Rock-N-Bowl II
Final Design Report

Bowl-Tronics

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Statement of Disclaimer

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Chapter 1

Introduction:

Bowling is a classic American past time enjoyed by people of all ages, but this seemingly simple game has been off-limits to people with a disability. Including this eager crowd of athletes is our priority, but the simple solutions will not cut it anymore. The goal of our senior project is to allow people with a disability to bowl in a whole new manner by incorporating spin and speed as variables, adding new dimensions to the world of assistive bowling.

Focusing on athletes in joystick operated power chairs will hopefully provide a number of athletes with various disabilities an unparalleled bowling experience. Our main clients are Mike Ward and Doug Carrol, as well as other local athletes in San Luis Obispo. By creating a customizable and universal bowling experience the Rock-N-Bowl II will bring new features previously unavailable in assistive bowling systems. We are also working closely with a team of Kinesiology experts, including Dr. Taylor, and trying to design a bowling device to work with as many different people as possible.

It is highly important to get the motion and strategy of bowling as close as possible to standard bowling. Using strategy and ball control allows people with a disability the opportunity to truly compete with a standard bowler. Spinning the ball consistently will be a key element of our design. The bowling device needs to allow curving the ball in for a strike like the professionals do. Also, the bowler needs to control the speed of the ball for optimal ball control. Giving the athlete this control will stimulate the athlete more than standard "ramp" bowling, and give them the thrill of competition the way they want.

Chapter 2

Background:

To design a device that best meets the needs of the user and to provide both an enriching experience and a robust, durable product, we need to understand the physical and mental capabilities of the user. Our main clients have restricted movements, but making ourselves aware of a wide variety of physical and mental disabilities will allow us to accommodate multiple users when designing our product. While conducting background research we found it most reasonable to expect the users to interact with the device as much as they are capable, so our system will need to be able to accommodate people with very limited motion.

Our team learned several important things in researching not only physical and mental disabilities, but also the basic human need for a sense of community common with family sports like bowling. We first acknowledged the need for excitement in the sport of

bowling. People who have disability are no different in their desire for challenge and sport. Therefore, the experience we provide our users is just as essential as the quality of our welds. This will play a huge role when designing our product. Our goal is to create a product where there is room for failure, room for frustration, and room for growth. Because one of our clients used to be an avid bowler and is still very interested in the competition of the sport, we plan to pay close attention to creating a challenging environment where the user will need to practice to be able to excel at a high level. Our other client is looking for more of a social environment, so the device also needs to be simple enough to be able to perform decently without extensive practice.

Other research conducted about competitive adaptive bowling was done to determine what to expect for the more advanced user. We also learned about the competitive adaptive bowling guidelines determined by the American Bowling Congress (ABC) from a reference text, Adapted Physical Education and Sport, by Joseph Winnick. Although competition guidelines are important, we also want to break the rules a little to provide a fun experience where the user can spin the ball, which isn't allowed in most international adapted bowling competitions.

Figure 1: Rock N Bowler 1

On top of research conducted on physical and mental disability, we researched other adapted bowling designs. The previous Cal Poly design, the Rock N Bowler I(see Figure 1)provided the user with a great experience, allowing them to learn and grow in their adapted bowling ability while connecting an otherwise neglected group to a classic game. The biggest problem with the previous design was that it didn't last very long. The Rock N Bowler achieved its goals of allowing the user to give spin to the ball upon delivery, and could even attach to the Universal Play Frame (UPF); however, it only lasted a few weeks in use before it broke. Having this information makes durability one of our greatest concerns in designing the improved Rock N Bowler II. The only thing better than giving a person with a disability the opportunity to bowl, is to allow them to bowl and become skilled with a device. After looking at the Rock N Bowler I we noticed that there was poor material selection that caused it to have structurally weak points. Other devices encountered on the market give a great model for structural design but many fail to emphasize the important idea of the Least Restrictive Environment (LRE), or giving the user the fullest possible

experience. The experience the user has with the bowling device is just as important as the structural integrity. After reviewing several different adapted bowling devices currently on the market, we see that the biggest improvement we can make is to enhance the experience of our client.

One of the best existing adaptive bowling apparatuses is the IKAN Bowler (see Figure 2). This design allows the bowler to use the momentum of the chair and height of the chair to make the ball roll down the alley, which creates a fuller bowling experience. It also has a sturdy ramp which gives it a strong and dependable life. The IKAN Bowler Company also produces a universal wheelchair attachment which allows anybody to use their product. We feel that the IKAN Bowler is a great bench mark to try to meet and/or exceed, thus we have set a lot of our engineering specifications based on its capabilities.

Figure 2: IKAN Bowler attached to a power chair

Another simple solution is the free standing bowling ramp produced by FlagHouse Inc.(see Figure 3below). This is just a basic ramp that you roll the ball down towards the pins. This ramp allows a quick change between users and it is easy to set up and use. The bowler simply pushes the ball down the ramp once it is in the desired position. After talking with some people that have used a similar device we realized that the light weight design and lack of mounting caused many problems for the user. When the ball is pushed down the ramp, the ramp physically moves from the forces on the ball. This makes the user dependent on two other people to hold the ramp steady so the ball rolls the way the user wants, which is the main problem.

Figure 3: Free standing bowling ramp produced by FlagHouse Inc.

Our team has learned from the strengths and weaknesses of previous designs both on the

market and in academia. Knowledge of these strengths and weaknesses coupled with a deeper understanding of our users' capabilities gives us a good idea of what is needed to achieve an inclusive environment in sport of bowling. These establish a good platform to start our design.

Objectives:

The top priority of this project is to simulate a bowling experience for a person with a disability that does not allow them to bowl conventionally. After talking with one of our clients and our sponsor, Dr. Taylor of the Kinesiology Department, we have come up with a list of requirements that will satisfy the needs of our users:

- The end product should be able to "throw" the ball close to the normal speed of a bowling ball, and it must curve the ball to enhance the bowling experience.
- All of the user interface should be within a six inch range of motion around the customer's hand.
- The device needs to easily attach to a wide variety of different wheelchair designs, and be easily adaptable to go from one chair to another.
- A personal assistant must be able to install it by unassisted, so the device cannot be too heavy or cumbersome to prevent a single person from installing it.
- Finally, the device must be easily transportable so that it can be used at multiple bowling alleys, even though we are planning on leaving the device at Mustang Lanes. Therefore, the device must come apart and fit in a car or truck for easy transportation.

In order to accomplish these requirements, we developed them as Engineering Specifications to guide our design process, as shown in Table 1, on the next page. These Specifications were derived from our House of Quality; see Appendix A which shows the importance of each specification to its intended user including the bowlers and any personal assistants that will be helping with set up. The unique thing about the House of Quality is that it takes into account all of the users and requirements for the project. Then Quality Function Deployment (QFD), which takes into account all aspects of the design process, was used to analyze the customer requirements and turn them into engineering specifications based on the conclusions drawn from the House of Quality discussed earlier. This also allows us to make a simpler specification list that narrows down exactly what the product needs to do.

The most critical requirements for our design will be Ball Speed, User Input Range, Spin Speed, and Life Span because all of these factors will affect our customer's bowling experience.

Ball speed is at the top of this list because the device we make should roll a bowling ball at a comparable speed to the average bowler. Many current designs roll the ball

relatively slowly and do not have the ability to vary the balls' speed. To do this we will mount the device to add some of the momentum from the chair to the ball.

Table 1: Engineering Specifications including: Risk, (H) High, (M) Medium, and (L) Low; and Compliance, (A) Analysis, (T) Test, (S) Similarity to Existing Designs, and (I) Inspection. Risk determines how critical the specification is to the design, and compliance determines how we will analyze that particular specification.

Spec. #	Parameter Description	Requirement or Target	Tolerance	Risk	Compliance
1	Ball speed	5 mph	Min	H	T
2	User Input Range	6 in^3	Max	H	T, S, I
3	Spin Speed	1 rad/s	Min	H	A, T
4	Wheelchair Speed	4 mph	Max	L	T, S
5	Expected Life Span	3000 games	Min	H	A
6	Setup Time	5 mins	Max	L	T
7	Accuracy	10" @ 60'	Max	M	T, I
8	Weight	70lbs	Max	L	A, T, S
9	Cost	1500 dollars	Max	M	A
10	Battery Life	1 hr	Min	L	A, T

The customers' only method of interacting with the device will have to be through simple hand movements and the motion of their own power chair. For this reason, a six inch box of motion around the user's hand will serve as our benchmark for how much our customer can interact with the device. This means that anything we make must be easy to use and require little activation pressure or movement.

One of the most important high risk specifications is spin speed, which is where the fun factor comes in. The more spin we can offer the customer, the more fun the bowling experience will be. This is also what will set our design apart from all the other assistive bowling devices, so the spin speed is quite crucial. By offering variable spin speed, we are providing a new bowling experience that will engage our customers more, and create a unique bowling feel that the other currently available devices cannot. This also gives the customer the least restrictive environment (LRE) that will simulate bowling in a whole new way.

Lastly, life span is of utmost importance for our design due to the disappointingly short life span of the Rock N Bowler I. Therefore, we have to use high factors of safety in our calculations, and ensure that everything has the proper tolerances for high reliability and infinite life.

Chapter 3

Design Development:

Taking the specifications that we created, we moved on to brainstorming solutions. We were able to come up with a lot of different ways to solve the problem. We broke the main problem into two main sections, spin and forward motion. We brainstormed different solutions to each problem and came up with the solutions in Table 2 below.

Table 2: This figure shows our initial ideas regarding how to solve our problem

Forward Motion	Spin
Ramp	Rifled Tube
Impulse Actuator	Rollers
Pitching Machine	Variable Friction
Cannon	N/A

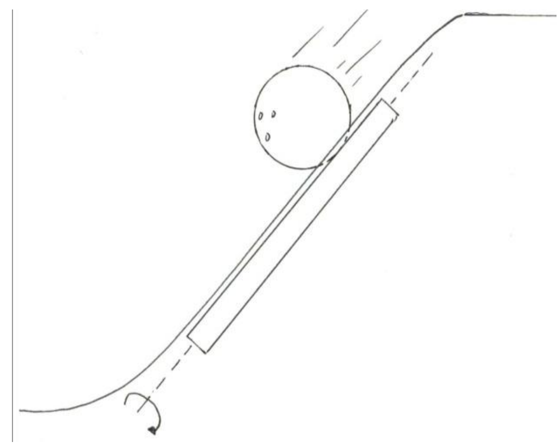

Figure 4: One set of sectional rollers down the middle of the rails

Top Concepts:

From these possible solutions we were able to mix and match the features to create a few leading candidates for our final design. One of our leading designs was a ramp with one roller on each rail angled down the slope, see Figure 4.This design allows us to get most of the device's length off the ground in front of the chair and elevate it over the user to increase mobility. Another concept that we came up with is using segmented rollers, see Figure 5, to allow a more gradual transition and still apply the same amount of spin. There is also the possibility of using a pitching machine type device at the top of the ramp, see Figure 6, so we can add as much spin as we want at the top of the ramp and then push the ball down the ramp. An idea that we had to add more speed to the ball was to make a spring loaded carriage, see Figure 7;this gives the ball an added kick down the ramp. We also tried the idea of ditching the ramp all together and using a ball launcher placed flat on the ground, see Figure 8. This idea was interesting because it potentially has a lot of power but it would be harder to use and would make the user even further

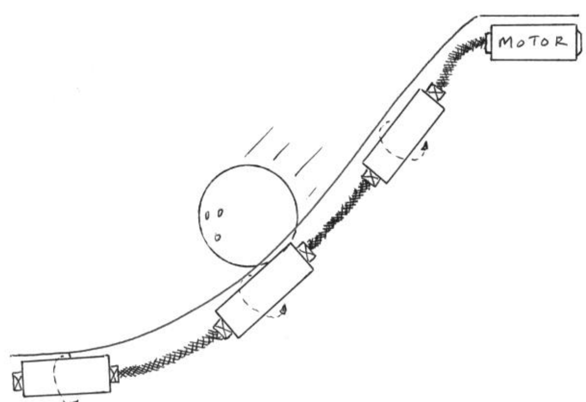

Figure 5: Segmented rollers down the middle of the rails

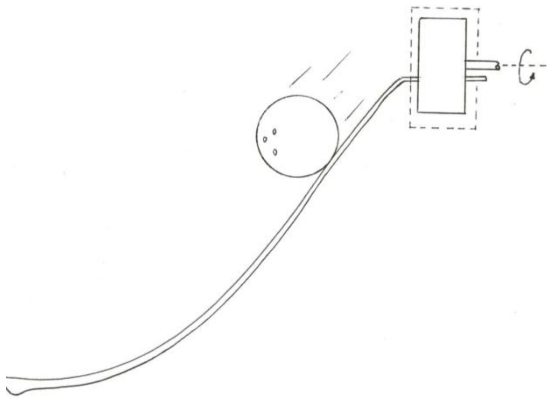

Figure 6: Pitching Machine at the top of the rails

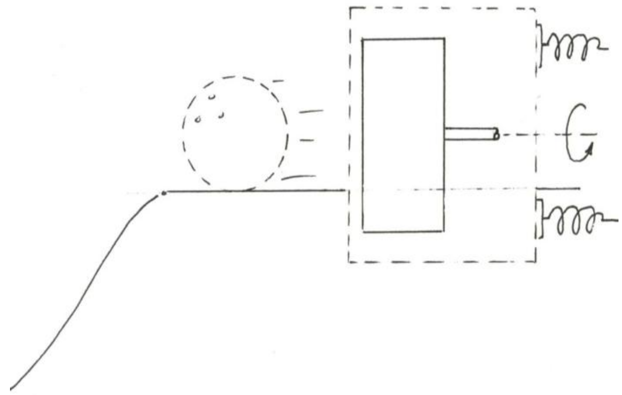

Figure 7: Pitching Machine on spring loaded carriage

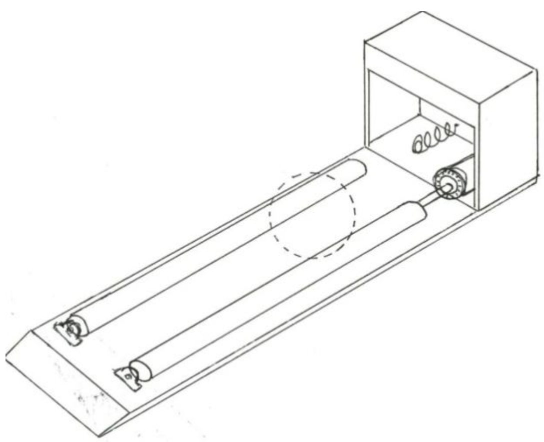

Figure 8: Flat non ramping spring loaded pitching machine

Figure 9: Ramp with two sets of rollers on the rails

from the ball; thus creating a distanced experience. The last idea that we are showing is a ramp with two sets of rollers, see Figure 9below, this allows for maximum spin while getting the majority of the length above the chair.

Selection Process

In order to narrow down the concepts to the best possible solution we used Pugh matrices, which can be seen in Appendix A, to compare possible solutions and see which ones were the most promising. Our first pass was comparing our solution ideas to the IKAN Bowler to make sure that what we created was better than the current solution, see Figure 45 in Appendix A. After the first pass at narrowing it down using Pugh matrices we had a three-way tie between some of our similar concepts, Figure 45inAppendix A. This led us to make another Pugh matrix using our perceived top design as the datum so we could see if it really was the best. The result of this Pugh matrix was interesting because one of our other concepts appeared to win, but upon a

closer look it won because it was better at less important specifications. We then moved on to compare these solutions in a more complicated weighted decision matrix, Figure 47Appendix A, which compares how well a concept satisfies a specification to how important that specification is. After this matrix we were able to decide on our best possible solution.

Testing:

Another important part of our concept development and selection was the prototype testing. Our first prototype used parts from the broken Rock N Bowler I; the test setup can be seen in Figure 10. We tested if we could generate spin using rollers on a slope, which was important so we could see if angled rollers are a viable solution. It was also necessary to determine if the spin applied by the rollers could be maintained when transitioning the ball from the angled

Table 3: Ramp Testing Results where heavier balls go faster, and the fastest speed recorded was 6.32 mph and the average speed was 5.95 mph

Ball Size (lb)	Height (in)	Speed (mph)
10	39	5.8
		5.37
	44.25	5.65
		5.83
	52.25	5.83
		5.73
12	39	5.47
		5.37
	44.25	6.23
		6.12
	52.25	6.22
		6.31
14	39	6.19
		5.96
	44.25	6.1
		6.32
	52.25	6.21
		6.31

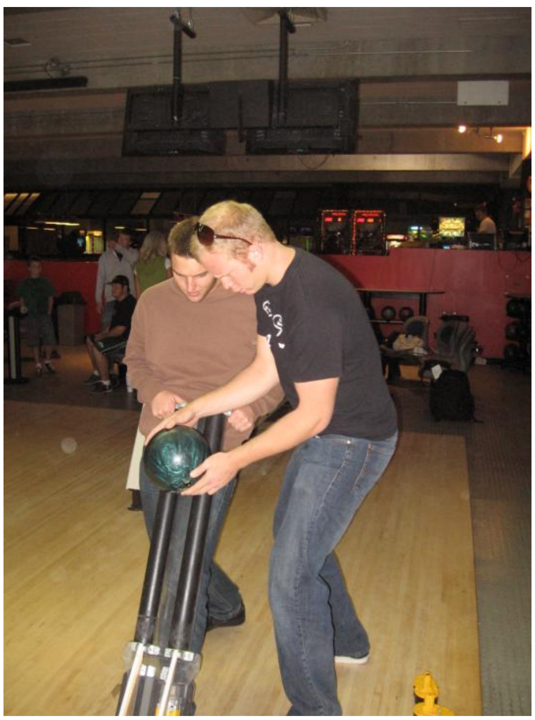

Figure 10: Modified Rock-N-Bowl 1 testing for spin

Figure 11: Ramp testing for spacing, height, and angle parameters

rollers to the horizontal floor. We were able to confirm that this was possible which allowed us move forward with our leading concept. The second prototype that we tested was a full sized ramp. This ramp allowed us to experiment with ramp height, angle, and rail spacing. From these tests we were able to find that we can reach approximately 6 miles per hour with a 4 foot ramp, shown in Figure 11. The most important thing that we learned from this prototype was the significance of having a smooth transition from ramp to the alley. When we tested the ramp at a larger height, we also decreased the transition time and increased the transition angle, because of how the ramp was constructed. These changes caused a lot of the ball energy to be lost at the foot of the ramp. This energy loss relates directly to the speed of the ball, so with steeper angles the ball speed stayed almost constant as shown in Table 3.

Chosen Concept

The concept that we have chosen to move forward with is the ramp with two sets of rollers, presented in Figure 12. From the decision matrices we concluded that this solution will provide the user with the best bowling experience. This solution gives the user the ability to apply the most spin to the ball and the most maneuverability with the bowler attached.

Figure 12: Conceptual solid model of our best design

Chapter 4

Description of the Final Design

After choosing our final concept we moved forward with figuring out all the details in each component. Our final design can be seen in Figure 13. Our design can be broken down in to four sections; the ramp, support, attachment, and controller.

The Ramp

The ramp is made of PVC sections and rollers. There are two sets of rollers, a powered one and a free spinning one. The powered rollers are made of polyurethane to create a high friction surface to transfer the rotation to the ball. The free-spinning roller is made of delrin to help eliminate any losses to friction the ball would get from that side of the ramp. The driven rollers will be powered by a Makita drill that is connected to the steel shaft down the middle of the roller. The drill power will be transmitted by a flexible shaft bit extension which is coupled to the shaft. The shaft is then coupled to another bit extension which connects to the

lower spinning roller. The shafts of each roller are supported by bearings on each end to allow them to spin freely. See the roller assembly in Figure 14.

Figure 13: Complete final design

The ramp is around 38 inches tall and at an angle of 50 degrees to allow the ball to get to 5 mph. This height also allows for the ball to be roughly in the user's lap to allow them to see over the ball and down the lane and to push the ball while the ramp is set in the stationary position.

Support

Our support allows for quick assembly because the ramp attaches with the use of a single nut in the top center of the support shown in Figure 15 on the next page. The support carries most of the weight of the bowler and provides a mounting surface for the motor, battery, and speed controller. One of the main features of the support that allows everyone to use the device is the locking casters. If for some reason the device is not able to mount to the power chair or wheelchair, the support's locking casters will be able to hold the bowler in place so the user can just use it in the stationary position. The stationary position still allows for spin control, but it limits the speed control the user has since there is not height adjustability and they will not be able to add speed to the ball from their chair.

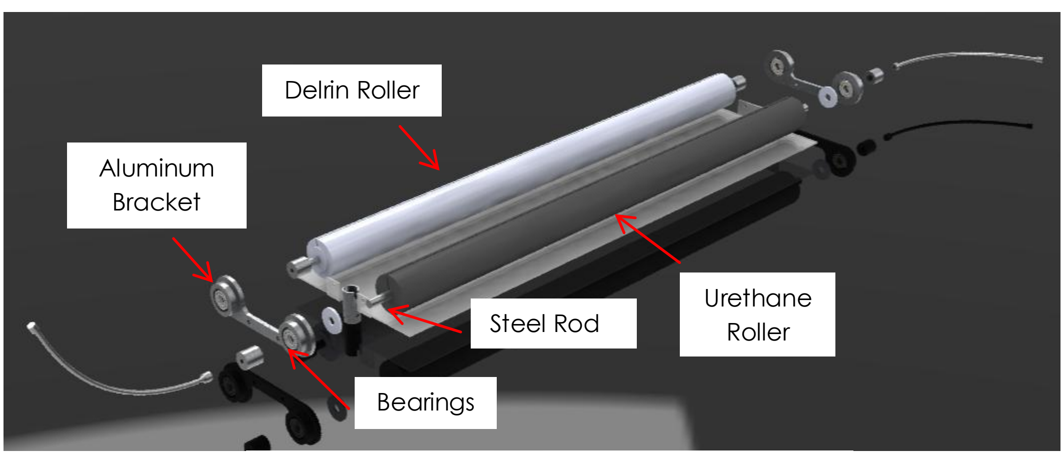

Figure 14: Roller assembly with labeled parts

Attachment

We decided to mount to strap attachments on the front of the chassis of his power chair, because it is the most rigid mounting point on our user's chair; the loops can be seen in Figure 16. The aptly named Gator Clamps are the solution to our mounting situation; their name will become more obvious after viewing Figure 17 below. We designed the Gator Attachment to be a flexible way of mounting to any power chair, wherein the clamps can mount to a wide variety of surfaces. The use of heavy duty pivot locking hinges enables the Gator Attachment to change height and mounting angle easily and quickly while maintaining rigidity. The Gators themselves are mounted within a telescoping steel tube that can change the distance the whole bowling device sits from the user. These tubes can also be adjusted side to side to allow different chair widths to be accommodated. The adjustability of our attachment allows for a more universal system that mounts to a wide variety of power chairs.

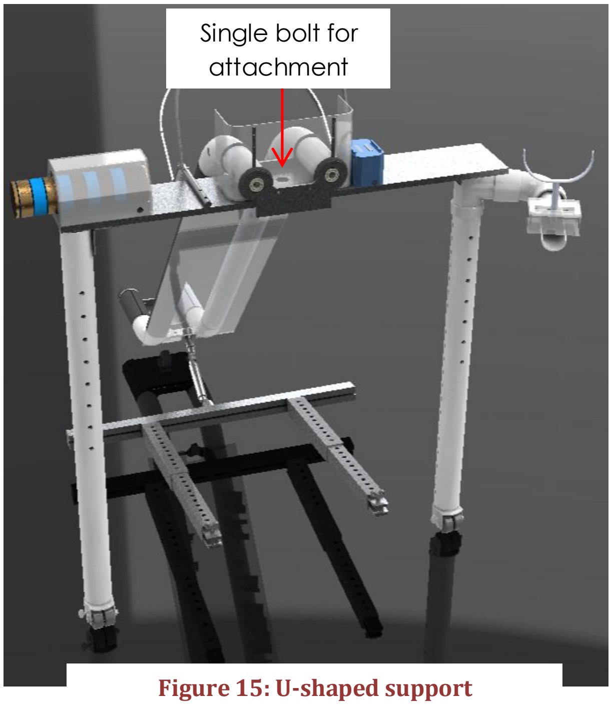

Figure 15: U-shaped support

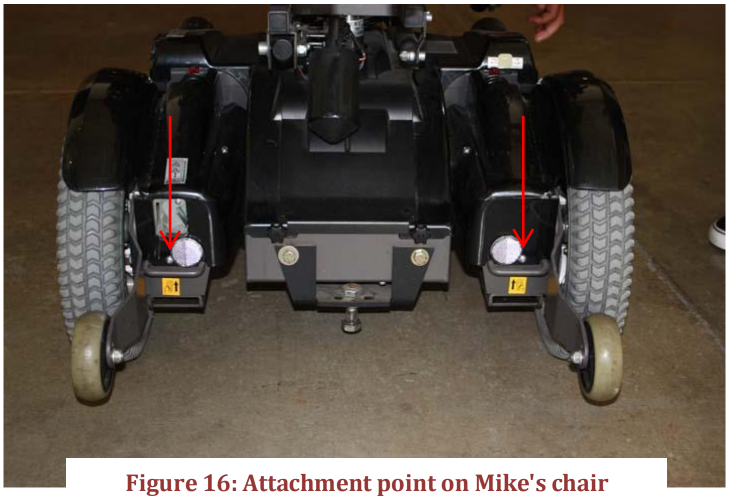

Figure 16: Attachment point on Mike's chair

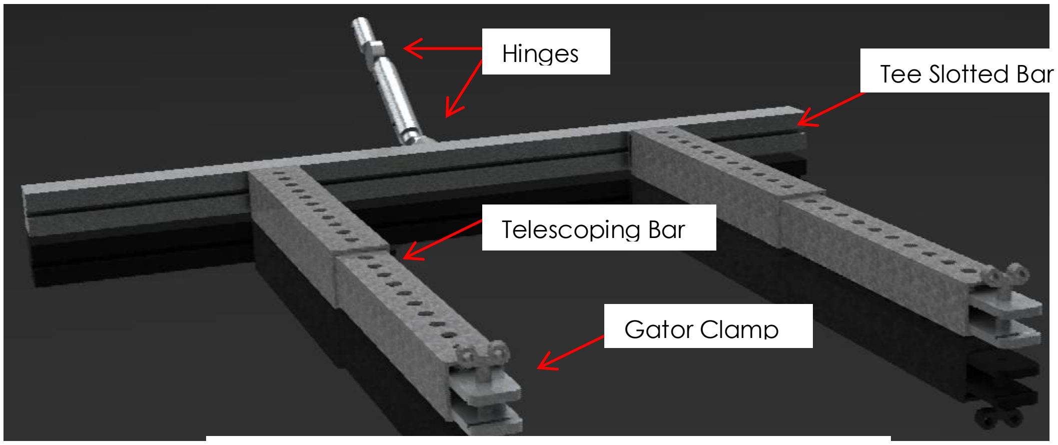

Figure 17: Gator Attachment with labeled parts

Controller

To reduce cost, we have decided to salvage parts from the drill that we originally were going to scrap. Thus, the controller will be dependent on the use of the drill's trigger for variable speed control, and by attaching a joystick to the trigger, our customer will be able to comfortably and easily change the speed of the spin applied to the ball. The actual box that the controller will be mounted in attaches to the u-support leg through the use of a sliding PVC collar that can lock into various heights and distances from the chair, as demonstrated in Figure 18. This will then create a customizable location of the control box which will include moving it to the other side of the support as well. The rollers do not turn themselves off automatically, so the user will need to put the joystick back into the neutral position after every bowl to stop the rollers. We expect there to be a learning curve in which the users figure out how far they need to move the joystick to get desirable results.

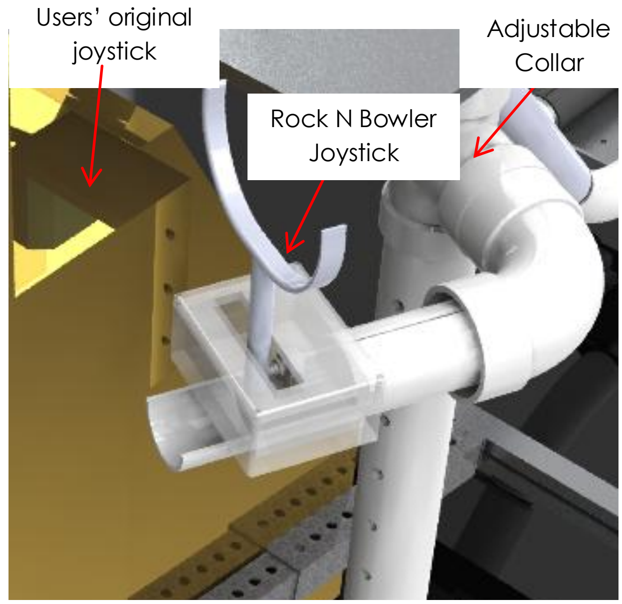

Figure 18: Controller close to the users' joystick

Analysis

There are many parts of the Rock-N-Bowl which are of concern based on the forces they see. For the most part, these areas are the ones where the ball is exerting its maximum forces on the ramp; see Figure 19, and the supporting columns that hold the weight of the device, see Figure 20 (see Appendix E).

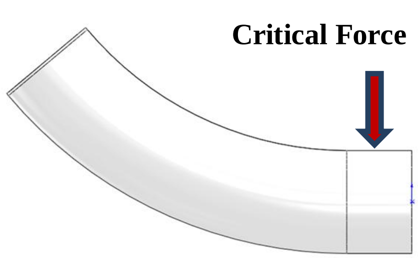

Figure 19: Location of the critical force on the ramp

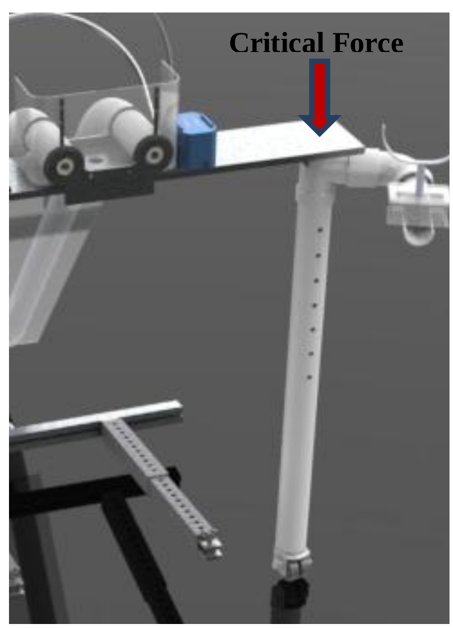

Figure 20: Critical force on the stand

Ball Speed

The speed of ball is crucial to the success of the bowler; if the device cannot roll the ball at a descent speed, the device will not be able to satisfy the needs of the user. After several meetings with our customer, measuring the speed of standard bowlers, and in depth discussion amongst ourselves, we came to the conclusion that the minimum speed of the bowling ball should be around 5 miles per hour. After some basic kinematic analysis, see Appendix E, we found that with a height of 39 inches we get a speed of 6.2 miles per hour at the end of the ramp. We chose the height of 39 inches so that the user can comfortably see over the ball and down the lane. This satisfies our spec, and using the wheelchair mount, the speed can be increased with the addition of forward motion of the wheelchair.

PVC Pipe Bend

The next point of concern is the PVC pipe bend because it is the weakest point of our design. Having PVC connected to two aluminum braces raises strength concerns for us, so we investigated the area. The first calculation done on the bend was the impact load caused by the ball. Assuming a ball weight of 16 pounds, we did the impact calculations to find that the maximum force the ball can inflict on the bend, see Appendix E. This impact force was found to be simply double the weight of the ball because the ball is not dropped onto the roller but simply applying its weight instantaneously to a point while still in contact with the ramp. The result yielded a shock loading of 32 pounds. We then used the shock loading to find the fatigue of the area due to the ball repeatedly pressing on the bend. Based on a two inch schedule 80 PVC pipe, we found that the fatigue factor of safety is 1.661, see Appendix E. This is a little lower than we had hoped, but this calculation was done using a 100 pound force instead of the 32 pound impact for extra safety. Lastly, to ensure that the PVC bend will hold, we found the simple stresses in the member using an impact force of 100 pounds, which is greater than the actual impact force. The calculation that was performed in EES yielded a factor of safety of 3.552, shown in Appendix E. This factor of safety is very high and shows us that the PVC bend will in fact be able to withstand the forces of a bowling ball.

PVC Support

We have chosen to use PVC as the legs of the Rock N Bowler II so they will bear the weight of the whole device. Therefore, detailed calculations were needed to prove that our material choice is justified. Our gut instinct was to assume that the member will buckle, so we said that we will apply a 200 pound force on the top of the device. We chose 200 pounds in case someone decides to sit on it. For this reason, a resulting force on the top of each member will be 100 pounds, and assuming a worst case scenario of a fixed free column in buckling, it was found that the PVC could hold 1277 pounds on each side, shown in Appendix E. Thus, the PVC will not buckle.

We also checked the deflection of the PVC legs while someone is sitting on it to prove its stability. In order to perform bending analysis on the column we used an offset of the axial load, from the caster offset, to create a moment on the beam. Again assuming a 100 pound force, the beam will only deflect .16 inches which means it will be very stable, see Appendix E.

Torque Requirements

The last place that our device can fail is in spinning the ball. We performed a torque analysis to prove that our device will be able to get a bowling ball spinning at our specified 1.4 radians per second. By assuming that the ball doesn't slip on the roller, it will take a 3.99 inch pound torque to get the ball spinning; see Appendix E. The drill that we plan on using has a maximum torque rating of 400 inch pounds which is way above what we need. Due to this large input torque the ability of the flex shafts used to transmit torque from the motor to the rollers has come into question. Since flex shafts don't really have published specs, we will need to further investigate the matter, but in our research we found a good ball park number for their maximum torque input to be around 156 inch pounds. To ensure that we do not break the flex shafts we will need to limit the drill electronically to only be able to output a maximum of 80 inch pounds of torque to get a factor of safety of two, and to increase the lifespan of all of the rotating components.

Safety Considerations

The safety of our users is of utmost importance to us since we do not want to injure anyone with our device. This is accomplished by using some clear plexiglass shields to protect the user from the rotating components of our design, see Figure 21. These shields will be around both the drill chuck and the rollers. The drill chuck was previously exposed, but due to its rotating nature we thought it best to cover it up to protect the user from potentially touching a rotating chuck. In addition, a longer shield will go the length of the rollers to make sure that the user's knees do not touch the rollers and possibly even get hit by a falling bowling ball. We have also designed a back-stop for the top of the bowler so that the ball cannot fall off the back of the device and into the lap of

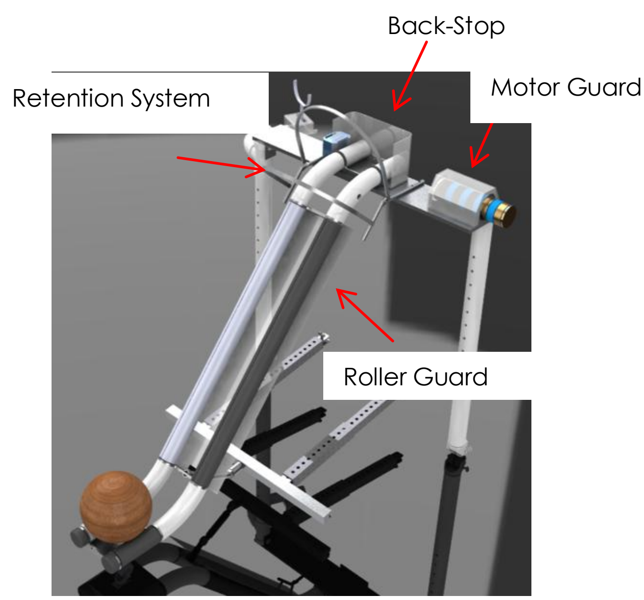

Figure 21: The safety consideration on our ramp.

the user. The back-stop is made up of plexiglass and aluminum L brackets to absorb the forces of the ball. All of these shields will be tamper proof unless it is necessary to access the component they are covering. We have also created an aluminum retention system at the top of the ramp to keep the ball on the ramp even with an inopportune turn by the user.

Material Selection

The basic materials of the Rock-N-Bowler include a plethora of steel and aluminum components along with some PVC. We chose materials based on both their weight in the modeled quantities and the strength for their particular application.

Ramp Materials

The ramp portion of our design uses a lot of different materials to sufficiently transmit spin to the bowling ball. The most important material selected for our ramp is the polyurethane for the rollers. Since the coefficient of friction of a perfect rubber on rubber contact is very nearly 1, we chose polyurethane rubber for the rollers because bowling balls are also made out of a harder polyurethane rubber. To contrast the polyurethane powered roller on one side, there will also be a delrin roller on the other side to allow the ball to slide easily and increase the performance of the spinning mechanism, see Figure 22. Bearings in an aluminum housing will be used to hold the

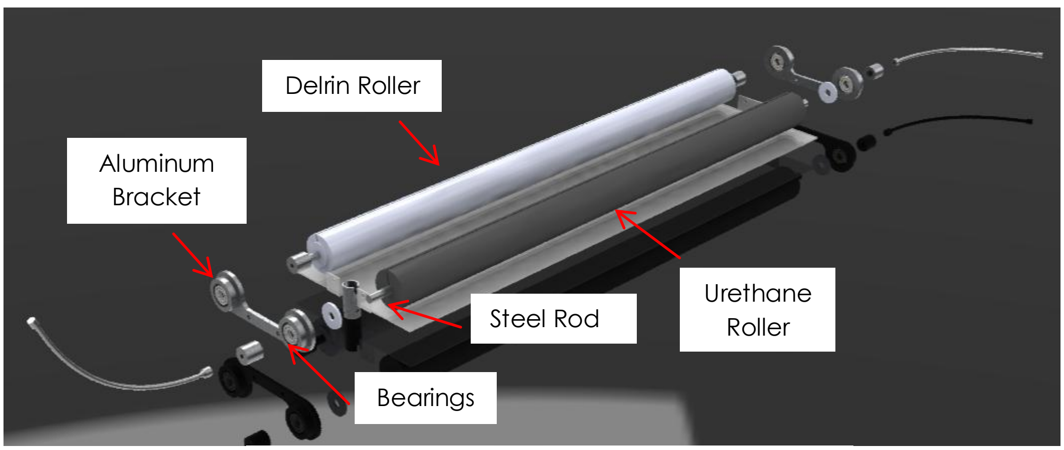

Figure 22: Roller assembly with labeled parts

rollers in place. These aluminum braces will also keep the rollers spaced equally while being light weight and easily machined. Since the PVC bend in the Analysis section could hold up to the balls' maximum force, just about any metallic material will hold up to the forces caused by the ball. Lastly, a steel rod will be inserted into the rollers to provide bending resistance and shaft whirl protection. This will be mirrored on the other side by mounting the delrin on a steel rod also.

U-Shaped Support

The top of the ramp will be mounted to a u-shaped support, see Figure 23 on the next page, that will be held up with PVC pipe legs because of their availability, low cost,

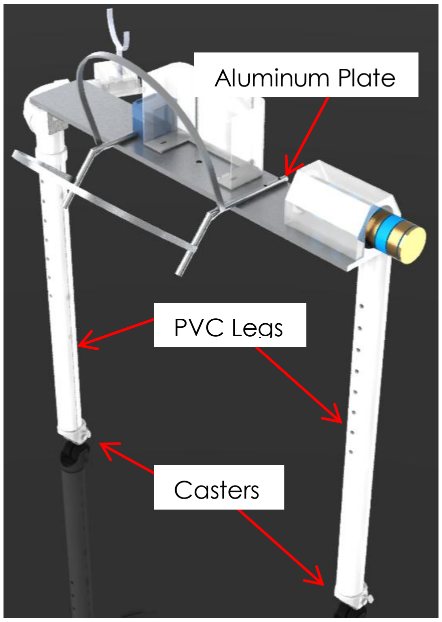

Figure 23: U mount with labeled components

and acceptable strength, see Analysis section. At the end of these legs there are lockable casters to allow for both easy rolling when the device is attached and stable stationary use when not attached. The other main component of the support is the top section made out of aluminum plate. This plate will be the main mounting point of the Ramp, Motor, and Battery. This plate will also hold the plexiglass safety guards because of its location above the user's lap.

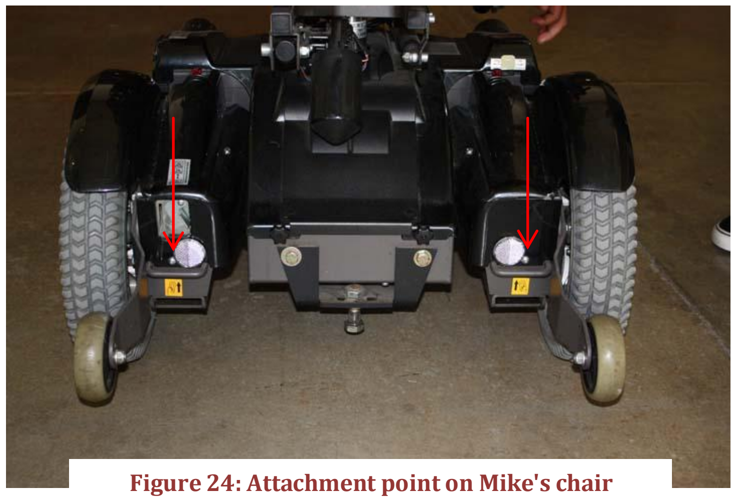

Figure 24: Attachment point on Mike's chair

Gator Attachment

In order to mount the device to the users' power chair, we will need to rigidly clamp to some part of a power chair. Based largely on our customer's power chair, we have decided to mount to the strap mounting point, see Figure 24above. This is a good rigid mounting point, and by making the attachment adjustable in both vertically and horizontally, the gator clamps will be able to reach many different locations on different power chairs. Even if for some reason the Gator's don't work, the caster wheels at the bottom of the u-support will be lockable to hold the bowler in place for anyone to use regardless of their power chair design.

