WATER FUN AT EXPLORATION STATION

FINAL DESIGN REPORT

SPONSORED BY
Deb Geaslen, Exploration Station

PREPARED BY
Aqueous Solutions
Sarah Means smeans@calpoly.edu
Natasha O'Connell-MacKay noconnel@calpoly.edu
Brandon Puccini bpuccini@calpoly.edu

Mechanical Engineering Dept.
California Polytechnic State University
San Luis Obispo
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1. EXECUTIVE SUMMARY

This document discusses additions that were made to an existing water feature for kids K-6th grade at Exploration Station. The additions include an electrical system with proximity detection, a filtration system, and educational water features. The installed electrical system contains three microwave motion sensors which signal a microcontroller to turn on or off an Internet of things relay. To ensure proper filtration, a filter with a UV bulb was installed and chlorine will be added by Exploration Station at appropriate intervals. Six educational water features were also installed. These water features were a racetrack, a magnetic wall with magnetic wall features, a water dome, water squirters, tipping whales and a snap-in grid.

2. INTRODUCTION

Exploration Station is a non-profit science center in Grover Beach, California whose goal is to provide fun and educational experiences to local youth. They regularly cater to local families, as well as host field trips from local schools. In 2017, Exploration Station sponsored the Water Fun senior project at California Polytechnic State University. The intent of the Water Fun project was to create an interactive water exhibit for children from kindergarten to 6th grade. Involved in the 2017 project were Cal Poly seniors Alejandro Gonzalez-Smith, Raymond Morales, Heriberto Rodriguez, and Nicholas Runyan. At the end of the project in June, the senior project team had made excellent progress on the structure of the water table for the exhibit, but due to time constraints they did not finish the electrical system or create the interactive water features desired by Exploration Station [1].

At the beginning of this senior project, Exploration Station has an unfinished water table which can be seen in Figure 1. They were sponsoring a second senior project team to finish the Water Fun exhibit. This iteration of the Water Fun exhibit involved finishing the electrical system, adding a filtration system to ensure safe water quality, and creating interactive water features for children from kindergarten to 6th grade.

Figure 1. Water Fun water table in January of 2018

To quantify this problem for the reader we have included a background section, which summarizes the state of the water table in January of 2018, the needs of the customers, and existing products and technology that relate to this project. Next, the objectives section discusses the engineering specifications required to meet the customer needs and outlines the scope of the project. The concept design development section discusses our design process and our selected designs. The final design section outlines how our final design was manufactured, assembled, and tested.

3. BACKGROUND

The water table at Exploration Station that we were adapting had several unfinished components. The three main sections of the water table were the electrical system, the plumbing system, and the interactive features. To begin understanding what would be needed for this project we met with our customers to discuss their wants and needs and researched existing products and patents.

3.1 CUSTOMER NEEDS

To learn about what our customers needed and wanted we used several methods to acquire information. First, we met with George Dubois and Jim Middlemist who are representatives from Exploration Station. Next, we interviewed several parents from the community who regularly interact with children and sent an online survey out to local teachers who instruct children in the desired age range. Finally, we consulted the recommendations of PlaySafe, which is a website created for parents to help them choose safe toys that are age appropriate to begin understanding the interests of children at different ages. A summary of each of these avenues of research is included below.

Exploration Station

We met with George Dubois and Jim Middlemist at Exploration Station for our interview with them to inspect the status of the water table. They were very pleased with the quality of the structure for the water table, but they also emphasized that it was important that they have a product that was ready for kids to play with at the end of this project. During our interview we discussed things that needed to be finished, and things they were interested in adding to the water table.

Electrical System

Exploration Station has an electrical contractor who will handle running electricity from the electrical box inside the water table to an electrical source.

Existing	Needs/Wants
• Electrical box for electrical components	• Hardware to connect electrical devices • Electrical connection from the electrical box in the water table to a source of electricity • Motion control system. Water table only turns on when someone is nearby

Plumbing System

Existing	Needs/Wants
• Water reservoir for pump • Pump: Alpine Cyclone 3100 Pond & Waterfall Pump • Piping system from pump to outlets in the water table • Valves to change flow through each outlet path	• Water filtration system. Chlorine preferred for bacteria/viruses • Need pipe connecting plumbing to the highest water feature outlet • Test piping for leaks and fix

Interactive Features

Existing	Needs/Wants
• Several plastic boats and other miscellaneous floating toys	• Suitable for 4-12 year olds • Variety of interactive water features • Educational component to features • Self-explanatory. Simple questions and pictographs okay.

When asked about the ideas presented by the previous senior project group, both Jim and George expressed that they liked the proposed water dome and the magnetic walls. Exploration Station recycles computer hardware, and they were interested in reusing hard drive magnets as part of the items being attached to the magnetic walls.

Local Parents

We interviewed several local parents to gain their perspective on what they thought would be interesting features for a water table and to access their concerns.

Interesting Ideas	Concerns
• Interactive elements such as buttons and levers • Water slides and ramps, possibly a platform to lift boats to the higher level of the water feature • Docks around the edges of the basin • Different surfaces to create rapids and changes in current • Fishing poles with magnets or small nets to fish things out of the water • Theme or decoration such as rainforest, Hawaii, or famous waterfalls • Buoyancy: Things that float at different levels in the water	• Features that cause water to squirt towards people could result in bullying • Kids like to dump water, which could result in the surrounding area becoming a slipping hazard • Swallowing parts • Taking things home with them

PlaySafe

To assess the interests of children in our target range we consulted PlaySafe, which is a resource created for parents to help them select age appropriate toys. PlaySafe had three age ranges within our target range which are summarized below [2].

3-6 Years Old

- Make-believe/imaginative play
- Hands-on exploration

6-9 Years Old

- Strategy and skill
- New information/experiences

9-12 Years Old

- Developing life-long interests
- Building/advanced construction
- Puzzles

3.2 EXISTING PRODUCTS

To explore the solutions that have already been developed, we did research into existing water tables and their features. An image and a summary of each feature has been included below.

Figure 2. Free Flowin' water table

A water table built in 2014 by the Cal Poly senior project group Free Flowin' for the San Luis Obispo Children's Museum. The table features two vortices and several sets of water jets along the sides of the basin. Although the vortices were very popular, there were issues with people throwing items other than the intended balls into them [1].

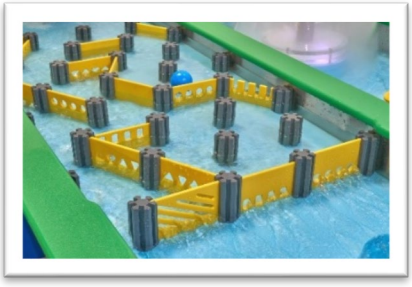


Figure 3. Maze water feature

A maze type system for diverting flow can be set up using removable weirs and dams. Floating balls or other toys down it would catch the attention of younger kids. This maze uses differently shaped barriers, each different cut-out shape would allow the water to move slightly differently, this could be intriguing to older kids. The grid system helps make setting up the maze straightforward while allowing for plenty of creativity [3].

Figure 4. Water sprayer feature

Water sprayers that the children can interact with to manipulate various features gives the children the ability to play around while preventing them from shooting water outside of the table. The location of these shooters makes their purpose self-explanatory, while giving children the freedom to use them with multiple features on the wall [3].

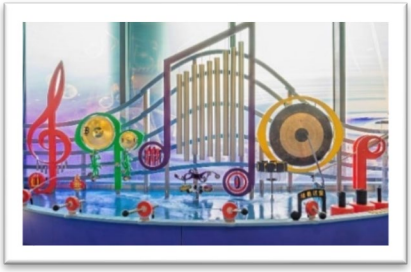


Figure 5. Noise in water features

Using features that create noise in the water table incorporates more of the senses. Touch and sight are well taken care of in other features, but incorporating sound would add more variety to the experience of playing with a water table [3].

Figure 6. Center of mass water feature

Another interesting feature displaying multiple phenomena of physics is shown to the left. The hollow red "pac-man" like disks are shaped and weighted such that the center of gravity is slightly off from its pivot point. As the disk becomes filled with water, its center of gravity starts to shift creating a moment about the pivot point. Once that moment is great enough, it will cause the disk to turn over and dump out its contents into the disk below it. The disk turns back, and the process is repeated until the disk below gets so full that it too turns and dumps the water out and so on [3].

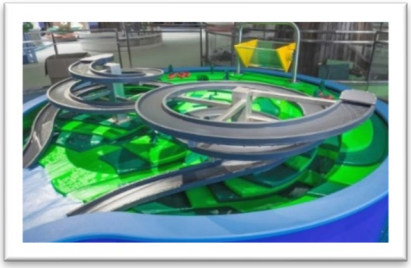


Figure 7. Race track water feature

Multi-level "race tracks" with water flowing down the track can be suitable for a wide age range. Younger children love racing things, and differently shaped and weighted objects could be provided for older children to test the effects of weight/ shape etc. [3].

Figure 8. Topographic floor water feature

Tables featuring a topographic floor can create waves and rapids when the water is flowing. This is an excellent feature to use floating toys with to demonstrate the motion of water [3].

Figure 9. Water wheel feature

Water wheels are a simple feature demonstrating the power of water that could either be continuously spinning or controlled by a child by directing water flow. There are several types of water wheels, some where water is applied axially, as shown, and some where the water is applied tangentially. Mixing up the types of water wheels used could inspire curiosity as to what makes the wheels turn [3].

3.3 PATENTS

To continue our research in existing product we conducted a patent search of the United States Patent Office. Table 1 summarizes the relevant patent information.

Table 1. Patents related to project

Patent Name and Number	Description
Retrofit water play structure and method **US 5741189 A**	• Converting a previously dry structure to incorporate water elements • Water jets, showers, nozzles, hoses, etc. installation included
Participatory water play apparatus **US 5662525 A**	• Structure comprised of play elements, water carrying conduits with attached water forming devices, valves, issuing water effects all controlled by participants • Interconnected pipes carrying water also strong enough to maintain structure
Participatory water play system **US 5820471 A**	• Structure comprised of cause-and-effect water elements • Water bucket that balances and occasionally spills over with too much water, bucket conveyor, jet that hits rotating propeller, funnel/piping systems
Portable waterplay structure **US 5820472 A**	• Portable structure designed for home use, assembly and disassembly, and adjustable water features • Nozzles, spouts, misc. other adjustable features
Construction water toy **US 5385472 A**	• Educational, vertically mounted water toy comprised of adjustable sequential flow diverting features to create downward flowing system • Designed to be used on bathtub wall • Water features may include wheels, pipes, nozzles, hourglass, dipper, sprayer, etc.
Child's Bathing Toy **US 3577675 A**	• System mounted to inside wall of bathtub • Contains interactive features such as a pump, nozzle, water powered components, teeter-totter bucket, carousel, turbine wheel, etc.
Water toy construction kit **US 5480336 A**	• Contains tubular elements and mating connectors to provide flow of water through • Tubes vary in flexibility, transparency, porosity, etc.

3.4 FILTRATION SYSTEM

To prevent bacteria, viruses, and particulate from building up in the water table, Exploration Station requested that we look for a suitable filtration system. Three common types of filters to remove particulate and debris were investigated, as well as two methods of neutralizing bacteria and viruses.

Particulate and Debris Filters

Sand Filtration

Sand filters are commonly used to remove particulate from swimming pools. They consist of a closed chamber that contains sand as the filter media. As water is pushed through the sand by the pressure created by the pump, particulate is caught on the grains of sand and prevented from recirculating. Typically, sand filters can remove particles that are as small as 20-100 microns.

Some positive qualities of sand filters are that they are easy to use, the sand only needs to be replaced about every five years and is inexpensive, and the filter performance increases as it becomes dirtier. Unfortunately, they also have a host of issues that can arise such as the sand gumming up and channels developing that allow water to pass through unfiltered. In addition, they require a pressurized container which can reduce the life of the pump, and backwashing to clean the filter consumes a lot of water.

Diatomaceous Earth (DE) Filtration

DE filters function the same way sand filters do, except they use diatomaceous earth as the filter media instead of sand. DE filters can remove particles that are as small as 3-5 microns. Since they trap smaller particles than sand filters, they also produce better water quality. However, in addition to the issues experienced by sand filters they also require that the filter media be changed regularly and they tend to be more expensive.

Cartridge Filtration

Cartridge filters typically have a housing that contains removable filter inserts that are replaced as needed. The filter inserts, or cartridges, can be made of a variety of material depending upon the application. Some of these materials include ceramic, carbon, and foam. In addition, the number of cartridges in the system often depends on the application. These filters can remove particulate down to 10-15 microns.

This filter has several great features. The first is that it is easy to maintain, and no backwashing is required. In addition, it does not require a pressurized chamber, so it impedes water flow less than a sand or DE filter. Finally, most fountain filters are cartridge filters, so these filters are available in a variety of sizes. There are also several

downsides to using this type of filter. First, maintenance costs can be higher due to the need to buy replacement filter cartridges. Second, this system may also require a secondary pump due to its inability to filter water quickly enough for the desired flowrate.

Bacteria and Viruses

Chlorine Water Treatment

Chlorine is a disinfectant which is added to water, in liquid or powder form, to kill bacteria, viruses, and protozoans. It is commonly used in public swimming pools and as part of the process for purifying public drinking water.

The best part of using chlorine is that it is the standard method of disinfecting drinking water and swimming pools. In addition, chlorine is inexpensive, available at local stores, and does not require extra hardware. However, it also adds maintenance because the level of chlorine in the water must be checked regularly and chlorine must be purchased.

Ultraviolet (UV) Filtration

UV water filters use short-wave ultraviolet radiation to neutralize harmful bacteria and viruses by altering their DNA to prevent them from multiplying. They are particularly beneficial for third world countries and rural properties that rely on rainwater due to their ability to prevent serious illness due to contamination from organic matter and excrement.

UV filters are very low maintenance and are effective against chlorine-resistant microorganisms. Unfortunately, they are not effective if there is any particulate in the water, they require electricity and add extra hardware, and the bulb must be replaced every 6 months.

3.5 ELECTRONIC CONTROL SYSTEM

We were requested to explore potential ways of turning on the water table when someone came in range. The three most common types of motion sensors were investigated to see if they could fill the needs of this project.

Passive Infrared (PIR)

PIRs contain a pyroelectric sensor, which detects levels of infrared radiation. All objects emit small amounts of radiation, and the hotter something is the more radiation it emits. PIRs detect changes in radiation in order to sense motion. Unfortunately, there are some issues using PIRs outdoors. Since PIRs use changes in the level of infrared radiation to detect motion, they can accidentally trigger if there are sudden changes in temperature or light level.

The most appealing thing about PIRs is that they only cost $2 to $10 per sensor. In addition, they also have adjustable triggering sensitivity, range, and delay. Unfortunately, there is a high probability that that changes in light or temperature will cause them to false trigger. Even worse, on very hot days the sensor may be unable to detect changes in radiation, which means it would not trigger at all.

Microwave

Unlike PIRs, which are passive because they monitor infrared radiation that is being radiated at them from nearby bodies, microwave sensors are active sensors. They emit high radio frequencies and monitor the frequency of the energy that bounces back at them. If the frequency of the energy that comes back to them has changed, then they know something is moving.

The most attractive features of microwave sensors are that they are not affected by temperature, humidity, noise, air dust, or light and that they have a wide detection range. These features are useful to this project, because they will not be triggered by many of the influences outside our control. On the other hand, these sensors can detect motion through walls which can make them difficult to position.

Ultrasound

Active ultrasound sensors emit sound waves that are around 40 kHz, which is outside the range of human hearing. When the sound waves hit an object, they are reflected back to the sensor. If the object is moving, the sound wave is disrupted, and the sensor detects a shift in the reflected wave.

Ultrasound sensors are useful because they do not require line of sight, are very sensitive, and have an adjustable range of approximately 40 feet. Unfortunately, they also have several downsides. The most relevant to our project are that high levels of noise or air flow may cause false triggering and that they are not suitable for selective coverage.

3.6 SAFETY

Since this feature will be an interactive water feature for children, safety was one of our primary concerns. In particular, we were concerned about the potential hazards of the features we would be designing, the quality of the water in the exhibit, and the hazards caused by having electricity near water. To address these concerns, we researched government regulations and standards relating to these issues and have summarized them below.

3.6.1 TOY SAFETY STANDARDS

The Standard Consumer Safety Specification for Toy Safety, or ASTM F963, by the United States Consumer Product Safety Commission has strict standards to which toys for children under 14 years old must be built and tested [4]. The intent of this document is to list potential

hazards that may not be immediately apparent but could occur during the life of the toy when subjected to reasonably foreseeable abuse. Some of the topics covered in this document are toxicology, small objects, accessible edges, and a variety of testing procedures. Excerpts from ASTM F963 that are relevant to this project can be found in Appendix A.

3.6.2 WATER QUALITY

Since no standards specific to our project exist, we looked at the standards for the water quality of public swimming pools. Although not all of the standards for pool water quality are applicable to our project, we believe this is a reasonable comparison because the kind of exposure experience by a child at a public pool is similar to the exposure they will have when interacting with our table. Title 22 of the California Code of Regulations has a set of standards for the quality of water in public pools [5]. The codes of interest from this document are 65527. Water Clarity, 65529. Public Pool Disinfection, 65530. Public Pool Water Characteristics, and 65533. Public Pool Cleanliness. Excerpts of these codes have been included in Appendix B. A discussion of how we intend to use these regulations is included in the Objectives section.

3.6.3 ELECTRICAL FIXTURES NEAR WATER

In this section standards and regulations for swimming pools and low-voltage electrical are considered. However, many of the electrical needs of the client will be seen to by a licensed electrical contractor. Excerpts from the standards and regulations pertaining to this project can be found in Appendix C and a discussion of how we intend to use these regulation is included in the Objectives section.

The California Health and Safety Code was consulted for the standards pertaining to electrical fixtures in and around public swimming pools [5]. The section of interest was 116049. Ground-fault interrupter, which requires that ground fault circuit interrupters be installed for circuits operating at more than 15 volts. In addition, it also requires that the afore mentioned ground fault circuit interrupters comply with Underwriter's Laboratory (UL) standards.

Title 8 of the California Code of Regulations was also consulted to determine safety standards for low-voltage electrical [6]. The sections of interest were §2340.5. Conductors, §2340.11. Deteriorating Agents, §2340.12. Mechanical Execution of Work, and §2340.17. Guarding of Energized Parts.

4. OBJECTIVES

Exploration Station has an unfinished water table. Currently, the electrical system does not work, there may be some leaks in the plumbing, and there are no features for their customers to interact with. Exploration Station needs a finished water table that has a working electrical system, does not leak, and has fun, interactive, educational features that appeal to kids K-6th grade. In addition, they are concerned about power consumption and they want an electrical control system that will only turn on the water table when someone approaches it.

4.1 QUALITY FUNCTION DEPLOYMENT

To develop our product properly, we need to have an accurate understanding of the problem. The Quality Function Deployment (QFD) helps identify the correct problem by translating customer needs and wants into measurable engineering specifications that can be targeted and eventually met. The QFD can be summarized in a House of Quality (Appendix D), which incorporates customer requirements, engineering specifications, competing products, and how these all relate to one another. Table 2 lists these specifications along with tolerances, how compliance with these specifications will be confirmed, and the level of risk involved.

Target values and associated tolerances for each specification were determined and recorded in the table above. The risk of not meeting the target value for each specification was ranked as either high risk (H), medium risk (M), or low risk (L). Compliance with these specifications was confirmed using various methods, including testing (T), engineering analysis (A), inspection (I), and similarity to an existing product (S).

Table 2. Engineering specifications

Spec #	Specification Description	Target (units)	Tolerance	Risk	Compliance
1	Duration of customer interaction	10(mins)	Min	M	I
2	Water quality	California Title 22 Codes: 65527, 65529, 65530, 65533	Min	M	T
3	Number of features	3	Min	L	I
4	Government toy regulations	ASTM F963	Min	M	S, I, T
5	Dryness test	No water on interior surfaces	---	L	T, I
6	Reservoir clearance	Removable	Min	M	T, I
7	Electrical box clearance	Swing open 90°	Min	L	T, I
8	Monthly expenses	$100	Max	M	A
9	Rated for outdoor use	UV and weather resistant	Min	M	S, A
10	Grant funding	$2000.00	Min	H	I
11	Government electrical regulations	Ground fault circuit interrupter installed, and California Title 8 Codes discussed below.	Min	L	I
12	Flowrate required	Approx. 2 GPM	Min	L	T, A
13	Component life	4 years	±1 year	H	A, T
14	Play-safe categories	1 from each age range	Min	M	S, I
15	Activation range	3 feet	±1 foot	M	T
16	Activation duration	5 minutes	± 1 minute	L	T

For reference, we have included a description of all the engineering specifications listed in Table 2.

1. The duration of customer interaction is a very general specification in which it incorporates more of an average than a case-by-case experience. We hope that the average customer will interact with our product for roughly 10 minutes. This will show that our product is both

interactive and entertaining if this target is met. Anything lower than 10 minutes would indicate to us that our product did not meet its needs of being interactive, educational, and visually appealing/intriguing.

2. Meeting the water quality specification depends on adhering to the standards described for water clarity, public pool disinfection, public pool cleanliness, and public pool water characteristics. These standards are outlined by the California Code of Regulations, more specifically the California Association of Environmental Health Admistrators. For a description of California Title 22 Codes: 65527, 65529, 65530, 65533 please see Appendix B. The following tests will be run after installation of the water filter and chlorine are complete to endure these standards are met.

   65527. Water Clarity: A visual inspection will be made of the water in the basin of the water table. If the water is cloudy or the bottom of the basin cannot be seen clearly, then the filter must be run until this condition is met.

   65529. Public Pool Disinfection: A test kit for measuring the disinfectant residual and pH will be used to measure the levels of chlorine and bromine in the water. The levels must correspond to the values in Appendix B or the water table will not be available for use until the appropriate chemical concentrations are reached.

   65530. Public Pool Water Characteristics: A test kit will be used to measure the pH, cyanuric acid concentration, and combined chlorine concentration. The levels must correspond to the values in Appendix B or the water table will not be available for use until the appropriate chemical concentrations are reached.

   65533. Public Pool Cleanliness: A visual inspection will be performed to ensure there are no floating debris in the water, and there is no algae or slime growing on the walls of the basin or reservoir.

3. The number of features we'd like to include in our product are at least three. Making sure this specification is met will be done by inspecting the features and making sure at least three are present.
4. Government toy regulations will be enforced through the standard ASTM F963. Our features will be tested, inspected, and compared to existing similar products to ensure that they meet these standards. The standards and testing relevant to this project can be found in Appendix A.
5. A dryness test will be implemented over the basin surface to ensure no leakage is occurring. If this test concludes that a pipe or fitting surface is wet when it should not be, then this specification will not be met. Visual inspections will be done periodically to ensure no leakage as well.
6. Reservoir clearance will be tested and inspected to see if the reservoir basin can be removed within 10 minutes. If it is not removable within this time period, this specification will not

be met. Modifications may be made to the previously structured system to help ensure this specification is met.

7. Much like the reservoir basin, the electrical box needs to have some clearance to be accessed. This will be tested and inspected by making sure the door to access the electrical box can swing open at least 90 degrees. If the door cannot open 90 degrees, the specification will not be met because it will hinder access to the electrical box.
8. The target monthly expenses for exploration station will be analyzed and aimed to be below $100. These expenses will be comprised of water usage, chlorine usage, electrical usage, and any other maintenance that may require a cost. If these expenses exceed $50, this specification will not be met.
9. Our product will be compared to existing similar products to see if it could be rated for outdoor use. This also may require analysis to see if it can withstand long-term exposure to wind, rain, UV rays, etc. If our product is not deemed suitable for outdoor use, this specification will not be met.
10. Grant funding is nearly essential to get this project off the ground. Being that Exploration Station is a non-profit, grant funding would contribute greatly to material and manufacturing costs where Exploration Station cannot help. Our goal is to get $2000.00 from grant funding, which is a lofty goal, but may be necessary to complete our project with what we have in mind. If at least $1500.00 is not raised through grant funding, this specification will not be met.
11. Because our project contains an electrical system near water, our product will be inspected to see if a ground fault current interrupter is installed. This is in accordance with Title 22 of the California Code of Regulation. If this ground fault current interrupter is not installed properly, this specification will not be met. In addition, the following tests and conditions will be met to follow the safety guidelines from Title 8 of the California Code of Regulation.

    §2340.5. Conductors

    All conductors used will be insulated and will be rated for the voltage, temperature, and location they are being used for. In addition, conductors will be different colors depending upon whether they are grounded, ungrounded, or equipment grounding conductors.

    §2340.11. Deteriorating Agents

    All conductors and electrical equipment shall be located in conduit or a box which is wet location rated, unless they are rated for use in a wet location.

    §2340.12. Mechanical Execution of Work

    Unused openings in electrical housings will be closed to prevent water entering through the opening. Conduit for conductor will be labeled so it is easy to identify and routed so it does not obscure access to other components. The inside of the electrical housing will be free of foreign materials such as paint or corrosive residues.

§2340.17. Guarding of Energized Parts.

Electrical equipment will be located in a wet location rated housing which is not accessible to non-authorized personnel.

12. Flow rate will need to be greater than 2 GPM to overcome the head with our product. Flow rate will be measured after all features are installed to ensure that the proper flow is reaching the entire table. If 2 GPM (this is subject to change depending on what features we have) is not achieved, then this specification will be considered unmet.
13. Components will be analyzed and tested to see if their expected life reaches three to five years. This will be difficult to meet because many different components will be included with our product. Features will range in size, function, and durability. The goal is to have all added features, existing features, and functions of the system to last 3-5 years. If this life expectancy is not met due to analysis and/or testing, the specification will be left unmet.
14. As mentioned earlier, we'd like to include three total features to our project, one for each age range. The age ranges, described by PlaySafe standards, are 3-6, 6-9, and 9-12 years old. Making sure this specification is met will simply be done by inspecting the features, comparing them to existing similar products, and making sure at least three fulfill the PlaySafe requirements, one for each age range.
15. The sensor's activation range will be tested to make sure it can detect movement within 4-6 meters away from the product. This signal will be sent to a controller to then actuate moving parts. Testing will be done from all directions of the table to see if the sensor's range is adequate. If our sensor cannot limit its detection range to 3 feet or less and properly send out a signal, then the specification will not be met.
16. The sensor's activation duration is desired to be 4-6 minutes long. This means once movement is detected, the system will continue running for 4-6 minutes. The duration will be tested by activating the sensor with movement and timing how long parts stay running. If the duration does not fall within 4-6 minutes, this specification will not be met.

5. CONCEPT DESIGN DEVELOPMENT

Many techniques were used for generating ideas for the features of the water table. One such method involved building some concept models which helped us generate more ideas and refine ones we already had. Some ideas were eliminated. We ended up with 26 concepts of features to consider for our final product and 7 solutions for proximity detection.

5.1 CONCEPT DEVELOPMENT PROCESS

To generate ideas for our project we completed three ideation activities as a group. First, we did a brainstorming session on a white board to come up with as many interactive features and components that we could think of. Second, we had a brainwriting activity for different ways to

manipulate water. Finally, we did another brainwriting activity to come up with ideas for the interactive walls on the small hexagon. Pictures from each of our ideation activities can be seen in Appendix E.

Next, we looked through all the ideas we had generated and chose several to create concept model of in order to provide a visual representation of our ideas, to further refine our ideas, and gain insight on the best way to design and manufacture these concepts. Pictures taken of our concept models can be found in [CDR Append- Fig].

After building concept models and discussing possible ways of manufacturing the ideas we had come up with we made a list of all the feature we thought it would be possible for us to manufacture. When considering manufacturing we kept in mind that we needed to be able to build multiple features in a limited period of time. Sketches the features we selected for consideration can be found in Appendix E.

5.2 CONCEPT SELECTION PROCESS

To determine the best concepts to pursue for our water table, weighted decision matrixes were used. In these matrices, various concepts are compared against each other by a list of important criteria that need to be met. Every concept is rated on how well that concept meets each individual criterion. Each of these criterions are given a weight based on how critical it is for that requirement to be met. The scores for each concept are summed up and this overall score is used to decide which concepts would be best.

Because of the various aspects involved in this project, our concepts were broken into categories each with their own weighted decision matrix. Proximity detection is one of these categories and has its own decision matrix that can be found in Appendix G. Because we will be creating multiple educational water features for the table, these feature concepts were broken into three separate categories based on the general function and goal: fixed, competitive, and customizable. Sketches of each of the features considered are provided and numbered in Appendix E. Weighted decision matrices for each category can also be found in Appendix G. A feature can fall under multiple categories if applicable and each feature concept is numbered and listed directly below the appropriate decision matrix in Appendix G. The reason for splitting up the educational water features into categories is to provide a wide variety in the user's experience and interaction with the table. At least one concept from each category was chosen to ensure feature variety in our final design.

5.2.1 FIXED FEATURES

A fixed feature is any feature that will be attached to the water table and will not be moved. The leading ideas for this section were the cup pyramid, the water dome, the waterwheel with LED, and the tipping buckets.

The selected features were decided through a weighted decision matrix shown in Appendix G. The criteria for the weighted decision matrix can also be found in Appendix G. The reasons why these features were selected are described in Appendix F.

5.2.2 COMPETITIVE FEATURES

Competitive features are those which can encourage more than one person at a time to compete with each other. Our selected ideas for the competitive features were the fixed racetrack and the water squirter with chimes/targets.

The selected features were decided through a weighted decision matrix shown in Appendix G. The criteria for the weighted decision matrix can also be found in Appendix G. The reasons why these features were selected are described in Appendix F.

5.2.3 CUSTOMIZABLE FEATURES

Customizable features are any feature that the user can move or change. These features would be very interactive and require creativity. The criteria used in the decision matrix, as well as descriptions are provided along with the decision matrix can be found in Appendix G. The leading ideas that were selected for this section were the magnetic wall and the snap in grid. The reasons why these features were selected are described in Appendix F.

5.2.4 PROXIMITY DETECTION

Proximity detection is the method of detecting whether someone is within range of the feature. The ideal range is 3 feet or closer to the walls of the large hexagon. Sketches of the ideas for proximity detection can be seen in Appendix E. Since the designs for passive infrared, microwave, and ultrasonic sensors are very similar one sketch is shown for all three designs. Similarly, only one sketch is shown for a force transducer and a contact switch. Although it was not included in the sketches, each of these designs have a switch which bypasses the proximity detection system, so Exploration Station can choose to have the water table always be on.

The designs that ranked the highest in the weighted decision matrix were the microwave sensor, with a score of 144, and the wall-mounted motion sensor, with a score of 141. Although the wall-mounted motion sensor scored almost as high as the microwave sensor, we decided that the lack of mobility of the wall-mounted motion sensor made it undesirable for this project. Due to this, we chose to pursue the microwave sensor. The assembly and mounting for the microwave sensor can be found in Figure H-8.

5.3 PROTOTYPES

Due to time constraints, we limited our prototypes to the features we considered to be the most complex, or that had the highest risk of failing. These features were the LED Waterwheel, the Tipping Whale and the Cup Pyramid. In addition, we also created a 1/3 scale model of the water table to position the features we intend to manufacture.

5.3.1 1/3 SCALE WATER TABLE MODEL

We created a 1/3 scale model of the water table in order to determine whether our selected features would fit on the table, and whether there would be any conflict between them. The hexagon structures of the water table were made out of 1 by 2 inch wood. The panels for the large hexagon were made out of 1/8th inch wood, and the panels for the small hexagon were made out of 1/8th inch acrylic. The basin was made out of 1/8th inch wood and coated with resin. All components and dimensions were based off of Solidworks^{TM} drawings made by the 2017 senior project group [1].

Figure 10. 1/3 Scale model table

5.3.2 LED WATERWHEEL

We chose to prototype the LED Waterwheel due to the interest of our sponsor. The LED Waterwheel was a high-risk feature because we were uncertain whether we would be able to achieve the rotational speed needed to create the voltage required to power the LED. In

addition, we wanted to determine whether laser cutting gears would be a good choice for future manufacturing. The assembly of the LED Waterwheel can be seen in Figure H-6.

To prototype the LED Waterwheel we used the laser cutter in the Mustang 60 machine shop at California Polytechnic State University to cut out the gears, the waterwheel faceplates, and the waterwheel vanes. The faceplates and the vanes were cut from 0.125 inch thick wood, and the gears were cut from 0.205 inch thick wood.

Before we connected the motor shaft to the pinion, we connected the leads to an LED and confirmed that the shaft could be rotated fast enough to light up the LED. Next, we connected a digital voltmeter across the LED and measured the voltage drop. We measured a voltage of 2.5 to 3 volts before the motor was connected to the pinion. Next, we connected the motor shaft to the pinion and placed the waterwheel under a running faucet. When the LED did not light up, we connected a digital voltmeter to the circuit. When connected to the pinion, the motor only generated 600 millivolts, which is much lower than the required voltage. Ultimately, we chose not to pursue the LED waterwheel due to time constraints, and concern about LEDs not providing enough light for people to see when outdoors.

5.3.3 CUP PYRAMID

The cup pyramid was chosen to prototype because we knew 3D printing prototypes was a viable option. Once the tipping whales were printed, we became confident that we could produce solid 3D printed prototypes as long as the part was designed correctly. We also wanted to prototype the cup pyramid because it scored well on the weighted decision matrix, and our sponsors marked it as one of their favorite concepts.

The cup pyramid consists of a variety of cups, as seen in Appendix H. The cups that have funnels at the bottom could not be 3D printed as such. The orientation of the part would make it nearly impossible to print, and even if it could print, the quality would not be up to par. For that reason, the cups were 3D printed with just the holes at the bottom (two with one hole and two with two holes). Plastic funnels were purchased on Amazon, cut down to concentrically fit with the holes on the cup, and glued in place. Therefore, four cups were prototyped in total: one hole, two holes, one funnel, and two funnels.

