1 | 171 |
| 12 | Engine_assem | Default | 1 | 9 |
| 12.1 | Engine_correct | Default | 1 | 126 |
| 12.2 | Intake Manifold | Default | 1 | 139 |
| 12.3 | Intake Throttle Body | Default | 1 | 140 |
| 12.4 | starter motor | Default | 1 | 174 |
| 13 | Gas_assem | Default | 1 | 13 |
| 13.1 | GP Mount | Default | 1 | 131 |
| 13.2 | GP Return Spring | Default | 1 | 134 |
| 13.3 | GP PedalSleeve | Default | 1 | 133 |
| 13.4 | Gas Pedal_Lever | Default | 2 | 129 |
| 13.5 | GP Pedal | Default | 1 | 132 |
| 13.6 | GP throttle_mount2 | Default | 1 | 135 |
| 13.7 | GP Mount Gusset2 | Default | 2 | 130 |
| 14 | Wiper | Default | 1 | 187 |
| 15 | HornInsulator | Default | 1 | 14 |
| 15.1 | Horn | Default | 1 | 137 |
| 15.2 | HornBox | Default | 1 | 138 |
| 16 | Engine Rear Tab | Default | 4 | 125 |
| 17 | Body_assem | Default | 1 | 2 |
| 17.1 | DR3model_rev1 | Body_base | 1 | 121 |
| 17.2 | DR3model_rev1 | Body_top | 1 | 121 |
| 17.3 | DR3model_rev1 | Windshield | 1 | 121 |
| 18 | Luggage_assem | Default | 1 | 17 |
| 18.1 | LuggageCorner | Default | 8 | 149 |
| 18.2 | LuggageSides | 19.18 | 4 | 150 |
| 18.3 | LuggageSides | 15.24 | 4 | 150 |
| 18.4 | LuggageSides | 7.37 | 4 | 150 |
| 19 | Seat_assem | Default | 1 | 22 |
| 19.1 | Seat | Default | 1 | 170 |
| 19.2 | Bend Supports | 20 | 4 | 104 |
| 19.3 | Bend Supports | 25 | 3 | 104 |

| | | | | |
|---|---|---|---|---|
| 19.4 | Bend Supports | 45 | 19 | 104 |
| 19.5 | Bend Supports | Default | 4 | 104 |
| 20 | Door_assem | Left | 1 | 7 |
| 20.1 | DR3model_rev1 | Door_left | 1 | 121 |
| 20.2 | DR3model_rev1 | Window_left | 1 | 121 |
| 20.3 | Door_LowerArm | Default | 1 | 119 |
| 20.4 | Door_arm | Default | 1 | 117 |
| 20.5 | DoorTabs | Default | 3 | 120 |
| 20.6 | Door_flange | Default | 2 | 118 |
| 21 | Door_assem | Right | 1 | 8 |
| 21.1 | DR3model_rev1 | Door_right | 1 | 121 |
| 21.2 | DR3model_rev1 | Window_right | 1 | 121 |
| 21.3 | Door_LowerArm | Default | 1 | 119 |
| 21.4 | Door_arm | Default | 1 | 117 |
| 21.5 | DoorTabs | Default | 3 | 120 |
| 21.6 | Door_flange | Default | 2 | 118 |
| 22 | WW_sides | Default | 1 | 189 |
| 23 | Cockpit Panels | Default | 1 | 114 |
| 24 | WW_top | Default | 1 | 190 |

# B Drawings


Scale 1:5
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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
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DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Axle_assem
SIZE
A
DWG. NO.
01
CONFIG.
Default
SCALE: 1:2
WEIGHT:
SHEET 1 OF 2
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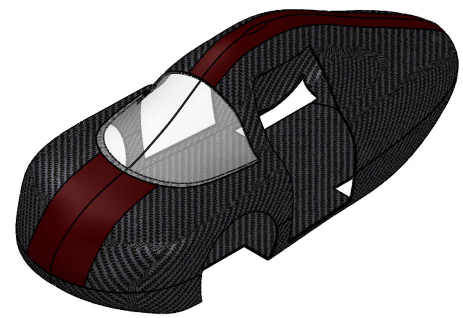
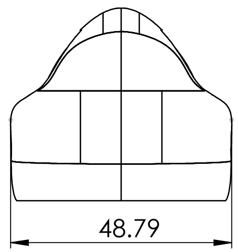
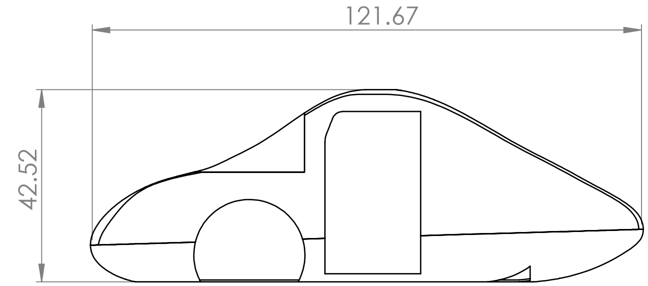
B B



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| | | INTERPRET GEOMETRIC<br>TOLERANCING PER: | COMMENTS: | | |
| | | MATERIAL | | | |
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| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:
Body_assem

| SIZE | DWG. NO. | CONFIG. |
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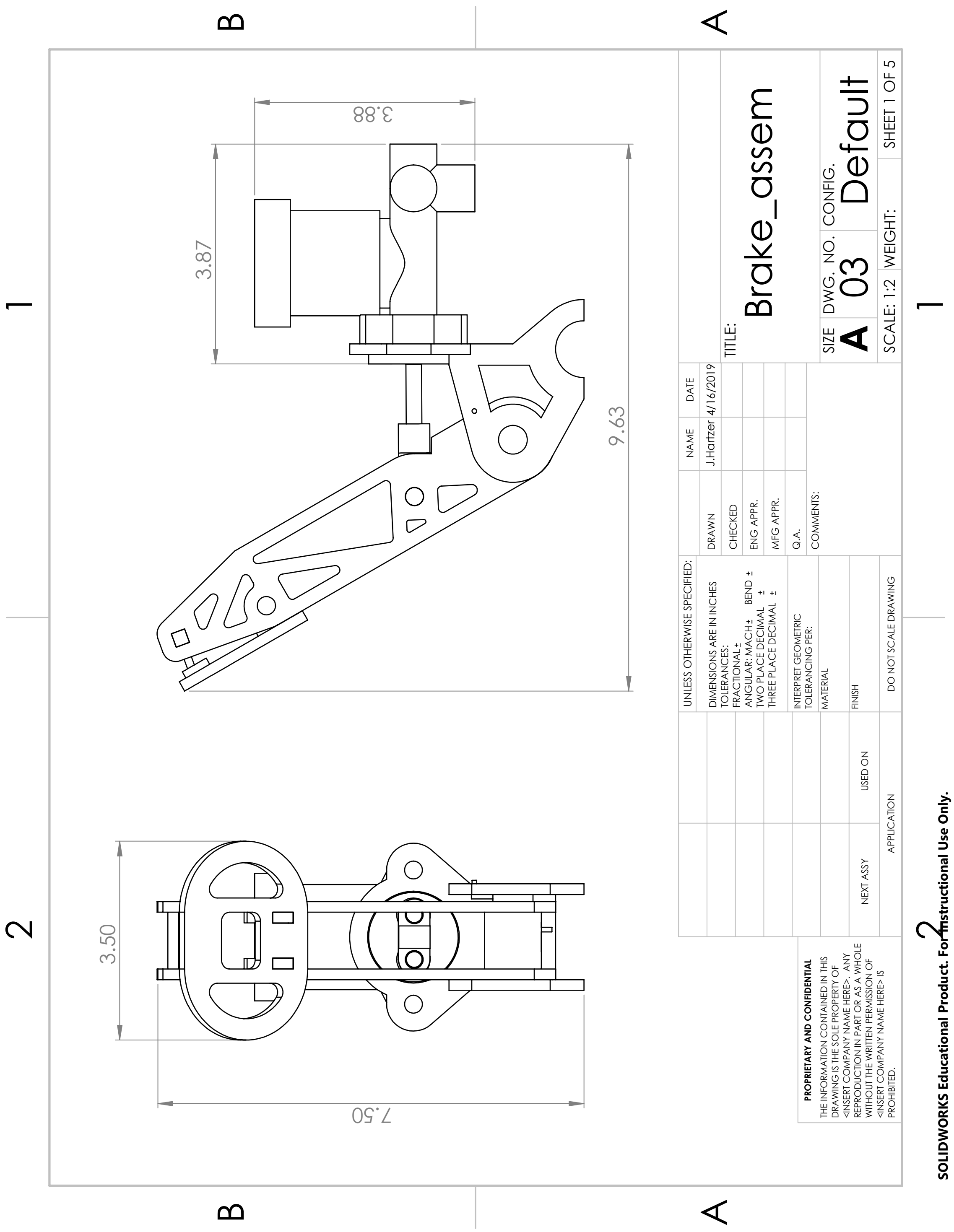
| A | 02 | Default |

SCALE: 1:30 WEIGHT: SHEET 1 OF 2



2 1


Brake_assem
3.88
3.87
9.63
3.50
7.50
NAME DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
TITLE:
SIZE A
DWG. NO. 03
CONFIG. Default
SCALE: 1:2
WEIGHT:
SHEET 1 OF 5
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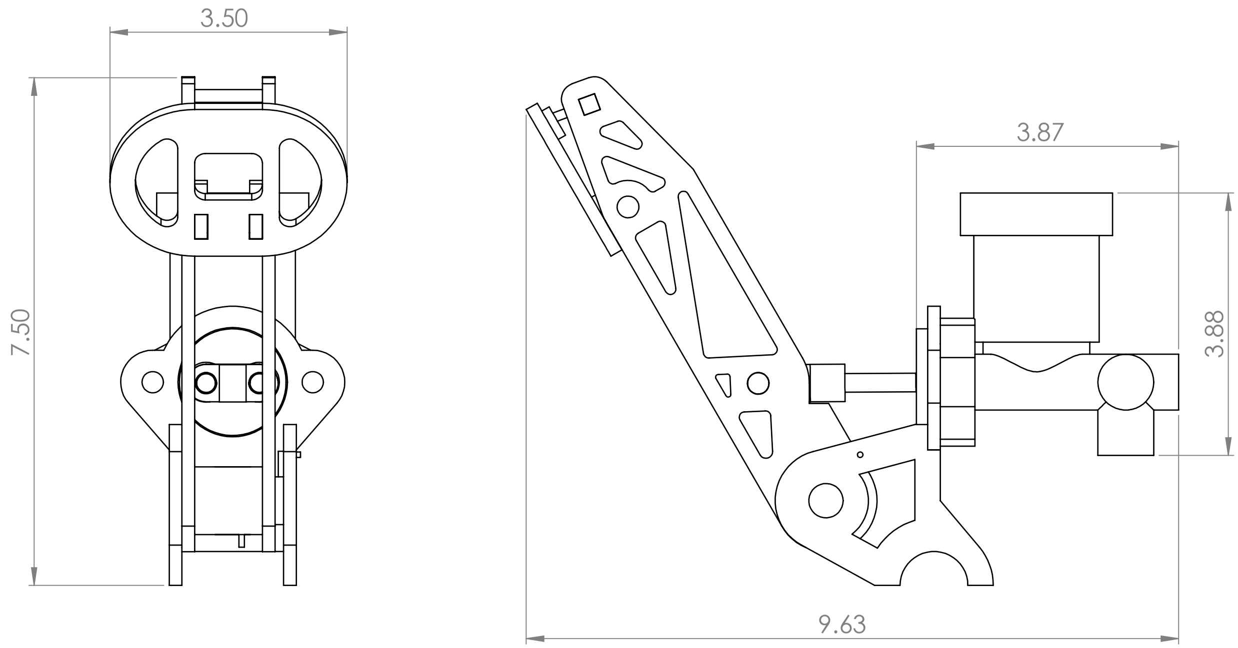


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| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Brake_assem

| SIZE | DWG. NO. | CONFIG. |
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| **A** | 03 | Default |
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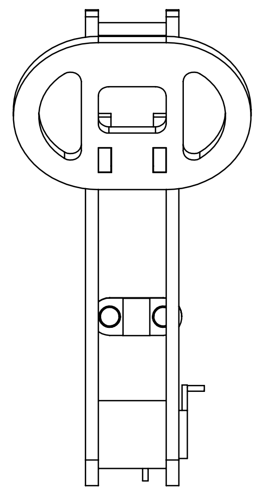

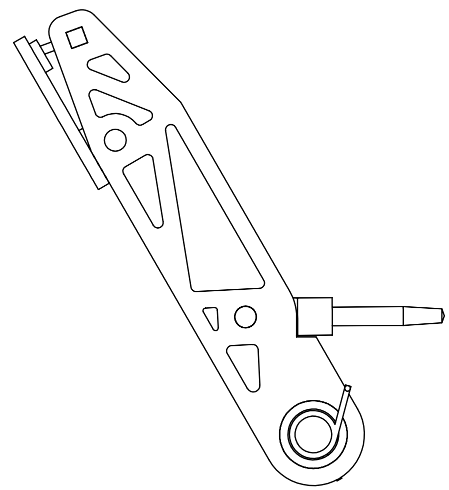

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| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
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TITLE:
Brake_assem

| SIZE | DWG. NO. | CONFIG. |
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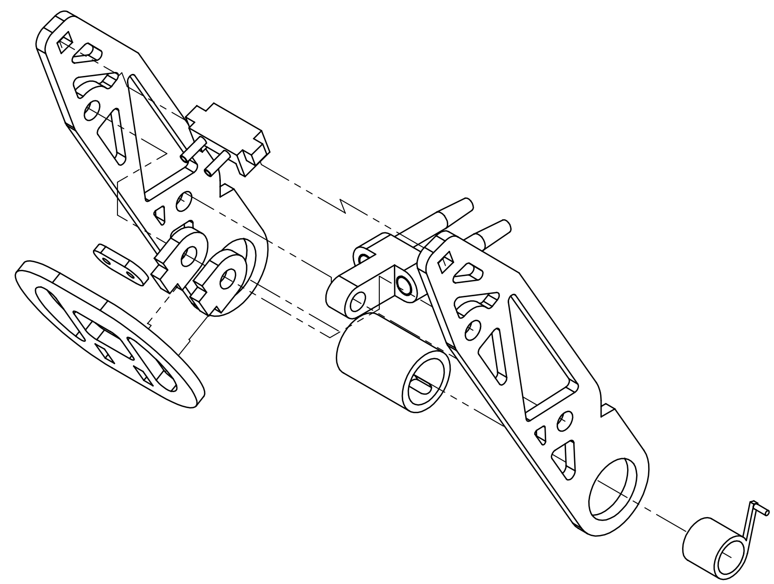
| **A** | 03 | Pedal |
| SCALE: 1:2 | WEIGHT: | SHEET 2 OF 5 |



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TITLE: Brake_assem

| SIZE | DWG. NO. | CONFIG. |
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| A | 03 | Pedal |
| SCALE: 1:2 | WEIGHT: | SHEET 3 OF 5 |

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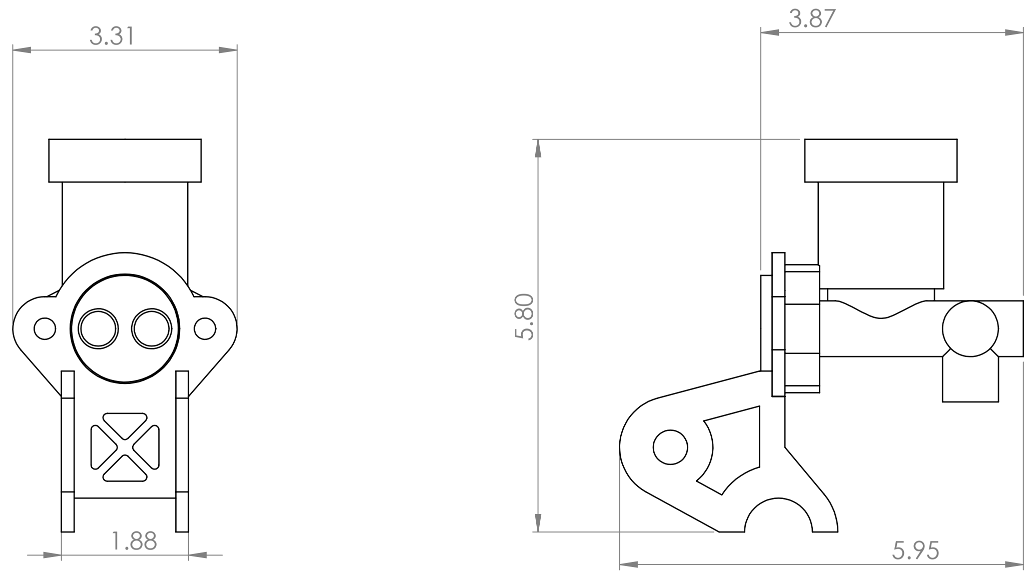


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ANGULAR: MACH ± BEND ±
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INTERPRET GEOMETRIC TOLERANCING PER:
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COMMENTS:

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TITLE:
# Brake_assem

SIZE **A** | DWG. NO. 03 | CONFIG. MC
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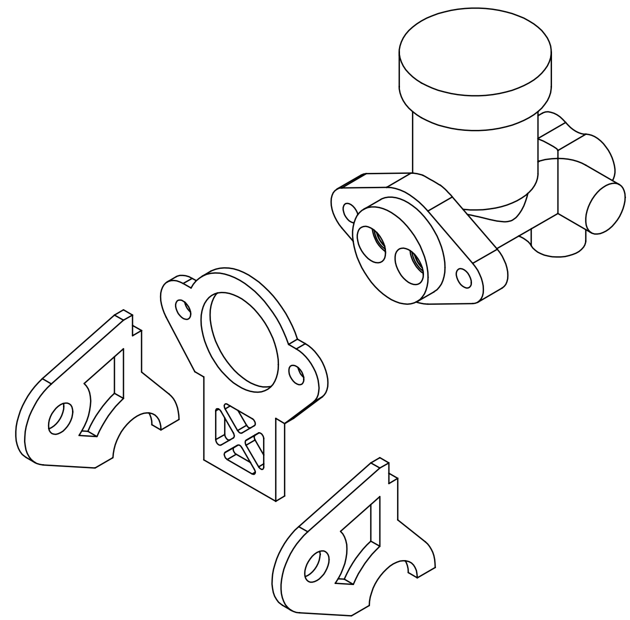

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TITLE:

# Brake_assem

| SIZE | DWG. NO. | CONFIG. |
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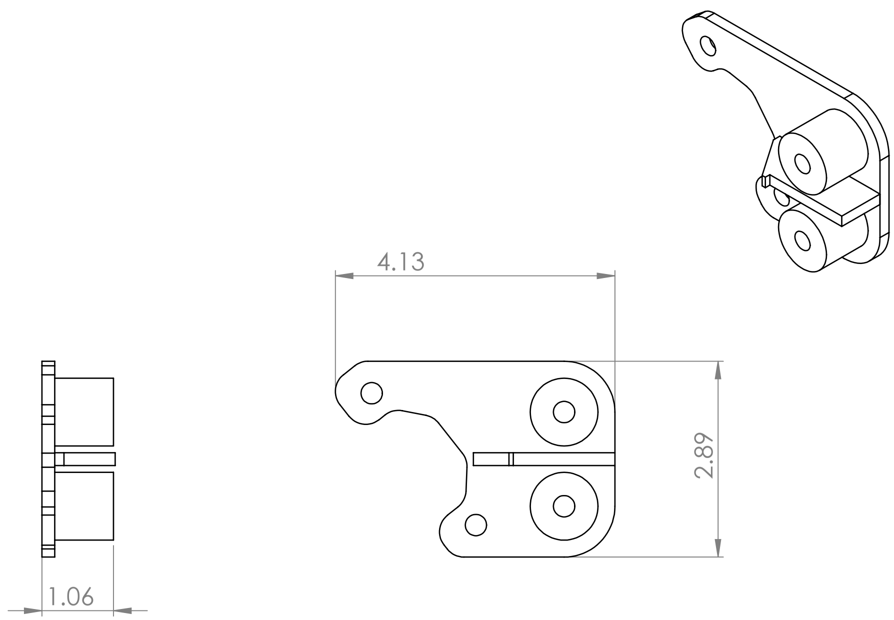
| SCALE: 1:2 | WEIGHT: | SHEET 5 OF 5 |

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TITLE:

BrakeMountRear_assem

| SIZE | DWG. NO. | CONFIG. |
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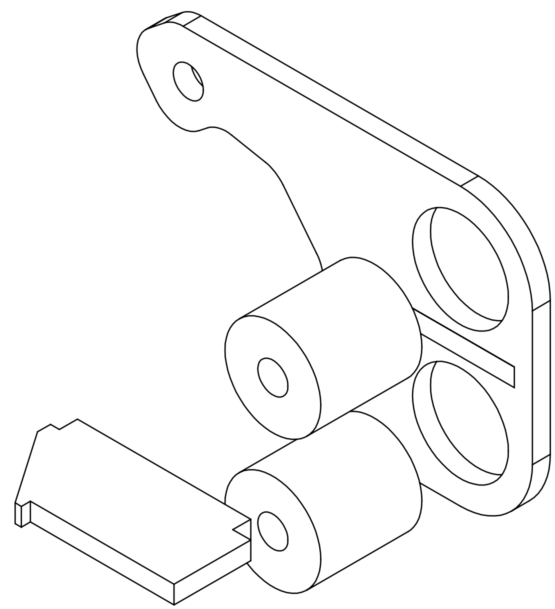

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TITLE:
BrakeMountRear
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| SIZE | DWG. NO. | CONFIG. |
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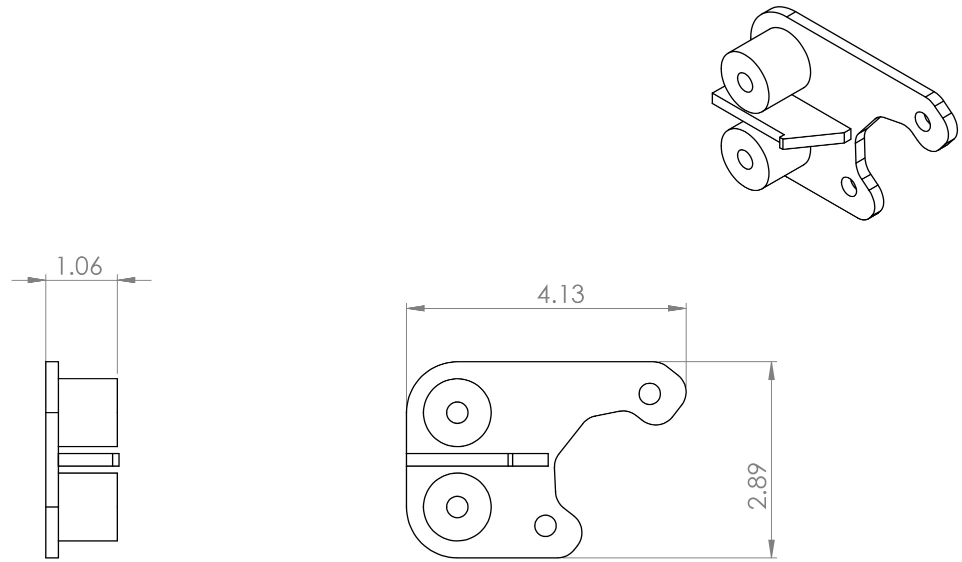


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UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
FRACTIONAL ±
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INTERPRET GEOMETRIC TOLERANCING PER:
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| DRAWN | J.Hartzer | 4/16/2019 |
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COMMENTS:

TITLE: BrakeMountRear_assem

| SIZE | DWG. NO. | CONFIG. |
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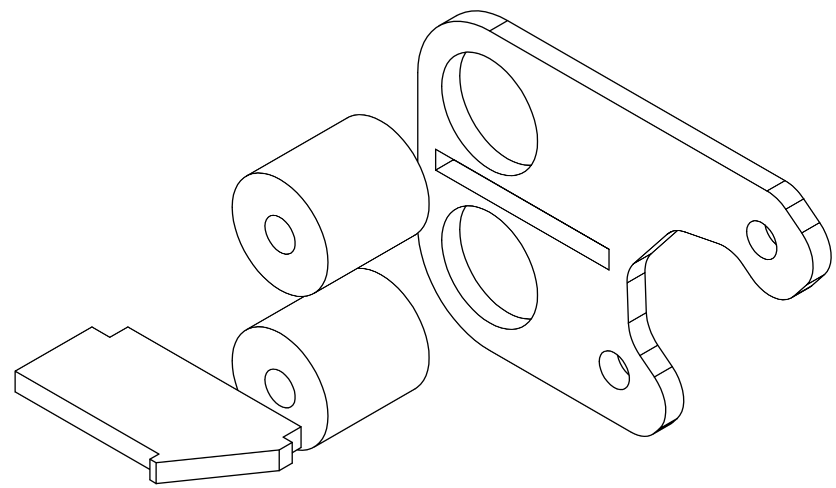
SCALE: 1:2 WEIGHT: SHEET 3 OF 4



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BrakeMountRear
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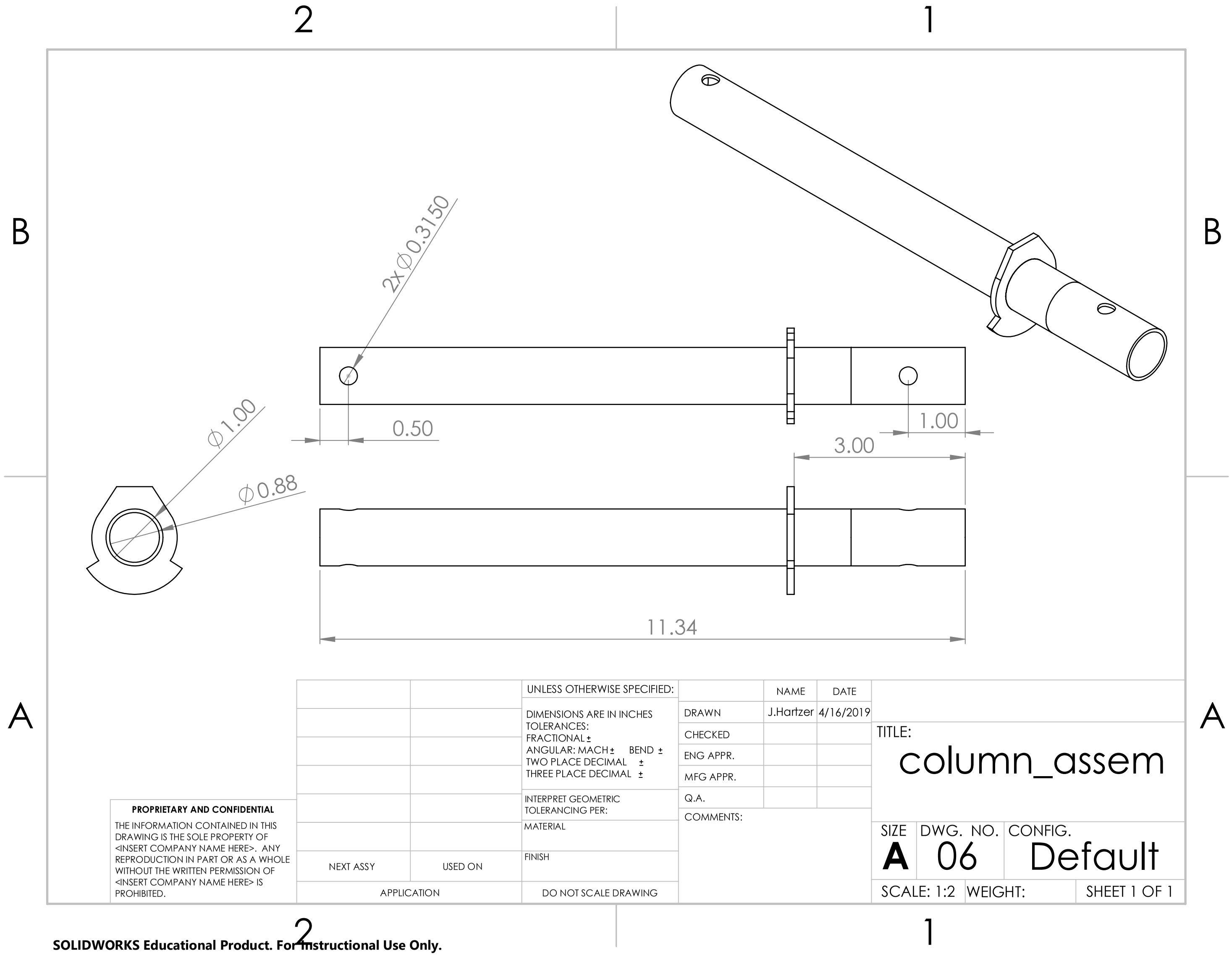
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ANGULAR: MACH ± BEND ±
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J.Hartzer
4/16/2019
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COMMENTS:
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CONFIG.
Default
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
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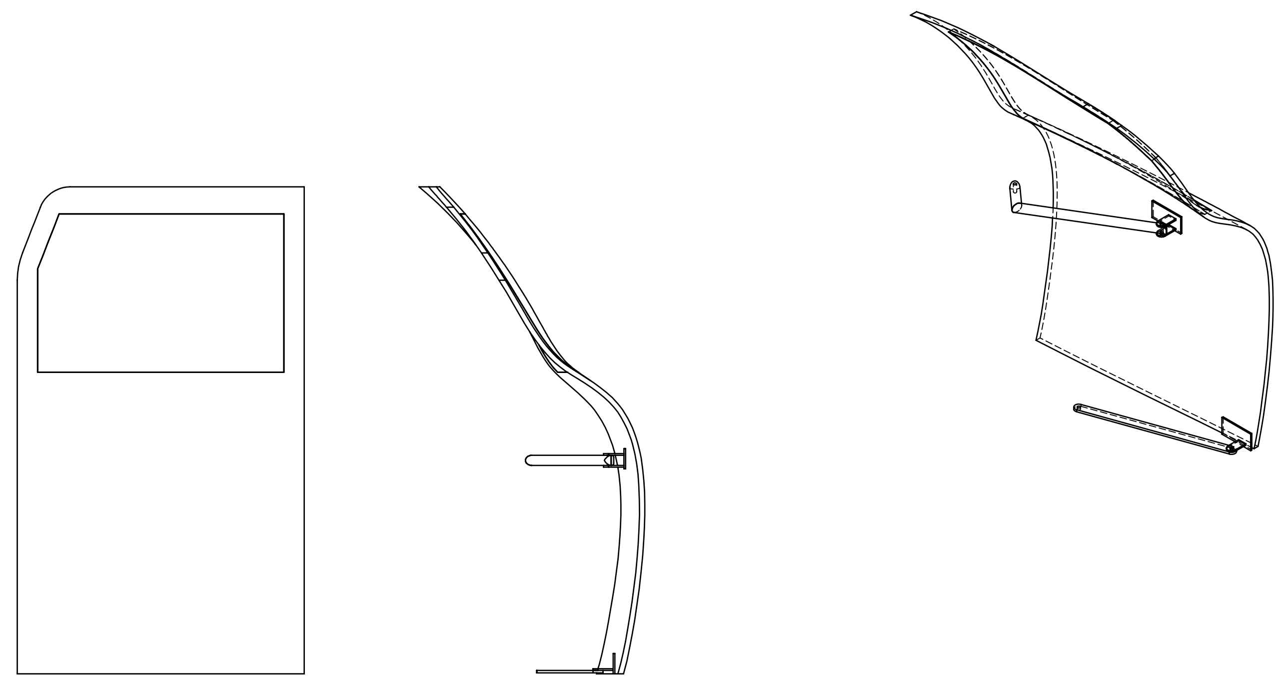

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TITLE: Door_assem

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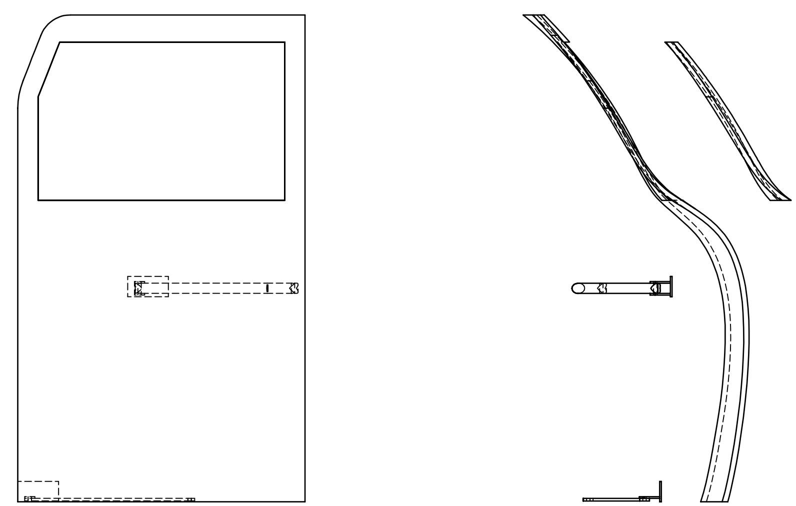

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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

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FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
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| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
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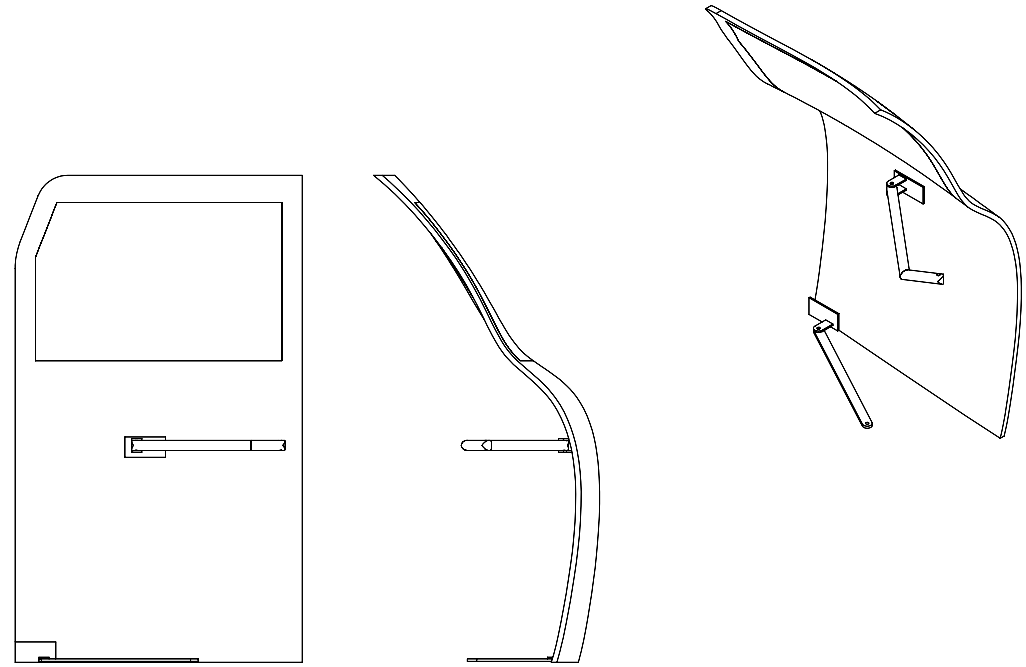
COMMENTS:

TITLE: Door_assem

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 07 | Left |

SCALE: 1:10 WEIGHT: SHEET 2 OF 4



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DO NOT SCALE DRAWING

| | NAME | DATE |
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| DRAWN | J.Hartzer | 4/16/2019 |
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COMMENTS:

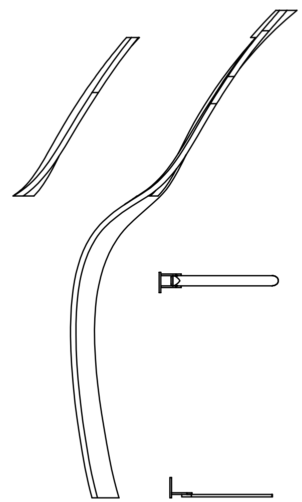
TITLE:

Door_assem

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 08 | Right |
| SCALE: 1:10 | WEIGHT: | SHEET 3 OF 4 |

2 1

B B



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| | | | ENG APPR. | | |
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| | | INTERPRET GEOMETRIC<br>TOLERANCING PER: | Q.A. | | |
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| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Door_assem

| SIZE | DWG. NO. | CONFIG. |
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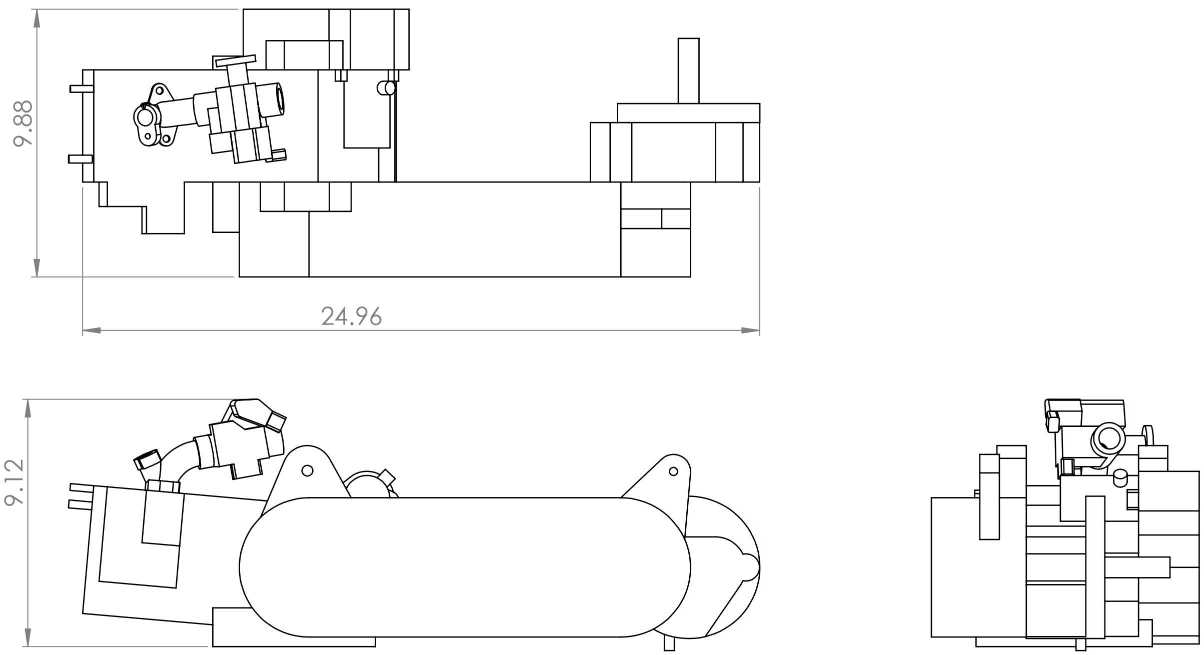
| A | 08 | Right |

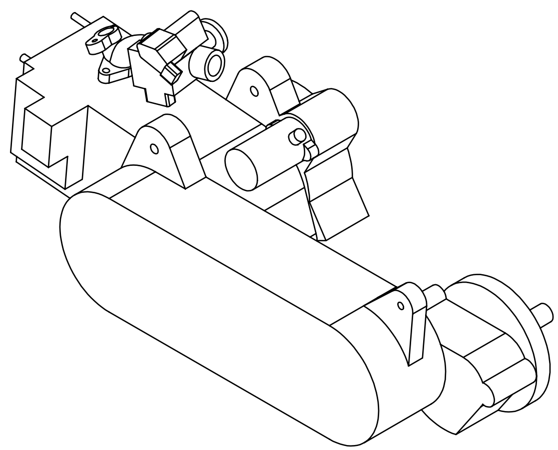
SCALE: 1:10 WEIGHT: SHEET 4 OF 4



2 1




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE:<br>Engine_assem |
| | | | CHECKED | | | |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC<br>TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A DWG. NO. 09 CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:5 WEIGHT: SHEET 1 OF 2 |



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Engine_assem

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
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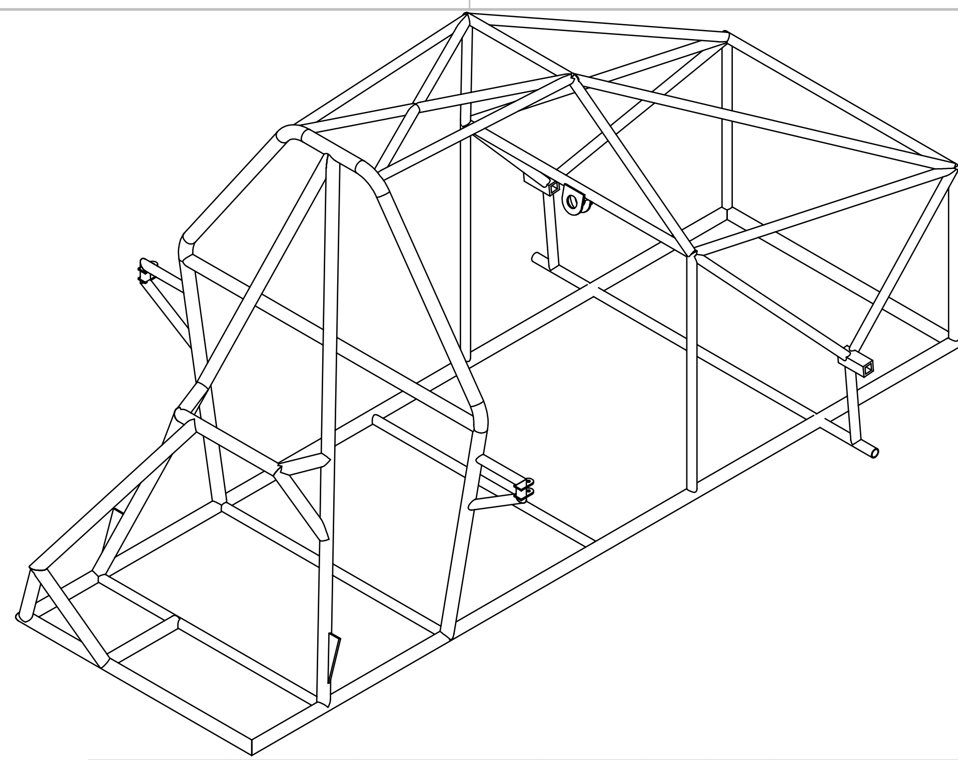
| SCALE: 1:5 | WEIGHT: | SHEET 2 OF 2 |



2 1

B B

A A

2 1

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| | |
|---|---|
| NEXT ASSY | USED ON |
| APPLICATION | |

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE:

# Frame_assem

| SIZE | DWG. NO. | CONFIG. |
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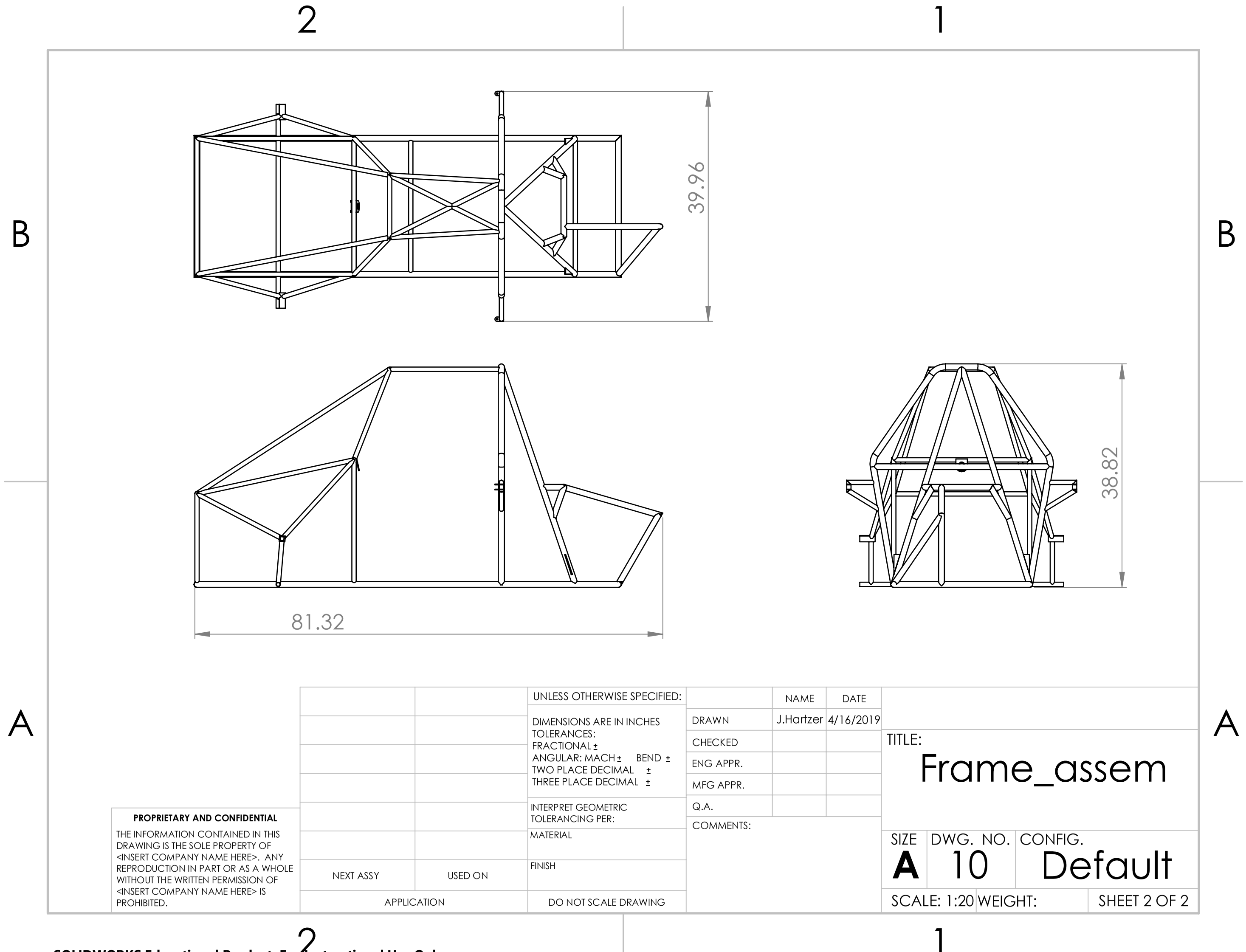
SCALE: 1:10 WEIGHT: SHEET 1 OF 2



2
1
B
A
39.96
81.32
38.82
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Frame_assem
SIZE
A
DWG. NO.
10
CONFIG.
Default
SCALE: 1:20
WEIGHT:
SHEET 2 OF 2
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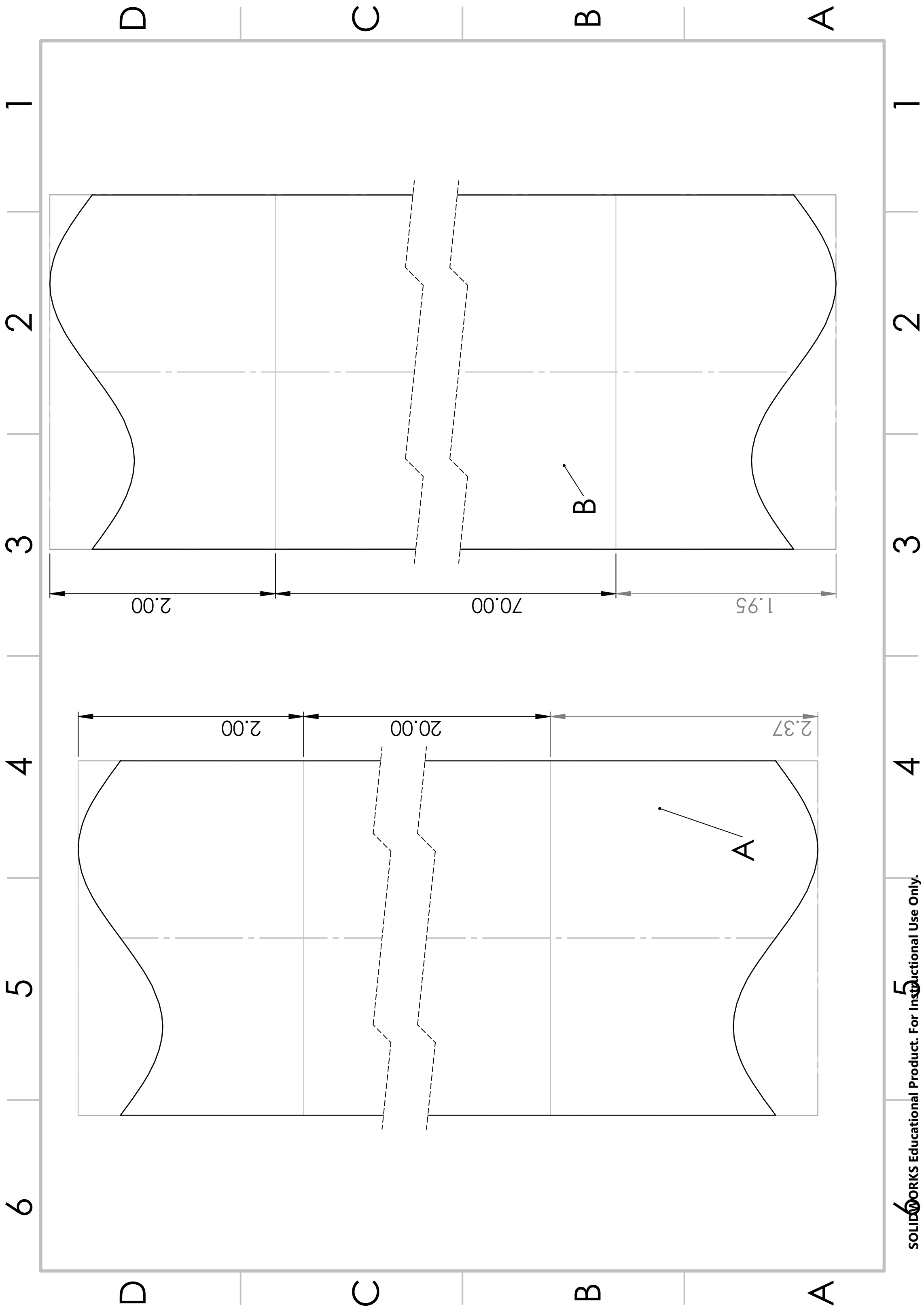
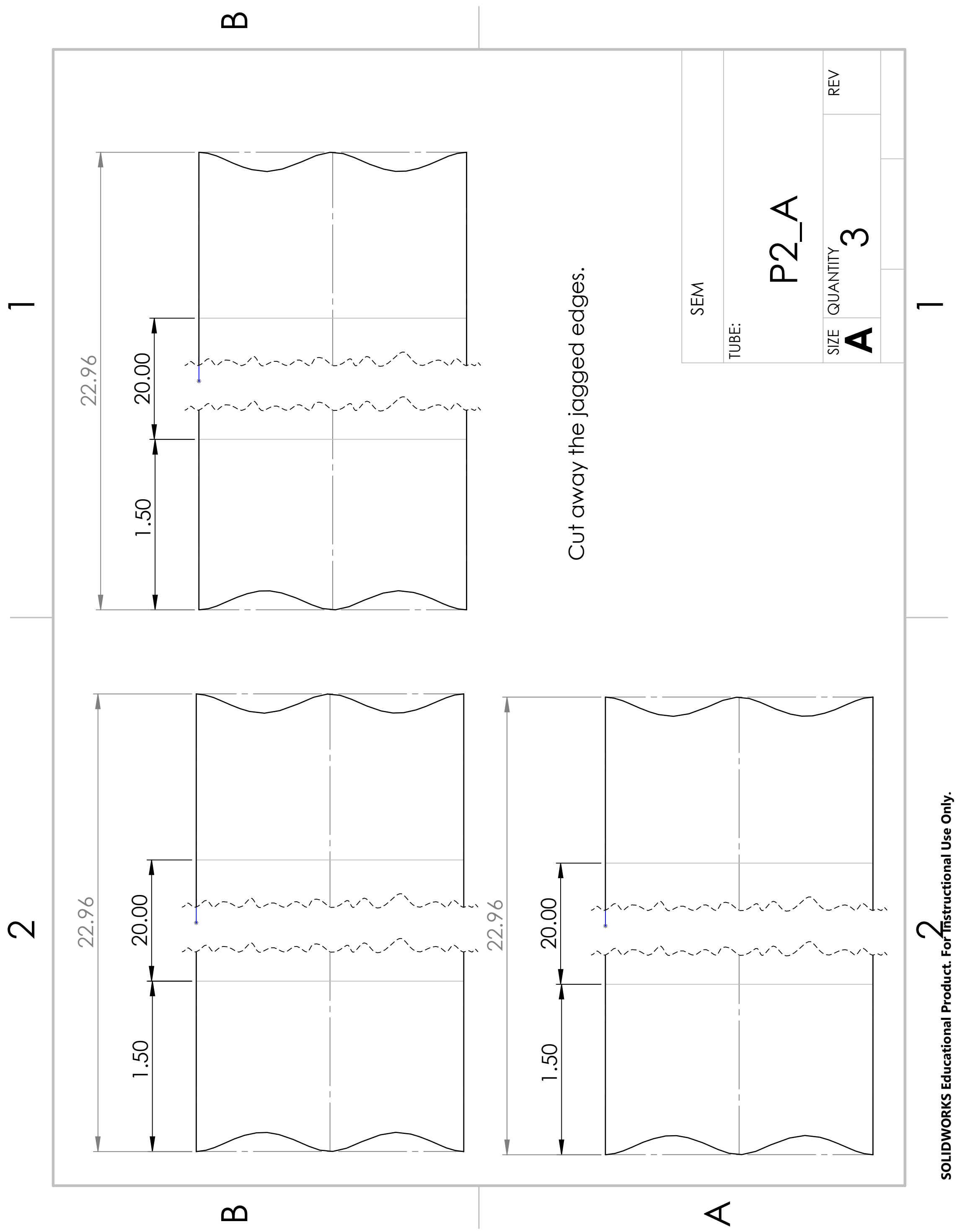
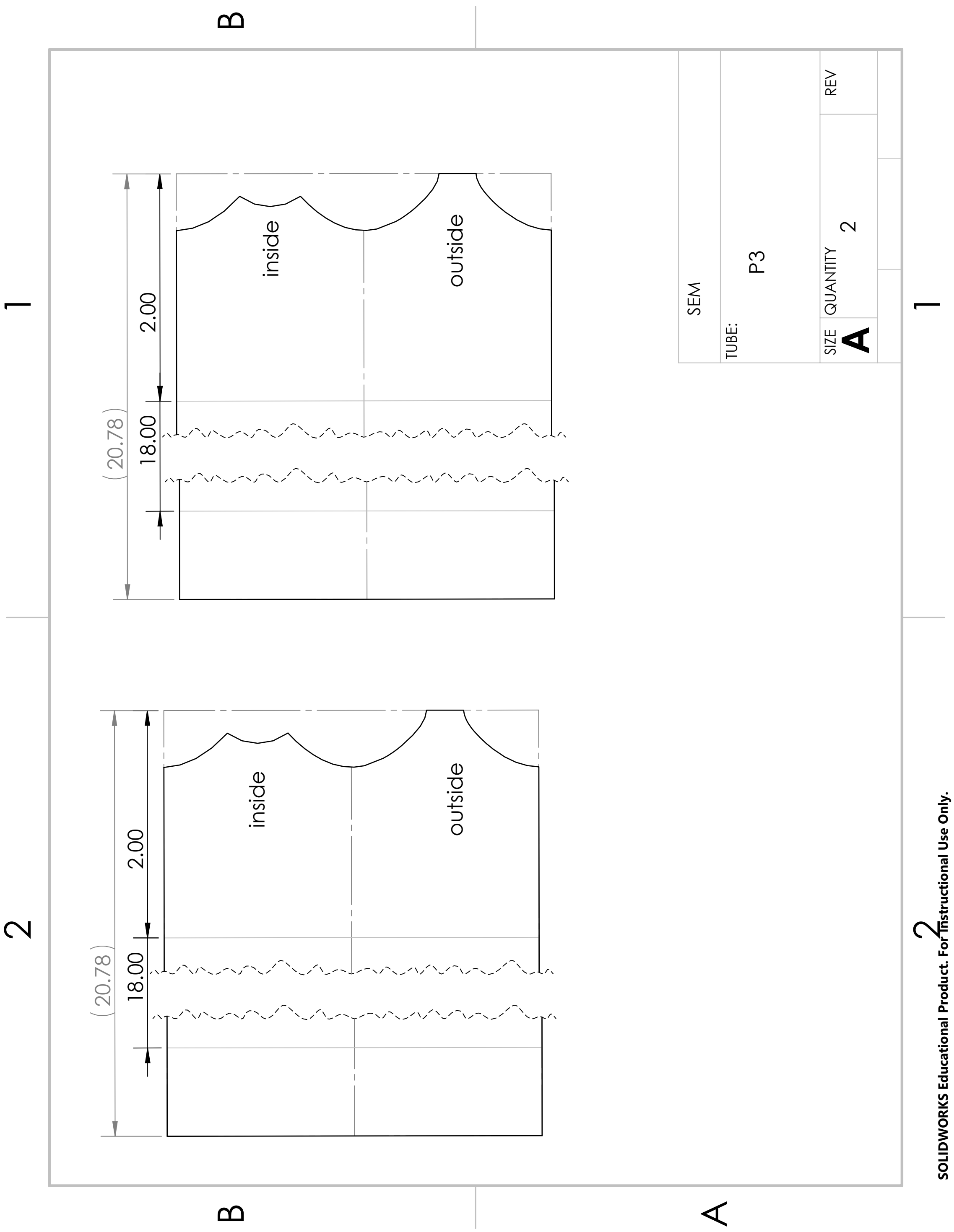
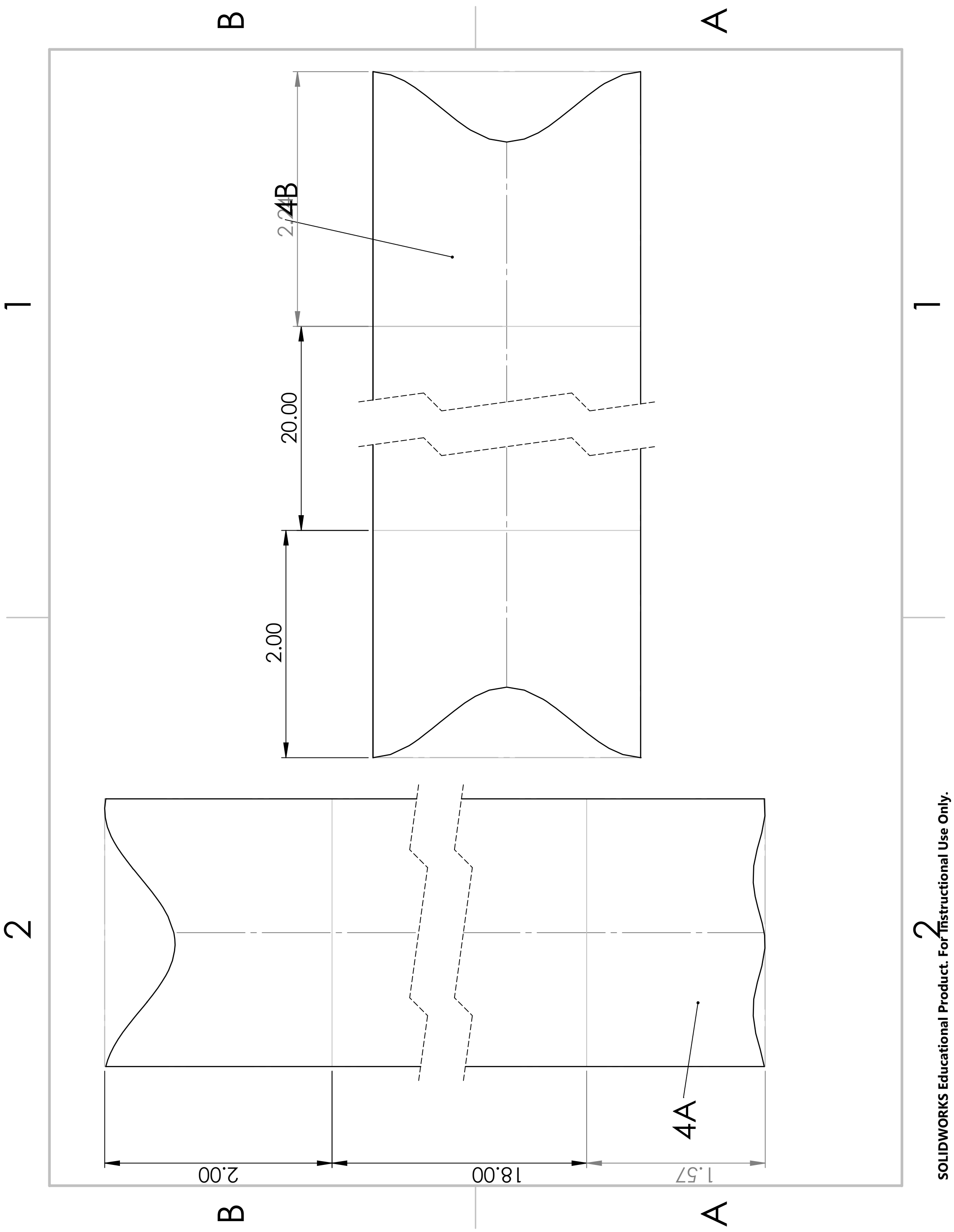
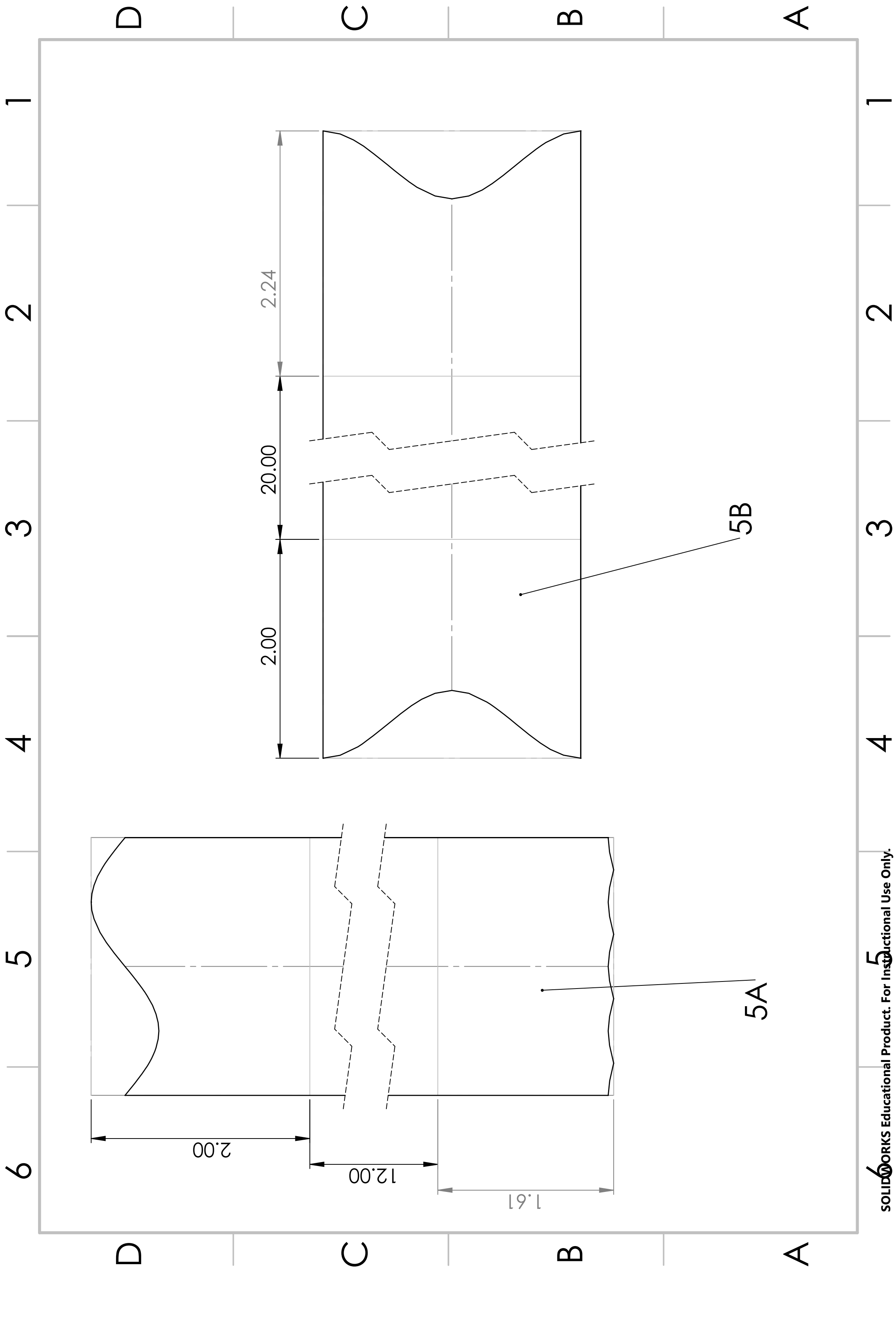

2.00
70.00
1.95
20.00
2.37
A
B
SOLIDWORKS Educational Product. For Instructional Use Only.

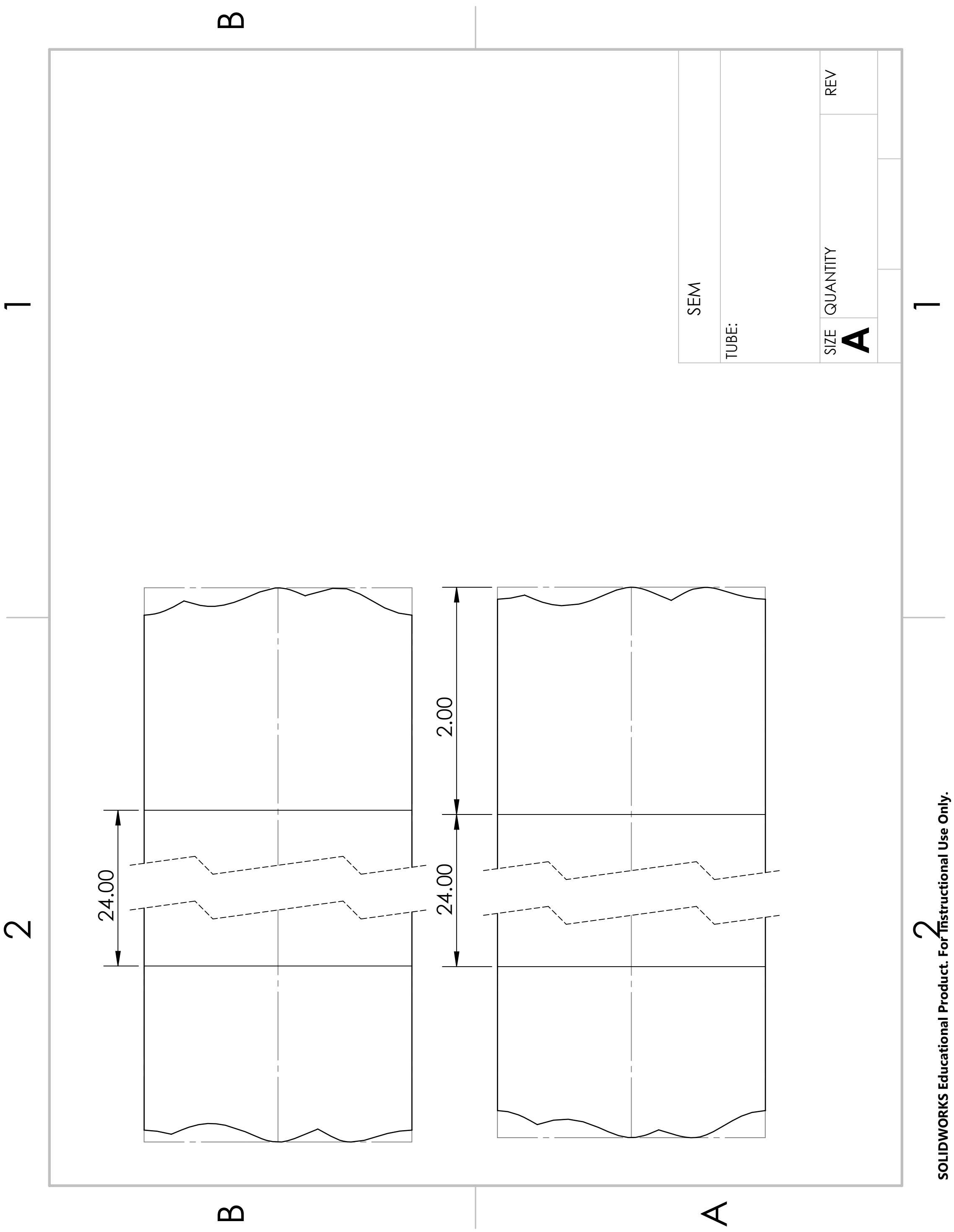

Cut away the jagged edges.
22.96
20.00
1.50
SEM
TUBE:
P2_A
SIZE
A
QUANTITY
3
REV
SOLIDWORKS Educational Product. For Instructional Use Only.


inside
outside
2.00
18.00
(20.78)
SEM
TUBE:
P3
SIZE
A
QUANTITY
2
REV
SOLIDWORKS Educational Product. For Instructional Use Only.

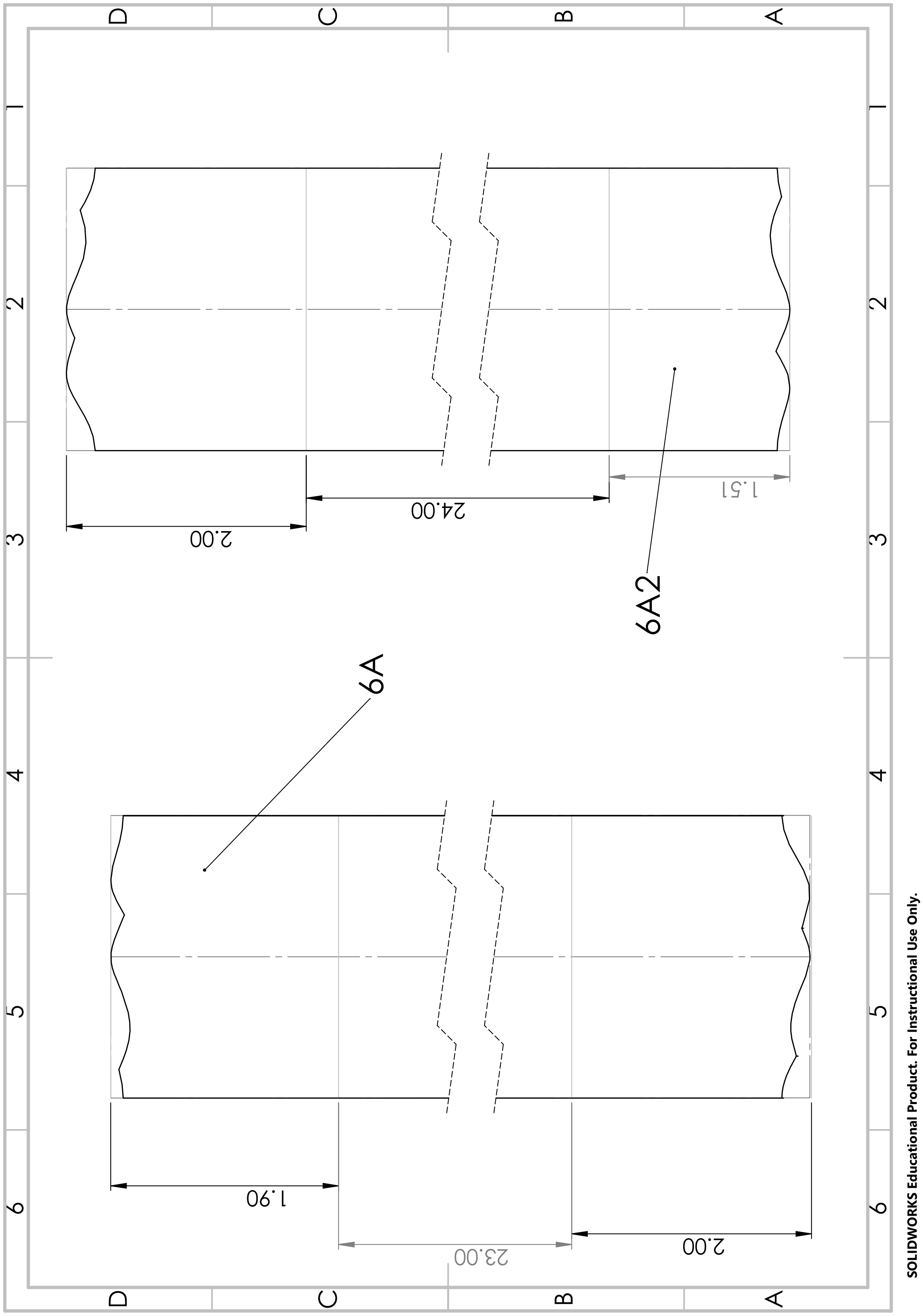


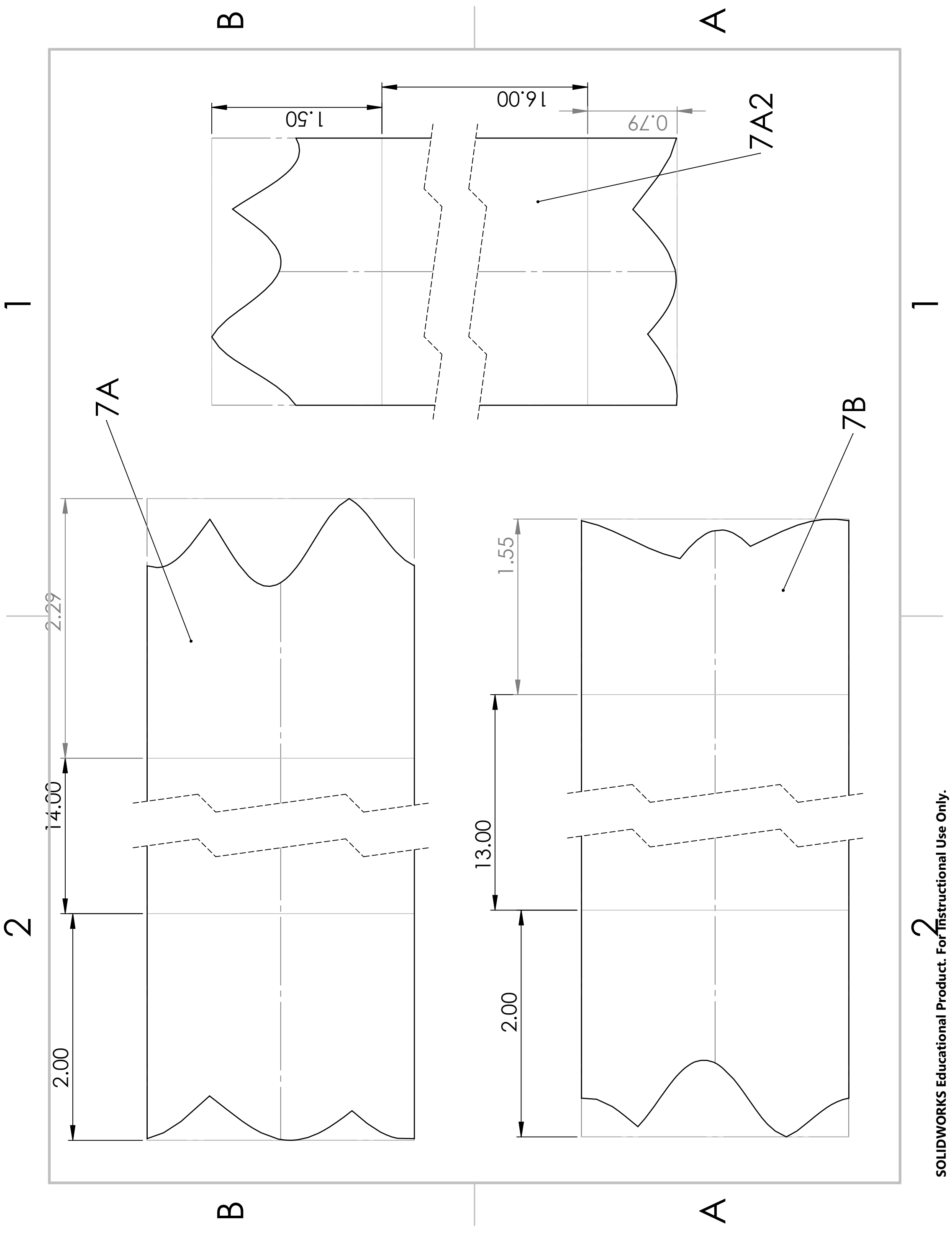
B
A
1
2
2.00
20.00
2.24
4B
2.00
18.00
1.57
4A
SOLIDWORKS Educational Product. For Instructional Use Only.

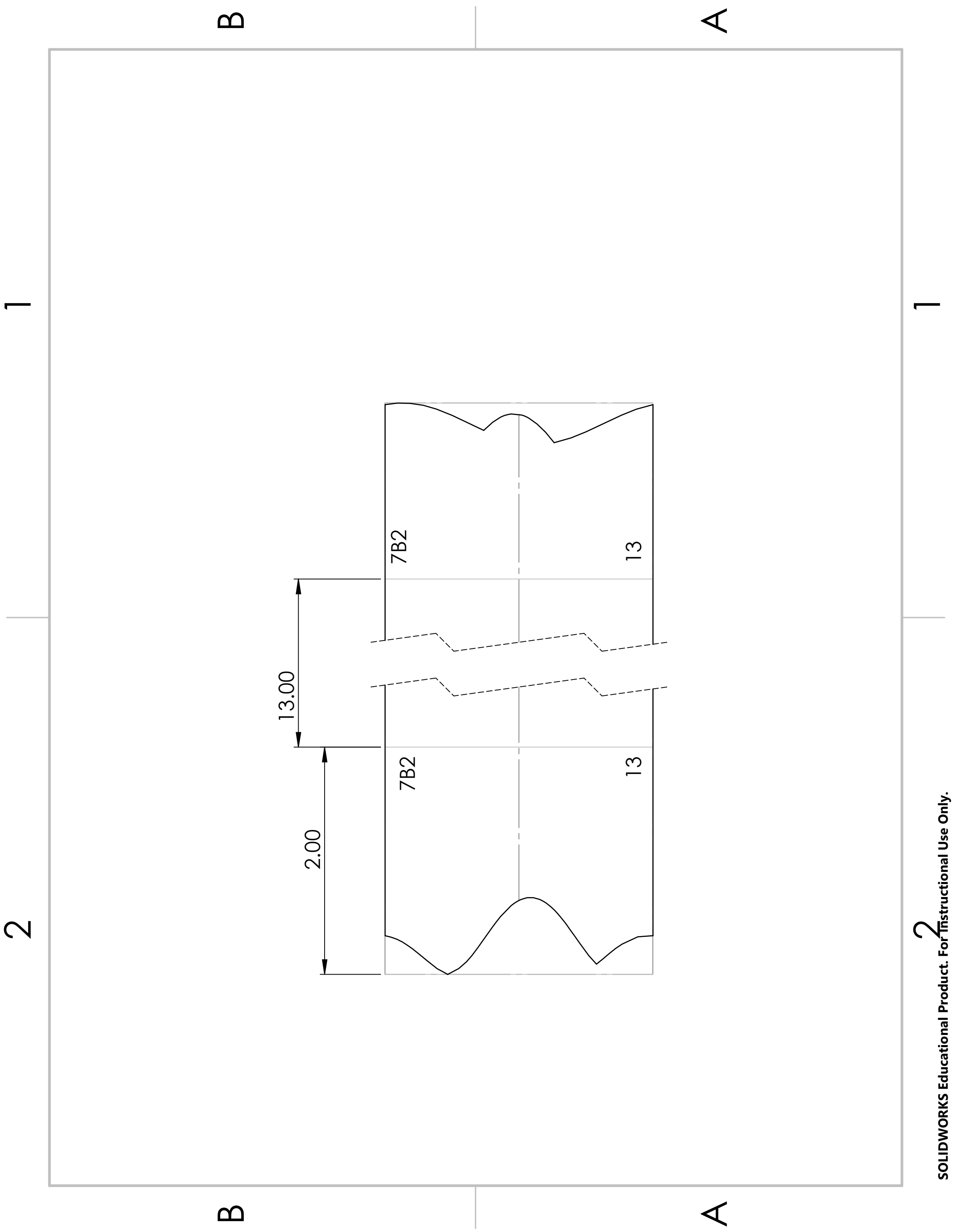

5A
5B
2.00
20.00
2.24
2.00
12.00
1.61
SOLIDWORKS Educational Product. For Instructional Use Only.



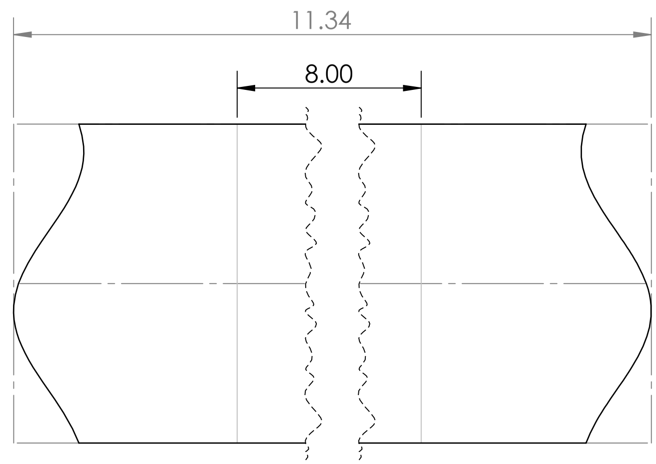
SEM
TUBE:
SIZE
A
QUANTITY
REV
2.00
24.00
24.00
SOLIDWORKS Educational Product. For Instructional Use Only.


6A
6A2
2.00
24.00
1.51
1.90
23.00
2.00
SOLIDWORKS Educational Product. For Instructional Use Only.

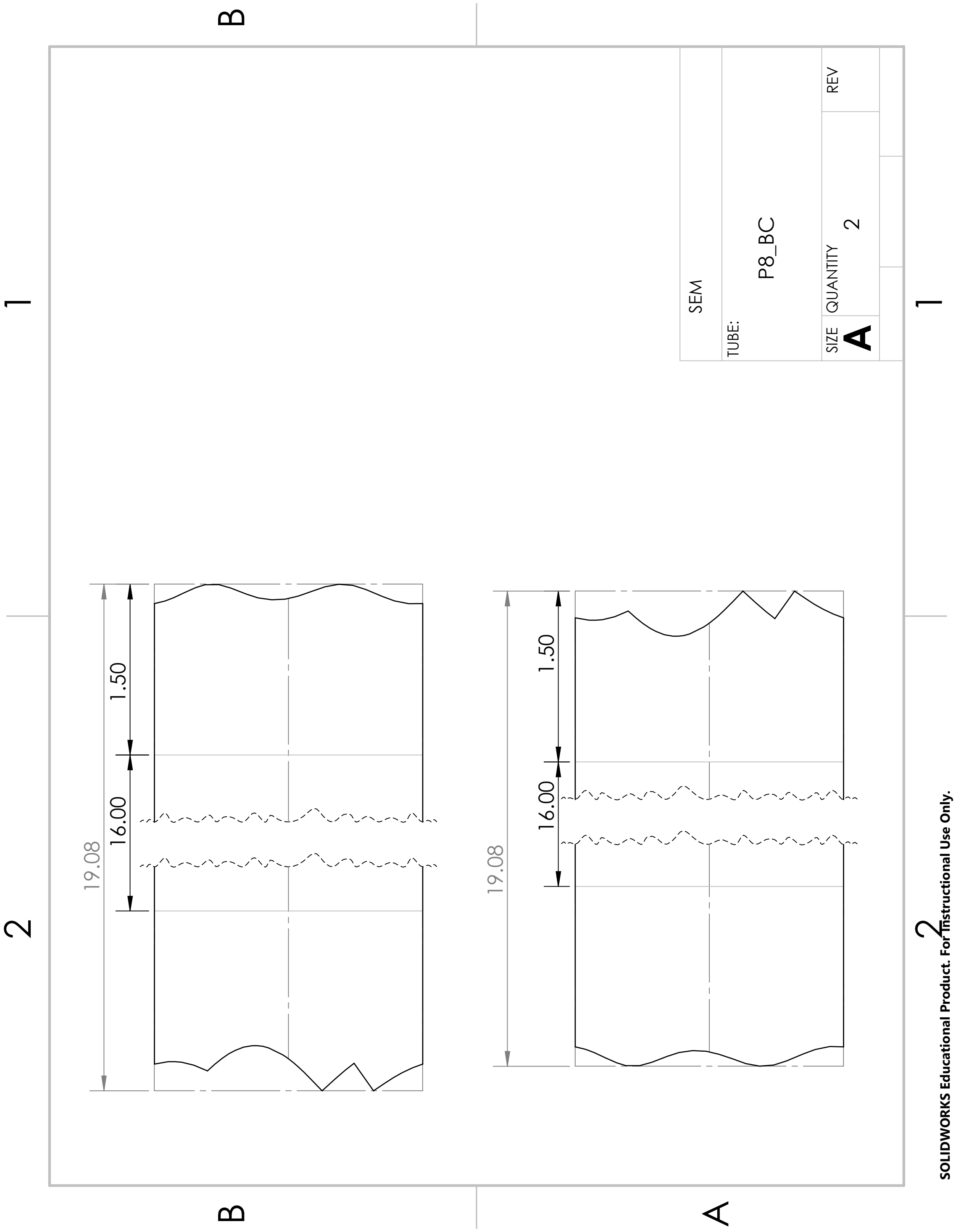

7A
7B
7A2
2.29
14.00
2.00
1.55
13.00
2.00
1.50
16.00
0.79
A
B
1
2
SOLIDWORKS Educational Product. For Instructional Use Only.


7B2
13
13.00
2.00
SOLIDWORKS Educational Product. For Instructional Use Only.


