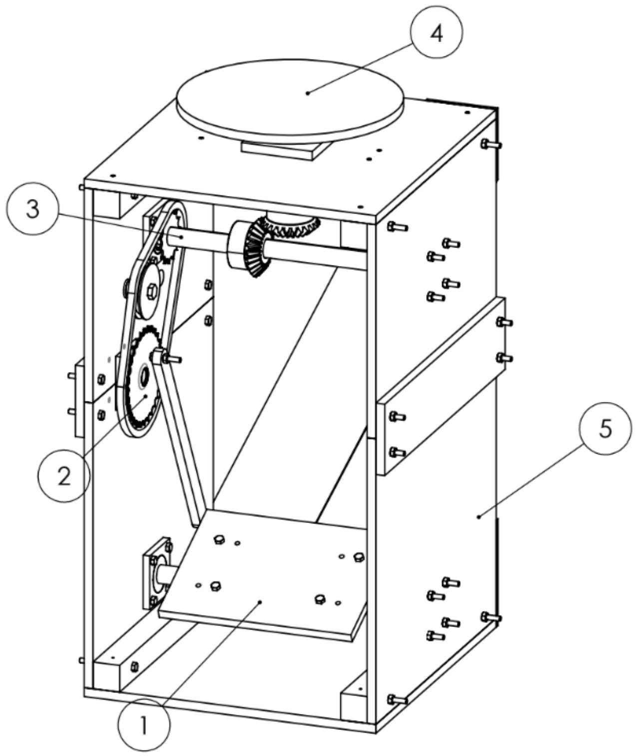
# Kickstart Wheels

ME 270 Final Report
Spring 2022 Section 4
Team 5





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# Executive Summary

Pottery is very popular throughout Africa. The use of ceramic dinnerware has been present for centuries and also held strong cultural significance to many nations throughout the continent such as vases and urns (Danchie, 2021). While there is no shortage of large stone slab kick wheels, they take up large spaces and can be tiresome to operate.  A new design focused on easing the process for creators was the primary focus of the new design.

Main focuses of the initial design included weighing consumer preferences and entrepreneur needs to make this project useful to the communities in Africa. This resulted in a design that uses no electricity to operate, and that is easy to operate, cheap to manufacture and maintain, durable, portable, and safe. The concern for an electricity free product comes from the lack of infrastructure supporting electric pottery wheels in the continent thus far, leading to high costs of operation and installation (Ayisi, 2019). Easy operation is important since creators using the product prefer to focus on the pots that they are working on rather than maintaining operation of the wheel (Roy, 2013). The concern over manufacturing and maintenance was drawn from concerns over costs of the machine potentially breaking down and needing to be fixed to continue operation for both consumers and entrepreneurs (Asante-Kyei, 2019). Durability, portability, and safety were primary concerns.

The final design included minor improvements deemed necessary after initial testing of the prototype. The most notable issue was the wobble of the wheel itself upon rotation. The team found that this was due to a lack of support in the bearing housing which led to the addition of two parts to better stabilize this feature of the wheel. After these changes, there was still a slight variation in the stability of the wheel, which led to the addition of two shaft collars located on top and bottom of the frame. After this, the team found that the pedal clearance had some interference. To combat this, the team reduced the size of the pedal while maintaining the strength necessary to operate the wheel. The last major change came in the drivetrain of the machine to improve ease of operation. This included adding a tensioner and moving the drive gear closer to the driven gear in the prototype to reduce the possibility of chain slippage.

After improving the initial design, tests for wheel speed, strength and operation were conducted. These resulted in the strength of the frame being confirmed and slightly reduced speeds than initially expected. This difference was deemed irrelevant when compared to wheel stability which was of more concern for the project.

Elements of the prototype that could further be improved include the chain and tensioner. Even after adding the tensioner, the chain system tended to occasionally misalign, leading to failure. The tensioner selected during the final adjustments had to be manually tightened, which would not allow for any variance in the chain, either. To fix this, a spring-based tensioner that allows for more forgiveness within the drivetrain would be appropriate.

Kick-Start wheels will be produced in Africa, specifically along the West and East coasts where there are large population centers (Evans, 2021). This reduces manufacturing and shipping costs for the production and distribution of the product, leading to lower costs for consumers. Additionally labor costs are significantly lower in these communities when compared to the United States, further reducing the overall cost of production.

With an initial investment cost of $250,000, production and sale of the wheel will not be profitable until early in the fourth year of production. Once the break-even point is reached however, the $600 revenue off of the $151.63 cost of production will quickly turn into high revenues for the entrepreneur. Compared to forwarding the cost of wiring a whole building for electric pottery wheels, this is a good deal.

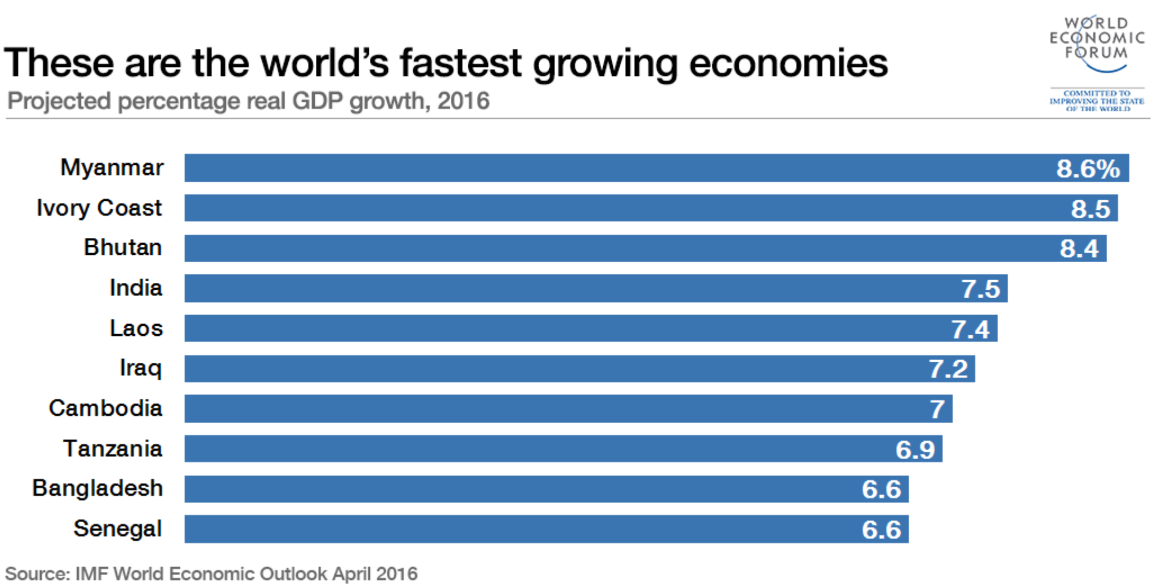
# 1. Project Description

The team's goal was to create a pottery wheel that could be produced and repaired by local craftsmen, and that would be compact, portable, and safe. Ceramic industries and independent entrepreneurs in coastal African countries are already producing pots, but are significantly behind international competitors because their output is constrained by their outdated throwing machines (or lack thereof, in some cases) (Ayentimi et al., 2017). The Kickstart Wheel would increase their productive output substantially and drive down repair costs.

On Africa's coasts, both on the East coast and the Gulf of Guinea, pottery is very common for both artistic and functional applications. In many countries on the coast, they do not have reliable electricity that is needed to power an electric pottery wheel. Many potters resort to hand-throwing without the use of a wheel, or use a large and inefficient slab wheel (Adu-Gyamerah, 2019). With the Kickstart Wheel, the team aimed to replace the large slab with miter gears tuned to assist the momentum of the wheel.

Economies in these countries have been growing fast (See Table 1). However, many of their industries, such as ceramics, are having difficulty competing with international markets, such as China. Not only will the Kickstart Wheel increase the efficiency of ceramic producers, but it will also lead to more employment on a local level. Industries would grow and hire more potters, and independent entrepreneurs would have an easier time entering and maintaining their place as local artisans.

**Table 1.** The fastest growing economies include ones on the Ivory Coast and Tanzania (Myer, 2016)




The Kickstart Wheel is intended for ceramic industries originating in coastal African communities. It can also triple small pot output for local artisans (Roy, 2013). As stated earlier, countries on Africa's coast already have a vibrant pottery and ceramic culture, so an entrepreneurial manufacturer of the machines also stands to gain from revenue through local artisans and ceramics manufacturers. Customers wanted a compact design, with reduced frequency of breaking down, and with better efficiency for the user to operate. The design had to be under 30 pounds, less than 72,000 cubic inches, and be made of parts that totaled less than $135 USD. To conclude, the team delivered a working prototype of the Kickstart Wheel, tested its maximum strength limits, and analyzed the prospects of running a business that manufactures the machines.

## 2. Customer Requirements

Pottery has been a staple of cultures along the African coasts for thousands of years. As such, communities have been using some of the same clay-forming techniques for generations, and the demand for pots used in daily life has been sustained in these communities to this day (Adu-Gyamerah, 2019). Foreign competition in the form of plastic pots and utensils, while cheap, do not have much appeal to these communities. So, at least there is a buffer before international competition completely swamps the market.

The primary customers for the Kickstart Wheel are the ceramics manufacturers on the African coasts. While traditional clay forming methods work just fine for local artisans, in factories, they do not produce ceramic products nearly fast enough (Asante-Kyei, 2019). Some manufacturers have changed from hand-coiling the clay to using slab pedal machines (such as one in Fig 2.), but these break down often and require more work energy from laborers. Other manufacturers changed to electric-powered machines, but these were too expensive to fuel, and even caused some manufacturing companies and plants to shut down (Ayisi, 2019). Manufacturers want a compromise machine that: is durable; produces quality pottery products; and does not require electric power.

**Figure 2.** Old slab wheel. These require a lot of kicking force to keep the wheel moving (Beales, 2021)

By the same token, entrepreneurs (the secondary customer of the machine) want to sell a machine that: is durable (just as the customer wants); is portable; and is not complex in design. Some tradesmen and repair experts live in coastal African cities, but they are few and far between (Ayentimi et al., 2017). As such, they can be relatively expensive, so the design required a relatively simple concept. The team selected most materials keeping this in mind, sticking to plywood, bolts, screws, and other common materials.

The project's size constraint was conducive to customer needs. As stated earlier, some companies cited the large space requirements of the slab wheels as cause for concern. Therefore, designs for the Kickstart Wheel were drawn with regard to maximum height, dissolvability, and limited appendages. Luckily, entrepreneurs are already often located near ports which have access to greater distribution networks. Because of this, a compactible design was one of the top priorities of the team.

Coming up with a machine that spun without electric power proved to be a challenge. The team wanted to ensure that such a machine could preserve the energy that a user would spend, by sharply curbing the effects of friction and jamming. The majority of the team's focus involved addressing this customer concern with different forms of mechanical advantage. In the end, gear reduction was one of the best contenders for the design, although many others competed for the team's attention.

## 3. Specifications and Benchmarking

The methods for making pottery along Africa's coasts are almost solidly cemented into the cultures there. On the one hand, traditional coiling methods are necessary for making large vessels such as the ones made by local artisans, which easily reach several feet in height and width (Danchie, 2021) (see Fig 3.).

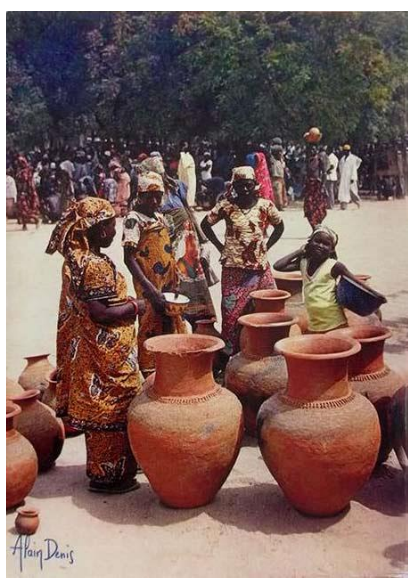



**Figure 3.** Some pots made in these communities are very large. The largest ones are about 125% of the height of the pots pictured here (African tribal…, 2017).

Potter’s wheels are not made to support the weight of such ceramic products. On the other hand, the traditional coiling method is a very slow process, and is inefficient for making vessels that could be supported on a potter's wheel. Realizing this, many ceramics companies along the coasts have moved to simple kick-wheel pottery machines, and unfortunately, with poor results. These machines are often in excess of 90 lbs, in need of constant repair, and require too much human power to spin (Asante-Kyei, 2019). Companies have also avoided using electric potter’s wheels due to their high fixed cost and high variable cost, as electrical power is difficult to acquire in these countries (Ayisi, 2019). Besides, electric wheels are complicated enough that if one breaks down, it would be difficult to find a local repairman to get the company’s machine back on track. Companies need a compromise, a machine that: does not require electric power, is not bulky in excess of 10 cubic feet, is not heavier than 90 lbs, and is sturdy enough to work without the constant necessity of repairs. The Kickstart Wheel had require no electricity, have a long service life, and be very affordable for artisans. The pottery wheel needed to spin at about 75-100 rpm, and to accomplish this, a gear system was required to tune the pedal speed to the desired wheel speed. The main challenge with such a model was designing a wheel-turning mechanism that did not fracture, shear, or strain often, but that was cheap and easy to repair. Finding the other parts, such as the frame and pedal materials for the machine, came more easily. Another design challenge was making the machine ergonomic to use, the range of motion of the pedal needed to be fairly short to make it comfortable and easy to use, that wasn’t explicitly required but if it wasn’t ergonomic the device would be almost impossible to use.

# 4. Design Concept

This portion of the concept generation for the potter’s wheel was instrumental in narrowing down the most important design features of the product. The function tree helped sort which functions of the machine would be most important (See Fig 4 on next page). Additionally, the flowcharts highlighted that there were two predominant sequences that a user could engage in to sculpt clay. The processes were not interchangeable. The most agreeable concept arose naturally from a combination of the best feature ideas to allow a seamless, cheap, and durable product.

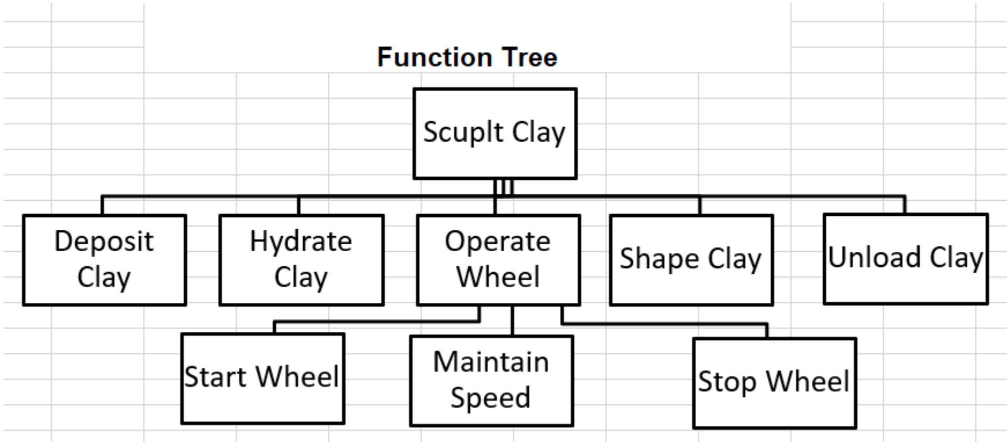



**Figure 4.** Function Tree for the Kickstart Wheel.

Upon functional analysis, the pottery wheel was fairly simple. The machine was designed to help the user sculpt clay, and, primarily, the machine had to be able to assist with the clay and operate the pottery wheel. The frame and form of the machine must conform to allow the user to mold the clay with minimal interference from the design. Additionally, the machine must facilitate clay molding by having an adaptable speed on the wheel. It must be able to be started, slowed down, and stopped consistently. The wheel and spinning mechanism was the portion that required the most detail and functional requirements.

The first concept drawn was the "Pedal Wheel" (see Fig 5.). The concept was formed around the idea that the operator would push a pedal to spin a crankshaft. That would, in turn, spin a pulley system which would provide a reduction in speed. The pulley system would then power the driveshaft which would have a bevel gear system that would transmit power up to the wheel head, spinning the work surface.

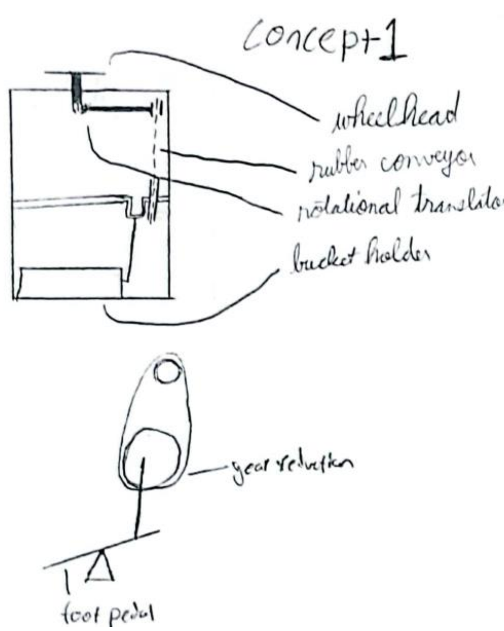



**Figure 5.** Pedal Wheel sketch.

The second concept drawn was the “Crank Wheel” (see Fig 6) The concept was formed around a pottery table with an inset wheel that was powered by a hand crank. Clay was loaded onto the wheel with a scoop and hydrated with a water reservoir mounted on the side of the table. The operator was able to get the wheel to start spinning by using a finger hole on the wheel. To keep the wheel spinning, the hand crank could be turned to spin the wheel. The wheel could be stopped by applying pressure on the wheel through the operator’s hand. The clay was sculpted with a profile gauge shaper, and the clay was finally removed from the wheel by using tongs.

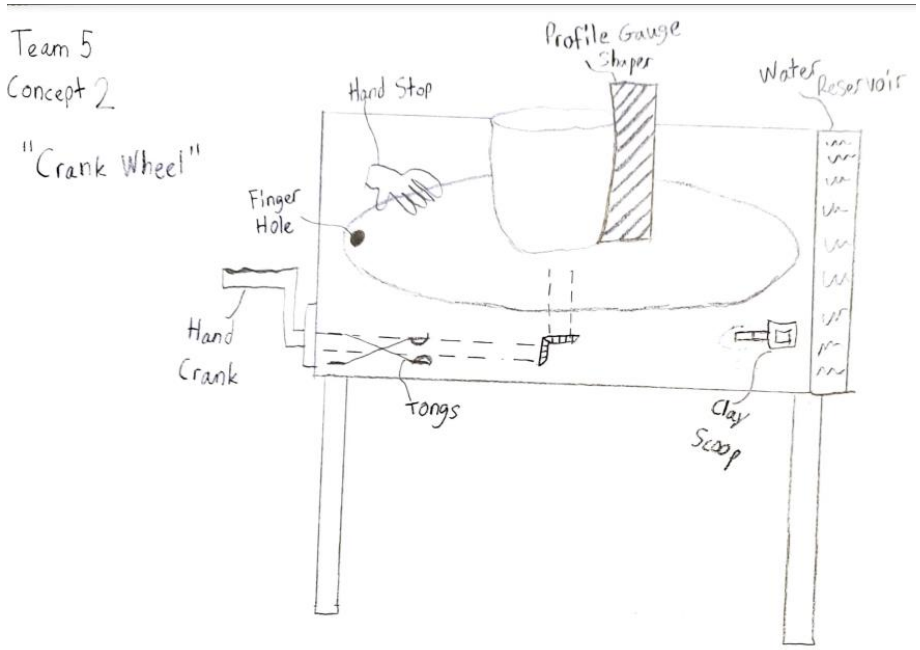



**Figure 6.** Crank Wheel sketch

The Drip Wheel concept involved the kickwheel with a drip bucket (see Fig 7 on next page). This concept incorporates some of the good aspects that were chosen for the final design. The main throwing wheel rests on a table, with its drive shaft running down through a hole in the table. It connects to the kickwheel system with a set of 1:1 ratio bevel gears. The operator spins the wheels by pushing up and down on a pedal. The flaws with the design were too large for this to be selected, however. The drip bucket adds a lot of height and weight to the design, and the same task can be done by the operator more efficiently. The hook device is also too awkward to remove the pottery with care.


**Figure 7.** Drip Wheel Concept

The fourth and final concept was designed with twin handles on each side of the wheelhead to allow the user to start the wheel in the desired direction (see Fig 8.). At the potter's feet there is a pedal attached to a piston system which adds power to the wheel through the shaft running below the wheel. This concept also includes a large water reservoir for the potter to draw from to hydrate the clay on the wheel as needed. This design also had a lighter wheelhead which would allow for faster spinning. To stop the machine in this concept, the user jams a stick into the bevel gears, stopping the wheel.

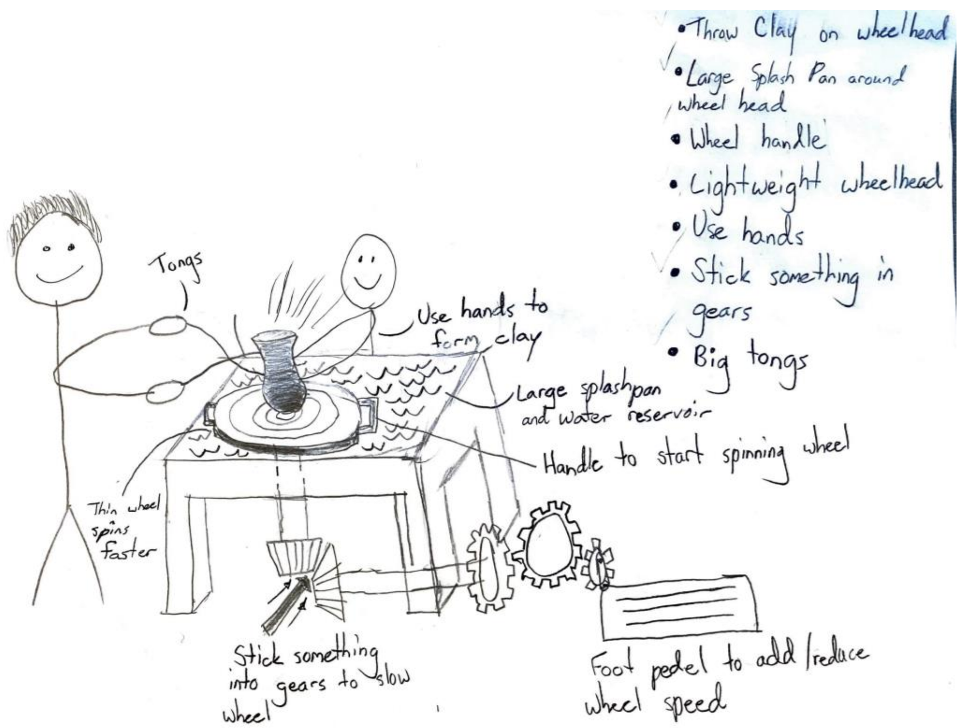



**Figure 8.** Pool Wheel sketch

The crank wheel was one of the simpler concepts due to the few moving parts involved in the hand crank to pottery wheel mechanism. The overall simplicity in the design also improved durability and ease of operation. The accessories for pottery-making also made it look like an attractive pick. However, the simple design also created a gap in efficiency compared to the other concepts because of the operator being required to maintain one hand on the hand crank at all times during the pottery spinning process. As a result of this analysis, the crank wheel was deemed too inefficient and the upsides did not contribute significantly enough to outweigh the concept's drawbacks. This is especially true when compared to the other designs, and was therefore not selected as the final concept.

The drip wheel had a few of the features that were also included in the final concept. The pedal-operated mechanism was ideal for the user because of the low-interference, highly-streamlined design. The mechanism would prevent rough handling of the machine, which preserves some durability. However, the large clay hydration mechanism (the drip bucket) proved too clunky to make it into the final design. It added a lot of height and weight to the design, and the same task could be done by the operator more efficiently (Goujon, 2019). The hook device was also too awkward to remove the pottery with care. For these reasons, this concept was not selected for the final design.

The pool wheel had many strengths such as the larger pedal wheel for more leverage and the reservoir for having plenty of water on hand for the artist to create their work. However, ultimately, this concept closely resembled a model currently in the market that the primary customers are already looking to replace (Asante-Kyei, 2019). This concept also fell short of becoming the final design because it lacked the mobility requirements that customers asked for (Marie, 2021). At the same time, the lightweight wheelhead in this concept would spin faster in comparison with other wheels, but it would also slow down much faster than a wheelhead with mass. This also was a complaint that the customers wanted addressed (Asante-Kyei, 2019). Finally, another drawback that didn't make the final cut was the twin handles on the sides on the wheelhead. These were unnecessary and just added cost without much benefit to the user.

The Pedal Wheel concept had a simple design and would be easy to produce. This concept was appealing because it had minimal parts keeping the machine simple and reliable. While the limited palette of accessories would require that the user do most of the clay shaping, customers were not complaining for lack of accessories in models currently on the market. Indeed, traditional shaping methods have already been in place for several hundred years, so no new shaping innovations are required of the machine (Adu-Gyamerah, 2019). One of the key features of this concept is that it has a simple but effective drivetrain. The drivetrain features a pedal connected to a crankshaft that drives a gear reduction system that would then power a driveshaft that would spin the wheel.

Overall, the Pedal Wheel had the most user-friendly mechanisms. Requiring too much human power to stop and start the wheel without intermediary features was not practical for the design, and also leads to lower durability from wear. One of the primary customer complaints was about pottery machines that broke down frequently (Asante-Kyei, 2019). Inadequate or missing features that require more rough human interaction with the machine is detrimental to this customer requirement. Additionally, the drivetrain was simple enough that it would be easy to repair and not overly complicated for local craftsmen to build. While all of the concepts avoided an electric-aided design, it is useful to note that this is because many ceramics companies have had to close down due to the high cost of electrical power in these regions (Ayisi, 2019). Not only does the decision matrix indicate that the Pedal Wheel is the superior design, but critical thinking also reveals this.

# 5. Function, Failure, and Analysis

The machine translates a pushing force from the user into rotational momentum. Starting with the known values of 100 N pushing force from human input with 1 m/s velocity, these are related to the tangential velocity of the pedal. Given the pedal length and ratio of pedal radius to drive wheel radius, one can solve for the rpm and torque of the drive wheel. From there, torque was the primary factor in the rest of the math model. Since the design will use a wheel reduction of 2 to 1, the new torque and rpm of the driveshaft also used that ratio. The last calculation was the conversion of the torque and rpm from the driveshaft to the final wheelhead rpm and torque via bevel gears. This conversion was simple, since the machine used 1:1 bevel gears to redirect the rotational power to the wheelhead. The model assumed negligible friction and energy loss throughout the system (see Fig 9.).

Variables

$F_f$ = Force applied by foot

$v_f$ = velocity of foot

$\tau_g$ = drive gear torque

$\omega_g$ = angular velocity of drive gear

p = driven gear / shaft torque

$\omega_g$ = angular velocity of drive gear

$T_{wheel}$ = Torque of wheel

$\omega_{wheel}$ = Angular velocity of wheel

Conversions:

$\tau_{pedal} = F_f$ * Pedal Length

$\omega_{pedal}$ (rpm) = [60 * $v_f$] / [Pedal Length * $\pi$]

$\tau_g = \tau_{pedal}$ * Ratio

$\omega_g = \omega_{pedal}$ / Ratio

| | | | | |
|---|---|---|---|---|
| Input System | Input | $F_f$ | 100 | N |
| | | $v_f$ | 1 | m/s |
| | Control | Length | 0.3 | m |
| | | Ratio | 1 | |
| | Output | $T_g$ | 25.4 | N*m |
| | | $\omega_g$ | 75.2 | rpm |

Conversions:

$\tau_p = \tau_g$ * Ratio

$\omega_p = \omega_g$ / Ratio

| | | | | |
|---|---|---|---|---|
| Input System | Input | $\tau_g$ | 25.4 | N*m |
| | | $\omega_g$ | 75.19 | rpm |
| | Control | Gear Ratio | 0.5 | constant |
| | Output | $\tau_p$ | 12.7 | N*m |
| | | $\omega_p$ | 150.4 | rpm |

Conversions:

$\tau_{wheel} = \tau_p$ * Ratio

$\omega_{wheel} = \omega_p$ / Ratio

| | | | | |
|---|---|---|---|---|
| Input System | Input | $\tau_p$ | 12.7 | N*m |
| | | $\omega_p$ | 150.38 | rpm |
| | Control | Ratio | 1 | |
| | Output | $\tau_{wheel}$ | 12.7 | N*m |
| | | $\omega_{wheel}$ | 150.4 | rpm |

**Figure 9.** Key Equations

The primary design conflicts encountered in the QFD trade offs were between the size and weight restrictions and the large pedal size. These conflicts were alleviated by shifting the axis of rotation of the pedal from the bottom edge of the pedal to the center of the pedal, which resulted in the same torque and angular velocity as the original design with a smaller overall pedal size reducing both volume and weight. Otherwise, many of the design features are complementary to the lightweight and transportable design desired by customers (Marie, 2021).

The DFMEA revealed just how integral each subsystem was in the design of the pottery wheel. Nearly every component, when damaged, causes the machine to fail or decrease efficiency in the primary function. This was reflected in the fact that the subsystems were all crucial to translating the initial human input into the final output, the rotating wheel head (see Fig 10.). Though the system was vulnerable to component failure, the majority of the subsystems were fabricated using tough materials and included bearings to reduce shear strain. As stated earlier, one of the primary concerns of customers was that the machine lasts without requiring constant repair and upkeep (Asante-Kyei, 2019). As such, a top priority in the design was using bearings on the axles and shafts. Perhaps the most worrying category of failure was in the frame, which had an RPN of 210. If it were to collapse, the user could be injured. Therefore, the frame had to be designed to support loads far in excess of practical applications, so as to maximally reduce the likelihood that this failure occurs.

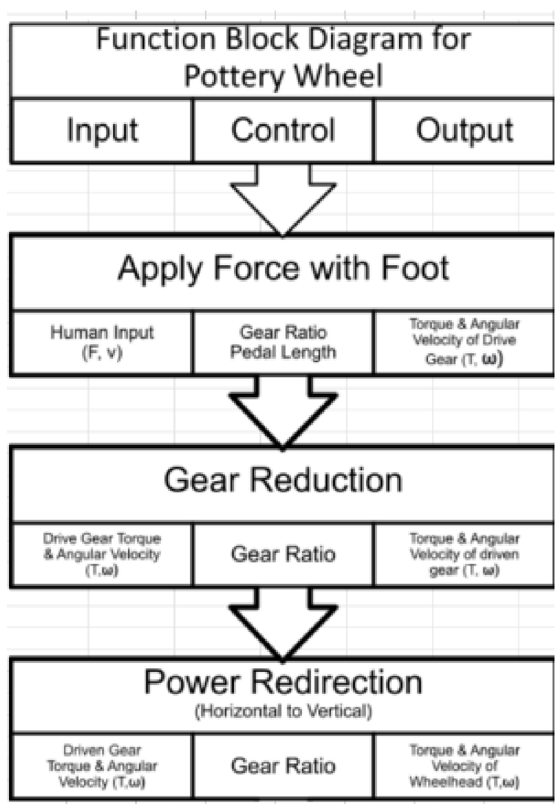



**Figure 10.** Function Block Diagram

# 6. Prototype

The AN0001 Kickstart Wheel was primarily composed of five subassemblies: the AN5001 Pottery Wheel w/ Vertical Bevel, the AN4001 Horizontal Bevel Gear Assembly, the AN3001 Lower Drive Gear w/ Rod, the AN2001 Foot Pedal Assembly, and the AN1001 Outer Box Assembly (see Fig 11.).

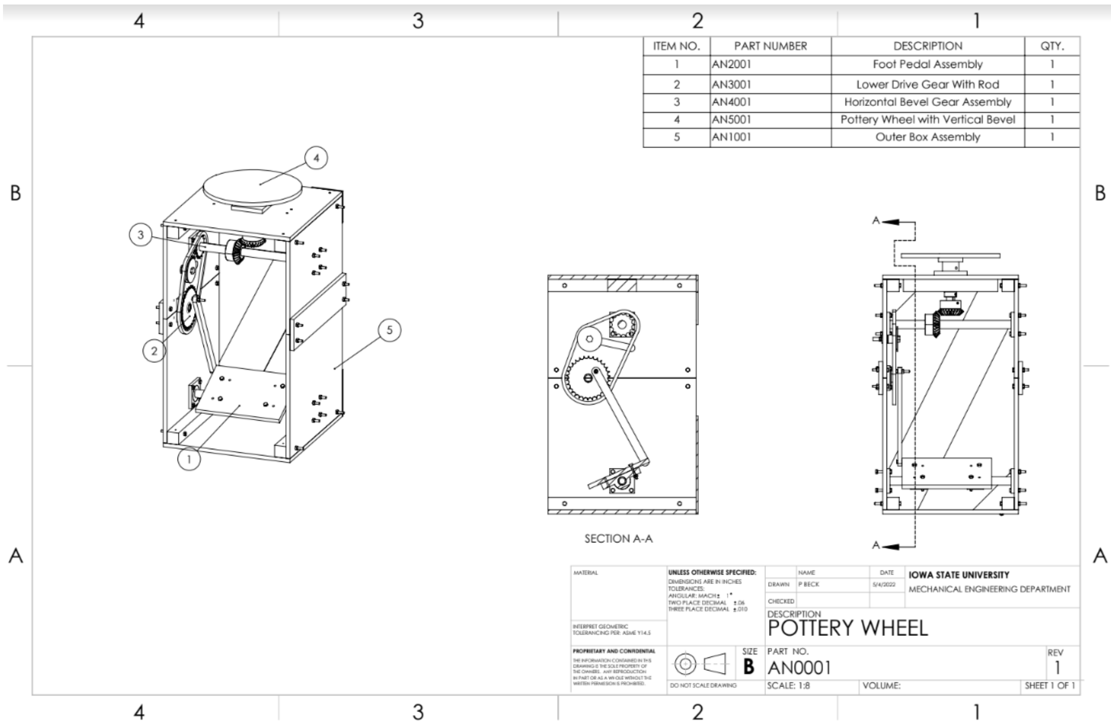



**Figure 11.** Main Assembly Drawing, composed of five subassemblies

Additionally, the Pottery Wheel w/ Vertical Bevel had two additional subassemblies, the Wheel & Flange, and the Support Bearing Sub-Assembly (see Fig 12 on next page).

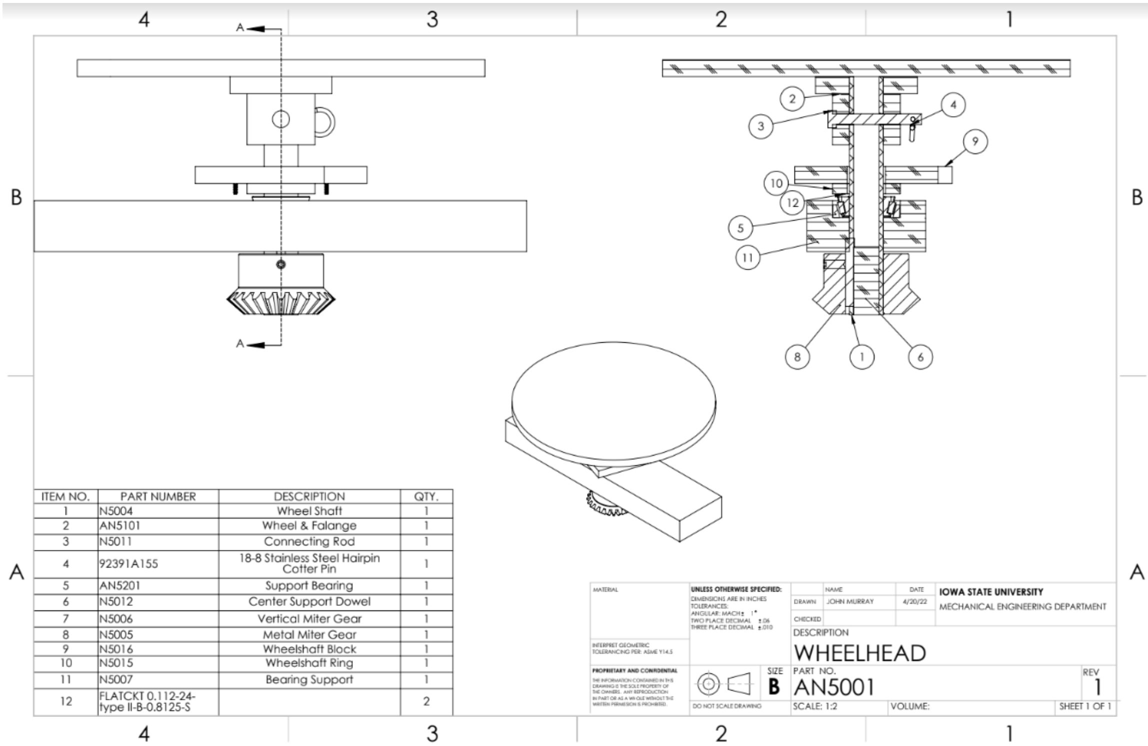



**Figure 12**. Wheelhead Subassembly. It has two subassemblies and some connecting parts.

The Outer Box was split into two halves for ease of storage and transportation, held together by gussets and hex bolts. Overall, the moving parts were held in place by Bearing Plates made of ½ inch plywood, designed to prevent wobbling and axial shifting of the shafts. The moving parts were housed inside the Outer Box, so that they are protected while being transported and do not catch miscellaneous items. The Miter Gears were fastened to the axles via keystock, each with its own key. Other parts were fastened to the Outer Box Assembly with the use of bolts, most of them ¼ inch.

Originally, the Outer Box was held together by metal gussets. However, considering the total cost of the prototype and the cost to the entrepreneur customer, wood gussets seemed more appropriate. Additionally, the manner of attaching and assembling the parts of the Wheel & Flange went through several revisions and ideas discussions before final selection. The main point of contention was attaching the Wheelhead in such a manner that several lb.-ft. of angular torque would not plastically deform the part, that the part would not contribute excessive weight, and that the part would not come so loose as to endanger the integrity of the whole machine. In the end, the use of a flange was chosen as the primary way to hold the Wheelhead to the Vertical Shaft. At first, the part drawings recorded the general material type in the title block, such as when using plastics or metals. However, the Boyd Lab technicians advised the team to put the specific material type in the title block instead. Also, the Boyd Lab technicians provided some formatting tips to conform the drawings to ANSI standards, so that they were easier for professionals to read.

The Kickstart Wheel did not have an overly complicated plan for part fabrication. The bulk of fabrication involved cutting and drilling holes in wood panels and metal stocks. Additional work was needed to fasten the parts together with bolts and screws, but this was simple work (see Fig 13.).

**Figure 13.** Evan retightening bolts

Raw wood materials such as ½ inch plywood, 2x2 panels, dowel rods, and 2x4 panels must be handled so that they do not form large cracks or deformations prior to assembly. It is highly unlikely that the wood portions of the machine would fail during use (i.e. when spinning pottery), so their integrity must be insured by the manufacturer(s) prior to sale of the machine. If there is any hassle in the constructing of the machine, it may be in the assembly of the parts. Wood parts cannot be excessively forced, pulled, or pushed to complete the assembly, as any large amounts of shearing, scraping, bending, or cracks will have massive effects on the efficiency of the machine during operation. A bent shaft, for example, would hardly allow rotation, and chipped wood holes for those shafts would resist rotation and hinder the primary function. Most of the machine prototype's wood was purchased from Lowes (Lowes A-E). The bolts, keystock, and other metallic materials, however, were purchased from Grainger and other online vendors as approved by Iowa State University, to ensure quality and low pricing (Grainger A-H, McMaster-Carr A-B). While roller chains can be purchased on Grainger, the products offered on Grainger had far more bulk than was necessary for the product. Roller chains such as those found on bikes are far more appropriate, and are also more accessible for the final customer, so their prices were used in the total (Amazon). Additionally, the model included four bearings. For the Horizontal Bevel and Lower Drive Gear w/ Rod, the three required bearings were easily acquired in the Boyd lab. They even matched. However, the Wheelhead & Flange assembly required a more specific bearing. It needed to be angled, in order to fit in a cup and support the weight of the wheel, but also, it needed to have the right inner diameter to fit cleanly onto the Vertical Shaft. As such, a tapered roller bearing was selected for the final design, as the Tapered Roller Bearing (Vxb.com).

By far, the most expensive portions of the assembly were the bearings. The primary complaint of customers was that frequent machine breakdowns were their primary concern (Asante-Kyei, 2019). As such, protecting the integrity of the shaft mechanisms was paramount, so the team was not going to sacrifice those bearings to lower the quality. That did, however, restrict some other design options that were cut for their expense, particularly surrounding the support of the Wheelhead and the Foot Pedal Assembly. But, in some cases, that allowed the team to see overpriced parts and search for cheaper (and more effective) alternatives after seeing the costs on the subassembly review. In this way, better roller chain links were selected for the Drive Chain, and the ⅛ inch nuts and bolts were replaced by ¼ inch nuts and bolts, where applicable.

# 7. Testing

At least three tests were necessary to prove that the machine functioned as desired. Again, customers were most primarily concerned with reducing the frequency of breakdowns of their machines, with the possibility of increased ease of repair if and when the machine does break down (Asante-Kyei, 2019).

The first test was designed to prove that the Wheelhead could achieve an angular velocity of at least 100 rotations per minute, in order to enable the user to throw clay properly while using the machine (Marie, 2021) (See Fig 14.). To achieve this, the miter gears had to be tested for slip, and the system had to be tested for overall friction. The tester ran five rounds of increasing the wheelhead speed until the maximum rpm was achieved, gathering the top speed for each round using a tachometer, which did not take long. The entire math model of the machine involved translating the human input velocity at the Foot Pedal into the angular velocity of the Wheelhead. Because of this, it was crucial to confirm that the machine's entire function was successful. It was predicted that the operator would be able to achieve the desired rpm with minimal friction from the axles and shafts.

