# Olympic Bocce Ballers

## Sponsor

Michael A. Lara

Regional Sports Manager
Special Olympics Southern California

**Final Design Report**

Prepared By:

Steven Erickson
sjericks@calpoly.edu

William Haley
whaley@calpoly.edu

Taylor Vaughan
tvaughan@calpoly.edu

6/6/2011

## Statement of Disclaimer

Since this project is a result of a class assignment, it has been graded and accepted as fulfillment of the course requirements. Acceptance does not imply technical accuracy or reliability. Any use of information in this report is done at the risk of the user. These risks may include catastrophic failure of the device or infringement of patent or copyright laws. California Polytechnic State University at San Luis Obispo and its staff cannot be held liable for any use or misuse of the project.

# *Table of Contents*

# *List of Figures*

# *List of Tables*

# *Executive Summary*

This report contains the design and manufacturing processes we followed to complete an adapted bocce ball device that can be used by people confined to joystick controlled power chairs. First, an introduction to our project is laid out, including a bit of background information on our sponsor and end user, a formal problem definition, an in-depth list of the customer requirements, and a list of engineering specifications that our design needed to meet.

Next, you will find background information on the game of bocce ball itself and some initial research that we compiled to obtain a better understanding of our project. Following that, we went through a design development phase. In this section, you will see how our team utilized many methods of idea generation to develop different ideas that could potentially solve the problem at hand. Through an idea selection process, we narrowed down our ideas and developed a conceptual model.

It can be seen in the report that after much iteration, we came up with our final design. The main idea behind our design is a compressed air gun. We believe that this will provide a fun experience to the user while taking appropriate measures to ensure the safety of the user and all those who are present. Not only will our device be very exciting use, it will also provide the end user with a decent amount of exercise. A breakdown of our final design can be found in chapter four. Our project is constructed out of PVC piping, consisting of two air tanks, a barrel to shoot the bocce ball, and a barrel to shoot the pallino. All of this is anchored down to a rotating table to change the horizontal angle the ball will shoot at and is also capable of changing the vertical angle. This is all fixed to the top shelf of a cart with an air compressor and battery enclosed on the lower shelf. We have engineering analysis to support all of our decisions in building this device. You will also see a breakdown of the cost and material selection.

Next will be the manufacturing process that we went through to complete our project. This is followed by extensive testing and results that prove that our design meets all specifications set forth.

Overall, this was a successful experience and we are proud of the end result. When we presented our project at the senior design exposition, it seemed to be a big hit. At the end of the report you will find a few recommendations that we have proposed to improve our design.

# Chapter 1: Introduction

## Sponsor Background

There are ten stakeholders invested in this project. Besides the three design engineers, we have a team of two kinesiology students, Courtney Mahaffey and Helena Wong, helping us with research, coordination, and etiquette training for this type of project. Our group and the kinesiology students each have individual project advisors, Dr. Widmann and Professor Taylor, respectively. We also have our main project sponsor, Michael Lara who is the regional sports manager for Special Olympics in SLO. Michael has told us to cater the project to someone with the same abilities as Ray Castro. Ray is a local special Olympian who is in a wheel chair and has limited use of his arms. The last, but very important stakeholder is Cal Poly. The outcome of our project has an effect on Cal Poly's reputation.

## Formal Problem Definition

We are striving to design and build an adaptive bocce ball device that can be used by persons with disabilities, specifically for people in joystick controlled wheel chairs. The most important aspect of this project is to make a device that allows for the athletes in power chairs to play independently. It would be ideal to create a device that can allow them to compete on a level playing field and also provide genuine fun. Delivering the satisfaction of being able to participate in physical activities and compete with others can be very healthy, especially for an individual who gets little to no exercise on a daily basis. Requiring physical motion to use this device will prove to be healthy and deliver emotional stimulation to the user, allowing them to connect on a social level with others.

## Objectives

Our goal for this project is to design and build an adaptive bocce ball device that promotes inclusion in the least restrictive way possible, to keep the game as real as possible for the user. After speaking with our sponsor, Michael Lara, we recieved a list of customer requirements that he felt the device should encompass. It was important that the device not be too big or too heavy so that it can fit in the back of a van / or pick-up truck and be transported from the vehicle to the site by two able bodied adults. Also, we should make it not too big so that it would be easily storable, no wider than a wheelchair, and would not obstruct the shooter's vision.

More often than not, bocce ball is played outdoors, so our device should be able to travel over various playing surfaces and should not require any plugs to run off of. So it needs to be self-powered, yet it should still be able to travel the distance of the court, and ideally, it should be able to last a couple of years.

Although we wanted to provide mental and physical exercise, we understood that persons with paraplegia have limited strength they can exert. We kept that in mind as we were designing this device and as well as what little range of hand motion they may or may not have.

For ease of maintenance and repair, this device had to be made with as many standard parts as possible. Though there were some items that had to be specially manufactured, the more “off the shelf” parts used, the better. With standard parts, the device is easily fixable if something were to go wrong.

With the use of many standard parts, we were able to reach reasonable cost for this project. We are aware that if our device is revolutionary, there will likely be people or groups who are willing to invest in it. It is for that reason, that we did not constrain ourselves with price, yet we knew that money was a big issue, especially since the Special Olympics is a non-profit organization.

A very important part of this project was to make sure that the device is free of major safety hazards in order to ensure the safety of the users and all those who are present. While making sure that our device was safe, we had to also make it fun. In order to keep the game as similar as possible to the real thing, we allowed the user to choose if they wanted backspin or not. Also, we designed the reload time in between shots to be as quick as possible to keep the game moving so the user does not get bored.

One of our tasks was to take the requirements set forth by our customer and to develop a set of engineering specifications from those. In order to do this, we used a quality function deployment method called the house of quality (found in Appendix A) to make customer requirements into engineering specifications, and gauge the importance of achieving the specification. We used the guidelines given to us by Michael Lara to decide on some important customer requirements. The customer requirements are on the left, with the engineering specifications on top. The “must have” customer requirements are marked with an asterisk, while the rest are weighted using our judgment. Then, existing competitive designs are judged for how well they meet these customer requirements on the right. Finally, the engineering specifications are placed on top to compare with the requirements to see how well the requirements are addressed. The importance of meeting each requirement is gauged at the bottom of the chart once each specification is checked against each requirement for correlation. Doing this allows us to estimate the importance of each requirement and be sure we will satisfy the customer.

Using the quality function deployment method helped us to determine engineering specifications from our customer requirements. These specifications can be found in Table 1 below and are summarized here. In the table, it shows the specification number, the parameter

description, the requirement or target with units, a tolerance to specify whether or not the target is a maximum or a minimum. The table also shows the risk associated with meeting that specification whether it be high (H), medium (M), or low (L), and the compliance which tells how we will determine if the specification is met using either analysis (A), testing (T), similarity to existing designs (S), or inspection (I).

We designed our product to weigh less than 100 pounds and not be bigger than 4’ tall, 1.5’ wide, and 3’ long. This was important so that the device fits inside the back of a van / pickup truck and be transported to the site by 2 able bodies.

Since our device will be used outside, we need to accommodate for the various surfaces ranging from compacted dirt, turf, or grass. In operation, the device uses no line voltages except for recharging the battery when the device is not in use. It must have the power to launch the bocce ball the full distance of the court, which is 60’. Based on the assumption that our device will be used at the Friday Club, for about an hour at a time, over the course of about 2 years, we estimated that it should withstand approximately 20,000 cycles.

Keeping in mind who we were designing for, we made sure to design controls that allow the user to adjust where the device shoots and also when to release the balls, with no more than 3 pounds force. We also made our user interface controllable within a theoretical 6” sphere, while still being able to shoot both the bocce ball and the pallino ball.

We also kept our design as simple as possible to help it last longer. We aimed to keep the number of our custom parts to a maximum of 10 in order to make repairs easier. These “easy fixes” help prolong the life of our device. This also helps us to keep the cost down. Although our maximum available fund is $1500, we do not envision using all of that to produce a prototype.

While maintaining a low cost for the overall project, we also wanted to ensure the safety of our users. Our device was designed to have no sharp edges or corners, no exposed moving parts, and contain a feature that will prevent accidental launching. It should also comply with ASTM F963-08, Standard consumer Safety Specification on Toy Safety. In addition to making this device as safe as we could, we also tried to include a few “fun factors”. It was important to make our device as true to the game as possible, to provide the user with the feeling that they are not restricted in any way. One ways we tried to do this was to allow back spin on the ball if wanted. We also tried to minimize the time it takes the reload the ball and shoot. Ideally, if the user is able to get a shot off and be ready to fire the next shot within 20 seconds, it would greatly enhance the speed of the game.

**Table 1:** **List of engineering specifications developed from the provided customer requirements.**

| Specification # | Parameter Description | Requirement or Target (units) | Tolerance | Risk | Compliance |
|---|---|---|---|---|---|
| 1 | Weight of Device | 100 lb | Max | L | A, I |
| 2 | Height of Device | 4 ft | Max | L | A, I |
| 3 | Width of Device | 1.5 ft | Max | L | A, I |
| 4 | Length of Device | 3 ft | Max | L | A, I |
| 5 | Power | No plug-in (for use) | | L | S, I |
| 6 | Distance Ball Will Travel | 60 ft | Max | M | A, T |
| 7 | Lifetime | 20,000 cycles | Min | M | A |
| 8 | Transportation | Movable by 2 able bodied humans | Max | L | A,T |
| 9 | User Input | 3 lb force | Max | M | A, T |
| 10 | User Control | 6” sphere | Max | H | I |
| 11 | Cost | $1500 | Max | L | A |
| 12 | Safety | ASTM F963-08 | Yes / No | M | T |
| 13 | Production (standard, off the shelf, parts) | No more than 10 custom parts | Min | M | I |
| 14 | Spin on Ball | Backspin only | Yes/no | H | T, I |
| 15 | Reload Time | 20 seconds | ±5 sec | M | T |
| 16 | Safety Factor | 2 | Min | M | A |

| | | | | | |
|---|---|---|---|---|---|
| 17 | Playing Surface | Works on compacted dirt, turf, grass | Min | L | T, S |

## Project Management

For this project, it was very important to assign individual duties to team members in order to assure that the project was moving along in the correct direction and according to schedule (see below for additional information pertaining to scheduling). It is difficult for each member to keep track of each individual aspect of this project by himself; therefore, we assigned responsibilities to each member, in which they were the primary one responsible for assuring that that particular part of the project is being done properly and in a timely manner. This does not necessarily mean that the person was responsible for completing that part of the project on their own. It is more just to ensure that their portion of the project for which they are responsible was completed by the group as a whole, so the group stayed on task and the project was completed on time.  Below were each group member's respective areas of the project for which they were responsible for:

**Steve Erickson**

- *Information gathering*
    - This position is responsible for gathering background research, finding important dimensions, and finding safety regulations. Also, keeping all of this information in one spot that we can access when necessary.
- *Prototype fabrications*
    - This position is responsible for overseeing the manufacturing of the adaptive bocce ball thrower prototype and is the chief fabricator.
- *Analyst*
    - This position is in charge of doing the analysis behind our product. He must make sure that the device is able to meet our specifications of lasting 20,000 cycles and 2 years.

**Taylor Vaughan**

- *Manufacturing considerations*

- This position is responsible for exploring all the different options available when it comes time to manufacture. Also, is in charge of performing research on available material.

- *Sponsor communicator*
    - This position is responsible for contacting the sponsor with any comments, questions, or concerns that we come across while working on this project. This is an important role to verify that we are consistently meeting the wants / needs set forth by the customer.
- *CAD modeling*
    - This position is in charge of all computer animated design related work. The final design must be fully documented in Solid works and hopefully contains a motion study of how the device actually works

**Will Haley**

- *Documentation of project progress*
    - This position is in charge of documenting the progress of the project, including but not limited to managing weekly status reports, delegating weekly assignments to group members, and making sure we remain on schedule.
- *Testing plans*
    - This position is responsible for making sure that the prototype meets each of our specifications that require testing. If something does not satisfy the test, he will be sure to find a correction that can be made to ensure that it will pass.
- *Evaluator / Critical Thinker*
    - This job requires the person to be brutally honest when needed. If something is not up to par or needs more work, this person has to let everyone know. This person needs to be constantly evaluating our design and making sure it is meeting the specifications at all times.

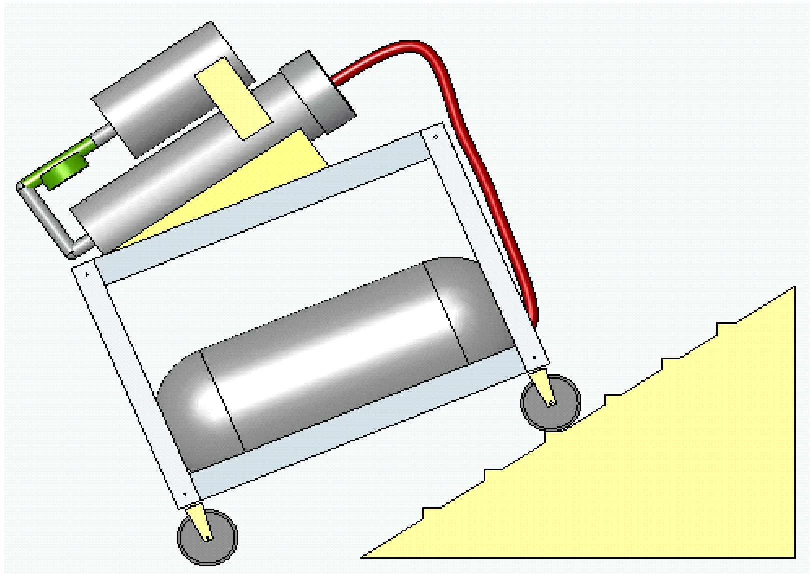
We created an in depth schedule called a Gantt chart to follow throughout the entire project which can be found in Appendix F.

# Chapter 2: Background

The game of Bocce Ball is played on a 12' by 60' court with two different sized balls. One is the pallino, a 2.4" diameter ball. The game begins by throwing the pallino to a spot on the court. After the pallino is thrown, the player who threw the pallino will throw his first Bocce ball. Each Bocce ball weighs about 2.2 lbs and is about 4.25" in diameter. The first player then tries to land his ball as close as possible to the pallino. Then, the next player will try to get his Bocce ball closer to the pallino. The player who has a ball closest to the pallino watches until someone else can get closer. If he is still closer and his opponent has thrown all his balls, he can then finish throwing his own. This process continues until all the Bocce balls have been thrown. The player who has a ball closest at the end will be awarded points. One point gets awarded for every ball closer than an opponent's ball to the pallino. The game can be played with 2, 4 or 8 players.

Our task is to make this game playable by a person who is in a power wheelchair. It is generally difficult to describe the abilities of these athletes because there is such a wide range of mobility among them. However, our sponsor Michael Lara told us that a good estimate of the maximum amount of force the athletes could apply was about 3 pounds. The users are mostly better at pushing things with their hands than pulling, but they are also able to squeeze things. Our group also met with one of the potential users, Ray Castro, to get a good idea of his range of movement. He was able to move his arms around well, but Michael Lara warned us that he was one of the most mobile of the power chair athletes. The wheelchair athletes play various games at what is called Friday Club every week. The device will be used here as well as some competitions. Some of the other games they play are Tee ball, Frisbee, and Golf.

Other Cal Poly students have taken on projects similar to this. One previous senior project (see Figure 1 below) used an air compressor to launch the ball, and a grooved inclined frame to vary the launch angle. This project worked, but it broke down fairly quickly, and it could only shoot the bocce ball 30 feet at the most. If we were to adopt a design like this, we would need to make sure to make it is more powerful and have a more comprehensive fatigue analysis. Also, there was no way to vary the power, so the only way the distance could be varied was to angle the entire system using the grooved inclined frame.



**<u>Figure 1</u>: Previous Cal Poly March 2004 senior design project for adaptive bocce ball by Anthony DeFont, Brett Fooks, and Eric Pangilinan. This device used an air compressor to shoot a maximum of 30 feet, with only one shot power level. In order to vary the shot distance, the system had to be manually raised using the inclined grooved frame.**

One intermediate design project (see Figure 2 below) used a catapult weight-lever system to launch the ball. This system would raise the free weight to a certain height, and then drop it to throw the ball. Depending on the height the weight was dropped from would determine how far the ball would be thrown. This design gave us the idea of using a catapult type launching system. These systems do not require any electricity however they require some type of spring or rubber band which our sponsor does not prefer.

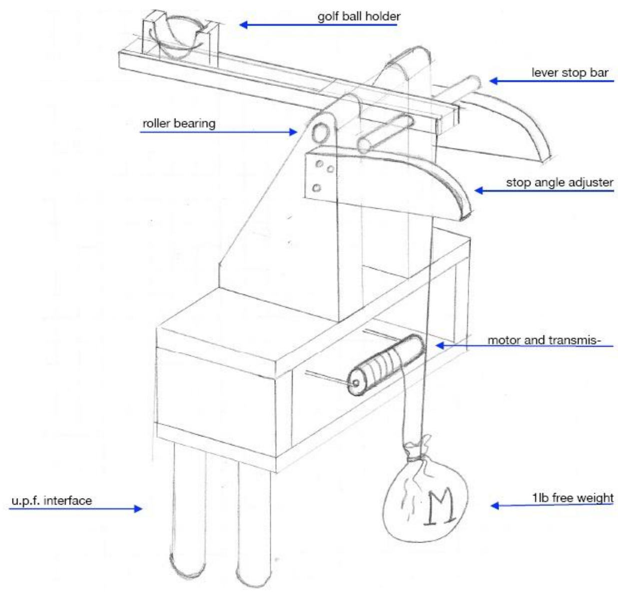
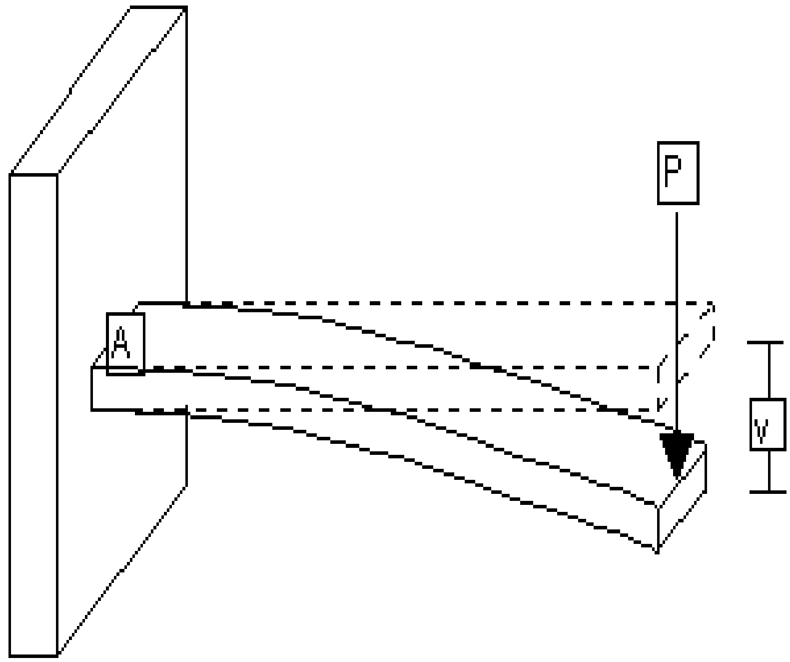



**Figure 2: Cal Poly Fall 2009 adaptive bocce ball intermediate design project by Eric Bates, Patrick Bernard, and Atlund Smith. In this project, the free weight M would be lifted by a motor and released by the user, which would cause the lever to jerk forward and throw the ball. The throw distance could be varied by releasing the free weight from different heights.**

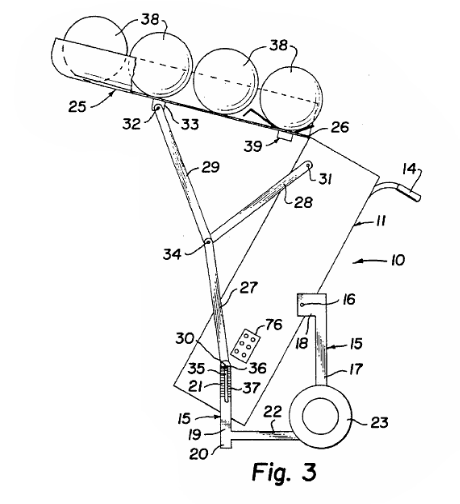
Another intermediate design project (see Figure 3 below) used a similar principle, but a cantilever beam was used as a spring to make the device like a catapult. For this project, the amount the cantilever beam was deflected would determine the throwing distance of the golf ball.




**<u>Figure 3</u>: Cal Poly Fall 2009 adaptive bocce ball intermediate design project concept by David Abuza, Brandon Coursey, and Adam Overton. The basic concept behind this project was causing deflections in a beam to store energy, and transferring that energy to the ball to throw it. The cantilever beam would be pulled back by a motor, and released by the user.**

Though the information from these intermediate design projects is very valuable, our main concern is that the projects may be too small scale. However, the projects expanded our range of ideas that could be used on our project.

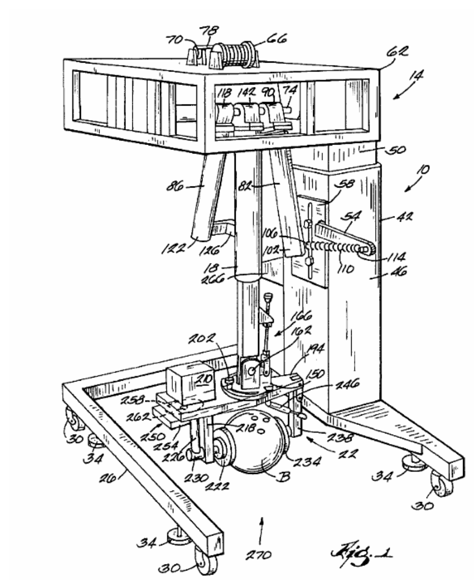
A patent search also yielded some helpful ideas for what we could do with this project. Patent No. 5,575,482 (see Figure 4 below) was similar to the air cannon idea mentioned earlier. We thought having something similar to this but with an adjustable launch angle could be a good idea to implement.




**<u>Figure 4</u>: Side view of patent 5,575,482. Device is used to throw Volleyballs.**

This patent introduced our group to the idea of a cannon type bocce ball thrower, and possibly an automatic reloading mechanism as is seen with the 4 balls lined up ready to be loaded into the device.

A patent that differs a lot from a cannon type was a swing arm type thrower, similar to patent No. 6,379,257 (see Figure 5 below). It would face downwards instead of upward to throw the ball. This solution would offer many more opportunities to give the athletes more exercise, whereas the ones that use an air compressor might not engage the user enough. One drawback to this design is that it may be difficult to load, and it may not be powerful enough to throw the required distance.



**<u>Figure 5</u>: Three dimensional view of patent 6,379,257. Ball thrower.**

From this patent, our group thought we could find a way to clamp onto a bocce ball while the clamp was attached to a swing arm. The user would be able to control the swing, and the time when the clamp was released. Doing this, the ball could be either rolled or thrown, and the user would have control over the throwing power.

# Chapter 3: Design Development

Our project has followed a standard design process. The first step of the design process was accomplished by communicating with everyone involved and making sure we understood exactly what our customers wanted. Not only were we actively communicating, but we made sure to have face to face meetings with everyone. We did this so that everyone on the team felt comfortable around each other and understood their roles, as well as the ultimate goal. From this, we created a list of requirements and specifications to send to our customers and received feedback and confirmation on them all.

## Conceptual Designs

In order to decide on our top concept, we had to come up with ideas that would solve the problem. To think of ideas, we started by brainstorming concepts, to do this, we needed to break down the objective into attributes and various functions that the design had to accomplish. Our two most important functions for the device were that it had to move an object, and that it needed to transfer energy while increasing the output force on the ball when compared to the input force from the user. The most important attribute of the design was that it needed to be safe. For each function and attribute we had a short brainstorming session where we wrote down as many ideas as possible that could potentially satisfy that requirement. Even the most farfetched ideas were considered so that we did not inhibit our creativity. We then combined an idea from each function/attribute category to come up with a potential solution to our design problem. We contributed more to this myriad of ideas by holding more brainstorming sessions and writing down any potential solutions in our logbooks.

Once we got all of these ideas, we made conceptual models of several of them to learn more. We ended up building four conceptual models. Our first conceptual model was a small catapult made using popsicle sticks and a torsion spring. What we learned about this model was that it was accurate once the user got the hang of how it worked, but it was important to angle the catapult backwards otherwise the little balls of paper it was shooting would go straight down.

The second model we made was a spring loaded cannon type. This model was able to shoot golf balls. What we learned from this model was that springs buckling could be an issue in the design and that the barrel of the cannon needed to be tight around the ball for improved accuracy.

The third conceptual model was a slingshot that we tested to see if it could throw a bocce ball far and it succeeded, but it raised some safety concerns. If the device were to fail, we were afraid that the ball may get thrown towards the user or a bystander and hurt them.

The final conceptual model we built was a second catapult, but with a tilted back launch pad. This device used a compression spring instead of a torsion spring to store energy and worked well. It caused for the paper balls to be lobbed higher in the air, which illustrated how important it was to vary the launch angle of the bocce ball. Rolling or lobbing the ball could be done if we had this feature.

## Concept Selection

After evaluating the conceptual models, we needed to narrow down our number of concepts to a select few. We did this by eliminating the impractical ideas that we thought of during brainstorming to get them down to the most viable. Then we made two Pugh matrices to evaluate how each idea satisfied our customer requirements. There was one matrix for how the ball would be thrown, and another for how the user would actuate the device. In the throwing matrix, the simple ramp idea had a lot of plusses, but it would be unable to satisfy some of the most important customer requirements. These important requirements were that the device had to be safe, user operated with minimal force, incorporate some exercise for the user, controlled using limited hand motion, and thrown the length of a standard Bocce ball court. Based on these five critical requirements, we decided that our top three throwing concepts would be the spring loaded cannon, the air gun, and the catapult.