6. FINAL DESIGN

For our final design we chose to include the following features,

1. No.1 Fixed Racetrack
2. No. 2 Cup Pyramid
3. No. 4 Water Dome
4. No. 10 Water Squirters
5. No. 11 Tipping Whales
6. No. 22 Snap-In Grid
7. No. 23 Miscellaneous Wall Features

The layout of the features on the water table can be seen in Figure 11.

Figure 11. Entire Table Design

In addition, we also selected a filter to meet the requirements in our engineering specifications and designed the electrical and proximity detection system. We decided to use a microwave sensor for the proximity detection system. Details regarding these features are discussed in the following sections, along with cost analysis for each feature. Overall, this project cost a total of $2,252.63. Two grant applications submitted to MESFAC and some donated items from Means Engineering, Inc. helped us manage this budget. A complete detailed budget can be found in Appendix K.

6.1 NO. 1 RACETRACK

The racetrack is a competitive feature for kids to race objects down a guided water track which leads into the snap-in grid. The racetrack is made of two polyurethane duct hoses supported by PVC rods and flanges. The rods are threaded on both ends and fit into the female threads of each flange. The top flange is connected to the duct hose with zip ties that are fed through the four holes in the flange. The bottom flanges were epoxied to the large basin in designated areas. The first two support rods and flanges are fastened to an aluminum bracket which is fastened to the metal frame of the table itself. This gives the start of the track extra support as it is the most vulnerable to kids grabbing and pulling on it. The racetrack starter piece assembly was then epoxied to each flange and duct hose at the start of the track. This assembly receives water from the table and feeds it into the duct hose. It is also where the ping pong balls will be placed by kids who use the track. A flexible hose adapter is epoxied to the starter piece, and a hose clamp attaches a flexible hose to it. The flexible hose comes from a T joint (one hose for each track) which then is joined to the large basin hose adapter through another flexible hose. A picture of the racetrack assembly can be seen in Figure 12.

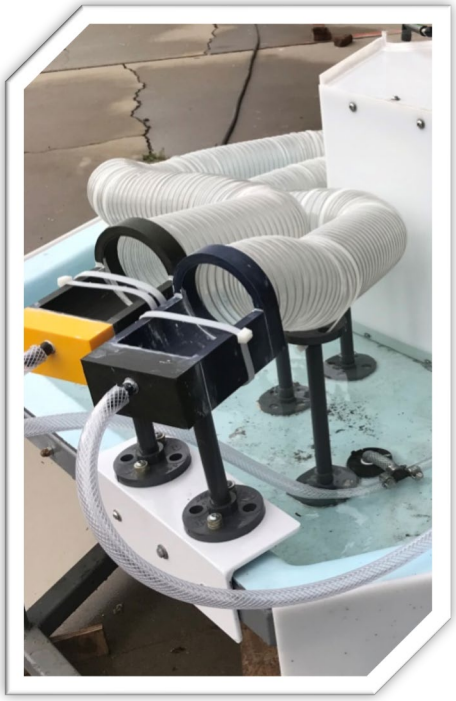


Figure 12. Beginning portion of racetrack feature with starter pieces, flexible hosing, and aluminum support brackets

6.1.1 ANALYSIS

Given that the height of the base of the lower basin is 24.5” off the ground, the racetrack was designed to be accessible by most kids who wanted to interact with it. According to the National Center for Education Statistics, the average height of boys coming into kindergarten

is 3’9”, and girls’ average height is 3’8”. Taking the girls’ average height, they stand a full 19.5” taller than the base of the lower basin. We designed the top of the start of the racetrack to stand 18” above the base of the lower basin. This may be difficult to reach for very short children, but there is a stepping stool present, so we determined this height would suffice.

Based on the materials we are using, the tests we performed on a physical prototype were more insightful than preliminary analysis via hand calculations or SolidWorks stress analysis. If force were exerted on the racetrack assembly, the likely point of failure would be the epoxy bonding parts together rather than the PVC pipes or flanges.

6.1.2 COST ANALYSIS

A condensed summary of costs for the racetrack assembly can be seen in Table 3.

Table 3. Condensed budget for the racetrack assembly

Description	Vendor	Est. Cost
Duct Hoses	McMaster-Carr	$122.71
Support Materials	McMaster-Carr/Home Depot	$267.02
3D Printed Start Pieces	Amazon	$42.02
	Est. Total with Tax:	**$431.75**

The largest contributor to the cost comes from the support materials. This is because safety is a primary concern and reducing the risk of the feature failing prevents injuries from potentially occurring.

6.1.3 SAFETY AND MAINTENANCE

Extra precaution was put into this racetrack’s support system to ensure failure was unlikely to occur. However, we did plan for failure to potentially happen. The most likely point of failure would be involving the starter pieces. The duct hose could potentially detach from the tube ring portion of the starter piece, and the flexible hose could be tugged on, causing a failure in the hose adapter portion of the starter piece. Both of these failures would require epoxy to be reapplied to the given area that became detached. Also, loose wire on the end of the duct hose was covered in epoxy to prevent exposed sharp metal from being a hazard.

We recommend Exploration Station does a weekly check-up test on the racetrack to ensure its sturdiness. This will consist of applying force down on it, away from the edge of the table, and toward the edge of the table. If nothing shows signs of degradation, then it passes.

6.2 NO. 2 CUP PYRAMID AND NO. 23 MAGNETIC WALL

Figure 13. Magnetic wall final design

The cup pyramid and magnetic wall features are both located on metal walls on the upper hexagon. The cup pyramid consists of six magnetic cup types that can be arranged to manipulate the flow of water down the upper hexagon wall. The goal is to fill up the bottom cup the fastest. The magnetic wall features consist of water wheels, teeter totters, and slides that move with and direct the flow of water down the upper hexagon wall. These features attach to the wall with a magnet housing, rod, and rod cap that are pre-assembled with the wall features. An example of the orientation of these cups and wall features can be seen in Figure 13.

Both the cup pyramid and magnetic wall features require water to be directed from the upper basin to the starting features on each wall. To accomplish this, we used a diverted piping system to direct water into the top feature, as seen in Figure 14.

Figure 14. Upper hexagon piping leading to magnetic walls

This feature then starts the path of water down, but off of the wall, to the remaining features. The water that collects in the upper basin is directed to flow off the remaining lower wall that does not involve the cup pyramid or wall features. The walls with the cup pyramids and wall features have an acrylic stopper at the top of each to ensure water does not unintendedly flow down these walls.

Figure 15 shows the waterwheel assembly, which is one of the three miscellaneous wall feature assemblies.

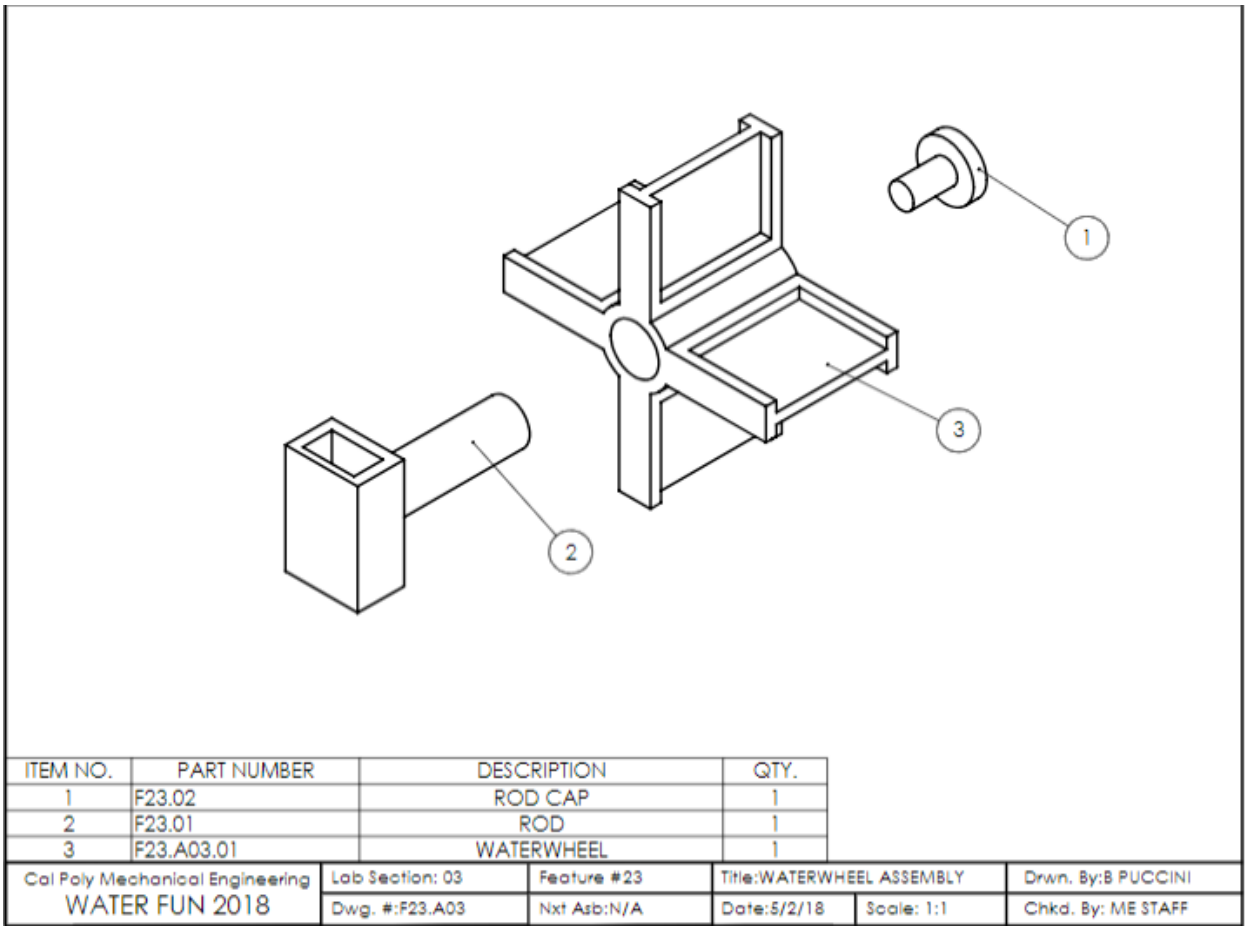


Figure 15. SolidWorks waterwheel assembly with designated components

6.2.1 ANALYSIS

To ensure secured placement for parts on the walls of the upper hexagon, magnets have to be strong enough to hold onto the metal sheet through a small amount of 3D printed filament. Ideally, these magnets would be pressed directly onto the metal wall. Unfortunately, to secure the magnets better, they need to be secured in a slot or housing. The minimum thickness for a given 3D printed piece is 2mm, or a little less than .08". Also, the tolerance for 3D printed parts is .050", so that needed to be considered when designing these features.

Two magnets are placed in separate slots for the cup pyramid parts, as seen in their drawings in Appendix I. Also, in this appendix the drawing for the rod of the miscellaneous wall features can be found and its magnet housing of four magnets. Both the slots and magnet housing were designed for 1" x .25" x .25" Apex magnets. Each of these magnets exhibits 13 pounds of pull strength, so combined these cups will theoretically contain 26 pounds of pull strength and the rods will contain 52 pounds. When tested, these magnets were able to provide enough pull strength to overcome the filament gap and provide a stable foundation for these wall features. These magnets also come in a much shorter length than magnets of similar pull strength. This is convenient because the cup pyramids do not need to be as tall. The water level never exceeds an inch in any cup at any time, so having a greater height just requires extra filament and more money to produce. Also, for the miscellaneous wall features, the reduced height saves space, so more features can fit on the wall at a given time.

6.2.2 COST ANALYSIS

A condensed summary of costs for the wall features can be seen in Table 4.

Table 4. A condensed budget for all the wall features including the cup pyramid parts

Description	Vendor	Est. Cost
3D printed parts	Amazon	$141.26
Hardware	Apex Magnets/Amazon/MetalsDepot	$293.81
Epoxy	3M	$0 (Covered in racetrack cost)
	Est. Total with Tax:	**$435.07**

The 3D printing cost is significant, but the majority of the expense comes from the hardware. This includes the sheet metal for the walls, the piping system, and the magnets.

6.2.3 SAFETY AND MAINTENANCE

To ensure these features are safe to use for kids, they were run through a series of tests. These tests, described in Appendix A, were performed to ensure the magnets will not be dislodged from the parts as well as ensuring that the parts themselves will not fracture. The tests included submerging the parts in water, placing them on and pulling them off a metal wall, dropping them, compressing them, and providing impact force to them. As long as these parts did not fracture, or the magnets did not become dislodged, the parts would be safe for the kids to handle, which we deemed so. All sharp corners on these parts were also sanded down.

If a part does fail in the future, an extra component of each feature was provided to Exploration Station as a replacement. If the failure is something involving epoxy such as the rod cap coming loose from the rod, or the magnet coming loose from its slot or housing, then Exploration Station could re-apply epoxy to the area to fix the part. We also recommend that Exploration Station checks the rotational mobility of the miscellaneous wall features on the rod weekly. This is to make sure the parts are still functioning properly in their ability to direct water flow down the upper hexagon walls.

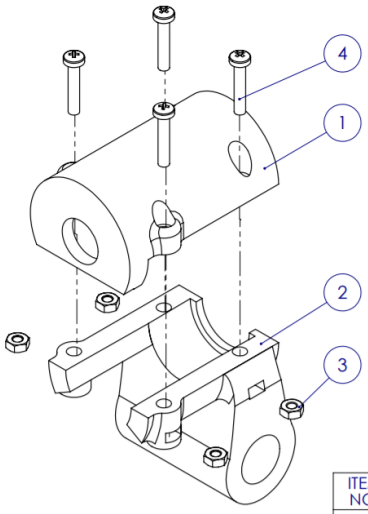
6.3 NO. 4 WATER DOME

The water dome is a purchased fixture located on top of the upper hexagon. It is connected in the center of the hexagon with a ¾ inch fitting, and water is fed to it via ¾ inch flex tubing and a bulkhead. The geometry of the water dome fixture causes the water to fall in a dome shape.

6.4 NO. 10 WATER SQUIRTERS

Figure 16. Water squirters final design

The final design of the water squirters Can be seen in Figure 16. The water squirters were altered due to the difficulty of performing maintenance on the original water squirter design. The new water squirters use garden hose nozzles which are attached to washdown casters by 3D printed casings. A garden hose was used to route water from the pump manifold to the water squirters. The new assembly of the water squirter casing can be seen in Figure 17.

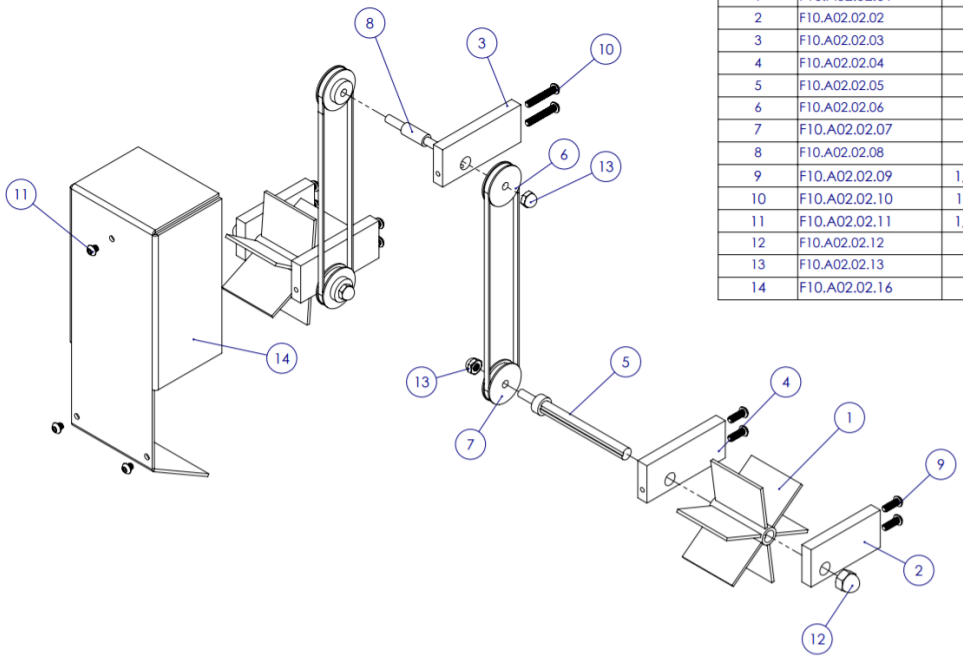


ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F10.A02.01.07	Top Casing	1
2	F10.A02.01.06	Bottom Casing	1
3	F10.A02.01.09	M3 x 0.5 Hex Nut	4
4	F10.A02.01.08	M3 x 0.5 x 16 Machine Screw	4

Figure 17. Water squirter casing assembly

The new water squirter casing is composed of a top and bottom casing which are both 3D printed out of Acrylonitirle Styrene Acrylate (ASA). The two parts sandwich the garden hose nozzle and are held together using M3 machine screws, which allows the water squirters to be disassembled for maintenance.

The targets for the water squirters are waterwheels, which drive timing pulleys. The timing pulleys are connected to another set of timing pulleys via timing belts. A small bird is attached to each of the timing belts. As the waterwheel for one of the targets rotates, the bird attached to the timing belt moves up or down depending upon which way the waterwheel is rotating. Rotation of the waterwheel is caused by a jet of water from one, or both, of the water squirters. The assembly of the targets can be seen in Figure 18.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F10.A02.02.01	Waterwheel	2
2	F10.A02.02.02	Wall brace 01	2
3	F10.A02.02.03	Wall brace 02	1
4	F10.A02.02.04	Wall brace 03	2
5	F10.A02.02.05	Waterwheel shaft	2
6	F10.A02.02.06	Drive pulley	4
7	F10.A02.02.07	Timing belt	1
8	F10.A02.02.08	Pulley shaft	1
9	F10.A02.02.09	1/4-20-2A-3/4 Machine Screw	8
10	F10.A02.02.10	1/4-20-2A-1.5 Machine Screw	2
11	F10.A02.02.11	1/4-20-2A-1/4 Machine Screw	3
12	F10.A02.02.12	1/2-20 UNC-2B cap nut	2
13	F10.A02.02.13	5/16-24 UNF-2B cap nut	4
14	F10.A02.02.16	Safety Cover	1

Figure 18. Target assembly

6.4.1 ANALYSIS

There were two potential issues with this feature that we performed analysis for. The first concern was that the water squirters could be used to spray people. To prevent this, we wanted to design a structure that would limit the motion of the squirters. The second concern was that the water jets may not reach the targets.

For our analysis, we created a model of this feature in excel so we could determine the dimensions and placement of the bar to limit the horizontal and vertical movement of the water squirters based upon the range of the water jets. To determine whether the water jet from the water squirters would have sufficient range to reach the targets, the height of the water jet was calculated at the wall of the upper hexagon for several outlet diameters at different angles. For each set of data, we also calculated the propulsive force of the water jet. The details of this analysis can be found in Appendix L.

6.4.2 COST ANALYSIS

The condensed budget for the water squirter feature can be seen in Table 5. For a detailed cost analysis, please see Appendix K.

Table 5. Water squirter feature condensed budget

Description	Vendor	Cost
Water squirter nozzle, hose and connectors	Home Depot	$83.36
Safety Cover, pulleys, shaft and belts	Amazon	$91.15
Water squirter holders	B&C Industrial Products, Inc.	$40.06
Aluminum stock, support plate, and fasteners	McMaster-Carr	$118.01
	Total with Tax:	**$332.58**

6.4.3 SAFETY AND MAINTENANCE

The water squirter and target assemblies have been designed so that they may be taken apart in case parts need to be replaced. To prevent users from dismantling the assemblies, we have specified hex fasteners. The parts that are most likely to fail are the waterwheel and the timing belt. We have provided additional timing belts to Exploration Station in case the belts fail, and we have confirmed that Exploration Station has access to 3D printing services and have provided the STL file needed to print the waterwheel if it breaks.

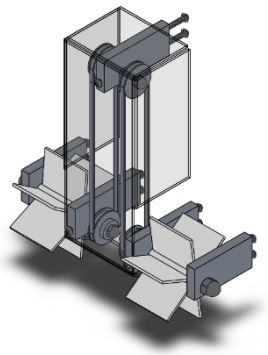


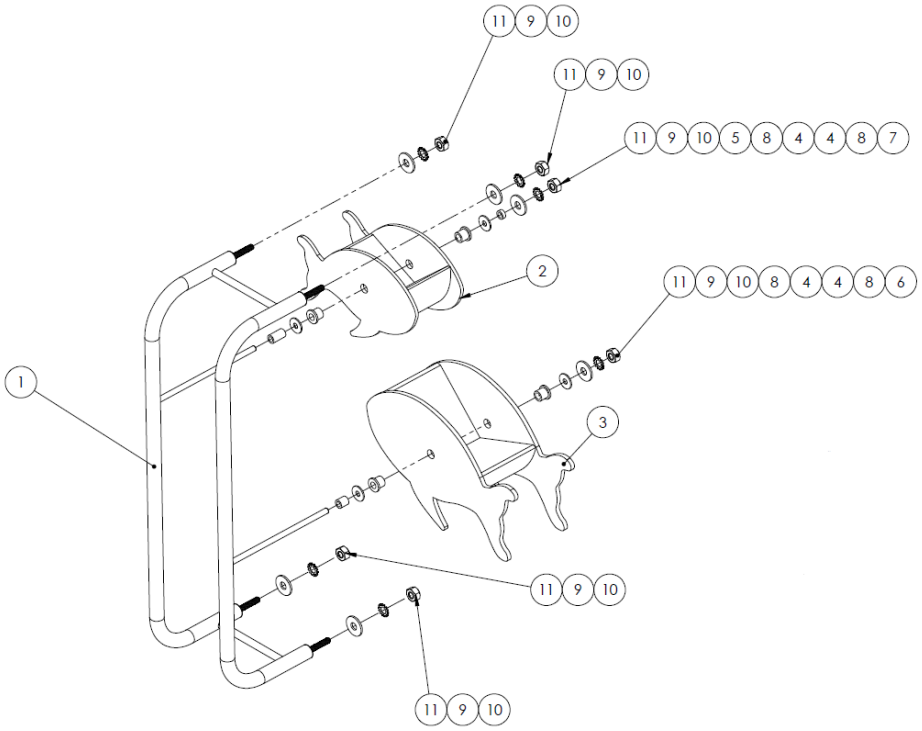
Figure 19. Water squirter safety cover

In addition to part failure, we were concerned about pinch points due to the timing pulleys and belts. To eliminate this hazard, we have installed a transparent plastic cover over this section of the water target assembly to prevent the user from harming themselves. This cover also prevents the user from being harmed by the timing belt if it fails and snaps off the assembly. The plastic cover can be seen in Figure 19.

6.5 NO. 11 TIPPING WHALES

The tipping whales is a variation of the tipping bucket concept, just shaped like a whale. A whale shape was selected because it is a fun shape that is related to water. The way this feature works is water is poured into the bucket, or whale, and once a certain water level is reached, the whale tips over, dumping out the water, then turns upright again.

The tipping whales were mounted on a metal stand and fixed against one of the tall walls of the upper hexagon. This feature consists of three 3d printed whales, a stainless steel stand and various hardware. The stand has been rigidly attached a wall of the upper hexagon along with a stainless steel plate behind the wall for additional support. The stand is removable to allow the customer to change out any components, such as the whales, if they are damaged over time. An exploded view of this assembly along with the corresponding bill of materials is shown in Figure 20.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F11.A03.01	New Stand Complete	1
2	F11.A02.03.01	Tipping Whale Small	1
3	F11.A02.03.02	Tipping Whale Large	1
4	F11.A02.01.09	#10 PTFE Ultra Low Friction Roller Bearing 2706T13	4
5	F11.A02.01.03	#10X 1/8" Stainless Steel Spacer 92320A460	1
6	F11.A02.01.01	#10 x 11/15" Stainless Steel Spacer 92320A757	1
7	F11.A02.01.02	#10 x 9/16" Stainless Steel Spacer 92320A772	1
8	F11.A02.01.10	#10 PTFE Ultra Low Friction Washer 95630A455	4
9	F11.A02.01.05	#10 Stainless Steel External tooth Lock Washer	6
10	F11.A02.01.04	#10 Stainless Steel Flat Washer	6
11	F11.A02.01.08	#10-32 Stainless Steel Hex Nut	6

Figure 20. Tipping Whale Exploded Diagram

The stand itself is made of stainless steel tubing bent to shape and welded. The stand and various hardware were manufactured and donated by Means Engineering Inc.

The overall height of this stand is 14.5 inches. Plumbing was routed to pour water into the top whale on the stand. A ball valve, ½" diameter PVC schedule 40 pipe, ½" polyvinyl flex tubing, ¾" to ½" brass tee, three PVC elbows, hose clamps and an end cap with an 1/8th inch hole in the center has been added to the existing plumbing system to achieve this. The water flow causes the top whale to fill with water until the whale tips over and fills the whale below it with water. More detailed dimensions of this assembly can be found in Appendix I.

6.5.1 ANALYSIS

This feature is very sensitive to changes in geometry. In order to get the whales to function properly, the center of gravity (COG) when the whale is empty needs to be below the COG when the whale is full with water. The pivot point of the whale needs to be above the COG when empty so that the whale remains upright when empty. The pivot point also needs to be below the COG when full so that the whale will tip over when full. The COG when empty also needs to be offset from the COG when full in the horizontal direction as well. The direction of the horizontal offset (either to the left or right) indicates the direction that the whale will tip. A layout of the different COGs and the pivot point is provided in Figure L-2.

The model had to be made out of a material that is less dense than water to create different COGs. Also an empty cavity had to be added that cannot be filled with water, shown in Figure L-2, (appendix L) in order to raise the COG when full. A cross-sectional view of the tipping whale design is provided in Figure L-3, which shows this cavity. Because of the complex geometry of the whale, Solidworks™ modeling was used to measure the two COGs.

The whales were 3d printed out of ASA. This material was chosen because it is water resistant, chlorine resistant, UV resistant and has adequate yield strength.

The stand itself needed to be able to withstand a child pulling on it or attempting to use the sand as a way to climb onto the table. To account for this, finite element analysis was performed on the assembly using Solidworks™ . A simulated 60 lb force was applied to the stand in various directions and the resulting deformation, strain, and von mises stresses were collected. The details of this analysis are included in Appendix L I was found that the stand would not deform more than 0.023 inches, and the yield strength of the stand, 25 kpsi, was not exceeded with this load. Therefore, this design will not break, which helps satisfy the requirements that this feature be safe and have a long life.

The material that was used to make the stand was 316L stainless steel round tubing. This material was chosen for its strength, durability and corrosion resistance. This did not affect our budget because the stand was manufactured and donated by Means Engineering Inc.

The height of the stand was determined by the length and geometry of the whales, allowing enough room for the whales to spin freely without colliding with one another. The size of the stainless steel tubing that is used for the frame was determined by the material Means Engineering had in stock and by the strength requirements of the frame. The partly threaded rods that the whale pivot around are also stainless steel and were made from 6" long partly threaded machine screws with the heads cut off because that was what was easily available. Using round tubing for the stand means that there will be no sharp corners for children to hurt themselves on which adds to the safety of this feature.

Plastic bushings were chosen for the assembly because while stainless steel is inherently water resistant, a residue can build up in the stainless steel from being exposed to hard water. This would create a rough surface that would inhibit the motion of the whales. The chemical resistant plastic bushings would allow the whale to freely rotate even in the presence of corrosion, which significantly extends the life of the feature.

6.5.2 COST ANALYSIS

Many components go into manufacturing this feature and a condensed budget list is provided in Table 6 below.

Table 6. Condensed Budget for No. 10 Tipping Whale

Description	Vendor	Cost
Complete Stainless Steel Stand	MEI	$0.00
Stainless steel Fasteners and Hardware	MEI	$0.00
Chemical resistant Plastic bushings	McMaster-Carr	$29.16
PVC Tube fittings and valves	Home Depot	$53.23
Easy-to-Form 304 Stainless Steel Wire Cloth 1ftx1ft	McMaster-Carr	$19.24
Hose Clamps	Home Depot	$8.10
Epoxy	Home Depot	$91.03
ASA Filament for 3D printing Whales	Amazon	$40.95
	Est. Total with Tax:	**$241.71**

The total cost for this feature is $241.71. A full detailed bill of materials and budget list for this feature can be found in Appendix I.

6.5.3 SAFETY AND MAINTENANCE

There are very few safety hazards related to this feature. As discussed before, the feature structure will not break if a child tries to bend the stand or climb on it. All corners on the feature will be rounded to avoid injury. The spinning whale are out of a child's reach, so pinching of fingers is unlikely. If a child were to touch one of the spinning whales, no injury would occur because of the slow speed at which the whales are rotating and the low mass of the rotating whales.

Very little maintenance is required for this feature because of the UV- resistant, chemical resistant, corrosion resistant, and water-resistant materials used. If maintenance or repair is needed, the customer would be able to easily remove and disassemble the entire feature from the table. Additional printed whales, as well as the STL files of the whales, will be provided to the customer so that they can easily replace or reprint a whale in the case that one breaks.

A failure mode effect analysis (FMEA) was performed and can be found in Appendix N.

6.6 NO. 22 SNAP-IN GRID

The snap in grid is made up of Duplo ™ sized Lego™ baseplates epoxied to the lower basin and have 3D printed walls attached to the tops of Duplo Legos ™ that the children will be able to move around. This grid begins at the exit of the fixed racetrack so that the children can create pathways to race boats through as they come out of the racetrack. The grid covers three sections of the hexagonal basin: Next to the racetrack exit and in front of one magnetic wall; In front of the tipping whale feature; In front of the second magnetic wall and stopping before the water squirters.

Three different pieces were provided for the children to customize the pathways: a wall, a weir, and a ramp. These pieces were intended to be 3D printed then bonded to the top of Duplo Legos ™ to ensure that they effectively snap onto the baseplates. However, due to issues with our 3D printer, we were only able to print one of each type of wall. Exploded drawings for these pieces are provided in Figure 21, Figure 22, and Figure 23 below. Detailed drawings with dimensions for these components are given in Appendix I.

Our sponsor has been provided with over 100 Duplo Legos that can be used on the snap-in grid to make walls instead.

ITEM	PART NUMBER	DESCRIPTION	QTY	UOM
1	F22.A03.01.01	2X4 DUPLO LEGO	1	EA
2	F22.A02.01.01	LEGO RAMP TOPPER	1	EA
3	F22.A03.01.02	JB WELD PLASTIC BONDER	.05	OZ
4	F22.A03.01.04	UV COATING	.1	OZ

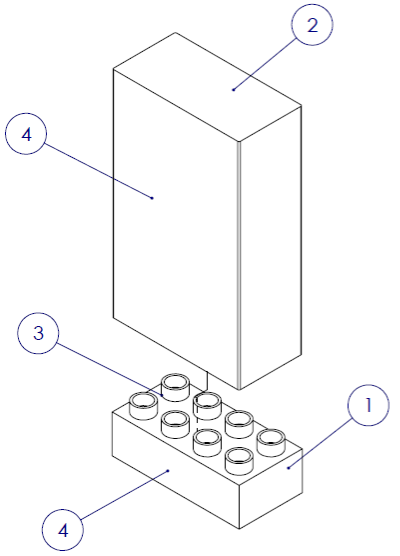


Figure 21. F22.A02.01 Lego Wall Exploded View

ITEM	PART NUMBER	DESCRIPTION	QTY	UOM
1	F22.A03.01.01	2X4 DUPLO LEGO	1	EA
2	F22.A02.02.01	LEGO RAMP TOPPER	1	EA
3	F22.A03.01.02	JB WELD PLASTIC BONDER	.05	OZ
4	F22.A03.01.04	UV COATING	.1	OZ

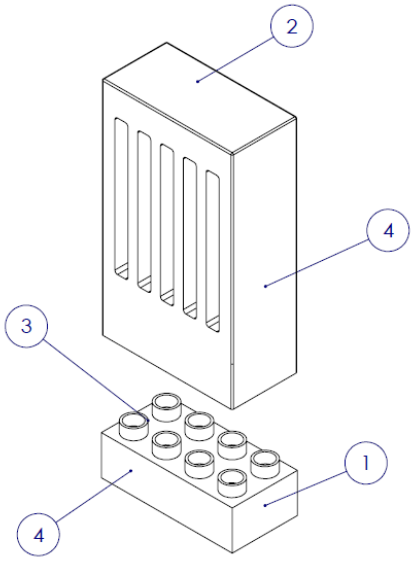


Figure 22.F22.A02.02 Lego Weir Exploded View

ITEM	PART NUMBER	DESCRIPTION	QTY	UOM
1	F22.A03.01.01	2X4 DUPLO LEGO	1	EA
2	F22.A02.03.01	LEGO RAMP TOPPER	1	EA
3	F22.A03.01.02	JB WELD PLASTIC BONDER	.05	OZ
4	F22.A03.01.04	UV COATING	.05	OZ

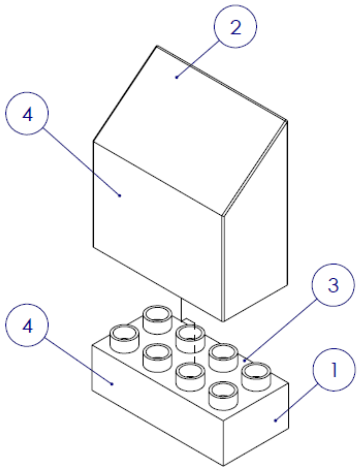


Figure 23. F22.A02.03 Lego Ramp Exploded View

6.6.1 ANALYSIS

To see if the dimensions of the 3d printed parts were sufficient to provide an adequate surface to apply the acrylic bonding agent to, and still be compatible with any Duplo Lego ™ 2X4 brick, a prototype was created using PLA at Cal Poly's Innovation Sandbox. When tested against numerous "Lego compatible" blocks, the prototype fit properly in all situations. This indicates that the determined geometry of these features yields successful results in the large quantities that were required. Unfortunalty, we were not able to produce the quantity of wall that we would have liked due to printer failure.