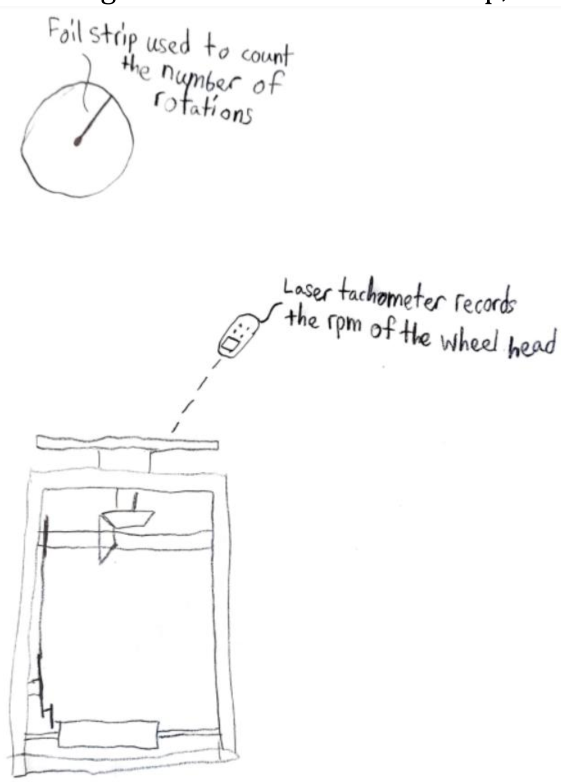



**Figure 14.** Concept sketch of the Wheelhead Speed Test

The second test was intended to prove that the Wheelhead could support the weight of wet clay as the operator threw clay onto the machine (see Fig 15.). The test was conducted by starting the wheel and adding 5 lb. weights in increments until the machine failed to spin. It was predicted that the Wheelhead could support up to 300 lbs of weight and would continue to spin while enduring this load. Adding this weight affected the math model by increasing the energy requirement to give the Wheelhead its momentum. Therefore, it was important to verify that the machine could spin the Wheelhead, even under extreme loads of clay for heavier projects by the operator.


**Figure 15.** Concept sketch of the Wheelhead Strength Test

Finally, the third test was made to measure deformation from use (see Fig 16.). Because a user could apply force to the Foot Pedal and Pedal Shaft in such a way that they could fracture, shear, or bend, measures had to be taken to ensure that the machine would not deform frequently or from occasionally rough use. The test involved applying weights to the Foot Pedal and Pedal Shaft in time increments, and recording their degree of deformation using a protractor. If a part deformed by several degrees, then the function of the whole machine would have been compromised. Thus, this important test was run through several rounds to ensure consistency. Regarding the math model, it is understandable that a user may not apply their foot in the precise correct location to generate motion on the machine, and so the leftover force from the input is accounted for in the strain of the Foot Pedal and Pedal Shaft. It was predicted that the machine would be able to handle 320 lbs of force (or about 44 Newtons) at this location with less than 2 degrees of deformation across its axes.

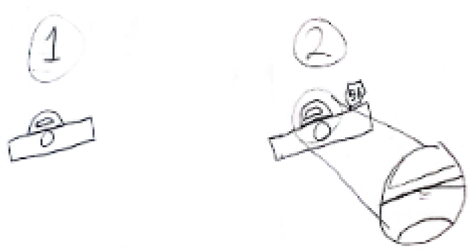



**Figure 16.** Concept sketch of Foot Pedal Strength Test.

The prototype for the Kickstart Wheel held up to the tests. After addressing problems in part manufacturing, the device functioned as desired. At the same time, testing results showed a resilience in the model which exceeded expectations.

The majority of problems that were encountered in manufacturing the prototype involved inconsistencies in reclaimed parts. The most noteworthy problems involved the warps in reclaimed plywood. When the team began assembling the Outer Box Assembly and Wheelhead Assembly, deflections in the surfaces of the plywood became apparent. The Outer Box Assembly was at least amenable to flexible screw tightness. In construction of the Wheelhead Assembly, however, the Wheelhead had to be given wedges of folds of paper in between it and the Wheelhead Flange in order to make it flat. Similarly, the reclaimed dowel rods and PVC pipes exhibited a slightly larger radius than expected that had to be shaved down in order to accommodate the Miter Gears and fit in the Bearing Blocks (see Fig 17.).


**Figure 17.** The Miter Gears fit on the first try.

Luckily, though, the shafts and axles were still straight, so they did not interfere with the functionality of the design. The team anticipated that welding the sprockets to the Sprocket-Bearing Shaft Connector would produce some warping in the sprockets. However, even though the parts were small, the warp was rather noticeable. Luckily, the machine's sprockets are not expected to experience shear, so the team cold-worked the sprockets back to a flat orientation. During the manufacturing stage, several plywood parts had to be remade, as they were destroyed in the manufacturing process. This led to some changes in their designs, specifically, making some plywood parts larger so that their base could handle the forces necessary to manufacture them. All in all, the processes were completed much faster than expected, and the MPIs were updated to reflect the time saved during the manufacturing process. Processes could be improved by allowing adjustable sections to compensate for low tolerances and misaligned parts involved in the machine's function.

Prior to testing, the machine had to be modified further in order to function properly. To start, the Drive Chain did not perfectly fit the space between the sprockets. To accommodate this, a new part was added to the Outer Box Assembly, the Tensioner, in order to adjust the tightness of the Drive Chain to the sprockets. Also, the space between the Lower Drive Gear With Rod and Foot Pedal Assembly needed to be balanced. The Connecting Bar was made longer (see Fig. 18), the Foot Pedal Assembly was sent closer to the front (towards the user), and the Lower Drive Gear With Rod was moved up and farther back (away from the user). Alterations like this were made just before testing.

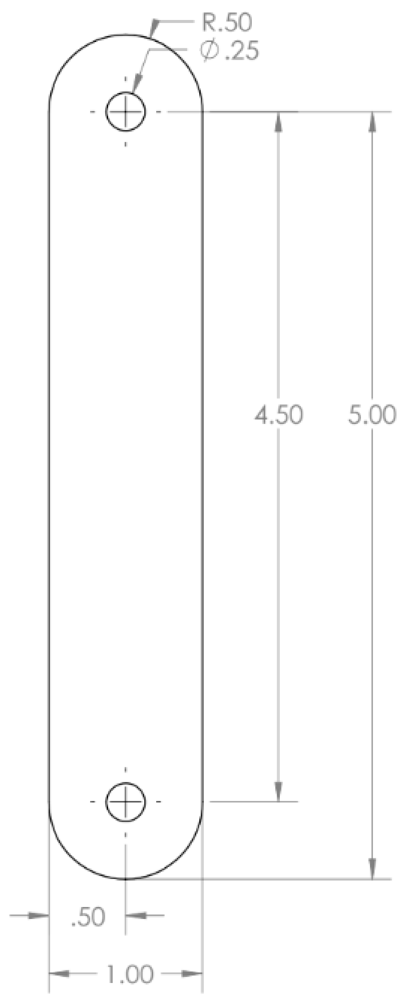
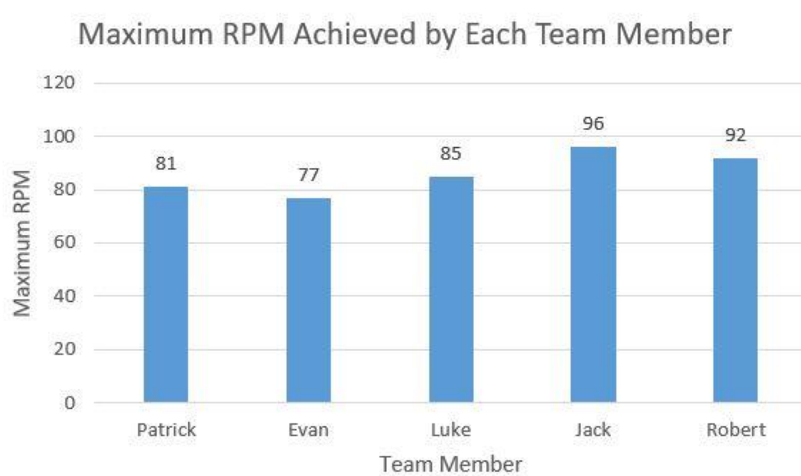



**Figure 18.** The Connecting Bar was extended from 3 ½ inches to 5 ½ inches.

The Wheelhead was able to be spun about as fast as predicted. Its maximum speed was 96 rpm, whereas the hypothesized max value was 100 rpm (see Table 19). Though it undershot the prediction of 150 rpm from the conceptual phase by a wide margin, this did not significantly hinder the design. 100 rpm is a very rapid speed for throwing clay pots, so a user is not expected to require that much power. Early in its design, the team replaced bearings in the Foot Pedal Assembly with nylon races, which may have hindered the design's max speed slightly. Additionally, a larger gear reduction ratio between the Drive Sprocket and Output Sprocket could be used to increase the max speed.

**Table 19.** Wheelhead Speed Test Results.

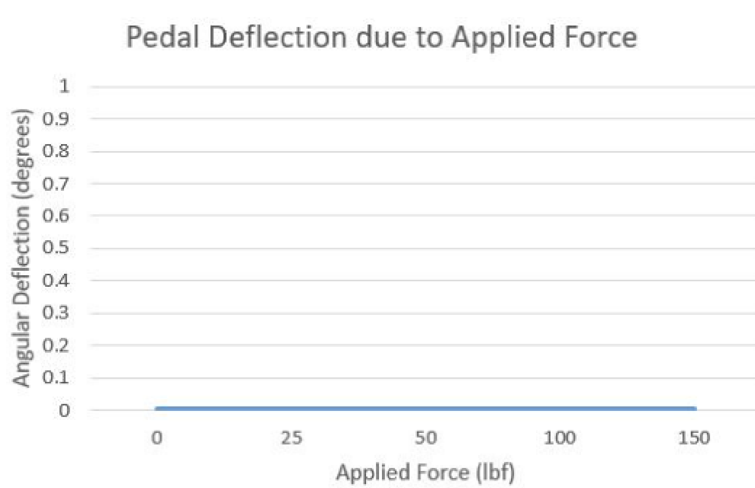


While the Wheelhead was not able to hold the predicted 20 lbs of weight while spinning, it was able to hold at least 15 lbs (see Fig 20.). As stated from market research, the machine was not expected to accommodate the throwing of large pottery vessels, but most small vessels will be well under 15 lbs. However, the failure at the critical weight limit was not due to friction between the Taper Roller Bearing and Taper Roller Bearing Cup, nor due to friction between Miter Gears. Rather, the frame began to deflect at that limit. As predicted in the math model, the gear reduction was not so underwhelming that the Wheelhead would refuse to turn under a heavy load.


**Figure 20.** Wheelhead Strength Test in progress.

The results from the pedal force test proved that the Pedal Shaft is not in danger of shearing or deforming due to excess force on the Foot Pedal. In fact, the Foot Pedal only began to bend slightly after 150 lbs of force were applied to it (see Table 21). The Pedal Shaft itself did not plastically deform from even this amount of force. So, while it is still recommended that the user start the wheel steadily for the sake of the Miter Gears, the Pedal Shaft and Foot Pedal are not in danger of breaking from user errors or mistakes. While some of the force applied to the machine is absorbed as strain by the Foot Pedal Assembly, it is not significant enough to cause concern.

**Table 21.** There was no recorded deflection during the Foot Pedal Strength Test



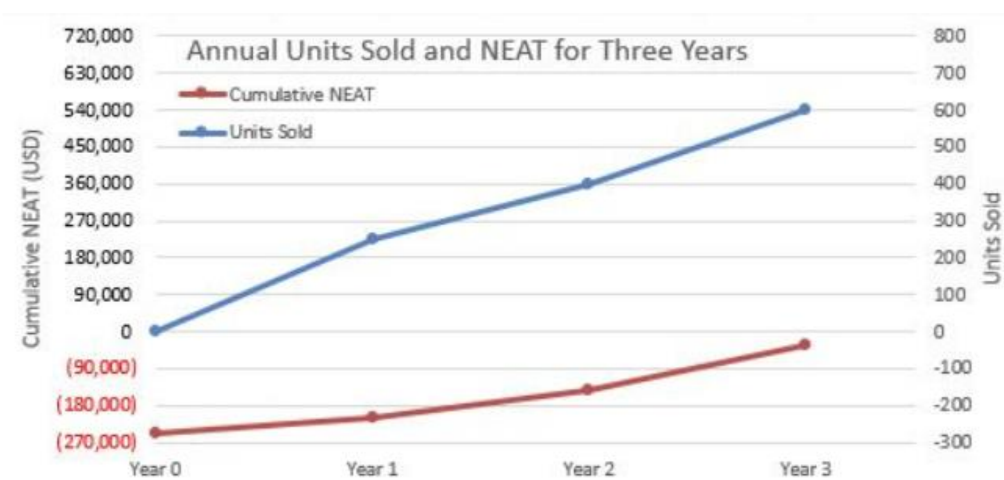
# 8. Business Plan & Design Sustainability

Kickstart Wheel manufacturing is a profitable enterprise for entrepreneurs along Africa's West and East coasts. Manufacturing the wheels requires only a few expensive machines, all of which would be operable with minimal training. Additionally, the location of population centers along the African coasts enables distribution and ease of acquiring the labor required to manufacture the product.

As alluded to earlier, Africa's West and East coasts have many population centers which would be advantageous for the manufacturing of Kickstart Wheels (Ayentimi et al., 2017). In particular, Dar Es Salaam in Tanzania (East coast), as well as Accra in Ghana and Douala in Cameroon (West coast) are poised to make the manufacture of Kickstart Wheels more lucrative (Danchie, 2021). Skilled labor is relatively rare in many of these countries, so having wheel factories in or near cities would cut down on costs to set up these factories, as well as upkeep costs on the factories (Ayentimi et al., 2017). For the manufacture of Kickstart Wheels, a factory must purchase: drill presses, lathes, welders, belt sanders, and assorted saw machines as necessary. They will also need: screwdrivers, hammers, wrenches, pvc cutters, steel pipe cutters, glue, chisels, hacksaws, jigsaws, and table saws. While many parts of the machine are manufactured, the unmodified parts include: miter gears (N5005), clevis pin (N5011), cotter pin (N5010), screws and bolts (N5014, N1006, N1007, N3009, N2008, N1009, N1014), and bearings (N5003, N4005). Due to both the product's rectangular shape and its assembly, it is relatively easy to ship and move. The product can be disassembled and packed into boxes by undoing the Outer Box Assembly. Additionally, factories at port cities can leverage international and coastal shipping to broaden their potential market.

Based on the business viability model, the manufacture of Kickstart Wheels is predicted to generate profit in the first year of production (see Table 22.). Initially, this was not the case. The first round of MPIs for the prototype parts, especially the wood parts, allocated two-to-four times as much paid labor to

**Table 22.** Business Viability: projected units sold and Net Earnings After Taxes



manufacture them. After being revised, the prototype's total cost was significantly reduced. However, there are a few things that could be done to further reduce the cost of production of the Kickstart Wheel. For one, having access to a 3D printer greatly assisted the manufacture of the prototype, specifically for the Miter Gear, N5005. It is understandable that entrepreneurs in coastal African countries would have difficulty acquiring 3D printers, relative to other parts that could achieve the same, while purchasing or manufacturing metal miter gears would increase the cost of production. As such, a possible replacement for the miter gears could be a belt fastened to the Output Shaft and Wheel Shaft, in order to translate the rotational motion. Another area where profitability could be improved is in replacing some of the bearings. During testing, it was found that none of the shafts experienced enough rotational force to warrant the use of an R16 Bearing. Early in the design, a pair of such bearings were cut and replaced with manufactured nylon races, to bring the prototype cost below the maximum. However, upon completion of the prototype, it is clear that not as many R16 Bearings are necessary for the design, which could be replaced to reduce costs. Finally, it was discovered that many of the holes drilled into wood, particularly on the Bearing Block, did not require the precision of a drill press. Holes that are intended for bolts could be easily tapped with a simple hand drill, which could save money spent on using a drill press during production. The Kickstart Wheel is easily manufactured at an efficient cost.

The Kickstart Wheel, due to its simple design, is highly sustainable. The majority of the manufactured parts are made from wood, which can be recycled or used by communities that still utilize tinder for fires. With less than 1,000 units produced each year, waste from PVC and metal shards are very minimal and easily disposed of. Similarly, the wood required for the machines is not likely to make a massive dent in the local tree population. Because of how profitable the enterprise is, workers in factories that manufacture the wheel have room to increase their wages, which supports economic sustainability. Additionally, many of them will learn skills on manufacturing machines like the lathe and drill press, which grow capital for other jobs that are high in demand (Asante-Kyei, 2019, Ayentimi et al., 2017). With these machines, precautions must be taken to ensure worker safety. It should be noted that, with the use of the Kickstart Wheel, locally made ceramic vessels will likely take up an even larger share of the cookware market in coastal African communities, which could lead to conflict with foreign competition, such as products from China, that are already not very popular in these regions (Adu-Gyamerah, 2019). All in all, though, the Kickstart Wheel is very sustainable into the future.

# 9. Final Design and Conclusion

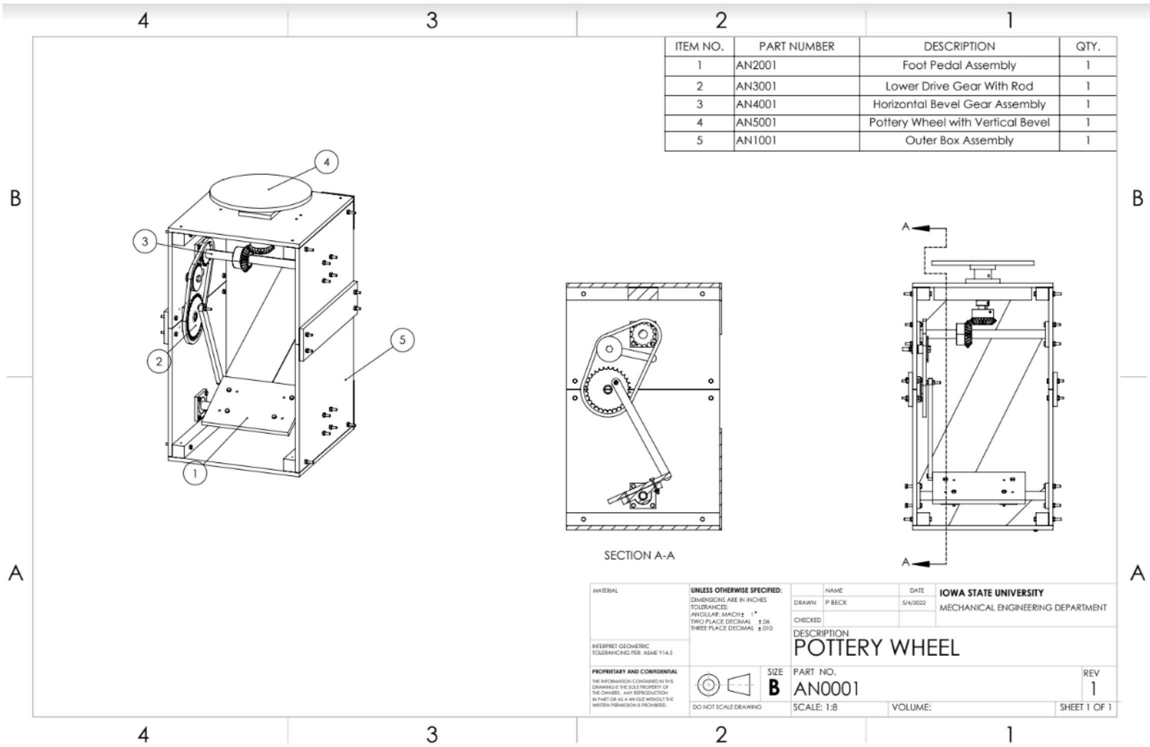



**Figure 23.** Final Design Assembly

With a unit price of $600, the Kickstart Wheel is commercially viable. While this is expensive compared to electric pottery wheels, it does save companies from having to wire a whole building to power electric machines. Additionally, the Kickstart Wheel had some sustainability characteristics worth considering. It was environmentally sustainable, due to easily disposed parts and locally collected materials. Additionally, the Kickstart Wheels fostered machine shop education for manufacturers, presenting an economic sustainability angle. Unfortunately, this precludes the machine from meeting the team's goal of making it under $100, as noted in the Project Charter (see Appendix A). The Kickstart Wheel acts as a suitable substitute for electric pottery wheels that are financially out of reach for coastal African ceramics manufacturers, which is key to its success. One feature that could threaten this success, however, is the highly vertical and top-heavy design of the machine. Because of this, it is more vulnerable to tipping over. Pottery vessels are very popular in coastal African countries, so potters and pottery are in high demand (Adu-Gyamera, 2019). The Kickstart Wheel was designed for budding ceramics factories along the coasts. However, compared to traditional methods, the Kickstart Wheel can also triple small vessel output for community artisans (Roy, 2013). While these artisans are also often engaged in producing large vessels that the Kickstart Wheel cannot accommodate, the product can still be a contender for the part of their craft that is dedicated to small and regular-sized vessels. As such, demand for the machines is expected to be high, so the model for commercial viability was started at 250 units sold in the first year. While the Kickstart Wheel is competing with commercially available electric pottery wheels, it has a distinct pair of advantages over them. For one, the electric wheels are not produced in many African countries, so fewer of them are available to the market. Additionally, not all buildings or communities in these countries have electric wiring, which is required to run the electric wheels. Some ceramics factories in Ghana have even had to shut down after transitioning to electric power production, due to the high cost of electricity there (Ayisi, 2019). The Kickstart Wheel is predicted to make a splash in coastal African markets.

As alluded to earlier, the final rendition of the Kickstart Wheel underwent some changes in function. To assist the Wheelhead in staying upright and stable, the Wheelhead Ring and Wheelhead block were added to the Wheelhead subassembly. These additions were relatively cheap, and did not greatly affect the price of the prototype. At the same time, this allowed the machine to function for a longer period before having to be realigned or repaired, which increased its appeal to customers that were looking for a robust machine. The additions also reduced chafing and friction along the axle, which aided in the efficiency of the wheel.

It was not anticipated that the Drive Chain would derail as much as it did. After adding a Tensioner to the Drive Gear Assembly, it still did not sit well during the machine's operation, even with a slide cut out in the frame to allow adjusting (see Fig 24.). Because of this, the team opted to change the length of the Connecting Rod, in order to sync the rotation of the Drive Sprocket and the movement of the Foot Pedal more closely. The system's "feel" changed significantly with this upgrade. Starting the pedal pattern became much easier, and maintaining a rhythm became feasible with this addition.

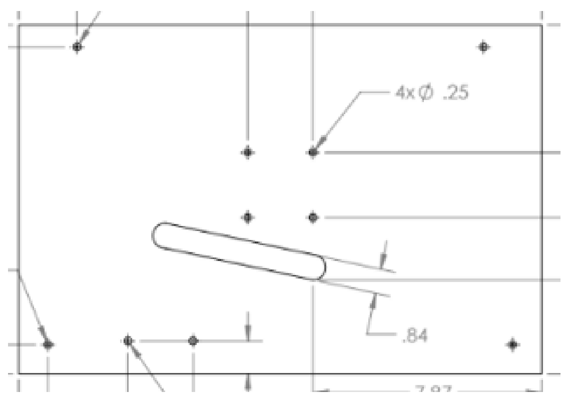



**Figure 24.** A "slot" was added to the side of the machine's frame, shaped like a rounded rod

When the Boyd Lab ran out of ¾ inch PVC, the team resorted to an aluminum rod that fit the dimensions for the Pedal Shaft. This was a major bonus. Later, when the Foot Pedal was tested for strength versus pushing forces onto it, the shaft did not budge, which proved that the Foot Pedal would not be in danger of failure. With that base covered, the team was able to focus on addressing the other failure concerns mentioned earlier in the final countdown for the project deadline.

While the team had to back down from its ambitions of using a total of five bearings in the design, the three that were kept proved very useful. Two were removed due to protype cost concerns, as the R16 bearings were priced at about $8 (Vxb.com). The replacement took the form of nylon races formed using the lathe, and were placed on the Pedal Shaft. Because the pedal shaft did not have to spin continuously, but instead exhibited a back-and-forth motion, the minimal friction that the team encountered was negligible, and, as mentioned earlier, the strength of the pedal still held up to large amounts of force. The three remaining bearings, however, are key to the design. Between the sprockets and the shafts, a lot of forces could throw off the momentum of the axles, which is why the team still deemed it necessary to include the two R16 Bearings on the Output Shaft. The Taper Roller Bearing was unique because, not only did it assist in the rotation of the Wheelhead, it also supported the weight of the wheelhead with its angled face. This allowed the team to stop worrying about support mechanisms for the machine early in design and jump-started other design concepts.

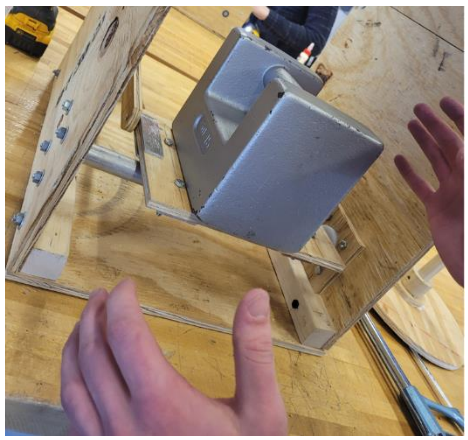


**Figure 25.** The team waits in anticipation of bending as the first 50 lb weight is placed on the foot pedal.

The original goals of the Kickstart Wheel were to deliver a machine that could assist in making clay pots without breaking down frequently and without using electricity. From the test results, it is clear that many of the features of the machine are resistant to wear, excessive use, and the occasional mishandling (see Fig 25.). After all, the machine's pedal can handle at least 150 lbs of force, and the wheelhead can support up to 15 lbs of wet clay, which are both far in excess of the hypothesized goals. Additionally, as desired by customers, the design is able to be disassembled and shipped relatively easily by deconstructing the Outer Box Assembly into two halves. When the machine is disassembled in this way, the Wheelhead does stick out a few inches, but luckily, it does not have any sharp or catching edges that present a hazard. Unfortunately, the customers' desire to have a smaller design than the slab wheel was not met fully. The team's original goal was to make a machine within 24x24x30 inches in dimension, while the final product was 18x18x42 inches in dimension. The slab wheel is much wider than the Kickstart Wheel, but the machine still takes up a decent amount of space. A possible way to counter this in a similar design would be to reduce the width of the Outer Box Assembly and choose a less bulky set of gears than the Miter Gears. As it is, the Kickstart Wheel required the internal space to allow all the parts to have no contact with stray edges or plywood faces.

All-in-all, the design could be improved by future engineers. The primary concern of such upgrades would likely be tailored to reducing the retail cost of the machine to customers, as $600 is a big ask. As mentioned earlier, it is possible that other gear reduction mechanisms could be implemented that would be cheaper than the miter gears. Also, the use of a bike chain, while initially thought practical, introduced several factors that made it more difficult than it first seemed. If the design could be upgraded to have fewer derailing incidents, then the machine would be much more popular and attractive to potential customers. Or, if the bike chain concept was exchanged for a different mechanism to transfer the rotational energy, that could potentially work as well. There is a lot of potential for ceramics industries and artisans along Africa's East and West coasts to utilize a machine that aids their craft.

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# Appendices

## A. Project Charter

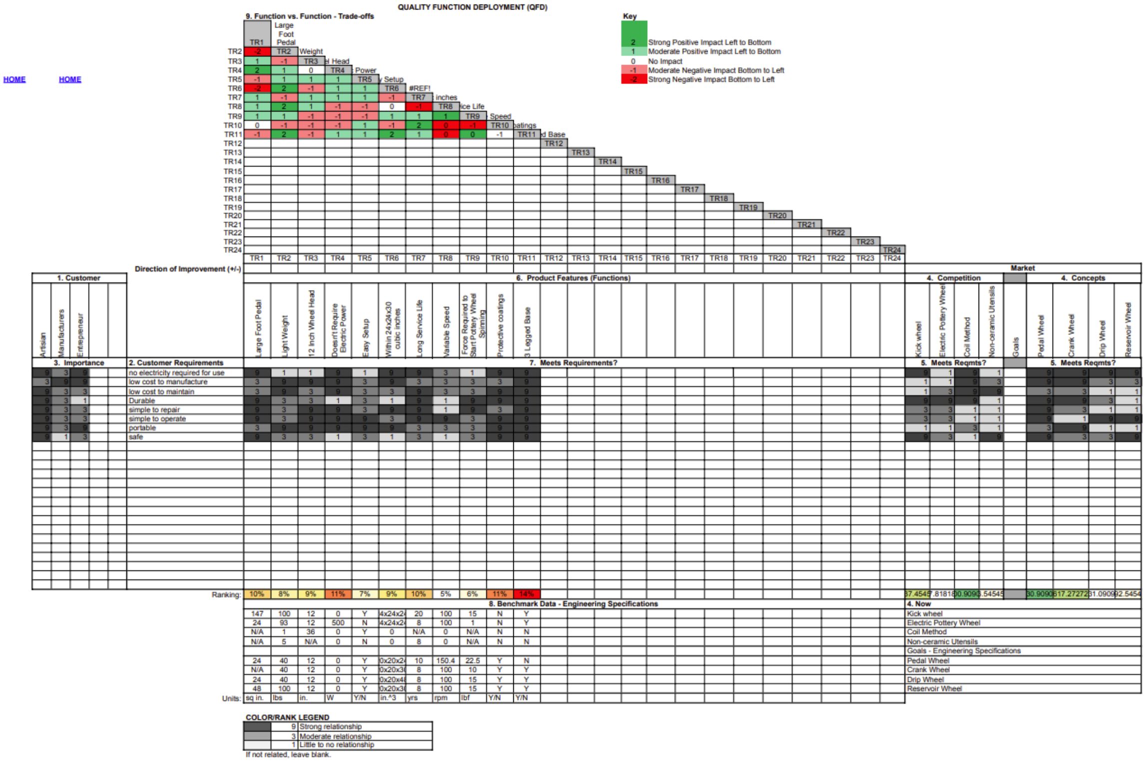
HOME

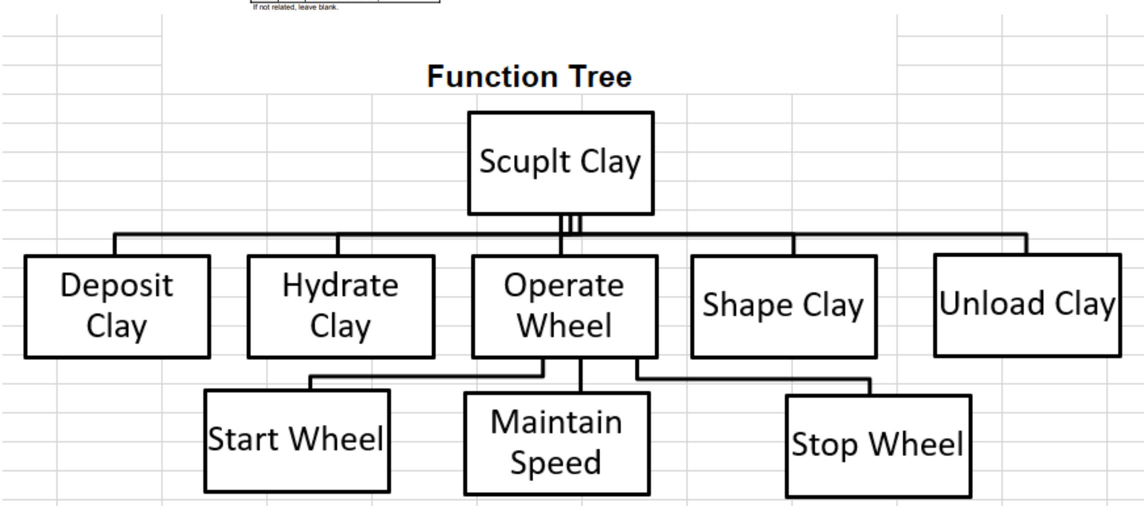
**Project Charter**

| | | | |
|---|---|---|---|
| **Project Name** | Kick-Start Wheels | | |
| **Team Members** | Patrick Beck, Robert Bengel, Jack Murray, Evan Schneider, Luke Zillig | | |
| **Section TA** | Faith Burroughs | | |
| **Section Instructor** | Prof. Messman | | |
| **Start Date** | 1/22/2022 | **End Date** | 5/6/2022 |

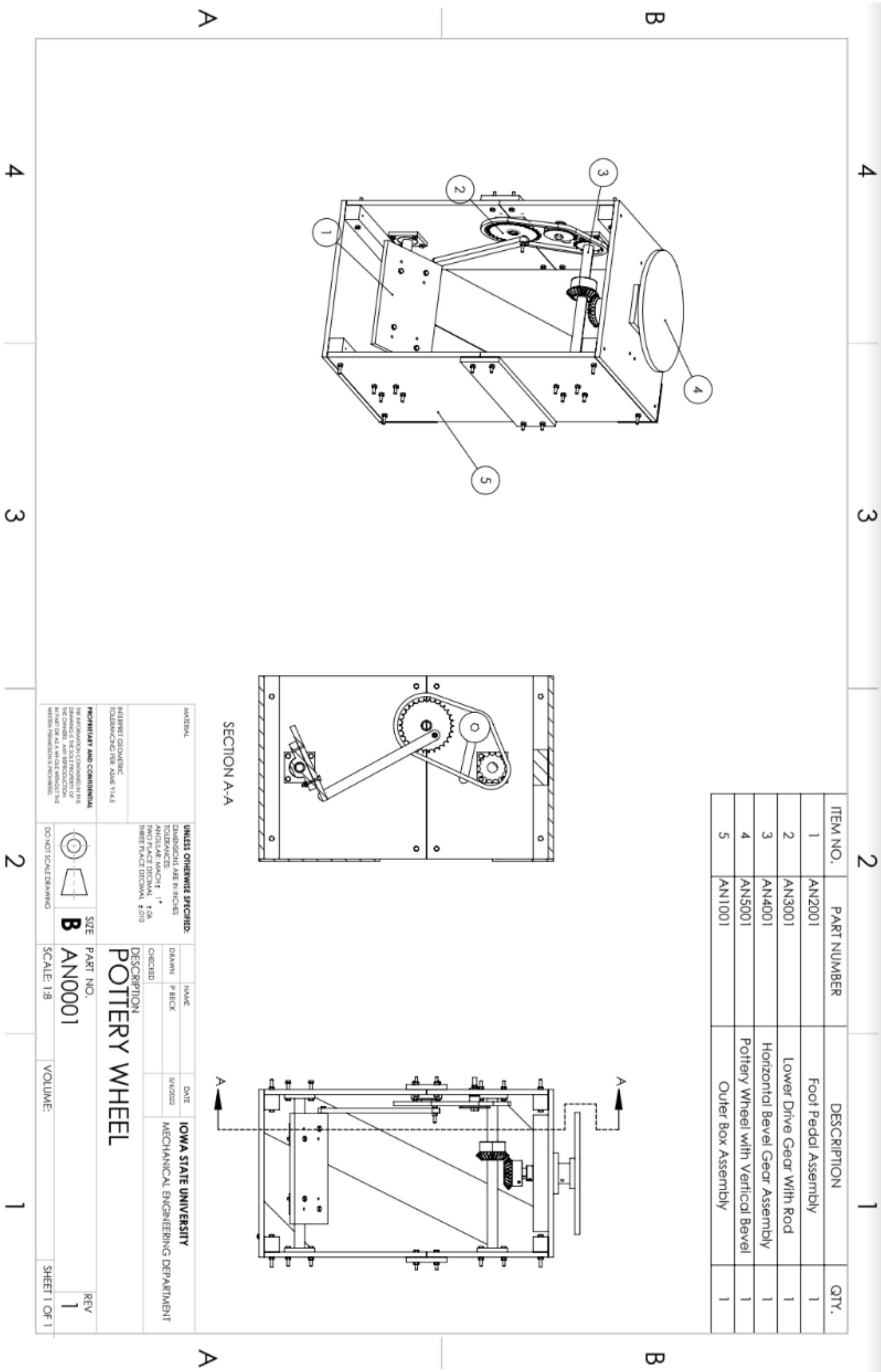
| **Element** | **Description** | **Team Charter** | | | |
|---|---|---|---|---|---|
| **Problem Statement** | Describe the situation and what is driving the need for a solution | On Africa's Sub-Saharan West coast, pottery is very common for both artistic and functional applications. Many potters there hand-throw their pottery without the use of a wheel, or use a large and inefficient slab wheel. We aim to replace the large slab with a more efficient wheel, which will allow current potters to increase their productivity and profit margins, thus allowing the economy of Ghana to improve as a result of the growing wealth among potters in the country. | | | |
| **Opportunity Statement** | Describe the market opportunities and the potential financial or social opportunities | Ceramic industries and independent artisans in Ghana are currently producing pots, but are significantly behind international competitors because their output is constrained by their outdated throwing machines. Our machine will increase their productive output substantially, and drive down repair costs, which will allow them to decrease prices and retake a significant share of the pottery industry in Ghana. | | | |
| **Importance of Project** | Describe the priorities that make this project necessary. Describe benefits to customers for doing this project. | Ghana's economy is growing fast. However, many of their industries, such as ceramics, are having difficulty competing with international markets, such as China. Not only will our machine increase the efficiency of ceramic producers in Ghana, but it will also lead to more employment on a local level. | | | |
| **Primary Customers** | Define the customers impacted by this project. Start with the end user, add all who are stakeholders. | This machine is intended to increase product output for ceramic industries and independent potters in Ghana. Ghana and its surrounding countries already have a vibrant pottery and ceramic culture, so an entrepreneurial manufacturer of our machines also stands to gain from revenue through local businesses. | | | |
| **Scope:** | Describe what this project will deliver at its completion. What defines this project as being "done"? | This project will deliver a prototype for a compact, portable, safe, and easily repaired potters' wheel. In addition, we will provide recommended final design, and a final report using business data. | | | |
| **Expectations / Deliverables** | Specify the project metrics that are key to the customers | Project Metrics | Goal | Accomplished | Units |
| | | Weight | 30 | Yes | lbs. |
| | | Cost | 100 | No | $ USD |
| | | Size | 24x24x30 | Yes | Inches |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| **Schedule** | Specify milestone dates, member responsible, and tasks' status | See attached Gantt chart | | | |
| **Team Resources** | Team Members | Areas of Responsibilty/Expertise | Contact Information (email/phone) | | |
| | Patrick Beck | SolidWorks, math analysis, research | pbeck@iastate.edu / 740-815-9901 | | |
| | Robert Bengel | SolidWorks, communication, writing | minisculegnome@gmail.com / 408-310-6401 | | |
| | Jack Murray | SolidWorks, pottery knowledge, woodworking | jmurray@iastate.edu / 952-388-9640 | | |
| | Evan Schneider | SolidWorks, math analysis, metal working | evansch@iastate.edu / 816-522-4306 | | |
| | Luke Zillig | SolidWorks, math analysis, woodworking | ldzillig@iastate.edu / 651-276-7305 | | |
| | | | | | |

# B. Justification for Selected Concept



# C. Approved Design Package



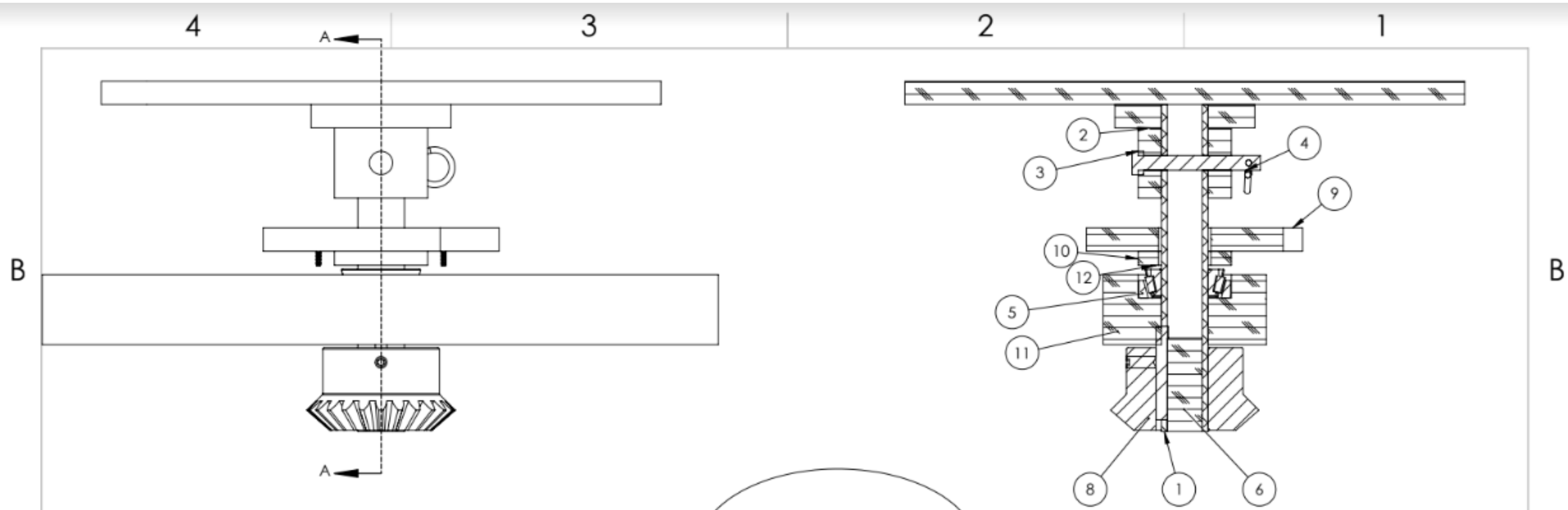
HOME

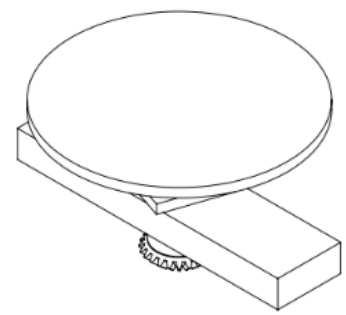
## Manufacturing Process Instruction

Part # : AN0001 Part Name: Pottery Wheel Prepared By: Patrick Beck

Team: Section 4 Team 5 -- Kick Start Wheels Sheet: 1 of 1 Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Attach (3) to (2) via the lag screw on (3) into the side mounted hole on (2) | Screwdriver | 0 | 0.05 | Ensure there is negligible friction between the connecting bar and (2) for proper operation of the assembly |
| 2 | Attach (2) and (3) to (1) using bolts from (2) and (3) respectively | Wrench | 0 | 0.05 | Ensure bolts are tightened to avoid unnecessary movement in the assembly |
| 3 | Attach (4) to (1) using bolts from (4) | Wrench | 0 | 0.05 | Ensure bolts are tightened to avoid unnecessary movement in the assembly |
| 4 | Attach chain from (4) to gear on (3) | Hands | 0 | 0.05 | Ensure chain is properly seated on both gears |
| 5 | Slide (5) into (1) | Hands/Hamme | 0 | 0.1 | Miter gear on (5) will need to be removed and replaced onto (5) to slide (5) into (1), ensure the bearing cup from (1) is properly inserted into (1) for assembly to function properly |
| 6 | Adjust miter gear location on (4) and (5) | nds/Screwdri | 0 | 0.05 | Adjust gears for proper connection and operation of the assembly |



| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | N5004 | Wheel Shaft | 1 |
| 2 | AN5101 | Wheel & Falange | 1 |
| 3 | N5011 | Connecting Rod | 1 |
| 4 | 92391A155 | 18-8 Stainless Steel Hairpin Cotter Pin | 1 |
| 5 | AN5201 | Support Bearing | 1 |
| 6 | N5012 | Center Support Dowel | 1 |
| 7 | N5006 | Vertical Miter Gear | 1 |
| 8 | N5005 | Metal Miter Gear | 1 |
| 9 | N5016 | Wheelshaft Block | 1 |
| 10 | N5015 | Wheelshaft Ring | 1 |
| 11 | N5007 | Bearing Support | 1 |
| 12 | FLATCKT 0.112-24-type II-B-0.8125-S | | 2 |