7F
7D
7D2
2.55
12.00
2.00
1.31
4.00
2.00
2.00
4.00
1.31
SOLIDWORKS Educational Product. For Instructional Use Only.




| SEM | | |
|---|---|---|
| TUBE: P8_A | | |
| SIZE A | QUANTITY 1 | REV |


SEM
TUBE:
P8_BC
QUANTITY
2
SIZE
A
REV
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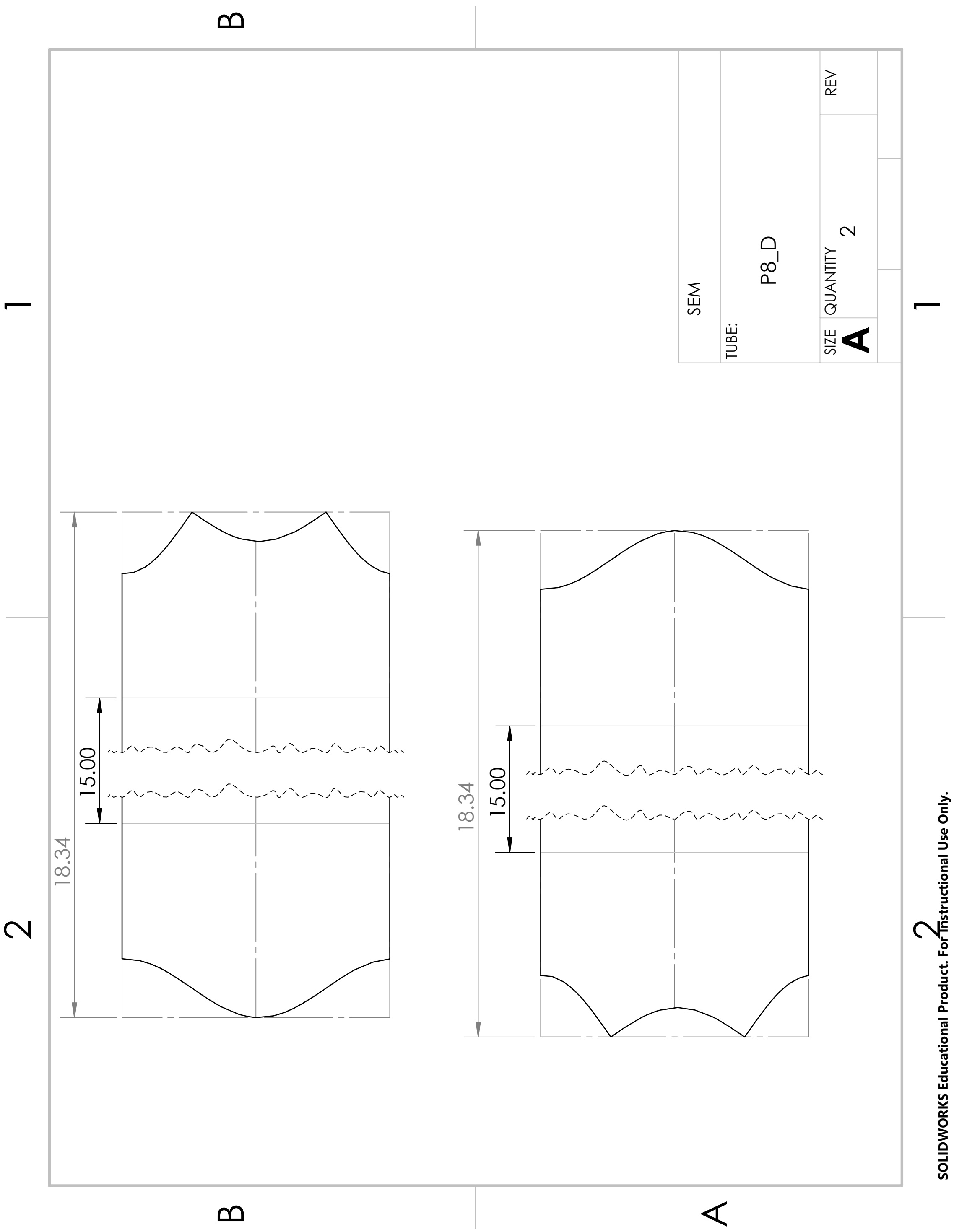
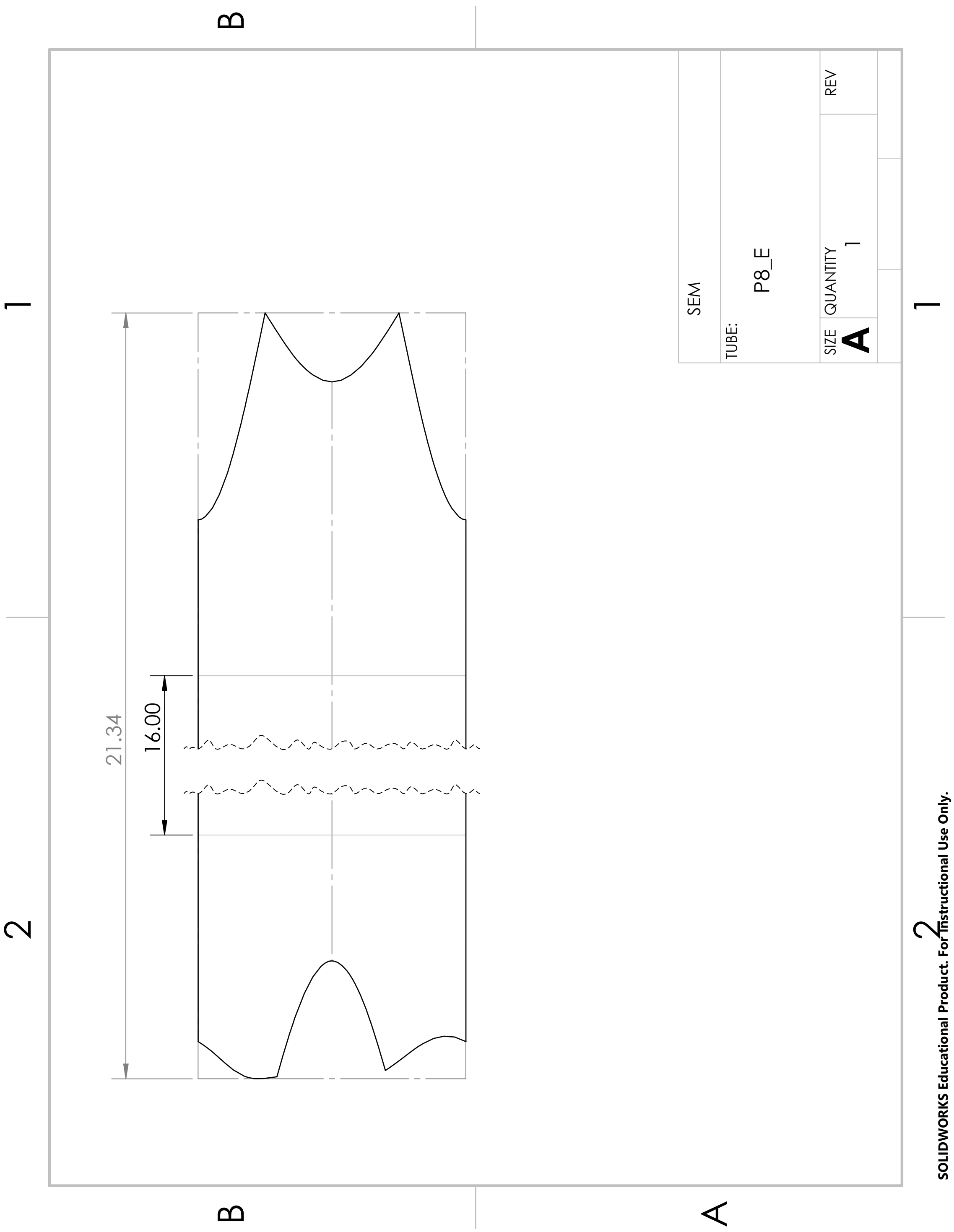
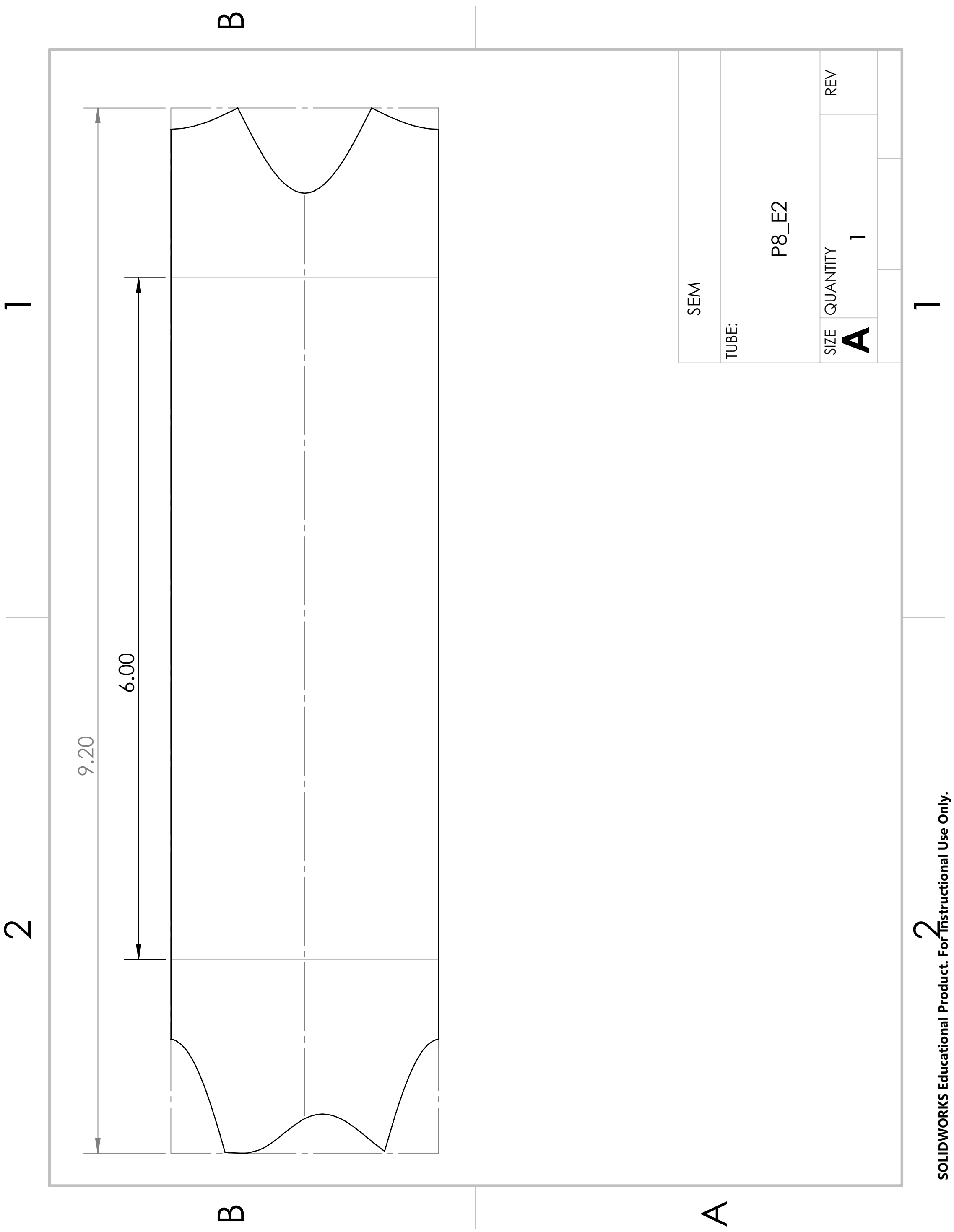
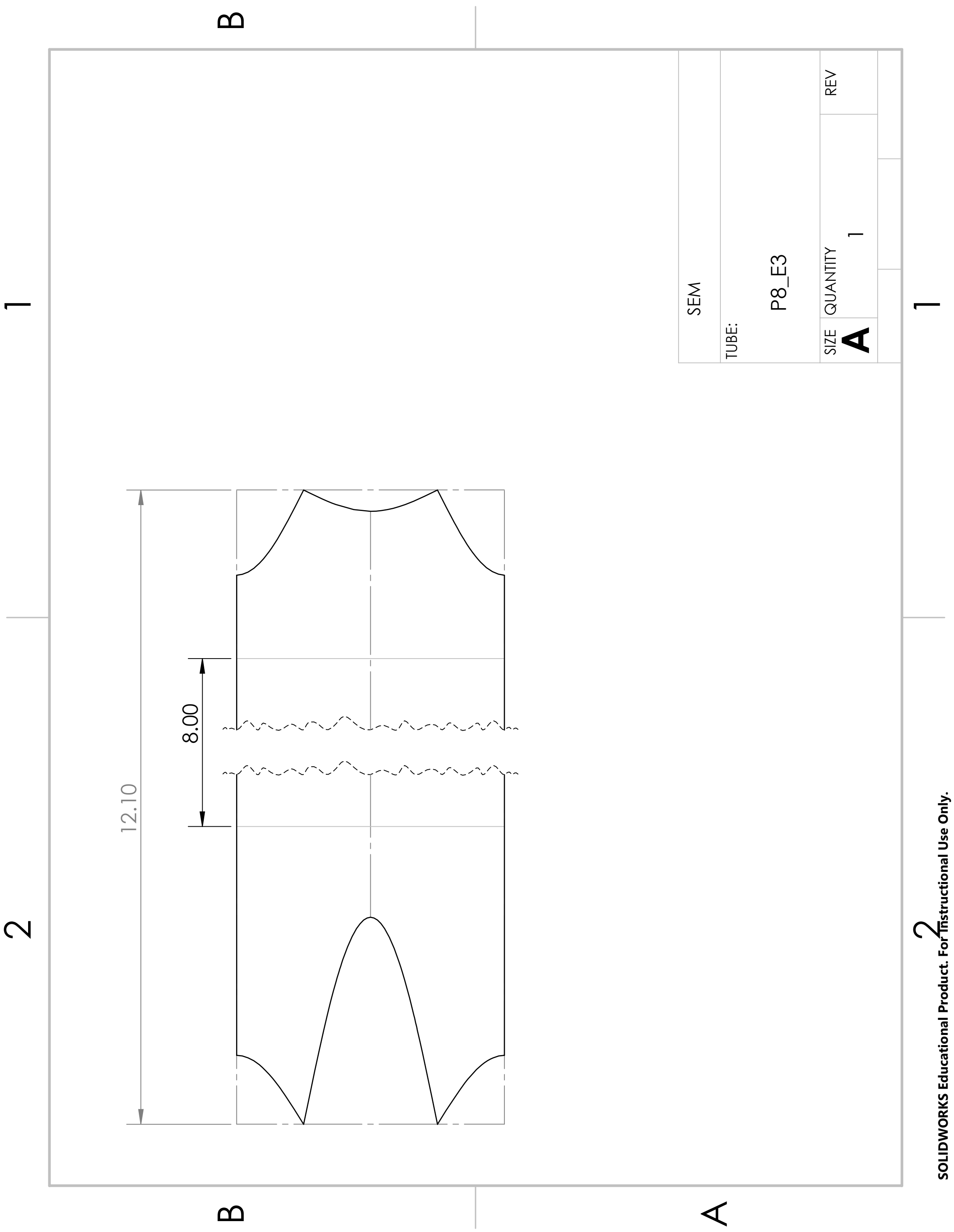
16.00
19.08
1.50
16.00
19.08
SOLIDWORKS Educational Product. For Instructional Use Only.

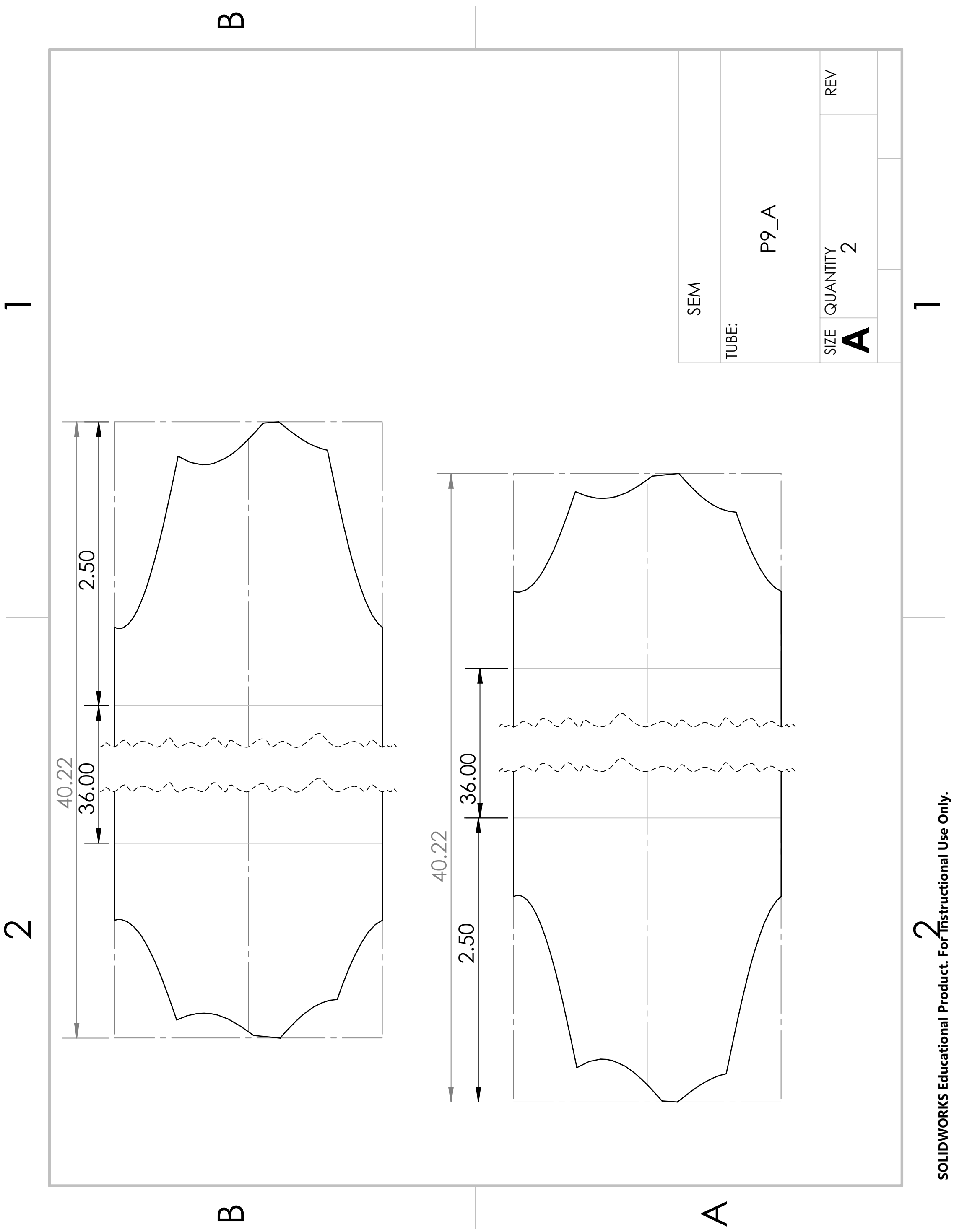

SEM
TUBE:
P8_D
SIZE
A
QUANTITY
2
REV
15.00
18.34
15.00
18.34
SOLIDWORKS Educational Product. For Instructional Use Only.

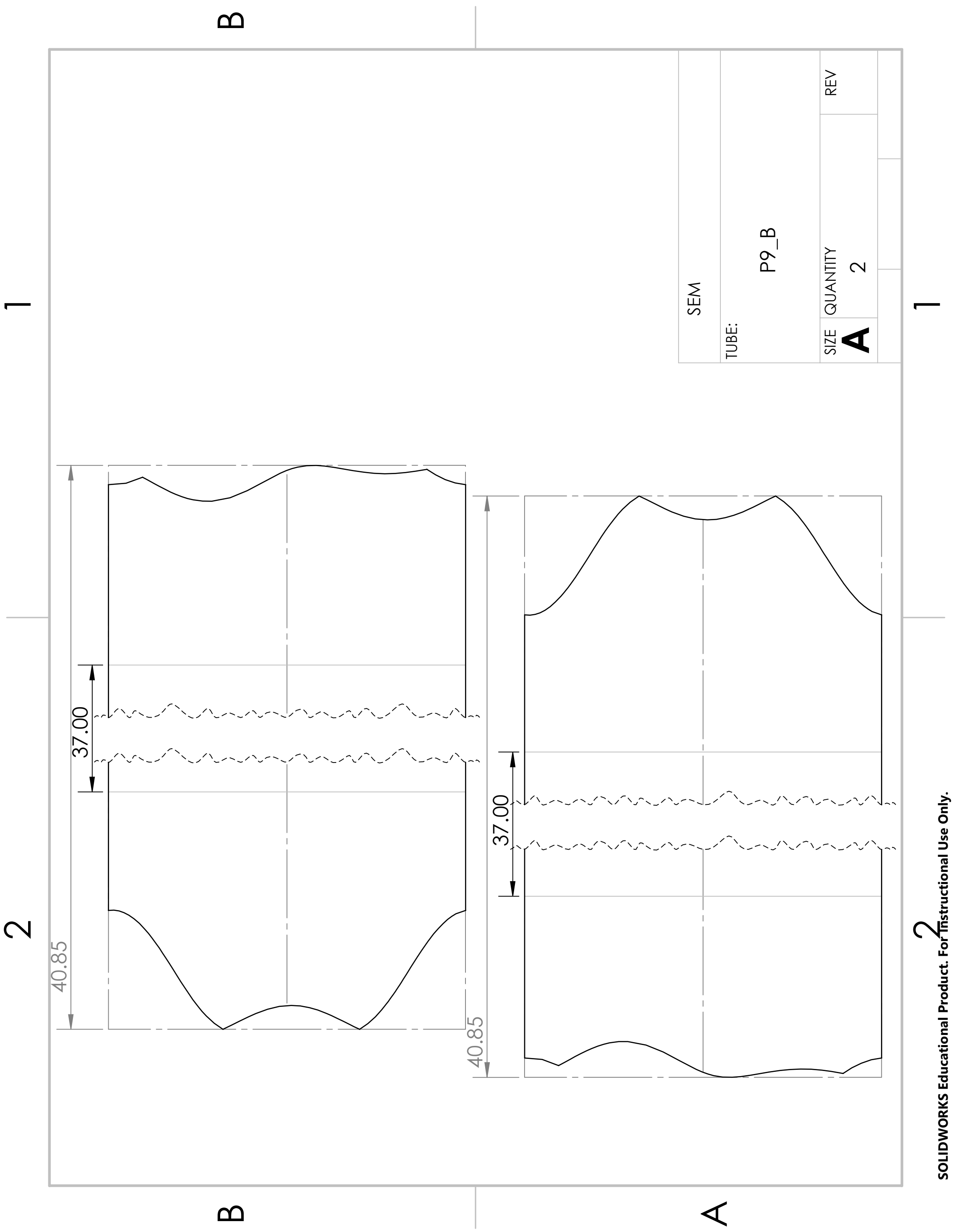

21.34
16.00
SEM
TUBE:
P8_E
SIZE
A
QUANTITY
1
REV
SOLIDWORKS Educational Product. For Instructional Use Only.



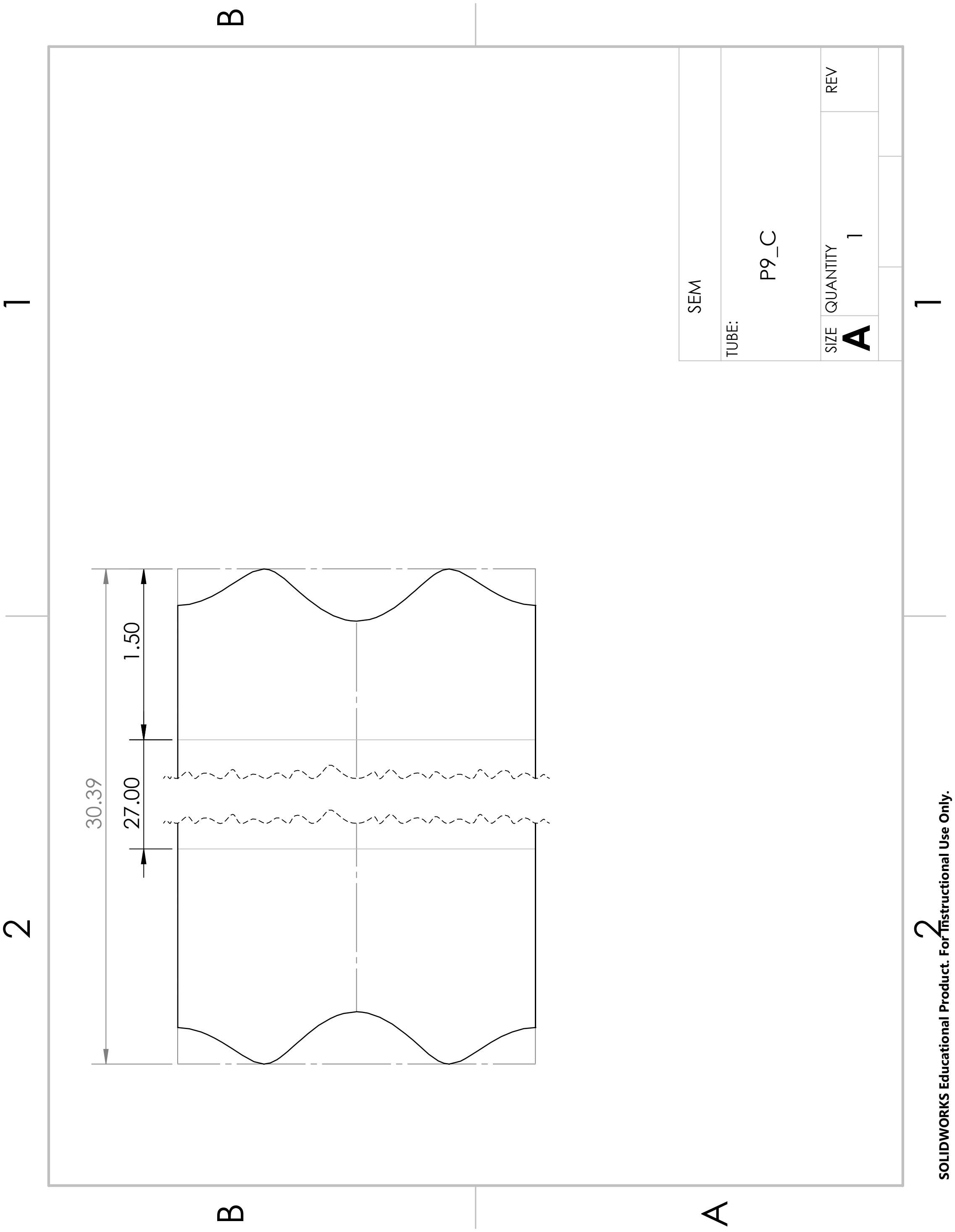
9.20
6.00
SEM
TUBE:
P8_E2
SIZE
A
QUANTITY
1
REV
SOLIDWORKS Educational Product. For Instructional Use Only.


SEM
TUBE:
P8_E3
SIZE
A
QUANTITY
1
REV
8.00
12.10
SOLIDWORKS Educational Product. For Instructional Use Only.

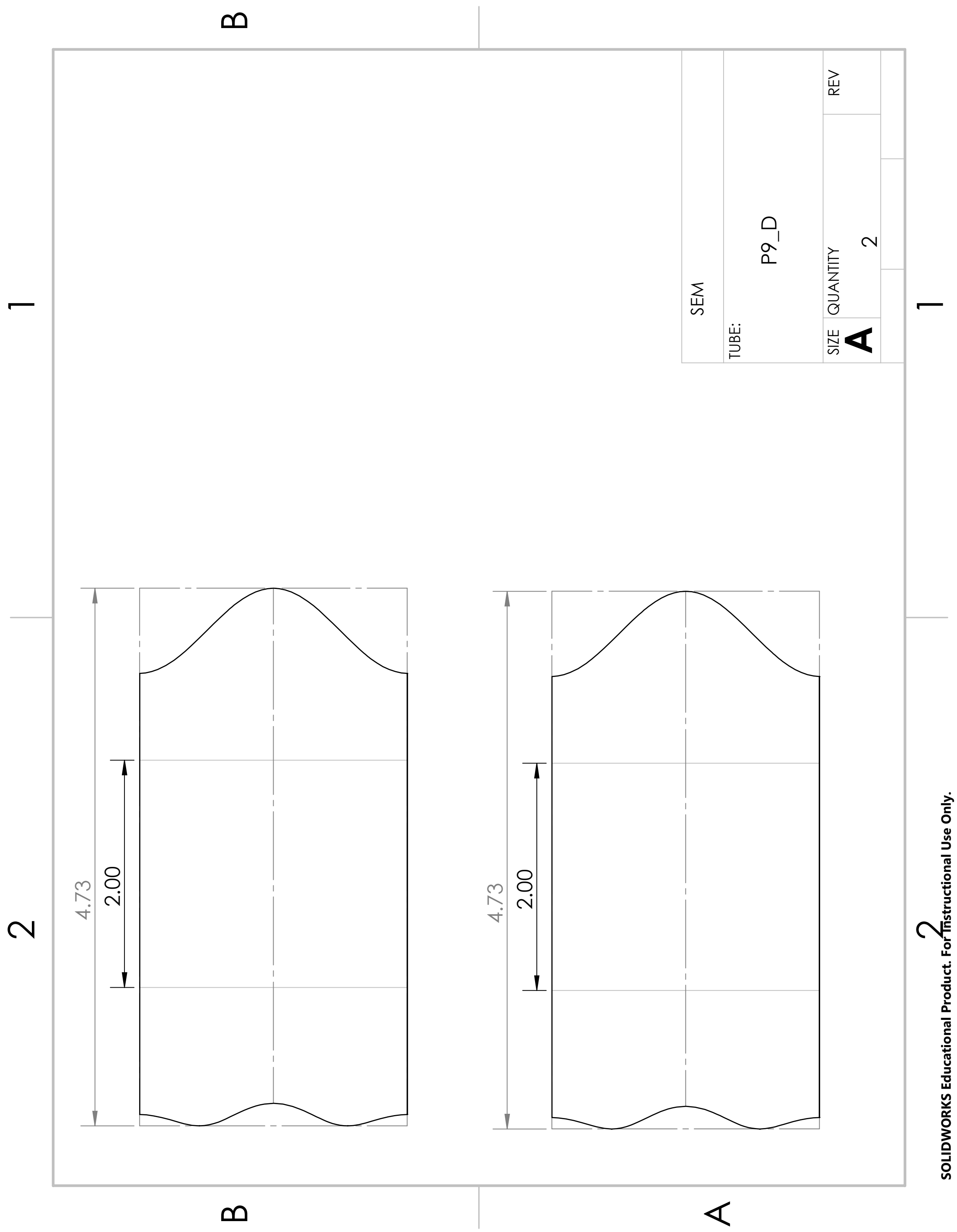

SEM
TUBE:
P9_A
SIZE
A
QUANTITY
2
REV
2.50
36.00
40.22
2.50
36.00
40.22
SOLIDWORKS Educational Product. For Instructional Use Only.



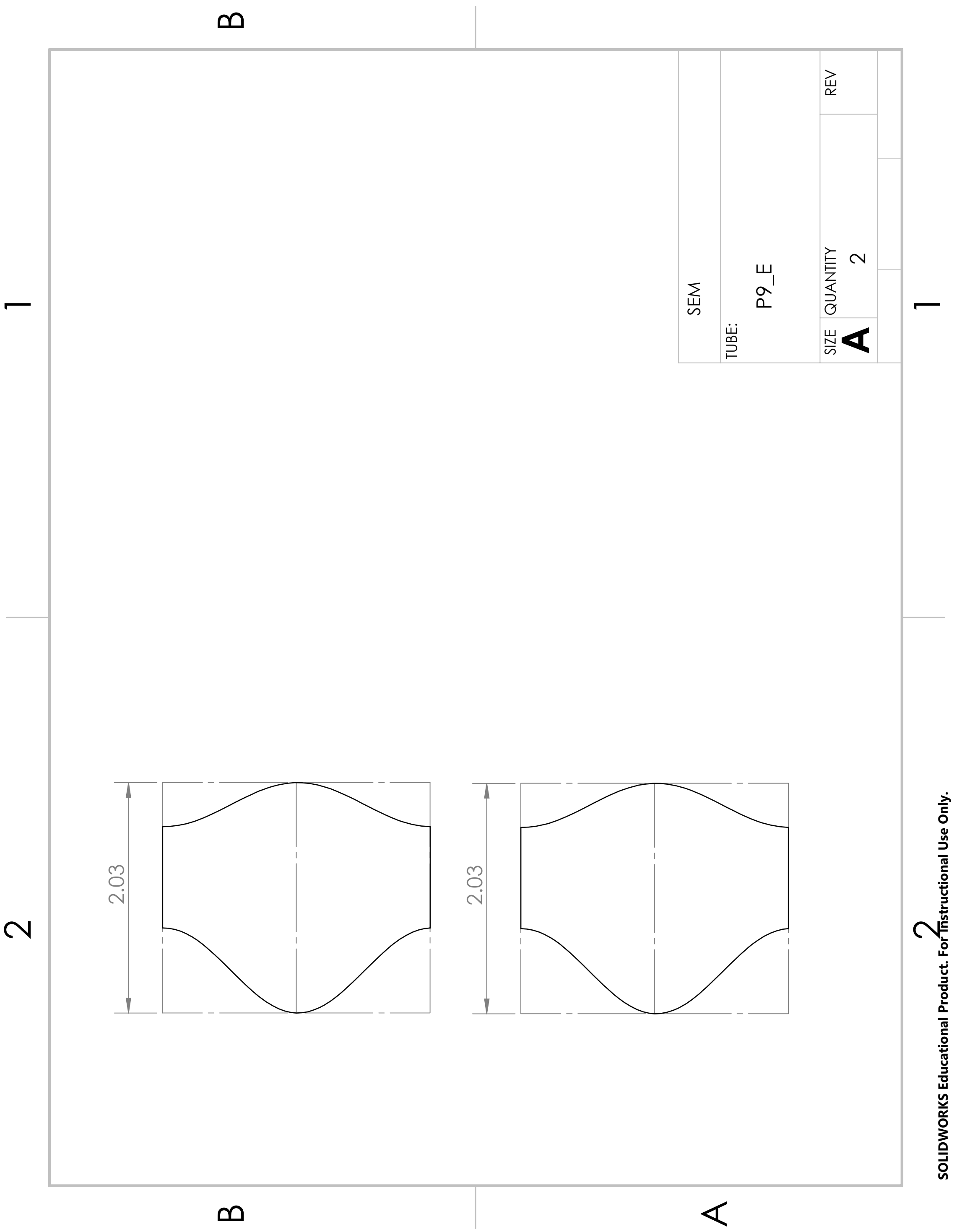
SEM
TUBE:
P9_B
SIZE
A
QUANTITY
2
REV
37.00
37.00
40.85
40.85
1
2
A
B
SOLIDWORKS Educational Product. For Instructional Use Only.



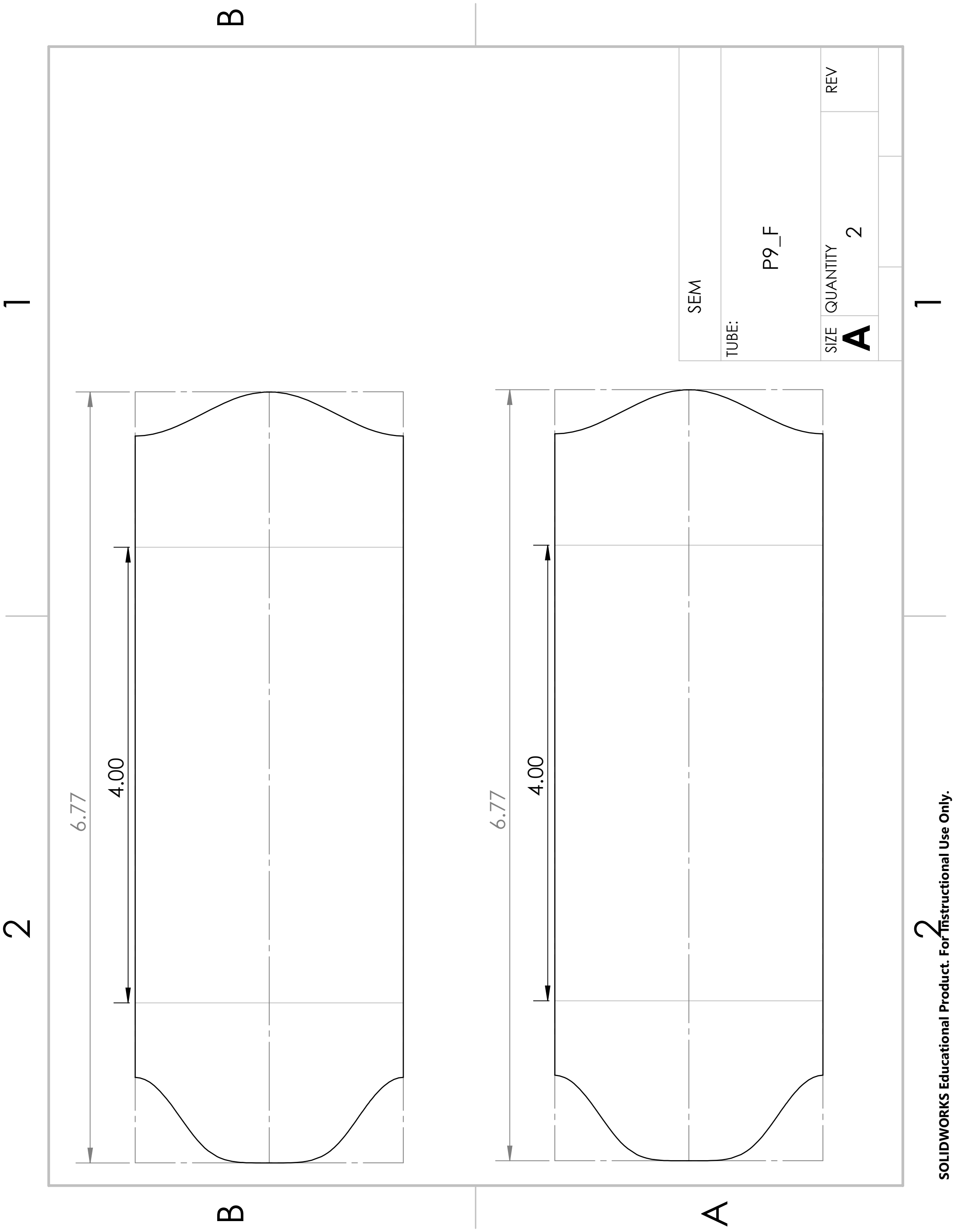
SEM
TUBE:
P9_C
SIZE
A
QUANTITY
1
REV
1.50
27.00
30.39
SOLIDWORKS Educational Product. For Instructional Use Only.



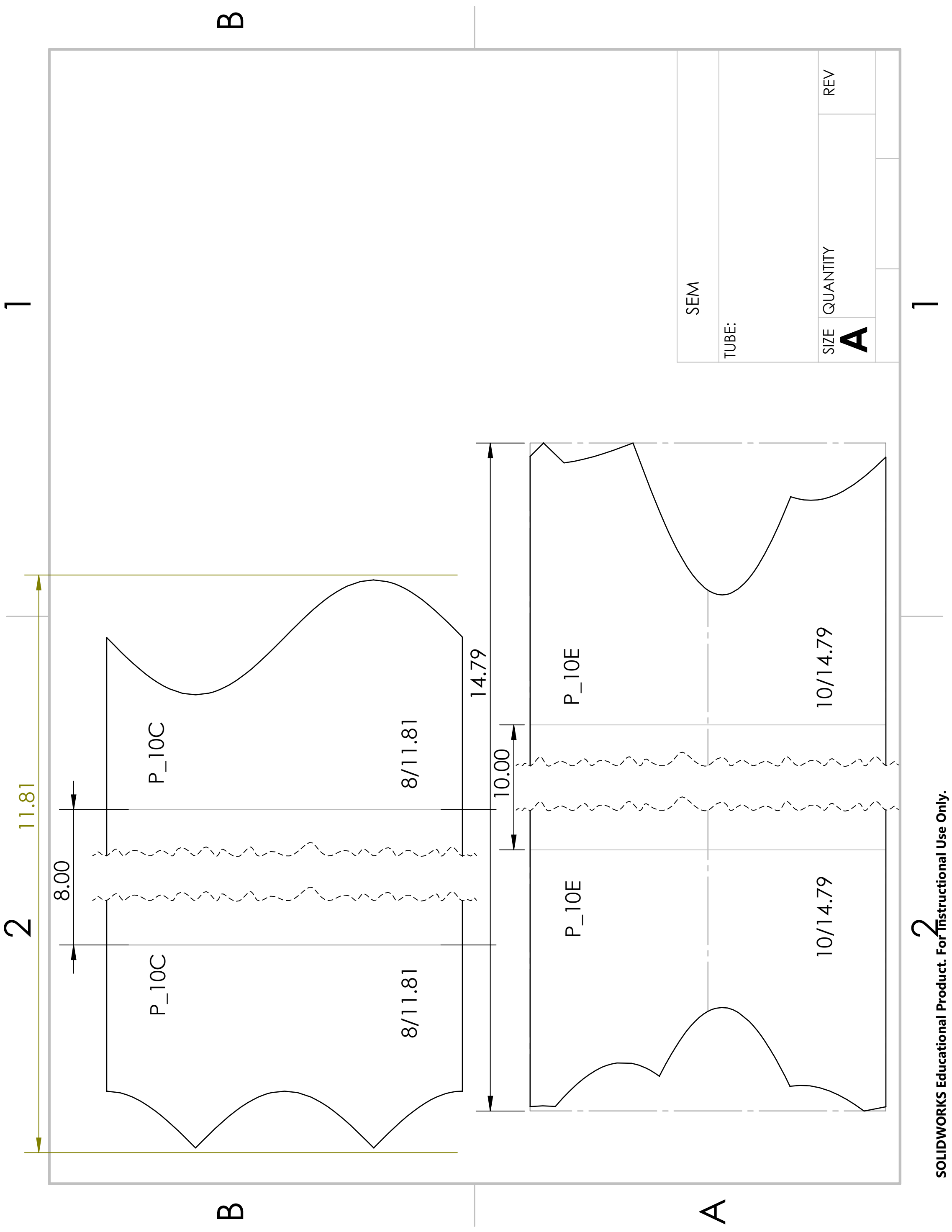
4.73
2.00
4.73
2.00
SEM
TUBE:
P9_D
SIZE
A
QUANTITY
2
REV
SOLIDWORKS Educational Product. For Instructional Use Only.



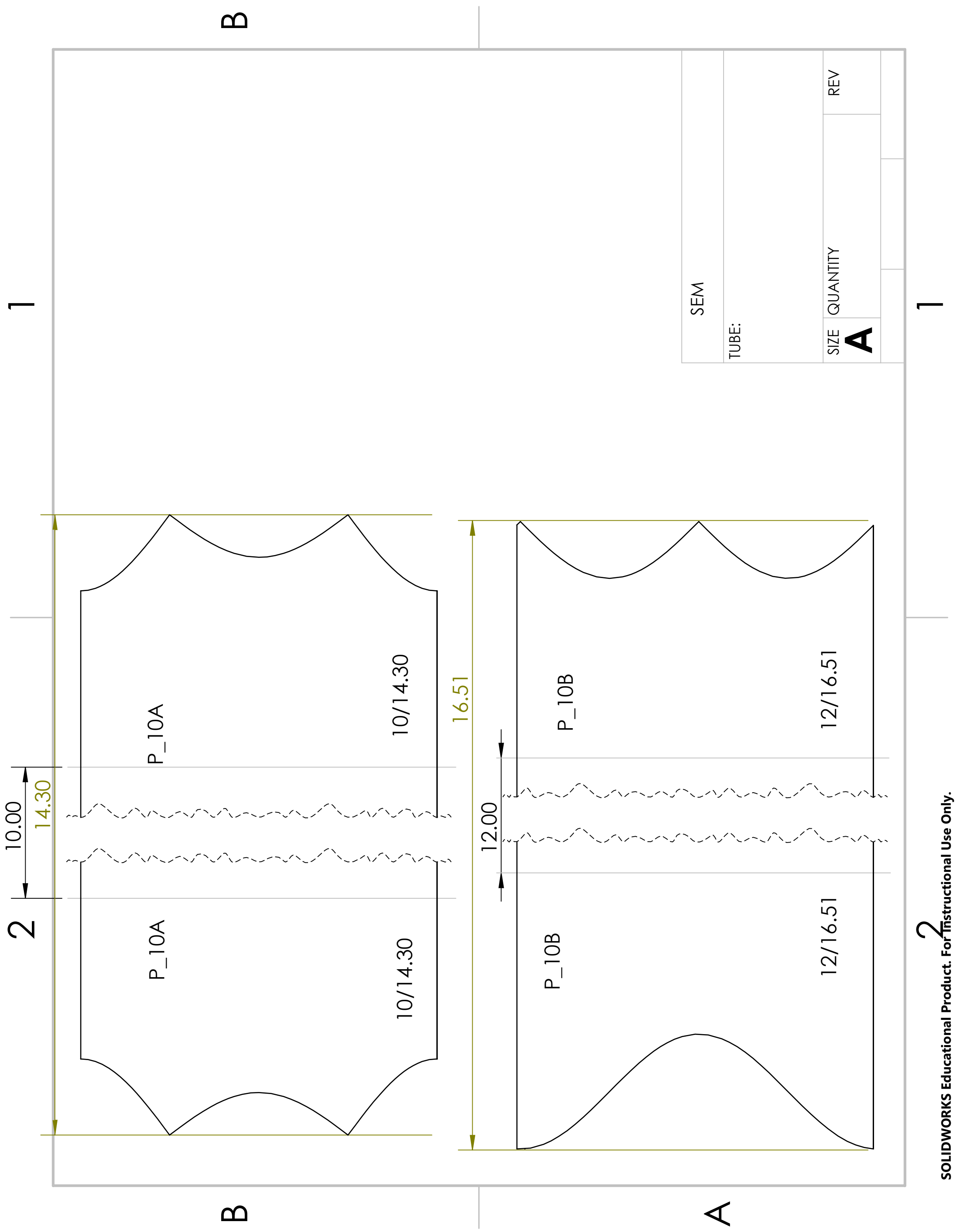
SEM
TUBE:
P9_E
SIZE
A
QUANTITY
2
REV
2.03
2.03
SOLIDWORKS Educational Product. For Instructional Use Only.

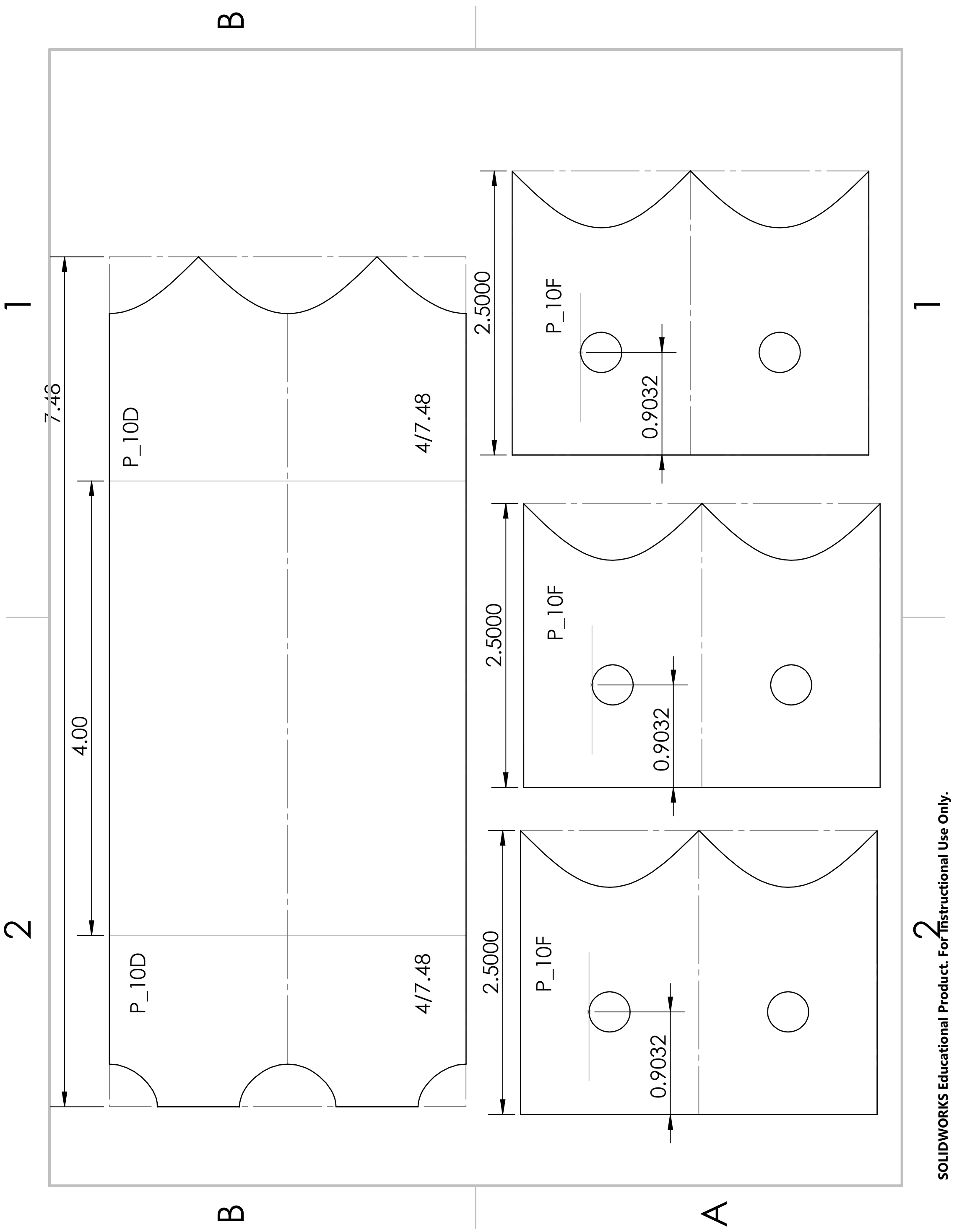


6.77
4.00
6.77
4.00
SEM
TUBE:
P9_F
SIZE
A
QUANTITY
2
REV
SOLIDWORKS Educational Product. For Instructional Use Only.

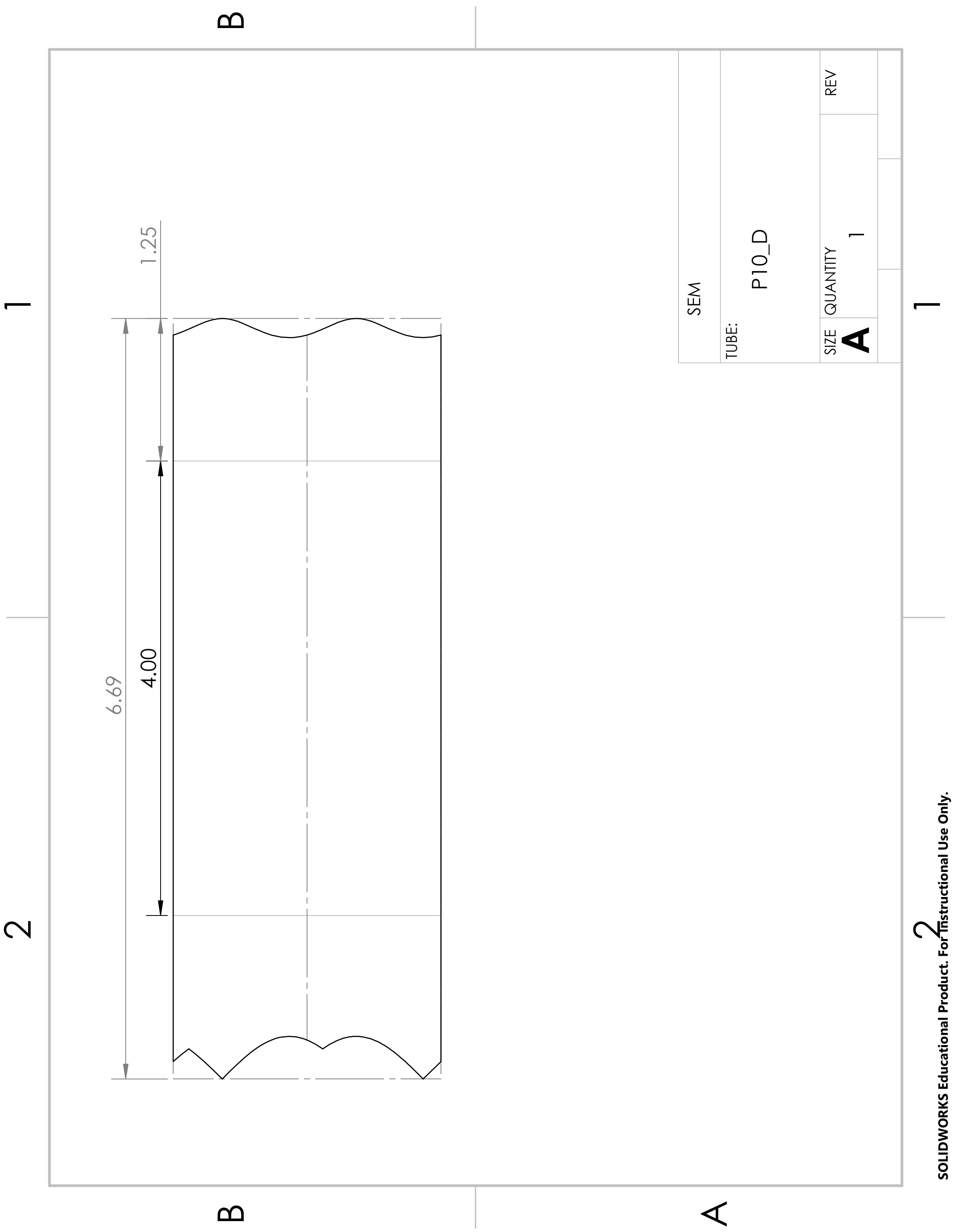


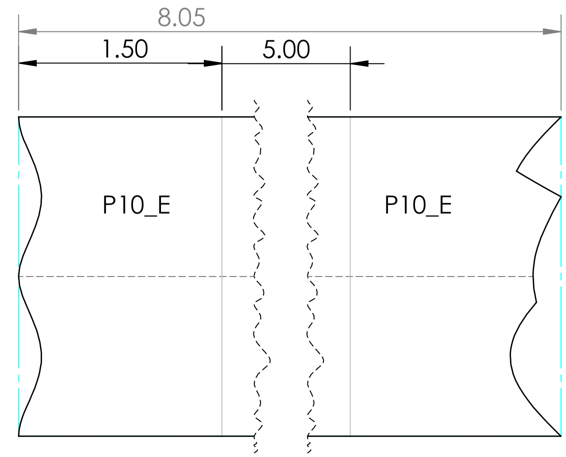
P_10C
8/11.81
P_10C
8/11.81
11.81
8.00
14.79
10.00
P_10E
10/14.79
P_10E
10/14.79
SEM
TUBE:
QUANTITY
REV
SIZE
A
1
2
A
B
SOLIDWORKS Educational Product. For Instructional Use Only.


P_10A
10/14.30
14.30
10.00
P_10B
12/16.51
16.51
12.00
SEM
TUBE:
SIZE
A
QUANTITY
REV
SOLIDWORKS Educational Product. For Instructional Use Only.

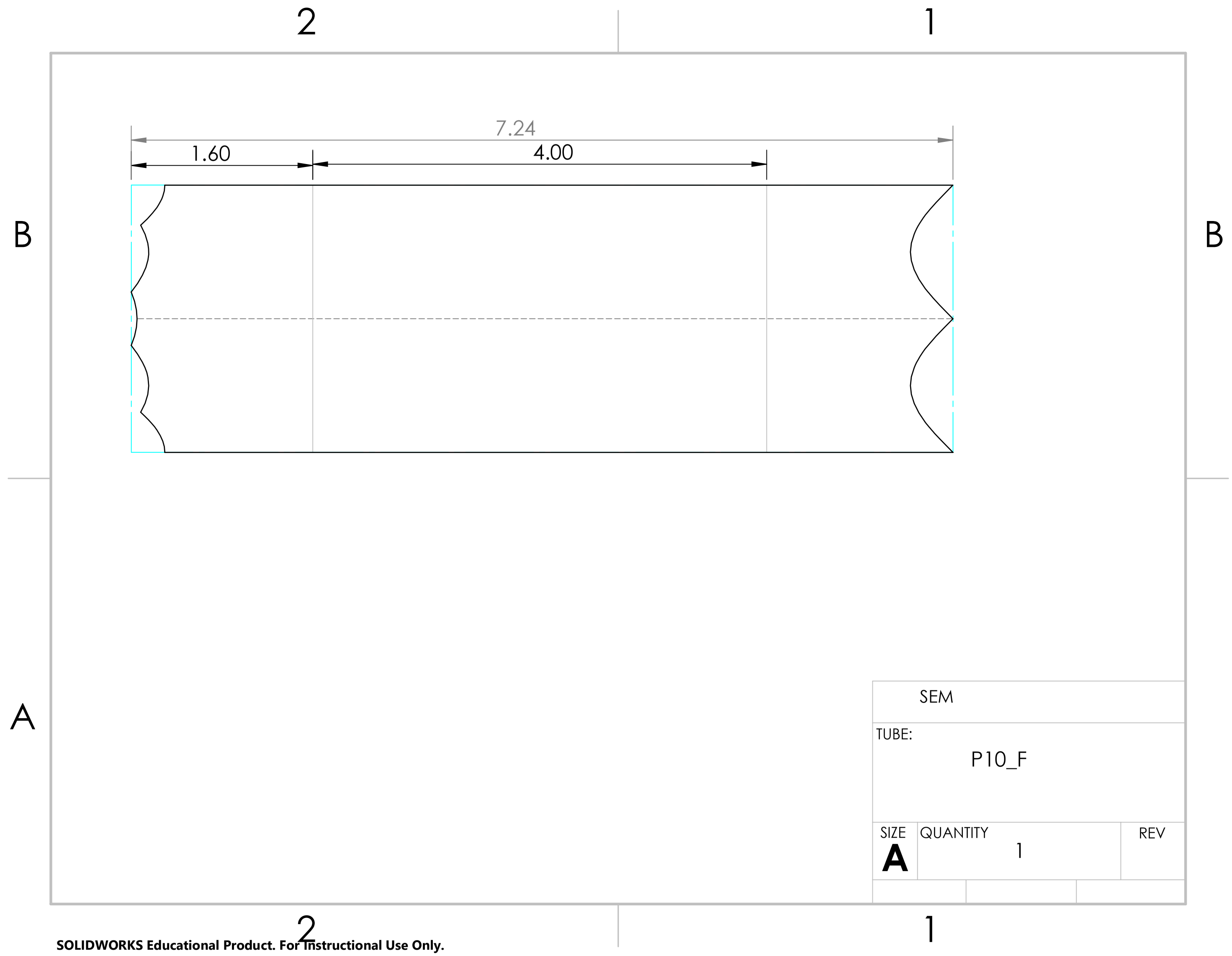


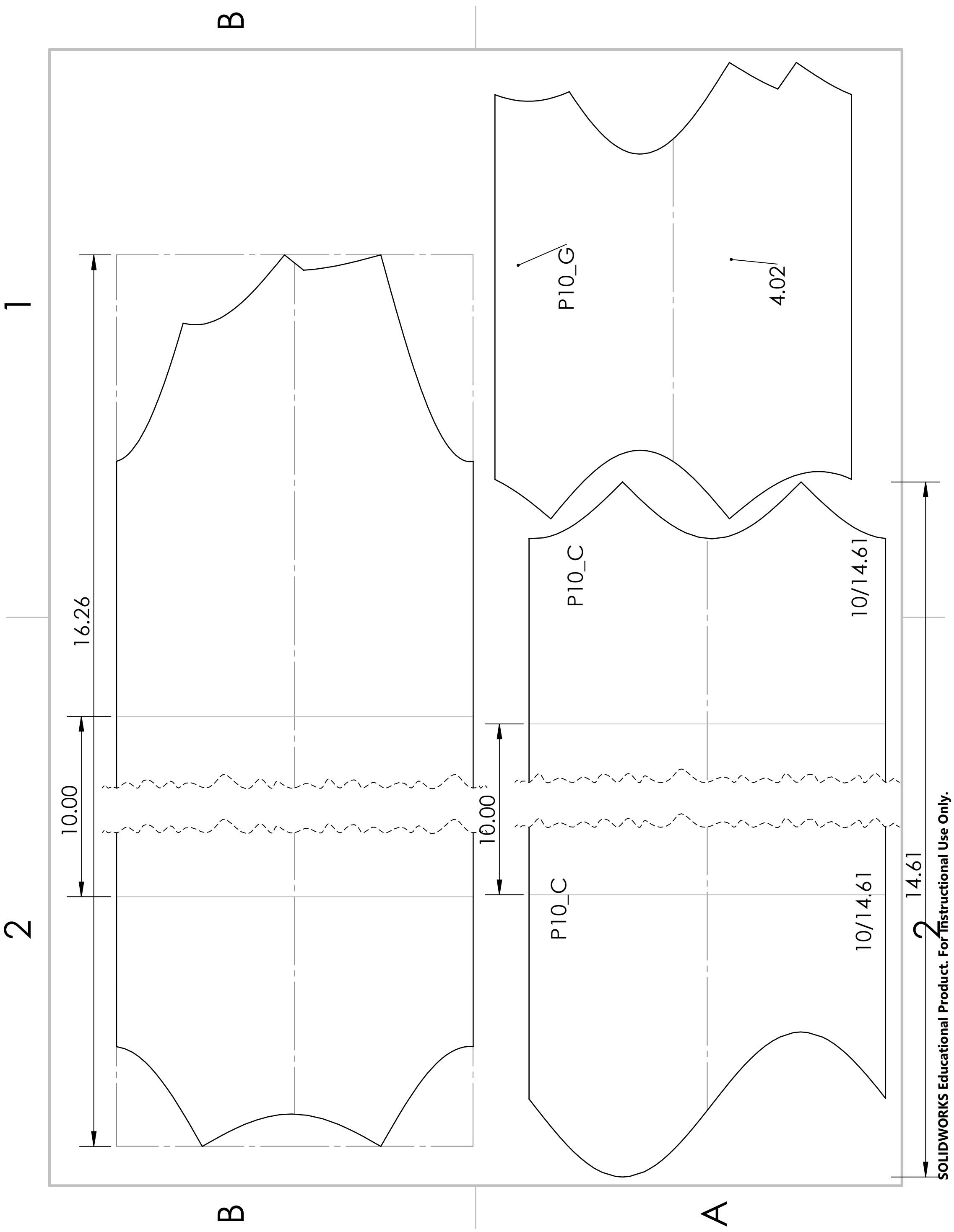
B
1
2
7.48
4.00
P_10D
4/7.48
P_10D
4/7.48
2.5000
P_10F
0.9032
2.5000
P_10F
0.9032
2.5000
P_10F
0.9032
1
2
B
A
SOLIDWORKS Educational Product. For Instructional Use Only.

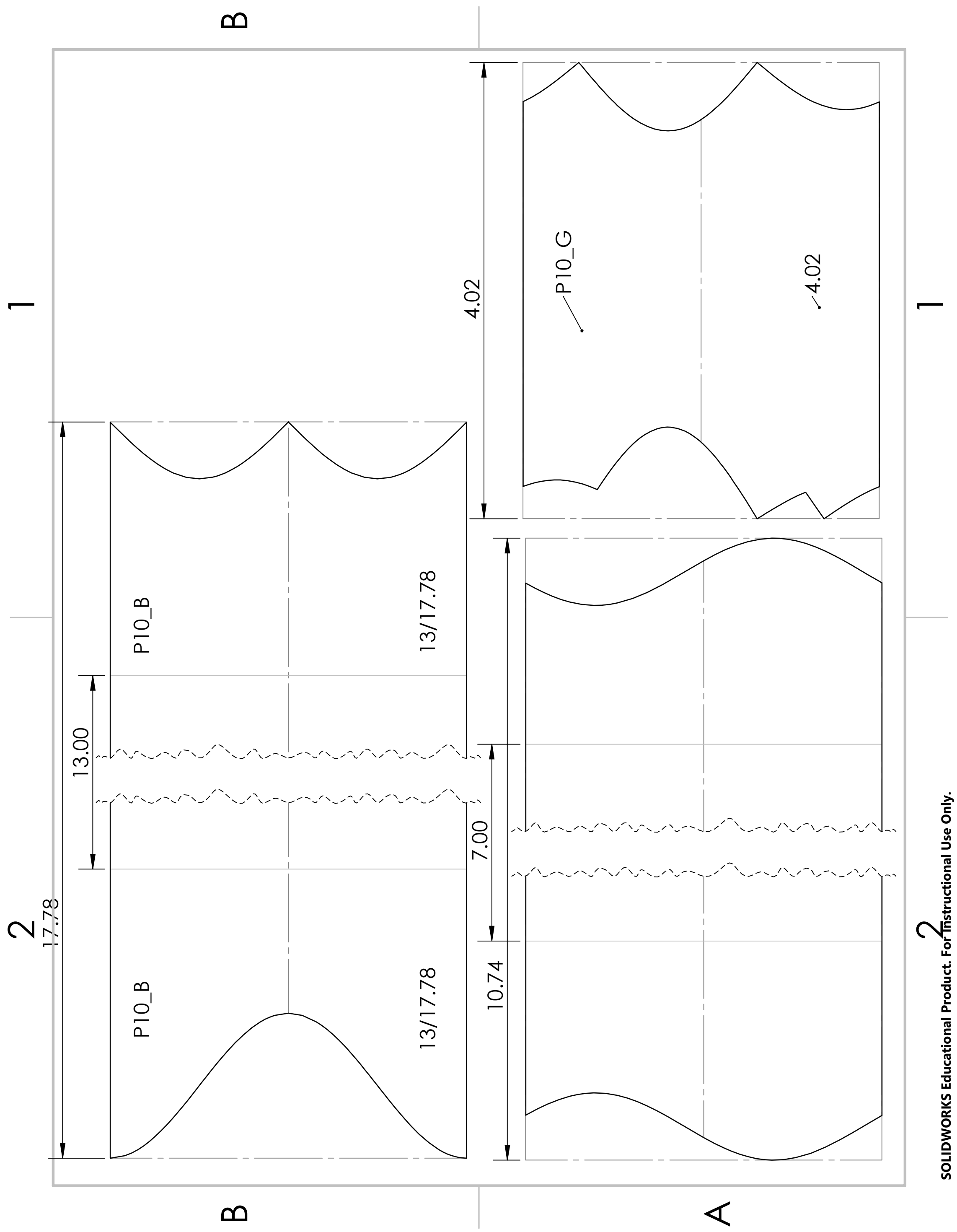

1.25
6.69
4.00
SEM
TUBE:
P10_D
SIZE
A
QUANTITY
1
REV
SOLIDWORKS Educational Product. For Instructional Use Only.

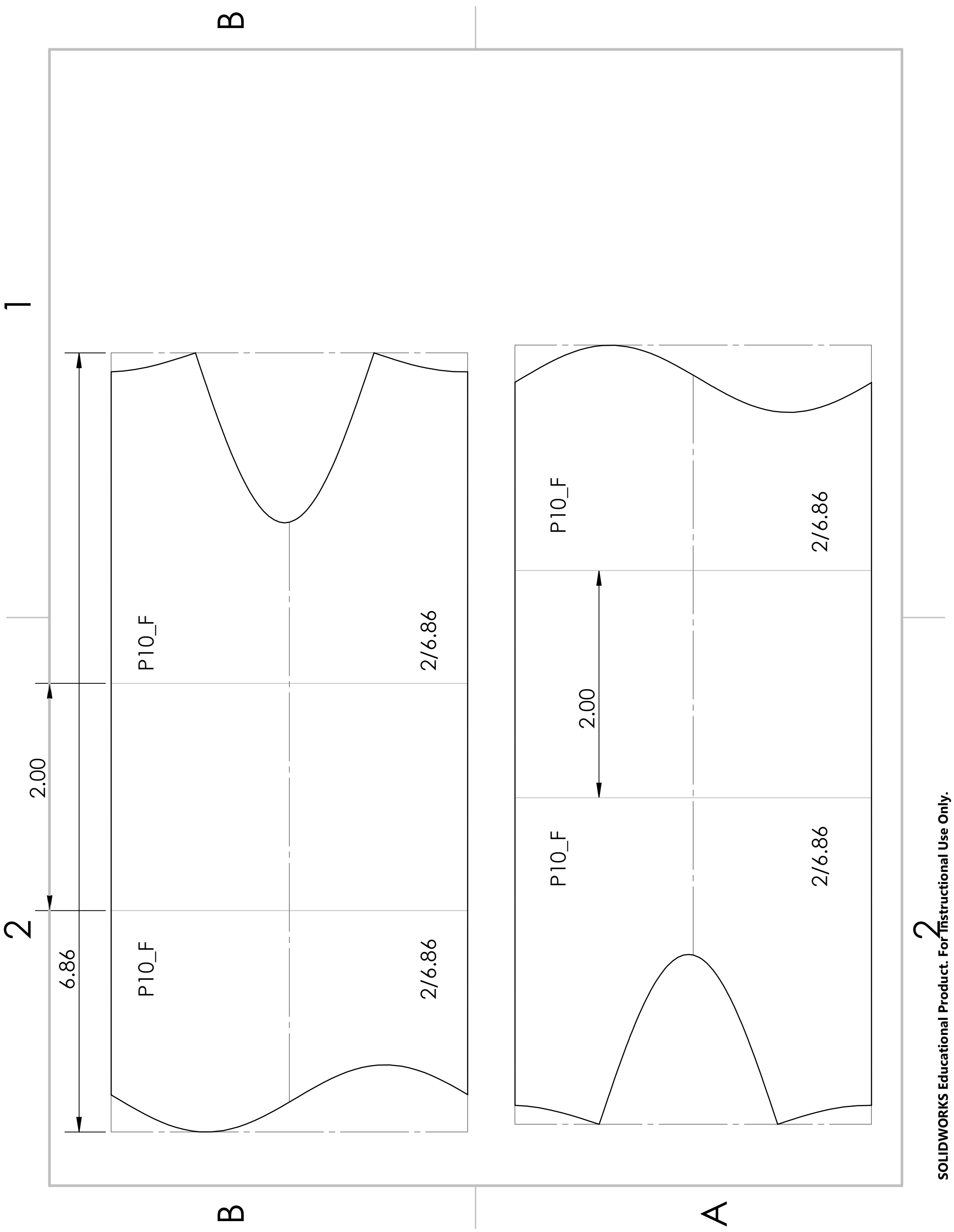



| | |
|---|---|
| SEM | |
| TUBE: P10_E | |
| SIZE A | QUANTITY 1 | REV |

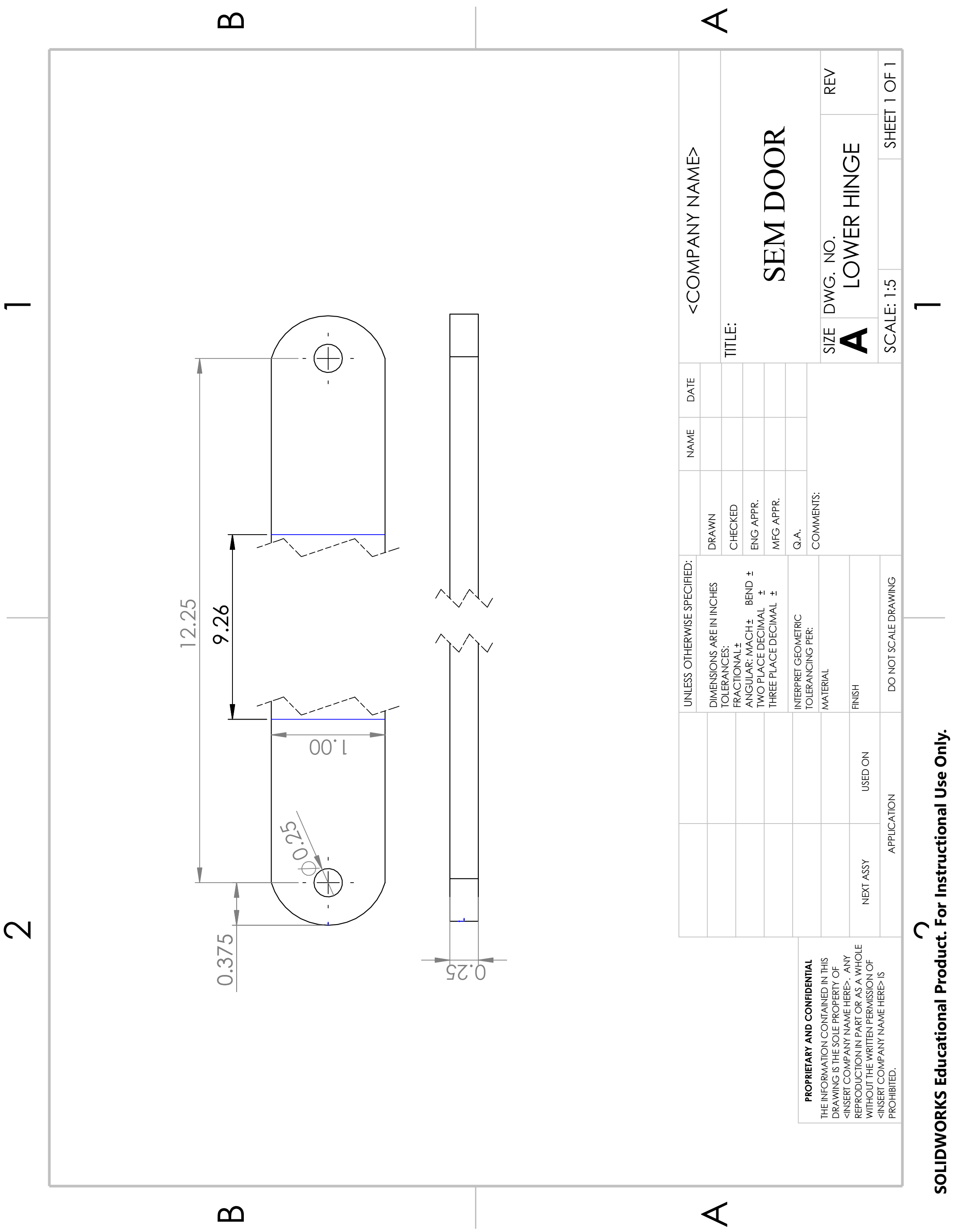

7.24
1.60
4.00
SEM
TUBE:
P10_F
SIZE
A
QUANTITY
1
REV
SOLIDWORKS Educational Product. For Instructional Use Only.


B
1
2
16.26
10.00
10.00
P10_G
4.02
P10_C
10/14.61
P10_C
10/14.61
14.61
2
SOLIDWORKS Educational Product. For Instructional Use Only.
B
A


B
1
2
4.02
P10_G
4.02
P10_B
13/17.78
13.00
17.78
P10_B
13/17.78
7.00
10.74
B
A
SOLIDWORKS Educational Product. For Instructional Use Only.



B
1
2
B
A
2
2.00
6.86
P10_F
2/6.86
P10_F
2/6.86
P10_F
2/6.86
2.00
P10_F
2/6.86
SOLIDWORKS Educational Product. For Instructional Use Only.


12.25
9.26
1.00
⌀0.25
0.375
0.25
<COMPANY NAME>
TITLE:
SEM DOOR
SIZE A
DWG. NO.
LOWER HINGE
REV
SCALE: 1:5
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
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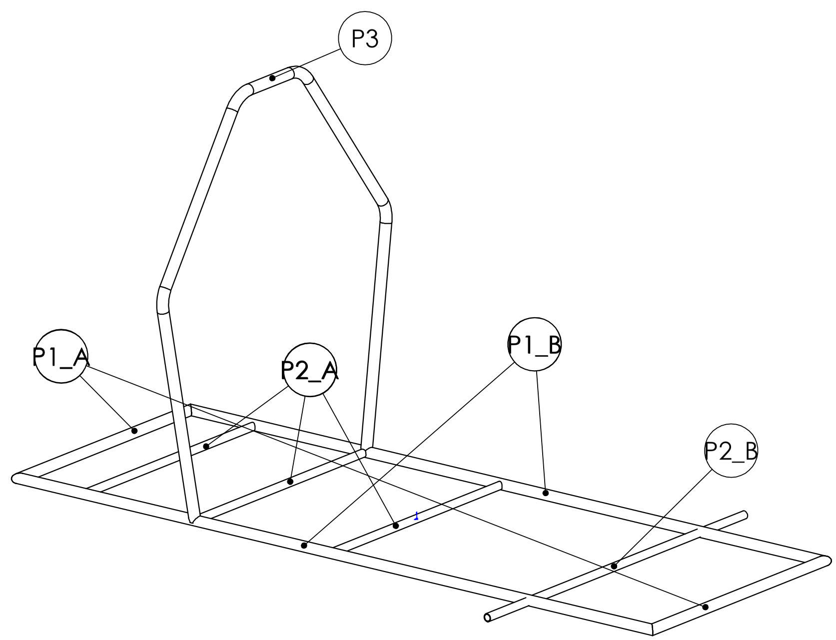
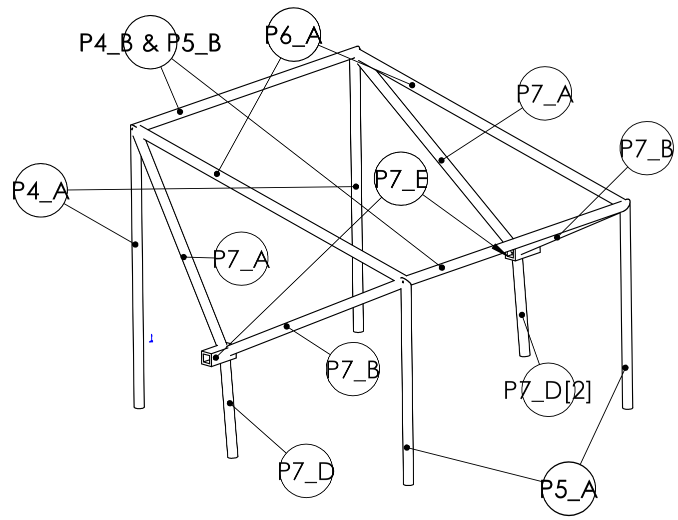
| ITEM NO. | QTY. | LENGTH |
|---|---|---|
| P1_A | 2 | 24.62 |
| P2_A | 3 | 22.96 |
| P1_B | 2 | 74.2 |
| P2_B | 1 | 35.43 |
| P3 | 1 | 91.35 |



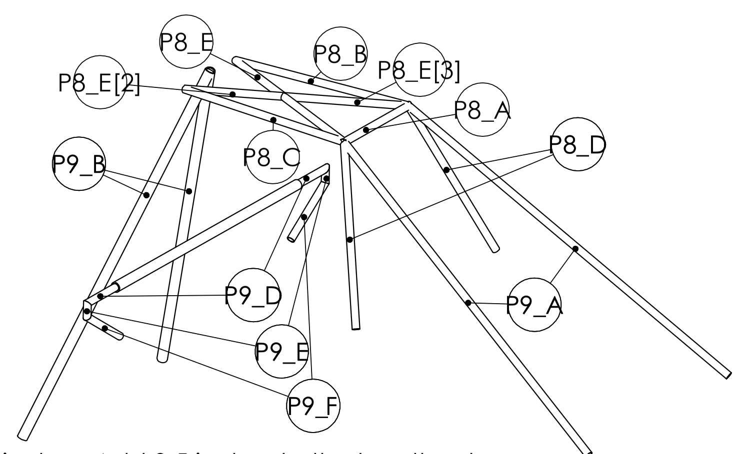

All dimensions given are in inches. Add 0.5 inches to the lengths above

| ITEM NO. | QTY. | LENGTH |
|---|---|---|
| P7_A | 2 | 19.25 |
| P7_B | 2 | 17.49 |
| P7_D | 1 | 8 |
| P4_A | 2 | 22.03 |
| P4_B & P5_B | 2 | 24.37 |
| P5_A | 2 | 16.12 |
| P6_A | 2 | 27.93 |
| P7_E | 2 | 2.67 |
| P7_D[2] | 1 | 8 |



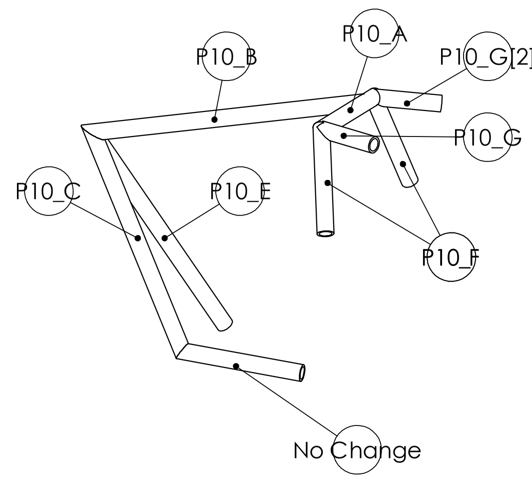

All dimensions given are in inches. Add 0.5 inches to the lengths above

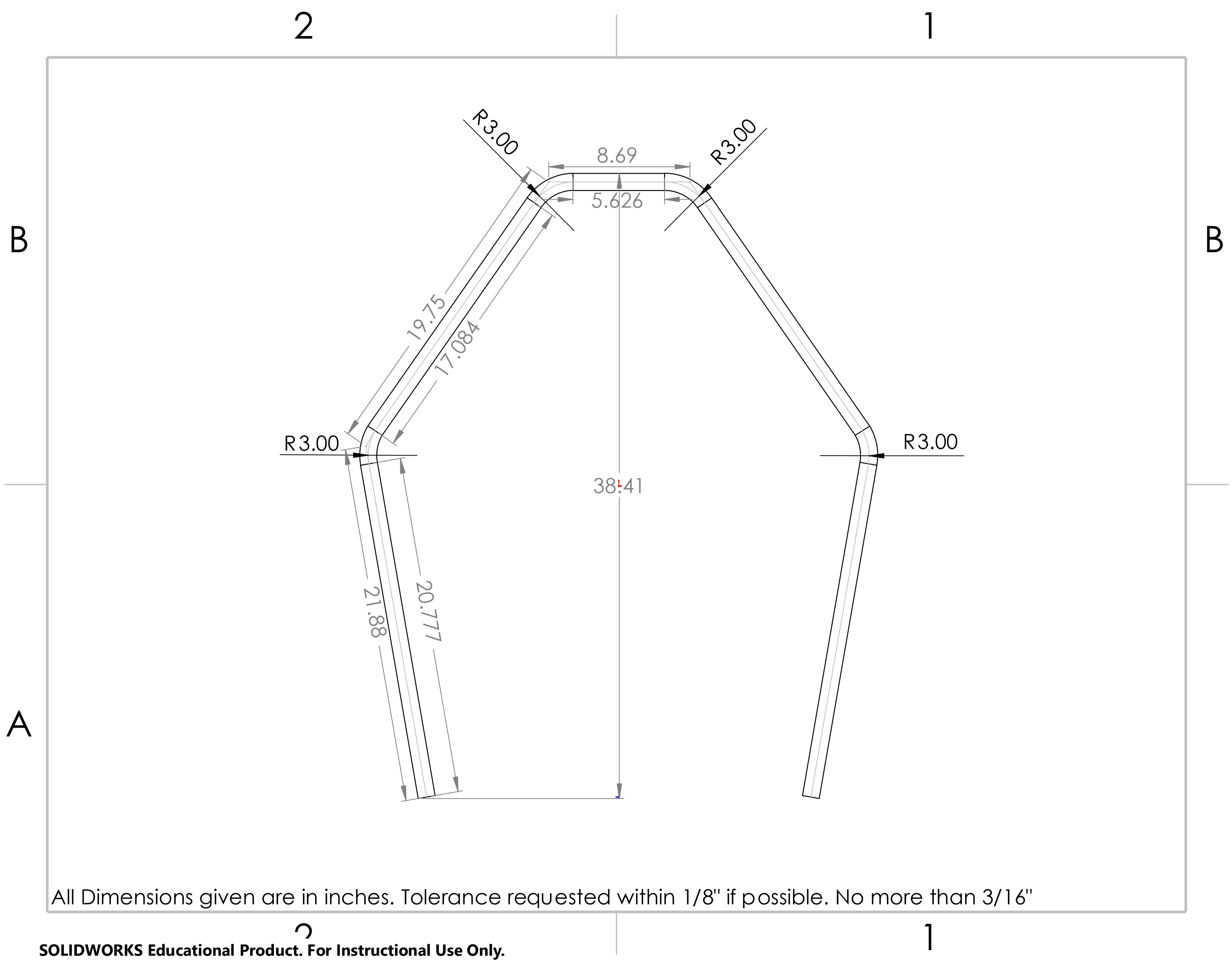
| ITEM NO. | QTY. | LENGTH |
|---|---|---|
| P8_A | 1 | 11.34 |
| P9_B | 2 | 41.63 |
| P9_C | 1 | 30.71 |
| P9_D | 2 | 5.1 |
| P9_E | 2 | 2.03 |
| P9_F | 2 | 7.14 |
| P8_D | 2 | 18.34 |
| P9_A | 2 | 40.38 |
| P8_B | 1 | 19.45 |
| P8_E | 1 | 21.71 |
| P8_E[2] | 1 | 9.6 |
| P8_E[3] | 1 | 12.1 |
| P8_C | 1 | 19.45 |



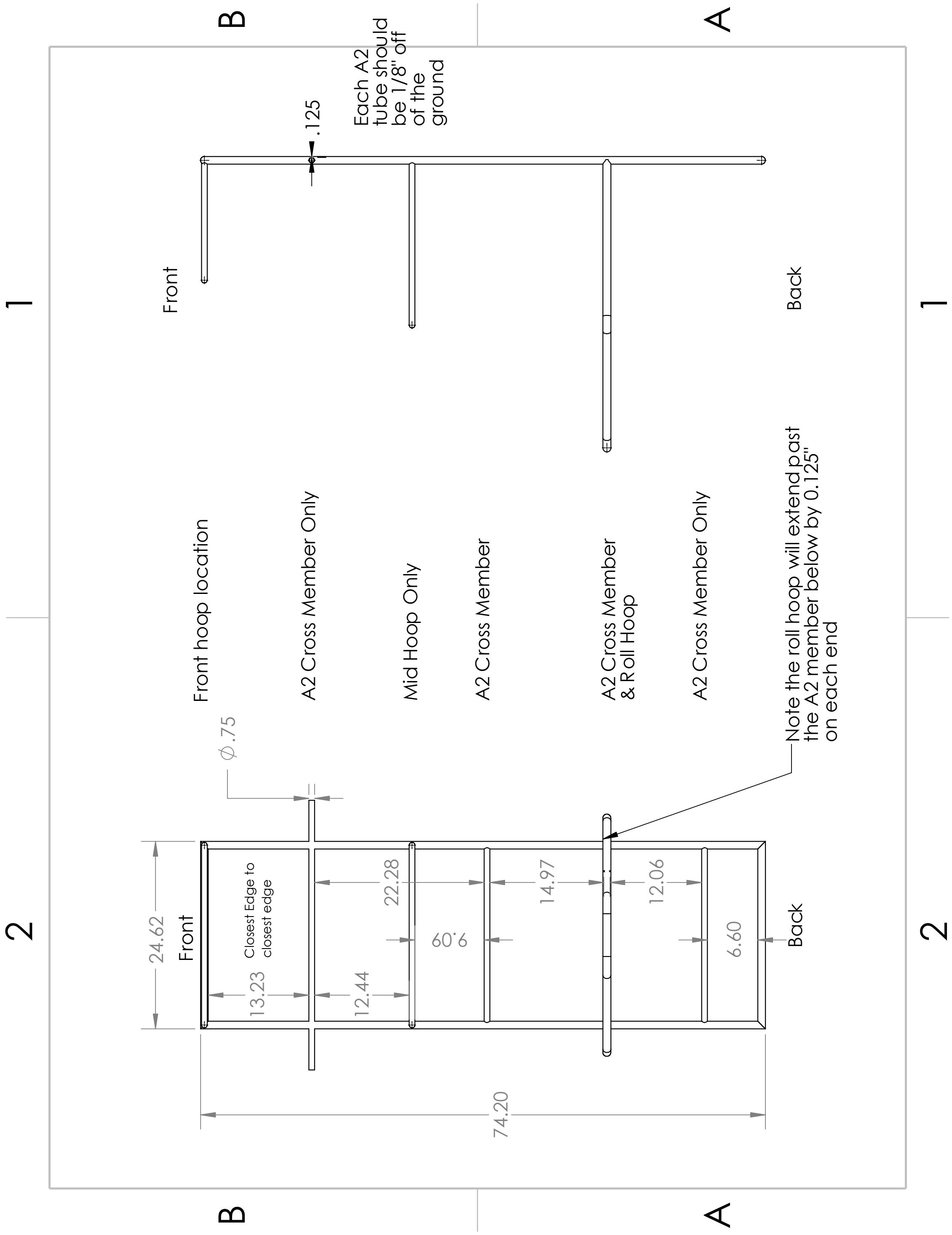

All dimensions given are in inches. Add 0.5 inches to the lengths above

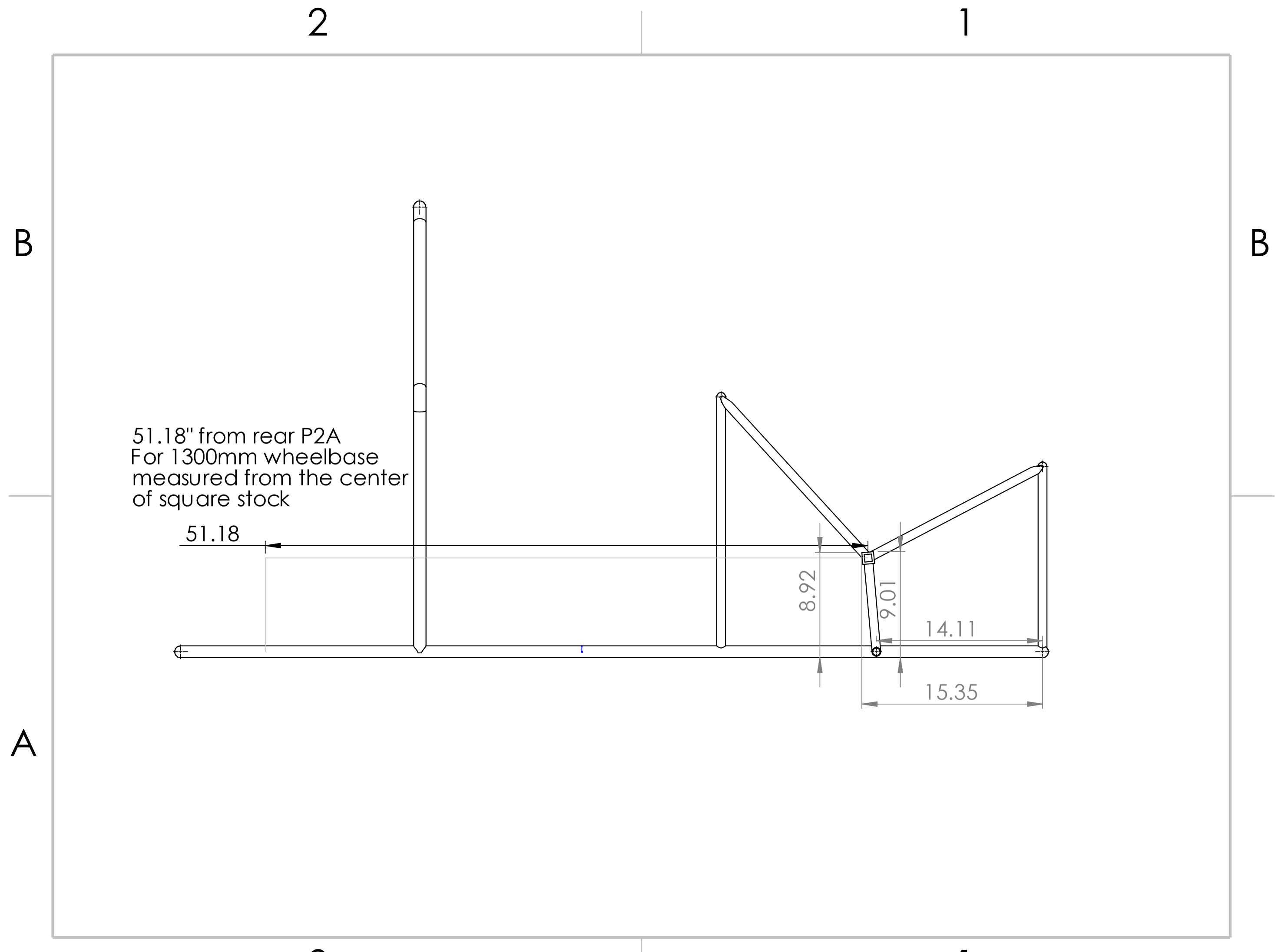
| ITEM NO. | QTY. | LENGTH |
|---|---|---|
| P10_C | 1 | 37.85 |
| P10_E | 1 | 41.3 |
| No Change | 1 | 19.73 |
| P10_B | 1 | 45.15 |
| P10_F | 2 | 17.42 |
| P10_A | 1 | 27.28 |
| P10_G[2] | 1 | 10.2 |
| P10_G | 1 | 10.2 |

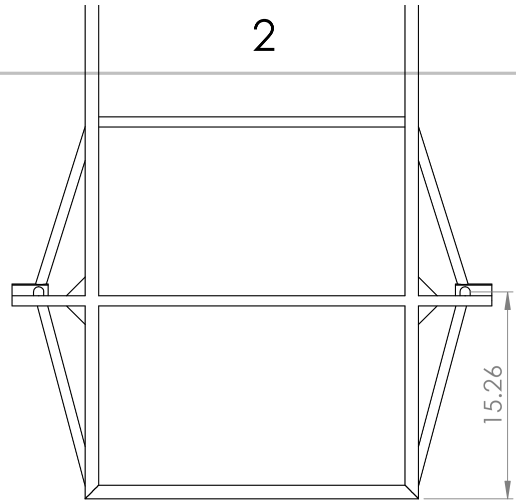





All Dimensions given are in inches. Tolerance requested within 1/8" if possible. No more than 3/16"


B
1
2
A
Each A2 tube should be 1/8" off of the ground
.125
Front
Back
Front hoop location
A2 Cross Member Only
Mid Hoop Only
A2 Cross Member
A2 Cross Member & Roll Hoop
A2 Cross Member Only
Note the roll hoop will extend past the A2 member below by 0.125" on each end
∅.75
24.62
Front
Closest Edge to closest edge
13.23
12.44
22.28
9.09
14.97
12.06
6.60
Back
74.20


2
1
B
B
A
51.18" from rear P2A
For 1300mm wheelbase
measured from the center
of square stock
51.18
8.92
9.01
14.11
15.35
1

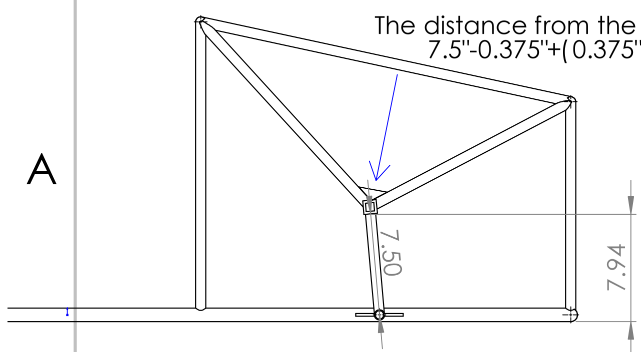



This is the distance from the front most edge of P1 to the center of the tube of P7. Add 0.375" to get 15.635" from the front edge to the location of the plywood plane.