**Table 2: Pugh matrix for launching concepts.**

| | Catapult | Sling shot | Jai Alai | Ramp | Air Gun | Plunger | Counter-Weight | See - Saw | Clamper - Thrower | Hydraulics | Belt Sander | Ball Pitcher |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lasts a couple years | S | S | + | + | + | D | S | S | S | - | - | S |
| Not wider than a wheelchair | - | - | S | + | S | | S | S | S | S | - | - |
| Easily Storable | - | + | S | + | S | | - | S | - | - | - | - |
| Must not obstruct user's vision | S | S | S | S | S | | S | S | S | S | S | S |
| Travel length of std BB court* | S | + | + | - | + | A | - | - | - | + | S | + |
| Light weight | - | + | + | + | - | | - | - | S | - | - | - |
| Easily transportable | - | + | S | + | S | | S | S | + | - | S | - |
| User operated with minimal force* | S | - | - | + | + | | S | - | S | + | + | + |
| Free of major saftey hazards* | - | - | - | + | + | T | - | - | - | - | - | - |
| Built with as many standard parts as possible | + | S | - | + | S | | + | + | + | - | - | S |
| Cannot use wall plug* | S | S | S | S | - | | S | S | S | S | - | - |
| Launch both pallino and bocce balls* | S | + | + | - | + | | S | S | - | S | S | - |
| Relatively low cost | S | + | - | + | - | | + | + | S | - | - | - |
| Controlled with limited hand motion | + | - | - | S | + | U | S | - | - | S | + | + |
| Include spin | - | - | - | - | S | | - | - | - | S | S | + |
| Can be used on various surfaces | S | S | S | - | S | | S | S | S | S | S | S |
| Sturdy | S | - | S | + | + | | S | S | S | - | S | S |
| Incorporates some exercise for user* | + | S | S | - | S | | S | S | S | S | - | - |
| Fast load / shoot time | - | - | S | - | - | M | - | - | - | S | S | + |
| SUM + | 4 | 6 | 4 | 10 | 7 | | 2 | 2 | 2 | 2 | 2 | 5 |
| SUM - | 7 | 7 | 6 | 6 | 4 | | 6 | 7 | 7 | 8 | 9 | 9 |
| SUM sames | 8 | 6 | 9 | 3 | 8 | | 11 | 10 | 10 | 9 | 8 | 5 |

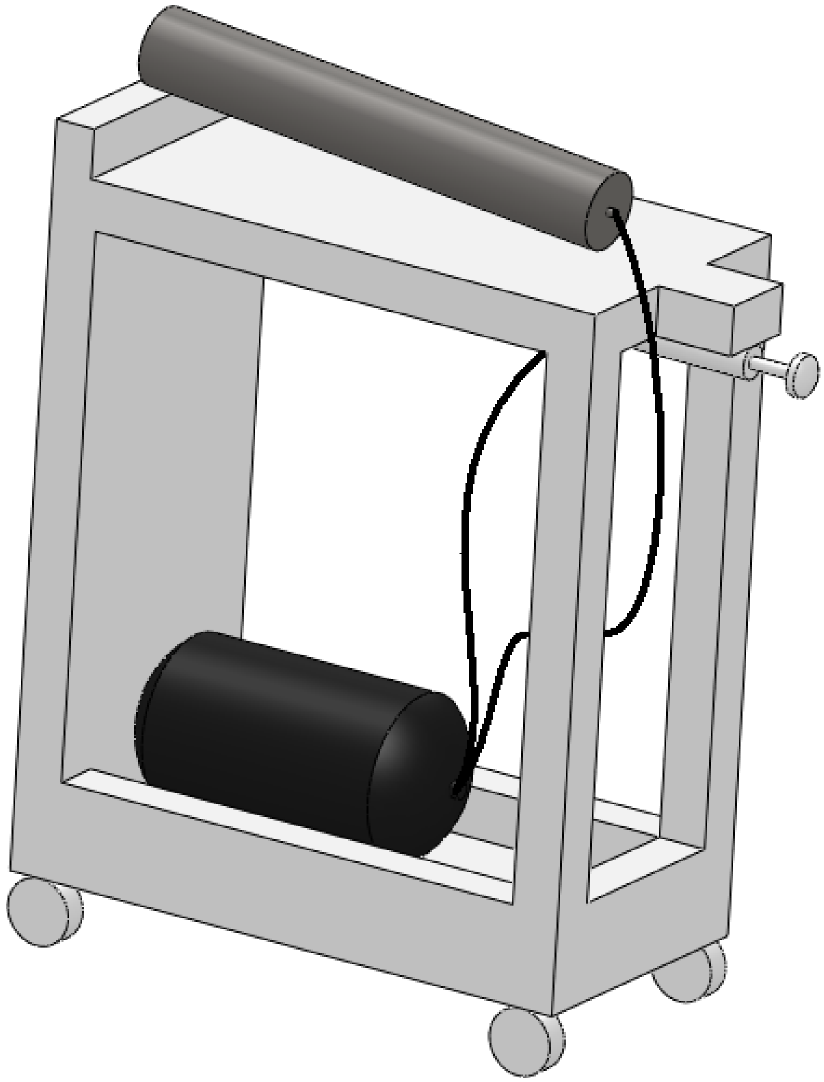
From the actuation Pugh matrix, we initially decided that our top two actuation concepts were the squeeze pump and the push pump. This was decided because they both incorporated some exercise for the user, which is a really important requirement for actuation. They are safer for the user since they won't contain as many safety hazards, especially pinch points, such as a lever or ratcheting system. However, as we progressed with our design project and did more analysis and tests, we discovered that requiring the user to fill the air tanks with some type of manual pump would be too difficult and take too long, since our tank is so large. This is why we decided to go with an air compressor.

**Table 3: Pugh matrix for actuation concepts.**

| | Ratchet | Lever | Motor | Squeezie Pump | Air Compressor | Push Pump | Crank |
|---|---|---|---|---|---|---|---|
| Lasts a couple years | + | + | D | - | S | S | + |
| Not wider than a wheelchair | - | - | | S | - | S | S |
| Easily Storable | - | S | | S | - | + | S |
| Must not obstruct user's vision | S | S | | S | + | S | S |
| Travel length of std BB court* | - | - | | - | + | - | - |
| Light weight | - | - | A | S | - | S | S |
| Easily transportable | S | S | | S | + | S | S |
| User operated with minimal force* | - | - | | - | + | - | - |
| Free of major saftey hazards* | - | - | | + | + | + | - |
| Built with as many standard parts as possible | + | + | | - | S | - | - |
| Cannot use wall plug* | + | + | T | + | + | + | + |
| Launch both pallino and bocce balls* | S | S | | S | S | S | S |
| Relatively low cost | + | + | | S | - | S | + |
| Controlled with limited hand motion | - | - | | - | + | - | - |
| Include spin | S | S | U | S | S | S | S |
| Can be used on various surfaces | S | S | | S | S | S | S |
| Sturdy | S | S | | S | + | S | - |
| Incorporates some exercise for user* | + | + | | + | S | + | + |
| Fast load / shoot time | - | - | M | - | S | - | - |
| Sum Minus | 8 | 7 | | 6 | 4 | 4 | 7 |
| Sum Plus | 5 | 5 | | 3 | 7 | 5 | 4 |
| Sum Sames | 6 | 7 | | 10 | 7 | 10 | 8 |

Finally, we decided to select our top concept to be the air cannon design, (see Figure 6 below), because our top actuation ideas were much easier to implement using this model. The squeeze pump and push pumps could be rigged to compress air in a pressure vessel, whereas for the other two designs, a mechanical system has to be made to convert the pumping energy into a spring displacement. Also, the air cannon concept satisfies our sponsor's safety concerns because there are fewer moving parts so the users are less likely to pinch themselves when operating the cannon. Unfortunately, later on in the project we discovered that pumping up a 300 cubic inch tank by hand would take too long. This led us to the decision of using an air compressor. Most air compressors require a wall plug which was strongly discouraged by our sponsor since bocce ball is almost always played outside. Our solution was to use a 12 V DC air compressor and a 12 V rechargeable battery to power it. This way, the battery can be recharged while not being used, and then it can be reattached to the cart and transported with the device when it is in use.

We performed some analysis to verify this concept which included projectile motion and tank sizing, which can be seen in the next section. The next step of our project is going to be procurement and construction of the final product. Once the product is built, we will begin rigorous testing of the device to make sure it meets or exceeds all of the previously defined specifications.



**<u>Figure 6</u>: Initial top conceptual design is the air cannon.**

## Proof of Concept Testing

1/11/11- Tested spin concept by adding a steak of tape on the ball and watching it upon release. The ball had a decent amount of spin added to it without too much reduction in distance. For this idea to work better, a larger piece of rubber is needed on the inside of the tube so that more spin can be added.

1/23/11 – Conducted a test to make sure air cannon could launch the bocce ball. The test had a very positive result, being able to propel the bocce ball with a reasonably low amount of air pressure. We also made sure to see if our idea for putting a rubber insert in the tube so the bocce ball would fit snugly worked and it did. We had to make the rubber insert a bit more

precise for the final prototype because if the ball fits too snuggly, it will experience a large amount of friction and require too much air pressure to launch.

# Chapter 4: Description of Final Design

## Overall Description / Layout

The final design (see Figure 7 below) uses a dual barrel setup for launching both the bocce ball and pallino. The scissor jack is used to raise and lower the barrels so the vertical launch angle can be adjusted, while the turntable allows for the user to adjust the horizontal launch angle. The air tanks are pressurized by the air compressor, which is powered by a 12 volt car battery. A cart is used so the device is compact, but easy to move. The whole assembly weighs about 150 pounds, but the battery can be removed to reduce the weight significantly.

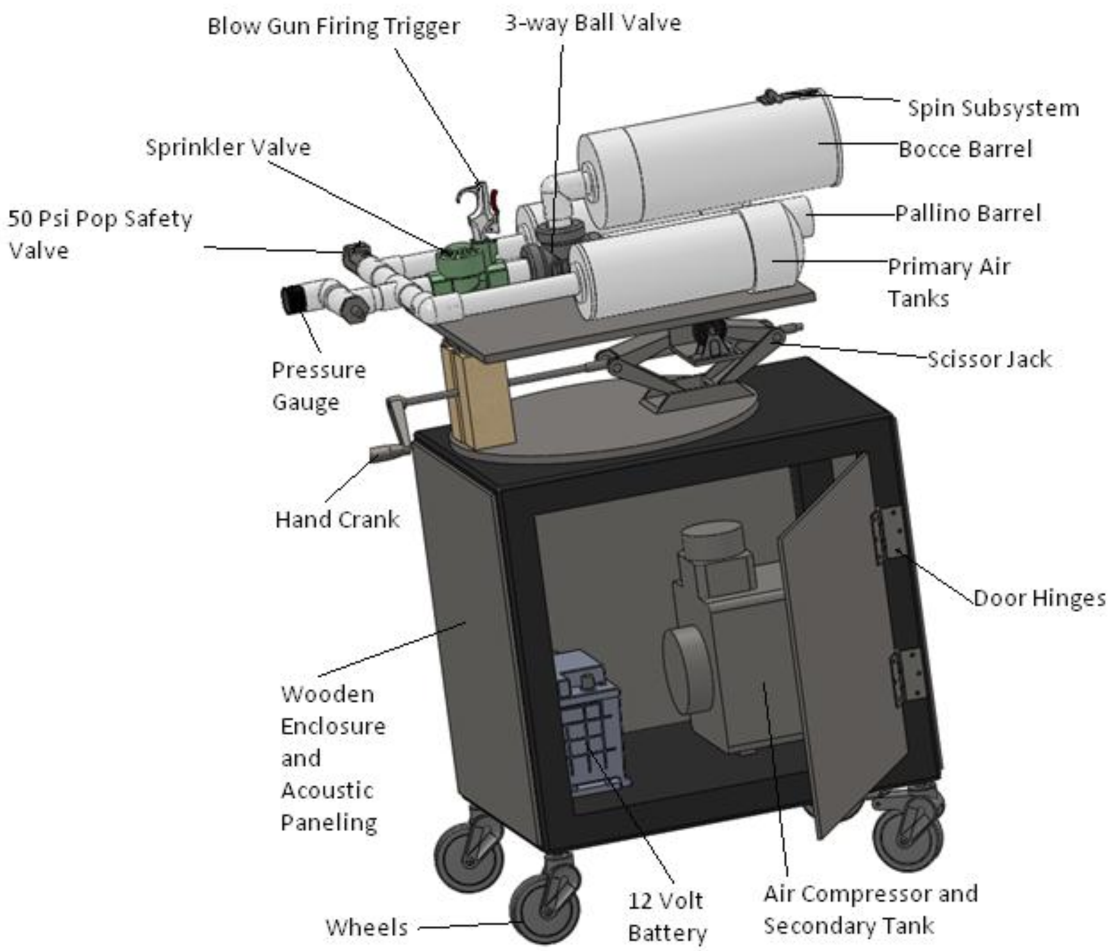



**Figure 7: Final Design Layout.**

## Detailed Design Description

Our final design is made up of three subsystems. There is a piping subsystem, a structural subsystem, and a powering subsystem. These systems are described in the following subsections.

### Piping subsystem

The piping subsystem is made up of PVC piping (see Figure 8 below). The layout allows for a large tank volume while occupying little space. This is accomplished by routing the two compressed air tanks alongside of the barrels. The two air tanks are 1' long each with a diameter of 4”, totaling a volume of 300in$^3$. The piping system has two barrels, one for launching the pallino and another for the bocce ball. Since PVC does not come in a standard size that fits a bocce ball or pallino we had to come up with a solution so both balls would have a snug fit. However, since the pallino ball requires a reasonably less amount of pressure to shoot, a rubber insert is not necessary even if the fit is not snug. For the bocce barrel, we had to buy rubber inserts in order to make a snug fit around the ball. The rubber inserts were placed into the barrels, layer by layer until a loose fit around the bocce ball was obtained. The final layer, a low friction metal called flashing, was then inserted to create a smooth and snug fit.

The piping system also uses two different valves, a sprinkler valve for releasing the air quickly, and a 3 port directional valve so the user can direct the compressed air into either barrel. For safety, the piping system has a pop safety valve that will release pressure if the tanks exceed 50psi. The system has an air fill valve for interface with the air compressor subsystem.

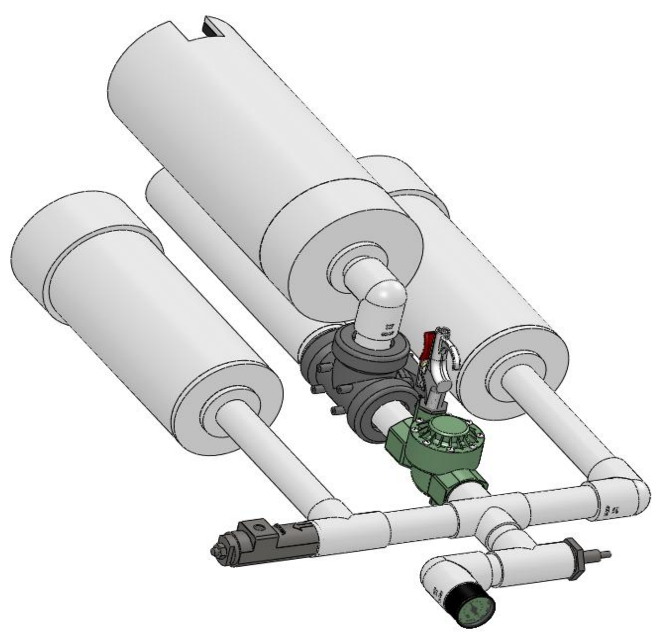
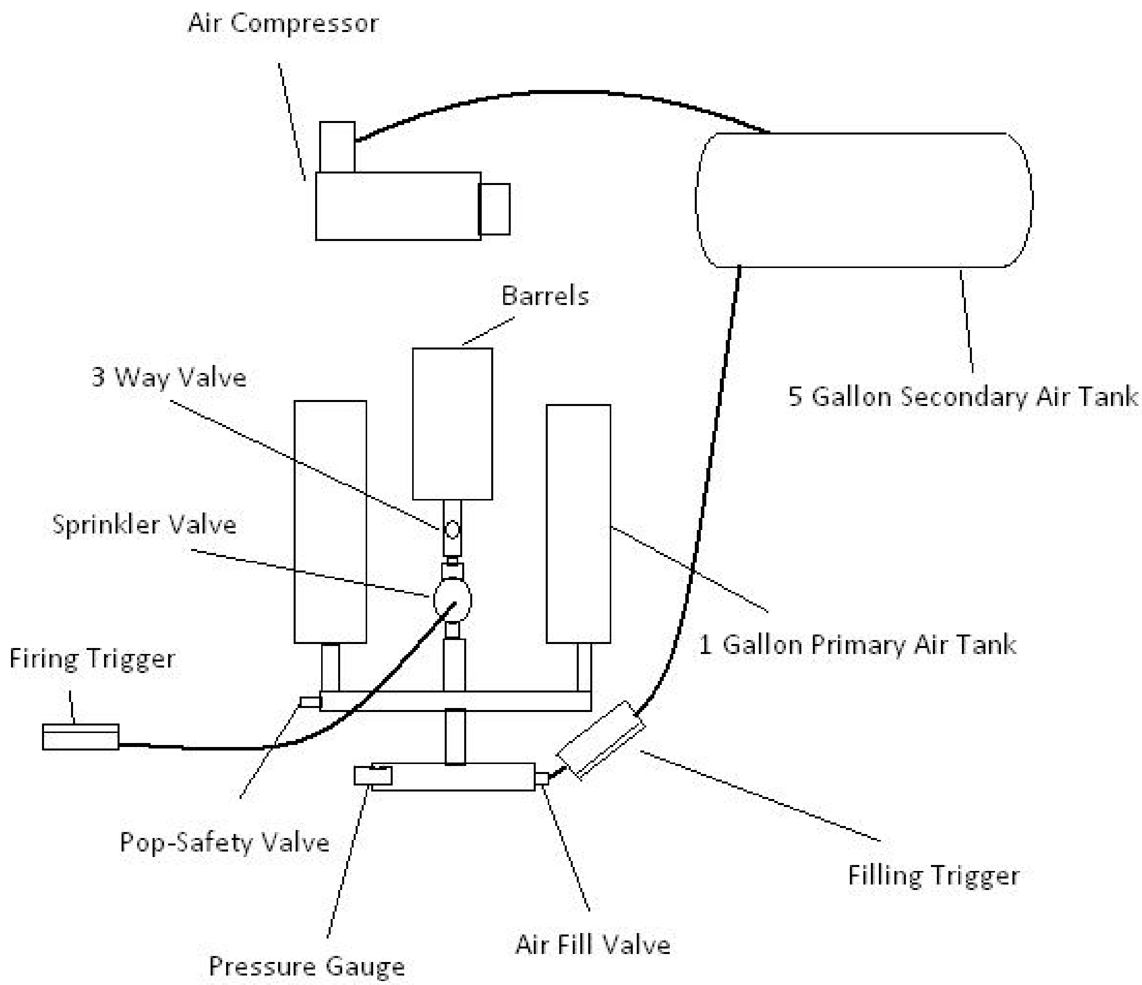


**Figure 8: Piping system for final design.**

A schematic of the pneumatic orientation can be seen below in figure 9. The air compressor is connected to a 5 gallon secondary tank, that tank is connected to the piping subsystem with a filling trigger in the hose.




**<u>Figure 9</u>: Piping Subsystem Schematic**

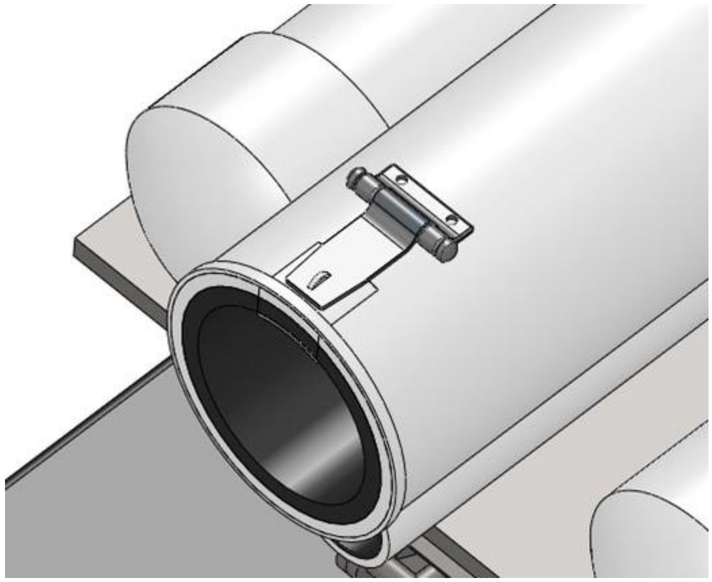


**Figure 10: Backspin feature.**

The backspin feature (see Figure 10 above) is also contained in this subsystem. To make backspin on the bocce ball possible, a rubber piece was added to the top of the inside of the bocce ball barrel. When the ball rolls over this rubber piece, a slight spin effect will be put on the ball. To remove backspin, there is a hinge on the outside of the barrel that can be pulled back so the rubber piece does not contact the ball during firing. In order to hold the PVC flap in place, a collar is put around the end of the barrel.

## Structural Subsystem

The structural subsystem (see Figure 11 below) is the portion of the design that supports the structure. The most important part of this subsystem is the cart. The cart has two different levels with the bottom level containing the air compressor and battery. The top level consists of the piping subsystem and the aiming system.

The cannon barrel is aimed using the scissor jack to change the vertical launch angle and a turntable to affect the horizontal launch angle. On top of the turntable is an 18” circular piece of wood that the wood spacers and jack stand on. The wood spacers are used so that when the scissor jack is at its lowest point, the air cannon is parallel to the ground.

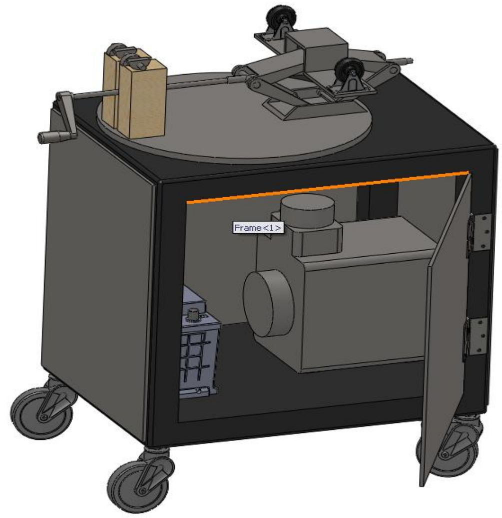



**Figure 11: Structural system for final design.**

## Powering Subsystem

The powering subsystem consists of the battery and the air compressor. This 12 volt battery was chosen because it can run on 30 amps for an hour before it needs to be recharged. It weighs 30 lbs. A 12 volt battery recharger will be supplied to our sponsor so the battery can be recharged when the device is not in use.

This air compressor was picked because it is powerful, but can still run off of a 12 volt battery. It can pump 2.54 cubic feet per minute at a pressure of 90 psi. It weighs 10.25 lbs. The air compressor connects to the air fill valve on the piping subsystem using pneumatic tubing.

Both the air compressor and the battery will be stored on the bottom shelf of the cart (see Figure 9), inside a sound reducing enclosure in order to help ensure the safety of our users, eliminate excessive noise, and to make the device is aesthetically pleasing.

An electrical schematic can be seen below in figure 12 which shows how the air compressor connects to the battery.

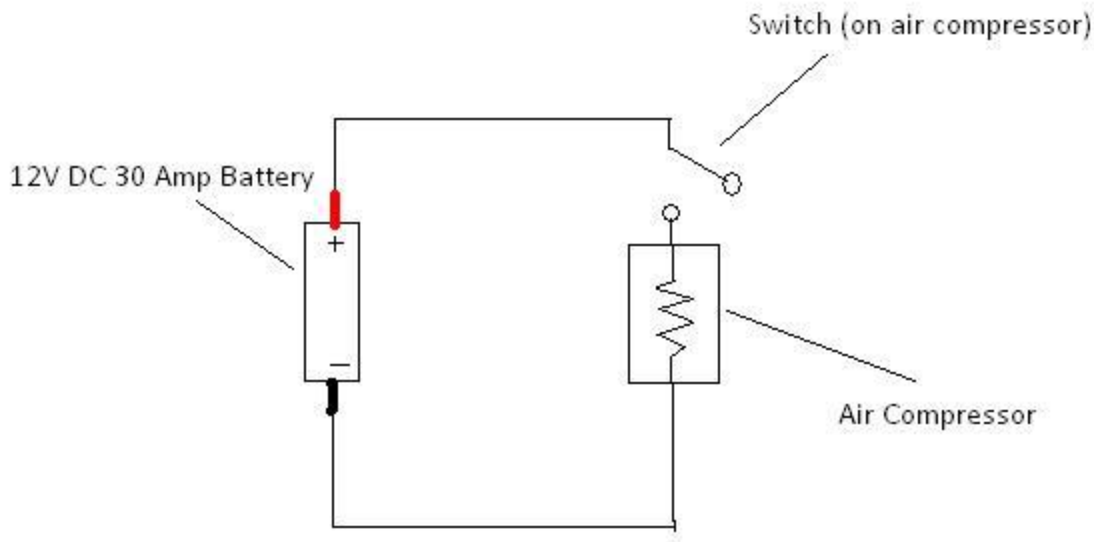



**Figure 12: Electrical Schematic.**

## Engineering Analysis

The first analysis we conducted was a projectile motion problem for the ball travelling through the air. The Special Olympics bocce ball court is 60 feet long, so we decided to make this the distance for the ball to travel in the air, despite the fact that it is not necessary for the ball to travel the length of the court in the air. This can help make up for losses due to friction in the barrel. The launch angle of the ball is also set at 45 degrees. Using these parameters, we found the velocity of the ball to be 62 ft/s when the ball leaves the barrel. Using the mass of 2.2lbs for the ball, we found the kinetic energy in the ball to be 131.72 foot pounds or 1580 inch pounds.

The next portion of our analysis was to determine the best initial tank pressure and barrel length. We started by assuming the expansion would be polytropic and adiabatic. Next, using excel we varied the barrel length, or $V_2$, the volume of expanded air right as the ball was leaving the barrel. We had five initial tank pressures, or $p_1$, varying from 10 to 50 psi. With a tank volume, or $V_1$ of 300 cubic inches, we could use the polytropic relation ("Fundamentals of Engineering Thermodynamics" Michael J. Moran and Howard N. Shapiro):

$$p_1 V_1^n = p_2 V_2^n$$

To solve for $p_2$, the pressure in the barrel and tanks as the ball is leaving the barrel assuming n is 1.4, since the expansion is polytropic and adiabatic.