MATERIAL

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

PROPRIETARY AND CONFIDENTIAL
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DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | JOHN MURRAY | 4/20/22 |
| CHECKED | | |

**IOWA STATE UNIVERSITY**
MECHANICAL ENGINEERING DEPARTMENT

DESCRIPTION
WHEELHEAD

SIZE B
PART NO. AN5001
REV 1

SCALE: 1:2 VOLUME: SHEET 1 OF 1

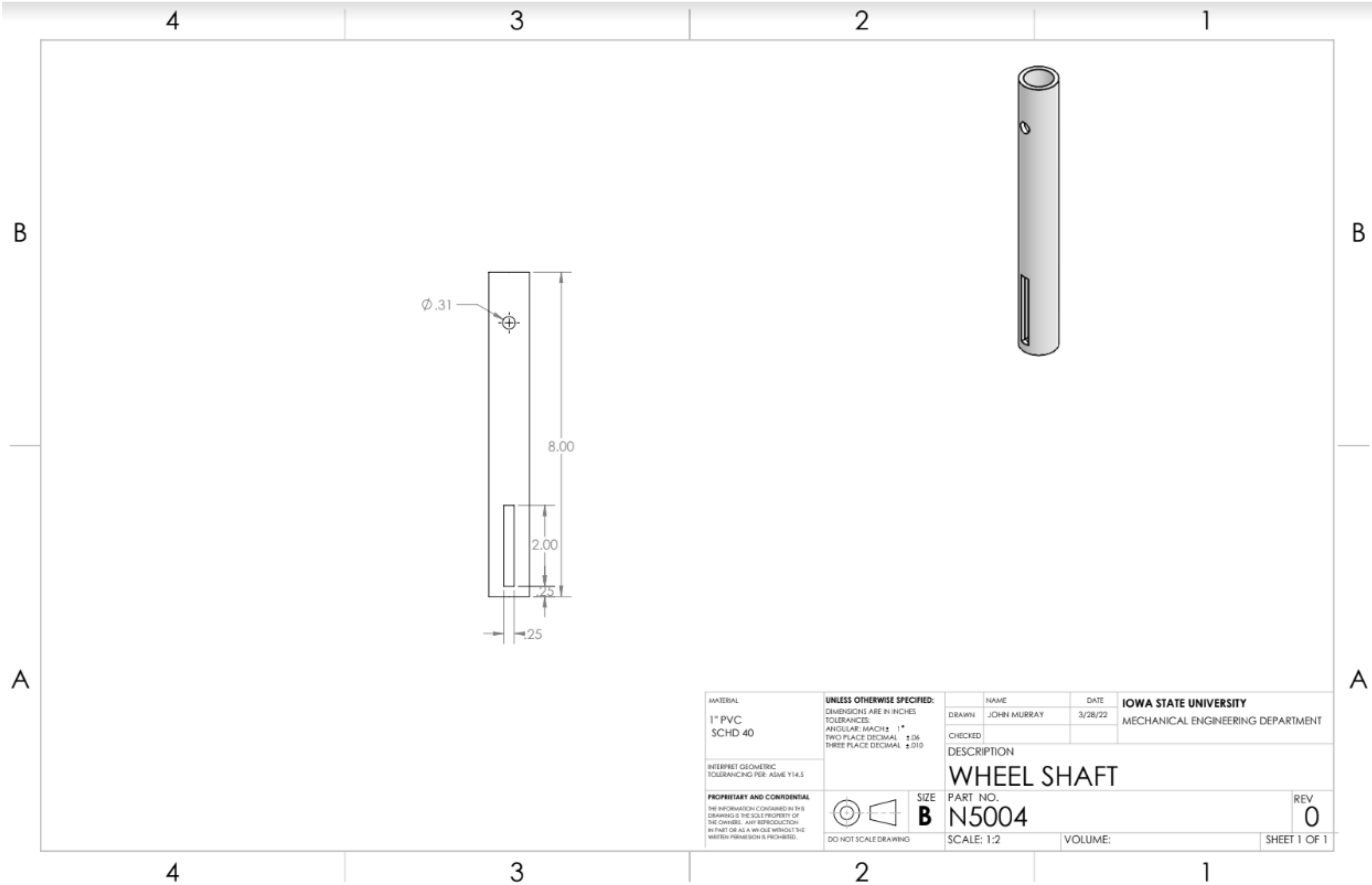
HOME

# Manufacturing Process Instruction

Part # : AN5001 Part Name: Pottery Wheel w/ Vertical Bevel Prepared By: John Murray

Team: Section 4 Team 5 Sheet: 1 of 1 Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Slide (2) on (1) | Hands | 0 | 0.05 | |
| 2 | Slide (3) through (2) and (1) | Hands | 0 | 0.05 | |
| 3 | Slide (4) into (3) | Hands | 0 | 0.05 | |
| 4 | Slide (8) around assembly | Hands | 0 | 0.05 | |
| 5 | Slide (5) into bottom of (1) | Hands | 0 | 0.05 | |
| 6 | Place (6) into key slot on (1) | Hands | 0 | 0.05 | |
| 7 | Slide (7) onto bottom of (1) | Hands | 0 | 0.05 | |
| 8 | Fasten (7) to (1) | Screwdriver | 0 | 0.05 | |



Ø .31
8.00
2.00
.25
.25
MATERIAL
1" PVC
SCHD 40
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
NAME
DATE
DRAWN
JOHN MURRAY
3/28/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
WHEEL SHAFT
SIZE
B
PART NO.
N5004
REV
0
DO NOT SCALE DRAWING
SCALE: 1:2
VOLUME:
SHEET 1 OF 1

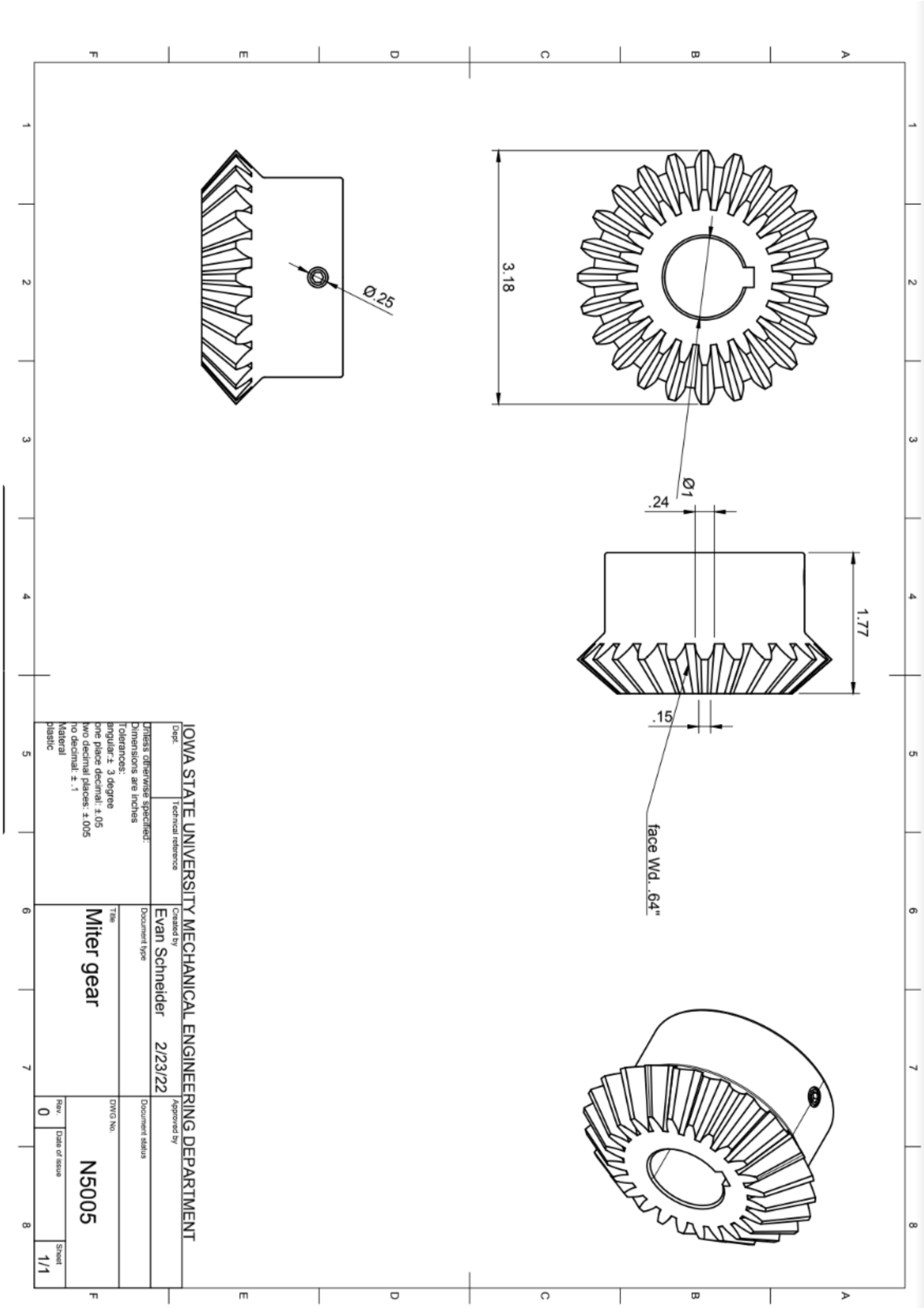
HOME

# Manufacturing Process Instruction

Part # : N5004 Part Name: Wheel Shaft Prepared By: John Murray

Team: Section 4 Team 5 Sheet: 1 of 1 Date: 3/26/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut pvc to desired length | PVC cutter | 0.1 | 0.1 | Cut square |
| 2 | Drill holes at each end of key channel | Drill press | 0.1 | 0.1 | Ensure tolerences are met |
| 3 | Cut key hole as specified | Jigsaw | 0.1 | 0.1 | Ensure tolerences are met |
| 4 | Drill top hole | Drill press | 0.1 | 0.1 | Through all |

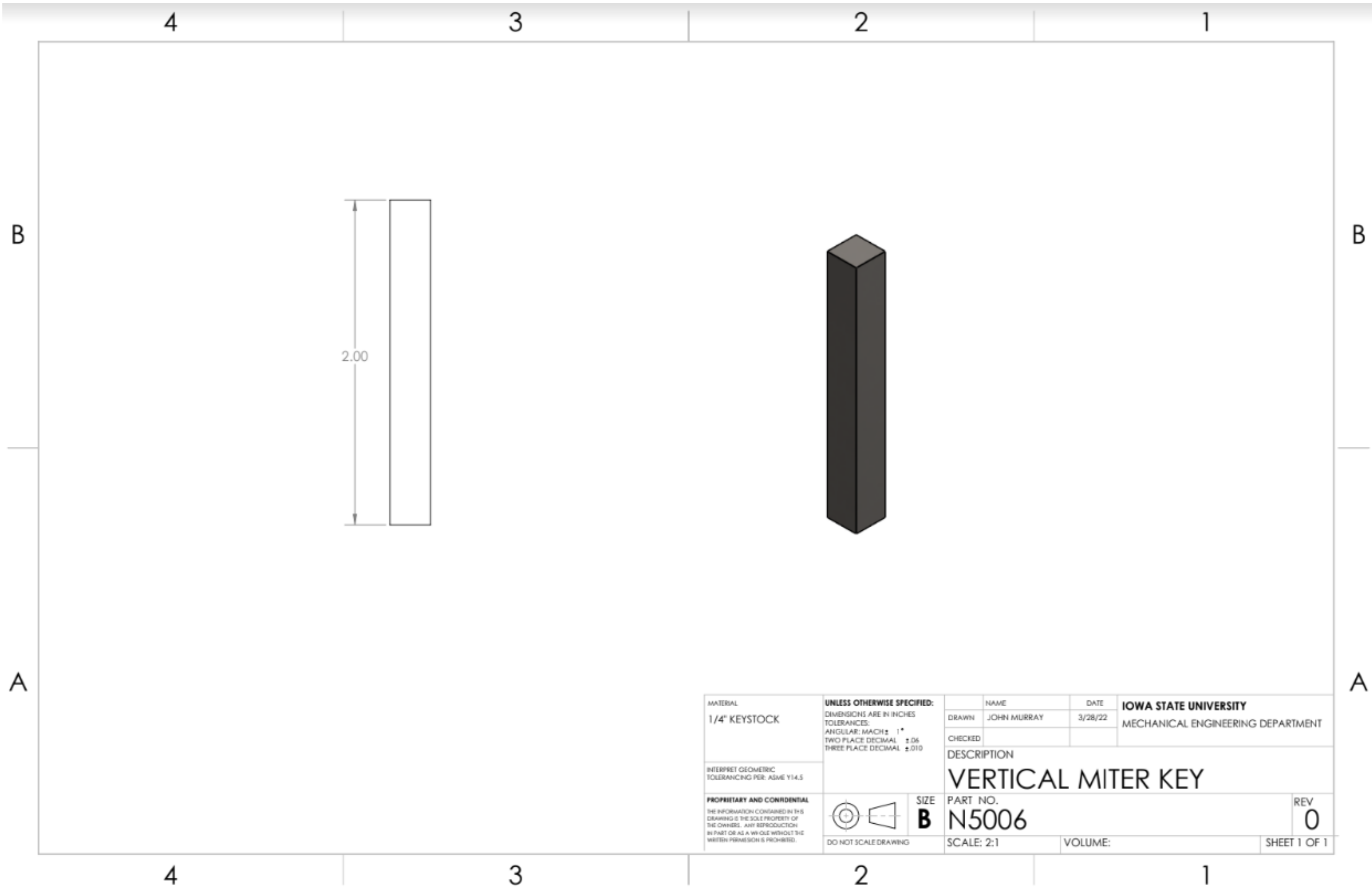

IOWA STATE UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
Dept.
Technical reference
Created by
Evan Schneider 2/23/22
Approved by
Document type
Document status
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular: ± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ±.1
Material
plastic
Title
Miter gear
DWG No.
N5005
Rev.
0
Date of issue
Sheet
1/1
3.18
Ø.25
Ø1
.24
1.77
.15
face Wd. .64"

HOME

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N5005 | Part Name: | MITER GEAR | Prepared By: | PATRICK BECK |
| Team: | SECTION 4 TEAM 5 -- KICK START WHEELS | Sheet: | 1 of 1 | Date: | 3/9/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | stimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | 3-D Print Miter Gear Using CAD Part | 3-D Printer | 0.2 | 0.1 | Operator Not Necessary During Printing of Part |


2.00
MATERIAL
1/4" KEYSTOCK
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
JOHN MURRAY
3/28/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
VERTICAL MITER KEY
SIZE
B
PART NO.
N5006
REV
0
SCALE: 2:1
VOLUME:
SHEET 1 OF 1

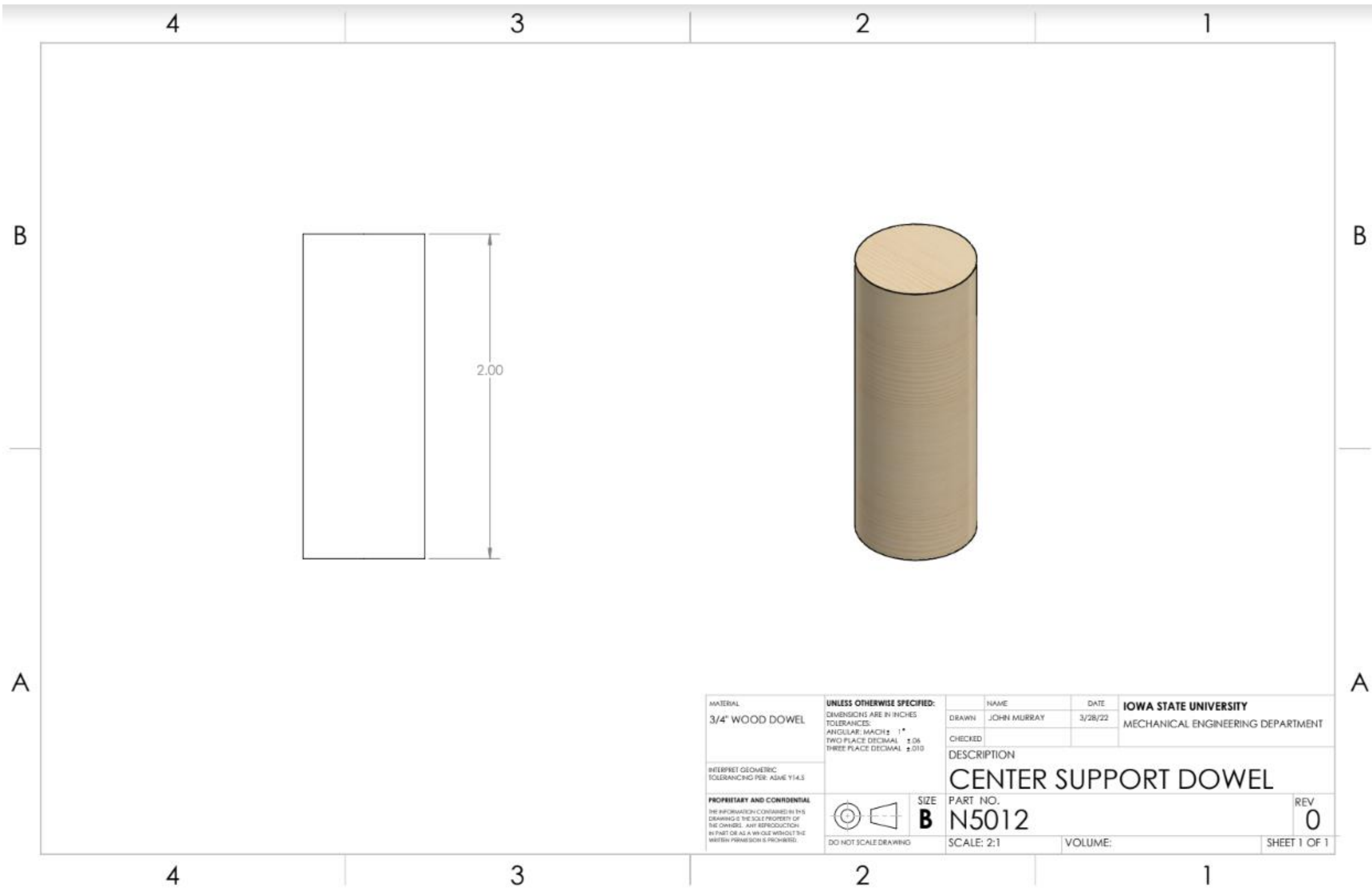
HOME

# Manufacturing Process Instruction

Part # : N5006 Part Name: Vertical Miter Key Prepared By: John Murray

Team: Section 4 Team 5 Sheet: 1 of 1 Date: 3/26/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut keystock to specified length | Hacksaw | 0.1 | 0.1 | Cut sqaure |


2.00
MATERIAL
3/4" WOOD DOWEL
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
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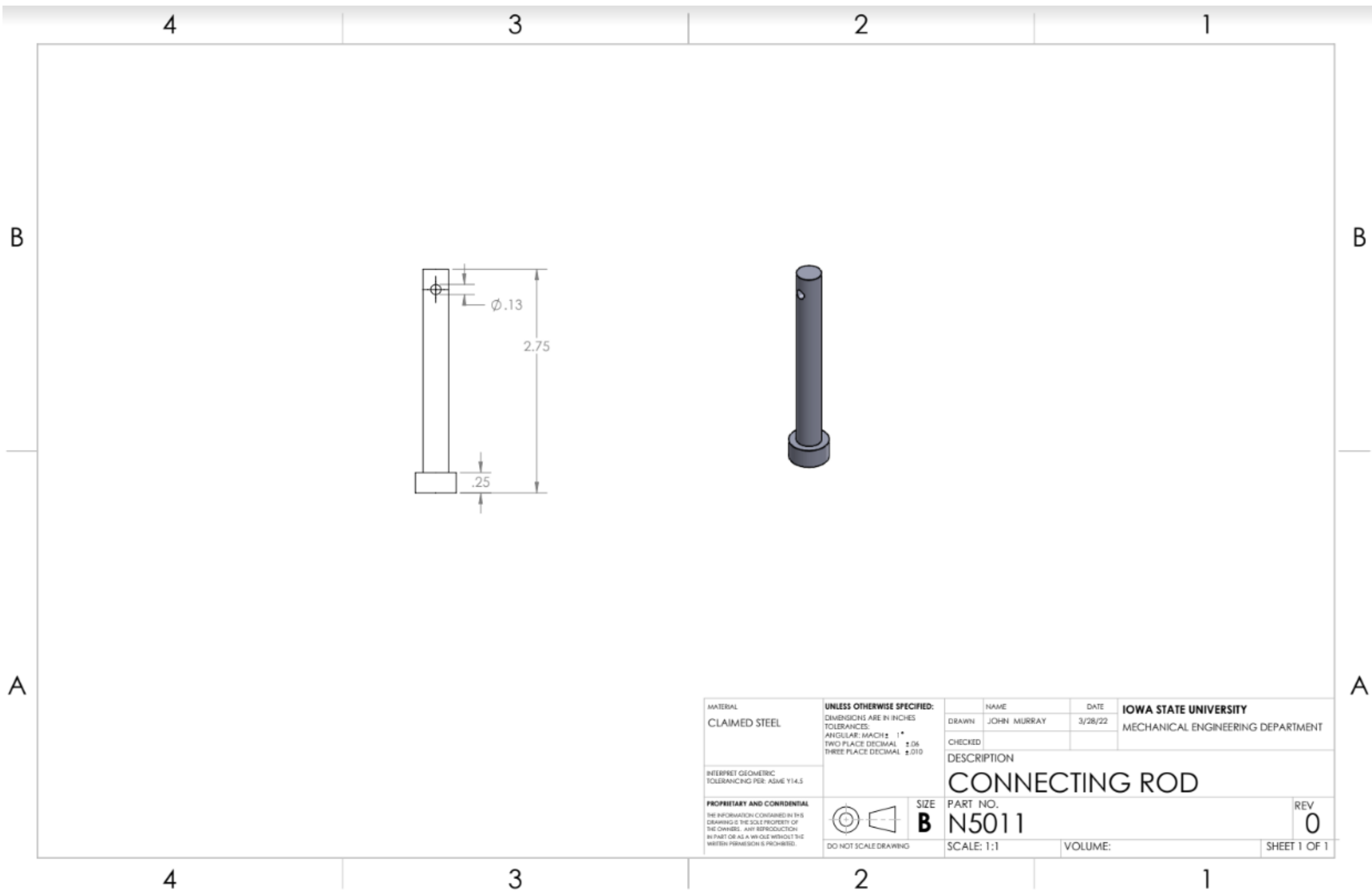
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
JOHN MURRAY
3/28/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
CENTER SUPPORT DOWEL
PART NO.
N5012
REV
0
SCALE: 2:1
VOLUME:
SHEET 1 OF 1

HOME

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N5012 | Part Name: | Center Support Dowel | Prepared By: | John Murray |
| Team: | Section 4 Team 5 | Sheet: | 1 of 1 | Date: | 3/26/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut 3/4" dowel to desired length | Hacksaw | 0.1 | 0.1 | |


4
3
2
1
B
A
Ø.13
2.75
.25
MATERIAL
CLAIMED STEEL
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
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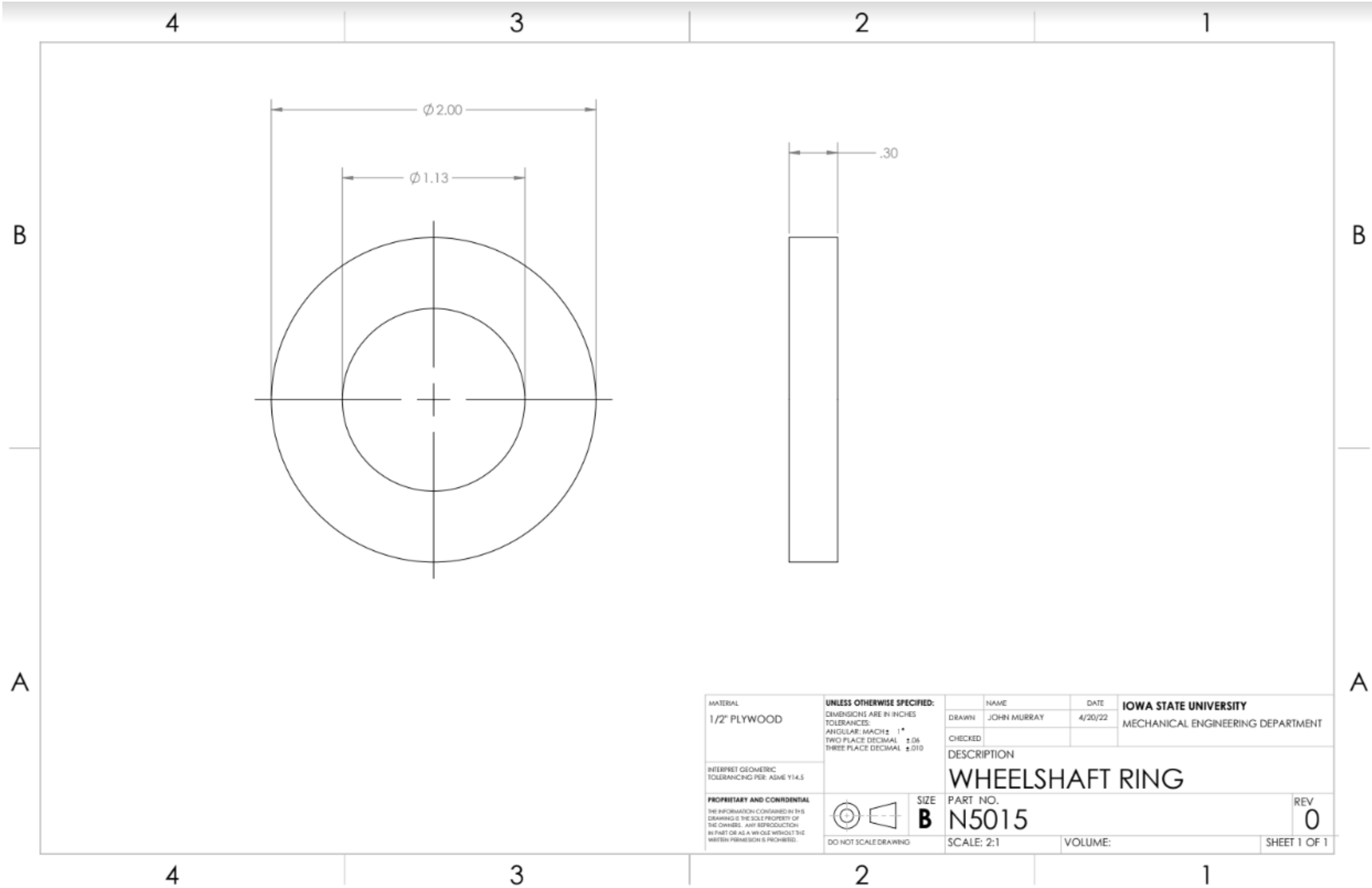
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
JOHN MURRAY
3/28/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
CONNECTING ROD
PART NO.
N5011
REV
0
SCALE: 1:1
VOLUME:
SHEET 1 OF 1

HOME

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N5011 | Part Name: | Connecting Rod | Prepared By: | John Murray |
| Team: | Section 4 Team 5 | Sheet: | 1 of 1 | Date: | 3/26/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut rod to drawing length | V-bandsaw | 0.1 | 0.1 | |
| 2 | Drill end hole as specified | Drill Press | 0.1 | 0.1 | |



4
3
2
1
B
A
Ø2.00
Ø1.13
.30
MATERIAL
1/2" PLYWOOD
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
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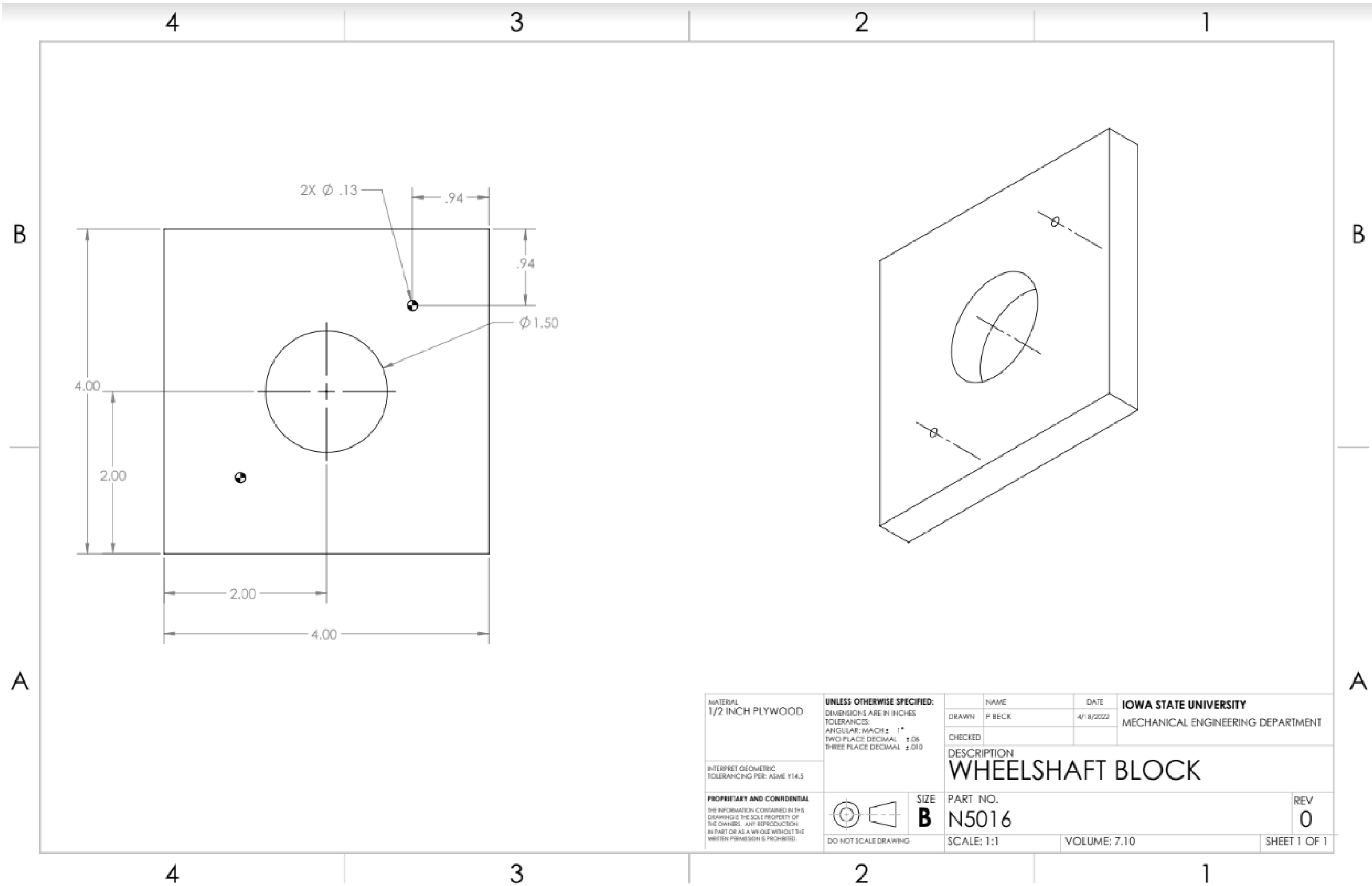
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
JOHN MURRAY
4/20/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
WHEELSHAFT RING
SIZE
B
PART NO.
N5015
REV
0
SCALE: 2:1
VOLUME:
SHEET 1 OF 1

HOME

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N5015 | Part Name: | Wheelshaft Ring | Prepared By: | John Murray |
| Team: | Kickstart Wheels | Sheet: | 1 of 1 | Date: | 2/18/2018 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Estimated Labor Hours Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Use 2" Holesaw blade to cut out a disc | Drill Press | 0.05 | 0.05 | |
| 2 | Use 1 1/8" Forstner Bit to cut center hole | Drill Press | 0.05 | 0.05 | Concentric with outer diameter |
| 3 | Cut off 1 of the three layers of plywood | Hacksaw | 0.05 | 0.05 | Use vice to hold piece |



2X Ø .13
.94
.94
Ø 1.50
4.00
2.00
2.00
4.00
MATERIAL
1/2 INCH PLYWOOD
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
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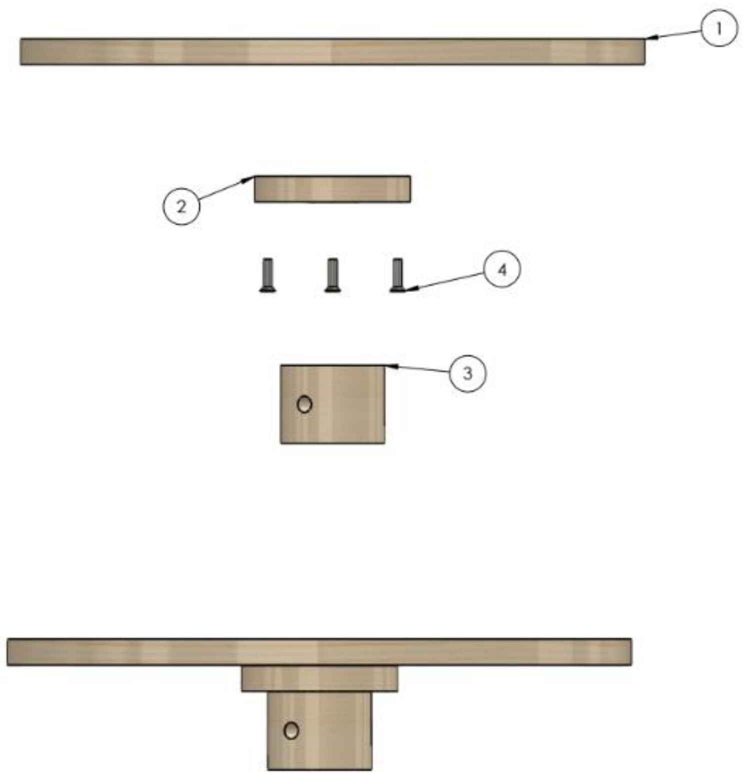
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
P BECK
4/18/2022
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
WHEELSHAFT BLOCK
PART NO.
N5016
REV
0
SCALE: 1:1
VOLUME: 7.10
SHEET 1 OF 1

## Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N5016 | Part Name: | Wheelshaft Block | Prepared By: | Robert Bengel |
| Team: | 5 | Sheet: | 1 of 1 | Date: | 4/18/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| | | | Set-up | Machine | |
| 1 | Cut board to specified width | Table Saw | 0 | 0 | |
| 2 | Cut board to specified side lengths | Miter Saw | 0 | 0.05 | |
| 3 | Drill mounting holes as specified | Drill Press | 0 | 0.05 | |
| 4 | Dril central hole as specified | Drill Press | 0 | 0.05 | |




| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | N5002 | Wheelhead | 1 |
| 2 | N5008 | Flange Base | 1 |
| 3 | N5009 | Flange | 1 |
| 4 | N5014 | 1/8" x 3/4" Flathead Screw | 4 |

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

PROPRIETARY AND CONFIDENTIAL
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | John Murray | 3/28/2022 |
| CHECKED | | |

IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

DESCRIPTION
WHEEL & FLANGE

SIZE B
PART NO. AN5101
REV 0

SCALE: 1:2
VOLUME:
SHEET 1 OF 1

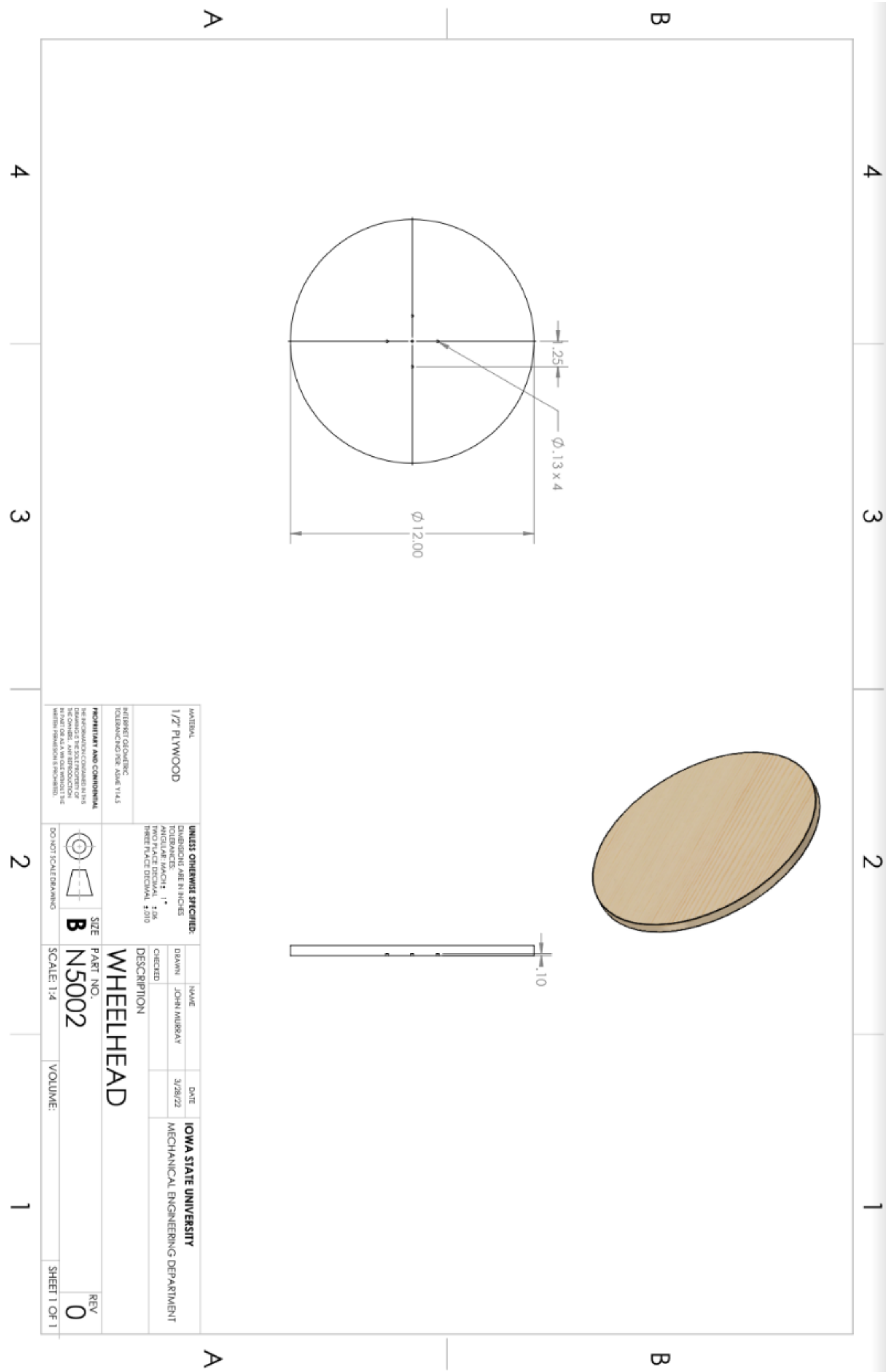
HOME

# Manufacturing Process Instruction

Part # : AN5101　Part Name: Wheel & Flange　Prepared By: John Murray

Team: Section 4 Team 5　Sheet: 1 of 1　Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Line up screwholes and glue (2) to (1) | Hands / Clamps | 0.05 | 0.05 | Let dry before further assembly |
| 2 | Insert (4) into (2) and (1) | Screwdriver | 0.05 | 0.05 | Screw flush to surface of 920 |
| 3 | Glue (3) to ( 2) | Hands / Clamps | 0.05 | 0.05 | Ensure center hole is concentric |