6.6.2 COST ANALYSIS

The materials required for this feature include, among other things, the PETG filament for 3D printing and the non-toxic UV-resistant coating which make up the main costs. A condensed budget breakdown is provided in Table 7. A complete detailed budget for this feature can be found in Appendix K.

Table 7. Snap in Grid Condensed Budget

Description	Vendor	Cost
152 2X4 Duplo Legos	Amazon; Strictly Briks	$72.35
ASA filament for 3D printing walls	Innofill 3D	$322.32
7 Duplo Lego Base Plates	Amazon: Crystal Deals	$39.98
JB Weld Plastic Bonder for Board to Basin	Home Depot	$134.80
	Est. Total with Tax:	**$569.45**

The budget required for this feature is a significant amount of money, which may be prohibitive.

6.6.3 SAFETY AND MAINTENANCE

The high cost of this feature is mainly due to the cost of the filament. While the walls were not printed, the ASA filament had already been purchased when the 3D printer broke, so the cost is still included in the budget.

A failure mode effect analysis (FMEA) was performed and can be found in Appendix N.

6.7 ELECTRICAL AND PROXIMITY DETECTION SYSTEM

Electricity was provided to the table from a wet-location rated extension cord with a GFCI. The plugs for all 120-volt circuits were installed by a licensed electrical contractor. The cords for all 120-volt circuits entering the electrical box were routed through strain relief cable glands, which prevent water from enter the electrical box. A layout of the locations of the components in the electrical and proximity detection system can be seen in Figure 24.

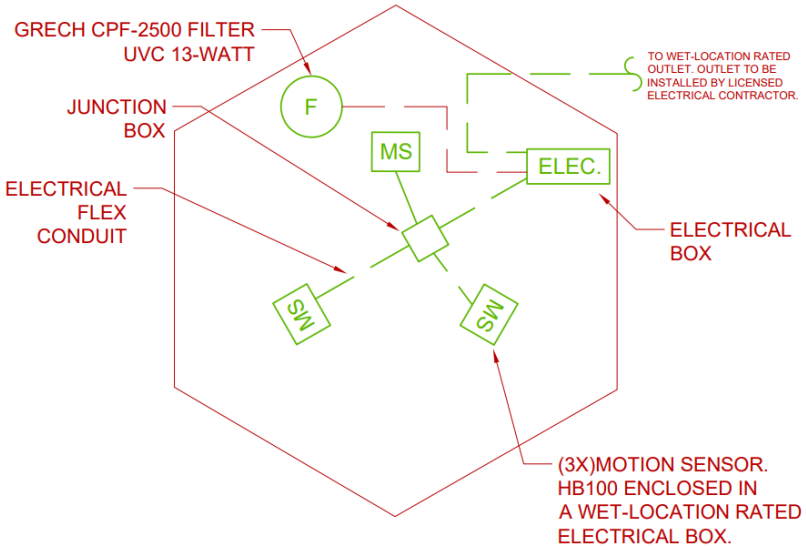


Figure 24. Electrical system layout

The proximity detection system detects motion within 3 feet of the water table and turns on the power to the pump and filter when motion is detected. The system uses HB100 microwave sensors to detect a doppler shift when movement occurs within their range. When motion is detected a signaled is sent to the microcontroller, which sends a high voltage to an Internet of Things relay. The relay turns on the outlet to the pump when a high voltage is received. Figure 25 is a line diagram depicting how each sensor is connected to the microwave controller.

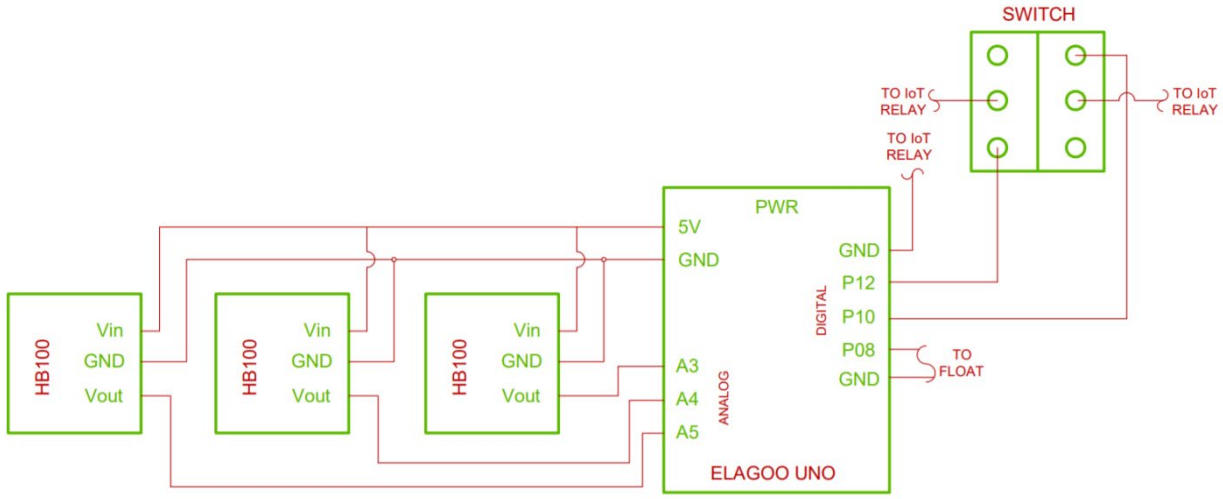


Figure 25. Low voltage line diagram

The following code is intended to activate an IoT relay in two modes, which are selected via a switch. The first mode, ALWAYS ON, maintains a digital HIGH signal to the relay. The second mode, SENSOR, sends a digital HIGH sign to the relay when motion is detected and maintains that signal for TIME_ON before shutting off unless further motion is detected. In addition, it also monitors the signal from a float. If the water level is too low, the IoT relay is shut off and will not activate in either mode until the water level is increased.

```
13    #define TIME_ON 5000                  // time the relay will be on in milliseconds
14    #define IN_PIN1 A3                    // voltage input from microwave sensor 1
15    #define IN_PIN2 A4                    // voltage input from microwave sensor 2
16    #define IN_PIN3 A5                    // voltage input from microwave sensor 3
17    #define SENSOR_PIN 12                 // IoT Relay connected to digital pin
18    #define ON_PIN 10                     // digital pin for always on
19    #define FLOAT_PIN 8                   // Float pin. High signal for low water
20    #define VOL_CEN 2.5                   // resting sensor input voltage
21    #define VOL_WID .2                    // voltage width for sensor
      detection (sensitivity)
22    #define BITS_TO_VOLTS (5.0/1023)      // conversion for sensors
24  void setup() {
25    Serial.begin(9600);                     // initialize serial communication at
      9600 bits per sec
```

```
26      pinMode(SENSOR_PIN, OUTPUT);              // digital sensor pin set to output
27      digitalWrite(SENSOR_PIN, LOW);            // initializes IoT relay to off
        state in SENSOR mode
28      pinMode(ON_PIN, OUTPUT);                  // digital always on pin set to output
29      digitalWrite(ON_PIN, LOW);                // initializes IoT relay to off
        state in ALWAYS_ON mode
30      pinMode(IN_PIN1, INPUT);                  // Analog pin set as input for sensor 1
31      pinMode(IN_PIN2, INPUT);                  // Analog pin set as input for sensor 2
32      pinMode(IN_PIN3, INPUT);                  // Analog pin set as input for sensor 3
33      pinMode(FLOAT_PIN, INPUT_PULLUP);         // digital float pin input
34    }
35
36    // main code which runs in a loop
37    void loop() {
38      float inVolt1;                                        // input voltage
39      float inVolt2;                                        // input voltage
40      float inVolt3;                                        // input voltage
41      static int state = 0;                                 // state of system (On or off)
42      static unsigned long timeOff = 0;
45      int floatVal = digitalRead(FLOAT_PIN);
46      // If the water level is high enough, turn on system
47      if(floatVal == HIGH){
48        inVolt1 = analogRead(IN_PIN1) * BITS_TO_VOLTS;        // sensor voltage
49        inVolt2 = analogRead(IN_PIN2) * BITS_TO_VOLTS;        // sensor voltage
50        inVolt3 = analogRead(IN_PIN3) * BITS_TO_VOLTS;        // sensor voltage
51        Serial.println(inVolt1);                              // print sensor voltage
          for troubleshooting
52        digitalWrite(ON_PIN, HIGH);                           // activate always on
circuit
53        }
52        // activate sensor circuit if signal is large enough
53        if((abs(inVolt1-VOL_CEN) > VOL_WID)||(abs(inVolt2-VOL_CEN) >
          VOL_WID)||(abs(inVolt3-VOL_CEN) > VOL_WID)){
54          digitalWrite(SENSOR_PIN, HIGH);
55          timeOff = millis() + TIME_ON;                     // time until table turns off
56          }
            // If no motion has been detected for TIME_ON, turn off relay.
57          If(millis() >= timeOff{
58             digitalWrite(SENSOR_PIN, LOW);
59          }
60          }
            // If water level is too low, turn off the relay
61          else{
62            digitalWrite(SENSOR_PIN, LOW);
63            digitalWrite(ON_PIN, LOW);
64          }
65          }
```

6.7.1 COST ANALYSIS

The values in Table 8 are the summarized costs of the components at the time of their purchase. For a detailed cost analysis, please see Appendix K.

Table 8. Electrical and proximity detection system condensed budget

Description	Vendor	Est. Cost
Electrical boxes, conduit and wire	Home Depot	$215.49
Motion sensors, microcontroller, and electrical components	Amazon	$156.00
	Total with Tax	**$371.49**

6.8 FILTRATION SYSTEM

The previous plumbing system consisted of a manifold with eight outlets connected to ¾-inch flexible tubing via ball valves. To filter the water in the reservoir so it is safe for contact with humans we installed a Grech CPF-2500 filter with UVC. This filter removes particulate and bacteria from the water and provides 40mJ/cm2 as required by the requirements from the California Code of Regulations in Appendix B at a flow rate between 400 and 500 GPH.

In addition to installing the filter, we fixed the leaks present in the existing pumping system. The leaks were occurring around the bulkheads that connect the fiberglass reservoir to the ¾-inch flexible tubing. The leaks were fixed by tightening the bulkheads so that they were sealing properly.

6.8.1 COST ANALYSIS

The summarized cost of the filtration system can be seen in Table 9. For a detailed cost analysis, please see Appendix K.

Table 9. Filtration system condensed budget

Description	Vendor	Est. Cost
Filter	Amazon	$118.51
Swing Check Valve	PVC Fittings Online	$12.52
PVC Cement	Home Depot	$9.88
Flexible Vinyl Tubing	Home Depot	$45.94
	Total with Tax:	**$186.86**

7. MANUFACTURING & ASSEMBLY

Items for this project were procured from the manufacturer as per Appendix K. Any exceptions are discussed below. In addition, manufacturing and assembly for each system in our final design is also discussed below.

7.1 NO. 1 RACETRACK

7.1.1 PROCUREMENT

The racetrack duct hose and support structures were purchased off McMaster-Carr. The starter pieces were 3D printed by Natasha in ASA. For a procurement list of all other items, please reference Appendix K.

7.1.2 MANUFACTURING AND ASSEMBLY

Tools and Equipment:

- Chop Saw
- Sand Paper
- Duct Tape
- Tin Snips
- Screw Driver

Procedure:

1. 3D printed starter pieces in ASA and epoxied them together, including the hose adapter piece.
2. Cut down the aluminum support bracket with a chop saw to 12". Drilled holes on top part of bracket for flanges fastening and bottom part for fastening to table.
3. Attached the bracket to the table after drilling holes for sockets in the table frame. Attached two flanges to the aluminum bracket with screws and socket nuts. The finished product can be seen in Figure 26.

Figure 26. Racetrack assembly process with aluminum bracket support with fastened flanges and epoxied flanges in the large reservoir

4. Cleaned the fiberglass large basin in designated spots for the flanges of the racetrack. Sanded down the spots and then cleaned again with IPA.
5. Applied epoxy to bottom of flanges and spots on table where flanges will go. Applied pressure on flanges and duct tape down for 24 hours without disruption. This can also be seen in Figure 26.
6. Screwed in support rods to flanges with specified heights arrangement.
7. Screwed in top flanges to support rods.
8. Laid down duct hoses on flange supports. Starting with the first flange not on the aluminum bracket, zip tied the hose down to the flange. Continued until the entire hose was zip tied down besides the start.
9. Cut off the excess material of the zip ties with tin snips.
10. Epoxied the starter pieces to the starting flanges. Epoxied the start of the duct hoses to the starter pieces. Let sit for 24 hours without disruptions.
11. Cut down short piece of flexible hosing to connect large basin hose adapter to pex tee. Cut down two more long pieces of flexible hosing to connect the hose adapter in the starter pieces to pex tee.
12. Clamped down all hoses with hose clamps.

7.2 NO. 2 CUP PYRAMID AND NO. 23 MAGNETIC WALL

7.2.1 PROCUREMENT

The cup pyramid, waterwheel, slide, teeter totter, rod, and rod cap pieces were 3D printed by Natasha in ASA. For a procurement list of all other items, please reference Appendix K.

7.2.2 MANUFACTURING AND ASSEMBLY

Tools and Equipment:

- Sand paper
- Band saw

Procedure:

1. 3D printed wall features and cups in ASA.
2. Obtained 3D printed parts and removed any leftover support material.
3. Sanded down any sharp edges of parts.
4. Obtained Apex magnets and placed them in designated slots of the cup pyramid parts. Also placed four Apex magnets in the designated housing of the rod parts.
5. Filled slots and housing with epoxy via syringe until it reached the top of the part. Made sure magnets are closest to the edge that will be in contact with the metal wall before applying epoxy. Let sit for 24 hours.
6. Sanded down leftover epoxy from top of parts.
7. For the cup pyramid parts, obtained plastic funnels and cut down to desired height on band saw. The funnels were inserted through the top of the cup and had about a millimeter of itself showing in the cup. Epoxied the funnel on the inside of the cup and on the bottom of the cup. Did this for half the amount of each type of pyramid cup. Let sit for 24 hours.
8. For the miscellaneous wall feature parts, assembled the features onto the rod. Then epoxied the rod cap to the rod. Let sit for 24 hours.
9. To divert water flow to the cups and wall features, piping was diverted from the original water dome hose to accommodate. This included a ball valve to a PVC tee, two elbows leading to gaskets on the top of the upper hexagon. This then led to another PVC tee above each gasket branching off to two elbows extended out by swing piping to two more elbows hanging over the edge.

7.3 NO. 4 WATER DOME

7.3.1 ASSEMBLY

The existing bulkheads installed on the water table have threaded ¾-inch fittings, as does the water dome nozzle that was ordered. To assemble, the nozzle was threaded into the existing bulkhead.

7.4 NO. 10 WATER SQUIRTERS

7.4.1 PROCUREMENT

For procurement of all items please see Appendix K.

7.4.2 MANUFACTURING

Target

Tools and equipment:

- Mill
  - ¾-inch endmill
  - 1/8-inch endmill
  - 35/64-inch drill
  - No. 7 drill
- Lathe
- Taps
  - ¼-20
- Dies
  - 5/16-24
  - ½-20

Procedure:

Please see the detail drawings in Appendix I for part dimensions and feature locations.

Part: **Wall Brace 01**
Quantity: **2**

Machine	Tools Required	Directions
Bandsaw		Cut bar stock to length. Should have 2 parts 3.8" in length
Mill	3/4" End mill	Machine ends of bar stock to 3.75"
Mill	3/4" End mill	Machine bottom and top of bar stock to 1.75"
Mill	35/64 drill bit	Drill shaft hole
Mill	#7 drill bit	Drill mounting holes
	1/4-20 tap	Tap mounting holes

Part: **Wall Brace 02&03**
Quantity: **1&2**

Machine	Tools Required	Directions
Bandsaw		Cut bar stock to length. Should have 3 parts 4.3" in length
Mill	3/4" End mill	Machine ends of bar stock to 4.25"
Mill	3/4" End mill	Machine bottom and top of bar stock to 1.75"
Mill	35/64 drill bit	Drill shaft hole
Mill	#7 drill bit	Drill mounting holes
Mill	#7 drill bit	Drill safety cover mounting hole
Mill	#7 drill bit	Drill set screw hole
	1/4-20 tap	Tap holes

Part: **Wheel Shaft**
Quantity: **2**

Machine	Tools Required	Directions
Miter saw		Cut delrin to length. Should have 2 parts 5.8" in length.
Lathe		Face ends until rod is 5.75" in length
Lathe		Turn rod diameter to 4.45"
Lathe	1/2-20 die	Cut external threads
Lathe		Turn rod diameter to 0.314"
Lathe	5/16-24 die	Cut external threads
Mill	1/8" endmill	Cut keyway

Part: **Pulley Shaft**
Quantity: **1**

Machine	Tools Required	Directions
Miter saw		Cut delrin to length. Should have 1 part 3.1" in length.
Lathe		Face ends until rod is 3.04" in length
Lathe		Turn rod diameter to .315" on both ends
Lathe	5/16-24 die	Cut external threads

Waterwheels and Water Squirter Housing

The waterwheels and water squirter housings were 3D printed out of Acrylonitirle Styrene Acrylate (ASA) using a Fused Filament Fabrication (FFF) 3D printer. Table 10 lists the settings used to slice the STL files for 3D printing, which are based upon the recommendations of the filament manufacturer.

Table 10. 3D printing settings

Layer height (mm)	0.12	Extruder temperature (°C)	240
Number of top and bottom layers	4	Heated bed temperature (°C)	100
Number of perimeter shells	3	Fan cooling speed	0
Infill percentage	20 %	Printing speed (mm/s)	60

Five layers of glue were applied to the glass bed of the 3D printer using a generic glue stick to aid the adhesion between the ASA filament and the glass bed. Since a 3D print is most likely to fail when laying down the first few layers, each print was watched closely until the 3D printer began printing the infill. Figure 27 shows one of the waterwheels in the middle of being printed.

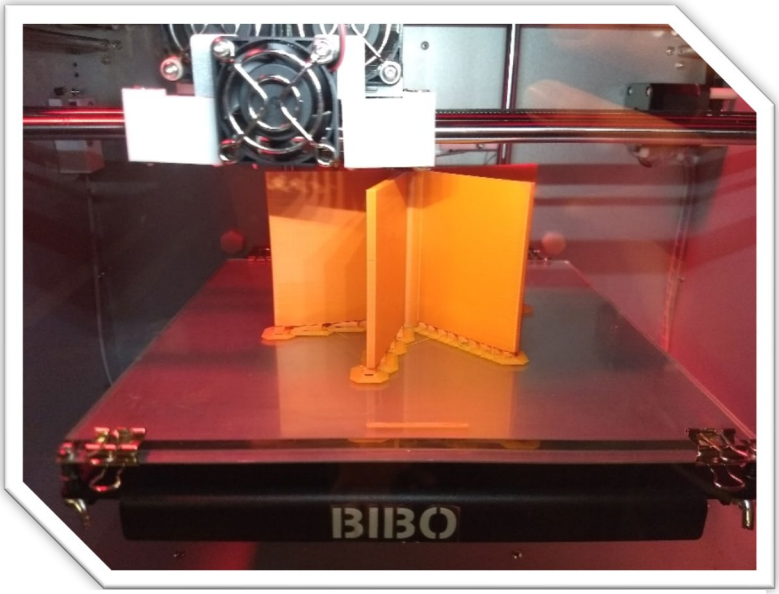


Figure 27. 3D printing example

7.4.3 ASSEMBLY

Water Squirter

Please see Figure 17 for reference during assembly.

Tools and Equipment:

- Phillips screw driver

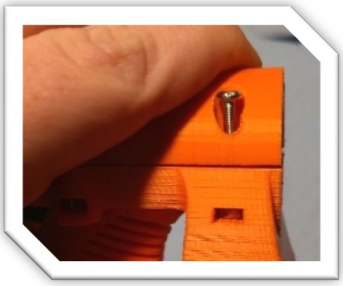
Procedure:

Step 1

Disassemble the garden hose nozzle by unscrewing the front nozzle and the back screw.

Step 2

Press the top and bottom casings on to the barrel of the garden hose nozzle.



Step 3

While applying pressure to the top and bottom of the casings slide an M3 screw in to the hole in the top casing. Next, slide an M3 hex nut into the slot in the bottom casing located below the hole in the top casing. Use the phillips screw driver to engage the screw and nut. Repeat with the three other attachment points. Finally, tighten all four screws until casing is secure.

Step 4

Reassemble the garden hose nozzle.

Step 5

Disassemble the washdown caster.

Step 6

Slide the caster bushing in to the hole inside the bottom casing.

Step 7

Reassemble the washdown caster.

Target

Please see Figure 18 for reference during assembly.

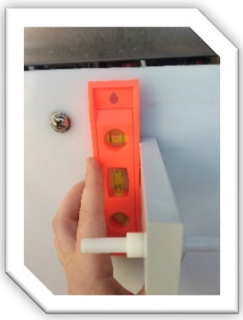
Tools:

- Set of allen keys
- Small level

Procedure:

Step 1

Slide the pulley shaft in to the hole in version 2 of the wall brace and secure it with a set screw. Next, connect the wall brace to the top two holes in the wall of the upper hexagon using 1-½" long ¼-20 screws.

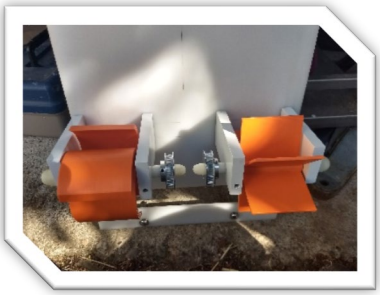


Step 2

Use a level to check that the wall brace is vertical. Adjust position if needed.

Step 3

Attach version 1 wall braces to the holes furthest from the center of the wall of the upper hexagon using ¾” long ¼-20 screws. Use step 2 to verfy the braces are level.
Next, slide the waterwheel shaft through the hole of the version 3 wall brace before sliding the waterwheel on to the shaft. Slide the end of the shaft through the hole in the outer wall brace. Secure the inner wall brace using ¾” long ¼-20 screws and verify the wall brace is vertical.

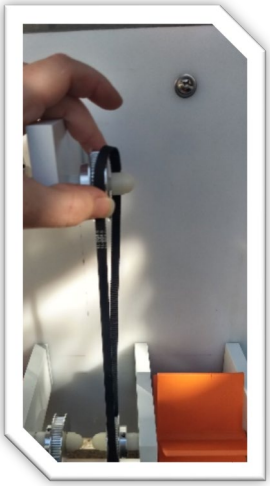


Step 4

Slide the timing pulley on to the shaft, then screw on the cap nuts to their respective sides of the waterwheel shaft. Tighten the set screws on the timing pulleys.

Step 5

Slide timing pulleys on to both sides of the pulley shaft, then screw the cap nuts on to either side of the shaft. Make sure that the set screws on the timing pulleys are loose, or removed entirely.



Step 6

Slide the timing belt over the bottom timing pulley, then pull it up until it is partially engaged with the from teeth of the top pulley. Slowly turn the top pulley until the timing belt is fully engaged with the top pulley.

Safety Cover

Tools:

- Acrylic bender. Custom made from plywood, aluminum U-channel, and 20 awg nickel chromium resistance wire.
- Power supply with leads.

Procedure:

Please note that the outer perimeter and the holes of the safety cover were cut using a laser cutter. The following procedure details how to bend the precut shape of the cover.

Step 1

With the power supply turned off, brace the safety cover against the straight edge guide and align the desire location of the bend over the nickel chromium wire in the center of the aluminum U-channel.

Step 2

Increase the power supplied to the nickel chromium wire until the wire glows orange.

Step 3

Once the acrylic softens, turn off the power supply and brace the fixed side of the cover. Quickly bend the other side by lifting the hinged plywood until is contacts the 90° stop. Continue to hold until the acrylic cools.

Step 4

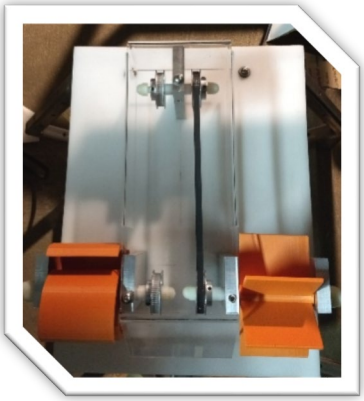
Repeat steps 1 through 3 for all 90° bends.

Step 5

Replace the 90° brace with a 60° brace.

Step 6

Repeat steps 1 through 3 for the 60° bend at the bottom of the safety cover.



Step 7

Attach the safety cover to the water squirter target.

Plumbing

To provide water to the water squirter feature, modifications were made to the old plumbing. These modifications are discussed in section 6.8. In addition, FIGURE X shows additional plumbing that was added specifically for the water squirter feature.

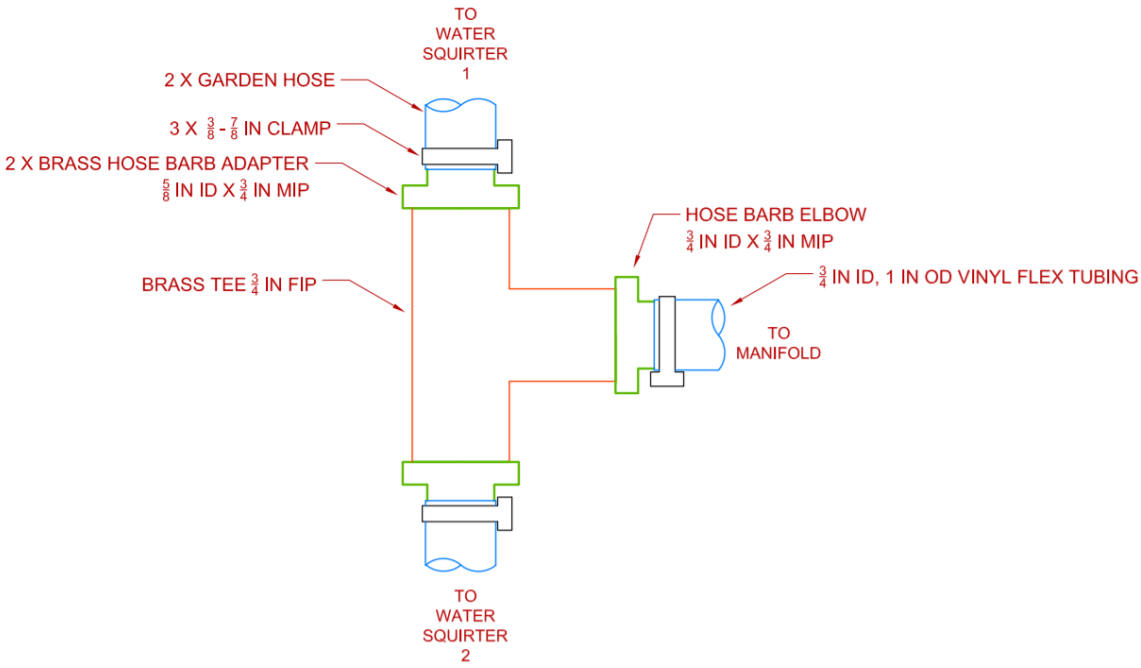


Figure 28. Water squirter plumbing addition

7.5 NO. 11 TIPPING WHALES

7.5.1 PROCUREMENT

The whales were 3D printed out of ASA by a Natasha O'Connell McKay on her personal 3D Printer. For the procurement of all other related materials see Appendix K.

7.5.2 MANUFACTURING

Tools and equipment:

- Tube bender
- 3D printer
- Drill press
    - No 7 drill bit
    - ¼ -20 tap
    - 0.26 in drill bit
    - Holesaw

Procedure:

1. Means Engineering cut the stainless steel tubes and bend into shape per the F11 drawing package in Appendix I

2. Means Engineering Inc. welded the tube components and PEM studs together per the F11 drawing package in Appendix I

3. After receiving the finished stand from Means Engineering Inc., holes are drilled into the metal support plate, INSERT PART NUMBER, using the drill press per the drawing

4. Use the drill press to drill similar holes into the white plastic wall

5. Epoxy two halves of the whale together

6. Drill hole into top of upper hexagon for the bulkhead passthrough Appendix I

7. Assemble whales and stand then cut ½ PVC to fit

8. Assemble PVC pieces and secure into the bulkhead passthrough.

7.5.3 ASSEMBLY

See drawing F11.B01 for assembly schematic in Appendix I.

Procedure:

1. Start with the upper hexagon removed from the table

2. Assemble the stand, wall, hardware, and whales together with the whale “heads” pointing towards each other per drawing F11.B01

3. Attach the wall to the upper hexagon frame.

4. Secure PVC parts through the bulkhead pass through. Add the remaining three plastic bushings, washers and spacers on the pivot rods per the schematic.

5. Return the upper hexagon to the basin. Secure part number F11.A02.01.01 and F11.A02.01.02 per the assembly drawing.

6. Attach the flex hosing in the upper hexagon to the corresponding outlet in the center of the table.

7. Turn the water on and adjust the ball valve so only a trickle of water comes out.

7.6 NO. 22 SNAP-IN GRID

7.6.1 PROCUREMENT

The walls and weirs were 3D printed by Natasha in ASA. Only three of these were printed before the printer broke. So we resorted to using plain Legos instead. For the procurement of all other related materials see the bill of materials in Appendix K.

7.6.2 MANUFACTURING AND ASSEMBLY

Tools and equipment:

- Box cutter
- Roller for epoxy

Procedure:

1. Cut boards to fit on the lower basin

2. Apply Legos onto the edges of boards to connect two adjacent bards and to ensure that the pegs are lined up across two adjacent boards

3. Clean the lower basin surface

4. Apply epoxy to basin and to the bottom of boards

5. Press boards onto basin

The main concern with the assembly of this feature is ensuring that the pegs of the Lego boards are lined up across two adjacent boards.

7.7 ELECTRICAL AND PROXIMITY DETECTION SYSTEM

The microcontroller and Internet of Things (IoT) relay were secured to the acrylic baseplate inside the electrical box supplied by Exploration Station. Low voltage wiring for the microwave sensors was run through outdoor, non-metallic, electrical flex conduit from the electrical box to the wet-location rated junction boxes housing the microwave sensors. The sensors and electrical box were mounted in the locations shown in Figure 24.

7.8 FILTRATION SYSTEM

In order to install the filter and several of the new water features, the old plumbing system was modified. Figure 29 shows diagrams of the old and the new plumbing configuration that was installed.

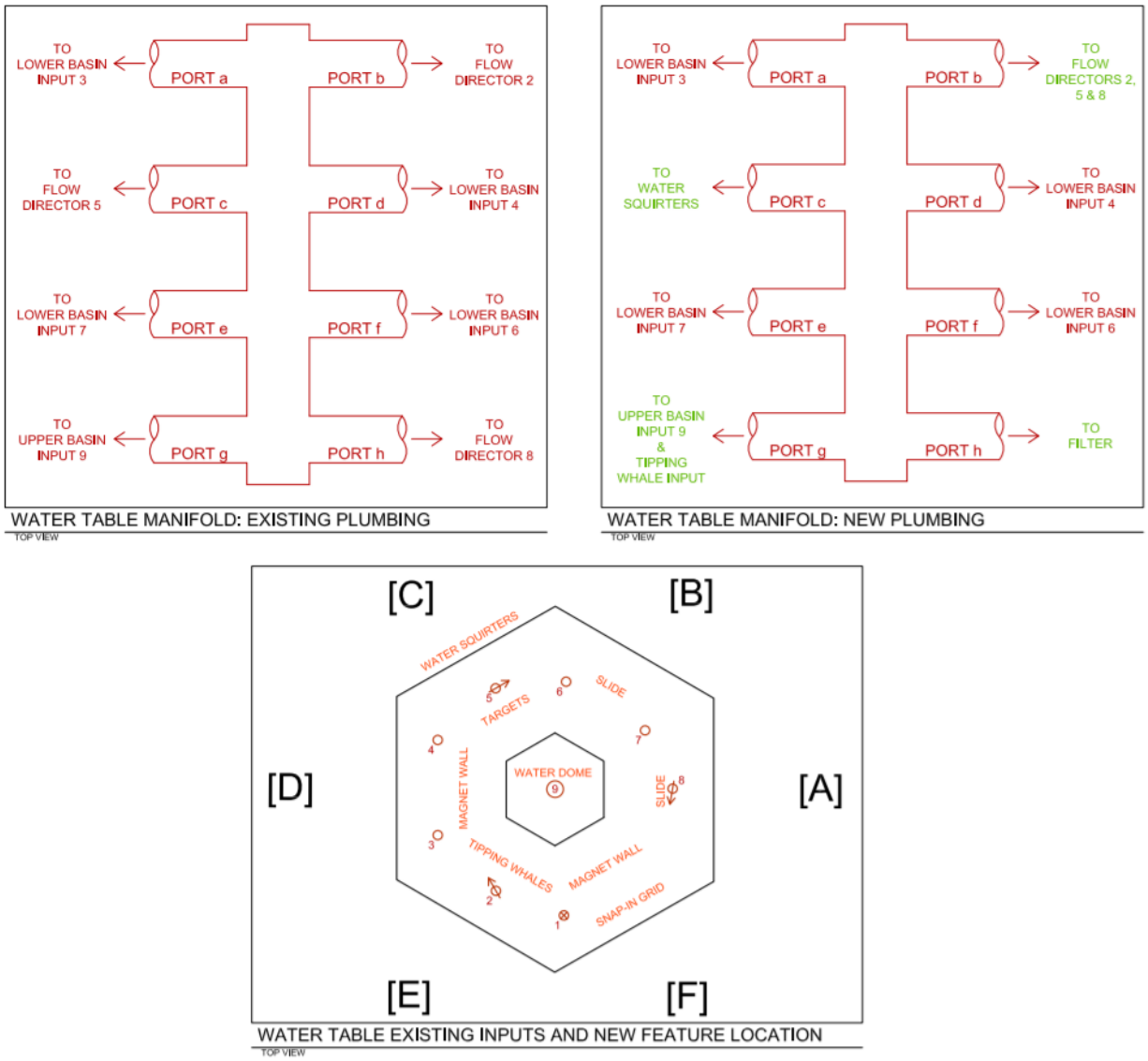


Figure 29. Overall plumbing diagram

8. DESIGN VERIFICATION PLAN

For the table of the design verification plan of this project, please see Appendix P.