Next using the polytropic work relation ("Fundamentals of Engineering Thermodynamics" Michael J. Moran and Howard N. Shapiro):

$$W = \frac{p_2V_2 - p_1V_1}{n-1}$$

We solved for the work done by the system, which would be added to the ball during the expansion

**Table 4: Barrel and tank size selection based on amount of energy required.**

| Length | 10psi | 20psi | 30psi | 40psi | 50psi |
|---|---|---|---|---|---|
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1 | 137.34 | 274.68 | 412.01 | 549.35 | 686.69 |
| 2 | 266.26 | 532.51 | 798.77 | 1065.03 | 1331.29 |
| 3 | 387.61 | 775.21 | 1162.82 | 1550.43 | 1938.04 |
| 4 | 502.12 | 1004.24 | 1506.35 | 2008.47 | 2510.59 |
| 5 | 610.43 | 1220.85 | 1831.28 | 2441.70 | 3052.13 |
| 6 | 713.08 | 1426.17 | 2139.25 | 2852.34 | 3565.42 |
| 7 | 810.58 | 1621.16 | 2431.74 | 3242.32 | 4052.91 |
| 8 | 903.35 | 1806.69 | 2710.04 | 3613.38 | 4516.73 |
| 9 | 991.76 | 1983.52 | 2975.27 | 3967.03 | 4958.79 |
| 10 | 1076.16 | 2152.31 | 3228.47 | 4304.63 | 5380.79 |
| 11 | 1156.85 | 2313.69 | 3470.54 | 4627.38 | 5784.23 |
| 12 | 1234.10 | 2468.19 | 3702.29 | 4936.38 | 6170.48 |
| 13 | 1308.15 | 2616.30 | 3924.45 | 5232.60 | 6540.75 |
| 14 | 1379.23 | 2758.46 | 4137.68 | 5516.91 | 6896.14 |
| 15 | 1447.53 | 2895.06 | 4342.59 | 5790.12 | 7237.65 |
| 16 | 1513.24 | 3026.47 | 4539.71 | 6052.95 | 7566.18 |
| 17 | 1576.51 | 3153.03 | 4729.54 | 6306.05 | 7882.56 |
| 18 | 1637.51 | 3275.02 | 4912.52 | 6550.03 | 8187.54 |

Table 4 shows the work done on the ball while varying the length of the barrel and initial pressure for a fixed tank size. The highlighted cells show the length at which the work done on the ball meets the energy needed of 1580 in-lb so the ball can travel the desired 60 feet. A 12" long barrel length was chosen as it fell between the values at 10 and 20psi. At higher pressures, a shorter barrel is required, but having a longer one will also aid in maintaining a straight flight path.

The next analysis we conducted was to make sure the users could move the jack stand up and down. We used a simple power screw analysis to determine if the force they can exert would be enough to do this. We started by assuming that the crank length that they would be applying the 3lb force to would be 4" long. This makes the input torque 12 in-lb.

Since we do not know most of the specifications for the power screw in the scissor jack, we used standard dimensions for the analysis.

Our assumptions:

Number of threads per inch = 10, so thread length is 0.1”

Friction factor for steel on steel = 0.25

Mean screw diameter = 0.375”

Then, using the equation (“Shigley’s Mechanical Engineering Design” Richard J. Budynas and J. Keith Nisbett):

$$T_R = \frac{F d_m}{2} \frac{l + \pi f d_m}{\pi d_m - f l}$$

In which

$$F = Force\ on\ power\ screw$$

$$d_m = mean\ screw\ diameter$$

$$l = thread\ length$$

$$f = friction\ factor$$

$$T_R = Torque\ to\ raise\ screw$$

We used the maximum friction fact for a steel power screw and solved for F, and learned that the maximum force that could be on the power screw would be 187 lbs. This is far more than we would possibly need to lift the subsystem.

The final piece of analysis we did dealt with the jack extension rod. We wanted to make sure that if someone were to lean on the rod, it would not snap. We used the equation (“Shigley’s Mechanical Engineering Design” Richard J. Budynas and J. Keith Nisbett):

$$\sigma = \frac{My}{I}$$

Where

*σ = Stress*

*M = Applied moment*

*y = Radius of rod*

*I = $2^{nd}$ Moment of area of rod*

The yield strength of our steel was assumed to be 40,00psi and with a factor of safety of 2, we used a sigma of 20,000psi. This allowed us to calculate the maximum force that could be applied to the rod, which came out to be 40 pounds. We thought this was a reasonable outcome considering our factor of safety. This calculation can be found in Appendix E.

# Cost Analysis

## Power System

Our heaviest subsystem is the powering system, which is mostly due to the weight of the battery. A breakdown of the weight and cost for the powering subsystem can be found below in Table 5. The air compressor that we decided on will run off a 12V rechargeable battery, and will be mounted on the bottom shelf of the cart. The battery will also be mounted on the bottom shelf of the cart, with the compressor, but will be detachable in order to recharge. Also, in case the whole unit is too heavy to move, the battery can be removed, and transported separately from the cart. The weight of the powering system came out to be just over 40lbs and it cost about $220.

**Table 5: Cost and Weight Breakdown of the Power System.**

| Component | Retailer | Weight [lbs] | Cost/Unit | Total Cost |
|---|---|---|---|---|
| 12 V 50 aH Battery | FactorysOnline.com | 30.5 | $100 | $100 |
| 12 V Recharger | Schumacher | N/A | $32 | $32 |
| 12 V Air Compressor | NorthernTool.com | 10.25 | $77.67 | $87.67 |
| Totals | N/A | 40.75 | N/A | $219.67 |

## Structural System

A cost breakdown can be found below in Table 6 for the structural subsystem. This system is composed of a turntable and a scissor jack that the piping system will be mounted to so that the user can adjust the vertical and horizontal angle the balls will be shot at. The rotating table will be mounted to the top of a 26” cart and controlled by the user. The bulk of these materials will be purchased from McmasterCarr, Ace Miner’s, and Home Depot. The total weight and cost of the aiming system come out to be about 60lbs and just under $530, respectively.

**Table 6: Cost and weight breakdown of the structural system.**

| Component | Retailer | Weight [lbs] | Cost/Unit | Units | Total Cost |
|---|---|---|---|---|---|
| Galvanized Steel Turntable | McMasterCarr | 0.2 | $3.47 | 1 | $3.47 |
| 1 Ton Scissor Jack | Choice Tool Supply | 4 | $17.27 | 1 | $17.27 |
| Plywood | Ace Miner's | 3 | 1.084/sq ft | 9 sq ft | $9.76 |
| H.WILSON Tuffy Utility Cart | C&H Distributors | 22 | $87.01 | 1 | $87.01 |
| Rubber Pipe Insert | Ace Miner's | 1 | $3.20 / ft | 6 ft | $19.20 |
| Rubber Jar Opener | Ace Miner's | 0.02 | $3.99 | 1 | $3.99 |
| Side Panel Hinges | Home Depot | 0.12 | $4.99 | 3 | $14.97 |
| Side Panel Latch | Ace Miner's | 0.1 | $3.93 | 1 | $3.93 |
| Hand Wheel | Reid Tool Supply | 7 | $53.35 | 1 | $53.35 |
| Barrel Support Hinge | Ace Miner's | 0.2 | $4.50 | 1 | $4.50 |
| Spin Hinge | Ace Miner's | 0.05 | $3.75 | 1 | $3.75 |
| Caster Wheel | Farm & Home Supply Center | 2.1 | $7.00 | 2 | $14.00 |
| Side Paneling | Home Depot | 3.4 | $6.43 | 2 | $12.86 |
| Sound Panels | Home Depot | 8.5 | $19.76 | 1 | $19.76 |
| Flat Bar | Home Depot | 0.5 | $7.60 | 1 | $7.60 |
| 5/8" Plated Steel Rod | Ace Miner's | 1 | $9.12 | 1 | $9.12 |
| Spray Paint | Home Depot | N/A | $4.67 | 6 | 28.02 |
| 18" Circular Wood Board | Home Depot | 2.67 | $18.59 | 1 | $18.59 |
| 8x3 Thick Board | Home Depot | 4.31 | $10.31 | 1 | $10.31 |
| Aluminum Flashing | Ace Miner's | 0.47 | $17.65 | 1 | $17.65 |
| Extra Shipping Considerations | N/A | N/A | N/A | N/A | $100.00 |
| Hardware | Ace Miner's | N/A | N/A | N/A | $70.00 |
| Totals | N/A | 60.64 | N/A | N/A | $529.11 |

## Piping System

A cost breakdown for the piping system which contains the bocce ball barrel, pallino barrel, and the air tanks can be found below in Table 7. All the piping is done with PVC pipe to help reduce cost. The majority of our components for the piping subsystem will be purchased from Ace

Miner's, McmasterCarr, FlexPVC, and NorthernTool. The total weight of the piping system is about 50lbs and the total cost is just over $265, as can be seen below

**<u>Table 7</u>: Cost and weight breakdown of the piping system.**

| Component | Retailer | Weight [lbs] | Cost/Unit | Units | Total Cost |
|---|---|---|---|---|---|
| 4" PVC pipe | Ace Miner's | 4.02 | $3.45 / ft | 2ft | $6.90 |
| 4" PVC caps | Ace Miner's | 1.7 | $6.99 | 2 | $13.98 |
| 4" to 2" slip-thread reducer | Ace Miner's | 2.1 | $3.49 | 2 | $6.98 |
| 2" to 1" slip-thread reducer | Ace Miner's | 0.34 | $1.99 | 3 | $5.97 |
| 2.5" to 1" slip-thread reducer | Ace Miner's | 0.6 | $2.49 | 1 | $2.49 |
| 1" PVC pipe | Ace Miner's | 2.2 | $ 0.65 / ft | 3 ft | $1.95 |
| 1" PVC elbows | Ace Miner's | 0.85 | $0.55 | 5 | $2.75 |
| Any Direction Diverting 3 way Ball Valve | McMasterCarr | 4 | $65.23 | 1 | $65.23 |
| 1/4" Brass pop safety valve | McMasterCarr | 0.05 | $6.26 | 1 | $6.26 |
| 1" to 1/2" slip-thread reducer | Ace Miner's | 0.15 | $0.65 | 3 | $1.95 |
| 1/2" to 1/4" thread-thread reducer | Ace Miner's | 0.27 | $1.14 | 3 | $3.42 |
| 1/4" Air Tank Valve | McMasterCarr | 0.1 | $3.94 | 1 | $3.94 |
| 0-100 psi Pressure Gauge | Ace Miner's | 0.2 | $18.98 | 1 | $18.98 |
| 0-60 psi Pressure Gauge | Ace Miner's | 0.2 | $10.34 | 1 | $10.34 |
| 1" PVC Tee connection | Ace Miner's | 0.24 | $0.65 | 2 | $1.30 |
| 2.5" PVC Pipe | Ace Miner's | 1.9 | $2.49 / ft | 1 ft | $2.49 |
| Sprinkler Valve | Orbit | 2.45 | $13.99 | 1 | $13.99 |
| 4 way 1" PVC Slip Connector | CreativeShelters.com | 0.31 | $2.48 | 1 | $2.48 |
| 5" PVC Pipe | FlexPVC.com | 6 | $17.90/ft | 1 ft | $17.90 |
| 5" to 2" PVC slip connector | FlexPVC.com | 1.1 | $7.22 | 1 | $7.22 |
| 5" PVC Coupling | FlexPVC.com | 2.3 | $7.93 | 2 | $15.86 |
| 4" PVC Coupling | Ace Miner's | 1.9 | $4.32 | 2 | $8.64 |
| 2.5" PVC Coupling | Ace Miner's | 0.72 | $0.98 | 1 | $0.98 |
| Brass Quick Release Valve | Ace Miner's | 0.72 | $5.65 | 2 | $11.30 |
| Blow gun | Northern Tool | 0.87 | $15.98 | 2 | $31.96 |
| 5 Gallon Air Tank | N/A | 15 | Donation | 1 | Donation |
| Totals | N/A | 50.29 | N/A | N/A | $265.26 |

## Total Cost

The total weight and cost breakdown for the entire device can be found below in Table 8. The weight and cost of our project has increased significantly from our conceptual design. This is mainly due to the fact that we are now using an air compressor and a battery to fill up our air tanks, as opposed to having the user do it with a pump. Although this reduces the amount of exercise for the user, we determined that it would take too long to fill up the air tanks we are using with only a hand pump. Using an air compressor will help speed up the process of filling up the air chamber before each shot.

**Table 8: Total weight and cost breakdown of entire device.**

| Subsystems | Weight (lbs) | Cost |
|---|---|---|
| Power | 40.75 | $219.67 |
| Piping | 50.29 | $265.26 |
| Structural | 60.64 | $529.11 |
| Totals | 151.68 | $1014.04 |

# Material, Geometry, and Component Selection

## Material

For our piping subsystem, we had to decide what the best material would be to use for our application. Originally we were thinking of using aluminum, but eventually decided to use PVC piping because it comes manufactured in standard sizes, is cheaper, lighter, and we would not have to machine it.

The paneling that encloses the bottom section of the cart is made out of a thin wood and sound board. We decided to use wood and sound board because they can be easily painted, they are sturdy materials, and will reduce noise from the air compressor. One of the panels will be attached to the car through hinges in order to allow access to the internal parts of the cart.

The circular piece that supports the jack and piping system, the wood piece underneath the piping system, and the spacers in the current design are made out of a quality wood. These pieces are painted Cal Poly colors to aid in the aesthetics of our design.

## Geometry

The main concern affecting the geometry of the device was the volume specification. We wanted the device to be completely contained within a 1.5’ wide x 4’ tall x 3’ long box. The main concern for us is exceeding the height specification, because if the device is too tall, the users will not be able to see the bocce ball court when they are making their shot.

## Components

*26”H Tuffy Utility Cart:* (see figure 13)

**Figure 13: Utility Cart.**

We decided to use the cart we picked mainly because of concerns with the height of the device. The cart we found is only 26” in height, and is a fairly low cost. If the height of our device is still a concern, we may alter the cart a bit to reduce its height while still being able to hold all the components we need it to.

*1 Ton Scissor Jack:* (see figure 14)

**Figure 14: Scissor Jack**

We decided to select this scissor jack so that the jack would not be too large and make the overall design too tall. The jack did not need to hold that much weight, so a 1 ton model was selected because it was the least expensive.

*12V 120 psi Q Industries Air Compressor:* (see figure 15)

**Figure 15: Air Compressor**

The *Q Industries SuperFlow Hi-Volume* air compressor runs off of a 12V battery and can compress air up to 120psi. This air compressor was selected because it maintains high performance while compressing air at high pressures. When compared to similar products, this air compressor was said to be quieter than most of its kind. Some of its features include pumping 2.54 cubic feet per minute at 90psi, has a pressure gauge on the device, and comes with a 16ft coiled hose.

*UB12500 12V Battery*: (see figure 16)


**Figure 16: 12V, 50aH Rechargeable Battery.**

This battery is being used in the design because of its high capacity. Since the air compressor draws 30amps, our design needs a battery that can satisfy our power needs. This battery can last for an hour while 30 amps are being drawn from it, which is enough for the athletes at Friday Club.

## Operating Procedure

Before operating the Bocce Ball device, there are a few tasks to complete. The first one is to make sure that the battery is fully charge. This is done by plugging in the 12-volt battery recharger and connecting the alligator clips to the battery (red clip to positive terminal, black clip to negative terminal). Ideally this is done the day before use, since it can take up to 5 hours to fully charge the battery. The battery was sized and selected for use at Friday Club, which only lasts about an hour, however, that implies continuous use. Fortunately, the way we have the system set up utilizes a secondary tank to store pressurized air so the air compressor does not have to be on constantly. This means the battery will last longer. This is ideal if the device is to be used during competition, which can last longer than 1 hour. During the senior design expo, we used the device for 3 hours, intermittently turning the air compressor on and off to refill secondary tank and the battery lasted the entire time.

Once battery is fully charged, it is placed inside the cart on the bottom left-hand side (see figure 17 below). Then the air compressor is attached to the battery using the red and black alligator clips. It is best to wait until the device is ready to be used before hooking up the air compressor to make sure that it does not drain the battery. However, it is beneficial to fill up the secondary tank to about 100psi before taking the device out to play. This is done by turning on the switch that is on the air compressor after it has been connected to the battery.

**<u>Figure 17:</u> Photo of inner workings of the Bocce Ball device. 12-volt battery is in the lower left corner, air compressor is in the upper left corner, and the secondary tank to store pressurized air up to 100psi is on the right. The air compressor connects to the secondary tank with the red hose, the yellow hose runs up through the top of the cart and connects the secondary tank to the primary tank. The air compressor is connected to the battery using alligator clips.**

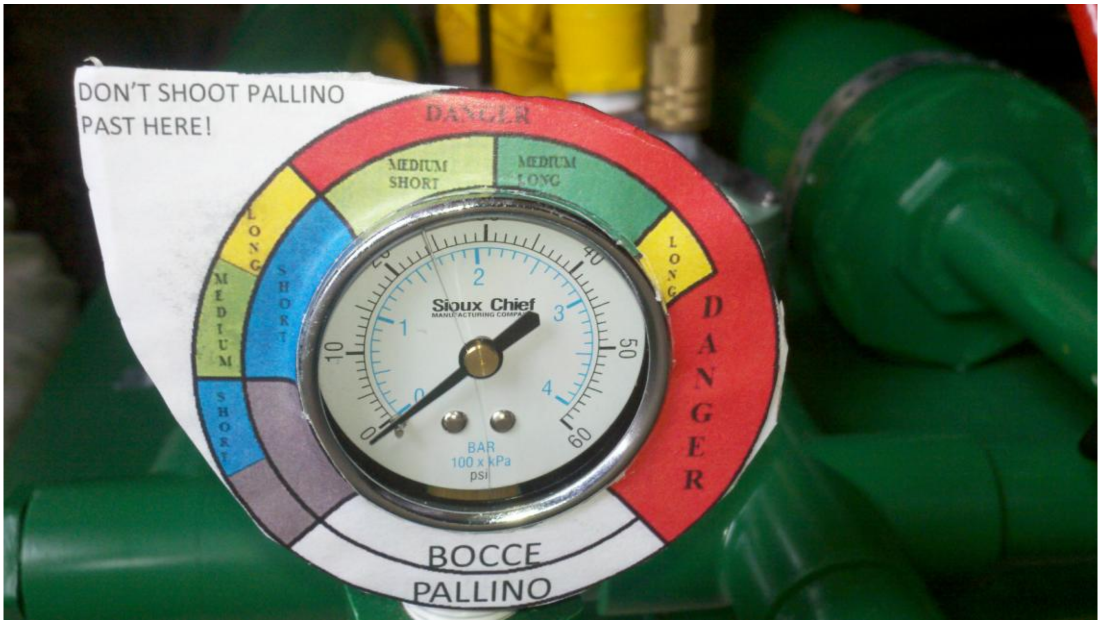
After preparation and transportation, the device is ready to be used out on the courts. The first thing to do is hook up the air compressor to the battery (red alligator clip to positive terminal, and black alligator clip to negative terminal). Then, be sure that the secondary tank has already been filled up to 100psi, by checking the pressure gauge on the tank. If this hasn't been done, complete this before beginning play. Keeping this tank full will help to decrease the time in between shots. The air compressor will typically need to be turned on to refill the tank every 4-6 shots fired, depending on how much air is used per shot. During play, the helper should occasionally open the cart door and check the pressure gage on the secondary tank. When it drops below about 55psi, the air compressor should be turned back on to fill the secondary tank back up to 100psi.

**Figure 18: 3-way valve orientation for pallino barrel, (valve is horizontal), on the left side and for bocce ball barrel, (valve is vertical), on the right side.**

Now the device is ready to be used. The first shot will be the pallino ball. While the helper holds onto the trigger (see figure 19 below to see location of trigger) the pallino should be inserted into the pallino barrel, which is the bottom yellow barrel. The 3-way valve needs to be in the horizontal position in order to direct the compressed air into the pallino barrel (if the 3-way valve is in the vertical position, air will be directed into the bocce ball barrel (see figure 18 above for orientations). Next the user should determine what angle they would like to shoot the ball at by turning the hand wheel (see figure 19 below). If they want to raise the launch angle, the hand wheel should be turned clockwise, if they want to lower it, counter clockwise.

**<u>Figure 19:</u> View from behind device where user would be sitting. Hand wheel can be seen and is used to raise or lower the angle the ball is shot at. Turning the hand wheel clockwise will raise it up, while turning it counter clockwise will lower it. The black and red blowgun connected to the red hose is the trigger. It releases the air in the primary tanks when squeezed to shoot the ball. The silver blowgun with the red handle connected to the yellow hose on the right side is used to fill up the primary tanks.**

Now the user is ready to begin filling up the primary air chambers, (green PVC tanks), using the blowgun on the right as seen in figure 19 above. By squeezing this blowgun, it opens up a valve allowing air to flow into the empty air chambers. Fill up the air chambers using the pressure gauge that is facing the user (see figure 20 below). When shooting the pallino, it is important for the helper to regulate how much the user fills up the tanks. Be sure not to fill up the tanks higher than 20psi when shooting the pallino. Since the pallino is much lighter than the bocce balls are, it will shoot much farther and can potentially be dangerous. Since we needed more pressure to be able to shoot the heavier bocce ball, we could not figure out a way to regulate how much pressure is used for the pallino, since both barrels use the same air chamber. Although there is a pop safety valve that is rated for 50psi that will release the air inside the tanks if it is pumped up past 50psi, the helper still has to pay attention and make sure that the pallino is not shot with more than 20 psi. Once the tanks have been filled and the helper ensures that they are not pressurized too high for the pallino, they hand the trigger to the user, and the user squeezes the trigger to fire the shot.




**<u>Figure 20:</u> Picture of calibrated pressure gauge. When shooting the bocce ball, follow the inner most circle that shows short (10-20psi), medium short (20-30psi), medium long (30-40psi), and long (40-45psi). Do not fill up past 45 psi! When shooting the pallino, follow the outer circle that shows short (5-10psi), medium (10-15psi), and long (15-20psi). Be sure not to shoot the pallino with more than 20 psi.**

Next, the user has to shoot the bocce ball. The 3-way valve must be rotated to the vertical position. At the request of the user, the helper should either engage or disengage the spin feature. For the spin feature, there is a hinge at the end of the barrel attached to a flap containing a rubber material to grip the ball and give it backspin as it exits the barrel. There is also a green collar that is used to either hold the flap down or up. For no spin, the flap should be flipped up and the collar placed on the end of the barrel to ensure that the flap does not fall down. To include backspin, take off the collar, put the flap down, then slide the green collar back over the end of the barrel. The spin feature can be seen in figure 21 below. Now the user is ready to aim his or her shot using the hand wheel to raise or lower the angle. Once the angle is set, the user can begin pumping up the tanks using the same blowgun as before. Using the pressure gauge calibration, pump up the primary air tanks to the desired amount. The helper gives the trigger to the user when they are ready to fire their shot.  Then the user squeezes the blowgun to shoot the ball.

**<u>Figure 21:</u> This picture shows spin feature not engaged (left) and spin feature engaged (right) with green collar on barrel to hold the flap up or down.**

When ready, the helper loads the next bocce ball and the user prepares for the next shot using the same procedure. After every 4-6 shots, the helper should open the door and check how much pressure is left in the secondary tank. If it drops below 55psi, turn on the air compressor and fill the secondary tank back up to 100psi. This can be done while the users play. If the user is filling up the primary tanks to prepare for a shot and the tanks will not fill up any more, it is most likely because the secondary tank is not pressurized high enough. This means the air compressor needs to be turned on.

Below are step-by-step instructions that should be followed when using the device:

<u>Step-By-Step Instructions</u>

1. Charge battery fully and pressurize secondary tank.
2. Once at the site, insert battery and connect air compressor to battery with alligator clips (red clip to positive terminal, black clip to negative terminal).
3. Insert pallino or bocce ball.
4. Ensure 3-way valve is either vertical (for bocce shot) or horizontal (for pallino shot).
5. Change vertical angle to desired position using the hand wheel (clockwise turn raises the device and counter clockwise turn lowers the device).
6. Helper engages/disengages spin feature (at user's request).

7. While helper holds the trigger (red and black squeeze gun with red hose), user pressurizes primary air chambers to desired pressure by using the fill trigger (blowgun on the right with yellow hose).
8. Aim shot in horizontal direction using hand wheel.
9. When the helper determines area is clear, they give the trigger to the user.
10. Squeeze trigger when ready to shoot.
11. Helper reloads ball for next shot, and holds trigger until ready for fire
12. Repeat steps 3-12 until round is over.

## Safety Considerations

To prevent Air tanks from being pressurized too high, there is a pop safety valve in the pipe assembly. If the pressure in the air tanks reaches 50psi, the pop safety valve will open, automatically causing the compressed air to flow out and maintain the pressure at 50psi. Furthermore, this valve can be pulled open by the user if they fill the air tanks past the desired pressure.

To prevent accidental firing by the user, the helper will hold the blowgun that is used to expose the sprinkler valve to atmospheric pressure. This is done so the user will not be able to fire until the helper knows that it is safe. Once the helper is certain that it is okay for the device to be shot, they will hand the blowgun to the athlete.

Finally, to keep the users away from the risk of electric shock, the cart is being outfitted with paneling so that the users cannot get hurt or injured by the air compressor or battery. The paneling will also help to keep the sound level low.

# Chapter 5: Design Realization

## Manufacturing

### Piping subsystem

The piping subsystem was mainly made out of PVC piping.  The majority of the components were put together using PVC glue and primer.  The pieces that used pipe threading were secured with thread tape to ensure that there were no leaks between each component.  In order for the sprinkler valve to be operable with a blowgun, it needed to be modified.  To do this, we drilled a hole through the top of the valve, removed the electronic actuation wires, and then sealed the areas where air could escape with plumber epoxy, see figure 22 below.  The three way valve needed to be modified with a mill so that the placement of the handle worked with our valve orientation.  Also, the handle of the valve was flattened so that it would not interfere with the tanks when pulled down.  Once this system was built, all the pipes were held onto a board using plumber tape.  This entire system was attached to the spacers on top of the turntable system with hinges.