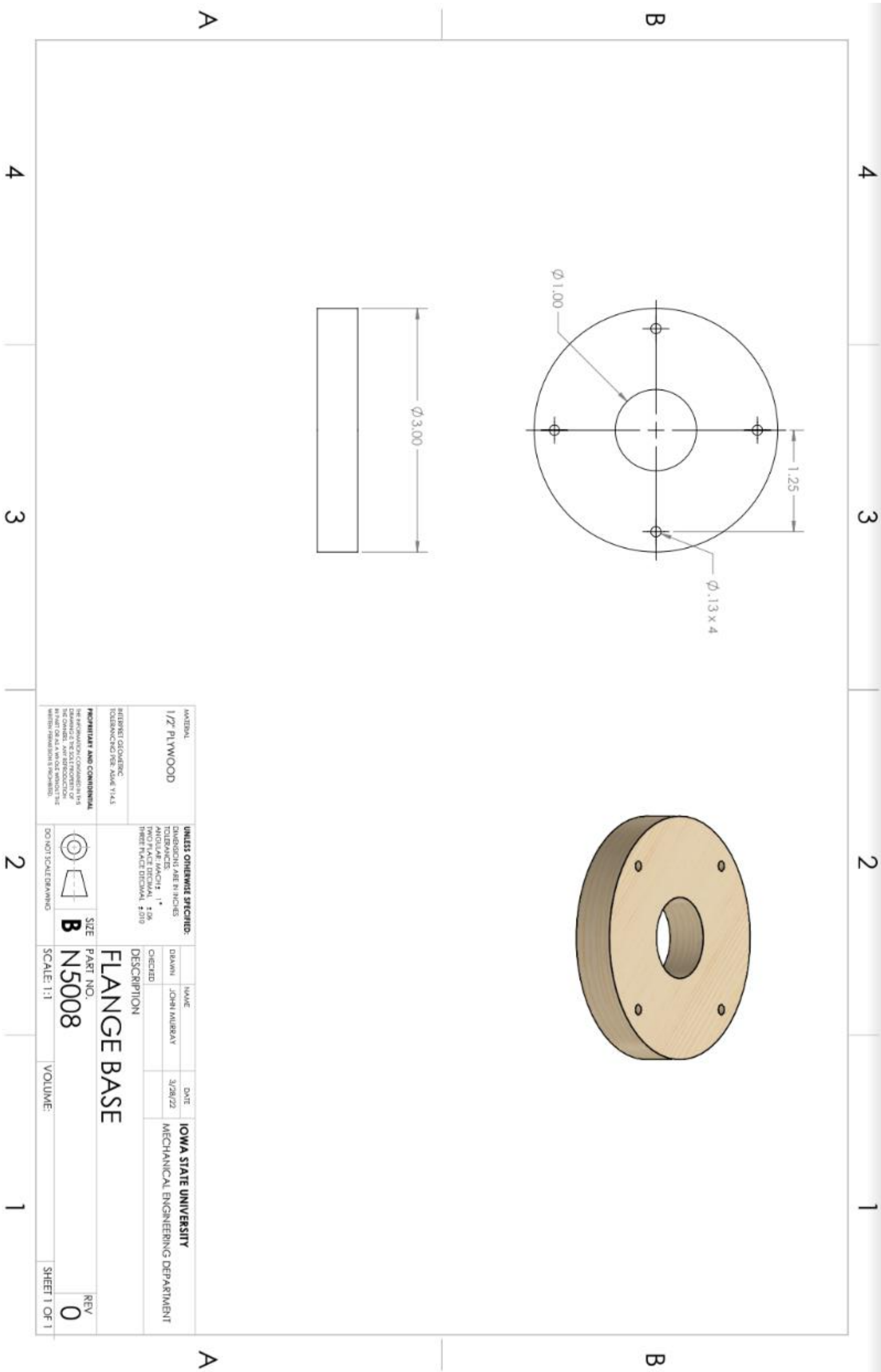

WHEELHEAD
PART NO.
N5002
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
MATERIAL
1/2" PLYWOOD
DRAWN JOHN MURRAY 3/28/22
SCALE: 1:4
SHEET 1 OF 1
SIZE B
REV 0
Ø12.00
Ø.13 x 4
.25
.10
DO NOT SCALE DRAWING
UNLESS OTHERWISE SPECIFIED:
PROPRIETARY AND CONFIDENTIAL

HOME

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N5002 | Part Name: | Wheelhead | Prepared By: | John Murray |
| Team: | ME 270 Section 4 Team 5 | Sheet: | 1 of 1 | Date: | 3/26/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut board to rough dimensions | Table Saw | 0.1 | 0.1 | Leave extra room for sanding |
| 2 | Cut out circle to specified diamter | V-Bandsaw | 0.1 | 0.1 | Leave extra room for sanding |
| 3 | Sand edges smooth into circle | Belt Sander | 0.1 | 0.1 | |


1.25
Ø.13 x 4
Ø1.00
Ø3.00
MATERIAL
1/2" PLYWOOD
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
NAME
DATE
DRAWN
JOHN MURRAY
3/28/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
FLANGE BASE
SIZE
B
PART NO.
N5008
REV
0
DO NOT SCALE DRAWING
SCALE: 1:1
VOLUME:
SHEET 1 OF 1

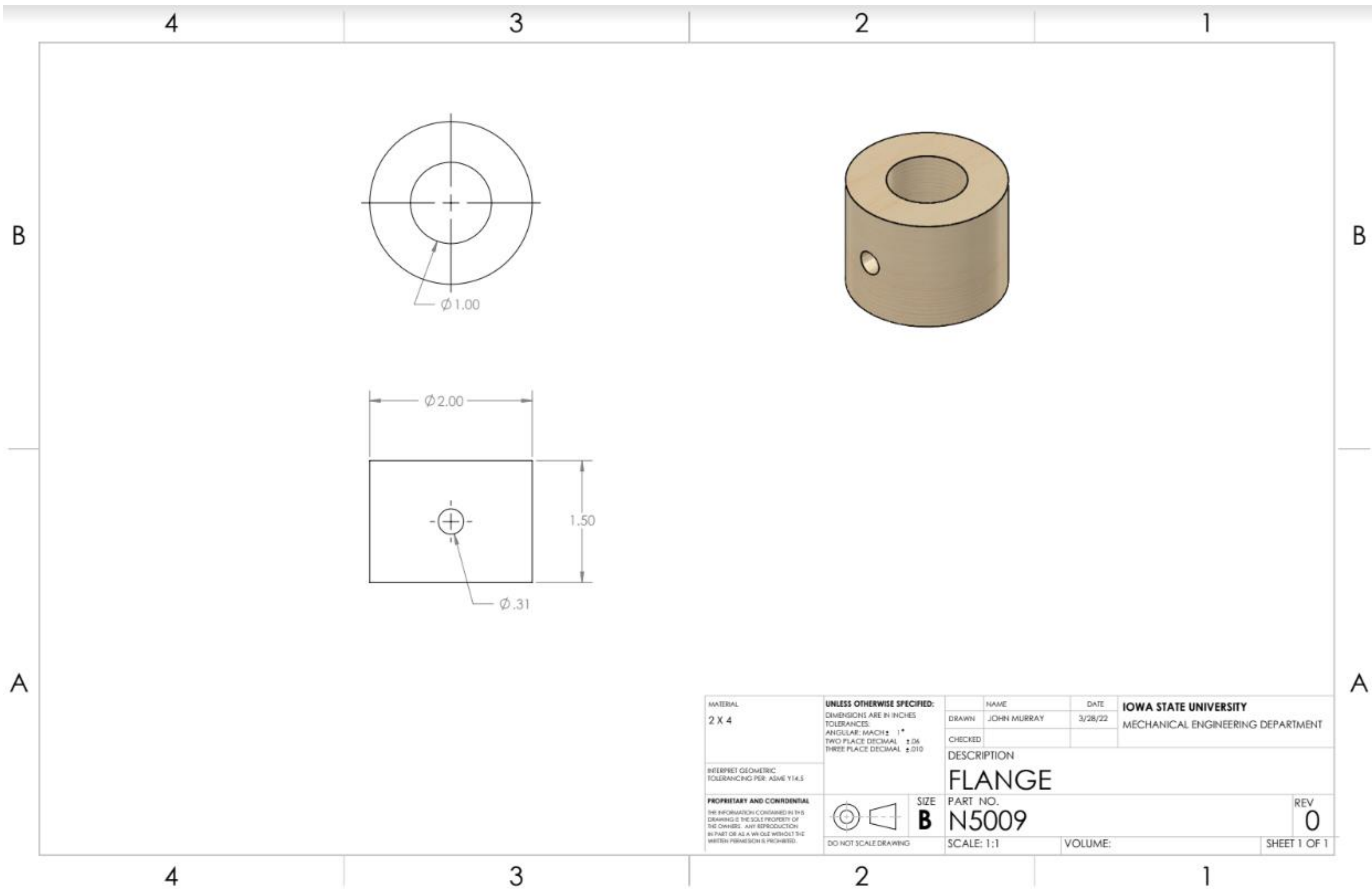
HOME

# Manufacturing Process Instruction

Part # : N5008 Part Name: Falange Base Prepared By: John Murray

Team: Section 4 Team 5 Sheet: 1 of 1 Date: 3/26/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut board to square | Table saw | 0.1 | 0.1 | Leave extra material |
| 2 | Cut circle out of board to desired diameter | V-Bandsaw | 0.1 | 0.1 | Leave extra material |
| 3 | Sand edges | Belt Sander | 0.1 | 0.1 | Sand to curve |


Ø1.00
Ø2.00
1.50
Ø.31
MATERIAL
2 X 4
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
JOHN MURRAY
3/28/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
FLANGE
SIZE
B
PART NO.
N5009
REV
0
SCALE: 1:1
VOLUME:
SHEET 1 OF 1

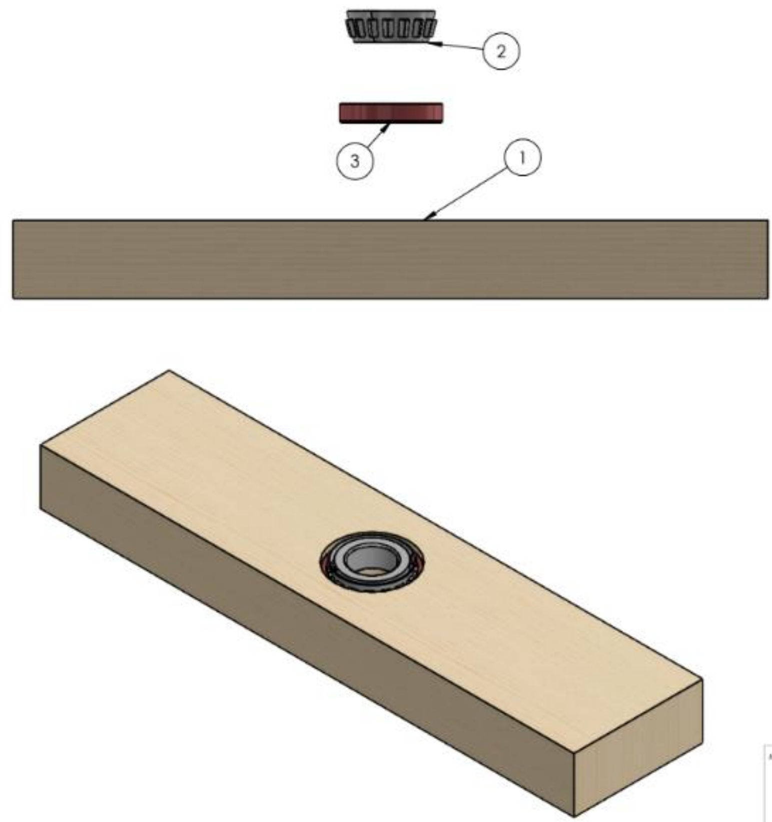
HOME

# Manufacturing Process Instruction

Part # : N5009 Part Name: Falange Prepared By: John Murray

Team: Section 4 Team 5 Sheet: 1 of 1 Date: 3/26/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut board square to rough dimesnions | Miter saw | 0.1 | 0.1 | Leave extra material |
| 2 | Drill side hole | Drill press | 0.1 | 0.1 | Through all |
| 3 | Drill center hole | Drill press | 0.1 | 0.1 | Through all |
| 4 | Cut board round to desired diamter | V-bandsaw | 0.1 | 0.1 | Leave extra material |
| 5 | Smooth edges | Belt Sander | 0.1 | 0.1 | Sand smooth |




| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | N5007 | Bearing Support | 1 |
| 2 | N5003 | Taper Roller Bearing | 1 |
| 3 | N5013 | Taper Roller Bearing Cup | 1 |

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

**PROPRIETARY AND CONFIDENTIAL**

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DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | John Murray | 3/28/2022 |
| CHECKED | | |

**IOWA STATE UNIVERSITY**
MECHANICAL ENGINEERING DEPARTMENT

DESCRIPTION
SUPPORT BEARING SUB-ASSEMBLY

SIZE **B** | PART NO. AN5201 | REV 0

SCALE: 1:2 | VOLUME: | SHEET 1 OF 1

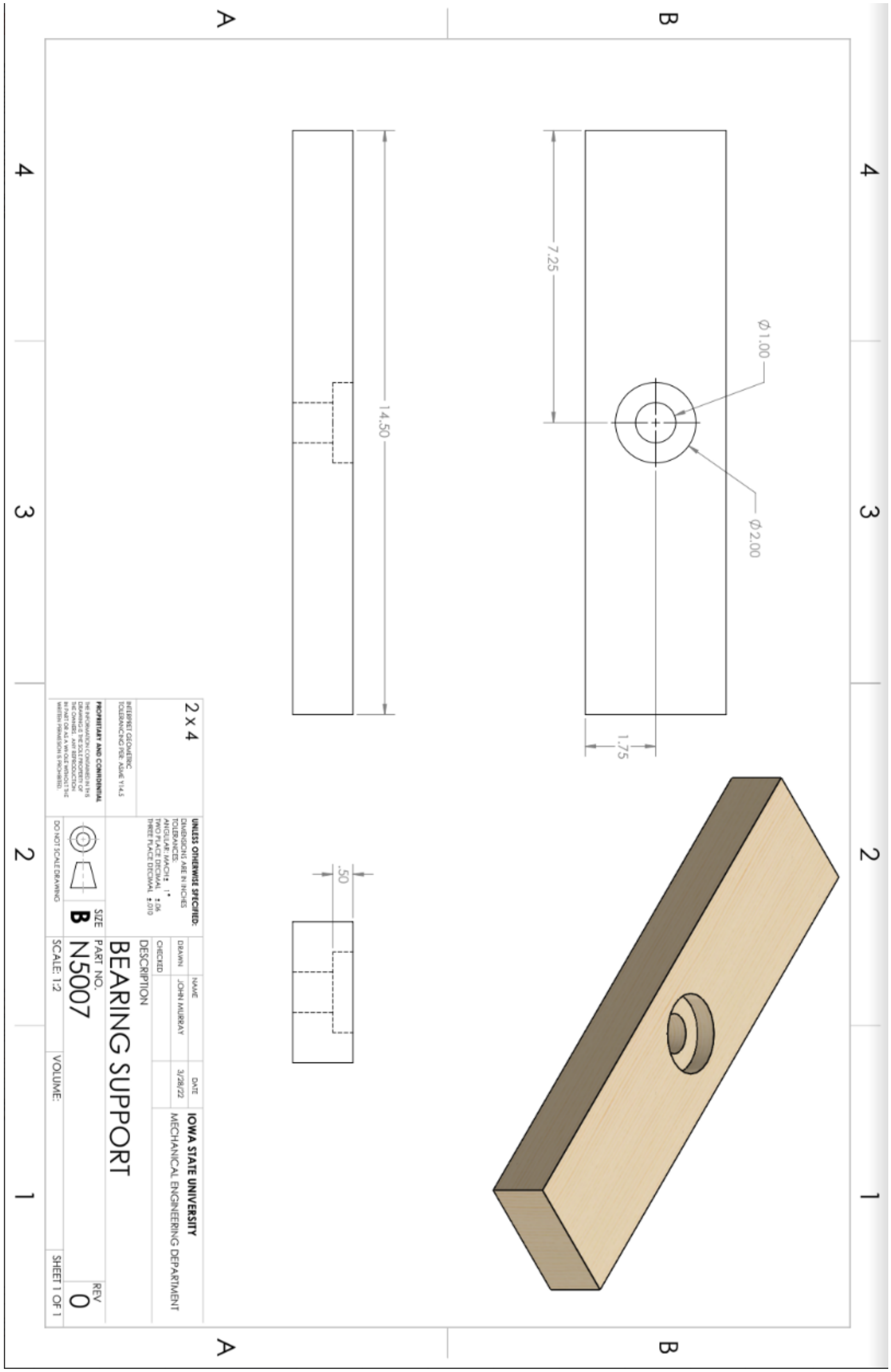
HOME

# Manufacturing Process Instruction

Part # : AN5201 Part Name: Support Bearing Sub-Assembly Prepared By: John Murray

Team: Section 4 Team 5 Sheet: 1 of 1 Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Glue (3) inside center hole of (1) | Hands | 0.05 | 0.05 | Let dry before further assembly |
| 2 | Insert (2) inside of center hole of assembly | Hands | 0.05 | 0.05 | |


Ø1.00
Ø2.00
7.25
14.50
1.75
.50
2 x 4
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
JOHN MURRAY
3/28/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
BEARING SUPPORT
PART NO.
N5007
REV
0
SCALE: 1:2
VOLUME:
SHEET 1 OF 1

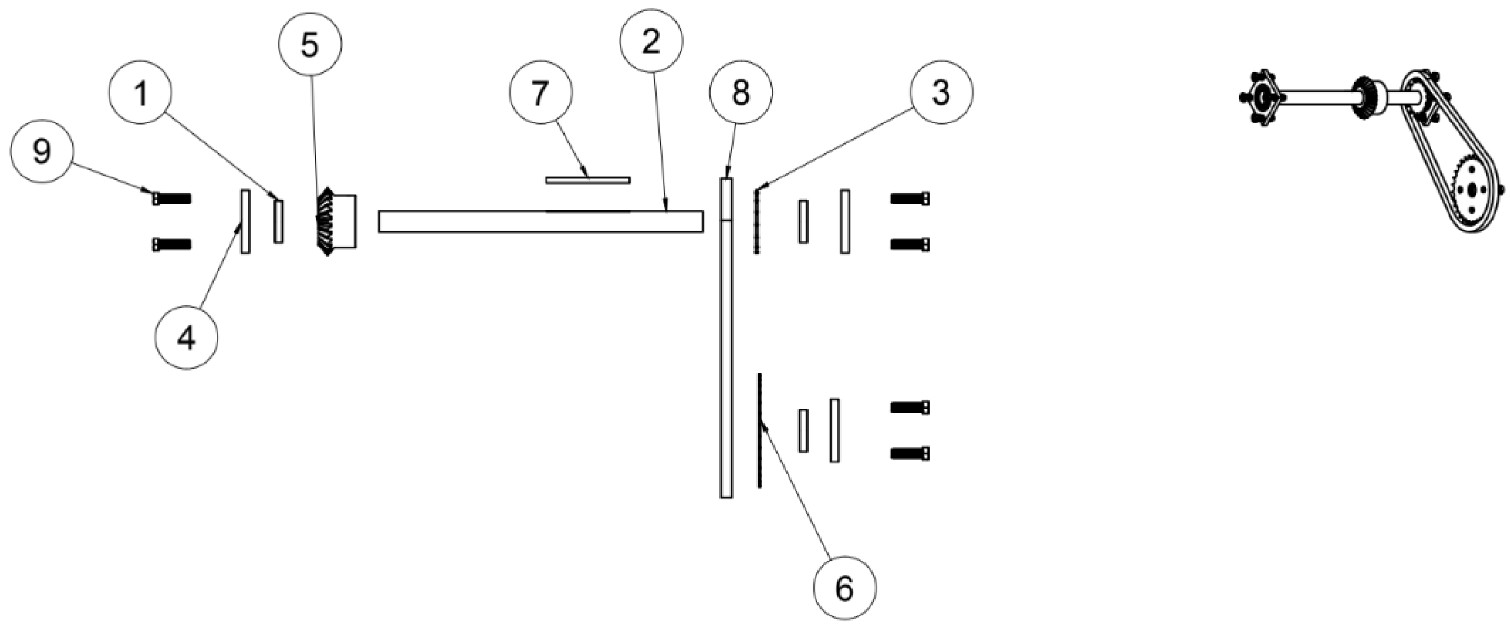
HOME

# Manufacturing Process Instruction

Part # : N5007 Part Name: Bearing Support Prepared By: John Murray

Team: Section 4 Team 5 Sheet: 1 of 1 Date: 3/26/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut board to specifed length | Miter Saw | 0.1 | 0.1 | Cut square |
| 2 | Drill top hole to desired depth | Drill Press | 0.1 | 0.1 | Ensure tolerence is met |
| 3 | Drill center hole | Drill Press | 0.1 | 0.1 | Through All |




| PARTS LIST | | | | |
|---|---|---|---|---|
| ITEM | QTY | PART NUMBER | DESCRIPTION | MATERIAL |
| 1 | 3 | N4005 | R16 bearing | STEEL |
| 2 | 1 | N4004 | Ouput shaft | PVC-PIPING |
| 3 | 1 | N4002 | Output sprocket | ALUMINUM |
| 4 | 3 | N2005 | Bearing Plate | PLYWOOD, FINISH |
| 5 | 1 | N5005 | Miter gear | NYLON 6 |
| 6 | 1 | N3002 | Drive Sprocket | ALUMINUM |
| 7 | 1 | N4007 | Horizontal miter gear key | STEEL |
| 8 | 1 | N4009 | Drive Chain | STEEL |
| 9 | 12 | N1007 | $\frac{1}{4}$"bolt | STEEL |

| | | | | |
|---|---|---|---|---|
| | PROJECT<br>ME 270 | | | |
| | TITLE<br>Horizontal bevel gear assembly | | | |
| APPROVED | SIZE | CODE | DWG NO | REV |
| CHECKED | B | | AN4001 | 0 |
| DRAWN Evan Schneider 3/29/22 | SCALE 1:5 | WEIGHT | | SHEET 1/1 |

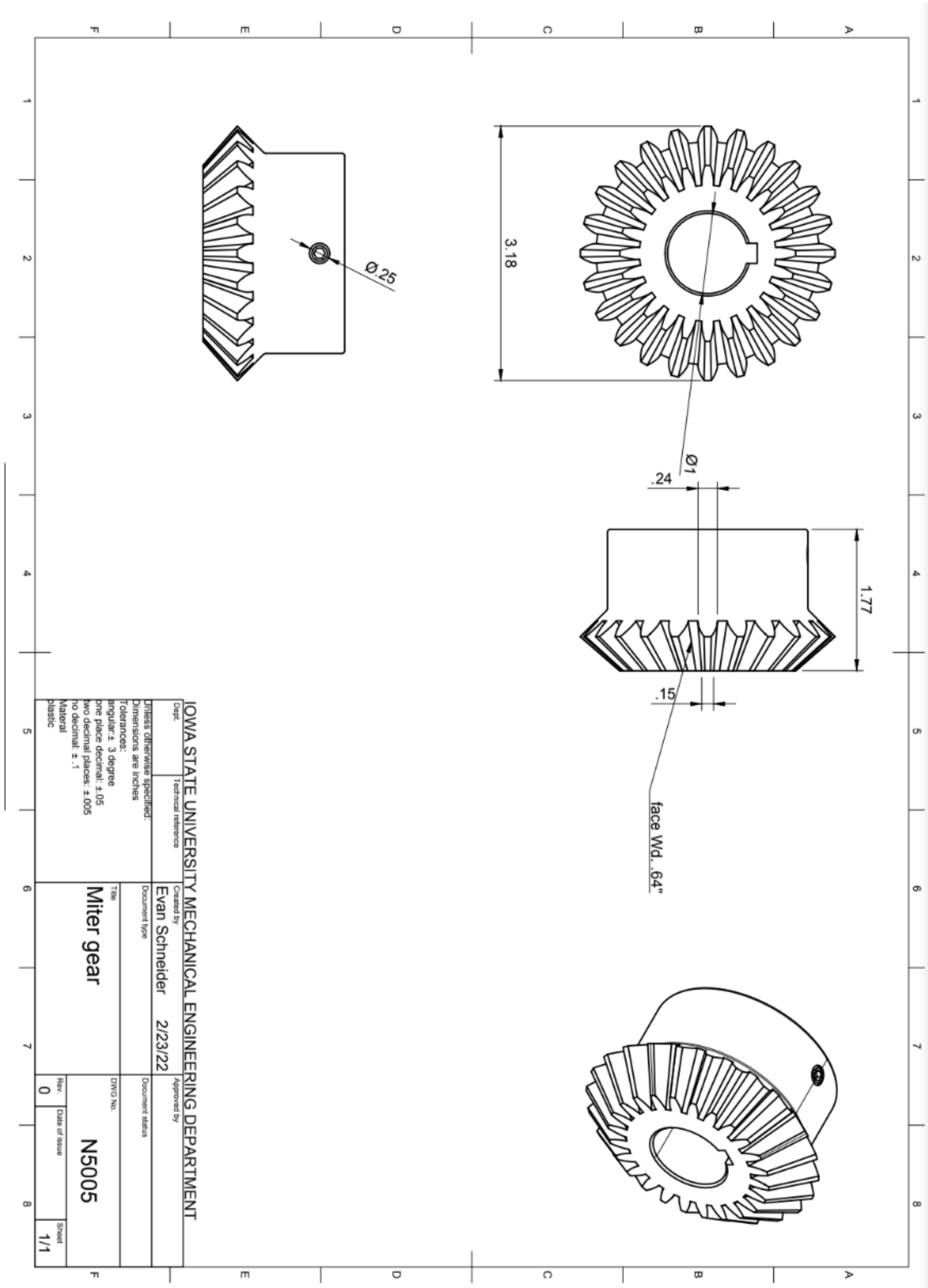
HOME

# Manufacturing Process Instruction

Part # : AN4001 Part Name: HORIZONTAL BEVEL GEAR ASSEMBLY Prepared By: PATRICK BECK

Team: SECTION 4 TEAM 5 -- KICK START WHEELS Sheet: 1 of 1 Date: 3/9/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | stimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Slide (5) onto (2) and glue securely | Hands/CA Glue | 0.05 | 0.1 | |
| 2 | Insert (7) into (2) | Hands | 0 | 0.05 | |
| 3 | Slide (3) onto (2) and tighten set screw in (3) | crewdriver/ Hand | 0 | 0.05 | |
| 4 | Tighten set screw in (5) | Screwdriver | 0 | 0.05 | |
| 5 | Slide (1) onto (2) at both ends of (2) | Hands/Hammer | 0.05 | 0.15 | Ensure (1) seated properly on (2) |
| 6 | Insert (1) into (4) | Hands | 0 | 0.05 | |
| 7 | Place (8) on (3) and connect teeth to chain | Hands | 0 | 0.05 | |
| 8 | Slide (1) onto (6) | Hands/Hammer | 0.05 | 0.1 | |
| 9 | slide (1) (mounted on (6)) into (4) | Hands | 0 | 0.05 | |
| 10 | Place (6) onto (8) and connect teeth to chain | Hands | 0 | 0.05 | |
| 11 | Screw in and tighten (9) into (4) | Wrench | 0 | 0.15 | nounting holes on (4) have (9) bolted on, 12 total |


3.18
Ø.25
Ø1
.24
1.77
.15
face Wd. .64"
IOWA STATE UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
Dept.
Technical reference
Created by
Evan Schneider 2/23/22
Approved by
Document type
Document status
Title
Miter gear
DWG No.
N5005
Rev.
0
Date of issue
Sheet
1/1
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular: ± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ± .1
Material
plastic

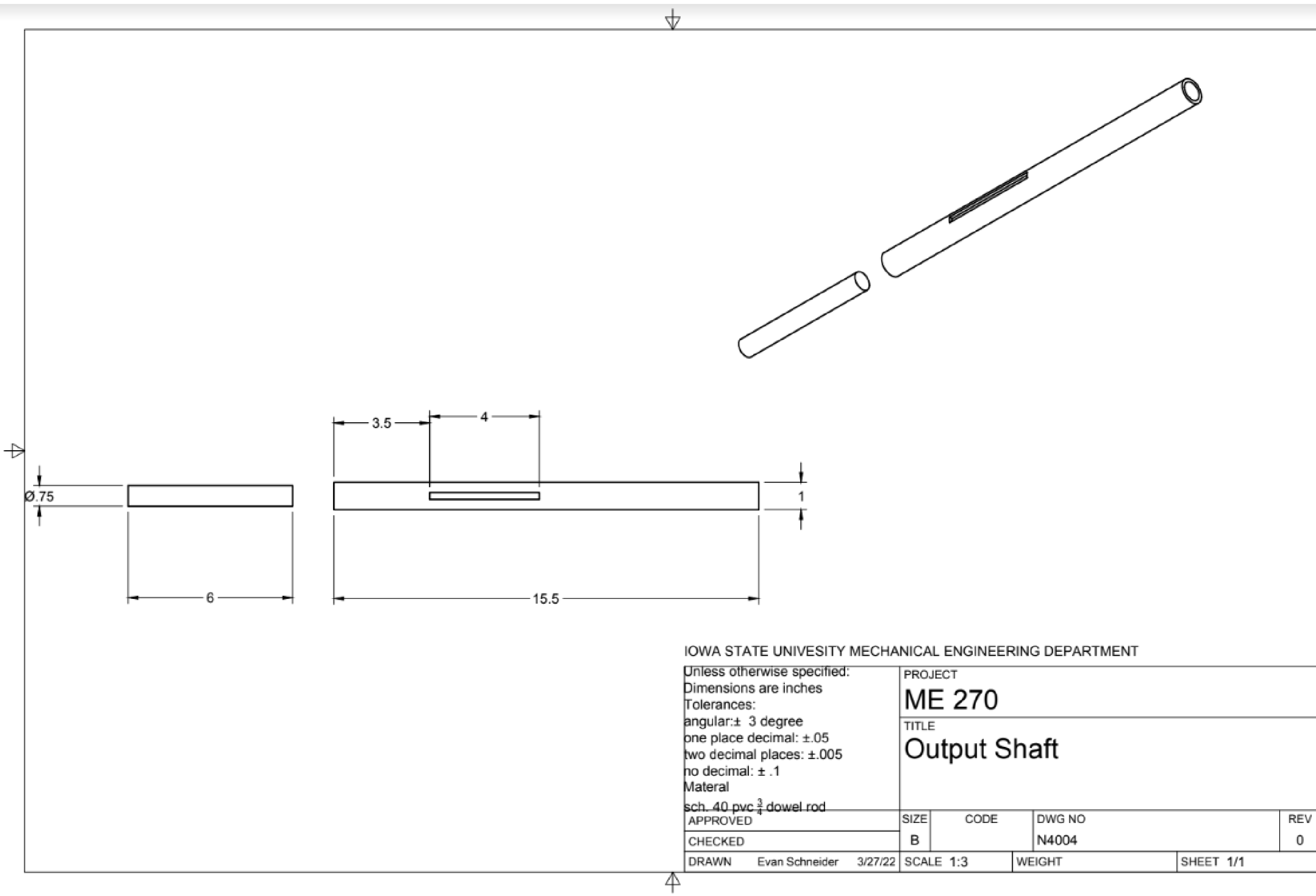
HOME

# Manufacturing Process Instruction

Part # : N5005 Part Name: MITER GEAR Prepared By: PATRICK BECK

Team: SECTION 4 TEAM 5 -- KICK START WHEELS Sheet: 1 of 1 Date: 3/9/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | stimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | 3-D Print Miter Gear Using CAD Part | 3-D Printer | 0.2 | 0.1 | Operator Not Necessary During Printing of Part |


Ø.75
6
3.5
4
15.5
1
IOWA STATE UNIVESITY MECHANICAL ENGINEERING DEPARTMENT
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular:± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ± .1
Materal
sch. 40 pvc 3/4 dowel rod
PROJECT
ME 270
TITLE
Output Shaft
APPROVED
CHECKED
DRAWN Evan Schneider 3/27/22
SIZE B
CODE
DWG NO N4004
REV 0
SCALE 1:3
WEIGHT
SHEET 1/1

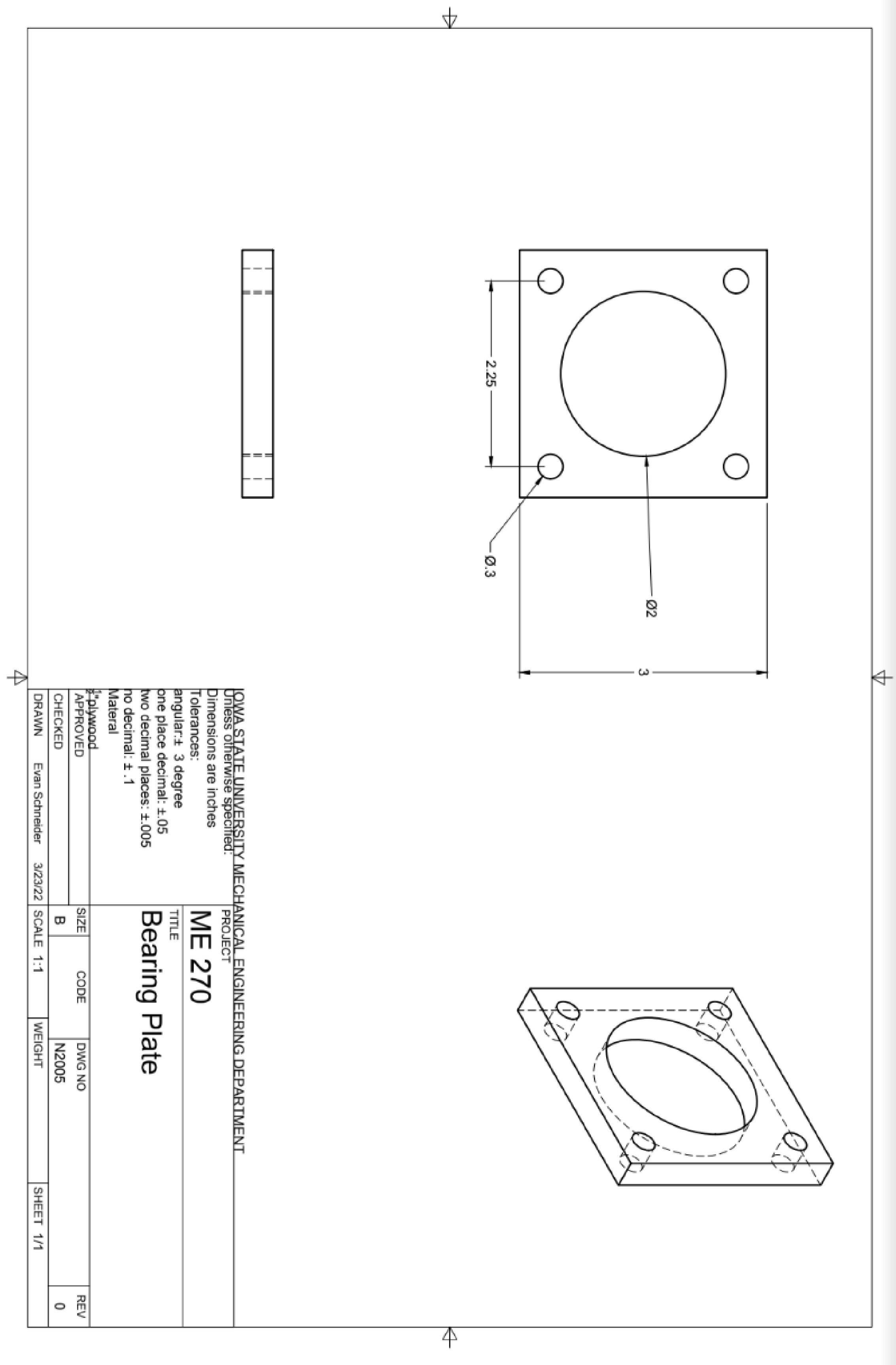
HOME

# Manufacturing Process Instruction

Part # : N4004 Part Name: OUTPUT SHAFT Prepared By: PATRICK BECK

Team: SECTION 4 TEAM 5 -- KICK START WHEELS Sheet: 1 of 1 Date: 3/9/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | stimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut pipe to length in drawing | PVC Cutter | 0.1 | 0.1 | Cut tubing square |
| 2 | Drill holes at each end of the key channel | Drill Press | 0.1 | 0.1 | Ensure tolerances are met |
| 3 | Cut key hole as specfied | Jigsaw | 0.1 | 0.1 | Ensure tolerances are met |


2.25
Ø.3
Ø2
3
IOWA STATE UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular:± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ± .1
Materal
¾" plywood
APPROVED
CHECKED
DRAWN Evan Schneider 3/23/22
PROJECT
ME 270
TITLE
Bearing Plate
SIZE
B
CODE
DWG NO
N2005
REV
0
SCALE 1:1
WEIGHT
SHEET 1/1

HOME

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N2005 | Part Name: | BEARING PLATE | Prepared By: | PATRICK BECK |
| Team: | SECTION 4 TEAM 5 -- KICK START WHEELS | Sheet: | 1 of 1 | Date: | 3/9/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | stimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut board to specified width | Table Saw | 0.1 | 0.1 | Ensure cuts are square |
| 2 | Cut board to specified side lengths | Miter Saw | 0.1 | 0.1 | Ensure cuts are square |
| 3 | Drill mounting holes as specified | Drill Press | 0.1 | 0.15 | Repeat for all four holes |
| 4 | Drill center bearing hole | Drill Press | 0.1 | 0.05 | |


IOWA STATE UNIVESITY MECHANICAL ENGINEERING DEPARTMENT

| | | | | | |
|---|---|---|---|---|---|
| Unless otherwise specified:<br>Dimensions are inches<br>Tolerances:<br>angular:± 3 degree<br>one place decimal: ±.05<br>two decimal places: ±.005<br>no decimal: ± .1<br>Materal<br>.25 key stock | PROJECT<br>ME 270<br>TITLE<br>Horizontal Miter Key | | | | |
| APPROVED | SIZE | CODE | DWG NO | | REV |
| CHECKED | B | | N4007 | | 0 |
| DRAWN Evan Schneider 3/23/22 | SCALE 1:1 | | WEIGHT | SHEET 1/1 | |

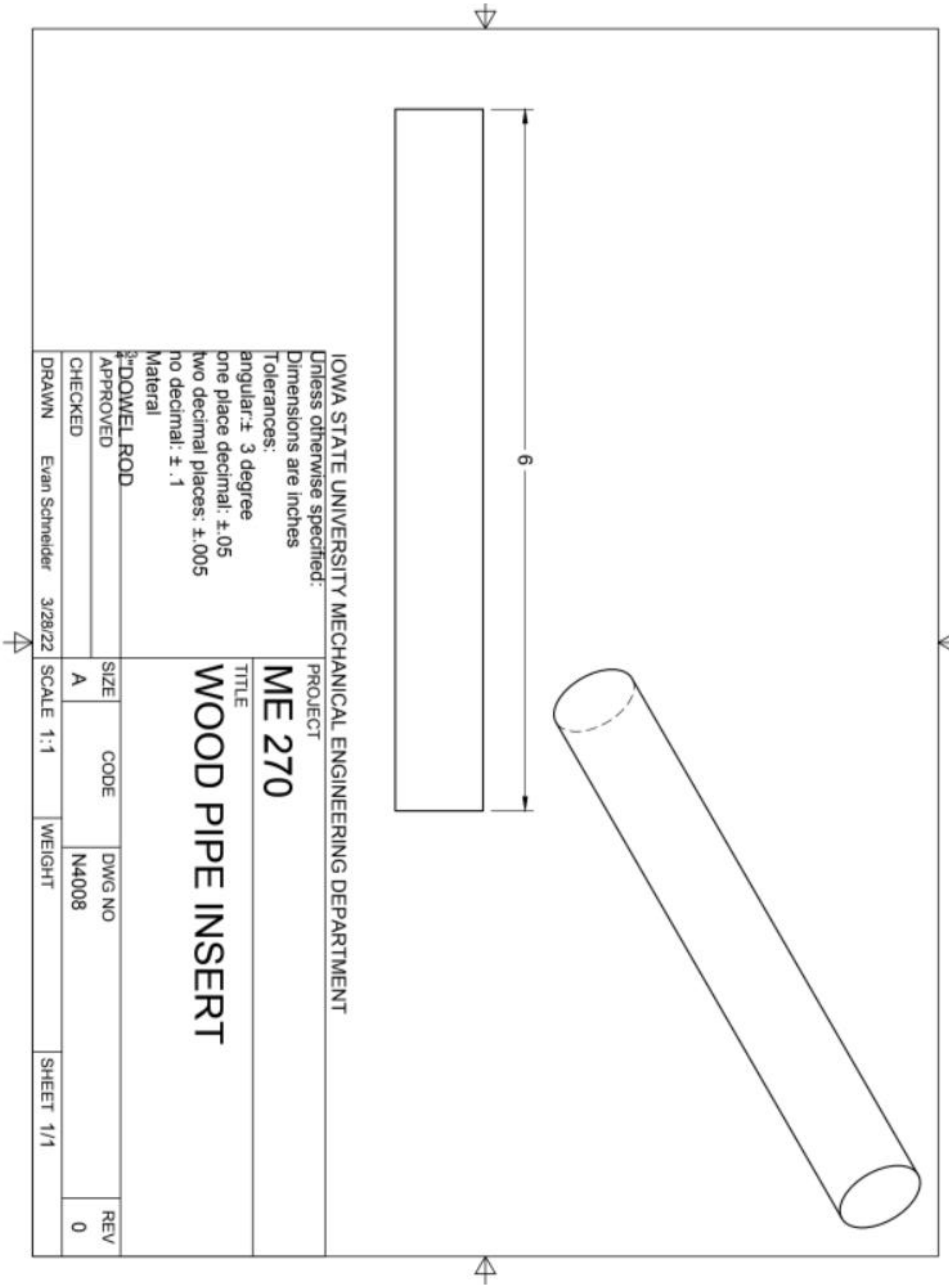
HOME

# Manufacturing Process Instruction

Part # : N4007 Part Name: HORIZONTAL MITER KEY Prepared By: PATRICK BECK

Team: SECTION 4 TEAM 5 -- KICK START WHEELS Sheet: 1 of 1 Date: 3/9/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut key stock to specifed length | Hacksaw | 0.05 | 0.1 | Cut stock square |