8.1 RACETRACK

The racetrack was tested to ensure both structural stability and competitiveness between the two tracks. As seen in Figure 30, the racetrack flanges and support rods were tested to see if they could withstand 10 pounds of pulling force. Each flange-rod connection was tested, and each passed.

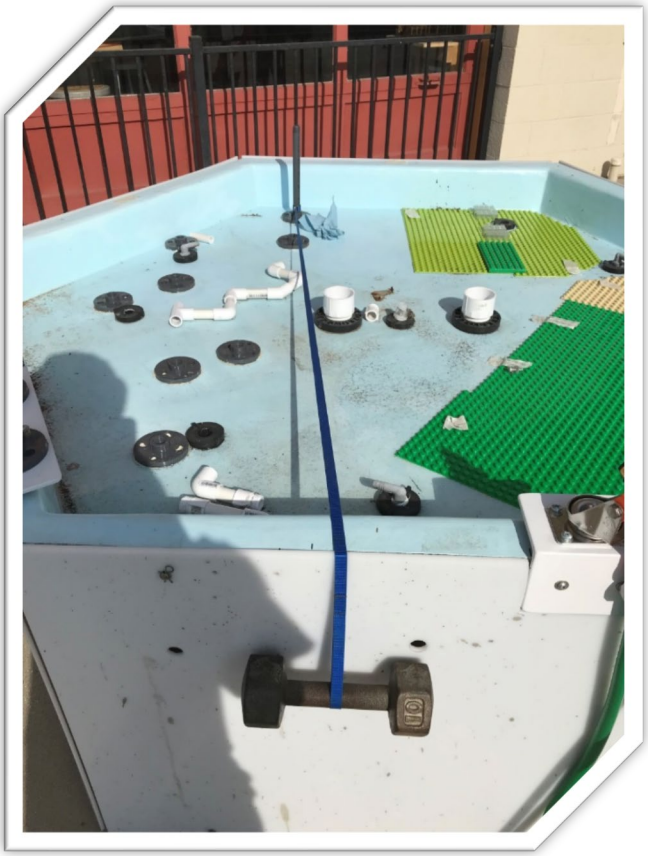


Figure 30. Racetrack rod and flange support structural test

The racetrack was also tested to ensure water and objects would flow down the track. When assembled on the table, a flexible hose was connected to each starter piece, and it was observed that these tests passed. Lastly, objects were raced down the tracks to make sure the race was competitive. After some adjusting, the tracks were deemed to be competitive, as objects would finish the path at nearly the same time.

8.2 CUP PYRAMID AND WALL FEATURES

The cups and wall features were initially tested with water from a hose. The water flowed well through each cup and feature, even from one cup and feature to another when they were orientated one on top of the other. Once the piping in the upper hexagon was established, the cups and features were tested on the walls to see how the flow was. Everything went well, as water was able to be transferred from the piping to the cups and features, also from cup to cup and feature to feature.

Referencing Appendix A, there are many strict standards and tests which toys with magnets need to go through. To summarize, the cups and features needed to be submerged in water, attached to the wall and pulled off, dropped, compressed, and impacted through a specific number of

cycles for each. For all tests, the magnets did not separate from the cup and feature and the part did not fracture.

8.3 TIPPING WHALES

Tests have been performed on the tipping whale geometry to see how well the whales hold water and tip. For the prototypes of the whales we printed the whale in two halves using PLA. The two halves were then epoxied together.

The testing procedure for this prototype was very simple: hang the whale on a 1/8-inch rod and pour water into the top. If the whale hangs correctly, tips over once filled with water, and then turns upright again when empty, the prototype is a success.

During prototyping of this feature, we realized that some design changes were necessary. For the first porotype, the pivot point was not in the ideal location so the whale when empty hung at such a steep angle that it could not get filled with water. For the second prototype, we moved the pivot point 0.01 inches closer to the COG when empty in the horizontal direction. This small change dramatically improved the way the empty whale hung, however it still was not ideal. In the following prototypes, slight changes to the pivot points were made as well as changes in the shape of the trough until we had created a prototype that functions properly.

We defined "functions properly" for this feature, as the whale tipping forward ten times in a row without tipping backwards and the whale must hold 40 ml of water before tipping over.

8.4 WATER SQUIRTERS

The water squirter feature was tested prior to assembly to ensure that the squirters would have the horizontal and vertical range to reach the targets and that they would have the hydraulic force needed to move the targets. Based upon testing from the previous iteration of this project, the maximum flow through each of the eight ports on the manifold was estimated to be 7 gpm. The water for both squirters comes from a single port on the manifold which is split via a tee connector. For this test it was assumed that the water was divided equally between the water squirters and that the head loss between the port and each water squirter was negligible.

Water Flow

For the system to function, the flow to the tested water squirter needed to be below 3.5 gpm, which is half of the total flow from the manifold. To estimate the flowrate, a hose was attached to a digital water flow meter which was then attached to one of the water squirter assemblies. As the digital flow meter recorded the volume of water, a stop watch was used to record the time. Values from this test can be found in Table 11. To calculate the flowrate, Q, equation 8.4.1 was used.

$$Q = \frac{V}{t}\ gpm \qquad \text{Eq 8.4.1}$$

Where,

V is the volume of water and
t is the time passed.

Next, the propagated uncertainty due to the uncertainty of the variables used to calculate the flow rate was derived. To calculate these values, the simplified form of the formula for propagation of error for multiplication and division was used, which is shown as equation 8.4.2.

$$u_Q = Q\sqrt{\left(\frac{u_V}{V}\right)^2 + \left(\frac{u_t}{t}\right)^2}\ gpm \qquad \text{Eq 8.4.2}$$

Table 11. Water squirter flow rate measurements

Volume of Water (gal)	Uncertainty (gal)	Time (min)	Uncertainty (min)	Flowrate (Q) (gpm)	Propagated Uncertainty (gpm)
1.1	±0.05	73	±.05	0.9	±0.041
1.4	±0.05	75	±.05	1.1	±0.040
1.6	±0.05	72	±.05	1.3	±0.042
			Average:	**1.1**	**±0.041**

Water Stream Range (F10.T01)

Figure 31. Water squirter range testing setup

Once the flowrate was measured, the water squirter was secured to a 2"X4" piece of wood and the vertical and horizontal range of the water squirter was measured. This setup can be seen in Figure 31. The vertical height of the water stream was measured 28 inches from the outlet of the water squirter, which is the distance between the water squirter and the target. The measured vertical range of the water stream was 14-¼", which was well above the required 8".

Hydraulic Force (F10.T02)

The final test for the water squirters was to make sure that they would be able to turn both waterwheels. This test was performed immediately after test F10.T01 with no adjustment to the flowrate. First, the assembled target was secured 28” away from the water squirter. Next, the water squirter was used to spin both waterwheels. Images of the setup and both waterwheels spinning can be seen in Figure 32, which verified that the hydraulic force from the water squirters would be able to power the waterwheel system.

Figure 32. Water squirter hydraulic force test

9. PROJECT MANAGEMENT

A Gantt chart, which is a project management tool used to layout necessary tasks and deadlines on a timeline, was created to ensure timely completion of our project. The Gantt chart can be found in Appendix O. For quick reference, the key milestones and deliverables for this project have been listed in Table 12.

Table 12. Key milestones and their date of completion

Deliverable	Date
Preliminary Design Review	6 March 2018
Interim Design Review	10 April 2018
CPConnect Grant Application	30 April 2018
Concept Design Review	4 May 2018
MESFAC Grant Application	5 May 2018
Manufacturing & Testing Review	5 June 2018
Final Design Report	7 December 2018

10. CONCLUSION & RECOMMENDATIONS

After acquiring the needed materials for this project, we began manufacturing our components and testing them as they were being manufactured. After iterating our designs until we achieved acceptable testing results, we were able to finish manufacturing of our final project components. All our components have been installed on the existing water table at exploration station. All components were tested again while on the table and it passes all tests. A flash drive with all the STL and CAD files will be provided to exploration station so that if a component needed to be replaced, they can easily do so. Discussed below are our recommendations and what we think the next steps are for this project.

10.1 RECOMMENDATIONS

10.1.1 MAGNETIC WALL FEATURES AND CUP PYRAMID

Due to the length of time 3D printing takes, it would have been wise to begin 3D printing earlier. In addition, several issues arose with the 3D printer during the 3D printing process which resulted in significant downtime of the 3D printer. Unfortunately, we were unable to begin 3D printing earlier than we did due to budget constraints. This resulted in us being unable to print all the components that we wanted to.

It is also recommended to ensure these features stay on the magnetic walls and avoid being placed anywhere else in or around the table.

10.1.2 RACETRACK

It would have been nice to have more time and epoxy the starter pieces one day at a time. This would have allowed for more accurate bonds and less epoxy visible on the pieces. It should also be noted that kids may tug on the flexible hosing at the start of the track. If there is a way to block this off or minimize the kids' interaction with this tubing, that would be advised. This tugging will likely not inhibit the functionality of the feature, but it could pose safety hazards.

10.1.3 SNAP-IN GRID

Due to the length of time 3D printing takes, it would have been wise to begin 3D printing earlier. In addition, several issues arose with the 3D printer during the 3D printing process which resulted in significant downtime of the 3D printer. Unfortunately, we were unable to begin 3D printing earlier than we did due to budget constraints. This resulted in us being unable to print all the components that we wanted to.

10.1.4 TIPPING WHALES

Find a marine epoxy that is either clear or paintable to hide the appearance of the white epoxy on the 3D printed whales.

10.1.5 WATER SQUIRTERS

The birds attached to the timing belts are not heavy enough to cause the waterwheel to spin backwards when no hydraulic force is applied. This means that the feature is less challenging than we had intended it to be. To fix this, Exploration Station may wish to add weight to the birds or use a difference object.

10.1.6 WATER DOME

The water dome that was ordered created a dome that was too large to fit within the constraints of the basin of the upper hexagon. In order to fix this problem, several water bell nozzles will need to be tested until one that has the correct profile is found. In addition, this feature is very susceptible to disturbances. When the wind blows, the shape of the dome is severely distorted. Since this feature is located outside, Exploration Station may wish to install a different fitting that creates water feature that will not be affected by wind.

10.1.7 ELECTRICAL AND PROXIMITY DETECTION

The relay that was used for this project only has two controllable outlets. Since the filter and pump are using these outlets, Exploration Station will not be able to add any additional electrical components to this system unless they find a different relay. Based upon out research, we did not see another prebuilt relay with outlets. If Exploration Station wishes to add additional components they will need to build a custom setup.

10.1.8 FILTRATION AND PLUMBING

Since we were working with a prebuilt plumbing system, some of the adaptations resulted in unintuitive plumbing. Ideally, the flexible tubing coming from the eight-port manifold would be entirely rerun so that the port providing water for a feature was located close to the feature.

10.2 NEXT STEPS

10.2.1 MAGNETIC WALL FEATURES AND CUP PYRAMID

If the 3D printer used for the first batch of features can return to operation, more parts will be supplied. If not, it is recommended to look for an alternative 3D printing source to print these parts. Also, the magnets should be ordered as the parts are made, and epoxy applied accordingly. The funnels should also be applied to half of the cup pyramid parts.

10.2.2 RACETRACK

It is recommended to divert the flow coming from the end of the racetrack to better leads the ping pong balls through the snap-in grid. It is also recommended to find a way to prevent kids from tugging on the flexible hosing at the start of the track.

10.2.3 SNAP-IN GRID

It is recommended to divert water flow more effectively through the grid so objects do not get stuck on the side of the table.

10.2.4 TIPPING WHALES

It is recommended that if the table will not be in use for a while, after the pump has been turned off, tip the whales over so that any water dumps out. This will help extend the whale's life and reduce the need for cleaning

11. WORKS CITED

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APPENDIX A THE STANDARD CONSUMER SAFETY SPECIFICATION FOR TOY SAFETY, ASTM F963

4.7 Accessible Edges

Toys shall not have accessible, potentially hazardous sharp edges. Toys that are intended to be assembled by an adult, and may contain unprotected potentially hazardous sharp edges in the unassembled state, shall be labeled in accordance with 5.8.

4.7.3 Metal Toys—Accessible metal edges, including holes and slots, shall be free of hazardous burrs and feathering, or shall be hemmed, rolled, or curled, or shall be covered with a permanently affixed device or finish.

4.7.4 Molded Toys—Accessible edges, corners, or mold parting areas of molded toys should be free of hazardous edges produced by burrs and flash or so protected that hazardous edges are not exposed.

4.9 Accessible Points

Toys shall not have accessible, potentially hazardous sharp points that may occur because of the following: configuration of the toy; assembly devices such as wires, pins, nails, and staples that are fastened poorly; poorly sheared sheet metal; burrs on screws; and splintered wood. Toys that are intended to be assembled by an adult and may contain potentially hazardous sharp points in the unassembled state shall be labeled in accordance with 5.8.

4.38 Magnets

This requirement is intended to address ingestion hazards associated with toys intended for children up to 14 years of age that contain a hazardous magnet. This requirement does not apply to magnets used in motors, relays, speakers, electrical components, and similar devices where the magnetic properties are not part of the play pattern of the toy.

4.38.1 Toys shall not contain a loose as-received hazardous magnet or a loose as-received hazardous magnetic component.

4.38.2 Toys shall not liberate a hazardous magnet or a hazardous magnetic component after being tested in accordance with the Magnet Test Methods specified in 8.25.

8.25 Magnet Test Methods

8.25.4 Magnet Use and Abuse Testing—Each unique component shall be tested per this section. A new component shall be used that has not been subjected to other use and abuse testing. All the testing in this section shall be performed in series on each unique component (that is, testing shall follow 8.25.4.1-8.25.4.8 in sequential order). However,

only wooden toys, toys intended to be used in water, and mouth pieces of mouth-actuated toys with magnets or magnetic component(s) shall be tested in accordance with 8.25.4.1.

8.25.4.1 Soaking Test for Magnets—Submerge the toy or toy component completely in a container of demineralized water at a temperature of 21.0 ±5.0°C for 4 minutes, remove the toy, shake off the excess water, and keep the toy at room temperature for 10 minutes. Perform the soaking test for a total of four cycles.

8.25.4.2 Cycling as Received—These tests are designed to simulate a reasonably foreseeable play pattern. It is possible for toys to contain a single magnet or a combination of magnets, magnetic components, or metal mating parts, or combinations thereof. Without damaging the toy, the magnetic parts shall be brought together to a distance that initiates magnetic attraction, released, and then pulled apart to the distance where magnetic attraction ceases. Each attachment and detachment shall count as one cycle. Perform the test one thousand (1000) cycles or until the magnet under test detaches from the toy, whichever occurs first. It is acceptable for the testing to be automated or to be performed manually.

> (1) Toys that Contain One Magnet Only and a Mating Metal Part—If no other magnets or magnetic parts are pro-vided with the toy, then the mating metal part or surface, according to the toy's intended play pattern, should be used for cycling purposes.

8.25.4.3 Drop Test—Test according to 8.7.1 or if applicable, 8.7.2.

> 8.7.1 Drop Test—Except for toys covered in 8.7.2, toys falling below the weight limit given below shall be dropped onto a specified impact area. The number of times the toy will be dropped, and the height from which it is dropped, is to be determined from Table 5. The toy shall be dropped in random orientation. The test sample shall be allowed to come to rest after each drop and shall be examined and evaluated before continuing. The impact medium shall consist of a 1⁄8-in. (3-mm) nominal thickness of Type IV vinyl composition tile, composition 1-asbestos free, as specified in Federal Specification SS-T-312B over at least a 2.5-in. (64-mm) thickness of concrete. The impact area shall be at least 3 ft^2 (0.3 m^2).

TABLE 5 Test Parameters for Use and Abuse Tests

Test	Age Category of Intended User, months	Numerical Value	
		Stated by the Voluntary Standard	Recommended for Toy Manufacturers
Drop test	0 to 18	10 × 4.5 ft ± 0.5 in. (137 cm)	4 ft, 6.5 in. (1.38 m)
	over 18 to 36	4 × 3.0 ft ± 0.5 in. (91 cm)	3 ft, 0.5 in. (0.93 m)
	over 36 to 96	4 × 3.0 ft ± 0.5 in. (91 cm)	3 ft, 0.5 in. (0.93 m)
Torque test	0 to 18	2 ± 0.2 in.·lbf (0.23 N·m)	2.2 in.·lbf (0.25 N·m)
	over 18 to 36	3 ± 0.2 in.·lbf (0.34 N·m)	3.2 in.·lbf (0.36 N·m)
	over 36 to 96	4 ± 0.2 in.·lbf (0.45 N·m)	4.2 in.·lbf (0.47 N·m)
Tension test	0 to 18	10 ± 0.5 lbf (44.5 N)	10.5 lbf (46.7 N)
	over 18 to 36	15 ± 0.5 lbf (66.8 N)	15.5 lbf (69.0 N)
	over 36 to 96	15 ± 0.5 lbf (66.8 N)	15.5 lbf (69.0 N)
Compression test	0 to 18	20 ± 0.5 lbf (89.0 N)	20.5 lbf (91.2 N)
	over 18 to 36	25 ± 0.5 lbf (111.3 N)	25.5 lbf (113.5 N)
	over 36 to 96	30 ± 0.5 lbf (133.5 N)	30.5 lbf (135.7 N)
Flexure test	0 to 18	10 ± 0.5 lbf (44.5 N)	10.5 lbf (46.7 N)
	over 18 to 36	15 ± 0.5 lbf (66.8 N)	15.5 lbf (69.0 N)
	over 36 to 96	15 ± 0.5 lbf (66.8 N)	15.5 lbf (69.0 N)

8.25.4.4 Torque Test—Test according to 8.8.

> 8.8 Torque Tests for Removal of Components—Any toy with a projection, part, or assembly that a child can grasp with at least the thumb and forefinger or the teeth shall be subject to this test. The amount of torque shall be determined from Table 5, according to the age group for which the toy is intended. The loading device used in the test shall be a torque gauge, torque wrench, or other appropriate device having an accuracy of ±0.2 in.·lbf (±0.02 N·m). A clamp capable of holding the test component firmly and transmitting a torsional force shall be used. The clamp is fastened to the test object or component with the toy fastened rigidly in any reasonable test position. The torque shall be applied evenly within a period of5sinaclockwise direction until either (1) a rotation of 180° from the original position has been attained, or (2) the required torque is exceeded. The maximum rotation or required torque shall be maintained for an additional 10 s. The torque shall then be removed and the test component permitted to return to a relaxed condition. This procedure shall then be repeated in a counterclockwise direction. Projections, parts, or assemblies that are mounted rigidly on an accessible rod or shaft designed to rotate along with the projections, parts, or assemblies shall be tested with the rod or shaft clamped to prevent rotation. If a component that is attached by a screw thread that has been assembled by the manufacturer, or that has been assembled to the manufacturer's instructions, becomes loosened during application of the required torque, continue to apply the torque until either (1) the required torque is exceeded, or (2) the part disassembles. The test should be terminated if it becomes obvious that the part under test will continue to rotate at less than the required torque limit and will not disassemble.

8.25.4.5 Tension Test—Test according to 8.9.

> 8.9 Tension Test for Removal of Components—Any projection of a toy that a child can grasp with at least the thumb and forefinger or the teeth shall be subjected to this test. The tension test shall be performed on the same components

of the toy subjected to the torque test described in8.8. The amount of force used shall be determined from Table 5, according to the age group for which the toy is intended. A clamp capable of applying a tension load to the test component shall be applied in a manner that will not affect the structural integrity of the attachment between the component and the toy. The loading device shall be a self-indicating gauge or other appropriate means having an accuracy of ±0.5 lb (±2 N). With the test sample fastened in a convenient position, an appropriate clamp shall be attached to the test object or component. The required tensile force shall be applied evenly, within a period of 5 s, parallel to the major axis of the test component, and maintained for an additional 10 s. The tension clamp shall then be removed, and a second clamp suitable for applying a tension load perpendicularly to the major axis of the test component shall be attached to the test object component. The required tensile force shall be applied evenly, within a period of 5 s, perpendicularly to the major axis of the test component and maintained for an additional 10 s.

8.25.4.6 Impact Test—Place the magnetic part or magnetic component in an orientation that is most likely to result in breakage on a plane horizontal steel surface and drop a metallic weight with a mass of 1.0±0.02 kg distributed over an area with a diameter of 80±2 mm through a distance of 100±2mm on to it. Determine if a hazardous magnet or a hazardous magnetic component is generated.

8.25.4.7 Compression Test—Test according to 8.10 (for magnets that are accessible but cannot be grasped as defined in8.9; an example of a magnet that is accessible but cannot be grasped is a magnet that is recessed.

8.25.4.8 Cycling – After Abuse Testing—Repeat the testing described in 8.25.4.2.

65527. Water Clarity

The pool operator shall maintain clear pool water while the public pool is in use. The pool operator shall close the public pool if the bottom of the pool at the maximum depth is not clearly visible from the deck. The pool operator shall not reopen the public pool for use until the pool water is clean and clear, and the bottom of the pool at the maximum depth is clearly visible from the deck. If the bottom of the pool is not visible 48 hours following inspection and closure by the enforcing agent, the enforcing agent may order the pool drained.

Authority cited: Sections 116035, 116050 and 131200, Health and Safety Code.

Reference: Sections 116040, 116043, 116050, 116053, and 116055, Health and Safety

65529. Public Pool Disinfection

(a) Public pools, when open or in use, shall be disinfected continuously by a chemical that imparts a disinfectant at concentrations consistent with subdivision (b) of this section. If halogens other than chlorine are used, residuals of equivalent strength shall be maintained.

(b) The minimum and maximum concentrations of disinfectant residuals in public pool water shall be:

	Free-Chlorine Residual				Bromine Residual	
	Without CYA		With CYA			
	Min	Max	Min	Max	Min	Max
Public Pools*	1.0 ppm	10.0 ppm	2.0 ppm	10.0 ppm	2.0 ppm	--
Public Spas, Wading Pools, and Spray Grounds	3.0 ppm	10.0 ppm	3.0 ppm	10.0 ppm	4.0 ppm	--

CYA = cyanuric acid; Min = minimum; Max= maximum; ppm= parts per million.
*This includes all public pools except spas, wading pools, and spray grounds.

Figure 33. Concentration of disinfectant in public pools

(c) In addition to the requirements in subdivisions (a) and (b), a spray ground and water features with an ultraviolet light disinfection system shall be disinfected continuously at a minimum of 40 mJ/cm2 by the ultraviolet light disinfection units while the spray ground and water features are in use. If the ultraviolet dosage rate drops below 40 mJ/cm2 the operator shall close the spray ground and water features.

(d) The enforcing agent may accept other disinfecting materials or methods after the pool operator has demonstrated to the enforcing agent that the materials or methods provide a readily measurable disinfectant residual in the public pool. The pool operator shall demonstrate to the enforcing agent that such materials or methods are at least as effective as the required chlorine concentration and do not have adverse physiological effects on pool users.

(e) The pool operator shall maintain a test kit for measuring the disinfectant residual, pH, and, if used, cyanuric acid concentration at the public pool. This test kit shall be available for use by the pool operator and the enforcing agent at all times the public pool is in use. The chlorine or bromine test kit shall be the diethyl-p-phenylenediamine (DPD) type or otherwise be capable of testing free-halogen residual. Chlorine test kits shall be capable of testing for free chlorine and total chlorine, such that combined chlorine concentrations can be determined.

Authority cited: Sections 116035, 116050 and 131200, Health and Safety Code.

Reference: Sections 116035, 116040, 116043, 116050 and 116055, Health and Safety Code

65530. Public Pool Water Characteristics

The pool operator shall maintain public pool water characteristics within the following ranges:

	Minimum	Maximum
pH	7.2	7.8
Cyanuric Acid Concentration	0.0 ppm	100.0 ppm
Combined Chlorine Concentration	0.0 ppm	0.4 ppm
Pool Water Temperature	Not Applicable	104° F

ppm = parts per million.

Figure 34. Public pool water characteristics

Authority cited: Sections 116035, 116050 and 131200, Health and Safety Code.

Reference: Sections 116035, 116040, 116043 and 116050, Health and Safety Code.

65533. Public Pool Cleanliness

(a) The pool operator shall maintain clean pool water while the public pool is in use. The pool operator shall not allow debris, including, but not limited to, floating scum, sputum, trash, or leaves, to accumulate in the public pool. The pool

operator shall ensure that water levels are maintained and operated to remove such material continuously through the pool skimming system in accordance with section 3136B, Title 24, California Code of Regulations.27

(b) The pool operator shall clean the bottom, sides, and other surfaces of the public pool as often as necessary to keep the bottom, sides, and public pool surfaces clean and free of slime and algae

Authority cited: Sections 116035, 116050 and 131200, Health and Safety Code.

Reference: Sections 116035, 116040, 116043 and 116050, Health and Safety Code

APPENDIX C CALIFORNIA ELECTRICAL REGULATIONS

Excerpt from:

California Health and Safety Code

Division 104. Environmental Health

Part 10. Recreational Safety

Chapter 5. Safe Recreational Water Use

Article 5. Swimming Pool Sanitation

116049. Ground-fault interrupter

(a) "Public swimming pool," as used in this section, means any public swimming pool defined in Section 116025 that is owned or operated by the state or any local governmental entity, including, but not limited to, any city, county, city and county, charter city, charter county, or charter city and county.

(b) All dry-niche light fixtures, and all underwater wet-niche light fixtures operating at more than 15 volts in public swimming pools shall be protected by a ground-fault circuit interrupter in the branch circuit, and all light fixtures in public swimming pools shall have encapsulated terminals. This subdivision is declaratory of existing law.

(c) Any public swimming pools that do not meet the requirements specified in subdivision (b) by January 1, 1995, shall be retrofitted to comply with these requirements by January 1, 1996.

(d) The ground-fault circuit interrupter required pursuant to this section shall comply with Underwriter's Laboratory standards.

(e) Any state or local governmental entity that owns or operates a public swimming pool shall have its public swimming pool inspected by a qualified inspector prior to July 1, 1996, to determine compliance with this section.

(f) A public swimming pool may charge a fee, or increase its fee charged, to the public for use of the pool, for the purpose of recovering the administrative and other costs of retrofitting pools in compliance with this section. The charge or increase due to this section shall terminate when funds sufficient to cover these costs are collected.

(g) All electrical work required for compliance with this section shall be performed by an electrician licensed pursuant to Chapter 9 (commencing with Section 7000) of Division 3 of the Business and Professions Code.

Excerpts from:

Title 8 of the California Code of Regulations

Subchapter 5. Electrical Safety Orders

Group 1. Low-Voltage Electrical Safety Orders

Article 4. Requirements for Electrical Installation

§2340.5. Conductors.

(a) Insulation. All conductors used for general wiring shall be insulated unless otherwise permitted in these safety orders.
(b) Type. The conductor insulation shall be of a type that is approved for the voltage, operating temperature, and location of use.
(c) Distinguishable. Insulated conductors shall be distinguishable by appropriate color or other suitable means as being grounded conductors, ungrounded conductors, or equipment grounding conductors.

Note: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

§2340.11. Deteriorating Agents.

(a) Unless approved for the purpose, no conductors or equipment shall be located:
    a. In damp or wet locations.
    b. Where exposed to gases, fumes, vapors, liquids, or other agents that have a deteriorating effect on the conductors or equipment.
    c. Where exposed to excessive temperatures.

Note: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

§2340.12. Mechanical Execution of Work.

Electric equipment shall be installed in a neat and workmanlike manner.

(a) Unused openings in boxes, raceways, auxiliary gutters, cabinets, equipment cases, or housings shall be effectively closed to afford protection substantially equivalent to the wall of the equipment.
(b) Conductors shall be racked to provide ready and safe access in underground and subsurface enclosures that persons enter for installation and maintenance.
(c) Internal parts of electrical equipment, including busbars, wiring terminals, insulators, and other surfaces, shall not be damaged or contaminated by foreign materials such as paint, plaster, cleaners, abrasives, or corrosive residues.

(d) There shall be no damaged parts that may adversely affect safe operation or mechanical strength of the equipment, such as parts that are broken, bent, cut, or deteriorated by corrosion, chemical action, or overheating.

Note: Authority cited: Section 142.3, Labor Code. Reference Section 142.3, Labor Code.

§2340.13. Mounting and Cooling of Equipment.

(a) Mounting. Electric equipment shall be firmly secured to the surface on which it is mounted. NOTE: Wooden plugs driven into holes in masonry, concrete, plaster, or similar materials are not considered secure means of fastening electric equipment.
(b) Electric equipment that depends on the natural circulation of air and convection principles for cooling of exposed surfaces shall be installed so that room airflow over such surfaces is not prevented by walls or by adjacent installed equipment. For equipment designed for floor mounting, clearance between top surfaces and adjacent surfaces shall be provided to dissipate rising warm air.
(c) Cooling. Electrical equipment provided with ventilating openings shall be installed and maintained so that free circulation of air through the equipment is not obstructed.

Note: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

§2340.17. Guarding of Energized Parts.

(a) Except as elsewhere required or permitted by these orders, energized parts of electric equipment operating at 50 volts or more shall be guarded against accidental contact by use of approved cabinets or other forms of approved enclosures or by any of the following means:
    a. By location in a room, vault, or similar enclosure that is accessible only to qualified persons.
    b. By suitable permanent, substantial partitions or screens so arranged that only qualified persons will have access to the space within reach of the energized parts. Any openings in such partitions or screens shall be so sized and located that persons are not likely to come into accidental contact with the energized parts or to bring conducting objects into contact with them.
    c. By location on a suitable balcony, gallery, or platform so elevated and otherwise located as to prevent access by unqualified persons; or
    d. By elevation of 8.0 feet (2.44 m) or more above the floor or other working surface.

Note: Authority cited: Section 142.3, Labor Code. Reference: Section 142.3, Labor Code.