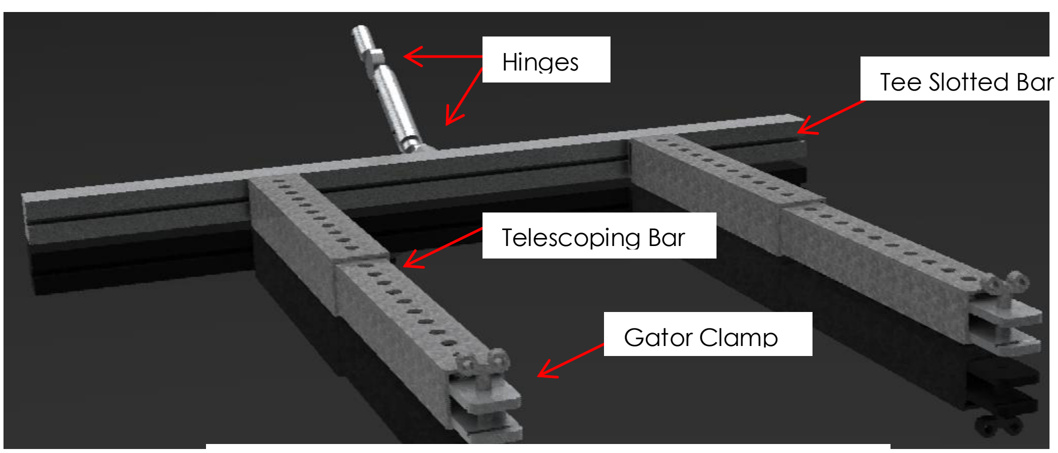

Figure 25: Gator Attachment with labeled parts

The most concerning part of the Gator attachment is the heavy duty quick locking hinges, which allow for fast adjustment of the Gator height and angle. The concern is that the hinges cost $107 each. In order to have a rigid mount, we need expensive heavy duty hinges so that attachment is easily accomplished and structurally sound. There are cheaper versions of these hinges, but they sacrifice strength by a factor of three. Next, to allow for different widths and distances of power chairs to the device, the gator attachment has a T-slotted bar with two telescoping rods to allow for width and distance adjustments. Lastly, the Gators themselves are at the end of the telescoping rod to grab onto whatever is easily accessible and rigid on the chassis of the chair, see Figure 25 on the previous page. This will allow for the greatest amount of flexibility in the mounting system.

Motor controller

Varying the speed of the rollers will allow the user to change the amount of hook on the bowling ball. To allow for user adjustable speed, we plan on using the drill trigger assembly by removing it from the grip. Next, the trigger will be mounted inside of a plastic project box that will have a slot to guide the joystick. By mounting the joystick with two 90 degree brackets, we will be able to tighten the through bolt enough to prevent the joystick from moving around on its own, but it will still be able to push against the trigger and cause the rollers to spin. The nature of bowling is that there is a wait time between bowls to allow for pin resetting and ball retrieval, so after a throw, the user should turn off the rollers to save power. This will keep the user from leaving the roller speed joystick in one position and having two identical throws, thereby creating a new skill of positioning the joystick in the right spot to get the desired spin.

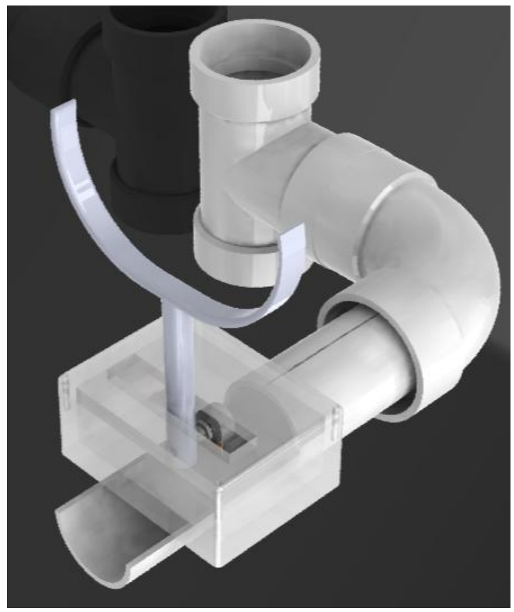

Figure 26: Controller assembly

The project box will house all of the electrical components of the controller and be mounted to the stand by a sliding and locking PVC collar. An elbow will bring the controller right next to the users' original joystick, to view the system see Figure 26 above. The use of PVC in the arm will provide an easy wire hiding system to make the support look clean and tidy. Castellating the bottom of the collar will let the user set how close the joystick will sit to the original joystick, because the castellation will fit into a pin for both radial and height adjustment to accommodate different users' preferences.

Special Fabrication

Due to the simplicity of our design, the only parts that need to be specially made are the aluminum braces that house the bearings and hold the rollers. These braces will need to be CNC milled to ensure that the arcs are precise, and that the nubs and bearings can press into them. Even though these parts need to be CNC machined, they are still an easy CNC project because they do not have any difficult contours; just simple three axis codes will suffice.

Assembly Instructions

To assemble the Rock-N-Bowl II requires just a single nut, and connecting a few simple electrical connectors. The Rock-N-Bowl II will break into two easily manageable pieces; the u-support and the ramp assembly. These two pieces will be attached, by design, with a single hand tightened nut at the top center of the support. The ramp will not rotate because of a lip on the mounting plate that keeps the plates in line. There are also quick release locking hinges at the bottom of the u-shaped support that connect the legs to the aluminum plate.

Maintenance and repair

The Rock-N-Bowl II is designed using components that require little to no maintenance. All of the bearings are sealed and do not require additional lubrication, and the drill is completely self-sufficient. The only regular maintenance required will be recharging the battery and using mineral spirits to wipe off any oils that have accumulated on the rails.

In the event that a part requires repair, the Rock-N-Bowl is held together with bolts that can be removed to open up a roller and get to any part necessary for repair. In addition, most of the parts are sold online and readily available for next day shipping if needed. The use of simple components that can be located in local hardware stores also increases the availability of replacement parts. The expensive and hard to find parts of the Rock-N-Bowl have been over designed to ensure longevity and reliability.

Cost

To ensure a sturdy and robust product, expensive materials were selected, and all crucial areas were designed with high factors of safety to make the product work as promised. To see the full pricing and detailed cost report see Appendix C. Below in Table 4is a simple cost breakdown of the various subsystems that make up the Rock-N-Bowler. You can see all the vendor specifications for the selected parts in Appendix D.

Table 4: Simple cost break down by sub system

Selected Parts	Description	Cost
Ramp	Full Roller Assembly	$413.12
U and Legs	Stand and Motor Mount	$134.09
Attachment	Gator Attachment	$318.69
Safety	Safety Guards	$71.21
Controller	Electronics and Joystick	$23.99
Misc.	All other Components	$65.96
Tax		$92.44
	Total Cost for 1	**$1227.75**
	Total Cost for 2	**$2174.05**

Testing

By inspection, the most critical point of our design is the flexible shaft system that delivers power to both of the rollers. After some torture tests of the flex shafts, we found that they catastrophically fail after only five minutes of being spun at 2000 RPM which means that a new power transmission method must be used. Using a drill motor, our options are gears, chains, or belts of which belts would be the easiest to implement without adding too much additional weight. The new model for the drive system can be seen in **Error! Reference source not found.**.

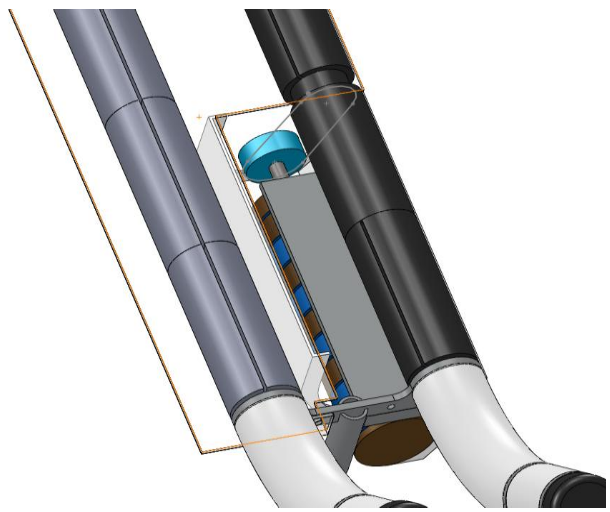

Figure 27: Revised system from spinning the rollers including a belt that goes over the top of the roller.

Chapter 5

Building the Rock-N-Bowl II proved to be quite challenging since all of the components were unique, and aside from nuts and bolts, none of the components are direct off the shelf parts. For this reason, every single part of the Rock-N-Bowl II was custom.

Since there was a very large amount of manufacturing to be done, the device was split into four sub-assemblies so that each team member could be working on a different

assembly simultaneously and increase productivity. The four assemblies were the Gator Attachment, Ramp, U-Stand, and Controller. For simplicity reasons, the Gator Attachment was the first assembly finished.

Gator Assembly

The Gator Assembly had the least custom parts and could therefore be built quickly and easily. The band saws and cold saws were used to cut the long pieces to length, and then mills were used to accurately drill holes in the desired locations. There was a small amount of turning necessary to make the connecting sleeves for the heavy duty pivot locking hinges, so the manual Lathes were used. Our original design involved welding the last sleeve to the T-Slot stock, but after some testing using the TIG welder, this design proved impossible due to the two dissimilar metals. Also, the original design used steel telescoping rods which ended up being far too heavy for the system to support (for more details see Appendix E), so new Aluminum Telescoping rods were designed to reduce weight without compromising adjustability.

Figure 28: Completed gator attachment waiting for other assemblies to be completed.

Ramp

The Ramp assembly was the most critical part of the whole design, and thus required some very advanced machining techniques to allow the system to spin and fit together. The crucial parts of the ramp assembly were the six braces that connected everything together. Since these braces used some pretty complicated geometries, machining them by hand would have been virtually impossible, so CNC mills were used to cut the braces out of a sheet of aluminum, see Figure 29. This was done using the Haas TM1-P CNC mill in the Mustang '60 machine shop. This machine was also used to make the large hole in the bottom plate for the low profile caster to sit in. To

Figure 29: Richard using the CNC mill to create the braces.

Figure 30: Richard press fitting the nubs into the braces.

Figure 31: Josh cutting the roller rods to length on an abrasive chop saw.

complete the brace assemblies, very high tolerance nubs needed to be machined to achieve a proper interference fit inside the brackets, see Figure 30. In this case, since the nubs were round, the Haas TL1 CNC lathe in the Cal Poly Hanger was used to ensure accuracy and repeatability.

Much simpler machinery was used to cut and turn the steel rods that are crucial for the structural integrity of the product, and in this case an abrasive chop saw, see Figure 31, and a Clausing Metosa Engine Lathe in the Cal Poly Hanger worked quite well. The top plate of the ramp was milled to size and drilled using a manual mill, and for this particular application, the Ganesh Vertical Knee mill, also in the Cal Poly Hanger, worked wonderfully. After the rods and braces were completed we were able to complete the roller assembly, see Figure 32.

Figure 32: Travis and Josh with the completed roller assembly

Some of the easier components on the ramp were simply cut using wood working tools like a Compound Miter Saw and drill press. In order to ensure the angle of the bent PVC sections we made a wooden jig to make each section the same size and angle, see Figure 33.

Figure 33: Travis cutting the bent PVC sections using the wooden jig.

The entire ramp assembly had the least amount of changes made during its production; however, we had initially planned on gluing the PVC sections, see Figure 34, to the aluminum nubs and after some testing the bond broke. This then required a new way of attaching the PVC to the nubs which was solved by inserting 27 screws down the length of the ramp. These screws not only held the ramp together better, but also increased the rigidity of the bowler significantly.

Figure 34: Josh assembling the ramp using the glue.

The last component added to the ramp was the torsion bar, see Figure 35. When the ramp was first assembled there were some major flexing issues in the ramp section, so to combat these and to stiffen the system, the torsion bar was installed down the center of the ramp. This solution actually ended up working very well, and eliminated the twisting effect the ramp was experiencing while being moved.

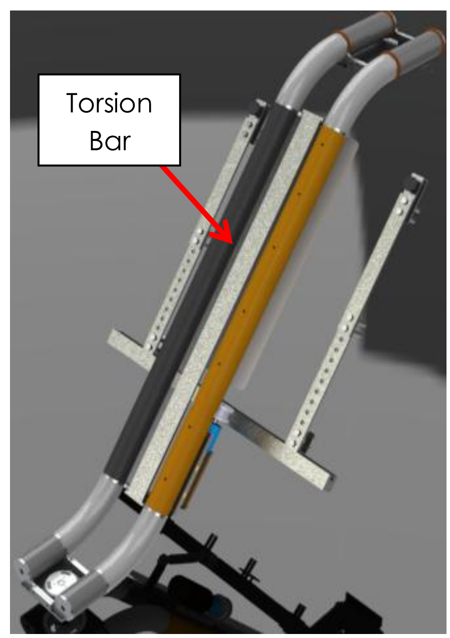

Figure 35: Completed ramp with torsion bar.

U-Stand

Building the U-Stand was supposed to be a simple job, but we ran into problems with its design after assembly. First off, the casters were attached to the two inch PVC end caps using a lathe to ensure accuracy. Then the two inch schedule 80 PVC pipe was cut to make the legs, and after this, we started having problems.

The first problem we noticed was that the table hinges, see Figure 36, used to allow the legs to fold up didn't have a uniform bolt pattern, so after much careful measuring, the holes were located and the top plate was drilled to reflect all of the mounting holes necessary. After the stand was complete and the ramp was set on it, the legs were flexing a lot more than the calculations (in Appendix E) predicted. Investigating this issue revealed that the hinges had quite a bit of slop in them, and when we attached the bowler to a power chair, it was apparent the slop was unacceptable. To fix this issue, aluminum inserts were machined to fit inside the legs and using a thumb screw, see Figure 37, force the legs to be pulled towards the plate, this solution fixed the slop in the hinges because it removed all of the stress on the hinges and translated it to the much stronger mounting plate. The last issue which caused a few problems was the connection to the ramp, originally, the top plate of the ramp was supposed to line up perfectly with the mounting plate on the stand. After making everything, one of the dimensions was slightly off and allowed the stand to twist a tiny bit with the ramp attached, so to fix it, two screws were inserted to keep the ramp in the right position.

Figure 36: Table hinge used to attach the legs to the u-plate

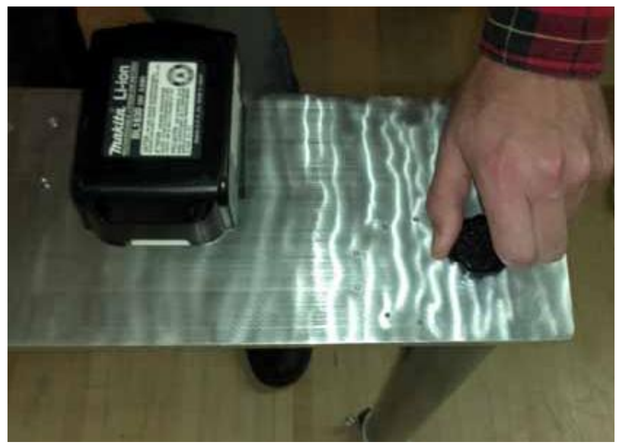

Figure 37: Thumb screw added to create the necessary leg rigidity.

Control Box

The last assembly which turned out to be one of the hardest was the control box. The original design used a joystick, just like the one found on our customers power chair, but we ran into some problems when trying to find a rotational potentiometer that could be fully activated using only a quarter turn. Thus, the idea of using the drill's control trigger was tested, but the return spring in the trigger was too strong which caused the joystick to move on its own.

We then found a sliding potentiometer that was large enough to have a desirable range of motion. This is exactly the point where we started having issues. A joystick inherently wants to apply a moment on something and the potentiometer only accepts side to side motion. After about six different designs using the joystick and sliding potentiometer, we found that connecting the two would be far too complicated to pursue any further, so a new design was tested. The new design used a nub that would slide in a track instead of a joystick. After acquiring a new box, which was smartly chosen as a conduit box to allow for direct mounting to the U-Stand, a new design with a large power switch, see Figure 38, and an ergonomic nub, see Figure 39, became the new user interface. This new design makes turning on the "spin" mechanism fast and easy. Most importantly, this design works very well for our customer. To allow for complete adjustability we cut castellations into the collar around the leg, see Figure 40, so the user can choose how far the controller is from their chair, which is valuable so that many different athletes can use it comfortably.

Figure 38: Control box showing the easy on/off switch.

Figure 39: Control box with the user using the sliding nub control.

Figure 40: Castellations being used to adjust the angle of the control box.

Recommendations for Future Manufacturing:

To simplify manufacturing in the future, purchasing components that are already close to their final size would cut down on machining time, and by changing some of the components to more readily available off-the-shelf components would help make manufacturing go a lot faster. In addition, better more high tech machines could be used to speed up the machining of most of the components. Also, using the most

recent drawings will ensure that all of the parts will be updated and compatible with each other.

Chapter 6

Test Description

In the design process we have encountered several specifications which we could not precisely design for because they require testing for validation. One such example is the final velocity of the bowling ball because it depends on too many factors that we could not determine, so a test needed to be done at the bowling alley to see if we meet our target velocity at the end of the bowling alley. Below in Table 5 is a detailed list of the testing that was will performed to verify that our product will return the desired results specified by our customer.

Table 5: Testing plan based on our specifications

Specification Description	Test Description	Acceptable Range
Ball Speed	Use the Speedometer at the end of the bowling alley to see if the ball goes fast enough	5mph
Spin Speed	Test to see if the ball can spin from oneside of the lane to the other	1 rad/s
Setup Time	Setup the bowler as fast we can	5 minutes
Accuracy	See if we can hit the pins at the end of the alley	10" @ 60'
Weight	Place the device on a large scale	70 lbs
Battery Life	Run the drill until the batteries fully discharge	1 hour
Pinch Points and Edge Prep	Go through and make sure there are no sharp edges	No sharp points
Stability	Lock the casters and apply a 20lbf to ensure it will not fall over	Does not fall over
Attachment	Try to attach the device to the customer's power chair	Attaches successfully
Repeatability	Test for the same results on multiple throws	10" @ 60'

Weight Testing:
Spec: 70 pounds

Measured Weight: 67 pounds

We tested the weight of the Rock N Bowler II using one of the scales in the Mustang 60 shop. We weighed it by holding all the pieces and weighing it and our bodies and then subtracting our body weight. This test will be done three times to confirm a good weight. We were looking for a weight around 70 pounds for the completed Rock N Bowler II. This test was completed once the final machining and assembling was completed.

Battery Life:
Spec: 1 hour

Measured: 13 minutes of continuous spinning per battery. There are two batteries and when being used correctly the rollers should be on for less than half the time bowling therefore we achieved the goal of an hour of bowling battery life.

We tested the battery life by fully charging one of the large batteries and then hooking it up to the powered roller and letting it run at full speed until the battery died. We did this test procedure three times to find an average battery life. This test was performed in the Bonderson work area. We were looking for a result of at least one hour before the battery dies to meet our specification.

User Control:
Spec: 6" box

Result: Within our user's range of motion and strength capabilities

We tested our controller box by allowing our athlete to use it to control the motor speed. We confirmed that the amount of force needed to move the controller joystick and launch the ball did not exceed our athlete's capabilities, see Figure 41. We also confirmed that the athlete has the ability to properly select roller spin speed. Lastly, to satisfy our specification, we confirmed that the user input range does not exceed the six inch box.

Figure 41: Athlete using the ramp in its stationary position.

Ball Speed:

Spec: 6 mph

Measured: 6 mph

To test ball speed, we brought the Rock N Bowler II to the Mustang Lanes and rolled varying size bowling balls from the top of the ramp with static initial conditions. We rolled each size ball (8, 10, 12, and 15 pound) ten times. The setup consisted of existing speedometers located at the end of each lane. Rock N Bowler II was placed at the foul line, as that represents the closest legal point to the pins. The speed readings given to us from the built in speedometers reflected the ball speed at the end of the lane. This reading was sufficient because our required speed reflects the final speed.

Set Up Time:

Spec: 5 minutes

Measured: less than 5 minutes

To test set up time, we first had all 3 major parts of the Rock N Bowler II (Ramp, Gator Attachment, and U-Stand) laid out on the ground, and then had one person time another team member to see how long it took to assemble and be ready to use. The common user will always have at least one helper with them, so we figured that only one member of our team at a time can set it up. We repeated this process so that each member will have to set it up. Our required set up time was five minutes, which was easily accomplished by all three members of our group, thus fulfilling our requirement.

Figure 42: Testing set-up and attachment time and stability.

Attachment Testing:

Spec: Ensure proper attachment

Result: Easily and firmly attaches to the users chair.

Testing the attachment was a critical part of our project because the device cannot "runaway," so to ensure a tight fit we made sure that each gator can hold 200 pounds. Since the device will weigh 70 pounds total, and we have two gators, this should be a sufficient test for attachment. To put a 100 pound

force on the gators, we will attach them to a stationary beam and see if they can support the weight of a group member since each of us weighs approximately 200 pounds.

Pinch Points:

Result: No pinch points are around the user. The only pinch points are at the leg hinges when assembling due to the legs swing out into position.

Pinch points required a very through test in which all of the moving parts were examined for possible areas where people could get hurt. This will be accomplished by moving all of the attachment pieces to their extremities, and the leg locking mechanisms to their extremes. We did not find any significant pinch points. The most dangerous component is the motor and spinning rollers which are either far away from the user or protected by a safety shield.

Edge Preparation:

Result: All edges and corners have been rounded to prevent the users from harming themselves

Edge preparation was critical to the safety of our users because the device is intended to be handled, so any burrs and imperfections needed to be eliminated while we were making the pieces, see Figure 43. Ensuring that all of our parts were properly de-burred and rounded while we were building saved us a lot of time when it came to testing the edge preparation. We ran our hands on all the edges and make sure that there was no way someone could hurt themselves.

Figure 43: Josh deburring edges to prevent cutting the user.

Accuracy Testing:

Spec: 10" at 60'

Measured: less than 10" variation at 60'

To test the accuracy of our bowler we brought it up to Mustang Lanes and tested to see if we could hit what we're aiming at. This was slightly subjective to the user since we had no experience with the device; however, we were able to replicate throws to ensure that the device is accurate. We recorded the scores we got bowling while using the device over our testing to see how you improve when you learn how to use the device. We saw a steady increase in scores throughout the testing. We started with a score of 95 and after two more games we ended with 124.

Management Plan

Josh Grip- Meeting Coordinator, Researcher, Quality Inspector and Solid Modeler

Meeting Coordinator- Josh makes sure that we have updated agendas for our meetings and that everyone who needs a copy has one. He will make sure that we have necessary discussions and that everyone is clear on what needs to be done.

Researcher- Josh is the lead in finding the necessary information for our team. He spear-heads looking into the current solutions to adaptive bowling and will continue to look into the information we need throughout the project.

Quality Inspector- Josh checks all critical dimensions of parts that are made and makes sure they are within tolerance.

Solid Modeler- Ensures that all Solid models are accurate, and comply with standard modeling conventions. In addition, Josh will provide the final part and assembly drawings for entire project.

Travis Rodrigues- Document Control, Progress Updater, Modeling Assistant, and Plastics Specialist

Document Control- Travis is the final document editor and will do the final formatting of the documents we submit. He will take on the responsibility of making sure documents are completed in a timely fashion and with acceptable quality.

Progress Updater- Travis will keep the constantly changing information of our groups Google Wave account current with the most pertinent information. This will keep the team updated on any developments so they can make decisions with current information.

Modeling Assistant- Travis provides smaller drawings and assemblies when Josh is overwhelmed.

Plastics Specialist- Travis is in charge of all plastic operations and assembly of PVC, Delrin, and Plexiglass components.

Richard Rozporka- Communication Coordinator, Manufacturing Coordinator, Material Selector and Writer

Communication Coordinator- Is the lead contact between the engineering group and all other outside people. He relays information both from the engineering group to the other stakeholders on the project and from the stake holders to the engineering group.

Manufacturing Coordinator- Richard is the most experienced manufacturer in our group so he will be in charge of making sure our designs are producible.

Material Selector- Richard researches and analyzes potential materials for use, and contacts resellers and manufacturers for quotes and information.

Writer- Richard writes the rough drafts of important documents and submits them to Travis and Josh for revision and inspection.

The upcoming events that need to be completed can be seen Appendix F.

Chapter 7

To preface the basis for these recommendations, it should be noted that the "spin" feature of our bowler can be significantly improved using a different design. The angled rollers apply spin to the ball; however the spin mostly angles the ball as it comes off of the ramp and doesn't create the hooking effect of a professional bowler. This is due to the ball rolling down the ramp. By rolling without slip, especially over the polyurethane roller, the ball picks up significant forward spin, and the roller simply shifts the axis of that spin. This off axis spin means that the ball rolls at an angle, but doesn't exactly hook. After extensive testing and research, we found that the location of the ball's finger holes will actually create the desired hooking effect.

Recommendations:

For future projects, the device does not need external devices to make the ball hook, by the nature of the varying cores in a bowling ball; some balls will hook naturally based on their mass moment of inertia. For this reason one of two things need to happen to "apply" spin: either the net effect of the bowler's spinning mechanism acts in only one direction, or the ball needs to be prespun and the rollers would have to allow the ball to slide with slip instead of rolling. One other idea is to use a sliding carriage like a roller coaster to get the ball going. Basically, if a new iteration of the project were to be made, the physics of bowling need to analyzed a little more carefully. When a good bowler puts spin on the ball, the ball is going significantly faster than our bowler, so to similarly replicate this motion, some kind of additional speed mechanism needs to be created.

The biggest challenges that we faced had to do with manufacturing, since every single piece of the project was essentially unique, building the device took a very long time. We have logged over 600 hours in the Cal Poly machine shops between the three of us, and with some better material selection we could have reduced that significantly. Simplicity is the key with design, and we most definitely did not try to make our device as simple as possible. On the contrary, as Appendix B illustrates, we have designed a lot of different parts that all take a long time to machine. This is mostly due to high manufacturing costs of outside machine shops, and the price of trying to get a professional machine shop to make small quantities of parts.

Due to our limited budget, we were slightly hindered in our material selections, more ideal materials could have been selected to reduce weight and improve performance, but these all come at a high cost. For example, our solid polyurethane roller could have easily been a polyurethane tube slipped over a wooden dowel, but the tube would have been custom. Most polyurethane specialists charge extra for having to make a custom mold and then add additional charges for only ordering one unit. The Delrin roller could have been replaced with a straight section of two inch PVC, but since we did not realize how heavy the solid delrin would be and the spinning aspect was unnecessary, we did not think of it. This change would make a significant difference in the end product because the torsion bar could be completely removed, and a lot of weight would be removed.

Another recommended change would be to use ball casters instead of wheel casters. The wheel casters have created some unwanted movement when the device is attached to a power chair. By constantly having to rotate the casters, the user has a lot to think about when bowling, and by using more versatile ball casters; the wheels would never create problems like they currently do.

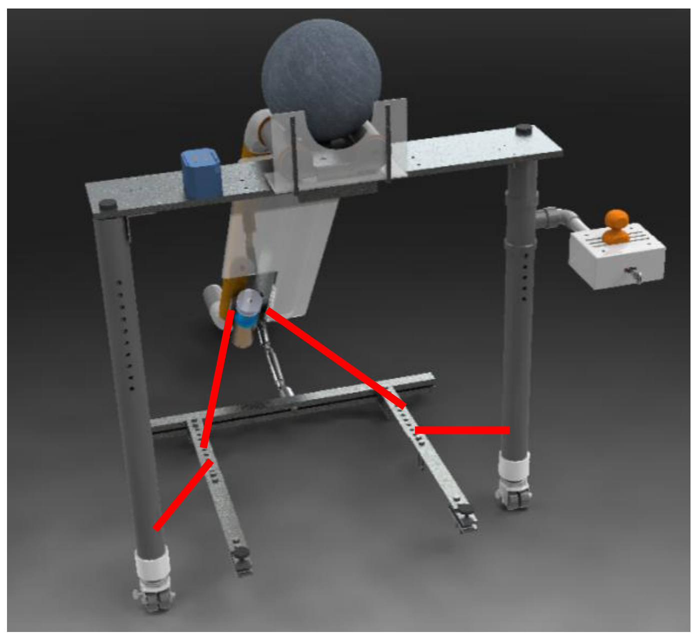

Figure 44: Rock N Bowl II with added rigidity bars.

Another issue with the Rock N Bowl II is the rigidity of the gator attachment in relation to the U-stand and ramp. We recommend possibly adding some bars or ropes to firmly attach the gator arms to each leg and the bottom of the ramp as Figure 44 shows. By firmly attaching the gator arms to the other assemblies the entire device would become more rigid and user friendly.

With that being said, our device is still being tested, and hopefully, users will find ways to make the Rock-N-Bowl work for them. Therefore, before recommending that the idea be scrapped and redone, we would like to suggest that the Rock-N-Bowl II be thoroughly tested and used by athletes until they become used to how the ball acts coming off the ramp. We have designed the device with a lot of adjustability and we have taken into consideration the needs of a lot of different users.

Conclusions:

The Rock-N-Bowl II is designed with a wide variety of users in mind, and adjustability is something that it does wonderfully. Whether it is being used as a stationary ramp, or an attached ramp, the Rock-N-Bowl II allows the user to choose the level of inclusion they desire. By pioneering the Variable Least Restrictive Environment (VLRE), users will be immersed in the sport of bowling in precisely the way they desire. Using revolutionary ideas that allow the bowler to bear its own weight, the Rock-N-Bowl II is a game changer in the world of assistive bowling

Reference

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All images are courtesy of www.google.images.com as accessed on 10/18/2010 sources!

Appendix A: QFD and Decision Matrices

House of Quality:

Rock-N-Bowl II

Dr. Taylor
Doug Carrol
Individuals in power wheelchairs
Helpers

Customer Requirements	Dr. Taylor	Doug Carrol	Individuals in Power Wheelchairs	Helpers	weighted sum	Weighting (Total 100)	Ball Speed	User Range of Motion	Spin Speed	Wheelchair Speed	Life	Time to set-up	Accuracy	Overall Weight	Cost	Electric Power	sum	shuffle board	basic ramp	I kan bowler	Big Robot	Rock-N-Bowler 1
Durable	9	10	10	5	92	9.80					9			9	9		27	10	10	10	10	1
Lightweight	5	2	2	8	35	3.73				3	3	9		9	9		33	10	9	10	0	6
Reasonable size	6	6	6	10	64	6.82	3	3	1	3		9		9	1		29	10	9	10	0	8
Attachable	8	4	4	10	58	6.18		3		3		9	3				18	0	0	8	0	8
Safe	10	10	10	10	100	10.65	3		3	9	3	1			1		20	10	8	9	8	9
Easy Use	10	10	10	10	100	10.65		9	3	3		9		3		3	30	6	8	10	2	8
Ball Spin	9	10	6	1	80	8.52	9	9	9				9		1	9	46	0	0	4	10	10
Ball Control	8	10	8	1	81	8.63	9	9	9	3			9		1	9	49	6	5	7	10	7
Repeatable	6	10	8	1	75	7.99	3	9	3				9			3	27	5	7	8	10	8
Storable	6	4	4	10	52	5.54					3	9		9	3		24	10	6	8	0	8
Cheap	8	6	5	1	59	6.28					3				9	1	13	10	10	9	0	7
Adjustable	7	3	3	8	47	5.01	3	9				9		3	1		25	10	0	10	0	10
Fun	10	10	10	6	96	10.22	9		9	9			9			3	39	6	6	8	2	9
					939	100											0					
																	0					
																	0					
normalized importance							11.27	13.55	11.38	9.87	5.56	11.74	11.23	9.34	7.82	8.25	100					
Units							mph	inches	rpm	mph	years	seconds	inches	lbs	dollars	watts						
Targets							15	6	20	4	5				750							
shuffle board							15	36	0	0	2				20							
basic ramp								12	0	0	2				50							
I kan bowler								6	0	4	1		good		748.93							
Big Robot							20	2	hella	0	1			hella	hella	hella						
Rock-N-Bowler 1								6	20	4	0.04				1000							

9	Srong Correlation
3	Medium Correlation
1	Small Correlation
Blank	No Correlation

Decision Matrices

Criteria	Concept									
	1	2	3	4	5	6	7	8		concept legend
Durable	D	-	-	-	-	-	-	-	1	IKAN ramp
Lightweight		-	-	-	-	-	-	-	2	flat spring launch
Reasonable size		s	s	-	s	s	-	s	3	ramp with pitching machine at top
Attachable	A	-	s	s	s	s	s	s	4	spring ramp with pitching machine
Safe		-	-	-	s	s	s	s	5	ramp with straight rollers
Easy Use		s	s	-	+	+	+	+	6	ramp with broken rollers
Ball Spin	T	+	+	+	+	+	+	+	7	ramp wih rollers at bottom
Ball Control		+	-	-	+	+	+	+	8	rolling rails
Repeatable		-	-	-	-	-	-	-		
Storable	U	-	-	-	s	s	-	S		
Affordable		-	-	-	-	-	-	-		
Adjustable		+	+	+	+	+	+	+		
Fun	M	+	+	+	+	+	+	+		
transportable		-	-	-	s	s	-	s		
mobility		-	s	-	s	s	-	s		
manufacurability		-	-	-	-	-	-	-		
Ball Speed		+	+	+	s	s	s	s	symbol legend	
sum +	-	5	4	4	5	5	5	5	+	better
sum -	-	10	9	12	5	5	9	5	-	worse
sum s	-	2	4	1	7	7	3	7	s	same

Figure 45: Preliminary Pugh Matrix which compared all of the designs we came up with to the DATUM, the IKAN Bowler.

Criteria	1	2	3	4	5	6	7	8
	Concept							
Durable	+	x	x	x	s	-	x	D
Lightweight	+	x	x	x	+	+	x	
Reasonable size	s	x	x	x	s	s	x	
Attachable	s	x	x	x	s	s	x	A
Safe	s	x	x	x	s	s	x	
Easy Use	-	x	x	x	s	s	x	
Ball Spin	-	x	x	x	-	-	x	T
Ball Control	-	x	x	x	s	s	x	
Repeatable	+	x	x	x	s	s	x	
Storable	s	x	x	x	s	s	x	U
Affordable	+	x	x	x	+	+	x	
Adjustable	-	x	x	x	s	s	x	
Fun	-	x	x	x	s	s	x	M
transportable	s	x	x	x	s	s	x	
mobility	s	x	x	x	s	s	x	
manufacurab ility	+	x	x	x	+	-	x	
Ball Speed	s	x	x	x	s	s	x	
sum +	5	0	0	0	3	2	0	
sum -	5	0	0	0	1	3	0	
sum s	7	0	0	0	13	12	0	

concept legend	
1	IKAN ramp
2	flat spring launch
3	ramp with pitching machine at top
4	spring ramp with pitching machine
5	ramp with straight rollers
6	ramp with broken rollers
7	ramp wih rollers at bottom
8	2 rollers

symbol legend	
+	better
-	worse
s	same

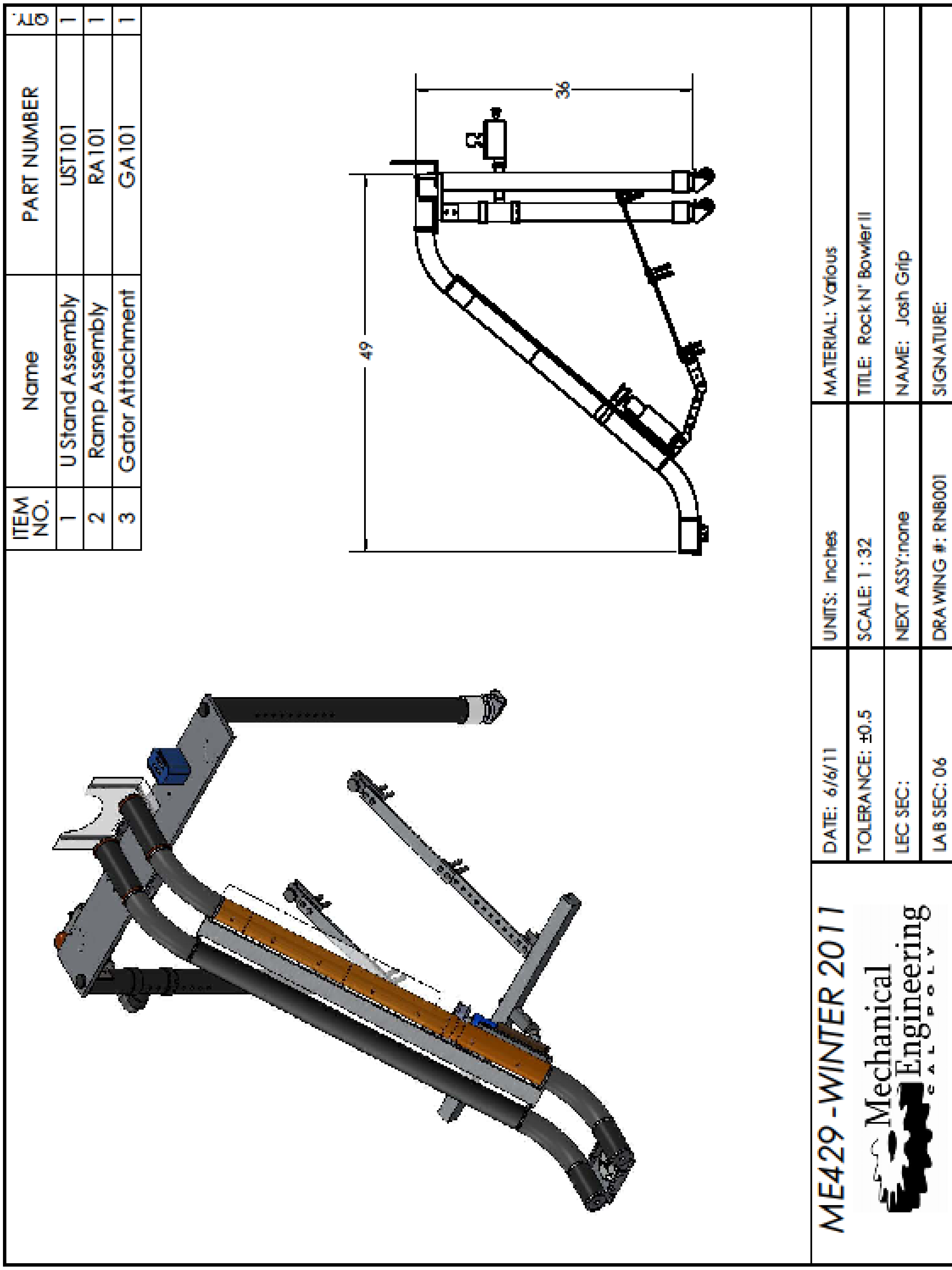
Figure 46: Pugh Matrix for our top three designs and comparing them to the DATUM, in this case it was the two sets of rollers design

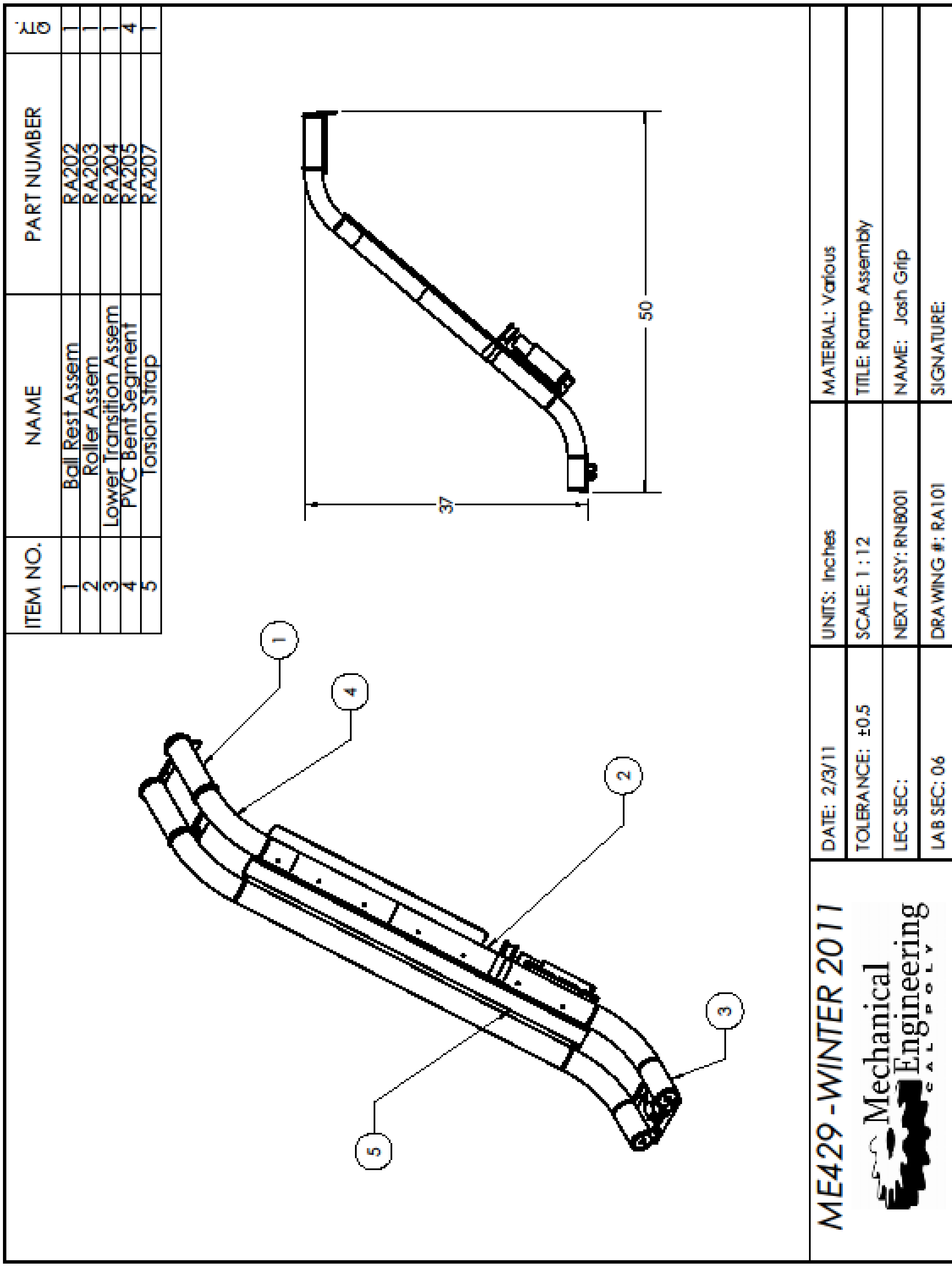
Criteria	Weight	Concept 1	Concept 2	Concept 3
Durable	0.0757	95	90	85
		7.1875	6.809211	6.430921
Lightweight	0.0288	100	90	85
		2.878289	2.590461	2.446546
Reasonable size	0.0526	95	90	90
		5	4.736842	4.736842
Attachable	0.0477	100	100	100
		4.769737	4.769737	4.769737
Safe	0.0822	95	95	95
		7.8125	7.8125	7.8125
Easy Use	0.0822	100	95	95
		8.223684	7.8125	7.8125
Ball Spin	0.0658	65	85	95
		4.276316	5.592105	6.25
Ball Control	0.0666	80	75	75
		5.328947	4.995888	4.995888
Repeatable	0.0617	95	85	90
		5.859375	5.242599	5.550987
Storable	0.0428	75	70	70
		3.207237	2.993421	2.993421
Affordable	0.0485	65	65	65
		3.153783	3.153783	3.153783
Adjustable	0.0387	10	75	80
		0.386513	2.898849	3.092105
Fun	0.0789	65	90	90
		5.131579	7.105263	7.105263
Transportable	0.0535	85	80	80
		4.543586	4.276316	4.276316
Mobility	0.0740	85	80	80
		6.291118	5.921053	5.921053
Manufacurability	0.0411	100	80	70
		4.111842	3.289474	2.878289
Ball Speed	0.0592	85	90	90
		5.032895	5.328947	5.328947
Total	1	83.1949	85.32895	85.5551 Satisfaction

concept legend	
1	IKAN ramp
2	ramp with straight rollers
3	2 rollers

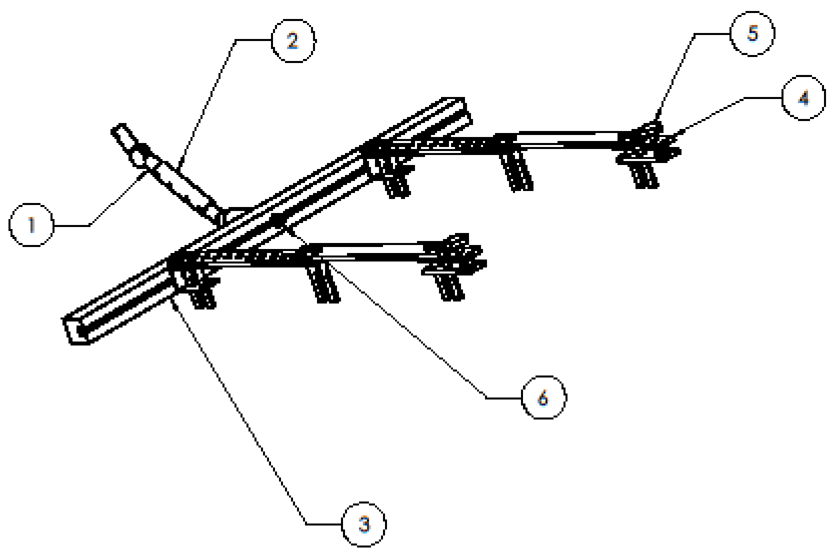
Figure 47: Weighted Decision Matrix which really tested the best design based on weight factors determined from the House of Quality in Appendix B