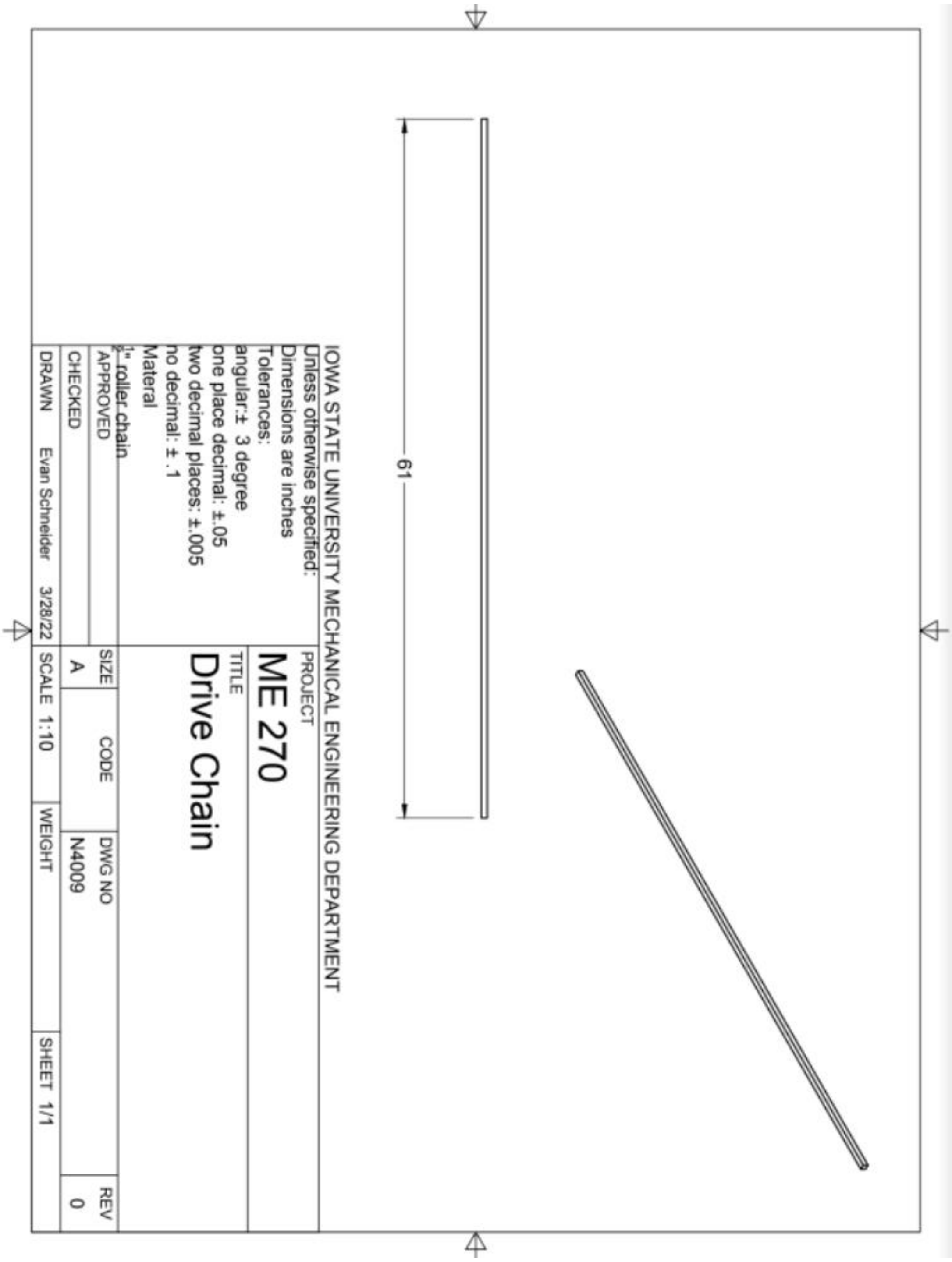

6
IOWA STATE UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular:± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ± .1
Materal
3/4"DOWEL ROD
APPROVED
CHECKED
DRAWN Evan Schneider 3/28/22
PROJECT
ME 270
TITLE
WOOD PIPE INSERT
SIZE A
CODE
DWG NO N4008
REV 0
SCALE 1:1
WEIGHT
SHEET 1/1

HOME

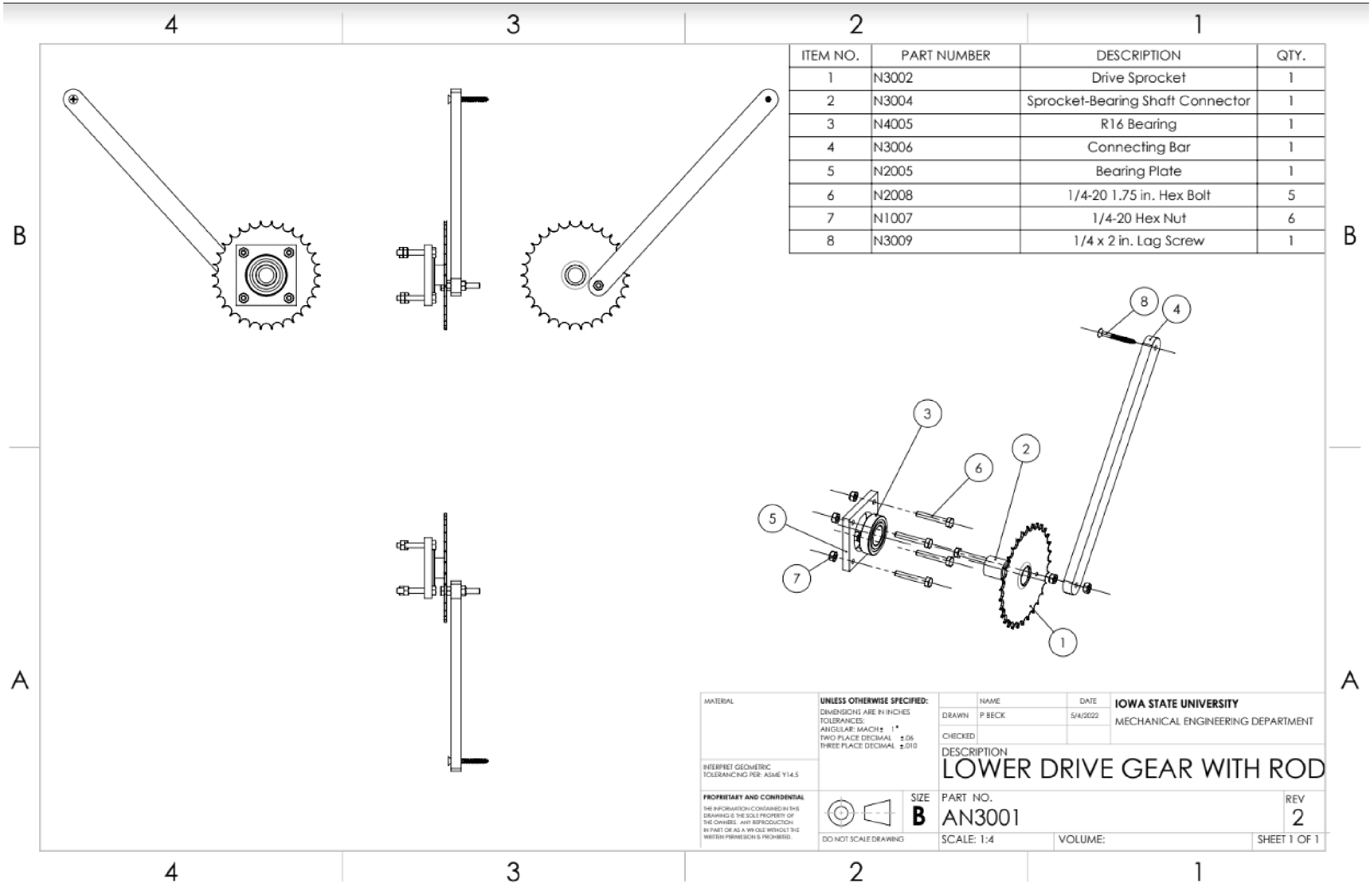
# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N4008 | Part Name: | WOOD PIPE INSERT | Prepared By: | PATRICK BECK |
| Team: | SECTION 4 TEAM 5 -- KICK START WHEELS | Sheet: | 1 of 1 | Date: | 3/9/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | :stimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut pipe to specified length | Miter Saw | 0.05 | 0.05 | Cut rod square |
| 2 | Cut key hole as specified | Chisel | 0.1 | 0.1 | hole square for all angles, ensure tolerances are |



61
IOWA STATE UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular:± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ± .1
Materal
1" roller chain
APPROVED
CHECKED
DRAWN Evan Schneider 3/28/22
PROJECT
ME 270
TITLE
Drive Chain
SIZE
A
CODE
DWG NO
N4009
REV
0
SCALE 1:10
WEIGHT
SHEET 1/1

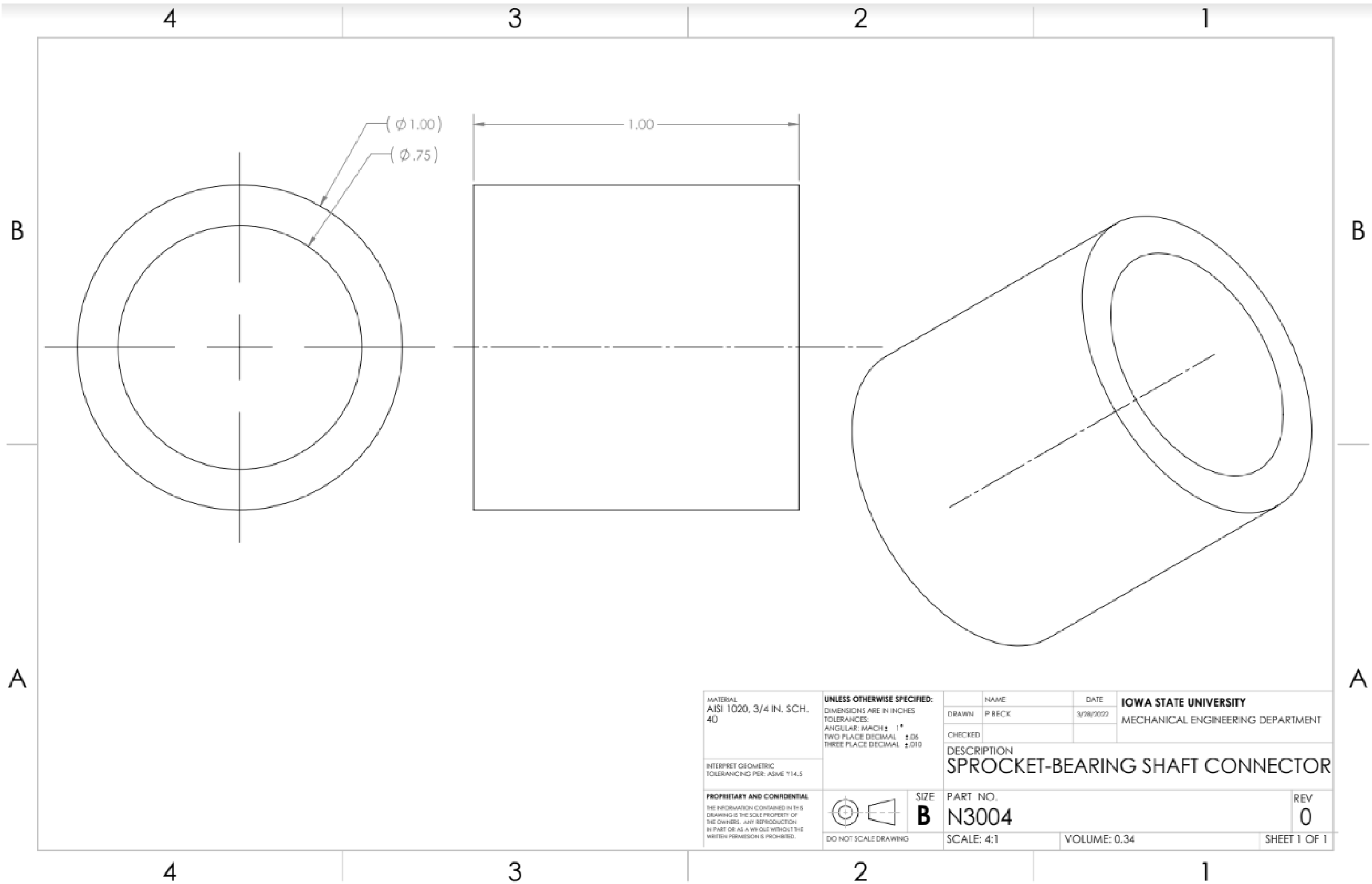



| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | N3002 | Drive Sprocket | 1 |
| 2 | N3004 | Sprocket-Bearing Shaft Connector | 1 |
| 3 | N4005 | R16 Bearing | 1 |
| 4 | N3006 | Connecting Bar | 1 |
| 5 | N2005 | Bearing Plate | 1 |
| 6 | N2008 | 1/4-20 1.75 in. Hex Bolt | 5 |
| 7 | N1007 | 1/4-20 Hex Nut | 6 |
| 8 | N3009 | 1/4 x 2 in. Lag Screw | 1 |

# Manufacturing Process Instruction

| | | | | | | |
|---|---|---|---|---|---|---|
| Part # : | AN3001 | Part Name: | Lower Drive Gear with Rod Assembly | | Prepared By: | Patrick Beck |
| Team: | Section 4 Team 5 -- Kick Start Wheels | Sheet: | 1 | of | 1 Date: | 3/28/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Weld (2) to (1) according to the connection shown in the drawing | Welder | 0.05 | 0.02 | Ensure (2) is centered on (1) |
| 2 | Slide (3) over (2) | Hammer/Hand | 0 | 0.01 | Ensure edges of (3) and (2) are flush |
| 3 | Insert (6) into (5) | Hands | 0 | 0.01 | (4 Total Bolts Used) |
| 4 | Insert (6) into (1) | Hands | 0 | 0.01 | (1 Total Bolt Used) |
| 5 | Screw (7) onto (6) | Hands | 0 | 0.01 | Tighten (7) until there is friction present between surfaces of parts (5 Total Nuts Used |
| 6 | Slide (3) into (5) | Hammer/Hands | 0 | 0.01 | |
| 7 | Insert (6) into hole in (4) | Hands | 0 | 0.01 | |
| 8 | Screw (7) onto (6) | Hands | 0 | 0.01 | Tighten (7) until there is friction present between surfaces of parts (1 Total Nut Used) |
| 9 | Insert (8) into outer/other hole in (4) | Hands | 0 | 0.01 | Ensure negligible friction between (8) and (4) when inserted |



4
3
2
1
B
A
( Ø1.00 )
( Ø.75 )
1.00
MATERIAL
AISI 1020, 3/4 IN. SCH. 40
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
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UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
SIZE
B
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
P BECK
3/28/2022
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
SPROCKET-BEARING SHAFT CONNECTOR
PART NO.
N3004
REV
0
SCALE: 4:1
VOLUME: 0.34
SHEET 1 OF 1

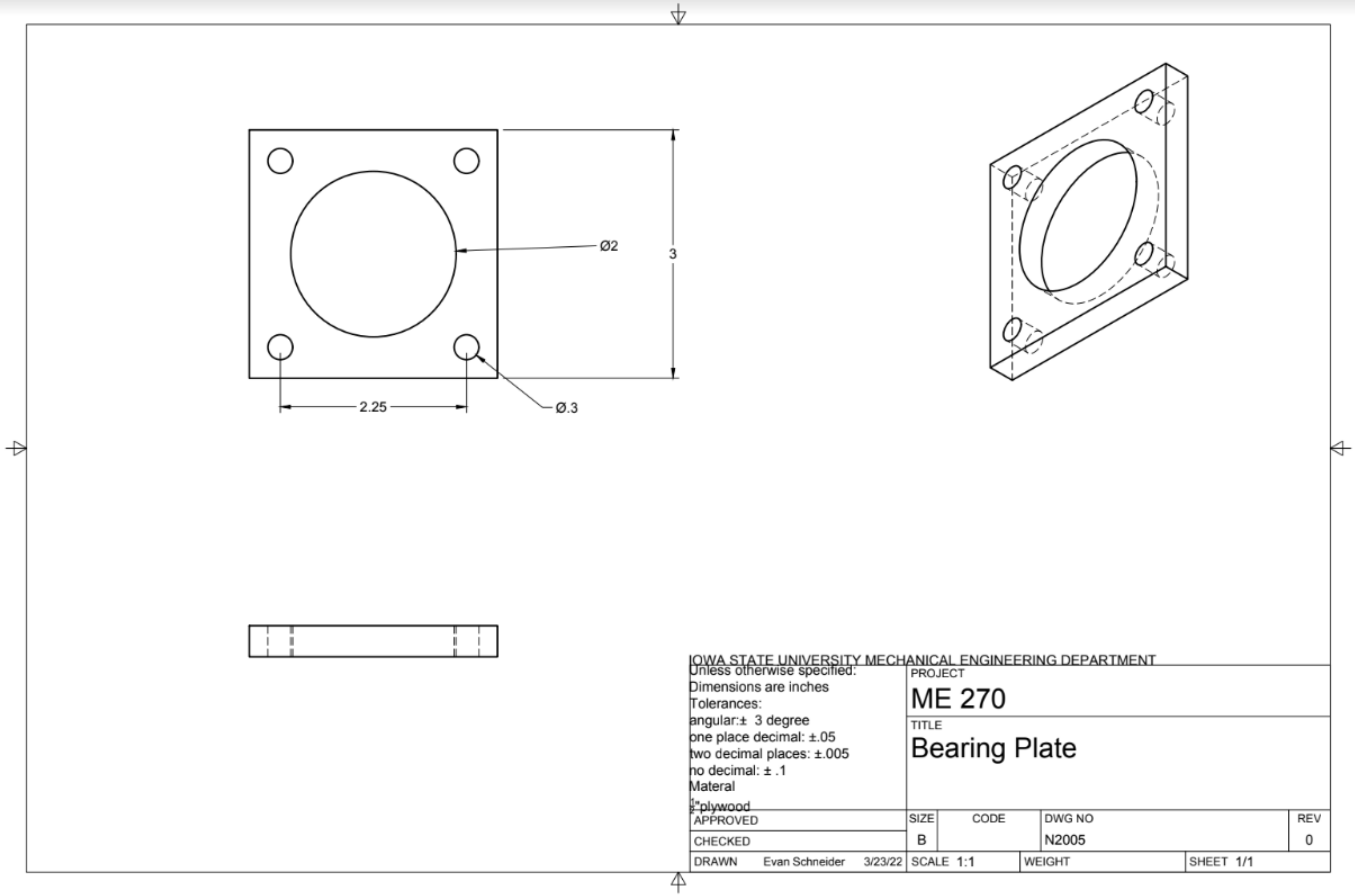
HOME

# Manufacturing Process Instruction

Part # : N3004 Part Name: Sprocket-Bearing Shaft Connector Prepared By: Patrick Beck

Team: Section 4 Team 5 -- Kick Start Wheels Sheet: 1 of 1 Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Cut pipe to specified length | Steel Pipe Cutte | 0.05 | 0.05 | Ensure cut is square |

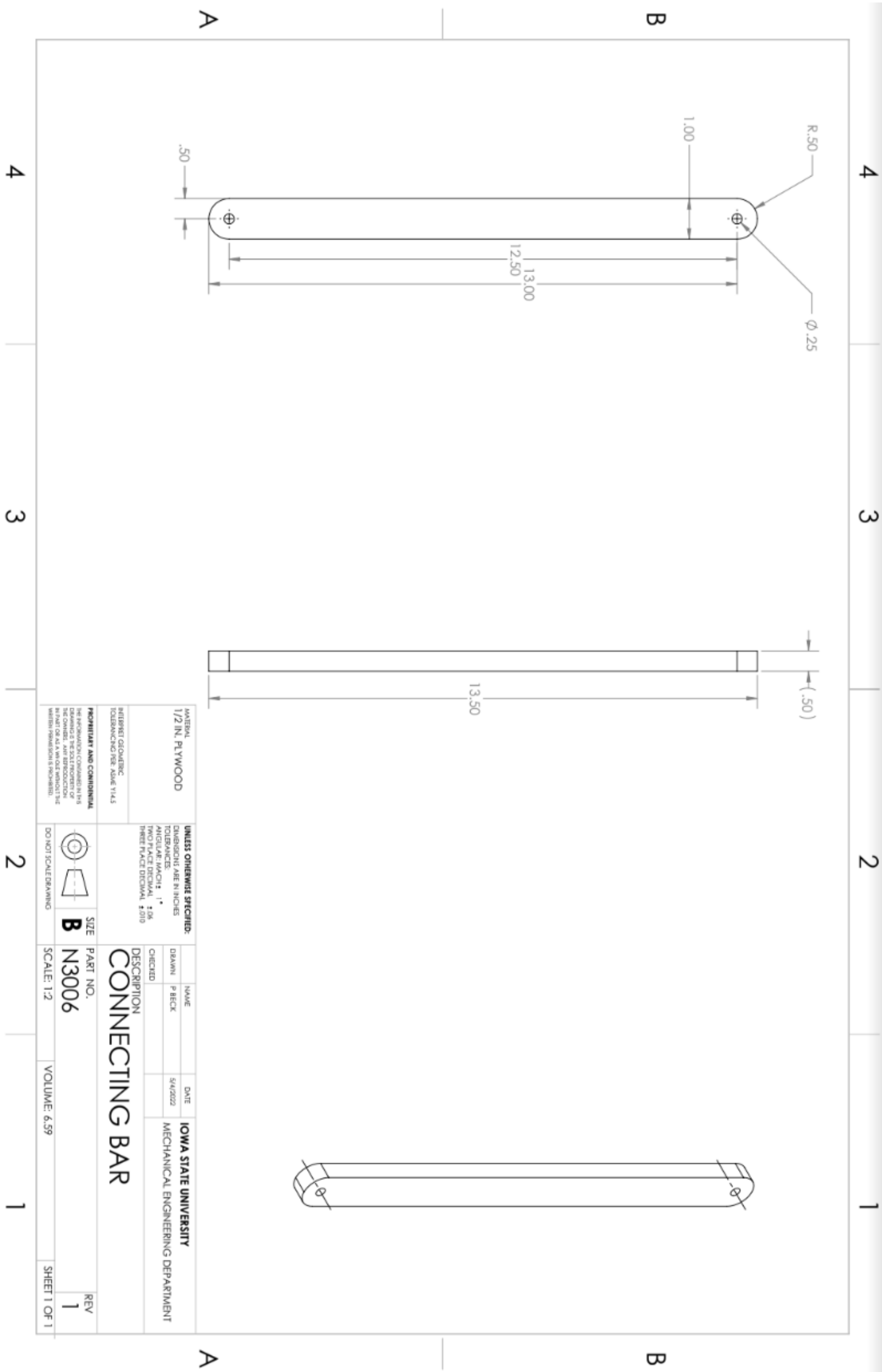

Ø2
3
2.25
Ø.3
IOWA STATE UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular:± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ± .1
Materal
½"plywood
APPROVED
CHECKED
DRAWN Evan Schneider 3/23/22
PROJECT
ME 270
TITLE
Bearing Plate
SIZE B
CODE
DWG NO N2005
REV 0
SCALE 1:1
WEIGHT
SHEET 1/1

HOME

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N2005 | Part Name: | BEARING PLATE | Prepared By: | PATRICK BECK |
| Team: | SECTION 4 TEAM 5 -- KICK START WHEELS | Sheet: | 1 of 1 | Date: | 3/9/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | stimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut board to specified width | Table Saw | 0.1 | 0.1 | Ensure cuts are square |
| 2 | Cut board to specified side lengths | Miter Saw | 0.1 | 0.1 | Ensure cuts are square |
| 3 | Drill mounting holes as specified | Drill Press | 0.1 | 0.15 | Repeat for all four holes |
| 4 | Drill center bearing hole | Drill Press | 0.1 | 0.05 | |


A
B
4
3
2
1
R.50
1.00
.50
12.50
13.00
Ø.25
13.50
(.50)
MATERIAL
1/2 IN. PLYWOOD
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
P BECK
5/4/2022
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
CONNECTING BAR
PART NO.
N3006
REV
1
SCALE: 1:2
VOLUME: 6.59
SHEET 1 OF 1

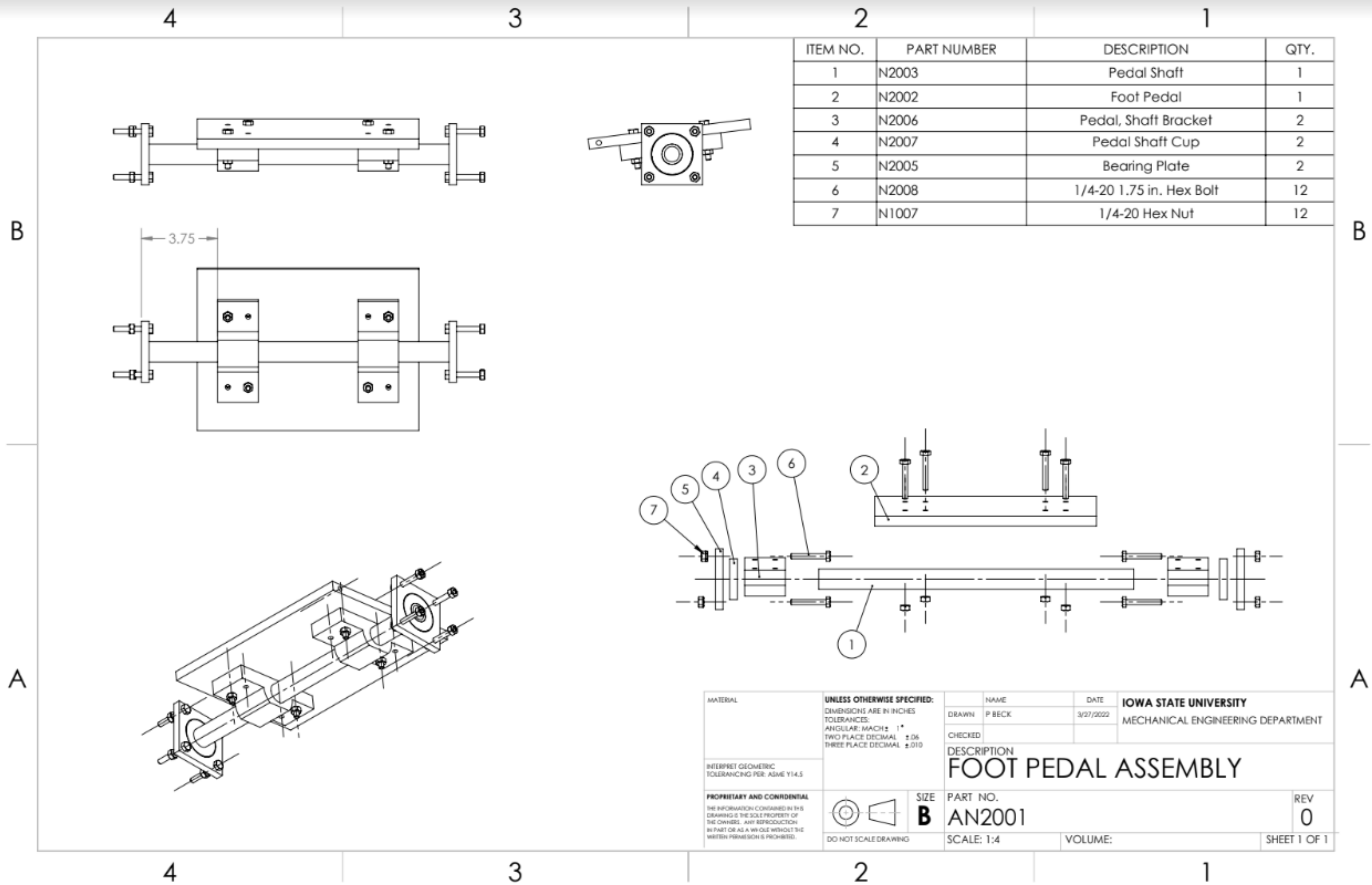
HOME

# Manufacturing Process Instruction

Part # : N3006 Part Name: Connecting Bar Prepared By: Patrick Beck

Team: Section 4 Team 5 -- Kick Start Wheels Sheet: 1 of 1 Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to specified width | Table Saw | 0.05 | 0.05 | Ensure cut is square |
| 2 | Cut wood to specified length | Miter Saw | 0.05 | 0.05 | Ensure cut is square |
| 3 | Drill bolt holes as specified in drawing | Drill Press | 0.05 | 0.05 | |
| 4 | Cut corner edge curves as specified in drawing | Vertical Band Saw | 0.05 | 0.1 | |




| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | N2003 | Pedal Shaft | 1 |
| 2 | N2002 | Foot Pedal | 1 |
| 3 | N2006 | Pedal, Shaft Bracket | 2 |
| 4 | N2007 | Pedal Shaft Cup | 2 |
| 5 | N2005 | Bearing Plate | 2 |
| 6 | N2008 | 1/4-20 1.75 in. Hex Bolt | 12 |
| 7 | N1007 | 1/4-20 Hex Nut | 12 |

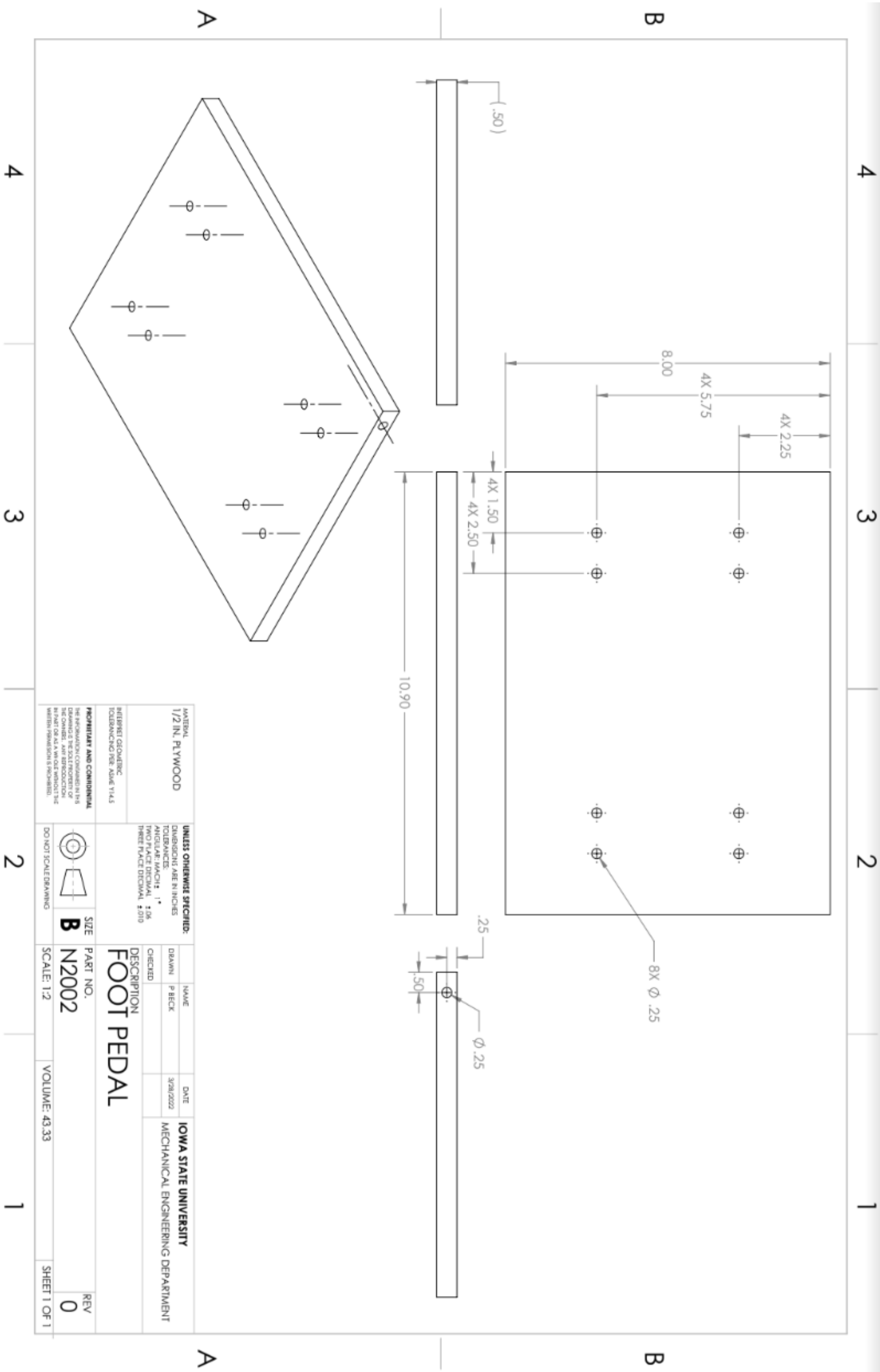
HOME

# Manufacturing Process Instruction

Part # : AN2001 Part Name: Foot Pedal Assembly Prepared By: Patrick Beck

Team: Section 4 Team 5 -- Kick Start Wheels Sheet: 1 of 1 Date: 3/28/2022

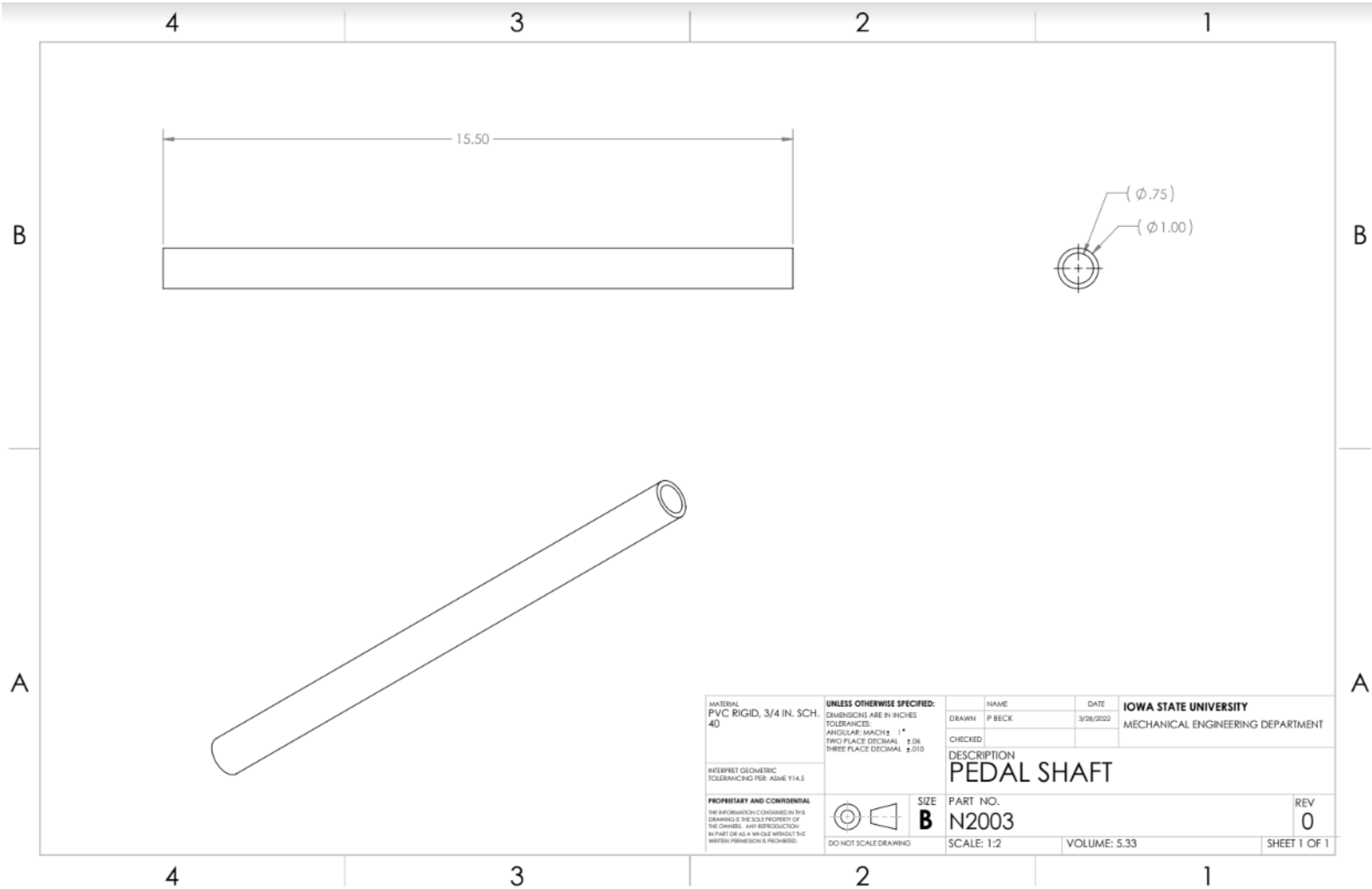
| Operation # | Operation/Process Instructions in detail step by step | Machine to be | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Insert (6) into (5) | Hands | 0 | 0.05 | eight total bolts used |
| 2 | Insert (6) through (2) and into (3) | Hands | 0 | 0.1 | four bolts total used, ensure two bolts are in each of the two (3) brackets |
| 3 | Screw (7) onto (6) | Hands/Wrench | 0 | 0.1 | 12 total nuts used, tighten bolts holding foot pedal to brackets with wrench, tighten bolts on bearing plates (5) by hand |
| 4 | Slide (3) onto (1) and glue in place according to drawing | Hands/CA Glue | 0.05 | 0.1 | Ensure (3) are in place prior to gluing for proper function of assembly |
| 5 | Slide (4) onto (1) | Hands/Hammer | 0 | 0.05 | |
| 6 | Slide (5) onto (4) | Hands | 0 | 0.05 | |


(.50)
8.00
4X 5.75
4X 2.25
4X 1.50
4X 2.50
10.90
.25
.50
8X Ø .25
Ø .25
MATERIAL
1/2 IN. PLYWOOD
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DRAWN P BECK
CHECKED
NAME
DATE
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
FOOT PEDAL
SIZE B
PART NO. N2002
REV 0
DO NOT SCALE DRAWING
SCALE: 1:2
VOLUME: 43.33
SHEET 1 OF 1

## Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N2002 | Part Name: | Foot Pedal | Prepared By: | Patrick Beck |
| Team: | Section 4 Team 5 -- Kick Start Wheels | Sheet: | 1 of 1 | Date: | 3/28/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to specified width | Table Saw | 0.02 | 0.05 | Cut wood square |
| 2 | Cut wood to specified length | Miter Saw | 0.01 | 0.05 | Cut wood square |
| 3 | Drill bolt holes as specifed | Drill Press | 0.02 | 0.05 | Repeat for all eight holes and ensure holes are drilled precisely for tolerances |

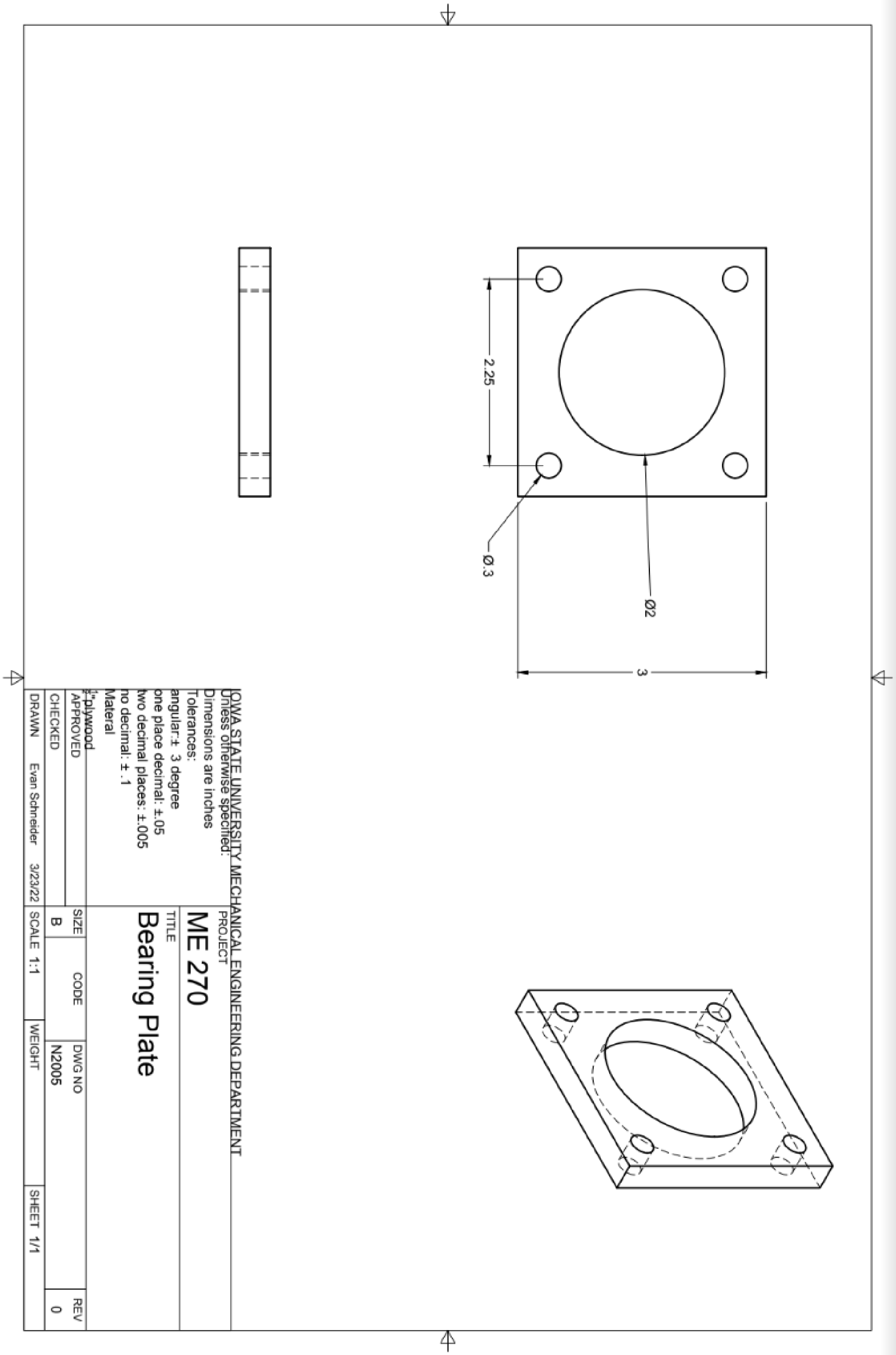

15.50
(Ø.75)
(Ø1.00)
MATERIAL
PVC RIGID, 3/4 IN. SCH. 40
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
NAME
DATE
DRAWN
P BECK
3/28/2022
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
PEDAL SHAFT
SIZE
B
PART NO.
N2003
REV
0
DO NOT SCALE DRAWING
SCALE: 1:2
VOLUME: 5.33
SHEET 1 OF 1