APPENDIX D HOUSE OF QUALITY

QFD: House of Quality
Project: Water Fun at Exploration Station
Revision: Version 1
Date: 1/31/18

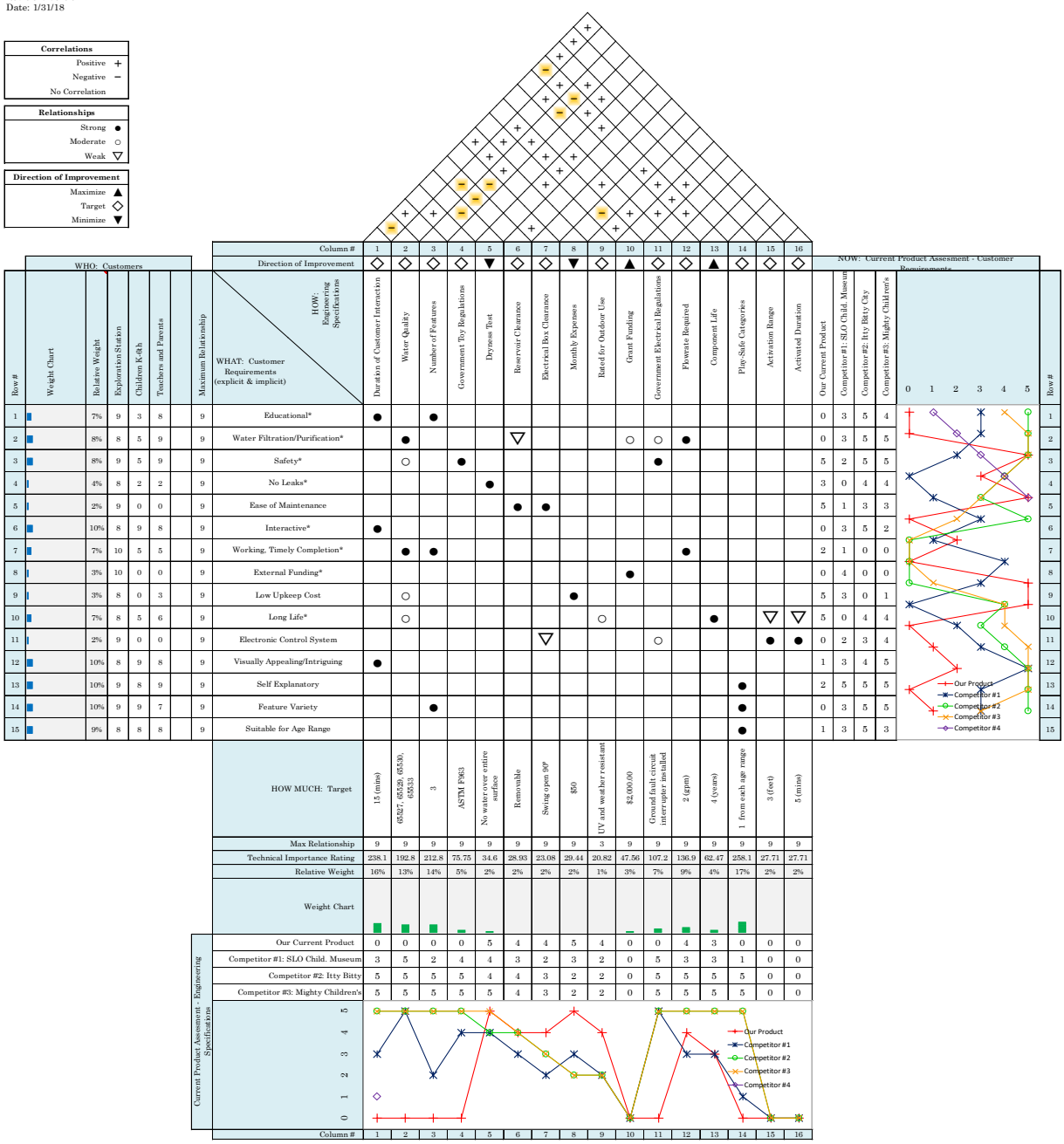
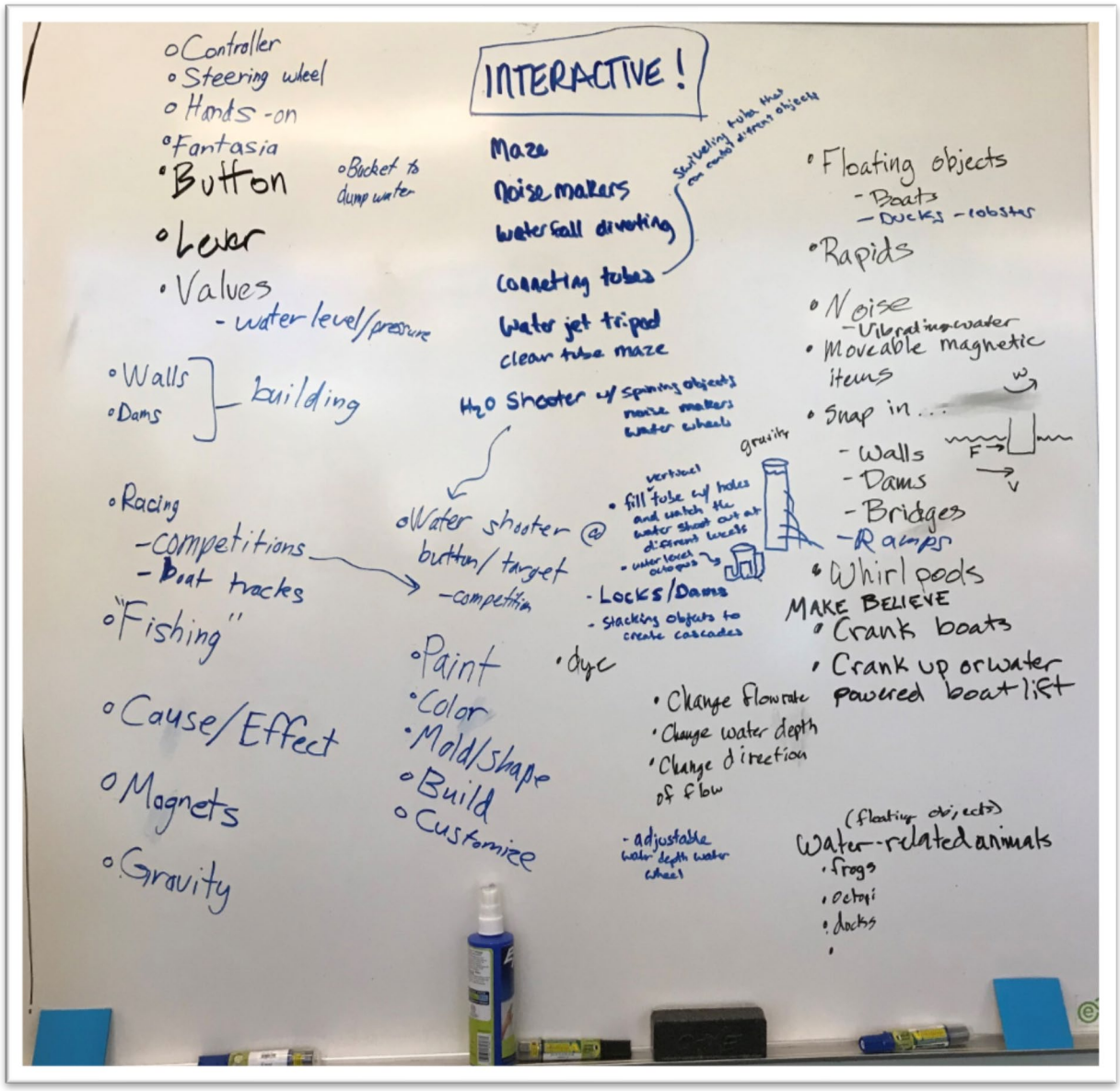
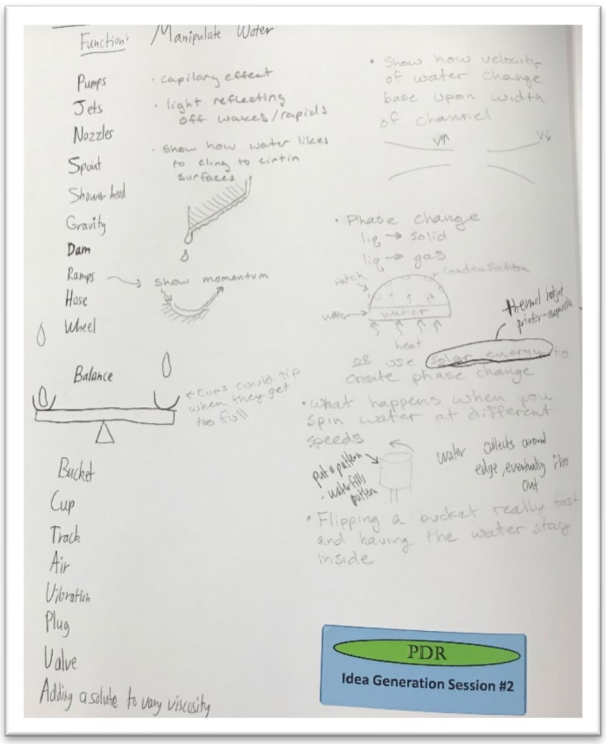


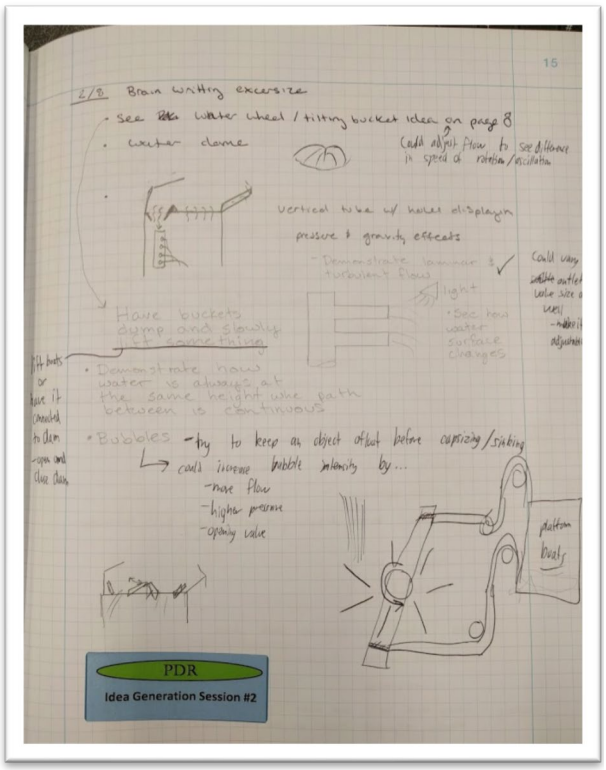
Figure D-1 House of quality

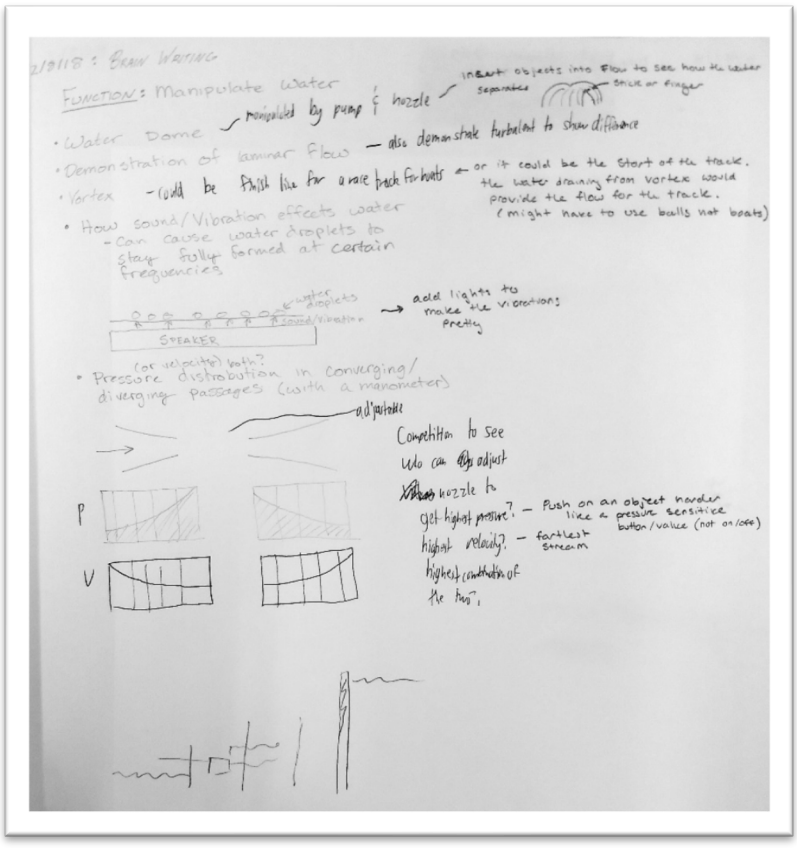
Ideation Sessions



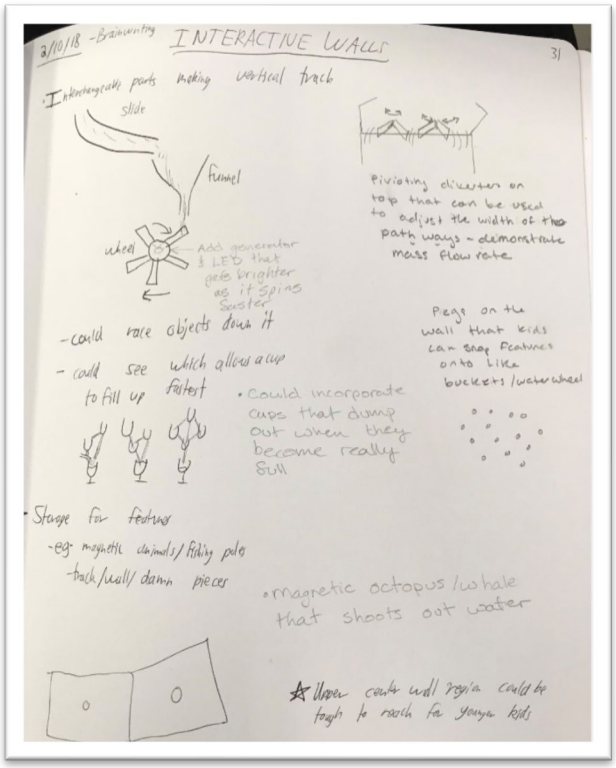
Session 1: Brainstorming interactive components

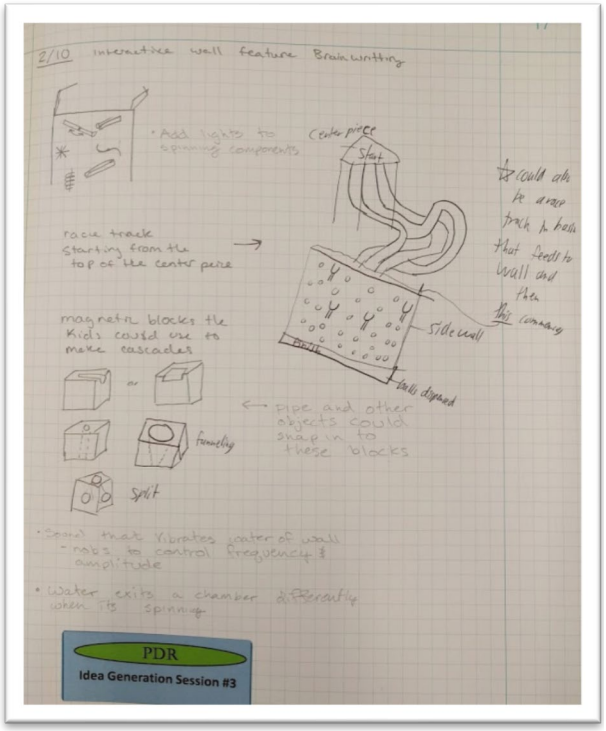


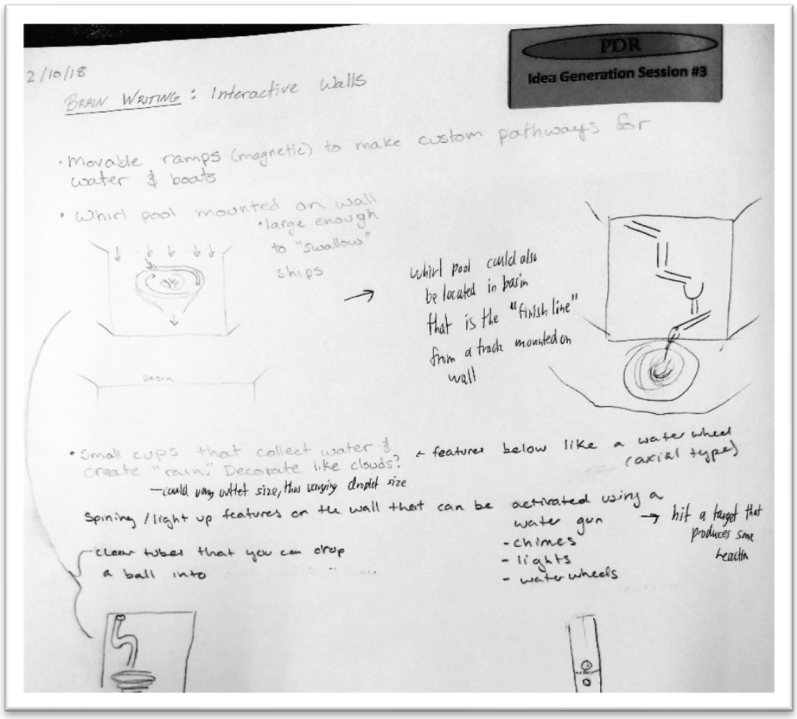




Session 2: Brainwriting for manipulating water

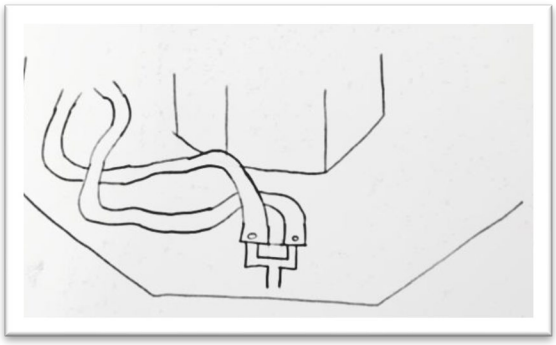




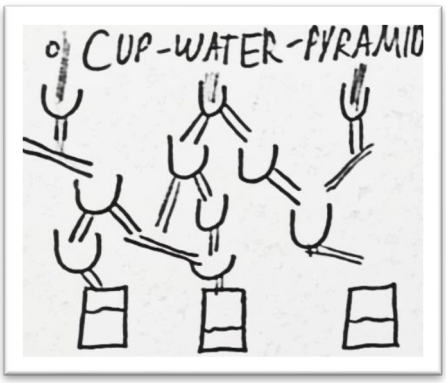


Session 3: Brainwriting for interactive walls

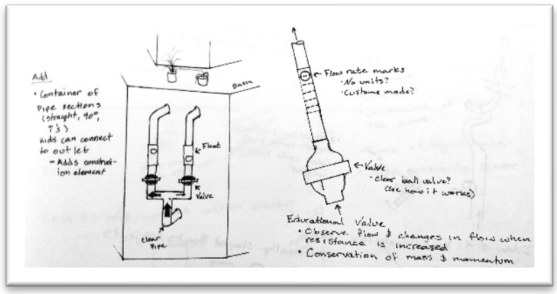
Feature Sketches



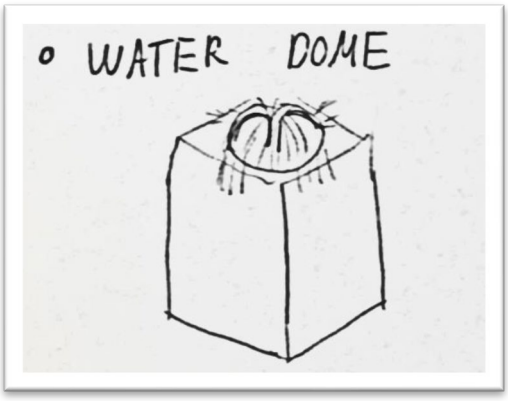
No. 1 Fixed Racetrack
Two racetracks for boats and other floating objects that will be attached to a platform that is secured to the lip of the lower basin.



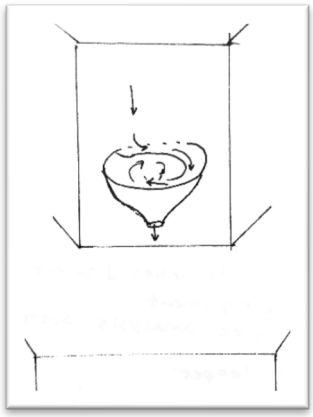
No. 2 Cup Water Pyramid
A series of magnetic cups that can be moved around the magnetic walls to direct the flow of water.



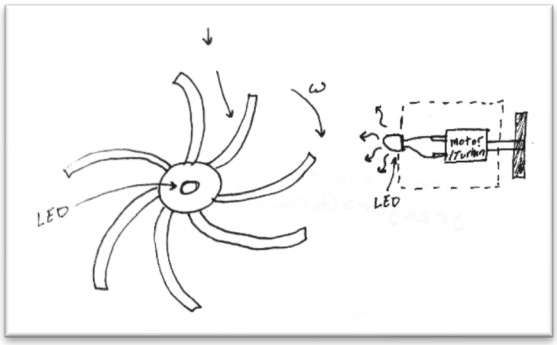
No. 3 Pipe Flow Demonstration
Two of the water outlets in the basin will be attached to valves on the outer walls of the large hexagon, which will allow children to adjust the relative flow of water.



No. 4 Water Dome
A water dome fixture which is attached to the outlet on top of the small hexagon.

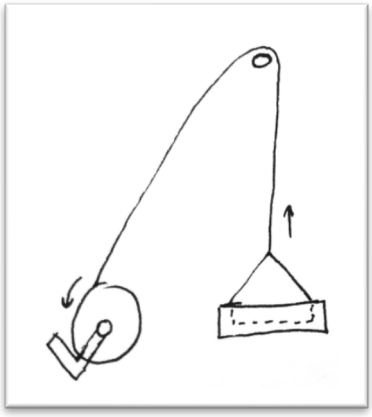


No. 5 Whirlpool

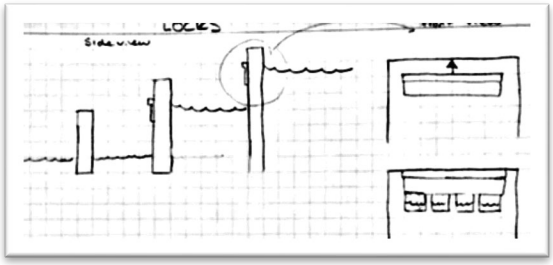


No. 6 Waterwheel with LED

The whirlpool would be in a clear container with water being supplied from the top and drain out of the bottom.

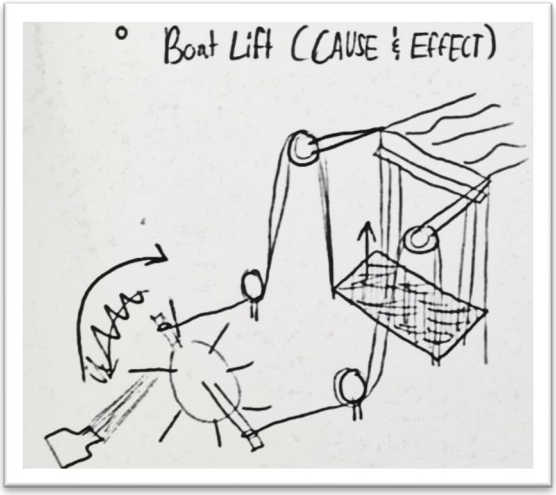


No. 7 Boat Lift: Crank
A crank operated boat lift that will allow children to move boat between the lower and upper basins.

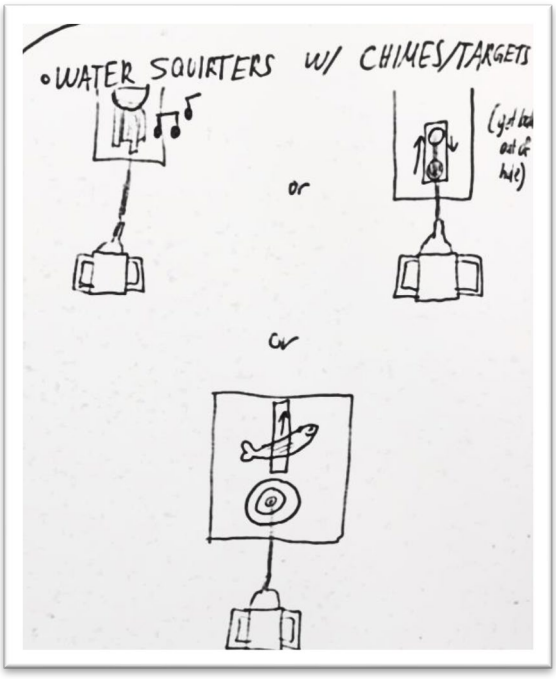


No. 9 Locks (Raising Boats)
A demonstration of real-life engineering, using locks to raise a bout from one water level to another.

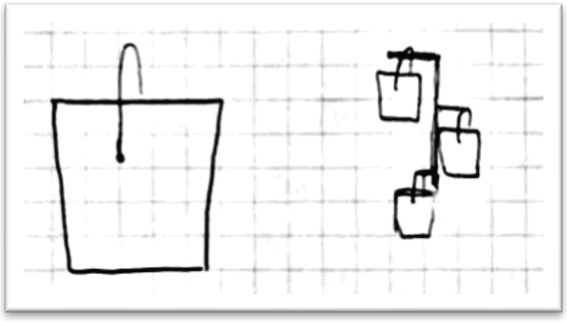
This waterwheel would be against an upper wall and moved by the flow of the water in the basin. The wheel would then power an LED.



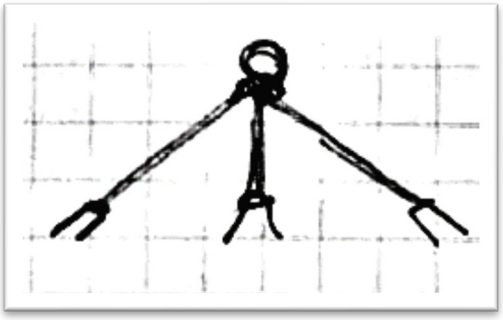
No. 8 Boat Lift: Cause and Effect
A boat lift that is raised through a series of pulleys and shaft attached to a water wheel.



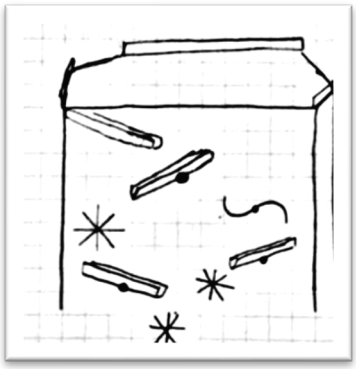
No. 10 Water Squirters with Chimes/Targets
Two water squirters attached to the lip of the basin that can swivel and pivot. Targets or chimes will be attached to the wall of the small hexagon for the children to shoot at.



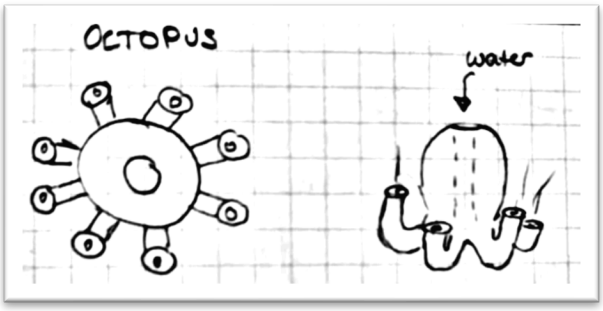
No. 11 Tipping Buckets
Buckets that are weighted such that once they are full, they tip over pouring out the water, then turn upright again.



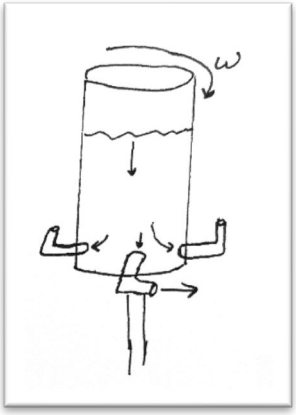
No. 12 Water Jet Tripod
Three water streams are oriented so that they meet at one point so that they can hold up a ball.



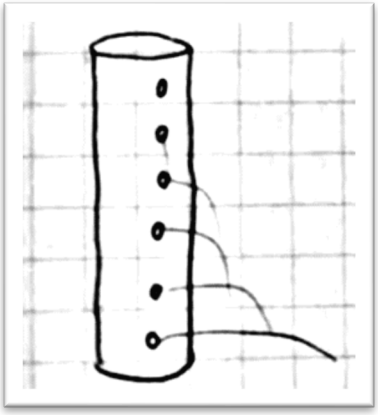
No. 13 Water Teeter-Totter
Water channels that are pinned and upper wall so that the user can pivot them to change water flow.



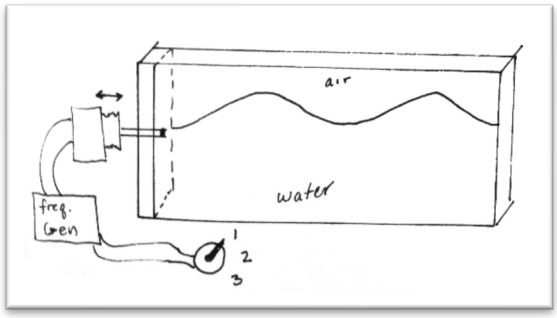
No. 14 Octopus with Water Streams
Water is poured in to the top and comes out of the different legs that are different lengths due to gravity, demonstrating water pressure.



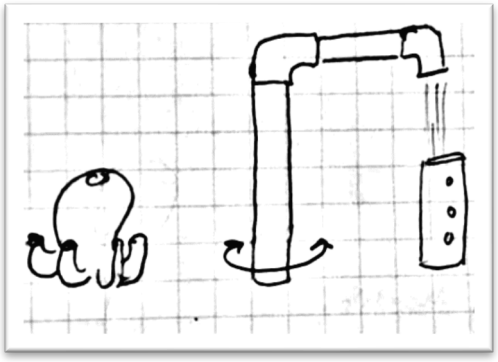
No. 15 Spinning Cup with Water Jets
A cup that is filled with water. Water exiting the 90° elbows causes the cup to spin.



No. 16 Vertical Tube with Holes
A vertical tube that will with water a demonstrates how water pressure determines the length of the water jet.

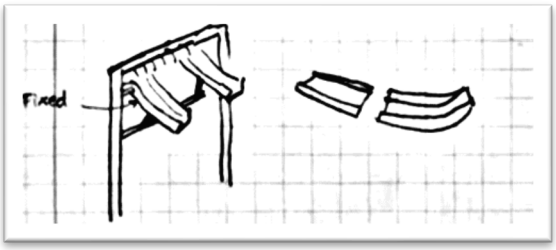


No. 17 Standing-Wave Display
A container with an oscillating wall that demonstrates constructive and destructive interference.

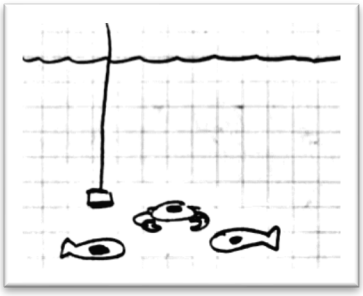


No. 18 Water Outlet with Pivot
A pivoting water outlet that lets children fill different objects.

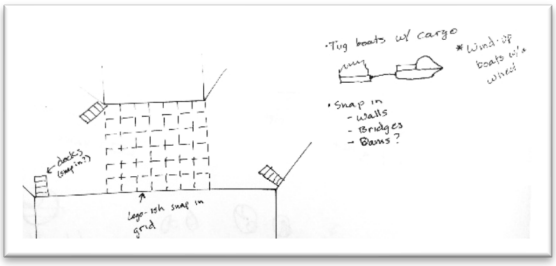
No. 19 Adjustable Water Channels
Adjustable walls at the top of the small hexagon that allow children to determine how water flows down the sidewalls.



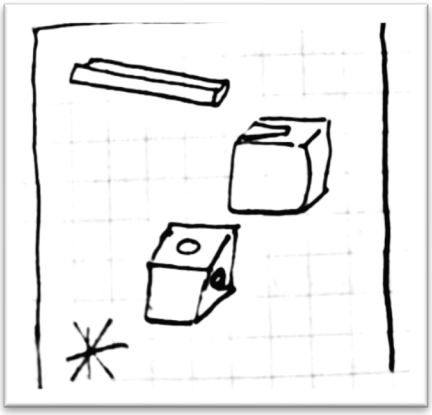
No. 20 Snap-Together Racetrack
A set of racetrack sections that allow children to build their own racetrack.



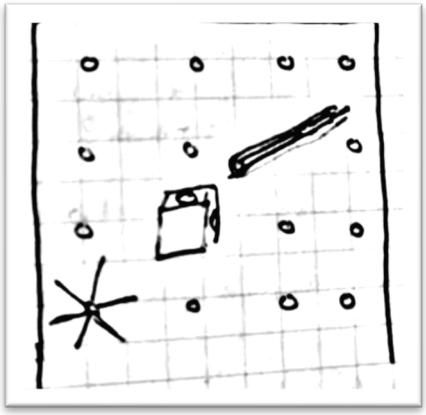
No. 21 Magnetic Fishing
Fishing poles with magnets at the end attached to floating, magnetic sea creatures in the large basin.



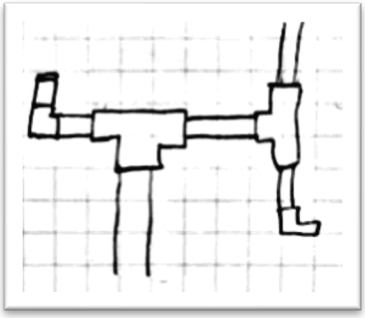
No. 22 Snap-In Grid
A snap-in grid located in the lower basin that lets children connect walls and other items to create their own pathways.



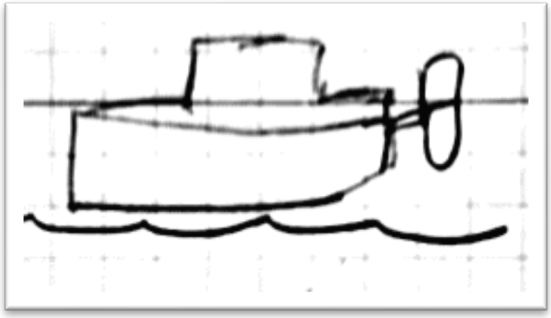
No. 23 Magnetic Wall
A metal wall attached to three of the walls of the small hexagon that has detachable magnetic objects that allow children to alter the flow of water.



No. 24 Pegboard Wall
A pegboard wall attached to three of the walls of the small hexagon that has detachable objects that fit on the pegs of the pegboard.



No. 25 Snap-Together Pipes
A set of pipes and joints that connect to the outlets in the large basin.



No. 26 Wind-Up Boats
Boats that the children can wind and will move around the large basin.

APPENDIX F CONCEPT DESIGN DEVELOPMENT

Concept Development Process

Water Slide

The first concept model we created was a water slide. The slide was created out of clear, rigid plastic tubing which was bent and shaped using a heat gun. We were interested to see how well the water flowed through the tube, and where a ball would get caught in the tube. Because it was a very rough concept model, it was difficult to get a good downward slope, retain water in the tube, and have the ball run down it uninterrupted.

Water Dome

The second concept model we tested was a 3D printed water dome fixture for a fountain [7]. We were testing the 3D model to see if it would produce a water dome suitable for the top of the water table. While it did produce a partial water dome, it appeared that the quality of the 3D print was not good enough to produce a full dome.

Tipping Cups

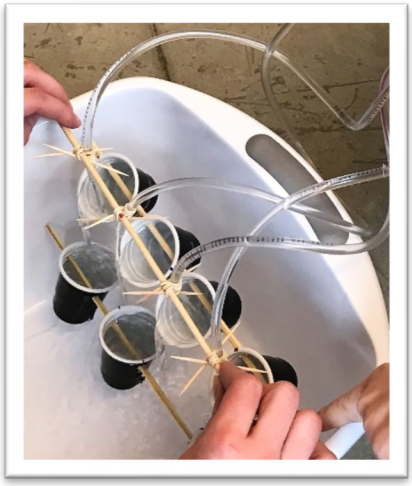
The third concept model built was a set of tipping cups. We varied the location of the pivot on each cup to see whether we could get a cup to tip reliably. Some of the cups tipped but did not return to an upright position and some of the cups did not tip at all. We determined that we needed to do further research and analysis to create more accurate models of this feature.