**<u>Figure 22:</u> Here is a picture of the modified sprinkler valve that we used to quickly release the air stored in the primary chambers into the barrels.**

### Turntable subsystem

The most difficult fabrications that needed to be done for the turntable subsystem were for the scissor jack extension rod.  First, the rod was welded to the hand wheel.  Then, to attach the rod to the scissor jack, we first milled a 0.28" slot into the other end of the rod, and drilled a hole through it.  We used a bolt to pin the end of the scissor jack to the rod, but this did not work because the rod began to yield.  To fix this problem, we cut off a bit of the rod with the yielded end, and then cut another slot out of the rod using the mill.  But this time, we welded

the rod and scissor jack piece together and the two pieces held together much better, this can be seen in figure 23 below. Another problem we ran into for this system was when we needed to attach the turntable to the cart. We decided to drill a small hole into the circular piece of wood that we could fit a screw through to attach the turntable piece onto the cart.

**<u>Figure 23:</u> Picture of scissor jack attached to rod (left) and hand wheel welded to rod (right)**

## Structural subsystem

The last fabrications that had to be done were to the cart. First, side panels were attached to it so that components like the battery and air compressor would only be accessible from the one side with the hinge, away from the user. After this, sound paneling was inserted on the inside of the cart to reduce the noise of the air compressor. Once this was done a problem with the cart came up. The top of the cart is made of plastic and started to bow down due to the weight of the piping subsystem. To combat this problem, we put a ¾ inch piece of wood on top of it.

# Chapter 6: Design Verification Plan

## DVP Description

We created a Design Verification Plan and Results table (DVP&R) that lays out how and what we will test for our design. This was to create a structured process to test our design and document our results to ensure that all of the engineering specifications set forth from the customer requirements have been met. It lists each of our specifications, a test description, sets acceptance criteria, states who is responsible, test stage, samples, timing, and test results. The test description and acceptance criteria describe the type of test that will be used for each specification and sets acceptance criteria to determine whether or not that specification is met. A member from our team is responsible for each test. The test stage represents at what point in the design process this feature will be looked at, a concept validation (CV), design verification (DV), or product and process validation (PV). Each of our tests will be performed in the design verification stage, since we are not putting this product into production, and we need to test our design, as opposed to our concept. The samples category specifies the quantity to be tested and what the type is. Then we have the start and finish date of when this testing will be completed, and a results column. The majority of our testing is to be done during and after the construction of the prototype. The most important of these tests will be the launch distance and safety concern tests. This is because if the device is unsafe and not able to propel the balls the entire distance, it will not be usable. Also, the mobility test will be important to ensure ease of transportability. The plan can be found in Appendix G.

## Testing Results

Our testing followed a strict plan called a Design Verification Plan (DVP), which was created to make sure our finished system met all of our specifications. We started testing simple dimension measurements. The design's width was supposed to be no wider than 1.5 feet, which it was. The height of the device was under our maximum allowable, 4 feet, unless the device was at its maximum launch angle. In this case, the device was only an inch too tall. The length of the unit is about 2.5 feet, which passes our 3 foot specification. Another dimension test we did was that it had to be operated within a 6 inch radius sphere. A ruler was used to measure the distance between all the controls and the launcher passed the test.

The next type of testing we preformed dealt with the distance that each ball needed to be launched. Both of the balls had to be moved 60 feet. At first our system failed this test with the bocce ball. However, fortunately for us this was an easy fix. In order to correct this problem, we changed the rating on our pressure release valve. The valve originally allowed for a maximum of 40 psi in the primary air tanks and we increased it to 50 psi. This increase in pressure allowed the bocce ball to reach the desired 50 feet. While testing the distance, several other simple tests could be checked off the DVP as well. The launcher used a 3-way ball

valve, which allowed the user to shoot either the pallino or the bocce ball. Since the air compressor is battery operated, it uses no wall plugs. It can be used on trimmed grass, turf, as well as compacted dirt. The next test the device passed was that it could only be made using 10 custom parts. Another test we were able to complete was the transportability test. The device could be transported by 2 people without too much strain. Also, the ball was able to have backspin upon release if desired, but the amount of spin that could be applied to the ball was limited. Finally, the cannon could be reloaded and shot within 20 seconds as long as the helper monitored the secondary tank and kept it pressurized.

Another simple tested we preformed was weighing the system. Since we did not have a large scale, this was a difficult task. First we took all the removable parts (battery, secondary tank, and air compressor) and weighed them separately. We then took a wooden box that could hold our launcher and weighed it. The launcher was placed on the box and the wooden box weight was subtracted from the total to get the weight of our device. The separate components were then added onto this number to get a final weight. The total came out to 155 pounds, which did not meet our specification. The device however was still relatively mobile. We also used a fishing weight scale to make sure the hand wheel for raising and lowering the launch angle could be actuated with less than 3 pounds force.

Some DVP tests were able to be completed by checking for things like pinch points and sharp edges. Although our device does contain a few of each of these, none of them are accessible by the user and will not be a safety concern to them.

There were some things that we tested that were not on our DVP as well. First of all, the noise output of the air compressor was a huge concern. We borrowed a decibel meter, took measurements with and without an enclosure at different distances, and compared them against several noise standards. These comparisons were:

- Normal conversation at 3-5 feet ranges from 60-70 dB
- City traffic from inside car is about 85 dB
- Level at which sustained exposure may result in hearing loss is 90-95 dB

A graph of these results can be found below in figure 24

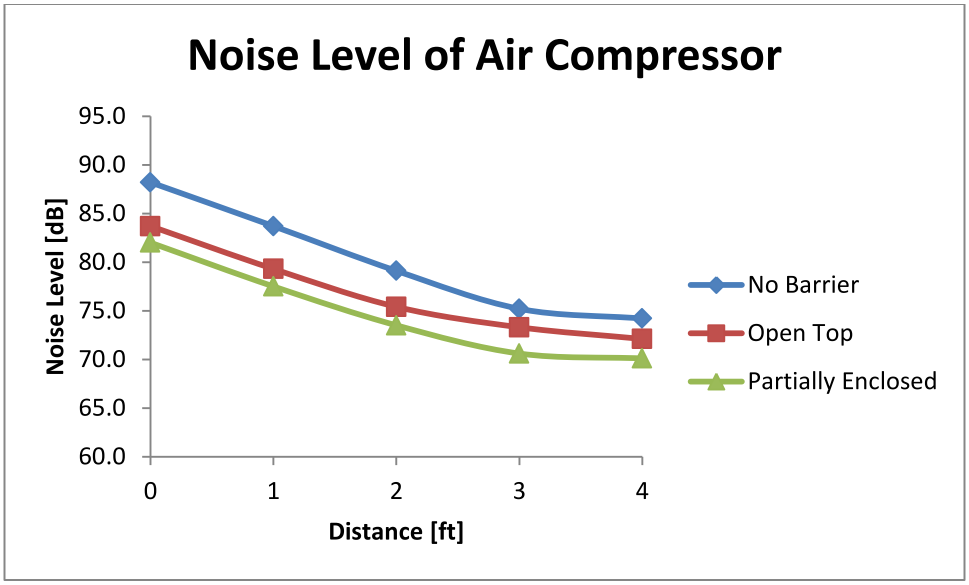



**Figure 24: Decibel meter readings of our air compressor at different distances and enclosures.**

We also did pressure testing (see figure 25 below) to make sure our piping system could maintain a certain pressure. The first tests went pretty bad with pressure leaking out of several orifices. Once we applied more thread tape, thread glue, PVC glue, and epoxy, our device held pressure much better. It currently only has a very slow leak when pumped up to the maximum pressure.

**Figure 25: Pressure Testing of PVC Tanks.**

The other non DVP test was with battery life. The battery was attached to the compressor and ran for 30 minutes straight. When in actual use, the air compressor is not on for more than 25-30 minutes in an hour. This proved to us that the battery would last for the hour-long Friday Club sessions. Also, during our Senior Project Expo, the device worked consistently from 4-7, with people using it off and on, with no problems.

The final thing we checked off the DVP was the total cost. The final cost came out to be $1014.04 which was under our goal of $1500.

# *Chapter 7: Conclusions and Recommendations*

## Conclusions

This project was designed to be a fun, inclusive, and safe way for persons in power chairs to compete in Bocce Ball. We found that using an air cannon would be fun for the athletes because of its power, and it could also provide exercise for the players when they need to change the horizontal and vertical launch angles. Also, adding game elements like backspin can make for an even more exciting and strategic game. We hope that by the end of this project, players in power chairs will be able to compete with a person without a disability on an equal playing field because of all the different ways they have of controlling their shots.

The analysis we conducted confirmed that this design will be able to throw the bocce ball the required distance. Also, the lifting mechanism will be able to be actuated by the users easily with only a small amount of force. Finally, the data sheets from the battery and air compressor manufacturers confirm that the battery will be able to last for all of Friday club, and the air compressor will be able to fill the air tank in a timely fashion.

Finally, the device can be altered in the future because the piping system is made out of PVC, and most of the parts used can be purchased. Dr. Kevin Taylor expressed interest in being able to have different attachments for filling the tank for users with different levels of ability. Though we are not doing this in this design, attachments can be added onto the piping system in the future to accommodate these different users to make the system more fun for them.

This design will be an effective means of satisfying our customer's needs. We will begin to procure materials and components for the design at their approval, and look forward to seeing it completed.

## Reccomendations

Though our project ended in success for us, there are some things we think would make the design even more robust. The device was only designed to last for one hour of Friday club, so if the users need the device to last even longer, then we would recommend another battery be purchased for longer games.

Another slight issue is that the turntable is too easy to turn, so when the user wants to raise and lower their shot, the turntable is likely to move away from where they are aiming. For this reason, it would be helpful to find a brake for the turntable when the user wants to adjust the angle with the hand wheel.

It would also be good to tweak the spin system a bit. It is disappointing that the spin has to be controlled by the helper, so the spin system could be modified so that the user is able to activate and deactivate it themselves.

The air compressor works fine and is effective at filling the secondary tank in a reasonable amount of time, but after continued use, it starts to get hot. Because of this issue, we recommend that the helper tries to limit the time that the air compressor stays on so that it has enough time to cool down between uses. It would also be nice to modify the compressor so that the on/off switch is more accessible to the helper. This is a lot more convenient than having to open the cart door every time the secondary tank needs to be refilled. Also, since the helper still needs to open the door and check the pressure in the secondary tank, this could be modified so a gauge can be placed on top of the cart where the user can monitor it without having to open up the cart.

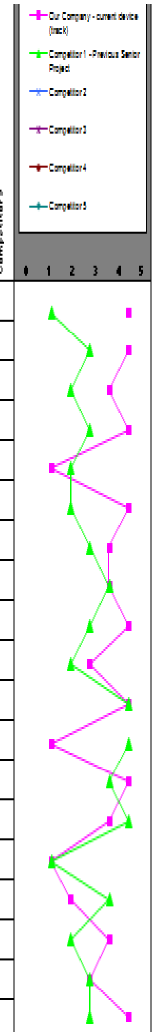
The extension rod coming off the scissor jack needs to be long for the user to reach it, but this causes high stress where the rod attaches to the jack. This connection has held up, but it would be a good idea to find a way to support the rod in two spots. This would help prevent a failure in the rod in extreme loading conditions, such as someone leaning or falling on the hand wheel.

Finally, the device is too tall to fit inside a car without laying it on its side. Future bocce ball launchers need to make more height considerations when building their design. Probably, the best way to transport the device is to use a pickup truck.

# *Appendices*

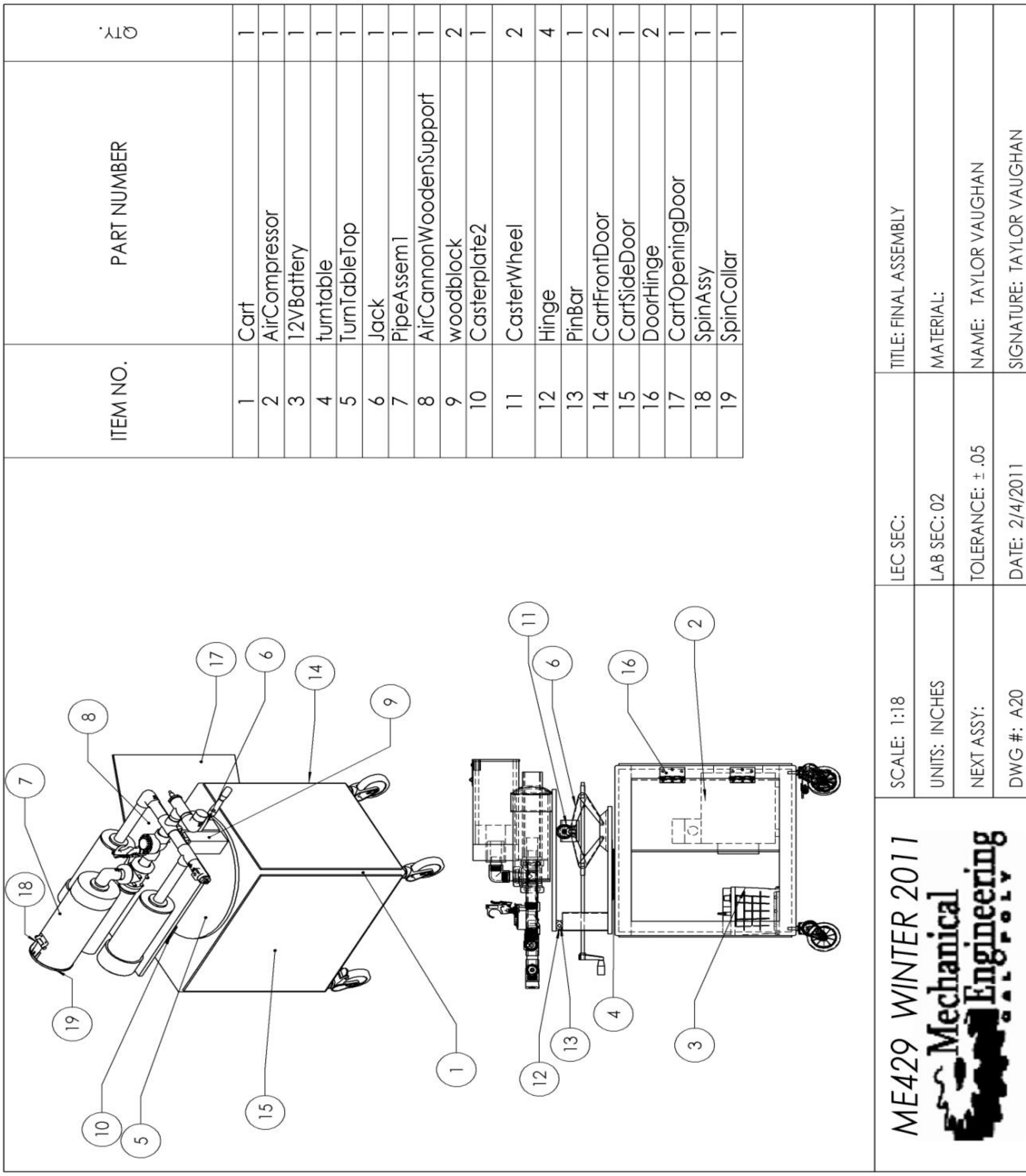
# Appendix A: QFD House of Quality

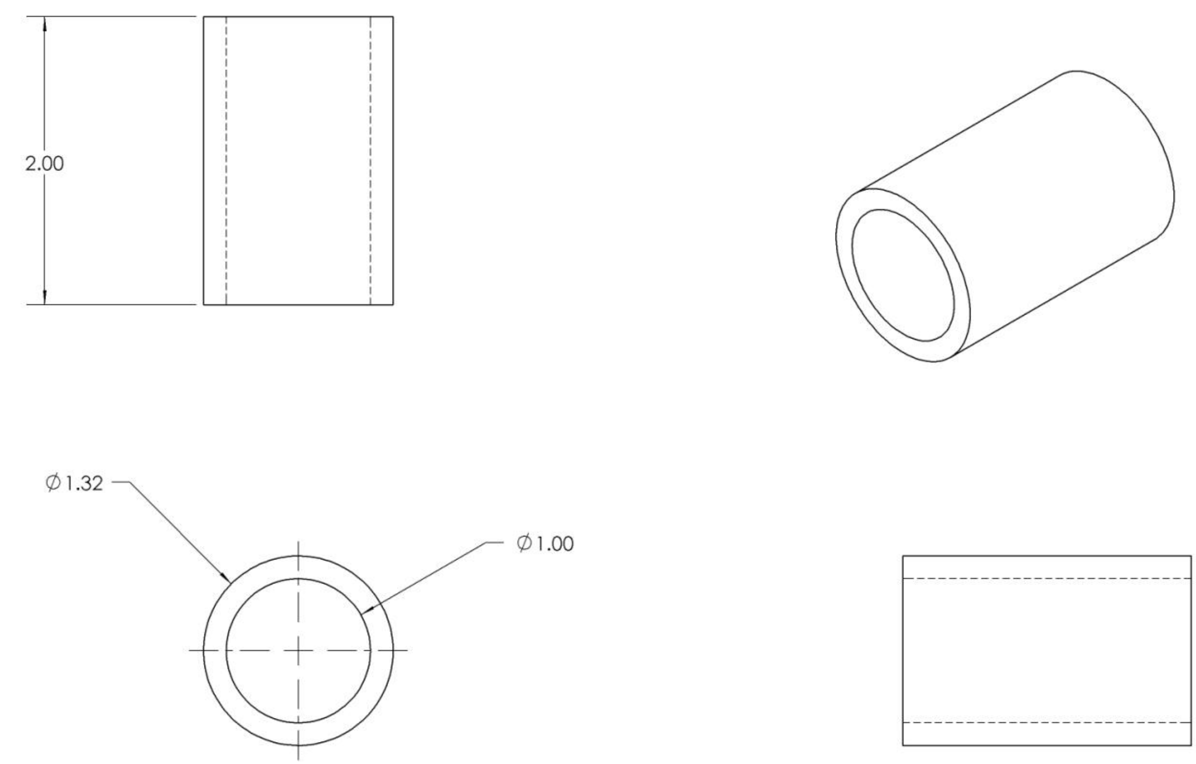
| Row # | Max Relationship Value in Row | Relative Weight | Weight / Importance | Demanded Quality (a.k.a. "Customer Requirements" or "Whats") \ Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") | Lasts 20,000 cycles | less than 1.5 ft in width | not bigger than 4 ft tall, 1.5 ft wide, 3 ft long, space | must not exceed 4 ft in height | Must not exceed 40 lbs | can shoot up to 91 feet | can be moved by 2 or less people | actuated with no more than 3 lbf | number of pinch points - 0 | number of sharp edges - 0 | No more than 10 custom parts | no wall plugs used | can shoot balls of 1.6" in diameter and 4.3" in diameter | less than $1500 | operated within 6"x6"x6" | ball is can be rotating when released | works on grass, turf, and compacted dirt | safety factor of at least 2 | Can be shot and reloaded within 20 seconds | Our Company - current device (track) | Competitor 1 - Previous Senior Project | Competitor 2 | Competitor 3 | Competitor 4 | Competitor 5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 9 | 7.8 | 6.0 | Lasts a couple years | Θ | | | | ▲ | ▲ | | ▲ | | | ▲ | | | O | | | | Θ | ▲ | 5 | 1 | | | | |
| 2 | 9 | 1.3 | 1.0 | Not wider than a wheelchair | | Θ | O | ▲ | ▲ | ▲ | Θ | | | | ▲ | | | ▲ | ▲ | ▲ | | O | | 5 | 3 | | | | |
| 3 | 9 | 3.9 | 3.0 | Easily Storable | | Θ | Θ | Θ | O | ▲ | ▲ | | | | ▲ | | | ▲ | ▲ | ▲ | ▲ | O | | 4 | 2 | | | | |
| 4 | 9 | 14.3 | 11.0 | Must not obstruct user's vision | | O | O | Θ | ▲ | ▲ | ▲ | ▲ | | | ▲ | | | ▲ | ▲ | | | ▲ | | 5 | 3 | | | | |
| 5 | 9 | | | Travel length of std BB court* | ▲ | | | | | Θ | | Θ | | | | O | O | Θ | ▲ | O | ▲ | ▲ | O | 1 | 2 | | | | |
| 6 | 9 | 5.2 | 4.0 | Lightweight | O | ▲ | O | O | Θ | ▲ | Θ | ▲ | | | O | | O | O | | ▲ | | Θ | | 5 | 2 | | | | |
| 7 | 9 | 9.1 | 7.0 | Easily transportable | | O | Θ | O | Θ | ▲ | Θ | | | | ▲ | | | ▲ | | ▲ | O | O | | 4 | 3 | | | | |
| 8 | 9 | | | User operated with minimal force* | ▲ | | | | | Θ | | Θ | | | | O | ▲ | O | Θ | O | | | Θ | 4 | 4 | | | | |
| 9 | 9 | | | Free of major safety hazards* | | ▲ | ▲ | ▲ | O | Θ | ▲ | O | | | ▲ | | | ▲ | ▲ | ▲ | | ▲ | ▲ | 5 | 3 | | | | |
| 10 | 9 | 11.7 | 9.0 | Built with as many standard parts as possible | ▲ | ▲ | ▲ | ▲ | ▲ | O | | O | | | Θ | O | ▲ | Θ | ▲ | O | | ▲ | O | 3 | 2 | | | | |
| 11 | 9 | | | Cannot use wall plug* | | | | | | O | | Θ | | | | Θ | | | O | O | Θ | | Θ | 5 | 5 | | | | |
| 12 | 9 | | | Launch both pallina and bocce balls* | | | | | | Θ | | O | | | ▲ | | Θ | O | | O | | | O | 1 | 5 | | | | |
| 13 | 9 | 10.4 | 8.0 | Relatively low cost | ▲ | ▲ | O | ▲ | O | O | ▲ | O | | | Θ | O | O | Θ | ▲ | O | ▲ | Θ | O | 5 | 4 | | | | |
| 14 | 9 | 14.3 | 11.0 | Controlled with limited hand motion | | | | | | Θ | | Θ | | | | ▲ | ▲ | ▲ | Θ | O | | | Θ | 4 | 5 | | | | |
| 15 | 9 | 2.6 | 2.0 | Includes spin | ▲ | ▲ | ▲ | | ▲ | ▲ | ▲ | O | | | ▲ | ▲ | O | O | O | Θ | O | | O | 1 | 1 | | | | |
| 16 | 9 | 0.0 | 0.0 | Can be used on various surfaces | | | | | | O | | | | | | | | ▲ | | O | Θ | | | 2 | 4 | | | | |
| 17 | 9 | 11.7 | 9.0 | Sturdy | Θ | O | O | O | O | ▲ | O | ▲ | | | Θ | | | Θ | | ▲ | | Θ | ▲ | 4 | 2 | | | | |
| 18 | 9 | | | Incorporates some exercise for user* | | | | | | O | | Θ | | | | ▲ | ▲ | ▲ | Θ | O | | | Θ | 3 | 3 | | | | |
| 19 | 9 | 7.8 | 6.0 | Fast load/shoot time | ▲ | | | | | ▲ | | O | | | | O | O | O | O | O | | | Θ | 5 | 3 | | | | |
| # | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| # | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| # | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| # | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| # | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Target or Limit Value | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Difficulty (0-Easy to Accomplish, 10-Extremely | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Max Relationship Value in Column | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | | | | | |
| | | | | Weight / Importance | 223.4 | 181.8 | 259.7 | 264.9 | 244.2 | 258.4 | 206.5 | 264.9 | | | 358.4 | 106.5 | 103.9 | 416.9 | 201.3 | 187.0 | 49.4 | 384.4 | 292.2 | | | | | | |
| | | | | Relative Weight | 5.6 | 4.5 | 6.5 | 6.6 | 6.1 | 6.5 | 5.2 | 6.6 | | | 9.0 | 2.7 | 2.6 | 10.4 | 5.0 | 4.7 | 1.2 | 9.6 | 7.3 | | | | | | |




Powered by QFD Online (http://www.QFDOnline.com)