# Manufacturing Process Instruction

Part # : N2003 Part Name: Pedal Shaft Prepared By: Patrick Beck

Team: Section 4 Team 5 -- Kick Start Wheels Sheet: 1 of 1 Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Cut pipe to specified length | PVC Cutter | 0.05 | 0.05 | Cut tubing square |


2.25
Ø.3
Ø2
3
IOWA STATE UNIVERSITY MECHANICAL ENGINEERING DEPARTMENT
Unless otherwise specified:
Dimensions are inches
Tolerances:
angular:± 3 degree
one place decimal: ±.05
two decimal places: ±.005
no decimal: ± .1
Material
½"-plywood
APPROVED
CHECKED
DRAWN Evan Schneider 3/23/22
PROJECT
ME 270
TITLE
Bearing Plate
SIZE
B
CODE
DWG NO
N2005
REV
0
SCALE 1:1
WEIGHT
SHEET 1/1

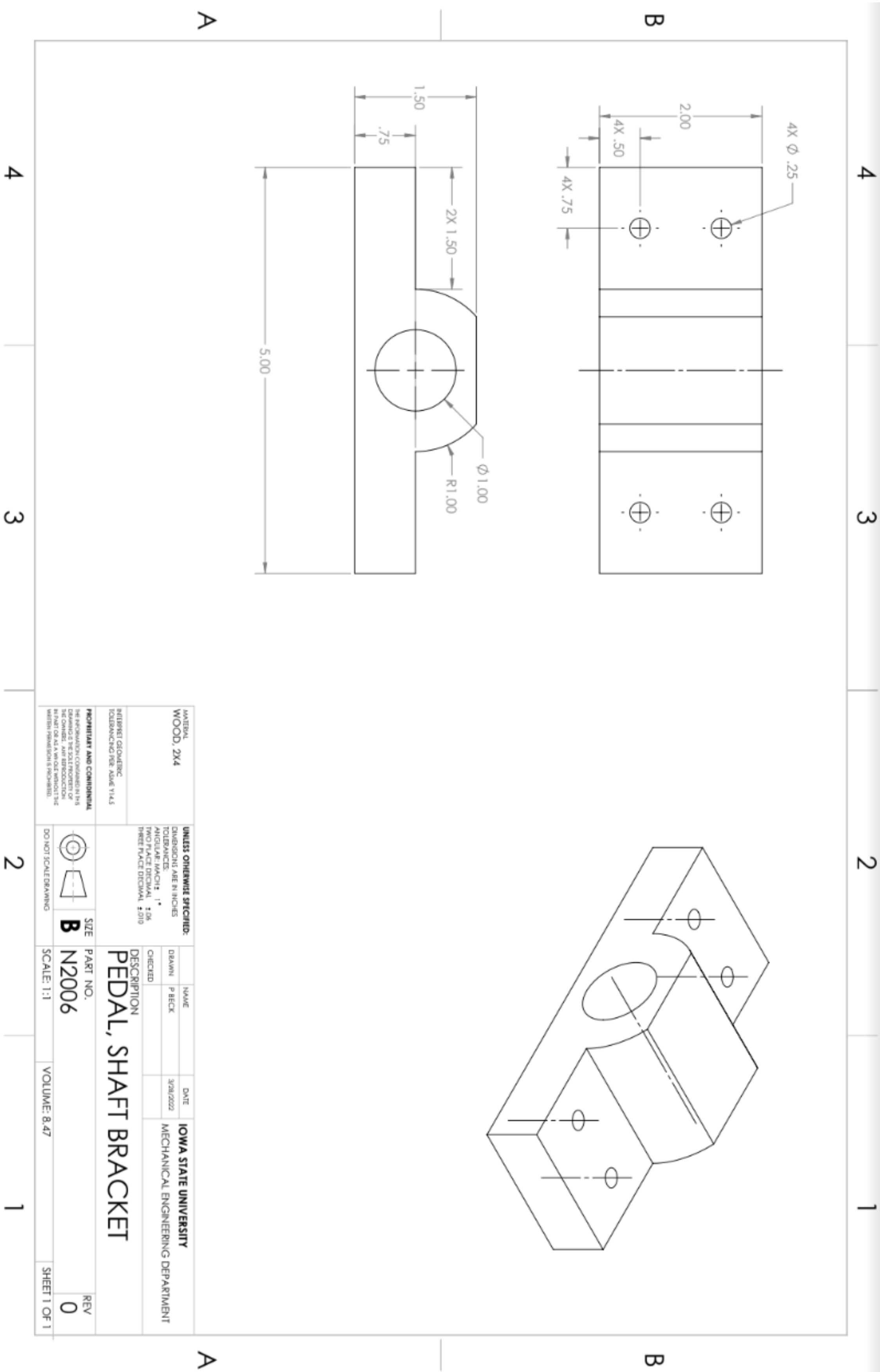
HOME

# Manufacturing Process Instruction

Part # : N2005 Part Name: BEARING PLATE Prepared By: PATRICK BECK

Team: SECTION 4 TEAM 5 -- KICK START WHEELS Sheet: 1 of 1 Date: 3/9/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut board to specified width | Table Saw | 0.1 | 0.1 | Ensure cuts are square |
| 2 | Cut board to specified side lengths | Miter Saw | 0.1 | 0.1 | Ensure cuts are square |
| 3 | Drill mounting holes as specified | Drill Press | 0.1 | 0.15 | Repeat for all four holes |
| 4 | Drill center bearing hole | Drill Press | 0.1 | 0.05 | |


4X Ø .25
2.00
4X .50
4X .75
1.50
.75
2X 1.50
5.00
Ø1.00
R1.00
MATERIAL
WOOD, 2X4
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
P BECK
3/28/2022
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
PEDAL, SHAFT BRACKET
SIZE
B
PART NO.
N2006
REV
0
SCALE: 1:1
VOLUME: 8.47
SHEET 1 OF 1

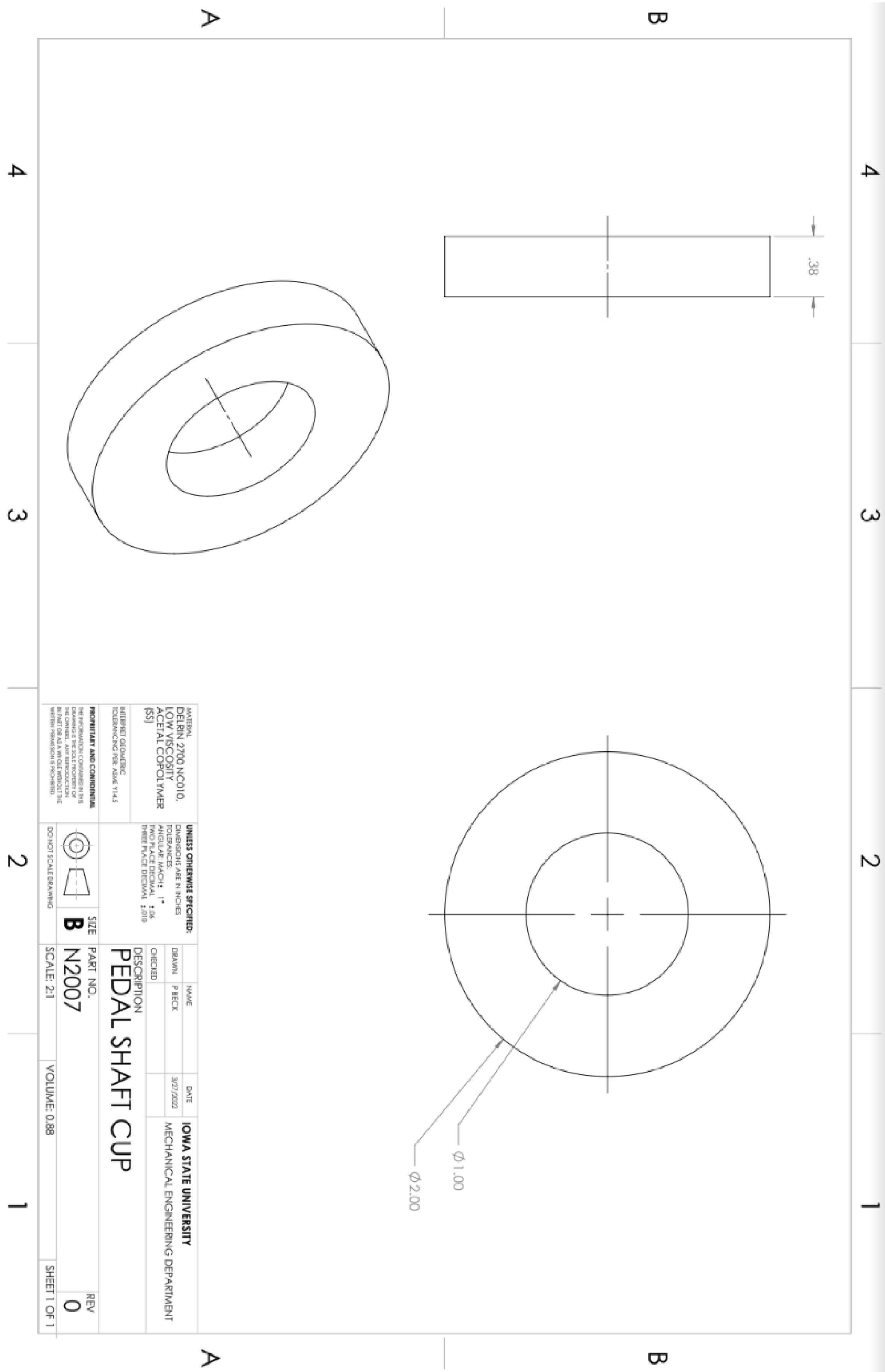
HOME

# Manufacturing Process Instruction

Part # : N2006 | Part Name: Shaft Bracket | Prepared By: Patrick Beck

Team: Section 4 Team 5 -- Kick Start Wheels | Sheet: 1 of 1 | Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to specifed width | Table Saw | 0.05 | 0.05 | Ensure cut is square |
| 2 | Cut wood to specifed length | Miter Saw | 0.05 | 0.05 | Ensure cut is square |
| 3 | Drill center shaft hole specified in drawing | Drill Press | 0.05 | 0.05 | |
| 4 | Cut the bracket to shape specified in drawing | ertical Band Sa | 0.1 | 0.05 | |
| 5 | Drill bolt holes as specifed in drawing | Drill Press | 0.1 | 0.05 | Ensure all four holes are drilled precisely for tolerances |



A
B
4
3
2
1
.38
Ø1.00
Ø2.00
MATERIAL
DELRIN 2700 NC010, LOW VISCOSITY ACETAL COPOLYMER (SS)
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
P BECK
3/27/2022
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
PEDAL SHAFT CUP
SIZE
B
PART NO.
N2007
REV
0
SCALE: 2:1
VOLUME: 0.88
SHEET 1 OF 1

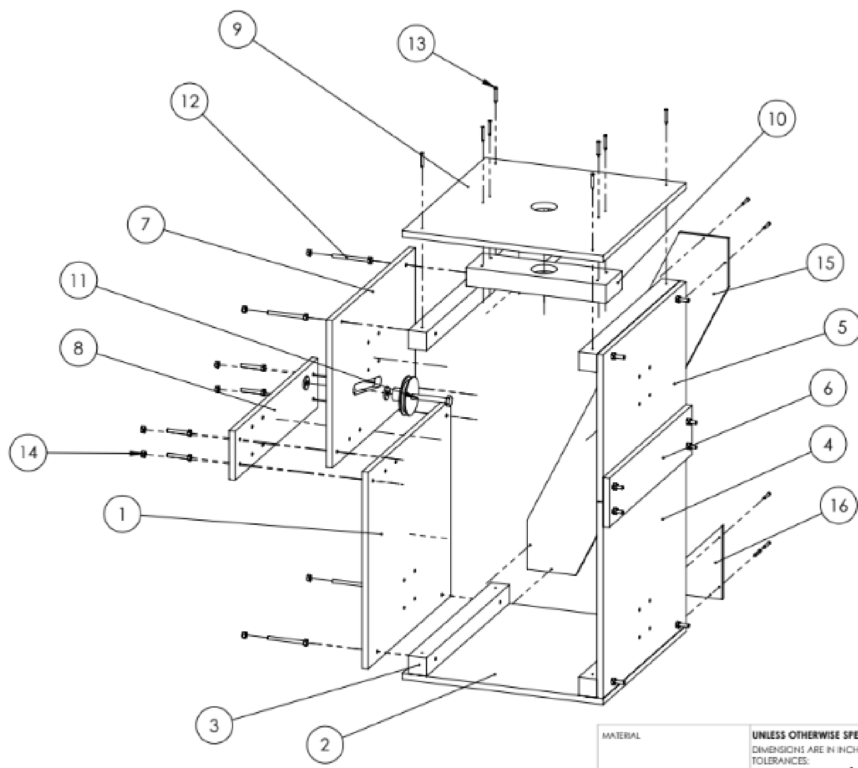
HOME

# Manufacturing Process Instruction

Part # : N2007 Part Name: Pedal Shaft Cup Prepared By: Patrick Beck

Team: Section 4 Team 5 -- Kick Start Wheels Sheet: 1 of 1 Date: 3/28/2022

| Operation # | Operation/Process Instructions in detail step by step | Machine to be | Estimated Labor Hours | | Remarks |
|---|---|---|---|---|---|
| 1 | Drill center shaft hole as specified | Drill Press | 0.05 | 0.05 | |
| 2 | Cut outer ring from plastic block as specified in drawing | Vertical Band | 0.05 | 0.05 | Ensure cut is a circle |




| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | N1021 | Box Wall Bottom Left | 1 |
| 2 | N1003 | Bottom Plate | 1 |
| 3 | N1008 | Corner Gusset | 4 |
| 4 | N1010 | Box Wall Bottom Right | 1 |
| 5 | N1011 | Box Wall Top Right | 1 |
| 6 | N1012 | Box Wall Bracket Right | 1 |
| 7 | N1019 | Box Wall Top Left | 1 |
| 8 | N1020 | Box Wall Bracket Left | 1 |
| 9 | N1004 | Top Plate | 1 |
| 10 | N1015 | Bearing Support Crossmember | 1 |
| 11 | N1018 | Tensioner | 1 |
| 12 | N1014 | 1/4-3in Bolt | 8 |
| 13 | N1009 | Num8 Wood Screw | 24 |
| 14 | N1007 | 1/4in Nut | 17 |
| 15 | N1016 | Long Gusset | 1 |
| 16 | N1017 | External Gusset | 2 |

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | LUKE ZILLIG | |
| CHECKED | | |

IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

DESCRIPTION
Exploded Assembly

SIZE B

PART NO. N1000

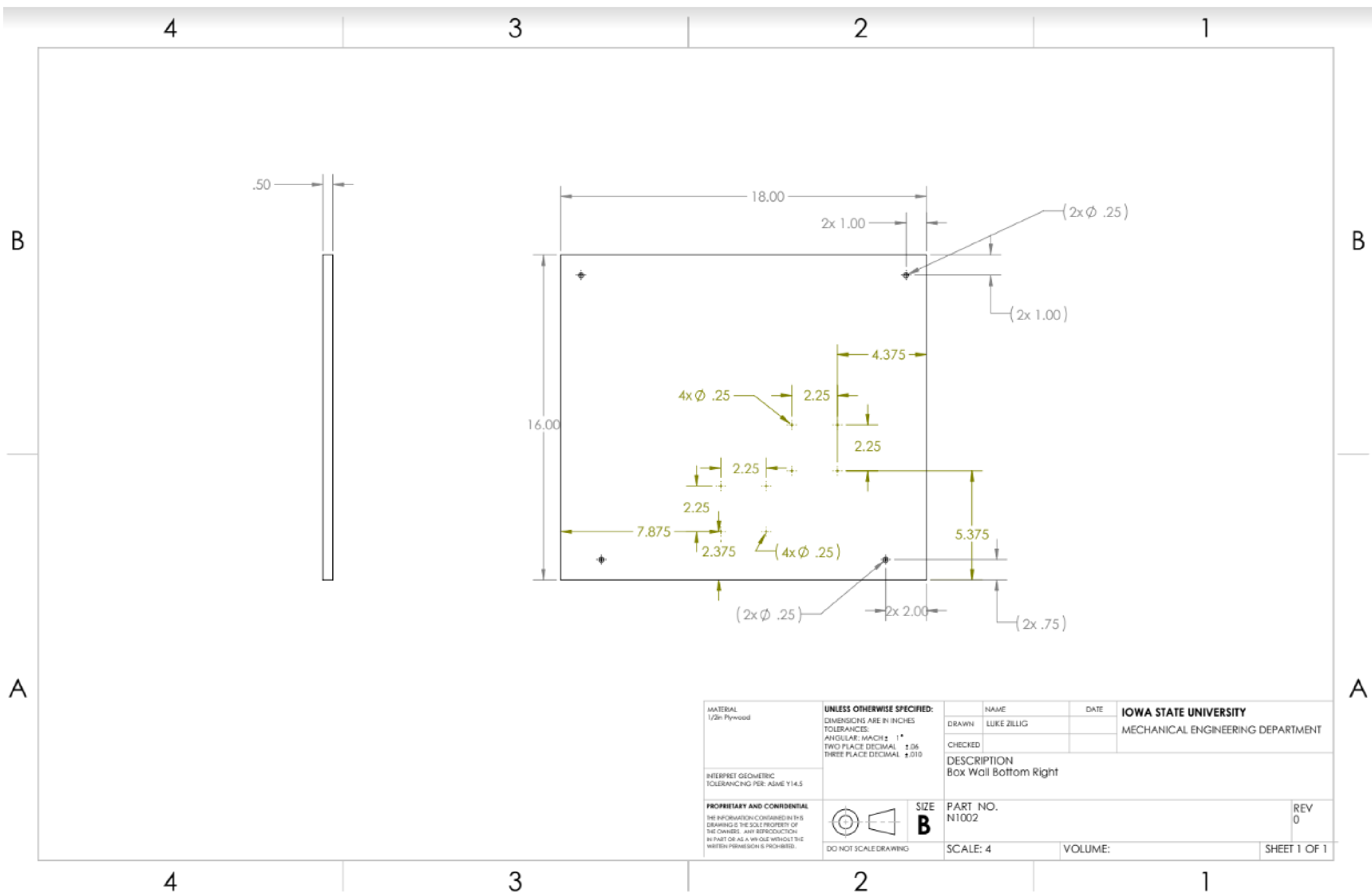
REV 1

SCALE: 1:16 VOLUME: SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | | |
|---|---|---|---|---|---|---|
| Part # : | N1001 | Part Name: | Outer Box Assebly | | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | 9 | of | 8 | Date: 3/28/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Screw Gussets (4) onto Bottom Plate (2) | Drill | 0.05 | 0.1 | use #8 2in wood screws |
| 2 | Bolt Box Wall Bottom Left and Right (1,5) onto Gussets (4) | Wrench | 0.05 | 0.1 | use 1/4inch bolts and nuts |
| 3 | Bolt Box Wall Brackets (7) onto Box Wall Bottom Left and Right (1,5) | Wrench | 0.05 | 0.15 | use 1/4inch bolts and nuts |
| 4 | Screw Gussets (4) onto Top Plate (3) | Drill | 0.05 | 0.1 | use #8 2in wood screws |
| 5 | Bolt Box Wall Tops (6) onto Gussets (4) | Wrench | 0.05 | 0.1 | use 1/4inch bolts and nuts |
| 6 | Bolt Box Wall Tops (6) onto Box Wall Brackets (7) | Wrench | 0.05 | 0.15 | use 1/4inch bolts and nuts |

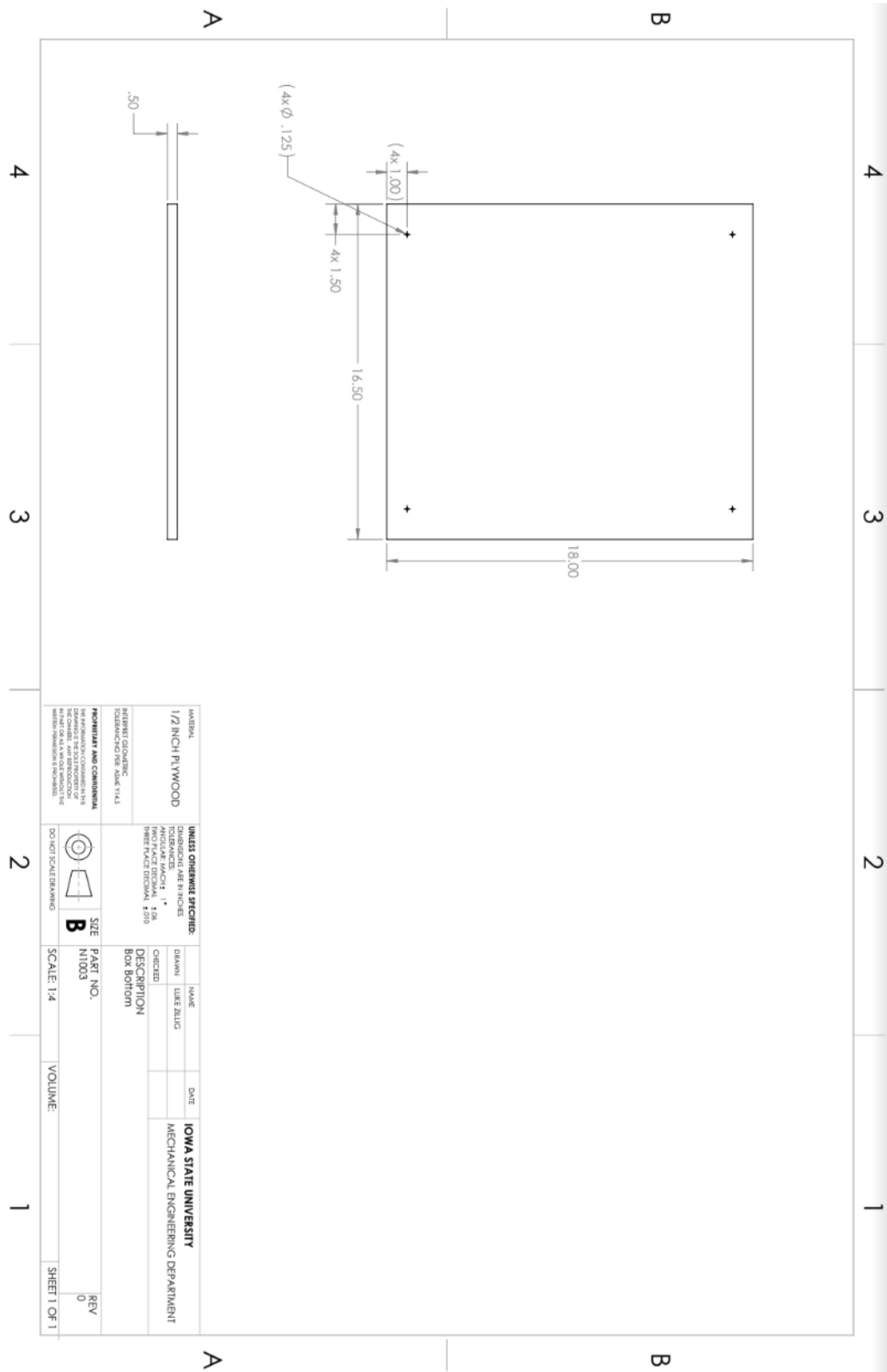


.50
18.00
2x 1.00
(2x Ø .25)
(2x 1.00)
4.375
4x Ø .25
2.25
2.25
16.00
2.25
2.25
7.875
2.375
(4x Ø .25)
5.375
(2x Ø .25)
2x 2.00
(2x .75)
MATERIAL
1/2in Plywood
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Wall Bottom Right
SIZE
B
PART NO.
N1002
REV
0
SCALE: 4
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1002 | Part Name: | Box Wall Bottom Left | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | 1 of 9 | Date: | 3/27/2022 |

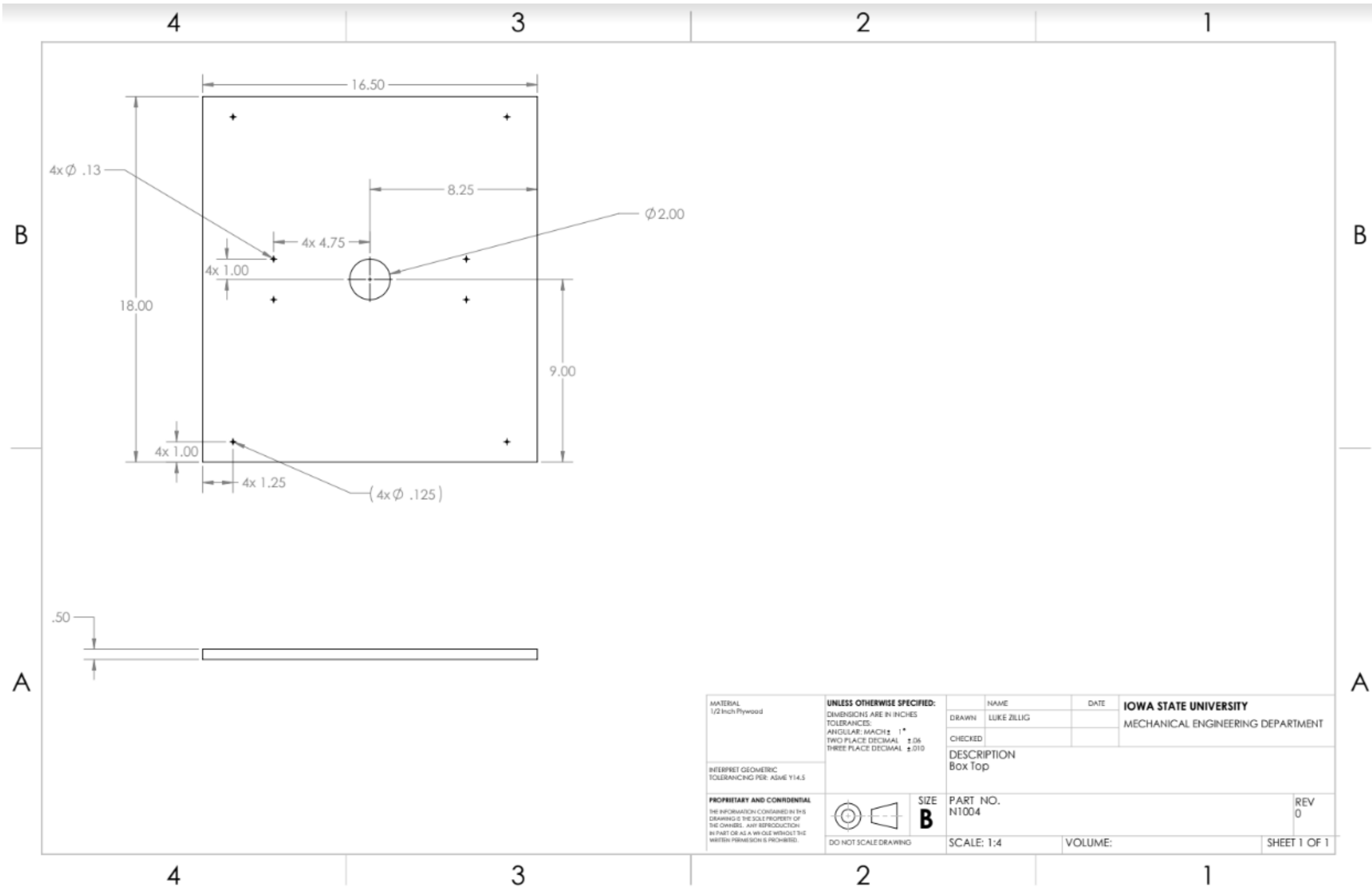
| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Estimated Labor Hours Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to specified length | Miter Saw | 0.1 | 0.05 | make sure saw is set to 90 degrees |
| 2 | Cut pience to specified width | Miter Saw | 0.1 | 0.05 | make sure saw is set to 90 degrees |
| 3 | Drill holes in specified locations | Drill Press | 0.1 | 0.1 | ensure proper RPM is set as to not delaminate wood |


(4x Ø .125)
(4x 1.00)
4x 1.50
16.50
18.00
.50
MATERIAL
1/2 INCH PLYWOOD
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DRAWN
CHECKED
NAME
LUKE ZILLIG
DATE
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Bottom
PART NO.
N1003
SIZE
B
REV
0
DO NOT SCALE DRAWING
SCALE: 1:4
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Part # : | N1003 | Part Name: | Bottom Plate | | | Prepared By: | Luke Zillig |
| Team: | Section4 Team 5 | Sheet: | 2 | of | 9 | Date: | 3/27/2022 |

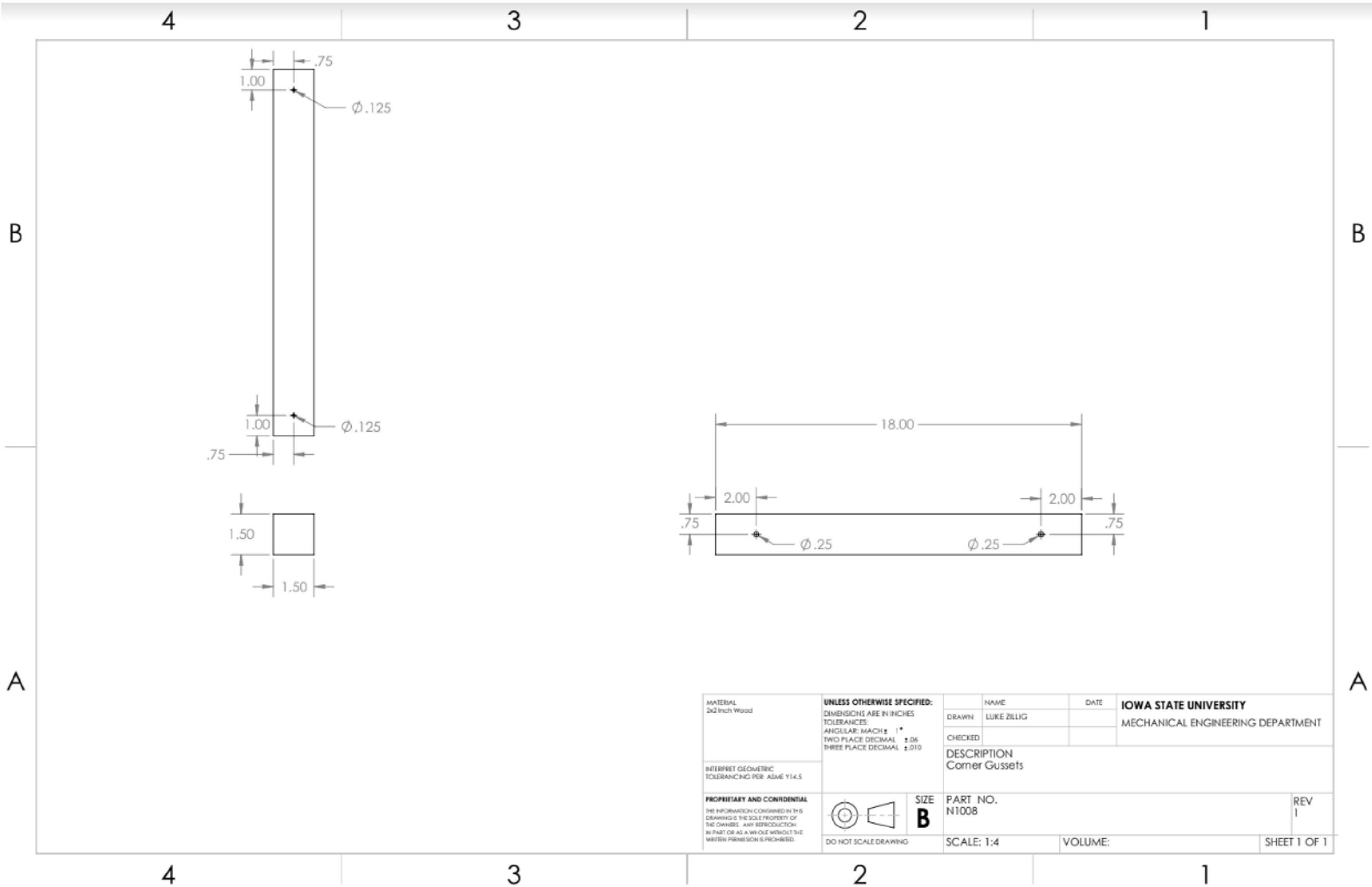
| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Estimated Labor Hours Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to specified length | Miter Saw | 0.1 | 0.05 | ensure saw is set to 90 degrees |
| 2 | Cut piece to specified width | Miter Saw | 0.1 | 0.05 | ensure saw is set to 90 degrees |
| 3 | Drill holes in specififed locations | Drill Press | 0.1 | 0.1 | Make sure drill is at proper RPMs as to not delaminate the wood |


16.50
18.00
8.25
9.00
4x Ø .13
Ø2.00
4x 4.75
4x 1.00
4x 1.00
4x 1.25
(4x Ø .125)
.50
MATERIAL
1/2 Inch Plywood
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Top
PART NO.
N1004
REV
0
SCALE: 1:4
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | | |
|---|---|---|---|---|---|---|
| Part # : | N1004 | Part Name: | Top Plate | | ʳrepared By: | Like Zillig |
| Team: | Section 4 Team 5 | Sheet: | 3 | of 9 | Date: | 3/27/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to specified length | Miter Saw | 0.1 | 0.05 | Ensure saw is set to 90 degrees |
| 2 | Cut piece to specified width | Miter Saw | 0.1 | 0.05 | Ensure saw is set to 90 degrees |
| 3 | Drill holes in specified locations | Drill Press | 0.1 | 0.1 | Set drill to proper RPMs as to not delaminate wood |
| 4 | Drill center shaft hole | Drill Press | 0.05 | 0.05 | Use forstner bit |



.75
1.00
Ø.125
1.00
Ø.125
.75
1.50
1.50
18.00
2.00
2.00
.75
.75
Ø.25
Ø.25
MATERIAL
2x2 Inch Wood
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
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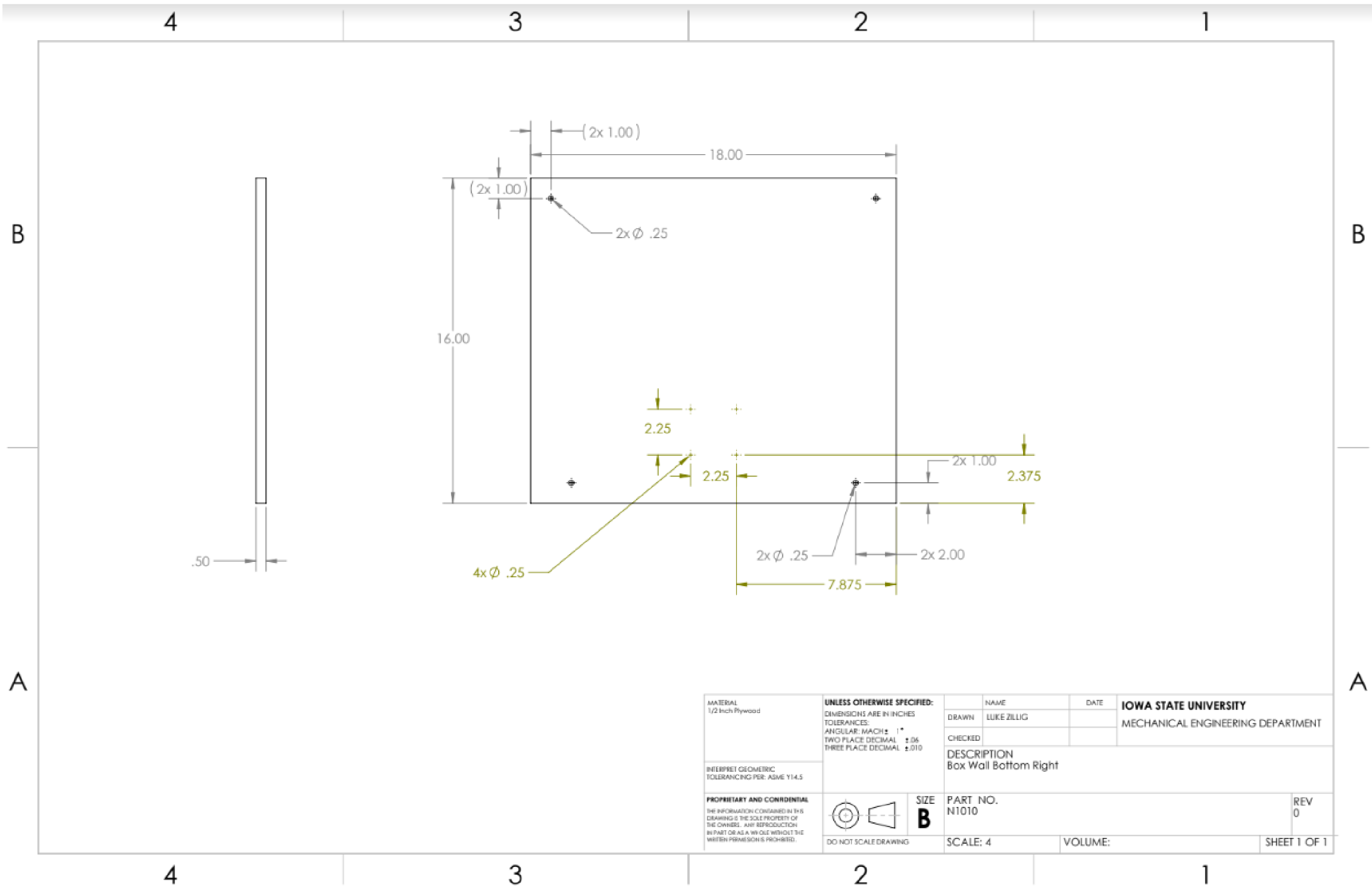
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Corner Gussets
PART NO.
N1008
REV
1
SCALE: 1:4
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1008 | Part Name: | Corner Gussets | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | 4 of 9 | Date: | 3/27/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Estimated Labor Hours Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to specfied length | Miter Saw | 0.05 | 0.05 | make sure saw is set to 90 degrees |
| 2 | Drill holes in specified locations (1/8 in) | Drill Press | 0.05 | 0.05 | use 1/8in twist bit |
| 3 | Drill holes in specified locations (1/4 in) | Drill Press | 0.05 | 0.05 | use 1/4in twist bit |

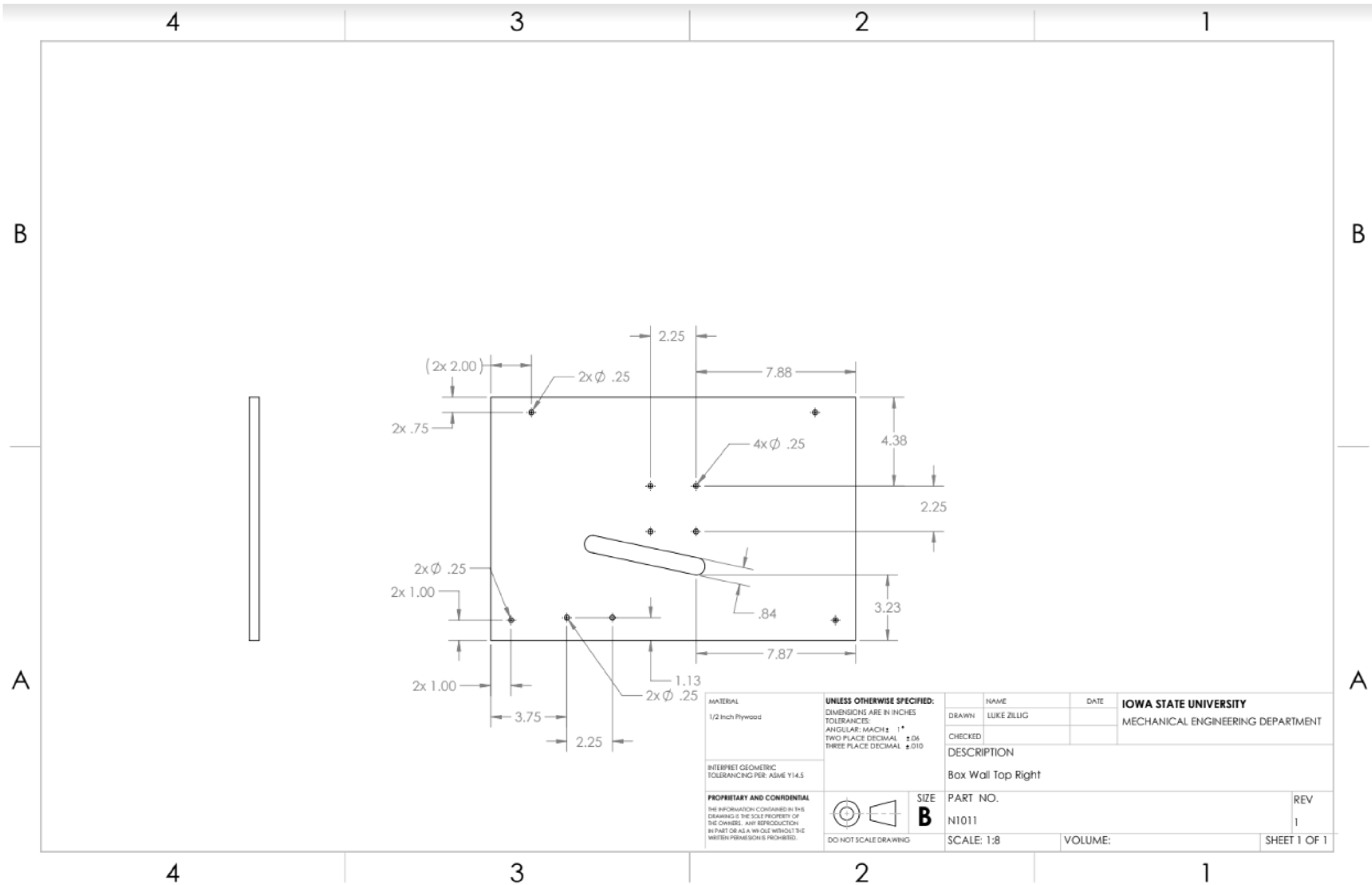


(2x 1.00)
18.00
(2x 1.00)
2x Ø .25
16.00
2.25
2.25
2x 1.00
2.375
.50
4x Ø .25
2x Ø .25
2x 2.00
7.875
MATERIAL
1/2 Inch Plywood
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Wall Bottom Right
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
SIZE
B
PART NO.
N1010
REV
0
DO NOT SCALE DRAWING
SCALE: 4
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1010 | Part Name: | Box Wall Bottom Right | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | 5 of 9 | Date: | 3/27/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to specified length | Miter Saw | 0.1 | 0.05 | Make sure saw is set to 90 degrees |
| 2 | Cut piece to specified width | Miter Saw | 0.1 | 0.05 | set drill to proper RPMs as to not delaminate wood |
| 3 | Drill holes where specified | Drill press | 0.1 | 0.1 | set drill to proper RPMs as to not delaminate wood |