Appendix B: Drawing Packet



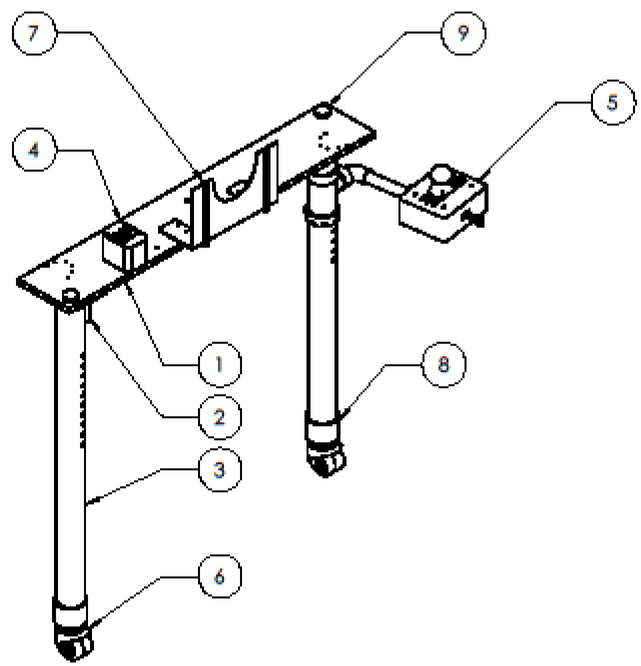

ITEM NO.
NAME
PART NUMBER
QTY.
1 Ball Rest Assem RA202 1
2 Roller Assem RA203 1
3 Lower Transition Assem RA204 1
4 PVC Bent Segment RA205 4
5 Torsion Strap RA207 1
37
50
1
2
3
4
5
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 2/3/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 12
NEXT ASSY: RNB001
DRAWING #: RA101
MATERIAL: Various
TITLE: Ramp Assembly
NAME: Josh Grip
SIGNATURE:

ITEM NO.	Name	PART NUMBER	QTY.
1	Pivot Locking Hines	1258A12	4
2	Hinge Connector	GA210	1
3	Horizontal Bar	GA208	1
4	Gator Arm Assembly	GA207	2
5	Thumb Screw	91185A813	2
6	Hex Nut	90715A135	1

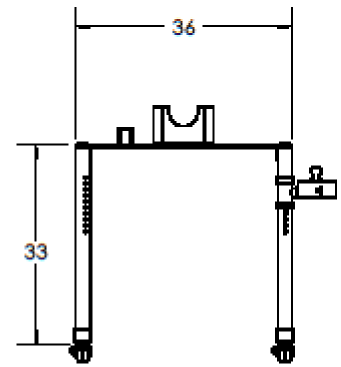


ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE: 1 : 12	TITLE: Gator Attachment
	LEC SEC:	NEXT ASSY: RNB001	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: GA101	SIGNATURE:

5 4 3 2 1



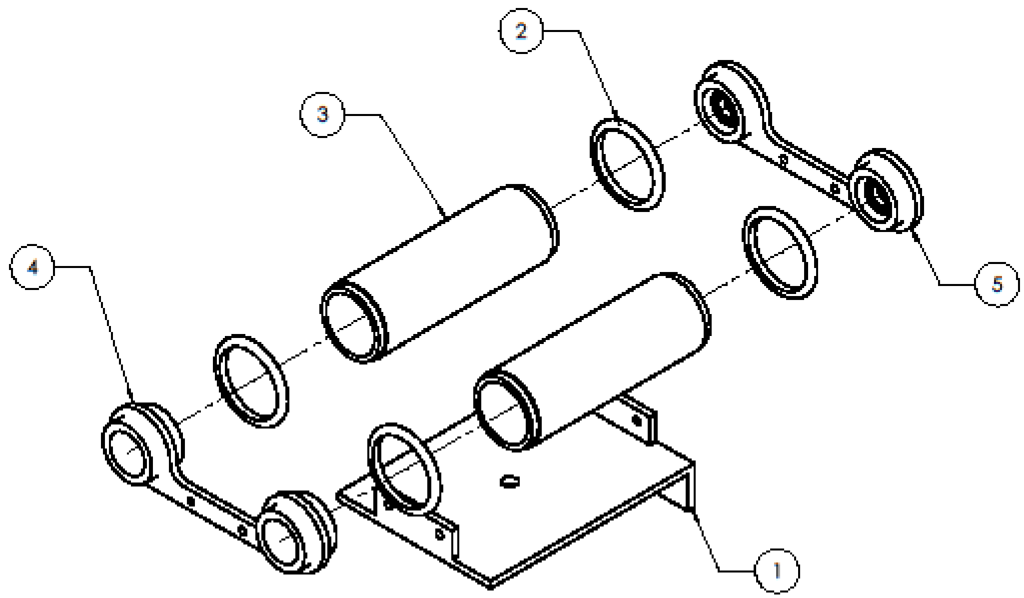
ITEM NO.	NAME	PART NUMBER	QTY.
1	Long Mount	UST202	1
2	Hinge	Hinge	4
3	Leg	UST203	2
4	Battery	Battery Proto	1
5	Controller Assembly	UST209	1
6	Lower Caster	Default	2
7	Back Shield Assem	UST210	1
8	Leg/Caster Nub	UST207	2
9	Thumb Screw	91185A813	2
10	Aluminum Insert	UST211	2
11		98330A235	1



ME429 -WINTER 2011			
Mechanical Engineering CAL POLY	DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
	TOLERANCE: ±0.5	SCALE: 1 : 2	TITLE: U Stand Assembly
	LEC SEC:	NEXT ASSY: RNB001	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: UST101	SIGNATURE:

5 4 3 2 1

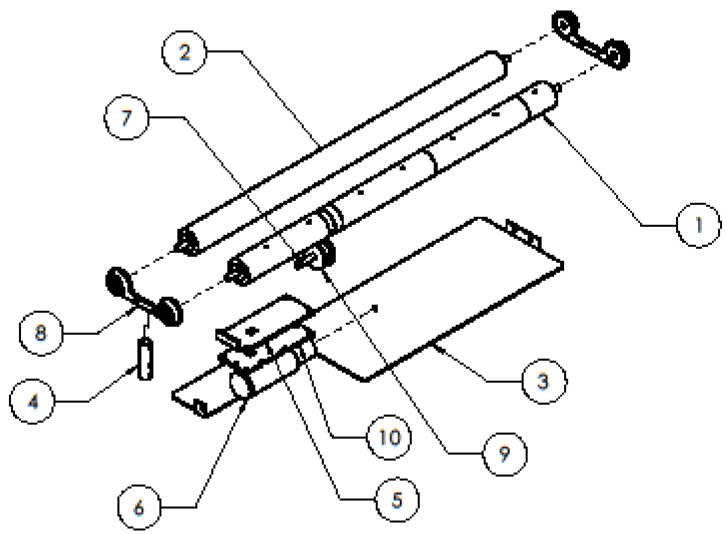
ITEM NO.	NAME	PART NUMBER	QTY.
1	Mounting Plate	RA305	1
2	O-Ring	9396K914	4
3	PVC Ball Rest	RA303	2
4	Full Brace Assem	RA307	1
5	Small Brace Assem	RA306	1



ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE: 1 : 4	TITLE: Ball Rest Assembly
	LEC SEC:	NEXT ASSY: RA101	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: RA202	SIGNATURE:

5 4 3 2 1

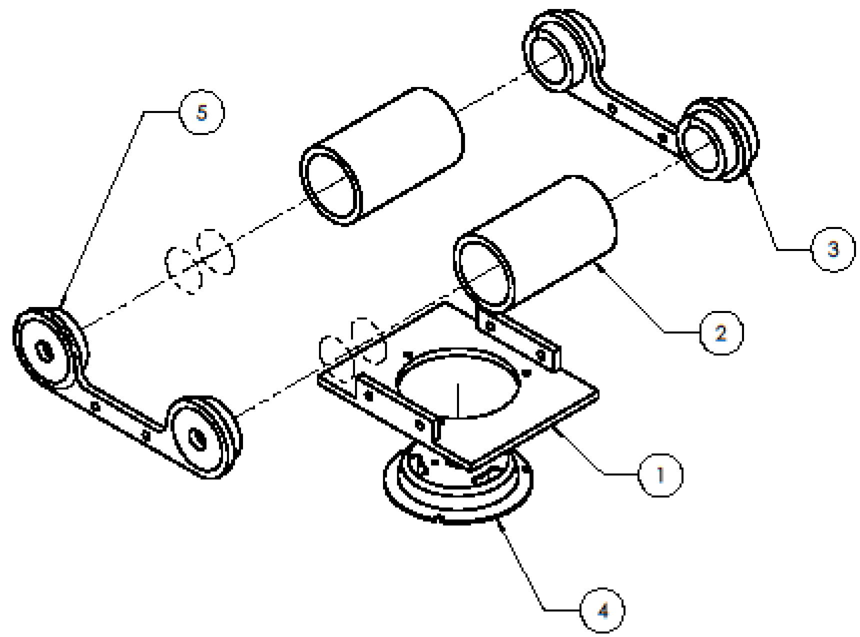
ITEM NO.	Name	PART NUMBER	QTY.
1	Roller Assem Poly	RA203	1
2	Roller Assem Delrin	RA203	1
3	Roller Shield	RA310	1
4	Gator Attach	RA311	1
5	Motor Mount Plate	RA318	1
6	Makita Motor	RA320	1
7	Pulley Shaft	RA321	1
8	Small Brace Assem	RA306	2
9	Motor Pulley	RA319	1
10	Motor Adjustment Plate	RA318B	1



ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE:1 : 8	TITLE: Large Roller Assembly
	LEC SEC:	NEXT ASSY: RA101	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: RA203	SIGNATURE:

5 4 3 2 1

ITEM NO.	NAME	PART NUMBER	QTY.
1	Lower Plate	RA316	1
2	4 inch PVC	RA312	2
3	Full Brace Assembly	RA307	1
4	Lower Caster	429250	1
5	Half Brace Assembly	RA306	1

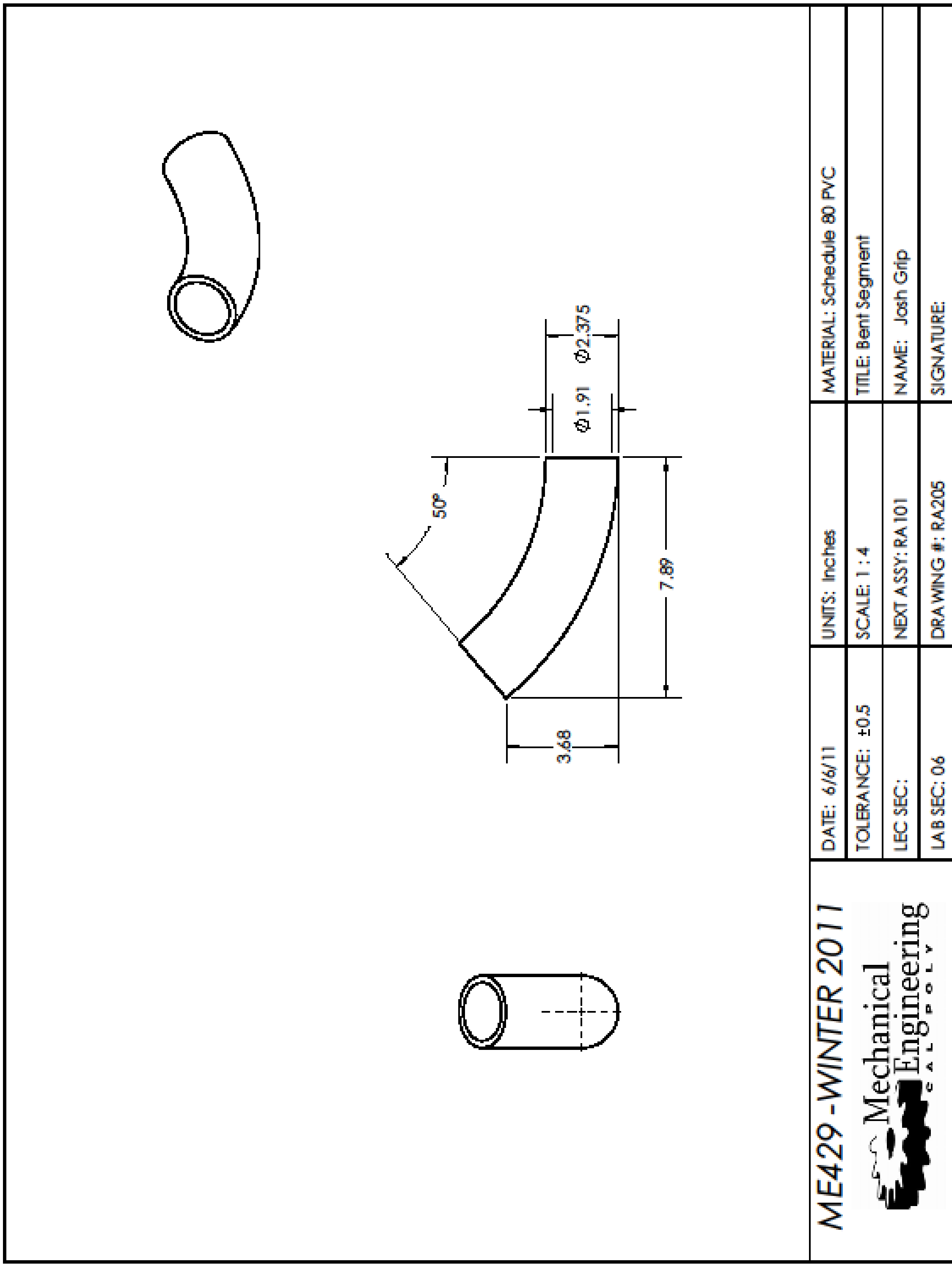


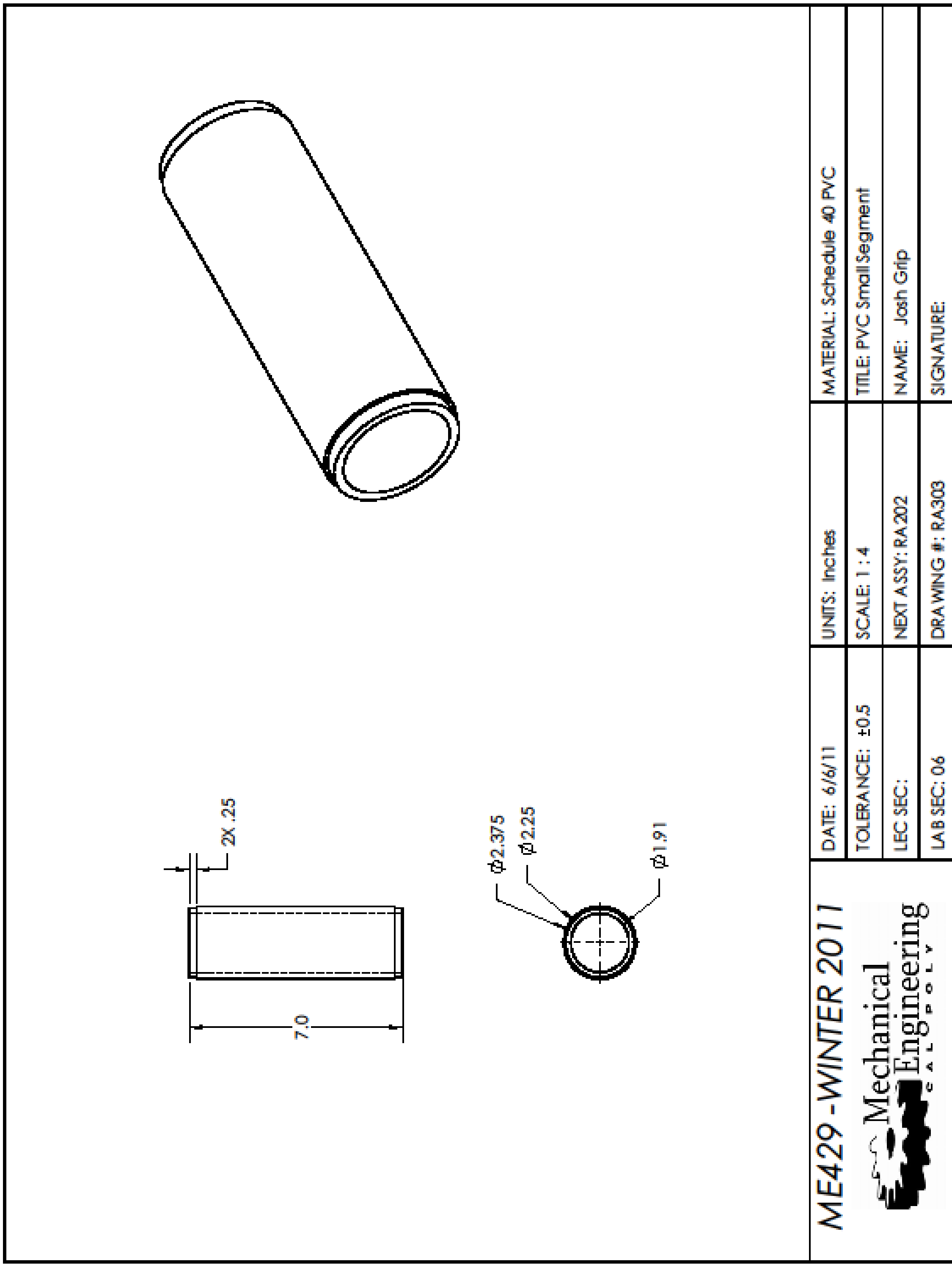
ME429 -WINTER 2011

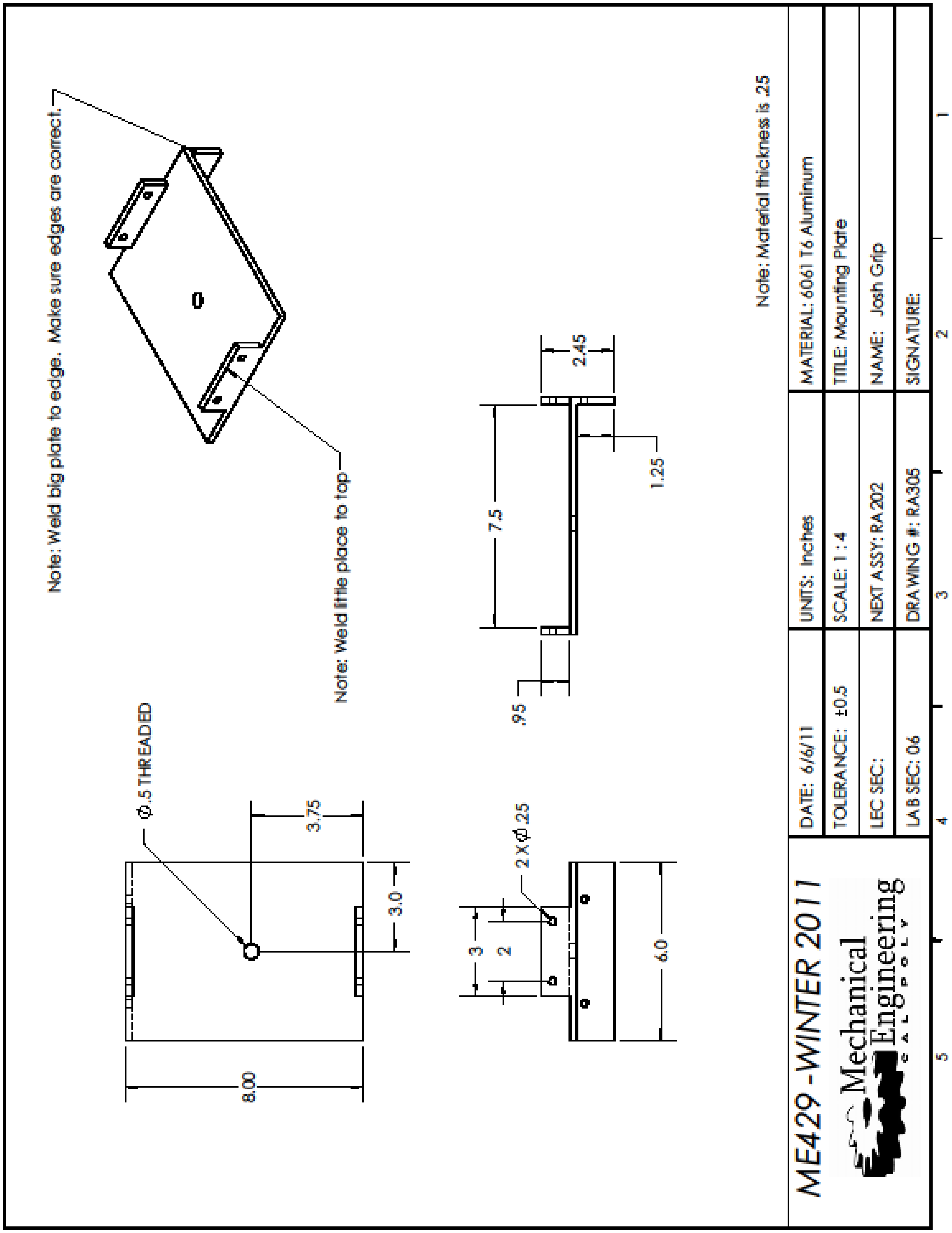
Mechanical Engineering CAL POLY

DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
TOLERANCE: ±0.5	SCALE: 1 : 4	TITLE: Lower Transition Assembly
LEC SEC:	NEXT ASSY: RA101	NAME: Josh Grip
LAB SEC: 06	DRAWING #: RA204	SIGNATURE:

5 4 3 2 1

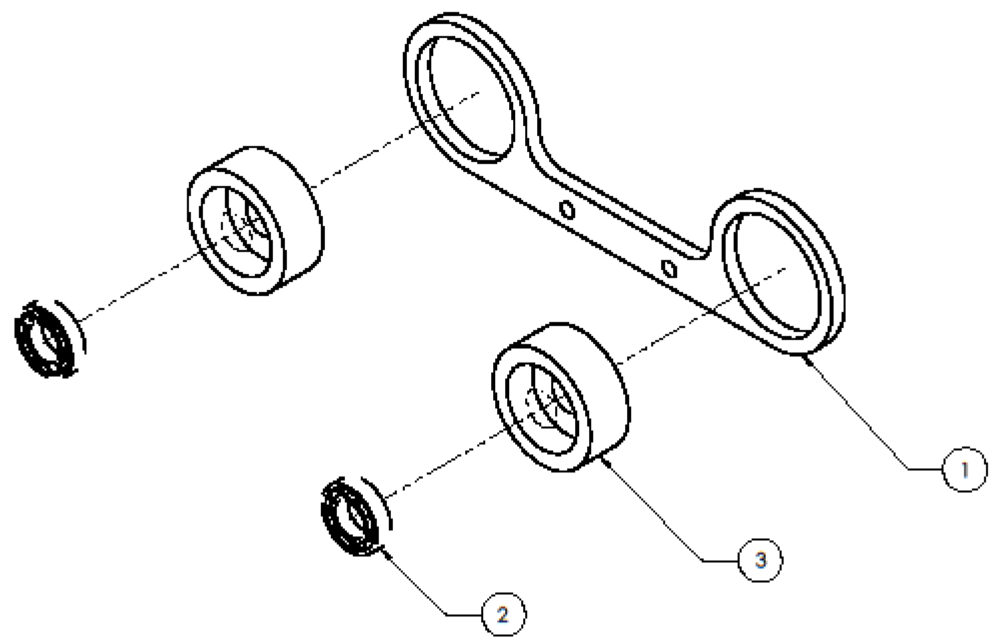

50°
Ø1.91
Ø2.375
7.89
3.68
MATERIAL: Schedule 80 PVC
TITLE: Bent Segment
NAME: Josh Grip
SIGNATURE:
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: RA101
DRAWING #: RA205
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
ME429-WINTER 2011
Mechanical Engineering
CAL POLY


2X .25
7.0
Ø2.375
Ø2.25
Ø1.91
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: RA202
DRAWING #: RA303
MATERIAL: Schedule 40 PVC
TITLE: PVC Small Segment
NAME: Josh Grip
SIGNATURE:



Note: Weld big plate to edge. Make sure edges are correct.
Note: Weld little place to top
Ø.5 THREADED
3.75
3.0
8.00
2 X Ø.25
3
2
6.0
.95
7.5
1.25
2.45
Note: Material thickness is .25
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: RA202
DRAWING #: RA305
MATERIAL: 6061 T6 Aluminum
TITLE: Mounting Plate
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

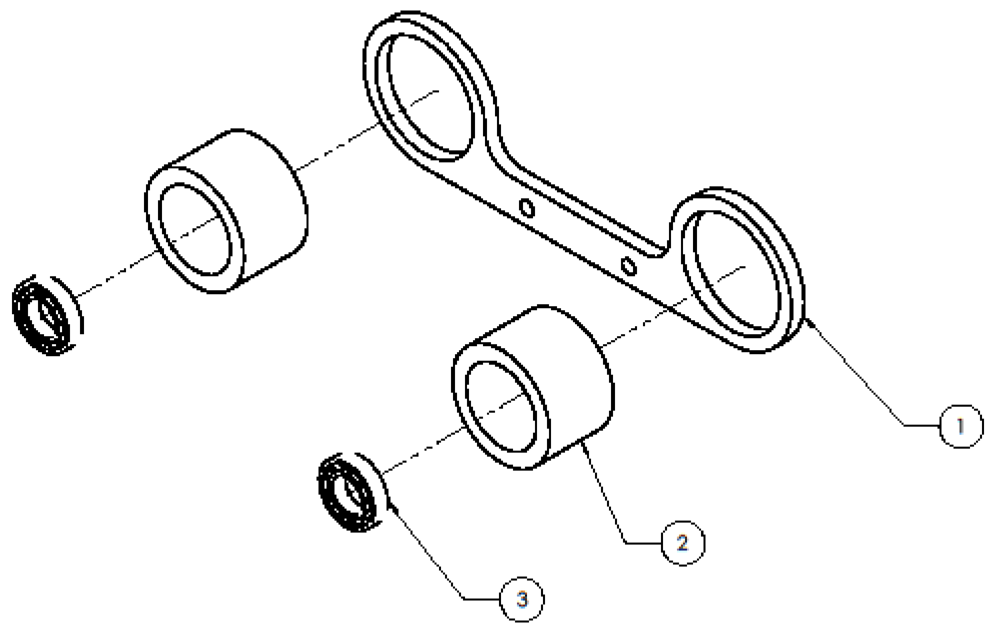
ITEM NO.	NAME	PART NUMBER	QTY.
1	Small Nub	RA408	2
2	Bearing	RA409	4
3	Brace	RA407	1



ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE: 1 : 2	TITLE: Half Brace Assembly
	LEC SEC:	NEXT ASSY: RA202	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: RA306	SIGNATURE:

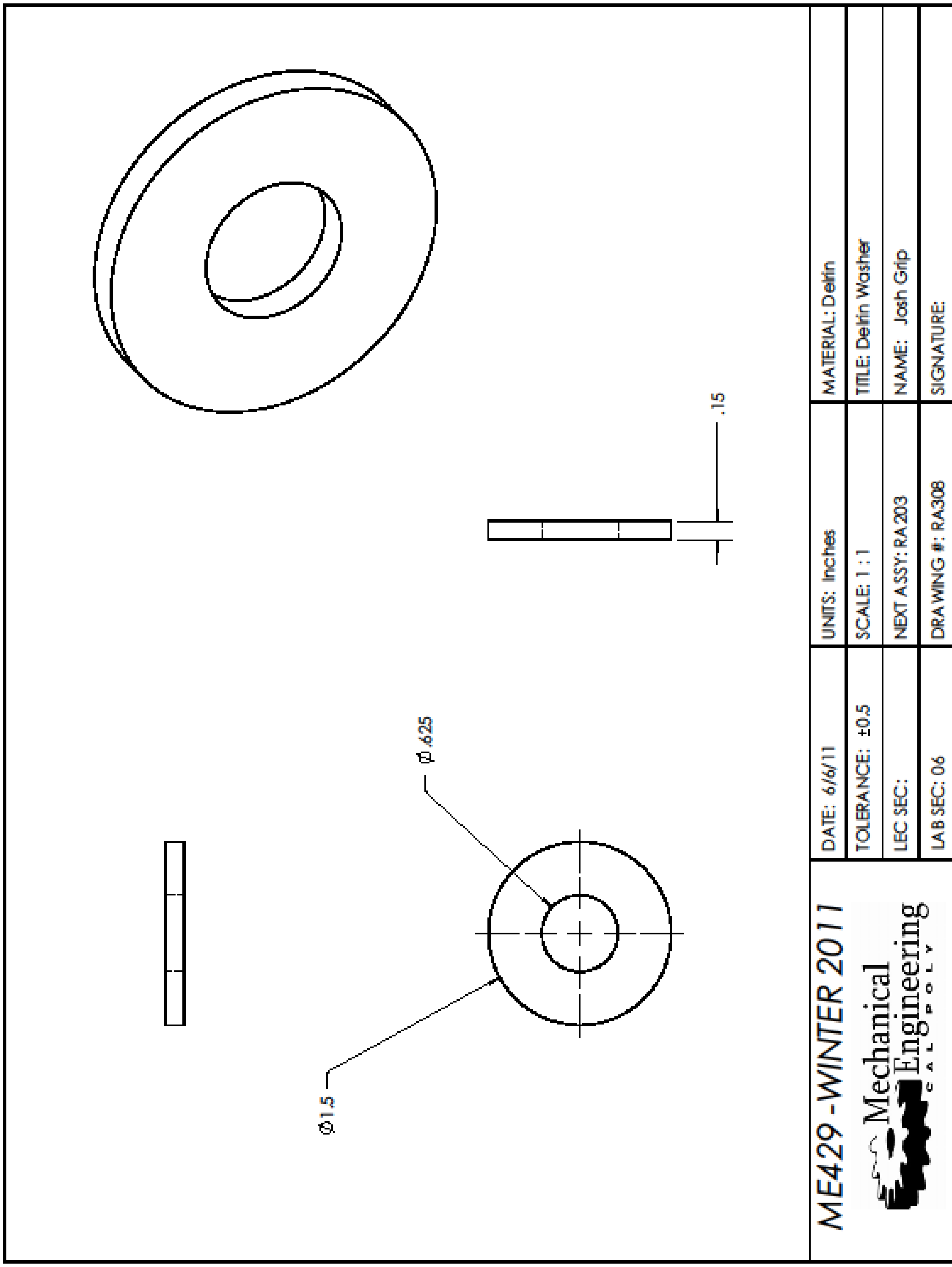
5 4 3 2 1

ITEM NO.	NAME	PART NUMBER	QTY.
1	Brace	RA407	1
2	Large Nub	RA410	2
3	Bearing	RA409	2

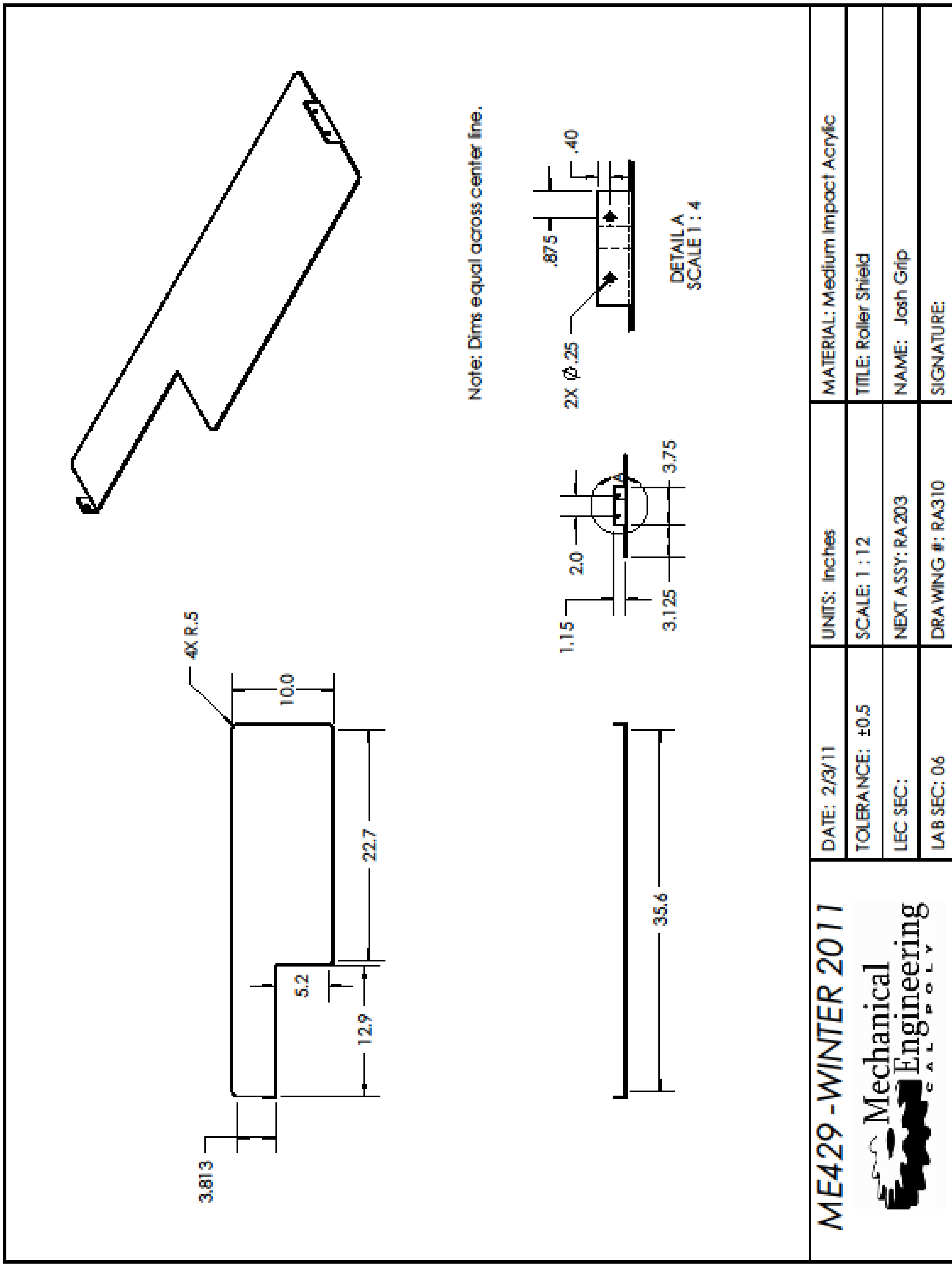


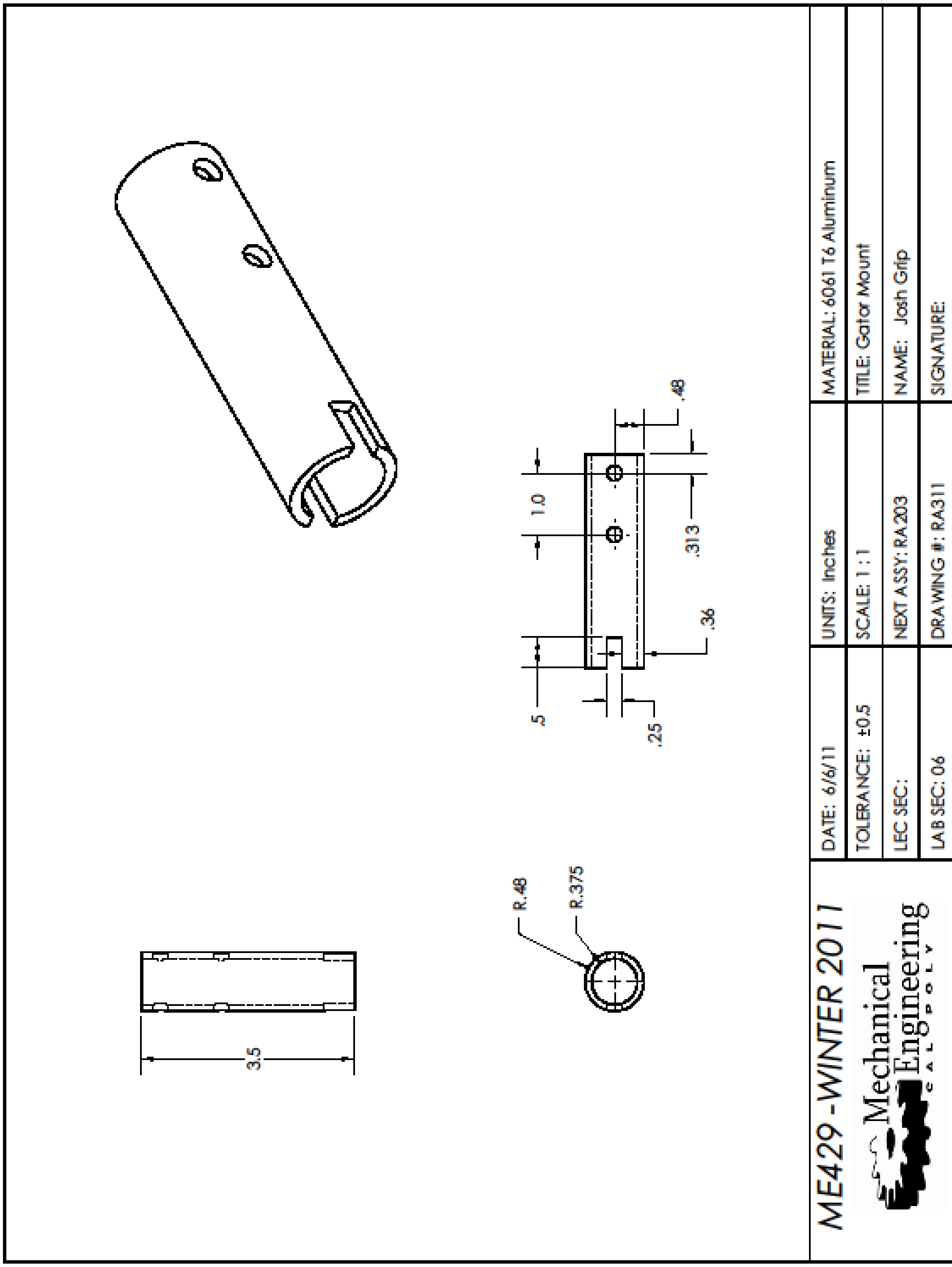
ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: 6061 T6 Aluminum
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE:1 : 2	TITLE: Double Brace Assembly
	LEC SEC:	NEXT ASSY: RA202	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: RA307	SIGNATURE:

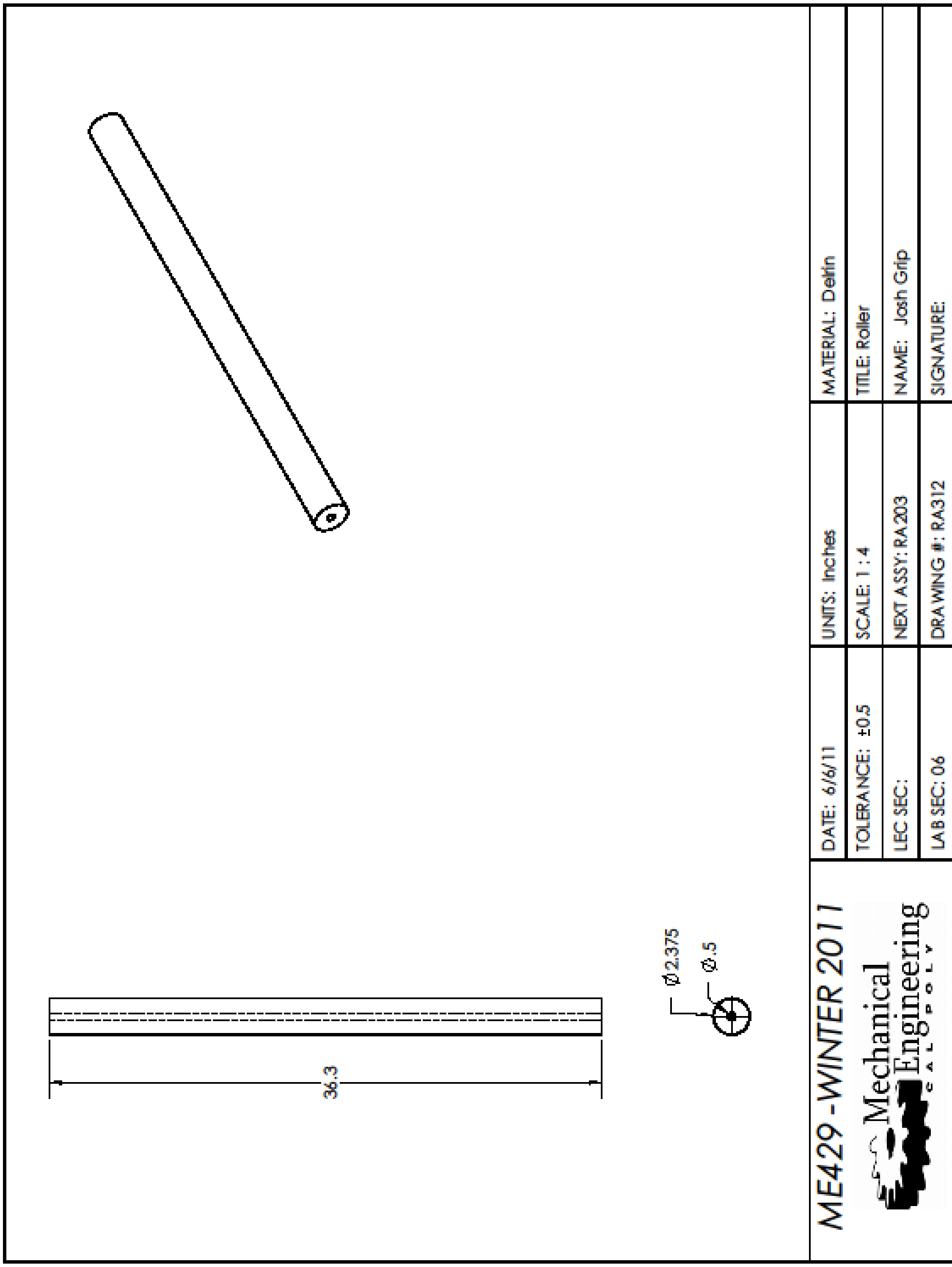
5 4 3 2 1

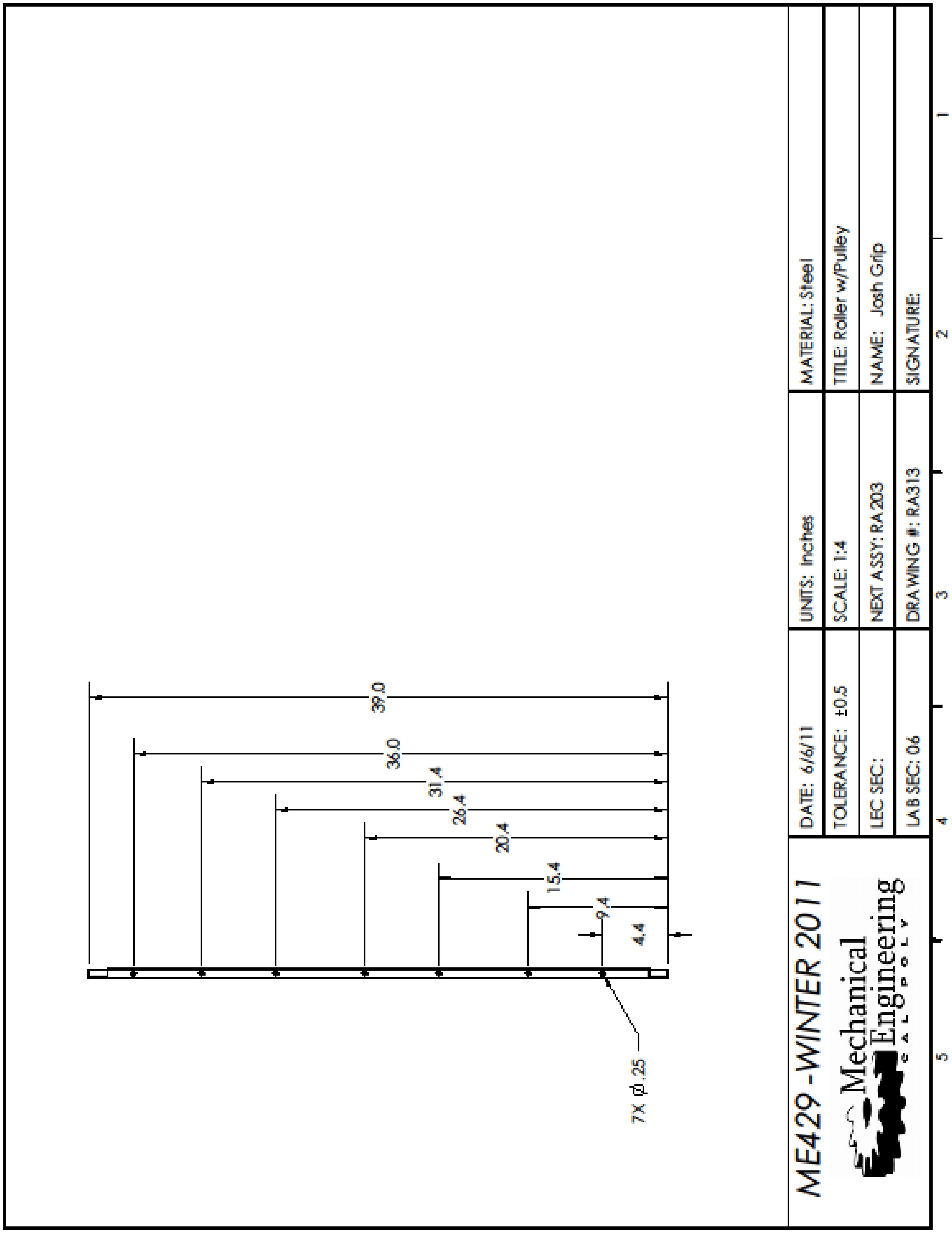


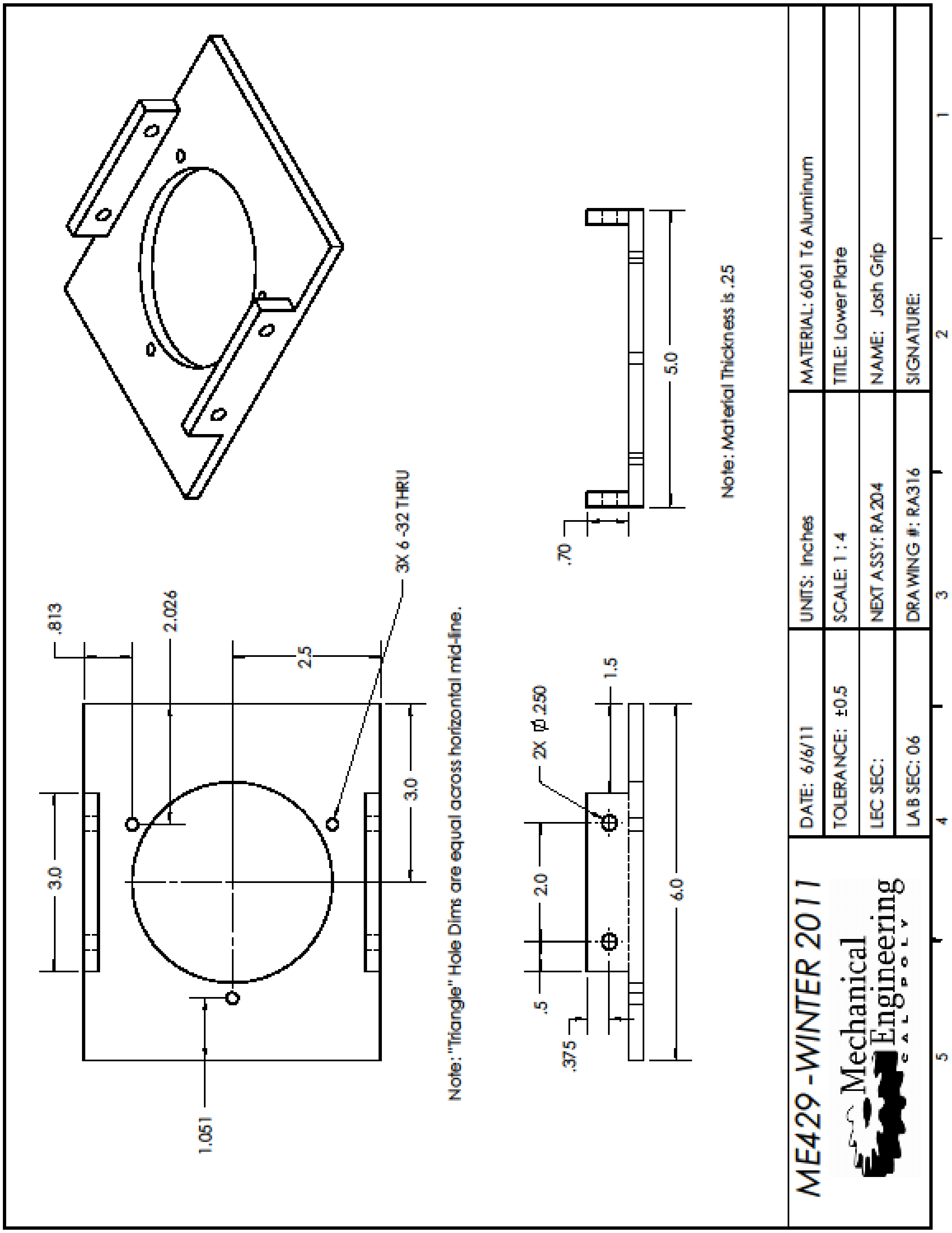
Ø1.5
Ø.625
.15
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:1
NEXT ASSY: RA203
DRAWING #: RA308
MATERIAL: Delrin
TITLE: Delrin Washer
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

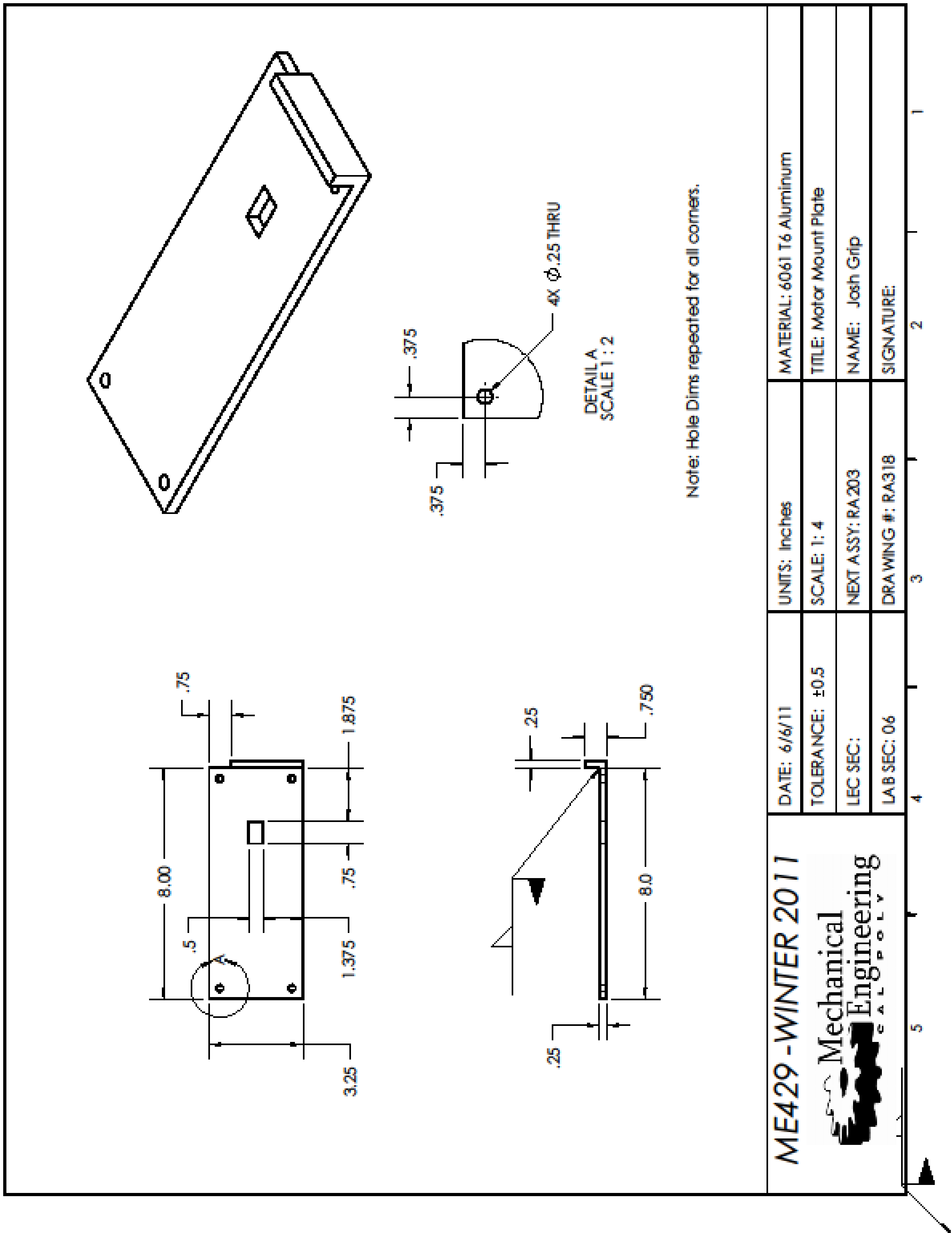

4X R.5
10.0
22.7
12.9
5.2
3.813
35.6
Note: Dims equal across center line.
1.15
2.0
3.125
3.75
2X Ø.25
.875
.40
DETAIL A
SCALE 1 : 4
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 2/3/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 12
NEXT ASSY: RA203
DRAWING #: RA310
MATERIAL: Medium Impact Acrylic
TITLE: Roller Shield
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


3.5
R.48
R.375
.5
.25
.36
.313
1.0
.48
MATERIAL: 6061 T6 Aluminum
TITLE: Gator Mount
NAME: Josh Grip
SIGNATURE:
UNITS: Inches
SCALE: 1:1
NEXT ASSY: RA203
DRAWING #: RA311
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
ME429-WINTER 2011
Mechanical Engineering CAL POLY

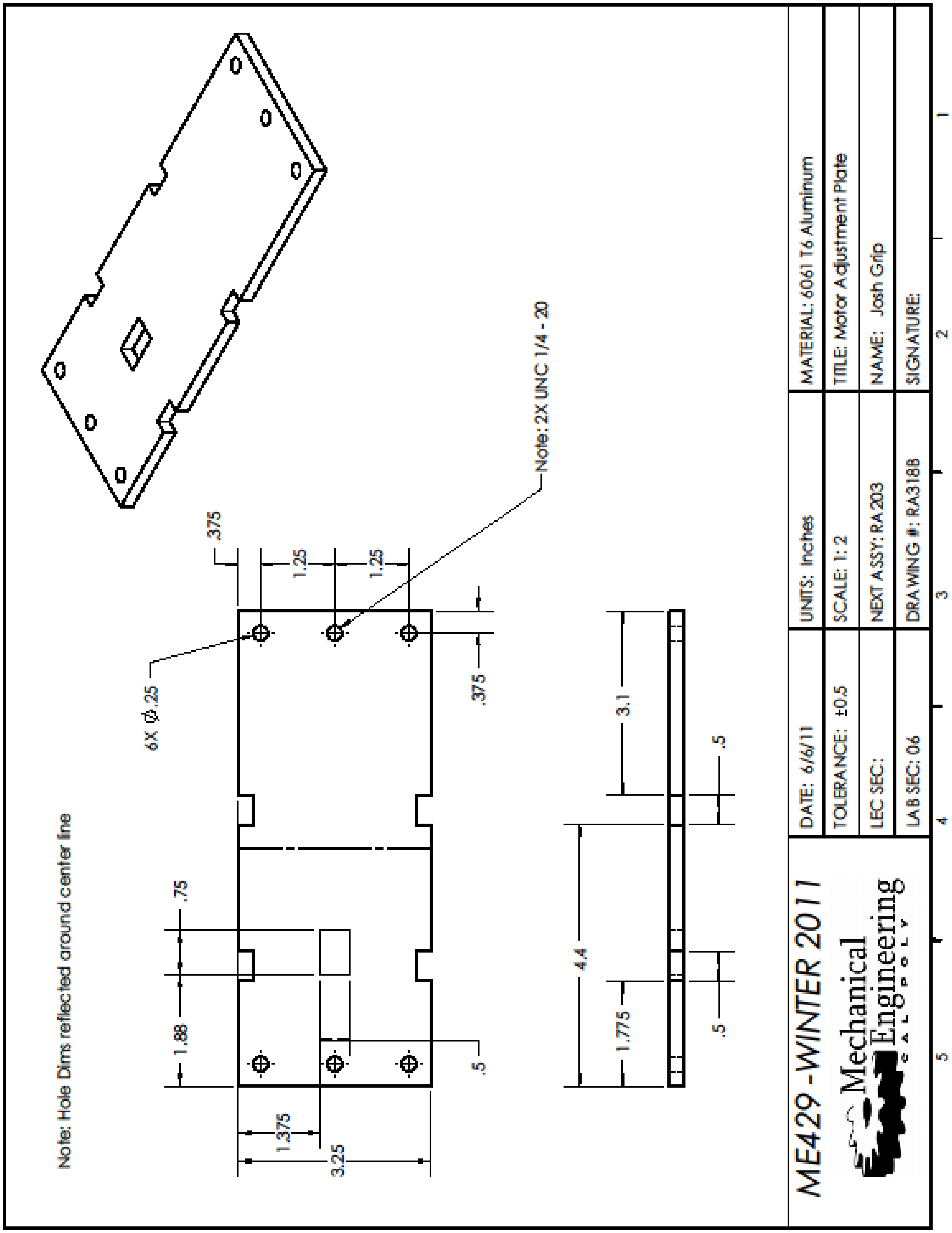

36.3
Ø2.375
Ø.5
ME429-WINTER 2011
Mechanical Engineering CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: RA203
DRAWING #: RA312
MATERIAL: Delrin
TITLE: Roller
NAME: Josh Grip
SIGNATURE:


39.0
36.0
31.4
26.4
20.4
15.4
9.4
4.4
7X ⌀.25
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:4
NEXT ASSY: RA203
DRAWING #: RA313
MATERIAL: Steel
TITLE: Roller w/Pulley
NAME: Josh Grip
SIGNATURE:

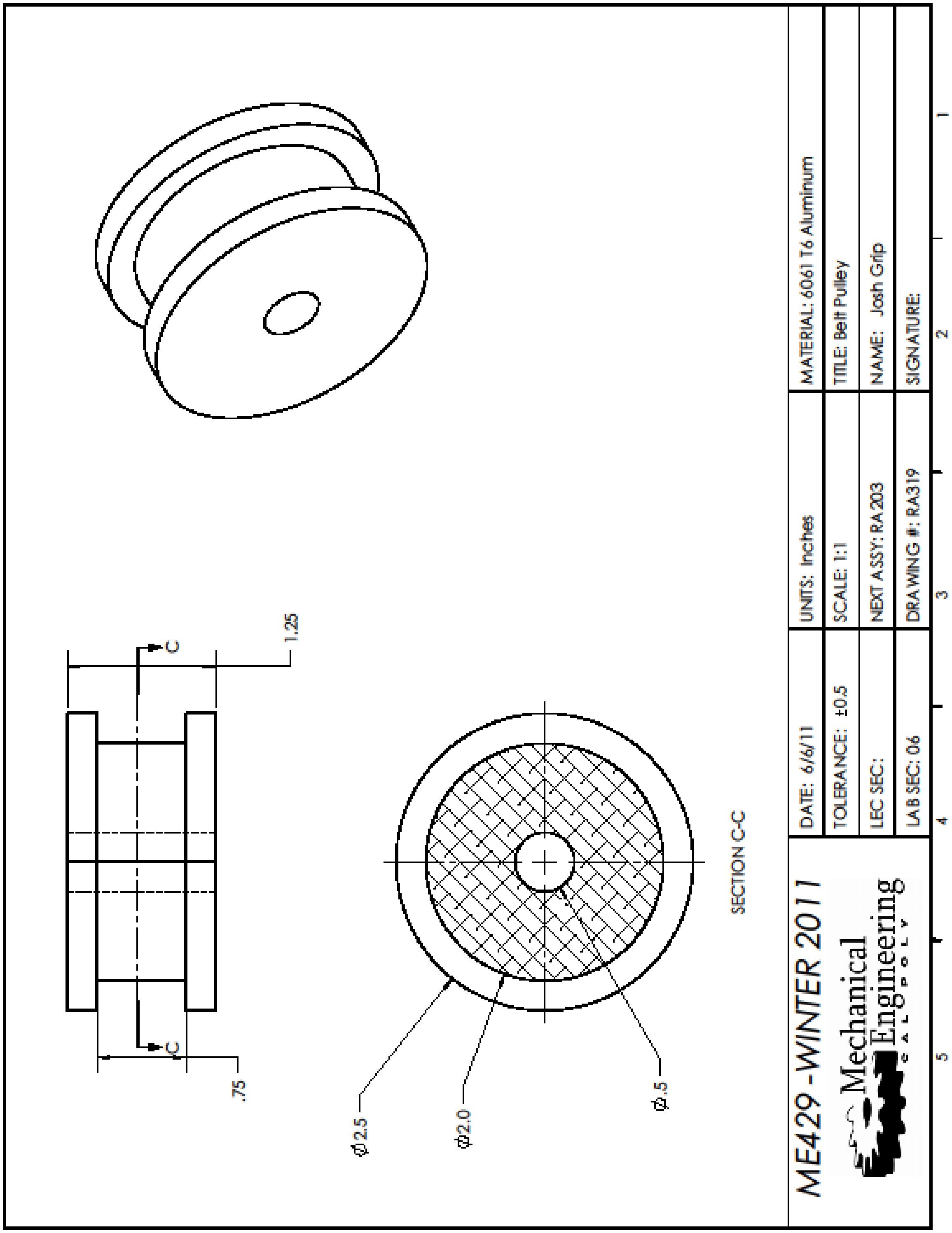

3.0
.813
2.026
2.5
3X 6-32 THRU
3.0
1.051
Note: "Triangle" Hole Dims are equal across horizontal mid-line.
2X Ø.250
2.0
1.5
.5
.375
6.0
.70
5.0
Note: Material Thickness is .25
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: RA204
DRAWING #: RA316
MATERIAL: 6061 T6 Aluminum
TITLE: Lower Plate
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5



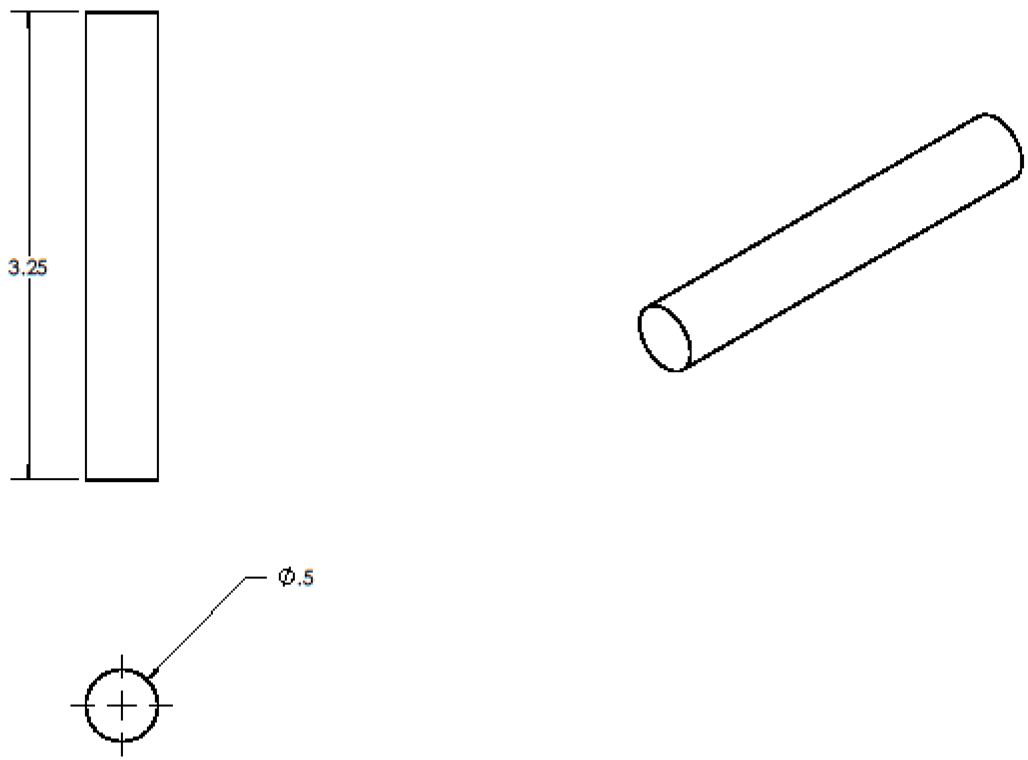
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1: 4
NEXT ASSY: RA203
DRAWING #: RA318
MATERIAL: 6061 T6 Aluminum
TITLE: Motor Mount Plate
NAME: Josh Grip
SIGNATURE:
Note: Hole Dims repeated for all corners.
DETAIL A
SCALE 1 : 2
4X ϕ.25 THRU
.375
.375
8.00
.75
1.875
.75
.5
1.375
3.25
.25
.750
8.0
.25
A
1
2
3
4
5



Note: Hole Dims reflected around center line
6X Ø.25
Note: 2X UNC 1/4 - 20
.375
1.25
1.25
.375
.75
1.88
1.375
3.25
.5
3.1
4.4
1.775
.5
.5
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1: 2
NEXT ASSY: RA203
DRAWING #: RA318B
MATERIAL: 6061 T6 Aluminum
TITLE: Motor Adjustment Plate
NAME: Josh Grip
SIGNATURE:

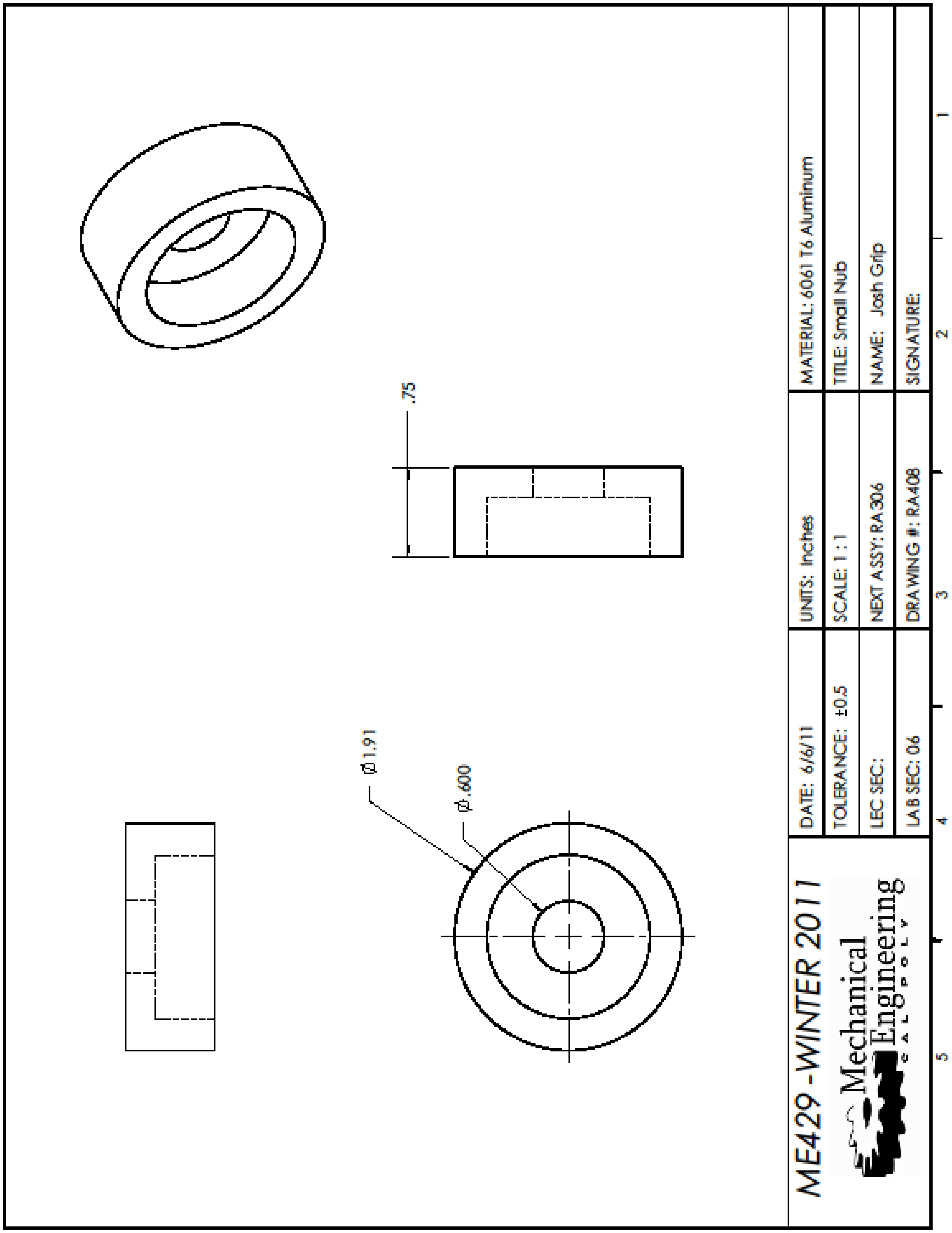


1.25
C
C
.75
⌀2.5
⌀2.0
⌀.5
SECTION C-C
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:1
NEXT ASSY: RA203
DRAWING #: RA319
MATERIAL: 6061 T6 Aluminum
TITLE: Belt Pulley
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

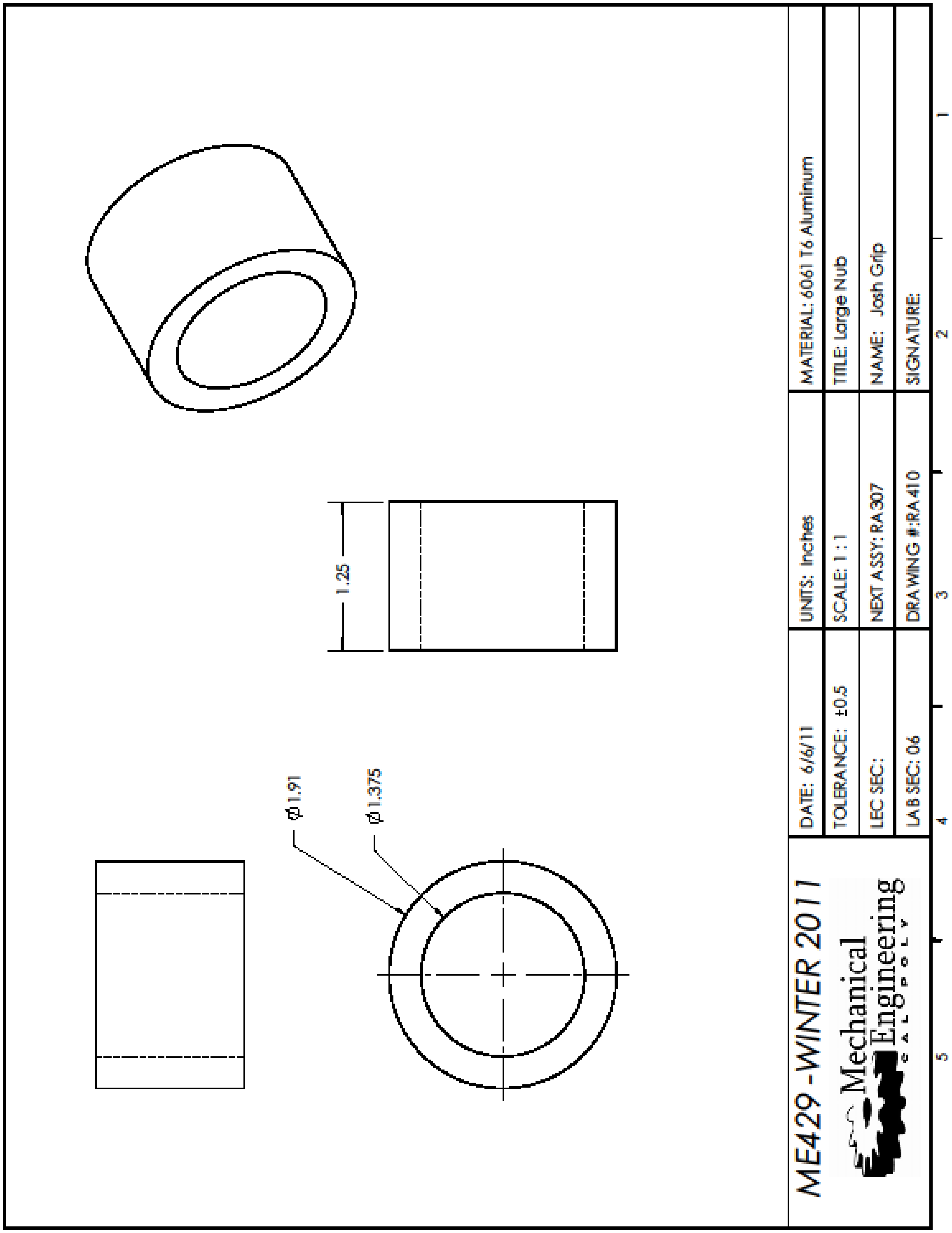


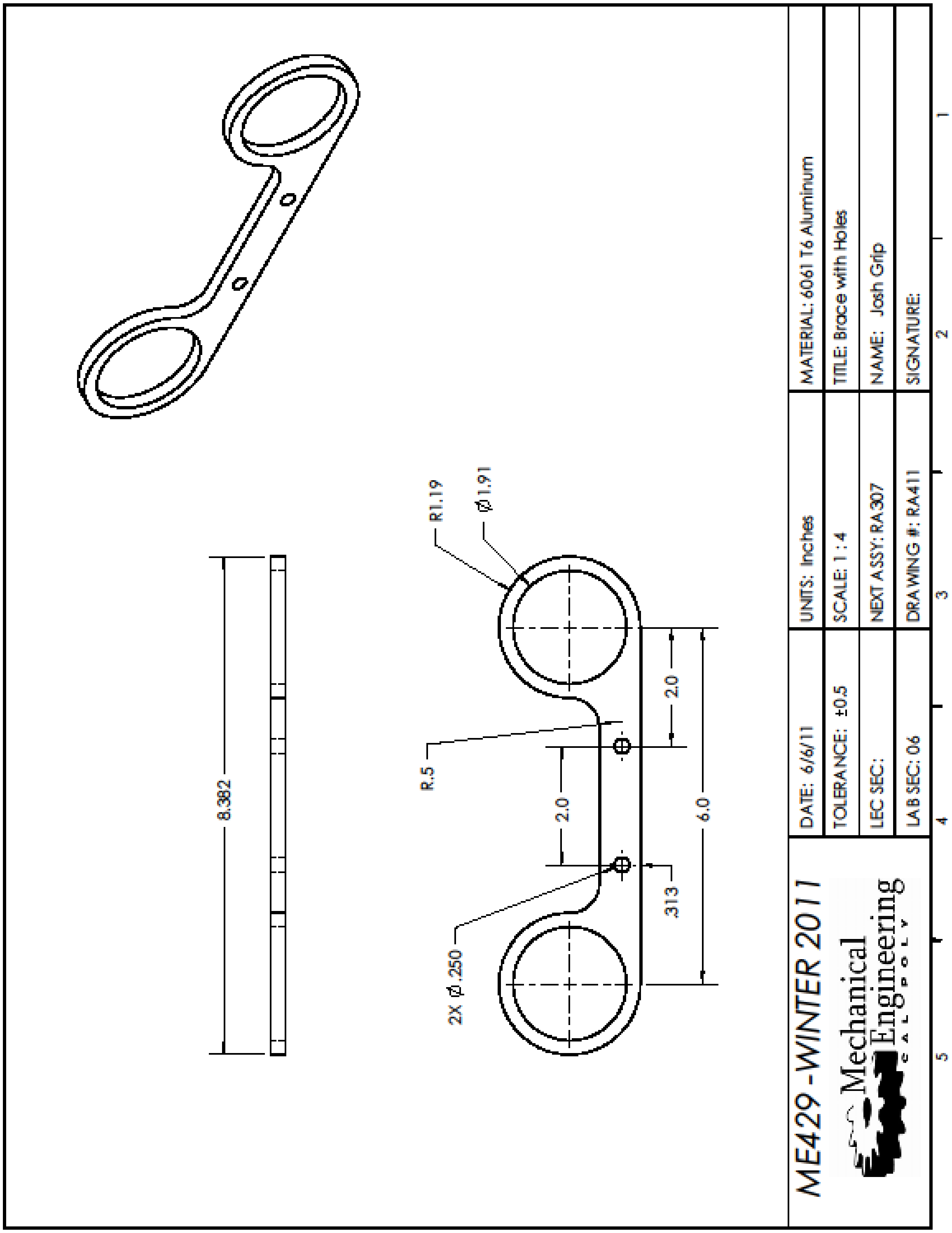
ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: 6061 T6 Aluminum
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE: 1: 1	TITLE: Motor Shaft
	LEC SEC:	NEXT ASSY: RA203	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: RA321	SIGNATURE:

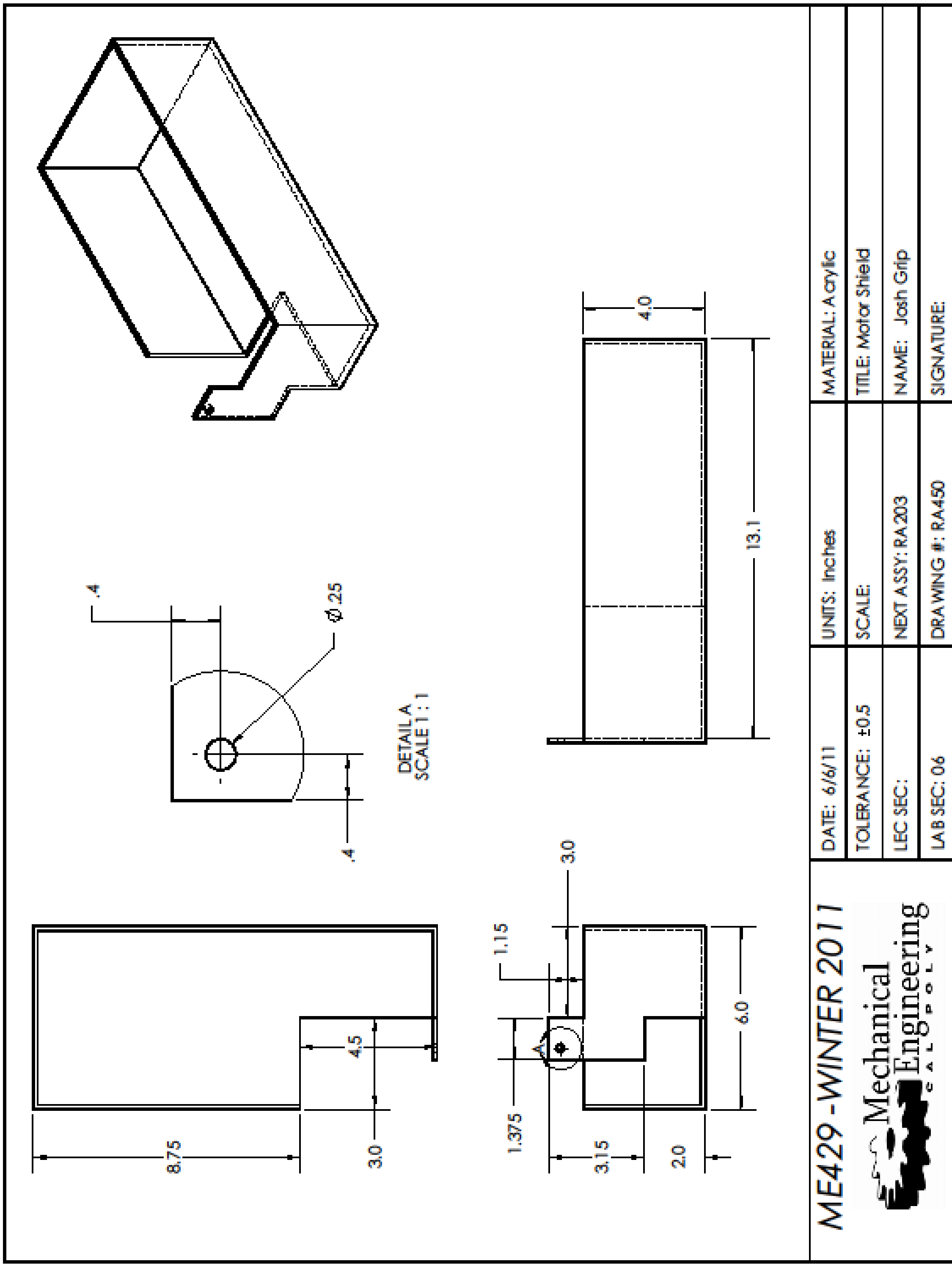
5 4 3 2 1



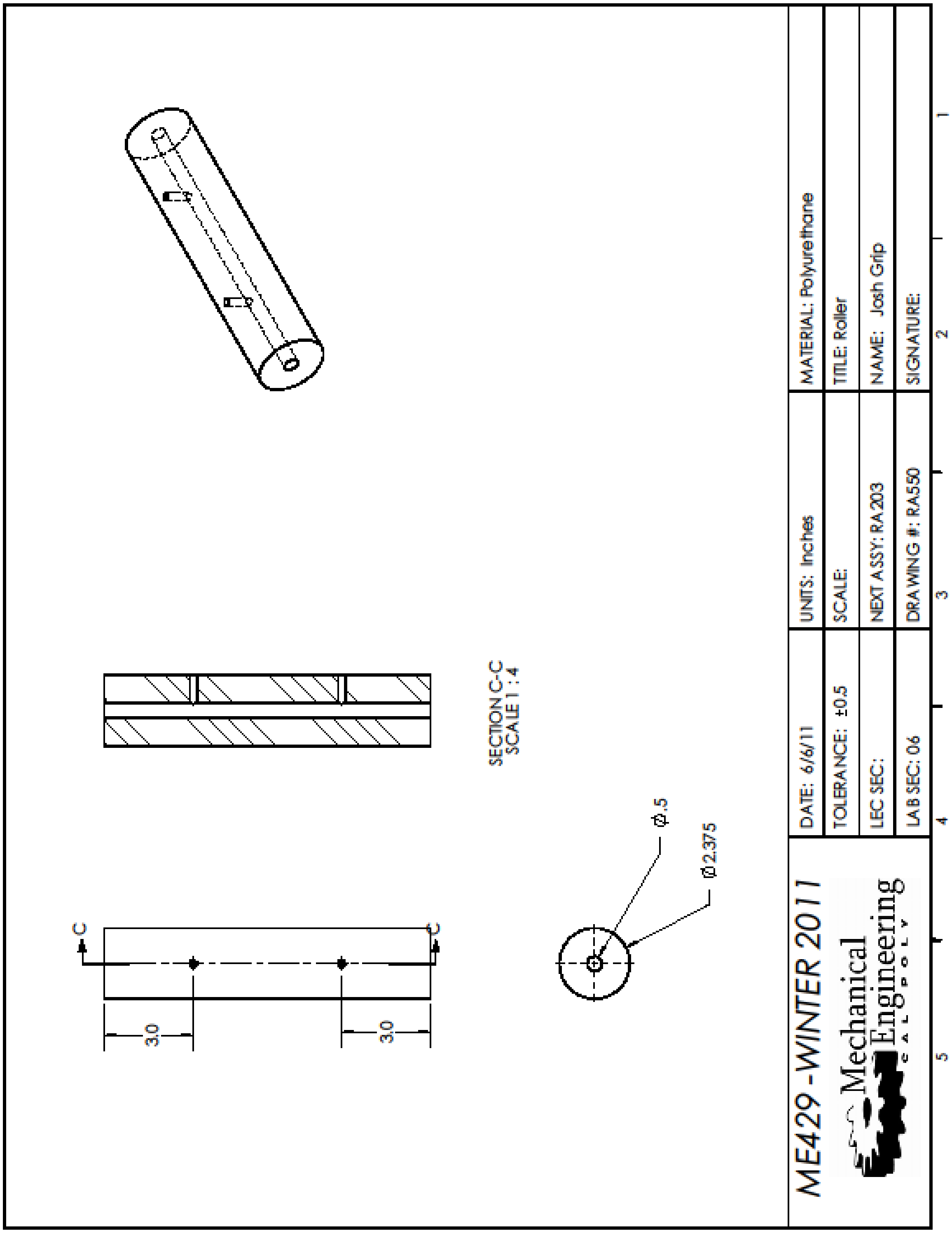
Ø1.91
Ø.600
.75
ME429-WINTER 2011
Mechanical Engineering CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 1
NEXT ASSY: RA306
DRAWING #: RA408
MATERIAL: 6061 T6 Aluminum
TITLE: Small Nub
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