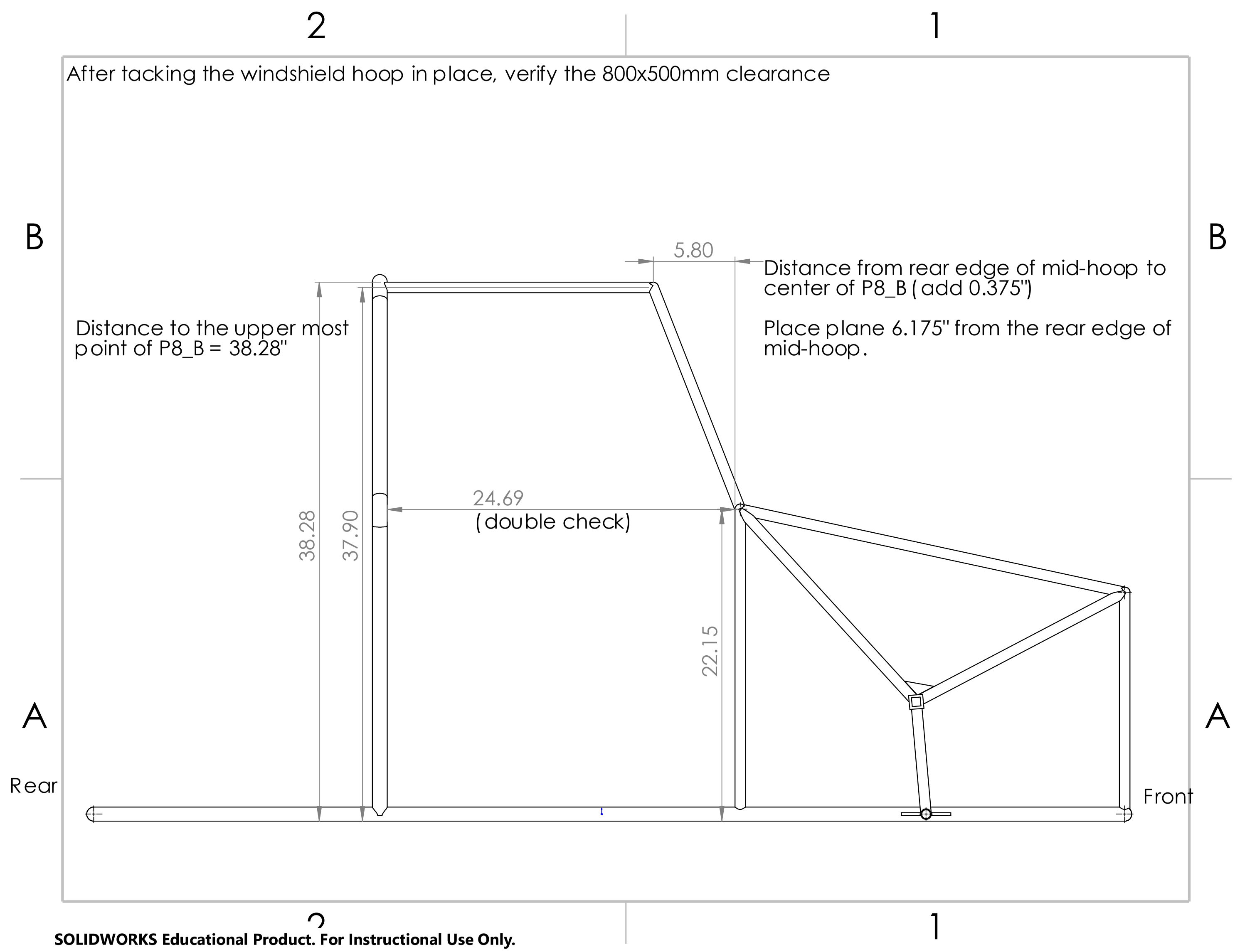
The 7.5" refers to the distance from the center of tube P2 to the center top position of P7_D.

The distance from the top of P2 to the front egde of P7_D =
7.5"-0.375"-(0.375"sin(5)) = 7.092"

The distance from the top of P2 to the rear edge of P7_D =
7.5"-0.375"+(0.375"sin(5)) = 7.158"




This is the height of tube P7_D off of the ground measured at the rear edge. The front edge is (0.375"sin(5deg)+7.94) or 7.97"



2
1
B
A
After tacking the windshield hoop in place, verify the 800x500mm clearance
5.80
Distance from rear edge of mid-hoop to center of P8_B ( add 0.375")
Place plane 6.175" from the rear edge of mid-hoop.
Distance to the upper most point of P8_B = 38.28"
24.69
( double check)
38.28
37.90
22.15
Rear
Front
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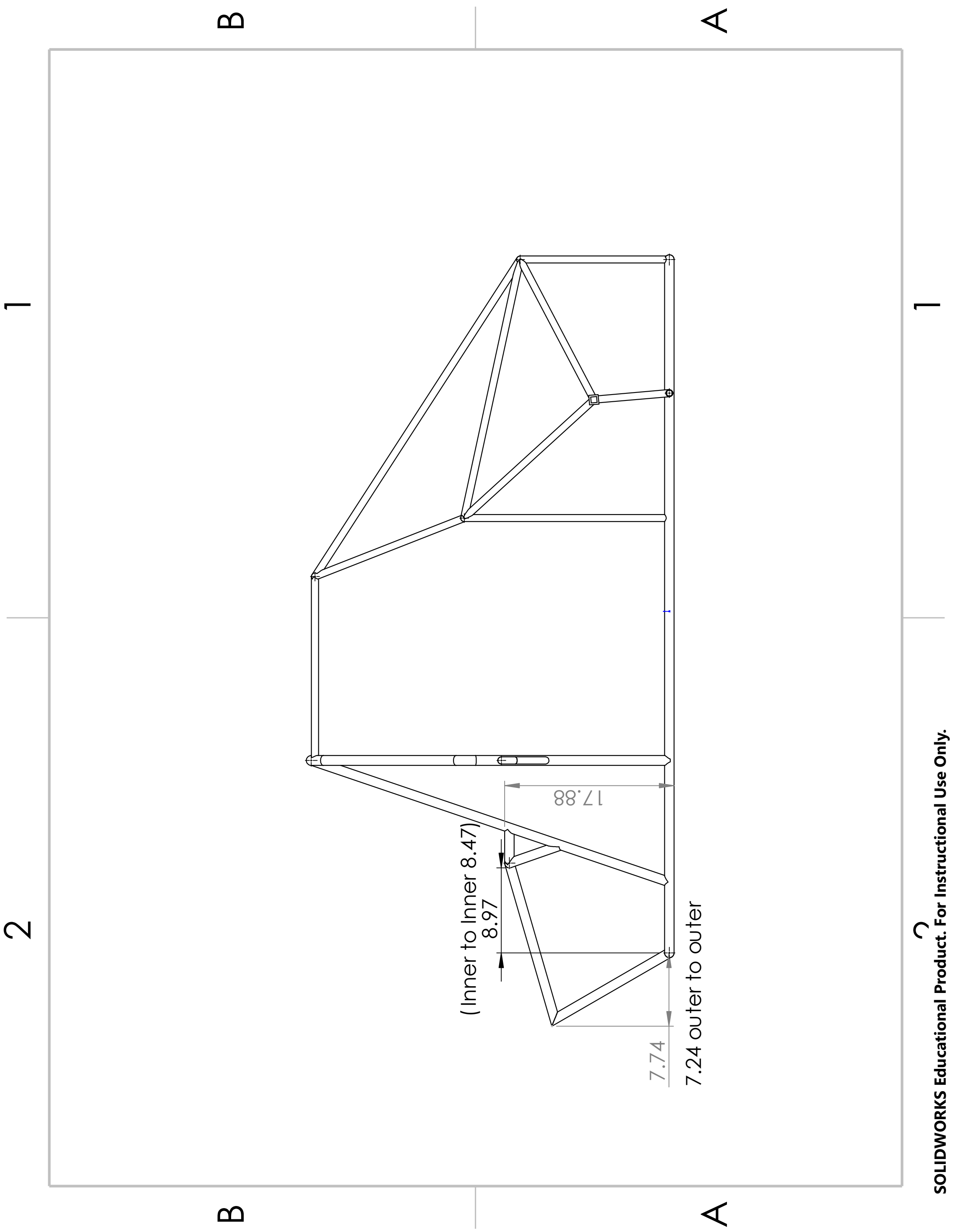
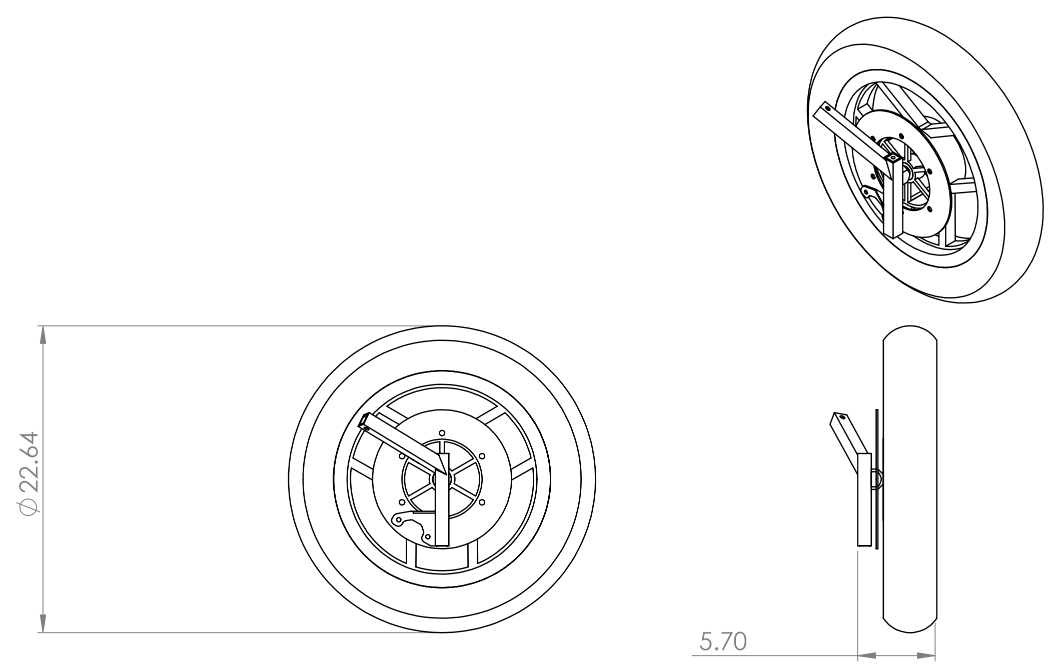
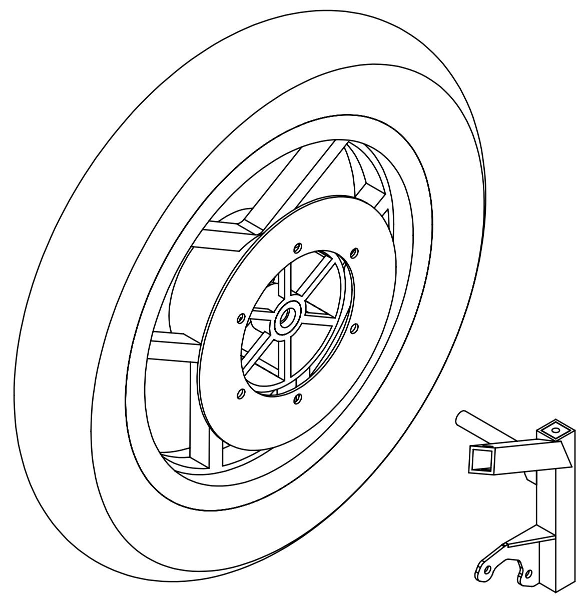

17.88
(Inner to Inner 8.47)
8.97
7.74
7.24 outer to outer
SOLIDWORKS Educational Product. For Instructional Use Only.




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:
# FrontWheel_Left

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 11 | Default |
| SCALE: 1:10 | WEIGHT: | SHEET 1 OF 2 |



| | | |
|---|---|---|
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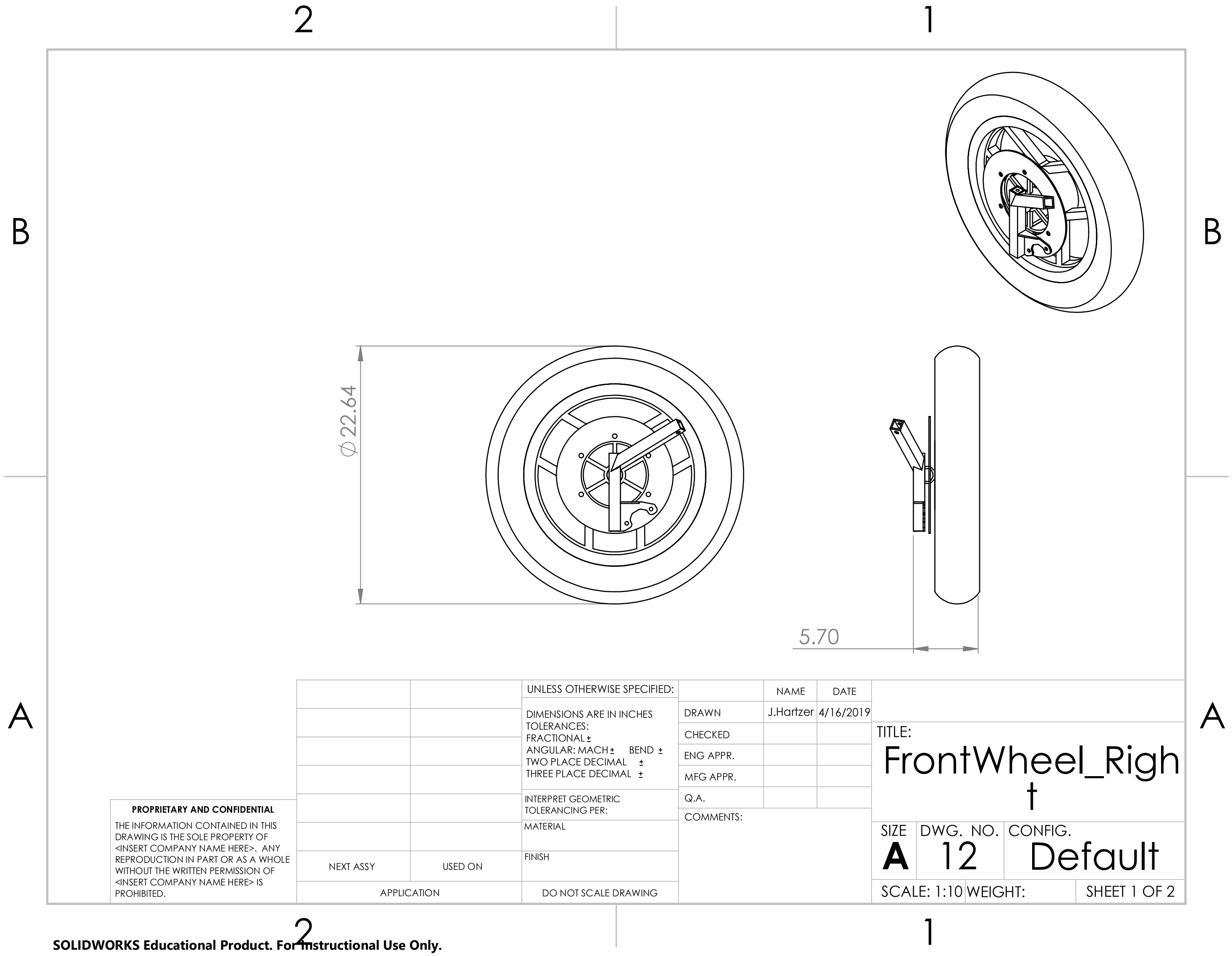
| | NEXT ASSY | USED ON |
| | APPLICATION | |

| | | |
|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME / DATE |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer 4/16/2019 |
| | CHECKED | |
| | ENG APPR. | |
| | MFG APPR. | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | |
| MATERIAL | COMMENTS: | |
| FINISH | | |
| DO NOT SCALE DRAWING | | |

TITLE:
FrontWheel_Left

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 11 | Default |
| SCALE: 1:5 | WEIGHT: | SHEET 2 OF 2 |


2
1
B
A
∅22.64
5.70
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
FrontWheel_Right
SIZE A
DWG. NO. 12
CONFIG. Default
SCALE: 1:10
WEIGHT:
SHEET 1 OF 2
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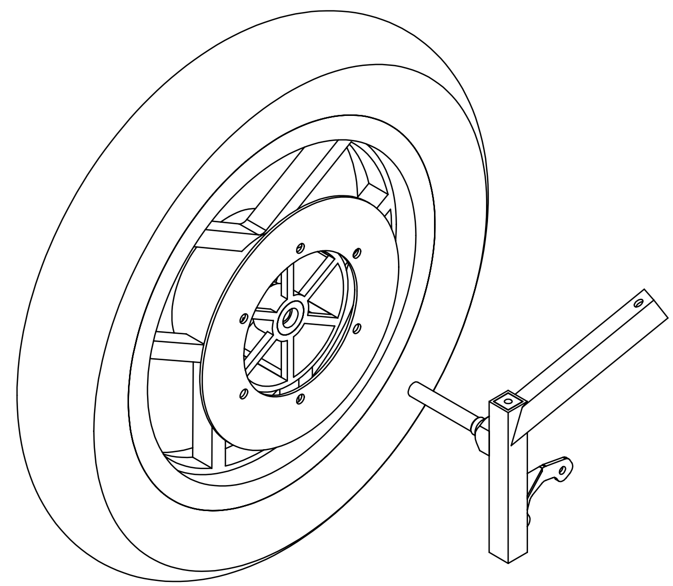
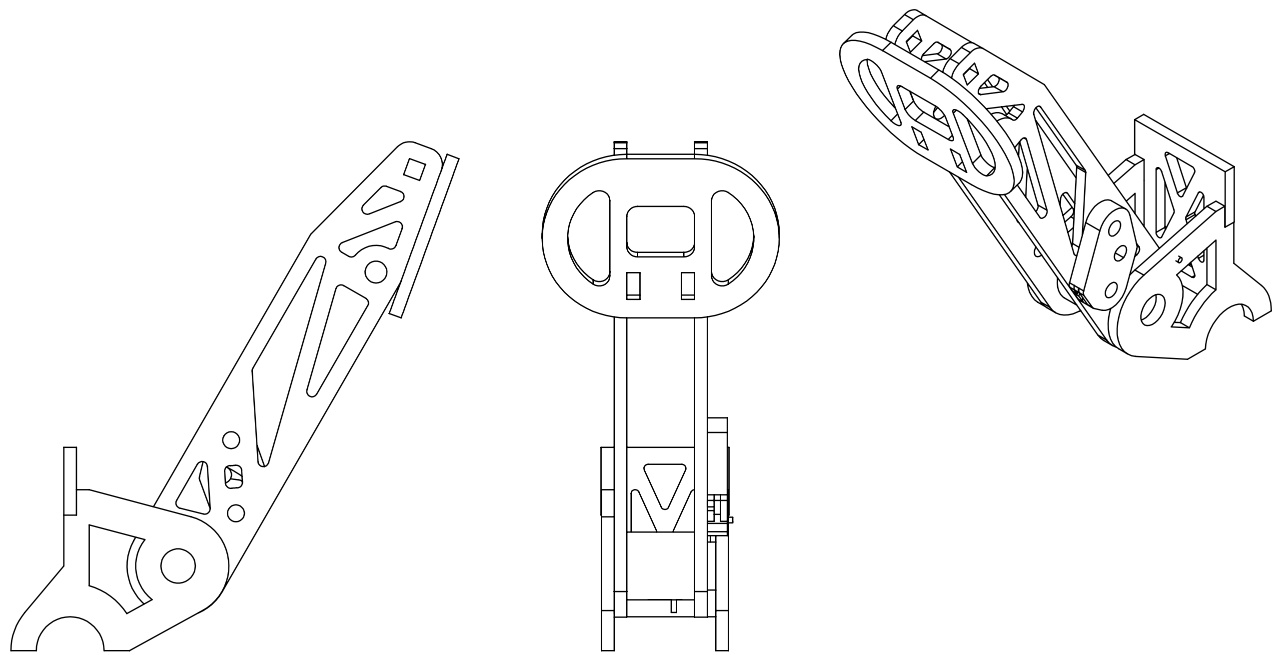


| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:
FrontWheel_Righ
t

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 12 | Default |
| SCALE: 1:5 | WEIGHT: | SHEET 2 OF 2 |



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| | |
|---|---|
| NEXT ASSY | USED ON |
| APPLICATION | |

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

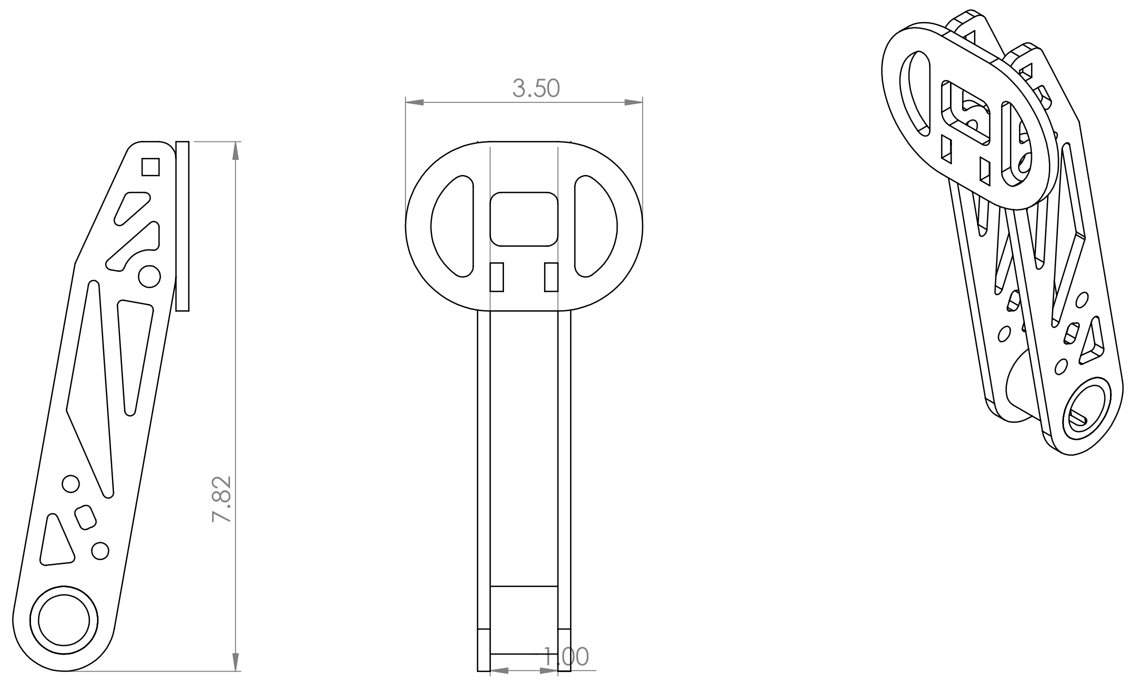
COMMENTS:

TITLE:

Gas_assem

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 13 | Default |

SCALE: 1:2 WEIGHT: SHEET 1 OF 5




| | | | | | |
|---|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: | |
| | CHECKED | | | Gas_assem | |
| | ENG APPR. | | | | |
| | MFG APPR. | | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | | |
| MATERIAL | COMMENTS: | | | SIZE A | DWG. NO. 13 / CONFIG. Pedal |
| FINISH | | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 1:2 | WEIGHT: / SHEET 2 OF 5 |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

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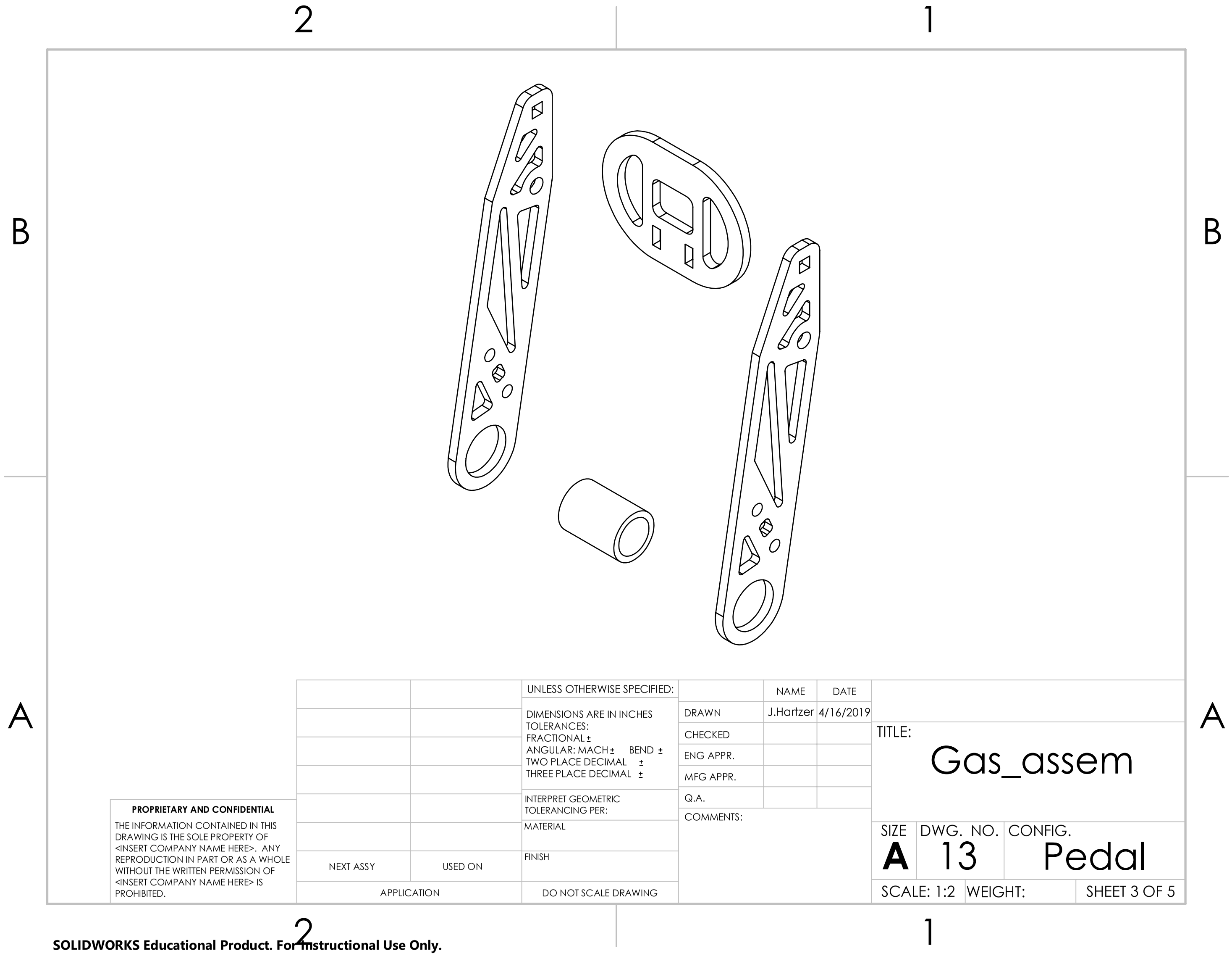
2
1
B
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Gas_assem
SIZE
A
DWG. NO.
13
CONFIG.
Pedal
SCALE: 1:2
WEIGHT:
SHEET 3 OF 5
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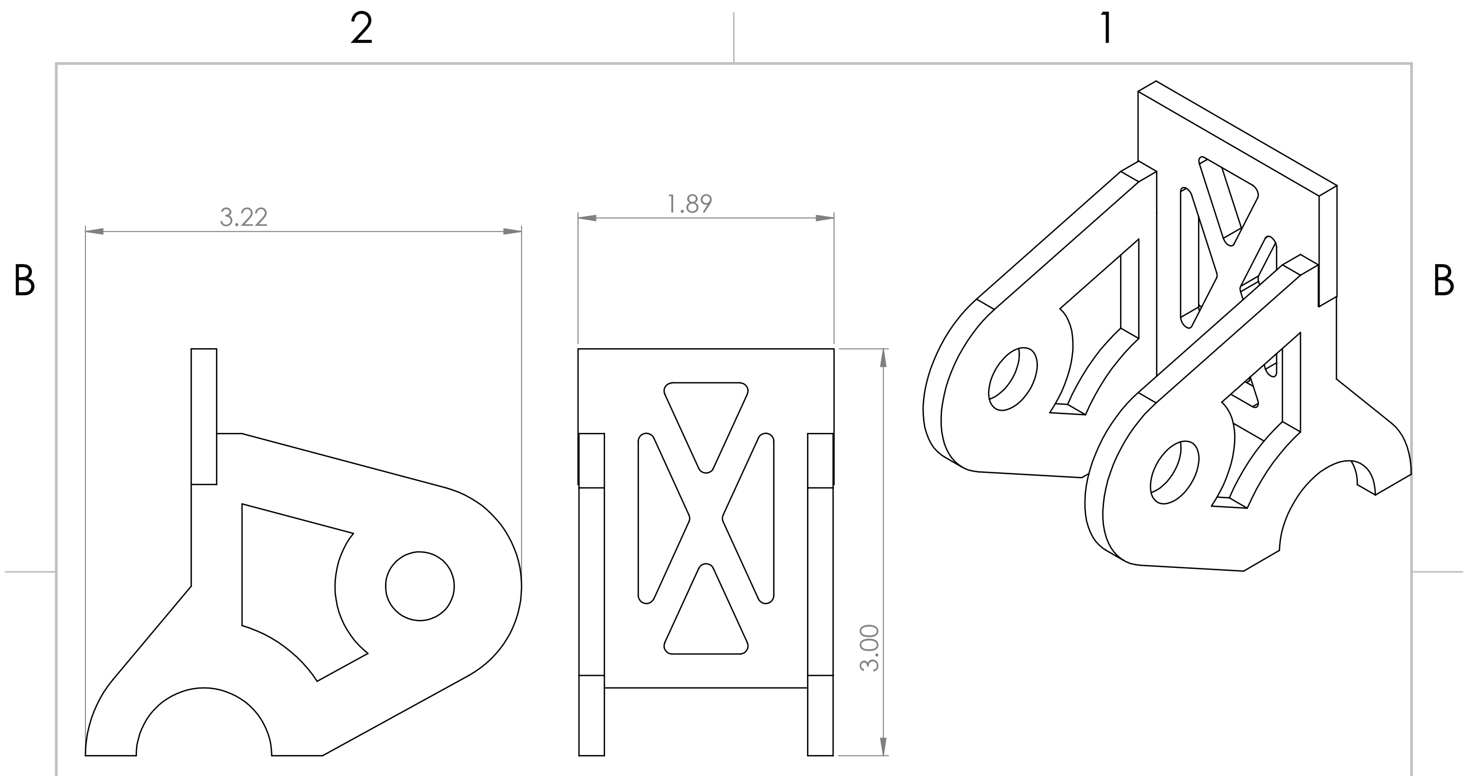


| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: Gas_assem |
| | | | CHECKED | | | |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A · DWG. NO. 13 · CONFIG. GPMount |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:1 · WEIGHT: · SHEET 4 OF 5 |

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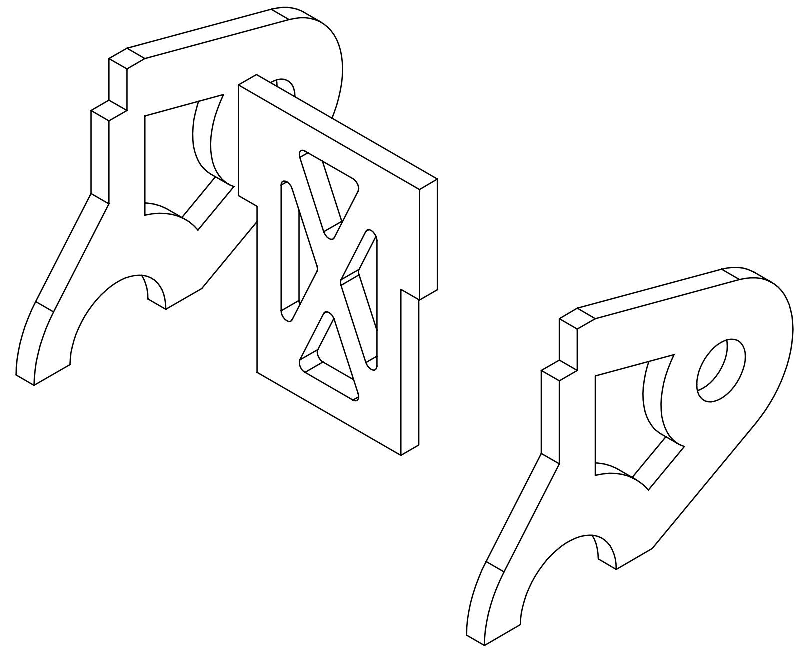
A A 2 1



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|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: |
| | CHECKED | | | Gas_assem |
| | ENG APPR. | | | |
| | MFG APPR. | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| MATERIAL | COMMENTS: | | | SIZE A DWG. NO. 13 CONFIG. GPMount |
| FINISH | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 1:1 WEIGHT: SHEET 5 OF 5 |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

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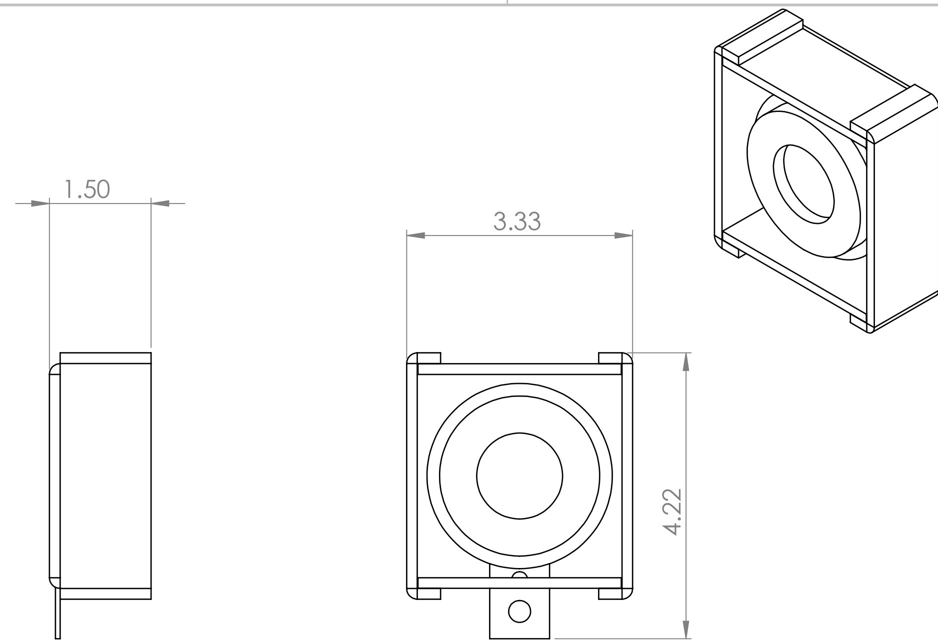
2 1 B A




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

HornInsulator

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 14 | Default |
| SCALE: 1:2 | WEIGHT: | SHEET 1 OF 2 |

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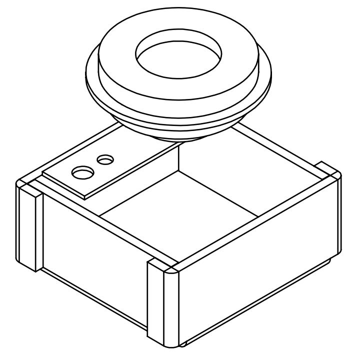
2 1 B A

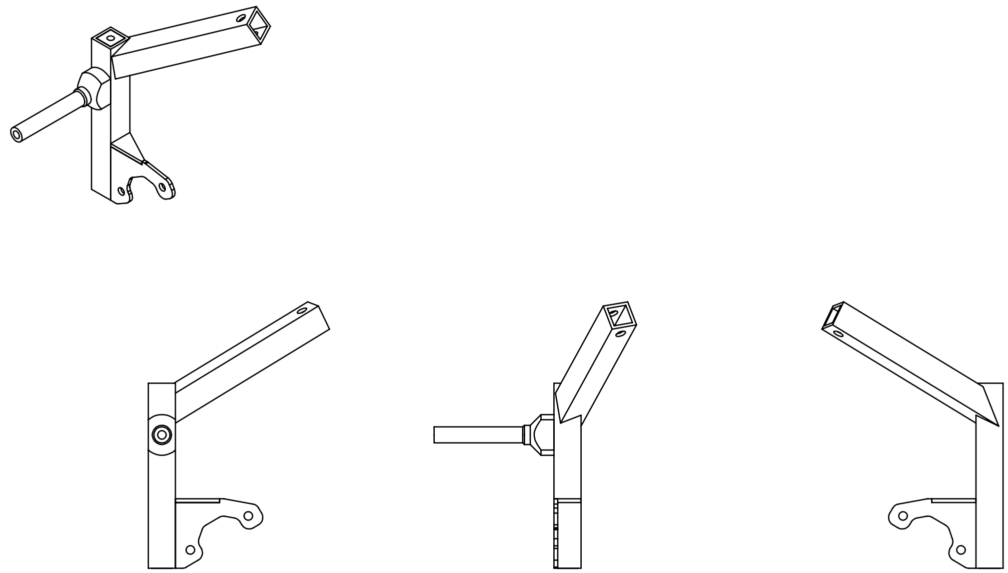


| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

# HornInsulator

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 14 | Default |
| SCALE: 1:2 | WEIGHT: | SHEET 2 OF 2 |



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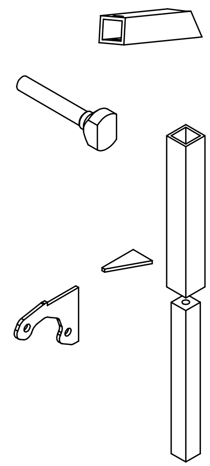
|---|---|---|---|---|---|
| | | UNLESS OTHERWISE SPECIFIED: | | | |
| | | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Knuckle_left

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 15 | Default |
| SCALE: 1:5 | WEIGHT: | SHEET 1 OF 2 |

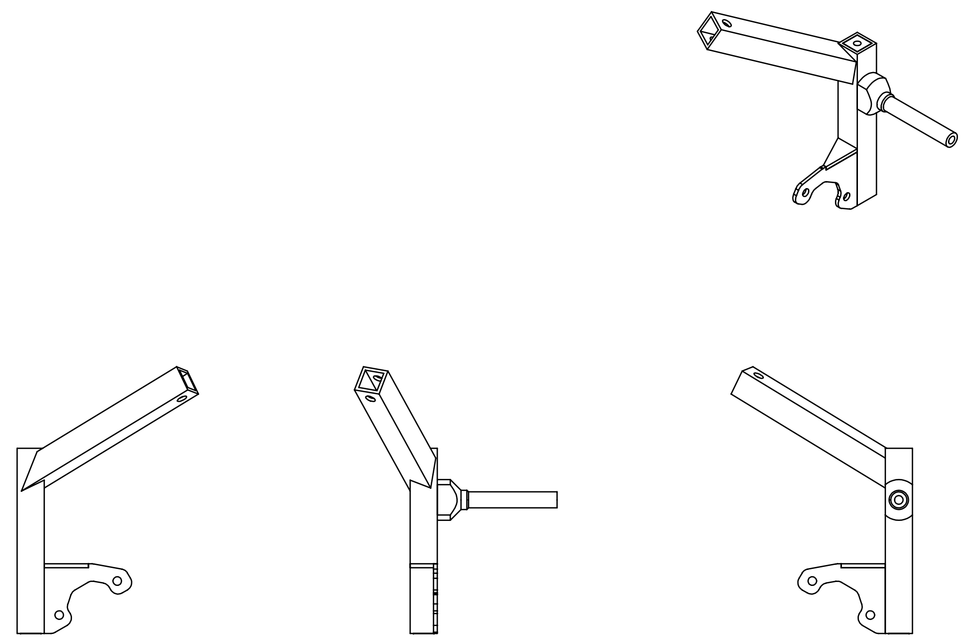


| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

# Knuckle_left

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 15 | Default |
| SCALE: 1:5 | WEIGHT: | SHEET 2 OF 2 |



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE:

Knuckle_right

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 16 | Default |

SCALE: 1:5 WEIGHT: SHEET 1 OF 2

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

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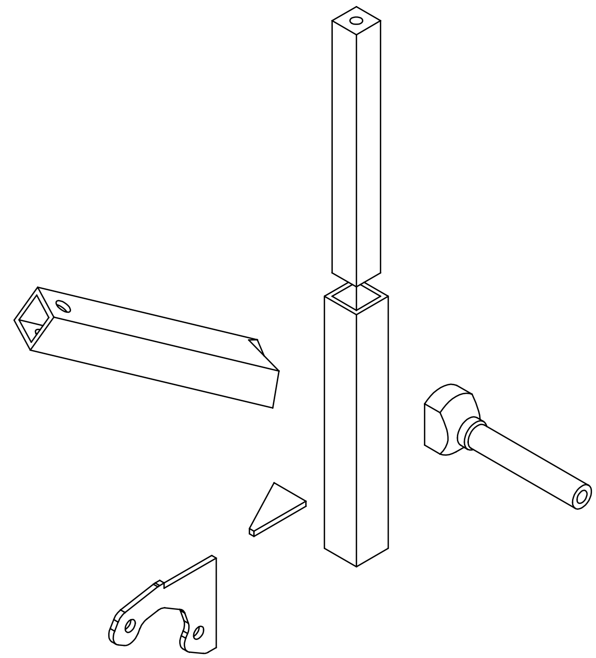
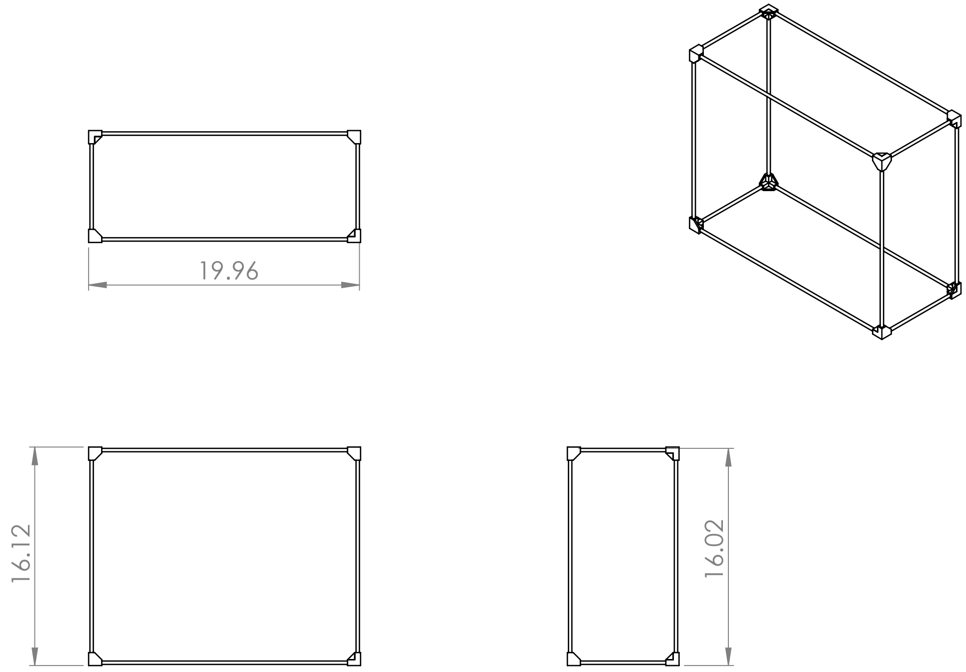


| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | |
| | | | CHECKED | | | TITLE: Knuckle_right |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A / DWG. NO. 16 / CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:3 / WEIGHT: / SHEET 2 OF 2 |




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

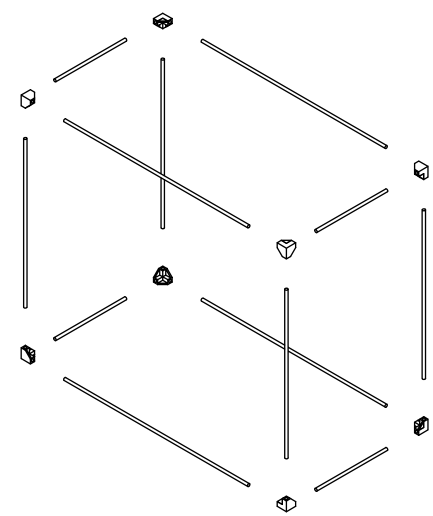
TITLE:

Luggage_assem

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 17 | Default |
| SCALE: 1:10 | WEIGHT: | SHEET 1 OF 2 |

2 1

B B



A A

| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

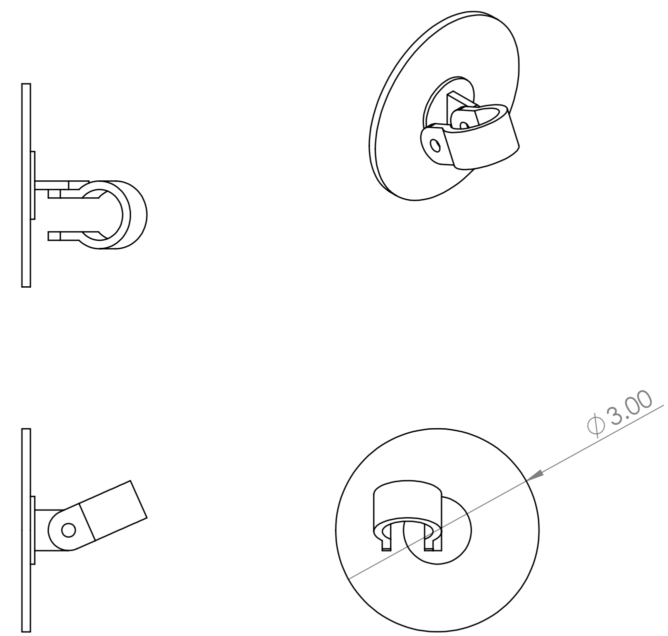
# Luggage_assem

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 17 | Default |

SCALE: 1:10 WEIGHT: SHEET 2 OF 2



2 1




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
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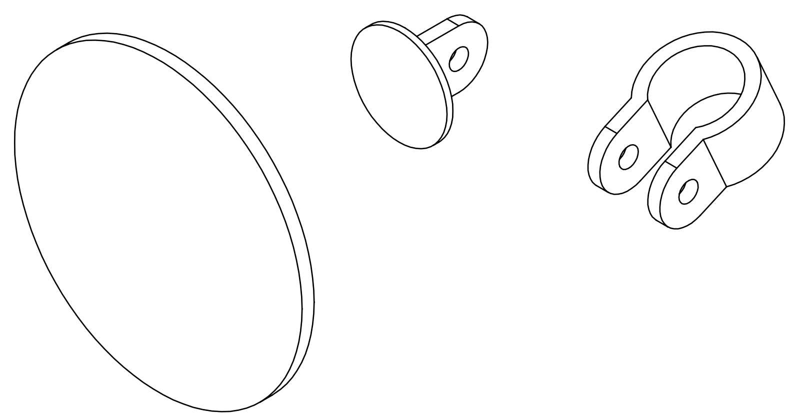
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC<br>TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Mirror_assem

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 18 | Default |
| SCALE: 1:2 | WEIGHT: | SHEET 1 OF 2 |



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
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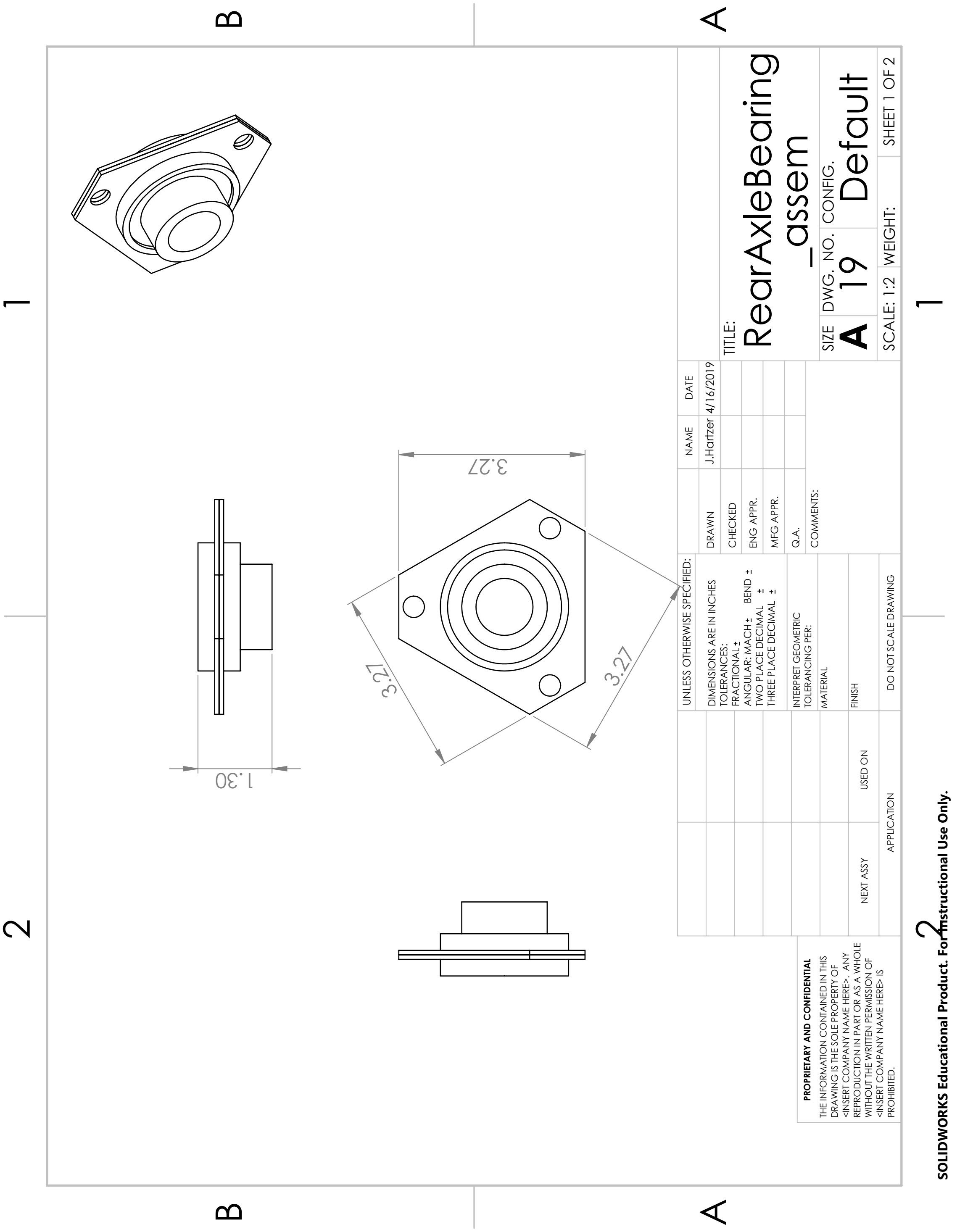
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | |
| | | | CHECKED | | | TITLE: Mirror_assem |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A DWG. NO. 18 CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:1 WEIGHT: SHEET 2 OF 2 |


TITLE:
RearAxleBearing
_assem
SIZE
A
DWG. NO.
19
CONFIG.
Default
SCALE: 1:2
WEIGHT:
SHEET 1 OF 2
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
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ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
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DO NOT SCALE DRAWING
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SOLIDWORKS Educational Product. For Instructional Use Only.

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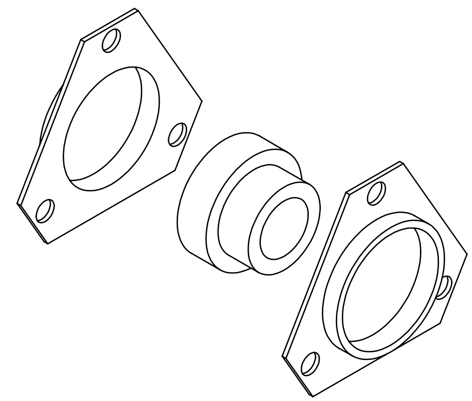

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| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
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| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: |
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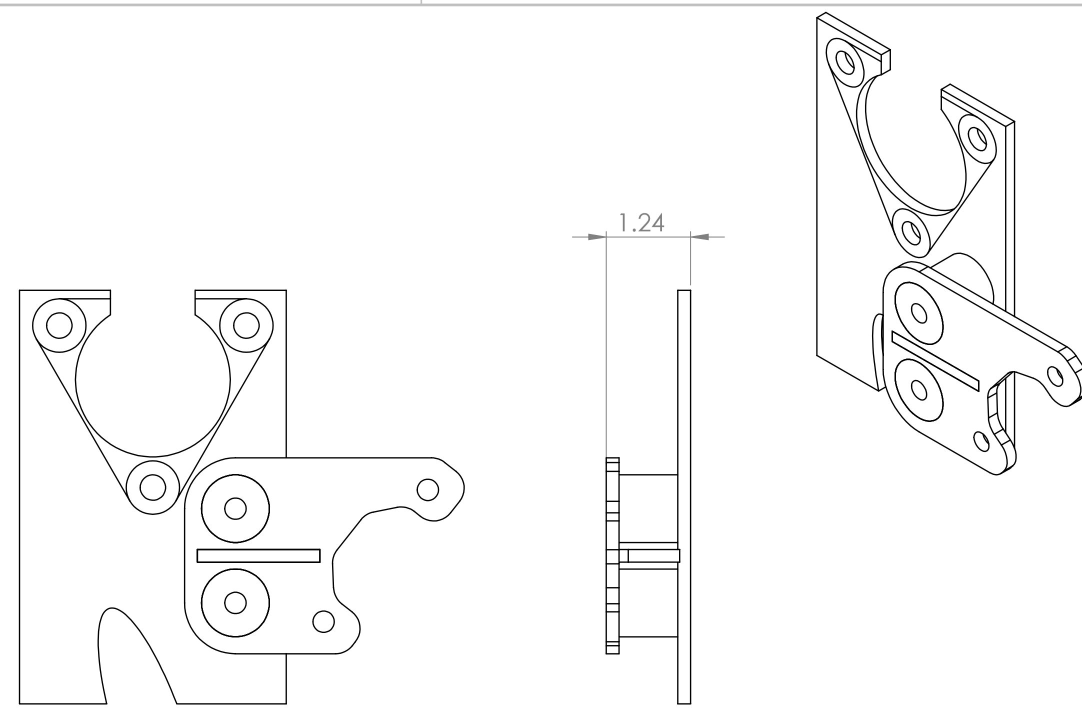
2 | 1




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
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| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
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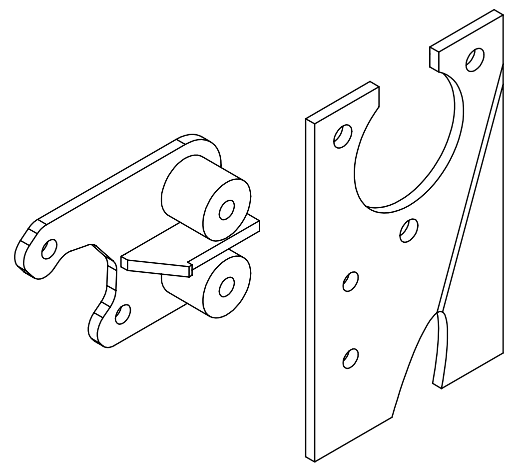
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

RearHangar_left

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 20 | Left |
| SCALE: 1:2 | WEIGHT: | SHEET 1 OF 2 |



| | | | | | |
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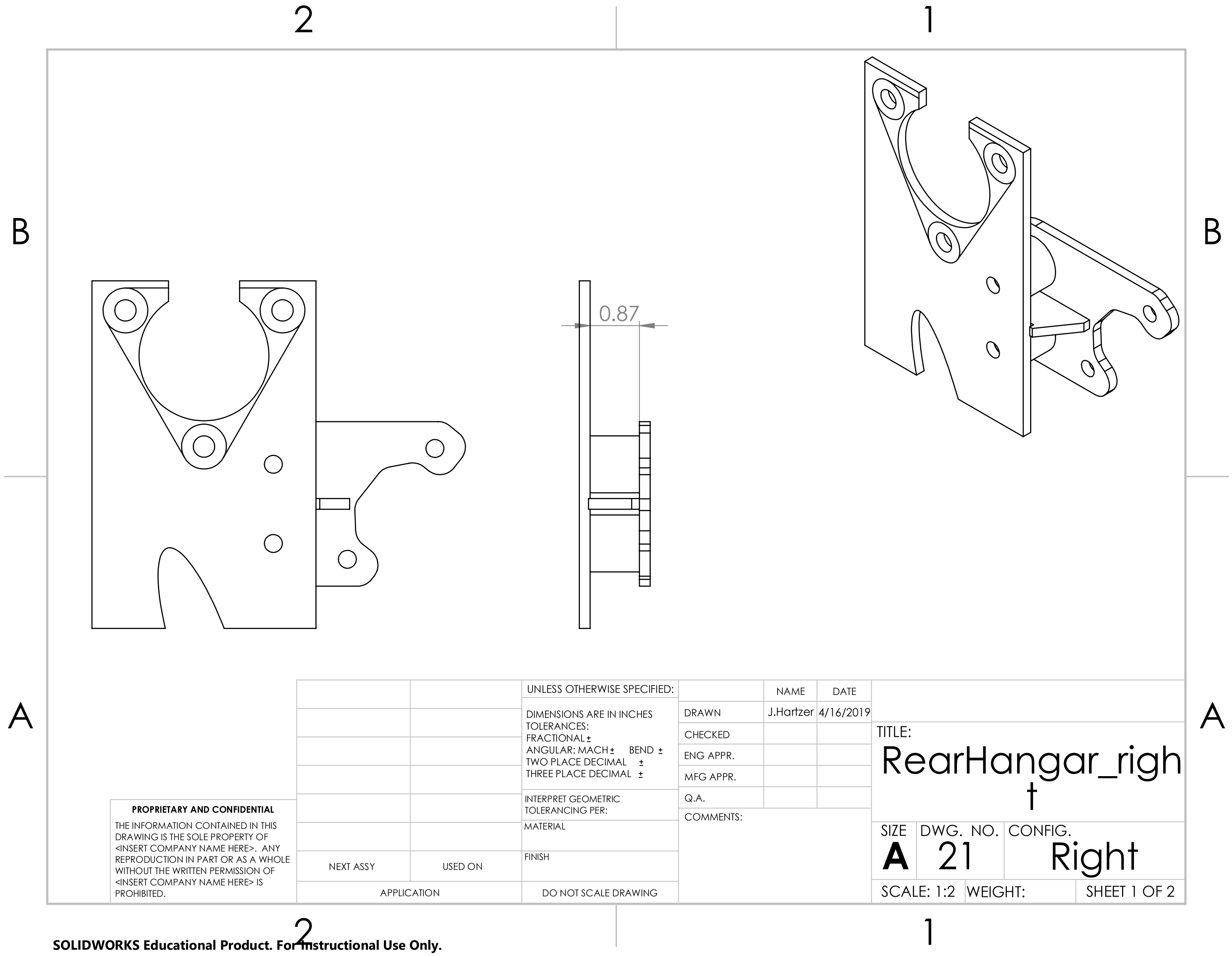
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: | |
| | CHECKED | | | RearHangar_left | |
| | ENG APPR. | | | | |
| | MFG APPR. | | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | | |
| MATERIAL | COMMENTS: | | | SIZE **A** | DWG. NO. 20 / CONFIG. Left |
| FINISH | | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 1:2 | WEIGHT: / SHEET 2 OF 2 |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |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UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
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THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
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DO NOT SCALE DRAWING
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APPLICATION
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J.Hartzer
4/16/2019
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ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
RearHangar_right
SIZE
A
DWG. NO.
21
CONFIG.
Right
SCALE: 1:2
WEIGHT:
SHEET 1 OF 2
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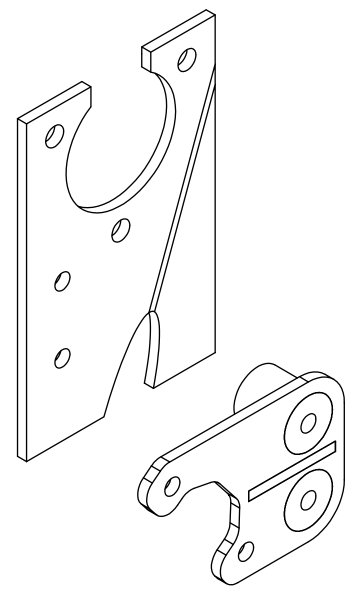

| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
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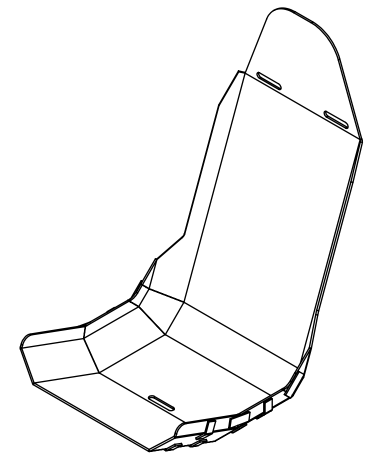
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | |
| | | | CHECKED | | | TITLE:<br>RearHangar_right |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A · DWG. NO. 21 · CONFIG. Right |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:2 · WEIGHT: · SHEET 2 OF 2 |

**PROPRIETARY AND CONFIDENTIAL**

| ITEM NO. | PART NUMBER | SW-Configuration Name(Configuration Name) | QTY. |
|---|---|---|---|
| 1 | Seat | Default | 1 |
| | | Default | - |
| 2 | Bend Supports | 20 | 4 |
| | | 20 | - |
| 3 | Bend Supports | 25 | 3 |
| | | 25 | - |
| 4 | Bend Supports | 45 | 19 |
| | | 45 | - |
| 5 | Bend Supports | Default | 4 |
| | | Default | - |



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
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INTERPRET GEOMETRIC TOLERANCING PER:
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DO NOT SCALE DRAWING

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APPLICATION

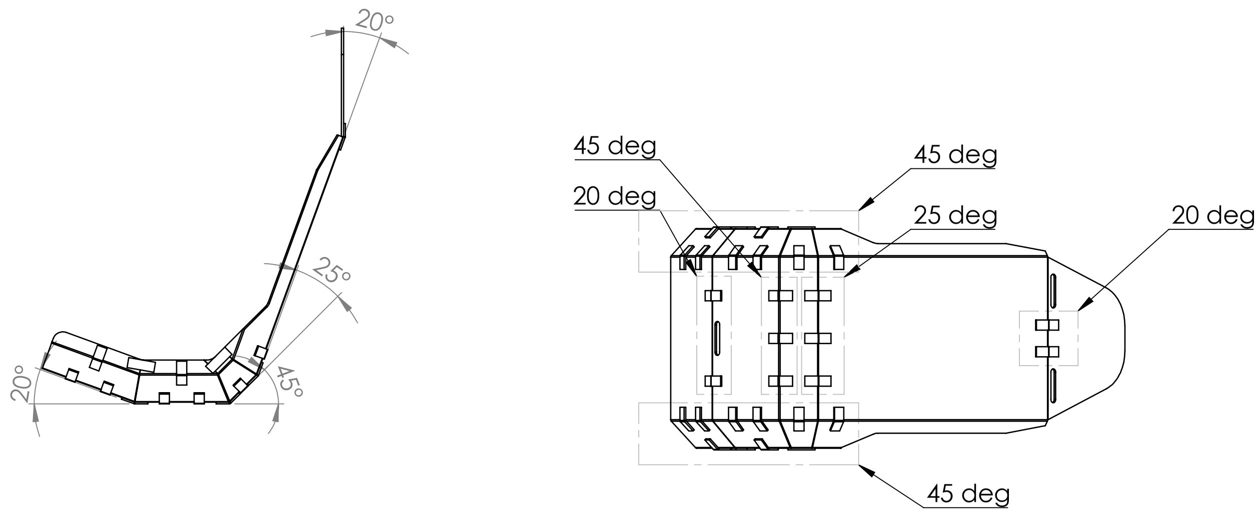
| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE: Seat_assem

SIZE A | DWG. NO. 22 | CONFIG. Default

SCALE: 1:10 WEIGHT: SHEET 1 OF 2

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| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
| | | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: Seat_assem |
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| | | | ENG APPR. | | | |
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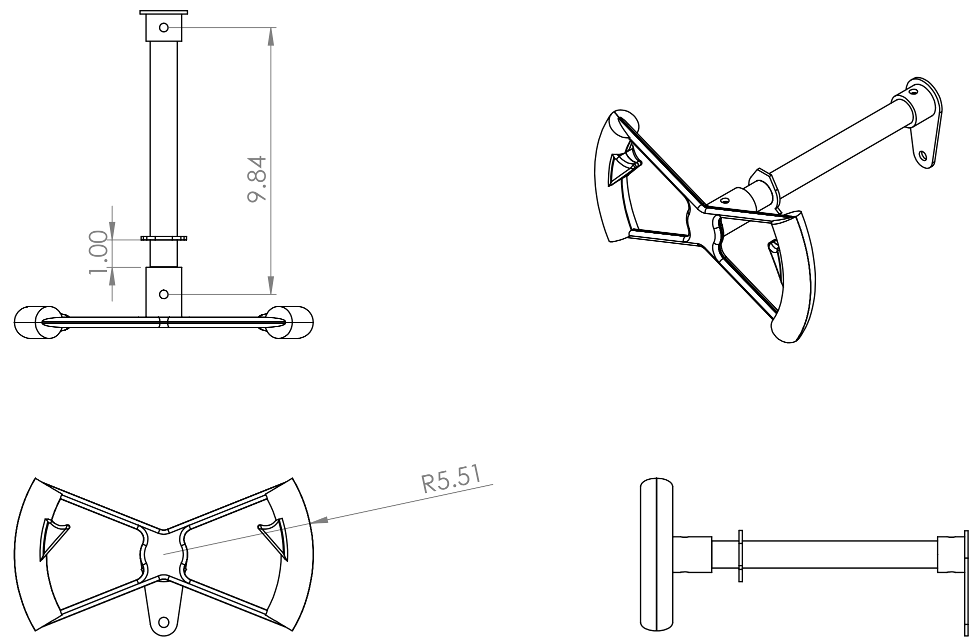
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A · DWG. NO. 22 · CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:10 · WEIGHT: · SHEET 2 OF 2 |

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| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: Steering Column_assem | | |
| | CHECKED | | | | | |
| | ENG APPR. | | | | | |
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| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | | | |
| MATERIAL | COMMENTS: | | | SIZE A | DWG. NO. 23 | CONFIG. Default |
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| DO NOT SCALE DRAWING | | | | SCALE: 1:5 | WEIGHT: | SHEET 1 OF 2 |

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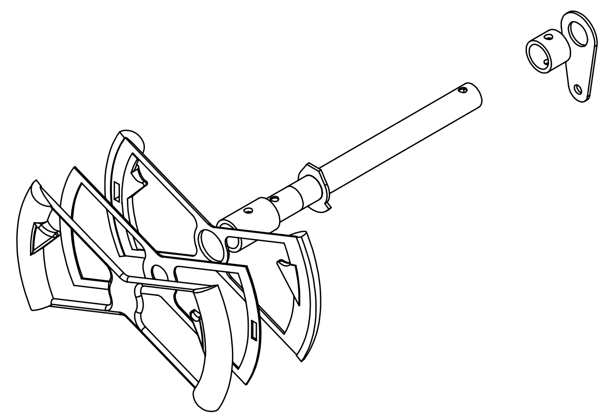
| APPLICATION | |



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TITLE:

Steering Column_assem

| SIZE | DWG. NO. | CONFIG. |
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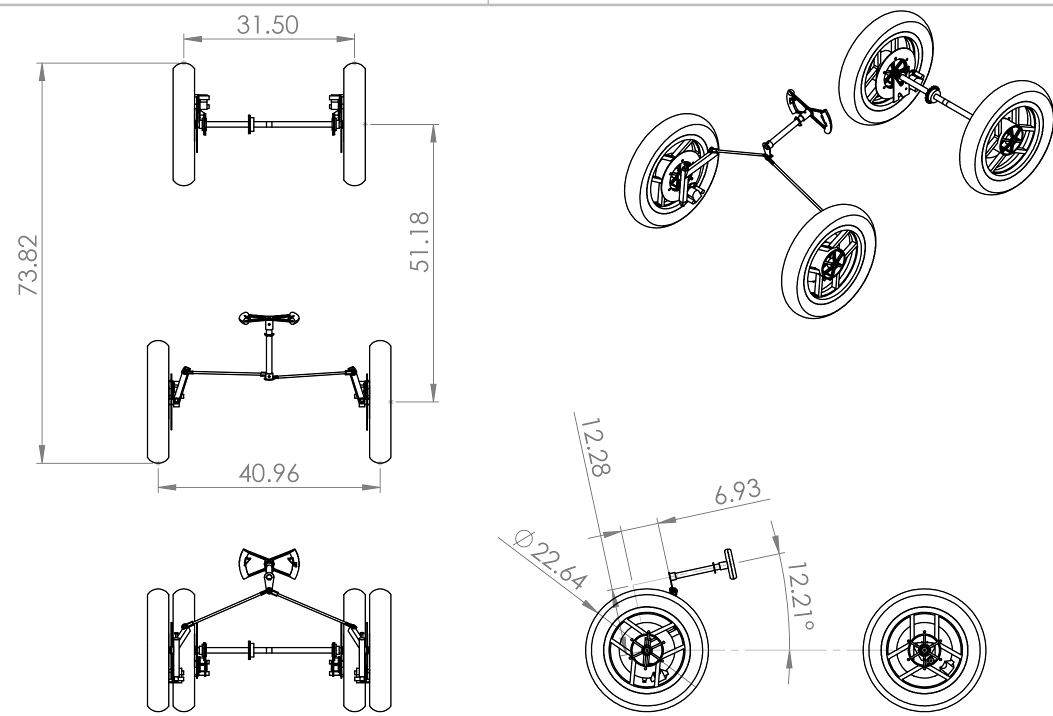
| SCALE: 1:5 | WEIGHT: | SHEET 2 OF 2 |

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| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: |
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| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
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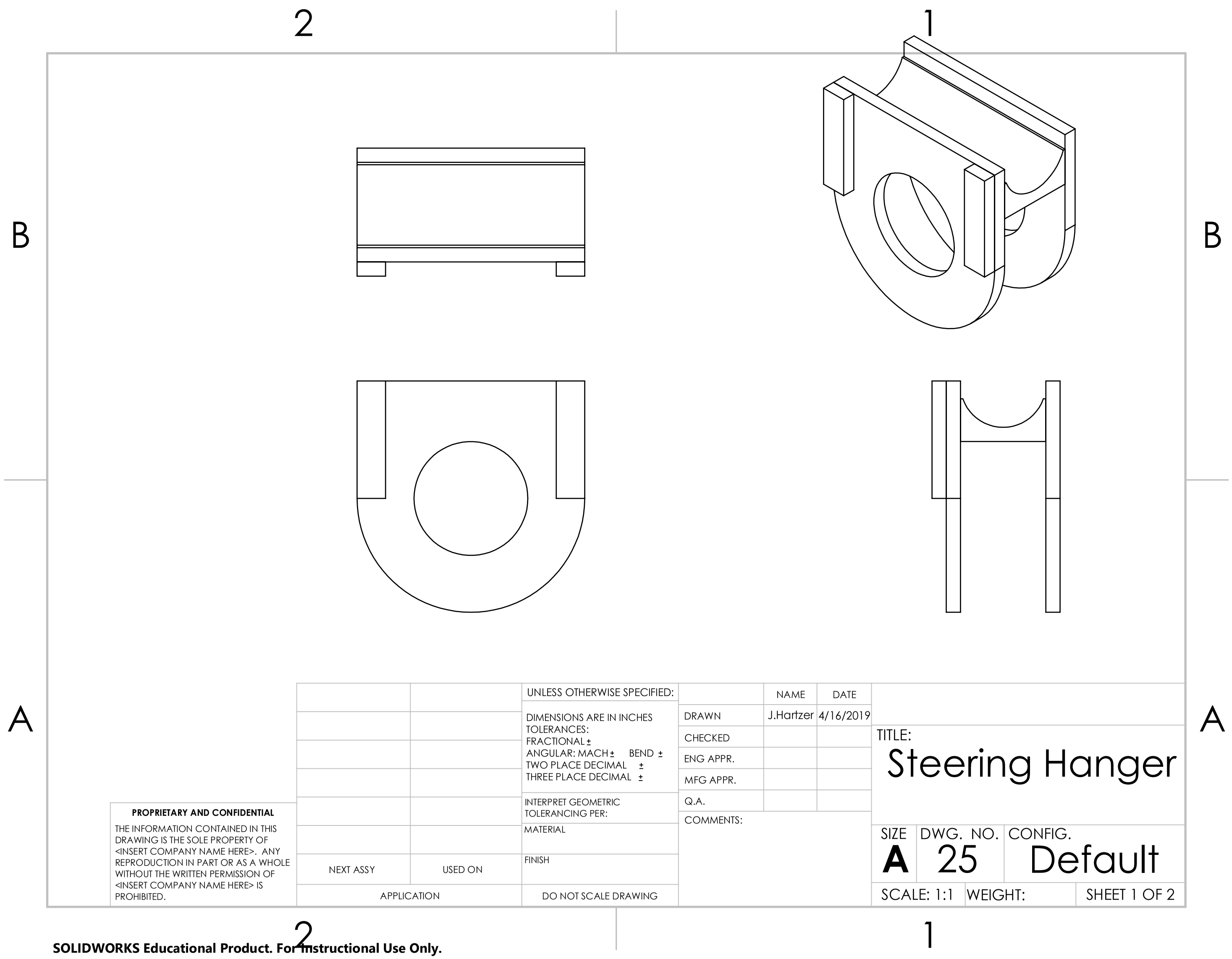
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:25 · WEIGHT: · SHEET 1 OF 1 |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ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
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INTERPRET GEOMETRIC TOLERANCING PER:
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CONFIG.
Default
SCALE: 1:1
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SHEET 1 OF 2
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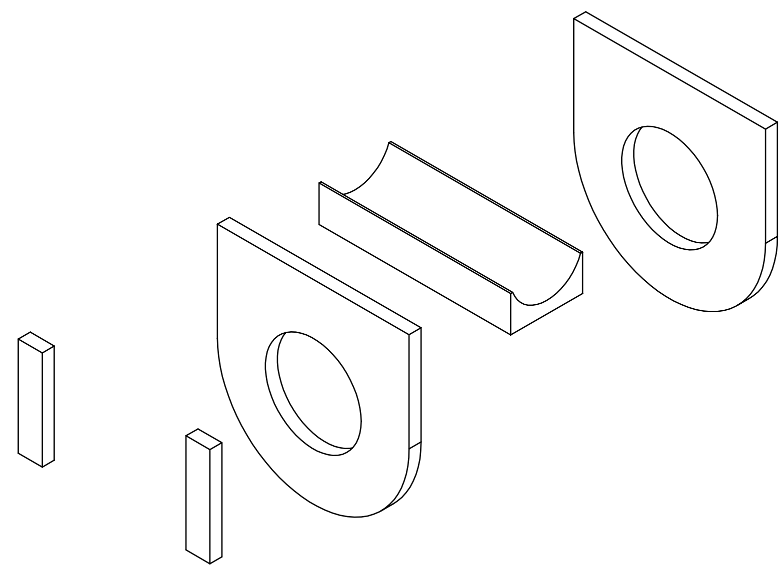

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| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: |
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| MATERIAL | COMMENTS: | | | SIZE A · DWG. NO. 25 · CONFIG. Default |
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| DO NOT SCALE DRAWING | | | | SCALE: 1:1 · WEIGHT: · SHEET 2 OF 2 |

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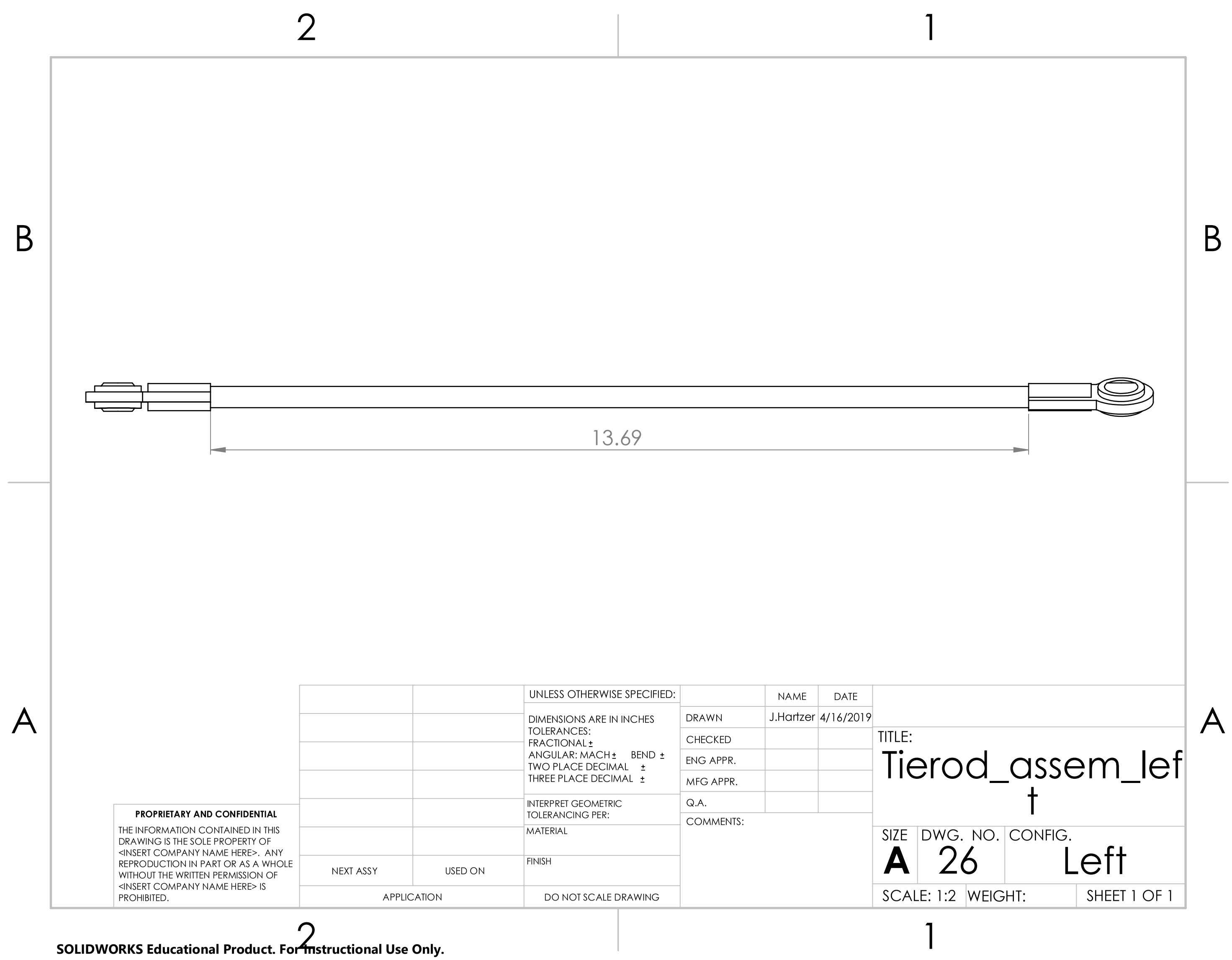