Cascade Blocks

The final concept model we made was a set of cascade blocks. These concept modeled blocks were large foam dice with tunnels and paths carved in them. Because of the roughness of the model, the water did not flow through the blocks as desired. More defined guidance from one block to the next would be required to get good flow through a series of blocks.

(a) Water slide

(b) Water dome



(c) Tipping water cups

(d) Cascade blocks

Concept models

Concept Selection Process

Fixed Features

Cup Pyramid

The cup water pyramid was selected largely due to its educational value and interactivity. It is also safe, easy to manufacture, requires no difficult plumbing modifications, durable, visually appealing, and cheap.

Water Dome

Another concept selected was the water dome. The water dome is a simple feature that does not require interaction and does not offer much educational value, but it is visually appealing, cheap, safe, and easy to assemble. It works well with all ages and is simple to maintain.

A 3D printed water dome was tested previously in the concept modeling stage. This proved that a 3D printed water dome may not suffice for our table, at least one at the quality we had. We determined it may be worth outsourcing to a better 3D printer, or possibly looking into buying one of a different material from a retailer. Whatever water dome we decide to proceed with, we could test it with a pump and tube to see if it performs as we want it to. This would include a nearly clear water layer falling in a complete dome on top of the upper hexagon.

LED Waterwheel

The LED waterwheel is a waterwheel that sits in the large basin and provides power to an LED. This feature is one of the more difficult to manufacture and maintain. In addition, it also contains some safety concerns due to electricity and pinching hazards. However, the educational value and visual appeal offered by LED waterwheel were very high.

Tipping Buckets

A tipping bucket is a weighted so that it remains upright when empty and will tip over when full of water. We are planning on having two of these buckets placed above each other so that when the top bucket gets full, it will dump out into the bucket below it. This second bucket would then tip over and dump water out into the basin once full. We made the bucket that the very bottom larger than the top one so that the top bucket have to fill up and tip over multiple times before the bottom bucket tips over.

The tipping buckets idea is visually appealing, suitable for all ages, safe, and self-explanatory. One main advantage of this concept is that it is very educational because it demonstrates the effects for gravity and center of mass as well as other mass properties. It does not have many downsides, and once the analysis is figured out for the design, manufacturing was not too difficult.

Competitive Features

Fixed Racetrack

The first of these selected concepts was the fixed racetrack. The fixed racetrack is extremely visually appealing and highly suitable for a wide range of ages. It is also easily maintained, interactive, exciting, self-explanatory, and requires little storage space. The fixed racetrack does a great job fulfilling our highly stressed criteria.

A fixed racetrack idea was roughly created in the concept modeling stage. This plastic track was bent using a heat gun, and its crude manipulating led to less than ideal results. In the future, this racetrack would need to be made out of a stronger material such as wood, sheet metal, or hard plastic. It has the possibility to be 3D printed or machined from stock material. It can also, and more ideally, be casted with a hard plastic or metal. This would

require making a preliminary model of the track to mold, which we will need to seek guidance for. A preliminary SolidWorks model of the racetrack can be seen in Appendix H.

The main challenge is creating a uniquely shaped track with twists and turns to attract the kids' attention. This requires either assembling many individual parts and forming them together or shaping one big piece of material. This racetrack will consist of two tracks side by side, so fitting the whole feature on the table without taking up too much space will also be a challenge.

Once created, the racetrack could be tested with a tube of water feeding the track and toy boats being raced down it. As long as both tracks are similar in race time, the boats do not get stuck, and there is some excitement while the feature remains safe, then the racetrack could be validated.

Water Squirters with Chimes/Targets

The next selected competitive feature is the water squirter with chimes/targets. This feature is very interactive, visually appealing and does not require much explanation to use. It would be very exciting for children 9 to 12 and does not need any storage space.

Customizable

Magnetic wall

The magnetic wall feature is a metal wall attached to one of the upper walls that has water flowing over it. Magnetic features, such as channels, funnels, tubes, waterwheels etc. can be placed on the wall and moved around by the user. This concept also encompasses the cup pyramid idea presented earlier.

The magnetic wall scored high in the weighted decision matrix because it is easy to manufacture and maintain, as there are no moving parts involved. It was also very interactive, lower cost, and is good in terms of storage space, as the movable components can be stored on the magnetic wall itself.

This wall would be made of stainless steel sheet metal and cut using a water jet cutter. The edges would be rounded and smoothed down, then the metal would be coated in waterproof and UV resistant paint. This would be attached to the outside of the existing walls using bolts. The magnetic features would be 3-D printed then a magnet would be attached.

The main risk for this feature is sealing the metal so that it would not rust after being exposed to water. Also the 3-D printed parts would need to be coated in waterproof and UV resistant material. These components will also need to be tested according to the toy safety standards for magnetic toys outlined in Appendix A, including the use and abuse test, soaking test, cycling as received test, torsion, tension, compression, impact, and drop tests.

Snap in grid

The snap in grid is a mat that lays on the bottom on the basin that can have components, such as walls, weirs, and dams can snap into it. This could be used to create a maze, a race track, or anything else the user wants. A layout of what this will look like can be found in Figure H-7.

The snap in grid scored high in the weighted decision matrix in various categories. It is easy to maintain as there are no moving parts, and the plumbing set up is very simple and would require not alteration of the current set up. The grid is also very interactive, very suitable for all age ranges, safe, inspires creativity and collaboration, and the building time is ideal.

To build the grid, a Duplo Lego™ mat was epoxied to the bottom of the basin. This is positioned next to the exit of the racetrack feature discussed previously. 3-D printed walls and weirs were intended to be epoxied to the top of Duplo Legos™ so that they can be attached to the mat to create channels and pathways to as a continuation of the racetrack feature or just to float boats along. 3-D printing was to be used to manufacture the additional parts for ease of manufacture.

Because we are using Legos ™, this feature is very self-explanatory as almost every child at any age know what to do when presented with Legos™. Also, because Legos™ are suitable for a broad range of ages, this design satisfies the age range criteria for our table. Additionally, because we are using Duplo Legos™, which are large, this feature is suitable for 3-6-year-olds for whom choking on small pieces is a concern.

Legos™ also can entertain children for long periods of time so this feature would get a lot of use, which is why this feature scored so high for build time.

This feature takes up a large section of the table allowing more space for building, creativity and to allow enough room for multiple users.

APPENDIX G DECISION MATRICES

Fixed Features

	IDEAS:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	Space Factor:	4	3	2	2	4	3	4	4	5	4	3	4	2	3	2	3	3	3	2
Factor	Weight																			
Educational	4	3	4	4	3	3	5	3	4	4	3	4	4	2	4	4	4	4	2	3
Safety	5	3	4	4	4	4	2	3	3	4	4	4	4	3	5	3	5	3	4	4
Ease of Maintenance	3	5	3	2	4	4	2	3	2	3	2	3	2	4	4	3	4	2	4	4
Ease of Manufacture	4	3	4	3	4	4	3	3	2	2	2	4	2	4	3	3	5	2	4	4
Interactive	4	5	5	4	2	2	3	4	3	5	5	2	2	3	2	3	2	3	3	4
Long Life	3	4	4	3	3	4	3	3	3	3	3	3	4	4	4	4	4	3	4	4
Visually Appealing	4	5	4	2	4	4	5	3	3	4	4	4	4	3	4	4	2	4	3	3
Self-Explanaotry	4	5	2	2	5	4	4	4	2	2	4	4	3	4	3	3	3	3	3	4
Suitable for Ages 3-6	5	4	2	2	4	4	3	3	2	2	3	4	3	3	5	4	3	3	4	2
Suitable for Ages 6-9	5	5	4	2	4	5	4	3	3	2	4	4	4	4	4	4	3	3	4	3
Suitable for Ages 9-12	5	5	5	3	4	5	5	4	4	3	5	5	4	4	3	5	4	3	3	4
Cost	3	3	4	3	4	4	3	3	4	3	3	3	3	3	3	3	5	1	4	4
Plumbing Setup	4	4	4	2	5	3	5	5	3	4	2	4	3	5	4	4	3	4	4	5
	Weighted Sum:	246	225	162	225	231	219	200	175	181	209	225	194	207	213	219	210	173	202	213

Legend					
1	No. 1	Fixed Racetrack	11	No. 11	Tipping buckets
2	No. 2	Cup water pyramid	12	No. 12	Water jet tripod
3	No. 3	Pipe flow demonstration	13	No. 13	Water teeter-totter
4	No. 4	Water dome	14	No. 14	Octopus with water streams
5	No. 5	Whirlpool	15	No. 15	Spinning cup with water jets
6	No. 6	Waterwheel with LED	16	No. 16	Vertical tube with holes
7	No. 7	Boat Lift: Crank	17	No. 17	Standing-wave display
8	No. 8	Boat lift: Cause and effect	18	No. 18	Water outlet with pivot
9	No. 9	Locks (raising boats)	19	No. 19	Adjustable Water Channels
10	No. 10	Water squirters with chimes/target			

Description of Criteria for Fixed Features

Educational

The educational value of the feature was weighted four out of five. It was determined by whether the feature provided education on water related principles.

Safety

Since this project is being designed for children, safety is very important and was weighted five out of five. The safety of each design was determined by considering potential injury to the user due to mechanical hazards, such as pinching.

Ease of Maintenance

Ease of maintenance was weighted three out of five. The ease of maintenance of each design was based on the number of components and how much time it would take to clean or service the feature.

Ease of Manufacture

Ease of manufacture was weighted four out of five because it corresponds to our ability to finish the project in a timely manner. The ease of manufacture was determined by considering the number of components and the technical difficulty of each design.

Interactive

Since Exploration Station was very interested in the features being interactive, this category was weighted four out of five. Interactivity was based upon how much physical touching the feature would receive, and whether the feature could be modified.

Long Life

Long life was weighted three out of five. The life of each design is based upon the number of components and whether it has components that are exposed to mechanical stress or potential weather damage.

Visual Appeal

Visual appeal was rated four out of five because it corresponds to how interested a child would be in the table and how often it will be used. A child is more likely to approach the water table and interact with the various features if the features on the table are visually appealing and able to catch attention from afar.

Self-Explanatory

Exploration Station requested that the interactive features on the water table would require no additional explanation of how to operate said feature. This is related to how likely a child is to interact with that feature and how much enjoyment and education that feature can provide. Because of this, the self-explanatory requirement was weighted four out of five.

Suitability for Age Ranges

For this criterion three different age ranges were considered: 3-6, 6-9, and 9-12. For each of the age ranges considered, suitability for age range was weighted five out of five because the feature will provide more entertainment and educational value to more children if the feature is suited for children at every age.

Cost

Cost was weighted three out of five. Exploration Station is a non-profit so money is a concern; however, there are grants available to cover some of the costs of manufacturing. Features that would require a large sum of money to manufacture or purchase were given lower scores.

Plumbing Setup

This criterion is indicative of how much effort it would take to alter the current plumbing set up to accommodate the feature in consideration. This is closely related to the ease of manufacture and would affect our ability to produce a finely tuned product within the given amount of time. The more the current plumbing system needs to be altered, the lower the score will be. The weight given to plumbing setup is four out of five.

Competitive Features

	IDEAS:	1	2	3	4	5
	Space Factor:	3	2	3	2	3
Factor	Weight					
Educational	3	3	3	3	2	4
Safety	5	3	3	4	2	4
Ease of Maintenance	3	5	2	2	2	2
Ease of Manufacture	4	3	2	2	5	2
Interactive	5	4	5	5	4	5
Long Life	3	4	2	3	2	2
Visually Appealing	4	5	4	5	3	3
Self-Explanaotry	4	5	3	5	2	4
Suitable for ages 3-6	5	4	3	3	5	3
Suitable for ages 6-9	5	5	4	4	1	5
Suitable for ages 9-12	5	5	5	5	1	5
Storage Space	3	4	2	4	2	3
Multiple Users/Collaboration	3	3	5	3	4	5
Cost	3	3	4	3	4	3
Plumbing Setup	4	4	3	2	5	5
Excitement	4	4	4	4	3	4
	Weighted Sum:	255	218	231	185	239

Legend		
1	No. 1	Fixed racetrack
2	No. 20	Snap together racetrack
3	No. 10	Water squirter with chimes/target
4	No. 21	Magnetic fishing
5	No. 22	Lower basin snap in grid/Legos

Description of Criteria for Competitive Features

Safety, ease of maintenance, ease of manufacture, long life, visually appealing, self-explanatory, suitable for age ranges, cost, and plumbing set-up are also criteria for competitive features and are weighted the same as they were for fixed features. The following criteria are those where either the weight changed or they were not previously mentioned as criteria.

Educational

The educational value of the feature was weighted three out of five. It was weighted less than it was for the fixed features because competitive features have less of an emphasis on being educational and more of an emphasis on being interactive and fun.

Interactive

The interactive criteria got raised to five out of five because there is more of an emphasis on this for competitive features over fixed features. We consider interactivity to be extremely important for this feature category.

Storage Space

Storage space was considered as a criterion to determine how much space a features parts would take up when it was not assembled and in use. The more space parts took up, the lower the score. Storage space was weighted three out of five.

Collaboration

Collaboration describes the extent to which users can interact with a given feature side-by-side with other users. It also takes into account how many users can interact with a feature at a given time. Collaboration was weighted three out of five.

Excitement

The excitement criteria takes into account how much fun we expect the feature to be for the users. We want the competition to be exciting so that kids keep wanting to interact with the feature. Excitement was weighted four out of five because we feel this is important to the potential success of a competitive feature.

Customizable Features

	IDEAS:	1	2	3	4	5	6	7
	Space Factor:	4	4	4	2	2	2	4
Factor	Weight							
Educational	3	3	3	3	4	2	3	4
Safety	5	3	3	4	3	4	3	4
Ease of Maintenance	3	4	4	4	4	4	3	3
Ease of Manufacture	4	4	3	3	3	5	2	2
Interactive	5	5	5	5	4	4	4	5
Long Life	3	3	3	3	3	3	3	3
Visually Appealing	4	4	3	4	3	2	2	2
Self-Explanaotry	4	3	3	4	3	3	3	3
Suitable for ages 3-6	5	3	3	5	4	5	5	3
Suitable for ages 6-9	5	3	3	5	3	1	1	4
Suitable for ages 9-12	5	2	2	4	2	1	1	4
Storage Space	4	4	4	3	2	2	2	2
Inspires Creativity	4	3	3	5	2	2	4	3
Building Time	2	3	2	5	3	3	3	3
Multiple Users/Collaboration	3	3	3	5	2	3	2	4
Cost	3	3	2	4	4	4	3	3
Plumbing Setup	4	4	4	5	4	5	5	4
	Weighted Sum:	222	209	278	205	205	190	221

Legend		
1	No. 23	Magnetic wall with ramps, cascade blocks, ect.
2	No. 24	Pegboard wall with ramps, cascade blocks, ect.
3	No. 22	Lower basin snap in grid/Legos
4	No. 25	Snap together pipes
5	No. 21	Magnetic fishing
6	No. 26	Wind up boats
7	No. 20	Snap together racetrack

Description of Criteria for Customizable Features

Criteria used for the decision matrix are similarly weighted to the criteria for the competitive features, including: educational, safety, ease of maintenance, ease of manufacture, interactive, long life, visual appeal, self-explanatory, suitability for age ranges, collaboration, cost, and plumbing. Storage space, inspires creativity, and building time are either weighted differently or not previously mentioned.

Storage Space

Storage space is weighted higher because it is assumed customizable features have more parts that would require extensive storage. It is weighted four out of five.

Inspires Creativity

Inspires creativity was weighted four out of five. The main goal of customizable features is to inspire the users to be creative, as it is important for children to exercise their imagination.

Building Time

Building time was weighted two out of five. This criterion corresponds to the amount of time the user would be actively changing and rearranging the customizable feature. If the building time is very short, the feature would not be very customizable and would not provide entertainment for very long. Also if the feature takes a very long time to assemble, the user might give up and move on to another feature.

Proximity Detection

	IDEAS:	1	2	3	4	5	6	7
Factor	Weight							
Safety	5	4	4	2	3	4	4	5
Ease of Maintenance	3	3	3	3	3	3	3	5
Ease of Manufacture	4	3	3	3	2	2	2	5
Long Life	5	4	4	3	4	4	4	5
Visually Appealing	4	2	5	2	3	4	4	3
Mobility	5	5	5	5	5	3	3	0
Range	3	2	2	0	3	5	5	3
Cost	4	4	3	3	3	2	2	5
Reliabilty	5	2	4	1	2	5	5	3
	Weighted Sum:	126	144	96	120	136	136	141

Legend	
1	Passive Infrared Sensor
2	Microwave Sensor
3	Ultrasonic Sensor
4	Capacitive Sensor
5	Pressure Plate: Force Transducer
6	Pressure Plate: Contact Switch
7	Wall-Mounted Motion Sensor

Description of Criteria for Proximity Detection Features

Because proximity detection is unique, its criteria will be described in entirety. Although certain criteria may be repeated from previous matrices, the description changes for proximity detection.

Safety

Since this project is being designed for children, safety is very important and was weighted five out of five. The safety of each design was determined by considering how much electrical wiring was needed and whether there were any mechanical hazards (pinch points, protrusions, ect.).

Ease of Maintenance

Ease of maintenance was weighted three out of five. The ease of maintenance of each design was based on the number of electrical components, how easy it would be to purchase the components, and how long it would take to replace a component if it failed. It was assumed that the more components in a design, the more likely it was that one of them would fail, so designs with many components ranked lower.

Ease of Manufacture

Ease of manufacture was weighted four out of five because it corresponds to our ability to finish this part of the project. The ease of manufacture was determined by considering the number of components and the technical difficulty of each design.

Long Life

Long life was weighted five out of five. The life of each design is based upon the number of components and whether it has components that are exposed to mechanical stress.

Visual Appeal

Visual appeal was weighted four out of five. The visual appeal of each design was based on whether parts of the design could be seen, and if so how many parts could be seen.

Mobility

Since the water table was designed with wheels so that it could easily be relocated, mobility was weighted five out five. The mobility of each design was determined by whether it could be moved with the water table and how easy it was to move.

Range

Range was weighted three out of five. The range of each design was determined by whether it would detect the proximity of someone within the desired range. Designs that had a detection range larger than 3 feet were ranked lower.

Cost

Cost was weighted four out of five. The cost of each design was determined by looking at the average cost of components available online.

Reliability

Since the water table will not activate, or will activate when no one is there, if the components are not reliable, reliability was weighted five out of five. The reliability of each design was determined by whether the electrical components in the design had any flaws that would cause them to falsely active or fail to activate. Since failure to activate means that the water table will not function, this flaw was considered more serious than false activation.

APPENDIX H CONCEPT LAYOUT DRAWINGS

Table with Features

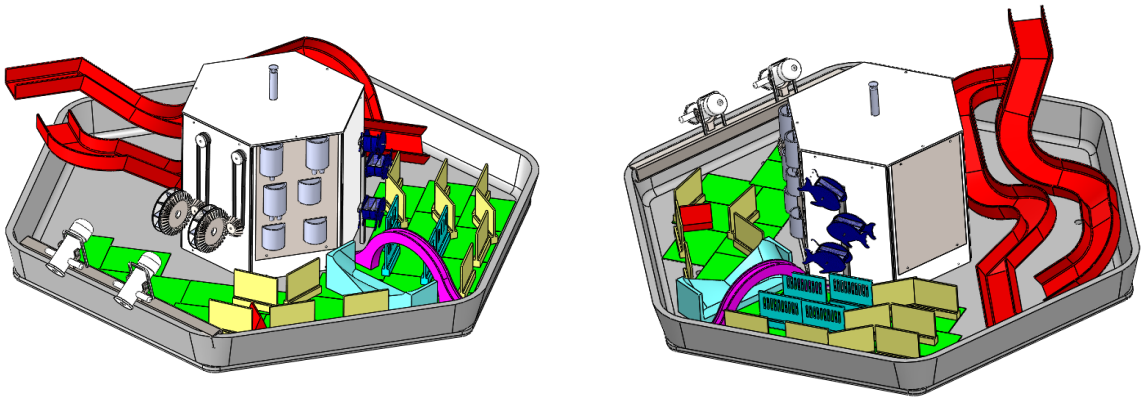


Figure H-1 CAD model of complete table

No. 1 Fixed Racetrack

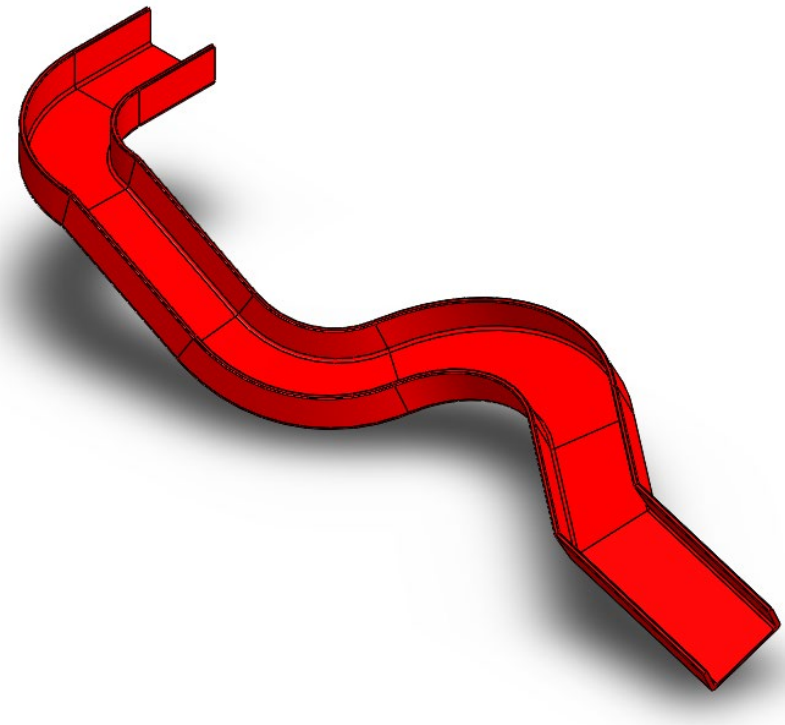
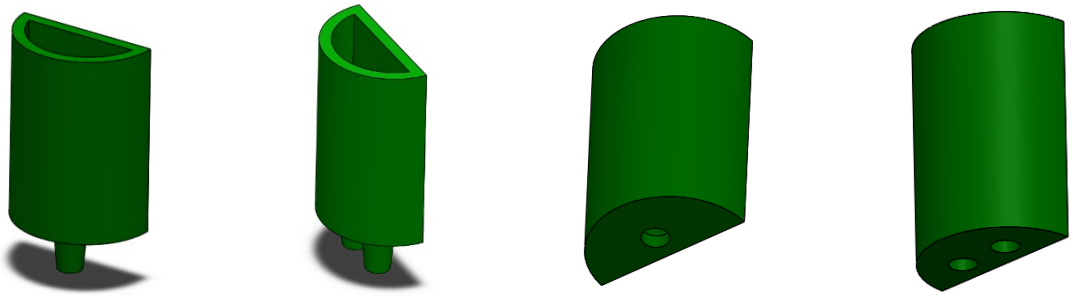


Figure H-2 No 1 Fixed racetrack concept drawing

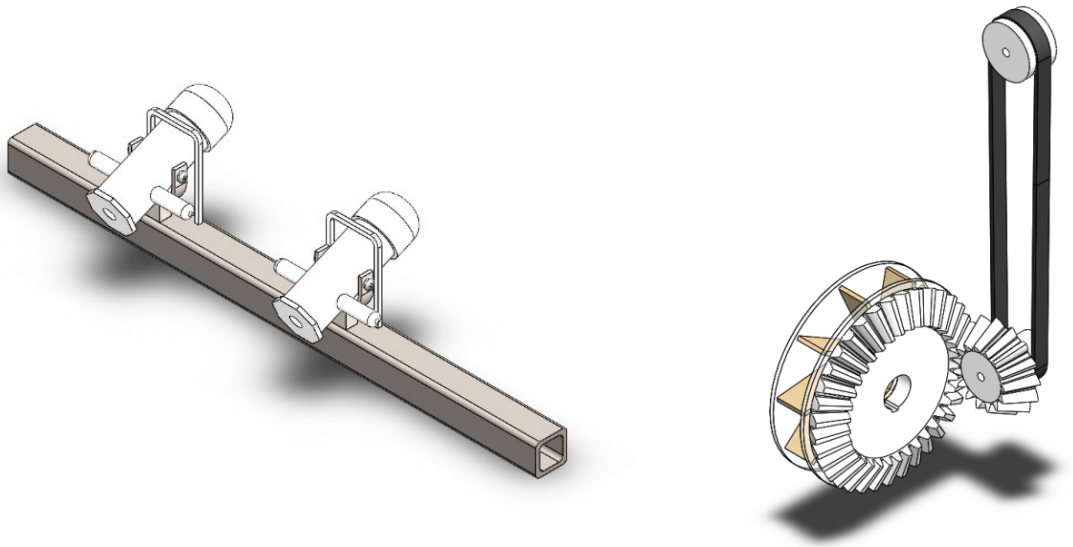
No. 2 Pyramid Cups



(a) 1 Funnel (b) 2 Funnels (c) 1 Hole (d) 2 Holes

Figure H-3 No 2 Pyramid cups concept drawing

No. 10 Water Squirters



(a) Water squirters (b) Target

Figure H-4 No 10 Water squirter concept drawing

No. 11 Tipping Whales

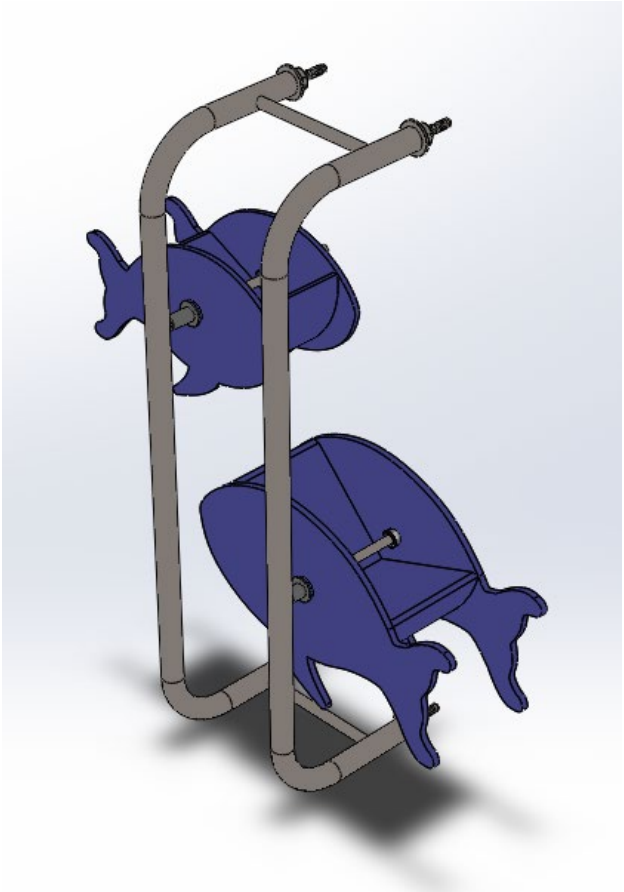
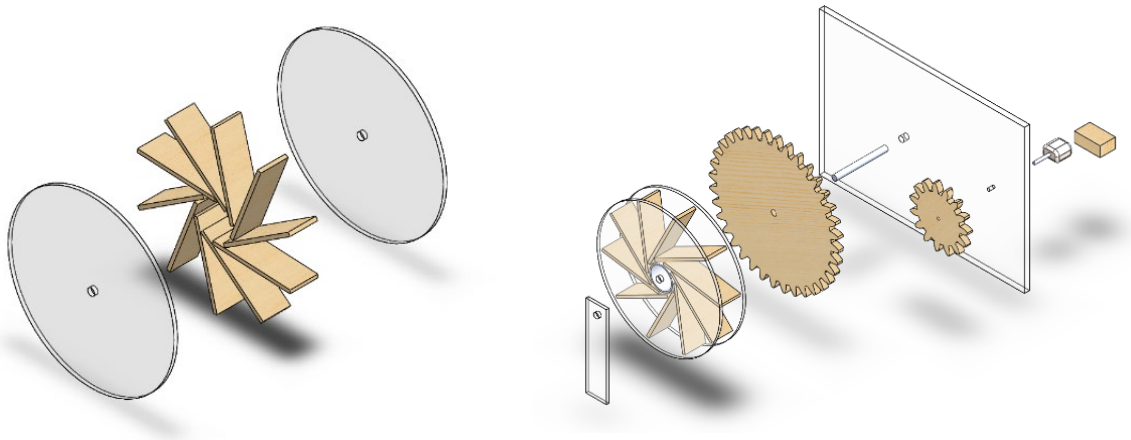


Figure H-5 No 11 Tipping whale concept drawing

No. 16 LED Waterwheel



(a) Waterwheel assembly (b) LED waterwheel feature

Figure H-6 No 16 LED waterwheel concept drawing

No. 22 Snap in grid

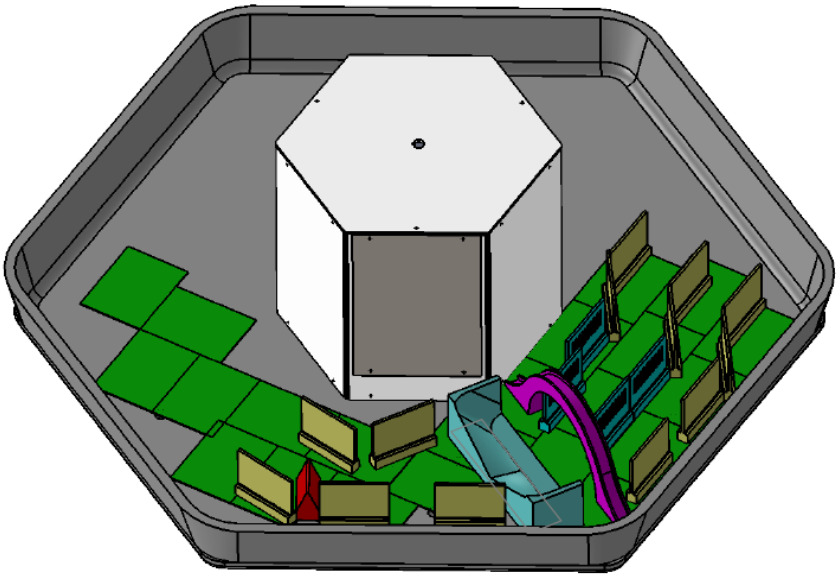


Figure H-7 No 22 Lego™ snap in grid with components

Proximity Detection

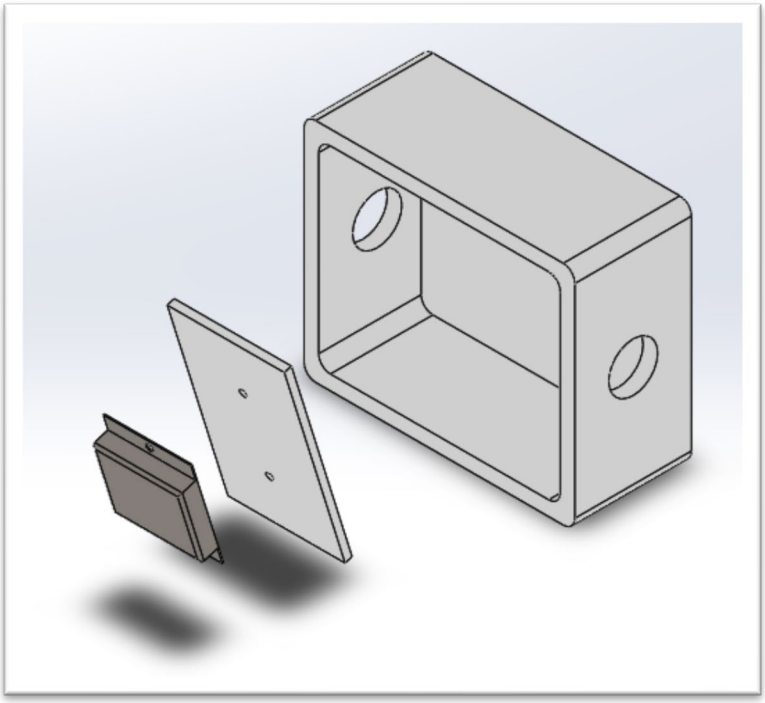
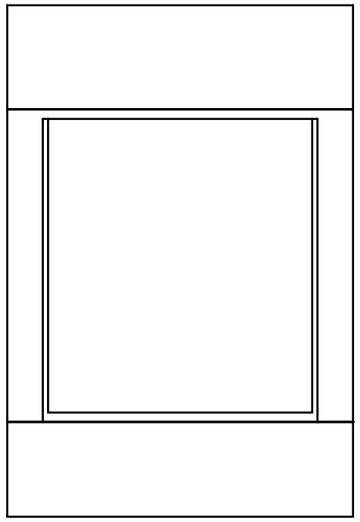
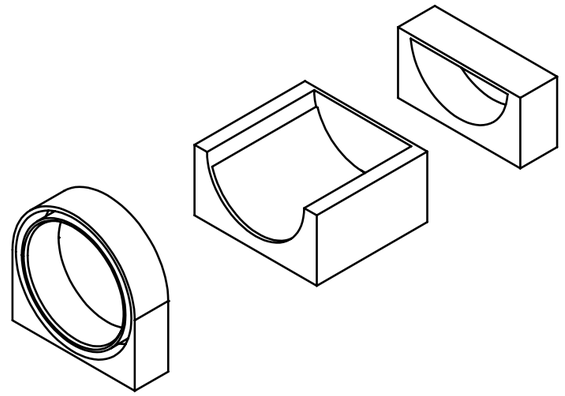