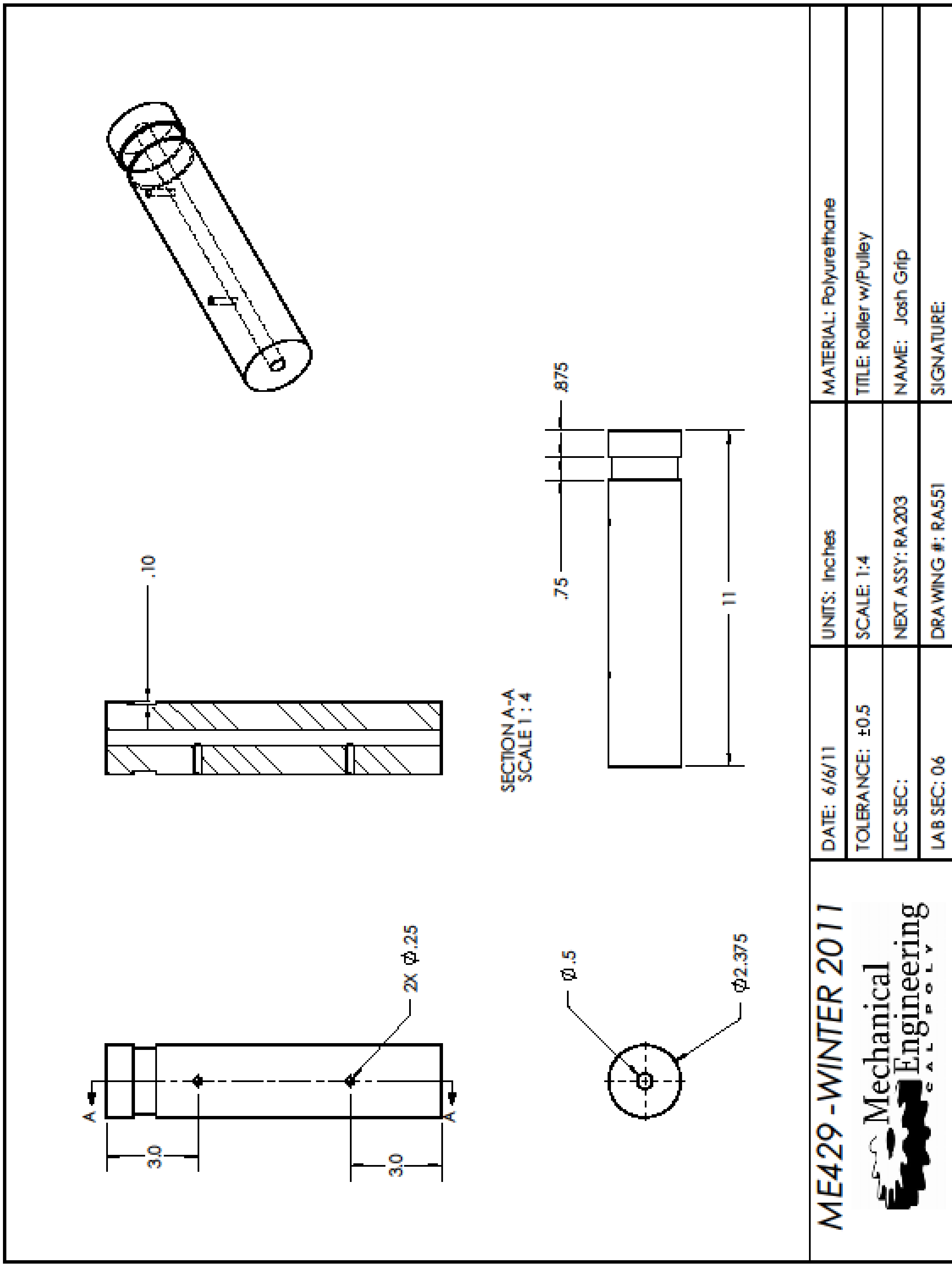

Ø1.91
Ø1.375
1.25
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 1
NEXT ASSY: RA307
DRAWING #: RA410
MATERIAL: 6061 T6 Aluminum
TITLE: Large Nub
NAME: Josh Grip
SIGNATURE:


8.382
R1.19
Ø1.91
R.5
2.0
2.0
6.0
2X Ø.250
.313
ME429-WINTER 2011
Mechanical Engineering CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: RA307
DRAWING #: RA411
MATERIAL: 6061 T6 Aluminum
TITLE: Brace with Holes
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

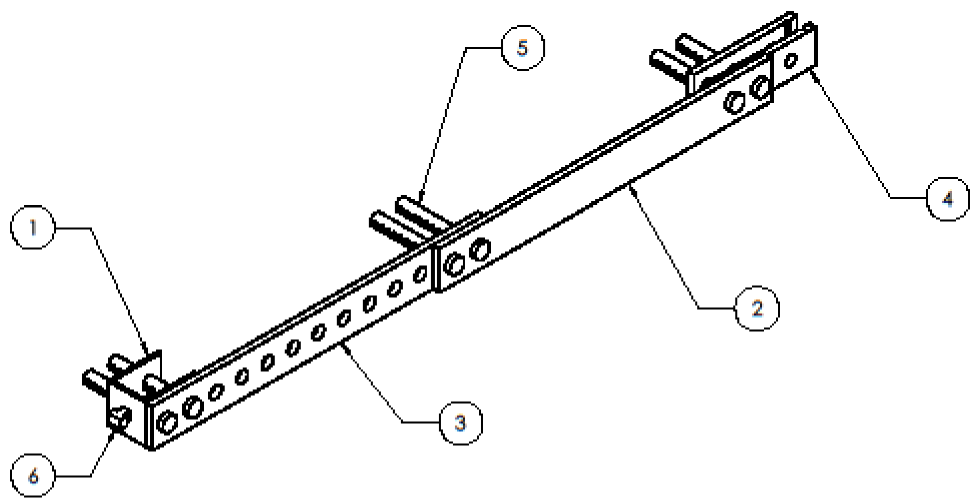


ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE:
NEXT ASSY: RA203
DRAWING #: RA450
MATERIAL: Acrylic
TITLE: Motor Shield
NAME: Josh Grip
SIGNATURE:
DETAIL A
SCALE 1 : 1
Ø.25
.4
.4
8.75
3.0
4.5
1.375
3.15
2.0
1.15
3.0
6.0
13.1
4.0


3.0
3.0
C
C
SECTION C-C
SCALE 1 : 4
Ø.5
Ø2.375
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE:
NEXT ASSY: RA203
DRAWING #: RA550
MATERIAL: Polyurethane
TITLE: Roller
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

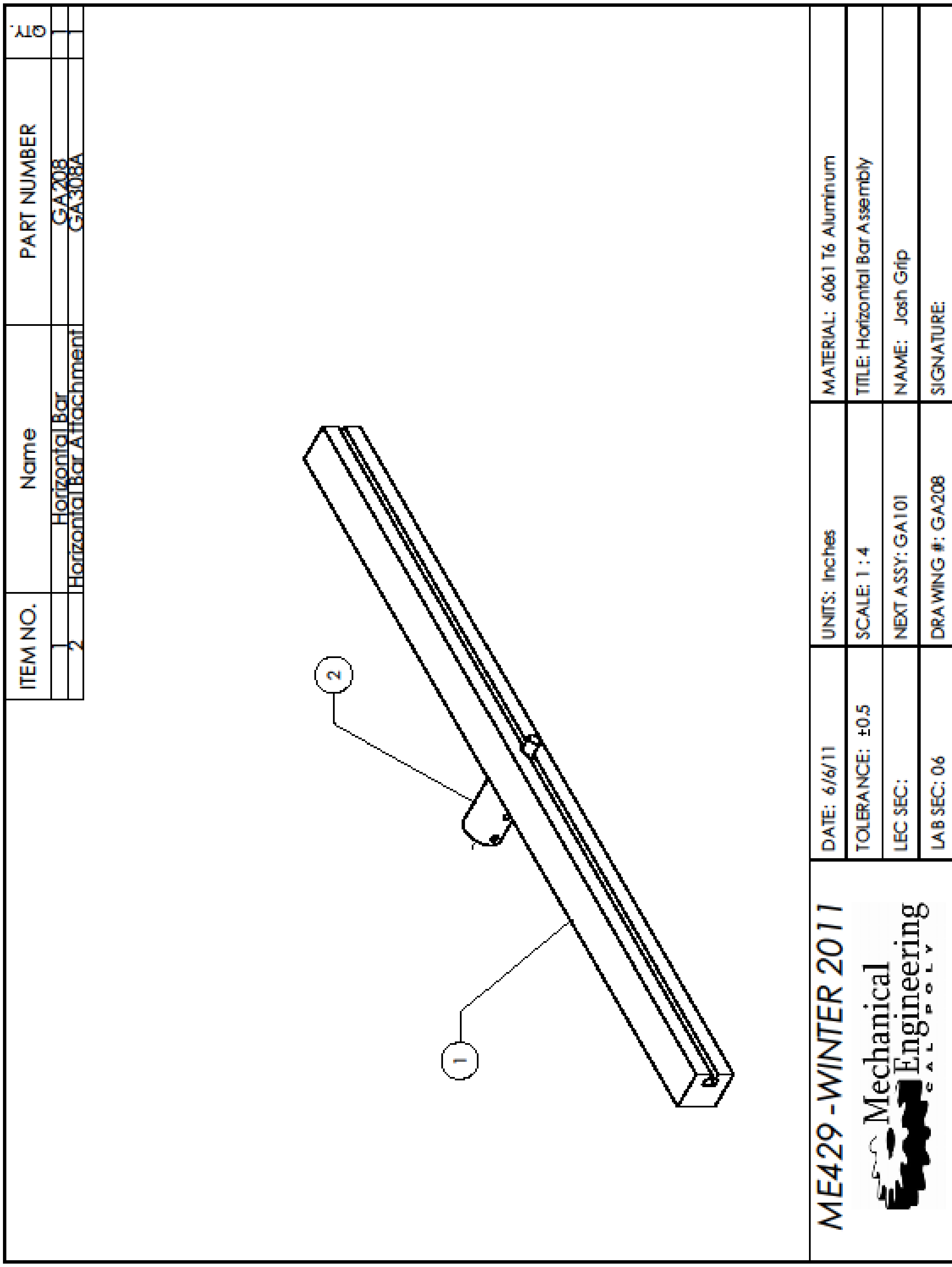

MATERIAL: Polyurethane
TITLE: Roller w/Pulley
NAME: Josh Grip
SIGNATURE:
UNITS: Inches
SCALE: 1:4
NEXT ASSY: RA203
DRAWING #: RA551
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
SECTION A-A
SCALE 1 : 4
.10
.875
.75
11
2X Ø.25
Ø.5
Ø2.375
3.0
3.0
A
A

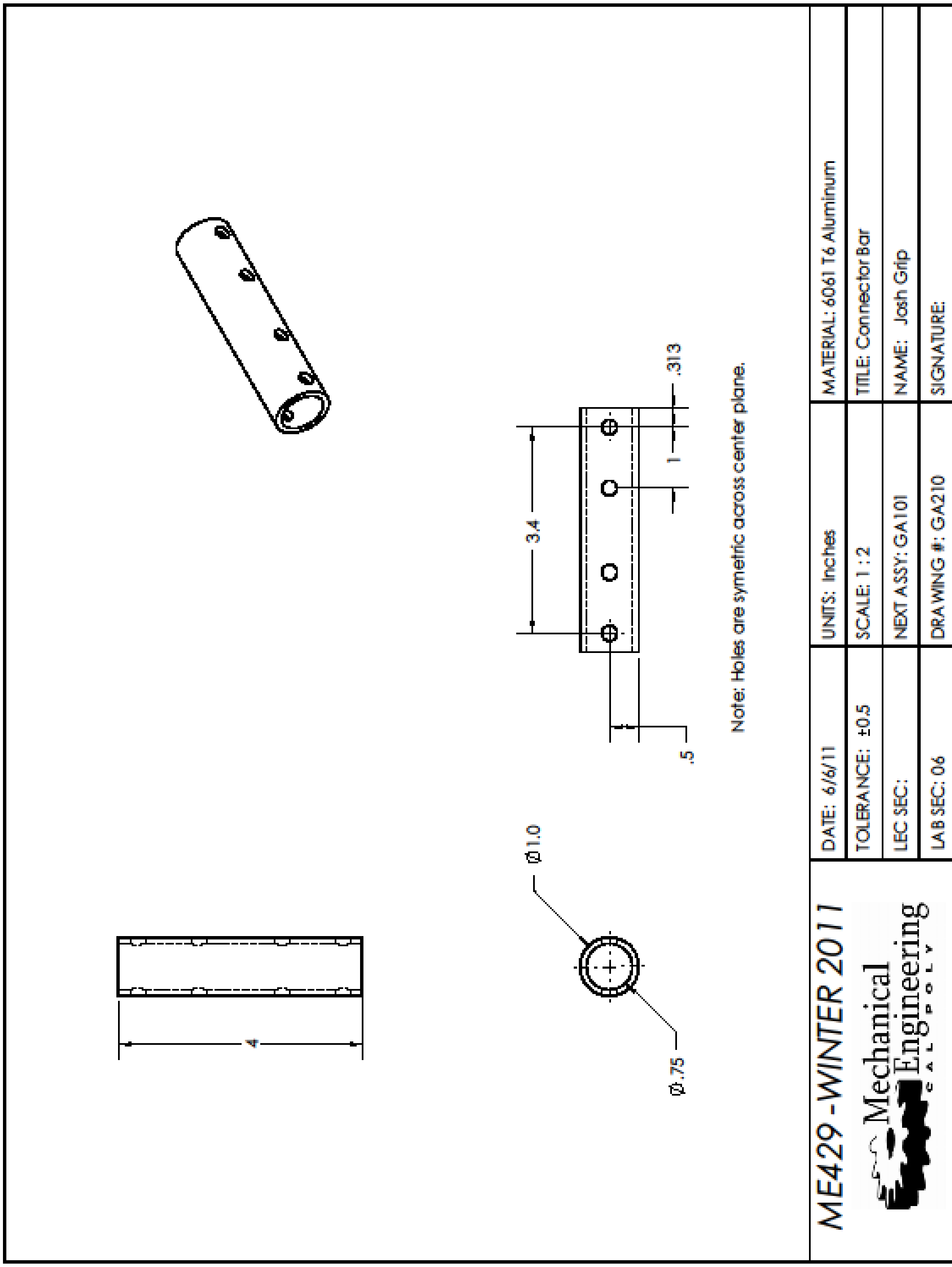
ITEM NO.	Name	PART NUMBER	QTY.
1	Gator Arm U Joint	GA221	1
2	Standard Gator Arm	GA204	1
3	Adjustable Gator Arm	GA203	1
4	Gator Jaws	GA341	2
5	Pin	98330A235	6
6	T Connector	GA462	1

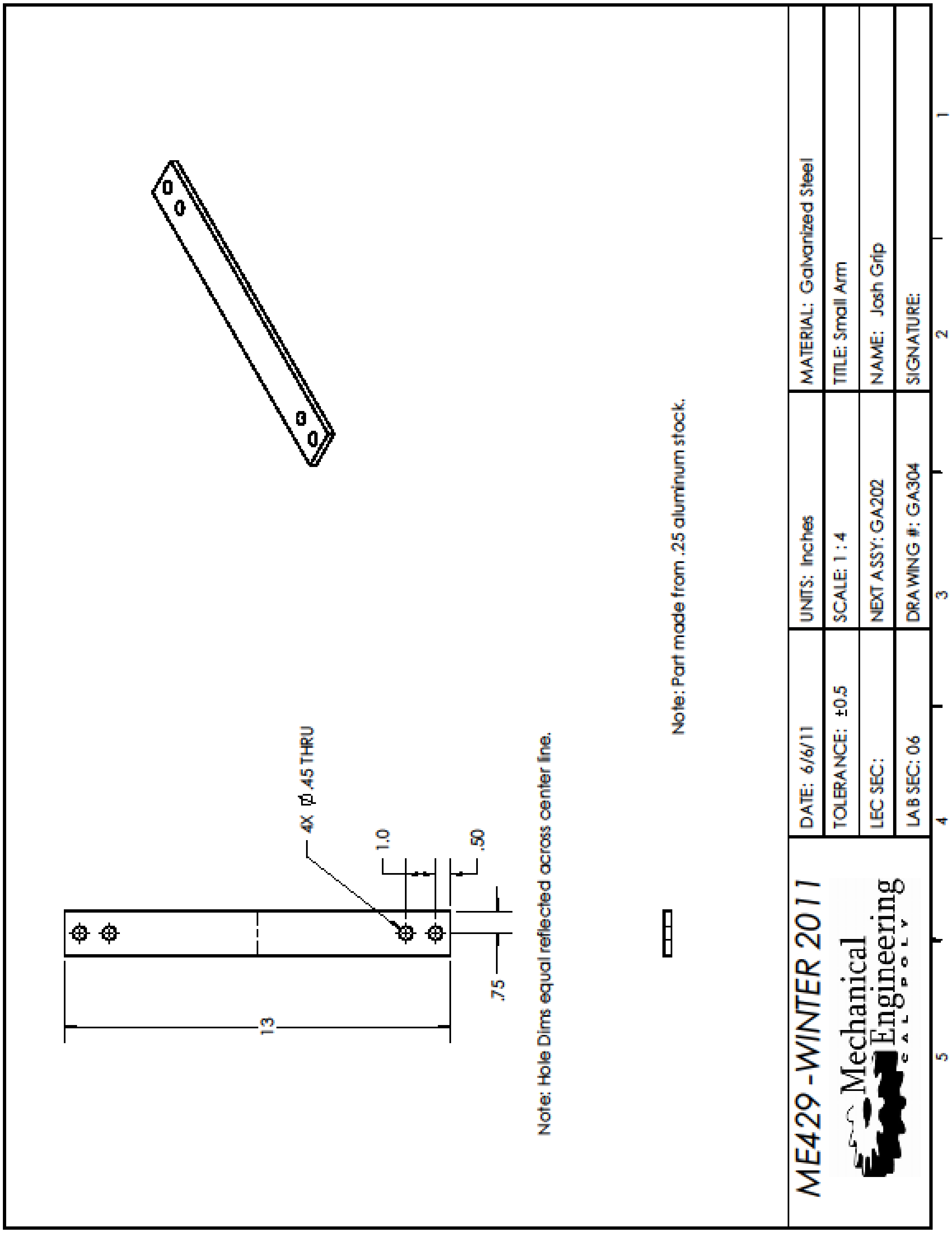


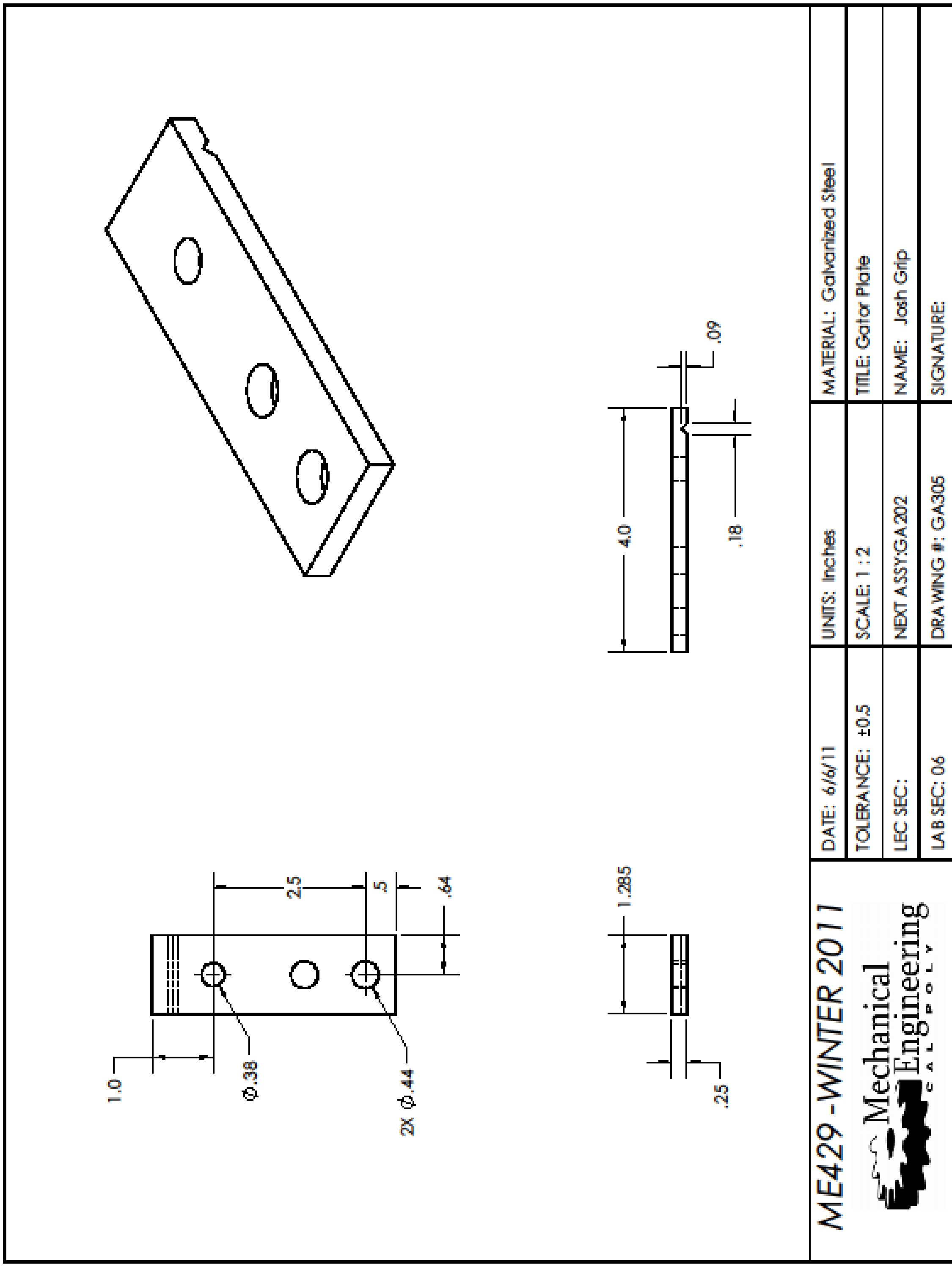
ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE: 1 : 4	TITLE: Gator Attachment
	LEC SEC:	NEXT ASSY: GA101	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: GA202	SIGNATURE:

5 4 3 2 1

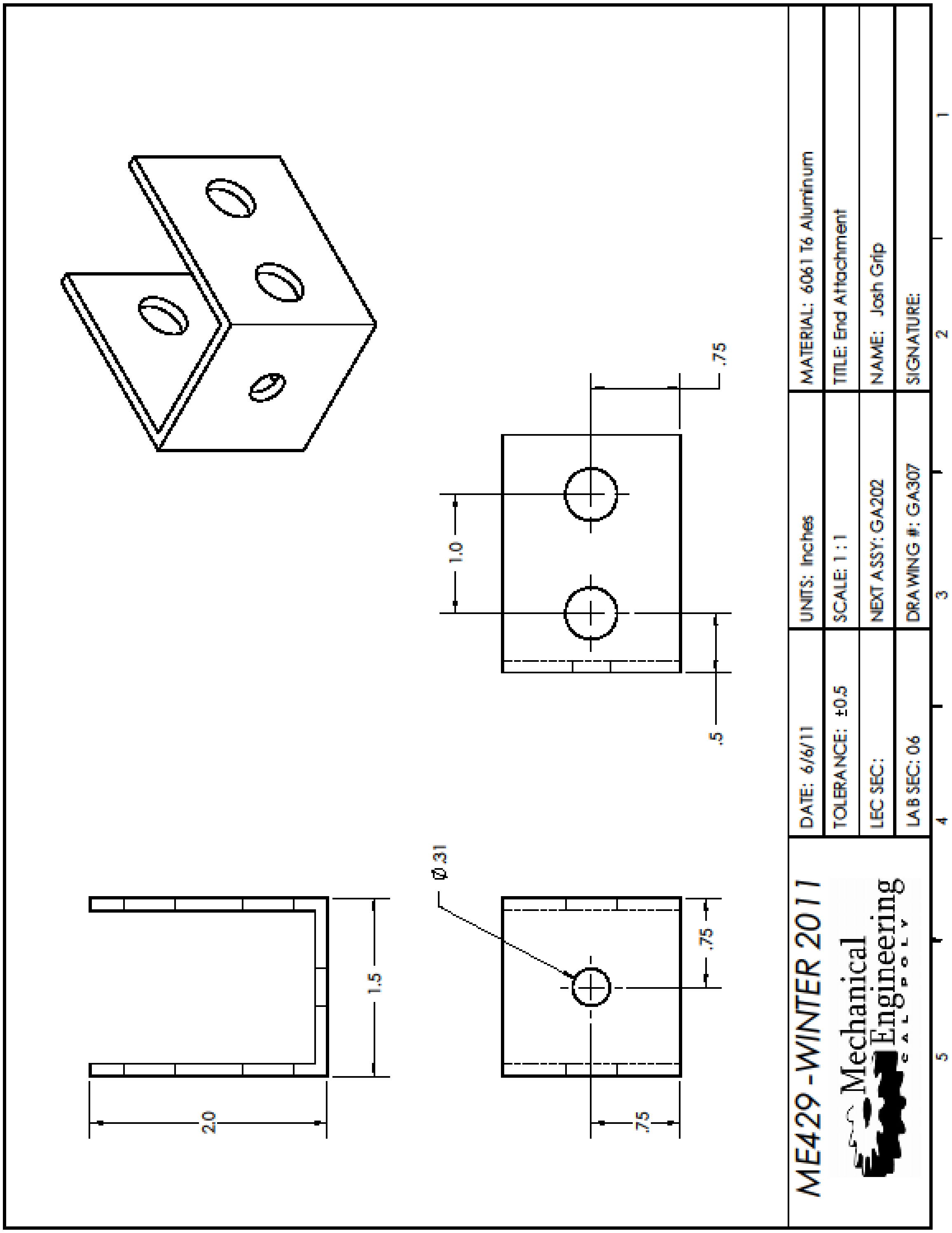

ITEM NO.
Name
PART NUMBER
QTY.
1
Horizontal Bar
GA208
1
2
Horizontal Bar Attachment
GA308A
1
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: GA101
DRAWING #: GA208
MATERIAL: 6061 T6 Aluminum
TITLE: Horizontal Bar Assembly
NAME: Josh Grip
SIGNATURE:

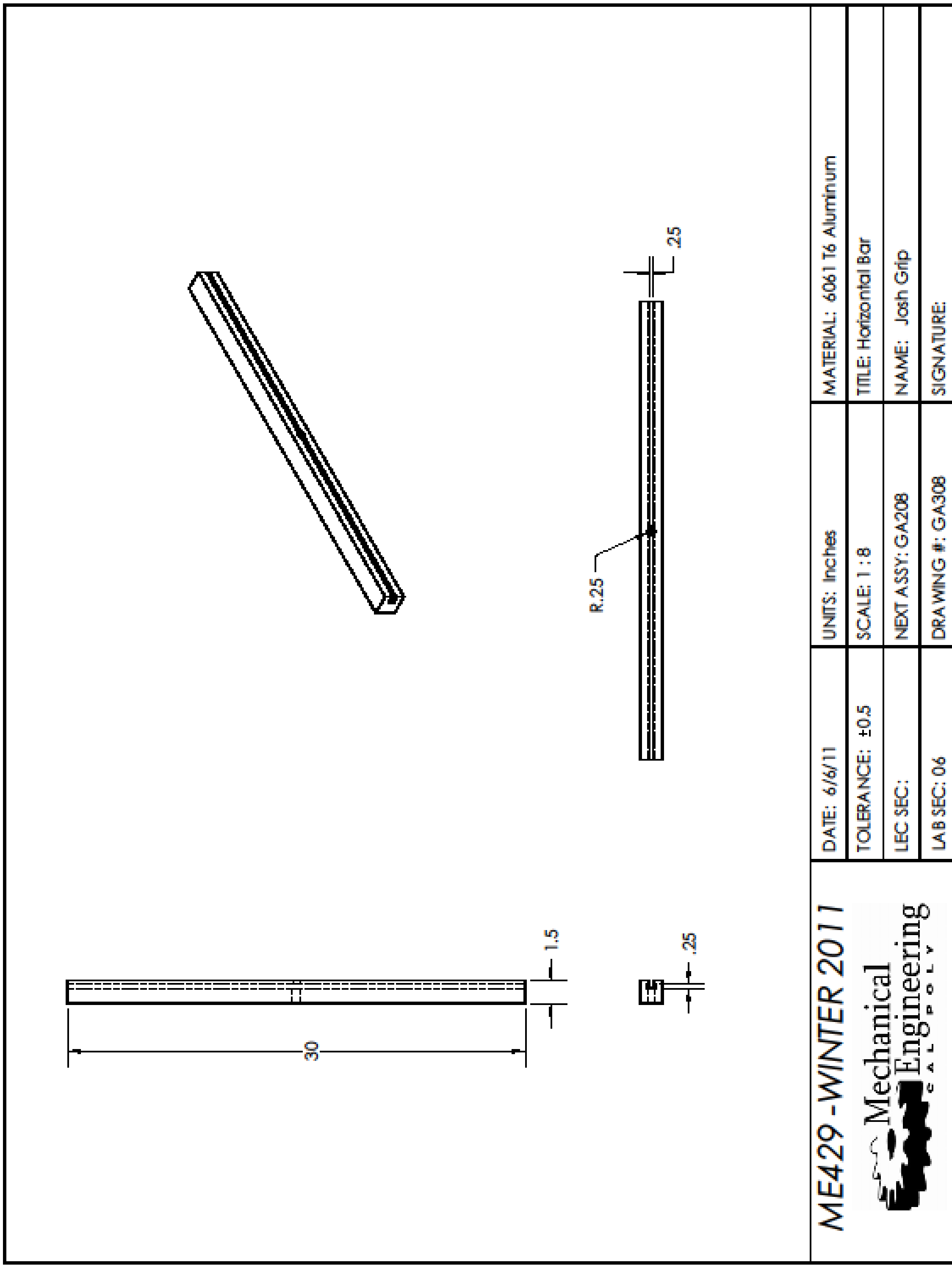

4
Ø1.0
Ø.75
3.4
.313
1
.5
Note: Holes are symetric across center plane.
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:2
NEXT ASSY: GA101
DRAWING #: GA210
MATERIAL: 6061 T6 Aluminum
TITLE: Connector Bar
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

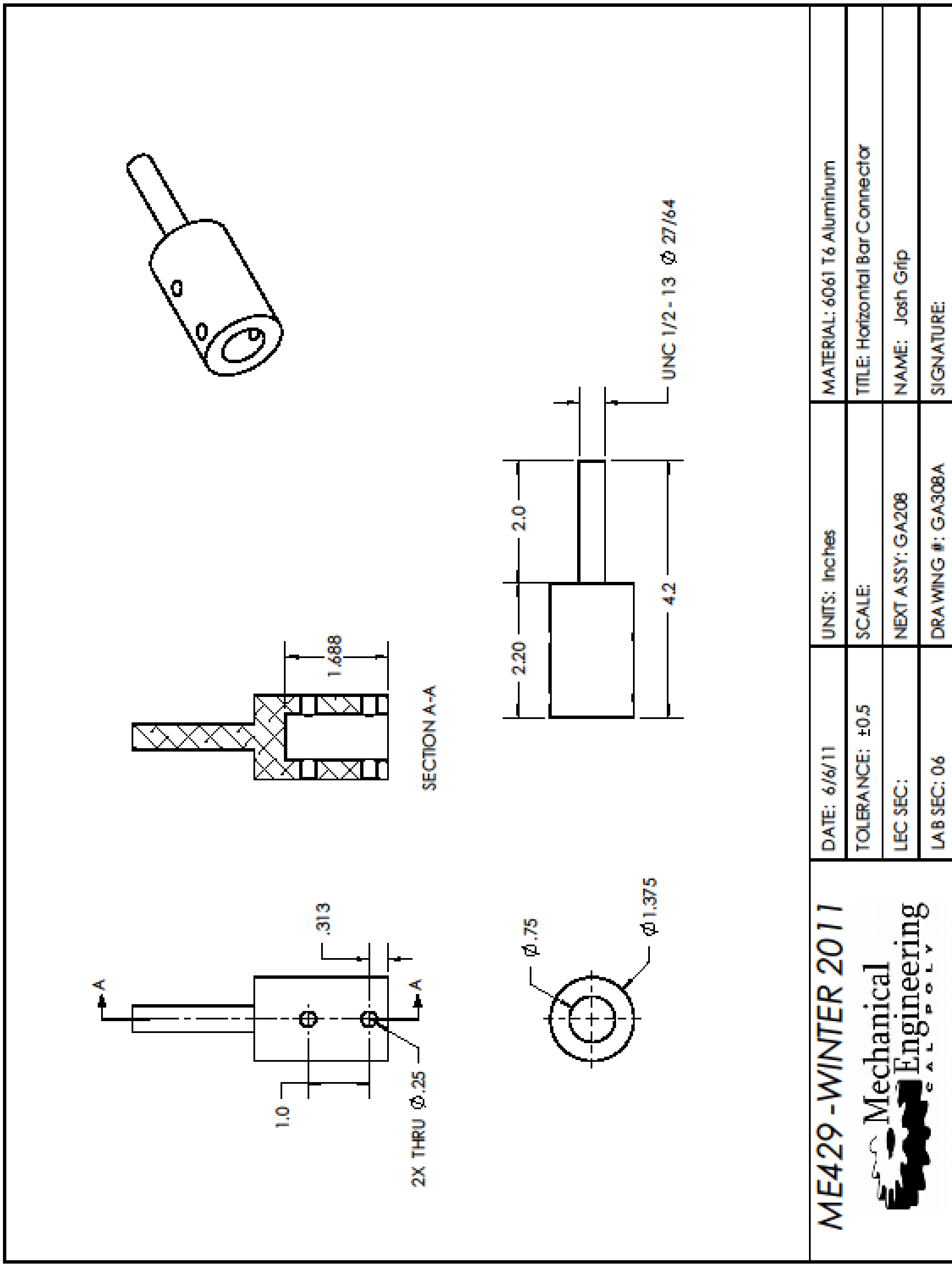

13
.75
1.0
.50
4X ⌀.45 THRU
Note: Hole Dims equal reflected across center line.
Note: Part made from .25 aluminum stock.
ME429 - WINTER 2011
Mechanical Engineering CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: GA202
DRAWING #: GA304
MATERIAL: Galvanized Steel
TITLE: Small Arm
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5



ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 2
NEXT ASSY:GA202
DRAWING #: GA305
MATERIAL: Galvanized Steel
TITLE: Gator Plate
NAME: Josh Grip
SIGNATURE:
1.0
Ø.38
2X Ø.44
2.5
.5
.64
1.285
.25
4.0
.18
.09

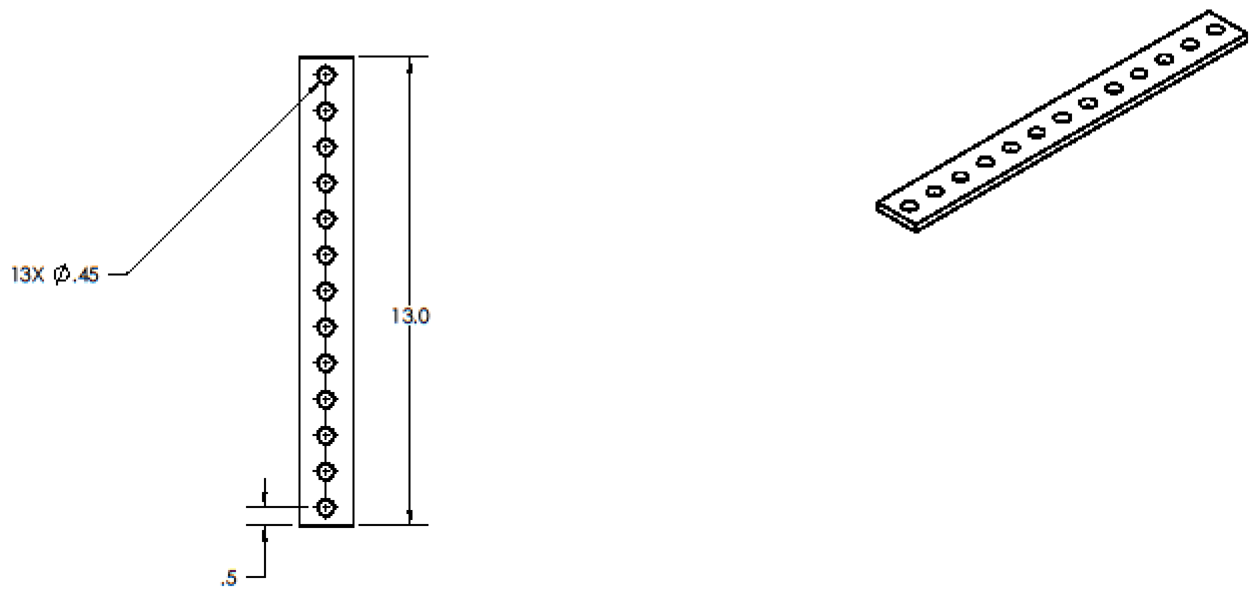

2.0
1.5
.75
Ø.31
.75
1.0
.75
.5
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 1
NEXT ASSY: GA202
DRAWING #: GA307
MATERIAL: 6061 T6 Aluminum
TITLE: End Attachment
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


30
1.5
.25
R.25
.25
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:8
NEXT ASSY: GA208
DRAWING #: GA308
MATERIAL: 6061 T6 Aluminum
TITLE: Horizontal Bar
NAME: Josh Grip
SIGNATURE:



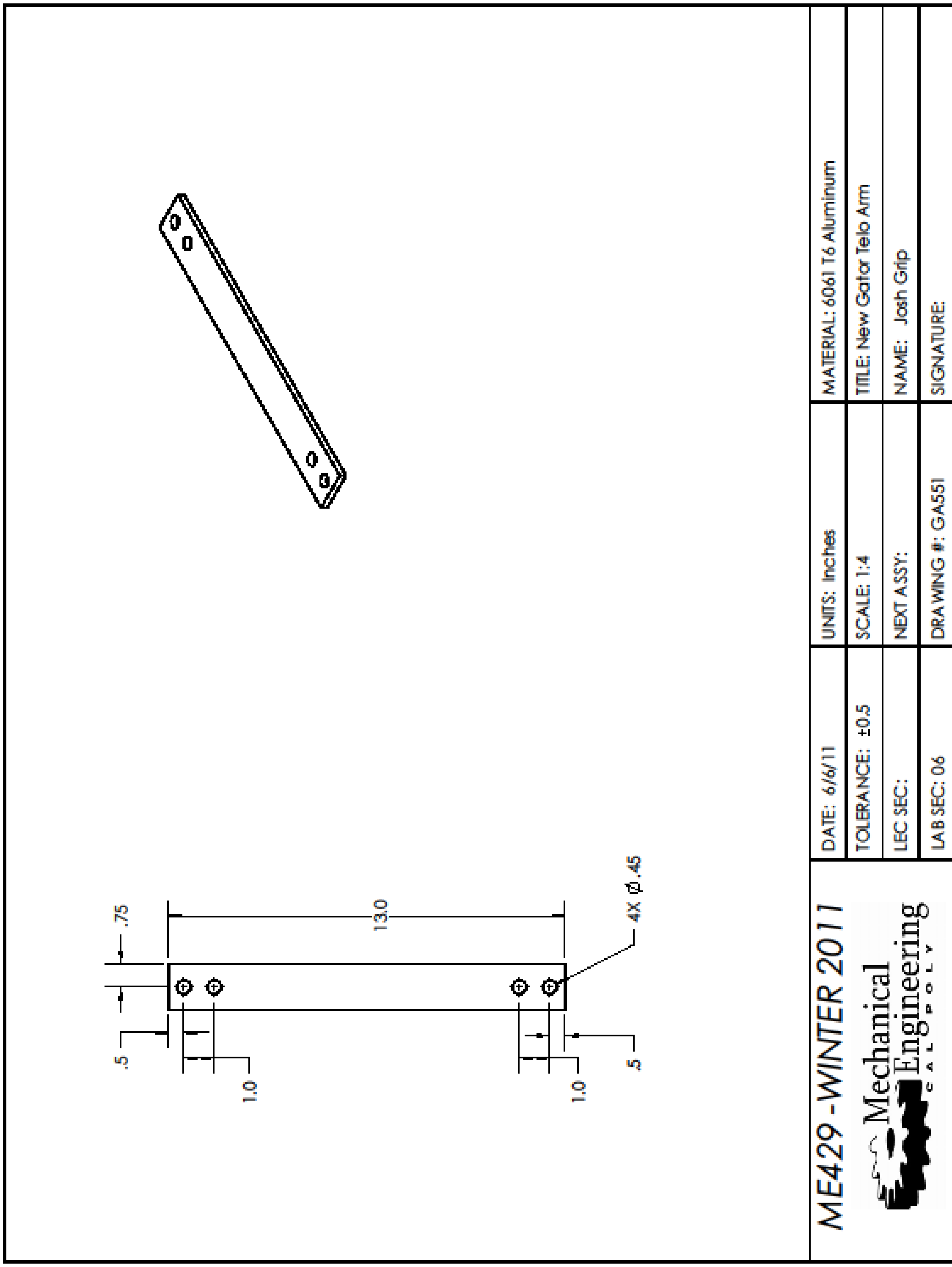
A
A
1.0
.313
2X THRU Ø .25
Ø.75
Ø1.375
SECTION A-A
1.688
2.20
2.0
4.2
UNC 1/2 - 13 Ø 27/64
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE:
NEXT ASSY: GA208
DRAWING #: GA308A
MATERIAL: 6061 T6 Aluminum
TITLE: Horizontal Bar Connector
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5