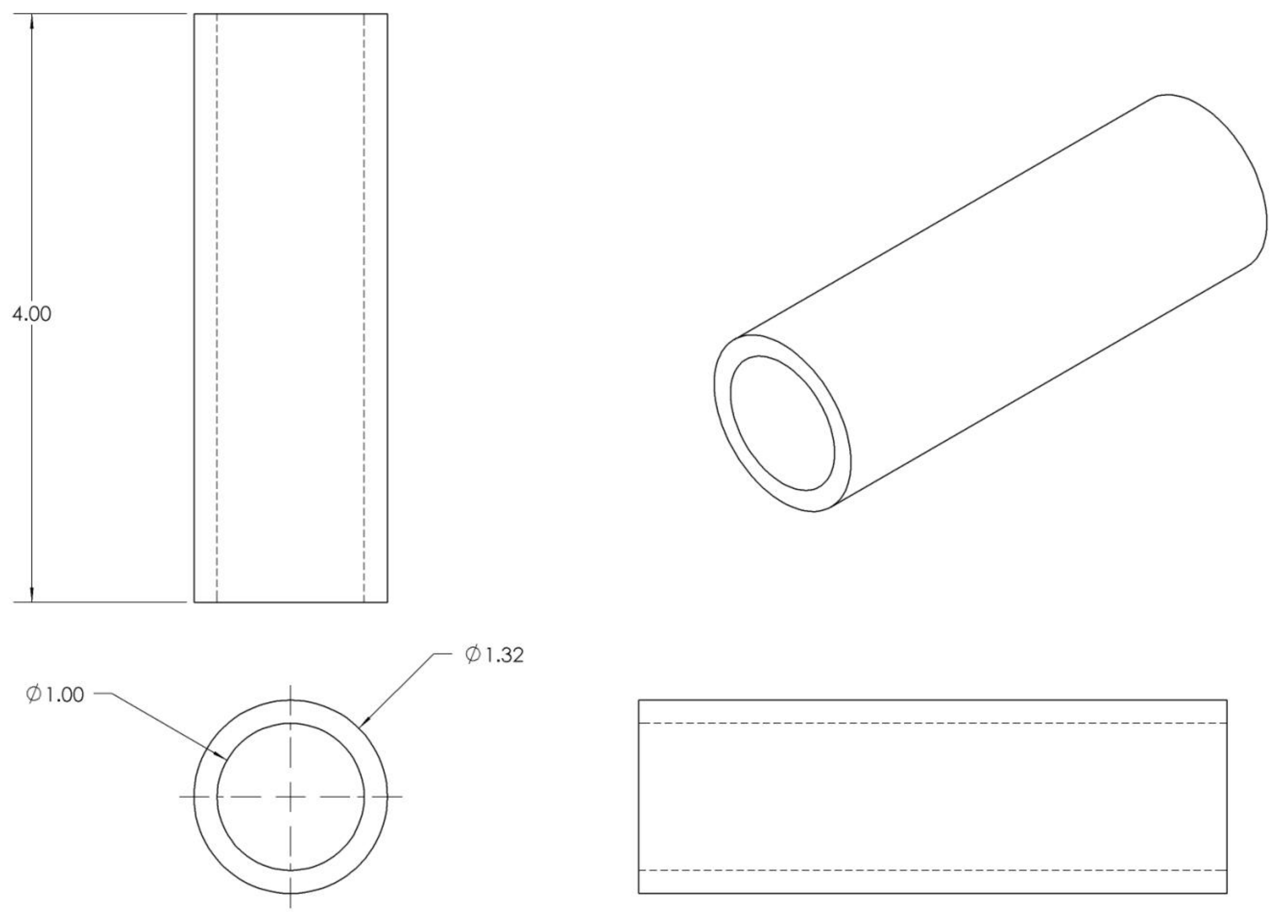
## Appendix B: Drawing Packet





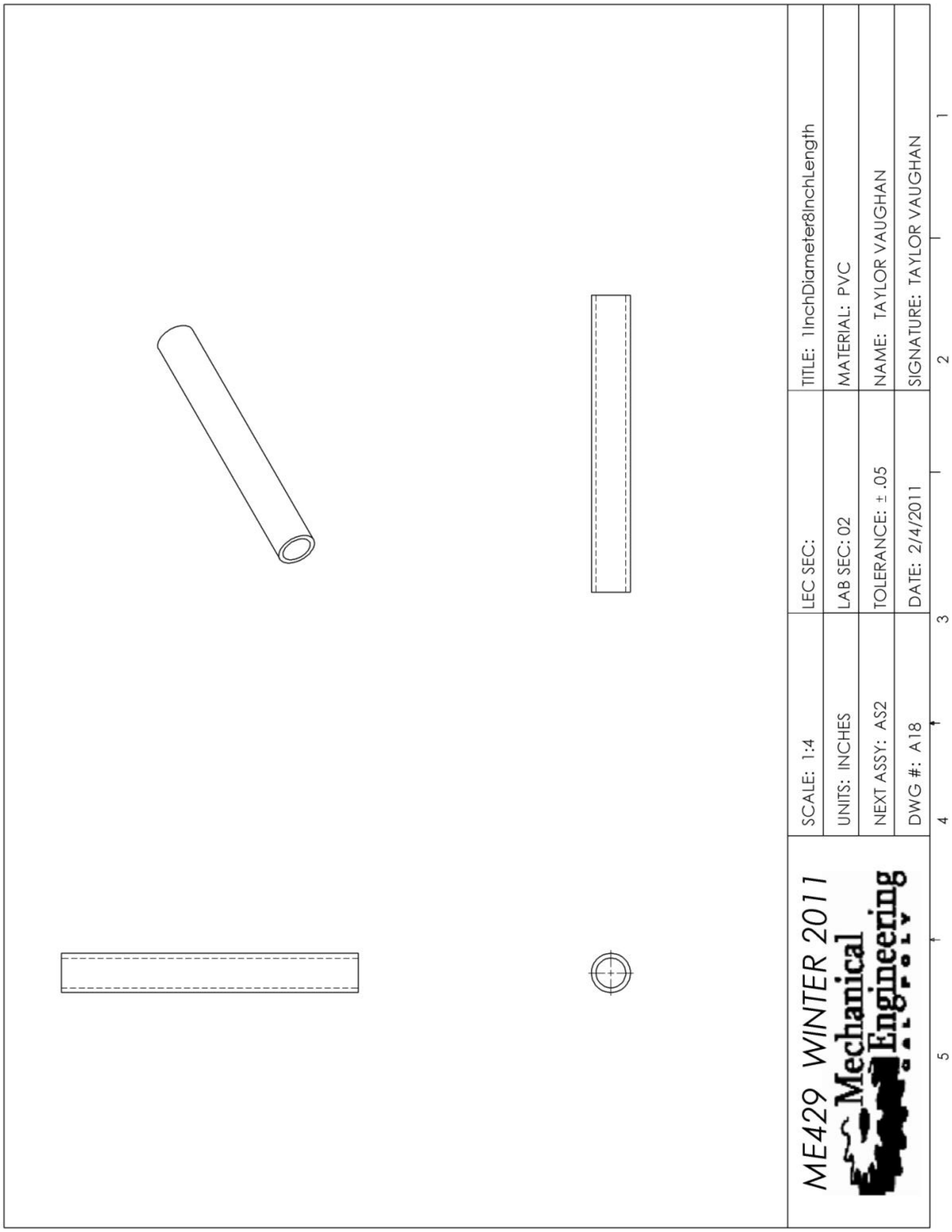

| | | | |
|---|---|---|---|
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:1 | LEC SEC: | TITLE: 1 INCH DIA 2 INCH LENGTH |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A20 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

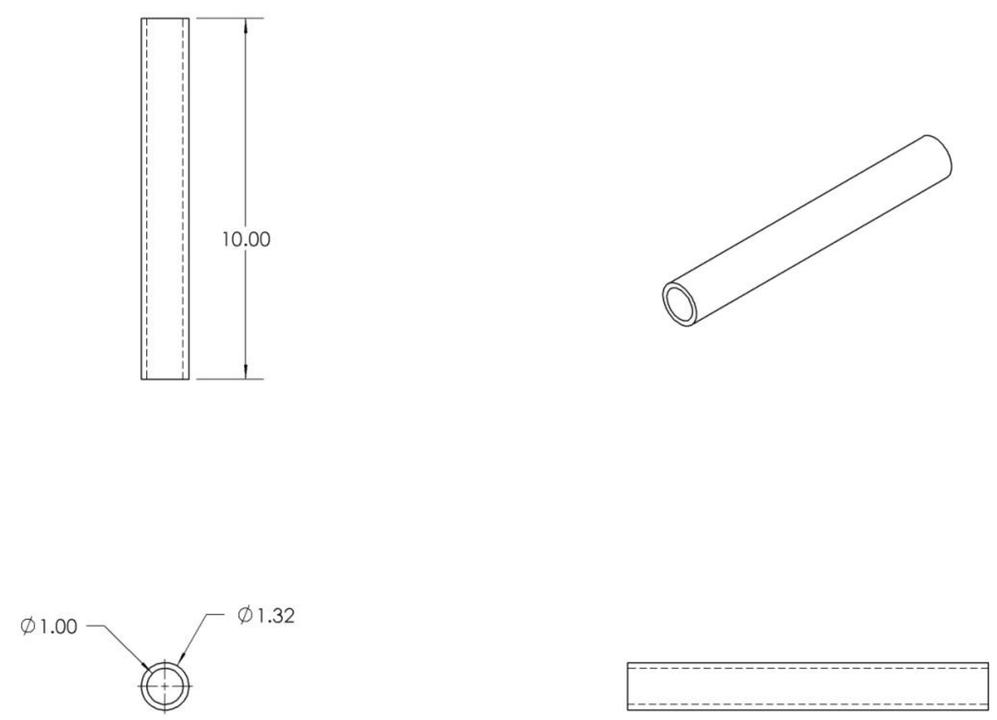
5 4 3 2 1




| | | | |
|---|---|---|---|
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:1 | LEC SEC: | TITLE: 1 INCH TUBE |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A19 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

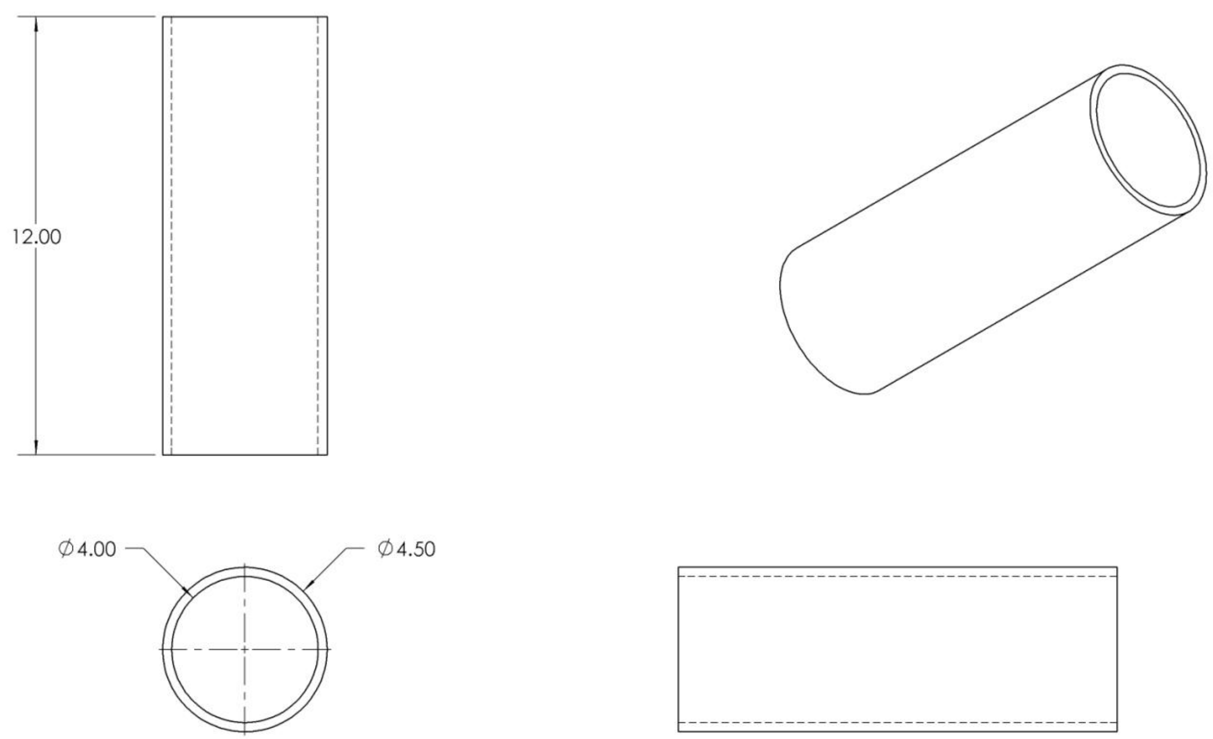
5 4 3 2 1


ME429 WINTER 2011
Mechanical Engineering
SCALE: 1:4
UNITS: INCHES
NEXT ASSY: AS2
DWG #: A18
LEC SEC:
LAB SEC: 02
TOLERANCE: ± .05
DATE: 2/4/2011
TITLE: 1InchDiameter8InchLength
MATERIAL: PVC
NAME: TAYLOR VAUGHAN
SIGNATURE: TAYLOR VAUGHAN
5
4
3
2
1



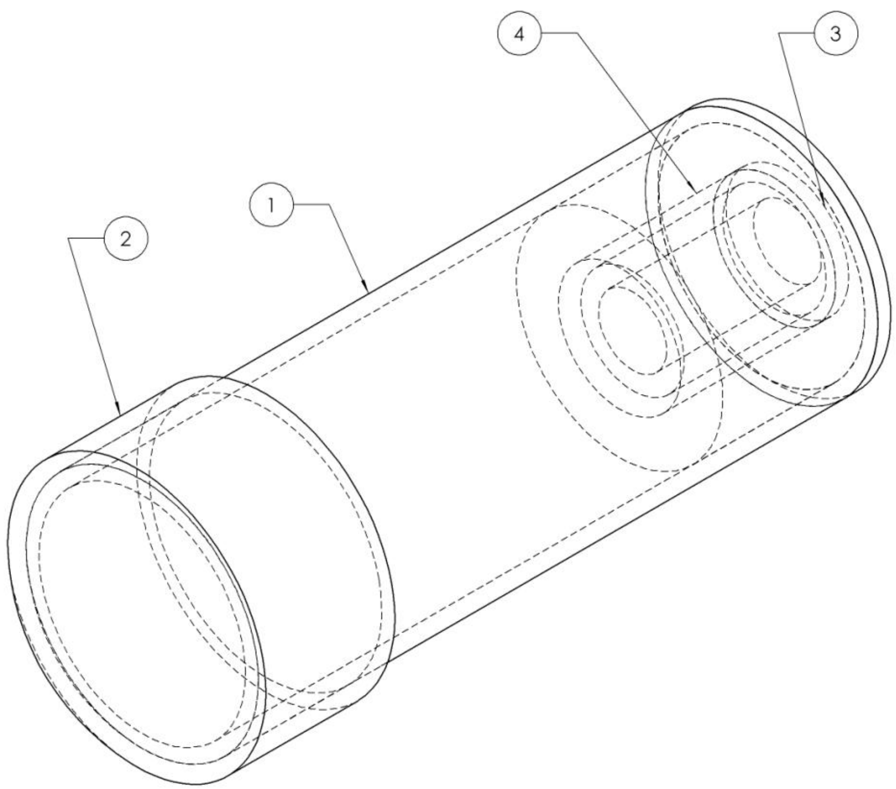

| | | | |
|---|---|---|---|
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:4 | LEC SEC: | TITLE: 1InchDiameter10InchLength |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A18 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1




| ME 429 WINTER 2011 | SCALE: 1:4 | LEC SEC: 01 | TITLE: AIR TANK TUBING |
|---|---|---|---|
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS3 | TOLERANCE: ±.05IN | NAME: TAYLOR VAUGHAN |
| | DWG #: A01 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

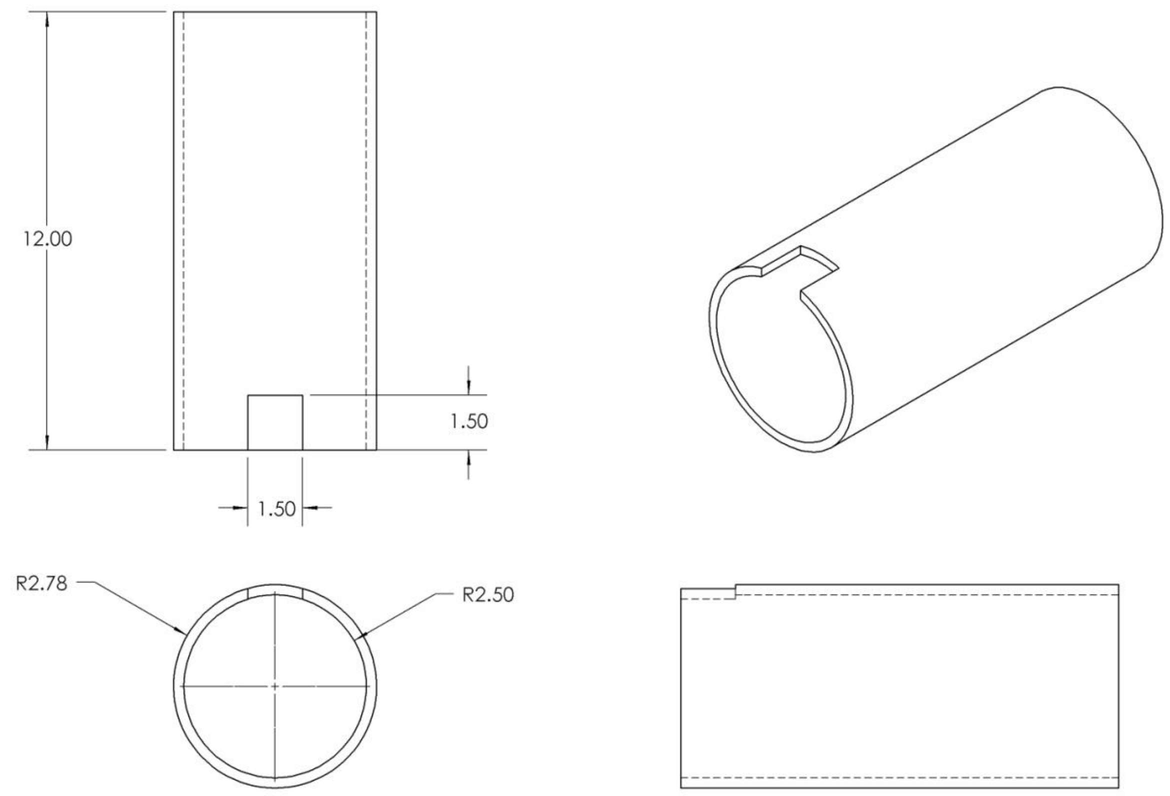
5 4 3 2 1




| ITEM NO. | PART NUMBER | QTY. |
|---|---|---|
| 1 | 1Ft4InchTube | 1 |
| 2 | 4InchEndCap | 1 |
| 3 | 2InchTo1InchReducer | 1 |
| 4 | 4InchTo2InchReducer | 1 |

| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:1 | LEC SEC: | TITLE: AIR TANK ASSEMBLY |
|---|---|---|---|
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A22 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

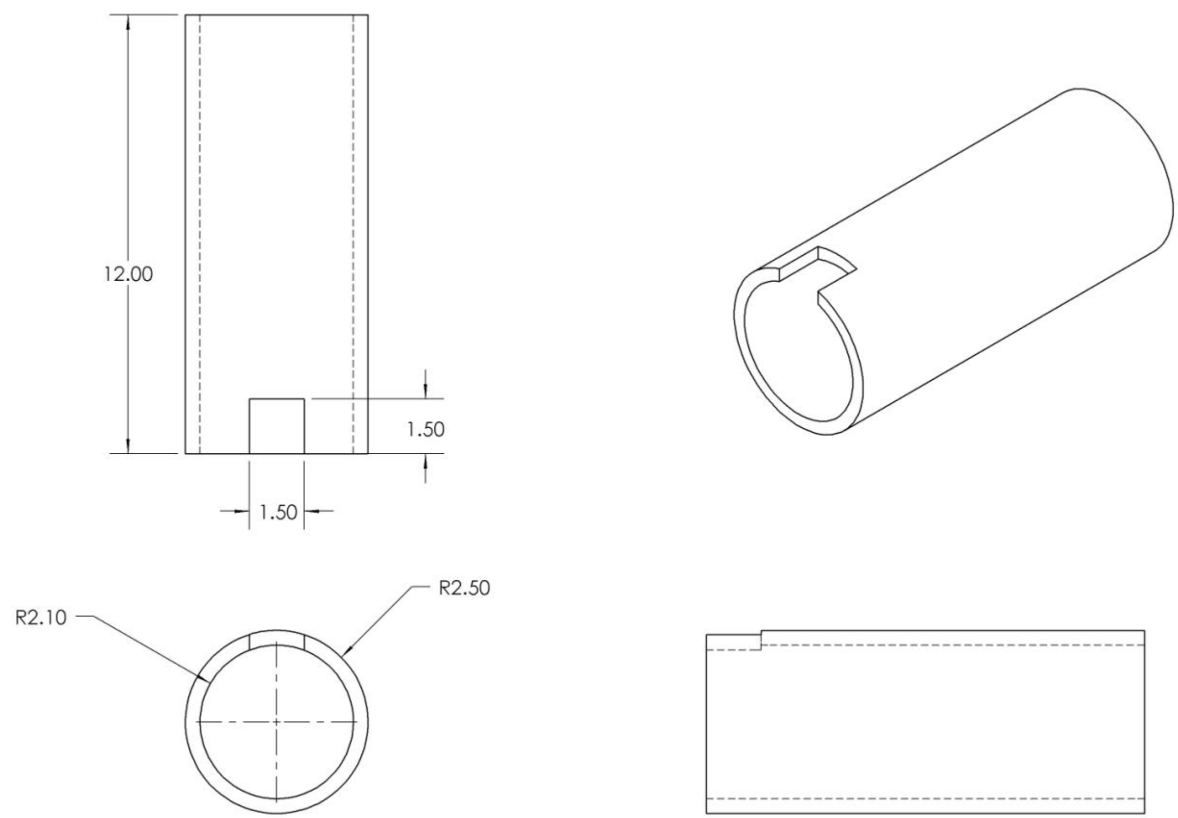
5 4 3 2 1




ME429 WINTER 2011
Mechanical Engineering
CAL POLY

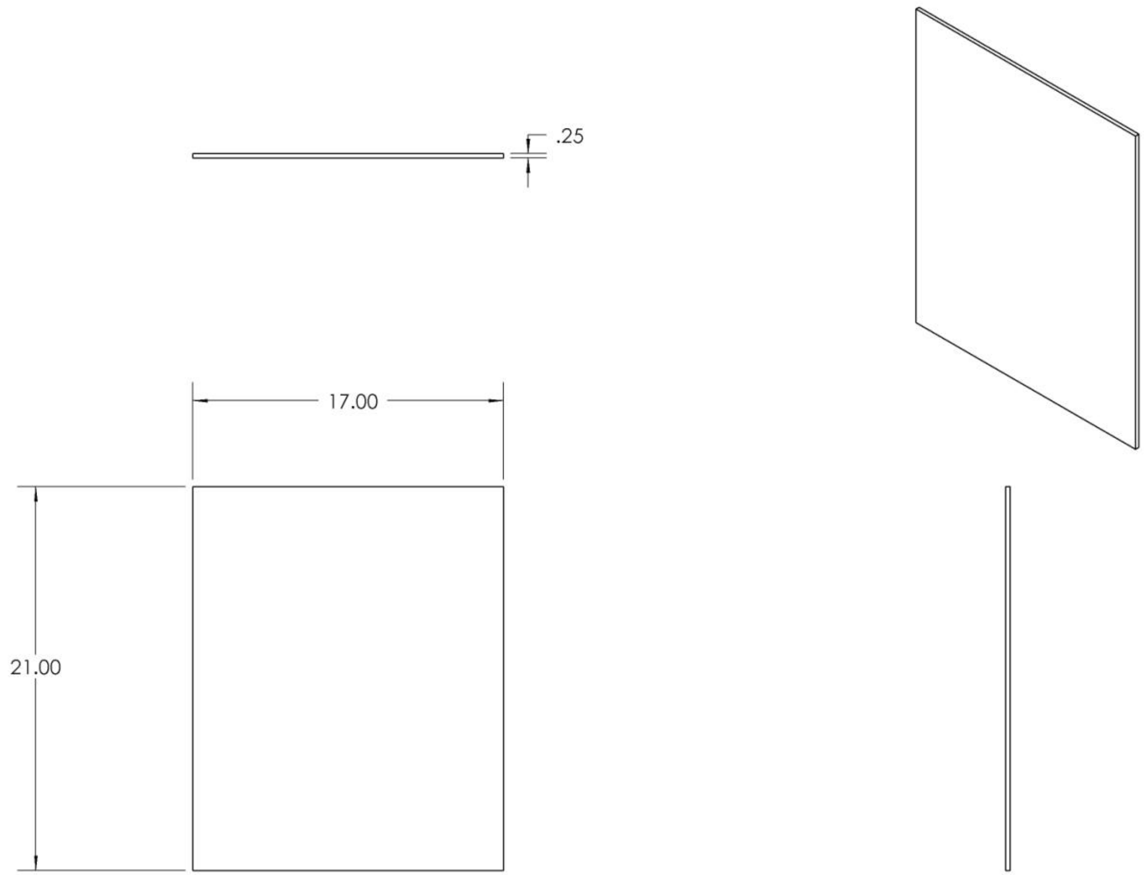
| | | |
|---|---|---|
| SCALE: 1:4 | LEC SEC: | TITLE: BOCCE BARREL |
| UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| DWG #: A02 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



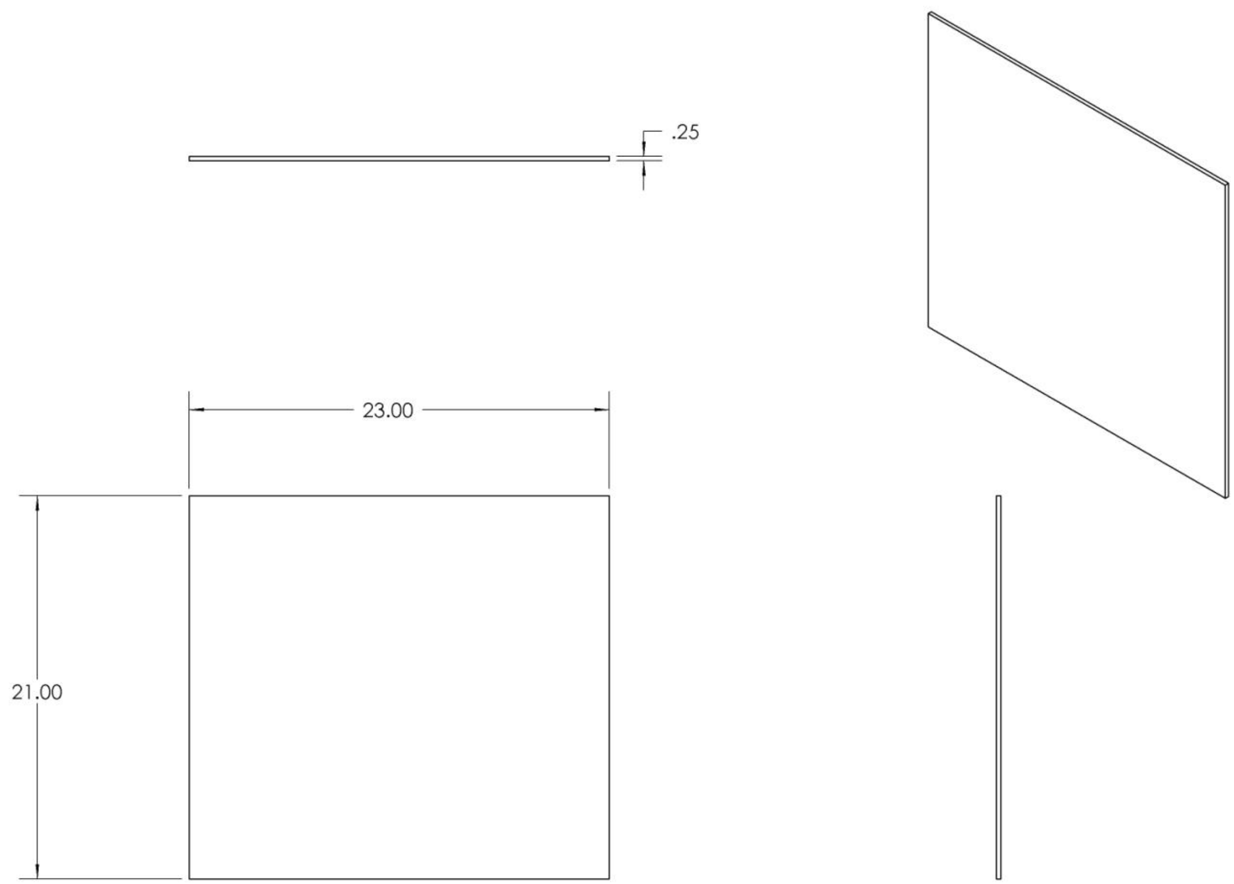

| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:4 | LEC SEC: | TITLE: BOCCE BARREL RUBBER INSERT |
|---|---|---|---|
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: RUBBER |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A04 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