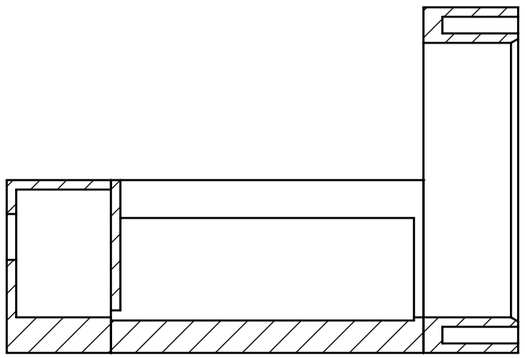
Figure H-8 Proximity detector concept layout

NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ± .050

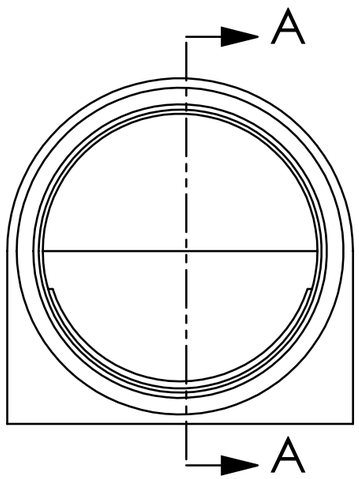
MANUFACTURING NOTES:
THIS PART IS INTENDED TO BE 3D PRINTED

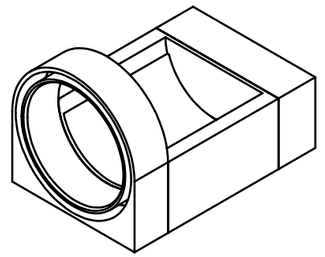






SECTION A-A
SCALE 1 : 2





Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section:03	Feature #1	Title:RACETRACK STARTER PIECE		Drwn. By:B PUCCINI
	Dwg. #:F01.A01	Nxt Asb:N/A	Date:12/5/18	Scale:1:2	Chkd. By: ME STAFF

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NOTES:

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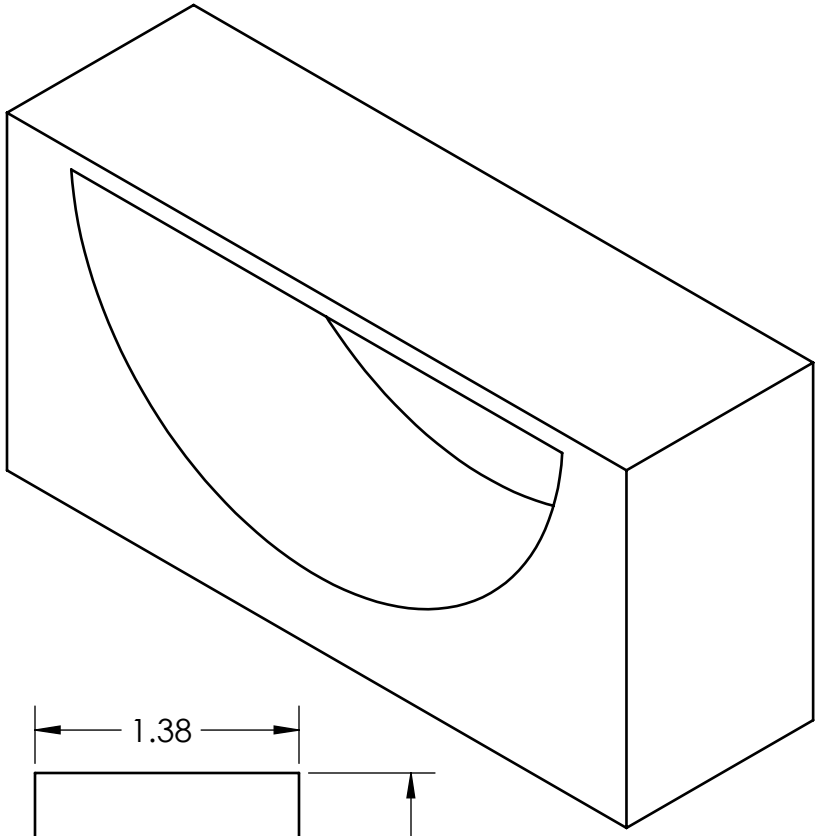
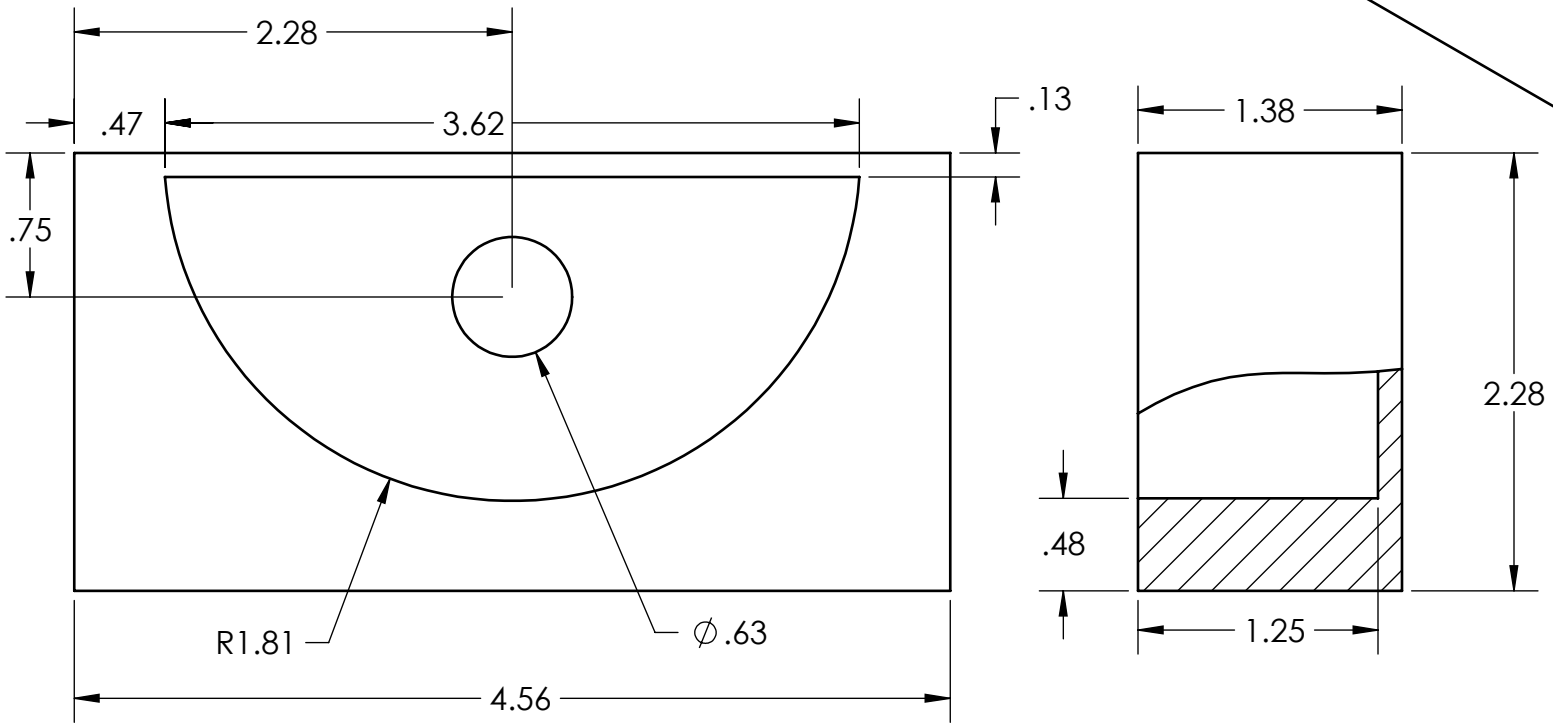
   X.XXX= ± .050

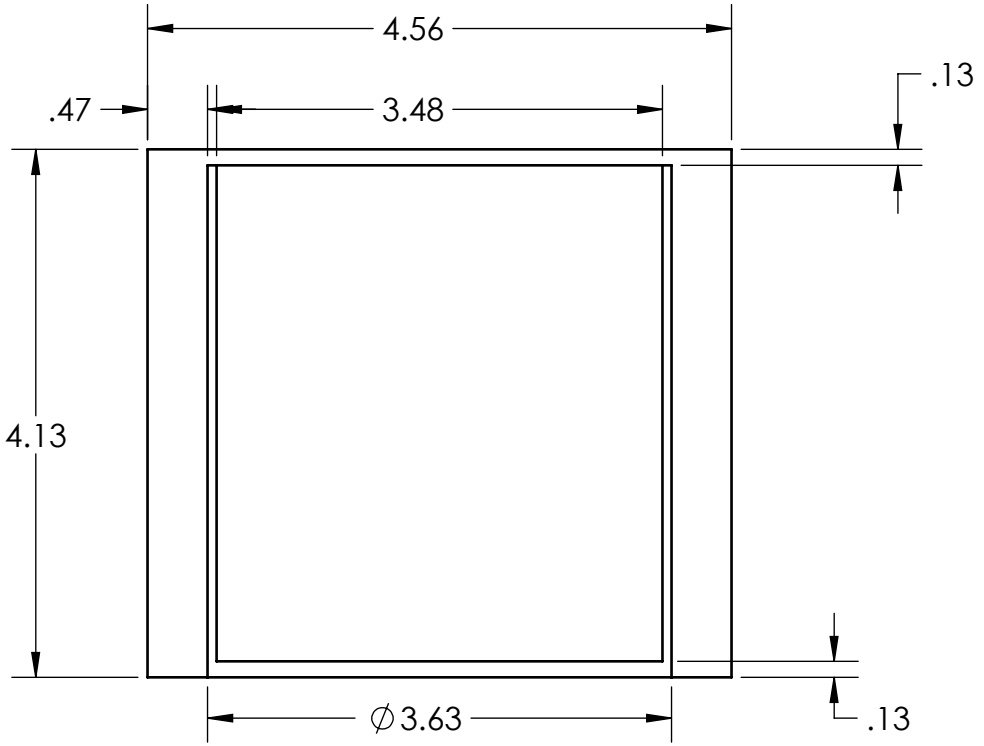
MANUFACTURING NOTES:

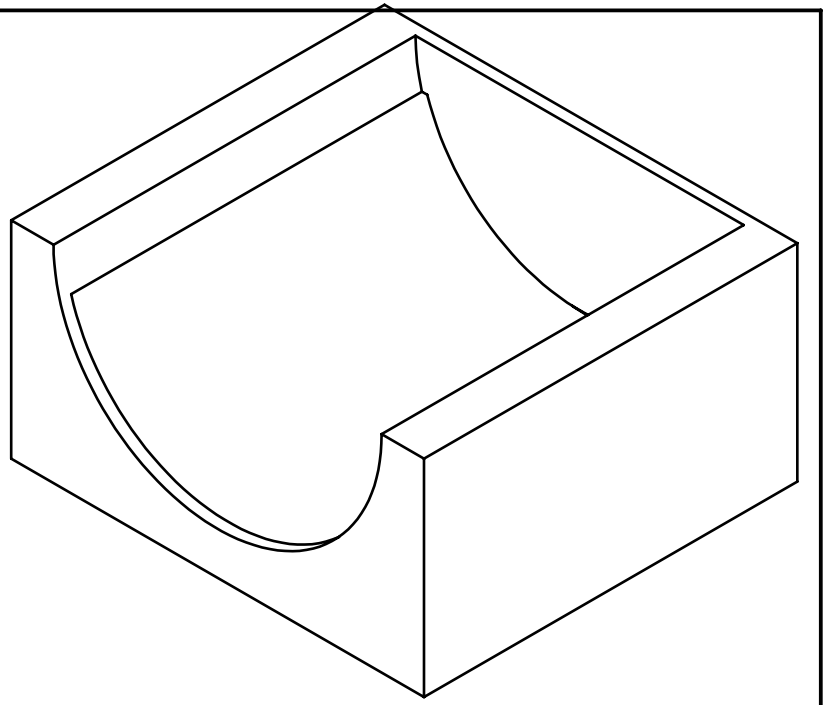
THIS PART IS INTENDED TO BE 3D PRINTED

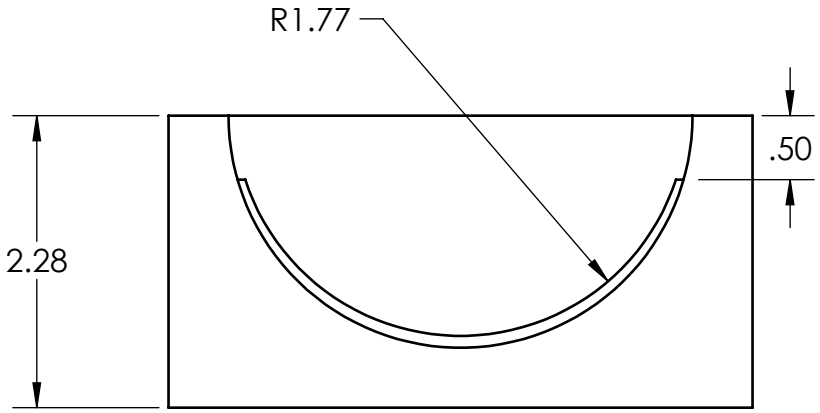




Cal Poly Mechanical Engineering	Lab Section:03	Feature #1	Title:HOSE CONNECTOR		Drwn. By:B PUCCINI
WATER FUN 2018	Dwg. #:F01.01	Nxt Asb:N/A	Date:12/5/18	Scale:1:1	Chkd. By: ME STAFF







NOTES:
UNLESS OTHERWISE SPECIFIED:
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2. TOLERANCES:
X.XXX= ± .050

MANUFACTURING NOTES:
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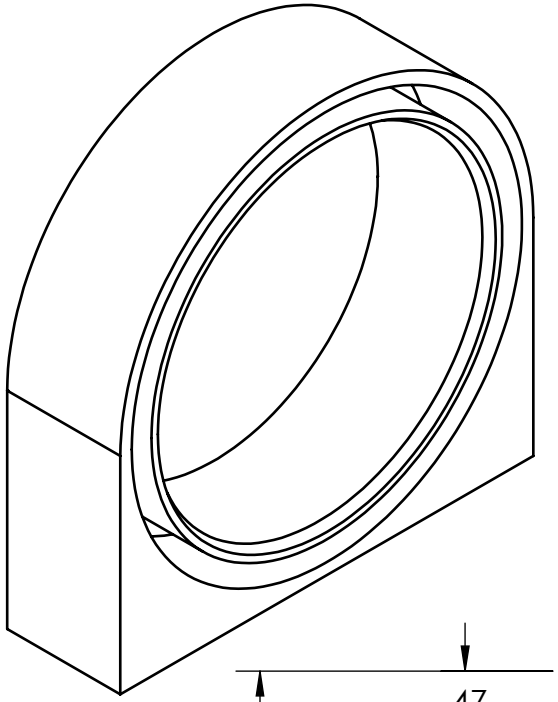
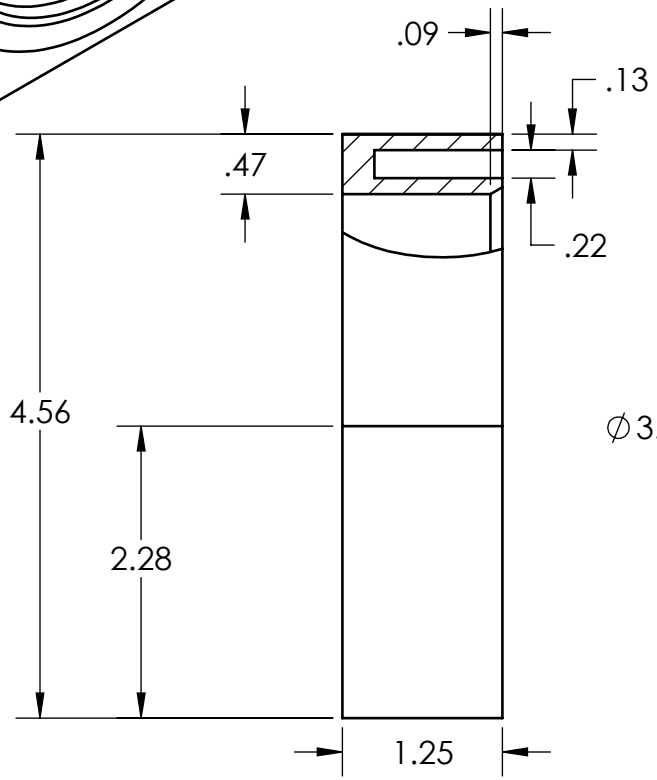
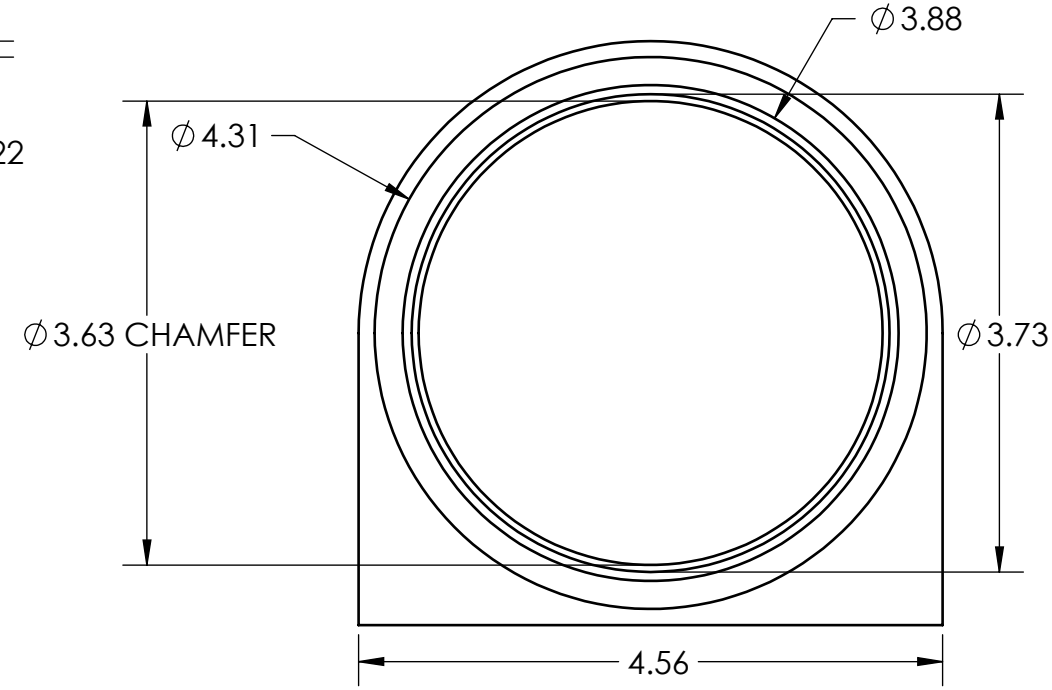
Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section:03	Feature #1	Title:OPEN SECTION		Drwn. By:B PUCCINI
	Dwg. #:F.01.02	Nxt Asb:N/A	Date:12/5/18	Scale:2:3	Chkd. By: ME STAFF



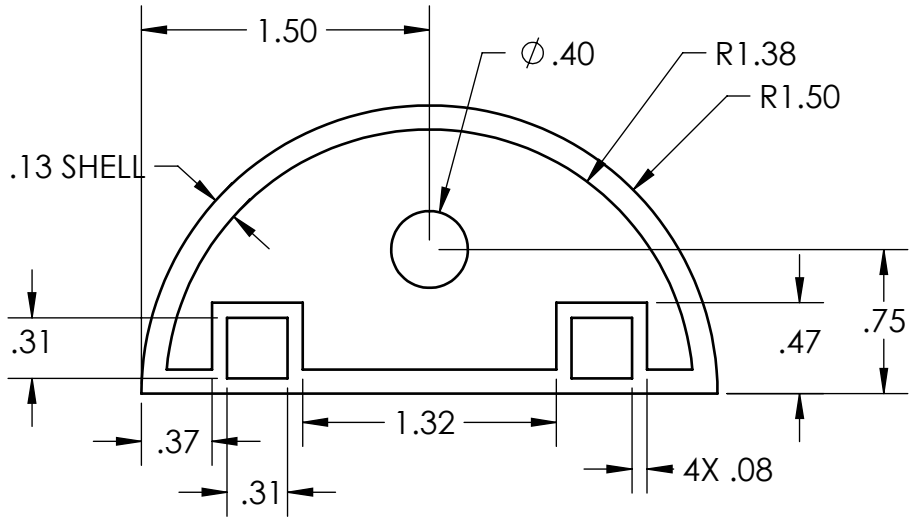
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ± .050

MANUFACTURING NOTES:
THIS PART IS INTENDED TO BE 3D PRINTED

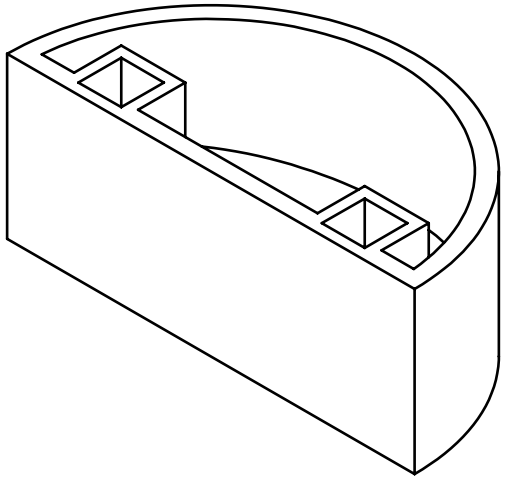


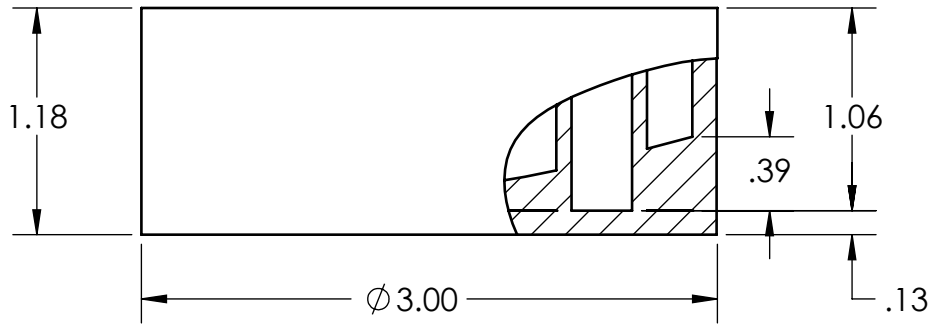


Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section:03	Feature #1	Title:TUBE RING		Drwn. By:B PUCCINI
	Dwg. #:F01.03	Nxt Asb:N/A	Date:12/5/18	Scale:2:3	Chkd. By: ME STAFF



NOTE: BOTH SLOTS SHARE SAME DIMENSIONS





NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ± .050

MANUFACTURING NOTES:
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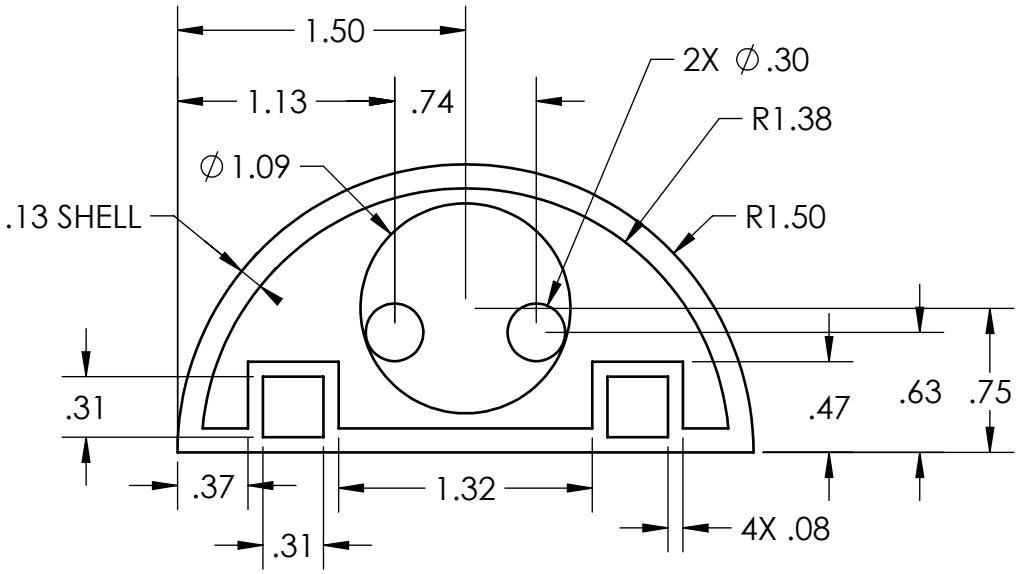
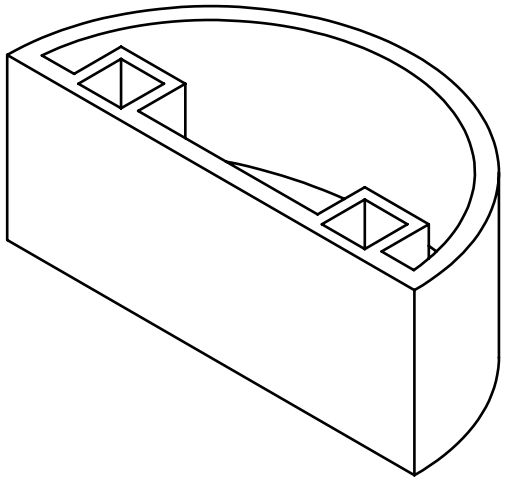
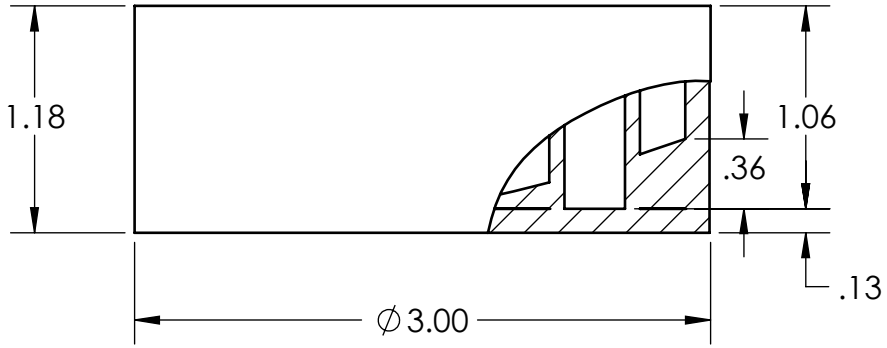
Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section:03	Feature #02	Title:SINGLE HOLE CUP		Drwn. By:B PUCCINI
	Dwg. #:F02.01	Nxt Asb:N/A	Date:12/5/18	Scale:1:1	Chkd. By: ME STAFF



NOTE: BOTH SLOTS SHARE SAME DIMENSIONS





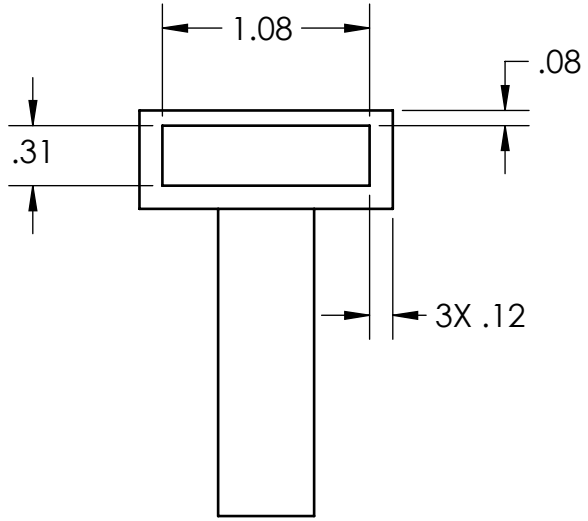
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ± .050

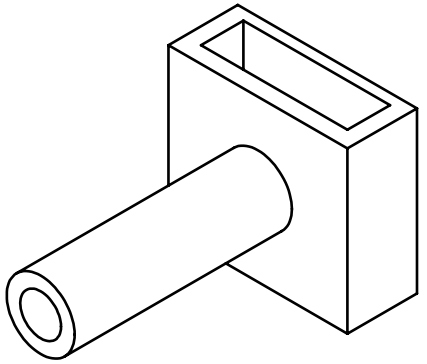
MANUFACTURING NOTES:
THIS PART IS INTENDED TO BE 3D PRINTED

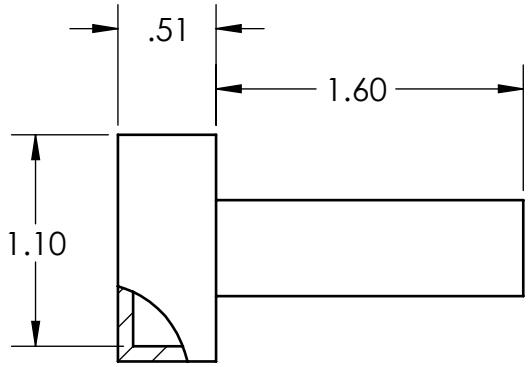
Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section:03	Feature #02	Title:DOUBLE HOLE CUP		Drwn. By:B PUCCINI
	Dwg. #:F02.02	Nxt Asb:N/A	Date:12/5/18	Scale:1:1	Chkd. By: ME STAFF

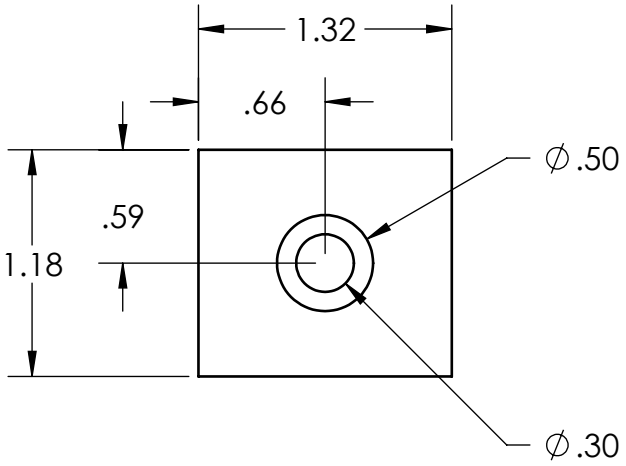
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ±.050

MANUFACTURING NOTES:
THIS PART IS INTENDED TO BE 3D PRINTED









Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section:03	Feature #23	Title:ROD		Drwn. By:B PUCCINI
	Dwg. #:F23.01	Nxt Asb:N/A	Date:12/5/18	Scale:1:1	Chkd. By: ME STAFF

NOTES:
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS IN INCHES
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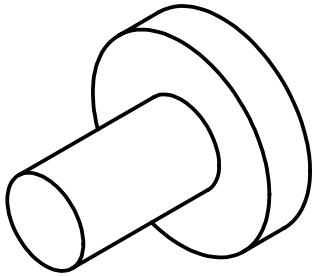
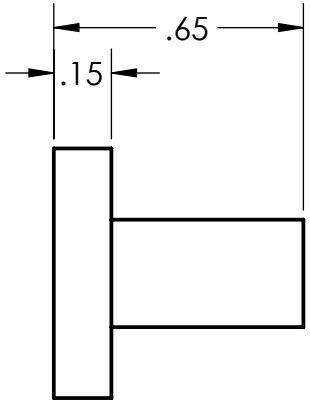
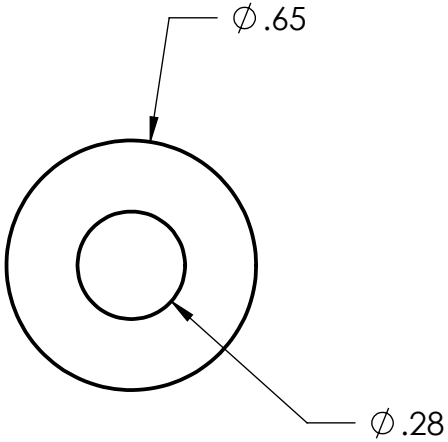
   X.XXX= ±.050