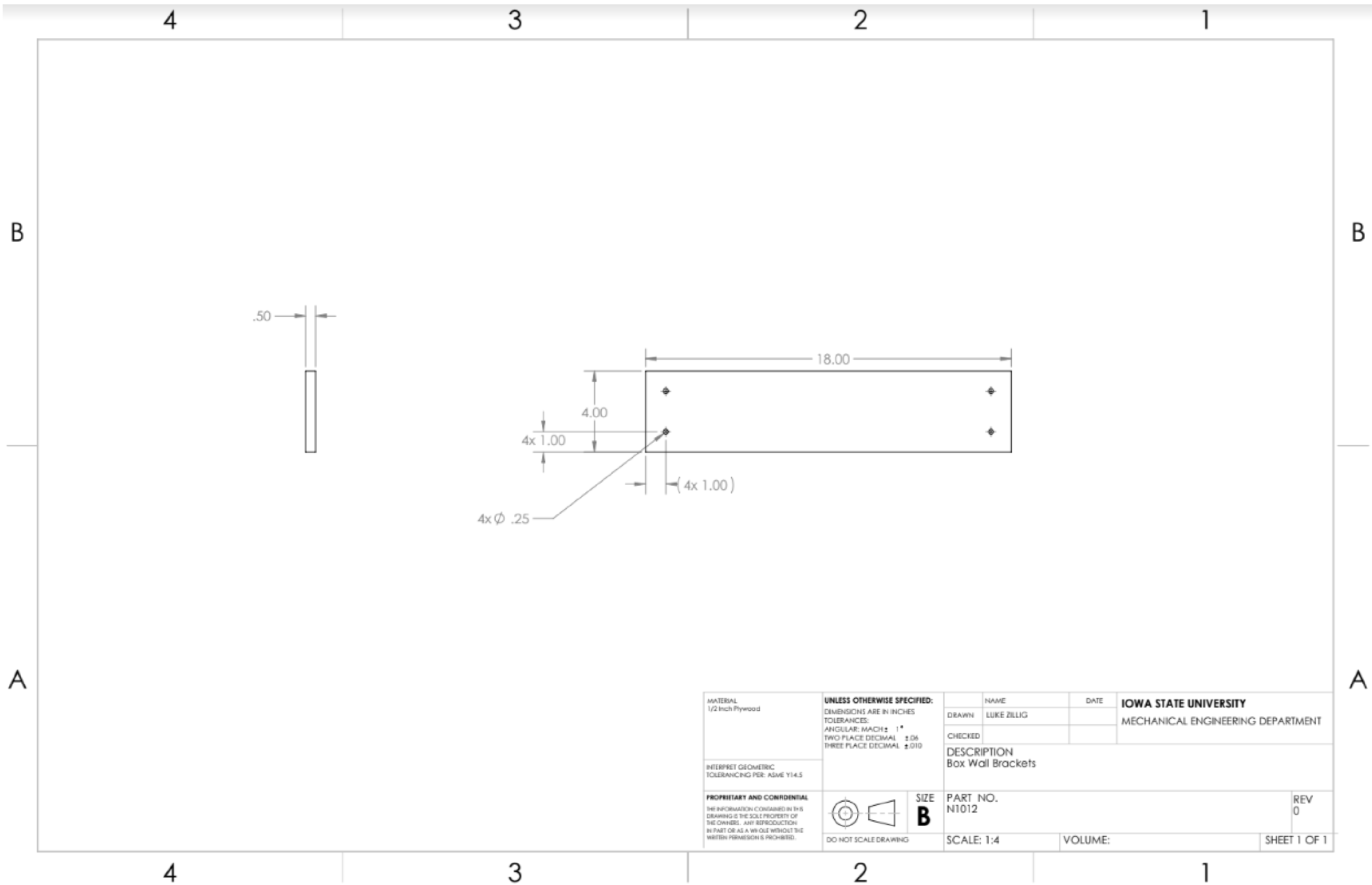


4
3
2
1
B
A
(2x 2.00)
2x Ø .25
2x .75
2.25
7.88
4x Ø .25
4.38
2.25
2x Ø .25
2x 1.00
.84
3.23
7.87
1.13
2x 1.00
2x Ø .25
3.75
2.25
MATERIAL
1/2 Inch Plywood
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Wall Top Right
PART NO.
N1011
REV
1
SCALE: 1:8
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1011 | Part Name: | Box Wall Top | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | 6 of 9 | Date: | 3/27/2022 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to specified length | Miter Saw | 0.1 | 0.05 | Make sure saw is set to 90 degrees |
| 2 | Cut piece to specified width | Miter Saw | 0.1 | 0.05 | Make sure saw is set to 90 degrees |
| 3 | Drill holes in specified locations | Drill Press | 0.1 | 0.1 | Set to proper RPMs as to not delaminate wood |

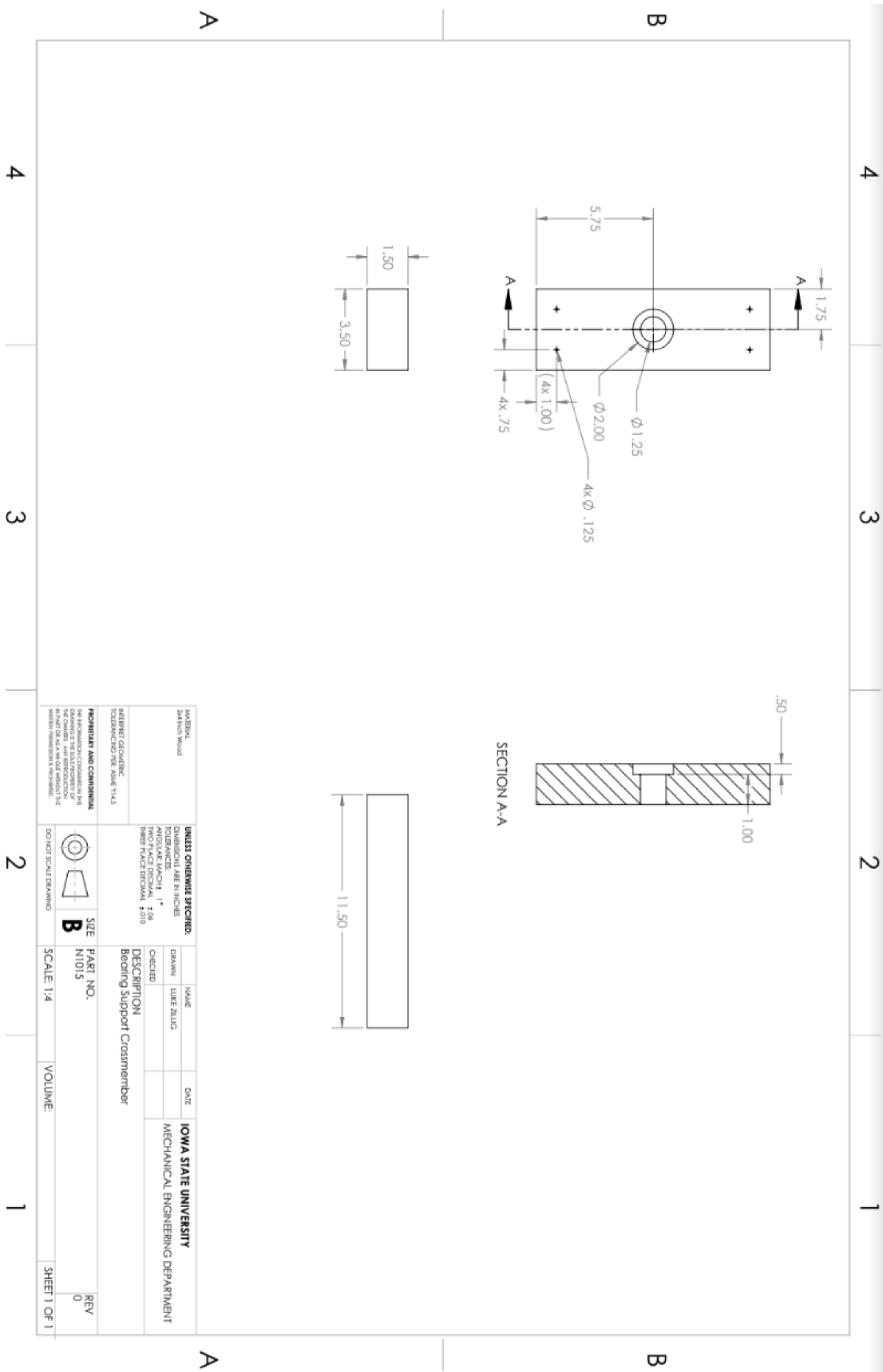


.50
18.00
4.00
4x 1.00
(4x 1.00)
4x Ø .25
MATERIAL
1/2 Inch Plywood
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Wall Brackets
PART NO.
N1012
REV
0
SCALE: 1:4
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1012 | Part Name: | Box Wall Brackets | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | 7 of 9 | Date: | 3/27/2022 |

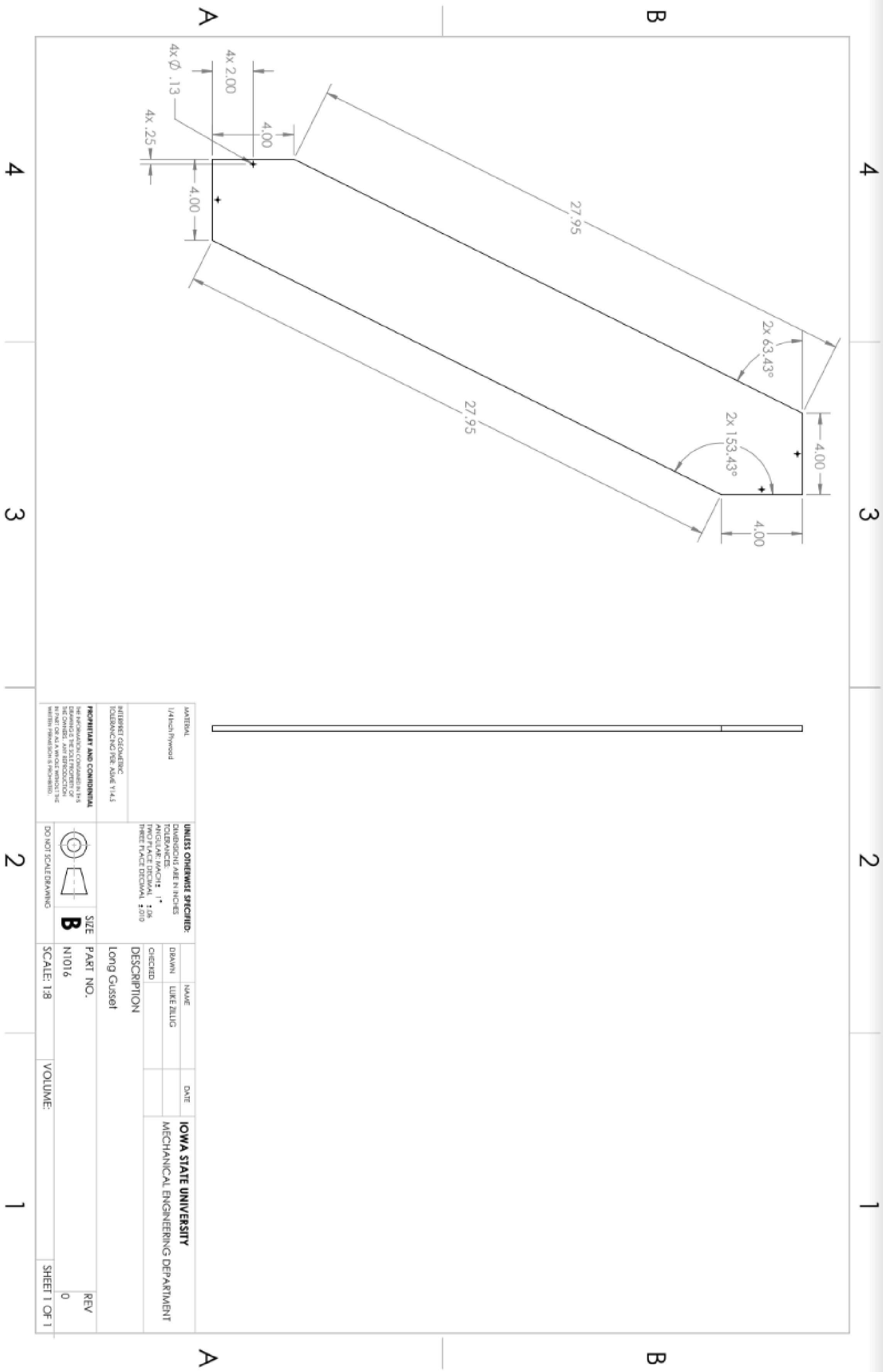
| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to speficied length | Miter Saw | 0.1 | 0.05 | make sure saw is set to 90 degrees |
| 2 | Cut piece to specified width | Miter Saw | 0.1 | 0.05 | make sure saw is set to 90 degrees |
| 3 | Drill holes in speficied locaitons | Drill press | 0.1 | 0.1 | set drill to proper RPMs as to not delmainate wood |


5.75
1.75
1.50
3.50
A
A
⌀1.25
⌀2.00
(4x 1.00)
4x .75
4x ⌀ .125
.50
1.00
SECTION A-A
11.50
MATERIAL
2x4 Inch Wood
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
DESCRIPTION
Bearing Support Crossmember
PART NO.
N1015
SCALE: 1:4
VOLUME:
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
REV
0
SHEET 1 OF 1

## Manufacturing Process Instruction

| | | | | | | |
|---|---|---|---|---|---|---|
| Part # : | N1015 | Part Name: | Bearing Support Crossmember | | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | 8 | of 9 | Date: | 3/27/2022 |

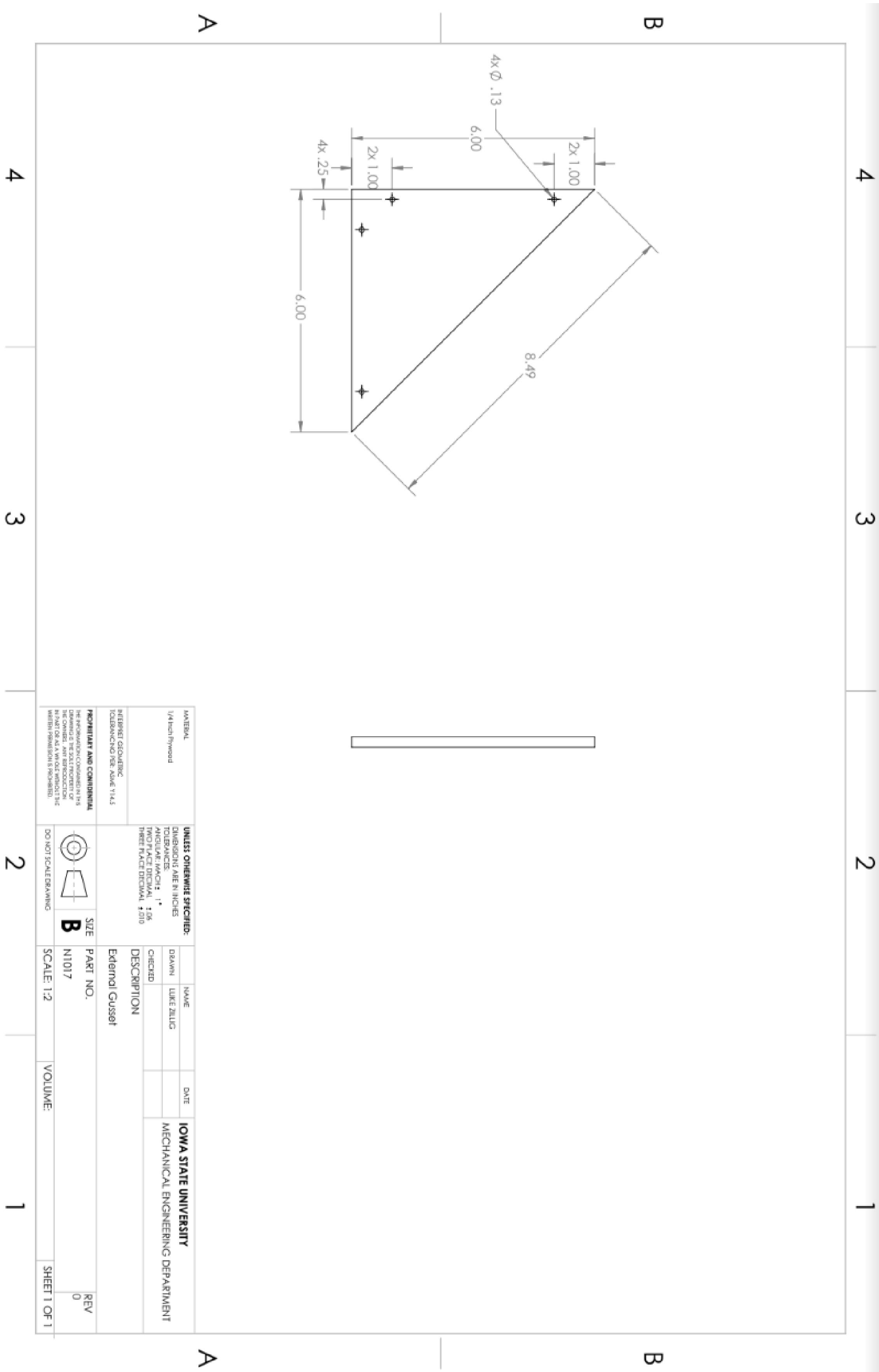
| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut piece to proper length | Miter Saw | 0.1 | 0.05 | make sure saw is set to 90 degrees |
| 2 | Drill holes in proper locations (1/8in) | Drill Press | 0.1 | 0.1 | use 1/8in twist bit |
| 3 | Drill Bearing Reiss hole (2in) | Drill Press | 0.15 | 0.15 | only drill .5in into wood, use 2in forstner bit |
| 4 | Drill main shaft hole (1.25in) | Drill Press | 0.15 | 0.1 | use 1.25in forstner bit |


4x Ø .13
4x 2.00
4.00
4x .25
4.00
27.95
2x 63.43°
4.00
2x 153.43°
27.95
4.00
MATERIAL
1/4 Inch Plywood
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
DESCRIPTION
Long Gusset
PART NO.
N1016
SCALE: 1:8
VOLUME:
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
REV
0
SHEET 1 OF 1
A
B
1
2
3
4

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1016 | Part Name: | Long Gusset | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | of | Date: | 2/18/2018 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Estimated Labor Hours Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to shape | Miter Saw | 0.05 | 0.15 | |

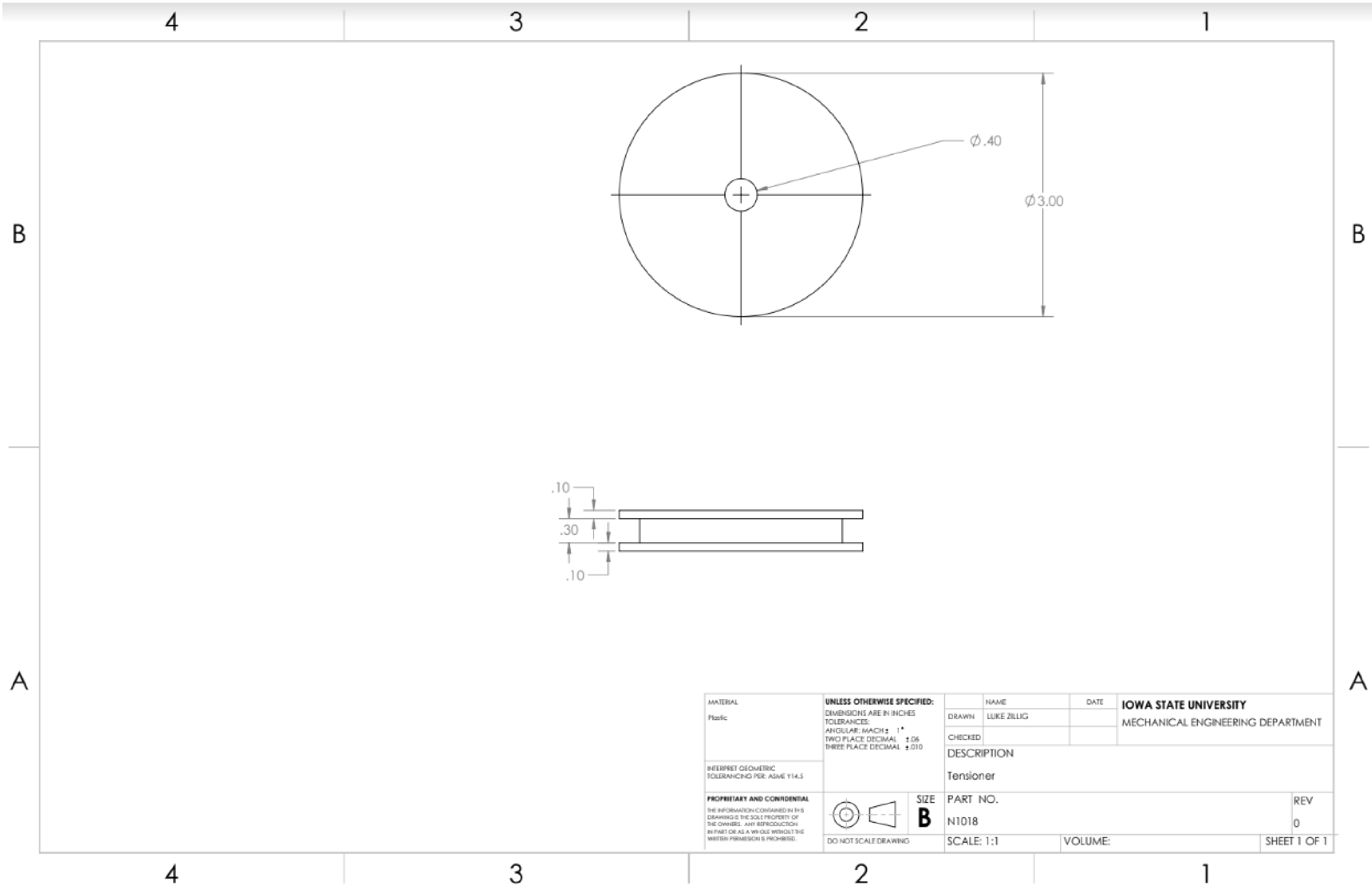


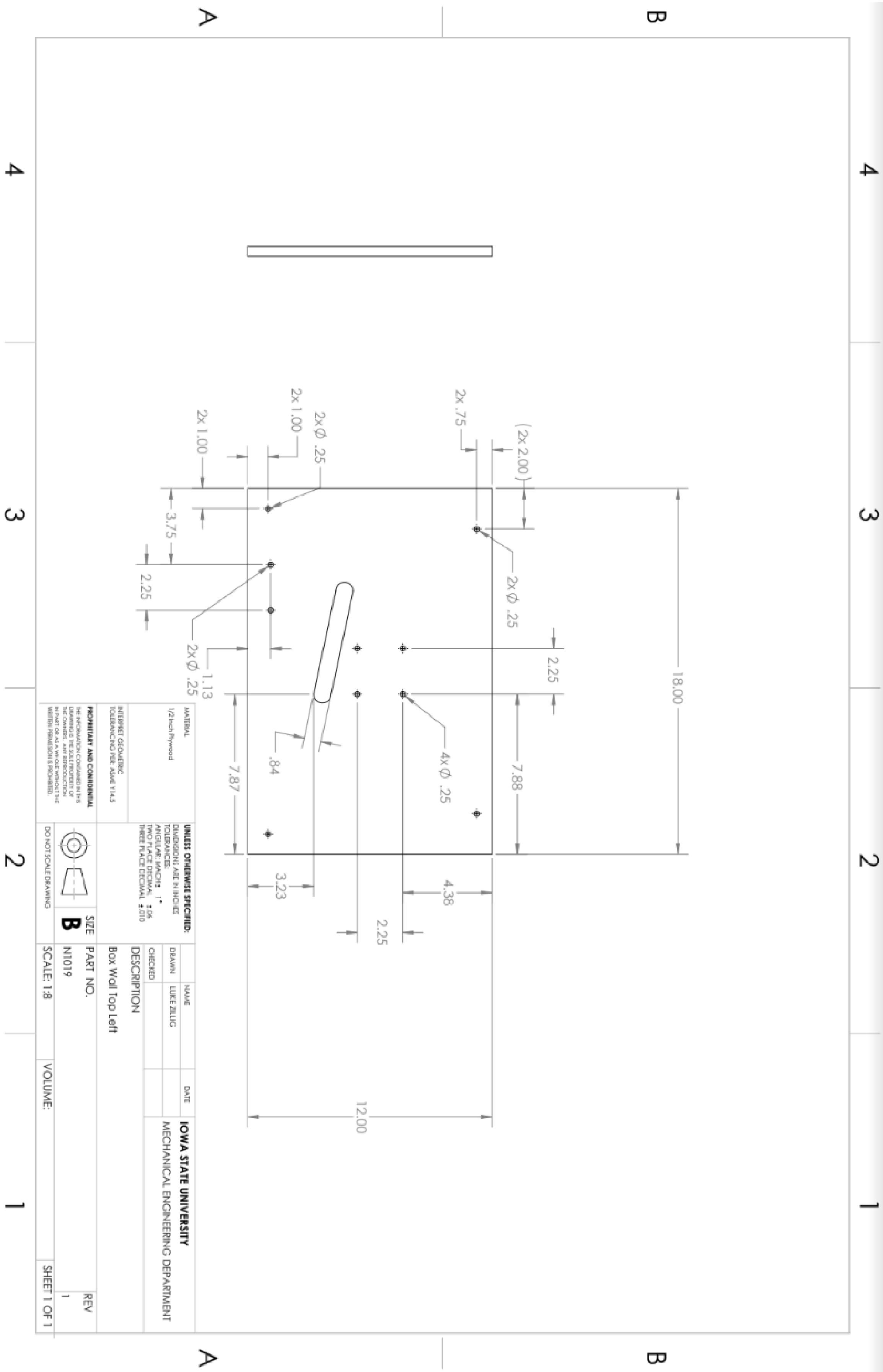
4x Ø .13
6.00
2x 1.00
2x 1.00
4x .25
6.00
8.49
MATERIAL
1/4 Inch Plywood
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ± .06
THREE PLACE DECIMAL ± .010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
DESCRIPTION
External Gusset
PART NO.
N1017
SCALE: 1:2
VOLUME:
REV
0
SHEET 1 OF 1
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1017 | Part Name: | External Gusset | ᴾrepared By: | Luke Zillig |
| Team: | Section4 Team 5 | Sheet: | of | Date: | 2/18/2018 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to shape | Miter Saw | 0.05 | 0.05 | |

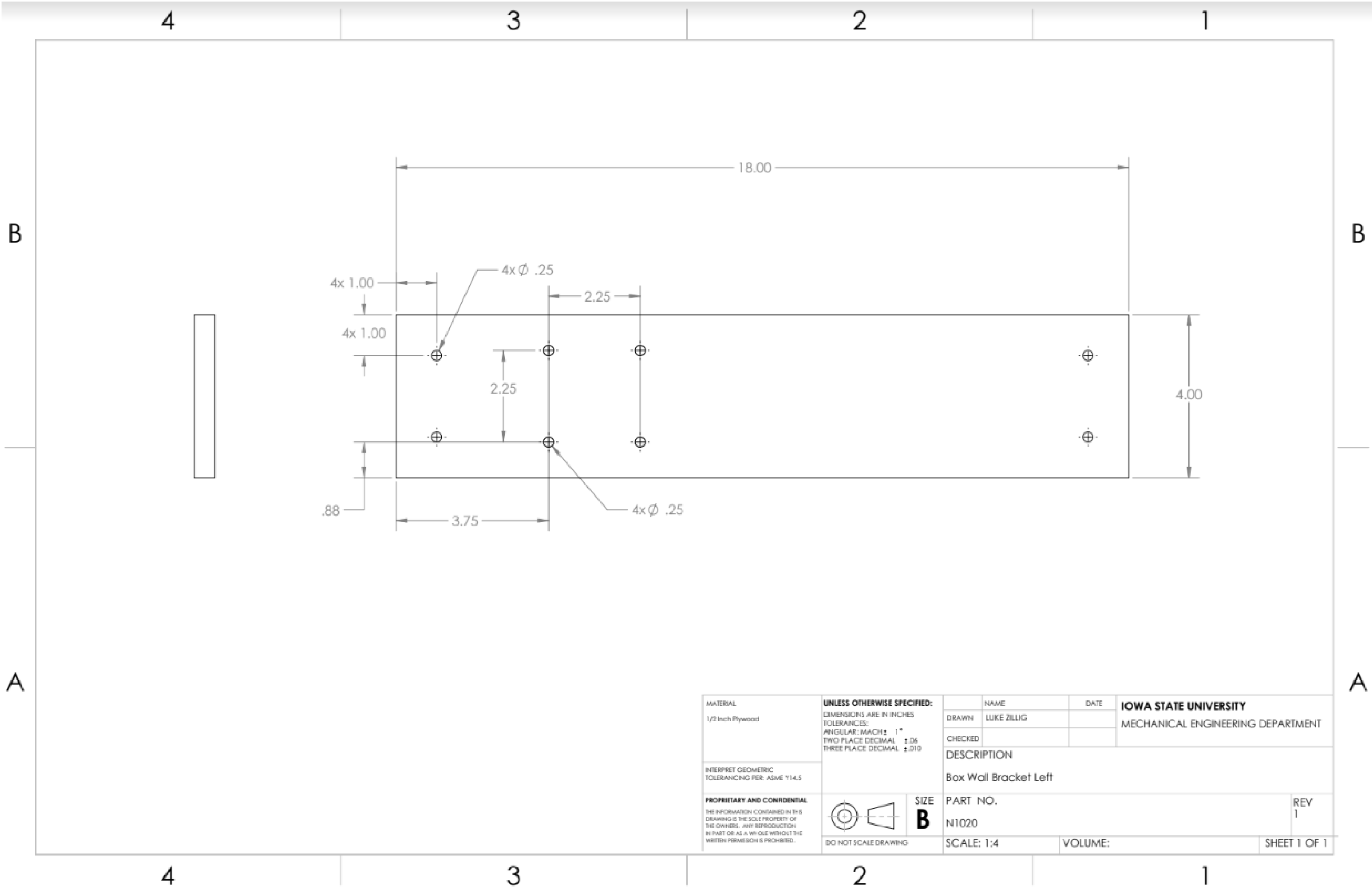

Ø.40
Ø3.00
.10
.30
.10
MATERIAL
Plastic
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Tensioner
SIZE
B
PART NO.
N1018
REV
0
DO NOT SCALE DRAWING
SCALE: 1:1
VOLUME:
SHEET 1 OF 1


IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
UNLESS OTHERWISE SPECIFIED:
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
DESCRIPTION
Box Wall Top Left
MATERIAL
1/2 Inch Plywood
PROPRIETARY AND CONFIDENTIAL
SIZE
B
PART NO.
N1019
REV
1
DO NOT SCALE DRAWING
SCALE: 1:8
VOLUME:
SHEET 1 OF 1
18.00
12.00
7.88
7.87
4.38
3.23
2.25
.84
1.13
3.75
2x 1.00
2x .75
(2x 2.00)
2x Ø .25
4x Ø .25

# Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1019 | Part Name: | Box Wall Top Left | Prepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | of | Date: | 2/18/2018 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to shape | Table Saw | 0.05 | 0.05 | |
| 2 | Drill holes in specified locations | Drill Press | 0.05 | 0.05 | Drill at right RPM |

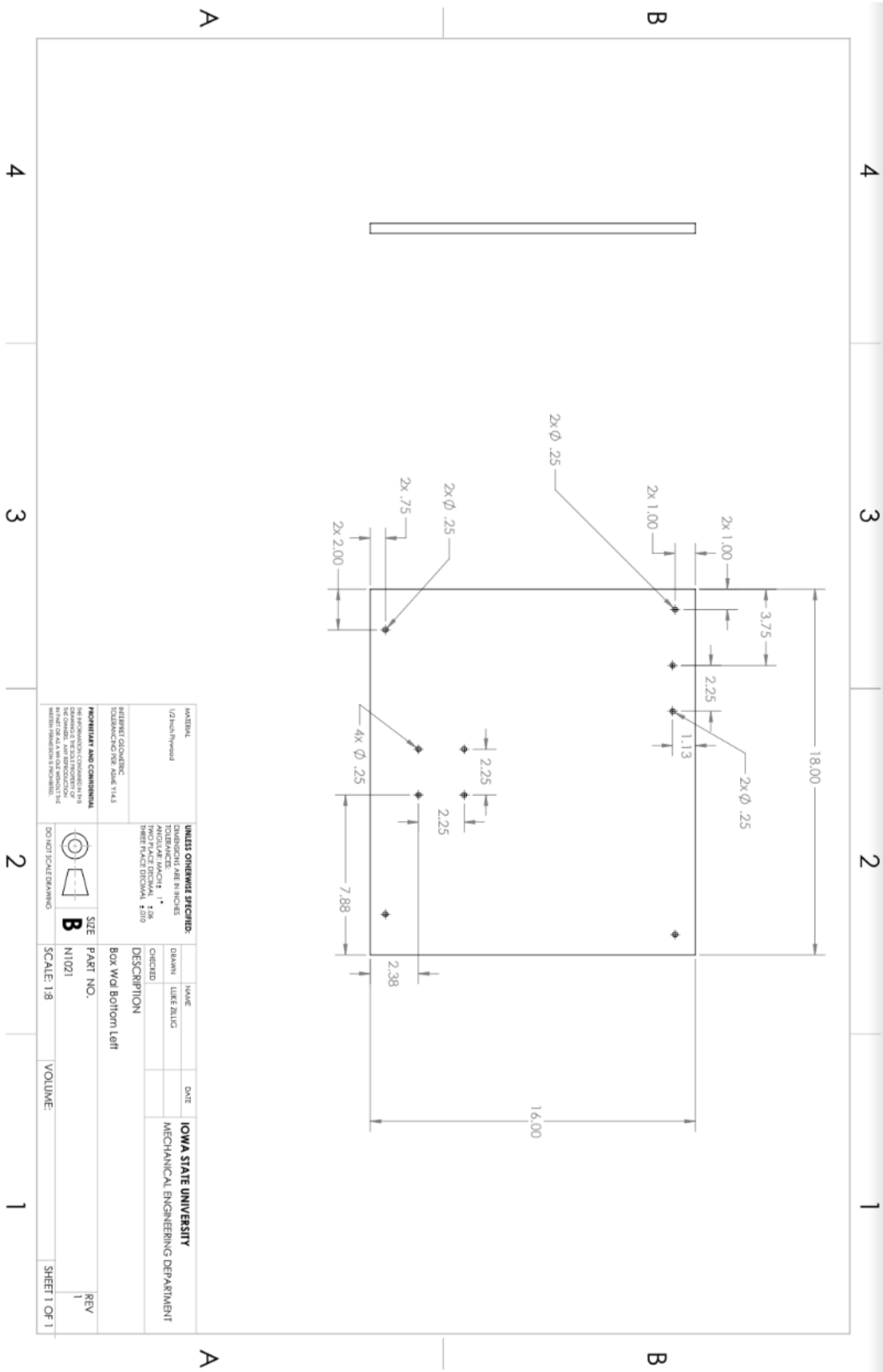


4
3
2
1
B
A
18.00
4x Ø .25
4x 1.00
2.25
4x 1.00
2.25
4.00
.88
3.75
4x Ø .25
MATERIAL
1/2 Inch Plywood
INTERPRET GEOMETRIC
TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
SIZE
B
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Wall Bracket Left
PART NO.
N1020
REV
1
SCALE: 1:4
VOLUME:
SHEET 1 OF 1

## Manufacturing Process Instruction

| | | | | | |
|---|---|---|---|---|---|
| Part # : | N1020 | Part Name: | Box Wall Bracket Left | ʾrepared By: | Luke Zillig |
| Team: | Section 4 Team 5 | Sheet: | of | Date: | 2/18/2018 |

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to shape | Table Saw | 0.05 | 0.05 | |
| 2 | Drill holes in specified locations | Drill Press | 0.05 | 0.05 | Drill at right RPM |


A
B
4
3
2
1
2x Ø .25
2x 1.00
2x 1.00
2x .75
2x Ø .25
2x 2.00
3.75
2.25
1.13
2x Ø .25
18.00
4x Ø .25
2.25
2.25
7.88
2.38
16.00
MATERIAL
1/2 Inch Plywood
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
NAME
DATE
DRAWN
LUKE ZILLIG
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
Box Wal Bottom Left
SIZE
B
PART NO.
N1021
REV
1
DO NOT SCALE DRAWING
SCALE: 1:8
VOLUME:
SHEET 1 OF 1

# Manufacturing Process Instruction

Part # : N1021 | Part Name: Box Wall Bottom Left | Prepared By: Luke Zillig

Team: Section 4 Team 5 | Sheet: of | Date: 2/18/2018

| Operation # | Operation/Process Instructions in detail step by step | Machine to be used | Estimated Labor Hours Set-up | Estimated Labor Hours Machine | Remarks |
|---|---|---|---|---|---|
| 1 | Cut wood to shape | Table Saw | 0.05 | 0.05 | |
| 2 | Drill holes in specified locations | Drill Press | 0.05 | 0.05 | Drill at right RPM |