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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
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Tierod_assem_left
SIZE A
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CONFIG. Left
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
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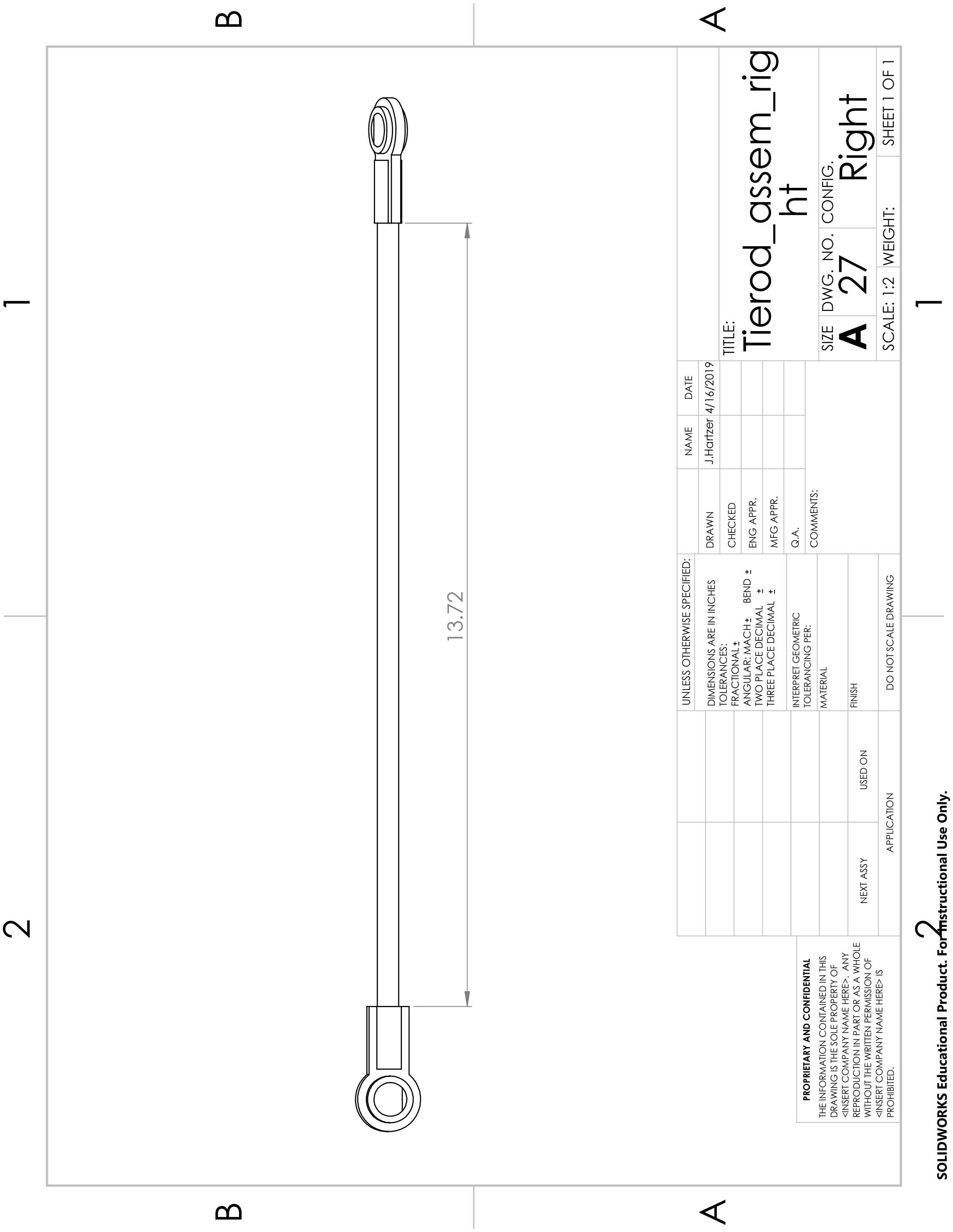
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APPLICATION
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TOLERANCES:
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MFG APPR.
Q.A.
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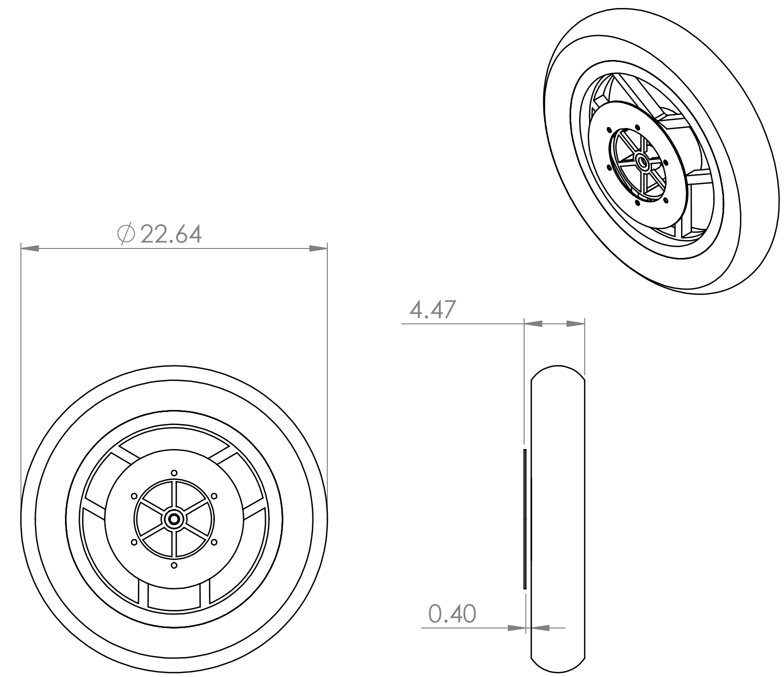
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
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| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
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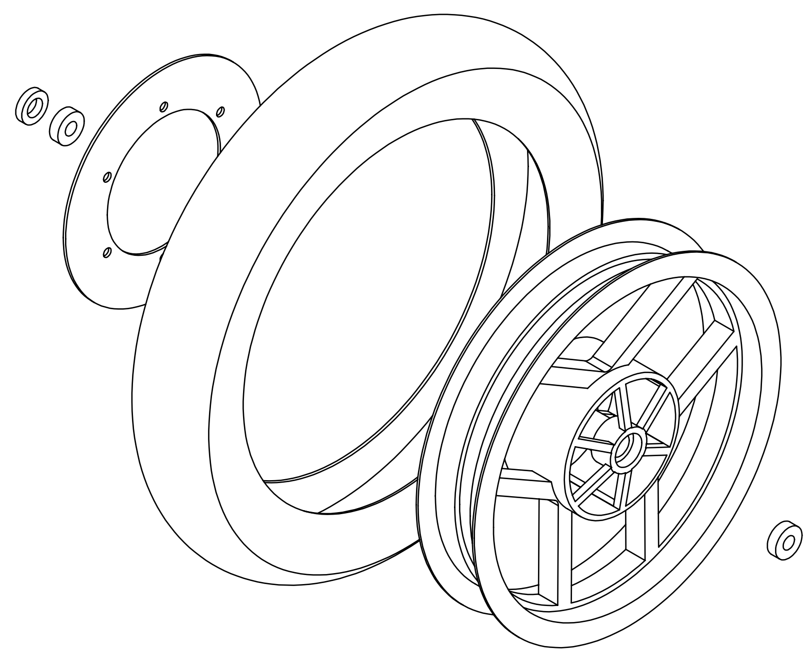
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Wheel Assem_front

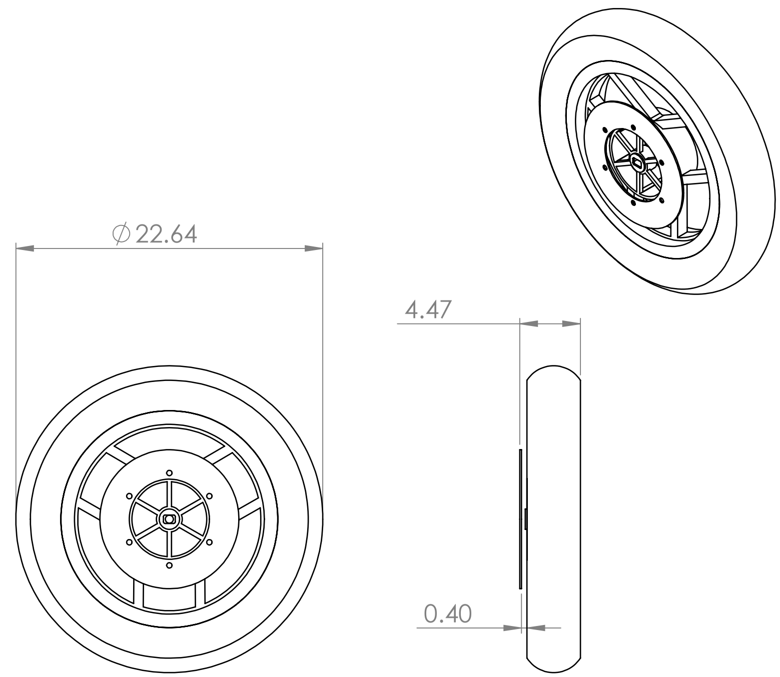
| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 28 | Front |
| SCALE: 1:10 | WEIGHT: | SHEET 1 OF 2 |



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | |
| | | | CHECKED | | | TITLE: Wheel Assem_front |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A · DWG. NO. 28 · CONFIG. Front |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:5 · WEIGHT: · SHEET 2 OF 2 |

2 1

B




A

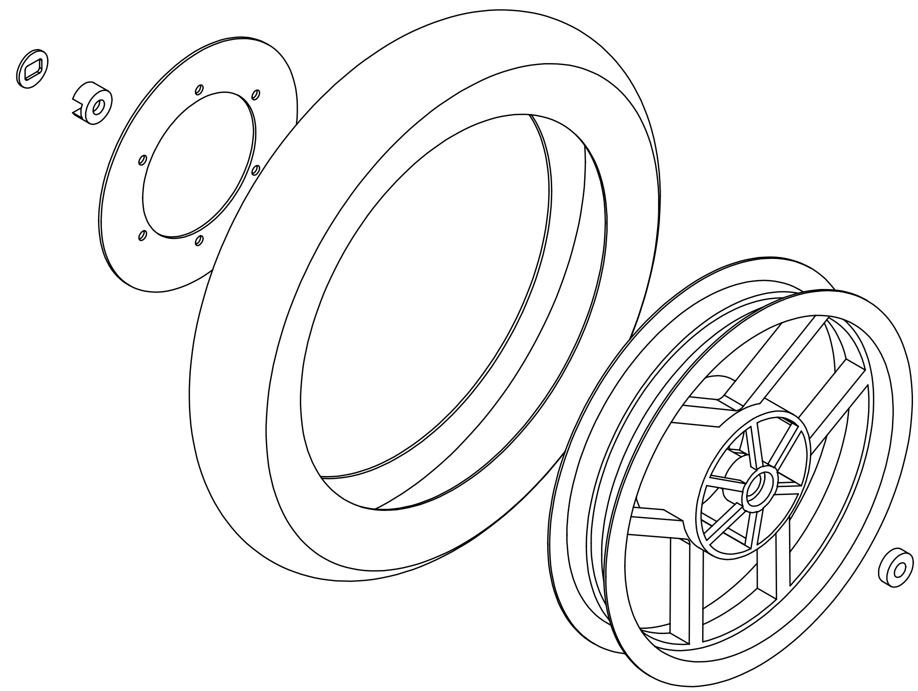
| | | | | | |
|---|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | | |
| DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: | Wheel Assem_rear |
| | CHECKED | | | | |
| | ENG APPR. | | | | |
| | MFG APPR. | | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | | |
| MATERIAL | COMMENTS: | | | SIZE A | DWG. NO. 29 | CONFIG. Rear |
| FINISH | | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 1:10 | WEIGHT: | SHEET 1 OF 2 |

| | |
|---|---|
| NEXT ASSY | USED ON |
| APPLICATION | |

**PROPRIETARY AND CONFIDENTIAL**



2 1



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | |
| | | | CHECKED | | | TITLE:<br>Wheel<br>Assem_rear |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC<br>TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL | COMMENTS: | | | SIZE A · DWG. NO. 29 · CONFIG. Rear |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:5 · WEIGHT: · SHEET 2 OF 2 |

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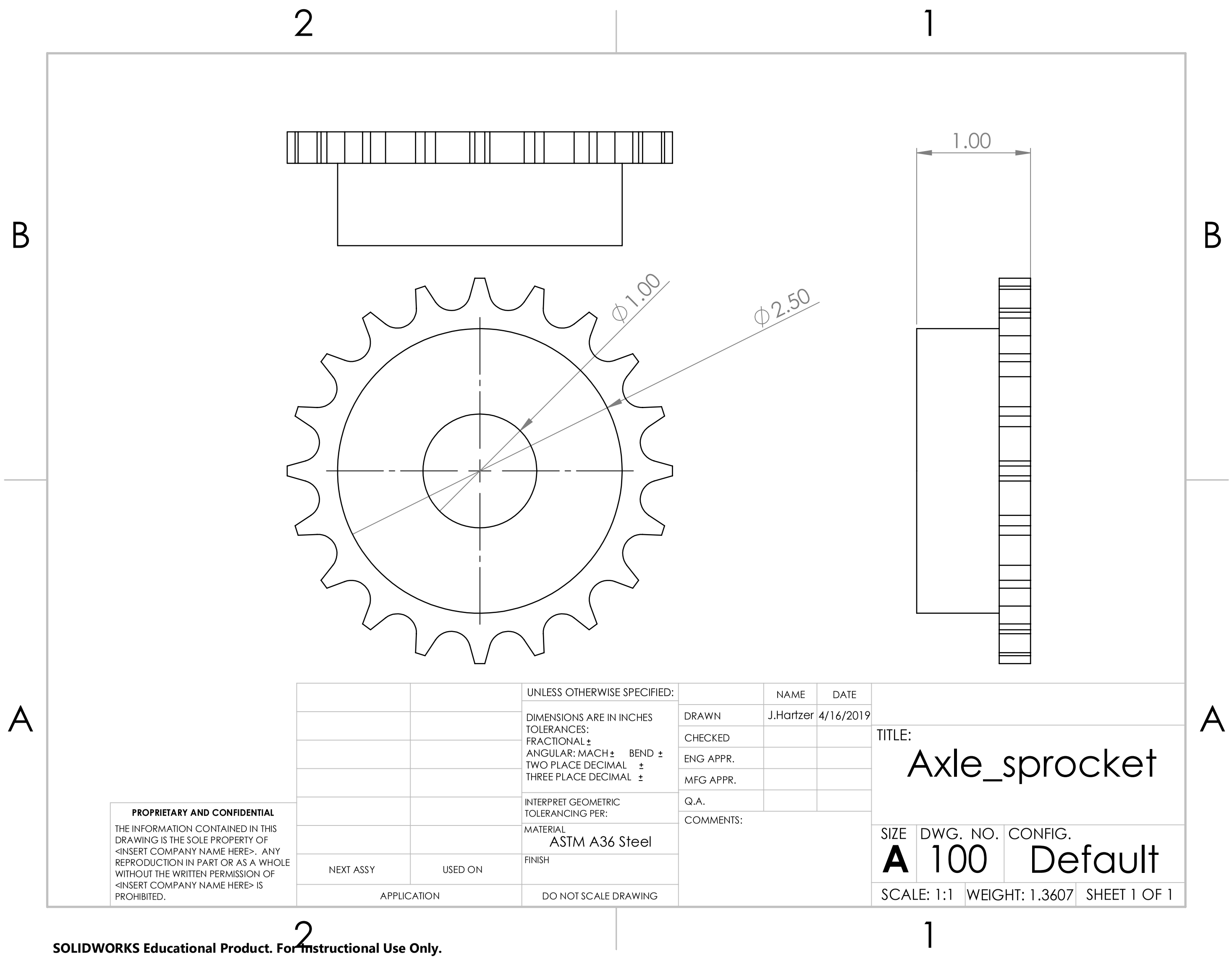

2
1
B
A
1.00
Ø1.00
Ø2.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Axle_sprocket
SIZE
A
DWG. NO.
100
CONFIG.
Default
SCALE: 1:1
WEIGHT: 1.3607
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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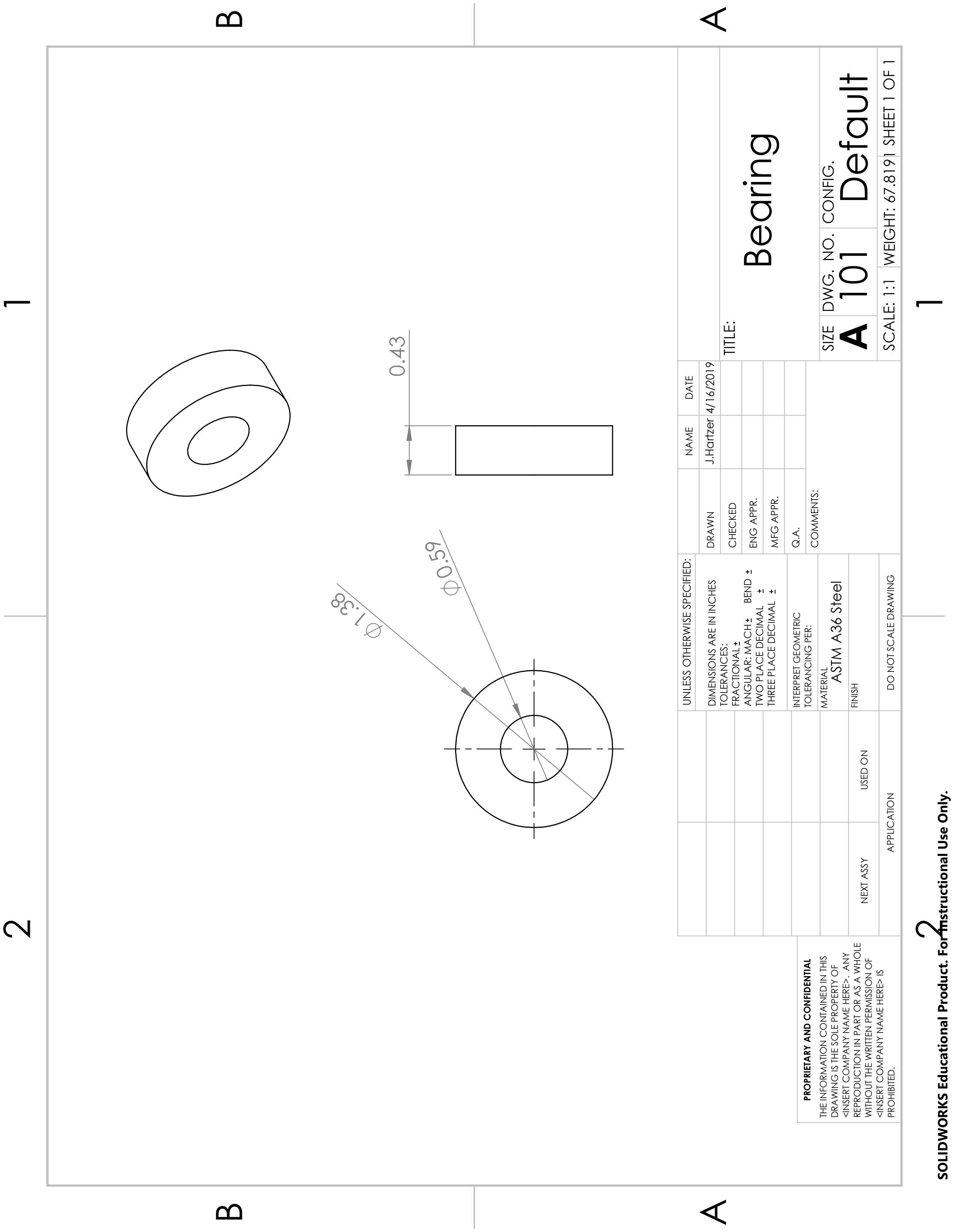

Bearing
TITLE:
SIZE
A
DWG. NO.
101
CONFIG.
Default
SCALE: 1:1
WEIGHT: 67.8191
SHEET 1 OF 1
0.43
Ø0.59
Ø1.38
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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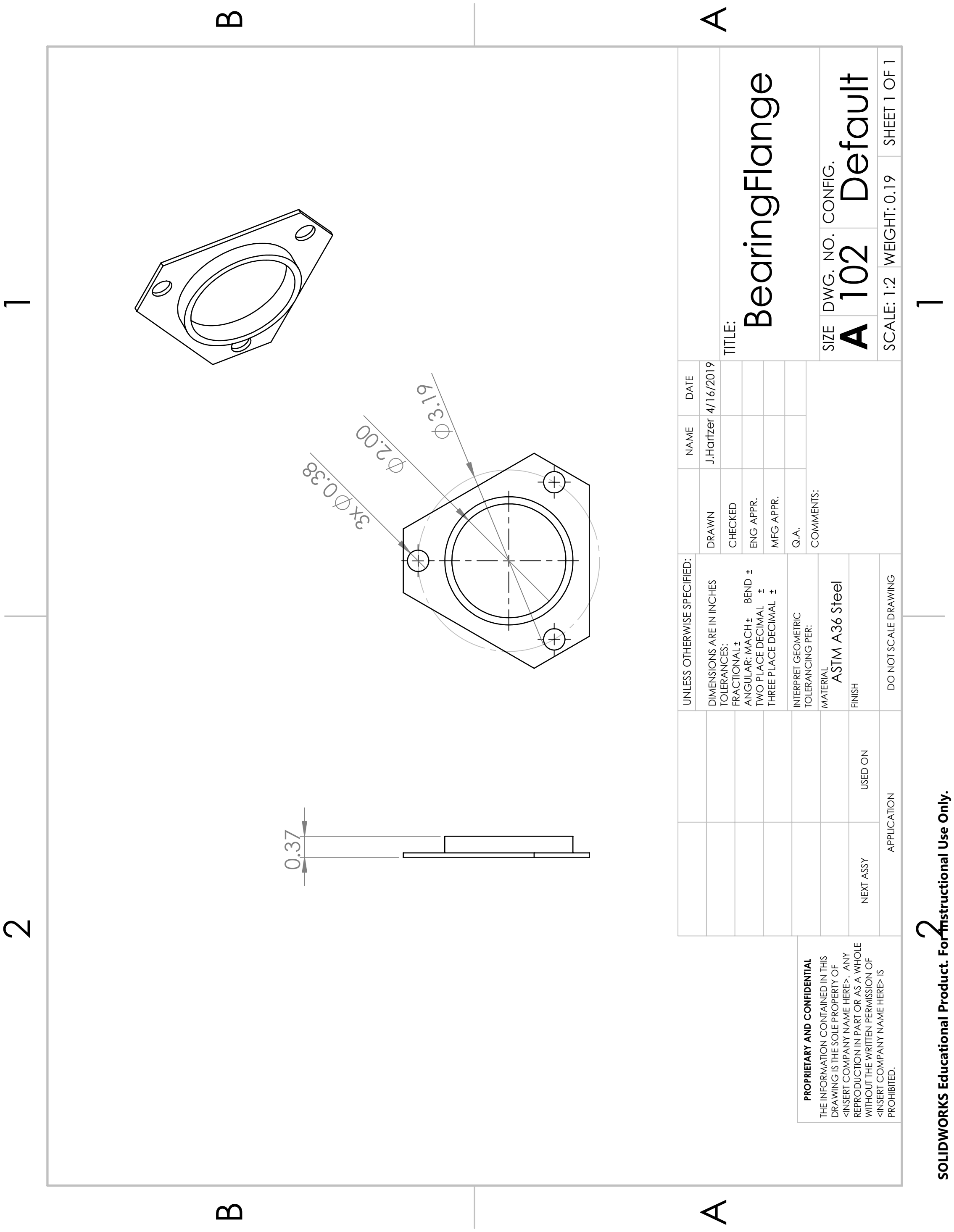
3X ⌀0.38
⌀2.00
⌀3.19
0.37
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
BearingFlange
SIZE
A
DWG. NO.
102
CONFIG.
Default
SCALE: 1:2
WEIGHT: 0.19
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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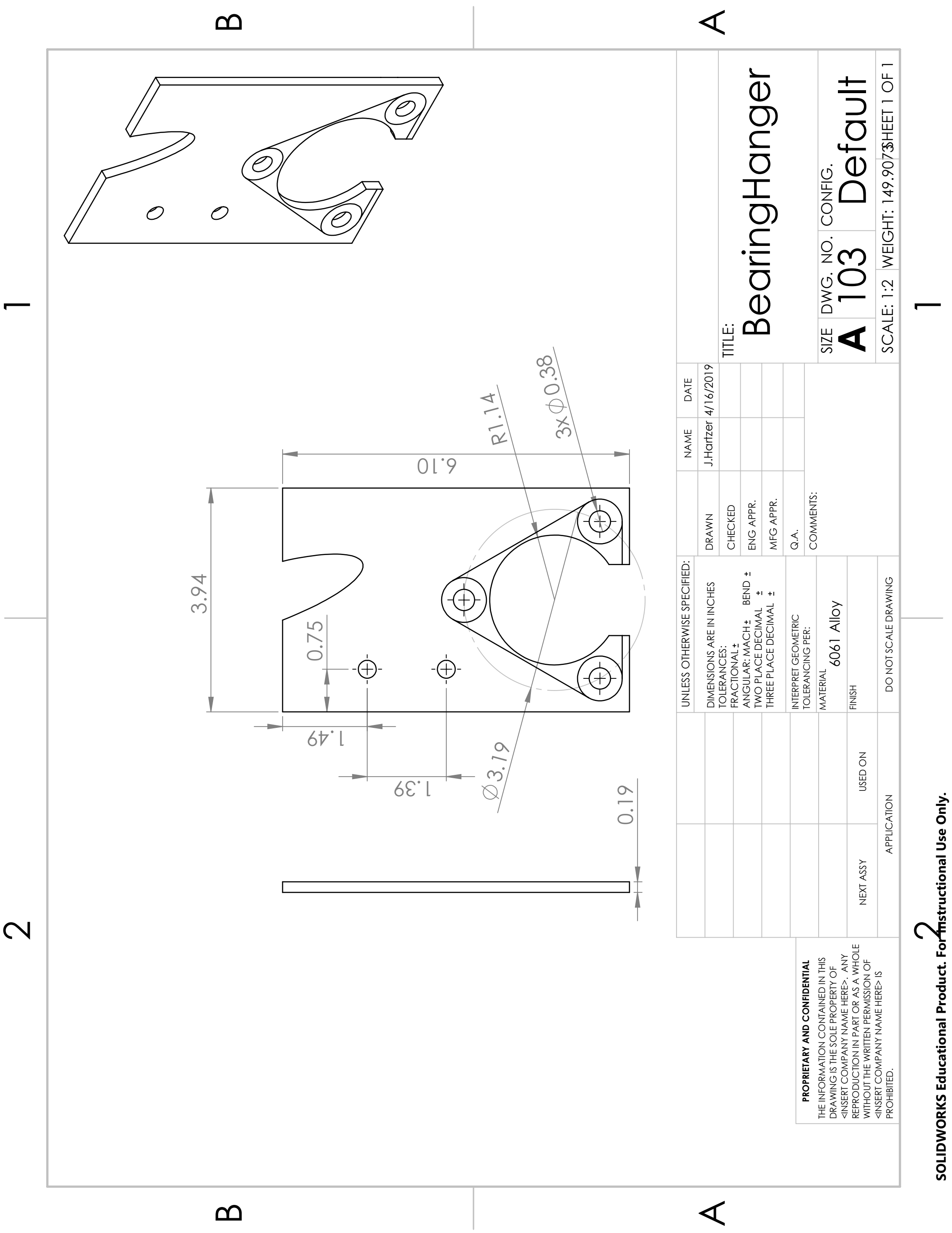

BearingHanger
TITLE:
SIZE A
DWG. NO. 103
CONFIG. Default
SCALE: 1:2
WEIGHT: 149.9073
SHEET 1 OF 1
NAME
DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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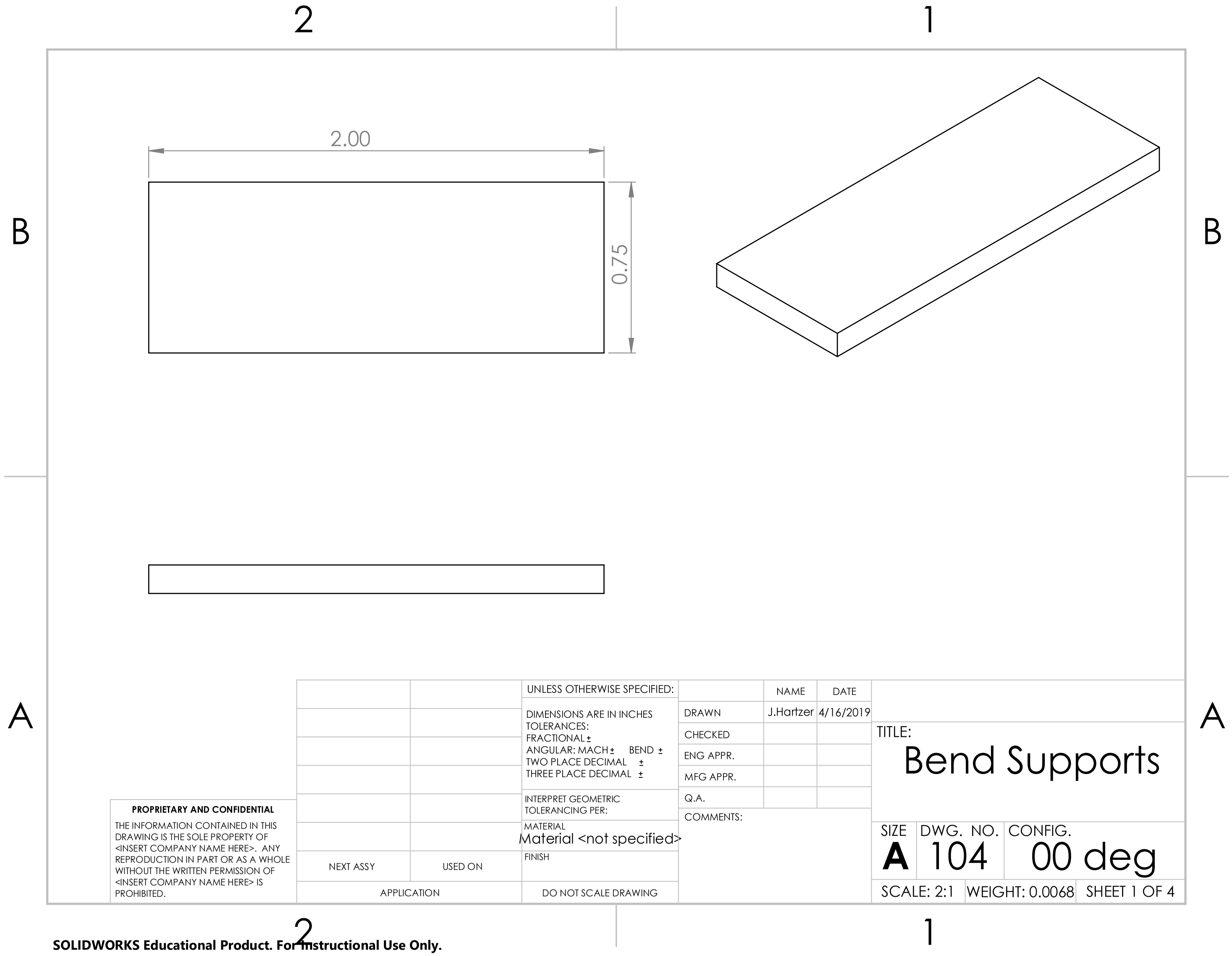
6.10
3.94
0.75
1.49
1.39
Ø3.19
R1.14
3X Ø0.38
0.19
A
B
1
2


2.00
0.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Bend Supports
SIZE
A
DWG. NO.
104
CONFIG.
00 deg
SCALE: 2:1
WEIGHT: 0.0068
SHEET 1 OF 4
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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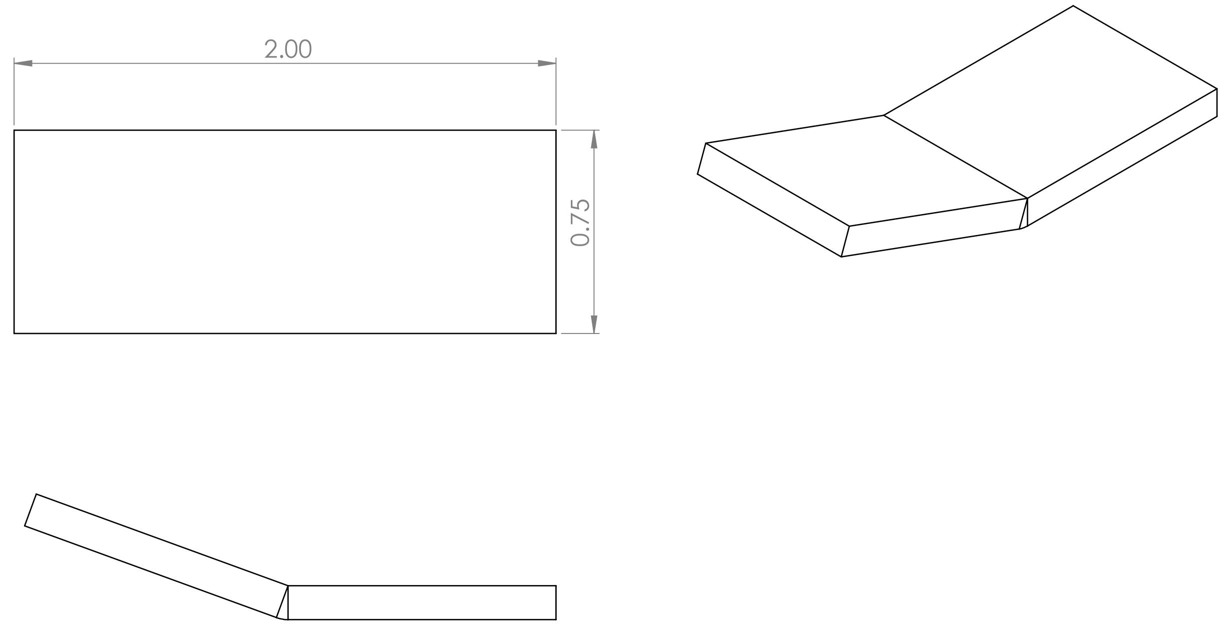



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Material <not specified>

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
| --- | --- | --- |
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

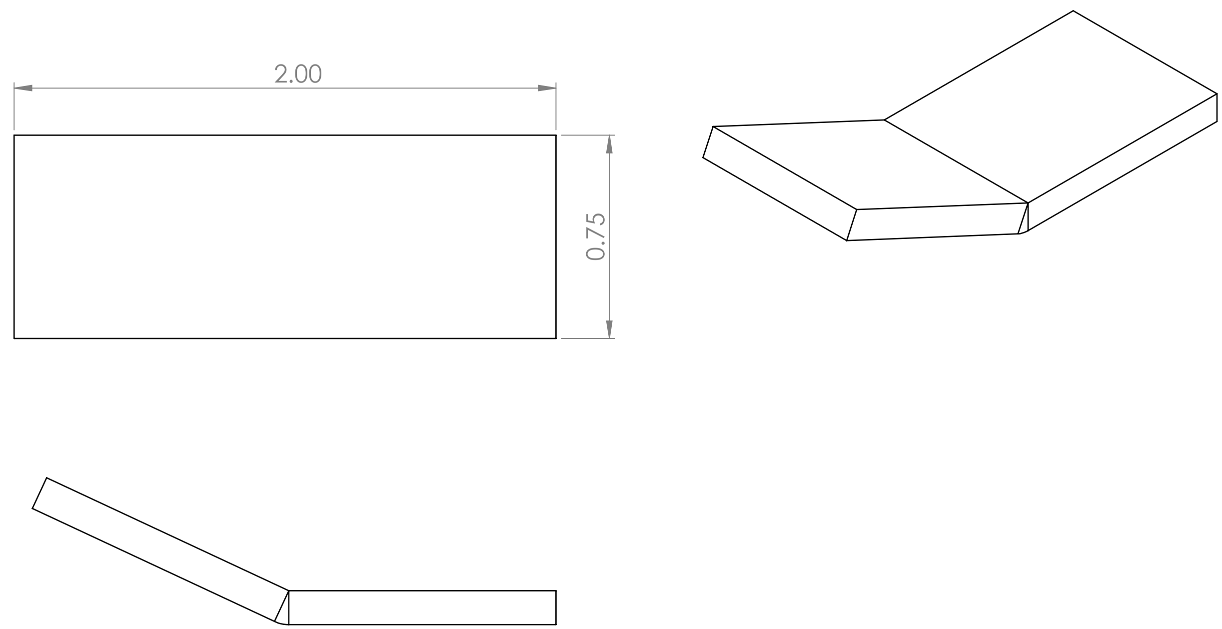
COMMENTS:

TITLE:
# Bend Supports

| SIZE | DWG. NO. | CONFIG. |
| --- | --- | --- |
| **A** | 104 | 20 deg |

SCALE: 2:1 | WEIGHT: 0.0068 | SHEET 2 OF 4

| NEXT ASSY | USED ON |
| --- | --- |
| APPLICATION | |




| | | |
|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME / DATE |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer 4/16/2019 |
| | CHECKED | |
| | ENG APPR. | |
| | MFG APPR. | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | |
| MATERIAL<br>Material <not specified> | COMMENTS: | |
| FINISH | | |
| DO NOT SCALE DRAWING | | |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

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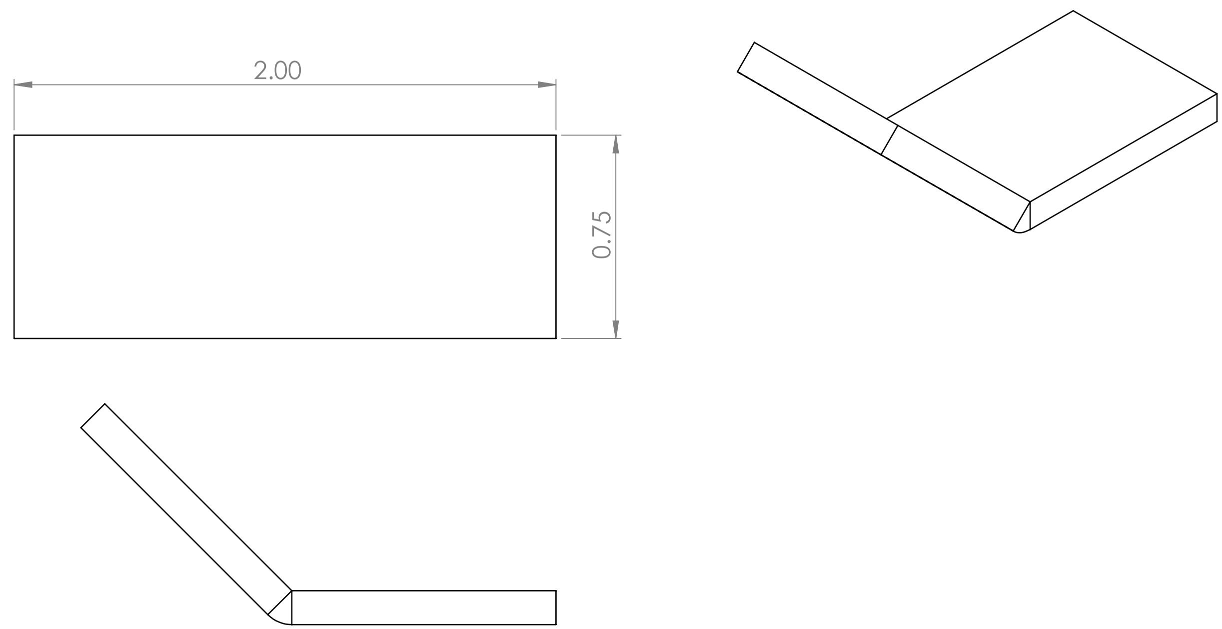
TITLE:

# Bend Supports

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 104 | 25 deg |
| SCALE: 2:1 | WEIGHT: 0.0068 | SHEET 3 OF 4 |




| | | | |
|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | CHECKED | | |
| | ENG APPR. | | |
| | MFG APPR. | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| MATERIAL<br>Material <not specified> | COMMENTS: | | |
| FINISH | | | |
| DO NOT SCALE DRAWING | | | |

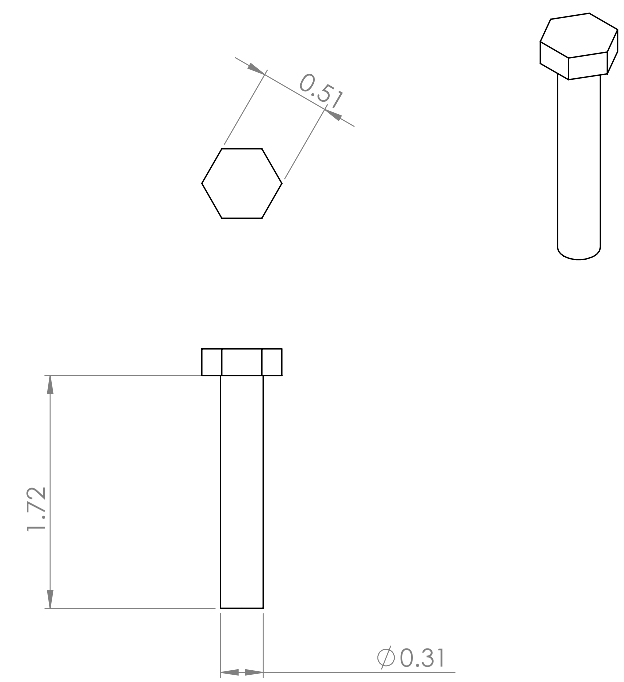
| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:

Bend Supports

SIZE **A** DWG. NO. 104 CONFIG. 45 deg

SCALE: 2:1 WEIGHT: 0.0068 SHEET 4 OF 4

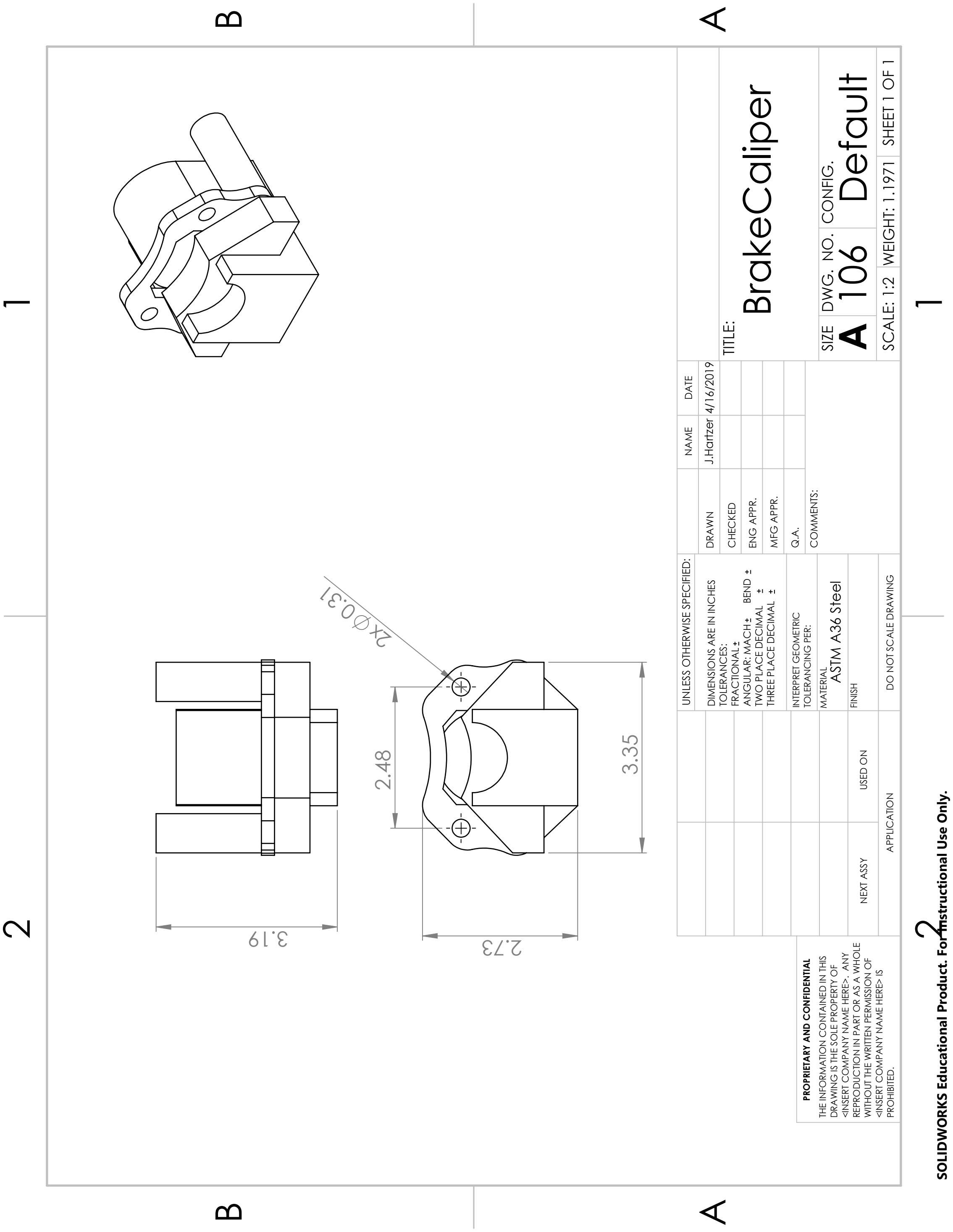



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL<br>Material <not specified> | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Bolt 8x50

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 105 | Default |
| SCALE: 1:1 | WEIGHT: 0.0064 | SHEET 1 OF 1 |


BrakeCaliper
TITLE:
SIZE A
DWG. NO. 106
CONFIG. Default
SCALE: 1:2
WEIGHT: 1.1971
SHEET 1 OF 1
NAME
DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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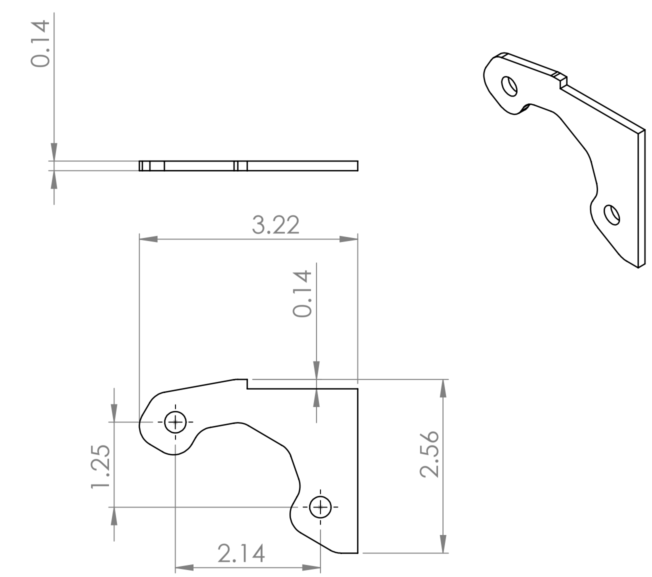
2X∅0.31
2.48
3.35
3.19
2.73
A
B
1
2




| | | |
|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME / DATE |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer 4/16/2019 |
| | CHECKED | |
| | ENG APPR. | |
| | MFG APPR. | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | |
| MATERIAL<br>ASTM A36 Steel | COMMENTS: | |
| FINISH | | |
| DO NOT SCALE DRAWING | | |

NEXT ASSY | USED ON

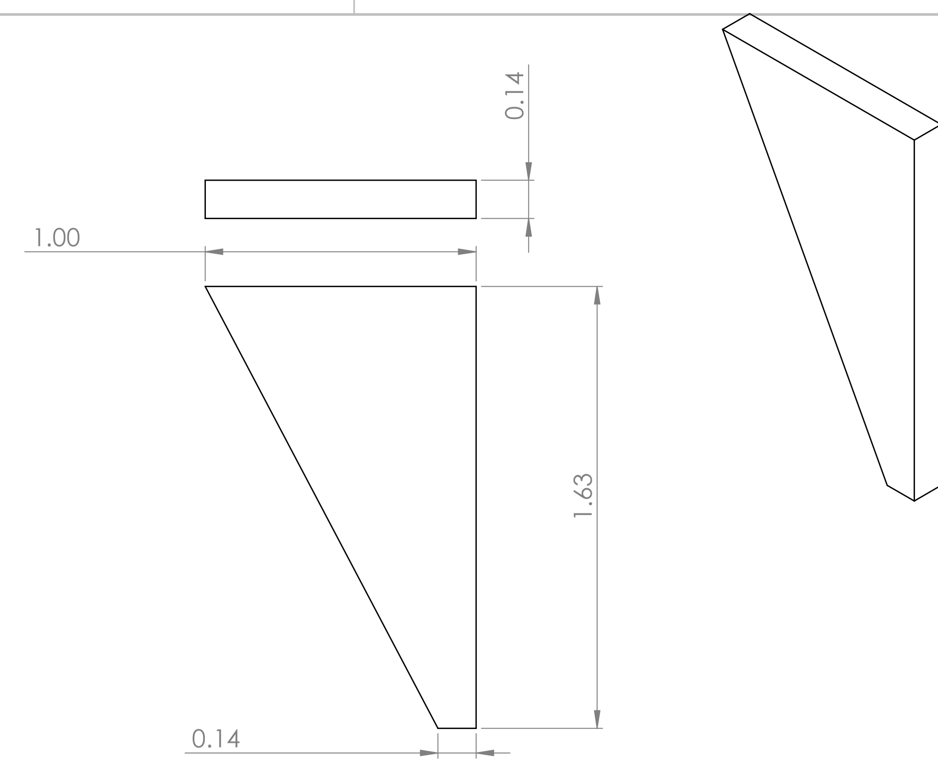
APPLICATION

TITLE:

# BrakeMountFron t

SIZE **A** | DWG. NO. 107 | CONFIG. Default

SCALE: 1:2 | WEIGHT: 0.1459 | SHEET 1 OF 1



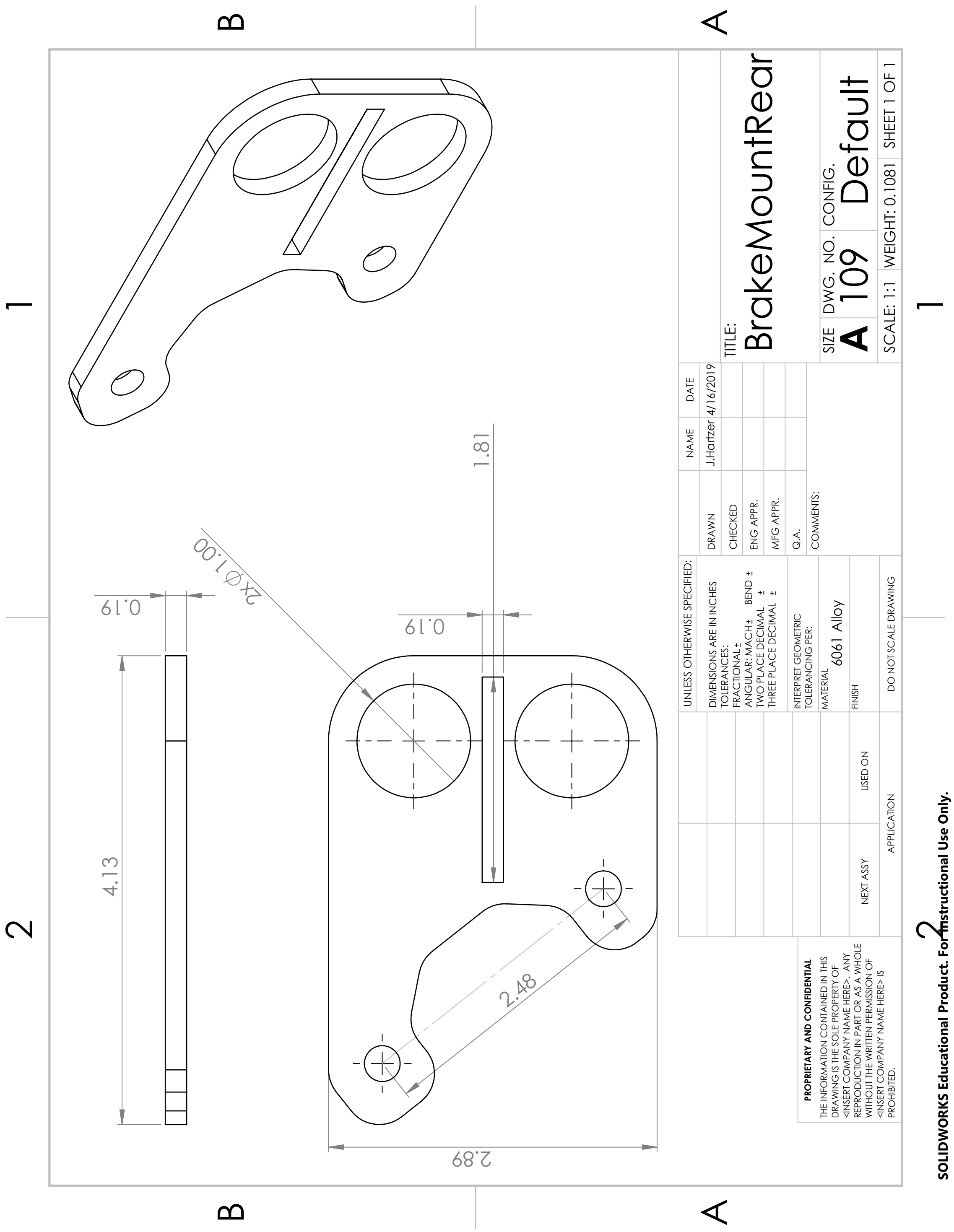

| | | |
|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | NAME | DATE |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN J.Hartzer | 4/16/2019 |
| | CHECKED | |
| | ENG APPR. | |
| | MFG APPR. | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | |
| MATERIAL ASTM A36 Steel | COMMENTS: | |
| FINISH | | |
| DO NOT SCALE DRAWING | | |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:

BrakeMountFront_gusset

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 108 | Default |
| SCALE: 2:1 | WEIGHT: 0.0371 | SHEET 1 OF 1 |


BrakeMountRear
TITLE:
SIZE A
DWG. NO. 109
CONFIG. Default
SCALE: 1:1
WEIGHT: 0.1081
SHEET 1 OF 1
NAME
DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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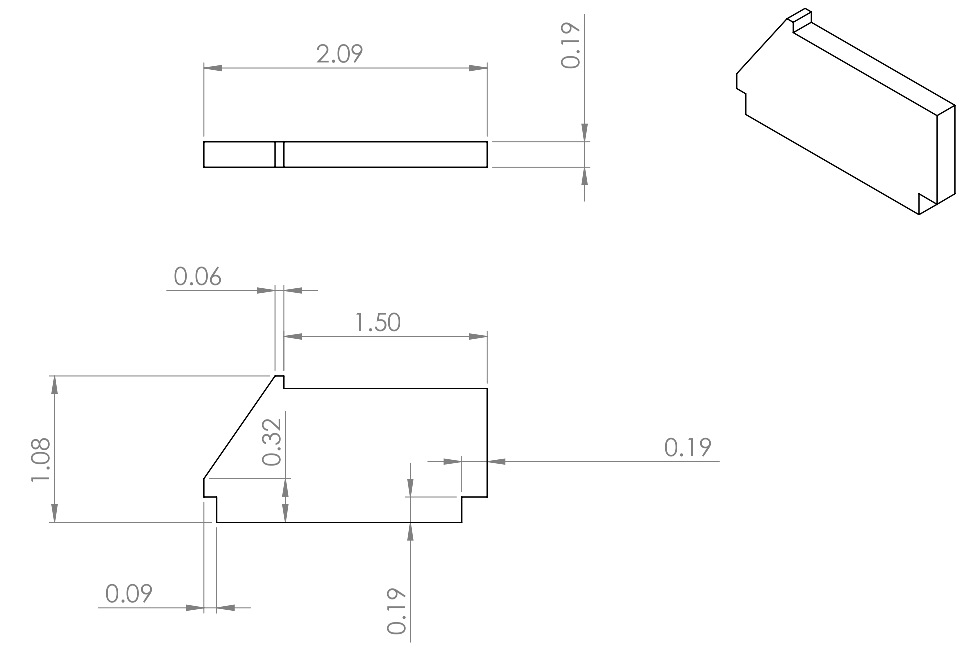
0.19
4.13
2X Ø1.00
0.19
1.81
2.48
2.89
A
B
1
2



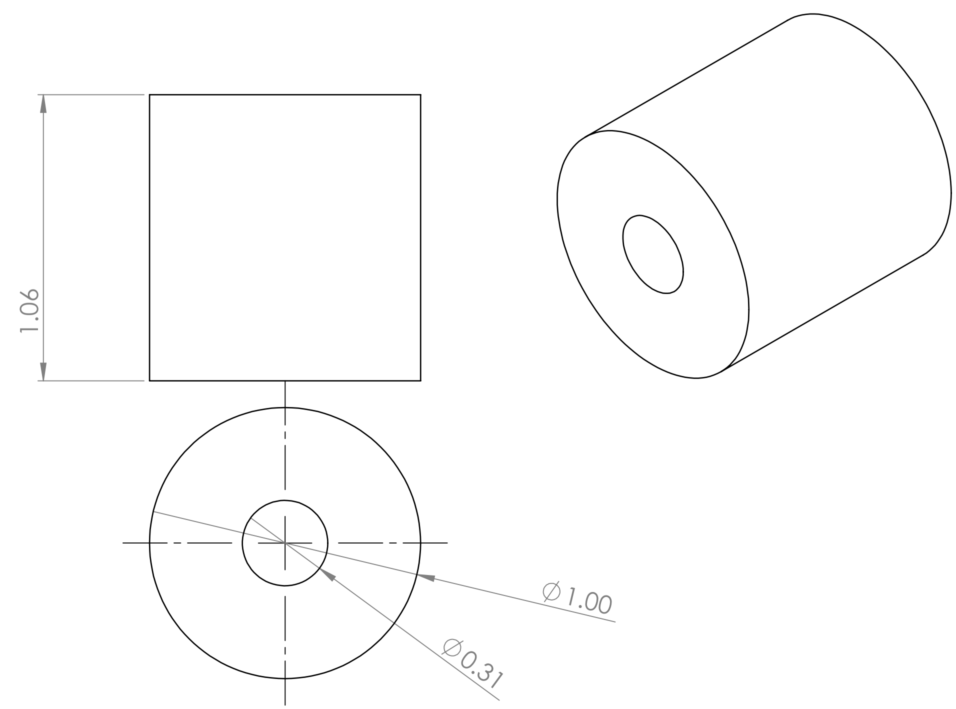

| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL<br>Material <not specified> | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

BrakeMountRear_gusset

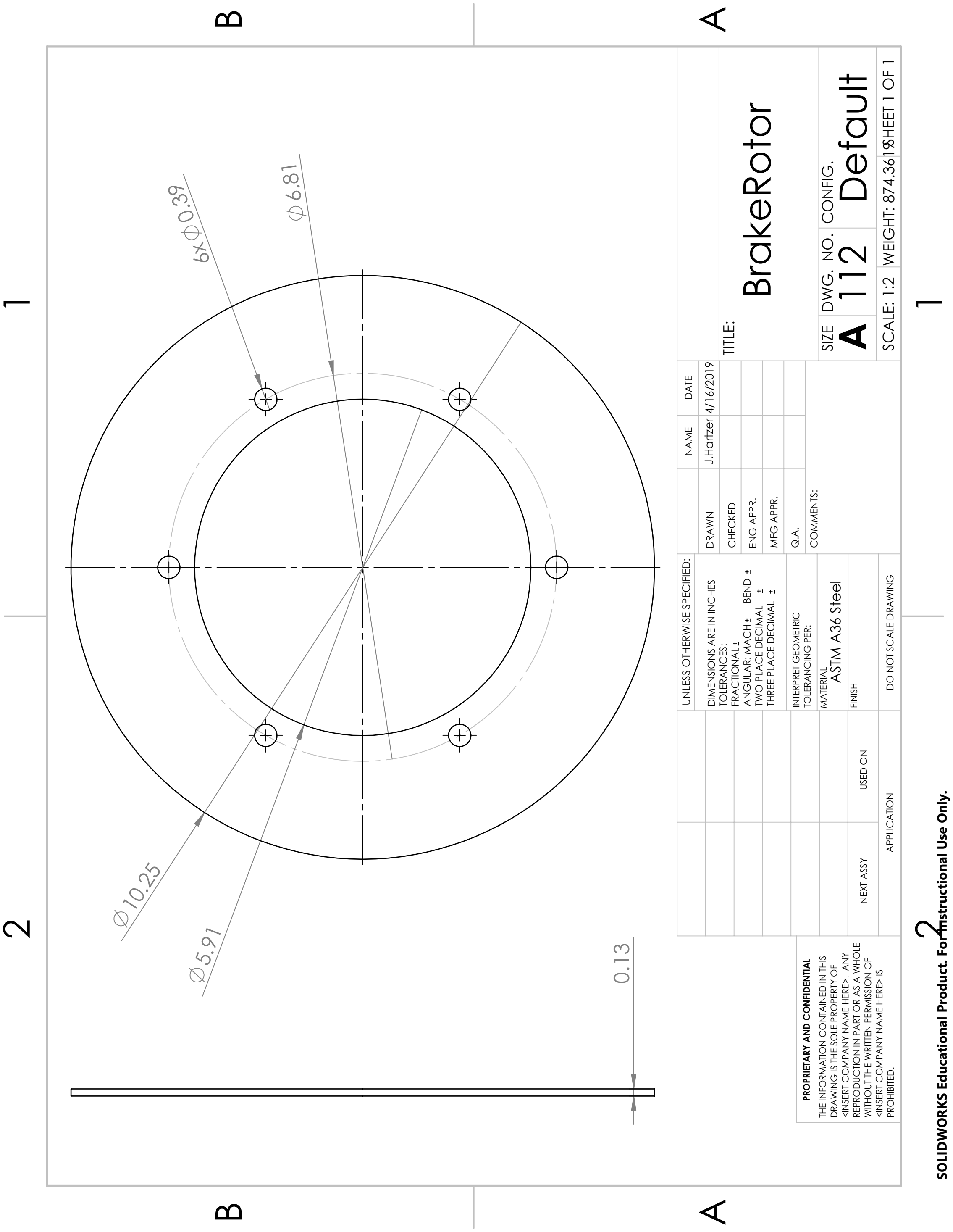
| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 110 | Default |

SCALE: 1:1 | WEIGHT: 0.0126 | SHEET 1 OF 1




| | | | | | | |
|---|---|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | | | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: | | |
| | CHECKED | | | BrakeMountRear_riser | | |
| | ENG APPR. | | | | | |
| | MFG APPR. | | | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | | | |
| MATERIAL<br>6061 Alloy | COMMENTS: | | | SIZE<br>**A** | DWG. NO.<br>111 | CONFIG.<br>Default |
| FINISH | | | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 2:1 | WEIGHT: 0.0728 | SHEET 1 OF 1 |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |



BrakeRotor
TITLE:
SIZE A
DWG. NO. 112
CONFIG. Default
SCALE: 1:2
WEIGHT: 874.36
SHEET 1 OF 1
6x ⌀0.39
⌀6.81
⌀10.25
⌀5.91
0.13
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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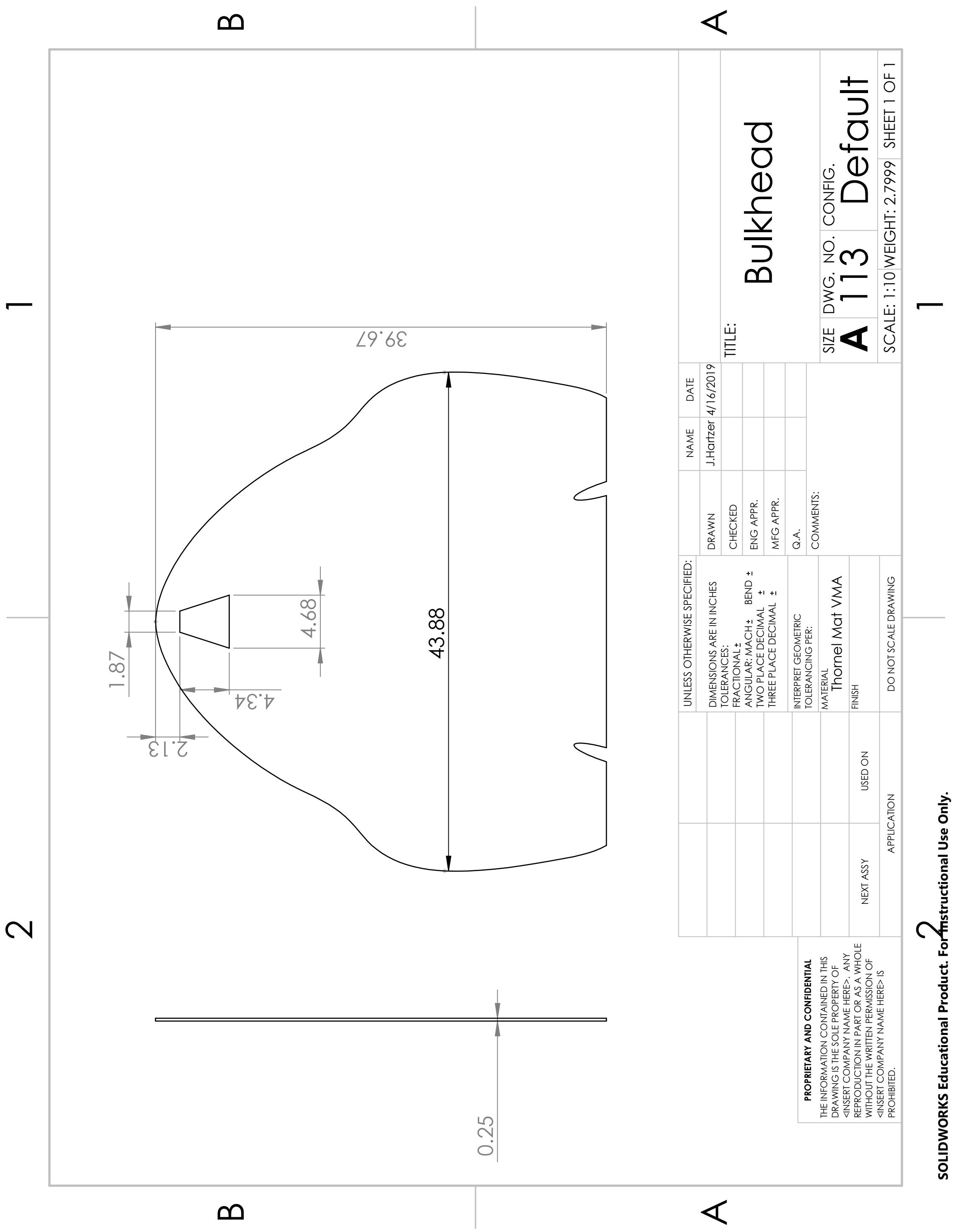
39.67
43.88
1.87
4.68
4.34
2.13
0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Thornel Mat VMA
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Bulkhead
SIZE
A
DWG. NO.
113
CONFIG.
Default
SCALE: 1:10
WEIGHT: 2.7999
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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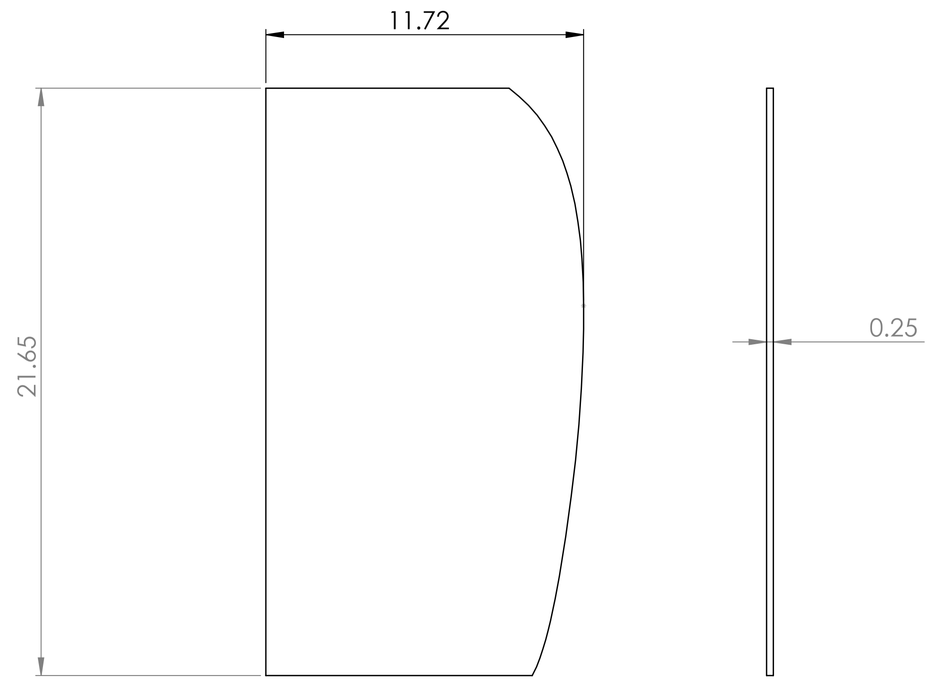



| | | | |
|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | CHECKED | | |
| | ENG APPR. | | |
| | MFG APPR. | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| MATERIAL<br>Thornel Mat VMA | COMMENTS: | | |
| FINISH | | | |
| DO NOT SCALE DRAWING | | | |

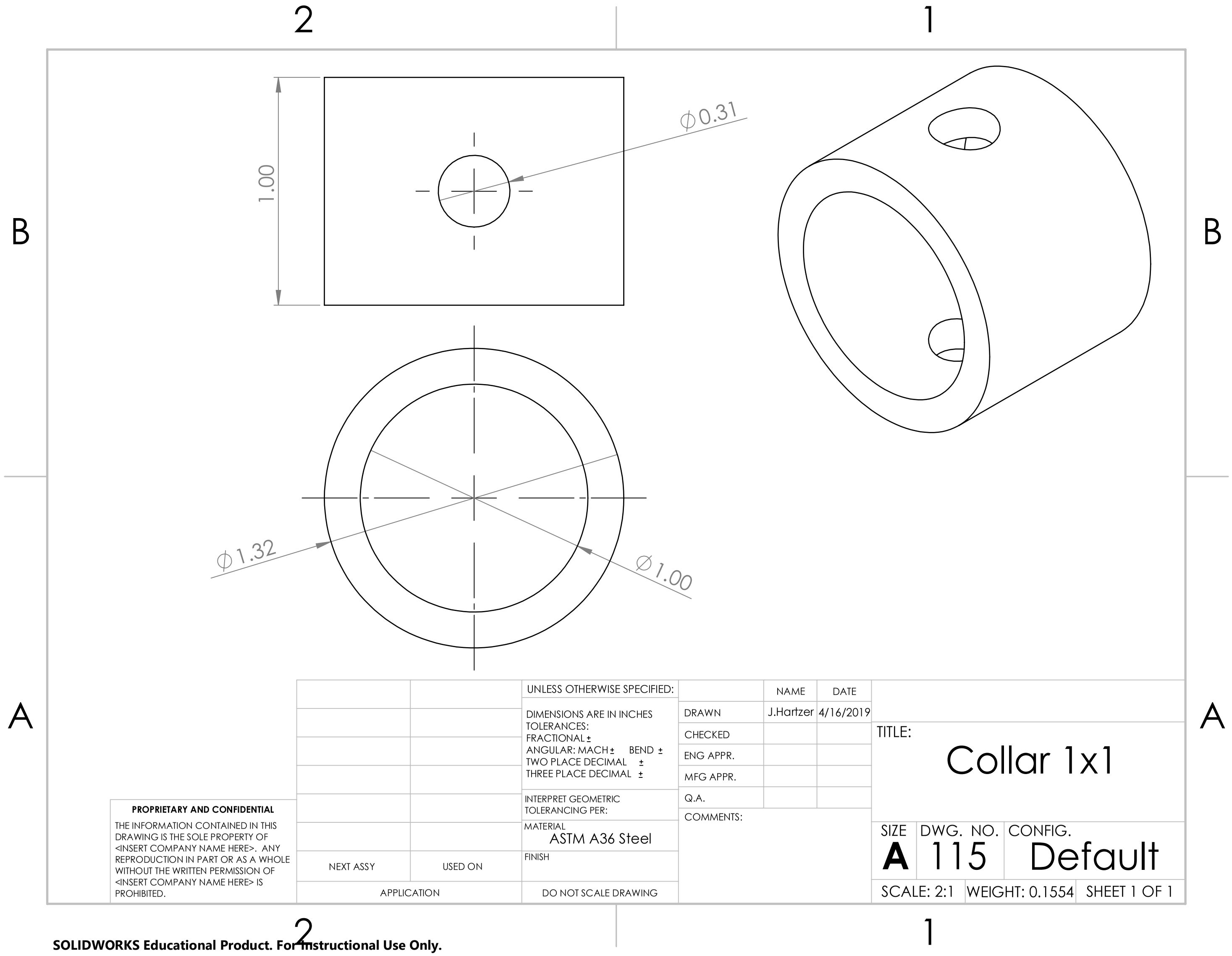
| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:

# Cockpit Panels

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 114 | Default |

SCALE: 1:5 | WEIGHT: 0.5512 | SHEET 1 OF 1


2
1
B
A
1.00
ϕ0.31
ϕ1.32
∅1.00
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Collar 1x1
SIZE
A
DWG. NO.
115
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.1554
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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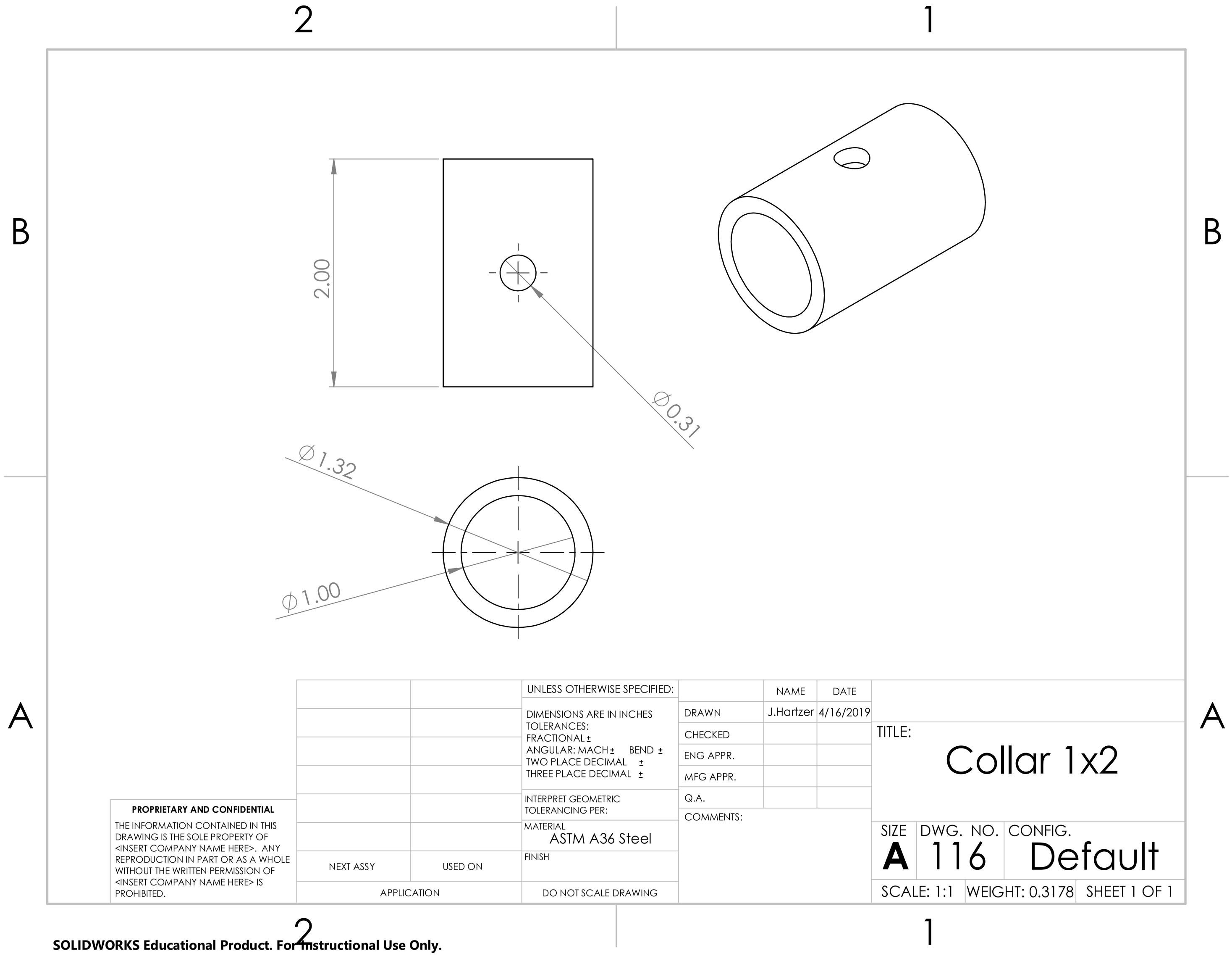
2
1
B
A
2.00
⌀0.31
⌀1.32
⌀1.00
PROPRIETARY AND CONFIDENTIAL
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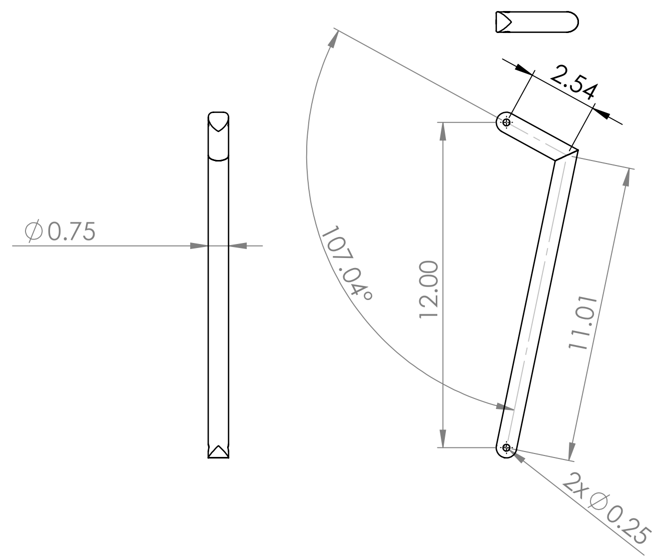
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Collar 1x2
SIZE
A
DWG. NO.
116
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.3178
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.