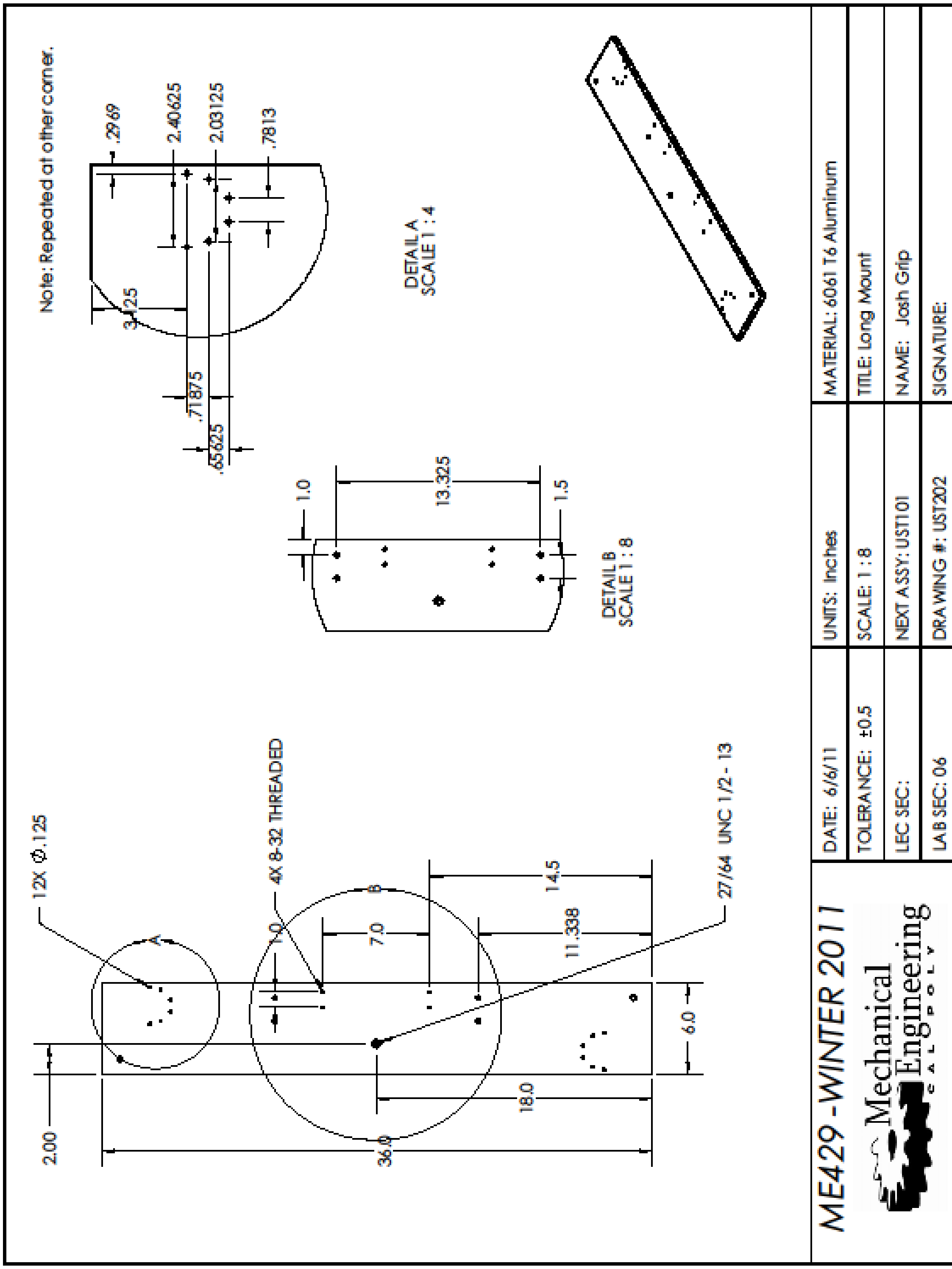
Note: 13 holes with 1 inch spacing

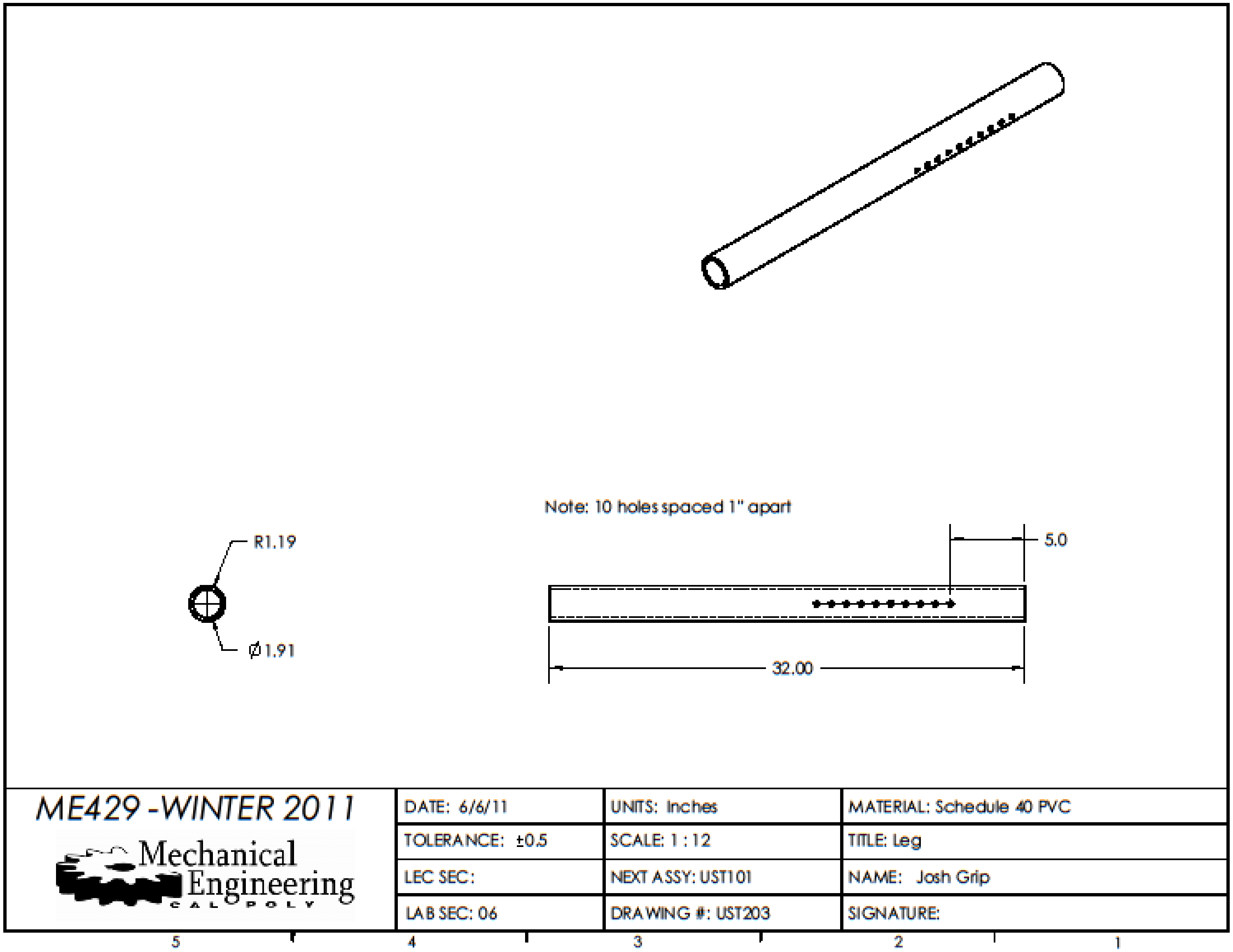


ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: 6061 T6 Aluminum
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE: 1:4	TITLE: New Gator Telo Adjust Arm
	LEC SEC:	NEXT ASSY: GA207	NAME: Josh Grip
	LAB SEC: 06	DRAWING #:GA500	SIGNATURE:

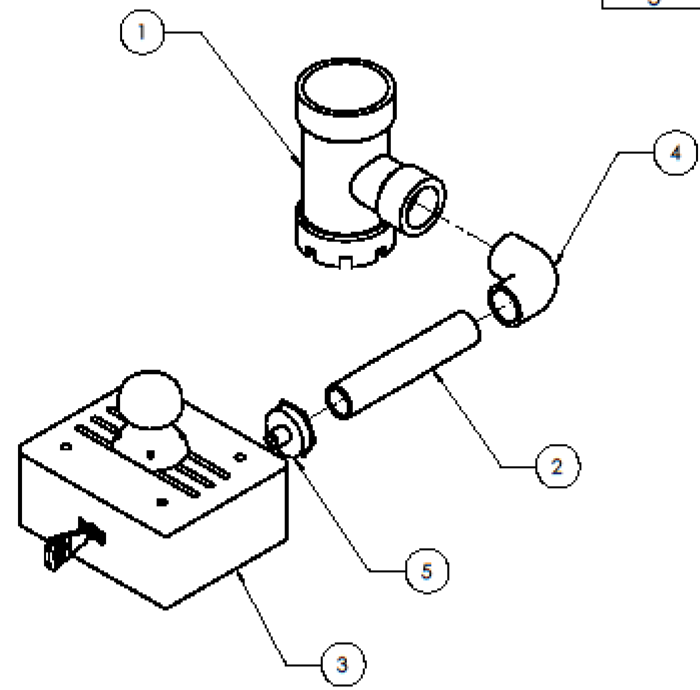
5 4 3 2 1


.75
13.0
4X Ø.45
.5
1.0
1.0
.5
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:4
NEXT ASSY:
DRAWING #: GA551
MATERIAL: 6061 T6 Aluminum
TITLE: New Gator Telo Arm
NAME: Josh Grip
SIGNATURE:


Note: Repeated at other corner.
.2969
2.40625
2.03125
.7813
3.125
.71875
.65625
DETAIL A
SCALE 1 : 4
1.0
13.325
1.5
DETAIL B
SCALE 1 : 8
12X Ø.125
4X 8-32 THREADED
27/64 UNC 1/2 - 13
2.00
1.0
7.0
14.5
11.338
6.0
18.0
36.0
A
B
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 8
NEXT ASSY: UST101
DRAWING #: UST202
MATERIAL: 6061 T6 Aluminum
TITLE: Long Mount
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


Note: 10 holes spaced 1" apart
5.0
32.00
R1.19
Ø1.91
ME429 -WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 12
NEXT ASSY: UST101
DRAWING #: UST203
MATERIAL: Schedule 40 PVC
TITLE: Leg
NAME: Josh Grip
SIGNATURE:
5
4
3
2
1

ITEM NO.	Name	PART NUMBER	QTY.
1	Casted Collar	UST318	1
2	PVC Extension	UST321	1
3	Controller Box	UST322	1
4	PVC Elbow	UST323	1
5	Hex Connector	UST324	1



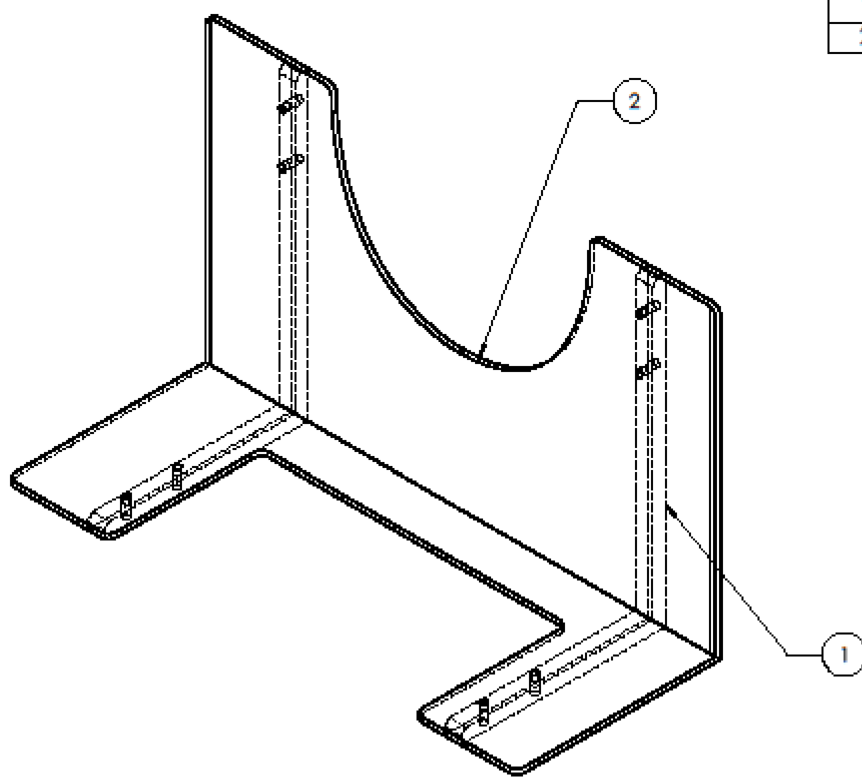
ME429 -WINTER 2011

Mechanical Engineering CAL POLY

DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
TOLERANCE: ±0.5	SCALE: 1:4	TITLE: Teloscoping Arm Assembly
LEC SEC:	NEXT ASSY: UST101	NAME: Josh Grip
LAB SEC: 06	DRAWING #: UST209	SIGNATURE:

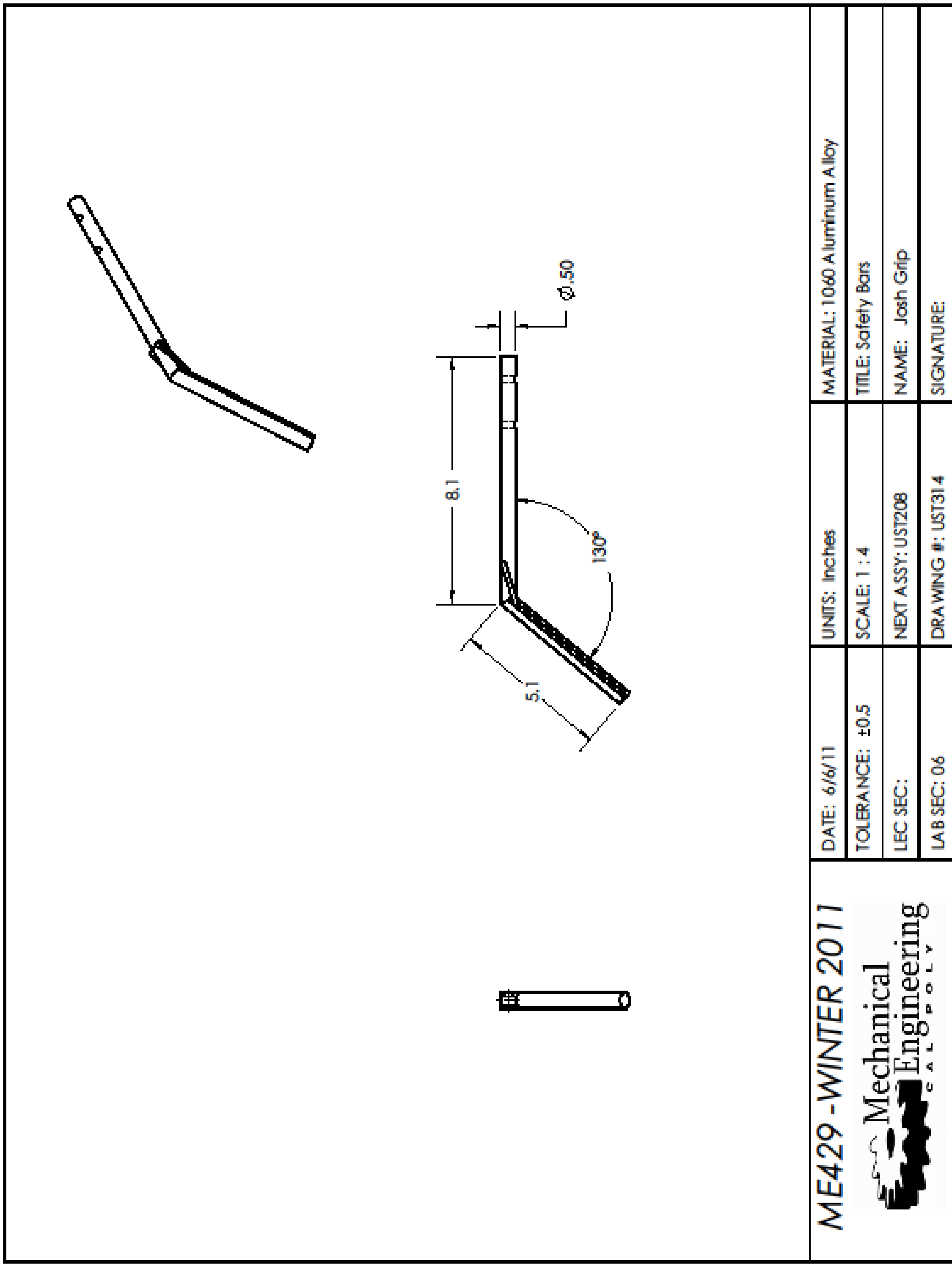
5 4 3 2 1

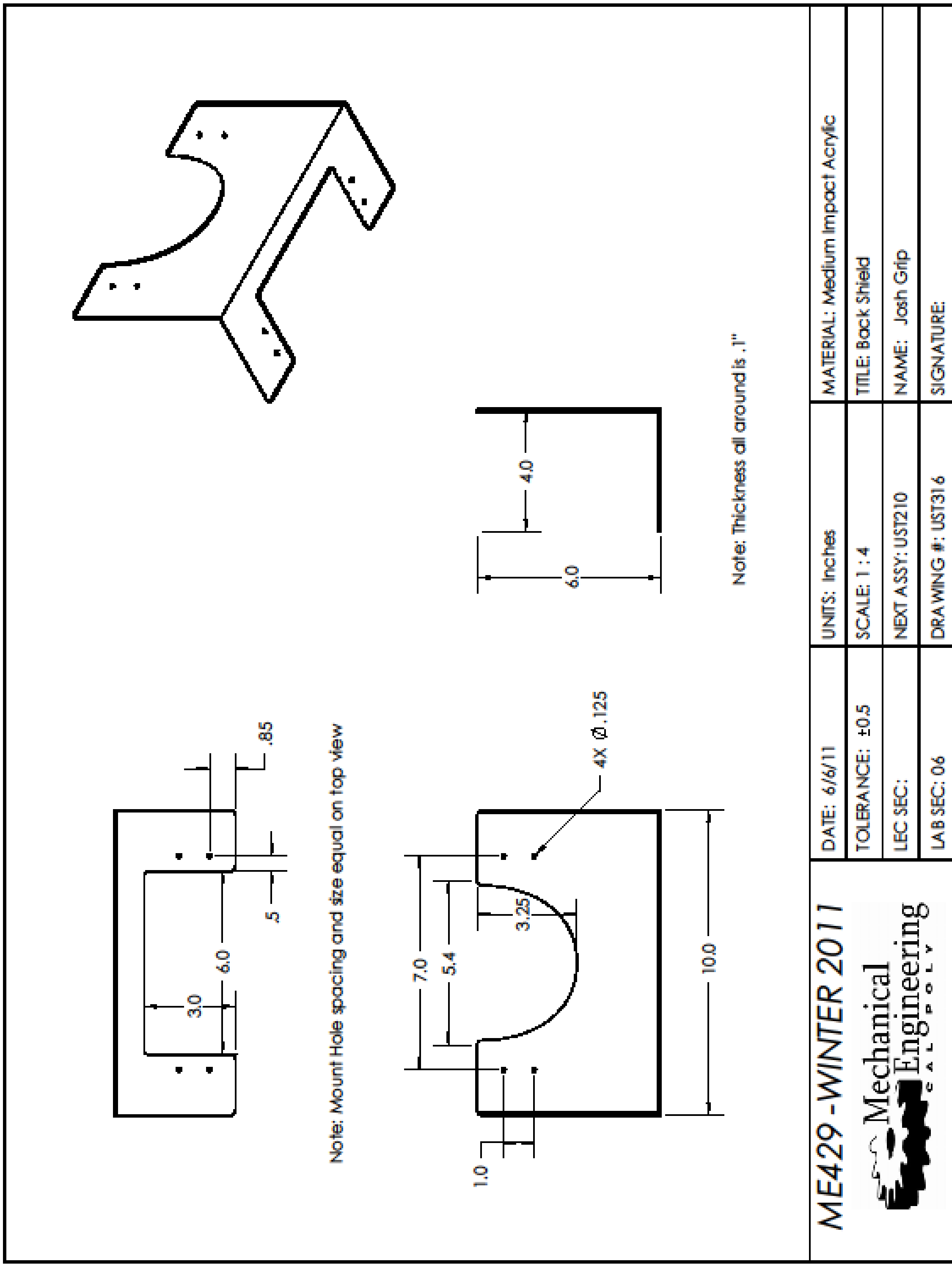
ITEM NO.	Name	PART NUMBER	QTY.
1	L Braces	UST317	2
2	Safety Shield	UST316	1

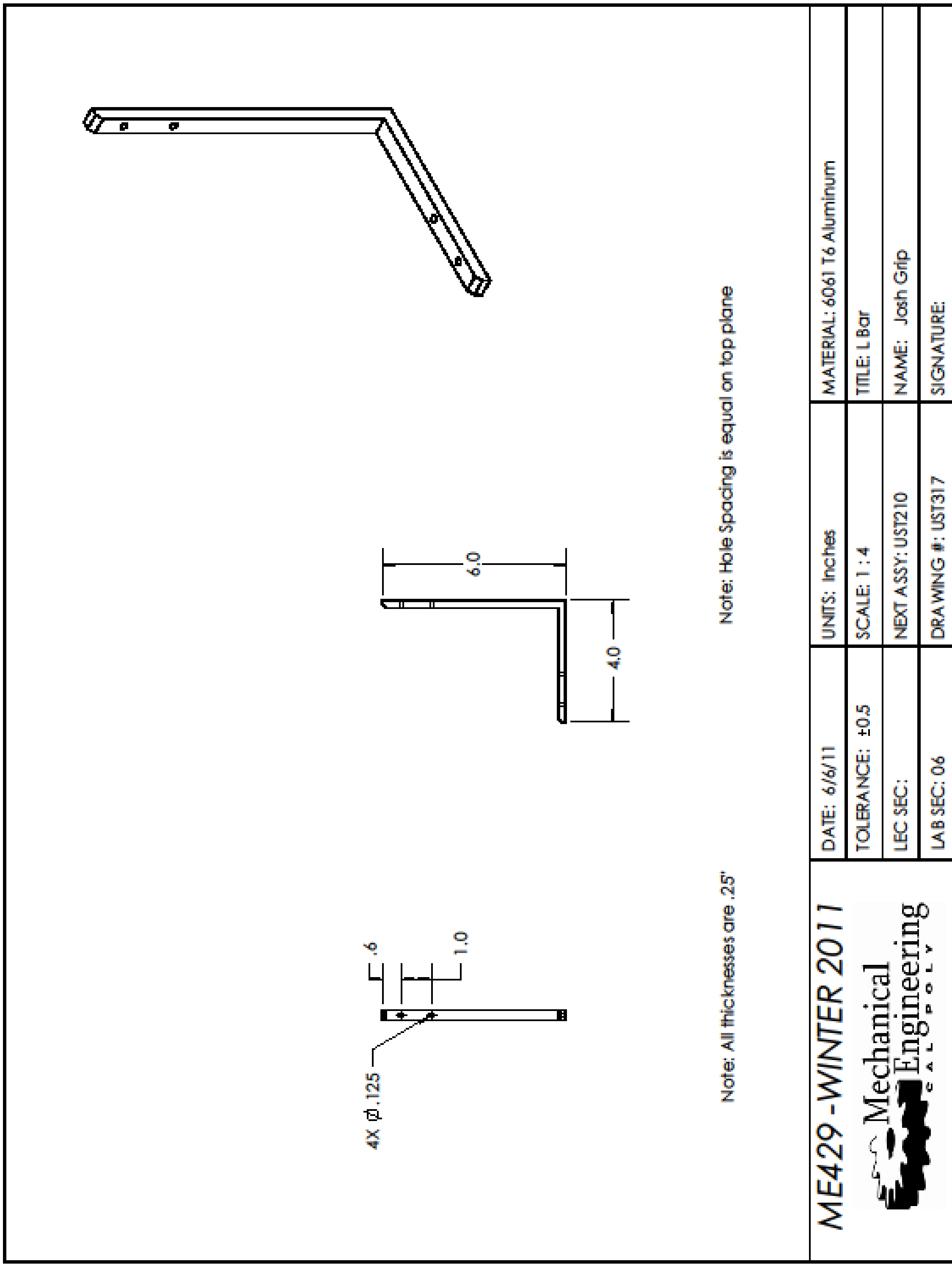


ME429 -WINTER 2011	DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
Mechanical Engineering CAL POLY	TOLERANCE: ±0.5	SCALE: 1 : 2	TITLE: Safety Shield Assembly
	LEC SEC:	NEXT ASSY: UST101	NAME: Josh Grip
	LAB SEC: 06	DRAWING #: UST210	SIGNATURE:

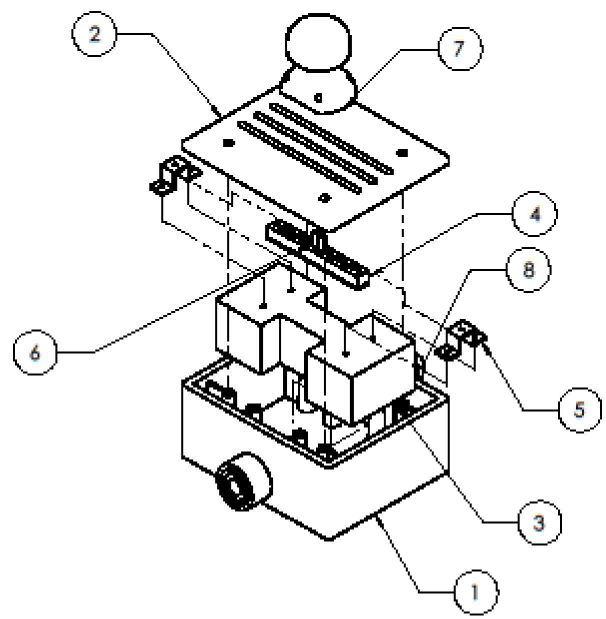
5 4 3 2 1


Ø.50
8.1
130°
5.1
MATERIAL: 1060 Aluminum Alloy
TITLE: Safety Bars
NAME: Josh Grip
SIGNATURE:
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: UST208
DRAWING #: UST314
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
ME429-WINTER 2011
Mechanical Engineering
CAL POLY


.85
.5
6.0
3.0
Note: Mount Hole spacing and size equal on top view
4X Ø.125
7.0
5.4
3.25
10.0
1.0
4.0
6.0
Note: Thickness all around is .1"
ME429 - WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: UST210
DRAWING #: UST316
MATERIAL: Medium Impact Acrylic
TITLE: Back Shield
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


6.0
4.0
4X ⌀.125
.6
1.0
Note: Hole Spacing is equal on top plane
Note: All thicknesses are .25"
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: UST210
DRAWING #: UST317
MATERIAL: 6061 T6 Aluminum
TITLE: L Bar
NAME: Josh Grip
SIGNATURE:

ITEM NO.	Name	PART NUMBER	QTY.
1	Box Bottom	UST440	1
2	Box Cap	UST441	1
3	Potentiometer Mount	UST422	1
4	Linear Potentiometer	UST423	1
5	Potentiometer Brace	UST424	2
6	Potentiometer Tab	UST423A	1
7	User Nub	UST422	1
8	Switch Tab	UST425	1
9	Switch Flex	UST425A	1

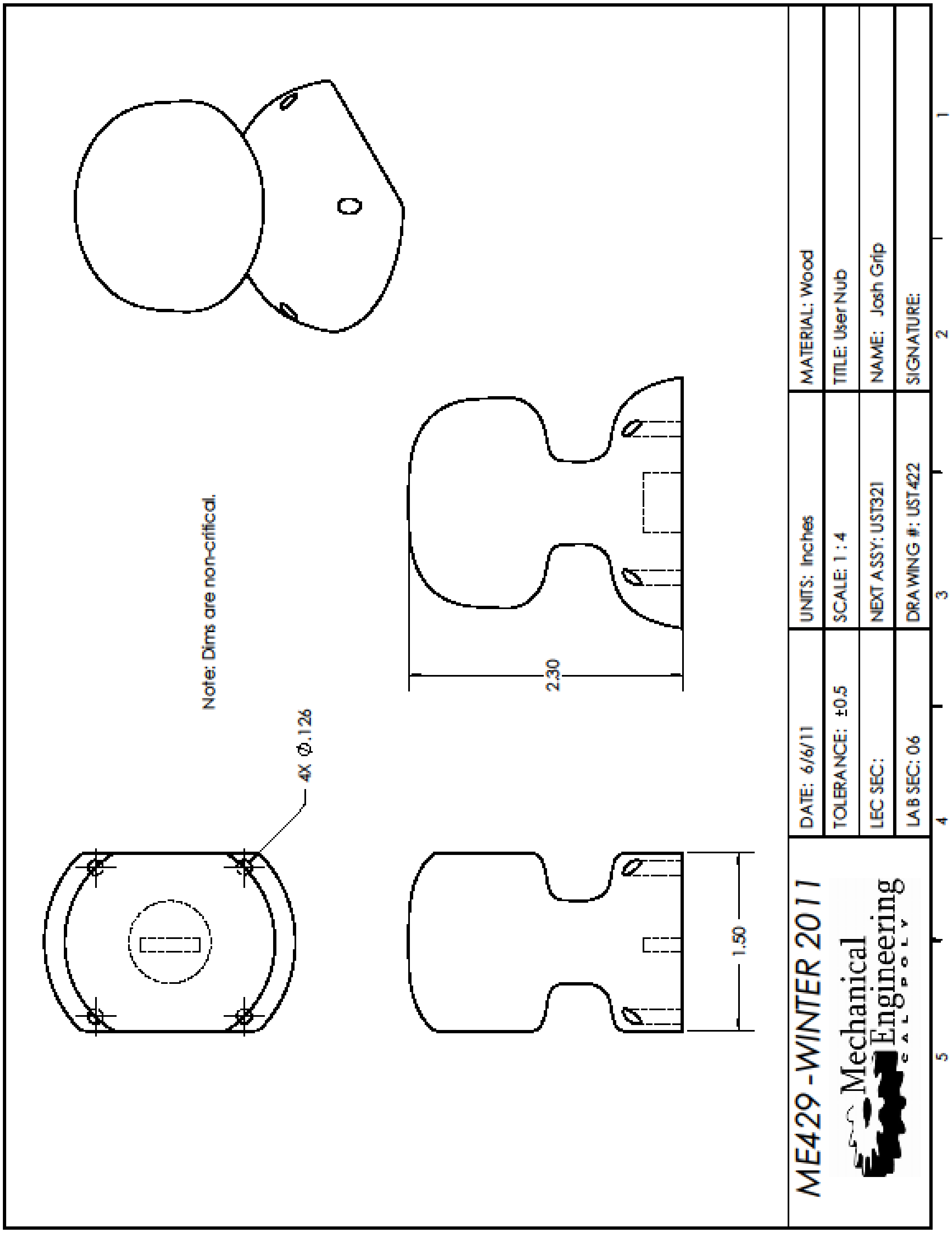


ME429 -WINTER 2011

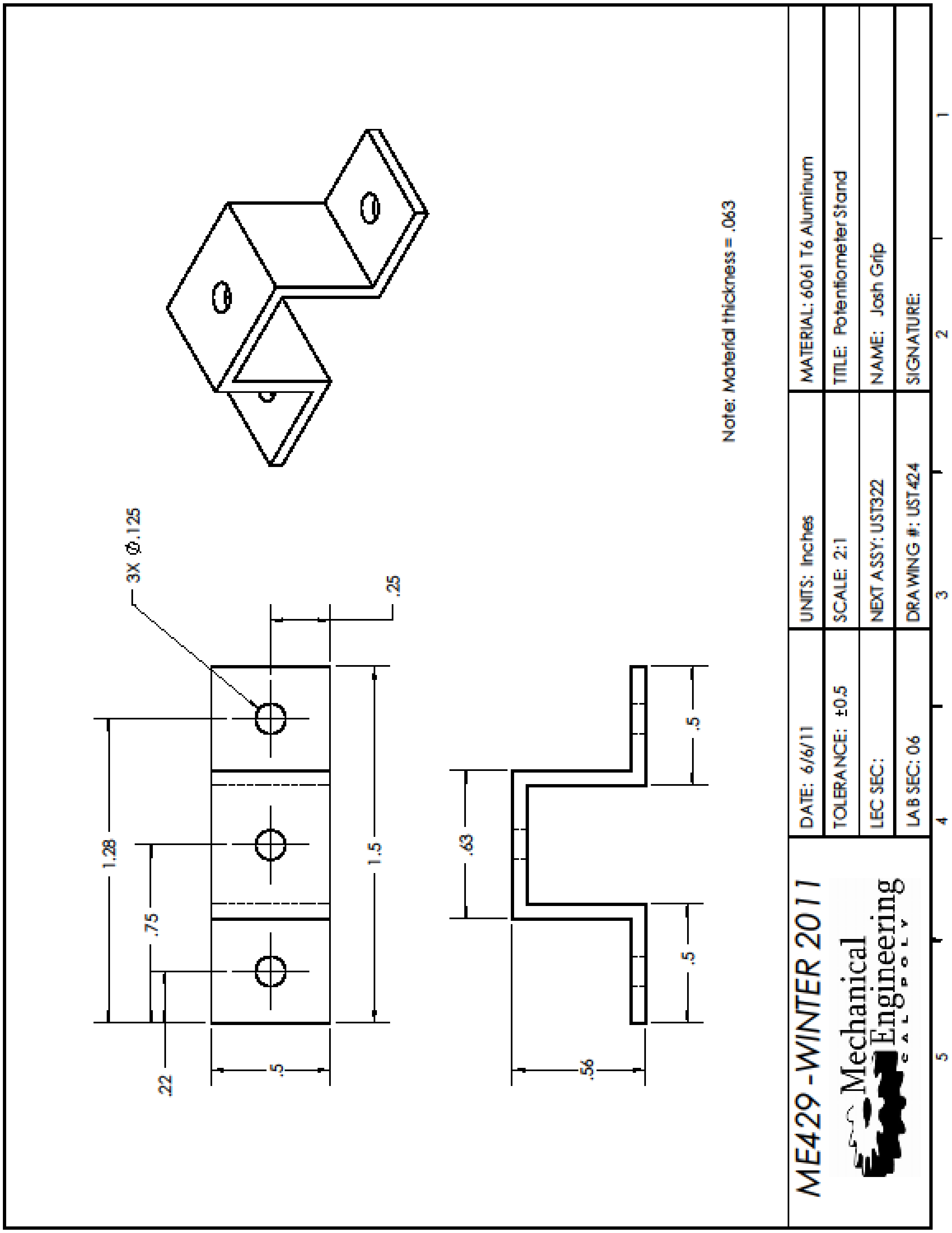
Mechanical Engineering CAL POLY

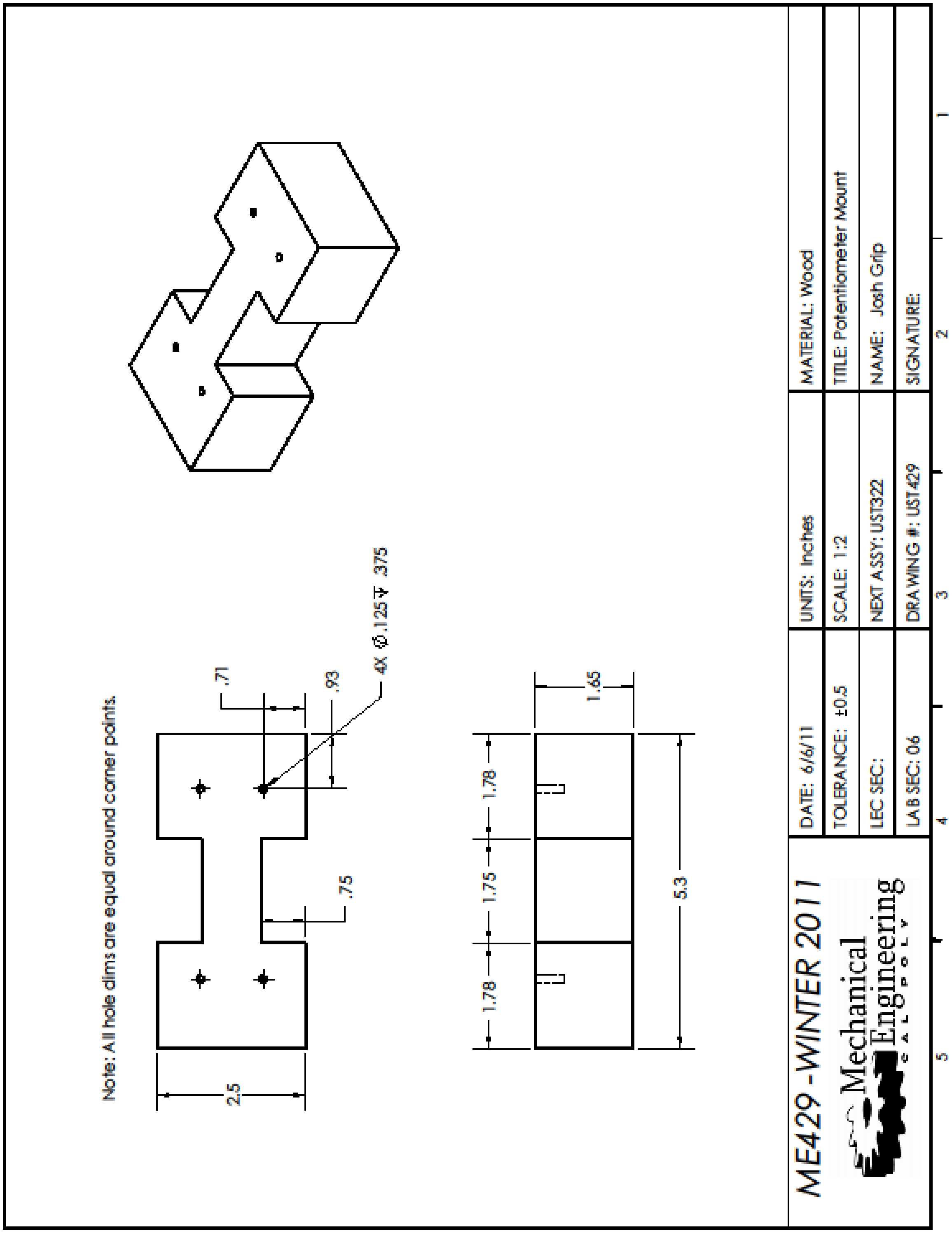
DATE: 6/6/11	UNITS: Inches	MATERIAL: Various
TOLERANCE: ±0.5	SCALE: 1:4	TITLE: Controller Box
LEC SEC:	NEXT ASSY: UST209	NAME: Josh Grip
LAB SEC: 06	DRAWING #: UST322	SIGNATURE:

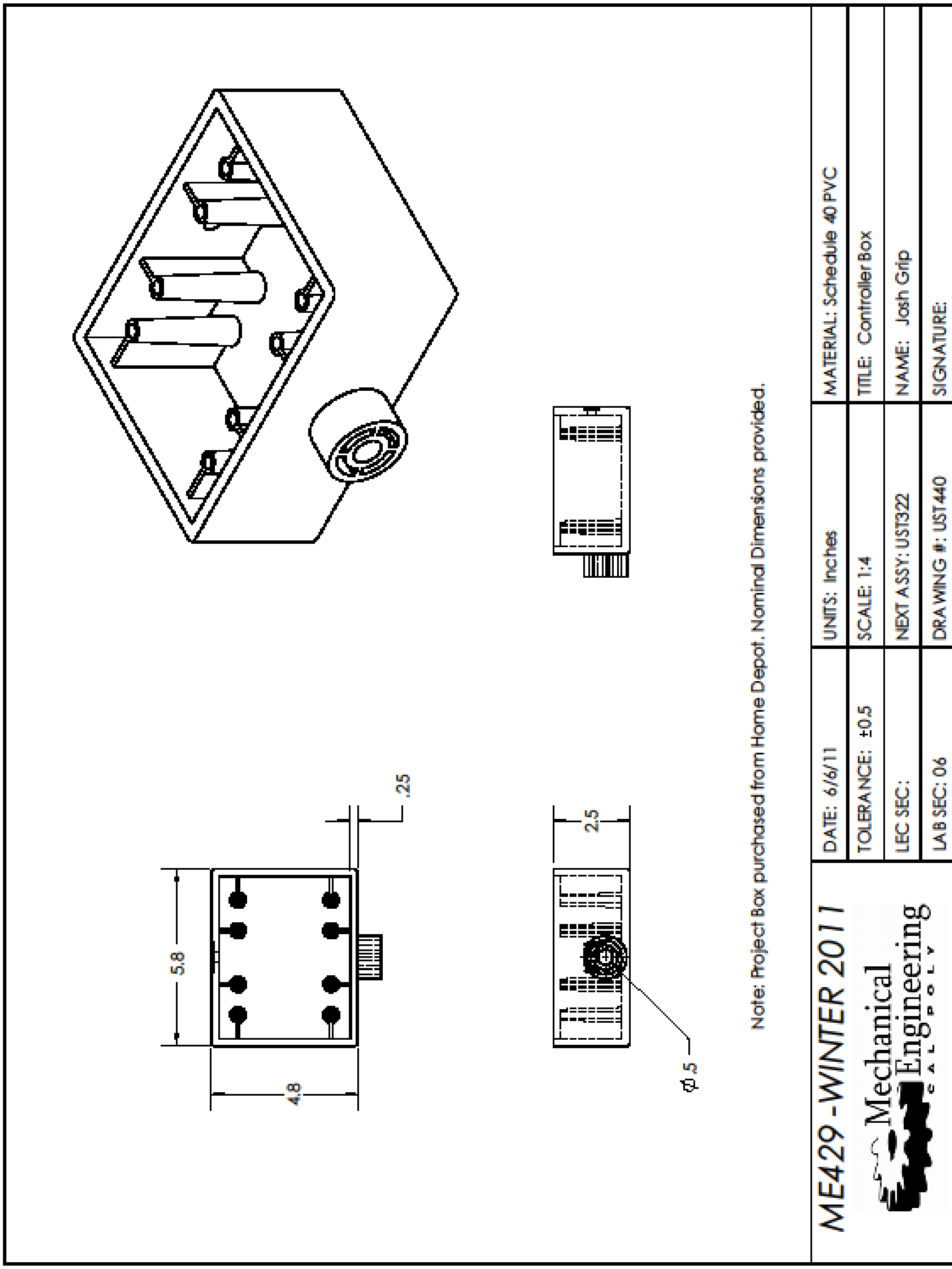
5 4 3 2 1

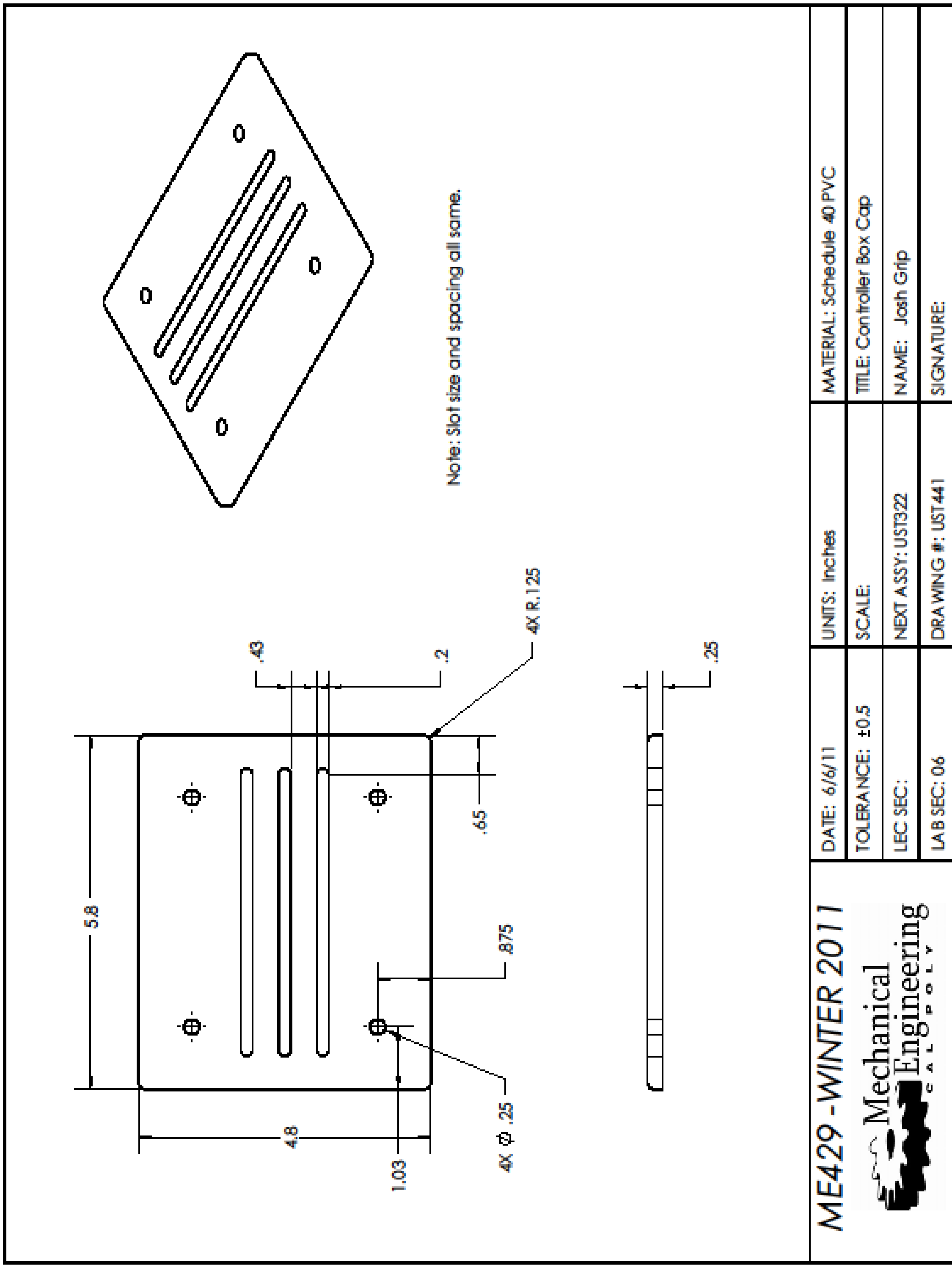


Note: Dims are non-critical.
4X ⌀.126
2.30
1.50
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1 : 4
NEXT ASSY: UST321
DRAWING #: UST422
MATERIAL: Wood
TITLE: User Nub
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


3X Ø.125
.25
1.28
.75
.22
.5
1.5
.63
.5
.5
.56
Note: Material thickness = .063
ME429 - WINTER 2011
Mechanical Engineering CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 2:1
NEXT ASSY: UST322
DRAWING #: UST424
MATERIAL: 6061 T6 Aluminum
TITLE: Potentiometer Stand
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


Note: All hole dims are equal around corner points.
2.5
.75
.71
.93
4X Ø.125 ↧ .375
1.78
1.75
1.78
1.65
5.3
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:2
NEXT ASSY: UST322
DRAWING #: UST429
MATERIAL: Wood
TITLE: Potentiometer Mount
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


5.8
4.8
.25
2.5
Ø.5
Note: Project Box purchased from Home Depot. Nominal Dimensions provided.
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE: 1:4
NEXT ASSY: UST322
DRAWING #: UST440
MATERIAL: Schedule 40 PVC
TITLE: Controller Box
NAME: Josh Grip
SIGNATURE:
1
2
3
4
5


Note: Slot size and spacing all same.
5.8
4.8
1.03
4X Ø .25
.875
.65
.43
.2
4X R.125
.25
ME429-WINTER 2011
Mechanical Engineering
CAL POLY
DATE: 6/6/11
TOLERANCE: ±0.5
LEC SEC:
LAB SEC: 06
UNITS: Inches
SCALE:
NEXT ASSY: UST322
DRAWING #: UST441
MATERIAL: Schedule 40 PVC
TITLE: Controller Box Cap
NAME: Josh Grip
SIGNATURE:

Appendix C: Cost and List of Vendors

Part	Description	Total Cost
RAMP	-	-
Rollers	Polyurethane 2 1/2"x12" roller	112.56
Roller	Delrin 2 1/2" x 3' rod	78.42
PVC bends	90 degree 80 gage pvc conduit	49.92
Steel rod	5/8"x 6' steel rod	29.56
Top of Ramp rest section	2" schedule 80 5' pipe	0.00
Brackets	1 aluminum bar 6'x2 1/2"x1/4" **	37.31
Bracket center tube	aluminum rod 2"x12"	38.34
Belt	Urethane Belt	0.00
Pulleys	2 1/2" OD 3" aluminum rod	14.42
Drill/Pulley connection	Aluminum rod 3/8"x 12"	0.00
Ramp to U mount plate	aluminum plate 6"x36"x1/4" (same stock as Motor mount)**	0.00
Bottom Mount Plate	aluminum plate 6"x36"x1/4" (same stock as Motor mount)**	0.00
Ball stop O-ring	Silcone O-ring with 2 3/4" od AND 2 1/4" ID 1/4" thick (5 pack)	4.92
Ball stop washer	PVC Scrap turned down to 2 1/4" OD 1/4" thick	0.00
Roller washer	Delrin rod 1' long	8.28
Casters	Low profile caster 3/4" height	4.76
bearings	1/2"x1 3/8"x7/16" Shielded Bearings	24.95
Loctite 480	Loctite 480 glue	45.70
U and LEGS	-	-
Casters	rubber wheel threaded stem caster 2 1/2" height	13.14
PVC caps	PVC Cap 2" sched 40	1.96
Locking Hinges	Locks open and closed 2 1/8"x2 1/4"x 3" Bronze plated	8.78
Leg-Hinge Inserts	Aluminum Rod Stock	-
PVC	2" schedule 80 2 5' pipe	17.04
U plate	aluminum plate 6"x36"x3/8"	45.90
Motor Mount	aluminum plate 6"x36"x1/4" (same stock as Motor mount)**	-
ATTACHMENT	-	-
Horizontal for attachment	80/20 10 SERIES 1501 1.5" X 1.5" MONO-SLOT T-SLOTTED EXTRUSION x 48"	26.26
Inner bar for telescope	Aluminum Plate 6'	37.66
Outer Bar for telescope	Aluminum Plate 6'	-
Gator Jaws	aluminum plate 36"x1 1/2"x1/4"	11.89
Gator Attach Bar	Square Aluminum Tubing 3/4"IDx1 1/4"ODx 12"	10.94
T-bracket connector	Aluminum Tube 1 1/2" x 3"x 12"	13.76
Pivot Locking Hinge	Pivoting hinge for bottom attachment Steel version	207.80
CONTROLER	-	-
PVC Elbow	1" pvc elbow	0.56
PVC Extension arm 1"	Schedule 40 PVC 1" 5' **	4.46

Joystick	Aluminum rod 3/8"x 12"	5.62
Potentiometer	Slide Potentiometer	18.91
Control box	Fuse Box	5.17
Drill and battery and motor controller	Makita drill and battery pack and band saw control	0.00
PVC T	Schedule 80 PVC reduction tee 2x1x2	7.26
Wires	18 gauge wire	6.30
SAFETY	-	-
Safety Sheild	12"x24"x1/8" Acrylic Plate	44.53
Safety Backing Brackets	1/2"x1/4"x6' Aluminum	7.76
Safety Backing	12"x24"x1/8" Acrylic Plate from sheild	0.00
Roller Backing	39.1"x24"x1/8" Acrylic Plate	0.00
Safety Bar	Aluminum Rod 1/2"x 36"	13.25
Safety Strap	Aluminum 3/16"x1/2"x36" strip	11.86
MISC	-	-
Bolts	Assoprted	30.00
Screws	3/8" long machine screws	30.00
Quick Pin	Spring-loaded quick-release clevis pins with head 3/8"x3 1/64" usable length (10 pack)	27.80
Torsion Strap	Aluminum Plate	18.63
Misc	shipping and other unforseen costs	50.00
	Total Cost	1227.75

Color Code	Source
(light green)	Mcmaster
(orange)	Home Depot
(blue)	Amazon
(lavender)	Ace Hardware Online
(yellow)	Precision Urethane
(light blue)	Drillspot
(gray)	VXB
(pink)	Hardware Source
(olive)	Opentip

Appendix D: Vendor Supplied Components

2/3/2011 McMaster-Carr - Item 8497K473

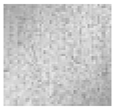
Plastics

Part Number: **8497K473** $26.15 per Ft.

Material	Acetal
Acetal Material	Acetal Copolymer
Backing	Plain Back
Finish	Smooth
Shape	Rods and Discs
Rods and Discs Type	Rod
Length	Cut-to-Length
Available Lengths	Sold in 1' increments
Maximum Continuous Length	4'
Diameter	2-1/2"
Diameter Tolerance	+.015"
Opaque	Black
Operating Temperature Range	-40° to +180° F
Softening Point	Not Rated
Performance Characteristic	Wash-Down Applications
Tensile Strength	Good
Impact Strength	Good
Tolerance	Standard
Hardness	Rockwell M78-M88
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM D6100

www.mcmaster.com/#8497k473/=avrxi0 1/1

Steel



Part Number: **8920K15** $12.56 Each

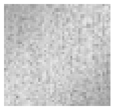
Material	General-Purpose Low-Carbon Steel
Alloy	1018
Low-Carbon Steel Type	1018 Carbon Steel
Finish/Coating	Unpolished (Mill)
Shape	Rods and Discs
Diameter	1/2"
Diameter Tolerance	-.003"
Length	6'
Length Tolerance	±6"
Straightness Tolerance	Not Rated
Tolerance	Standard
Hardness	Brinell 126-167
Maximum Attainable Hardness	Rockwell C60-C62
Yield Strength	54,000 to 70,000 psi
Melting Point	2700°F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM A108
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

Plastic Pipe Fittings and Pipe

Part Number: **48855K16** $17.04 Each

Shape	Pipe
Pipe Type	Unthreaded
Pipe to Pipe Connection	Unthreaded (pipe)
System of Measurement	Inch
Schedule	80
Pipe/Thread Size	2"
Length	10'
Inside Diameter	1.913"
Outside Diameter	2.375"
Perforation Type	Solid Pipe
Material	PVC
Color	Dark Gray
Maximum Pressure @ 73° F	400 psi
Temperature Range	Up to 140° F
Specifications Met	American Society for Testing and Materials (ASTM), National Sanitation Foundation (NSF)
ASTM Specification	ASTM D1784, ASTM D1785
NSF Specification	NSF 61
WARNING	Never use plastic pipe fittings with compressed air or gas.

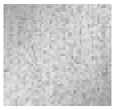
Aluminum



Part Number: **8975K686** — $31.37 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Sheets, Bars, Strips, and Cubes
Sheets, Bars, Strips, and Cubes Type	Plain
Finish/Coating	Unpolished (Mill)
Edge Type	Square
Tolerance	Standard
Thickness	1/4"
Thickness Tolerance	±.008"
Length	6'
Length Tolerance	±1"
Width	2-1/2"
Width Tolerance	±.024"
Test Report	Without Test Report
Temper	T6511
Hardness	60-95 Brinell
Yield Strength	35,000 psi
Flatness Tolerance	Not Rated
Temperature Range	-320° to +300° F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

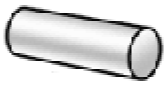
Aluminum



Part Number: **8974K711** $19.17 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Rods and Discs
Finish/Coating	Unpolished (Mill)
Tolerance	Standard
Diameter	2"
Diameter Tolerance	±.024"
Length	12"
Length Tolerance	±1"
Straightness Tolerance	Not Rated
Test Report	Without Test Report
Temper	T6511
Hardness	95 Brinell
Yield Strength	35,000 psi
Temperature Range	-320° to +300° F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

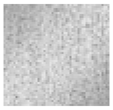
Aluminum



Part Number: **9062K211** $14.40 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Rods and Discs
Finish/Coating	Precision Ground
Tolerance	Tight
Diameter	1"
Diameter Tolerance	-.0005"
Length	12"
Length Tolerance	±1"
Straightness Tolerance	.001" per foot
Test Report	Without Test Report
Temper	T6511
Hardness	Not Rated
Yield Strength	35,000 psi
Temperature Range	-320° to +300° F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

Aluminum



Part Number: **8975K438** $36.65 Each

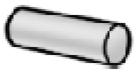
Material	Multipurpose Aluminum (Alloy 6061)
Shape	Sheets, Bars, Strips, and Cubes
Sheets, Bars, Strips, and Cubes Type	Plain
Finish/Coating	Unpolished (Mill)
Edge Type	Square
Tolerance	Standard
Thickness	1/4"
Thickness Tolerance	±.008"
Length	36"
Length Tolerance	±1"
Width	6"
Width Tolerance	±.044"
Test Report	Without Test Report
Temper	T6511
Hardness	60-95 Brinell
Yield Strength	35,000 psi
Flatness Tolerance	Not Rated
Temperature Range	-320° to +300° F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

O-Rings, Cord Stock, and Accessories

Part Number: **9396K914** $4.92 per Pack of 5

AS568A Dash Number	407
Type	O-Ring
O-Ring Type	Standard
Cross Section Shape	Round
Width	1/4"
Actual Width	.275"
Inside Diameter	2-1/4"
Actual Inside Diameter	2.225"
Outside Diameter	2-3/4"
Actual Outside Diameter	2.775"
Material	Silicone
Silicone Type	Standard, FDA Compliant
Durometer	Hard
Durometer Shore	Shore A: 70
Temperature Range	-65° to +450°F
Color	Red-Orange
Specifications Met	Food and Drug Administration (FDA)
FDA Specification	FDA Compliant

Plastics



Part Number: **8576K25** $9.19 per Ft.

Material	Acetal
Acetal Material	Delrin
Backing	Plain Back
Finish	Smooth
Shape	Rods and Discs
Rods and Discs Type	Rod
Length	Cut-to-Length
Available Lengths	Sold in 1' increments
Maximum Continuous Length	5'
Diameter	1-1/2"
Diameter Tolerance	+.005"
Opaque	Black
Operating Temperature Range	-20° to +180° F
Softening Point	Not Rated
Tensile Strength	Good
Impact Strength	Good
Tolerance	Standard
Hardness	Rockwell M 89-94
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM D6100

Material Safety Data Sheet

LOCTITE®　　Henkel

Revision Number: 002.1　　**Issue date:** 06/21/2010

1. PRODUCT AND COMPANY IDENTIFICATION

Product name: 480 Prism® Instant Adhesive, Black Toughened
Product type: Cyanoacrylate

Company address:
Henkel Corporation
One Henkel Way
Rocky Hill, Connecticut 06067

IDH number: 135466
Item number: 48040
Region: United States
Contact information:
Telephone: 860.571.5100
Emergency telephone: 860.571.5100
Internet: www.henkelna.com

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Physical state: Liquid
Color: Black
Odor: Sharp, Irritating

HMIS:

HEALTH:	2
FLAMMABILITY:	2
PHYSICAL HAZARD:	1
Personal Protection:	See MSDS Section 8

WARNING: BONDS SKIN IN SECONDS.
COMBUSTIBLE LIQUID AND VAPOR.
MAY CAUSE EYE, SKIN AND RESPIRATORY TRACT IRRITATION.

Relevant routes of exposure: Skin, Inhalation, Eyes

Potential Health Effects

Inhalation: Exposure to vapors above the established exposure limit results in respiratory irritation, which may lead to difficulty in breathing and tightness in the chest.

Skin contact: Bonds skin in seconds. May cause skin irritation. Cyanoacrylates have been reported to cause allergic reaction but due to rapid polymerization at the skin surface, an allergic response is rare. Cyanoacrylates generate heat on solidification. In rare circumstances a large drop will burn the skin. Cured adhesive does not present a health hazard even if bonded to the skin.

Eye contact: Irritating to eyes. Causes excessive tearing. Eyelids may bond.

Ingestion: Not expected to be harmful by ingestion. Rapidly polymerizes (solidifies) and bonds in mouth. It is almost impossible to swallow.

Existing conditions aggravated by exposure: Eye, skin, and respiratory disorders.

This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

See Section 11 for additional toxicological information.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous components	CAS NUMBER	%
Ethyl 2-cyanoacrylate	7085-85-0	60 - 100
Ethylene Copolymer Rubber	Proprietary	5 - 10
Carbon black	1333-86-4	1 - 5
Hydroquinone	123-31-9	0.1 - 1

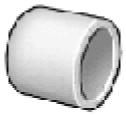
IDH number: 135466　　Product name: 480 Prism® Instant Adhesive, Black Toughened
Page 1 of 5

Casters

Part Number: **2834T63** $6.57 Each

Capacity	75 lbs.
Stem Style	Threaded
Mounting Type	Stem
Caster Type	Swivel with Brake
Wheel Material	Rubber
Floor Material	Asphalt, Brick, Ceramic Tile, Concrete, Dirt, Hardwood, Linoleum, Ribbed, Steel, Terrazzo
Wheel Diameter	2"
Wheel Width	15/16"
Mount Height	2-1/2"
Rubber Wheel Material	Solid Rubber
Frame Material Type	Steel
Frame Construction	Cold Formed
Frame Finish/Coating	Nickel Plated
Stem Diameter	5/16"-18
Stem Length	1"
Application	General Purpose, Furniture
Wheel Bearing Type	Plain Bore (No Bearings)
Swivel Bearings	Double Ball
Leg Thickness	1/16"
Brake Style	Side Wheel Brake
Wheel Durometer	80A
Wheel Color	Black
Number of Wheels	One
McMaster-Carr Name	Economy Threaded-Stem Casters
Specifications Met	Not Rated

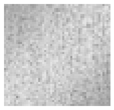
Plastic Pipe Fittings and Pipe



Part Number: **4880K56** $0.98 Each

Shape	Cap
Pipe to Pipe Connection	Socket-Weld x Socket-Weld
System of Measurement	Inch
Schedule	40
Pipe/Thread Size	2"
Material	PVC
Color	White
Temperature Range	Up to 140° F
Specifications Met	American Society for Testing and Materials (ASTM), National Sanitation Foundation (NSF)
ASTM Specification	ASTM D1784, ASTM D2466
NSF Specification	NSF 61
WARNING	Never use plastic pipe fittings with compressed air or gas.

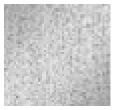
Aluminum



Part Number: **8975K214** $45.90 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Sheets, Bars, Strips, and Cubes
Sheets, Bars, Strips, and Cubes Type	Plain
Finish/Coating	Unpolished (Mill)
Edge Type	Square
Tolerance	Standard
Thickness	3/8"
Thickness Tolerance	±.008"
Length	36"
Length Tolerance	±1"
Width	6"
Width Tolerance	±.044"
Test Report	Without Test Report
Temper	T6511
Hardness	60-95 Brinell
Yield Strength	35,000 psi
Flatness Tolerance	Not Rated
Temperature Range	-320° to +300° F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

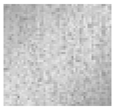
Aluminum



Part Number: **8975K563** $11.89 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Sheets, Bars, Strips, and Cubes
Sheets, Bars, Strips, and Cubes Type	Plain
Finish/Coating	Unpolished (Mill)
Edge Type	Square
Tolerance	Standard
Thickness	1/4"
Thickness Tolerance	±.008"
Length	36"
Length Tolerance	±1"
Width	1-1/2"
Width Tolerance	±.014"
Test Report	Without Test Report
Temper	T6511
Hardness	60-95 Brinell
Yield Strength	35,000 psi
Flatness Tolerance	Not Rated
Temperature Range	-320° to +300° F
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

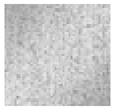
Aluminum

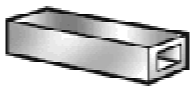


Part Number: **9056K291** $10.94 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Tubes
Tube Type	Round
Finish/Coating	Unpolished (Mill)
Round Tube Type	Single-Wall
Tolerance	Standard
Wall Thickness	1/4"
Wall Thickness Tolerance	±.025"
Length	12"
Length Tolerance	±1"
Inside Diameter	3/4"
Outside Diameter	1-1/4"
Outside Diameter Tolerance	±.015"
Straightness Tolerance	.010" per foot
Test Report	Without Test Report
Temper	T6
Hardness	95 Brinell
Yield Strength	40,000 psi
Temperature Range	-320° to +300° F
Application	Structural Tubes
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B429
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

Aluminum



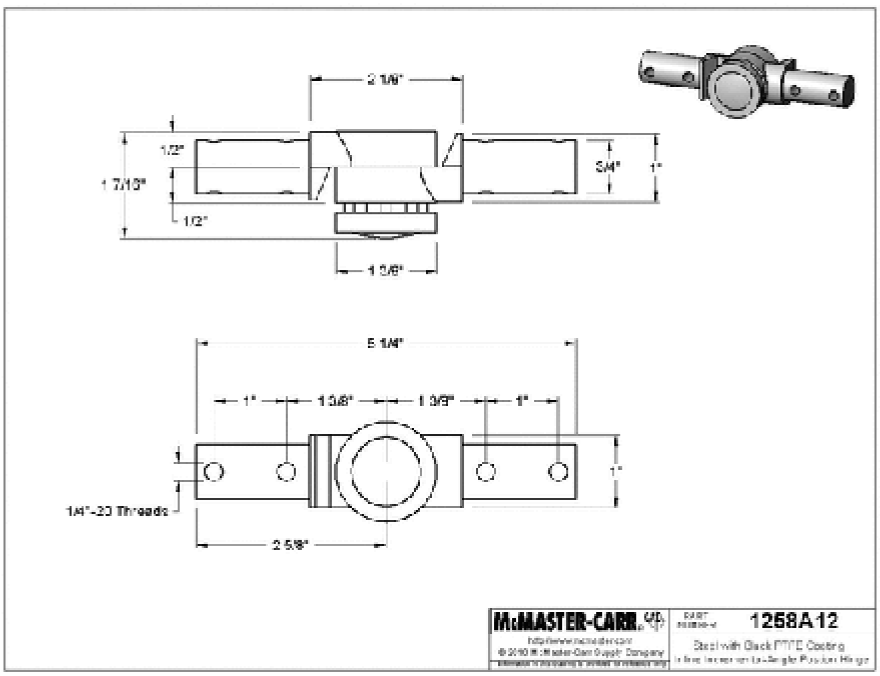


Part Number: **88935K621** $8.06 Each

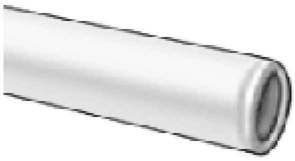
Material	Ultra-Corrosion-Resistant Architectural Aluminum (Alloy 6063)
Shape	Tubes
Tube Type	Square/Rectangular
Finish/Coating	Unpolished (Mill)
Tolerance	Standard
Wall Thickness	1/8"
Wall Thickness Tolerance	±.013"
Length	12"
Length Tolerance	±1/2"
Height x Width	1-1/2" x 2"
Straightness Tolerance	Not Rated
Test Report	Without Test Report
Temper	T52
Hardness	60 Brinell
Yield Strength	16,000 to 25,000 psi
Temperature Range	-320° to +212° F
Application	Structural Tubes
Specifications Met	American Society for Testing and Materials (ASTM)
ASTM Specification	ASTM B221
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

Hinges

Part Number: 1258A12	$103.90 Each
Mounting Style	Surface-Mount, Mortise-Mount
Type	Position, Lever, and Friction Hinge
Position, Lever, and Friction Hinge Type	Incremental-Angle Position
Incremental-Angle Position Style	Inline
Base Material	Steel
Steel Material	Plain Steel
Finish	Painted/Coated
Painted/Coated Finish	Black PTFE Plastic Coated
Mounting Holes	With Holes
Hole Type	Tapped
Maximum Capacity (lbs.)	Not Rated
Overall Height	5-1/4"
Number of Mounting Holes	4
Screw Size	1/4"-20
Torque, in.-lbs.	2,040
Color	Black
Range of Motion	220°
Handing	Reversible
Specifications Met	Not Rated
Note	Mounting screws not included.



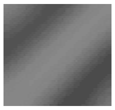
Plastic Pipe Fittings and Pipe

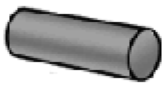


Part Number: **48925K93** $4.46 Each

Shape	Pipe
Pipe Type	Unthreaded
Pipe to Pipe Connection	Unthreaded (pipe)
System of Measurement	Inch
Schedule	40
Pipe/Thread Size	1"
Length	5'
Inside Diameter	1.033"
Outside Diameter	1.315"
Perforation Type	Solid Pipe
Material	PVC
Color	White
Maximum Pressure @ 73° F	450 psi
Temperature Range	Up to 140° F
Specifications Met	American Society for Testing and Materials (ASTM), Canadian Standards Association (CSA), National Sanitation Foundation (NSF)
ASTM Specification	ASTM D1784, ASTM D1785
CSA Specification	CSA B137.3-99
NSF Specification	NSF 61
WARNING	Never use plastic pipe fittings with compressed air or gas.

Aluminum

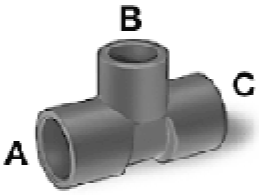




Part Number: **6750K151** $5.62 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Rods and Discs
Finish/Coating	Anodized
Anodized Type	Hard Anodized
Tolerance	Standard
Coating Thickness	.001" to .002"
Diameter	3/8"
Diameter Tolerance	±.008"
Length	12"
Length Tolerance	±1/16"
Straightness Tolerance	Not Rated
Test Report	Without Test Report
Temper	T6 or T6511 (Before Anodization)
Hardness	Rockwell C70
Yield Strength	40,000 psi
Color	Dark Brown Coating
Temperature Range	-320° to +300° F
Specifications Met	Military Specifications (MIL)
MIL Specification	MIL-A-8625 (Coating only)
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

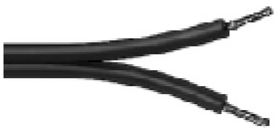
Plastic Pipe Fittings and Pipe



Part Number: **4881K148** $7.26 Each

Shape	Tee
Tee Type Pipe to Pipe	Reducing Tee
Pipe to Pipe Connection	Socket-Weld x Socket-Weld
System of Measurement	Inch
Schedule	80
Pipe Size, (A) x (B) x (C)	2" x 1" x 2"
Material	PVC
Color	Dark Gray
Temperature Range	Up to 140° F
Specifications Met	American Society for Testing and Materials (ASTM), National Sanitation Foundation (NSF)
ASTM Specification	ASTM D2467
NSF Specification	NSF 61
WARNING	Never use plastic pipe fittings with compressed air or gas.

Electrical Wire, Cable, and Cords



Part Number: **8104K111**

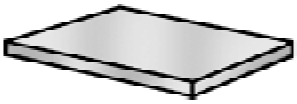
1-249 Ft. $0.21 per Ft.
250 or more $0.17 per Ft.

Type	Multiconductor Cable and Cord
Multiconductor Cable and Cord Type	Lamp Cable
Cable Type	SPT-1
Volts	300 VAC
Amps	10
Gauge (AWG)	18
Number of Conductors	2
Width x Thickness (Flat)	.21" x .11"
Length	Cut-to-length (per foot)
Available Lengths	50, 100, or 250 feet
Maximum Continuous Length	250'
Shielded	Unshielded
Conductor Type	Stranded
Conductor Material	Copper
Conductor Insulation Material	PVC
Jacket Color	Black
Temperature Range	-4° to +140° F (-20° to +60° C)
Specifications Met	Canadian Standards Association (CSA), Underwriters Laboratories (UL)
CSA Specification	CSA Certified
UL Specification	UL Listed

Hinges

Part Number: 1635A12	$1.57 Each
Mounting Style	Surface-Mount
Type	Door/Butt Hinge
Door/Butt Hinge Type	General Purpose
Base Material	Plastic
Plastic Material	Polypropylene
Finish	Unfinished
Pin Material	Nylon
Pin Finish	Unfinished
Mounting Holes	With Holes
Hole Type	Countersunk
Maximum Capacity (lbs.)	Not Rated
Open Width	2"
Leaf Height	2"
Leaf Thickness	.187"
Pin Diameter	1/4"
Number of Mounting Holes	4
Screw Size	#10
Color	White
Range of Motion	90°
Pin	Nonremovable Pin
Handing	Reversible
Specifications Met	Not Rated
Temperature Range	Not Rated
Note	Mounting screws not included.

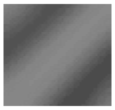
Plastics

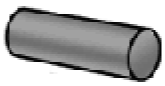


Part Number: **8560K262** $44.52 Each

Material	Acrylic
Acrylic Material	Cast Acrylic
Backing	Plain Back
Finish	Smooth
Shape	Sheets, Bars, Strips, and Cubes
Sheets, Bars, Strips, and Cubes Type	Rectangular Sheet
Sheet Style	Standard
Thickness	1/8"
Thickness Tolerance	+.015", -.025"
Length	48"
Length Tolerance	±1/4"
Width	24"
Width Tolerance	±1/4"
Clear	Clear with No Tint
Operating Temperature Range	-20° to +170° F
Softening Point	+196° to +239° F
Performance Characteristic	Weather Resistant
Tensile Strength	Good
Impact Strength	Poor
Tolerance	Standard
Hardness	Rockwell M90-M103
Specifications Met	Not Rated

Aluminum

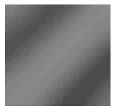


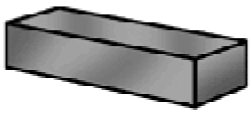


Part Number: **6750K163** $13.25 Each

Material	Multipurpose Aluminum (Alloy 6061)
Shape	Rods and Discs
Finish/Coating	Anodized
Anodized Type	Hard Anodized
Tolerance	Standard
Coating Thickness	.001" to .002"
Diameter	1/2"
Diameter Tolerance	±.009"
Length	36"
Length Tolerance	±1/16"
Straightness Tolerance	Not Rated
Test Report	Without Test Report
Temper	T6 or T6511 (Before Anodization)
Hardness	Rockwell C70
Yield Strength	40,000 psi
Color	Dark Brown Coating
Temperature Range	-320° to +300° F
Specifications Met	Military Specifications (MIL)
MIL Specification	MIL-A-8625 (Coating only)
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

Aluminum

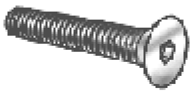




Part Number: **6023K113** — $11.86 Each

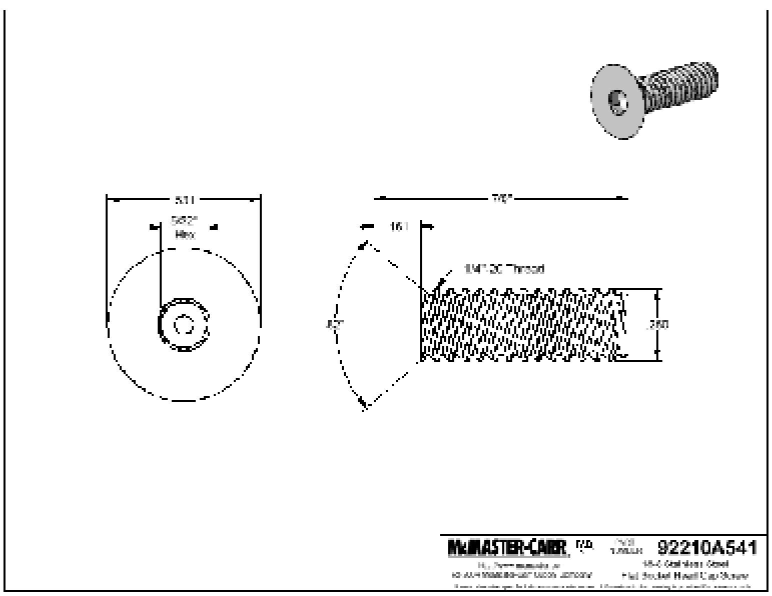
Material	Multipurpose Aluminum (Alloy 6061)
Shape	Sheets, Bars, Strips, and Cubes
Sheets, Bars, Strips, and Cubes Type	Plain
Finish/Coating	Anodized
Anodized Type	Hard Anodized
Edge Type	Square
Tolerance	Standard
Thickness	3/16"
Thickness Tolerance	±.007"
Coating Thickness	.001" to .002"
Length	36"
Length Tolerance	±1/16"
Width	1/2"
Width Tolerance	±.014"
Test Report	Without Test Report
Temper	T6511 (Before Anodization)
Hardness	Rockwell C70 (with coating)
Yield Strength	40,000 psi (Before Anodization)
Color	Dark Brown Coating
Flatness Tolerance	Not Rated
Temperature Range	-320° to +300° F
Specifications Met	Military Specifications (MIL)
MIL Specification	MIL-A-8625 (Coating only)
WARNING	Hardness and yield strength are not guaranteed and are intended only as a basis for comparison.

Socket Cap Screws



Part Number: **92210A541** $4.71 per Pack of 25

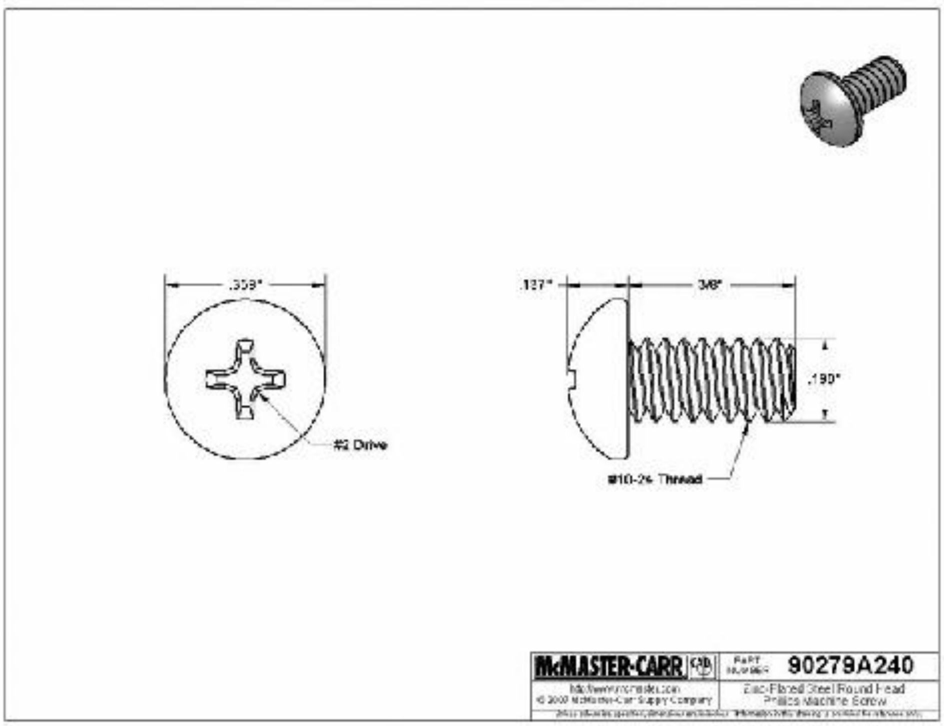
Head Style	Flat
Material Type	Stainless Steel
Finish	Plain
Class	Not Rated
Stainless Steel Type	18-8 Stainless Steel
Drive Style	Hex Socket
Inch Thread Size	1/4"-20
Length	7/8"
Thread Length	Fully Threaded
Thread Direction	Right Handed
Tip Type	Plain
Self-Locking Method	None
Screw Quantity	Individual Screw
Hex Size	5/32"
Head Diameter	.531"
Head Height	.161"
Undercut Head	No
Head Angle	82°
Rockwell Hardness	B70
Minimum Tensile Strength	70,000 psi
Thread Fit	Class 3A
Specifications Met	Not Rated
Note	To select the right size countersink, the body diameter of the countersink must be equal to or larger than the head diameter of the screw being countersunk. The angle of the countersink must also match the head angle of the screw.



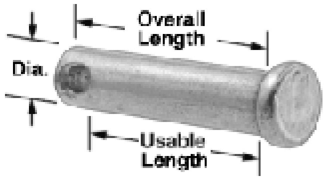
Machine Screws

Part Number: **90279A240** — $4.30 per Pack of 100

Head Style	Round
Round Head Style	Round
Material Type	Steel
Finish	Zinc-Plated
Steel Type	Plain Steel
Self Locking Element	None
Drive Style	Phillips
System of Measurement	Inch
Inch Thread Size	10-24
Thread Length	Fully Threaded
Length	3/8"
Decimal Size	.190"
Head Diameter	.359"
Head Height	.137"
Drive	#2
Rockwell Hardness	Minimum B60
Minimum Tensile Strength	Not Rated
Specifications Met	Not Rated
Screw Quantity	Individual Screw



Pins



Part Number: 97245A185	$6.95 per Pack of 10
Material Type	Steel
Finish	Zinc-Plated
Pin Type	Clevis Pins
Clevis Pin Type	Standard
System of Measurement	Inch
Diameter	3/8"
Actual Diameter (Min.-Max.)	.364"-.379"
Actual Head Diameter (Min.-Max.)	.485"-.515"
Actual Head Height (Min.-Max)	.110"-.130"
Recommended Cotter Pin Diameter	1/8"
Overall Length	3-1/4"
Usable Length	3-1/64"
For Use in Hole Diameter	3/8"
Rockwell Hardness	Minimum B80
Specifications Met	Not Rated

STOCKCAP

Log In to Your Account

Your Shopping Cart : Items: 0 Subtotal: $0.00

Search: GO!

Short Caps

S CAPS-1.750-0.500-0.065-701-89-BLACK-PKG 50 PCS PER BAG-STOCK

Product Number:	787748
Inside Diameter "A" (In.):	1.750
Inside Length "B" (In.):	0.500
Wall Thickness "C" (In.):	0.065
Inside Length Tolerance (In.):	0.438 - 0.562
Wall Tolerance (In.):	0.055 - 0.075
Packaging:	50 / BAG
Color:	BLACK

Price : $3.10

Quantity: 1 Add To Cart (View Cart)

GRAINGER

Conduit Clamp, Screw On, 2 In, Steel

Conduit Clamp, Screw On, Conduit Size 2 In., Material of Construction Steel, Max. Load 400 Lb., Thread Size 11/32 In Mounting Hole In., Zinc Plated Finish, Anchors Conduit To The Wall, Stud And Ceiling, May Be Used With Beam Clamps, Standards UL/CUL

Grainger Item #	4RH25
Price (ea.)	**$2.82**
Brand	COOPER B-LINE
Mfr. Model #	BL1450
Ship Qty.	1
Sell Qty. (Will-Call)	1
Ship Weight (lbs.)	0.24
Usually Ships	Today
Catalog Page No.	514

Price shown may not reflect your price. Log in or register.