ME270 EXAMPLE PROJECT - INDENTED BOM AND COSTING

| | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Level 6 | Part Name | REV | Manufactured (Yes/No) | Raw Stock Source (Boyd Stock/Purchase) | Qty | Per Unit Cost | Subtotal | Material | Setup Time for Saw, Drill, and Sander (hr/part) | Mfg. Time for Saw, Drill, and Sander (hr/part)2 | Setup Time for Manual Lathe, Welder (hr/part) | Mfg Time for Manual Lathe & Welder (hr/part) | Setup Time for Casting, CNC Machine, Injection Molding (hr/part) | Mfg Time for Casting, CNC Machine, Injection Molding (hr/part) | Assembly Time (hr/part) | Per Part Manufacturing Cost | Line Item Manufacturing Subtotal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Part Numbers and Information | | | | | | | | Prototype Material Sourcing/Cost | | | | | | Prototype Manufacturing Cost Information: Rate for Drill, Saw, Sander ($/hr) $ 50.00 | Rate for Manual Lathe, Mill, Welder ($/hr) $ 100.00 | Rate for CNC Machine, Casting, and Injection Molding ($/hr) $ 200.00 | Rate for Assembly Time ($/hr) $ 50.00 | | | | | |
| 1 | AN0001 | | | | | | Pottery Wheel | 0 | Yes | N/a | 1 | | $ - | | | | | | | | 0.35 | $ 17.50 | $ 17.50 |
| 2 | → | AN5001 | | | | | Pottery Wheel w/ Vertical Bevel | 0 | Yes | N/a | 1 | | $ - | | | | | | | | 0.10 | $ 5.00 | $ 5.00 |
| 3 | | → | N5004 | | | | Wheel Shaft | 0 | Yes | Boyd Stock | 1 | $ 0.48 | $ 0.48 | 3/4 Inch PVC | 0.10 | 0.10 | | | | | | $ 10.00 | $ 10.00 |
| 4 | | | N5005 | | | | Miter Gear | 0 | Yes | N/a | 1 | $ 1.00 | $ 1.00 | 3D-Print Miter Gear | | | | | | | 0.10 | $ 5.00 | $ 5.00 |
| 5 | | | N5006 | | | | Vertical Miter Key | 0 | Yes | Boyd Stock | 1 | $ 0.26 | $ 0.26 | Keystock | | 0.05 | | | | | | $ 2.50 | $ 2.50 |
| 6 | | | N5012 | | | | Center Support Dowel | 0 | Yes | Boyd Stock | 1 | $ 0.26 | $ 0.26 | 3/4 Inch Dowel Rod | | 0.05 | | | | | | $ 2.50 | $ 2.50 |
| 7 | | | N5011 | | | | Connecting Rod | 0 | Yes | Boyd Stock | 1 | $ 0.55 | $ 0.55 | 1004-1045 Carbon Steel Clevis Pin | 0.05 | 0.10 | | | | | | $ 7.50 | $ 7.50 |
| 8 | | | N5010 | | | | Stainless Steel Hairpin Cotter Pin | N/a | No | Boyd Stock | 1 | $ 0.30 | $ 0.30 | Stainless Steel Hairpin Cotter Pin | | | | | | | | $ - | $ - |
| 9 | | | N5015 | | | | Wheelshaft Ring | 0 | Yes | Boyd Stock | 1 | $ 0.04 | $ 0.04 | 1/2 Inch Plywood | | | | | | | | $ - | $ - |
| 10 | | | N5016 | | | | Wheelshaft Block | 0 | Yes | Boyd Stock | 1 | $ 0.68 | $ 0.68 | 1/2 Inch Plywood | | 0.15 | | | | | | $ 7.50 | $ 7.50 |
| 11 | | | AN5101 | | | | Wheel & Flange | 0 | Yes | N/a | 1 | | $ - | | | | | | | | 0.10 | $ 5.00 | $ 5.00 |
| 12 | | | → | N5002 | | | Wheelhead | 0 | Yes | Boyd Stock | 1 | $ 1.36 | $ 1.36 | 1/2 Inch Plywood | | 0.20 | | | | | | $ 10.00 | $ 10.00 |
| 13 | | | | N5008 | | | Flange Base | 0 | Yes | Boyd Stock | 1 | $ 0.07 | $ 0.07 | 1/2 Inch Plywood | | 0.10 | | | | | | $ 5.00 | $ 5.00 |
| 14 | | | | N5009 | | | Flange | 0 | Yes | Boyd Stock | 1 | $ 0.17 | $ 0.17 | 2x4 Wood | | 0.10 | | | | | | $ 5.00 | $ 5.00 |
| 15 | | | | N5014 | | | 1/8" x 3/4 Inch Flathead Screw | N/a | No | Boyd Stock | 4 | $ 0.04 | $ 0.16 | 1/8" x 3/4 Inch Flathead Screw | | | | | | | | $ - | $ - |
| 16 | | | AN5201 | | | | Support Bearing Sub-Assembly | 0 | Yes | N/a | 1 | | | | | | | | | | | $ - | $ - |
| 17 | | | → | N5007 | | | Bearing Support | 0 | Yes | Boyd Stock | 1 | $ 1.00 | $ 1.00 | 2x4 Wood | 0.10 | 0.10 | | | | | | $ 10.00 | $ 10.00 |
| 18 | | | | N5003 | | | Taper Roller Bearing | N/a | No | Purchase | 1 | $ 10.00 | $ 10.00 | Tapered Roller Bearing | | | | | | | | $ - | $ - |
| 19 | | | | N5013 | | | Taper Roller Bearing Cup | N/a | No | Boyd Stock | 1 | $ 1.20 | $ 1.20 | Aluminum | | | | | | | | $ - | $ - |
| 20 | | AN4001 | | | | | Horizontal Bevel Gear Assembly | 0 | Yes | N/a | 1 | | $ - | | | | | | | | 0.15 | $ 7.50 | $ 7.50 |
| 21 | | → | N4002 | | | | Output Sprocket | N/a | No | Boyd Stock | 1 | $ 11.57 | $ 11.57 | Sprocket | | | | | | | | $ - | $ - |
| 22 | | | N5005 | | | | Miter Gear | 0 | Yes | N/a | 1 | $ 1.00 | $ 1.00 | 3D-Print Miter Gear | | | | | | | 0.10 | $ 5.00 | $ 5.00 |
| 23 | | | N4004 | | | | Output Shaft | 0 | Yes | Boyd Stock | 1 | $ 0.80 | $ 0.80 | 3/4 Inch PVC | 0.10 | 0.10 | | | | | | $ 10.00 | $ 10.00 |
| 24 | | | N4005 | | | | R16 Bearing | N/a | No | Boyd Stock | 2 | $ 7.77 | $ 15.54 | R16 Bearing | | | | | | | | $ - | $ - |
| 25 | | | N2005 | | | | Bearing Plate | 1 | Yes | Boyd Stock | 2 | $ 1.21 | $ 2.42 | 1/2 Inch Plywood | 0.10 | 0.10 | | | | | | $ 10.00 | $ 20.00 |
| 26 | | | N4007 | | | | Horizontal Miter Key | 0 | Yes | Boyd Stock | 1 | $ 0.26 | $ 0.26 | Keystock | | 0.05 | | | | | | $ 2.50 | $ 2.50 |
| 27 | | | N4008 | | | | Wood Pipe Insert | 0 | Yes | Boyd Stock | 1 | $ 0.26 | $ 0.26 | 3/4 Inch Dowel Rod | | 0.10 | | | | | | $ 5.00 | $ 5.00 |
| 28 | | | N4009 | | | | Drive Chain | N/a | No | Boyd Stock | 1 | $ 8.50 | $ 8.50 | Bike Chain | | | | | | | | $ - | $ - |
| 29 | | | N1006 | | | | 1/4 Inch Bolt | N/a | No | Boyd Stock | 8 | $ 0.04 | $ 0.32 | 1/4 Inch Bolt | | | | | | | | $ - | $ - |
| 30 | | | N1007 | | | | 1/4 Inch Nut | N/a | No | Boyd Stock | 8 | $ 0.05 | $ 0.40 | 1/4 Inch Nut | | | | | | | | $ - | $ - |
| 31 | | AN3001 | | | | | Lower Drive Gear w/ Rod | 0 | Yes | N/a | 1 | | $ - | | | | | | | | 0.15 | $ 7.50 | $ 7.50 |
| 32 | | → | N3002 | | | | Drive Sprocket | N/a | No | Boyd Stock | 1 | $ 11.57 | $ 11.57 | Sprocket | | | | | | | | $ - | $ - |
| 33 | | | N4005 | | | | R16 Bearing | N/a | No | Boyd Stock | 1 | $ 7.77 | $ 7.77 | R16 Bearing | | | | | | | | $ - | $ - |
| 34 | | | N3004 | | | | Sprocket-Bearing Shaft Connector | 0 | Yes | Boyd Stock | 1 | $ 3.30 | $ 3.30 | 1/2 Inch Plywood | 0.05 | 0.05 | | | | | | $ 5.00 | $ 5.00 |
| 35 | | | N2005 | | | | Bearing Plate | 1 | Yes | Boyd Stock | 1 | $ 1.21 | $ 1.21 | 1/2 Inch Plywood | 0.10 | 0.10 | | | | | | $ 10.00 | $ 10.00 |
| 36 | | | N3006 | | | | Connecting Bar | 1 | Yes | Boyd Stock | 1 | $ 0.42 | $ 0.42 | 1/2 Inch Plywood | 0.05 | 0.15 | | | | | | $ 10.00 | $ 10.00 |
| 37 | | | N3009 | | | | 1/4 x 2 Inch Lag Screw | N/a | No | Boyd Stock | 1 | $ 0.07 | $ 0.07 | 1/4 x 2 Inch Lag Screw | | | | | | | | $ - | $ - |
| 38 | | | N2008 | | | | 1/4 -20 1.75 Inch Hex Bolt | N/a | No | Boyd Stock | 4 | $ 0.08 | $ 0.32 | 1/4 -20 1.75 Inch Hex Bolt | | | | | | | | $ - | $ - |
| 39 | | | N1007 | | | | 1/4 -20 Hex Nut | N/a | No | Boyd Stock | 5 | $ 0.05 | $ 0.25 | 1/4 -20 Hex Nut | | | | | | | | $ - | $ - |
| 40 | | AN2001 | | | | | Foot Pedal Assembly | 0 | Yes | N/a | 1 | | $ - | | | | | | | | 0.15 | $ 7.50 | $ 7.50 |
| 41 | | → | N2002 | | | | Foot Pedal | 0 | Yes | Boyd Stock | 1 | $ 2.72 | $ 2.72 | 1/2 Inch Plywood | 0.05 | 0.15 | | | | | | $ 10.00 | $ 10.00 |
| 42 | | | N2003 | | | | Pedal Shaft | 0 | Yes | Boyd Stock | 1 | $ 0.80 | $ 0.80 | 3/4 Inch PVC | | 0.05 | | | | | | $ 2.50 | $ 2.50 |
| 43 | | | N2005 | | | | Bearing Plate | 1 | Yes | Boyd Stock | 2 | $ 1.21 | $ 2.42 | 1/2 Inch Plywood | 0.10 | 0.10 | | | | | | $ 10.00 | $ 20.00 |
| 44 | | | N2006 | | | | Pedal, Shaft Bracket | 0 | Yes | Boyd Stock | 2 | $ 1.36 | $ 2.72 | 2x4 Wood | 0.05 | 0.15 | | | | | | $ 10.00 | $ 20.00 |
| 45 | | | N2007 | | | | Pedal Shaft Cup | 0 | Yes | Boyd Stock | 2 | $ 0.53 | $ 1.06 | Nylon Plastic | | 0.05 | | | | | | $ 2.50 | $ 5.00 |
| 46 | | | N2008 | | | | 1/4 -20 1.75 Inch Hex Bolt | N/a | No | Boyd Stock | 12 | $ 0.08 | $ 0.96 | 1/4 -20 1.75 Inch Hex Bolt | | | | | | | | $ - | $ - |
| 47 | | | N1007 | | | | 1/4 -20 Hex Nut | N/a | No | Boyd Stock | 12 | $ 0.05 | $ 0.60 | 1/4 -20 Hex Nut | | | | | | | | $ - | $ - |
| 48 | | AN1001 | | | | | Outer Box Assembly | 0 | Yes | N/a | 1 | | $ - | | 0.10 | 0.20 | | | | | 0.15 | $ 22.50 | $ 22.50 |
| 49 | | → | N1002 | | | | Box Wall Bottom Left | 0 | Yes | Boyd Stock | 1 | $ 3.00 | $ 3.00 | 1/2 Inch Plywood | 0.05 | 0.20 | | | | | | $ 12.50 | $ 12.50 |
| 50 | | | N1003 | | | | Bottom Plate | 0 | Yes | Boyd Stock | 1 | $ 3.10 | $ 3.10 | 1/2 Inch Plywood | | 0.10 | | | | | | $ 5.00 | $ 5.00 |
| 51 | | | N1004 | | | | Top Plate | 0 | Yes | Boyd Stock | 1 | $ 3.10 | $ 3.10 | 1/2 Inch Plywood | 0.10 | 0.20 | | | | | | $ 15.00 | $ 15.00 |
| 52 | | | N2008 | | | | 1/4 -20 1.75 Inch Hex Bolt | N/a | No | Boyd Stock | 8 | $ 0.08 | $ 0.64 | 1/4 -20 1.75 Inch Hex Bolt | | | | | | | | $ - | $ - |
| 53 | | | N1007 | | | | 1/4 Inch Nut | N/a | No | Boyd Stock | 16 | $ 0.05 | $ 0.80 | 1/4 Inch Nut | | | | | | | | $ - | $ - |
| 54 | | | N1008 | | | | Corner Gusset | 0 | Yes | Boyd Stock | 4 | $ 0.82 | $ 3.28 | 2x2 Wood | | 0.05 | | | | | | $ 2.50 | $ 10.00 |
| 55 | | | N1009 | | | | 2 Inch Number 8 Wood Screw | N/a | No | Boyd Stock | 26 | $ 0.01 | $ 0.26 | 2 Inch Number 8 Wood Screw | | | | | | | | $ - | $ - |
| 56 | | | N1010 | | | | Box Wall Bottom Right | 0 | Yes | Boyd Stock | 1 | $ 3.00 | $ 3.00 | 1/2 Inch Plywood | 0.05 | 0.15 | | | | | | $ 10.00 | $ 10.00 |
| 57 | | | N1011 | | | | Box Wall Top Right | 0 | Yes | Boyd Stock | 1 | $ 2.25 | $ 2.25 | 1/2 Inch Plywood | | 0.15 | | | | | | $ 7.50 | $ 7.50 |
| 58 | | | N1012 | | | | Box Wall Bracket Right | 0 | Yes | Boyd Stock | 1 | $ 1.50 | $ 1.50 | 1/2 Inch Plywood | | 0.05 | | | | | | $ 2.50 | $ 2.50 |
| 59 | | | N1014 | | | | 1/4 -20 3 Inch Hex Bolt | N/a | No | Boyd Stock | 8 | $ 0.24 | $ 1.92 | 1/4 -20 3 Inch Hex Bolt | | | | | | | | $ - | $ - |
| 60 | | | N1015 | | | | Bearing Support Crossmember | 0 | Yes | Boyd Stock | 1 | $ 1.30 | $ 1.30 | 2x4 Wood | 0.05 | 0.15 | | | | | | $ 10.00 | $ 10.00 |
| 61 | | | N1016 | | | | Long Gusset | 0 | Yes | Boyd Stock | 1 | $ 2.00 | $ 2.00 | 1/2 Inch Plywood | | 0.05 | | | | | | $ 2.50 | $ 2.50 |
| 62 | | | N1017 | | | | External Gusset | 0 | Yes | Boyd Stock | 2 | $ 0.45 | $ 0.90 | 1/2 Inch Plywood | | 0.05 | | | | | | $ 2.50 | $ 5.00 |
| 63 | | | N1018 | | | | Tensioner | N/a | No | Boyd Stock | 1 | $ 1.00 | $ 1.00 | Tensioner Pulley | | | | | | | | $ - | $ - |
| 64 | | | N1019 | | | | Box Wall Top Left | 0 | Yes | Boyd Stock | 1 | $ 2.25 | $ 2.25 | 1/2 Inch Plywood | | 0.15 | | | | | | $ 7.50 | $ 7.50 |
| 65 | | | N1020 | | | | Box Wall Bracket Left | 0 | Yes | Boyd Stock | 1 | $ 1.50 | $ 1.50 | 1/2 Inch Plywood | | 0.05 | | | | | | $ 2.50 | $ 2.50 |
| 66 | | | N1021 | | | | Box Wall Bottom Left | 0 | Yes | Boyd Stock | 1 | $ 3.00 | $ 3.00 | 1/2 Inch Plywood | 0.05 | 0.15 | | | | | | $ 10.00 | $ 10.00 |
| | | | | | | | | | | | | | | | | | | | | | | $ - | $ - |
| | | | | | | | | | Total Prototype Material Cost | | | | $ 129.59 | | Total Prototype Manufacturing Cost | | | $ 362.50 | | | | | |
| | | | | | | | | | | | | | | | | Total Prototype Cost | | $ 492.09 | | | | | |

## D. Fabrication

### <u>ME 270 Engineering Change Notification (ECN)</u>

**Team: 5 - Kick-Start Wheels   Section: 4**

This form must be filled out and signed before any significant fabrication change is implemented.

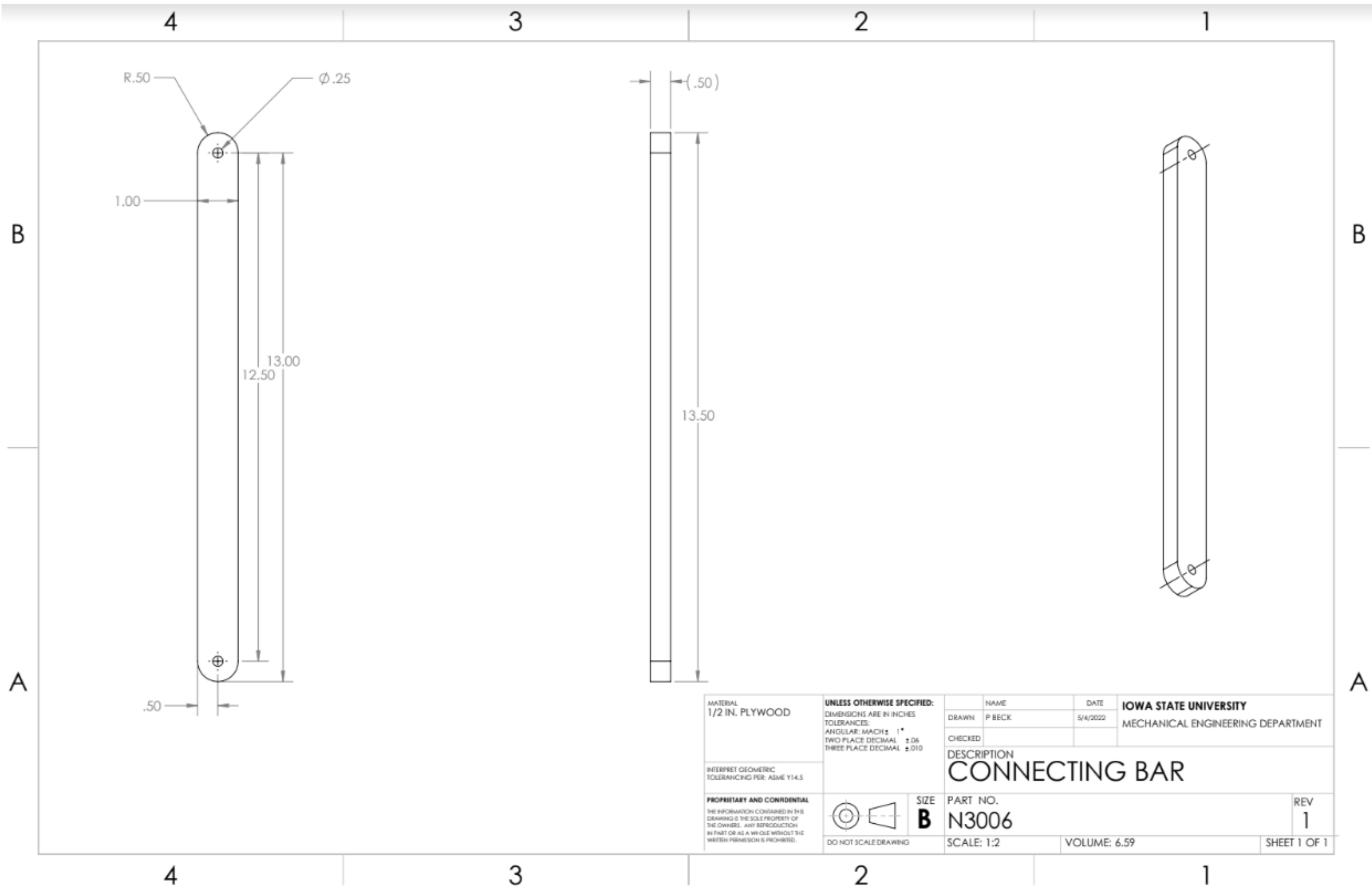
**Requester:** Patrick Beck   **Date:** 04/18/2022

**Current Issue:** With the current connecting rod in place, the drive gear is unable to complete a full rotation cycle due to the connecting rod being too short for the current assembly.

**Proposed Change(s):** Our proposed change is to remanufacture the current connecting rod part with a new overall length that is 2 inches longer than the current connecting rod.

Instructor or TA signature:______________________________________________

**Instructor's / TA's comments:**



R.50
Ø.25
1.00
12.50
13.00
.50
(.50)
13.50
MATERIAL
1/2 IN. PLYWOOD
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
P BECK
5/4/2022
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
CONNECTING BAR
PART NO.
N3006
REV
1
SCALE: 1:2
VOLUME: 6.59
SHEET 1 OF 1

## ME 270 Engineering Change Notification (ECN)

**Team: 5 - Kick-Start Wheels  Section: 4**

This form must be filled out and signed before any significant fabrication change is implemented.

**Requester:** Patrick Beck **Date:** 4/18/2022

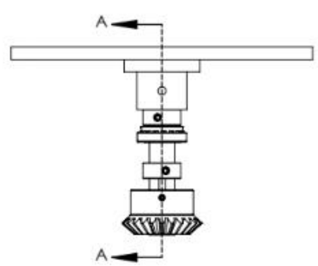
**Current Issue:** The Wheelhead bearing is popping out of it's bearing cup while the wheelhead is spinning during normal operation.

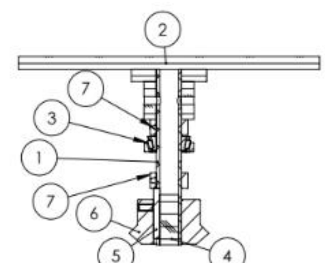
**Proposed Change(s):** N5016 Wheelshaft Block and N5015 Wheelshaft Ring were added to the wheelhead sub-assembly. N5015 seals the gap between the bearing and N5016, thus putting pressure on the bearing to stay seated in the bearing cup. N5016 is rigidly mounted to the top of the outer box and compresses N5015 into the top of the wheelshaft bearing to prevent the bearing from becoming unseated in the bearing cup.

Instructor or TA signature:______________________________________________

**Instructor's / TA's comments:**

| ITEM NO. | PART NUMBER | DESCRIPTION | QTY. |
|---|---|---|---|
| 1 | N5004 | Wheel Shaft | 1 |
| 2 | AN5101 | Wheel & Falange | 1 |
| 3 | AN5201 | Bearing & Cup | 1 |
| 4 | N5012 | Center Support Dowel | 1 |
| 5 | N5006 | Vetical Miter Key | 1 |
| 6 | N5005 | Metal Miter Gear | 1 |
| 7 | 9414T19 | Set Screw Shaft Collar | 2 |




SECTION A-A

MATERIAL

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5

**PROPRIETARY AND CONFIDENTIAL**

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.

**UNLESS OTHERWISE SPECIFIED:**
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010

DO NOT SCALE DRAWING

| | NAME | DATE |
|---|---|---|
| DRAWN | JACK MURRAY | 4/29/22 |
| CHECKED | | |

**IOWA STATE UNIVERSITY**
MECHANICAL ENGINEERING DEPARTMENT

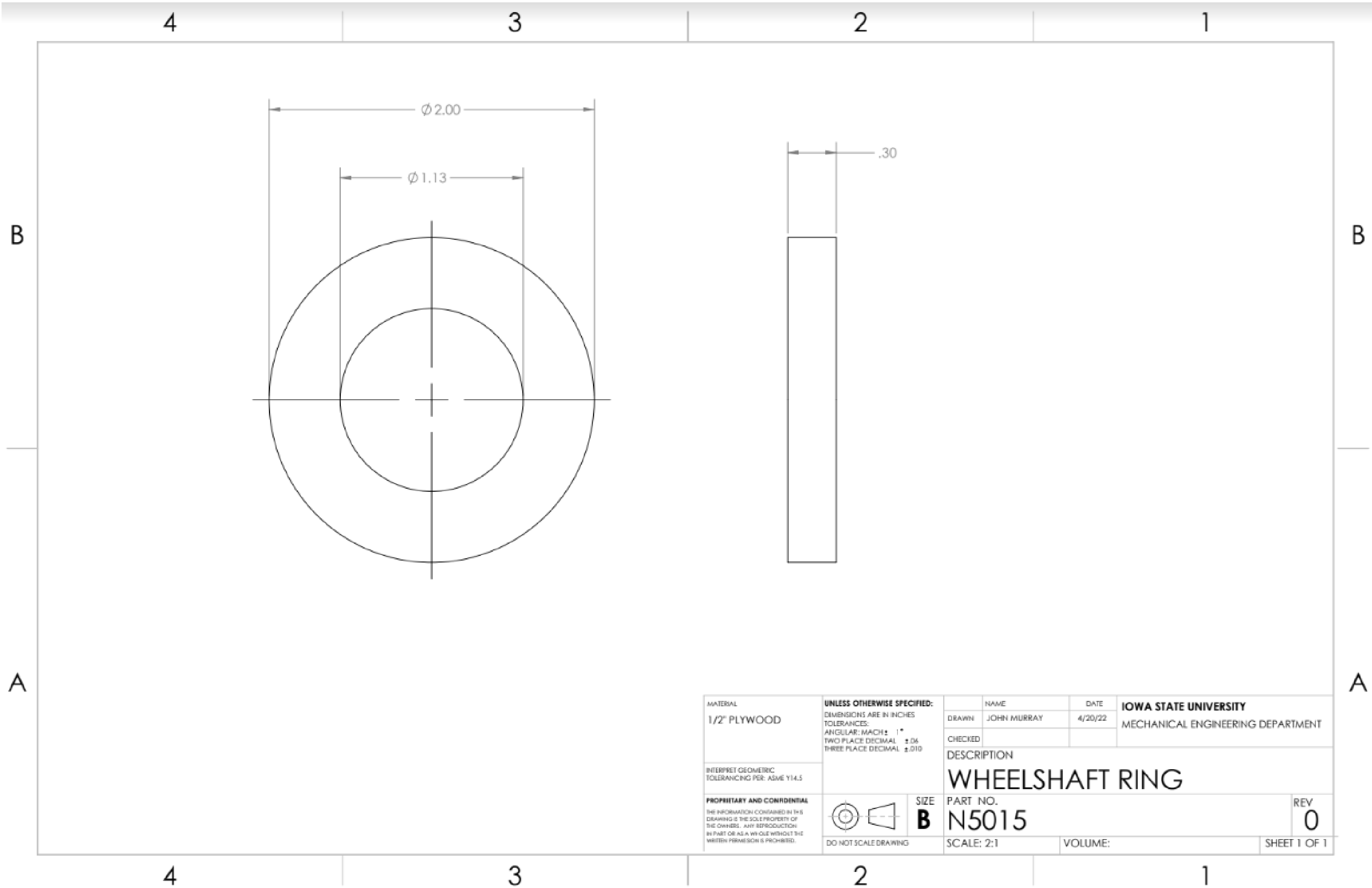
DESCRIPTION
WHEELHEAD ASSEMBLY

SIZE B

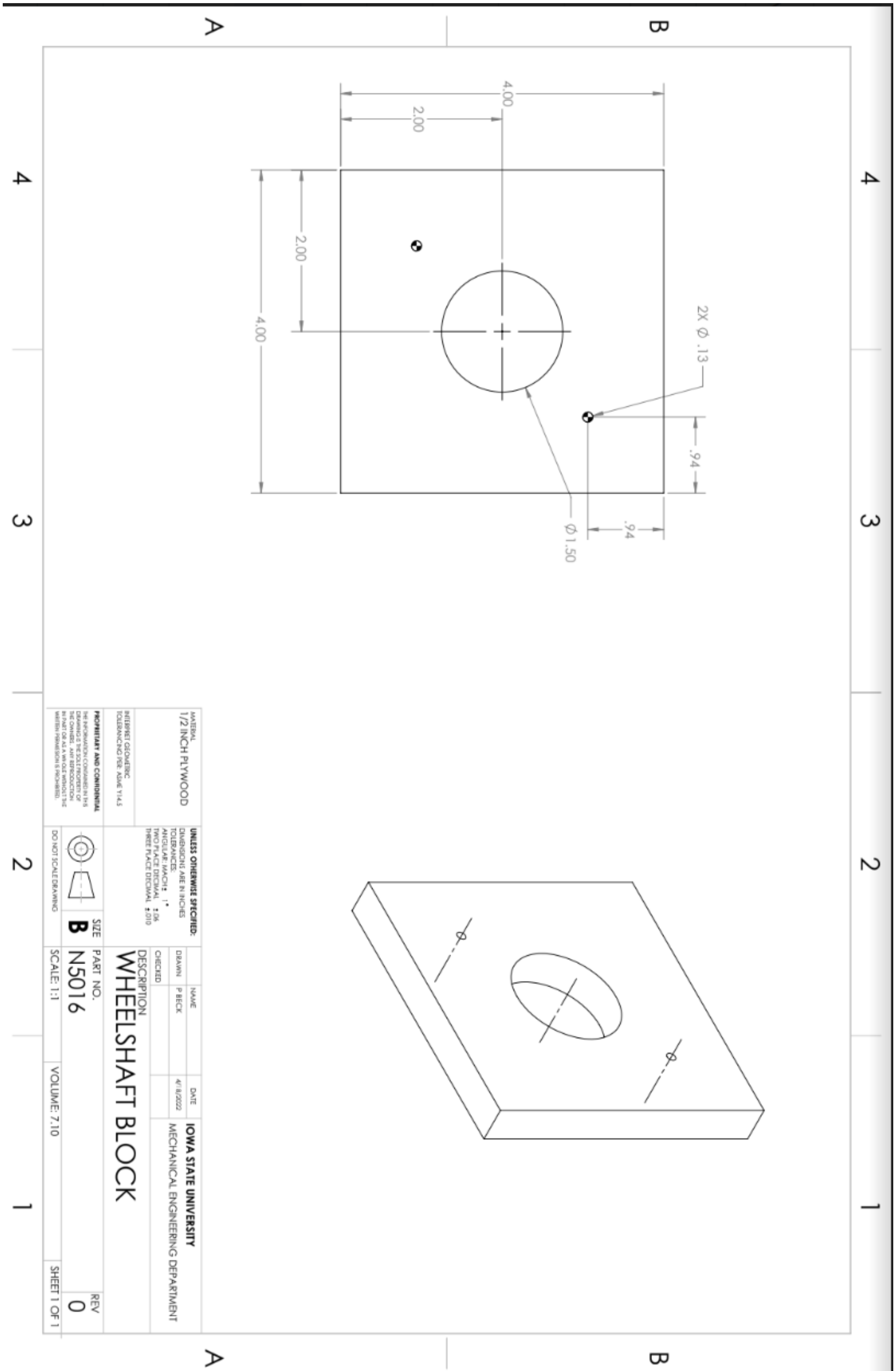
PART NO. AN5001

REV 1

SCALE: 1:4 VOLUME: SHEET 1 OF 1



Ø2.00
Ø1.13
.30
MATERIAL
1/2" PLYWOOD
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF THE OWNERS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION IS PROHIBITED.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: MACH ± 1°
TWO PLACE DECIMAL ±.06
THREE PLACE DECIMAL ±.010
DO NOT SCALE DRAWING
SIZE
B
NAME
DATE
DRAWN
JOHN MURRAY
4/20/22
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
WHEELSHAFT RING
PART NO.
N5015
REV
0
SCALE: 2:1
VOLUME:
SHEET 1 OF 1



4.00
2.00
2.00
4.00
2X Ø .13
.94
.94
Ø 1.50
MATERIAL
1/2 INCH PLYWOOD
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5
PROPRIETARY AND CONFIDENTIAL
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
P BECK
CHECKED
IOWA STATE UNIVERSITY
MECHANICAL ENGINEERING DEPARTMENT
DESCRIPTION
WHEELSHAFT BLOCK
SIZE
B
PART NO.
N5016
REV
0
SCALE: 1:1
VOLUME: 7.10
SHEET 1 OF 1

# E. Testing Plan – Methodology

**Test 1: Wheelhead Speed Test**

(Create a new sheet for each test to be performed.) (Expand as necessary. Print Test Plan and Test Results on separate pages.)

**TEST PLAN**

***1. Purpose of Test***

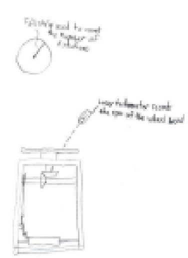
Function to be tested
Pedal to wheel head drive system

Failure mode to be tested
Problematic slip with the gears, belt, or miter gears; Unnecessary friction in the drive system reducing rpm output

Data to be collected
Angular Velocity of the Wheel Head

***Hypothesis***
The operator will be able to operate the foot pedal and achieve a maximum angular velocity of 100 rotations per minute (rpm)

***2. Description of Test Procedures***

| Test procedures | Description of data collection | Team member duties | Schematic/sketch |
|---|---|---|---|
| 1. Connect tachometer measure strip to the wheel head | Record the maximum rpm acheived during each set and determine the overall maximum rpm | Evan attaches tachometer to wheel head |  |
| 2. Operate the wheel head by use of the foot pedal | | Jack operates the foot pedal | |
| 3. Record the maximum achieved rpm as read by tachometer gauge | | Patrick observes the tachometer readings | |
| Repeat steps 2 and 3 for a total of five sets | | Robert records the maximum rpms | |
| | | Luke observes the entire pottery wheel for any signs of damage during the test | |
| | | Each member rotates for each set to attempt to get the highest rpm possible | |

***3. Relevant Math Model***

The operator applies a force and linear velocity to the foot pedal, which is transferred to torque and angular velocity at the drive gear. The angular velocity and torque is then altered via gear ratio out of the output gear, transferred to a horizontal rotation from vertical rotation through miter gears, and then outputted to the wheel head as a final angular velocity and torque.

| **Parameters Held Constant** | **Units** |
|---|---|
| Gear ratio between drive and output gears | **None** |
| Available surface area of the foot pedal to push on | |

| **Parameters Varied** | **Units** |
|---|---|
| Linear velocity applied at foot pedal | m/s |

| **Dependent variable** | **Units** |
|---|---|
| Angular velocity of the wheel head | rpm |

***4. Schedule and Test Location***

Date: 04/20/2022

Time: 2:20 p.m.

Location: Boyd Lab

Notes:

| ***5. Equipment and Materials Needed for Test*** | **Accuracy of instrumentation** |
|---|---|
| 1 Tachometer | +/- 0.05% |
| 2 Pencil/Paper | N/A |
| 3 | |
| 4 | |

**Test 1: Wheelhead Speed Test**

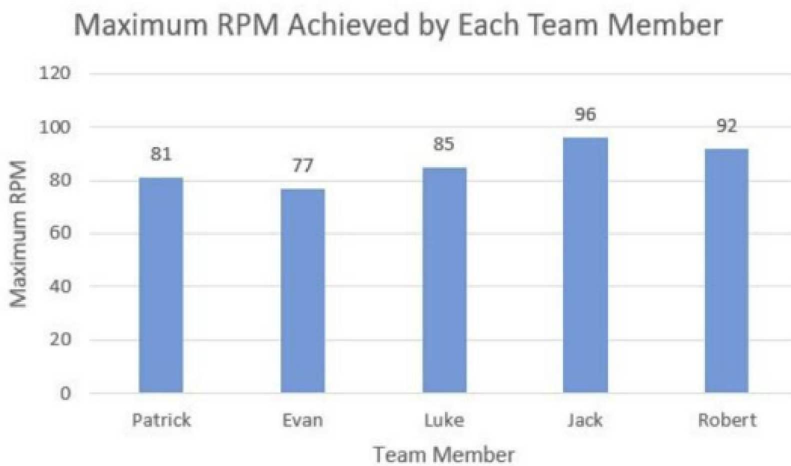
(Create a new sheet for each test to be performed.)

**TEST RESULTS**

*1.* ***Quick Summary:*** The test was done by each member of the team turning the output shaft with their hands as fast as they could, which would turn the wheelhead shaft. The maximum rpm achieved during our wheel head speed test was 96 rpm. This did not validate our hypothesis of 100 rpm or the model prediction value of 150 rpm. While the prototype did not achieve the goal, it did achieve an rpm very close to the goal, which is resonable based on the challenges encountered during the build phase. It was probably slower than expected because we underestimated the total weight of the wheelhead. Additionally, since the pedal shaft wasn't on a bearing, its friction on the reaces may have slowed down the motion.

***2. Test Results***

| Parameter | Measured value | Units |
|---|---|---|
| Maximum wheel head speed | 96 | rpm |



## Test 2: Wheelhead Strength Test

(Create a new sheet for each test to be performed.) (Expand as necessary. Print Test Plan and Test Results on separate pages.)

### TEST PLAN

***1. Purpose of Test***

Function to be tested

Ability to support and operate under load

Failure mode to be tested

Failure to operate normally

Data to be collected

Total weight supported until rough operation

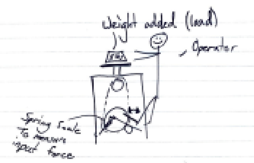
***Hypothesis***

The wheel will continue to operate normally and easily under a load of up to 20lb

***2. Description of Test Procedures***

| Test procedures | Description of data collection | Team member duties |
|---|---|---|
| Add initial weight of 5 lbs. | Record weight added | Jack adds weight, Luke Records |
| Operate Machine | Record wether machine operates normally or not | Patrick spins wheel, Luke Records |
| Continue adding weight in 5lb incriments | Record weight added | Jack addes weight, Luke records |
| Operate Machine | Record operating RPM | Robert spins wheel, Luke records |
| Repeat steps 3 and 4 until machine fails to meet requirements | Once wheel begins to reach failure switch to 1lb incriments | |

**Schematic/sketch**




***3. Relevant Math Model***

For this test, the outcome will be determined to be operating smoothly based on the input force staying under our original goal of 22.5 lbs. and the operator qualitatively deciding how well the wheel is operating under said load on a pass/fail basis.

| **Parameters Held Constant** | | **Units** |
|---|---|---|
| Input Force | held within range | lbf |

| **Parameters Varied** | **Units** |
|---|---|
| Load | lbf |

| **Dependent variables** | **Units** |
|---|---|
| Smooth Operation | Pass/Fail |

***4. Schedule and Test Location***

| | |
|---|---|
| Date: | 4/25/22 |
| Time: | 2:25 PM |
| Location: | Hoover 1360 |
| Notes: | |

| ***5. Equipment and Materials Needed for Test*** | | ***Accuracy of instrumentation*** | |
|---|---|---|---|
| 1 | Spring Scale | To .1 lbf | |
| 2 | Weights | | 5% |

## Test 2: Wheelhead Strength Test

(Create a new sheet for each test to be performed.)

**TEST RESULTS**

1. ***Quick Summary:*** The wheel did not support and operate as smoothly as we had predicted under applied loads to the wheelhead. We initially were expected the wheel to operate smoothly up to 20lbs but were only able to operate the wheel up to 15lbs. This was mostly due to the frame failing rather than friction in the shaft/gears that we originally assumed would be the cause of failure. The load only started to impact the structure of the frame after 10lbs were added with complete failure at weight added over 15lbs. When testing for wheelhead strength, we used 2.5, 5, and 10 lb weights to slowly add weight in 2.5 lb increments to the top of the wheel. Once the weight was loaded we then operated the wheel to test if it would function correctly. For weights under 10 lbs, the wheel operated normally and was able to spin smoothly. After adding additional weight we noticed bending in the frame which eventually led to failure of the wheel. Before failure we were able to reach 15 lbs of weight added on top of the wheel. Our hypothesis was proven wrong since our wheel did not operate up to 20 lbs. This type of failure was unexpected and to account for this we added additional support to our frame to ensure there is less bending and in return we were able to get smoother operation at higher weights.

***2. Test Results***

| Parameter | Measured value | Units |
|---|---|---|
| Weight Supported | 15 | lbf |

## Test 3: Pedal Force Test

(Create a new sheet for each test to be performed.) (Expand as necessary. Print Test Plan and Test Results on separate pages.)

### TEST PLAN

***1. Purpose of Test***

**Function to be tested**

Foot Pedal and Drive Shaft compatibility function

**Failure mode to be tested**

Foot Pedal force, shear, and impulse upper limits; Pedal Shaft force, shear, and impulse upper limits

**Data to be collected**

Deformation of the Foot Pedal and/or Pedal Shaft (in degrees); Force strength applied

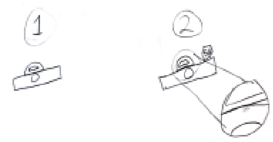
***Hypothesis***

The Pedal Shaft will not experience visible deformation for forces between 0 and 150 lbs force (about 0 to 667 Newtons).

***2. Description of Test Procedures***

| Test procedures | Description of data collection | Team member duties |
|---|---|---|
| 1. Measure Foot Pedal initial bend with protractor | Recorded deformation angles due to weight placement | Patrick measures initial bend |
| 2. Apply 5 lb weight to one corner of Foot Pedal | | Jack applies and takes off weight |
| 3. Measure deformation with protractor | Recorded deformation angles due to weight placement | Patrick records change in Foot Pedal Shape |
| 4. Repeat steps 2 and 3 for each corner, and for 10, 25, and 50 lb weights. | | |

**Schematic/sketch**




***3. Relevant Math Model***

This test measures the resistance of the Foot Pedal to the initial force input from the operator. The operator applies this force to the Foot Pedal in order to move the Drive Gear which translates this input into spinning the wheel, as the machine was designed. However, the Foot Pedal and Pedal Shaft must be able to reasonably accomodate forces applied directly on the axle's midsection, as well as occassional strong forces from the operator during its lifetime. If the test yields negative results (i.e. the Foot Pedal or Pedal Shaft experiences large deformation), different materials and/or designs must be applied to the parts in order to correct this defect

| Parameters Held Constant | Units |
|---|---|
| shaft length | in |
| pedal size | in^2 |

| Parameters Varied | Units |
|---|---|
| weight magnitude | lbs |

| Dependent variable | Units |
|---|---|
| degrees change in bend | degrees |

***4. Schedule and Test Location***

| | |
|---|---|
| Date: | 4/25 |
| Time: | 2:30 |
| Location: | Hoover 1360 |

Notes:

| *5. Equipment and Materials Needed for Test* | Accuracy of instrumentation |
|---|---|
| 1. 5, 10, 25, and 50 lb weights | .2 lbs |
| 2. Protractor | 2 degrees |
| 3. Ruler | 1/16 |
| 4. Pencil + Paper | |

**Test 3: Pedal Force Test**

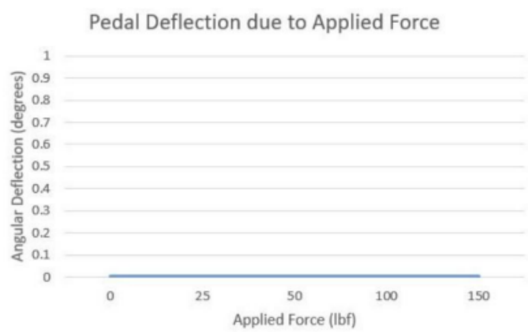
(Create a new sheet for each test to be performed.)

**TEST RESULTS**

*1. **Detailed Analysis:*** The test results were an overall success. Our hypothesis was validated as the pedal was able to withstand 150 lbs of force and continue to operate normally. Additionally, there was no measured deflection during the test, which added to the evidence of how strong the pedal assembly is. The foot pedal strength test was accomplished by placing 25 and 50 lb weights over the center section of the foot pedal assembly, while the assembly was mounted in the prototype. Both angular deflection of the pedal and total weight supported were measured. Our hypothesis was that the wheel would support a maximum load of 150 lbs with no indicated angular deflection. The hypothesis was validated as the pedal assembly was proven able to support the weight with no measurable deflection. While we did not have any explicit pedal strength benchmarks or specifications to meet, the strength of the assembly does add credibility to the overall durability of our design, which is a primary customer concern.

***2. Test Results***

| Parameter | Measured value | Units |
|---|---|---|
| Degrees of Bend | 0 | degrees |
| Weight Supported | 150 | lbf |



## F. Final Design Assembly Drawing