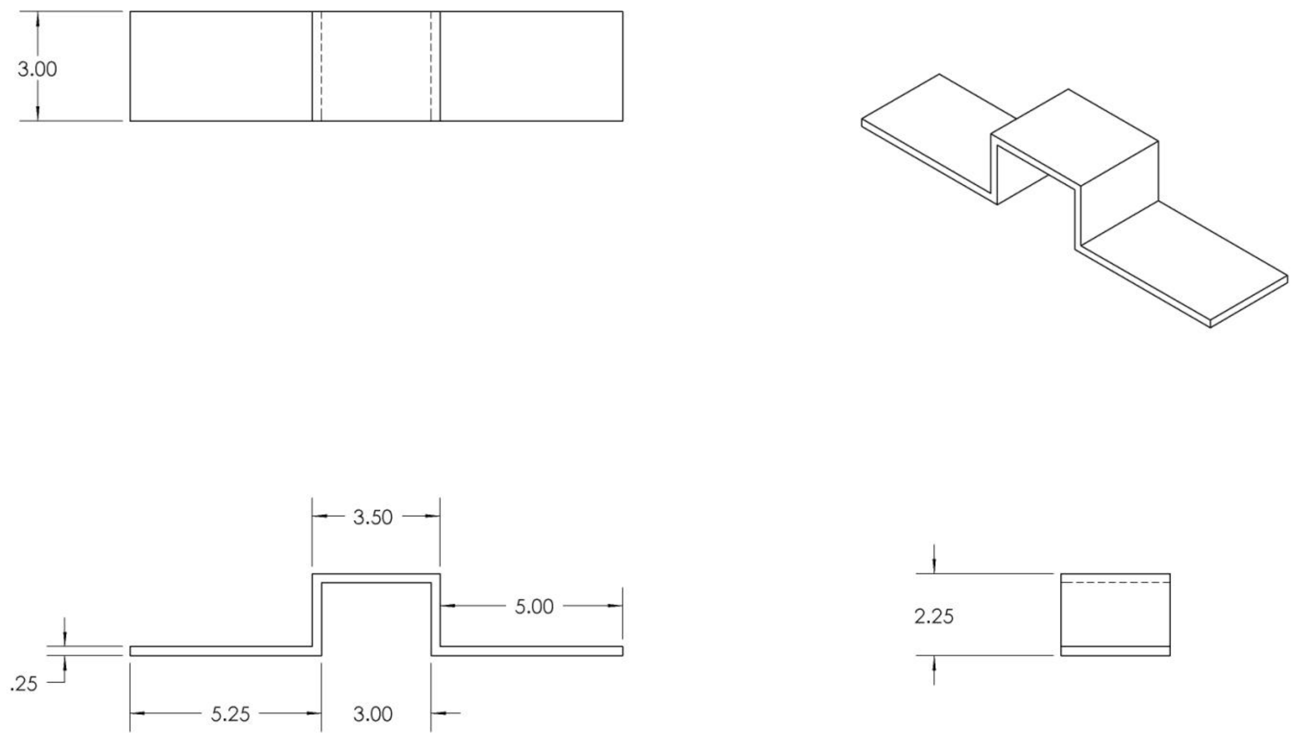

| | | | |
|---|---|---|---|
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:8 | LEC SEC: | TITLE: CART FRONT PANEL |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: STEEL |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A08 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



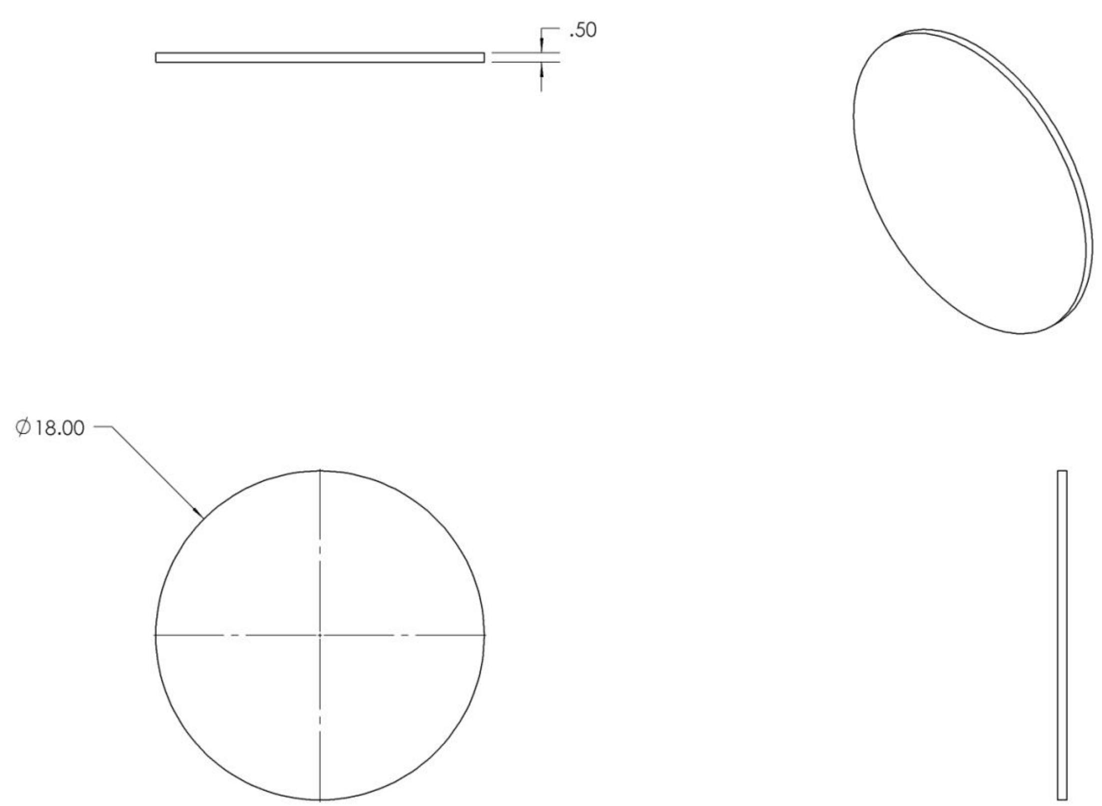

| | | | |
|---|---|---|---|
| ME429 WINTER 2011 | SCALE: 1:8 | LEC SEC: | TITLE: CART SIDE PANEL |
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: STEEL |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A09 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



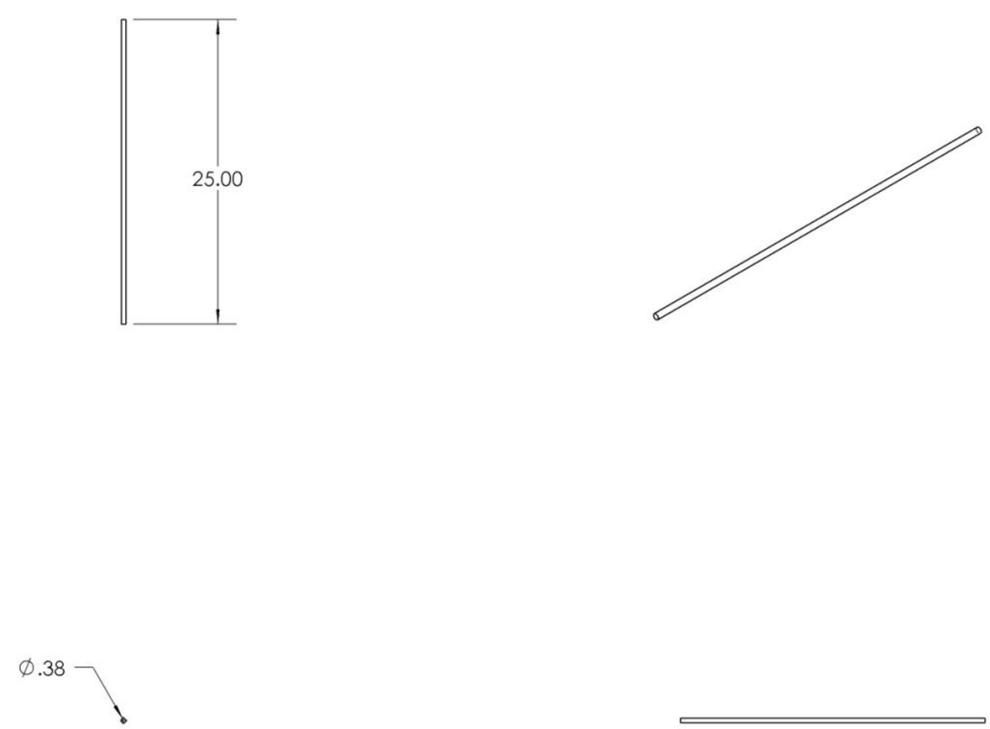

| ME429 WINTER 2011 — Mechanical Engineering CAL POLY | SCALE: 1:4 | LEC SEC: | TITLE: CASTER FRAME |
|---|---|---|---|
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: STEEL |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A17 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



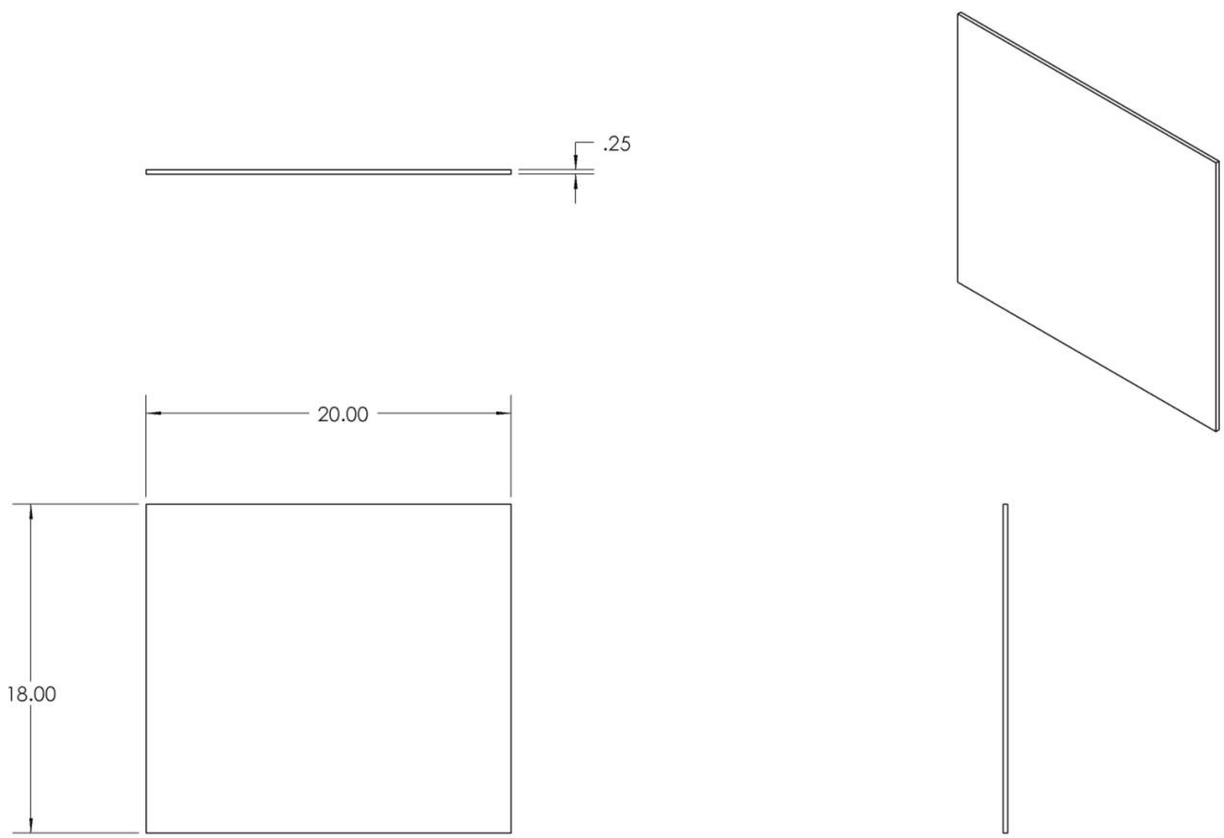

| | | | |
|---|---|---|---|
| ME429 WINTER 2011<br>Mechanical Engineering CAL POLY | SCALE: 1:8 | LEC SEC: | TITLE: CIRCULAR SUPPORT BOARD |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PLYWOOD |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A13 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



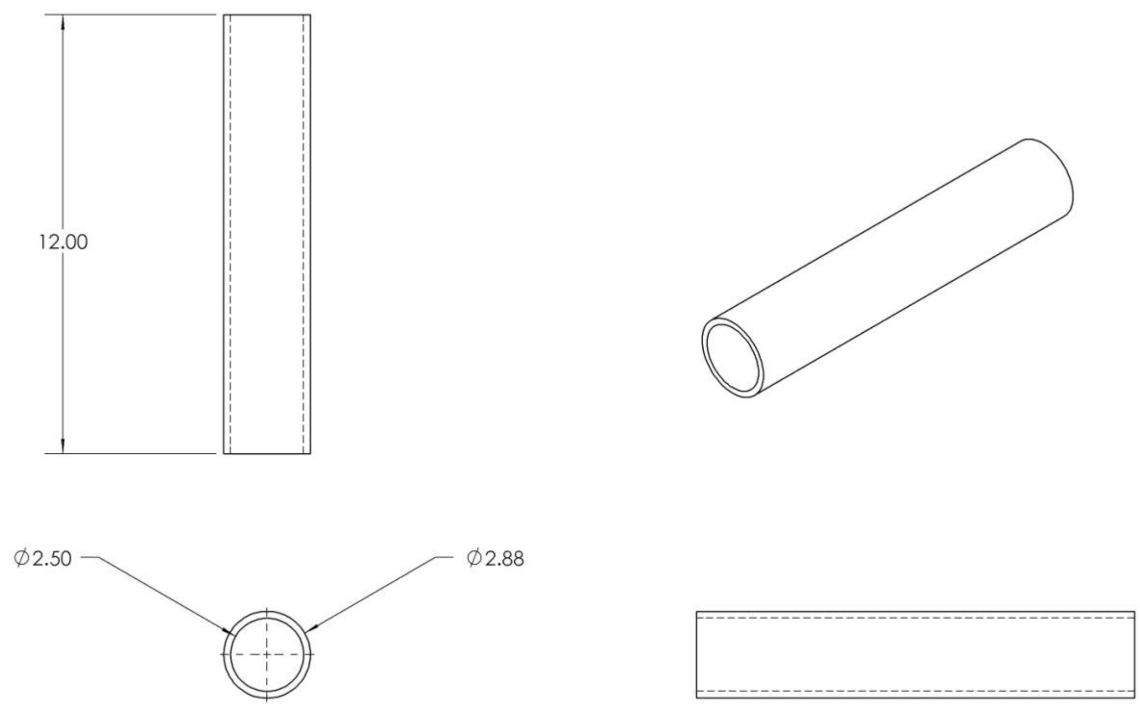

| ME429 WINTER 2011 | SCALE: 1:12 | LEC SEC: | TITLE: EXTEND JACK SCREW ROD |
|---|---|---|---|
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: STEEL |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A16 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



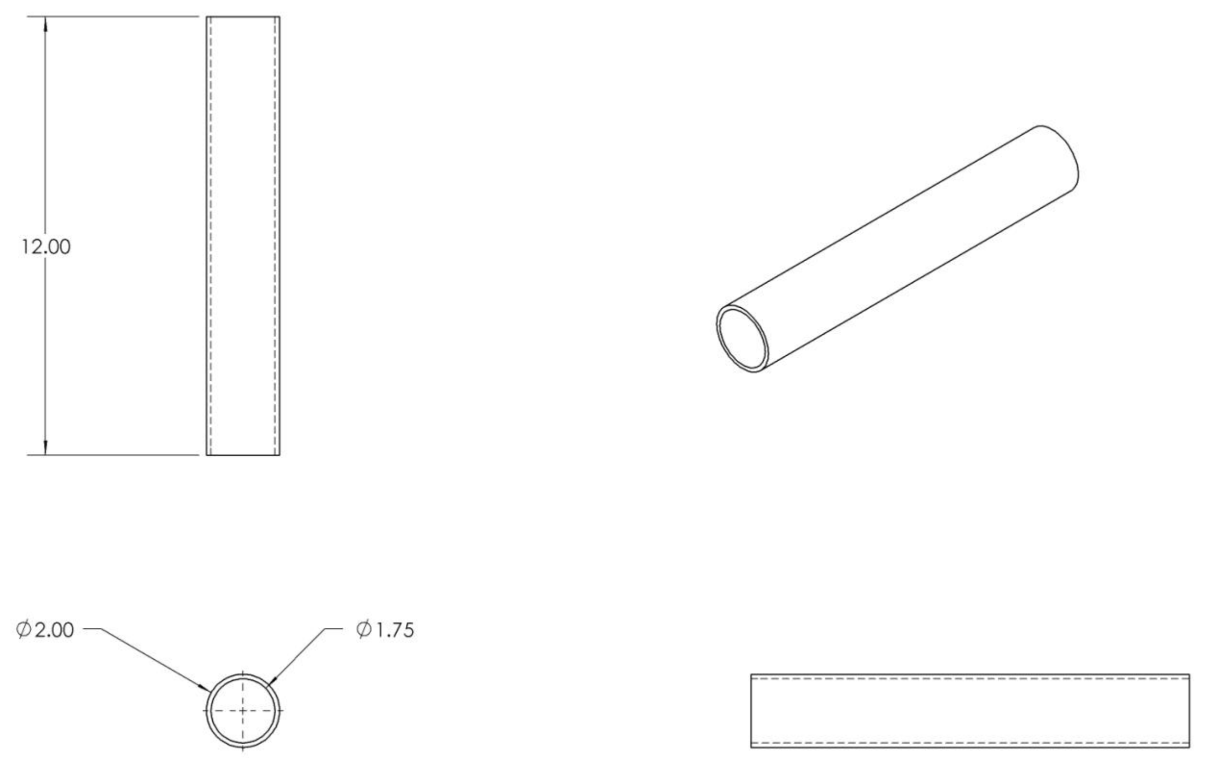

| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:8 | LEC SEC: | TITLE: OPENING CART SIDE PANEL |
|---|---|---|---|
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: STEEL |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A10 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



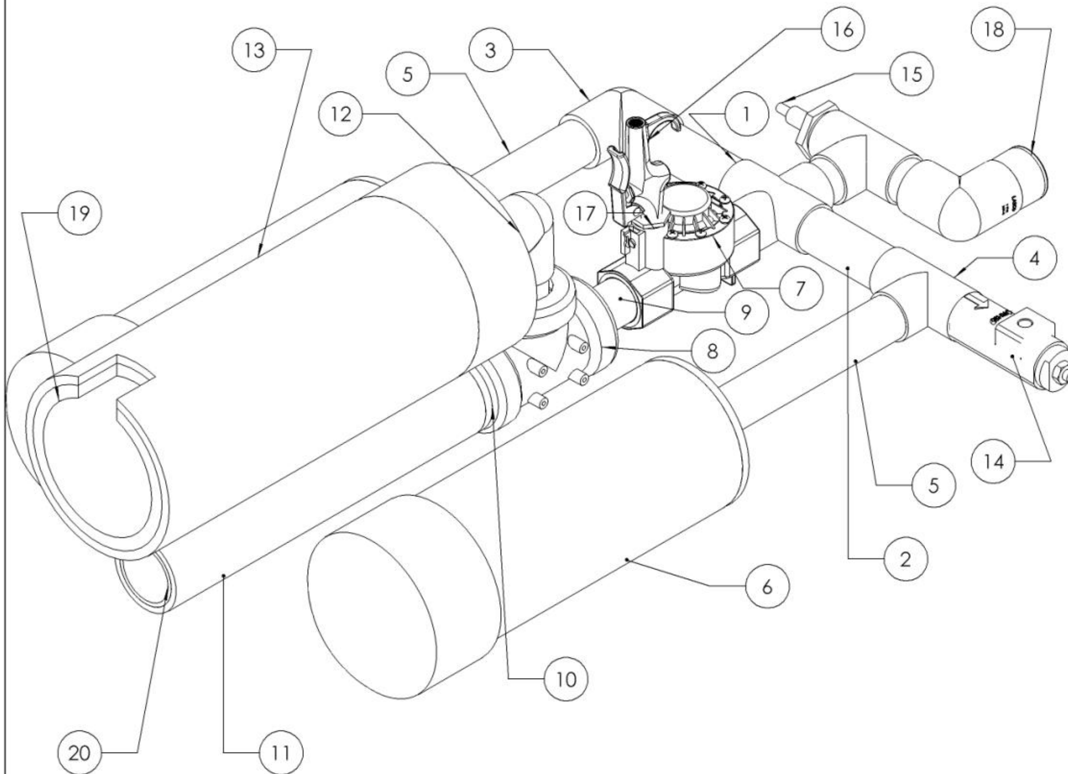

| | | | |
|---|---|---|---|
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:4 | LEC SEC: | TITLE: PALINO BARREL |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A03 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1




| | | | |
|---|---|---|---|
| ME429 WINTER 2011 | SCALE: 1:4 | LEC SEC: | TITLE: PALINO BARREL INSERT |
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: RUBBER |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A05 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

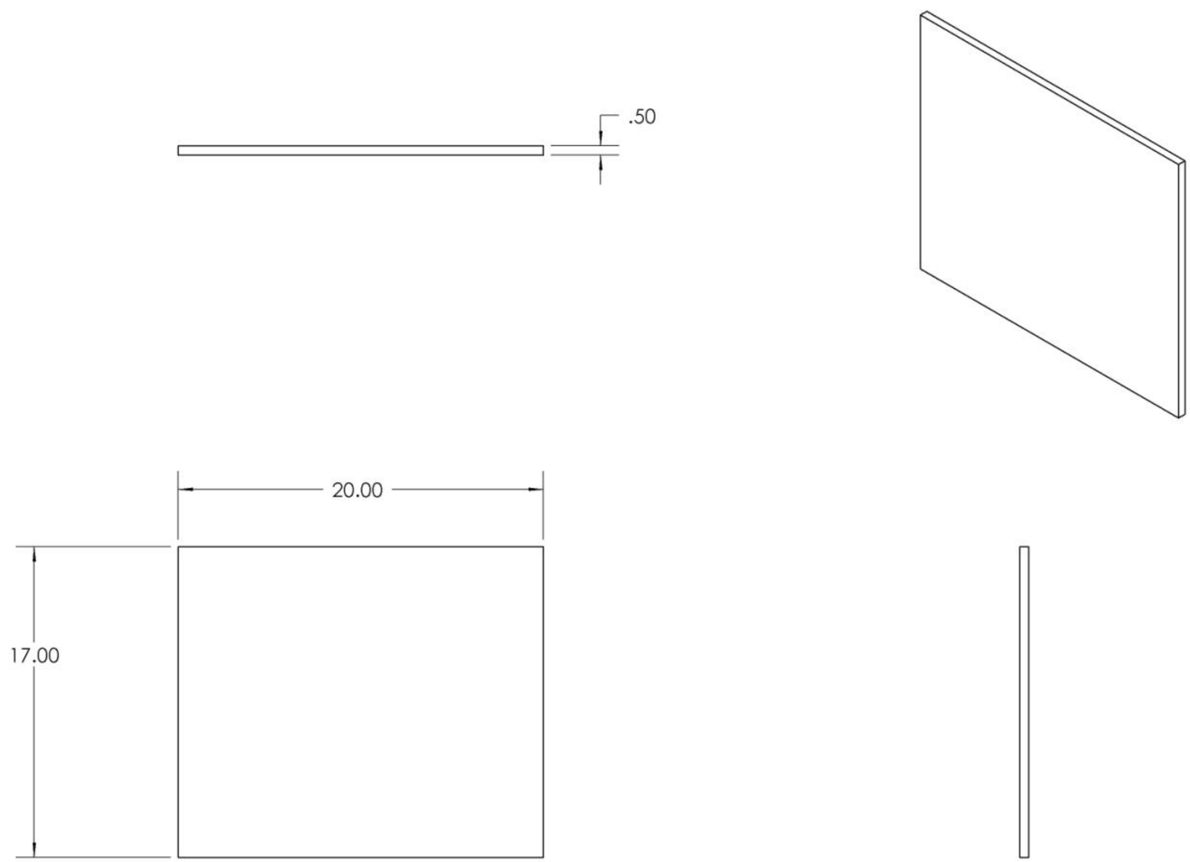
5 4 3 2 1




| ITEM NO. | PART NUMBER | QTY. |
| --- | --- | --- |
| 1 | 4WayConnector | 1 |
| 2 | 1InchTube | 2 |
| 3 | 1InchElbow | 3 |
| 4 | 1InchTeeConnector | 2 |
| 5 | 1inchD8InchL | 2 |
| 6 | 4InchTank | 2 |
| 7 | sprinklervalve | 1 |
| 8 | 1inch3wayvalve | 1 |
| 9 | 1InchD1InchL | 6 |
| 10 | 2.5InchTo1InchReducer | 2 |
| 11 | PalinoBarrel | 1 |
| 12 | 2Inchto5Expander | 1 |
| 13 | BocceBarrel | 1 |
| 14 | PopSafetyValve | 1 |
| 15 | BikeValve | 1 |
| 16 | blowgun | 1 |
| 17 | 3-8To1-4Coupling | 1 |
| 18 | Gauge | 1 |
| 19 | RubberSleeve | 1 |
| 20 | PalinoInsert | 1 |