Additional Info

Conduit and Cable Hangers and Clamps

Tech Specs

Item: Conduit Clamp
Type: Screw On
Conduit Size (In.): 2
Material of Construction: Steel
Max. Load (Lb.): 400
Thread Size (In.): 11/32" Mounting Hole
Finish: Zinc Plated
Function: Anchors Conduit To The Wall, Stud And Ceiling, May Be Used With Beam Clamps
Standards: UL/CUL
Package Quantity: 1

Notes & Restrictions

There are currently no notes or restrictions for this item.

MSDS

This item does not require a **Material Safety Data Sheet (MSDS).**

Required Accessories

There are currently no required accessories for this item.

Optional Accessories

There are currently no optional accessories for this item.

Alternate Products

Conduit Clamp, Screw On, 2 In

Item #: 2KWP7
Brand: CADDY
Usually Ships: Today
Price (ea): $3.19

Conduit Clip, 1/2-3/4In Conduit Size

Item #: 4RHV2
Brand: COOPER B-LINE
Usually Ships: Today
Price (ea): $0.91

Repair Parts

A Repair Part may be available for this item. Visit our Repair Parts Center or contact your local branch for more information.

accessories in the box

Project Enclosure (5x2.5x2")

Model: 270-1803 | **Catalog #:** 270-1803

$3.99

(6 Ratings) Write a Review Read 6 Reviews

AVAILABILITY: IN STOCK Usually ships in 1 - 2 business days

ADD TO CART

FIND IT IN STORE This item is available at most stores.

Add to Wish List
Email a Friend
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Need more help?
See technical specifications
See features of this product

You Might Also Want

Rosin Core Solder (8.0 Oz.)

$9.89

5-Piece Basic Soldering Set

$7.99

Kronus™ 25-Piece Mini Tool Set

$8.47

PRODUCT SUMMARY TECH SPECS

Tinker inside the box.

Perfect for electronic hobbies, science kits and more! Constructed of durable ABS plastic, this enclosure features four standoffs in the bottom corners to support a PC board. Standoffs are 1/4" high with holes that accepts a #4 screw. Slots are provided on all four sides of the enclosure to allow a PC board to be mounted horizontally or vertically along the length or width of the enclosure. Enclosure includes aluminum and plastic lids. Partial cutouts for DB-9 or HD-15 connectors.

- Durable ABS box

WHAT'S IN THE BOX

Project Box
Plastic lid
Aluminum lid

SHIPPING

Usually Ships In 1 - 2 Business Days

What shipping method is right for me?

Appendix E: Detailed Analysis

File:C:\Users\meuser\AppData\Local\Temp\Ball Speed.EES 2/4/2011 3:53:54 AM Page 1

EES Ver. 8.595: #552: For use by Mech. Engin. Students and Faculty at Cal Poly

$v_{ft,s,1}^{2} \cdot m_{ball} \cdot 0.5 + 0.5 \cdot I_g \cdot \omega_1^{2} = m_{ball} \cdot g \cdot h$ *Work energy finding $v_{ft,s}$*

$v_1 = v_{ft,s,1} \cdot 0.6818 \text{ [mph/(ft/s)]}$ *velocity from height of ramp in mph*

$Crr = 0.002$ *rolling resistance coefficent*

$N_f = 12$ *Normal force created by the ball lbf*

$angle = 45$ *ramp angle*

$F = Crr \cdot N_f$ *Friction force lbf*

$a = \dfrac{F}{m_{ball}}$ *accelration caused by the friction in ft/s^2*

$l = 62$ *length of the bowling alley in ft*

$t = \dfrac{l}{v_{ft,s,1}}$ *Approximation of the time the ball is rolling in sec*

$\omega_1 = \dfrac{v_{ft,s,1}}{r_{ball}}$ *rotational speed*

$\omega_2 = \dfrac{v_{ft,s,2}}{r_{ball}}$ *rotational speed*

$r_{ball} = \dfrac{8.59}{2} \cdot 1 \text{ [in]} \cdot \dfrac{1 \text{ [ft]}}{12 \text{ [in]}}$ *bowling ball radius*

$I_{sphere} = 2 \cdot m_{ball} \cdot \dfrac{r_{ball}^{2}}{5}$ *I of a shere*

$I_{ball} = 0.184 \text{ [(in-oz-s}^{2}\text{)/lbf]} \cdot weight \cdot \dfrac{1}{16} \cdot 1 \text{ [lbf/oz]} \cdot 32.2 \text{ [slug-ft/s}^{2}\text{-lbf]} \cdot \dfrac{1}{12} \cdot 1 \text{ [ft/in]}$ *I of ball from random guy*

$I_{shell} = 2 \cdot m_{ball} \cdot \dfrac{r_{ball}^{2}}{3}$ *I of a shell*

$weight = 16 \text{ [lbf]}$ *ball weight*

$m_{ball} = \dfrac{weight}{32.2 \text{ [lbf/slug]}}$ *ball mass*

$g = 32.2 \text{ [ft/s}^{2}\text{]}$ *gravity*

$I_g \cdot \omega_1 + m_{ball} \cdot v_{ft,s,1} \cdot r_{ball} \cdot \sin[angle] = I_g \cdot \omega_2 + m_{ball} \cdot v_{ft,s,2} \cdot r_{ball}$ *conservation of momentum*

$v_2 = v_{ft,s,2} \cdot 0.6818 \text{ [mph/(ft/s)]}$ *velocity at bottom of ramp*

$I_g = I_{shell}$ *I used*

$v_f = [v_{ft,s,2} - a \cdot t] \cdot 0.6818 \text{ [mph/(ft/s)]}$

SOLUTION
Unit Settings: SI C kPa kJ mass deg
(Shell, Run 10)

a = 0.0483 [ft/s^2]
Crr = 0.002
g = 32.2 [ft/s^2]
I_{ball} = 0.4937 [slug-ft^2]
I_{shell} = 0.04244 [slug-ft^2]
l = 62 [ft]
N_f = 12 [lbf]
ω_2 = 40.49 [rad/s]
t = 3.526 [s]
v_2 = 9.881 [mph]
$v_{ft,s,1}$ = 17.58 [ft/s]
weight = 16 [lbf]

angle = 45 [degrees]
F = 0.024 [lbf]
h = 8 [ft]
I_g = 0.04244 [slug-ft^2]
I_{sphere} = 0.02546 [slug-ft^2]
m_{ball} = 0.4969 [slug]
ω_1 = 49.12 [rad/s]
r_{ball} = 0.3579 [ft]
v_1 = 11.99 [mph]
v_f = 9.765 [mph]
$v_{ft,s,2}$ = 14.49 [ft/s]

No unit problems were detected.

Parametric Table: Shell

	h [ft]	v_1 [mph]	v_2 [mph]	v_f [mph]
Run 1	2	5.994	4.94	4.708
Run 2	*2.667*	6.921	5.705	5.504
Run 3	*3.333*	7.738	6.378	6.198
Run 4	*4*	8.477	6.987	6.823
Run 5	*4.667*	9.156	7.547	7.395
Run 6	*5.333*	9.788	8.068	7.926
Run 7	*6*	10.38	8.557	8.423
Run 8	*6.667*	10.94	9.02	8.893
Run 9	*7.333*	11.48	9.46	9.339
Run 10	*8*	11.99	9.881	9.765

1/13/11

Eq. 4-59

$$F = W + W\left[1 + \left(\frac{2hk}{W}\right)\right]^{1/2}$$

* if h=0 which means the ball is in constant contact with the rails

$$F = W + W[1+0]^{1/2}$$

$$F = 2W$$

W = 16 lbs

F = 32 lbs Round up to 100 lbs

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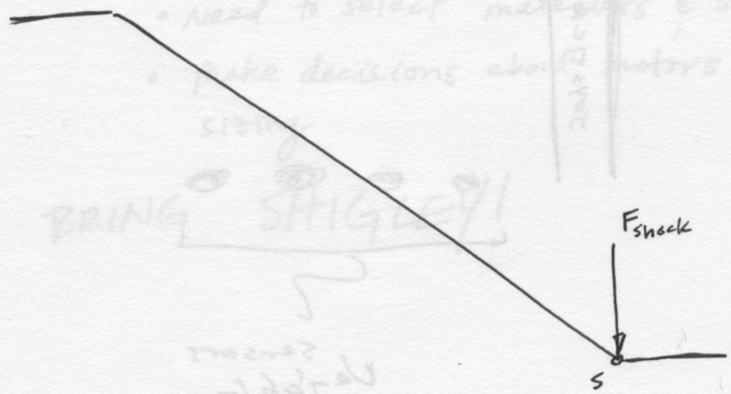
Calculations 1/13/11



Calculations: (using Shigley's)

1. Shock load @ S
2. Size of critical areas
3. Caster Specs
4. Bearing sizes
5. Radius of curvature
6. Stability

1. Shock load

Assumption: Ball constantly contacting rail. (h=0)

$$F = k\delta = W + W\left[1 + \left(\frac{2hk}{W}\right)\right]^{1/2}$$

$$\longrightarrow F = 2W$$

Using max ball weight of 16 lbf.

$$F_{max} = 2(16\ lb_f)$$

$$\boxed{(F_{shock})_{max} = 32\ lb_f}$$

Joshy

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2.a Static Failure

Selecting Failure criteria (Shigley's)

- Ductile Behavior (Polycarbonate Materials)
- $S_{yt} \neq S_{yc}$
- Therefore use Ductile Coulomb-Mohr (DCM)

$$\frac{\sigma_1}{S_t} - \frac{\sigma_3}{S_c} = \frac{1}{n} \quad \ldots(1) \qquad S_{sy} = \frac{(S_{yt})(S_{yc})}{S_{yt}+S_{yc}} \quad \ldots(2)$$

Given: n, S_{yc} for ABS, S_{yt} for ABS

$S_{yc} = 6750$ psi, $n = 3$

$S_{yt} = 6500$ psi

Find: $\tau_{max} \longrightarrow d$

(2)

$$S_{sy} = \frac{(6500\text{ psi})(6750\text{ psi})}{(6750) + (6500)}$$

$$S_{sy} = 3311.32 \text{ psi}$$

From Shigley pg 221

$$\tau = \frac{S_{sy}}{n}$$

$$\tau = \frac{3311.32 \text{ psi}}{3}$$

$$\boxed{\tau_{max} = 1103.77 \text{ psi}}$$

Josh Ig

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```
P=100 [lbf]                                   "Impact Force"
S_yc=8000 [psi]                               "Compressive
 Yield Strength"
S_yt=5900 [psi]                               "Tensile Yield
 Strength"
d_i=1.913 [in]                                "Outer diameter
 of shaft"
d_o=2.375 [in]                                "schedule 40 or
 80 size harvel.com/pipepvc-sch40-80-dim.asp"
d_o/2-d_i/2=t                                 "Thickness of tube"
S_sy=(S_yt*S_yc)/(S_yt+S_yc)                  "Shear Strength"
tau_max=S_sy/n                                "max shear stress"
{n=2                                          "factor of safety"}
tau_max=(sigma^2+tau^2)^.5                    "max shear from
 mohr"
sigma=(M*d_o/2)/I                             "Stress from
 moment"
I=pi/64*(d_o^4-d_i^4)
tau=2*V/A                                     "Straight Shear
 stress"
V=103                                         "Shear load"
A=pi*((d_o/2)^2-(d_i/2)^2)                    "Cross sectional
 area"
M=V*x                                         "Moment"
x=7 [in]                                      "Moment lever
arm"
```

SOLUTION

Unit Settings: SI C kPa kJ mass deg

A = 1.556 [in^2]	d_i = 1.913 [in]	d_o = 2.375 [in]
I = 0.9044 [in^4]	M = 721 [in-lbf]	n = 3.552 [-]
P = 100 [lbf]	σ = 946.7 [psi]	S_{sy} = 3396 [psi]
S_{yc} = 8000 [psi]	S_{yt} = 5900 [psi]	t = 0.231 [in]
τ = 132.4 [psi]	τ_{max} = 955.9 [psi]	V = 103 [lbf]
x = 7 [in]		

No unit problems were detected.

2.6 Fatigue Failure:

use Modified Goodman Equation

$$n_f = \frac{1}{\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}}}$$

But use modified Goodman for combined loading case. (Shigley pg 310)

$$\sigma'_a = \left\{ \left[(K_f)_{bending} (\sigma_a)_{bending} + (K_f)_{axial} \frac{(\sigma_a)_{axial}}{0.85} \right]^2 + 3\left[(K_{fs})_{torsion} (\tau_a)_{torsion} \right]^2 \right\}^{1/2}$$

$$\sigma'_m = \left\{ \left[(K_f)_{bending} (\sigma_m)_{bending} + (K_f)_{axial} (\sigma_m)_{axial} \right]^2 + 3\left[(K_{fs})_{torsion} (\tau_m)_{torsion} \right]^2 \right\}^{1/2}$$

Neglecting pure axial stresses from negligable friction on caster's. σ'_a & σ'_m equations become. ⟶

Josh Ising

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$$\sigma'_a = \left\{ \left[(K_f)_{bending} (\sigma_a)_{bending} \right]^2 + 3\left[(K_{fs})_{torsion} (\tau_a)_{torsion} \right]^2 \right\}^{1/2}$$

$$\sigma'_m = \left\{ \left[(K_f)_{bending} (\sigma_m)_{bending} \right]^2 + 3\left[(K_{fs})_{torsion} (\tau_m)_{torsion} \right]^2 \right\}^{1/2}$$

Modified Goodman becomes...

$$n_f = \frac{1}{\frac{\sigma'_a}{S_e} + \frac{\sigma'_m}{S_{ut}}}$$

$S_{ut} \simeq 2000$ psi

$n_f = 3$

Now Find: S_e ... and Marin Factors

$S_e = k_a k_b k_c k_d k_e * S_e'$

$K_a = 1$ ← not metal. K_a factors in book tabulated for metal

$K_b = 0.91 d^{-0.157}$ (for $2'' < d < 10''$)

$K_c = 1.0$ ← combined loading

$K_d = 1.0$ ← polycarbonate

$K_e = 0.814$ ← 99% reliable

→

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$Se' = 0.5 S_{ut}$ ⟵ $S_{ut} \le 200$ Kpsi

$Se' = 0.5(2000 \text{ psi})$

$Se' = 1{,}000 \text{ psi}$

$Se = (1)(0.91 d^{-0.157})(1)(1)(0.814)(1{,}000 \text{ psi})$

$Se = 740.74 d^{-0.157}$

- - - - - - - - - - - - - - - - - - -

Now find σ_a' & σ_m' . . .

<u>K_f & K_{fs}:</u> (notch sensitivity factors)

No Notches ⟶ $K_f = K_{fs} = 1$

$$\sigma_a' = \left\{ (\sigma_a)_{bend}^2 + 3\tau_a^2 \right\}^{1/2}$$

$$\sigma_m' = \left\{ (\sigma_m)_{bend}^2 + 3\tau_m^2 \right\}^2$$

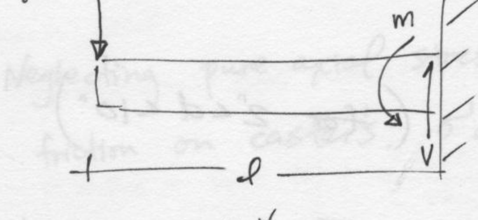
$\tau_{max} = \tau_a$

$\sigma_{max} = \sigma_a$

$\tau_m = \frac{\tau_a}{2}$

$\sigma_m = \frac{\sigma_a}{2}$

End section of ramp:



$M = 100 l$

$V = 100$

$$\tau = \frac{2V}{A}$$

Josh

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$P = 100$ [lbf] *Impact Force*

$d_i = 1.913$ [in] *Outer diameter of shaft*

$d_o = 2.375$ [in]

$\frac{d_o}{2} - \frac{d_i}{2} = t$ *Thickness of tube*

$\tau_{max} = \left[\sigma^2 + \tau^2\right]^{0.5}$ *max shear from mohr*

$\sigma = \frac{M \cdot \frac{d_o}{2}}{I}$ *Stress from moment*

$I = \frac{\pi}{64} \cdot \left[d_o^4 - d_i^4\right]$

$\tau = 2 \cdot \frac{V}{A}$ *Straight Shear stress*

$V = 103$ [lbf]

$A = \pi \cdot \left[\left(\frac{d_o}{2}\right)^2 - \left(\frac{d_i}{2}\right)^2\right]$ *Cross sectional area*

$M = V \cdot x$ *Moment*

$x = 7$ [in] *Moment lever arm*

$n_f = \frac{1}{\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_{ut}}}$

$S_{ut} = 6500$ [psi] *ultimate strength*

$S_e = 0.5 \cdot S_{ut} \cdot k_a \cdot k_b \cdot k_c \cdot k_d \cdot k_e \cdot k_f$

$\sigma_a = \frac{\sigma_{max}}{2}$

$\sigma_m = \frac{\sigma_{max}}{2}$

$\sigma_{max} = 2 \cdot \tau_{max}$

$\sigma_{ave} = \frac{\sigma_{max}}{2}$

$\tau_{ave} = \frac{\tau_{max}}{2}$

$k_a = 1$

$k_b = 0.91 \cdot d_o^{-0.157}$

$k_c = 1$

$k_d = 1$

$k_e = 0.814$

$k_f = 1$

$$N = \left[\frac{\sigma_{max}}{a_1}\right]^{\left[\frac{1}{b}\right]}$$

$$a_1 = \frac{[f \cdot S_{ut}]^2}{S_e}$$

$$b = -1 / 3 \cdot \frac{\ln\left[f \cdot \frac{S_{ut}}{S_e}\right]}{\ln[10]}$$

$f = 0.9$

$$games = \frac{N}{21}$$

SOLUTION

Unit Settings: SI C kPa kJ mass deg

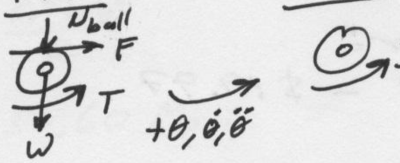
$A = 1.556$ [in^2]	$a_1 = 16283$	$b = -0.1482$
$d_i = 1.913$ [in]	$d_o = 2.375$ [in]	$f = 0.9$
games = 90215	$I = 0.9044$ [in^4]	$k_a = 1$
$k_b = 0.7944$	$k_c = 1$	$k_d = 1$
$k_e = 0.814$	$k_f = 1$	$M = 721$ [lbf-in]
$N = 1.895E+06$ [-]	$n_f = 1.661$ [-]	$P = 100$ [lbf]
$\sigma = 946.7$ [psi]	$\sigma_a = 955.9$ [psi]	$\sigma_{ave} = 955.9$ [psi]
$\sigma_m = 955.9$ [psi]	$\sigma_{max} = 1912$ [psi]	$S_e = 2102$ [psi]
$S_{ut} = 6500$ [psi]	$t = 0.231$ [in]	$\tau = 132.4$ [psi]
$\tau_{ave} = 478$ [psi]	$\tau_{max} = 955.9$ [psi]	$V = 103$ [lbf]
$x = 7$ [in]		

3 potential unit problems were detected.

Torque Requirements Total
(including ball and roller)

Roller:

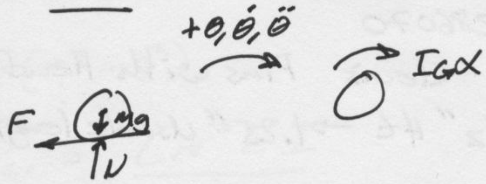
FBD: MAD: $\Sigma M = \bar{I}\alpha$



$$T - F r_R = I_G \alpha \longrightarrow (1)$$

Ball:

FBD: MAD: $\Sigma M = \bar{I}\alpha$



$$F r_B = I_G \alpha$$

$$F = \frac{I_G \alpha}{r_B} \longrightarrow (2)$$

Combining (1) & (2)

$$T = \left(\frac{I_G \alpha}{r_B}\right)_{ball} r_R + (I_G \alpha)_{roller} \longrightarrow (3)$$

$$I_{G ball} = \frac{2}{3} m r^2$$

$$I_{G roller} = \frac{m r^2}{32}$$

$$\alpha_{ball} = \omega / t = \frac{1 \text{ rad/s}}{.363 \text{ s}}$$

$$\alpha_{roller} = \omega / t = \frac{3.617 \text{ rad/s}}{.363 \text{ s}}$$

Substituting into (3)

$$T = \frac{2}{3} m_b r_b r_R \alpha_b + \frac{1}{32} m_R r_R^2 \alpha_R$$

$$T = \frac{2}{3}\left(\frac{16 \text{ lbm}}{32.174}\right)(4.295 \text{ in})(1 \text{ in})(2.755 \text{ rad/s}^2) + \left(\frac{7.32 \text{ lbm}}{32.174}\right)\left(\frac{1}{32}\right)(9.96 \text{ rad/s}^2)$$

$$\boxed{T = 3.99 \text{ lb-in}}$$

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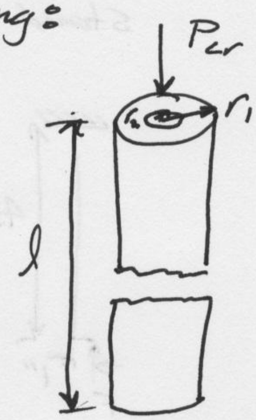
Stand Beam Buckling:



$$\frac{P_{cr}}{A} = \frac{C\pi^2 E}{(l/k)^2}$$

$$k = \sqrt{\frac{r_1^2 + r_2^2}{2}}$$

$E = .35 - .60$ Mpsi

End condition: $C = 1/4$

$l = 45''$

$A = \pi(r_1^2 - r_2^2)$

Pipes:

1" ø OD = 1.315 ID = .936

$r_1 = .658''$

$r_2 = .468''$

$$P_{cr} = \frac{C\pi^2 E I}{l^2}$$

$$I = Ak^2$$

$$I = \pi(r_1^2 - r_2^2)\left(\frac{r_1^2 + r_2^2}{2}\right)$$

$$I = \pi(.658^2 - .468^2)\left(\frac{.658^2 + .468^2}{2}\right) = .420 \text{ in}^4$$

$$P_{cr} = \frac{(1/4)\pi^2(.35\times10^6 \text{ psi})(.420 \text{ in}^4)}{(45 \text{ in})^2}$$

$$\boxed{P_{cr} = 179 \text{ lbf}}$$

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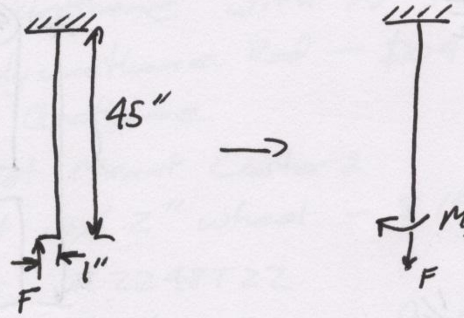
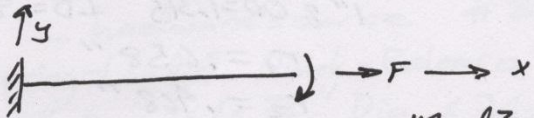
Stand Beam Bending



Equivalent to:



Max deflection: $y_{max} = \dfrac{M_B l^2}{2EI}$

$M_B = Fr = 100\ lbf \times 1" = 100\ lb\text{-}in$

$E = .35 - .60\ Mpsi$

$I = Ak^2$

$k = \sqrt{\dfrac{r_1^2 + r_2^2}{2}}$

1" sch 80:
$r_1 = .658"$
$r_2 = .468"$

2" sch 80:
$r_1 = 1.188"$
$r_2 = .957"$

1.5" sch 80:
$r_1 = .95"$
$r_2 = .738"$

$$y_{max} = \frac{(100\ lb\text{-}in)(45\ in)^2}{2(.35\times10^6 psi)(\pi(r_1^2 - r_2^2))\left(\frac{r_1^2 + r_2^2}{2}\right)}$$

$$y_{max} = \frac{(100\ lb\text{-}in)(45\ in)^2}{2(.35\times10^6 psi)(\pi(.658^2 in - .468^2 in))\left(\frac{(.658\ in)^2 + (.468\ in)^2}{2}\right)}$$

$\boxed{y_{max} = 1.32\ in}$ for 1" sch 80 PVC

$\boxed{y_{max} = .16\ in}$ for 2" sch 80 PVC

$\boxed{y_{max} = .356\ in}$ for 1.5" sch 80 PVC

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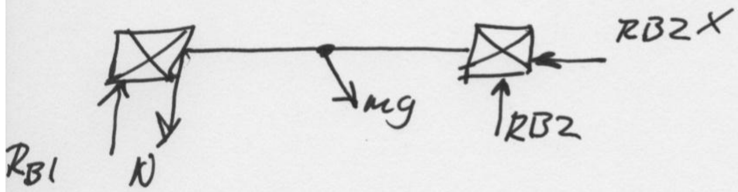
Bearing Selection:

Roller:



$\Sigma F_x = 0$

$mg \sin 60 = R_{B2X}$

$R_{B2X} = 6.5$ lbf

*Axial Load

$\Sigma F_y = 0$

$N + mg\cos 60 = R_{B1} + R_{B2}$

$\Sigma M_{RB2} = 0$

$18 \times mg\cos 60 + 36N = 36 R_{B1}$

$R_{B1} = \frac{1}{2} mg\cos 60 + N$

$R_{B1} = 15.73$ lbf

*Radial Load

$F_R = 15.73$ [lbf] $F_a = 6.5$ [lbf]

$V = 1$ ← inner ring spinning

$\frac{F_e}{VF_r} = 1$ when $\frac{F_a}{VF_r} \le e$

$e \geq \frac{6.5}{15.73}$ ∴ $e \geq .4132$

$F_e = F_r$

$F_a/C_o = .396$ T-11-1: (Shigley)

$C_o = \frac{F_a}{.396} = 16.41$ [lbf]

$X_1 = 1$ $Y_1 = 0$

$X_2 = .56$ $Y_2 = 1.06$

$F_e = X_i V F_r + Y_i F_a$

$F_{e1} = 15.73$

$F_{e2} = .56 \times 15.73 + 1.06 \times 6.5 = 15.70$

* Use the bigger $F_{e1} = 15.73$ [lbf]

$C_{10} = F_D \left(\frac{L_D n_D 60}{L_R n_R 60} \right)^{1/a}$ where $a = 3$ for ball bearings

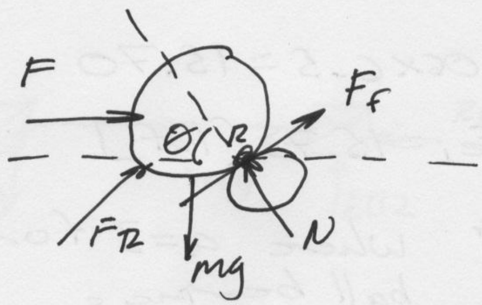
$L_R n_R 60$ = No. of rated cycles : 10^6

$L_D = 90{,}000 h$

$C_{10} = 15.73 \left(\frac{90{,}000 \times 1700 \times 60}{10^6} \right)^{1/3} = 329 \text{ lbf}$

$329 \text{ lbf} \times \frac{.004448 \text{ kN}}{\text{lbf}} = \boxed{1.465 \text{ kN}}$

Force to push ball out:

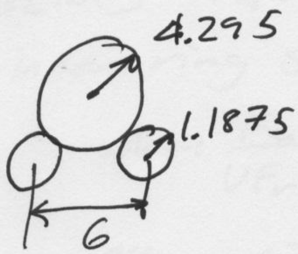


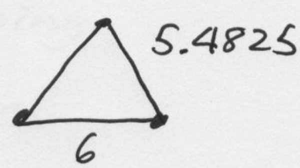
$\Sigma M_R = 0$

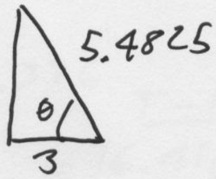
$\cancel{r} F \sin\theta = mg \cos\theta \cancel{r}$

$F = \dfrac{mg}{\tan\theta}$

$F = \dfrac{16}{\tan(56.83°)} = \boxed{10.5 \text{ lbf}}$







$\theta = \cos^{-1}\left(\dfrac{3}{5.4825}\right)$

$\theta = 56.83°$

Appendix F: Planning

Task Name	Duration	Start	Finish	Predecessors	Resource Names
Preliminary and Conceptual Ideation and Research for the good of man	**41 days?**	**Tue 10/12/10**	**Tue 12/7/10**		
Project Requirements	6 days	Tue 10/12/10	Tue 10/19/10		Josh Grip
Brainstorming	1 day?	Thu 10/21/10	Thu 10/21/10		Richard Rozporka
Minature Mockups	30 days?	Tue 10/19/10	Mon 11/29/10		Richard Rozporka
Pugh Matrix	2 days?	Tue 11/30/10	Wed 12/1/10	4	Josh Grip,Richard Rozporka,Travis Rodrigues
Conceptual Model Due	0 days	Tue 11/9/10	Tue 11/9/10		Travis Rodrigues,Josh Grip,Richard Rozporka
Conceptual Design Report	19 days?	Tue 11/9/10	Fri 12/3/10	6	Travis Rodrigues
Conceptual Design Report	0 days	Fri 12/3/10	Fri 12/3/10	7	
Conceptual Design Review with Sponsor	1 day?	Tue 12/7/10	Tue 12/7/10		Josh Grip,Richard Rozporka,Travis Rodrigues
Design and Analysis	**83 days?**	**Fri 11/12/10**	**Tue 3/8/11**		
Drawings/Layouts/Analysis	50 days?	Fri 11/12/10	Thu 1/20/11		Josh Grip
Student Presentations	6 days?	Tue 1/18/11	Tue 1/25/11	13	Josh Grip,Richard Rozporka,Travis Rodrigues
Student Presentations	0 days	Tue 1/18/11	Tue 1/18/11		Josh Grip,Richard Rozporka,Travis Rodrigues
Design Report	12 days?	Tue 1/18/11	Wed 2/2/11		Travis Rodrigues
Design Report Due	0 days	Wed 2/2/11	Wed 2/2/11	14	Travis Rodrigues
Project Update Memo	25 days?	Wed 2/2/11	Tue 3/8/11		Travis Rodrigues
Project Update Memo	0 days	Tue 3/8/11	Tue 3/8/11	16	Travis Rodrigues
Manufacturing	**57 days?**	**Mon 2/7/11**	**Tue 4/26/11**		
Order Parts	38 days	Mon 2/7/11	Wed 3/30/11		Richard Rozporka
Manufacturing and Test Review	1 day?	Wed 3/30/11	Wed 3/30/11	11	Richard Rozporka
Manufacturing and Test Review	0 days	Wed 3/30/11	Wed 3/30/11	20	Richard Rozporka

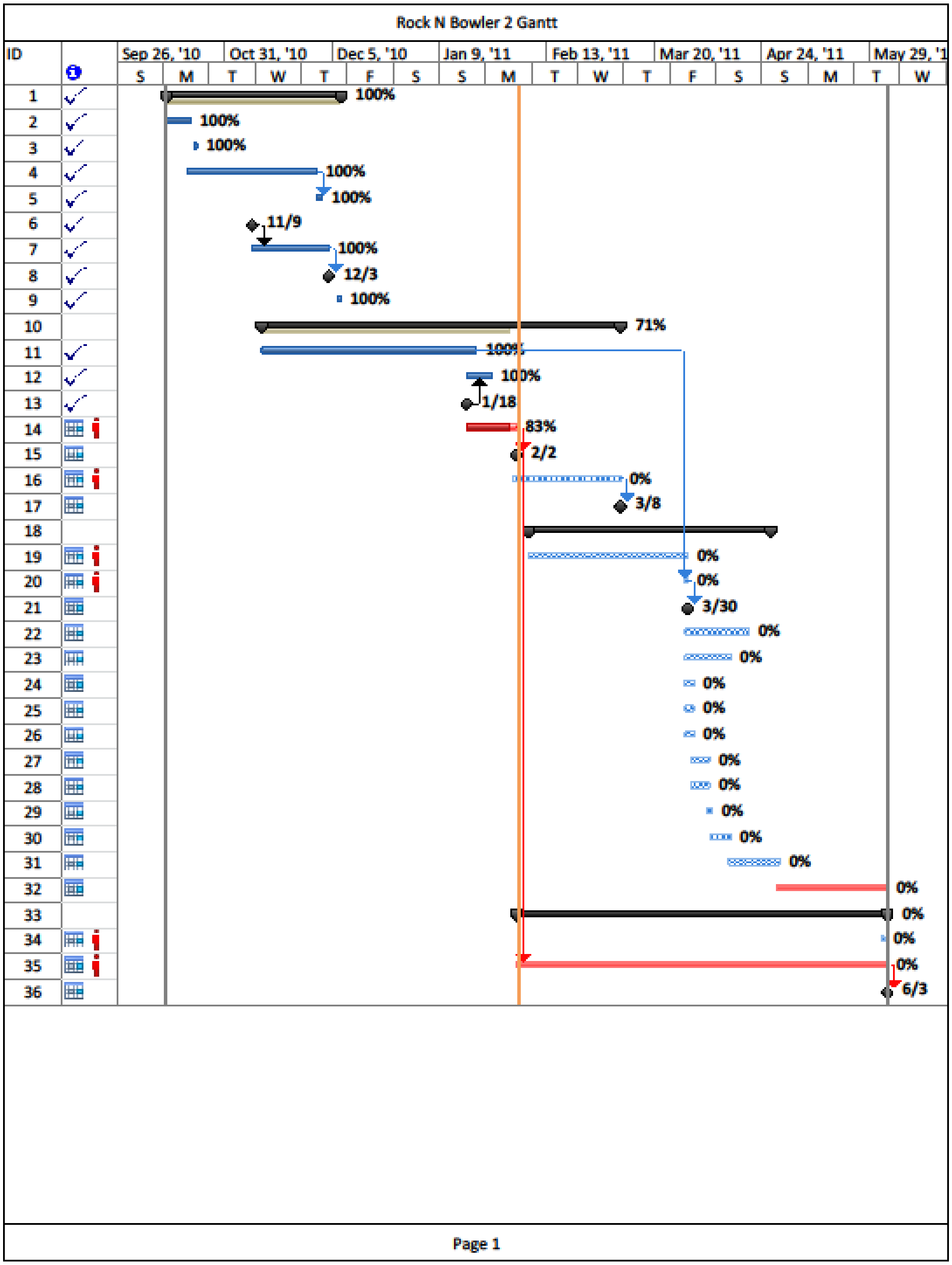


Figure 48: Gantt Chart

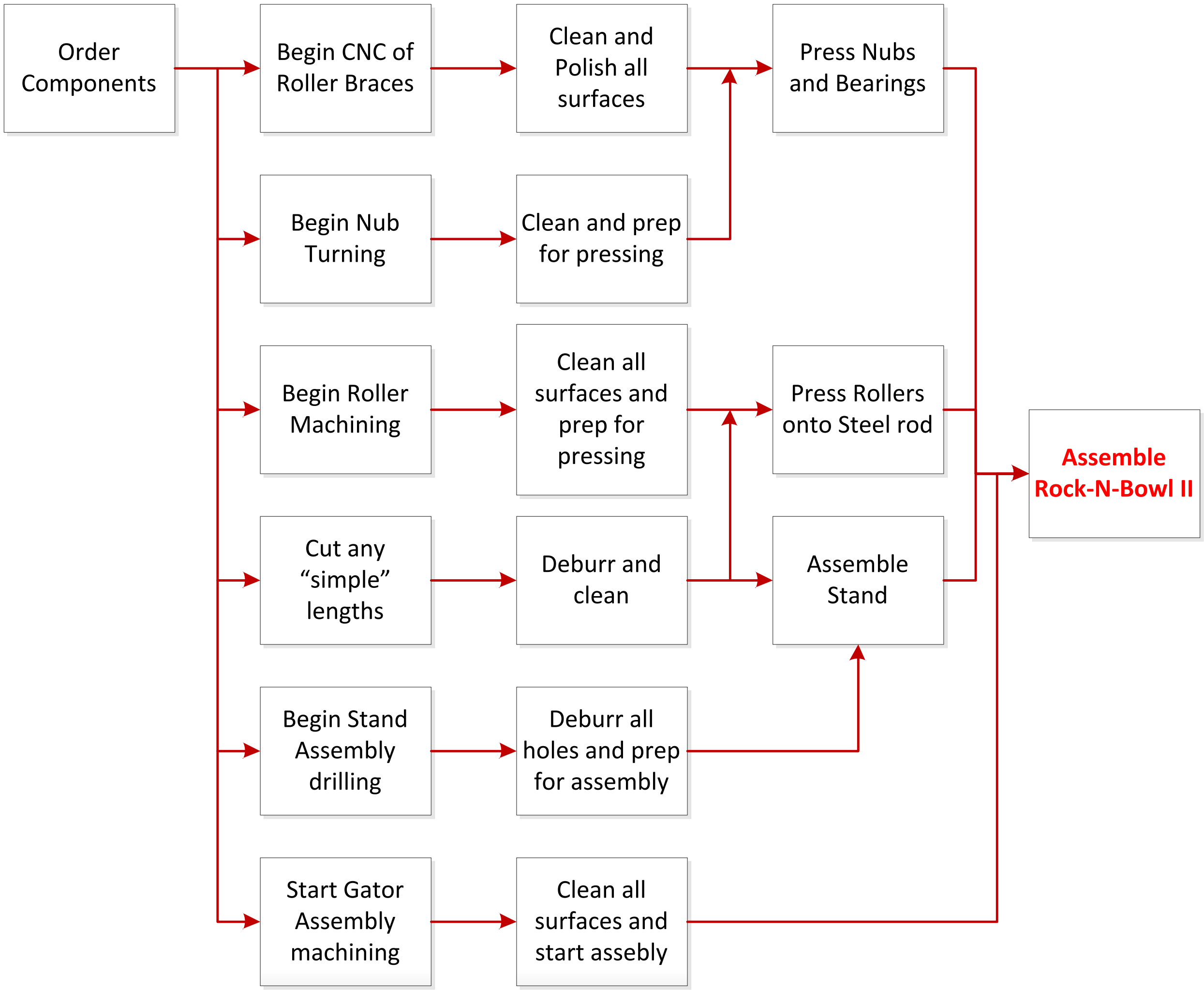


Figure 49: Manufacturing plan

Table 6: Rock N Bowl II DVP&R

Rock N Bowl II DVP&R

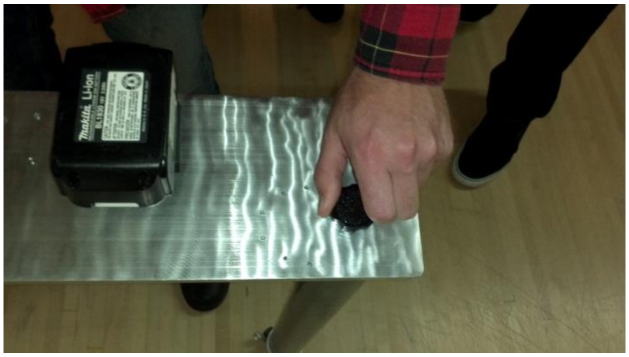
TEST PLAN										TEST REPORT			
						SAMPLES		TIMING		TEST RESULTS			
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	NOTES
1	Ball Speed	Bowling alley speedometer	6 mph min	JG	CV	20	B	6/4/2011	6/4/2011	6 mph	all	none	ball consistent at 6 mph
2	User Input Range	No motion larger than 6"	Mike Test	RR	CV	1	B	6/2/2011	6/2/2011	passed	yes	none	user can easily control the spin
3	Spin Speed	Watch ball on the alley	1.4 rad/s	All	DV	20	B	6/4/2011	6/4/2011	passed	all	none	The ball can travel from one edge of the lane to the gutter on the other
4	Expected Life Span	Factor of safety	2	JG	PV	1	B	6/4/2011	6/4/2011	passed	yes	none	
5	Setup Time	Time the setup	5 mins max	TR	PV	2	B	6/4/2011	6/4/2011	passed	all	none	
6	Accuracy	Score high at the lanes	10" @ 60'	TR	PV	20	B	6/4/2011	6/4/2011	passed	18	2	repeatable scored a 124
7	Weight	Scale	70 lbs max	JG	PV	3	B	6/4/2011	6/4/2011	67 lbs	all	none	
8	Battery Life	Go Bowling!	1 hours min	RR	DV	3	B	6/4/2011	6/4/2011	13 min continuous	all	none	Passed because spinner is not on for more than a quarter of the time
10	Ball Friction	Transmit Spin	ball spins with roller	TR	DV	1	B	5/27/2011	5/27/2011	passed	yes		ball picts up spin from the roller
11	Attachment	attach to wheel chair	attach	RR	CV	1	B	5/13/2011	5/13/2011	passed	yes		gators firmly grab the chair

Appendix G: User Manual

Setup Process:

1.) Set ramp on table ledge
2.) Unscrew thumb screws from the top of the legs
3.) Unlatch hinges to allow legs to deploy

4.) Screw thumb screws into top of U-Stand, and tighten



5.) Unscrew center thumb screw in U-Stand

6.) Hold U-Stand in one hand and ramp in the other

7.) Put top ramp plate on U-Stand and line up holes

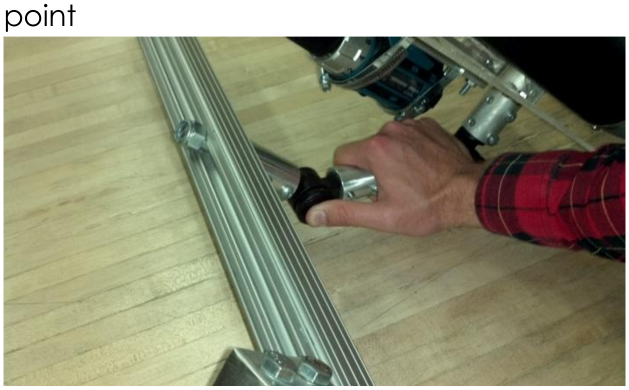
8.) Tighten center thumb screw

9.) Connect power cord from ramp to U-Stand

10.) Insert Battery into Battery Holster

11.) Position Control Box to correct angle and height

12.) Attach Gator Bars to power chair by adjusting pivot locking hinges and Gator Arms to correct position and tighten thumb screws onto power chair attachment point



-OR (For stationary use)-

Lock leg casters to keep ramp stationary

Bowling Process:

-If Attached to Power chair:

1.) Roll backwards to proper approach distance
2.) Roll forwa casters to forward position (Note: The helper can do th gling)

3.) Place bal d O-rings

4.) Take note of hole position (this will affect curvature of throw)
5.) Roll forward when ready (with or without spin)
6.) Stop quickly before end of ramp reaches foul line on lane
7.) Watch ball roll!

-Not Attached:

1.) Approach Ramp
2.) Place ball on top behind O-rings
3.) Reach through back shield and push ball forward