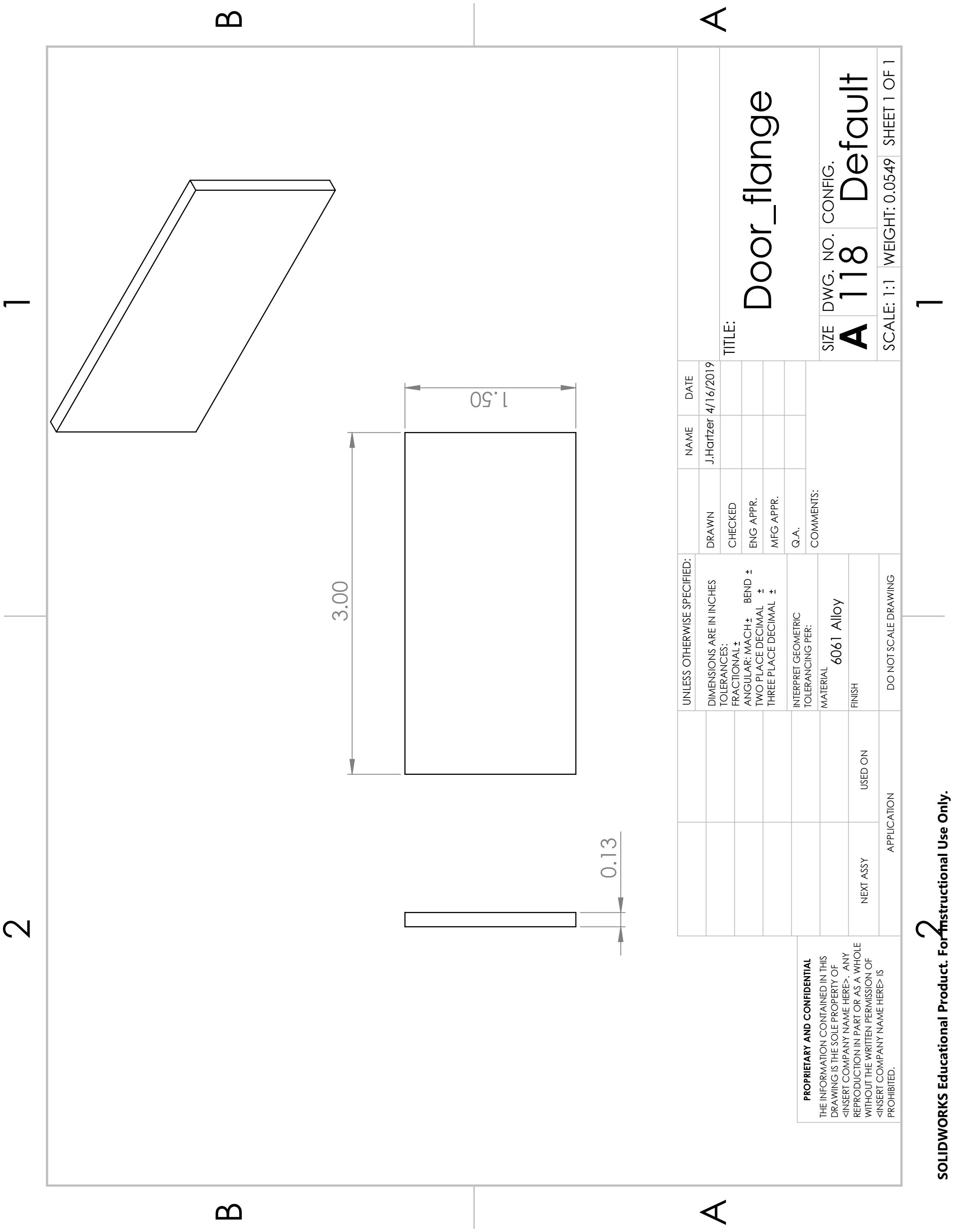



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL Material <not specified> | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

Door_arm

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 117 | Default |
| SCALE: 1:5 | WEIGHT: 0.2237 | SHEET 1 OF 1 |



1
2
A
B
3.00
1.50
0.13
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Door_flange
SIZE
A
DWG. NO.
118
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0549
SHEET 1 OF 1
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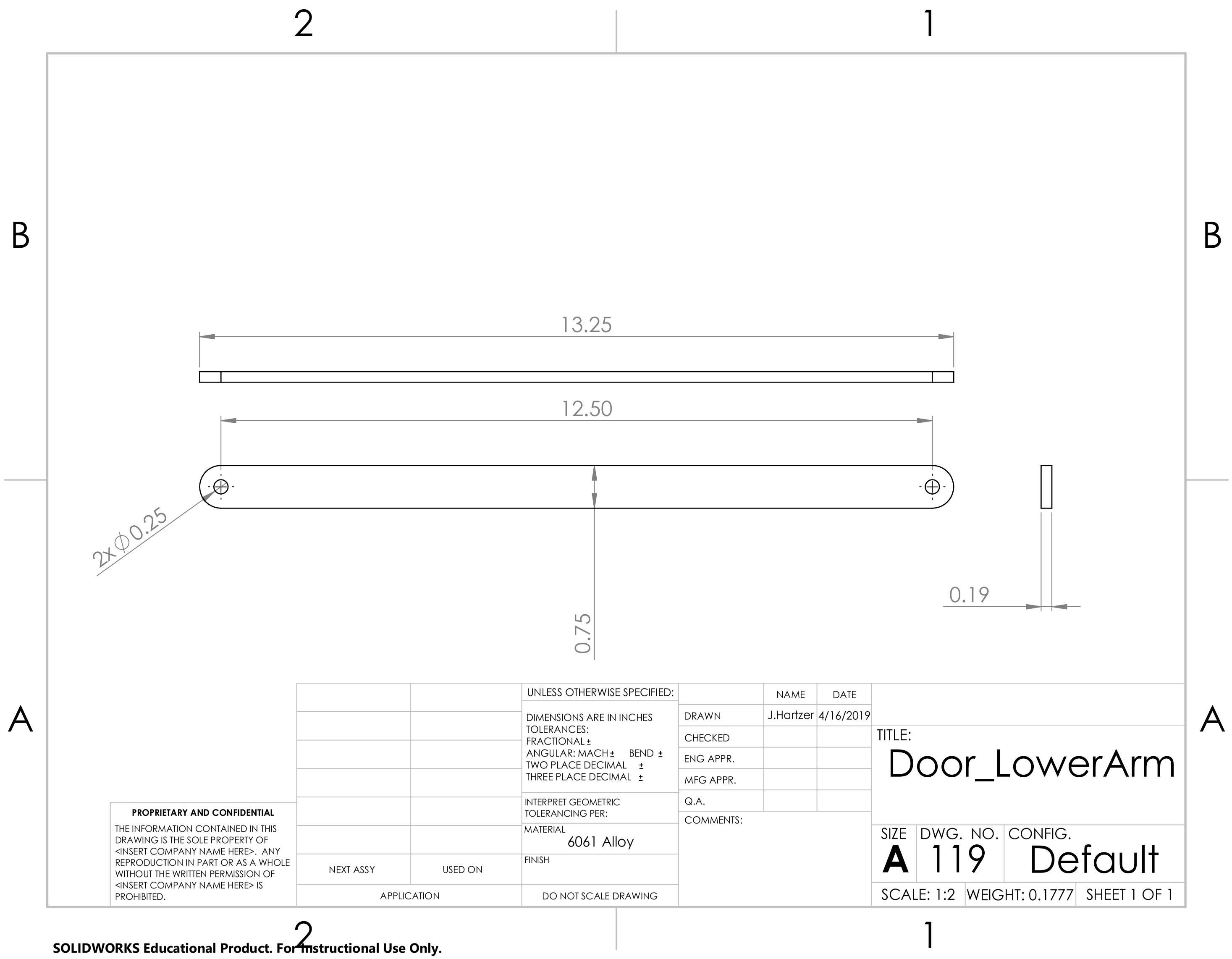

13.25
12.50
2x∅0.25
0.75
0.19
2
1
B
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Door_LowerArm
SIZE
A
DWG. NO.
119
CONFIG.
Default
SCALE: 1:2
WEIGHT: 0.1777
SHEET 1 OF 1
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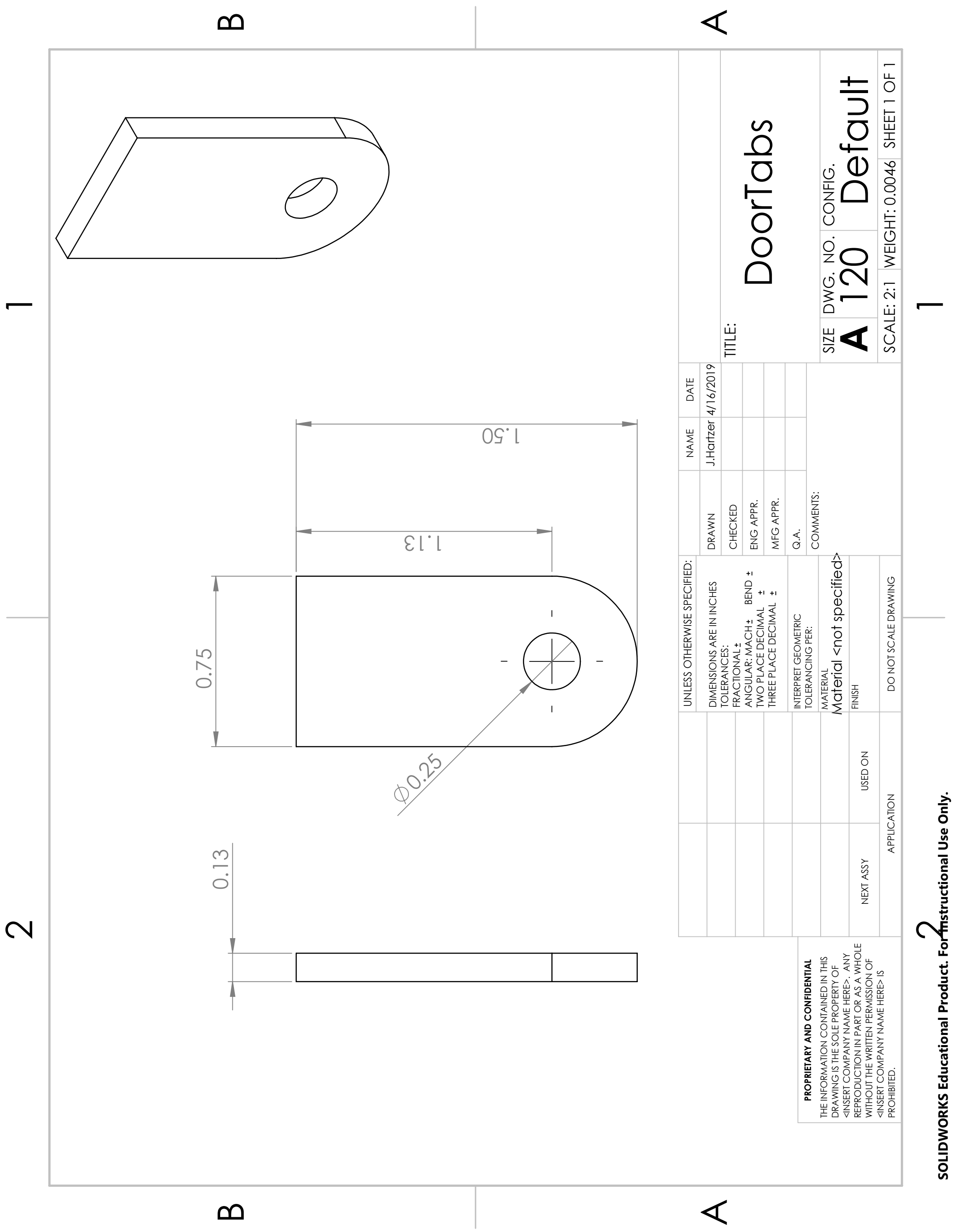

0.13
0.75
1.13
1.50
Ø0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
DoorTabs
SIZE
A
DWG. NO.
120
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0046
SHEET 1 OF 1
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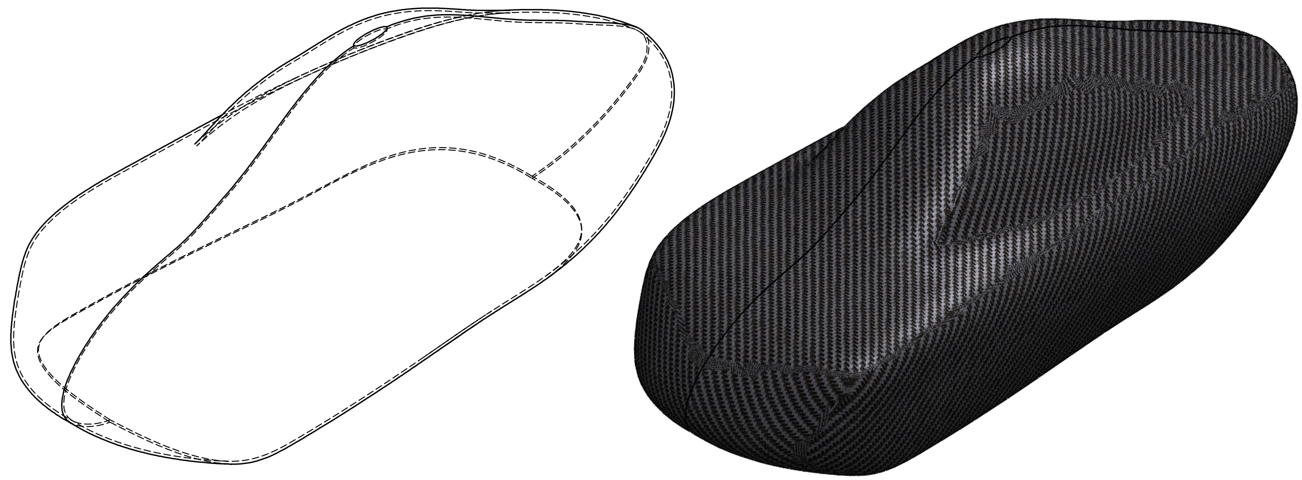

| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL ABS PC | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

DR3model_rev1

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 121 | Default |

SCALE: 1:20 WEIGHT: 55.1155 SHEET 1 OF 9

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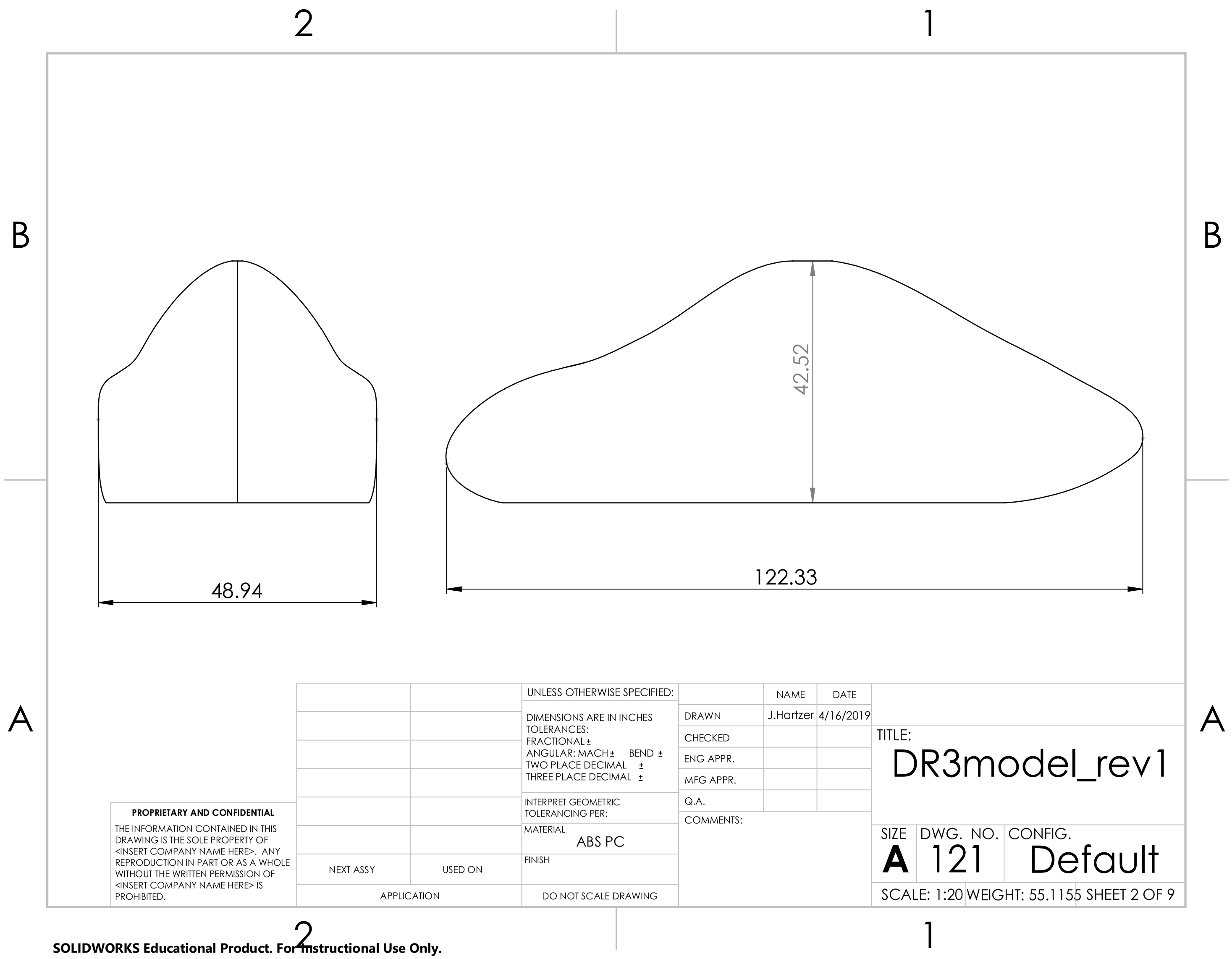
2
1
B
A
48.94
122.33
42.52
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS PC
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
DR3model_rev1
SIZE
A
DWG. NO.
121
CONFIG.
Default
SCALE: 1:20
WEIGHT: 55.1155
SHEET 2 OF 9
PROPRIETARY AND CONFIDENTIAL
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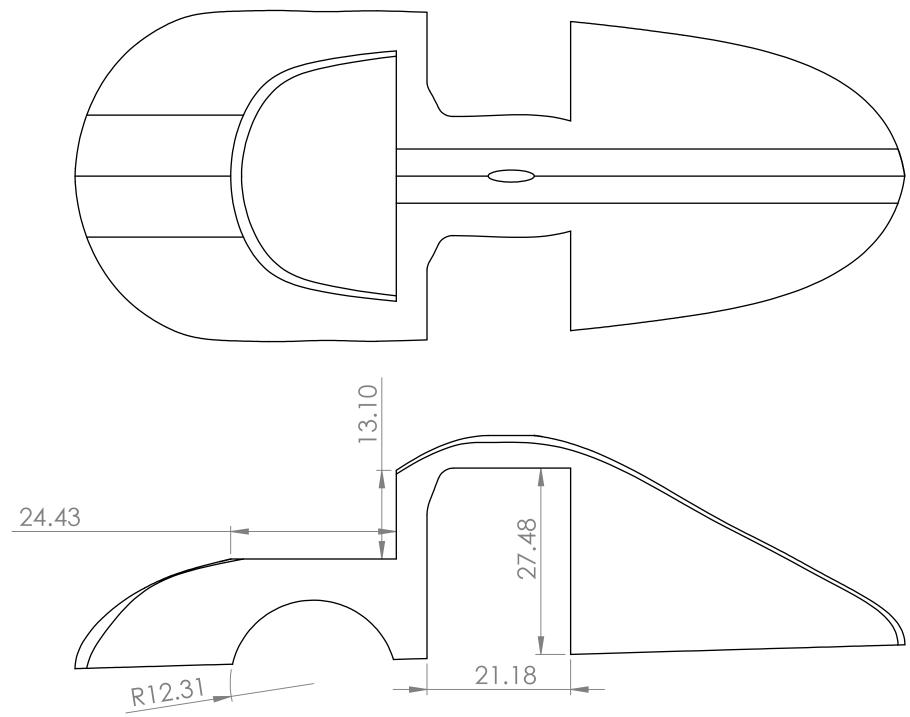
2 1

B




A

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| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
ABS PC

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

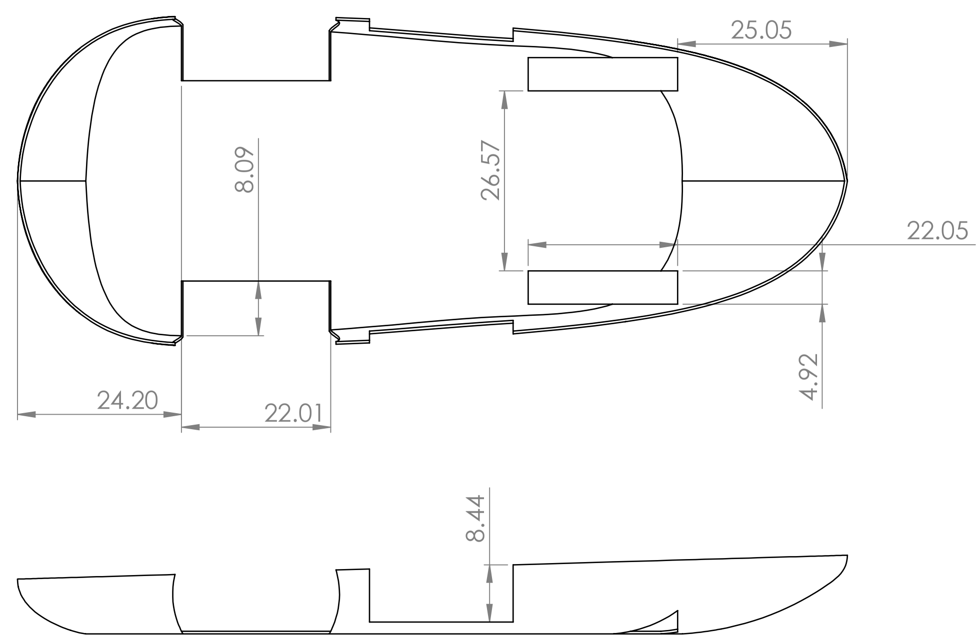
COMMENTS:

TITLE:
DR3model_rev1

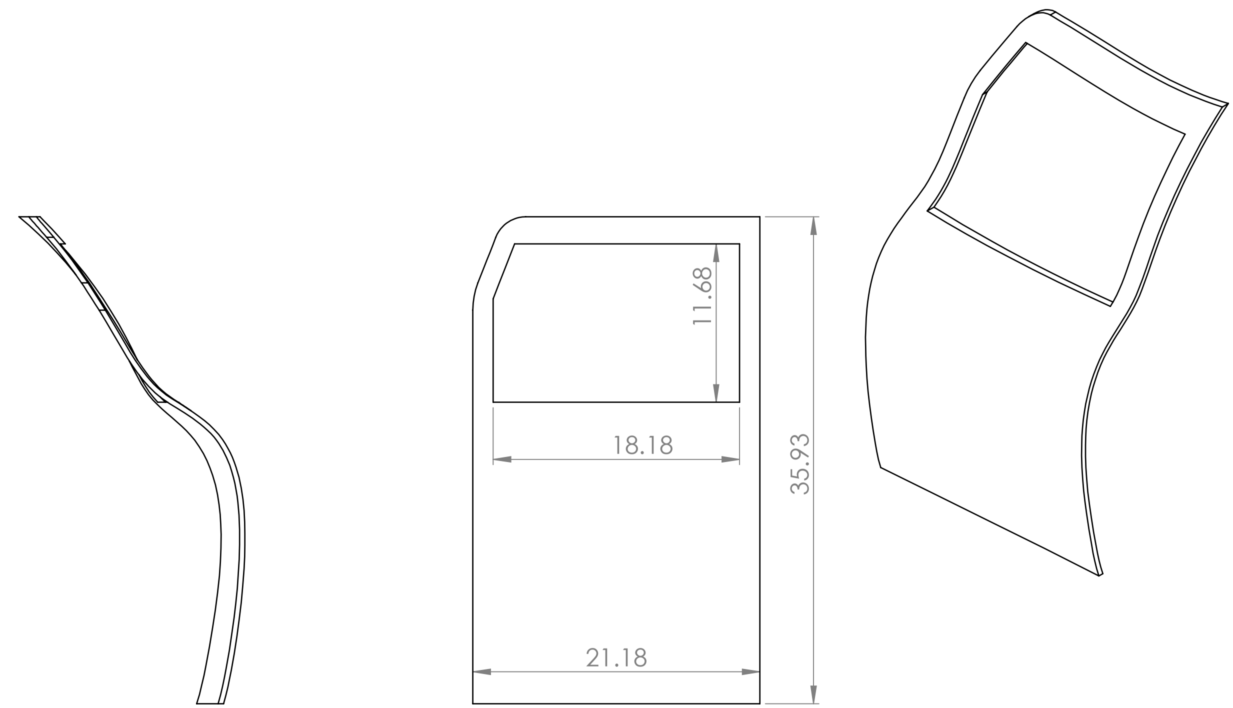
| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 121 | Body Top |

SCALE: 1:20 WEIGHT: 55.1155 SHEET 3 OF 9

2 1




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: |
| | | | CHECKED | | | DR3model_rev1 |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL<br>ABS PC | COMMENTS: | | | SIZE A DWG. NO. 121 CONFIG. Body Bot. |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:20 WEIGHT: 55.1155 SHEET 4 OF 9 |

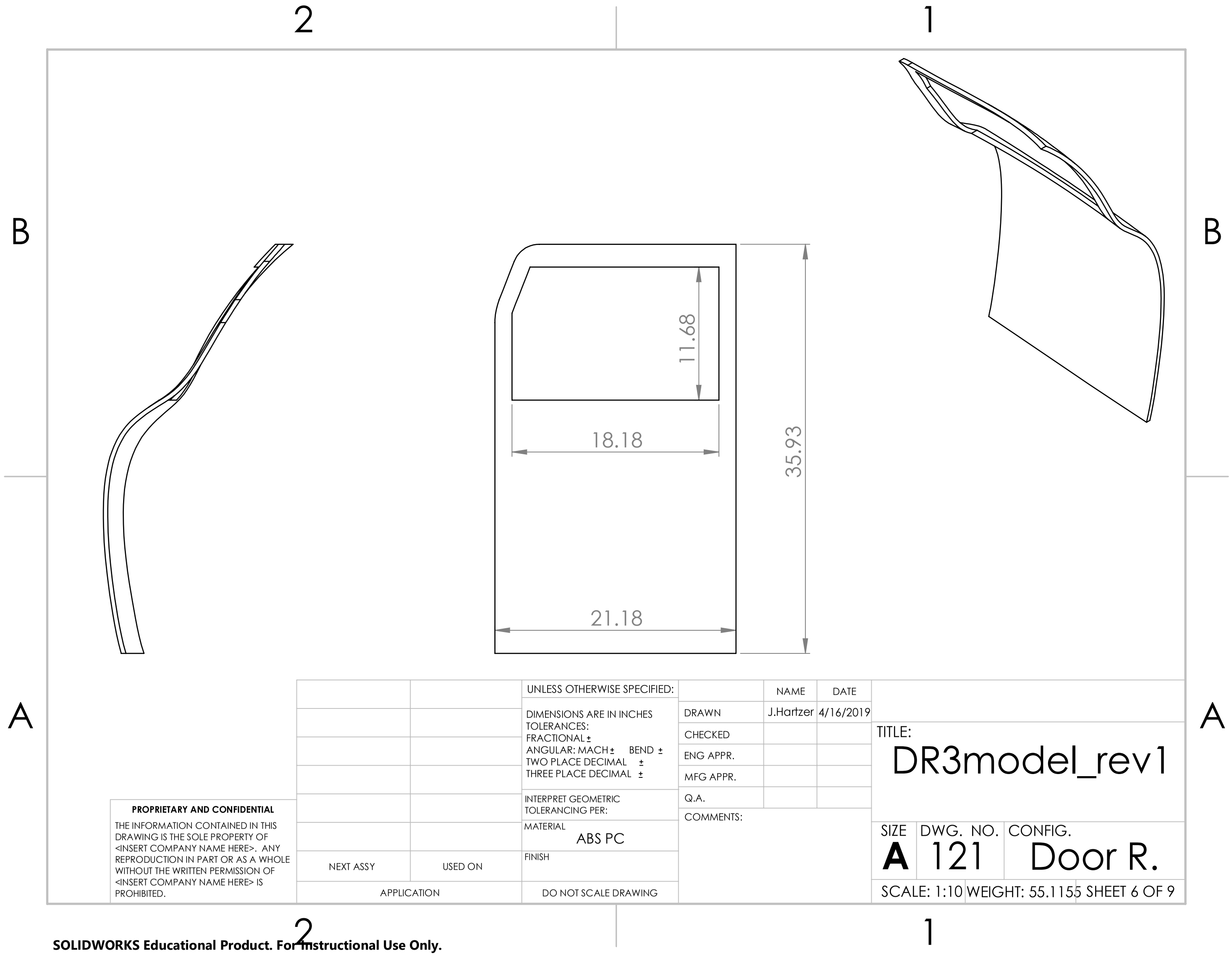



| | | | |
|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
| DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | CHECKED | | |
| | ENG APPR. | | |
| | MFG APPR. | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| MATERIAL ABS PC | COMMENTS: | | |
| FINISH | | | |
| DO NOT SCALE DRAWING | | | |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:
DR3model_rev1

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 121 | Door Left |
| SCALE: 1:10 | WEIGHT: 55.1155 | SHEET 5 OF 9 |


2
1
B
A
11.68
18.18
35.93
21.18
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS PC
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
DR3model_rev1
SIZE
A
DWG. NO.
121
CONFIG.
Door R.
SCALE: 1:10 WEIGHT: 55.1155 SHEET 6 OF 9
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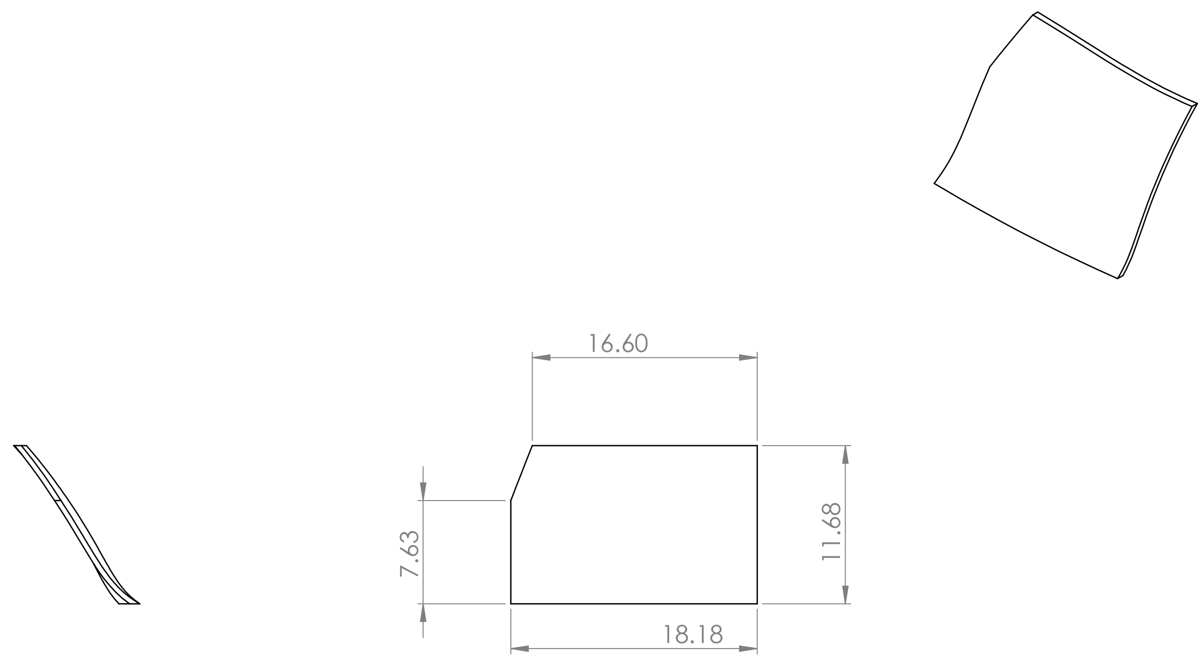



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL: ABS PC

FINISH

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

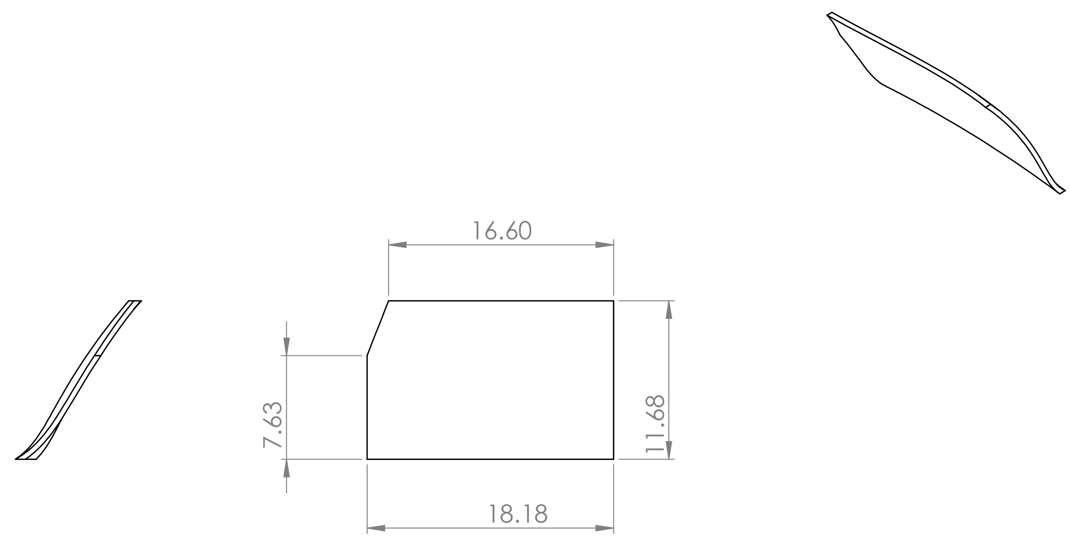
| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

DO NOT SCALE DRAWING

TITLE: DR3model_rev1

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 121 | Wind. L. |

SCALE: 1:10 WEIGHT: 55.1155 SHEET 7 OF 9




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: DR3model_rev1 |
| | | | CHECKED | | | |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL ABS PC | COMMENTS: | | | SIZE A DWG. NO. 121 CONFIG. Wind. R. |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:10 WEIGHT: 55.1155 SHEET 8 OF 9 |

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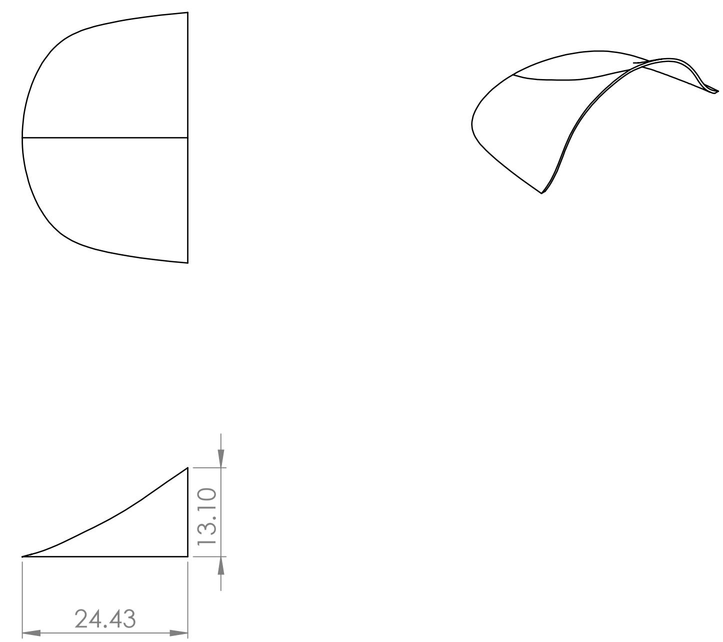



| | |
|---|---|
| UNLESS OTHERWISE SPECIFIED: | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | |
| INTERPRET GEOMETRIC<br>TOLERANCING PER: | |
| MATERIAL | ABS PC |
| FINISH | |
| DO NOT SCALE DRAWING | |

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |
| COMMENTS: | | |

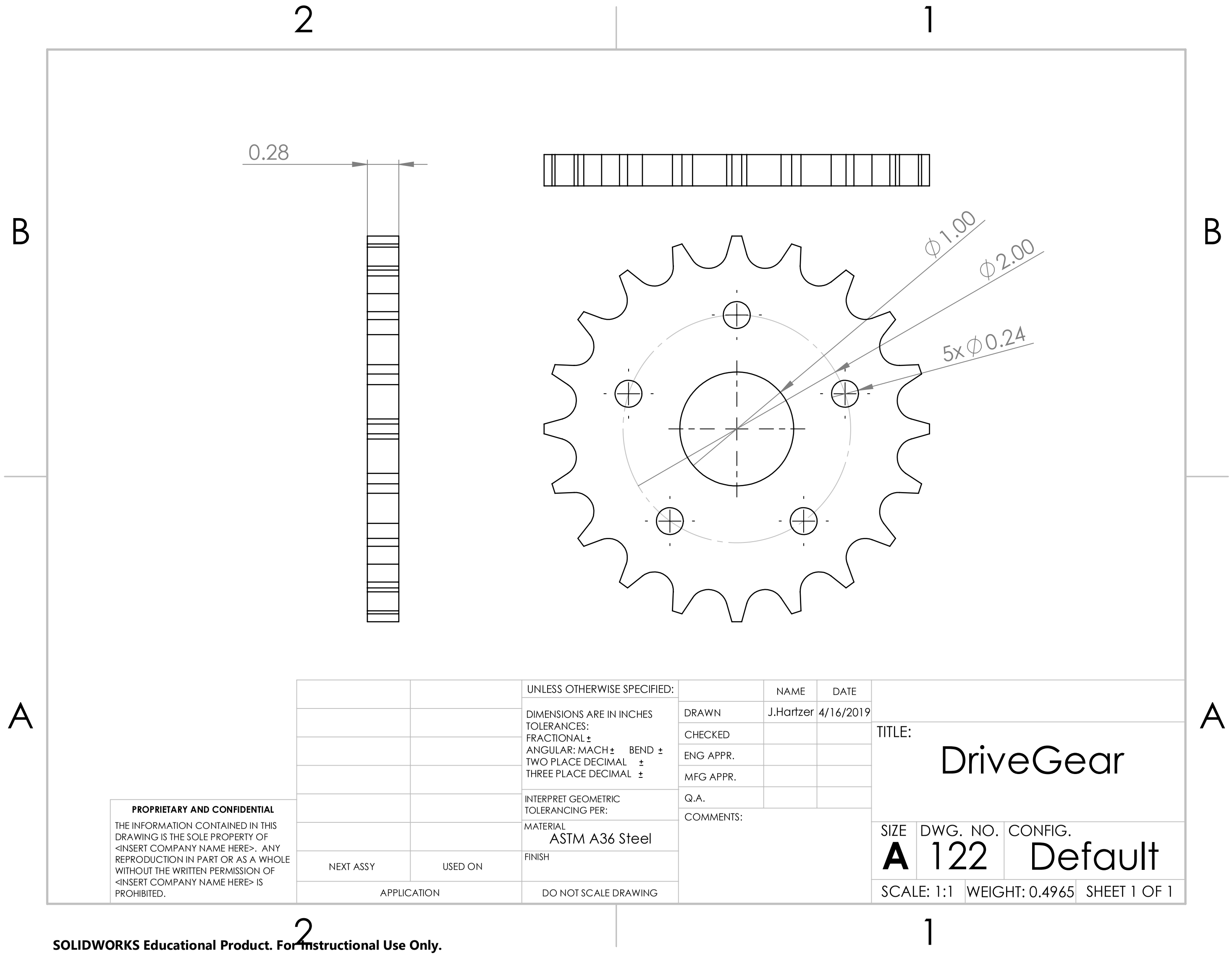
| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:

DR3model_rev1

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 121 | Wndshld. |

SCALE: 1:20 WEIGHT: 55.1155 SHEET 9 OF 9


0.28
⌀1.00
⌀2.00
5x⌀0.24
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
DriveGear
SIZE
A
DWG. NO.
122
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.4965
SHEET 1 OF 1
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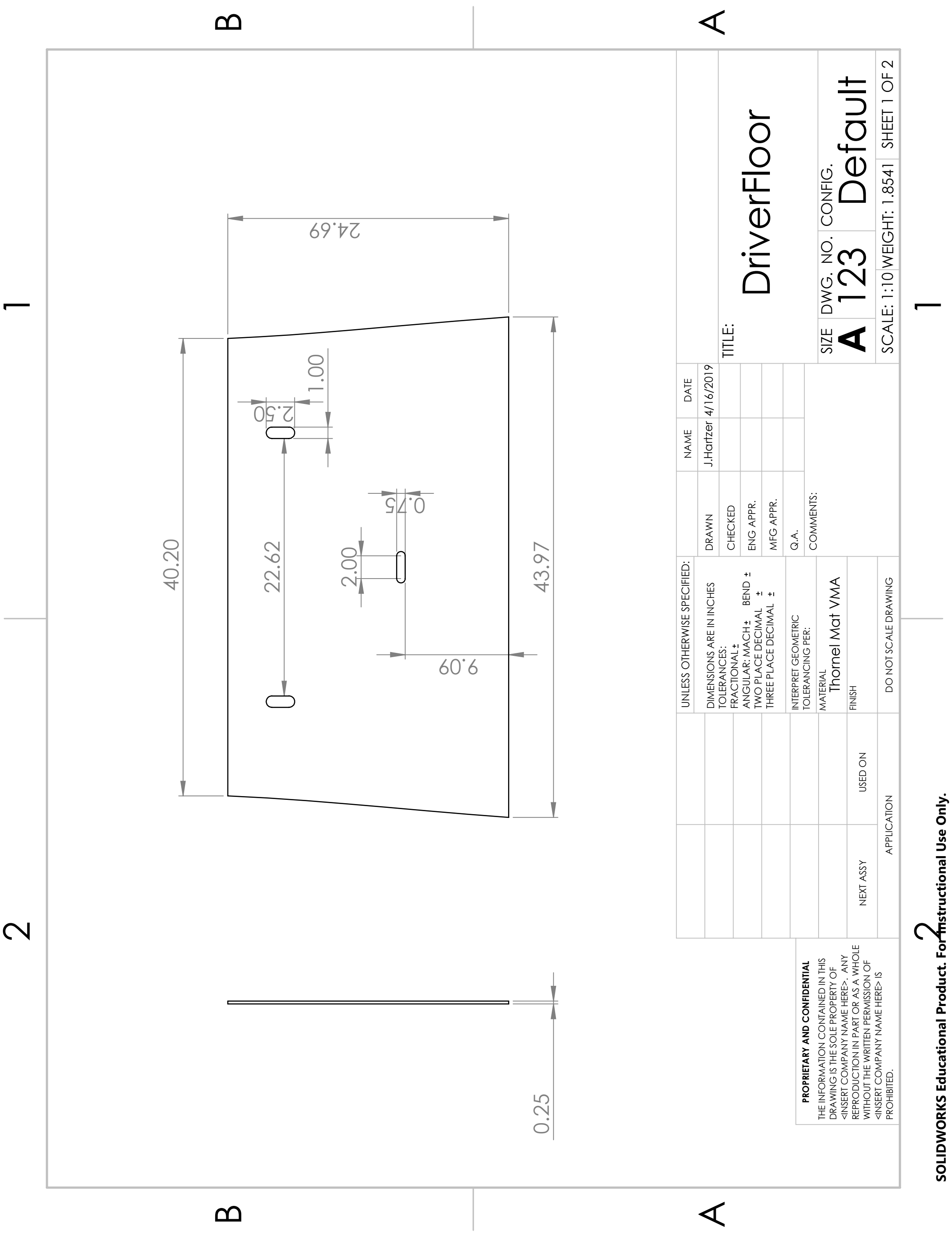

24.69
40.20
22.62
2.50
1.00
0.75
2.00
9.09
43.97
0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Thornel Mat VMA
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
DriverFloor
SIZE
A
DWG. NO.
123
CONFIG.
Default
SCALE: 1:10
WEIGHT: 1.8541
SHEET 1 OF 2
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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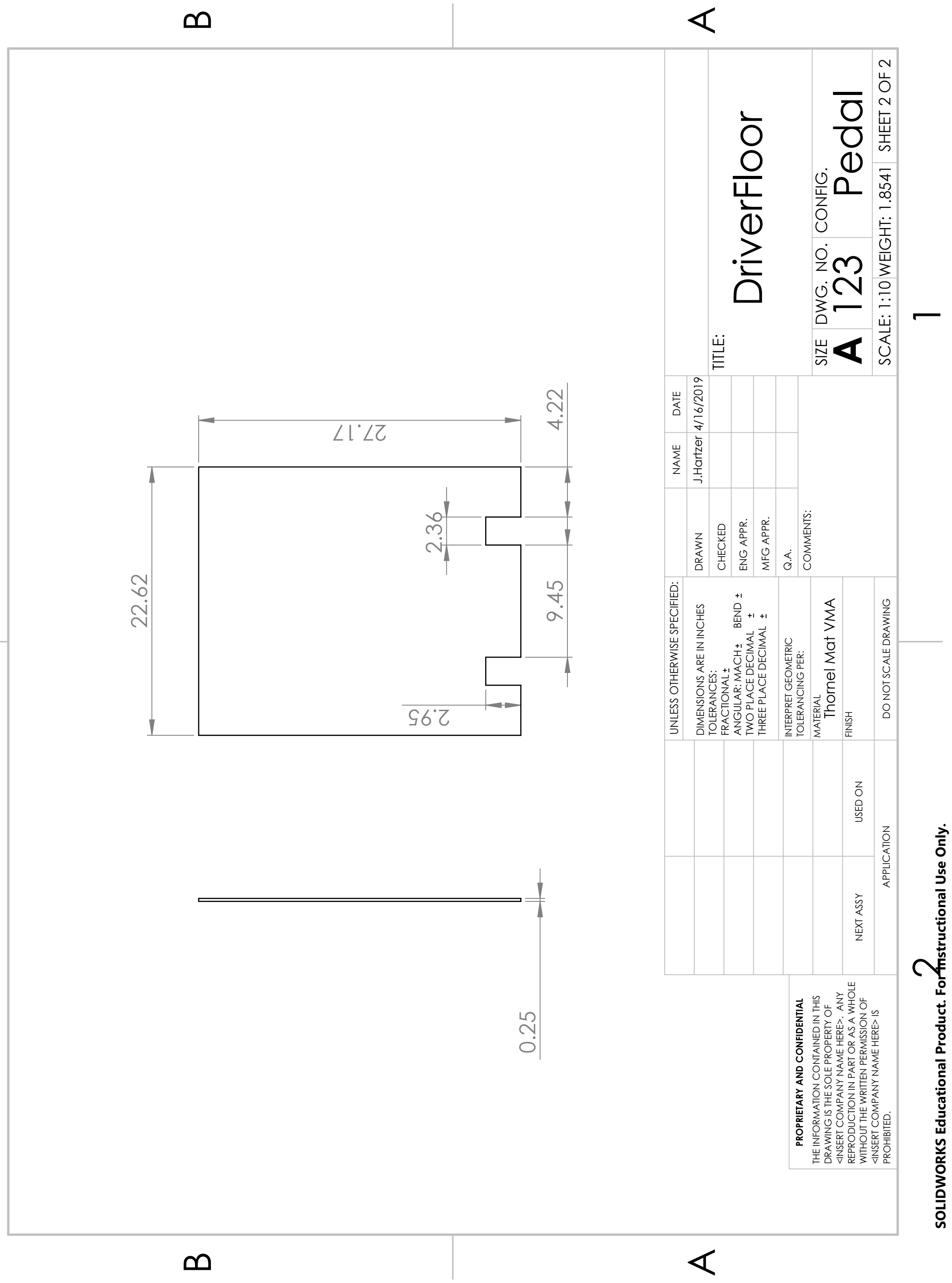

DriverFloor
TITLE:
SIZE
A
DWG. NO.
123
CONFIG.
Pedal
SCALE: 1:10
WEIGHT: 1.8541
SHEET 2 OF 2
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Thornel Mat VMA
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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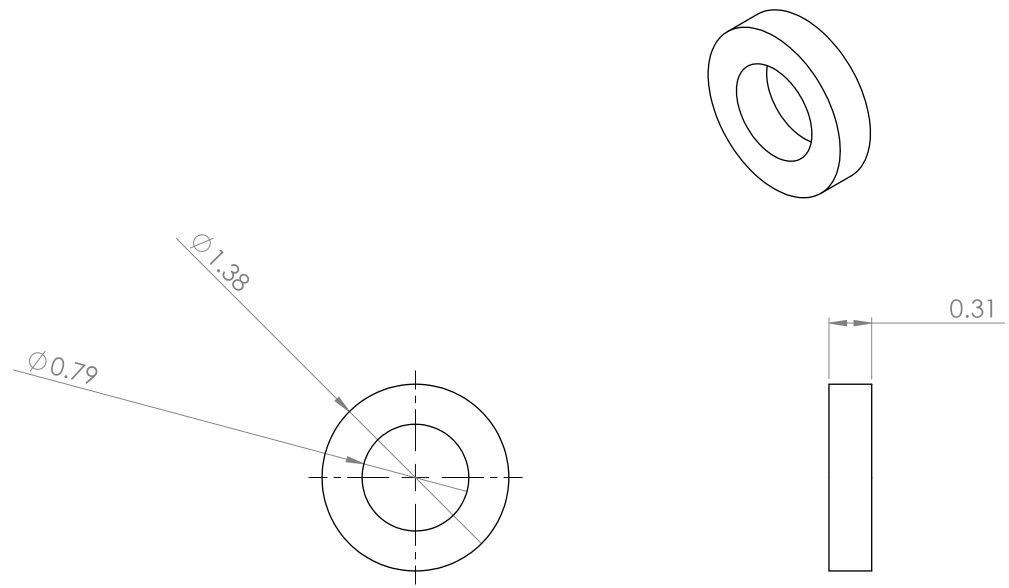
SOLIDWORKS Educational Product. For Instructional Use Only.
27.17
22.62
4.22
2.36
9.45
2.95
0.25
A
B
1
2





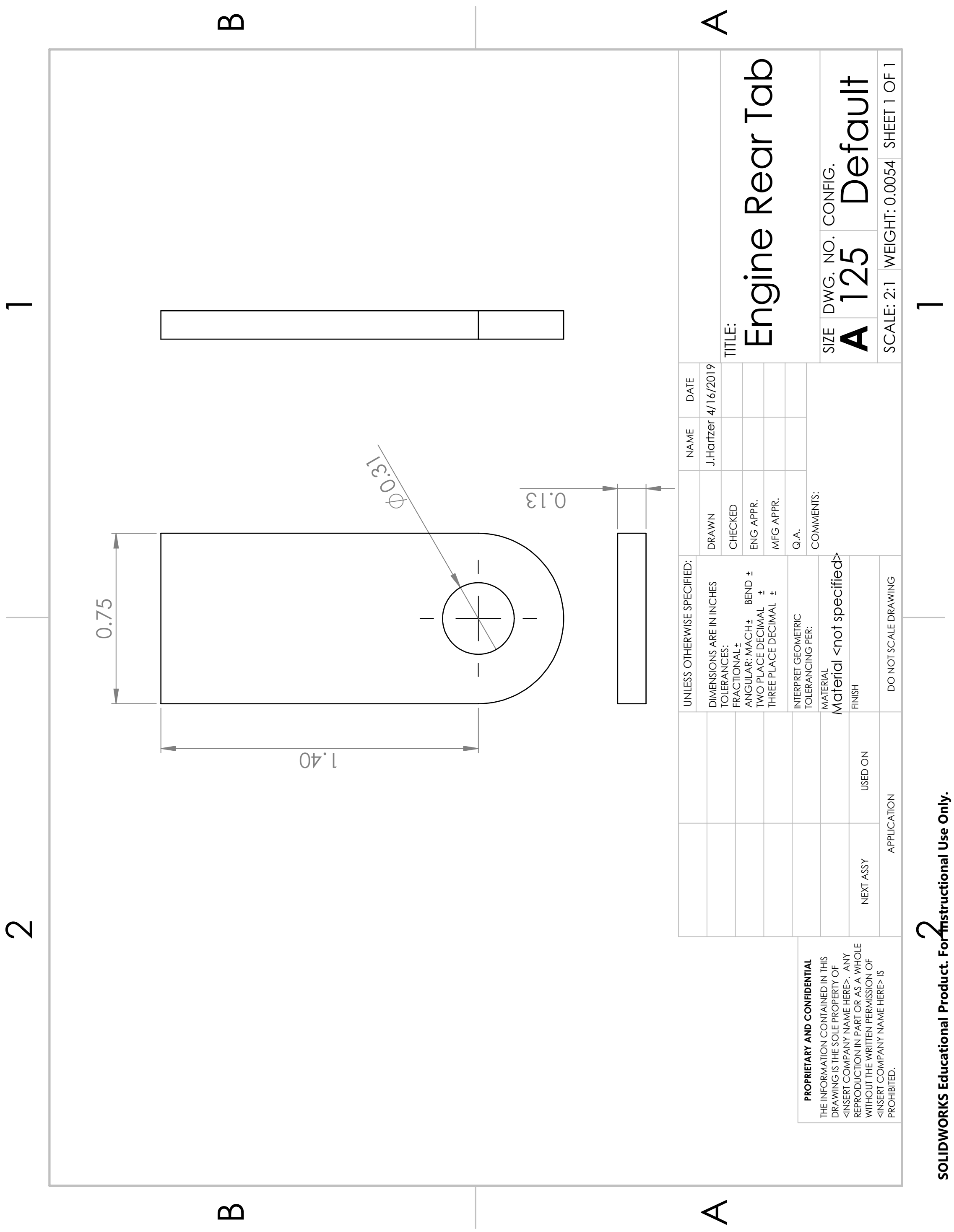

| | |
|---|---|
| UNLESS OTHERWISE SPECIFIED: | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | |
| INTERPRET GEOMETRIC TOLERANCING PER: | |
| MATERIAL | Rubber |
| FINISH | |
| DO NOT SCALE DRAWING | |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |
| COMMENTS: | | |

TITLE: **DustSeal**

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 124 | Default |
| SCALE: 1:1 | WEIGHT: 0.0114 | SHEET 1 OF 1 |


Engine Rear Tab
TITLE:
SIZE
A
DWG. NO.
125
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0054
SHEET 1 OF 1
0.75
1.40
Φ0.31
0.13
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC
TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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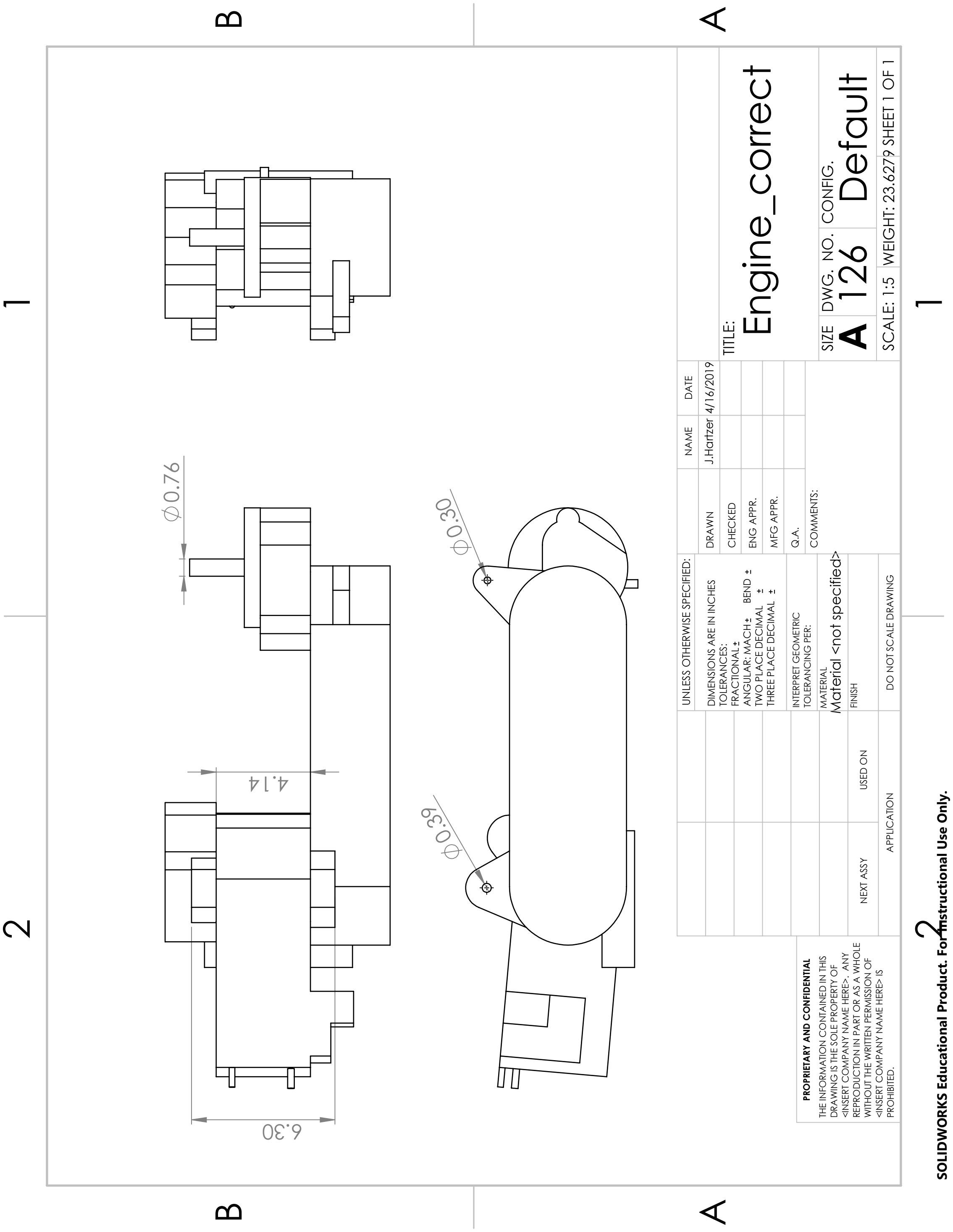

Ø0.76
Ø0.30
Ø0.39
4.14
6.30
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Engine_correct
SIZE
A
DWG. NO.
126
CONFIG.
Default
SCALE: 1:5
WEIGHT: 23.6279
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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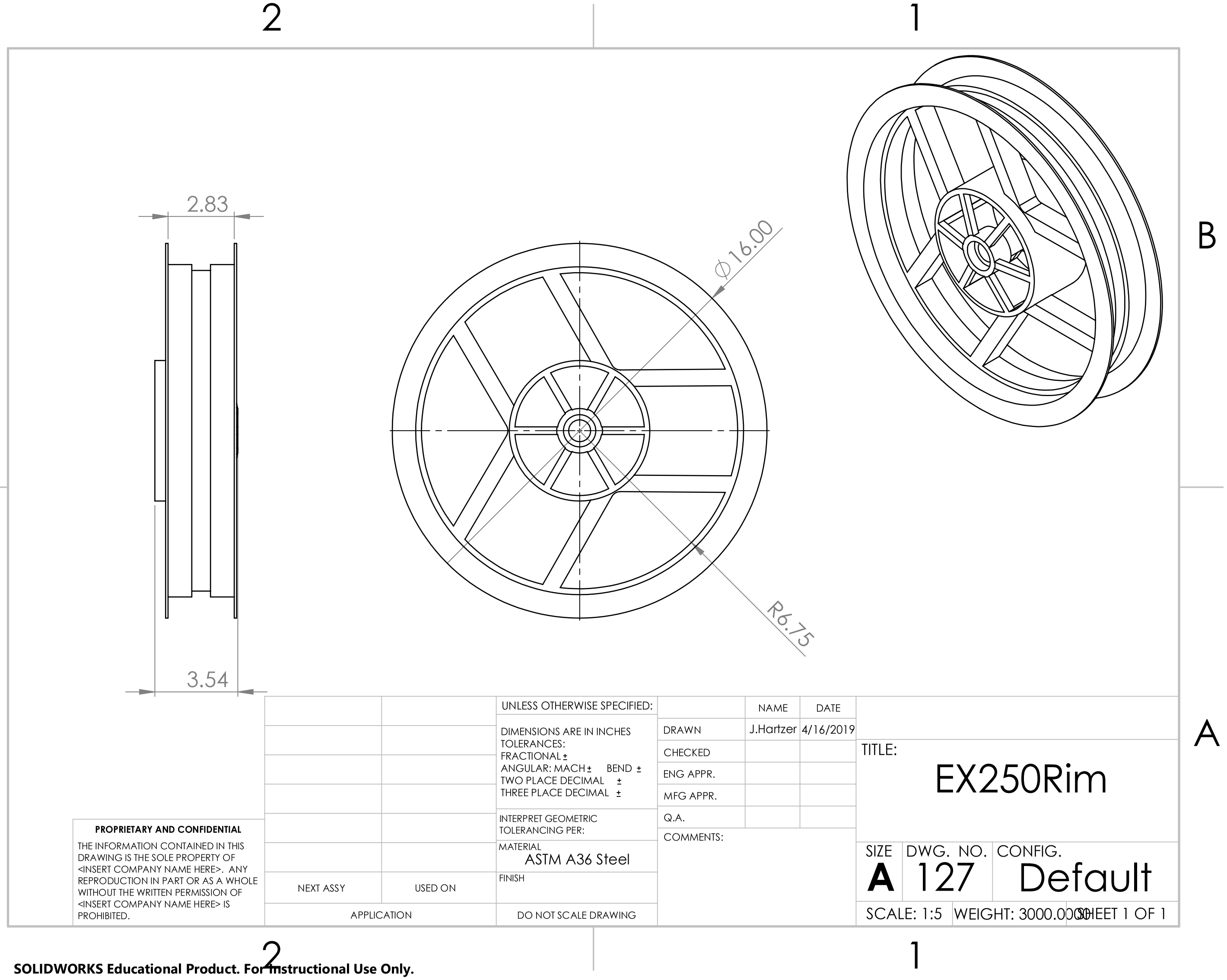
2
1
B
A
2.83
3.54
∅16.00
R6.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
EX250Rim
SIZE A
DWG. NO. 127
CONFIG. Default
SCALE: 1:5
WEIGHT: 3000.00
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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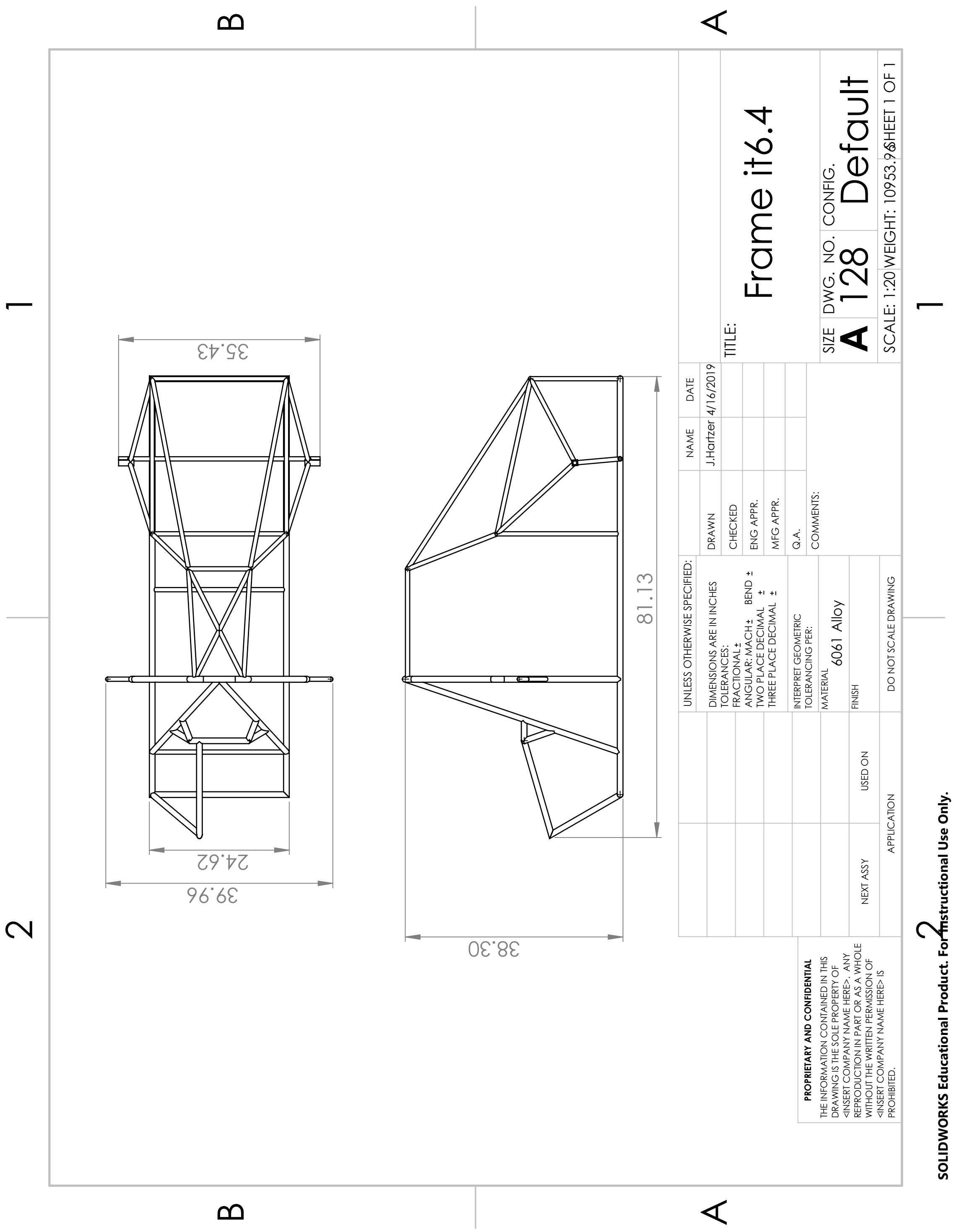
35.43
81.13
24.62
39.96
38.30
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Frame it6.4
SIZE
A
DWG. NO.
128
CONFIG.
Default
SCALE: 1:20
WEIGHT: 10953.96
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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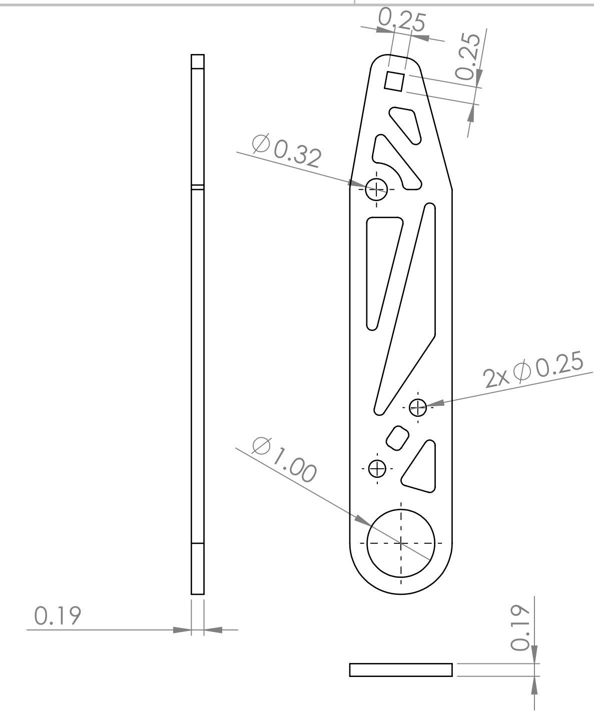


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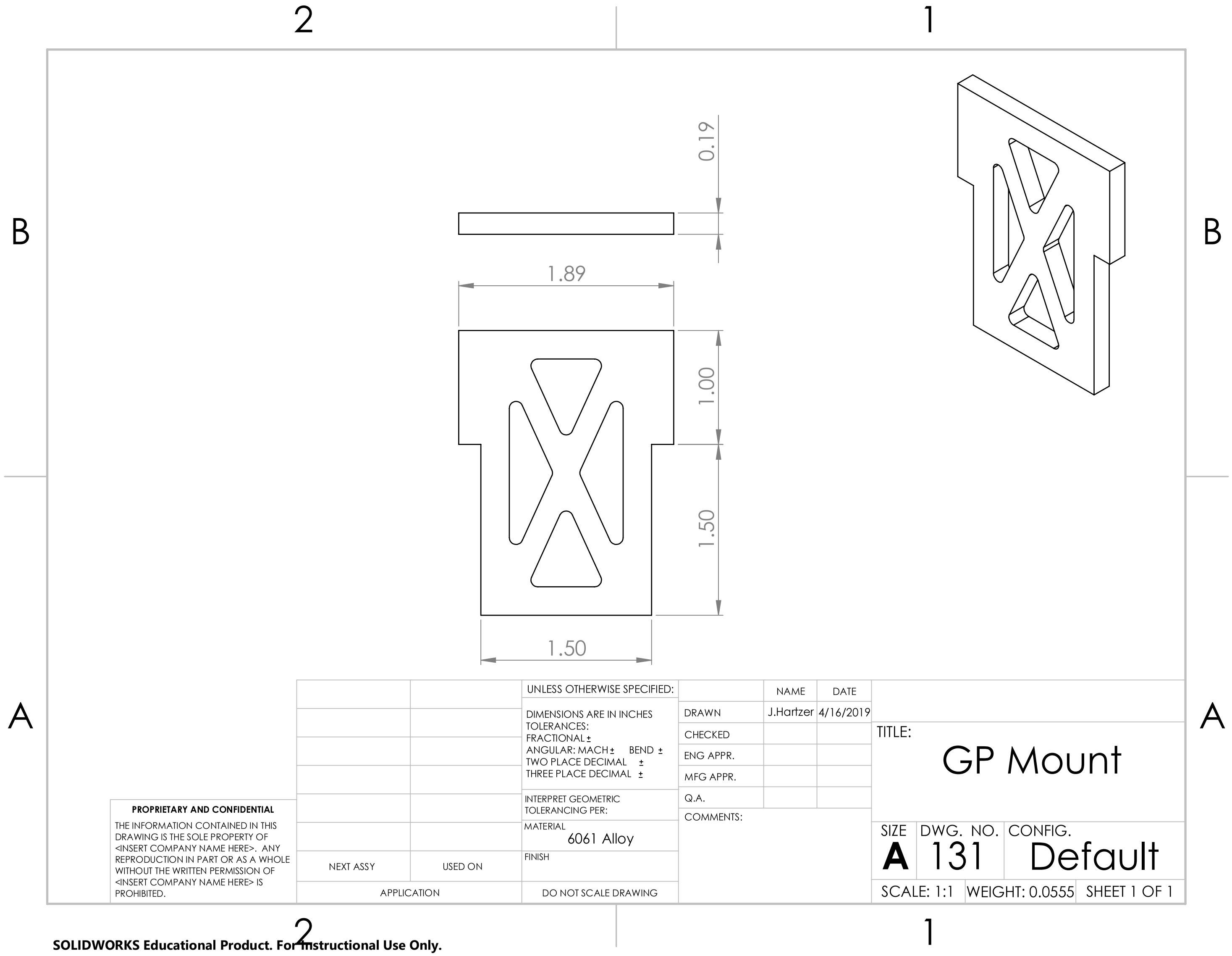
| | | | | | |
|---|---|---|---|---|---|
| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL<br>6061 Alloy | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

# Gas Pedal_Lever

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 129 | Default |
| SCALE: 1:2 | WEIGHT: 0.1346 | SHEET 1 OF 1 |



0.19
1.89
1.00
1.50
1.50
PROPRIETARY AND CONFIDENTIAL
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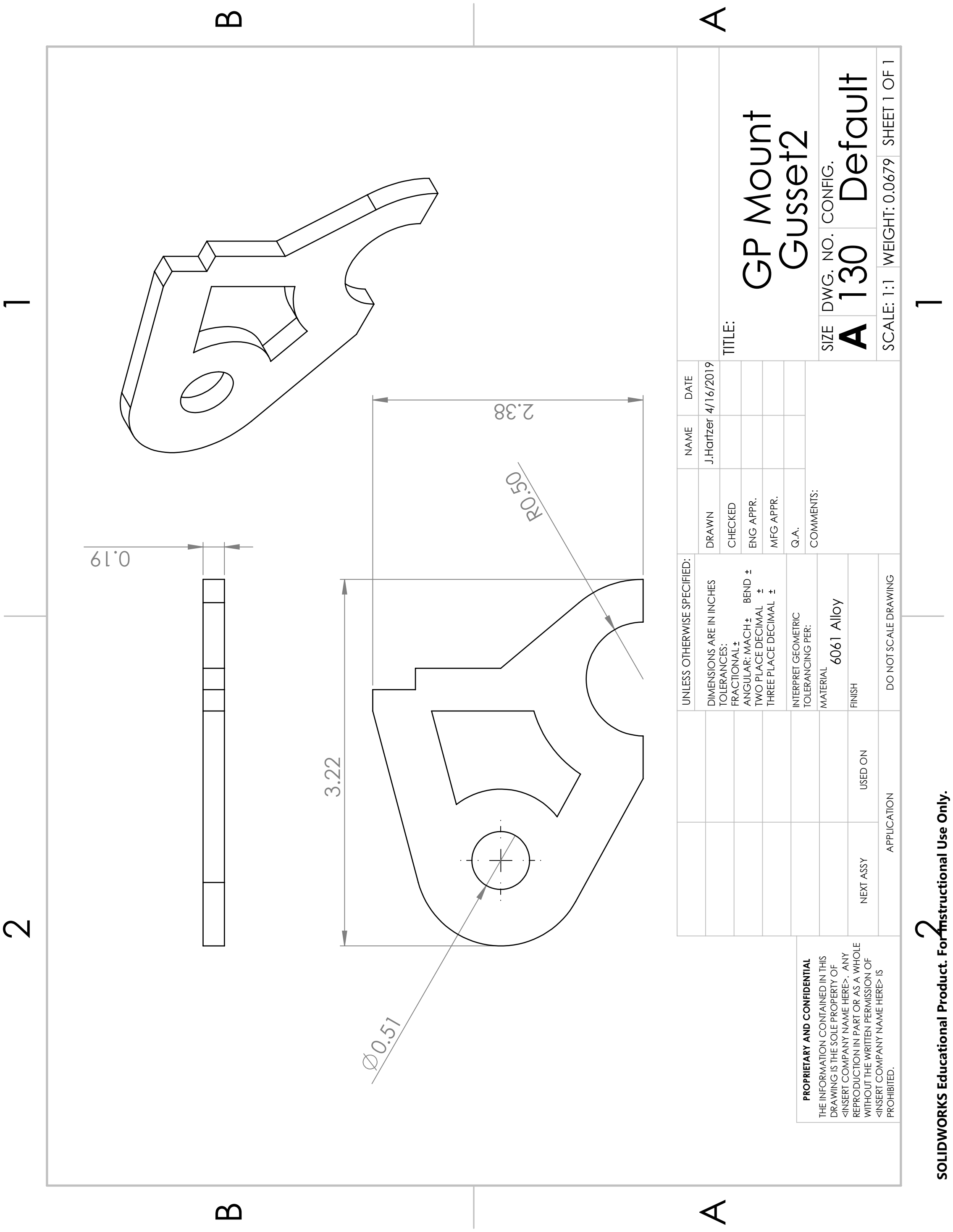
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
GP Mount
SIZE
A
DWG. NO.
131
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0555
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.


GP Mount Gusset2
TITLE:
SIZE A
DWG. NO. 130
CONFIG. Default
SCALE: 1:1
WEIGHT: 0.0679
SHEET 1 OF 1
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
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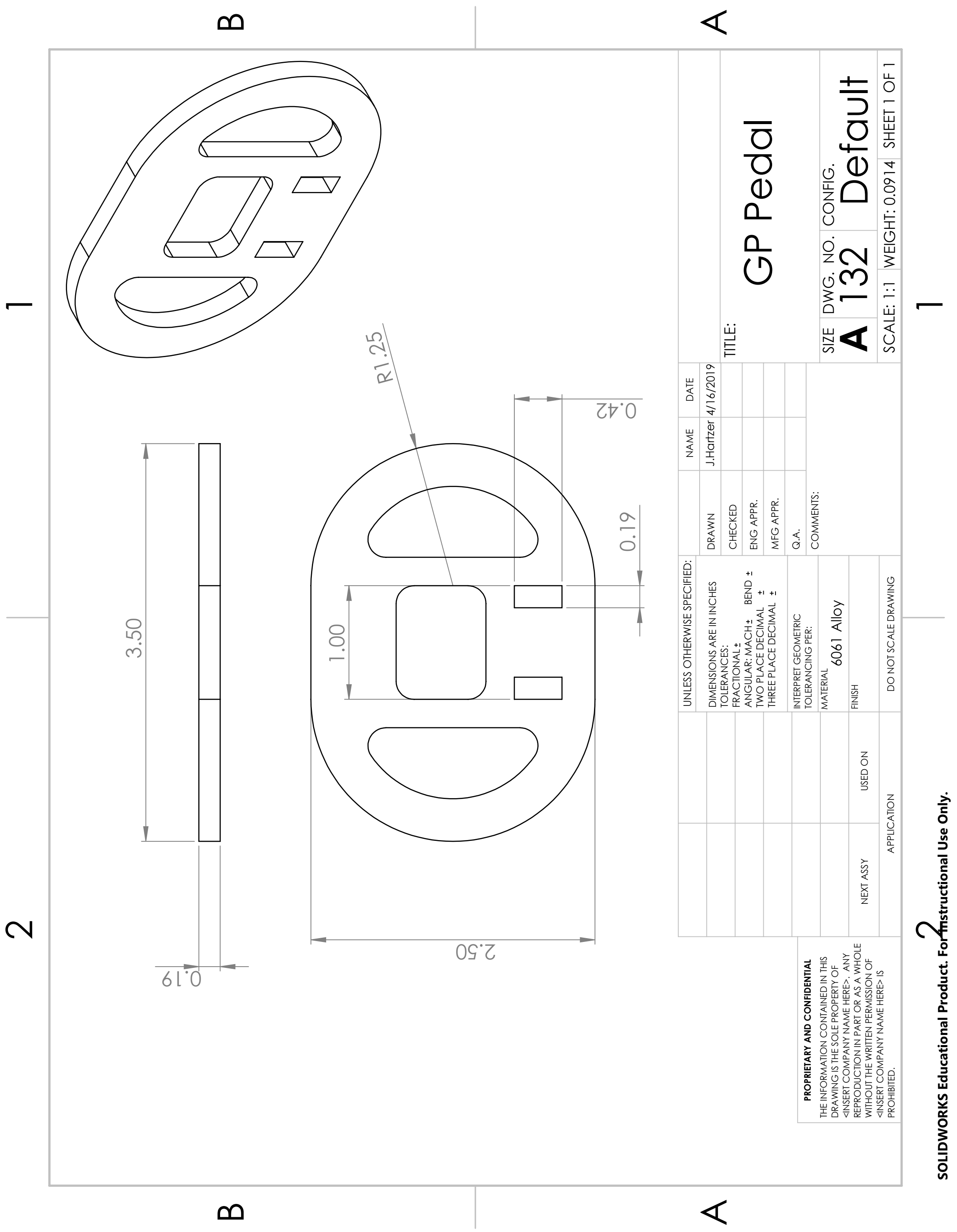
0.19
2.38
R0.50
3.22
Ø0.51
A
B
1
2


3.50
1.00
R1.25
0.42
0.19
2.50
0.19
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
GP Pedal
SIZE
A
DWG. NO.
132
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0914
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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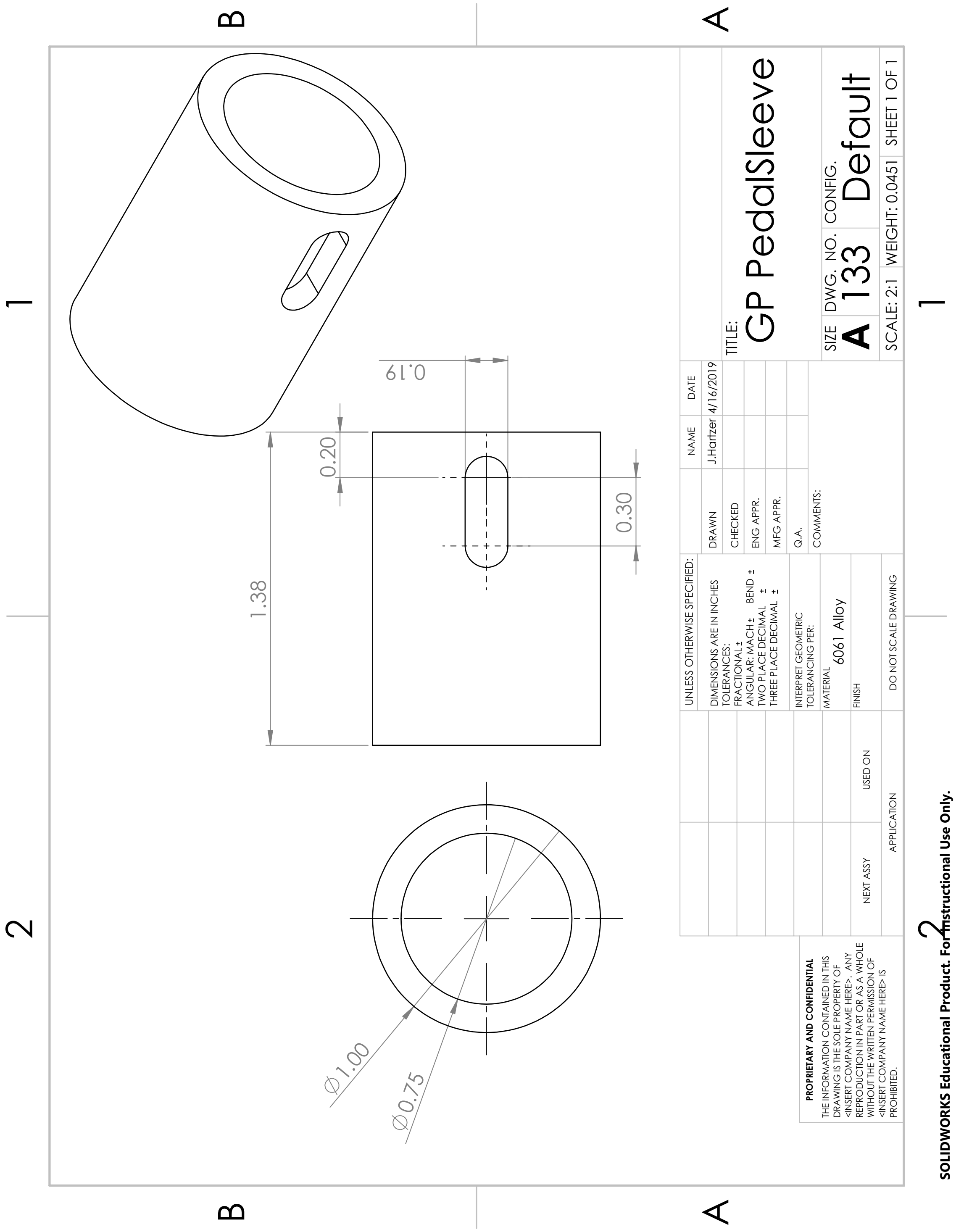

GP PedalSleeve
TITLE:
SIZE A
DWG. NO. 133
CONFIG. Default
SCALE: 2:1
WEIGHT: 0.0451
SHEET 1 OF 1
NAME
DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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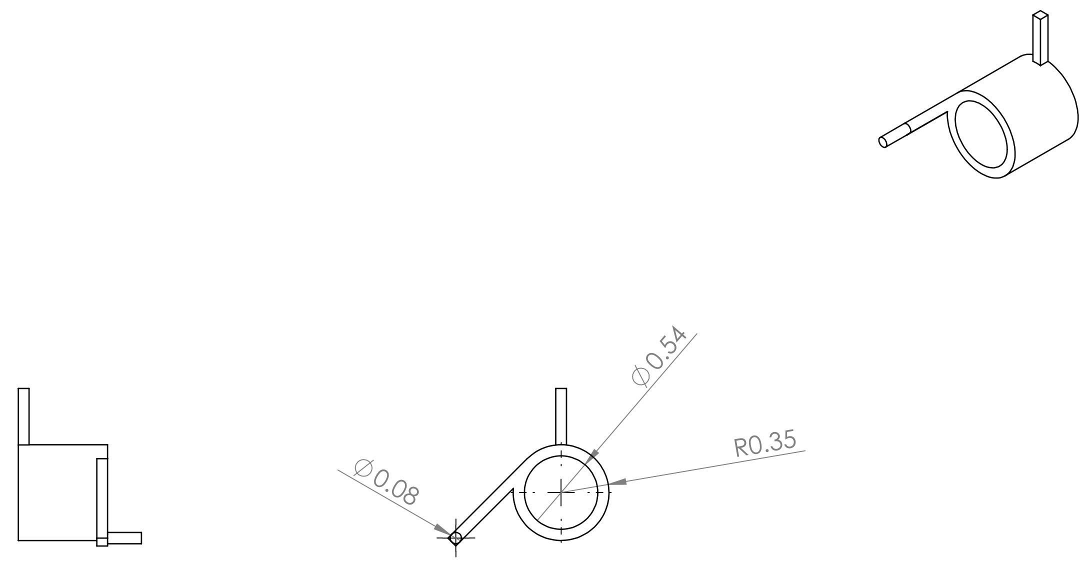
0.19
0.20
0.30
1.38
Ø1.00
Ø0.75




UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
ASTM A36 Steel

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

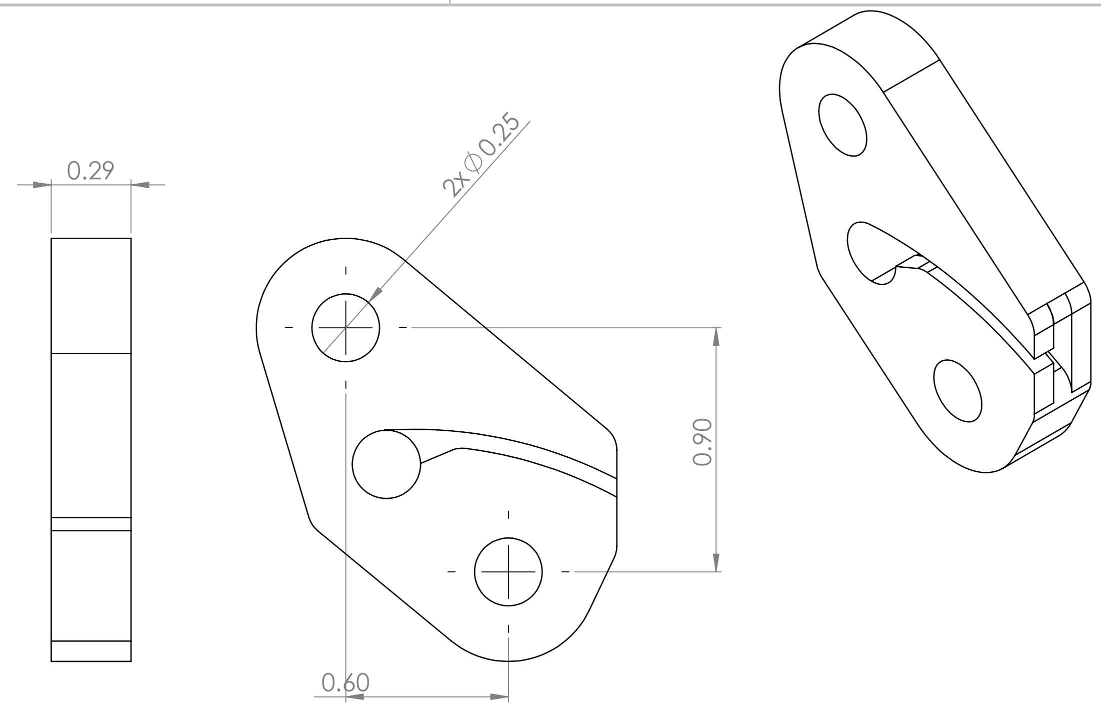
TITLE:
GP Return Spring

SIZE A | DWG. NO. 134 | CONFIG. Default

SCALE: 1:1 | WEIGHT: 0.0326 | SHEET 1 OF 1

NEXT ASSY | USED ON

APPLICATION

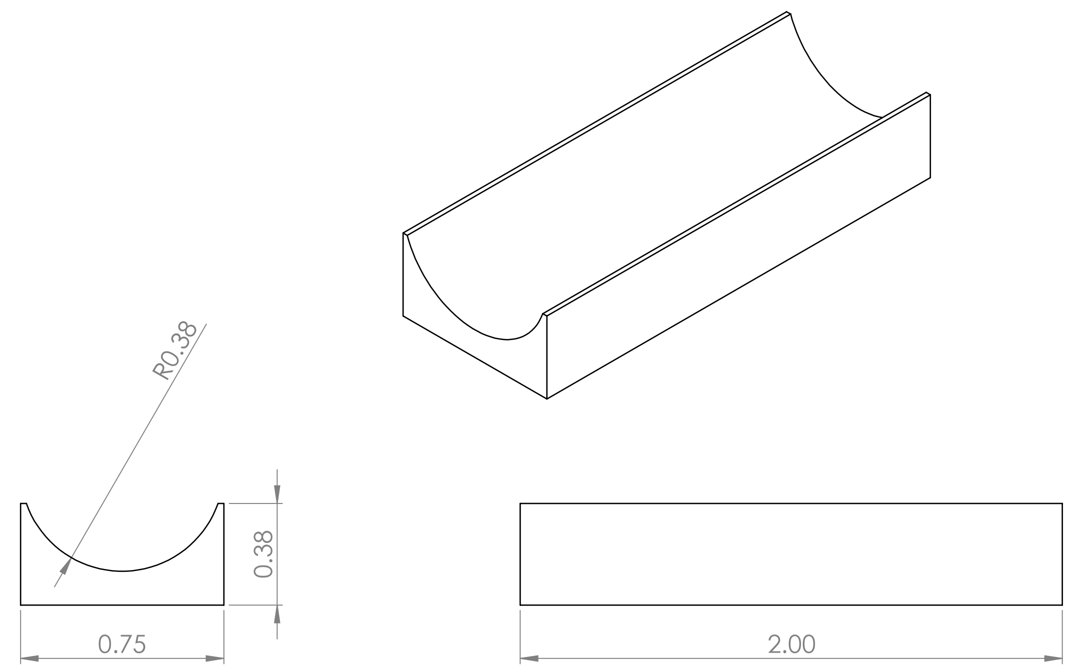



| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | CHECKED | | |
| | ENG APPR. | | |
| | MFG APPR. | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| MATERIAL ABS | COMMENTS: | | |
| FINISH | | | |
| DO NOT SCALE DRAWING | | | |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:
GP
throttle_mount2

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 135 | Default |
| SCALE: 2:1 | WEIGHT: 0.0124 | SHEET 1 OF 1 |




| | |
|---|---|
| UNLESS OTHERWISE SPECIFIED: | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | |
| INTERPRET GEOMETRIC TOLERANCING PER: | |
| MATERIAL | 6061 Alloy |
| FINISH | |
| DO NOT SCALE DRAWING | |

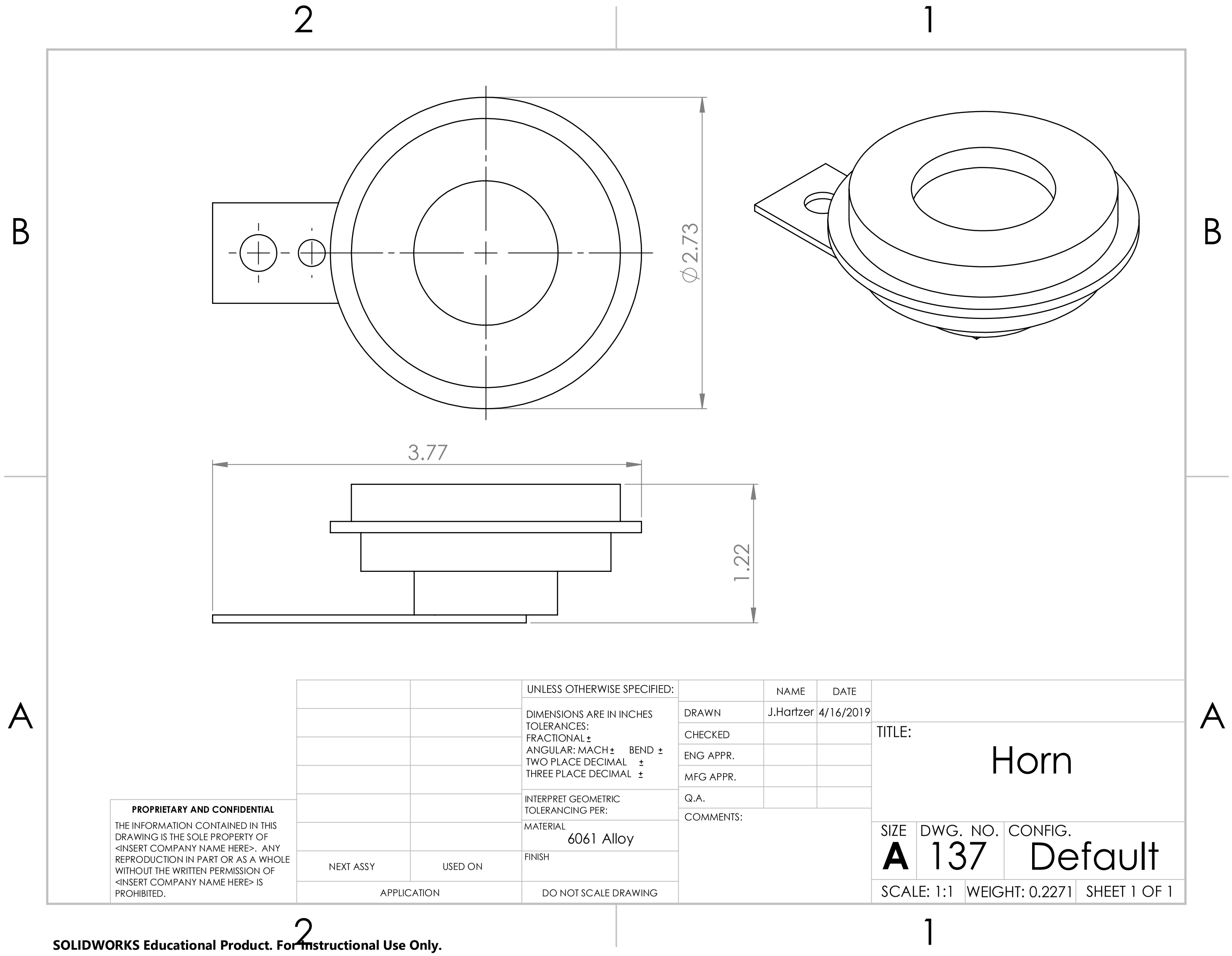
| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |
| COMMENTS: | | |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:

HangerSpacer

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 136 | Default |
| SCALE: 2:1 | WEIGHT: 0.0297 | SHEET 1 OF 1 |



2
1
B
A
⌀2.73
3.77
1.22
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Horn
SIZE
A
DWG. NO.
137
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.2271
SHEET 1 OF 1
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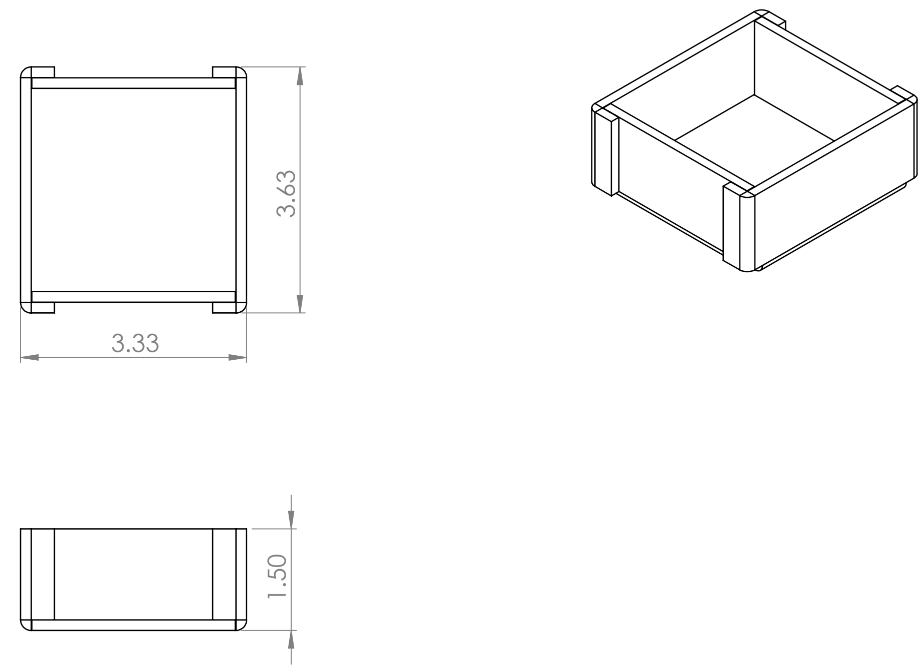



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
ABS

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

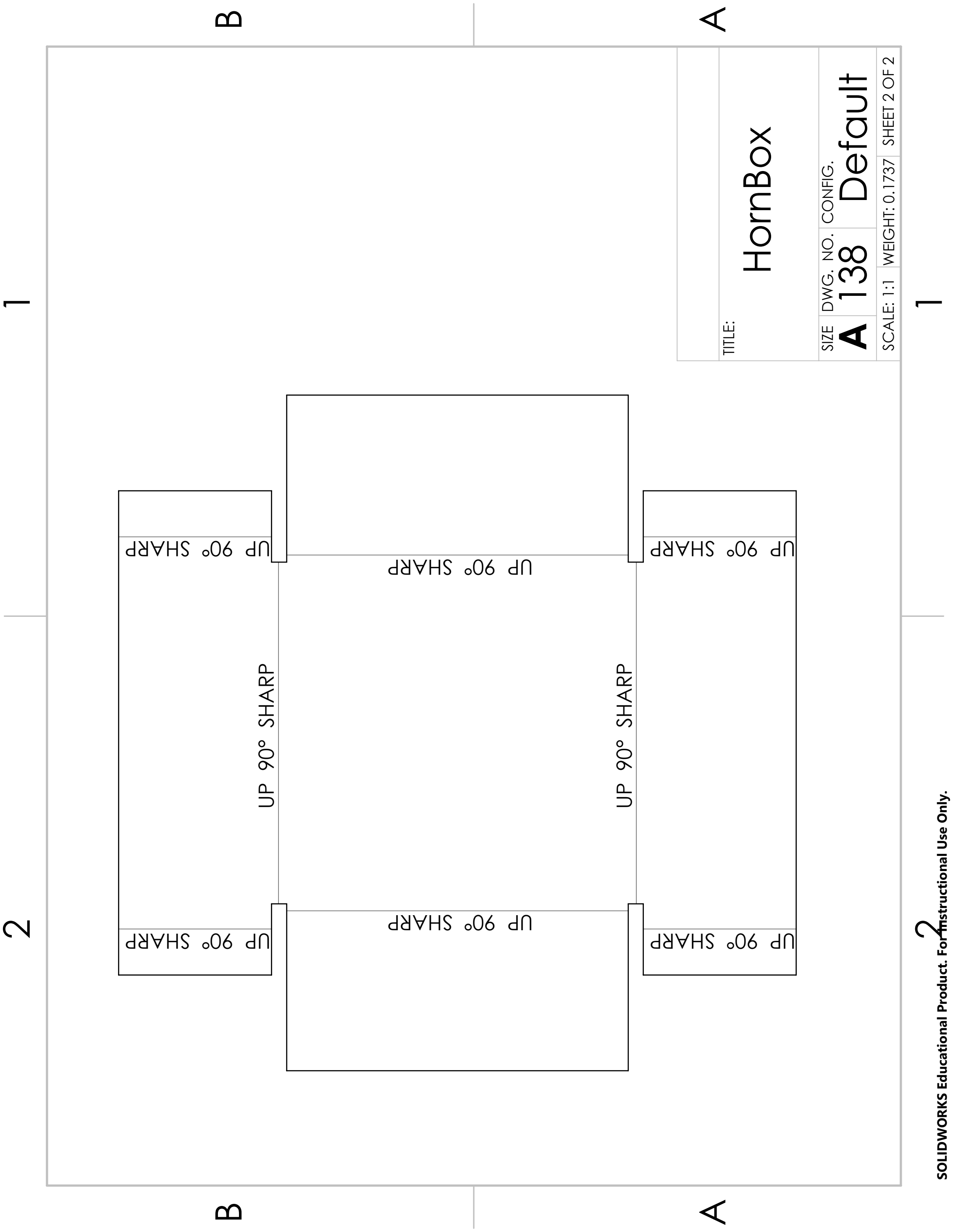
TITLE:

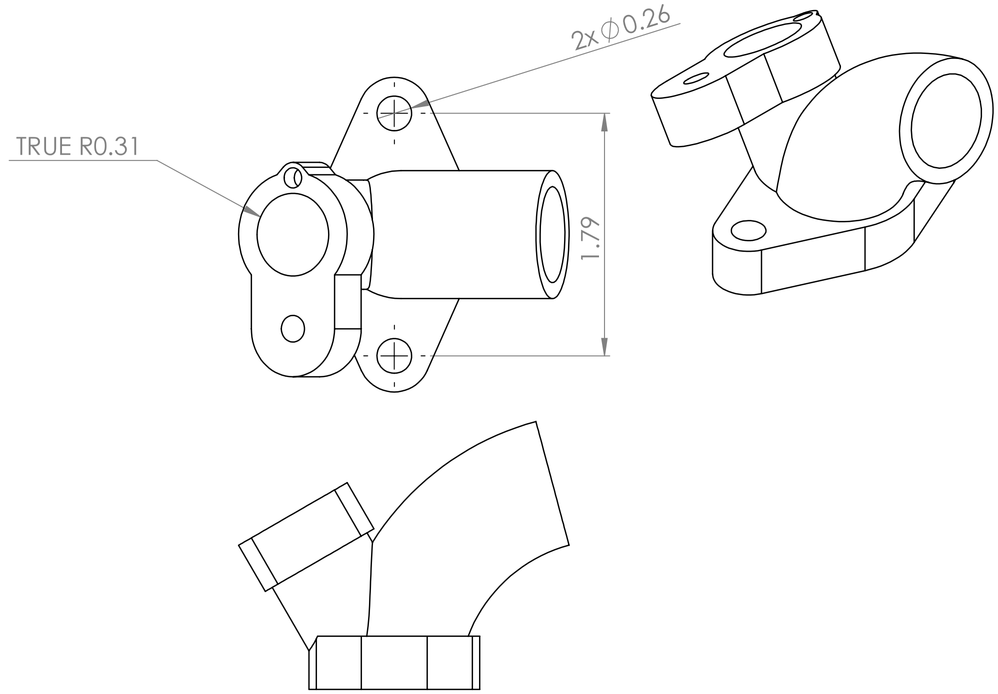
# HornBox

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 138 | Default |

SCALE: 1:2 WEIGHT: 0.1737 SHEET 1 OF 2

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |


UP 90° SHARP
UP 90° SHARP
UP 90° SHARP
UP 90° SHARP
UP 90° SHARP
UP 90° SHARP
UP 90° SHARP
UP 90° SHARP
TITLE:
HornBox
SIZE
A
DWG. NO.
138
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.1737
SHEET 2 OF 2
SOLIDWORKS Educational Product. For Instructional Use Only.