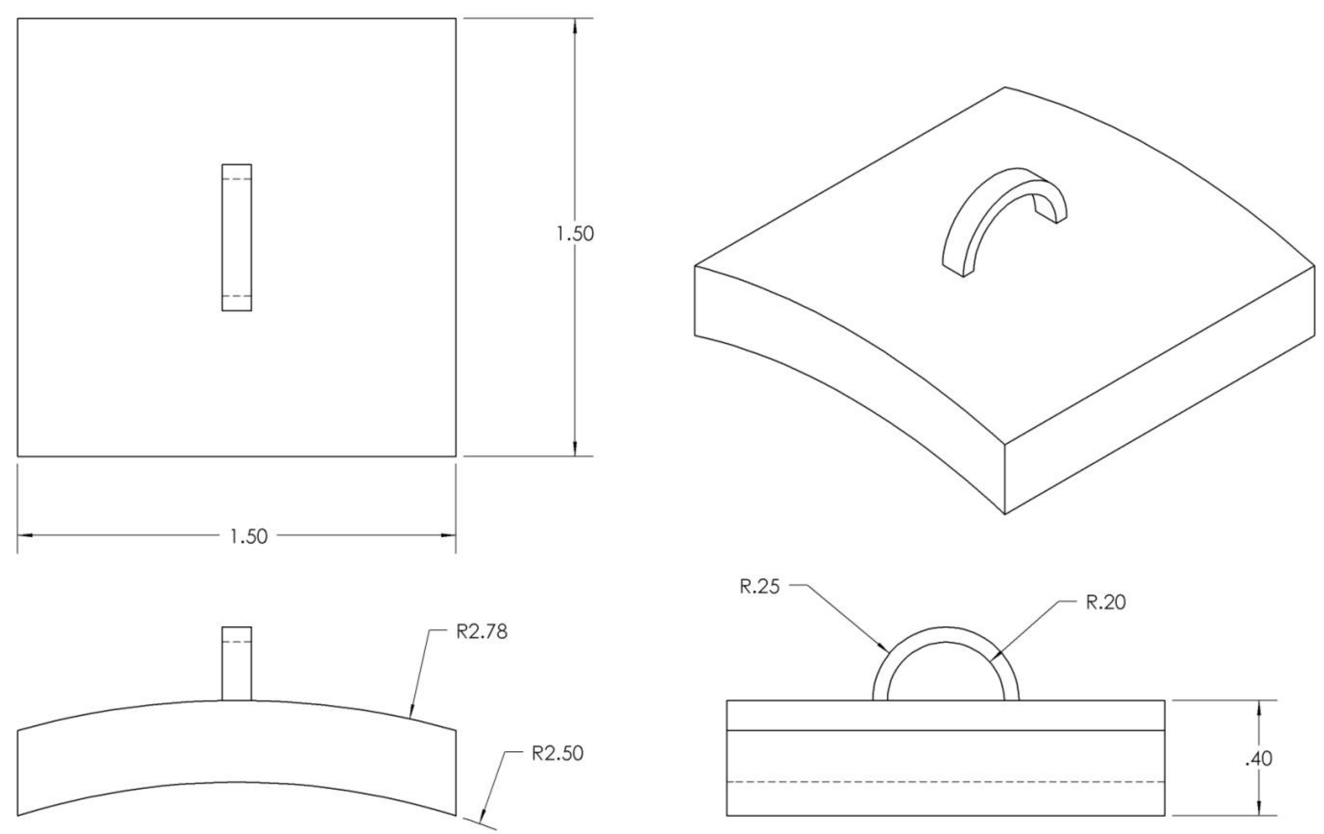
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:8 | LEC SEC: | TITLE: PIPING ASSEMBLY |
| --- | --- | --- | --- |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A21 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



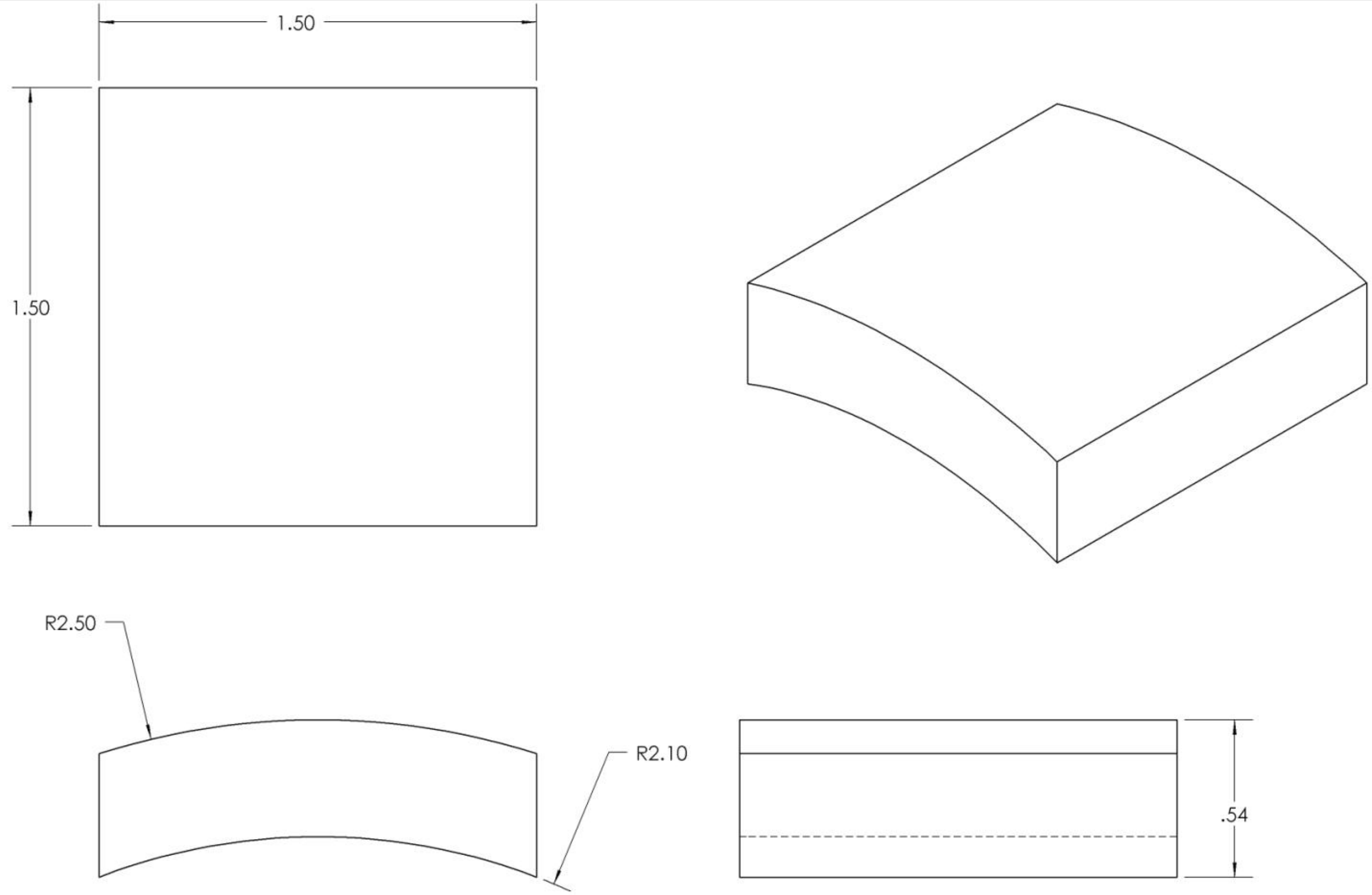

| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:8 | LEC SEC: | TITLE: PIPING SUPPORT BOARD |
|---|---|---|---|
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PLYWOOD |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A14 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



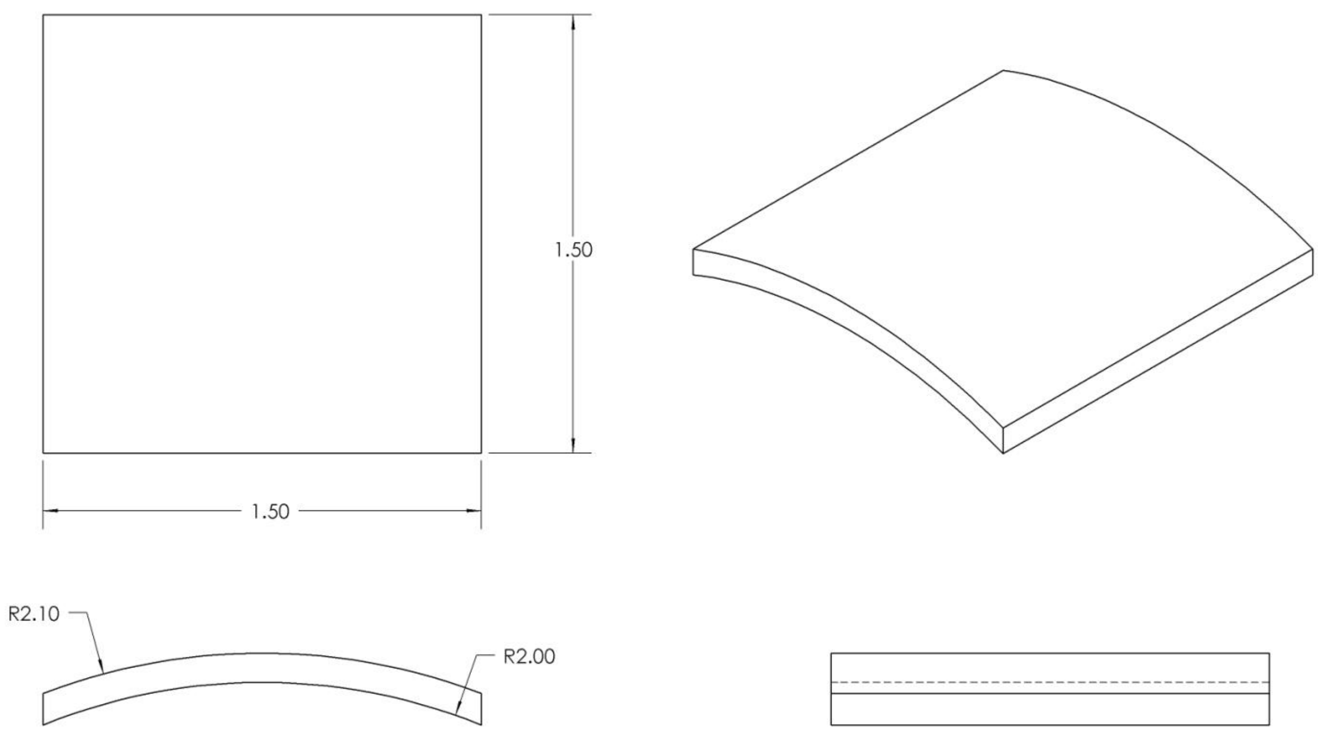

| | | | |
|---|---|---|---|
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 2:1 | LEC SEC: | TITLE: PVC SPIN CUTOUT |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A11 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1



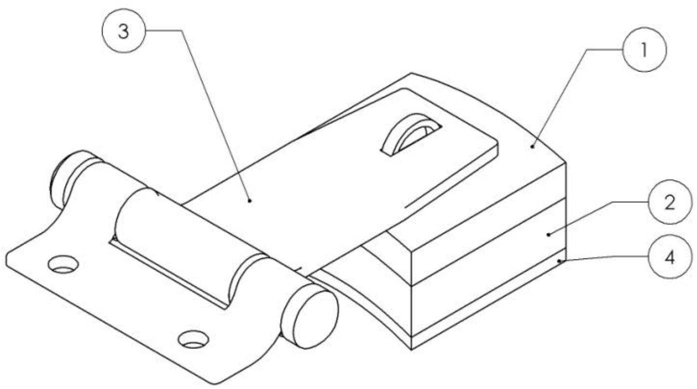

| | | | |
|---|---|---|---|
| ME429 WINTER 2011 | SCALE: 2:1 | LEC SEC: | TITLE: RUBBER INSERT CUTOUT |
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: RUBBER |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A12 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1




| | | | |
|---|---|---|---|
| ME429 WINTER 2011 | SCALE: 2:1 | LEC SEC: | TITLE: RUBBER SPIN PIECE |
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: STICKY RUBBER |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A07 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

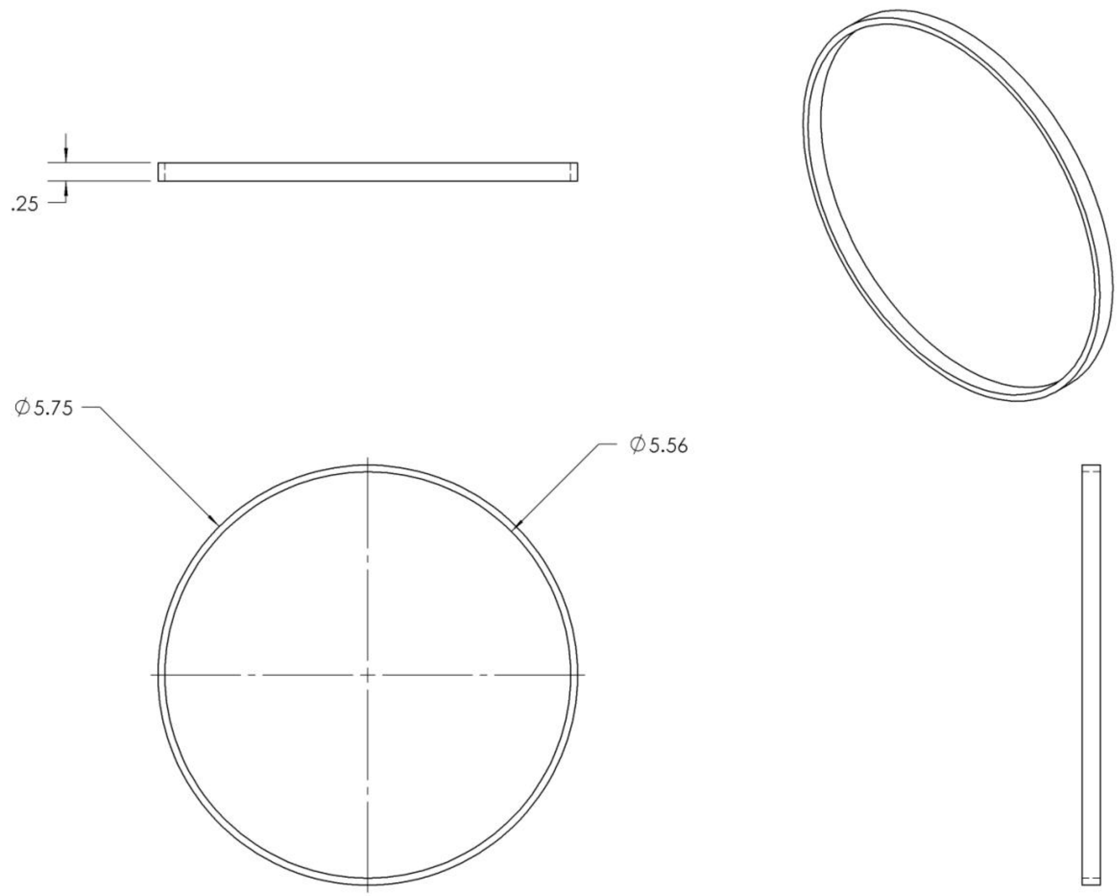
5 4 3 2 1




| ITEM NO. | PART NUMBER | QTY. |
|---|---|---|
| 1 | SpinCutoutTop | 1 |
| 2 | RubberCutout | 1 |
| 3 | SpinHinge | 1 |
| 4 | RubberSpinPatch | 1 |

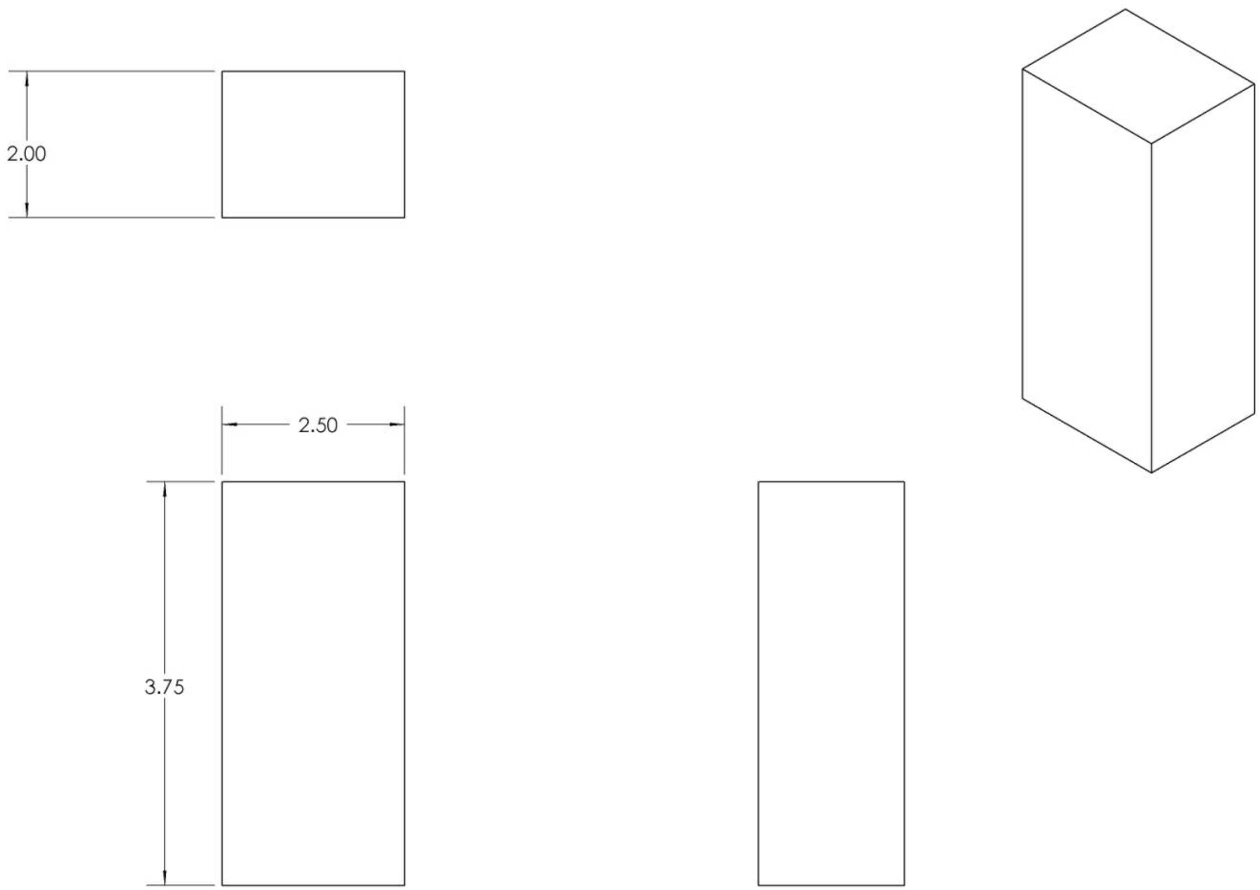
| ME429 WINTER 2011 | SCALE: 1:1 | LEC SEC: | TITLE: SPIN ASSEMBLY |
|---|---|---|---|
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A21 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1




| | | | |
|---|---|---|---|
| ME429 WINTER 2011 Mechanical Engineering CAL POLY | SCALE: 1:2 | LEC SEC: | TITLE: SPIN LOCK COLLAR |
| | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PVC |
| | NEXT ASSY: AS2 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A06 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1




| | | | |
|---|---|---|---|
| ME429 WINTER 2011 | SCALE: 1:2 | LEC SEC: | TITLE: WOODEN BLOCK |
| Mechanical Engineering CAL POLY | UNITS: INCHES | LAB SEC: 02 | MATERIAL: PLYWOOD |
| | NEXT ASSY: AS1 | TOLERANCE: ± .05 | NAME: TAYLOR VAUGHAN |
| | DWG #: A15 | DATE: 2/4/2011 | SIGNATURE: TAYLOR VAUGHAN |

5 4 3 2 1

## Appendix C: Vendors List

**McMasterCarr Contact Info:**

| | |
|---|---|
| Address: | 200 Aurora Industrial Pkwy. |
| | Aurora, OH 44202-8087 |
| Mail: | P.O. Box 94930 |
| | Cleveland, OH 44101-4930 |
| E-Mail: | cle.sales@mcmaster.com |
| Phone: | (330) 995-5500 |
| | (330) 342-3330 |
| Fax: | (330) 995-9600 |

**FactorysOnline.com Contact Info**

| | |
|---|---|
| Address: | 322 Culver Blvd. #224 |
| | Playa Del Rey, CA 90293 |
| E-Mail: | info@Factorysonline.com |
| Phone: | (310)-301-4480 |

**Schumacher Contact Info:**

| | |
|---|---|
| Address: | Schumacher Electric Corporation |
| | 801 Business Center Drive |
| | Mount Prospect, IL 60056 |
| E-Mail: | info@schumacherelectric.com |
| Phone: | (800)-621-5485 |
| Fax: | (847)-298-1698 |

**Northern Tool Contact Info:**

| | |
|---|---|
| Address: | 2800 Southcross Drive West |
| | Burnsville, Minnesota 55306 |
| Phone: | (800)-221-0516 |
| Fax: | (952)-882-6927 |

**Ace Miners Hardware Contact Info:**

| | |
|---|---|
| Address: | 2034 Santa Barbara Ave, |
| | San Luis Obispo, Ca, 93401 |
| Phone: | (805) 543-2191 |
| Fax: | (805) 543-2197 |

**Orbit Irrigation Products, Inc Contact Info:**

| | |
|---|---|
| Mail: | P.O. Box 328 |
| | Bountiful, Utah 84011 |
| Phone: | (801)-299-5555 |
| Fax: | (801)-299-5549 |

**Creative Shelters Contact Info:**

| | |
|---|---|
| Mail: | 1792 N. 42nd Street |
| | Springfield, OR 97477 |
| Phone: | (541)-988-5876 |
| Fax: | (541)-988-3502 |

**FlexPVC.com Contact Info:**

| | |
|---|---|
| Mail: | PVC Distributors |
| | 1970 N Leslie St #632 |
| | Pahrump, NV 89060 |
| Phone: | 888-PVC-FLEX |

**Choice Tool Supply Contact Info:**

| | |
|---|---|
| Address: | 2206 Sammonds Road |
| | Plant City, Florida 33563 |
| Phone: | (813)-764-0612 |
| Fax: | (813)-764-0621 |

**C&H Distributors Contact Info:**

| | |
|---|---|
| Mail: | C&H Distributors, LLC. |
| | 770 South 70th Street |
| | P.O. Box 14770 |
| | Milwaukee, WI 53214-0770 |
| E-Mail: | customerservice@chdist.com |
| Phone: | (888)-316-2223 |
| Fax: | (800)-336-1331 |

**Farm & Home Supply Center Contact Info:**

| | |
|---|---|
| Mail: | 19411 S. Malloy Praire Rd. |
| | Cheney, WA. 99004 |
| Phone: | (509)-239-4507 |
| Fax: | (509)-239-4593 |

## Appendix D: Component Specification and Data Sheets

### Battery Specifications:

| Specification | |
|---|---|
| **Nominal Voltage** | 12 volts |
| **Nominal Capacity** | 77° F (25° C) |
| 20-hr. (2.50A) | 50.0 Ah |
| 10-hr. (4.65A) | 46.5 Ah |
| 5-hr. (8.50A) | 42.5 Ah |
| 1-hr. (30.00A) | 30.0 Ah |
| **Approximate Weight** | 32 lbs (14.5 kgs) |
| **Internal Resistance** (approx.) | 11 mΩ |

### Air Compressor Specification sheet:

KEY SPECS

| | |
|---|---|
| **CFM at 90 PSI** | 2.54 |
| **Max. PSI** | 120 |
| **Total Cylinders** | 1 |
| **Required Power** | 12V |
| **Dimensions L x W x H (in.)** | 11 7/32 x 7 7/8 x 9 |
| **Manufacturer Warranty** | 2 years consumer use / 1 year commercial use |
| **Ship Weight** | 10.25 lbs |

# Appendix E: Detailed Analysis

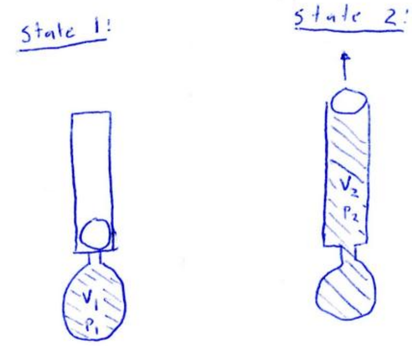
Barrel Length Sample Calculations: USING WORK ON BALL

$P_1$ = Initial Pressure = 30 psi

$V_1$ = Tank Volume = 300 in$^3$

Barrel length = 1 ft = 12 in

Barrel ID = 4.25"




ASSUMPTIONS:

1) Polytropic expansion, $PV^n = c$

2) Adiabatic process, $n = 1.4$

$$P_1 V_1^n = P_2 V_2^n$$

$$P_1 \left(\frac{V_1}{V_2}\right)^n = P_2$$

find $V_2$

$$V_2 = V_1 + \frac{\pi}{4} d^2 L$$

$$V_2 = 300 + \left(\frac{\pi}{4} 4^2\right) 12$$

$$V_2 = 450 \text{ in}^3$$

$$P_2 = 17 \text{ psi}$$

$$W = \frac{P_2 V_2 - P_1 V_1}{1 - n}$$

$$\boxed{W = 3368 \text{ lb-in}}$$

Repeat using different sized barrels and initial pressures to find best Length.