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NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING

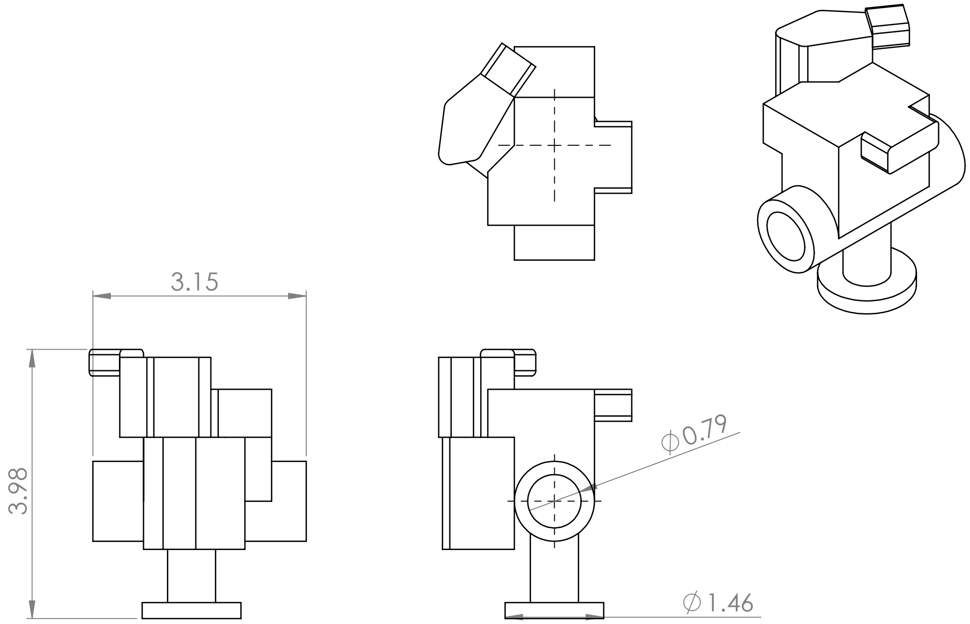
| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE:
# Intake Manifold

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 139 | Default |

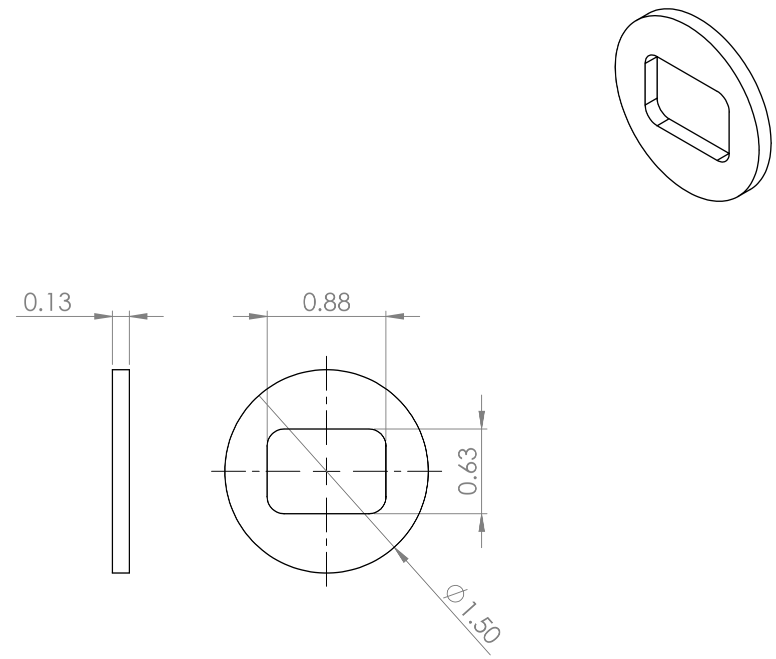
SCALE: 1:1 | WEIGHT: 0.0510 | SHEET 1 OF 1



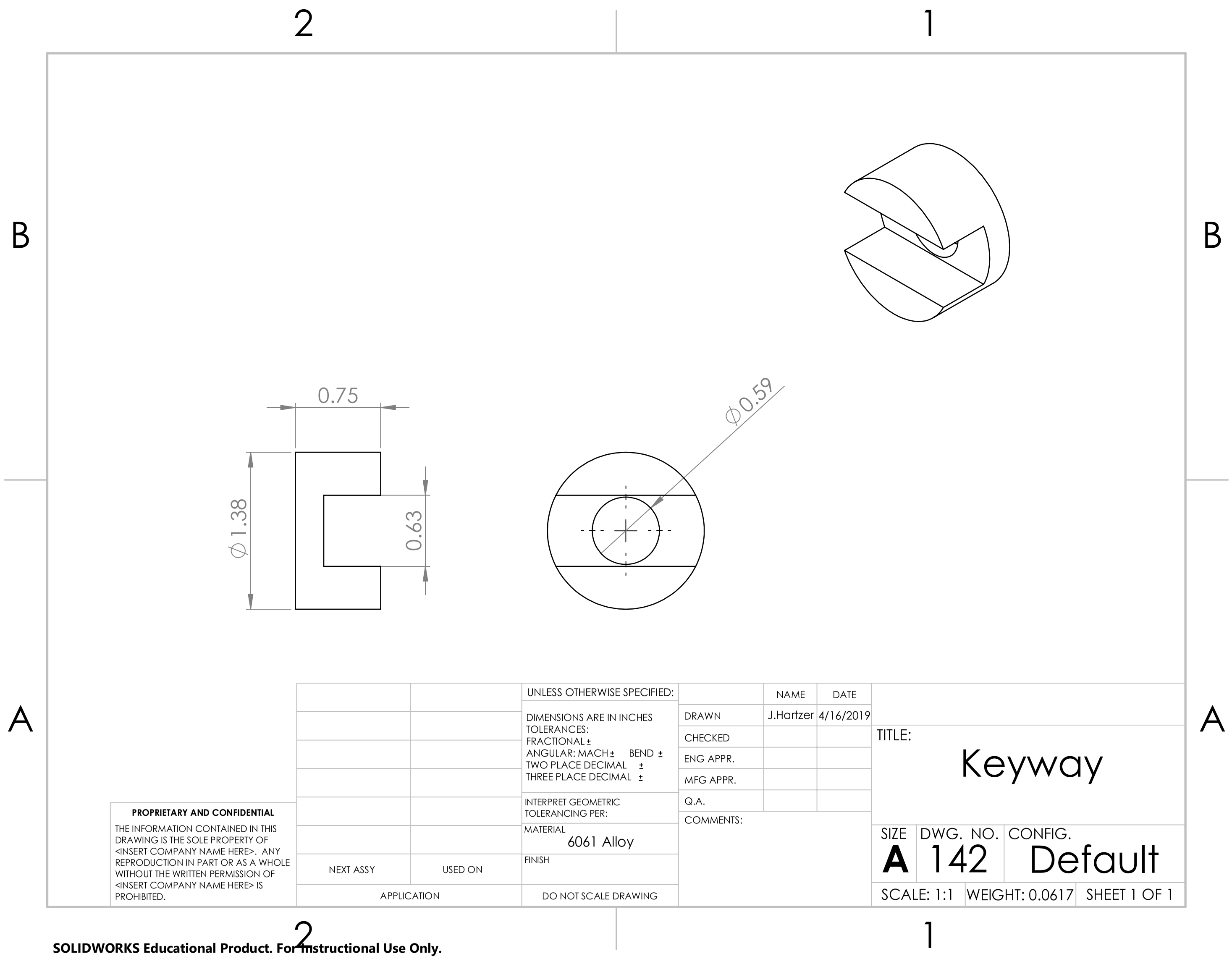

| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL Material <not specified> | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:
Intake Throttle Body

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 140 | Default |
| SCALE: 1:2 | WEIGHT: 0.3141 | SHEET 1 OF 1 |




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: |
| | | | CHECKED | | | KeySpacer |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL<br>1060 Alloy | COMMENTS: | | | SIZE A · DWG. NO. 141 · CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:1 · WEIGHT: 0.0150 · SHEET 1 OF 1 |


2
1
B
A
0.75
∅1.38
0.63
∅0.59
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Keyway
SIZE
A
DWG. NO.
142
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0617
SHEET 1 OF 1
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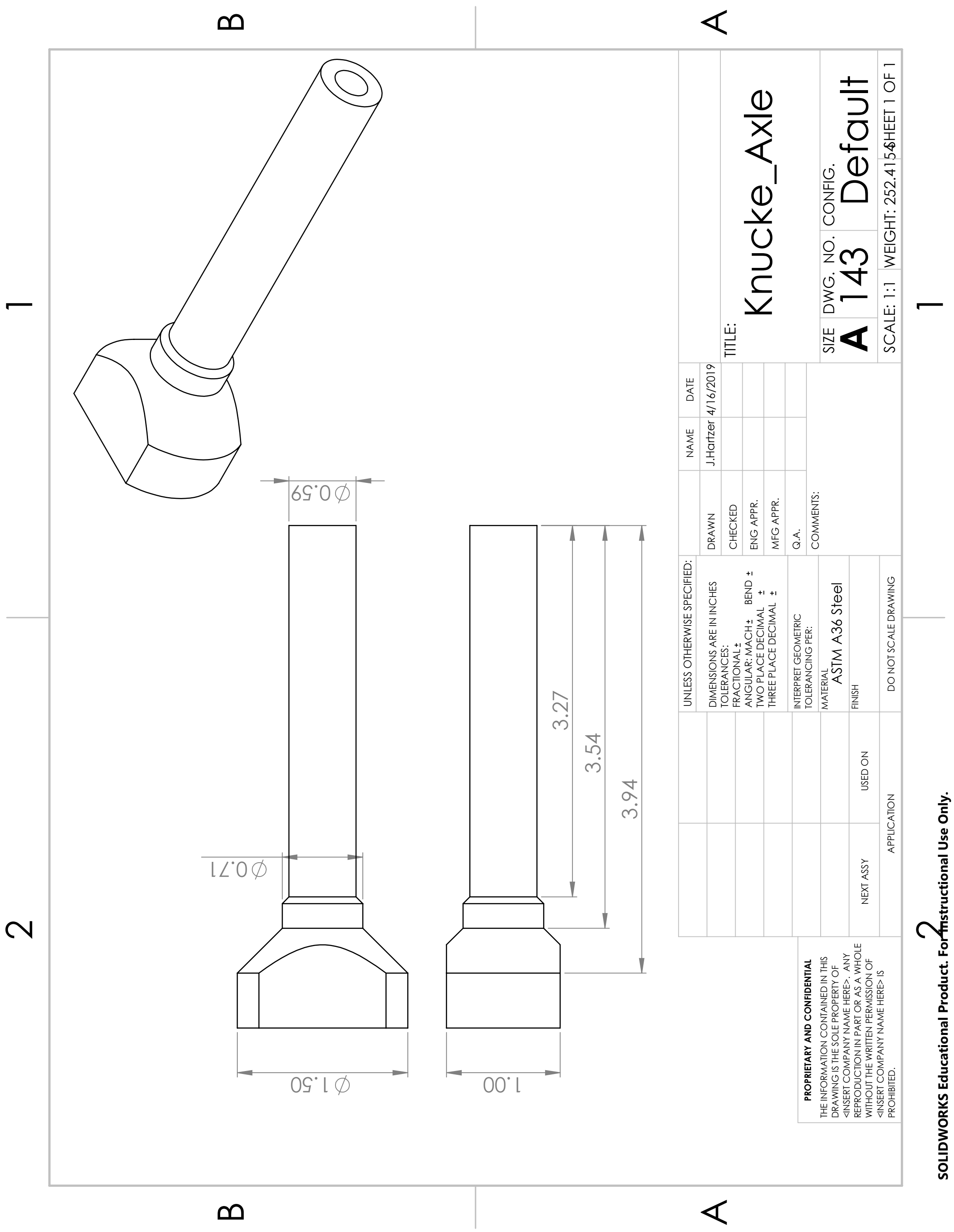
Knucke_Axle
TITLE:
SIZE A
DWG. NO. 143
CONFIG. Default
SCALE: 1:1
WEIGHT: 252.4154
SHEET 1 OF 1
DRAWN J.Hartzer 4/16/2019
NAME
DATE
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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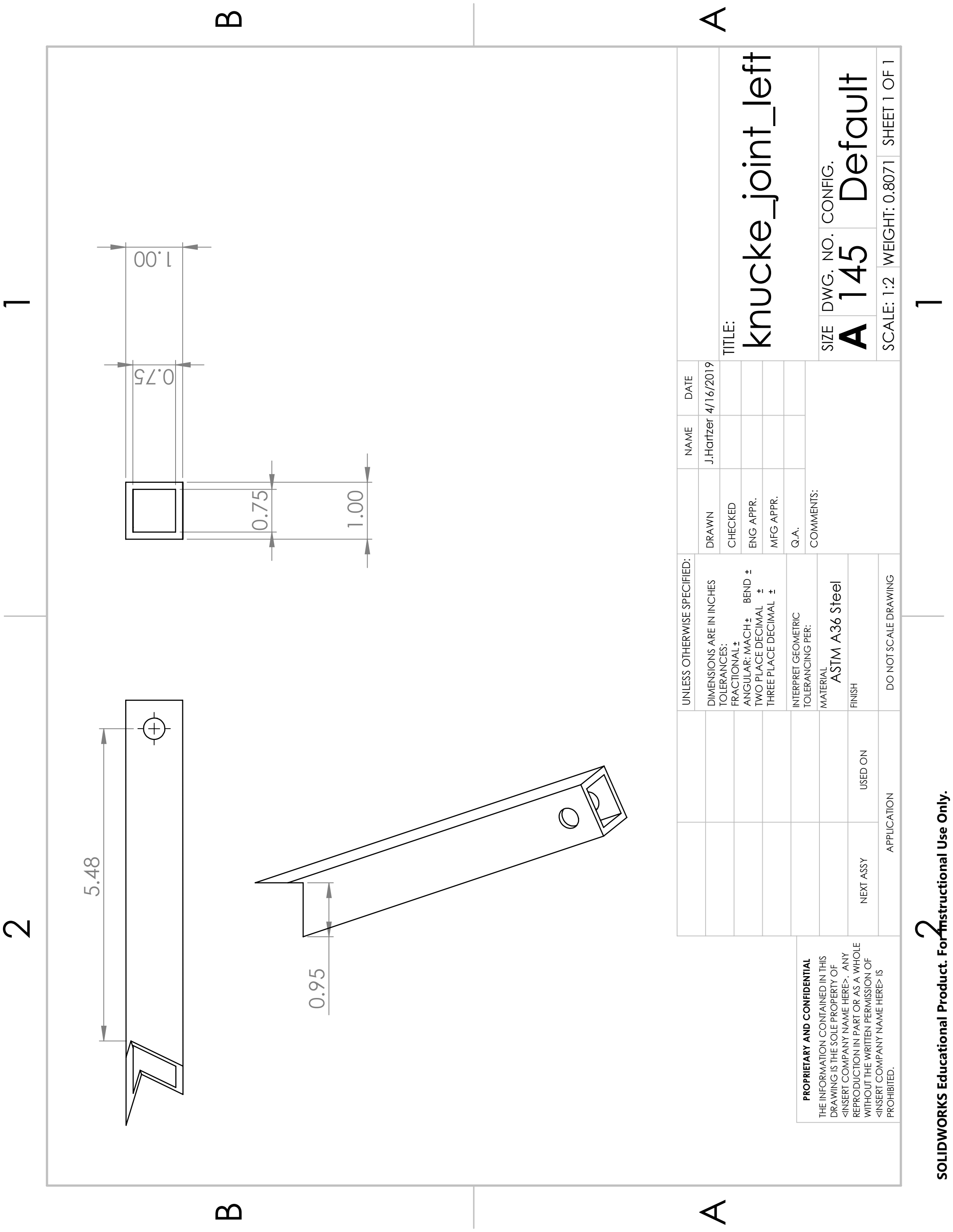
∅0.59
∅0.71
∅1.50
1.00
3.27
3.54
3.94
A
B
1
2


knucke_joint_left
TITLE:
SIZE A
DWG. NO. 145
CONFIG. Default
SCALE: 1:2
WEIGHT: 0.8071
SHEET 1 OF 1
DRAWN J.Hartzer 4/16/2019
NAME
DATE
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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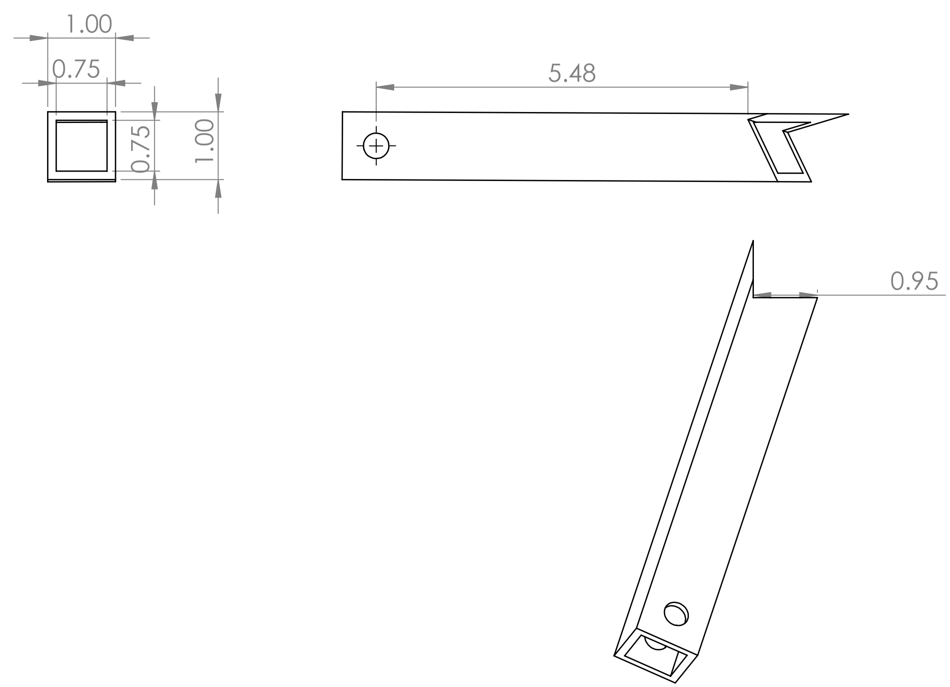
1.00
0.75
0.75
1.00
5.48
0.95
A
B
1
2

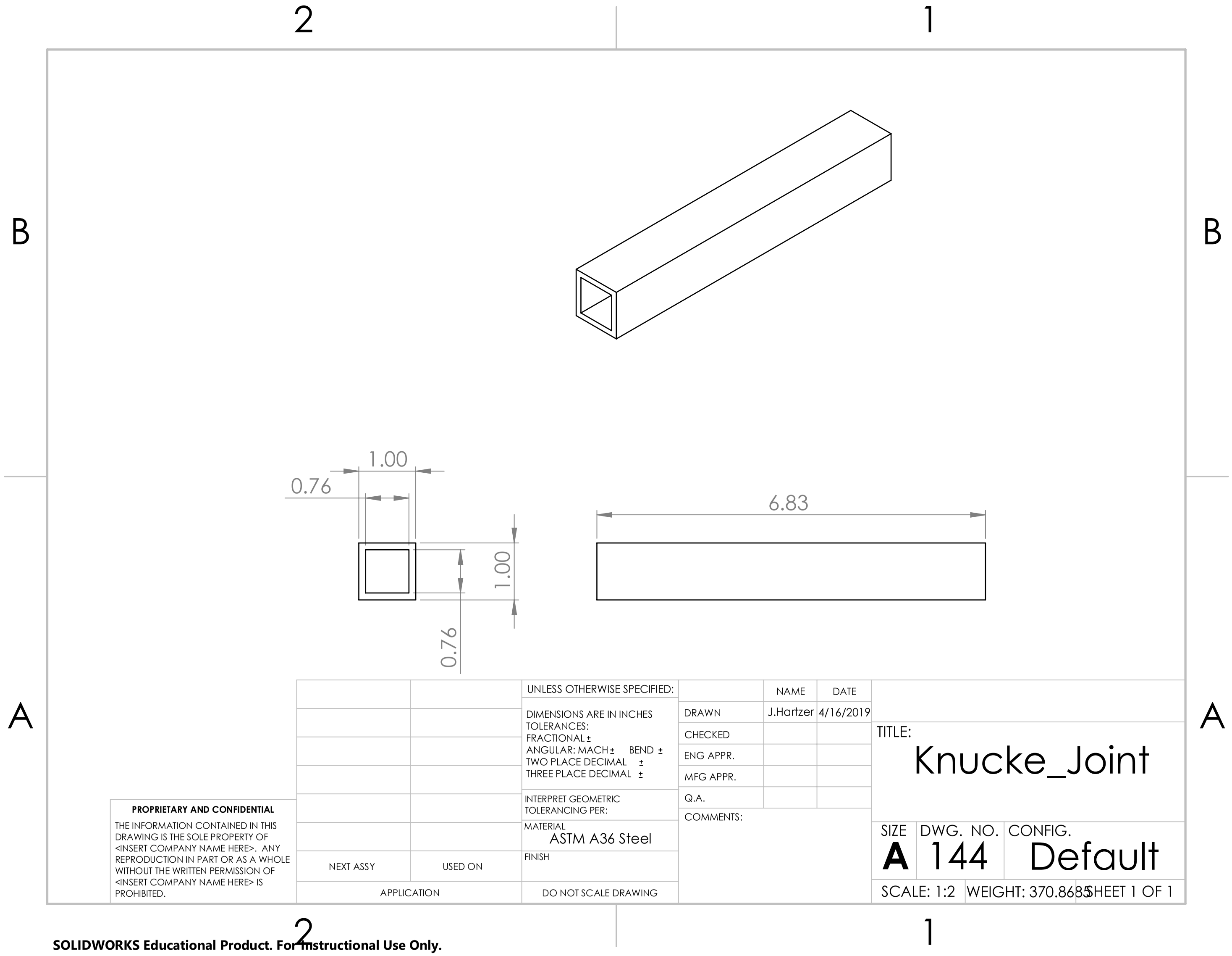



| | |
|---|---|
| UNLESS OTHERWISE SPECIFIED: | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | |
| INTERPRET GEOMETRIC TOLERANCING PER: | |
| MATERIAL | ASTM A36 Steel |
| FINISH | |
| NEXT ASSY | USED ON |
| APPLICATION | DO NOT SCALE DRAWING |

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |
| COMMENTS: | | |

TITLE: knucke_joint_right

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 146 | Default |
| SCALE: 1:2 | WEIGHT: 0.8071 | SHEET 1 OF 1 |



1.00
0.76
6.83
1.00
0.76
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Knucke_Joint
SIZE
A
DWG. NO.
144
CONFIG.
Default
SCALE: 1:2
WEIGHT: 370.8685
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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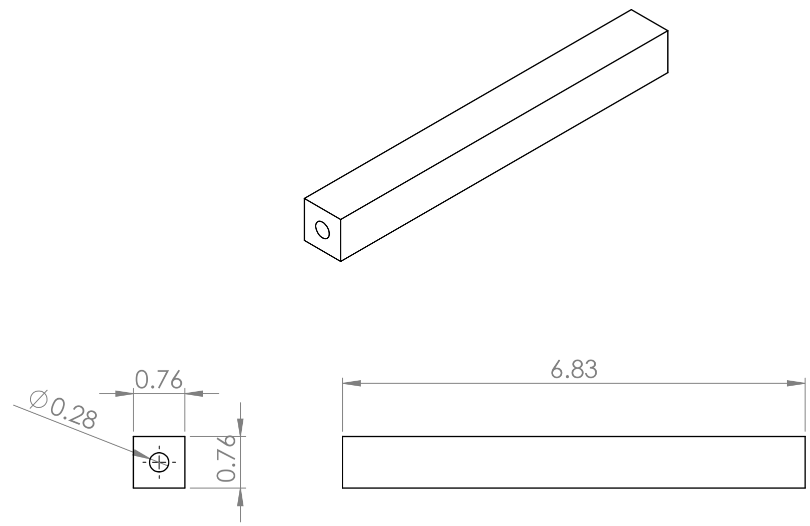
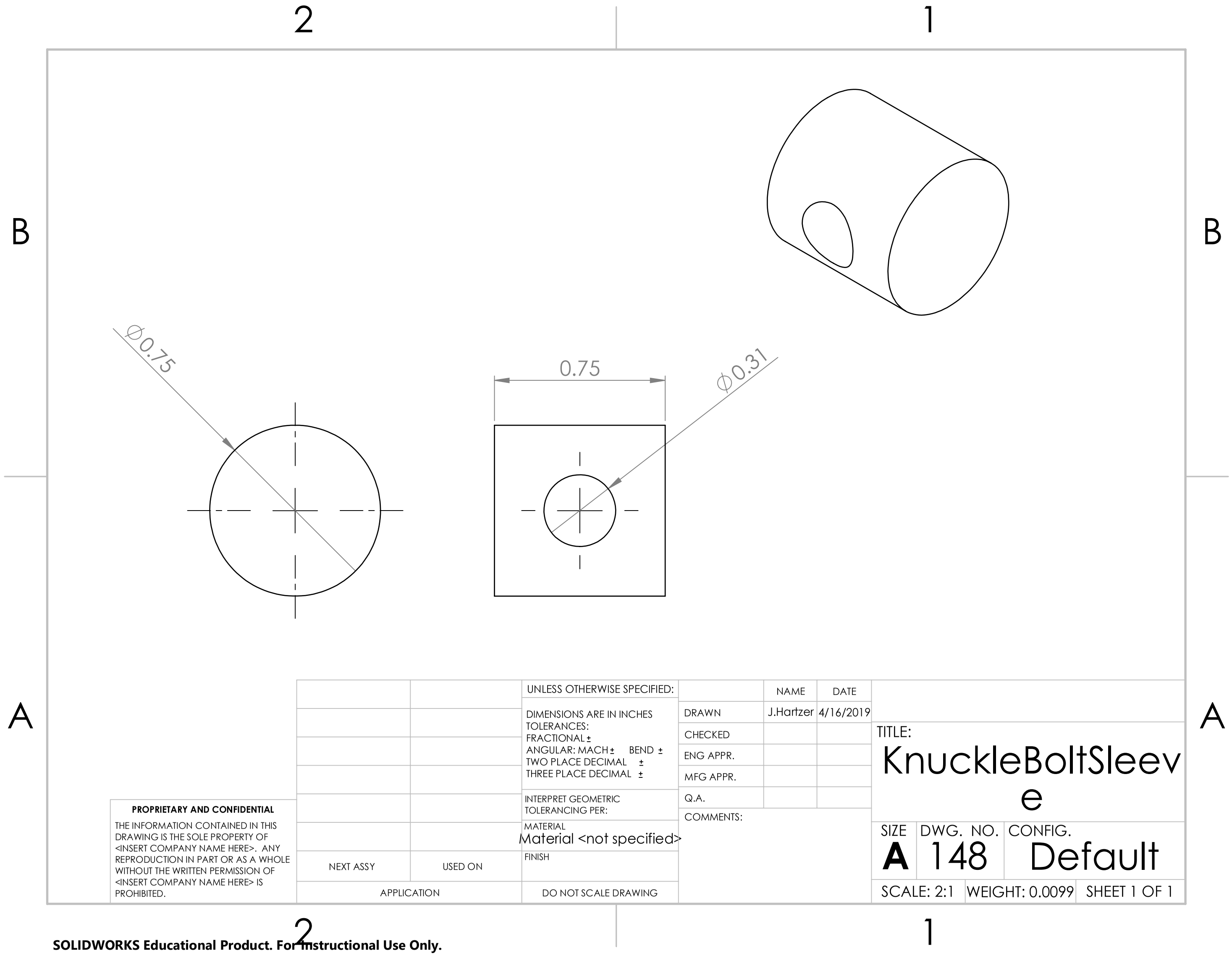



| | | | |
|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
| DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 |
| | CHECKED | | |
| | ENG APPR. | | |
| | MFG APPR. | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| MATERIAL 6061 Alloy | COMMENTS: | | |
| FINISH | | | |
| DO NOT SCALE DRAWING | | | |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:
# Knuckle_Insert

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 147 | Default |
| SCALE: 1:2 | WEIGHT: 0.3703 | SHEET 1 OF 1 |



2
1
B
A
Ø0.75
0.75
Ø0.31
PROPRIETARY AND CONFIDENTIAL
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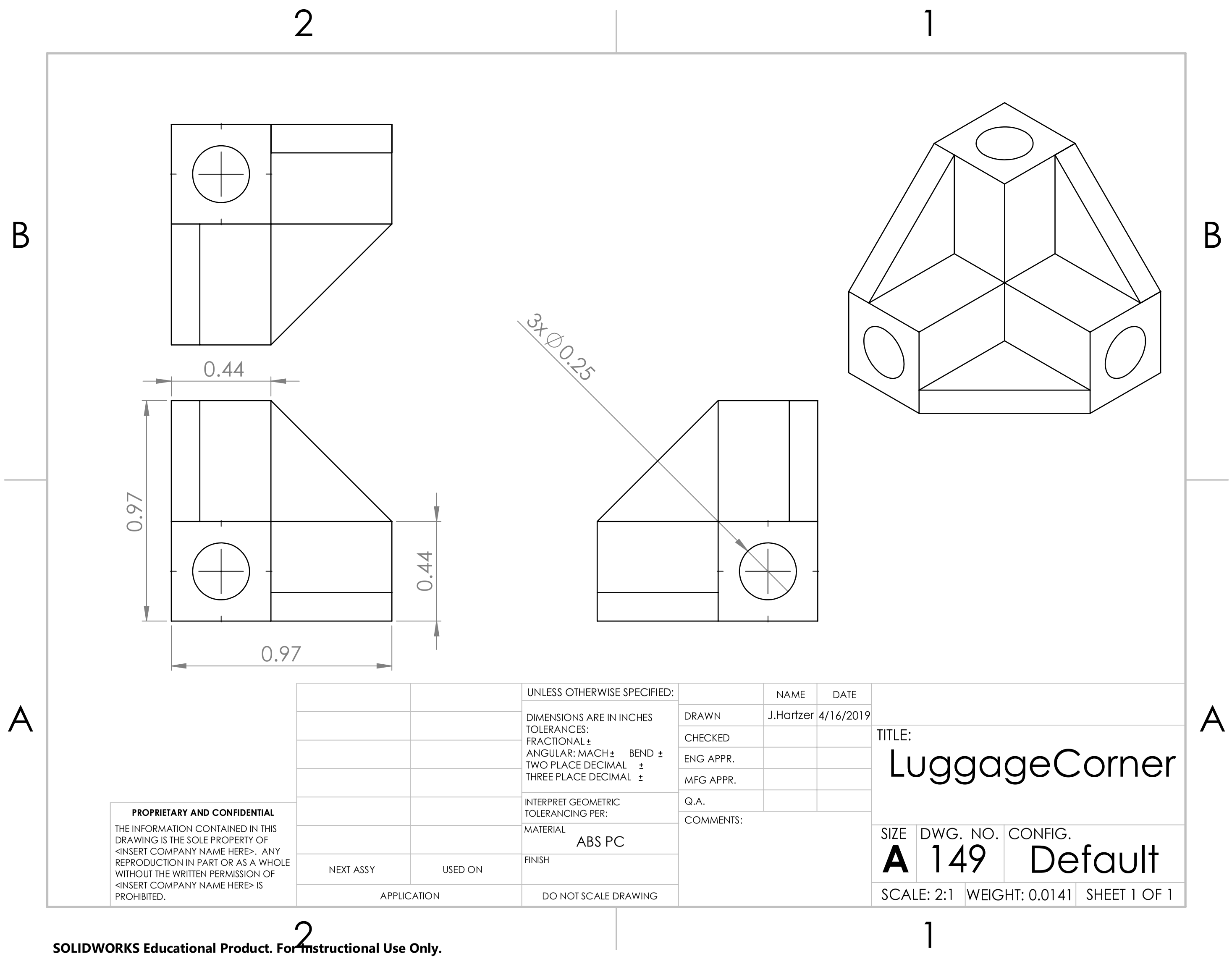
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
KnuckleBoltSleeve
SIZE
A
DWG. NO.
148
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0099
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.


2
1
B
A
0.44
0.97
0.44
0.97
3x∅0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS PC
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
LuggageCorner
SIZE
A
DWG. NO.
149
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0141
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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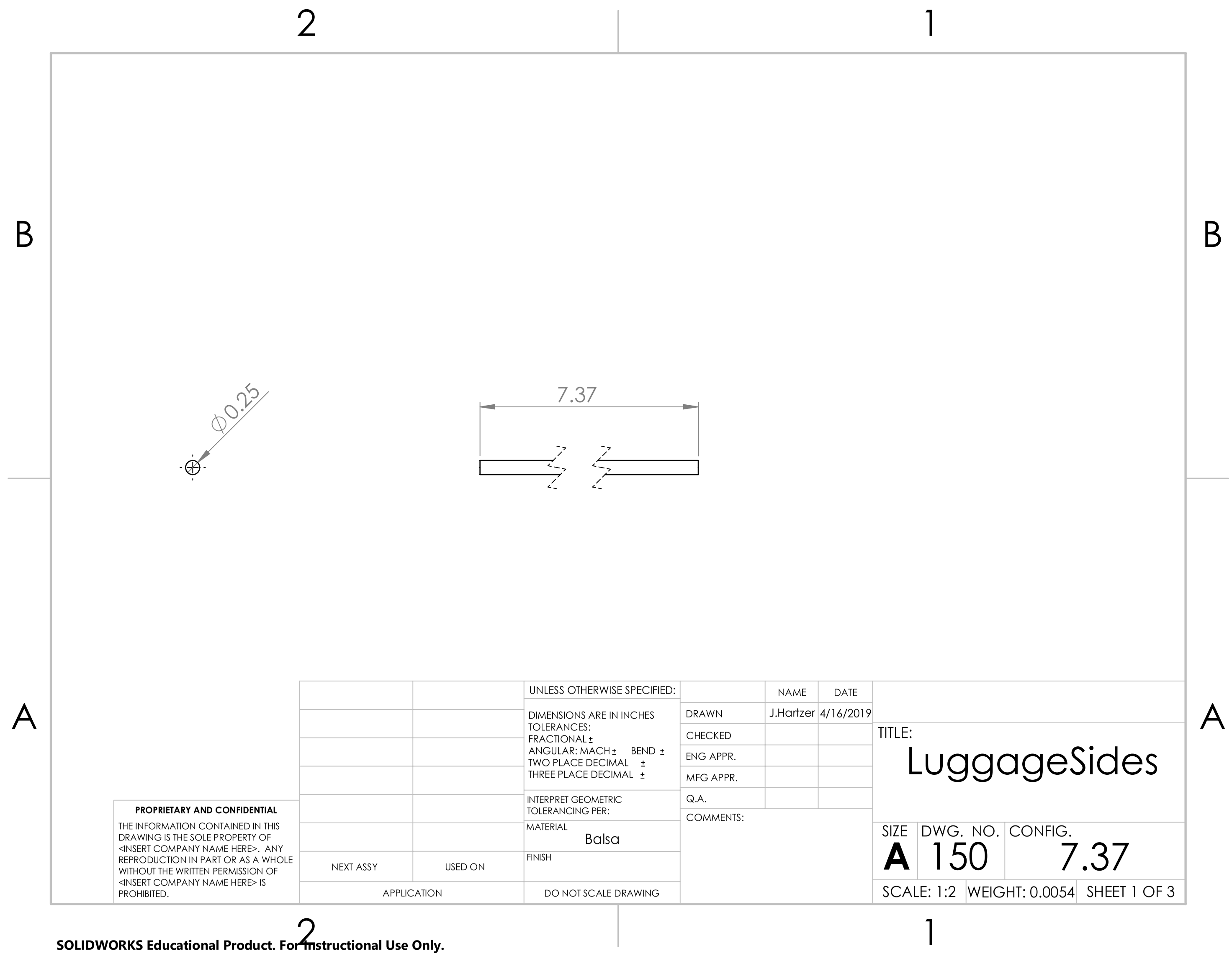
2
1
B
A
Ø0.25
7.37
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Balsa
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
LuggageSides
SIZE
A
DWG. NO.
150
CONFIG.
7.37
SCALE: 1:2
WEIGHT: 0.0054
SHEET 1 OF 3
PROPRIETARY AND CONFIDENTIAL
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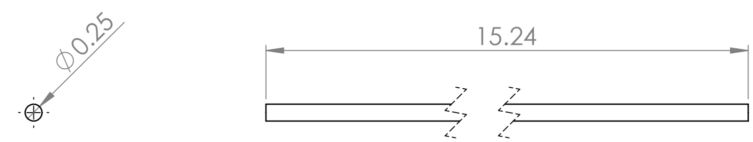


| | | | | |
|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE:<br>LuggageSides |
| | CHECKED | | | |
| | ENG APPR. | | | |
| | MFG APPR. | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| MATERIAL<br>Balsa | COMMENTS: | | | SIZE A · DWG. NO. 150 · CONFIG. 15.24 |
| FINISH | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 1:2 · WEIGHT: 0.0054 · SHEET 2 OF 3 |

| | |
|---|---|
| NEXT ASSY | USED ON |
| APPLICATION | |

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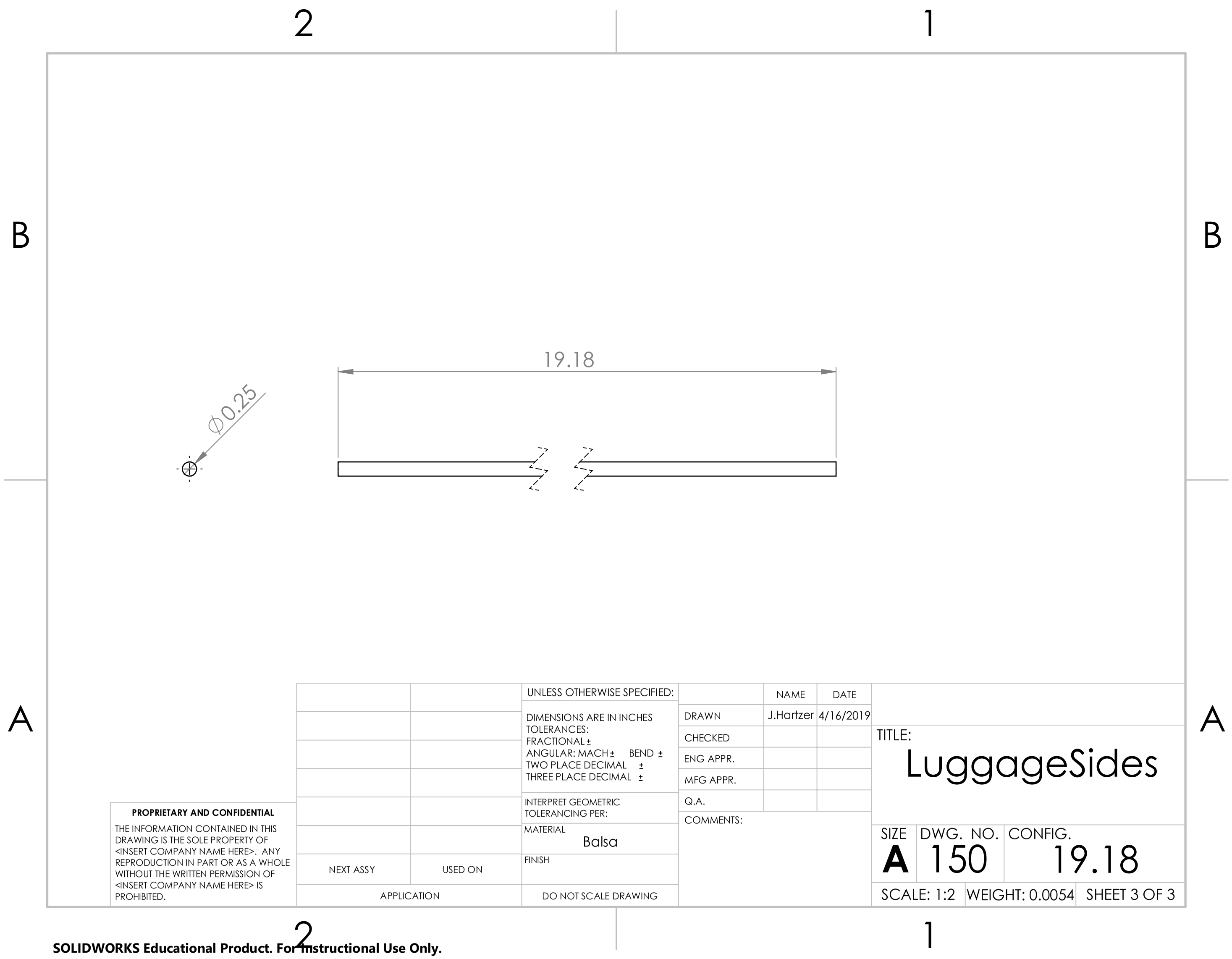
2
1
B
A
19.18
Ø0.25
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Balsa
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
LuggageSides
SIZE
A
DWG. NO.
150
CONFIG.
19.18
SCALE: 1:2
WEIGHT: 0.0054
SHEET 3 OF 3
PROPRIETARY AND CONFIDENTIAL
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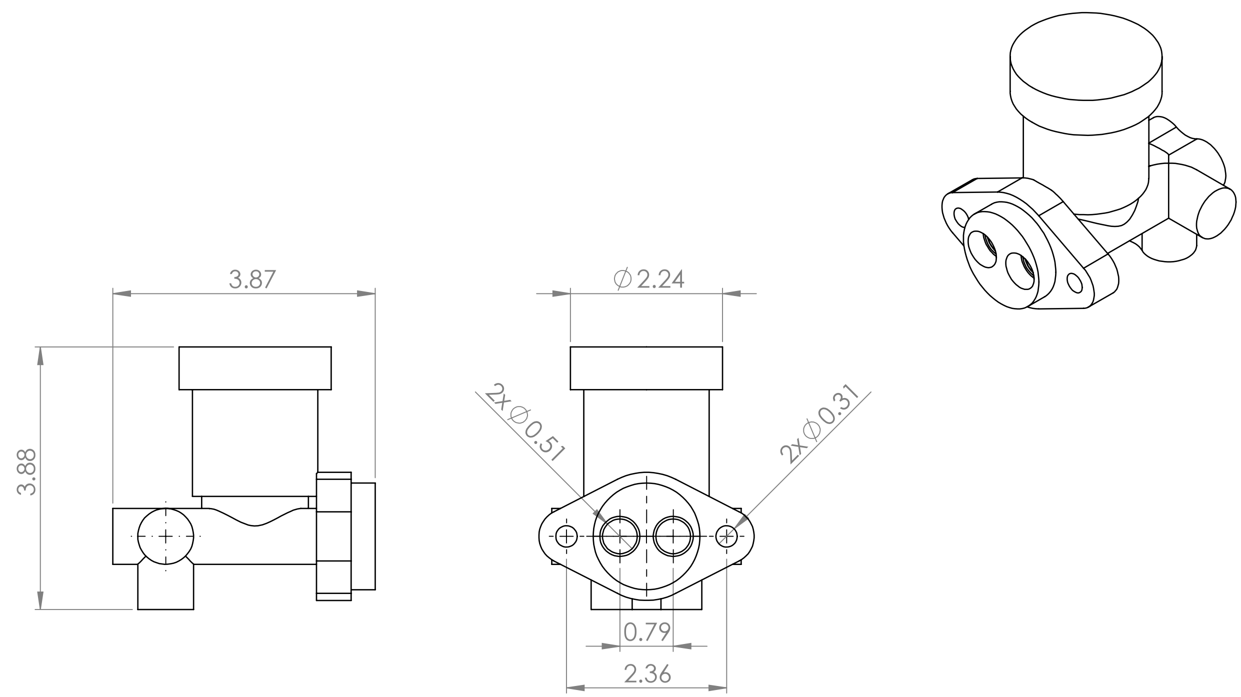


| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: |
| | | | CHECKED | | | master cylinder |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL<br>Material <not specified> | COMMENTS: | | | SIZE A DWG. NO. 151 CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:2 WEIGHT: 0.4196 SHEET 1 OF 1 |

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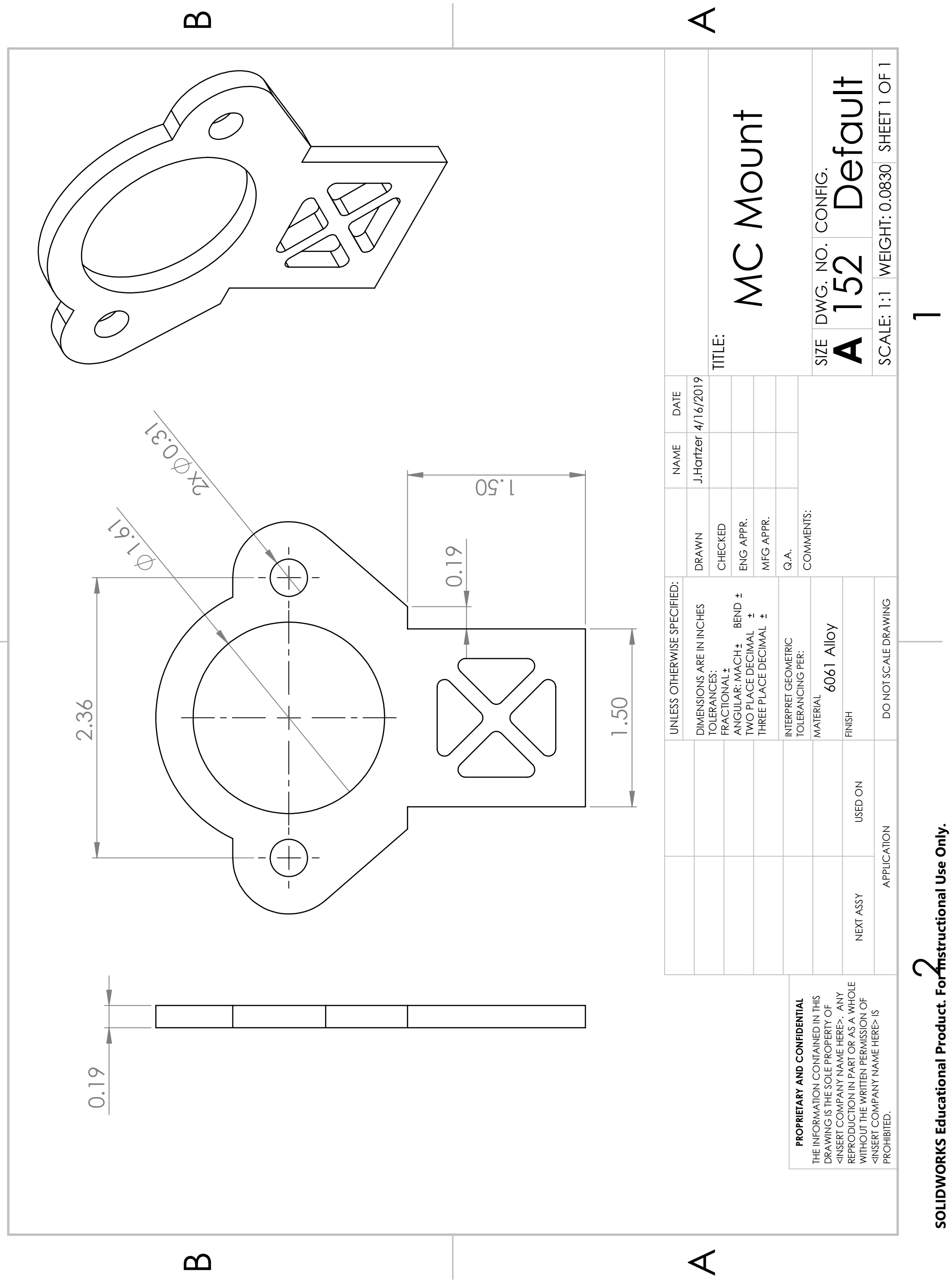

2.36
1.50
1.50
0.19
0.19
Ø1.61
2XØ0.31
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
MC Mount
SIZE
A
DWG. NO.
152
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0830
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
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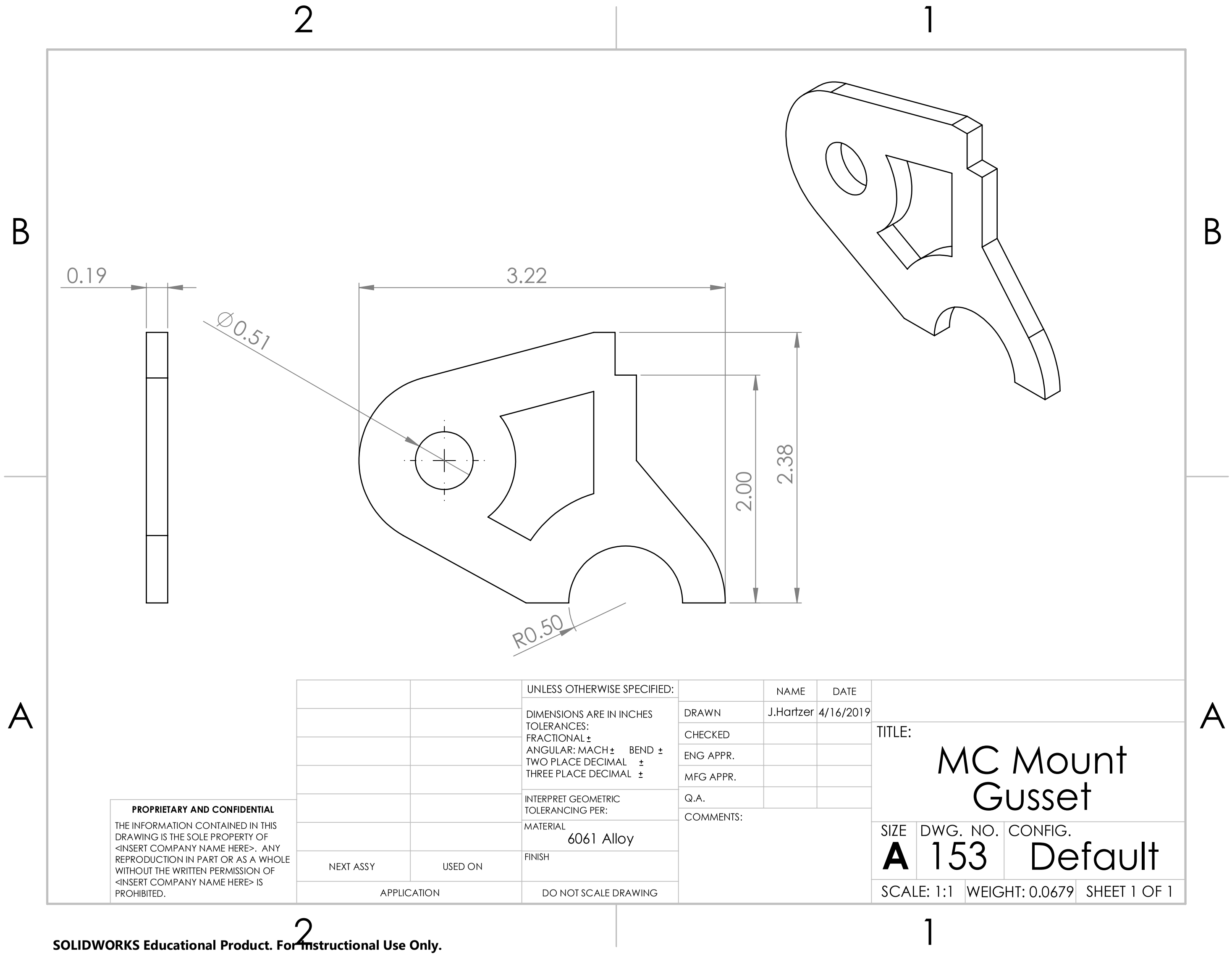
0.19
3.22
⌀0.51
2.00
2.38
R0.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
MC Mount Gusset
SIZE
A
DWG. NO.
153
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0679
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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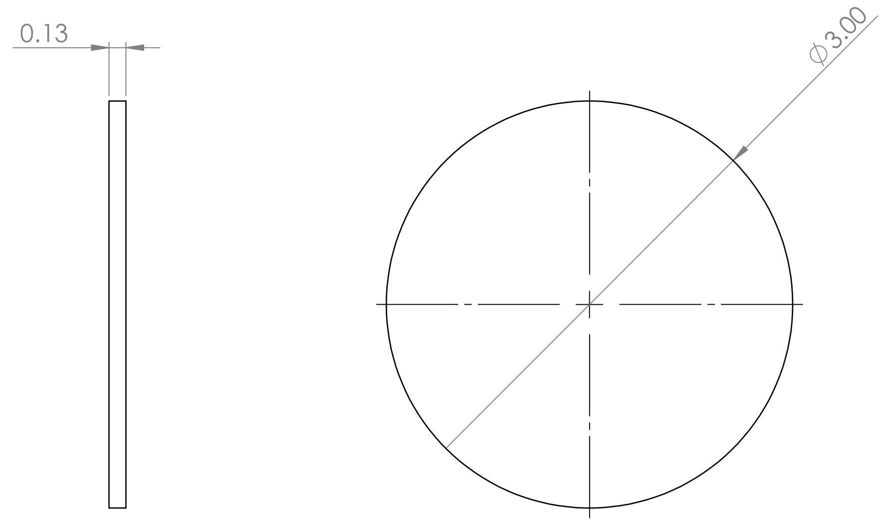


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| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Material <not specified>

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE:

# Mirror

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 154 | Default |
| SCALE: 1:1 | WEIGHT: 0.0319 | SHEET 1 OF 1 |

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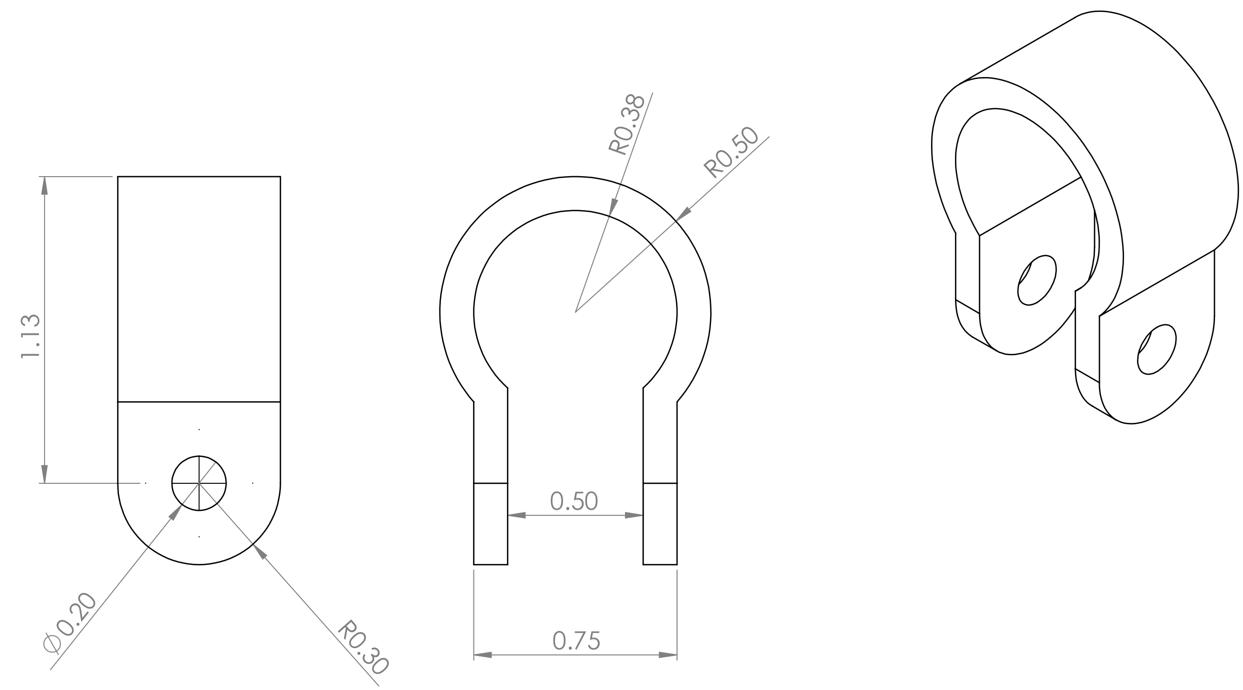



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Material <not specified>

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/16/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

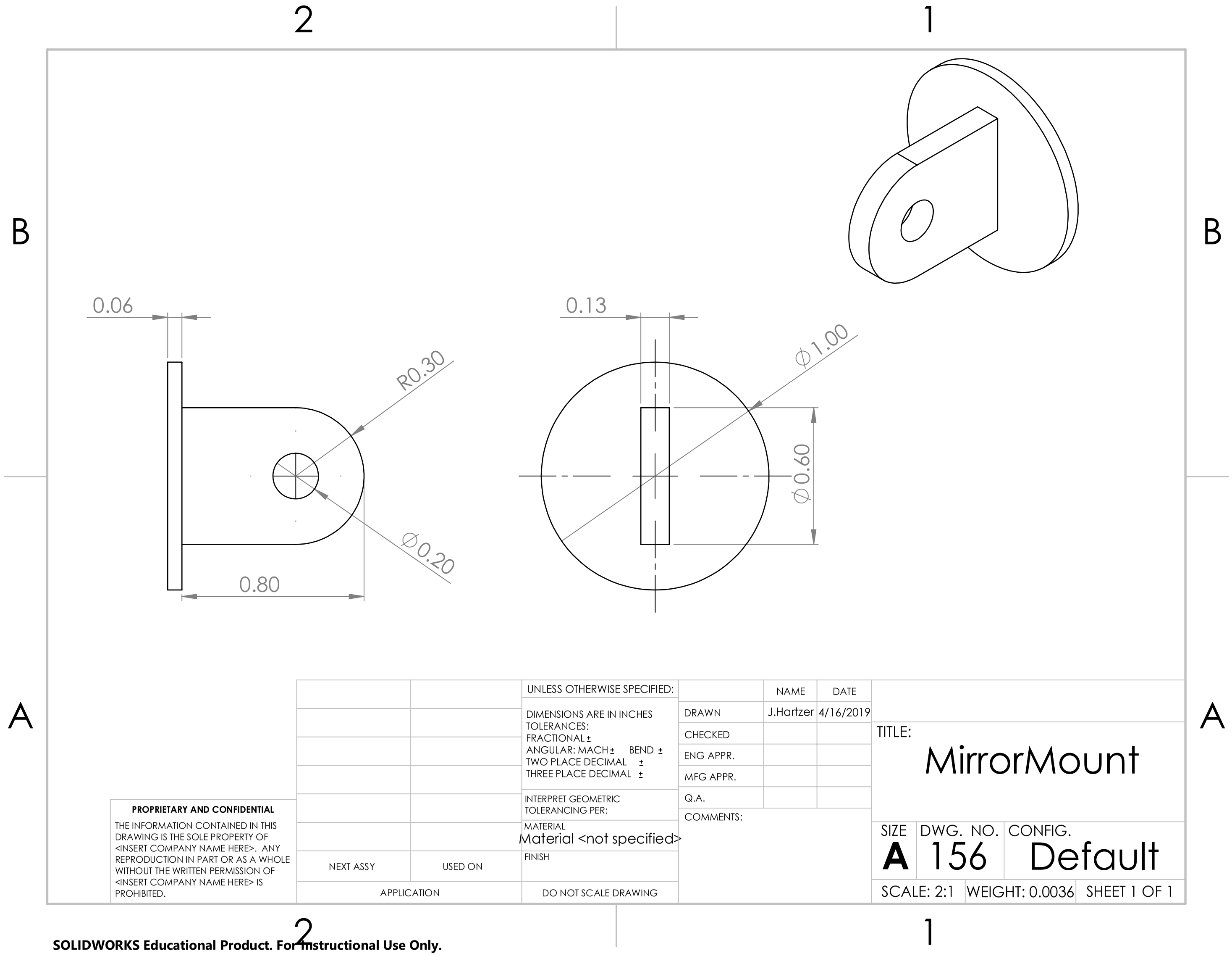
COMMENTS:

NEXT ASSY | USED ON
APPLICATION

TITLE:
MirrorFrameMount

SIZE A | DWG. NO. 155 | CONFIG. Default

SCALE: 2:1 | WEIGHT: 0.0083 | SHEET 1 OF 1


0.06
R0.30
Ø0.20
0.80
0.13
Ø1.00
Ø0.60
PROPRIETARY AND CONFIDENTIAL
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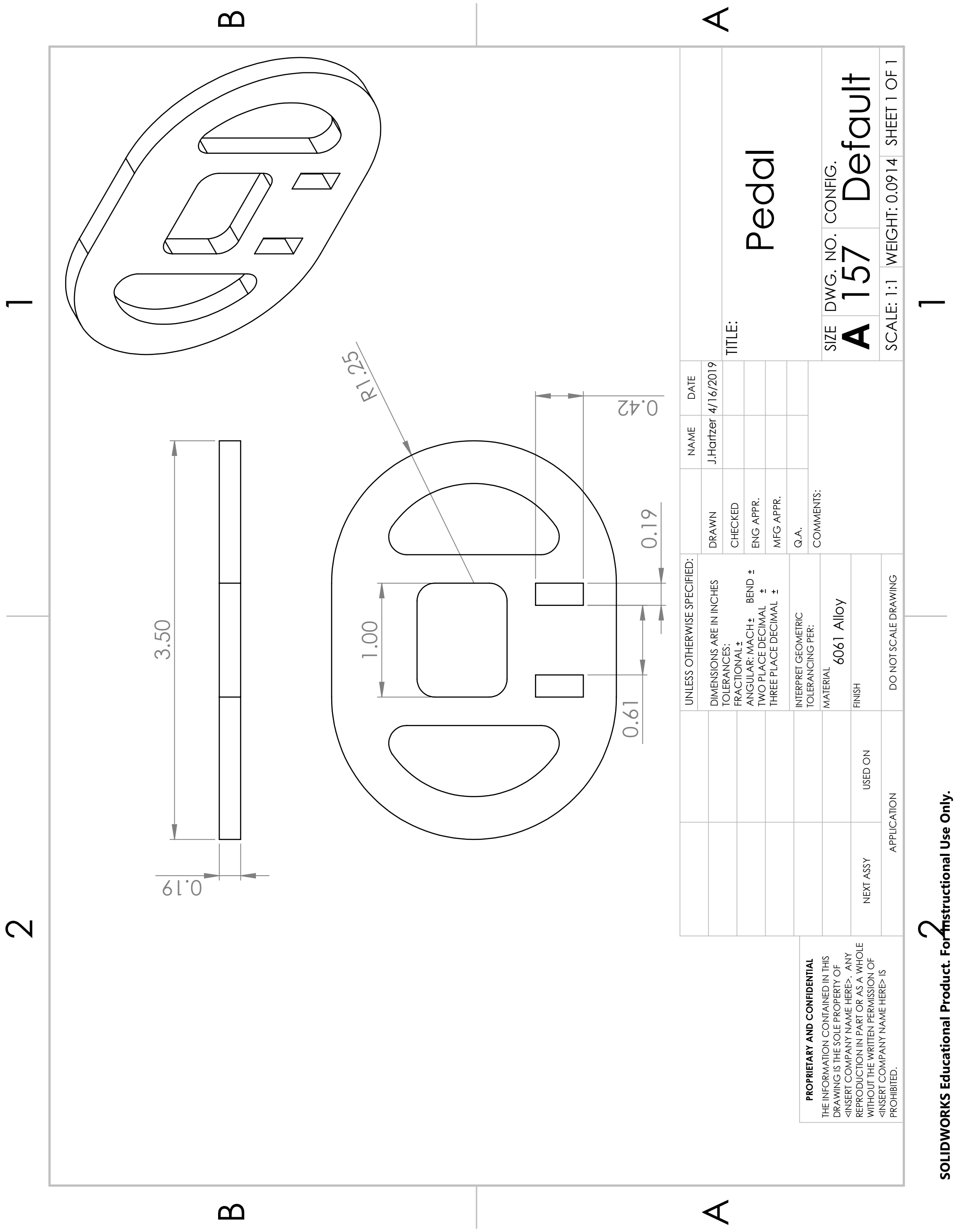
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
MirrorMount
SIZE
A
DWG. NO.
156
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0036
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.



3.50
0.19
1.00
R1.25
0.42
0.19
0.61
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Pedal
SIZE
A
DWG. NO.
157
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0914
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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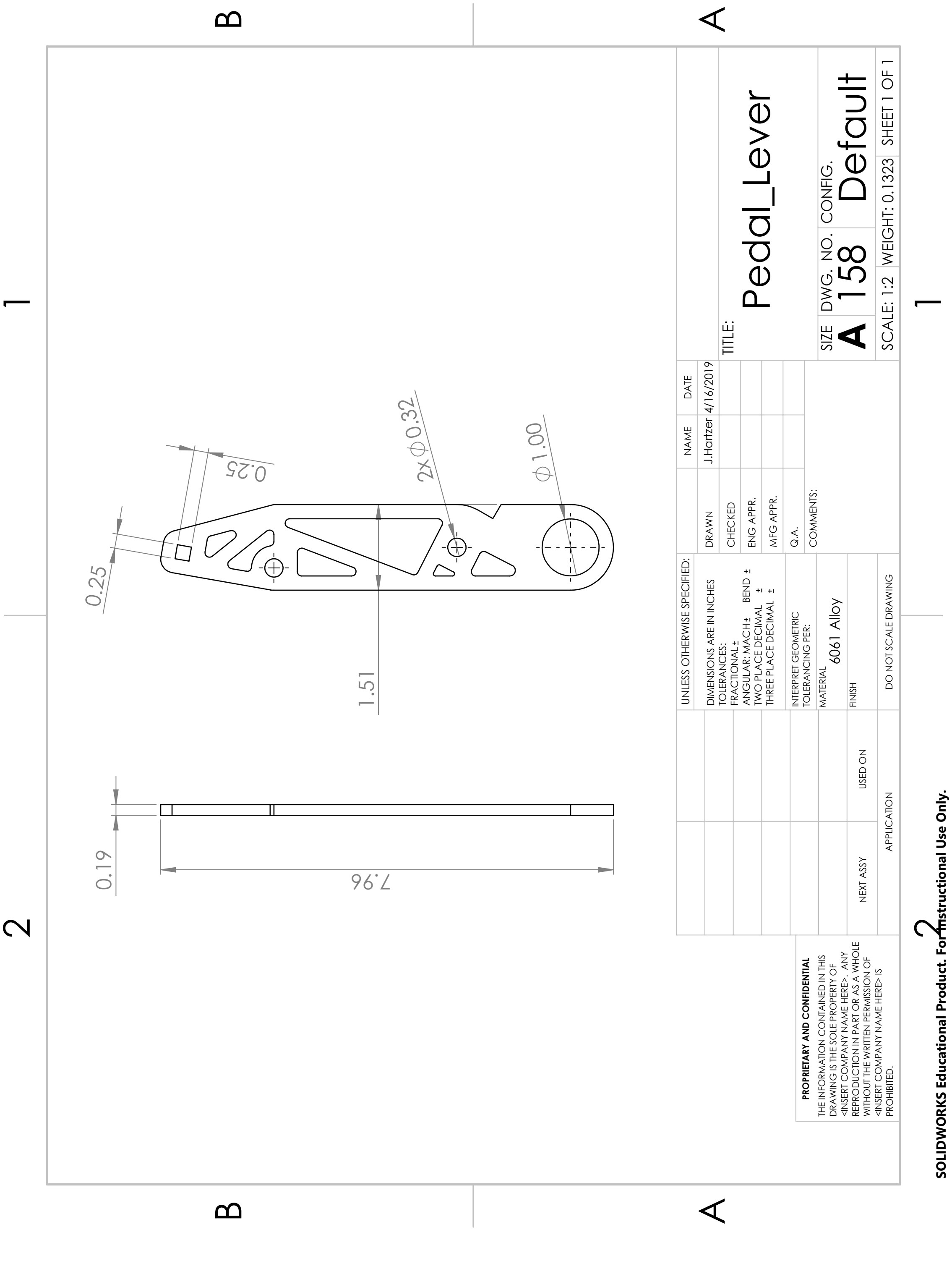

B
A
1
2
0.19
7.96
0.25
0.25
1.51
2X ϕ0.32
ϕ1.00
NAME
DATE
DRAWN
J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
TITLE:
Pedal_Lever
SIZE
A
DWG. NO.
158
CONFIG.
Default
SCALE: 1:2
WEIGHT: 0.1323
SHEET 1 OF 1
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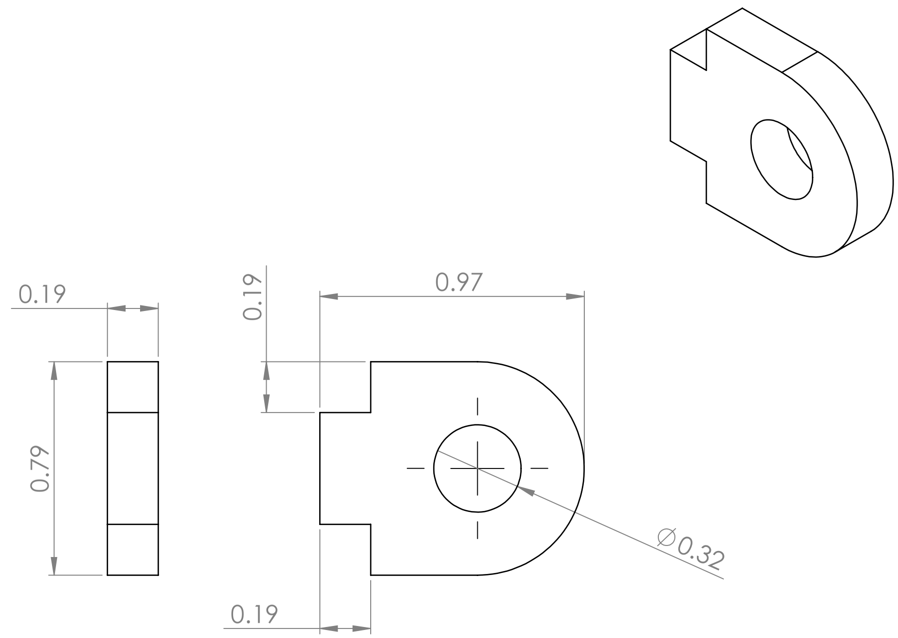
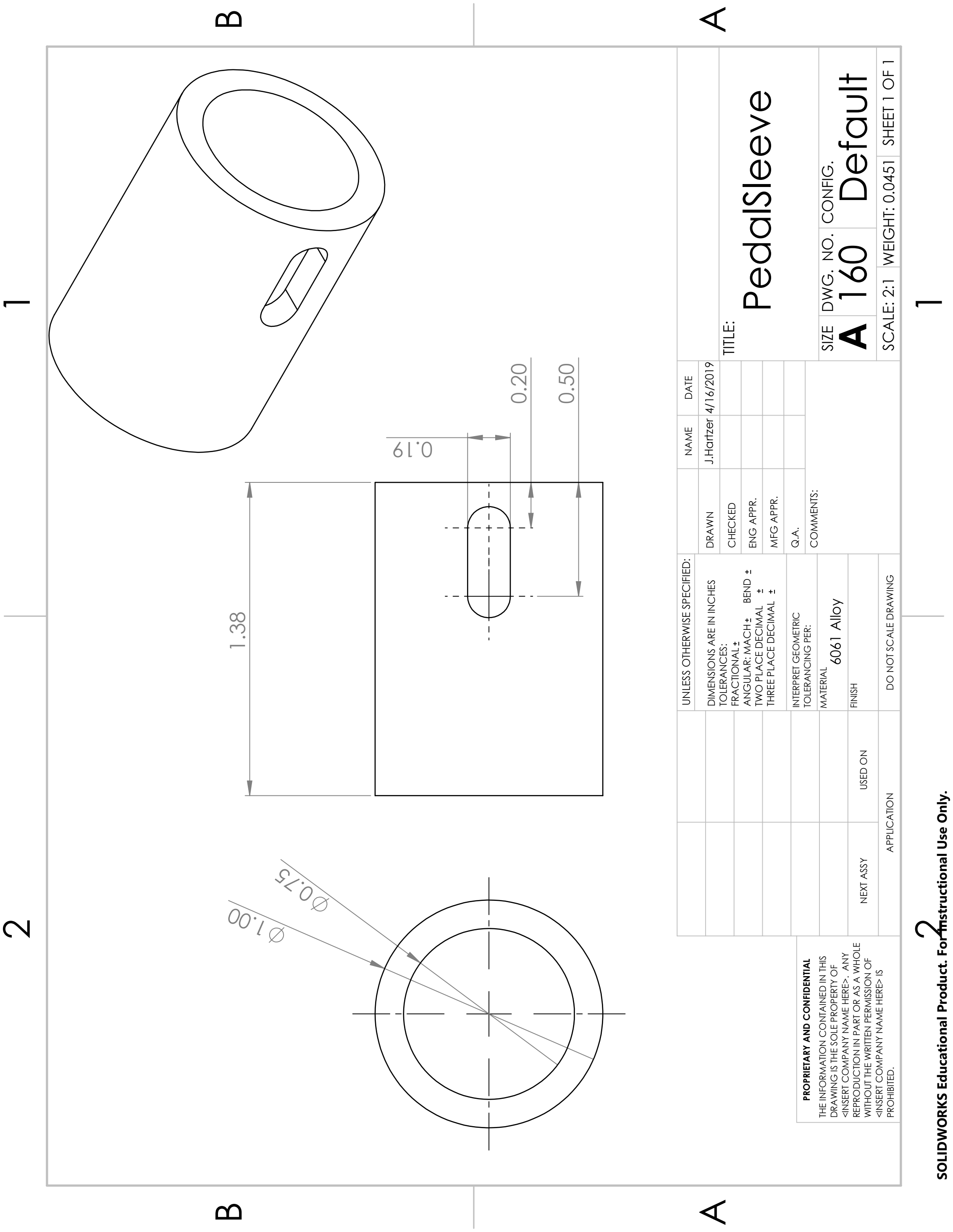



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/16/2019 | TITLE: PedalPivot |
| | | | CHECKED | | | |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL 6061 Alloy | COMMENTS: | | | SIZE A DWG. NO. 159 CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 2:1 WEIGHT: 0.0100 SHEET 1 OF 1 |



PedalSleeve
TITLE:
SIZE A
DWG. NO. 160
CONFIG. Default
SCALE: 2:1
WEIGHT: 0.0451
SHEET 1 OF 1
NAME DATE
DRAWN J.Hartzer 4/16/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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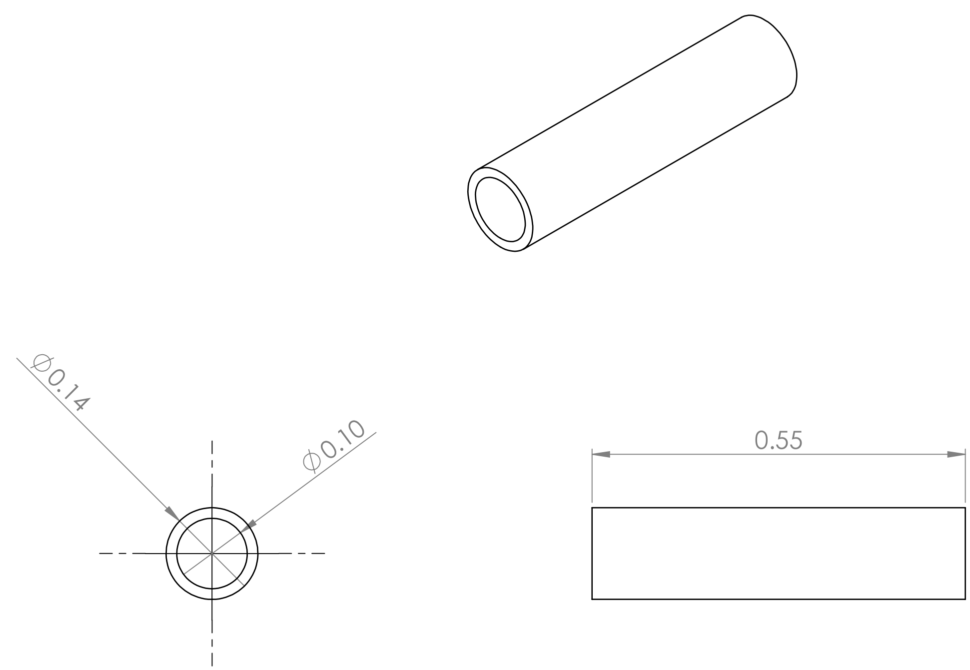
1.38
0.19
0.20
0.50
Ø0.75
Ø1.00
A
B
1
2
SOLIDWORKS Educational Product. For Instructional Use Only.




UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
ASTM A36 Steel

FINISH

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/17/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

TITLE:

# Pencil Spring

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 161 | Default |

SCALE: 5:1 WEIGHT: 0.0009 SHEET 1 OF 1

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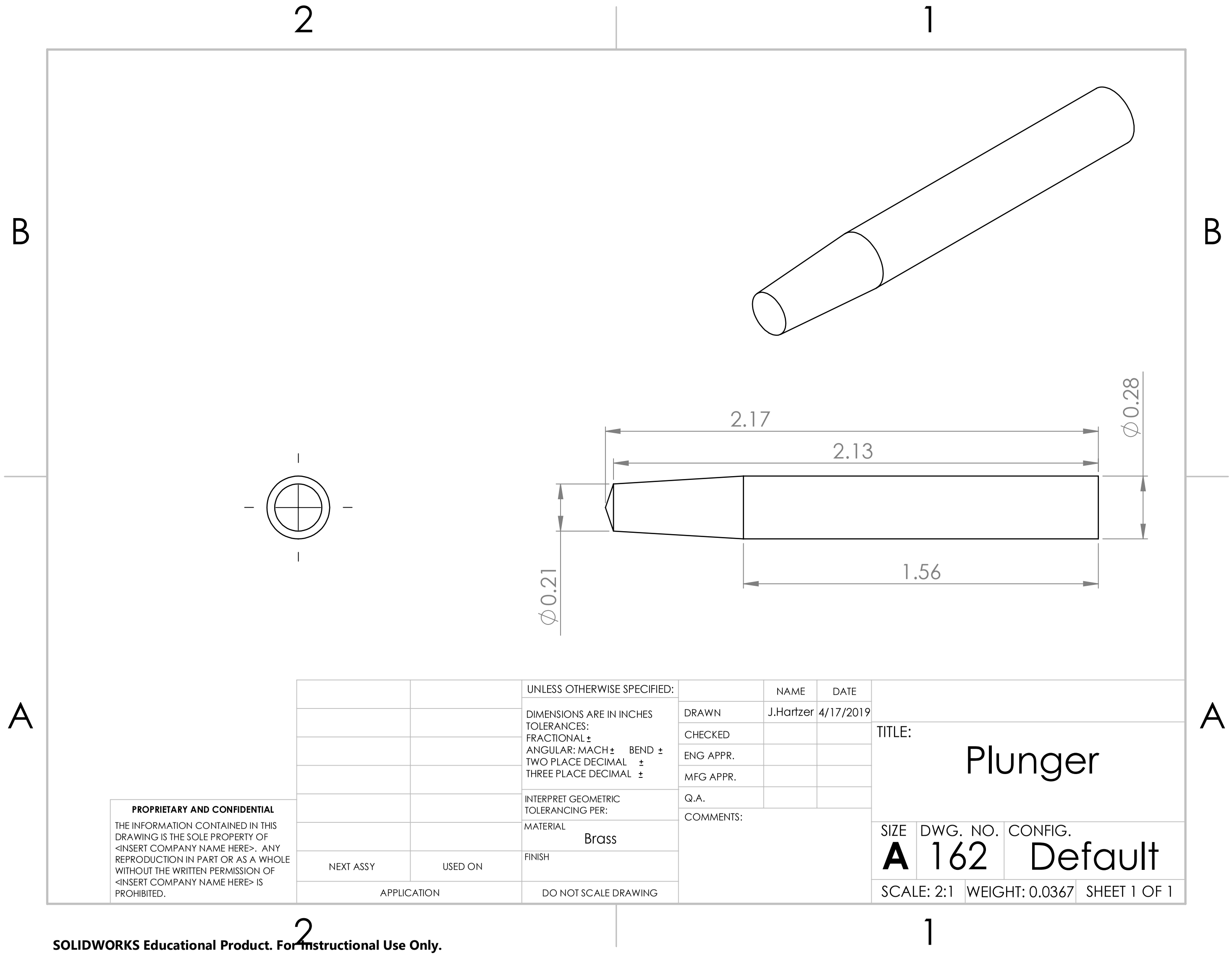

2.17
2.13
1.56
Ø0.28
Ø0.21
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Brass
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Plunger
SIZE
A
DWG. NO.
162
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0367
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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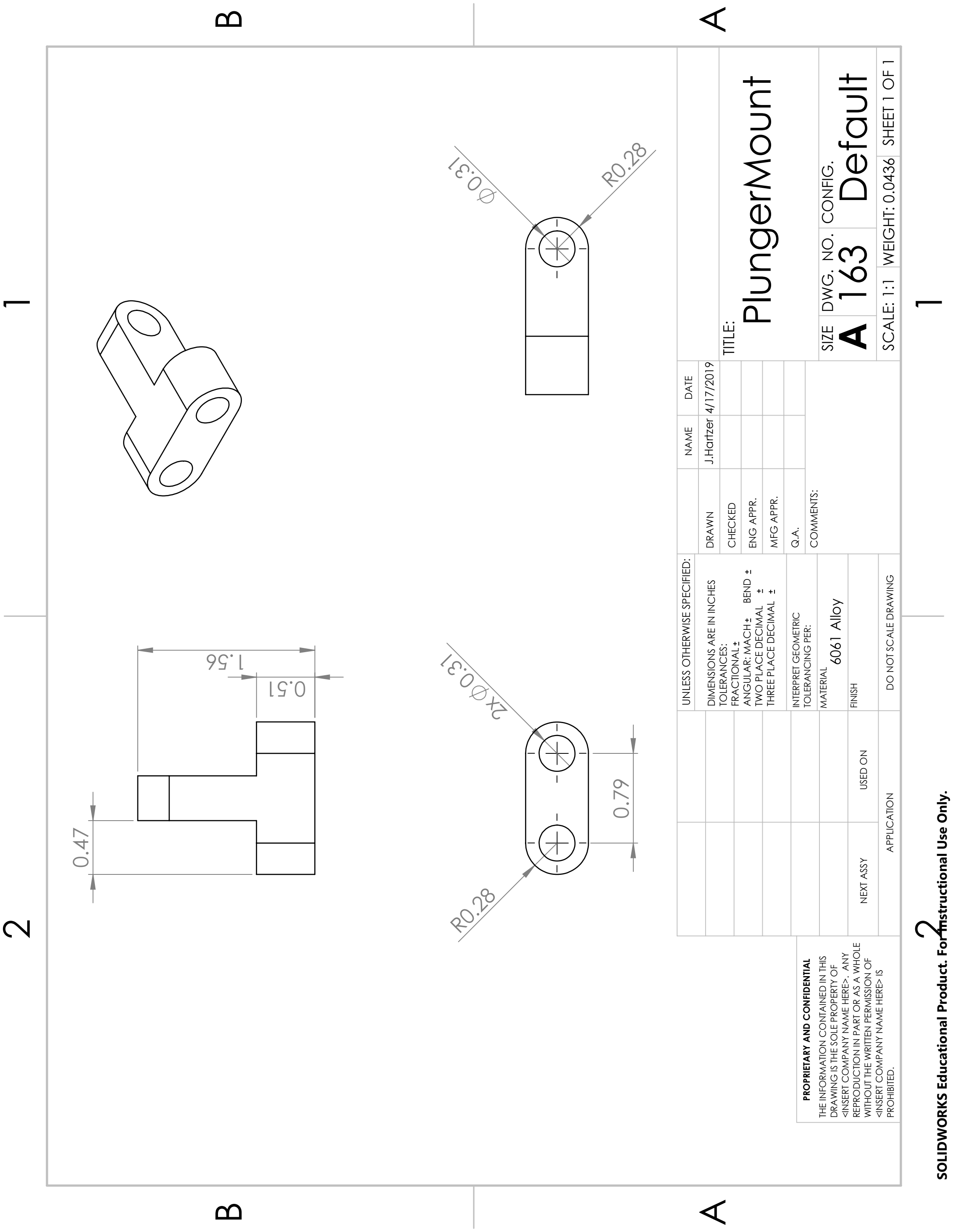

PlungerMount
TITLE:
SIZE A
DWG. NO. 163
CONFIG. Default
SCALE: 1:1
WEIGHT: 0.0436
SHEET 1 OF 1
DRAWN J.Hartzer 4/17/2019
NAME
DATE
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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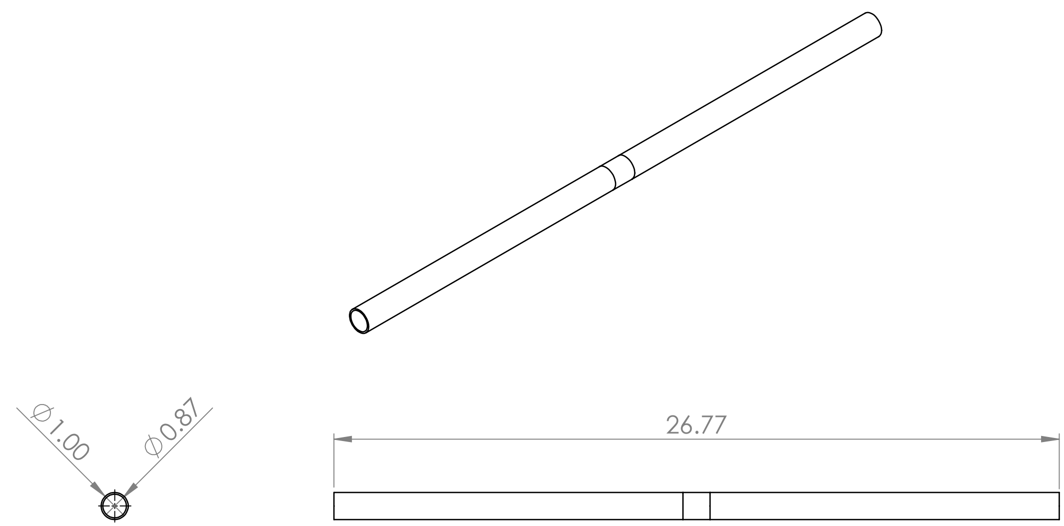
1.56
0.51
0.47
0.79
2X∅0.31
R0.28
∅0.31
R0.28
A
B
1
2
SOLIDWORKS Educational Product. For Instructional Use Only.




PROPRIETARY AND CONFIDENTIAL

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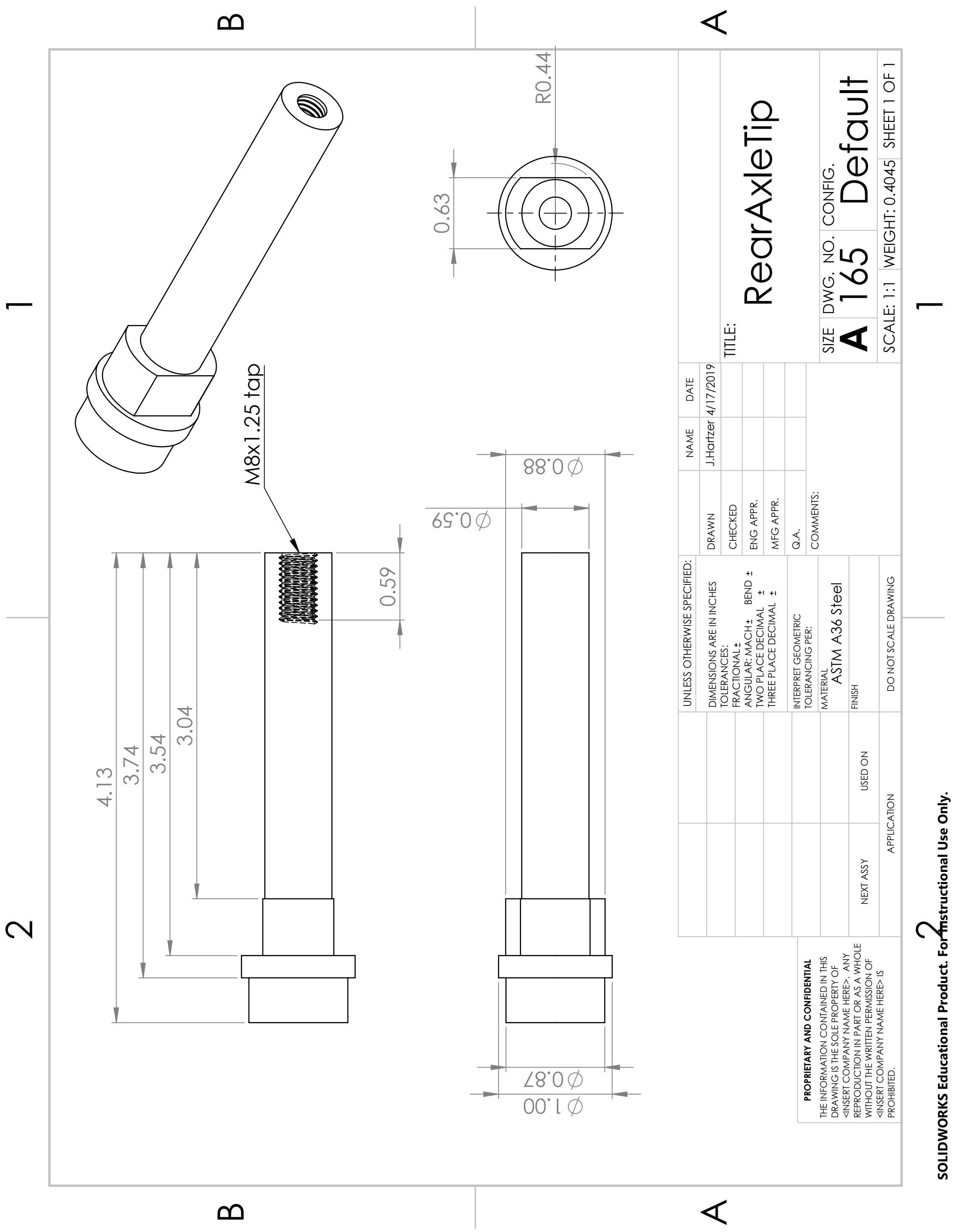
| NEXT ASSY | USED ON | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL<br>ASTM A36 Steel | COMMENTS: | | |
| | | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

# Rear Axle

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 164 | Default |
| SCALE: 1:5 | WEIGHT: 657.54 | SHEET 1 OF 1 |

SOLIDWORKS Educational Product. For Instructional Use Only.


M8x1.25 tap
4.13
3.74
3.54
3.04
0.59
∅0.59
∅0.88
∅0.87
∅1.00
0.63
R0.44
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
J.Hartzer
4/17/2019
TITLE:
RearAxleTip
SIZE
A
DWG. NO.
165
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.4045
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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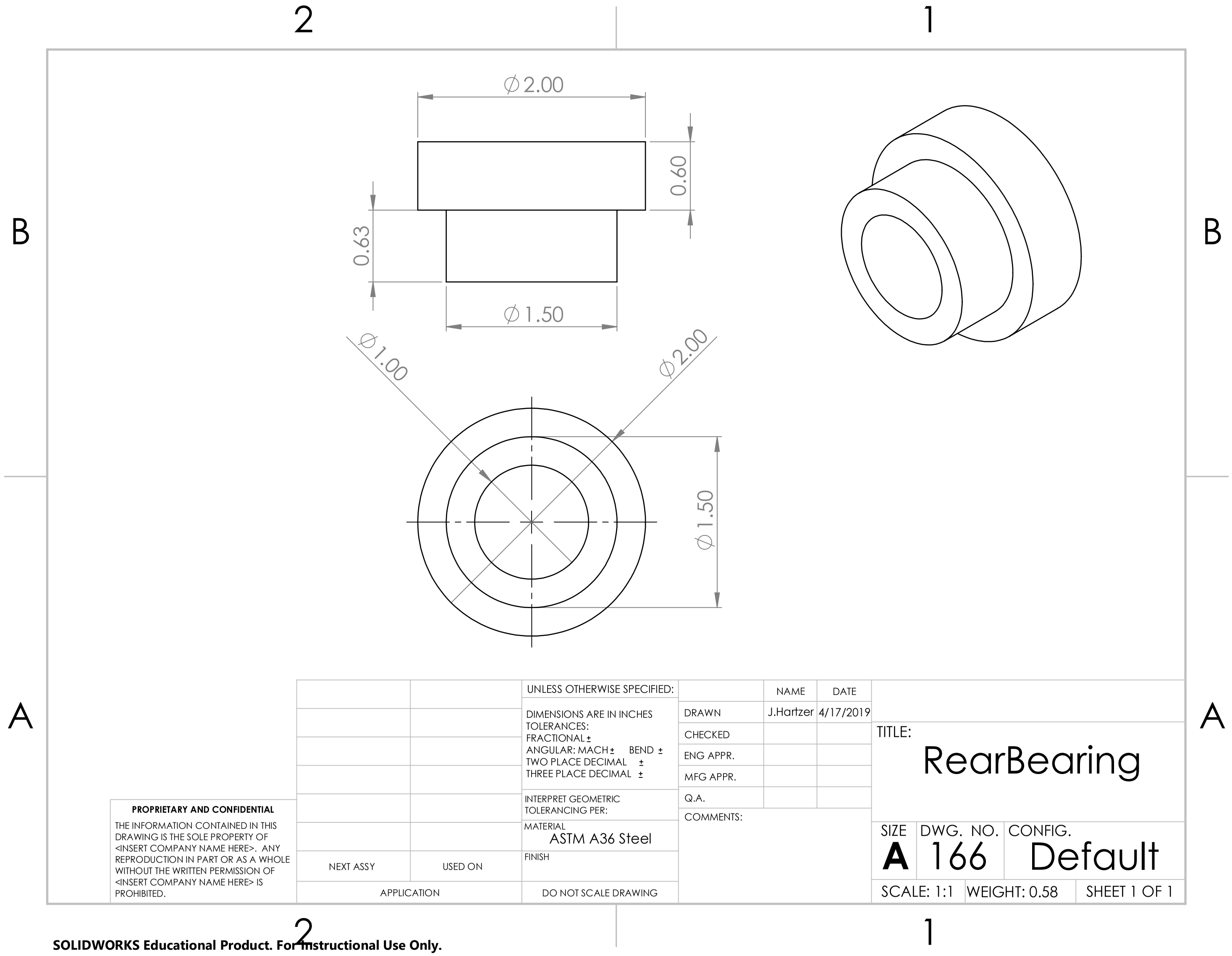
2
1
B
A
∅2.00
0.60
0.63
∅1.50
∅1.00
∅2.00
∅1.50
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
RearBearing
SIZE
A
DWG. NO.
166
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.58
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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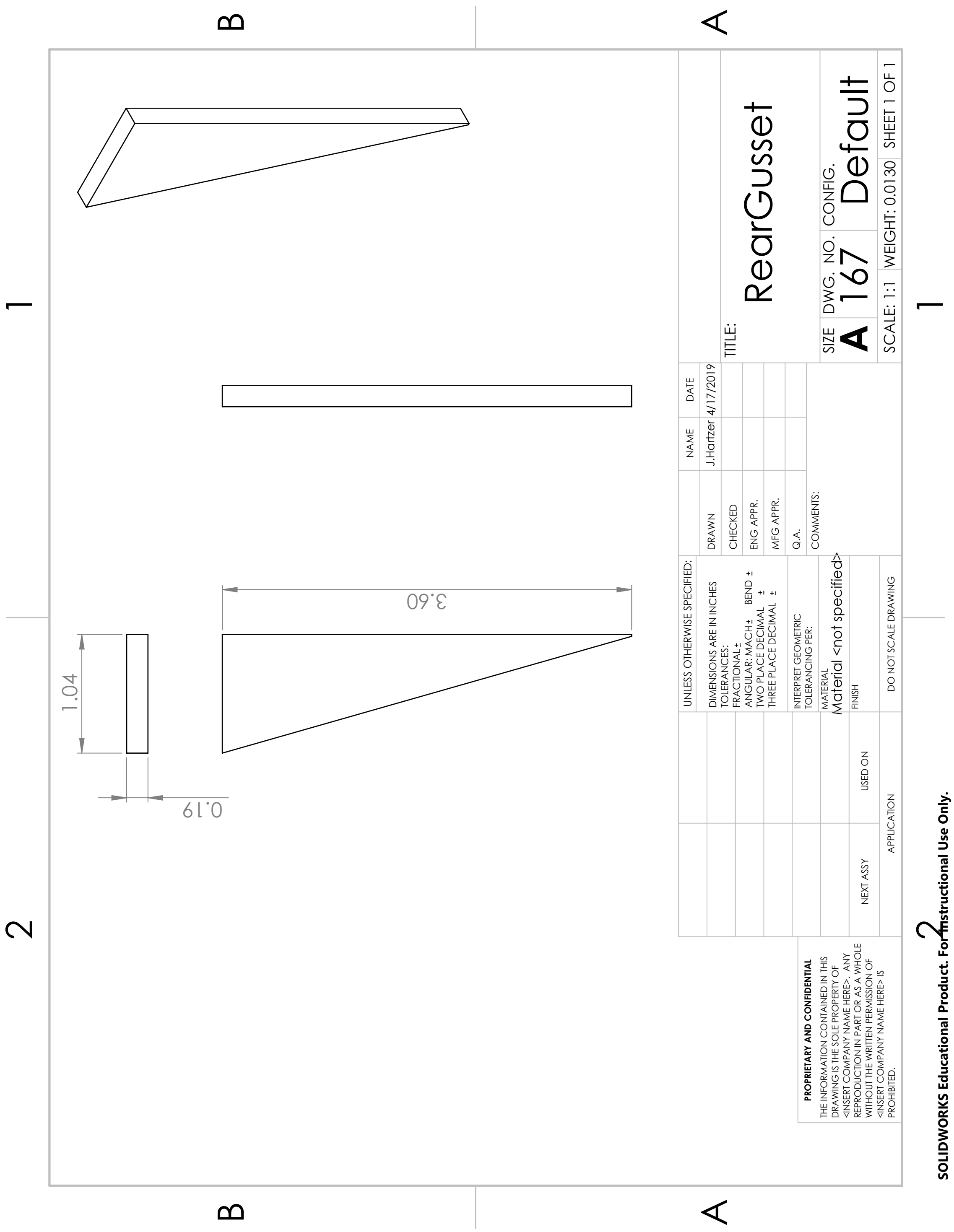
RearGusset
TITLE:
SIZE
A
DWG. NO.
167
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0130
SHEET 1 OF 1
1.04
0.19
3.60
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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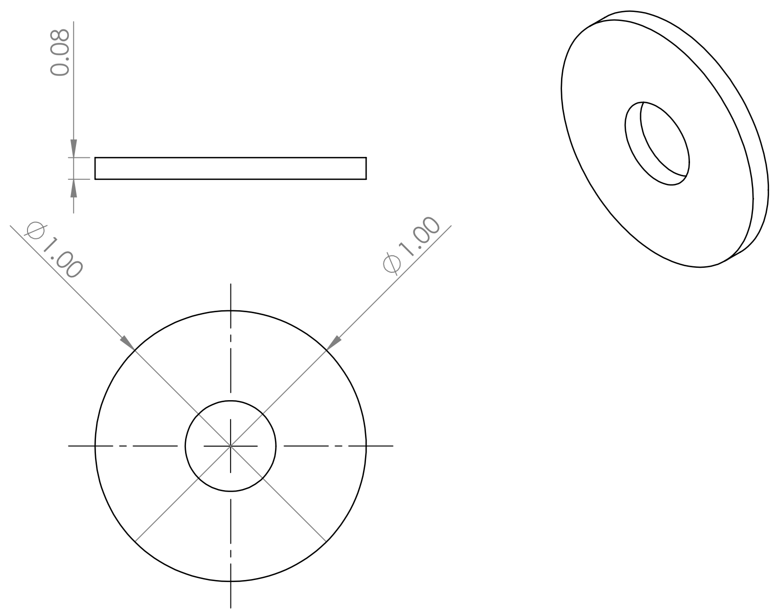
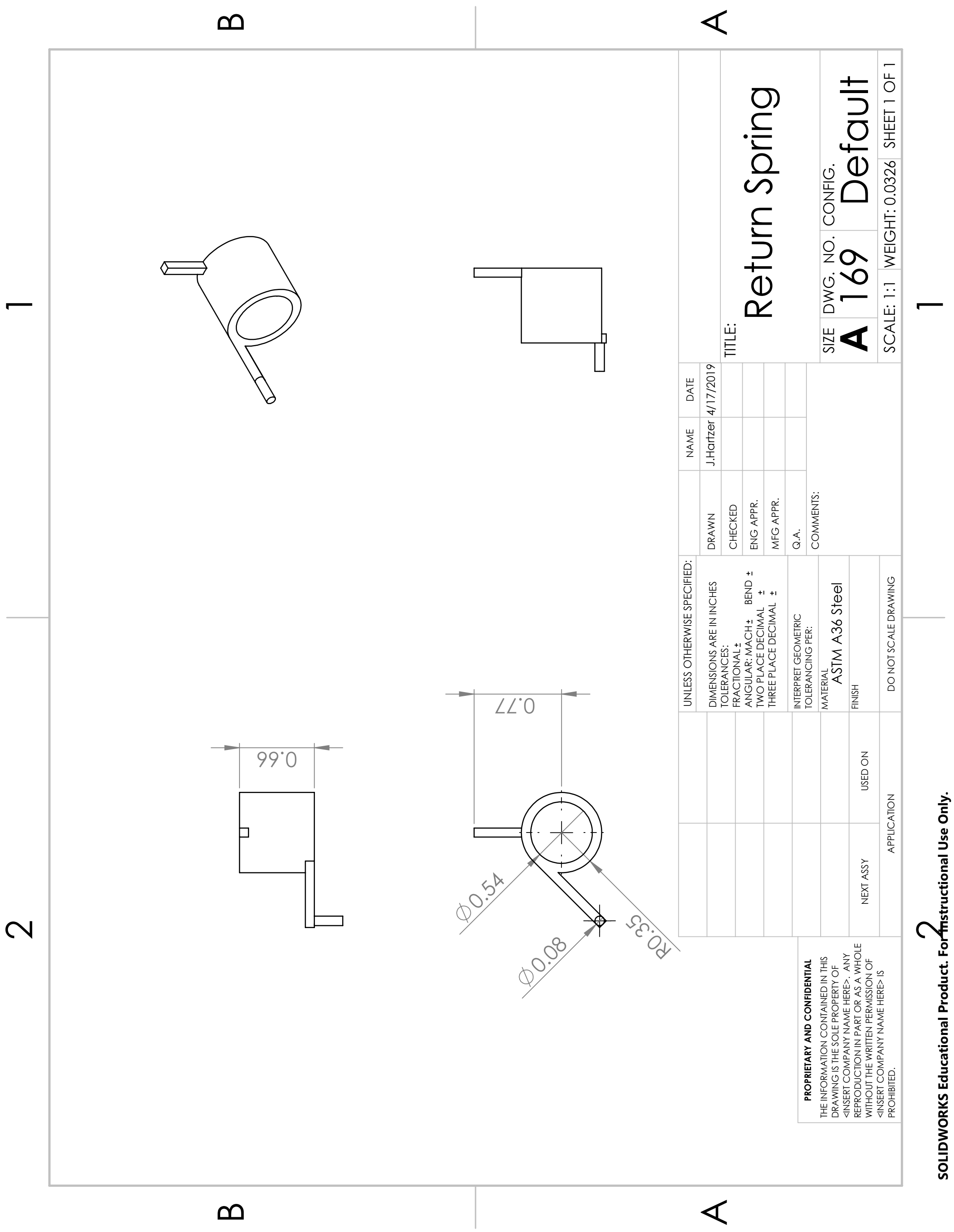



| | | | | | |
|---|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 | TITLE: | Retaining Washer |
| | CHECKED | | | | |
| | ENG APPR. | | | | |
| | MFG APPR. | | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | | |
| MATERIAL 6061 Alloy | COMMENTS: | | | SIZE A | DWG. NO. 168 / CONFIG. Default |
| FINISH | | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 2:1 | WEIGHT: 0.0054 / SHEET 1 OF 1 |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |



0.66
0.77
⌀0.54
⌀0.08
R0.35
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Return Spring
SIZE
A
DWG. NO.
169
CONFIG.
Default
SCALE: 1:1
WEIGHT: 0.0326
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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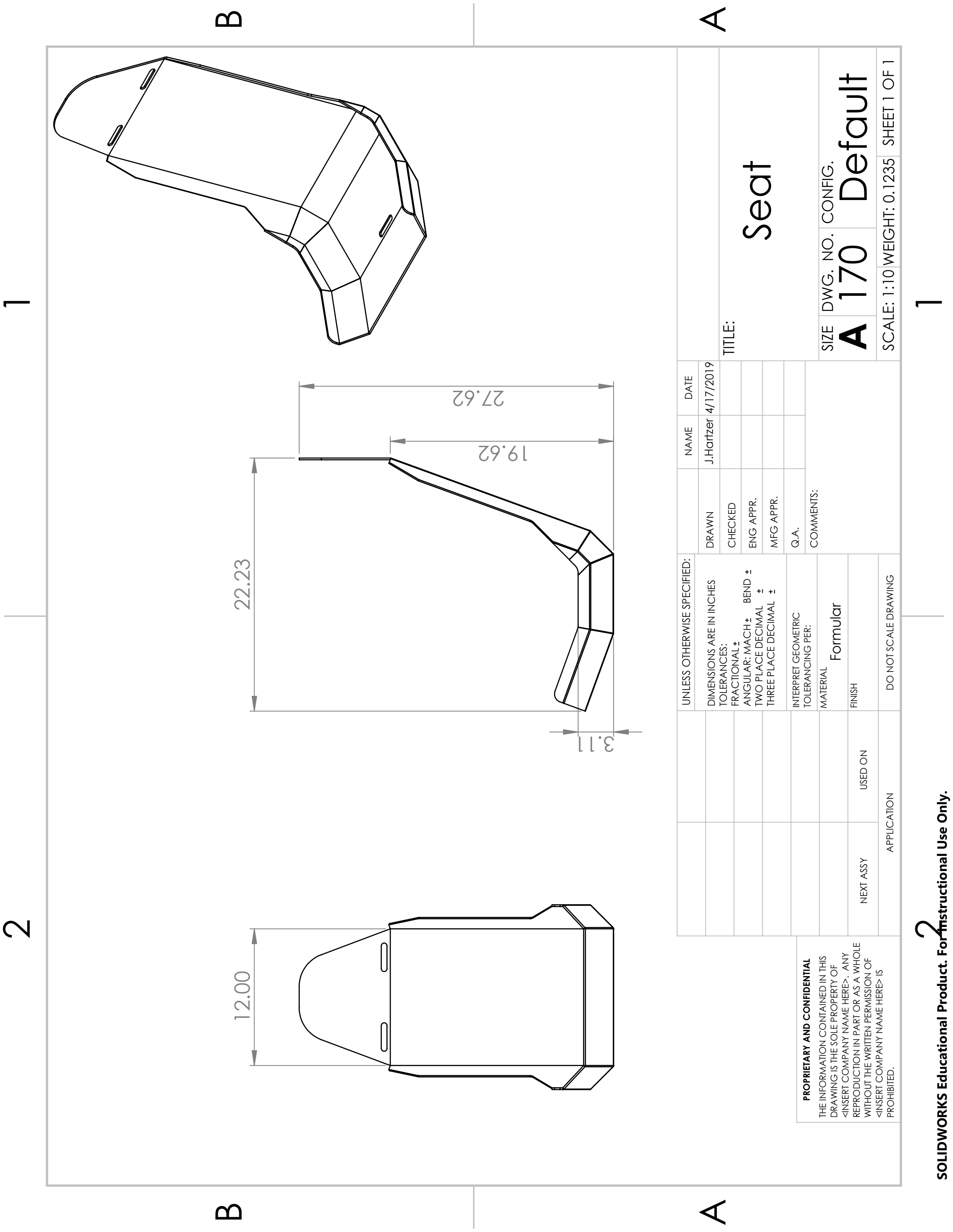

12.00
22.23
19.62
27.62
3.11
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Formular
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Seat
SIZE
A
DWG. NO.
170
CONFIG.
Default
SCALE: 1:10
WEIGHT: 0.1235
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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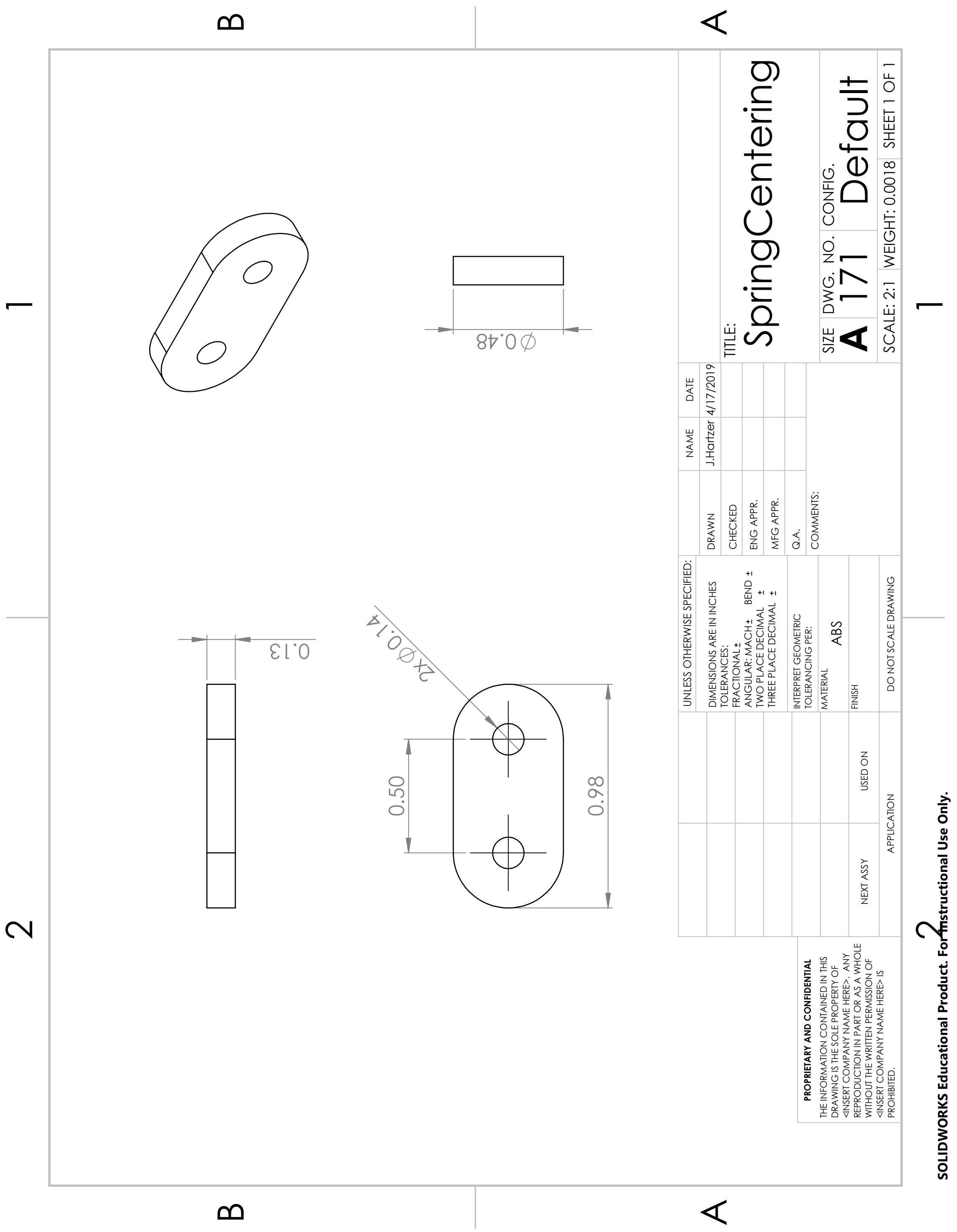

SpringCentering
TITLE:
SIZE
A
DWG. NO.
171
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0018
SHEET 1 OF 1
0.13
2X∅0.14
0.50
0.98
∅0.48
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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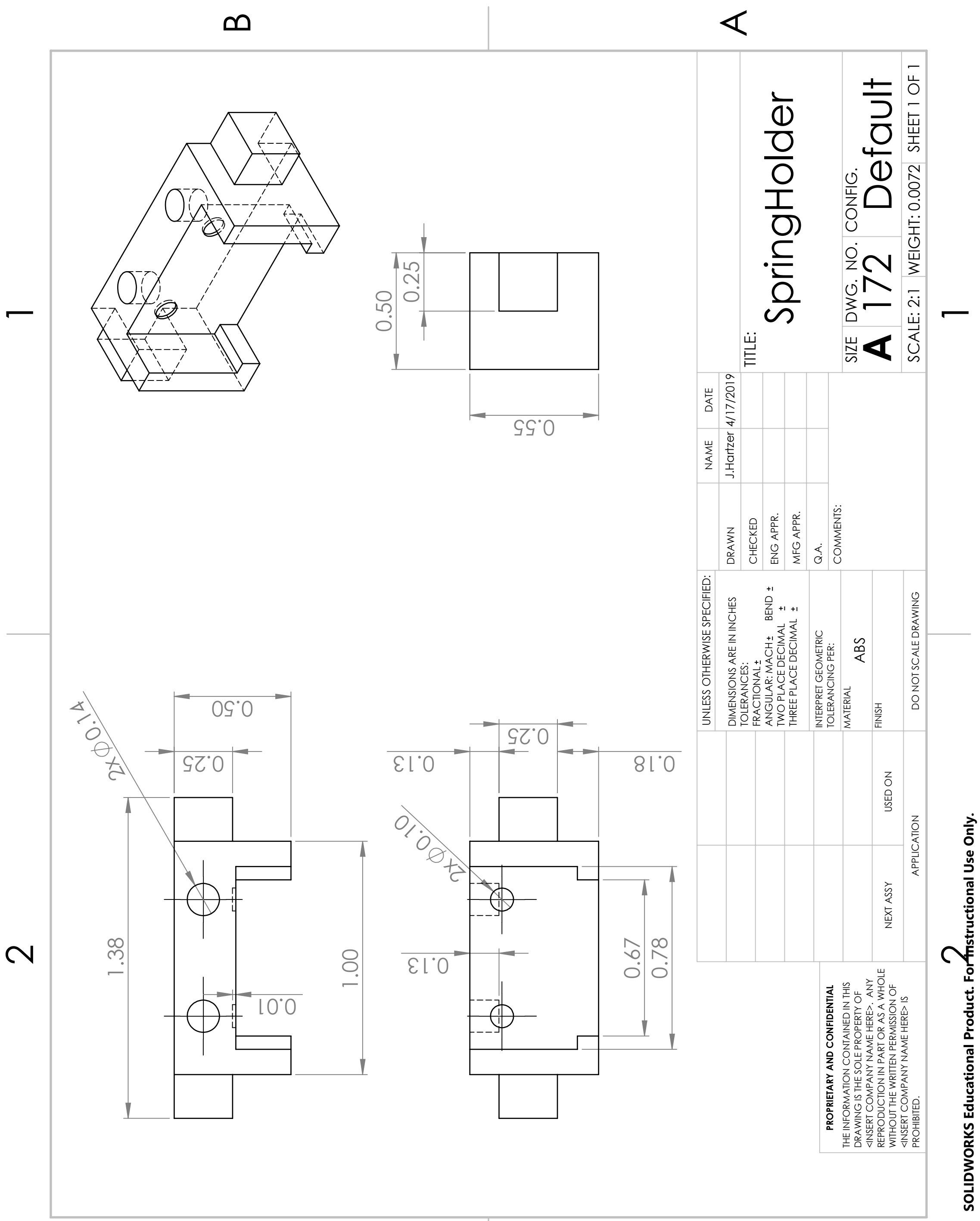

SpringHolder
TITLE:
SIZE
A
DWG. NO.
172
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0072
SHEET 1 OF 1
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ABS
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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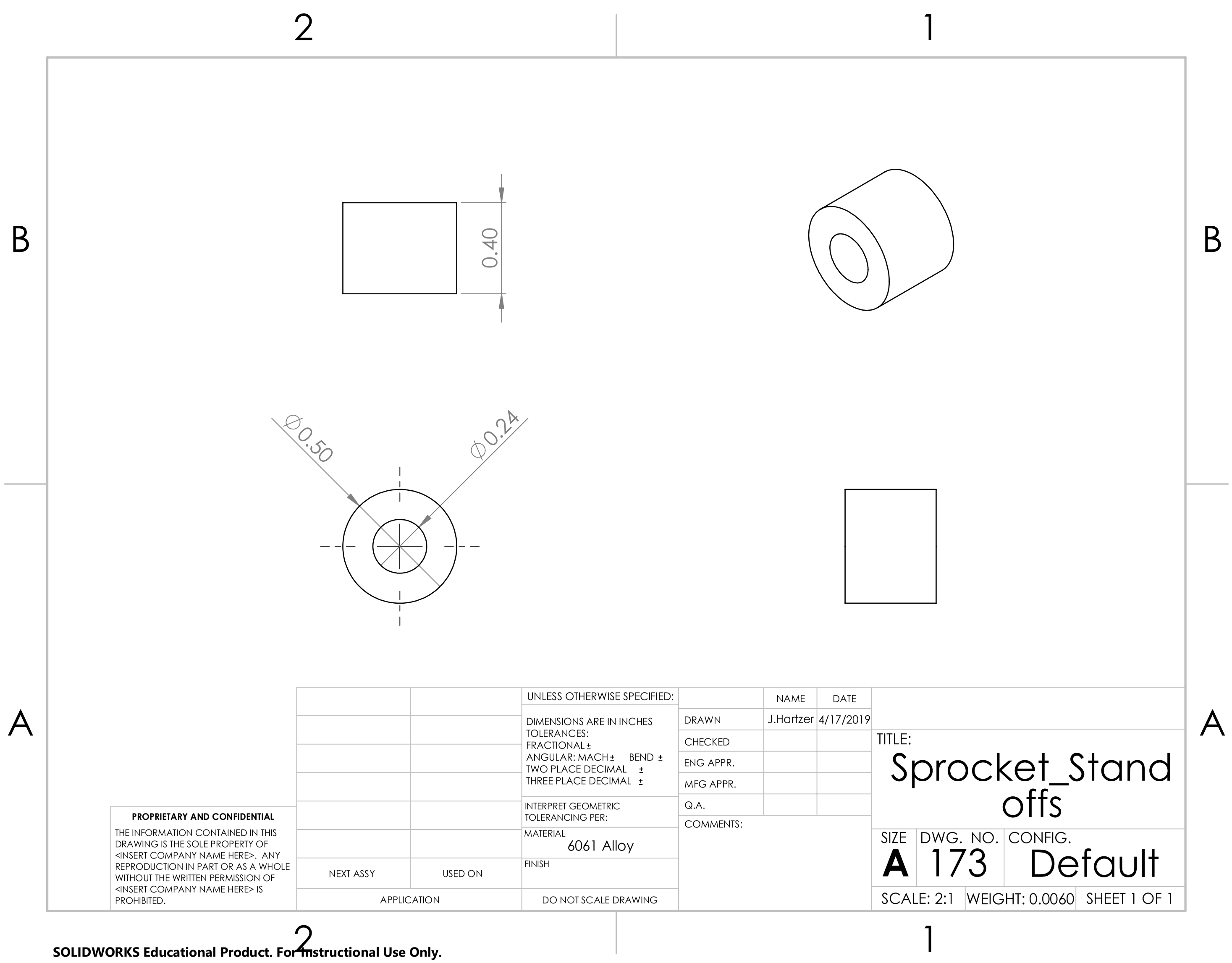
2X⌀0.14
2X⌀0.10
1.38
1.00
0.50
0.25
0.01
0.13
0.13
0.18
0.25
0.67
0.78
0.50
0.25
0.55
A
B
1
2



2
1
B
A
0.40
⌀0.50
⌀0.24
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
6061 Alloy
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Sprocket_Stand offs
SIZE
A
DWG. NO.
173
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0060
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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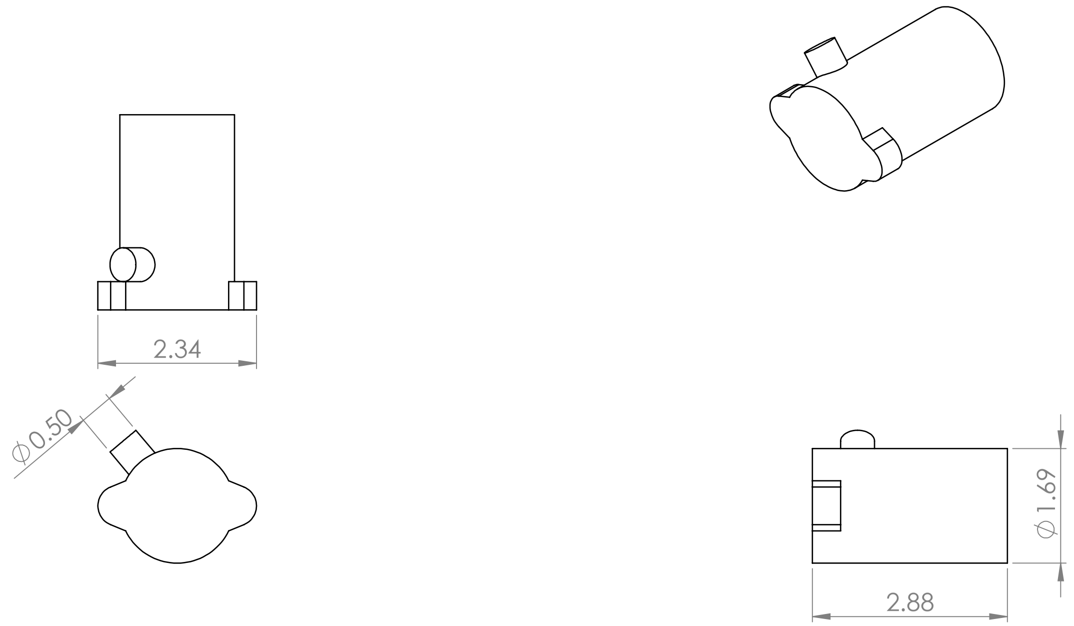



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Material <not specified>

FINISH

DO NOT SCALE DRAWING

NEXT ASSY | USED ON
APPLICATION

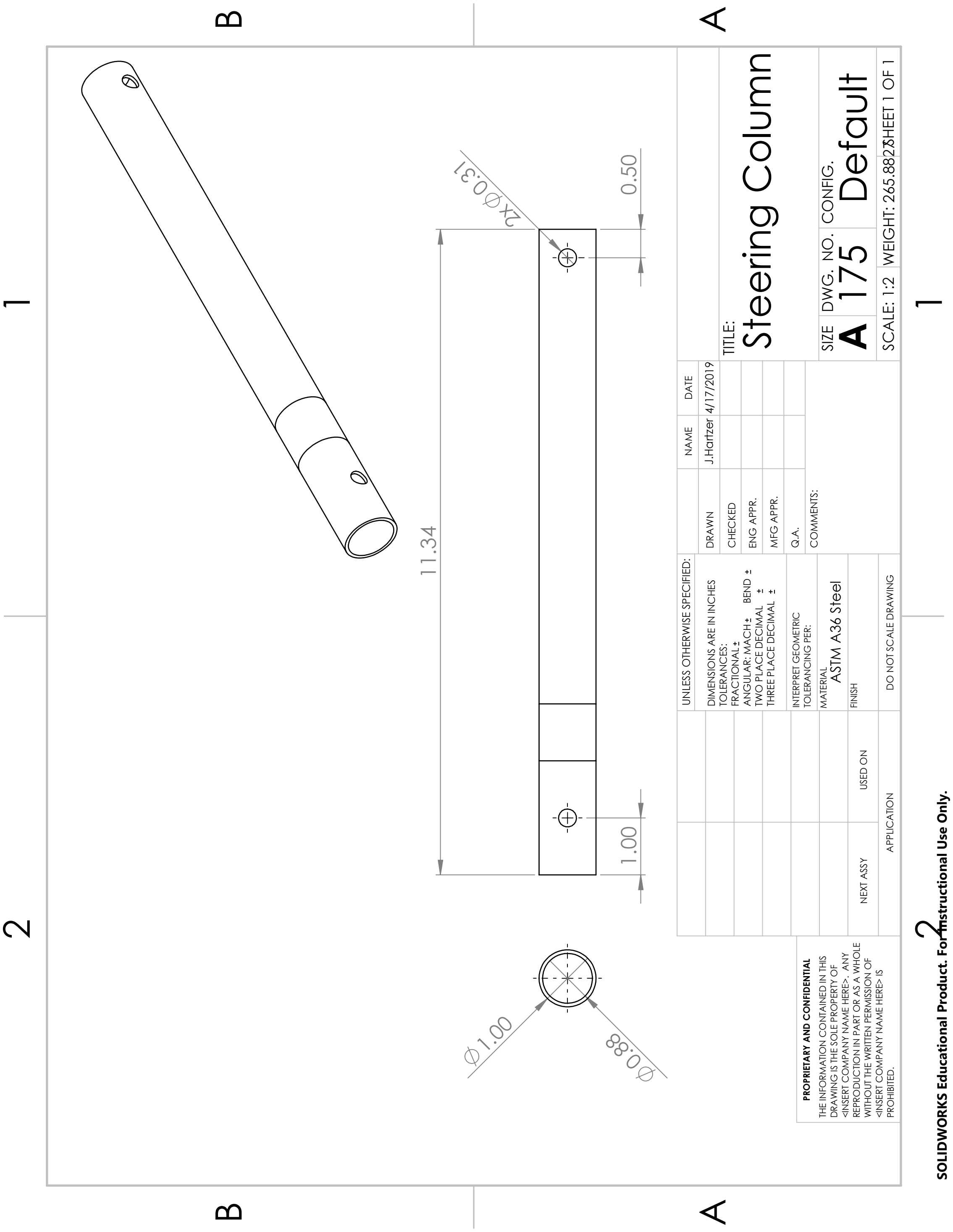
| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/17/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE:
# starter motor

SIZE A | DWG. NO. 174 | CONFIG. Default

SCALE: 1:2 | WEIGHT: 0.2413 | SHEET 1 OF 1



2x Ø0.31
0.50
11.34
1.00
Ø1.00
Ø0.88
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Steering Column
SIZE
A
DWG. NO.
175
CONFIG.
Default
SCALE: 1:2
WEIGHT: 265.8823
SHEET 1 OF 1
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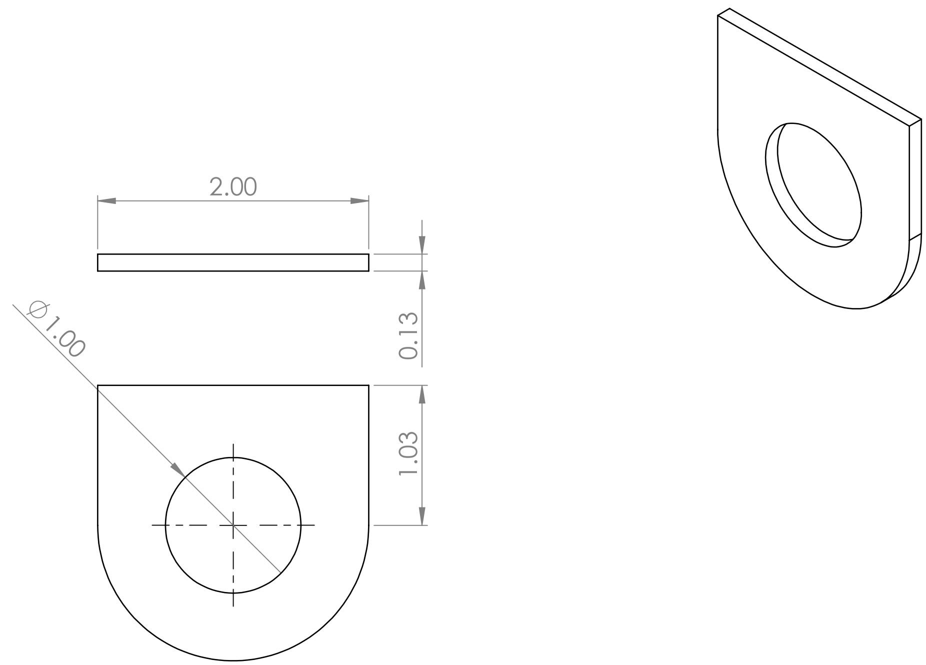
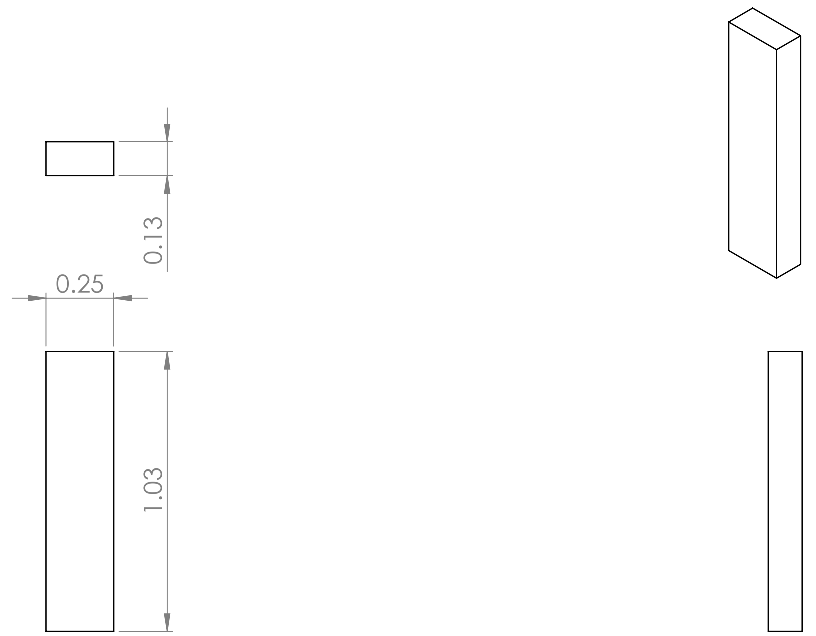



| | | | | |
|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 | |
| | CHECKED | | | TITLE:<br>Steering Hanger |
| | ENG APPR. | | | |
| | MFG APPR. | | | |
| INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| MATERIAL<br>6061 Alloy | COMMENTS: | | | SIZE A | DWG. NO. 176 | CONFIG. Default |
| FINISH | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 1:1 | WEIGHT: 15.7645 | SHEET 1 OF 1 |

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

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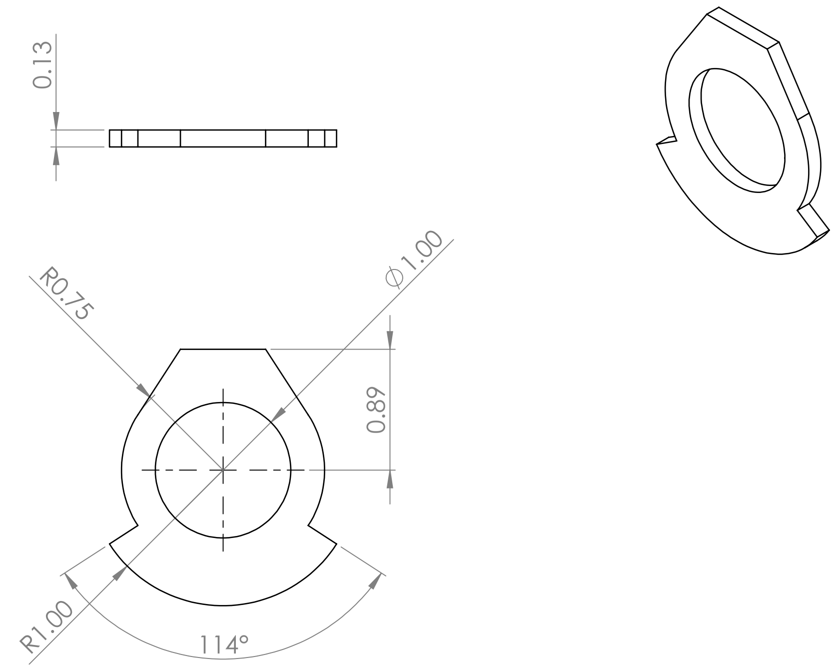
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | |
| | | MATERIAL<br>Material <not specified> | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

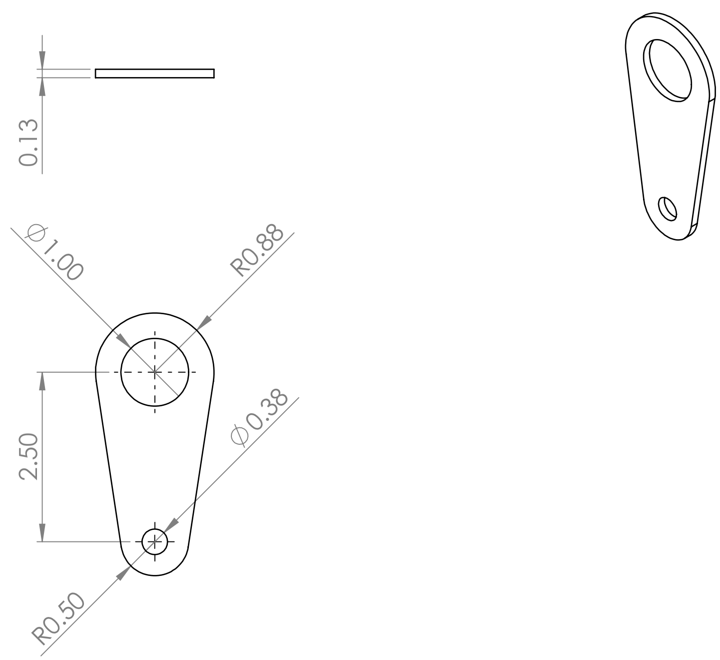
TITLE:

Steering Stopper_tab

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 178 | Default |
| SCALE: 2:1 | WEIGHT: 0.0012 | SHEET 1 OF 1 |




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 | TITLE:<br>Steering Stopper |
| | | | CHECKED | | | |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL<br>ASTM A36 Steel | COMMENTS: | | | SIZE A · DWG. NO. 177 · CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:1 · WEIGHT: 0.0557 · SHEET 1 OF 1 |




| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
|---|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 | TITLE: Steering Tab |
| | | | CHECKED | | | |
| | | | ENG APPR. | | | |
| | | | MFG APPR. | | | |
| | | INTERPRET GEOMETRIC TOLERANCING PER: | Q.A. | | | |
| | | MATERIAL<br>ASTM A36 Steel | COMMENTS: | | | SIZE A · DWG. NO. 179 · CONFIG. Default |
| NEXT ASSY | USED ON | FINISH | | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | | SCALE: 1:2 · WEIGHT: 0.15 · SHEET 1 OF 1 |

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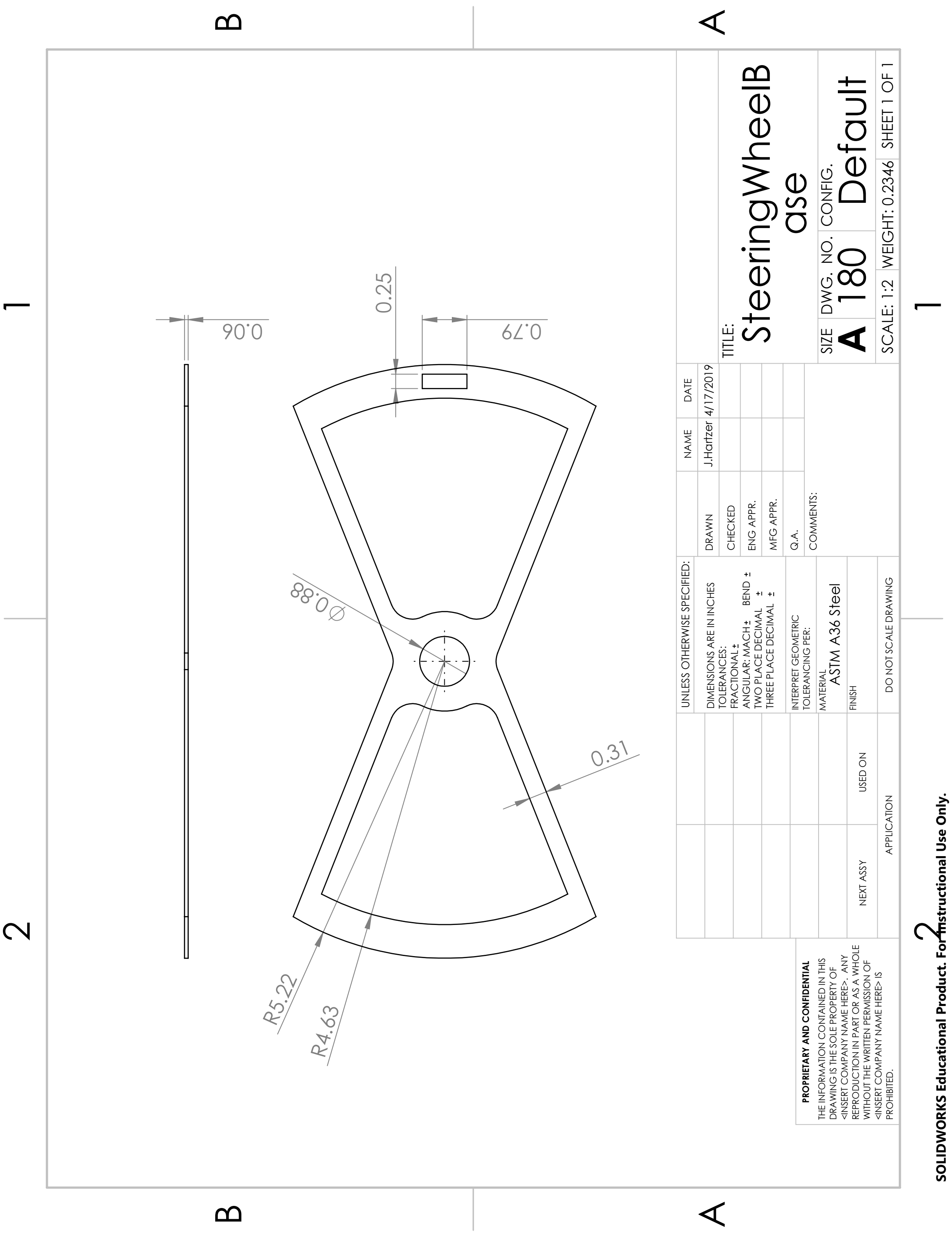

B
A
1
2
0.25
0.06
0.79
⌀0.88
0.31
R5.22
R4.63
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SteeringWheelBase
SIZE
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DWG. NO.
180
CONFIG.
Default
SCALE: 1:2
WEIGHT: 0.2346
SHEET 1 OF 1
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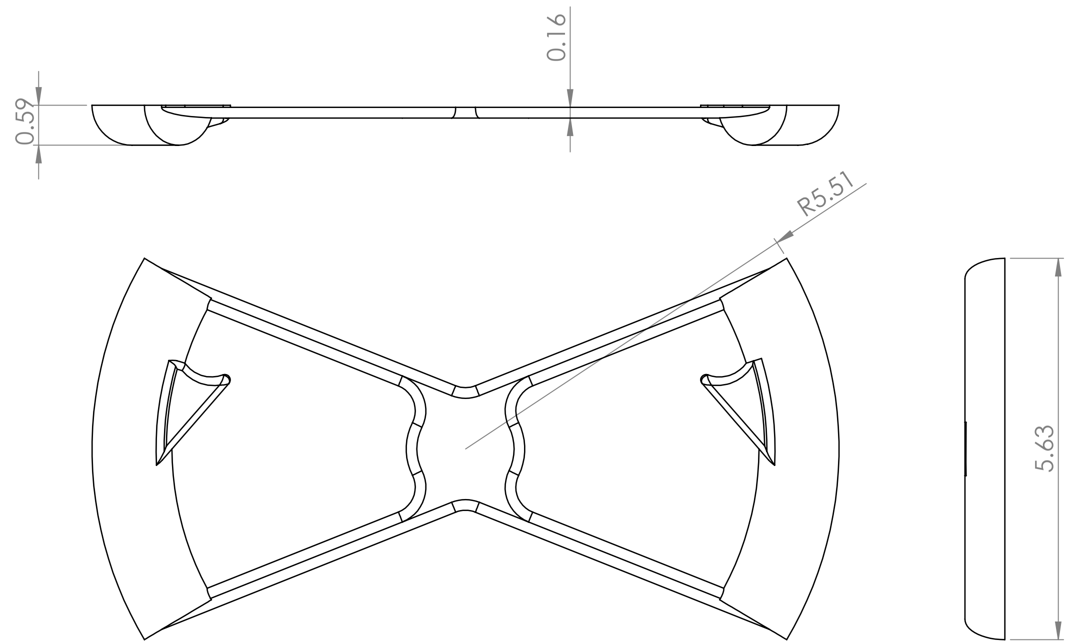
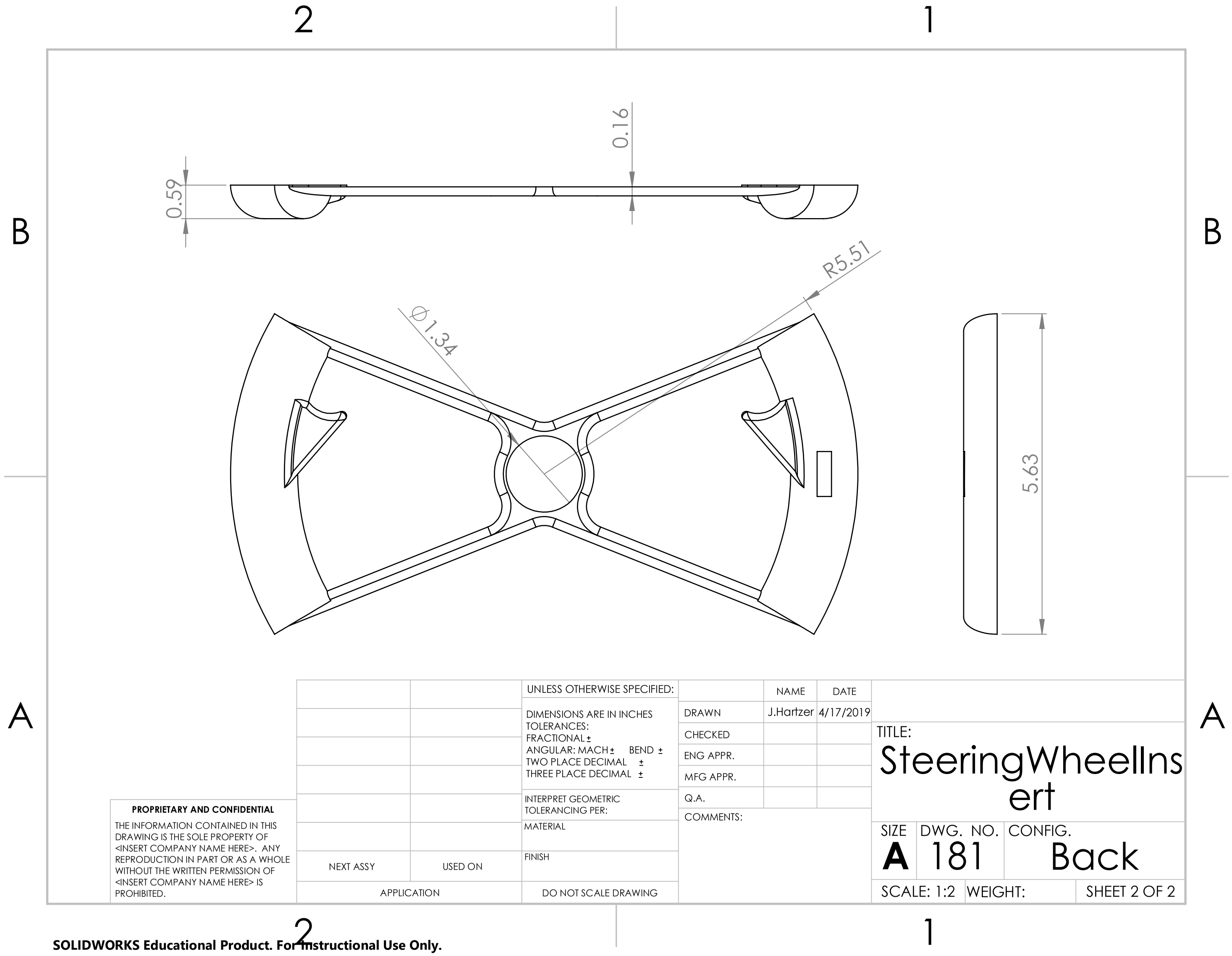



| | | UNLESS OTHERWISE SPECIFIED: | | NAME | DATE |
|---|---|---|---|---|---|
| | | DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 |
| | | | CHECKED | | |
| | | | ENG APPR. | | |
| | | | MFG APPR. | | |
| | | INTERPRET GEOMETRIC<br>TOLERANCING PER: | Q.A. | | |
| | | MATERIAL | COMMENTS: | | |
| NEXT ASSY | USED ON | FINISH | | | |
| APPLICATION | | DO NOT SCALE DRAWING | | | |

TITLE:

SteeringWheelInsert

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| **A** | 181 | Front |
| SCALE: 1:2 | WEIGHT: | SHEET 1 OF 2 |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1
B
A
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0.16
R5.51
Ø1.34
5.63
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SteeringWheelInsert
SIZE
A
DWG. NO.
181
CONFIG.
Back
SCALE: 1:2
WEIGHT:
SHEET 2 OF 2
PROPRIETARY AND CONFIDENTIAL
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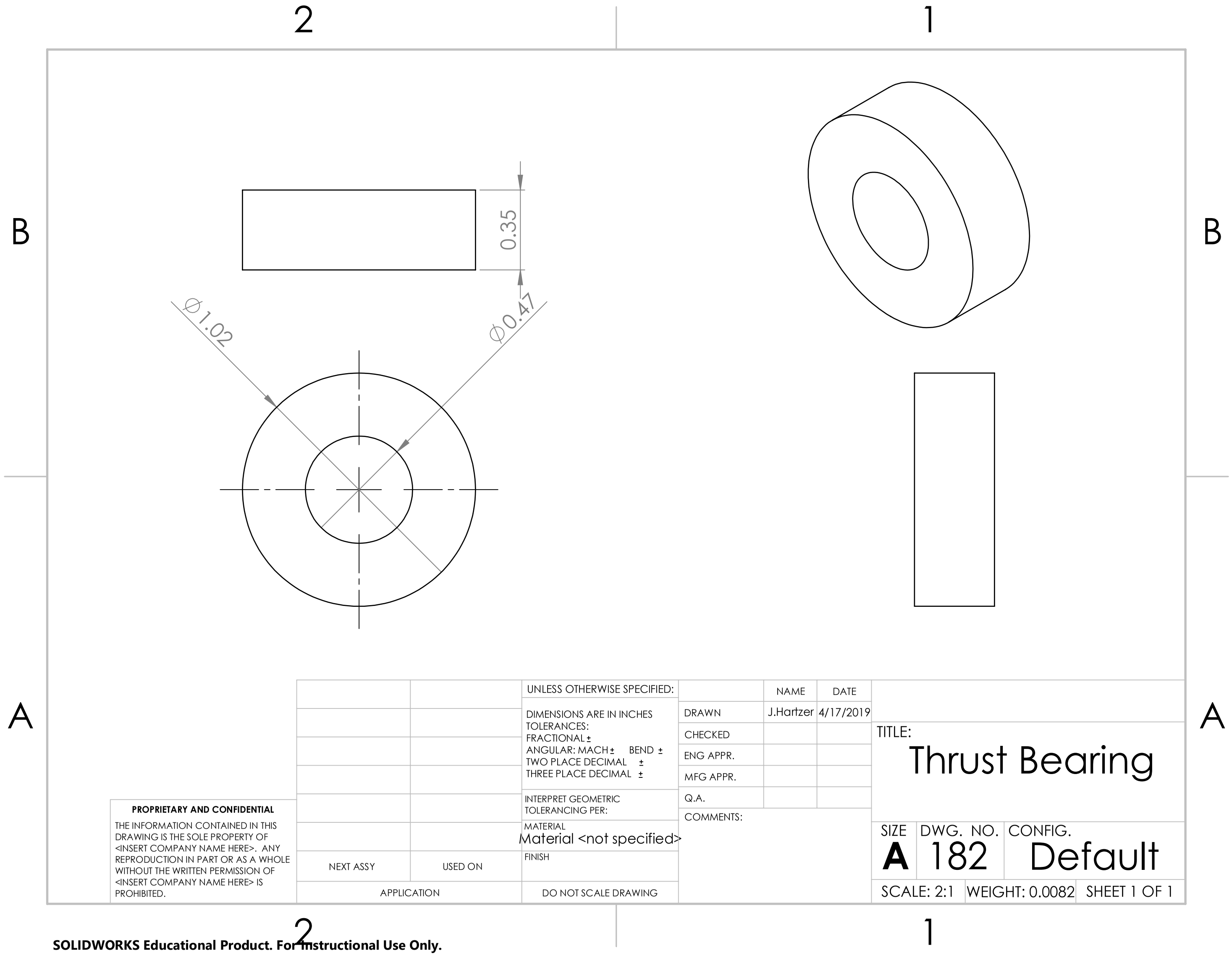

2
1
B
A
0.35
∅1.02
∅0.47
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
Thrust Bearing
SIZE
A
DWG. NO.
182
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0082
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
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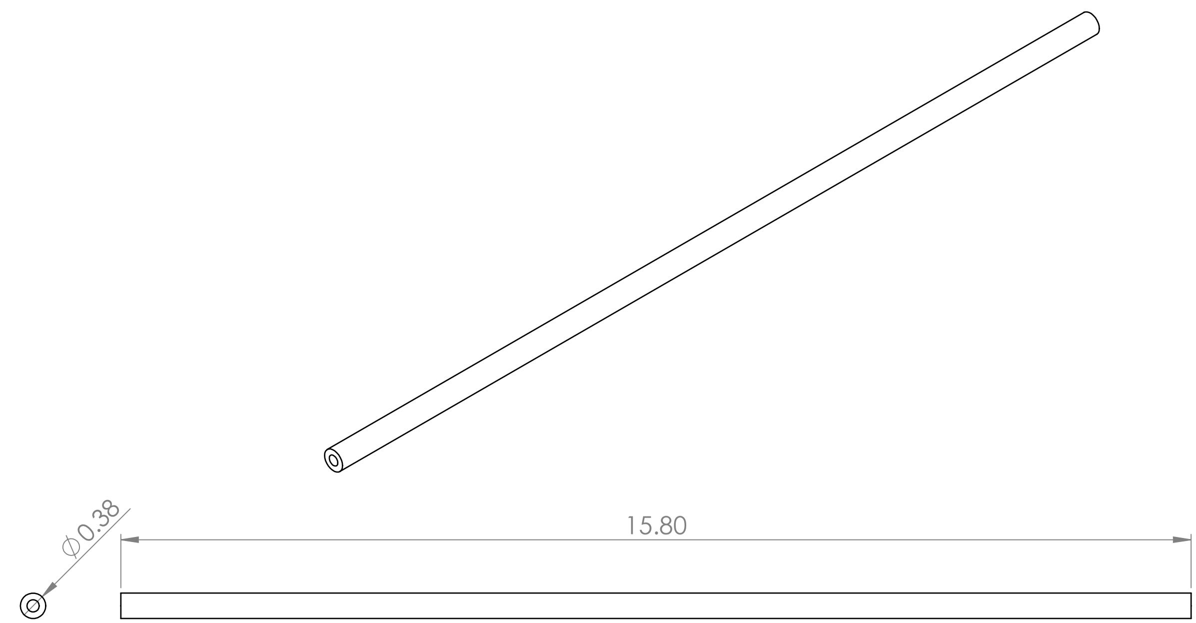


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|---|---|
| APPLICATION | |

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
ASTM A36 Steel

FINISH

DO NOT SCALE DRAWING

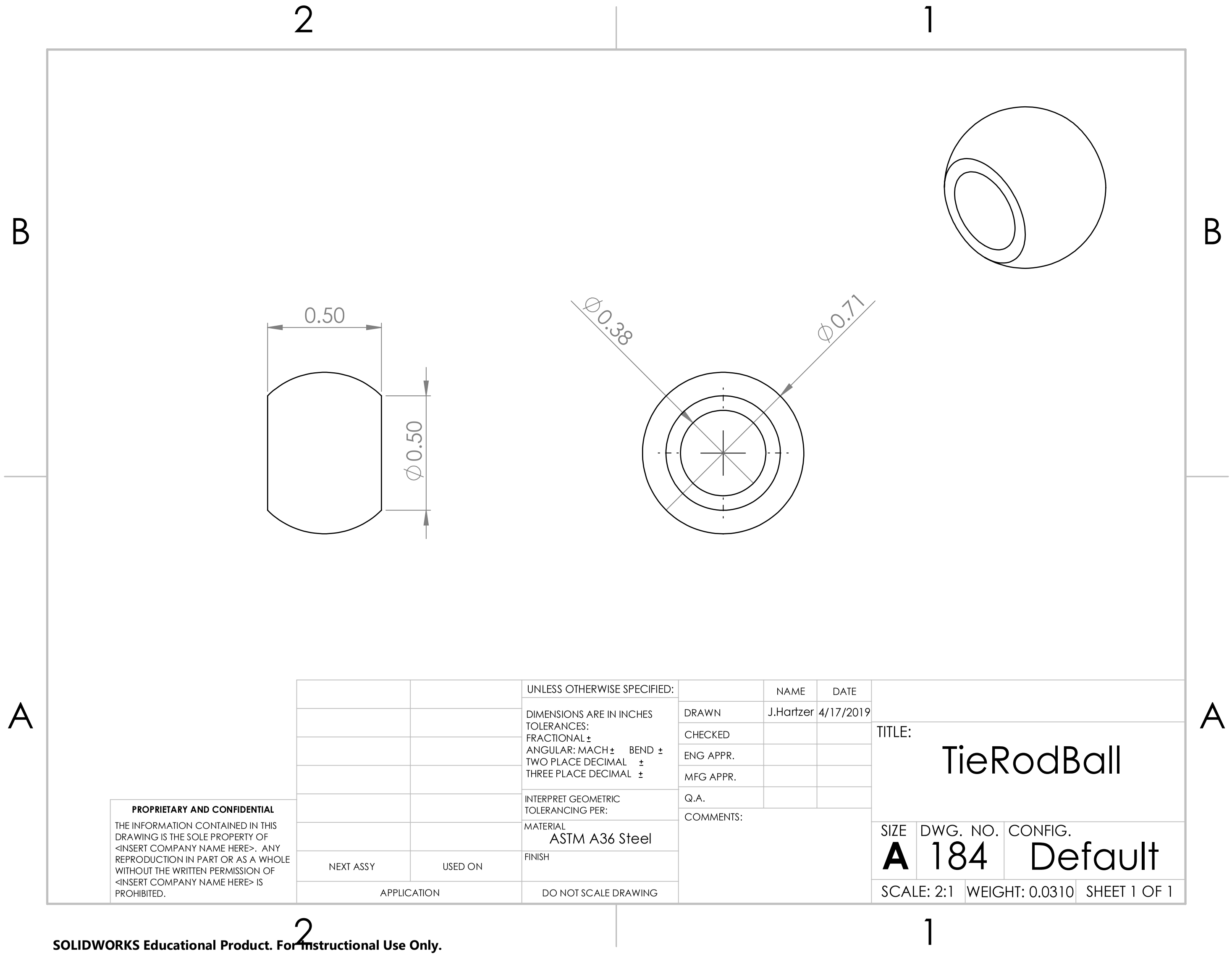
| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/17/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE:

TieRod

| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 183 | Default |
| SCALE: 1:2 | WEIGHT: 0.3809 | SHEET 1 OF 1 |


2
1
B
A
0.50
⌀0.50
⌀0.38
⌀0.71
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
TieRodBall
SIZE
A
DWG. NO.
184
CONFIG.
Default
SCALE: 2:1
WEIGHT: 0.0310
SHEET 1 OF 1
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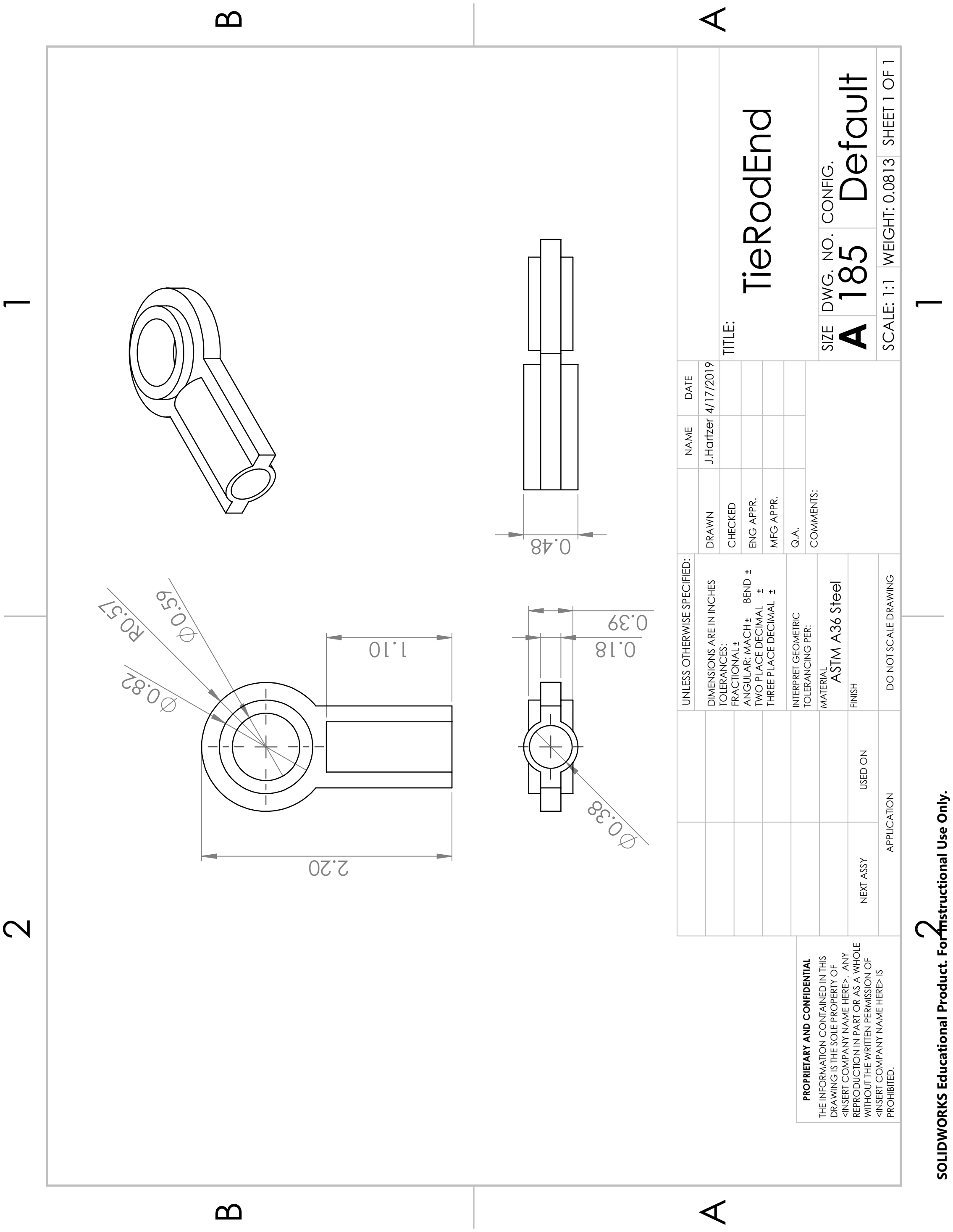
TieRodEnd
TITLE:
SIZE A
DWG. NO. 185
CONFIG. Default
SCALE: 1:1
WEIGHT: 0.0813
SHEET 1 OF 1
NAME
DATE
DRAWN J.Hartzer 4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
ASTM A36 Steel
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
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Ø0.59
Ø0.82
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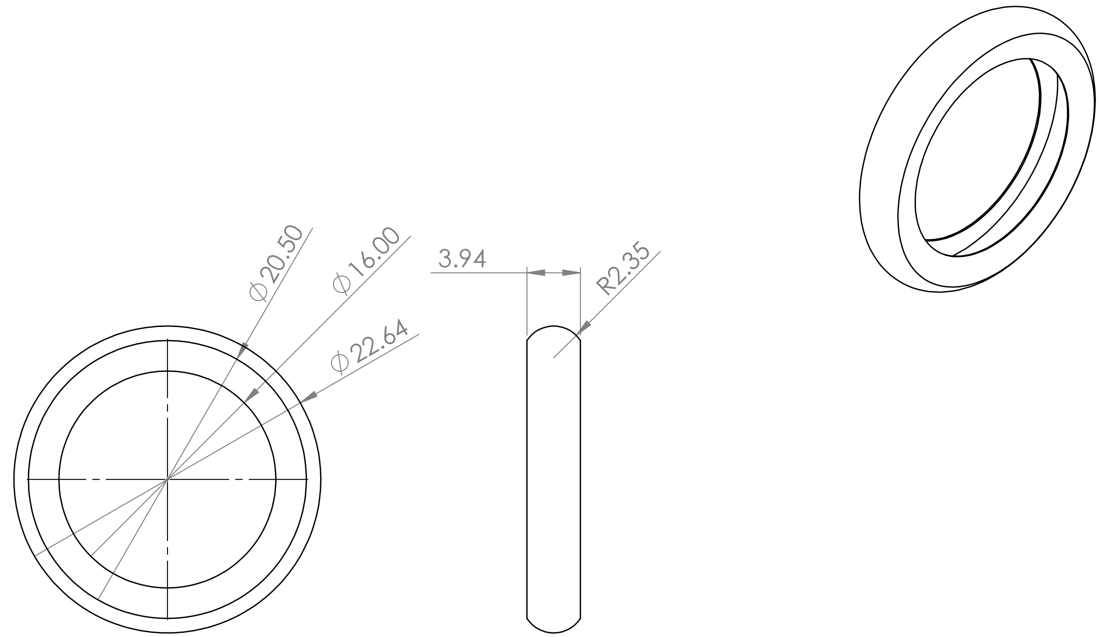
Ø0.38
0.48
A
B
1
2




| | | | | |
|---|---|---|---|---|
| UNLESS OTHERWISE SPECIFIED: | | NAME | DATE | |
| DIMENSIONS ARE IN INCHES<br>TOLERANCES:<br>FRACTIONAL ±<br>ANGULAR: MACH ± BEND ±<br>TWO PLACE DECIMAL ±<br>THREE PLACE DECIMAL ± | DRAWN | J.Hartzer | 4/17/2019 | |
| | CHECKED | | | TITLE: |
| | ENG APPR. | | | Tire |
| | MFG APPR. | | | |
| INTERPRET GEOMETRIC<br>TOLERANCING PER: | Q.A. | | | |
| MATERIAL<br>Natural Rubber | COMMENTS: | | | SIZE A · DWG. NO. 186 · CONFIG. Default |
| FINISH | | | | |
| DO NOT SCALE DRAWING | | | | SCALE: 1:10 · WEIGHT: 4500.00 · SHEET 1 OF 1 |

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|---|---|
| APPLICATION | |

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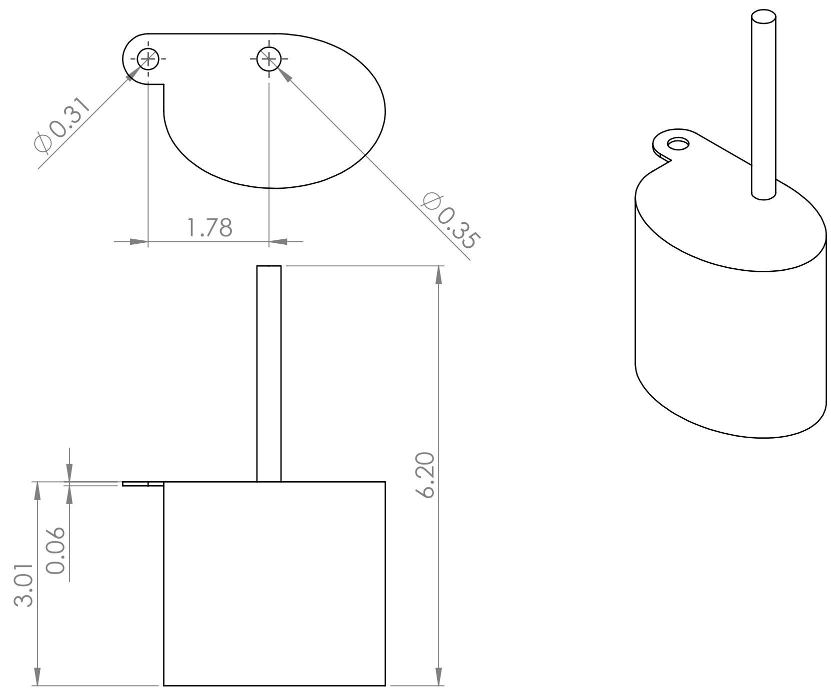


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NEXT ASSY | USED ON

APPLICATION

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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
ASTM A36 Steel

FINISH

DO NOT SCALE DRAWING

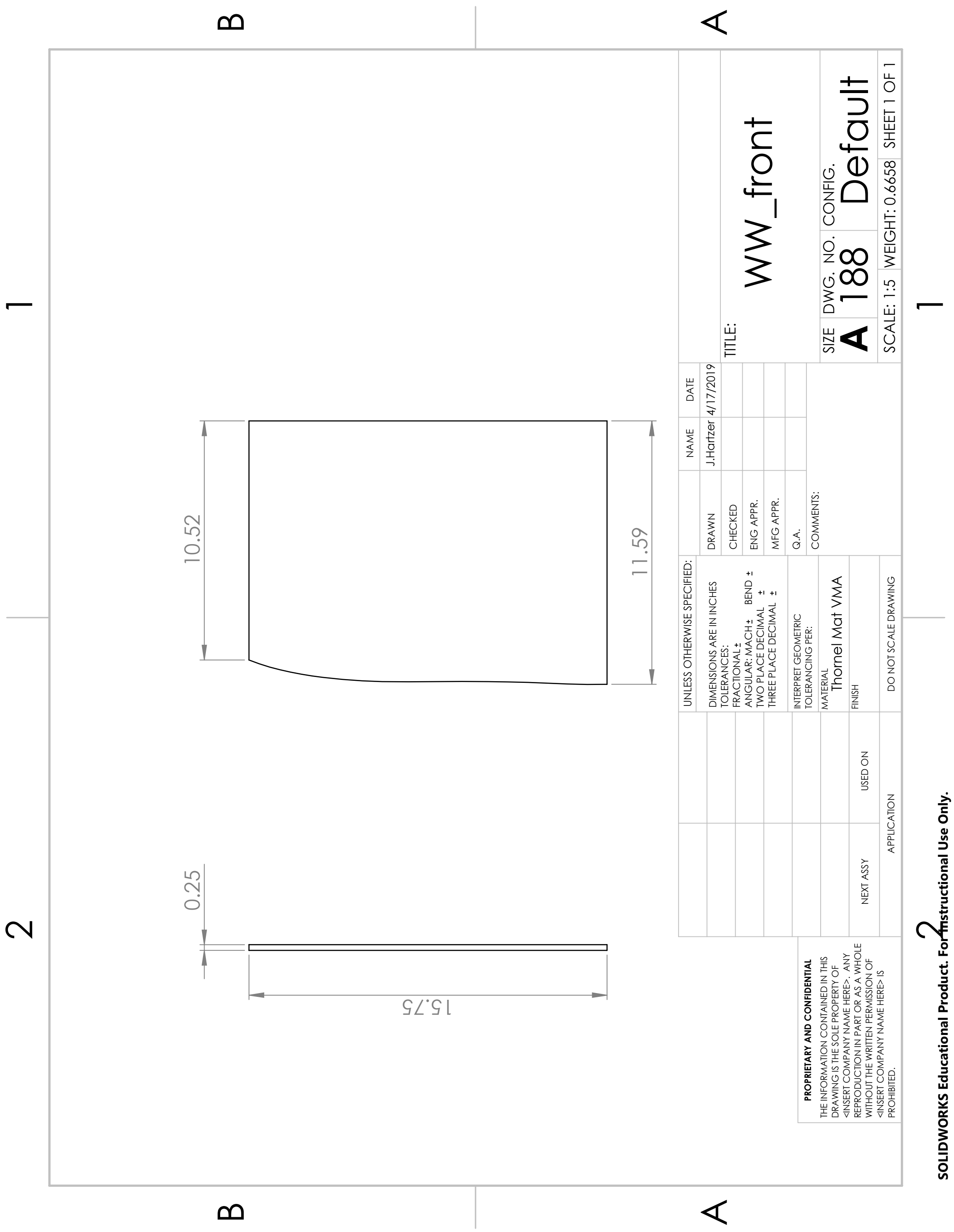
| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/17/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |

COMMENTS:

TITLE: Wiper

SIZE A | DWG. NO. 187 | CONFIG. Default

SCALE: 1:2 | WEIGHT: 5.1070 | SHEET 1 OF 1


10.52
11.59
0.25
15.75
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DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Thornel Mat VMA
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
WW_front
SIZE
A
DWG. NO.
188
CONFIG.
Default
SCALE: 1:5
WEIGHT: 0.6658
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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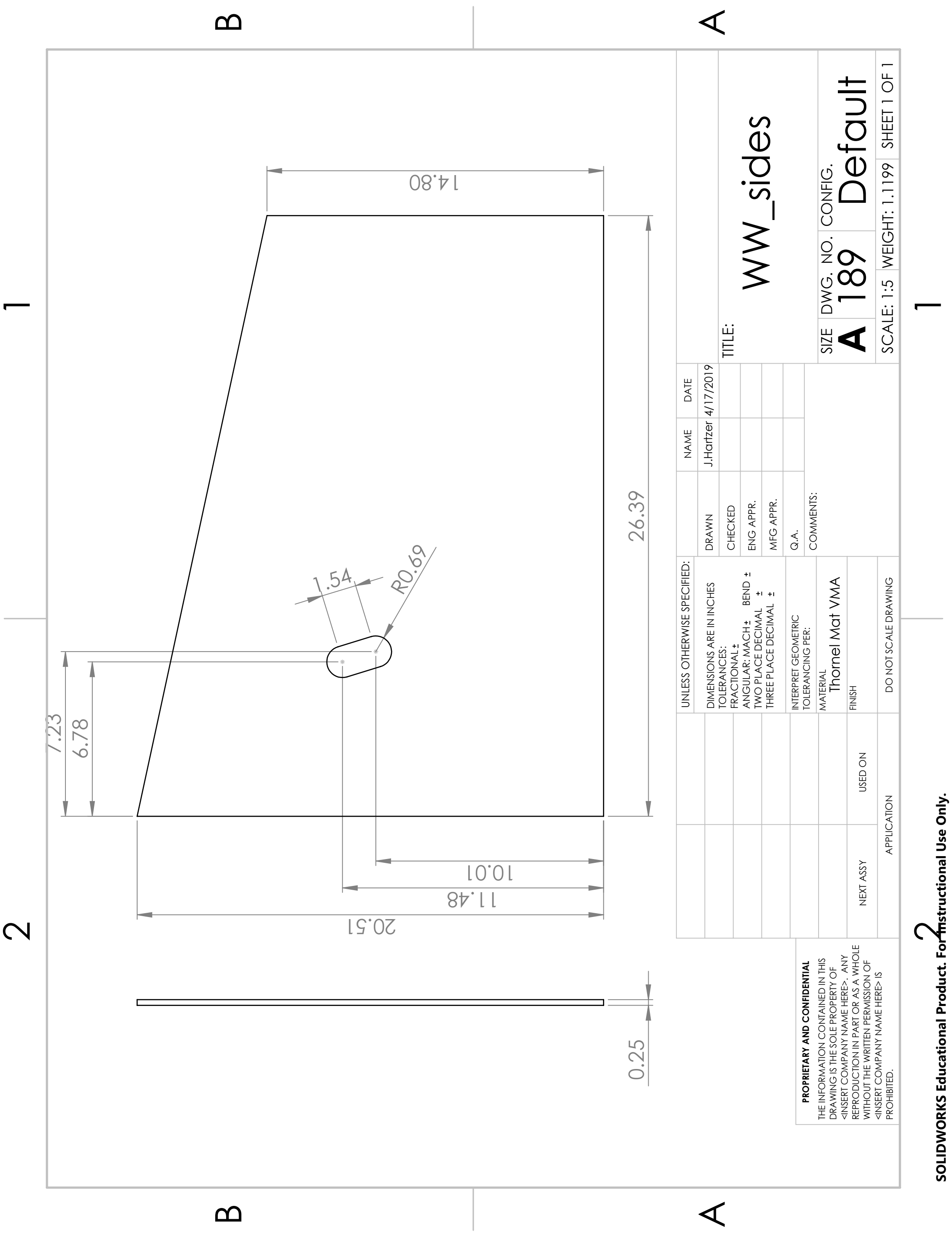
WW_sides
TITLE:
SIZE A
DWG. NO. 189
CONFIG. Default
SCALE: 1:5
WEIGHT: 1.1199
SHEET 1 OF 1
NAME
DATE
DRAWN J.Hartzer 4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Thornel Mat VMA
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
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14.80
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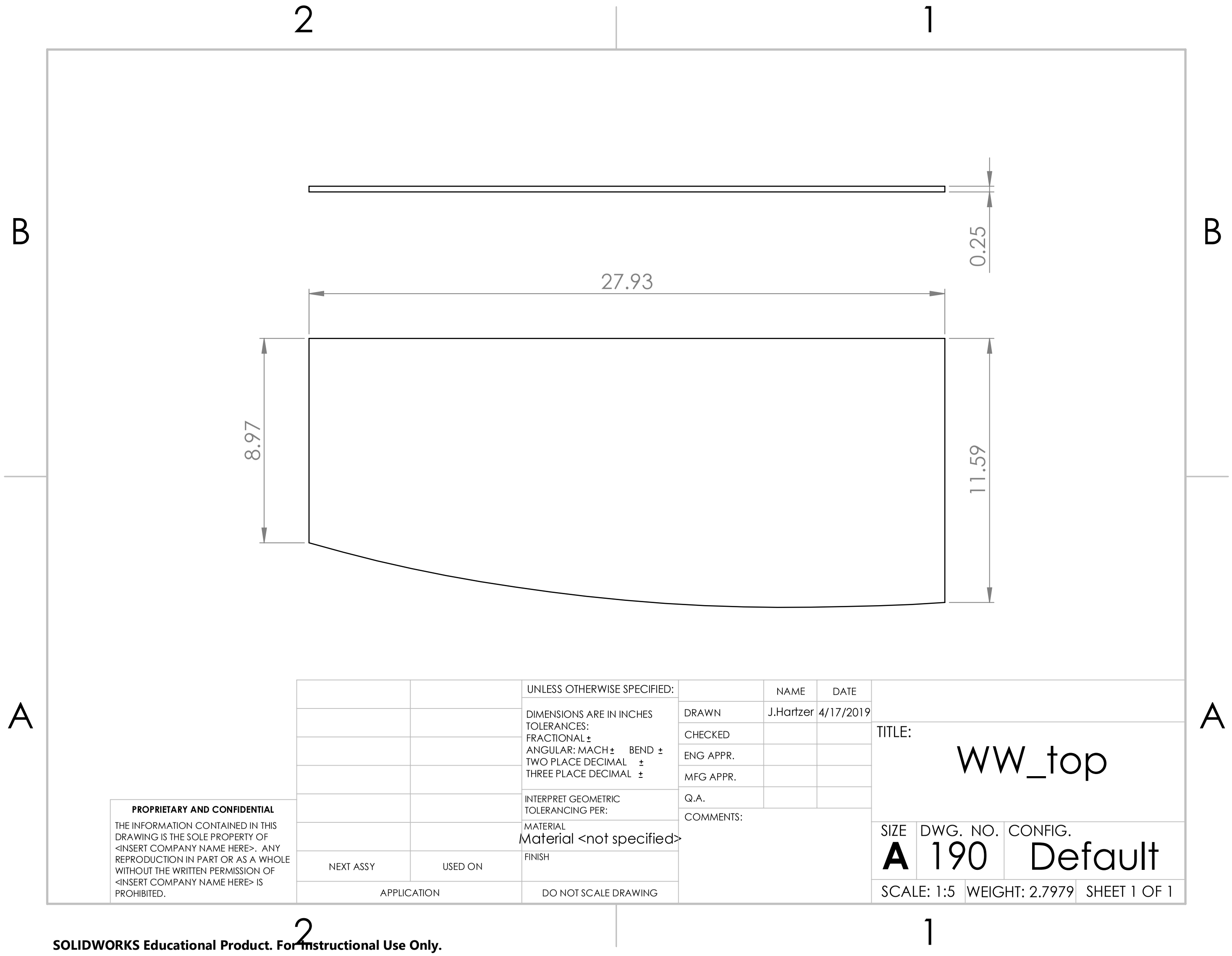
1.54
R0.69
7.23
6.78
10.01
11.48
20.51
0.25
A
B
1
2


2
1
B
A
0.25
27.93
8.97
11.59
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
Material <not specified>
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
J.Hartzer
4/17/2019
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
WW_top
SIZE
A
DWG. NO.
190
CONFIG.
Default
SCALE: 1:5
WEIGHT: 2.7979
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
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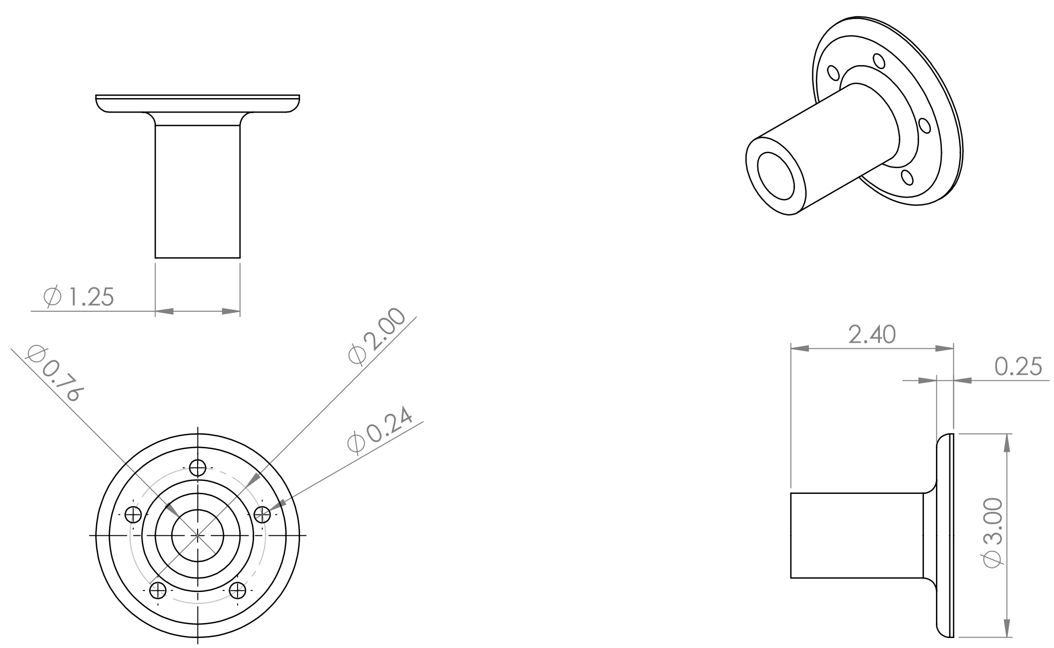



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL
Material <not specified>

FINISH

DO NOT SCALE DRAWING

| NEXT ASSY | USED ON |
|---|---|
| APPLICATION | |

| | NAME | DATE |
|---|---|---|
| DRAWN | J.Hartzer | 4/17/2019 |
| CHECKED | | |
| ENG APPR. | | |
| MFG APPR. | | |
| Q.A. | | |
| COMMENTS: | | |

TITLE:

Zuma Hub_machined

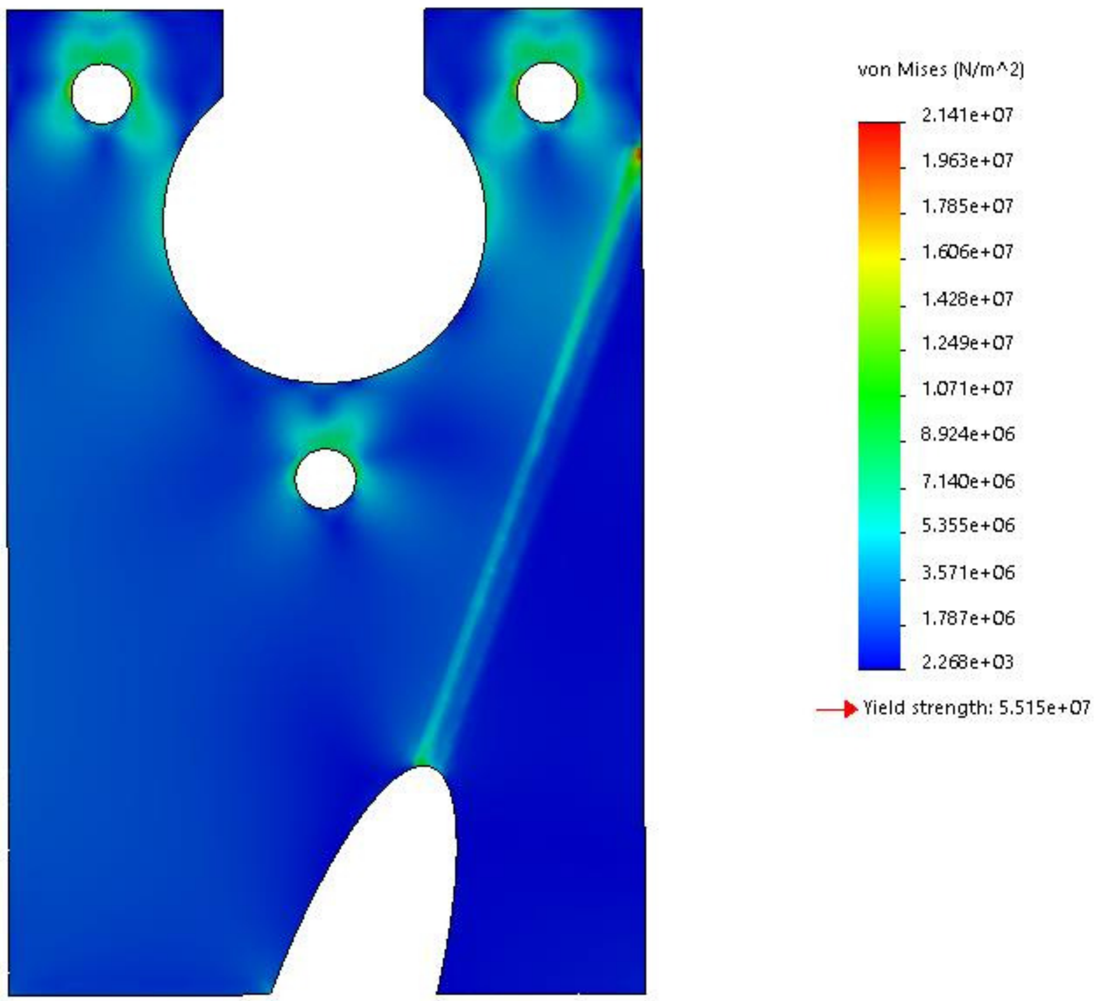
| SIZE | DWG. NO. | CONFIG. |
|---|---|---|
| A | 191 | Default |

SCALE: 1:2 WEIGHT: 0.1161 SHEET 1 OF 1

# C FEA

Bottom and gusset line fixed

Bearing Load: 1000N

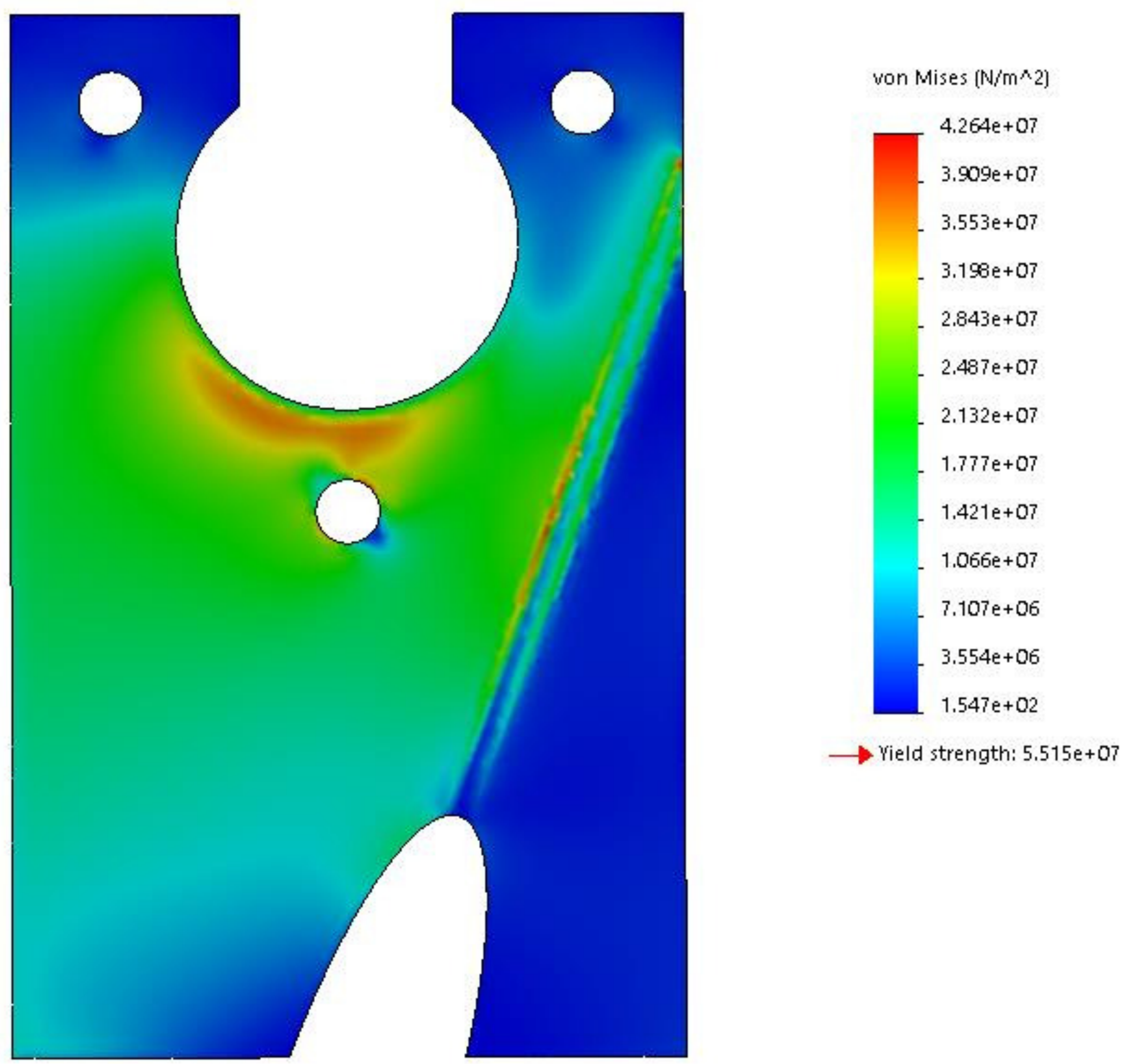



FOS 6.2

Figure 79: Bearing Hanger Load Test

250 N at bolting points

Fixed at bottom and gusset line




FOS 1.5

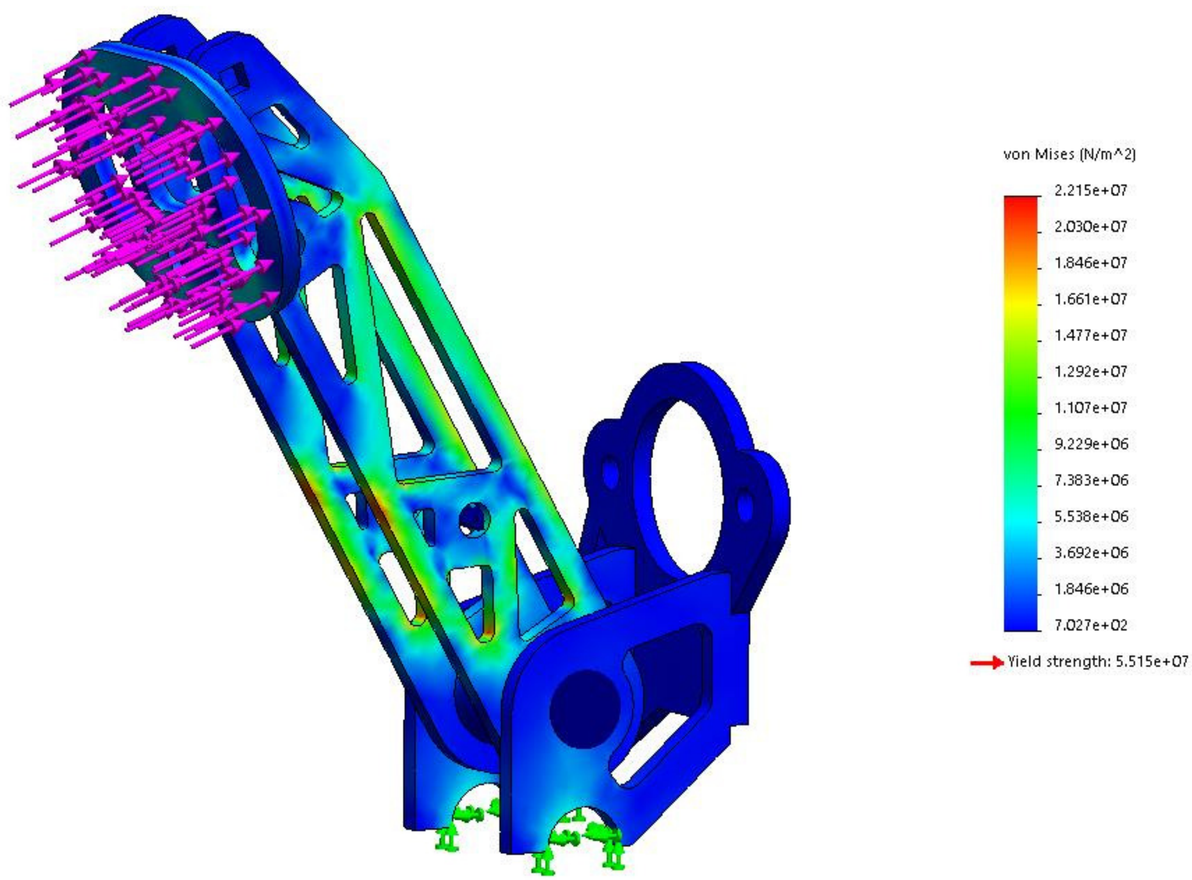
Figure 80: Bearing Hanger Turning Test

200 N at Pedal

Pin connection from pedal to gussets

Bearing connection to plungers

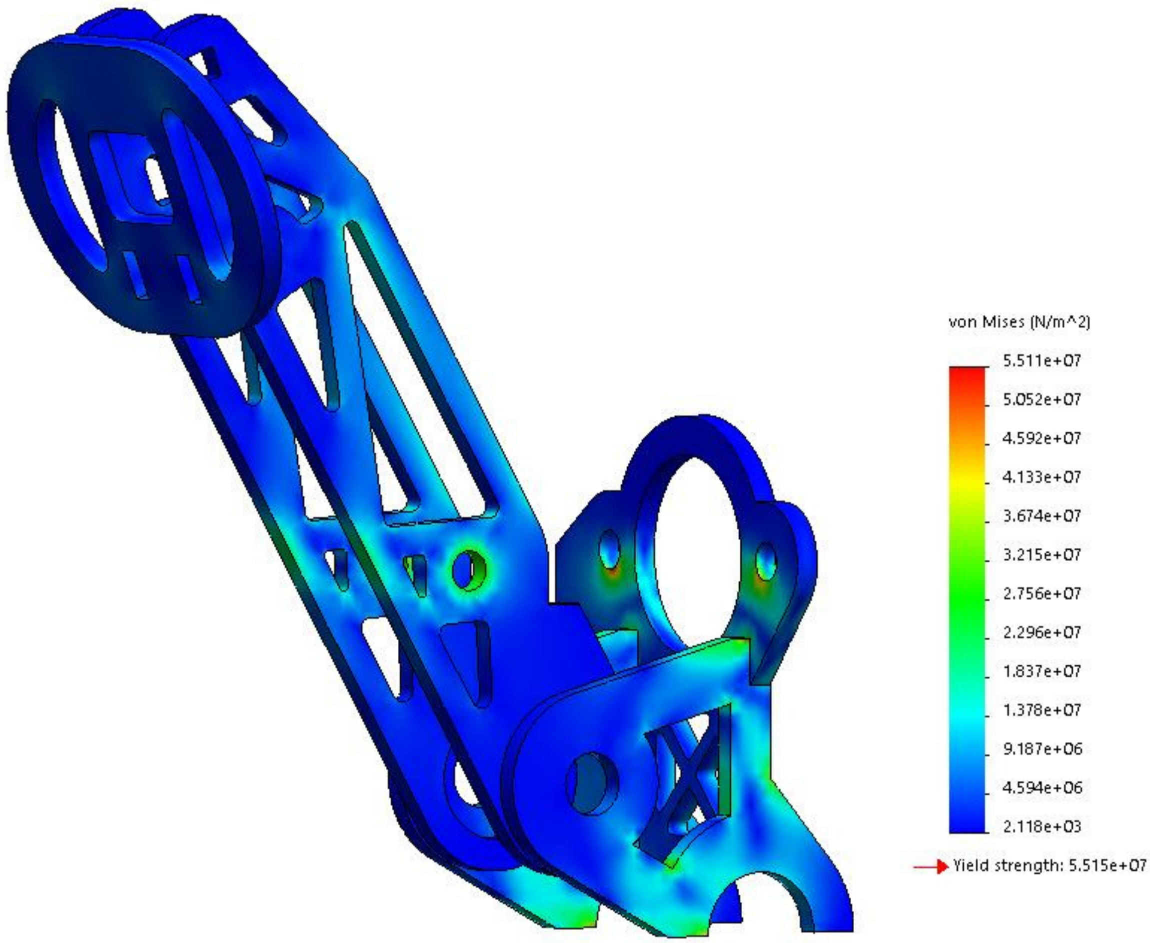
Fixed at weld points




FOS = 3.1

Figure 81: Brake Pedal Assembly Load Test

200 N at Pedal

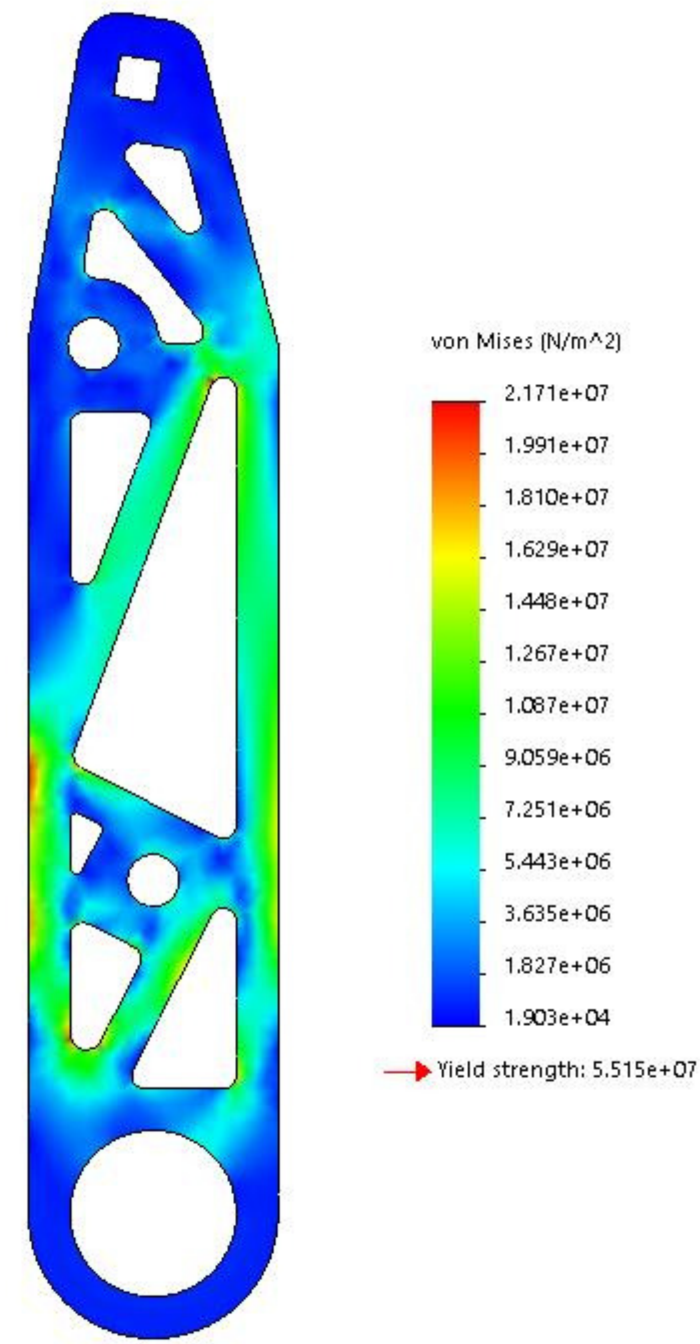



FOS 2.0

Figure 82: Brake Pedal Assembly Stress Test

100 N applied to pedal surface

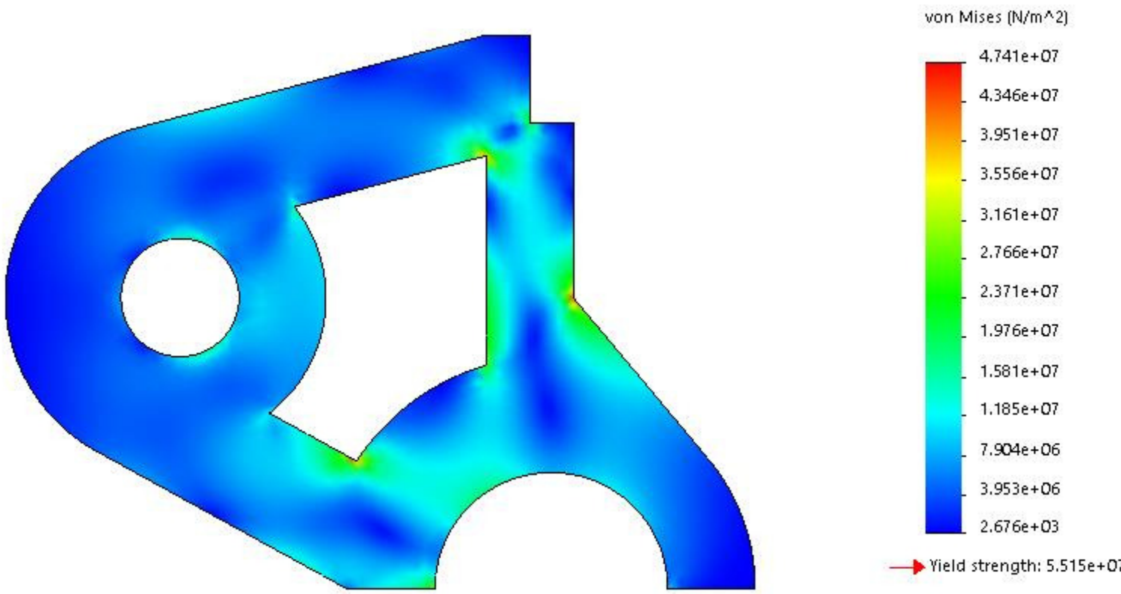
Bearing supports at mounting holes




FOS 3.0

Figure 83: Brake Pedal Lever Load Test

450 N at Pin

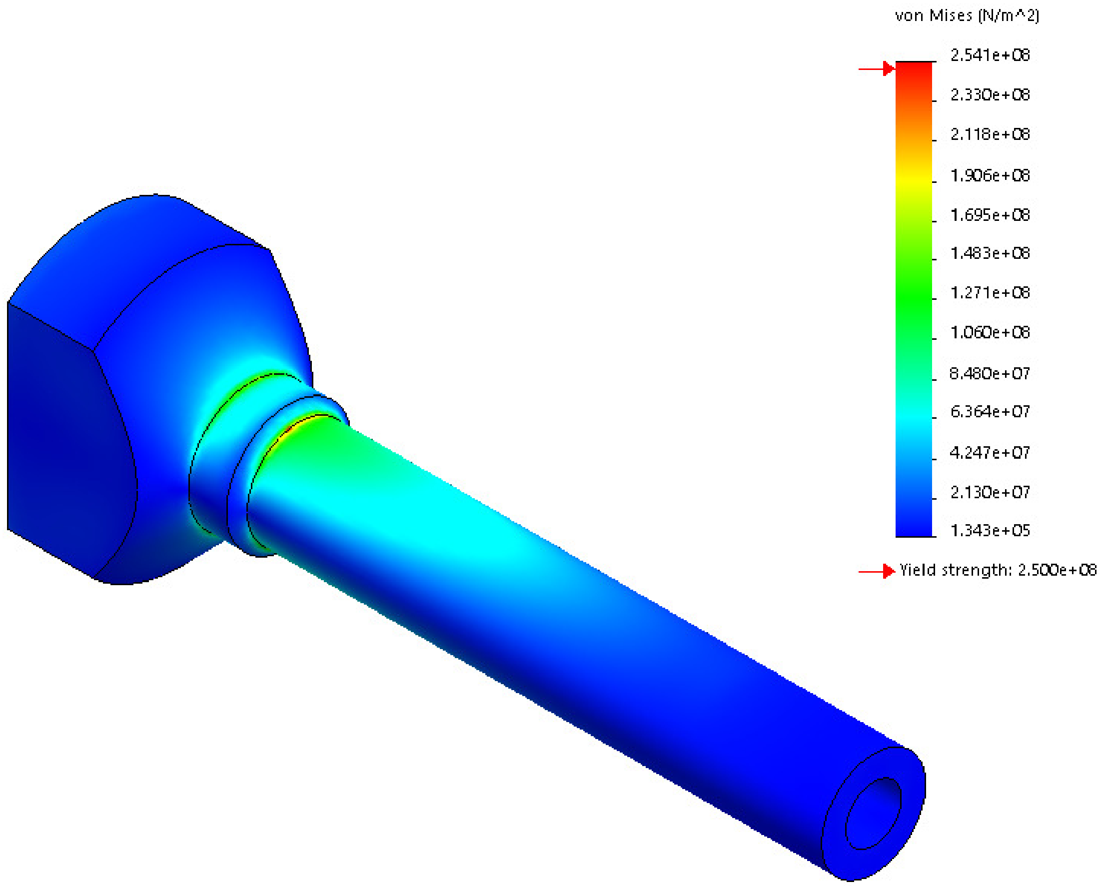



FOS 2.0

Figure 84: Gusset Bearing Test

End Fixed

Bearing Load: 1000N

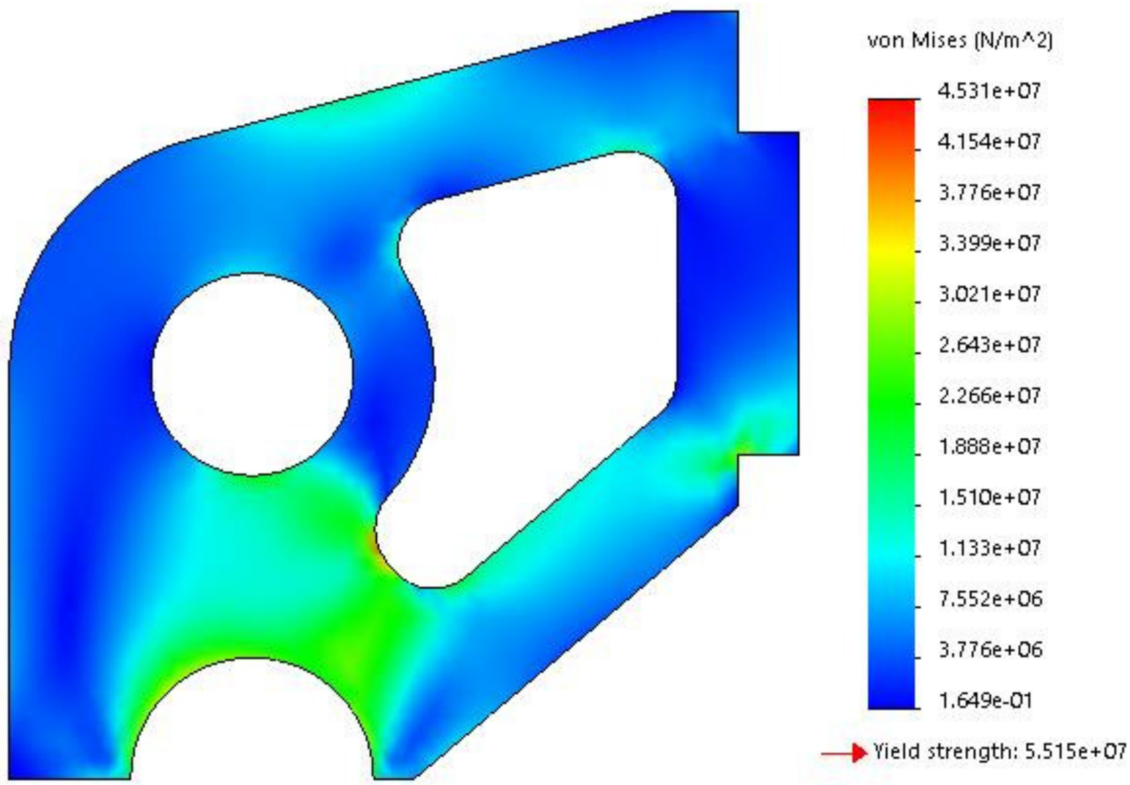



FOS 2.2

Figure 85: Knuckle Axle Load Test

15 Nm applied to pedal mounting

Bearing supports at hole

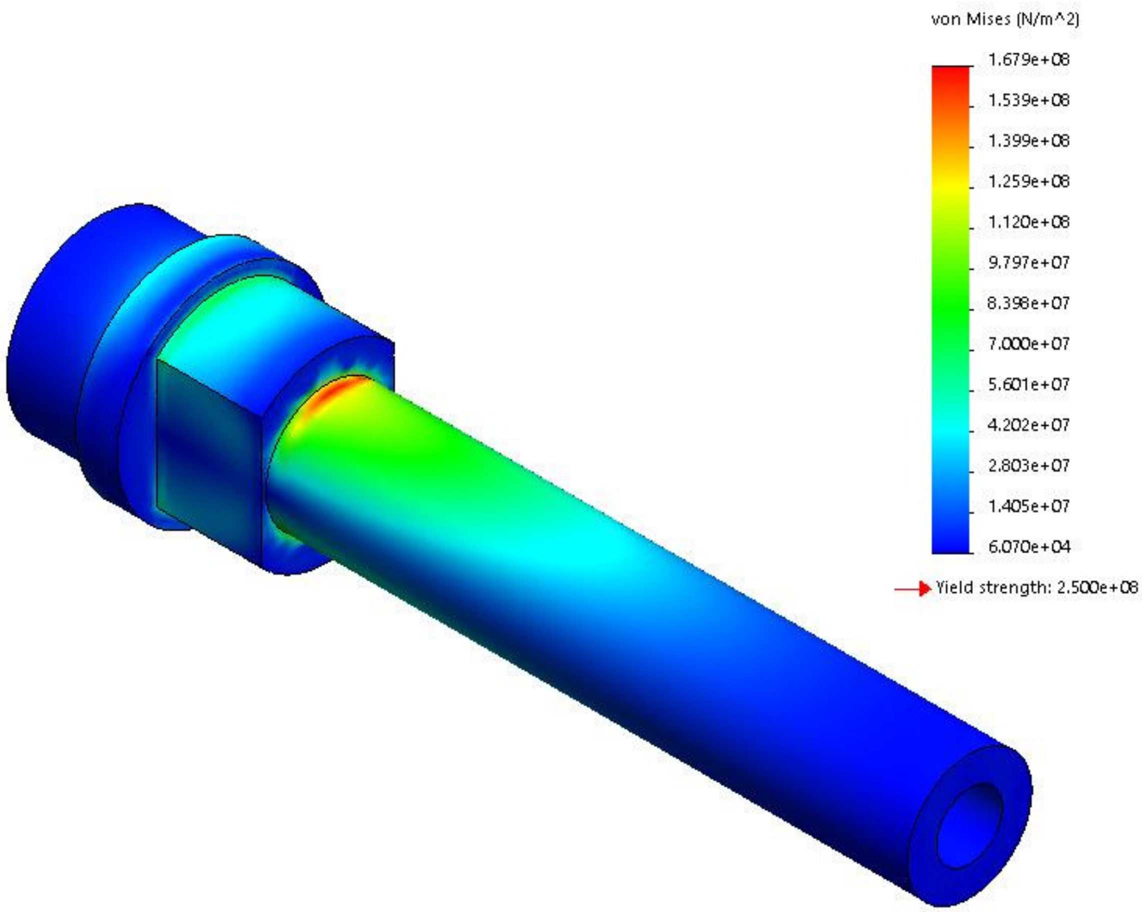



FOS 2.0

Figure 86: Master Cylinder Gusset Torque Test

1000 N on bearing

Fixed at end

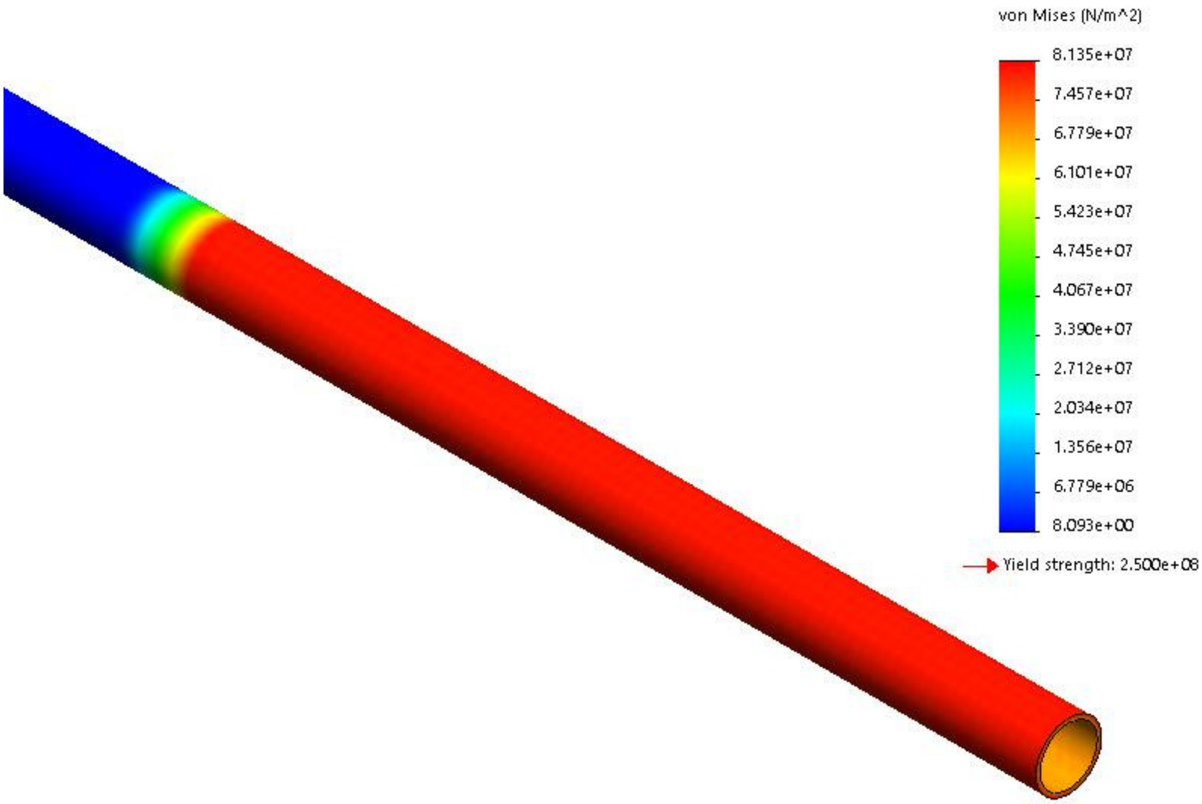



FOS 2.0

Figure 87: Rear Axle Load Test

Fixed at Tip

63.09 Nm Torque applied to center




FOS 3.1

Figure 88: Rear Axle Torque Test

# D Risk Analysis

## D.1 Job Safety Analysis

Table 9: Job Safety Analysis by Subteam: Frame

| Steps | Hazards | Controls |
|---|---|---|
| Cutting tubes for the frame and coping | 1. Projectiles of metal can blind or potentially injure user when grinding.<br>2. Grinding wheel can shatter if used improperly or not securely fastened.<br>3. Fresh cut edges on tubes are sharp and can cause cuts if handled without gloves. | 1. Wear safety glasses and a full face shield when grinding as well as long pants and closed toe shoes.<br>2. Secure the grinding wheel ensuring it is flush with the mounting flange. Only use the cutting wheel for cutting at 90 °. Never use the cutting wheel to grind down a surface.<br>3. Grind sharp edges to a bevel when handling parts without gloves. |
| Welding the Frame | 1. Arcing can cause blindness for the welder or bystander.<br>2. Aluminum has a property similar to glass in that it looks the same hot as it does cold. User could experience dangerous burns.<br>3. Fumes from inert gases can asphyxiate the user or bystanders to the process.<br>4. Welding can cause sunburn due to the brightness and intensity of the arc. | 1. Ensure all personnel involved with the process directly are wearing eye protection with at least shade of 10. Bystanders can wear shade 5 protection when behind an additional screen. Make sure that the automatic welding hood is functional before beginning to weld by performing a small arc test to see if the shading changes.<br>2. Clearly indicate and separate hot aluminum from cold.<br>3. Utilize an exhaust hood when welding to eliminate inerting gas and other fumes from the surroundings.<br>4. Wear proper PPE for welding including FRC, long shirt, high collar, long pants, and leather shoes. |
| Lifting heavy parts and equipment | 1. Could cause muscle strain or injury to feet if dropped. | 1. Lift heavy items with legs not the back by keeping the object close to the body. Wear the appropriate PPE such as closed toed shoes and or gloves when working in the machine shop or build area. |

Table 10: Job Safety Analysis by Subteam: Powertrain

| **Steps** | **Hazards** | **Controls** |
|---|---|---|
| Cleaning and Dismantling the Engine | 1. Fluids can eject from pressurized lines. 2. Residual grease and dirt can conceal sharp edges or small sharp grains of metal. | 1. Wear safety glasses when dismantling the engine while fluid is present inside. 2. Use gloves when working on the engine as a means for a barrier. |
| Testing and tuning the engine | 1. Unfastened parts can result in vibrations and a possible failure of rotating or moving component. 2. Fumes from exhaust gases can asphyxiate the user or bystanders to the process. 3. Faults in electrical systems can result in an ignition source external to the engine | 1. Bolt down the engine to the proper torque specs on the engine mount. Ensure all moving parts are properly fastened and configured. 2. Perform engine testing only in well ventilated areas constantly purged with fresh air or outdoors. 3. Always keep a fire extinguisher nearby properly rated to extinguish electrical, metal, and hydrocarbon based fires (Dry powder based fire extinguisher capable for class A, B, C and D). |
| Combining and Removing the Engine Sub assembly from the Frame | 1. Could cause muscle strain or injury to feet if dropped. 2. Hard to reach areas for fasteners may expose assemblers to risk of cuts or scrapes from the metal. | 1. Lift heavy items with legs not the back by keeping the object close to the body. Wear the appropriate PPE when working in the machine shop or build area. 2. It is recommended that the team wear mechanics gloves anytime there needs to be work done with assembly of metal or heavy parts. |

Table 11: Job Safety Analysis by Subteam: Body

| Steps | Hazards | Controls |
|---|---|---|
| Hot Wire Cutting | 1. Heat from hot wire. 2. Impacting aluminum beams while inside | 1. Stay clear of the hot wire cutter when it is operating. 2. While inside the cutter to pick up parts, safety glasses must be work and caution must be taking walking around the beams. |
| Sanding the foam | 1. Fine polystyrene particles can be inhaled by bystanders. 2. Sandpaper can cut and scrape users' hands 3.Fine polystyrene can enter eyes. | 1. 3M masks are worn to prevent small particulates from entering lungs through the mouth or nose. 2. Gloves are worn during sanding process 3. Safety glasses are worn to prevent small particulates from sticking to the user's eyes. |
| Fiberglass Layup | 1. Hot Epoxy sticks to cloths and skin. 2. Fiberglass fibers can become lodged into skin and cause irritation. | 1. Plastic overalls are worn to prevent epoxy from sticking to user. 2. Gloves are worn during the layup to prevent fibers and epoxy from touching or penetrating skin. |

## D.2 FMECA/FMA

Table 12: FMECA Table

| Potential Failure | Severity | Occurrence | Detection | RPN |
|---|---|---|---|---|
| Misinterpretation of SEM Rules | 10 | 4 | 6 | 240 |
| Delays in Receiving Parts | 8 | 3 | 5 | 120 |
| Improper CAD Dimensions | 8 | 4 | 3 | 96 |
| Assemble Chassis Improperly | 10 | 3 | 3 | 90 |
| Loss of Saved Work | 9 | 1 | 3 | 27 |
| Depressurization of fuel | 10 | 3 | 7 | 210 |
| Chain Disengages | 10 | 4 | 5 | 200 |

| | | | | |
|---|---|---|---|---|
| Running out of Fuel | 10 | 3 | 6 | 180 |
| Spark Plug Failure | 8 | 5 | 4 | 160 |
| Leaking Fuel | 9 | 2 | 5 | 90 |
| Engine Locks Up | 8 | 3 | 3 | 72 |
| Engine Backfires | 8 | 2 | 3 | 48 |
| Accelerator pedal locks up | 10 | 1 | 3 | 30 |
| Leaking Coolant | 4 | 3 | 2 | 24 |
| Tire falls off | 10 | 3 | 7 | 210 |
| Axle Cracking | 9 | 3 | 7 | 189 |
| Axle Misalignment | 6 | 4 | 7 | 168 |
| Short Circuit | 8 | 4 | 5 | 160 |
| Battery out of charge | 10 | 3 | 5 | 150 |
| Tire pops | 9 | 3 | 5 | 135 |
| Kill Switch Fails | 10 | 3 | 4 | 120 |
| Brake Pedal locks up | 10 | 2 | 5 | 100 |
| Leaking Brake Fluid | 8 | 3 | 4 | 96 |
| Tire leaks air | 4 | 5 | 4 | 80 |
| Improperly calibrated brake calipers | 6 | 3 | 4 | 72 |
| Vehicle impact with another vehicle | 10 | 4 | 5 | 200 |
| Vehicle impact with a static object | 9 | 4 | 5 | 180 |
| Welds have poor penetration | 8 | 3 | 7 | 168 |
| Door gets stuck | 8 | 4 | 4 | 128 |
| Carbon Fiber Delaminates | 9 | 2 | 5 | 90 |
| Bolts in the body loosen | 9 | 2 | 5 | 90 |
| Door Attachment Fails | 7 | 4 | 3 | 84 |
| Carbon Fiber cracks | 8 | 3 | 3 | 72 |
| Epoxy cracks | 7 | 2 | 5 | 70 |
| Improper mixing of the epoxy | 4 | 3 | 4 | 48 |

Table 13: Failure Modes Analysis Table

| **Potential Failure** | **Cause** | **Consequence** | **Action Taken** |
|---:|---:|---:|---:|
| Misinterpretation of SEM Rules | This could be caused by incorrect interpretation of the rules, or not correctly taking note of all rules | A consequence of this would be being unable to compete | To remedy this, each member of the team has been tasked with reading the rules multiple times through and has contacted the judges if there is any possibility of a misunderstanding |
| Delays in Receiving Parts | This could be caused by ordering parts too late, or issues caused by the seller | A consequence of this would be experiencing delays in the time line for the project and being unable to work on components that have not been received | To remedy this, time for shipping has been considered in the Gantt chart and flex time has been added |
| Improper CAD Dimensions | This could be caused through a mistake in inserting dimensions in SolidWorks | A consequence of this would be an collision, gap, or similar error during assembly | To remedy this, the assembly will be checked for such collisions or dimensional errors |
| Assemble Chassis Improperly | This could be caused by errors in labeling of parts or misunderstanding the overall assembly | A consequence of this would be wasting material, delaying the project, and possibly damaging the chassis | To remedy this, parts are labelled as they are produced to ensure there are no duplicates or such errors |
| Loss of Saved Work | This could be caused by a computer crash | A consequence of this would be wasted time or forgotten progress | To remedy this, assemblies will be archived and individuals using CAD will save often (SolidWorks recommends a frequency greater than every 20 minutes) |
| Depressurization of fuel | This could be caused by a leak in the pressurized air system | A consequence of this would be the fuel injector not working properly, which would starve the engine | To remedy this, Teflon tape and epoxy will be used to effectively seal all the pressure components. Additionally, a pressurization test will be performed to validate this system |
| Chain Disengages | This could be caused by improper chain tensioning | A consequence of this would be losing power to the wheels | To remedy this, the engine will be rigidly mounted at the position that keeps the chain taught |

| | | | |
|---|---|---|---|
| Running out of Fuel | This could be caused by a leak or poor running conditions of the engine | A consequence of this would be not completing the competition | To remedy this, multiple tests will be performed on a test track to validate the vehicle's ability to finish the course |
| Spark Plug Failure | This could be caused by carbon buildup on the spark plug from impurities | A consequence of this would be the engine shutting down and invalidating the run | To remedy this, an air filter will be used to scrub the air and the fuel lines will be cleaned of any impurity |
| Leaking Fuel | This could be caused by poor seals on the fuel line | A consequence of this would be reducing the efficiency of the vehicle or possibly being unable to complete the competition | To remedy this, the fuel lines will be verified and multiple runs will be performed. Additionally, old seals and gaskets will be replaced |
| Engine Locks Up | This could be caused by the engine overheating | A consequence of this would be destruction of the engine | To remedy this, the engine will be properly oiled and cooled with a radiator loop |
| Engine Backfires | This could be caused by the engine burning extremely rich | A consequence of this would be greatly reduced fuel efficiency | To remedy this, the engine will tuned using ECU tuning software to ensure the correct amount of fuel is being injected |
| Accelerator pedal locks up | This could be caused by debris falling in the way of the pedal | A consequence of this would be an inability to control the engine | To remedy this, there will be no loose components in the driver compartment |
| Leaking Coolant | This could be caused by improper seals on the coolant lines | A consequence of this would be an ineffective radiator loop and the possibility of engine lockup | To remedy this, the coolant lines will be sealed with epoxy and Teflon tape where necessary, and old seals will be replaced |
| Tire falls off | This could be caused by the retaining bolt coming lose during competition | A consequence of this would be an inability to finish the competition | To remedy this, purple Loctite will be used to retain the bolts during vibration |
| Axle Cracking | This could be caused by excess load experience by the axle or improper welds | A consequence of this would be inability to drive the car and complete the competition | To remedy this, FEA was performed on the axles and a FOS of 2 was required to pass |

| | | | |
|---|---|---|---|
| Axle Misalignment | This could be caused by errors in the manufacturing process | A consequence of this would be greater rolling resistance and therefore lower fuel-efficiency | To remedy this, the tie rods will be tuned manually to the final assembly in order to ensure Ackerman steering geometry |
| Short Circuit | This could be caused by improper insulation on the wiring | A consequence of this would be safety concerns and loss of electrical power | To remedy this, all wiring connections will be sealed with heat-shrink tubing, immersed in epoxy, or enclosed in a insulated connector |
| Battery out of charge | This could be caused by excessive use of the starter, or a short-circuit | A consequence of this would be the inability to start the car or operate any of the electronics | To remedy this, multiple batteries will be kept, and the battery will be charged before each run. Additionally, multiple test runs will be performed to validate the battery's ability to last the entire competition |
| Tire pops | This could be caused by debris on the road | A consequence of this would be a flat tire and an inability to complete the competition | To remedy this, the course will be verified as clear of sharp objects before the run |
| Kill Switch Fails | This could be caused by vibration engaging the switch | A consequence of this would be an inability to complete the competition | To remedy this, a switch with a sufficiently strong enough spring will be selected |
| Accelerator pedal locks up | This could be caused by debris falling in the way of the pedal | A consequence of this would be an inability to control the brakes | To remedy this, there will be no loose components in the driver compartment |
| Leaking Brake Fluid | This could be caused by improper seals on the brake line components | A consequence of this would be an inability to control the brakes | To remedy this, fresh sealing washers will be used and the brake system will be tested prior to competition |
| Tire leaks air | This could be caused by an clogged valve-stem | A consequence of this would be lower fuel-efficiency and possibility the inability to complete the competition | To remedy this, the tires will be checked for their ability to hold air in the weeks before competition |
| Improperly calibrated brake calipers | This could be caused by excess brake fluid in the lines | A consequence of this would be lower fuel-economy due to the always-engaged brakes | To remedy this, the brakes will be depressed entirely when setting up the master cylinder |

| | | | |
|---|---|---|---|
| Vehicle impact with another vehicle | This could be caused by poor driving style | A consequence of this would be possible failure of the body or chassis, or ejection from the race | To remedy this, all rules regarding passing and driving will be observed during the competition |
| Vehicle impact with a static object | This could be caused by poor driving style | consequence of this would be possible failure of the body or chassis, or ejection from the race | To remedy this, the driver will spend time practicing maneuvers in the vehicle to ensure comfort in maneuverability |
| Welds have poor penetration | This could be caused by poor welding technique | A consequence of this would be lower-than-expected weld strengths and failure of welded components | To remedy this, time will be spent to practice welding and practice piece weld penetration will be verified. When this has been done, the welders will proceed to weld the frame |
| Door gets stuck | This could be caused by an improper latch or the torquing of the frame | A consequence of this would be the inability for the driver to egress the vehicle in the required ten seconds | To remedy this, time will be spent practicing entering and exiting the vehicle |
| Carbon Fiber Delaminates | This could be caused by improper penetration of epoxy during the layup process | A consequence of this would be reduced strength of carbon fiber components | To remedy this, rubber paddles will be used during the layup process to force epoxy into the fiber and ensure penetration |
| Bolts in the body loosen | This could be caused by vibration during driving | A consequence of this would be components coming loose or falling off of the frame | To remedy this, purple Loctite will be used to thread lock components |
| Carbon Fiber cracks | This could be caused by excess stress on the carbon fiber parts | A consequence of this would be loss of strength of carbon fiber components | To remedy this, parts were designed with high factors of safety of greater than 2.0 |
| Epoxy cracks | This could be caused by excess stress on the carbon fiber parts | A consequence of this would be loss of strength of carbon fiber components | To remedy this, parts were designed with high factors of safety of greater than 2.0 |
| Improper mixing of the epoxy | This could be caused by using the incorrect proportions of epoxy and hardener | A consequence of this would be weak or ineffective epoxy | To remedy this, the needed volume and mass will be calculated beforehand and a precision scale will be used to verify the proportions |

## D.3 Fault Tree Analysis

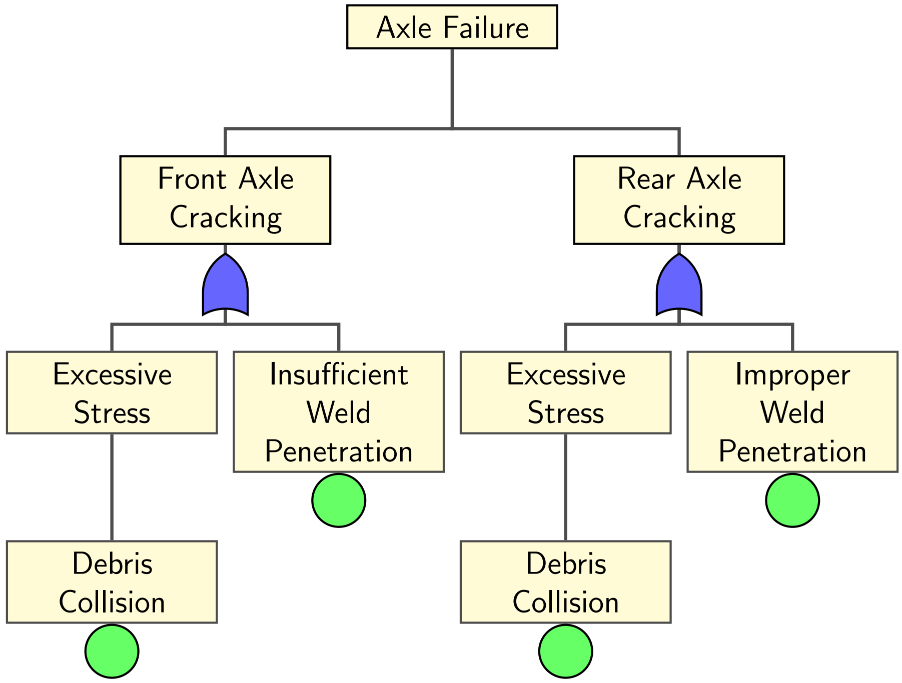



Figure 89: Axle Fault-Tree Analysis

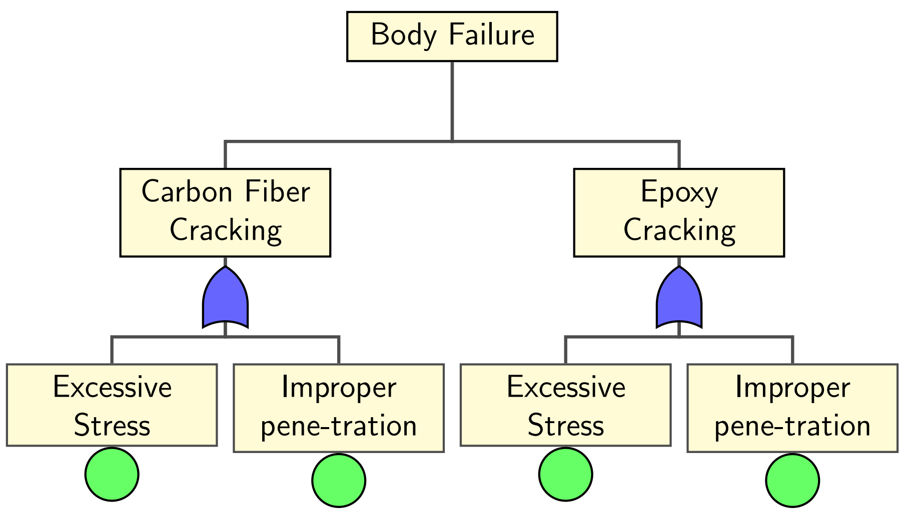



Figure 90: Body Fault-Tree Analysis

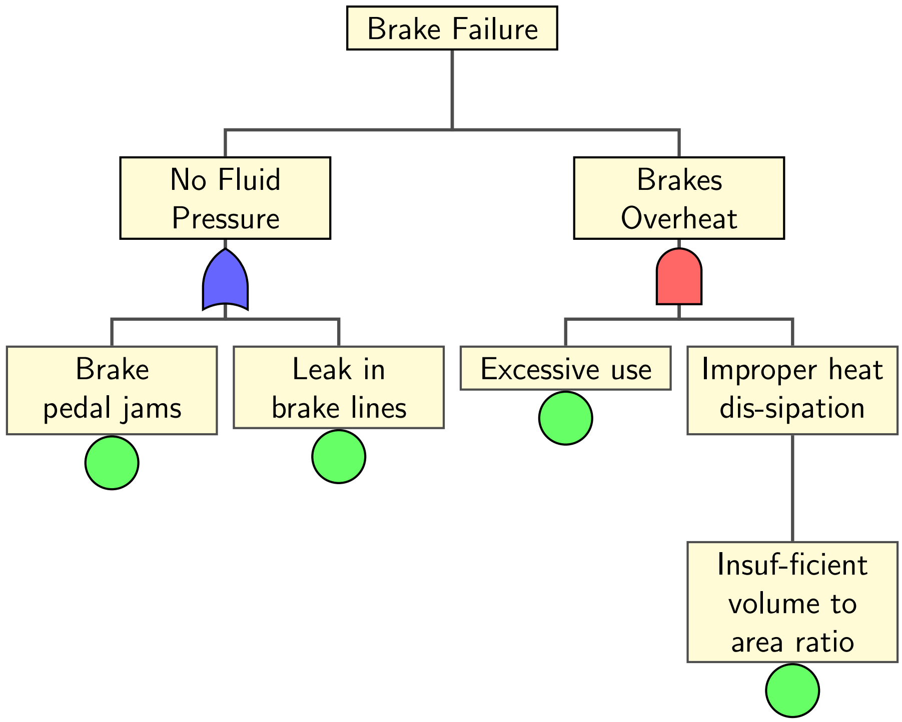



Figure 91: Brake Fault-Tree Analysis

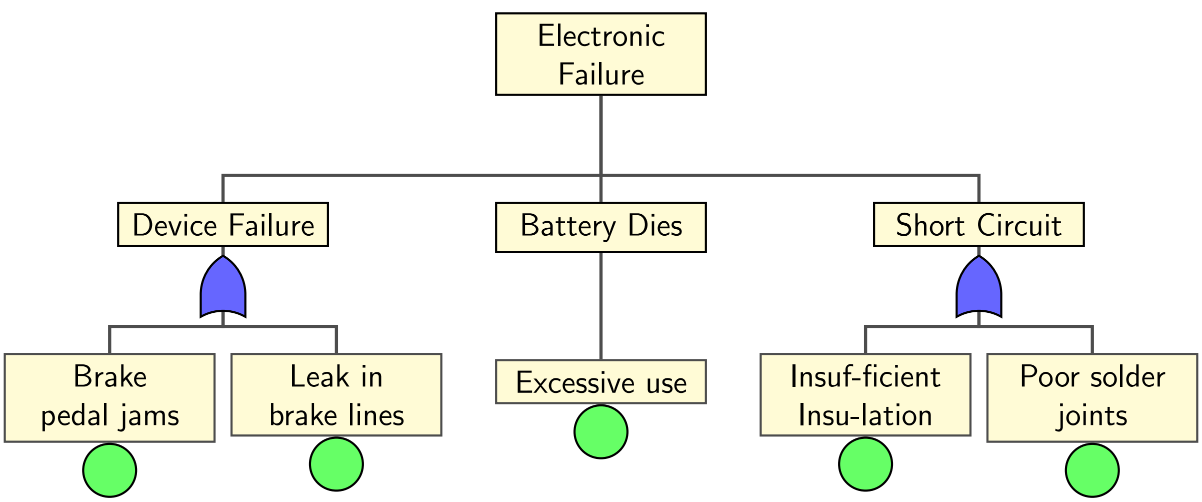



Figure 92: Electronics Fault-Tree Analysis

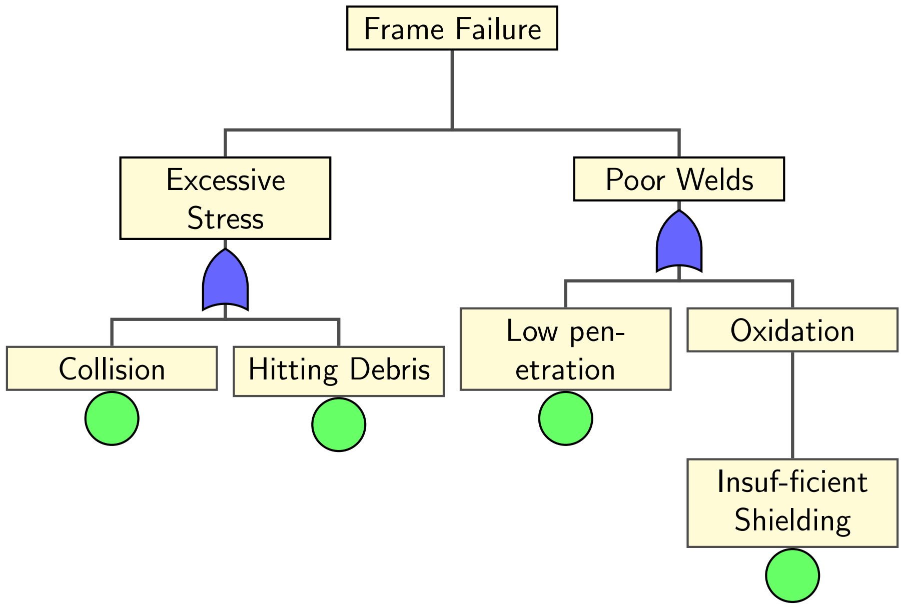



Figure 93: Frame Fault-Tree Analysis

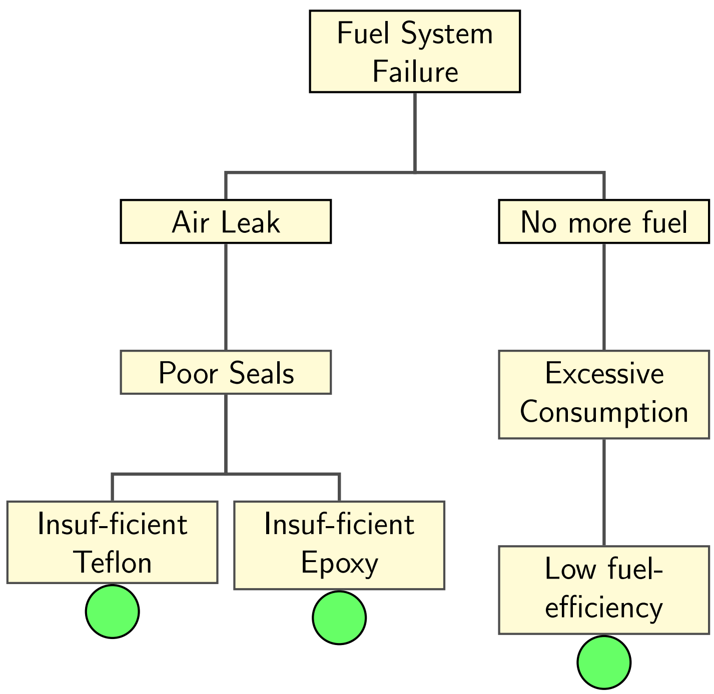



Figure 94: Fuel System Fault-Tree Analysis

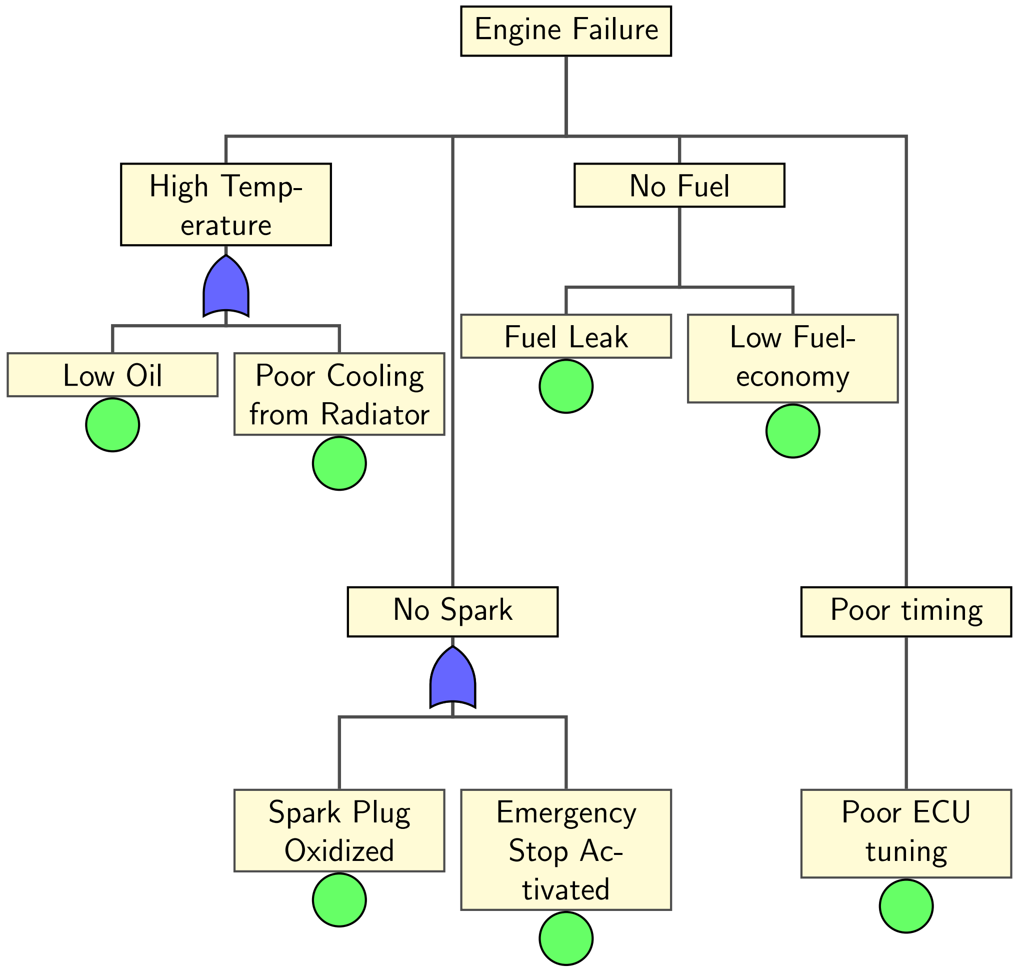



Figure 95: Powertrain Fault-Tree Analysis

# E Detailed Finances

## E.1 Budget

Table 14: Team Budget

| Power Train | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Engine | $500.00 | 1 | $500.00 |
| Fuel Tank System | $175.00 | 1 | $175.00 |
| Radiator | $100.00 | 1 | $100.00 |
| Pressure Tank Gauges/Valves | $100.00 | 1 | $100.00 |
| Accelerator Pedal | $50.00 | 1 | $50.00 |
| Tubing | $50.00 | 1 | $50.00 |
| Muffler | $50.00 | 1 | $50.00 |
| ECU | $150.00 | 1 | $150.00 |
| Starter Equipment | $75.00 | 1 | $75.00 |
| Pipe Inlet Assembly | $200.00 | 1 | $200.00 |
| Powertrain Assembly | $15 | 5 | $75.00 |
| Testing | $100 | 2 | $200.00 |
| Powertrain Installation | $15 | 5 | $75.00 |
| | | **Subtotal** | **$1,800.00** |

| Body | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Driver Cell Interior | | | $200.00 |
| Foam | | | $891.00 |
| Foam, wood, glue | | | $50.00 |
| Epoxy | $128.00 | 6 | $768.00 |
| Fiberglass Sheets | $150.00 | | $150.00 |
| Fairing Filler | | 1 Gallon | $110.00 |
| StyroShield | $144.00 | 2 | $288.00 |
| Mold Release Agent | | 1 Gallons | $24.75 |
| Polycarbonate Windshield | $120.57 | 1 | $120.57 |
| Rivets | | | $20.00 |
| Paint | | 1 Gallon | $39.99 |
| Stickers | $10 | 4 | $40.00 |
| Carbon Fiber | $5,000 | 1 | $5,000.00 |

| | | | |
|---|---|---|---|
| CNC | 100 | 50 | $5,000.00 |
| Sanding | 15 | 8 | $120.00 |
| Mold Prep | 15 | 8 | $120.00 |
| Carbon Fiber Layup | $15 | 3 | $45.00 |
| Post Processing | $15 | 10 | $150.00 |
| Painting | $15 | 2 | $30.00 |
| | | **Subtotal** | **$13,167.31** |

| **Frame** | **Unit Cost** | **Quantity** | **Item Cost** |
|---|---|---|---|
| Al 6061 Tubing | $223.60 | 1 | $223.60 |
| Tabs | $35.86 | 1 | $35.86 |
| Seat | $40.00 | 1 | $40.00 |
| Wheel Well (Hardboard Tempered 2'x4') | $4.99 | 3 | $14.97 |
| Bulkhead (4x4 sheet 6061) | $99.96 | 1 | $99.96 |
| Mirrors | $5.16 | 1 | $5.16 |
| Coping | $100.00 | 20 | $2,000.00 |
| Welding | $100.00 | 100 | $10,000.00 |
| | | **Subtotal** | **$12,419.55** |

| **Steering** | **Unit Cost** | **Quantity** | **Item Cost** |
|---|---|---|---|
| Rims, Tires, and Calipers | $90.00 | 4 | $360.00 |
| Rear Bearing Kit | $39.94 | 1 | $39.94 |
| Tie rod ends | $10.44 | 1 | $10.44 |
| Pedal Assembly | $25.00 | 1 | $25.00 |
| Master Cylinder | $22.09 | 1 | $22.09 |
| DOT 3 Brake Fluid | $13.23 | 1 | $13.23 |
| Hydraulic Lines (short) | $4.99 | 4 | $19.96 |
| Hydraulic Lines (long) | $13.99 | 2 | $27.98 |
| Hydraulic line splitter | $6.99 | 2 | $13.98 |
| Thrust Bearings | $8.69 | 1 | $8.69 |
| Front Axle | $21.50 | 1 | $21.50 |
| Front Knuckle | $14.08 | 1 | $14.08 |
| Front Knuckle Insert | $11.80 | 1 | $11.80 |
| Rear Axle | $24.68 | 1 | $24.68 |
| Steering Column | $0.00 | 1 | $0.00 |
| Steering Column Collar | $16.50 | 1 | $16.50 |

| | | | |
|---|---|---|---|
| Steering Wheel | $30.26 | 1 | $30.26 |
| Steering Tabs and Stopper | $0.00 | 1 | $0.00 |
| Axle Hanger | $35.47 | 1 | $35.47 |
| Keyway | $0.00 | 1 | $0.00 |
| Tie Rods) | $17.21 | 1 | $17.21 |
| Coping & Machining | $100.00 | 2 | $200.00 |
| Welding | $100.00 | 5 | $500.00 |
| Brakeline Assembly | $15.00 | 8 | $120.00 |
| Axle & Knuckle Installation | $15.00 | 2 | $30.00 |
| Brakeline Installation | $15.00 | 1 | $15.00 |
| Lathe | 100 | 60 | $6,000.00 |
| Mill | 100 | 20 | $2,000.00 |
| Surface Grinding | 100 | 18 | $1,800.00 |
| | | **Subtotal** | **$11,377.81** |

| Electronics | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Kill switch | $5.00 | 2 | $10.00 |
| Dead man switch | $1.35 | 1 | $1.35 |
| White LEDs | $0.21 | 20 | $4.10 |
| Yellow LEDs | $0.21 | 20 | $4.10 |
| Red LEDs | $0.21 | 20 | $4.10 |
| Flasher Circuit | $5.96 | 1 | $5.96 |
| Three-way toggle | $4.66 | 1 | $4.66 |
| Brake switch | $1.35 | 1 | $1.35 |
| Wiper Assembly | $48.28 | 1 | $48.28 |
| Hazard Switch | $0.58 | 1 | $0.58 |
| Headlight Switch | $0.58 | 1 | $0.58 |
| Wiper Switch | $0.58 | 1 | $0.58 |
| Horn | $8.88 | 1 | $8.88 |
| Horn Button | $3.93 | 1 | $3.93 |
| Red Primary Wire | $9.84 | 1 | $9.84 |
| Black Grounding Wire | $9.84 | 1 | $9.84 |
| Battery | $25.00 | 1 | $25.00 |
| Battery Charger | $20.00 | 1 | $20.00 |
| Assembly | $15.00 | 8 | $120.00 |

| | | | |
|---|---|---|---|
| Installation | $15.00 | 5 | $75.00 |
| | | **Subtotal** | **$358.13** |

| | |
|---|---|
| **Total** | **$39,122.80** |
| **Shipping** | **$3,912.28** |

| | |
|---|---|
| **Grand Total** | **$43,035.08** |

# F Cost Model

Table 15: Cost Model

| Power Train | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Engine | $500.00 | 1 | $500.00 |
| Fuel Tank System | $175.00 | 1 | $175.00 |
| Radiator | $100.00 | 1 | $100.00 |
| Pressure Tank Guages/Valves | $100.00 | 1 | $100.00 |
| Accelerator Pedal | $50.00 | 1 | $50.00 |
| Tubing | $50.00 | 1 | $50.00 |
| Muffler | $50.00 | 1 | $50.00 |
| ECU | $150.00 | 1 | $150.00 |
| Starter Equipment | $75.00 | 1 | $75.00 |
| Pipe Inlet Assembly | $200.00 | 1 | $200.00 |
| Powertrain Assembly | $15 | 5 | $75.00 |
| Testing | $100 | 2 | $200.00 |
| Powertrain Installation | $15 | 5 | $75.00 |
| | | **Subtotal** | **$1,800.00** |

| Body | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Driver Cell Interior | | | $200.00 |
| Foam | | | $891.00 |
| Foam, wood, glue | | | $50.00 |
| Epoxy | $128.00 | 6 | $768.00 |
| Fiberglass Sheets | $150.00 | | $150.00 |
| Fairing Filler | | 1 Gallon | $110.00 |
| StyroShield | $144.00 | 2 | $288.00 |
| Mold Release Agent (Fibrelease) | | 1 Gallons | $24.75 |
| Polycarbonate Windshield | $120.57 | 1 | $120.57 |
| Rivets | | | $20.00 |
| Paint | | 1 Gallon | $39.99 |
| Stickers | $10 | 4 | $40.00 |
| Carbon Fiber | $5,000 | 1 | $5,000.00 |
| CNC | 100 | 50 | $5,000.00 |
| Sanding | 15 | 8 | $120.00 |
| Mold Prep | 15 | 8 | $120.00 |

| | | | |
|---|---|---|---|
| Carbon Fiber Layup | $15 | 3 | $45.00 |
| Post Processing | $15 | 10 | $150.00 |
| Painting | $15 | 2 | $30.00 |
| | | **Subtotal** | **$13,167.31** |

| Frame | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Al 6061 Tubing | $223.60 | 1 | $223.60 |
| Tabs | $35.86 | 1 | $35.86 |
| Seat | $40.00 | 1 | $40.00 |
| Wheel Well | $4.99 | 3 | $14.97 |
| Bulkhead | $99.96 | 1 | $99.96 |
| Mirrors | $5.16 | 1 | $5.16 |
| Coping | $100.00 | 20 | $2,000.00 |
| Welding | $100.00 | 100 | $10,000.00 |
| | | **Subtotal** | **$12,419.55** |

| Steering | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Rims, Tires, and Calipers | $90.00 | 4 | $360.00 |
| Rear Bearing Kit | $39.94 | 1 | $39.94 |
| Tie rod ends | $10.44 | 1 | $10.44 |
| Pedal Assembly | $25.00 | 1 | $25.00 |
| Master Cylinder | $22.09 | 1 | $22.09 |
| DOT 3 Brake Fluid | $13.23 | 1 | $13.23 |
| Hydraulic Lines (short) | $4.99 | 4 | $19.96 |
| Hydraulic Lines (long) | $13.99 | 2 | $27.98 |
| Hydraulic line splitter | $6.99 | 2 | $13.98 |
| Thrust Bearings (1in OD 1/2 in ID) | $8.69 | 1 | $8.69 |
| Front Axle | $21.50 | 1 | $21.50 |
| Front Knuckle | $14.08 | 1 | $14.08 |
| Front Knuckle Insert | $11.80 | 1 | $11.80 |
| Rear Axle | $24.68 | 1 | $24.68 |
| Steering Column | $0.00 | 1 | $0.00 |
| Steering Column Collar | $16.50 | 1 | $16.50 |
| Steering Wheel | $30.26 | 1 | $30.26 |
| Steering Tabs and Stoppers | $0.00 | 1 | $0.00 |
| Axle Hanger | $35.47 | 1 | $35.47 |

| | | | |
|---|---|---|---|
| Keyway | $0.00 | 1 | $0.00 |
| Tie Rods | $17.21 | 1 | $17.21 |
| Coping & Machining | $100.00 | 2 | $200.00 |
| Welding | $100.00 | 5 | $500.00 |
| Brakeline Assembly | $15.00 | 8 | $120.00 |
| Axle & Knuckle Installation | $15.00 | 2 | $30.00 |
| Brakeline Installation | $15.00 | 1 | $15.00 |
| Lathe | 100 | 60 | $6,000.00 |
| Mill | 100 | 20 | $2,000.00 |
| Surface Grinding | 100 | 18 | $1,800.00 |
| | | **Subtotal** | **$11,377.81** |

| Electronics | Unit Cost | Quantity | Item Cost |
|---|---|---|---|
| Kill switch | $5.00 | 2 | $10.00 |
| Dead man switch | $1.35 | 1 | $1.35 |
| White LEDs | $0.21 | 20 | $4.10 |
| Yellow LEDs | $0.21 | 20 | $4.10 |
| Red LEDs | $0.21 | 20 | $4.10 |
| Flasher Circuit | $5.96 | 1 | $5.96 |
| Three-way toggle | $4.66 | 1 | $4.66 |
| Brake switch | $1.35 | 1 | $1.35 |
| Wiper Assembly | $48.28 | 1 | $48.28 |
| Hazard Switch | $0.58 | 1 | $0.58 |
| Headlight Switch | $0.58 | 1 | $0.58 |
| Wiper Switch | $0.58 | 1 | $0.58 |
| Horn | $8.88 | 1 | $8.88 |
| Horn Button | $3.93 | 1 | $3.93 |
| Red Primary Wire | $9.84 | 1 | $9.84 |
| Black Grounding Wire | $9.84 | 1 | $9.84 |
| Battery | $25.00 | 1 | $25.00 |
| Battery Charger | $20.00 | 1 | $20.00 |
| Assembly | $15.00 | 8 | $120.00 |
| Installation | $15.00 | 5 | $75.00 |
| | | **Subtotal** | **$358.13** |

| | |
|---|---|
| **Total** | **$39,122.80** |

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|---|---|
| **Shipping** | **$3,912.28** |

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|---|---|
| **Grand Total** | **$43,035.08** |