# Calculations for Power Screw Lifting

Estimate number of threads per inch ≈ 10 tpi

Friction Factor for steel on steel = 0.25

Screw size = 0.375"

Crank Length = 4"

Input Force = 3 lbf

ASSUMPTIONS:

1) SQUARE THREADS

2)

USE EQ'N

$$T_R = \frac{F d_m}{2}\left(\frac{l + \pi f d_m}{\pi d_m - f l}\right)$$

$T_R$ = Crank Length × Input Force

$T_R$ = 12 in-lbf

$$l = \frac{1}{tpi}$$

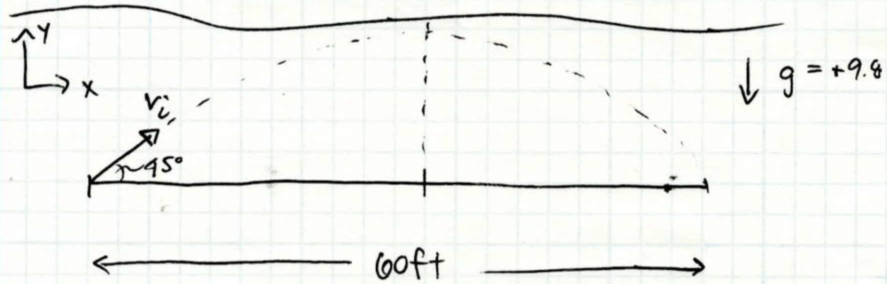
$$l = \frac{1}{10}''$$

$$12\,in\text{-}lbf = \frac{F(0.375'')}{2}\left(\frac{\frac{1}{10}'' + \pi(0.25)(0.375'')}{\pi(0.375'') - 0.25(\frac{1}{10}'')}\right)$$

**Max Force F on screw = 187 lbf**

Far more than we need for our application

# PROJECTILE MOTION ANALYSIS




DISTANCE OF COURT: 60ft ⇒ 18.3m

MASS: 2.2 lbs ⇒ 1.01 kg

IN Y-DIR: $v_f^2 = v_i^2 + 2a\Delta s$

@ $\Delta s = 30ft$ (OR $\frac{18.3m}{2}$) ⇒ $0 = (v_i \sin 45°)^2 + 2(-9.81\ m/s^2)\left(\frac{18.3m}{2}\right)$

$0 = (v_i^2)\sin^2 45 - 179.5\ m^2/s^2$

$v_i^2 = 359.05\ m^2/s^2$

$v_i = 18.9\ m/s$

OR ⇒ $v_i = 62\ ft/s$

KINETIC ENERGY IN BALL:

$K.E. = \frac{1}{2} m v_i^2$

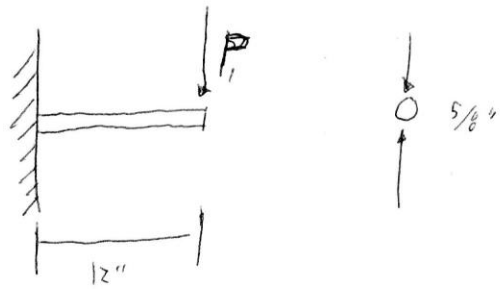
$= \frac{1}{2}(2.2\ lb)\left[\frac{1\ slug}{32.2\ lb}\right](62\ ft/s)$

K.E. = 131.72 ft-lb OR 1580 in-lb

## Rod Stress Sample Calculation:

### Assumptions:

1. $\sigma_y = 40{,}000$ psi
2. Rod is a cantilever beam




### Given:

$\sigma_y = 40{,}000$ psi

$n_s = 2$

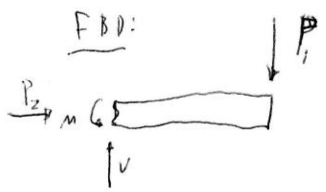
$L = 12''$

$d = 5/8''$

### Find:

$P_{1max}$

### FBD:




Max stress location is on top of rod at connection

$$\sigma = \frac{My}{I} \qquad \sigma_{max} = \frac{\sigma_y}{2} = 20{,}000 \text{ psi}$$

$$20{,}000 \text{ psi} = \frac{M\left(\frac{5}{16}''\right)}{\frac{\pi}{64}\left(\frac{5}{8}\right)^4}$$

$M_{max} = 480$ in-lb

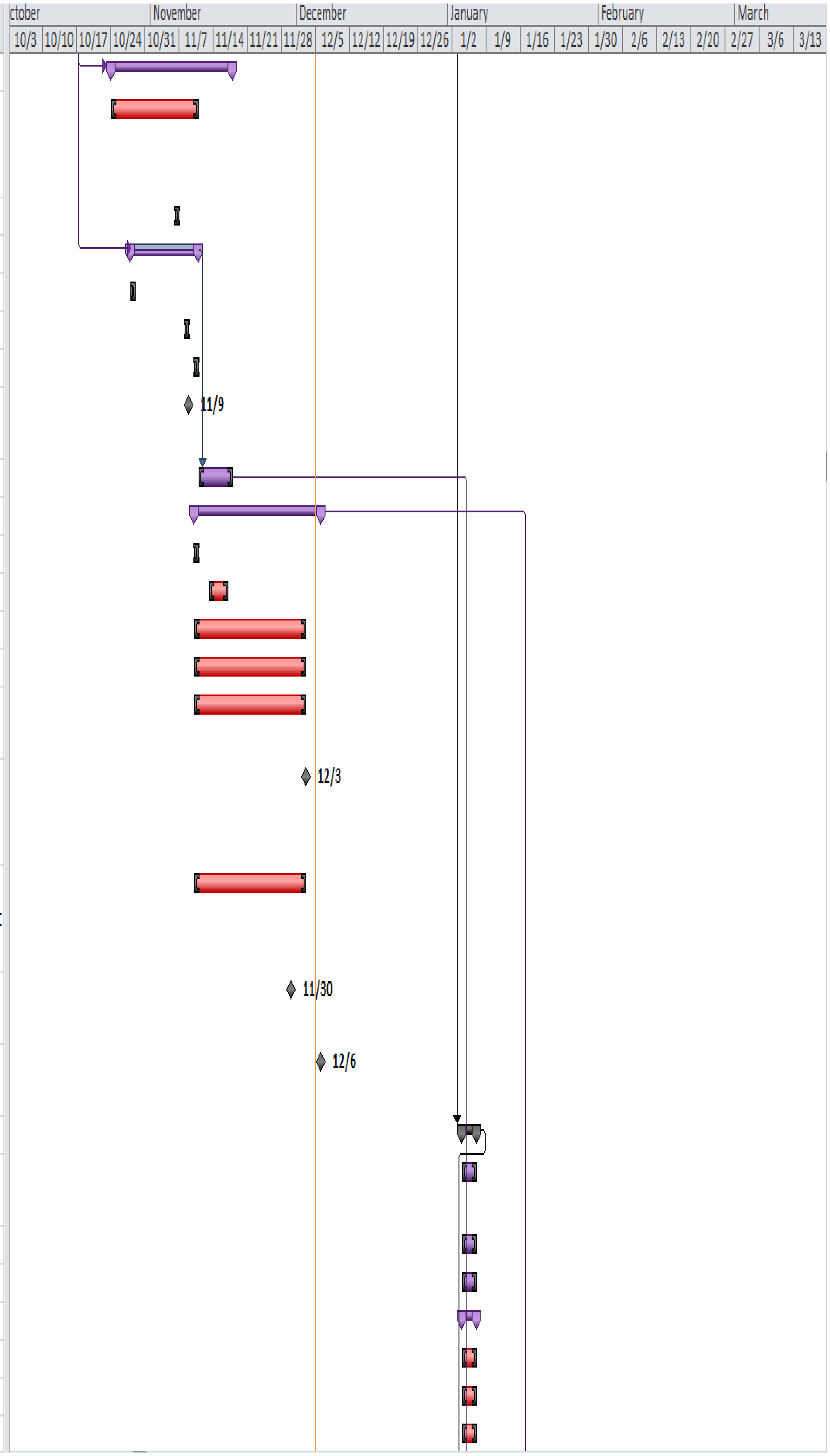
$$\boxed{F_{max} = 40 \text{ lbf}}$$

# Appendix F: Gantt Chart

| ID | WBS | Task Name |
|---|---|---|
| 1 | **1** | **Team Building** |
| 2 | 1.1 | Team Meal |
| 3 | 1.2 | Team Contract |
| 4 | 1.3 | Gantt Chart |
| 5 | 1.4 | Yellow Tag Hours |
| 6 | **2** | **Define Problem** |
| 7 | **2.1** | **Background Research** |
| 8 | 2.1.1 | Patent Searches |
| 9 | 2.1.2 | Peruse through older Bocce Ball Projects |
| 10 | 2.1.3 | General Bocce Ball Research |
| 11 | 2.1.4 | Etiquette Training |
| 12 | 2.1.5 | Attend Friday Club |
| 13 | **2.2** | **Meet With Sponsors** |
| 14 | 2.2.1 | Meet With Michael Lara |
| 15 | 2.2.2 | Meet With Kevin Taylor |
| 16 | 2.3 | Acquire Customer Requirements |
| 17 | **2.4** | **Define Engineering Specifications** |
| 18 | 2.4.1 | Find ASTM Safety Specifications |
| 19 | 2.4.2 | House of Quality (QFD) |
| 20 | **2.5** | **Write Design Proposal** |
| 21 | 2.5.1 | Describe Objectives |
| 22 | 2.5.2 | Describe Method of Approach |
| 23 | 2.5.3 | Develop Management Plan |
| 24 | 2.5.4 | Deliver Design Proposa |
| 25 | **3** | **Picking Concept** |
| 26 | **3.1** | **Idea Generation** |
| 27 | 3.1.1 | Functional Decomposition |
| 28 | 3.1.2 | Brainstorming |
| 29 | 3.1.3 | Morphological Analysis |
| 30 | **3.2** | **Concept Refinement** |

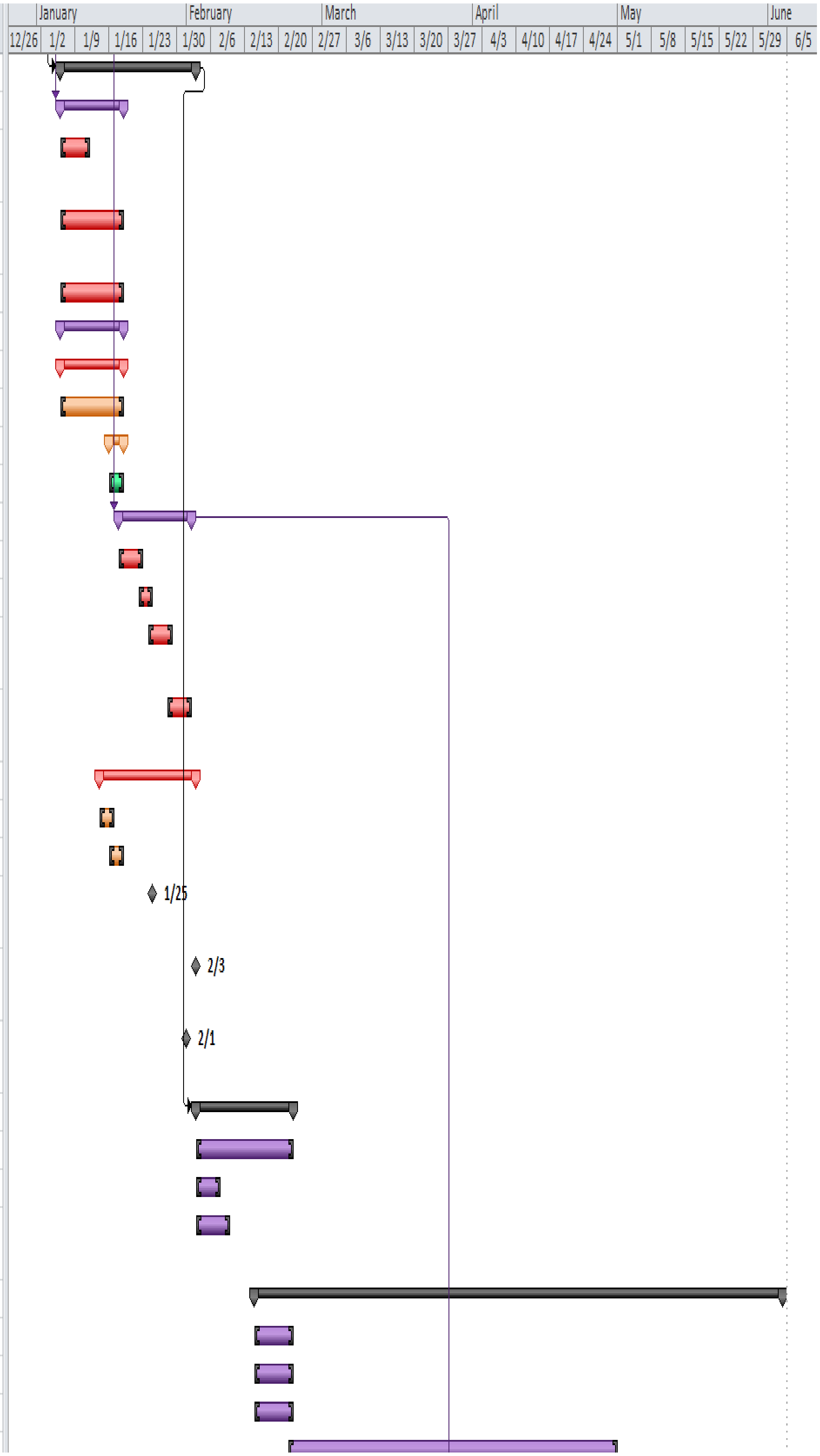
Gantt Chart (con't)

| | WBS | Task Name |
|---|---|---|
| 30 | 3.2 | Concept Refinement |
| 31 | 3.2.1 | Sponsor/Advisor Feedback on Design Proposal |
| 32 | 3.2.2 | Pugh Matrix |
| 33 | 3.2.3 | Conceptual Models |
| 34 | 3.2.3.1 | Buy Materials |
| 35 | 3.2.3.2 | Build Models |
| 36 | 3.2.3.3 | Evaluate Models |
| 37 | 3.2.3.4 | Present Conceptual Models |
| 38 | 3.2.4 | Select Top Concept |
| 39 | 3.3 | Conceptual Design Report |
| 40 | 3.3.1 | Update Specifications |
| 41 | 3.3.2 | Make Basic CAD Models |
| 42 | 3.3.3 | Means of Approach |
| 43 | 3.3.4 | Basic Analysis |
| 44 | 3.3.5 | Preliminary Plans for Construction and Testing |
| 45 | 3.3.6 | Deliver Conceptual Design Report to Advisor/Sponsor |
| 46 | 3.3.7 | Create Conceptual Design Presentation That Sums up Report |
| 47 | 3.3.8 | Deliver Presentation to Lab Group |
| 48 | 3.3.9 | Deliver Presentation to Sponsor |
| 49 | 4 | Design Layout |
| 50 | 4.1 | Preliminary Solid Modelling |
| 51 | 4.2 | Preliminary Analysis |
| 52 | 4.3 | Plan Testing |
| 53 | 4.4 | System Breakdown |
| 54 | 4.4.1 | System Layout Planning |
| 55 | 4.4.2 | Decide on Subsystems |
| 56 | 4.5 | Materials Selection |



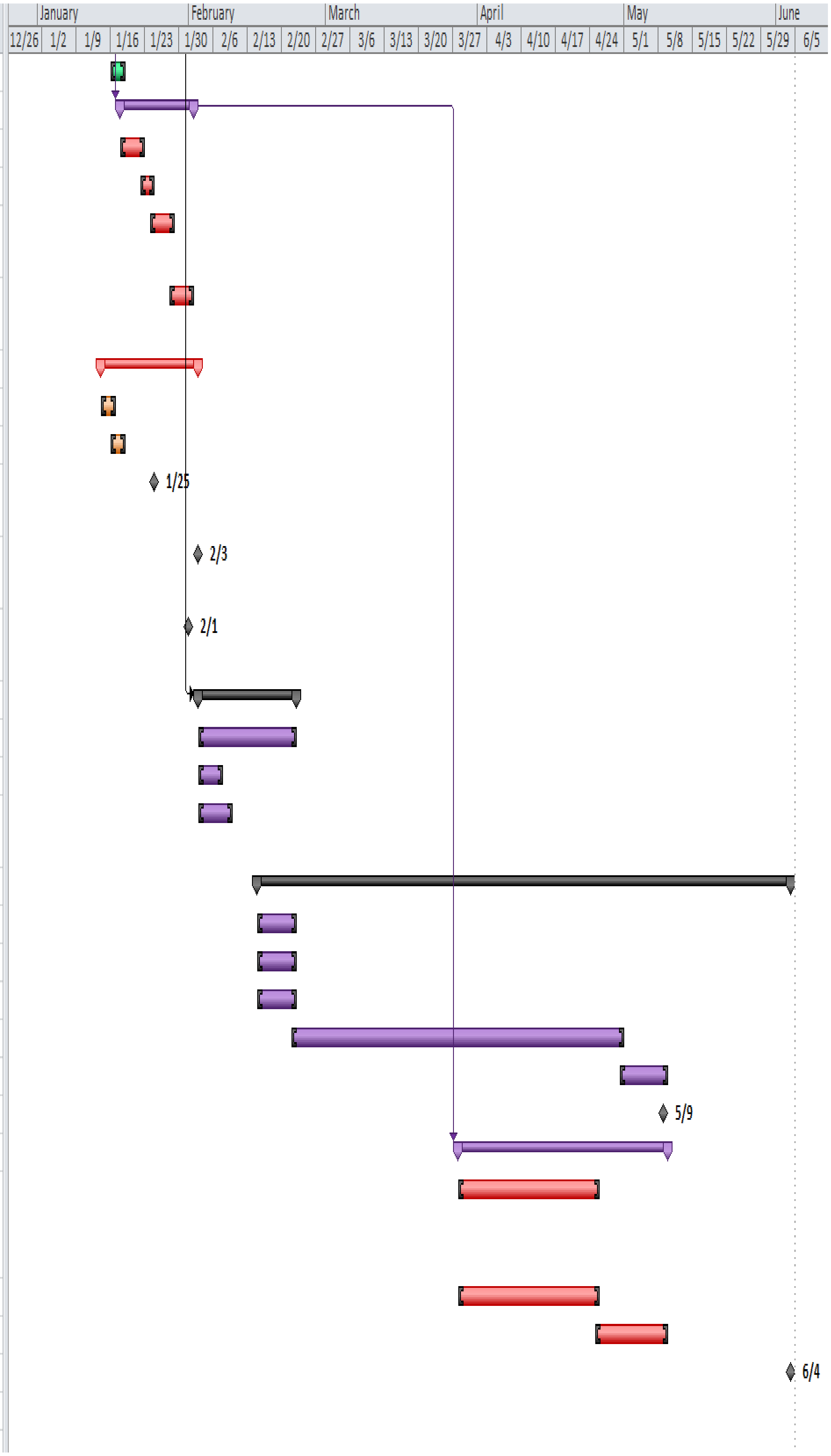
Gantt Chart (con't)

| | WBS | Task Name |
|---|---|---|
| 57 | 5 | **Detailed Design** |
| 58 | 5.1 | **Detailed Analysis** |
| 59 | 5.1.1 | Justification of Material Selection |
| 60 | 5.1.2 | Ensure all Design Specifications are met |
| 61 | 5.1.3 | Cost Analysis |
| 62 | 5.2 | **Detailed Drawings** |
| 63 | 5.2.1 | **Solid Modelling** |
| 64 | 5.2.1.1 | Parts Drawings |
| 65 | 5.2.1.2 | **Assembly Drawings** |
| 66 | 5.2.1.2.: | Bill of Materials |
| 67 | 5.3 | **Final Design Report** |
| 68 | 5.3.1 | Describe Final Design |
| 69 | 5.3.2 | Safety Considerations |
| 70 | 5.3.3 | Fabrication and Assembly Instructions |
| 71 | 5.3.4 | Maintenance and Repair Considerations |
| 72 | 5.3.5 | **Create a Presentation** |
| 73 | 5.3.5.1 | Write Presentation |
| 74 | 5.3.5.2 | Practice Presentation |
| 75 | 5.3.5.3 | Deliver Presentation to Class |
| 76 | 5.3.5.4 | Deliver Presentation to Sponsor |
| 77 | 5.3.6 | Deliver Design Report to Advisor/Sponsor |
| 78 | 6 | **Procurement** |
| 79 | 6.1 | Purchase Materials |
| 80 | 6.2 | Make Building Schedule |
| 81 | 6.3 | Research Material Delivery Time |
| 82 | 7 | **Build Prototype** |
| 83 | 7.1 | Learn Machining |
| 84 | 7.2 | Learn Welding |
| 85 | 7.3 | Learn Fabricating |
| 86 | 7.4 | Assemble Prototype |



Gantt Chart (con't)

| | WBS | Task Name |
|---|---|---|
| 66 | 5.2.1.2.: | Bill of Materials |
| 67 | 5.3 | Final Design Report |
| 68 | 5.3.1 | Describe Final Design |
| 69 | 5.3.2 | Safety Considerations |
| 70 | 5.3.3 | Fabrication and Assembly Instructions |
| 71 | 5.3.4 | Maintenance and Repair Considerations |
| 72 | 5.3.5 | Create a Presentation |
| 73 | 5.3.5.1 | Write Presentation |
| 74 | 5.3.5.2 | Practice Presentation |
| 75 | 5.3.5.3 | Deliver Presentation to Class |
| 76 | 5.3.5.4 | Deliver Presentation to Sponsor |
| 77 | 5.3.6 | Deliver Design Report to Advisor/Sponsor |
| 78 | 6 | Procurement |
| 79 | 6.1 | Purchase Materials |
| 80 | 6.2 | Make Building Schedule |
| 81 | 6.3 | Research Material Delivery Time |
| 82 | 7 | Build Prototype |
| 83 | 7.1 | Learn Machining |
| 84 | 7.2 | Learn Welding |
| 85 | 7.3 | Learn Fabricating |
| 86 | 7.4 | Assemble Prototype |
| 87 | 7.5 | Test Prototype |
| 88 | 7.6 | Deliver Prototype |
| 89 | 7.7 | Final Report |
| 90 | 7.7.1 | Update Previous Report From Sponsor/Advisor Feedback |
| 91 | 7.7.2 | Update Cad Models |
| 92 | 7.7.3 | Final Analysis |
| 93 | 7.8 | Senior Project Design Expo |



# Appendix G: DVP&R

| ME428/ME481 DVP&R Format | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Report Date | 1/11/2011 | Sponsor | Michael Lara | | | | | | Component/Assembly | Bocce Launcher | REPORTING ENGINEER: | | |
| TEST PLAN | | | | | | | | | | TEST REPORT | | | |
| Item No | Specification or Clause Reference | Test Description | Acceptance Criteria | Test Responsibilit | Test Stage | SAMPLES | | TIMING | | TEST RESULTS | | | NOTES |
| | | | | | | Quantity | Type | Start date | Finish date | Test Result | Quantity Pass | Quantity Fail | |
| 1 | Lasts 20,000 cycles | Fatigue Analysis | 20,000 cycles min | Taylor | DV | 1 | B | 1/12/2011 | 1/18/2011 | PASS | 1 | 0 | |
| 2 | Less than 1.5 feet in width | Measurement Test | 1.5 feet max | Steve | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | |
| 3 | not bigger 3 feet in length | Measurement Test | 3ft max length | Will | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | At min height, it is an inch longer than 3 feet |
| 4 | must not exceed 4ft in height | Measurement Test | 4ft max height | Taylor | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | At max height, it is just over 4 feet |
| 5 | Must not exceed 100lbs | Weight Test / Analysis | 100 lbs max | Steve | DV | 1 | B | 4/30/2011 | 5/9/2011 | FAIL | 0 | 1 | Final system weighed 155 pounds with battery |
| 6 | can shoot up to 60 feet | Shot distance measurement test | 60 ft max | Will | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | |
| 7 | can be moved by 2 or less people | Transportation Test | 2 people max | Taylor | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | |
| 8 | actuated with less than 3lbf | Force Transducer Test | 3lbf max | Steve | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | |
| 9 | number of pinch points = 0 | Inspection | zero | Will | DV | 1 | B | 4/30/2011 | 5/9/2011 | FAIL | 0 | 1 | While in use, the operator is not exposed to these pinch points |
| 10 | number of sharp edges = 0 | Inspection | zero | Taylor | DV | 1 | B | 4/30/2011 | 5/9/2011 | FAIL | 0 | 1 | While in use, the operator is not exposed to these sharp edges |
| 11 | No more than 10 custom parts | Bill of materials Inspection | 10 custom parts max | Steve | DV | 1 | B | 1/16/2011 | 1/18/2011 | PASS | 1 | 0 | 9 custom parts |
| 12 | No wall plugs used | Inspection | zero | Will | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | Works for at least 1 hour with out having to recharge battery |
| 15 | can shoot balls of 1.6" diameter and 4.2" diameter | Barrel diameter measurement | pass/fail | Taylor | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | |
| 16 | less than $1500 | Bill of materials inspection | $1500 max | Steve | DV | 1 | B | 1/16/2011 | 1/18/2011 | PASS | 1 | 0 | Final cost = $ 1014.14 |
| 17 | operated with hand motion in a 6" sphere | Human Measurement Test | 6" sphere max | Will | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | |
| 18 | ball is rotating when released | Spin Test | pass/ fail | Taylor | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | Backspin only |
| 19 | works on grass, turf, and compacted dirt | Surface Test | pass/ fail | Steve | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | Trimmed grass only |
| 20 | safety factor of at least 2 | Safety Factor Analysis | safety factor of 2 min | Will | DV | 1 | B | 1/12/2011 | 1/18/2011 | PASS | 1 | 0 | |
| 21 | can be shot and reloaded within 20 seconds | Performance Test | 20 seconds max | Taylor | DV | 1 | B | 4/30/2011 | 5/9/2011 | PASS | 1 | 0 | Passes test as long as helped keeps secondary tank pressurized. |