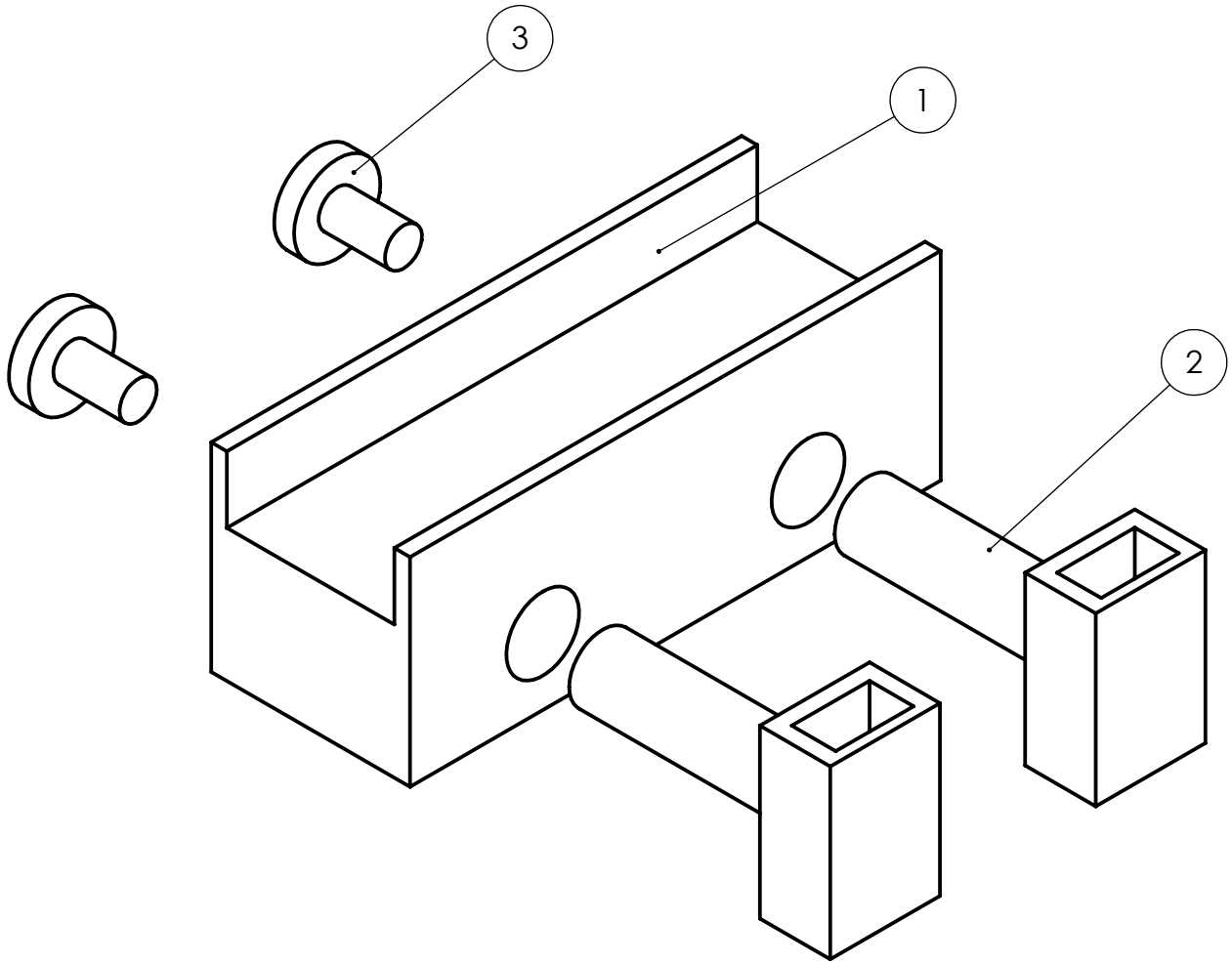
MANUFACTURING NOTES:
THIS PART IS INTENDED TO BE 3D PRINTED







Cal Poly Mechanical Engineering	Lab Section: 03	Feature #23	Title:ROD CAP		Drwn. By:B PUCCINI
WATER FUN 2018	Dwg. #: F23.02	Nxt Asb:N/A	Date:5/2/18	Scale:2:1	Chkd. By: ME STAFF



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F23.A01.01	SLIDE	1
2	F23.01	ROD	2
3	F23.02	ROD CAP	2

Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature #23	Title:SLIDE ASSEMBLY		Drwn. By:B PUCCINI
	Dwg. #:F23.A01	Nxt Asb: N/A	Date:5/2/18	Scale:1:1	Chkd. By: ME STAFF

NOTES:
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X.XXX= ±.050

MANUFACTURING NOTES:
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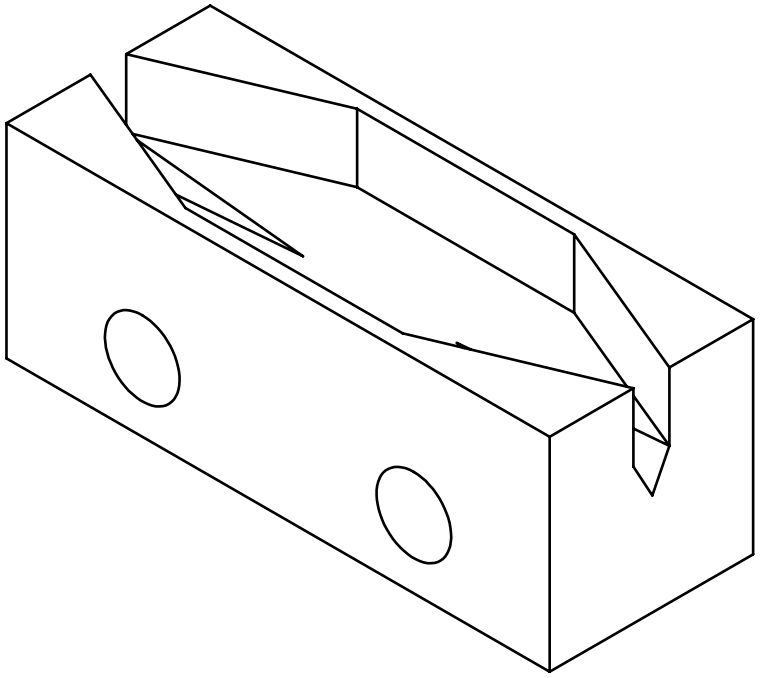
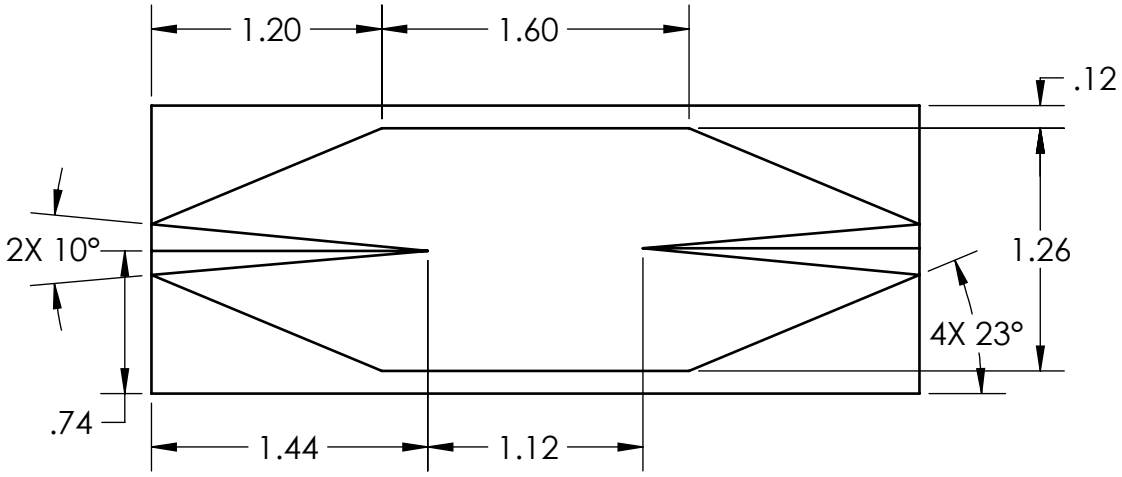
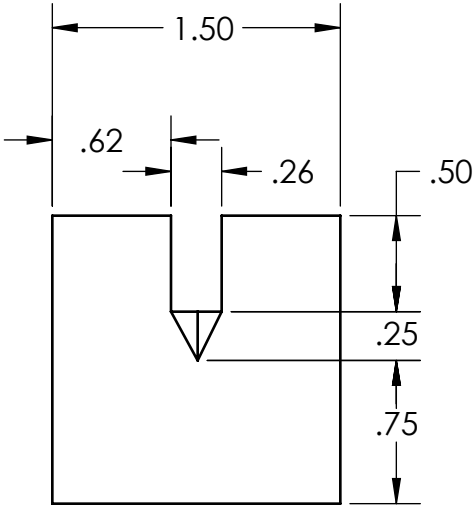
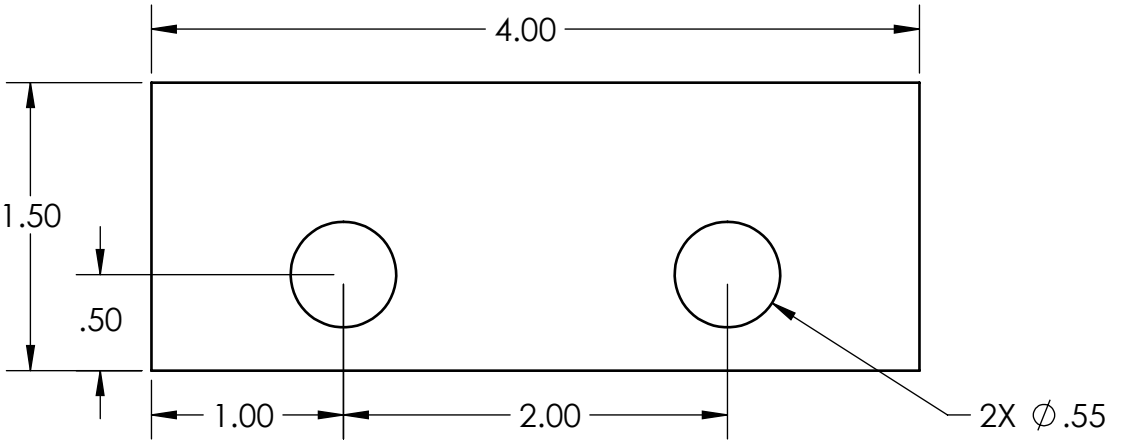
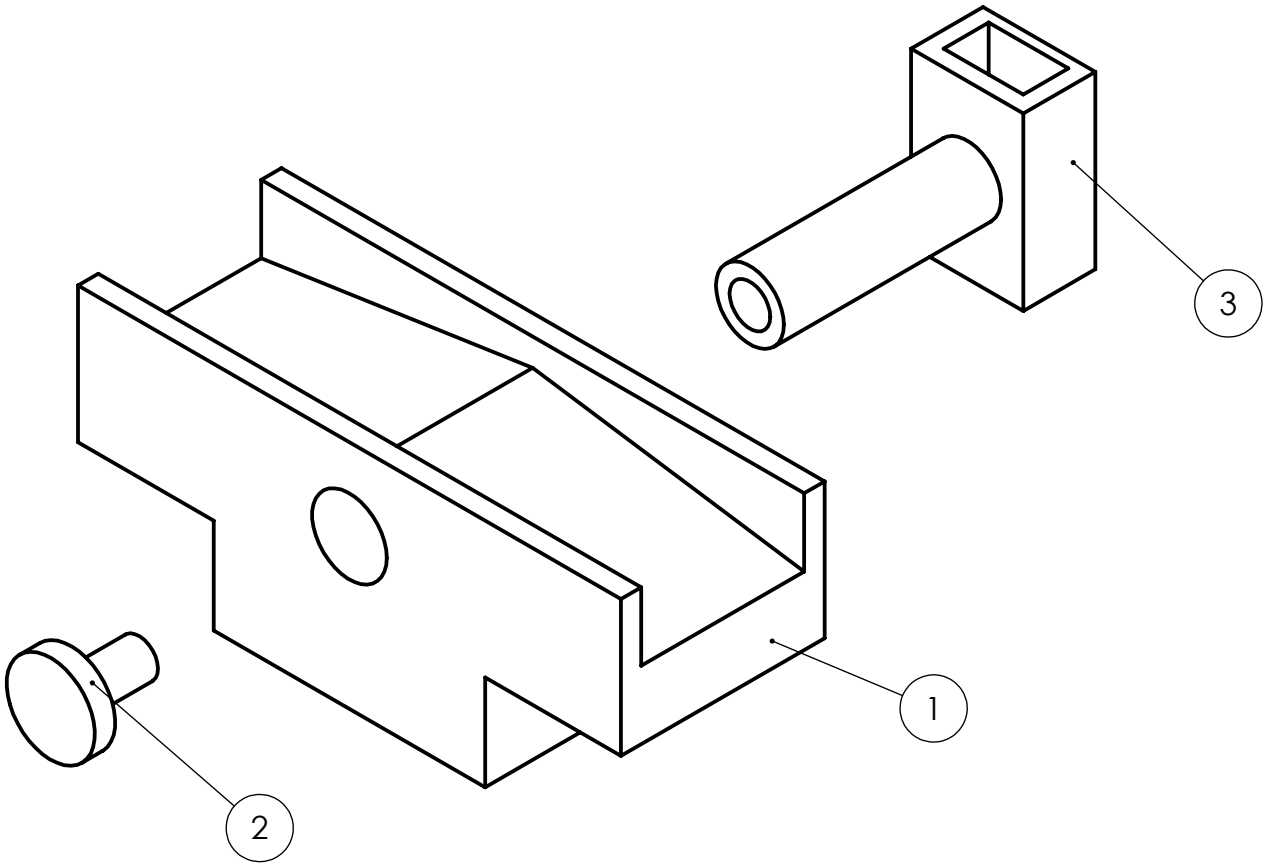








Cal Poly Mechanical Engineering	Lab Section:03	Feature #23	Title:SLIDE		Drwn. By:B PUCCINI
WATER FUN 2018	Dwg.#:F23.A01.01	Nxt Asb:N/A	Date:12/5/18	Scale:1:1	Chkd. By: ME STAFF



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
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2	F23.02	ROD CAP	1
3	F23.01	ROD	1

Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature #23	Title:TEETER TOTTER ASSEMBLY		Drwn. By:B PUCCINI
	Dwg. #: F23.A02	Nxt Asb:N/A	Date:5/2/18	Scale:1:1	Chkd. By: ME STAFF

NOTES:

UNLESS OTHERWISE SPECIFIED:

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2. TOLERANCES:
   X.XXX= ± .050

MANUFACTURING NOTES:

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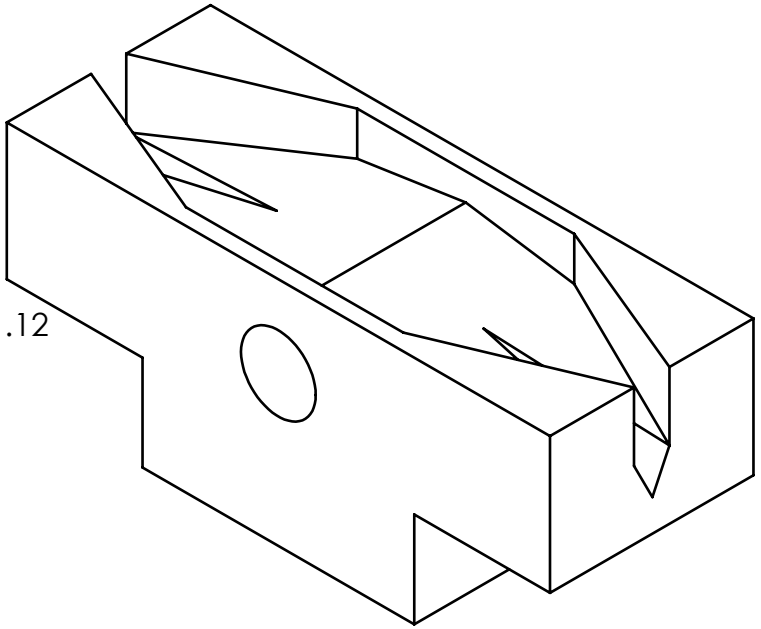
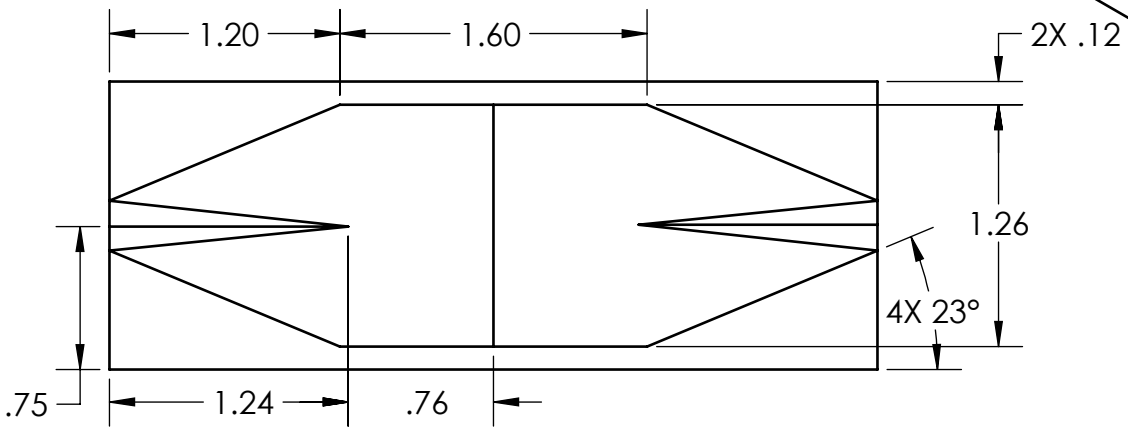
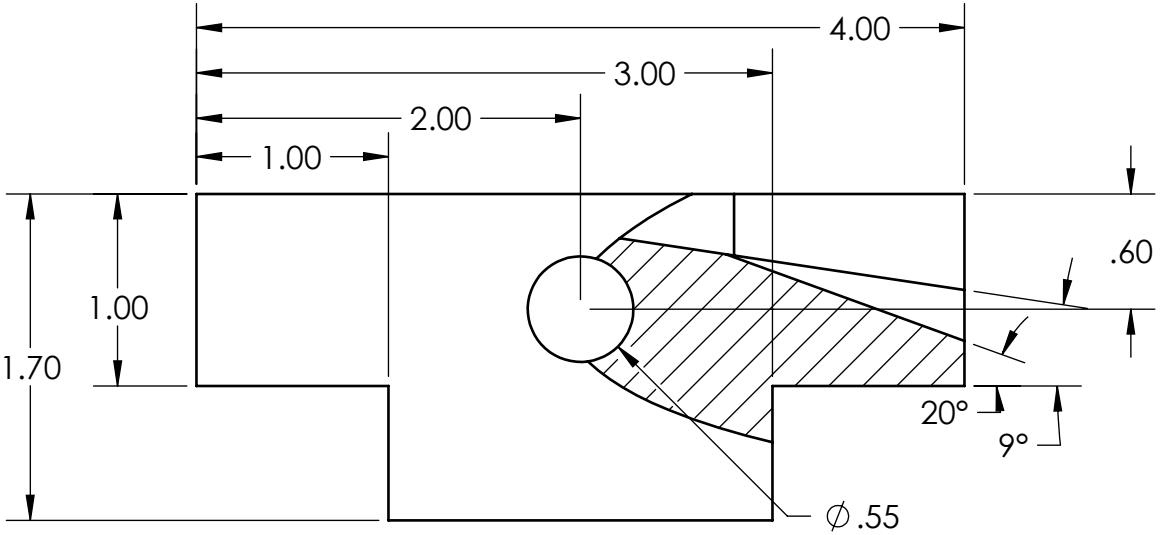
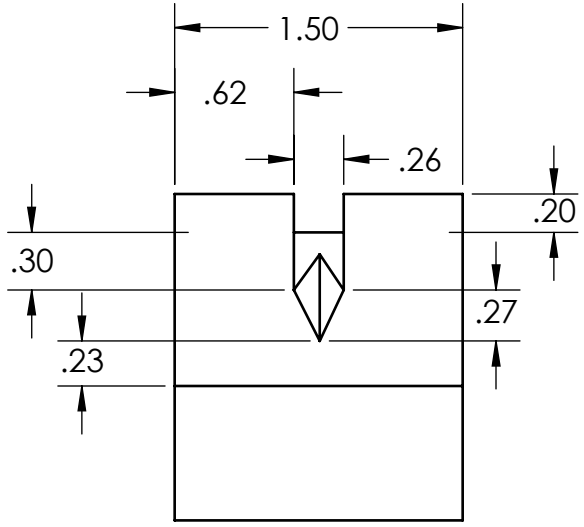
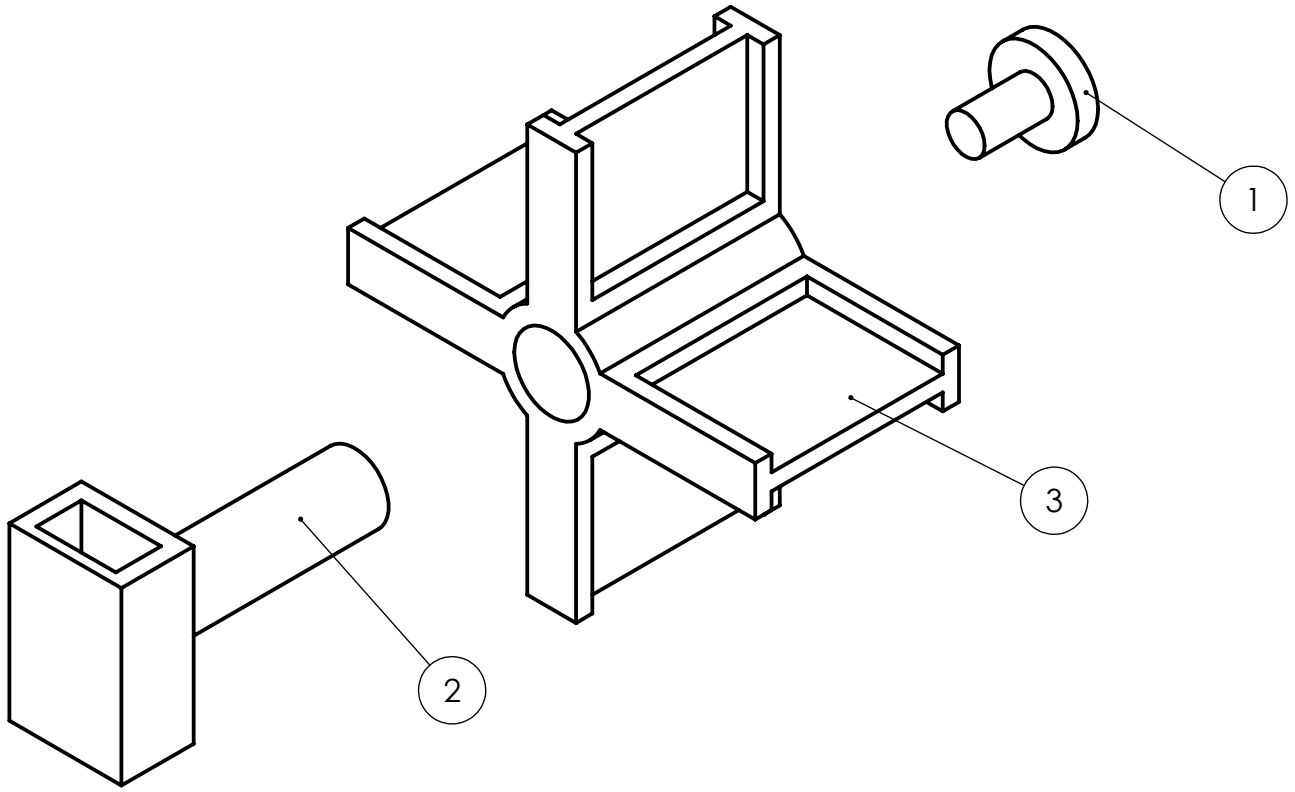








Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section:03	Feature #23	Title:TEETER TOTTER		Drwn. By:B PUCCINI
	Dwg.#:F23.A02.01	Nxt Asb:N/A	Date:12/5/18	Scale:1:1	Chkd. By: ME STAFF

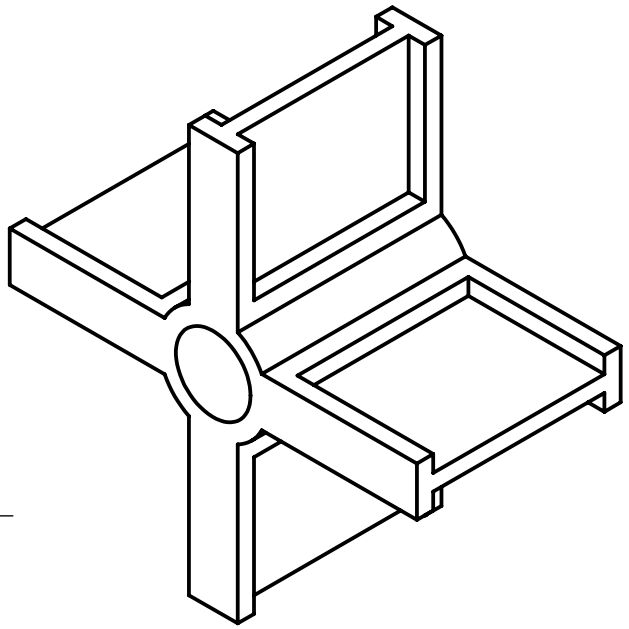


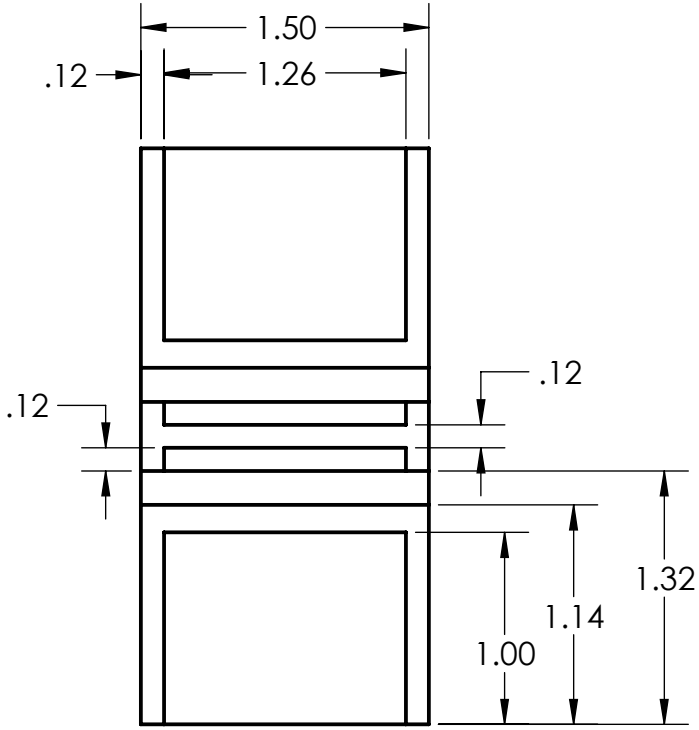
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F23.02	ROD CAP	1
2	F23.01	ROD	1
3	F23.A03.01	WATERWHEEL	1

Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature #23	Title:WATERWHEEL ASSEMBLY		Drwn. By:B PUCCINI
	Dwg. #:F23.A03	Nxt Asb:N/A	Date:5/2/18	Scale: 1:1	Chkd. By: ME STAFF

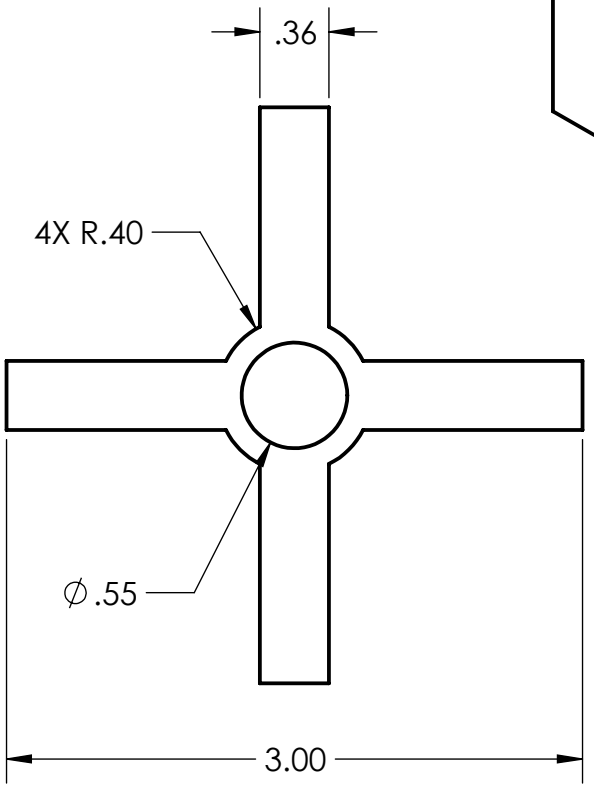
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XXX= ±.050

MANUFACTURING NOTES:
THIS PART IS INTENDED TO BE 3D PRINTED

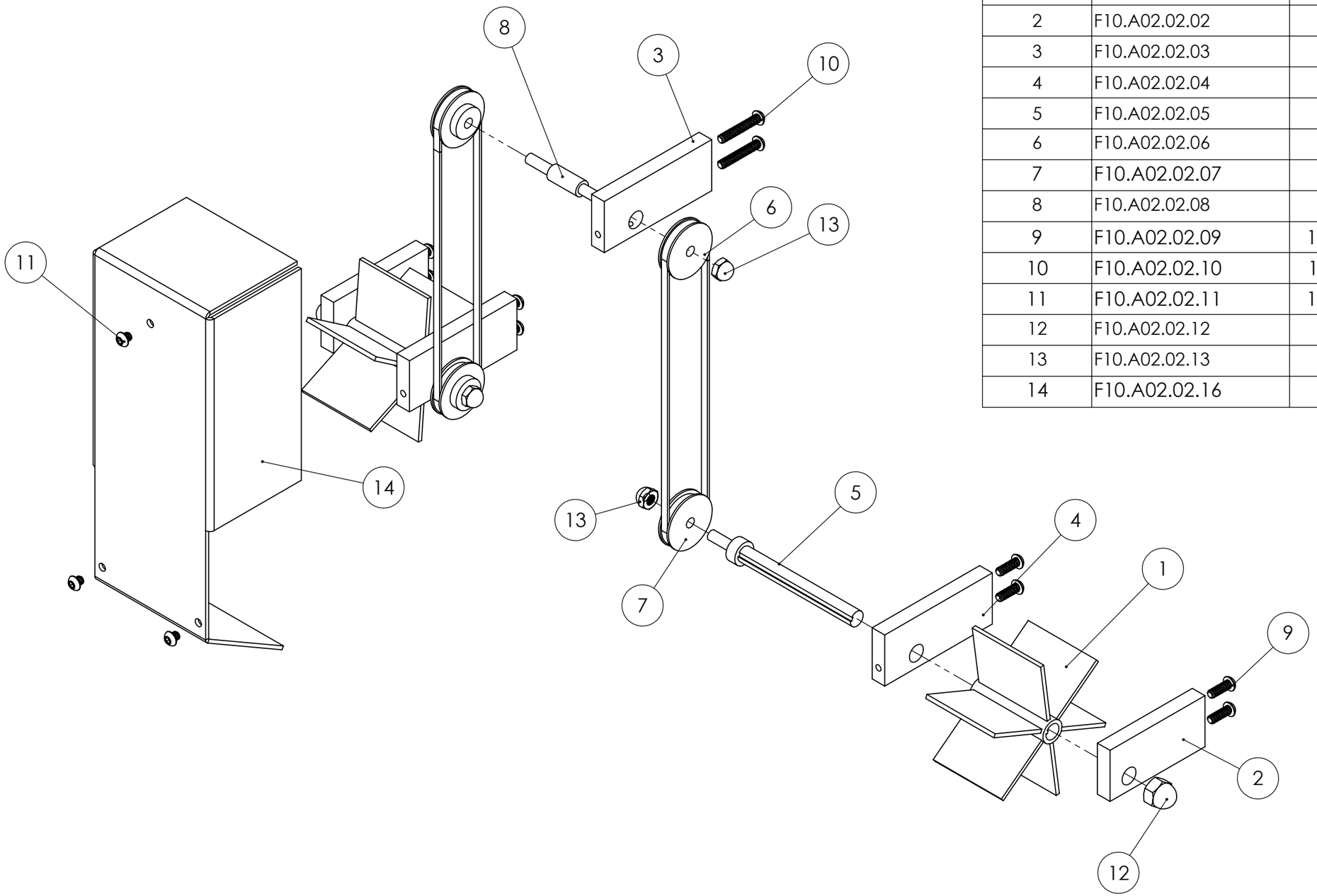




NOTE: EACH FLANGE IS IDENTICAL AND FOLLOWS THESE DIMENSIONS



Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature #23	Title:WATERWHEEL		Drwn. By:B PUCCINI
	Dwg. #: F23.A03.01	Nxt Asb:N/A	Date:5/2/18	Scale:1:1	Chkd. By: ME STAFF



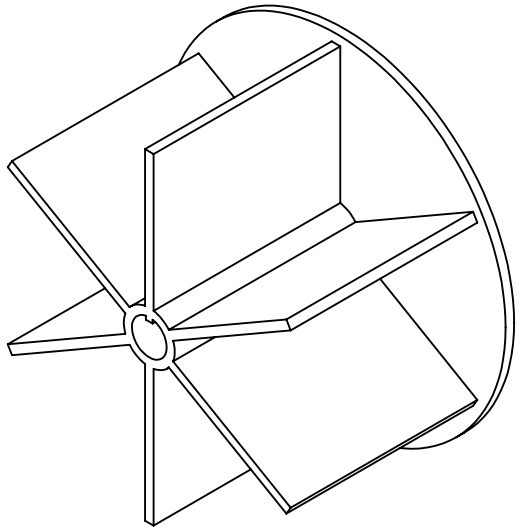
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F10.A02.02.01	Waterwheel	2
2	F10.A02.02.02	Wall brace 01	2
3	F10.A02.02.03	Wall brace 02	1
4	F10.A02.02.04	Wall brace 03	2
5	F10.A02.02.05	Waterwheel shaft	2
6	F10.A02.02.06	Drive pulley	4
7	F10.A02.02.07	Timing belt	1
8	F10.A02.02.08	Pulley shaft	1
9	F10.A02.02.09	1/4-20-2A-3/4 Machine Screw	8
10	F10.A02.02.10	1/4-20-2A-1.5 Machine Screw	2
11	F10.A02.02.11	1/4-20-2A-1/4 Machine Screw	3
12	F10.A02.02.12	1/2-20 UNC-2B cap nut	2
13	F10.A02.02.13	5/16-24 UNF-2B cap nut	4
14	F10.A02.02.16	Safety Cover	1

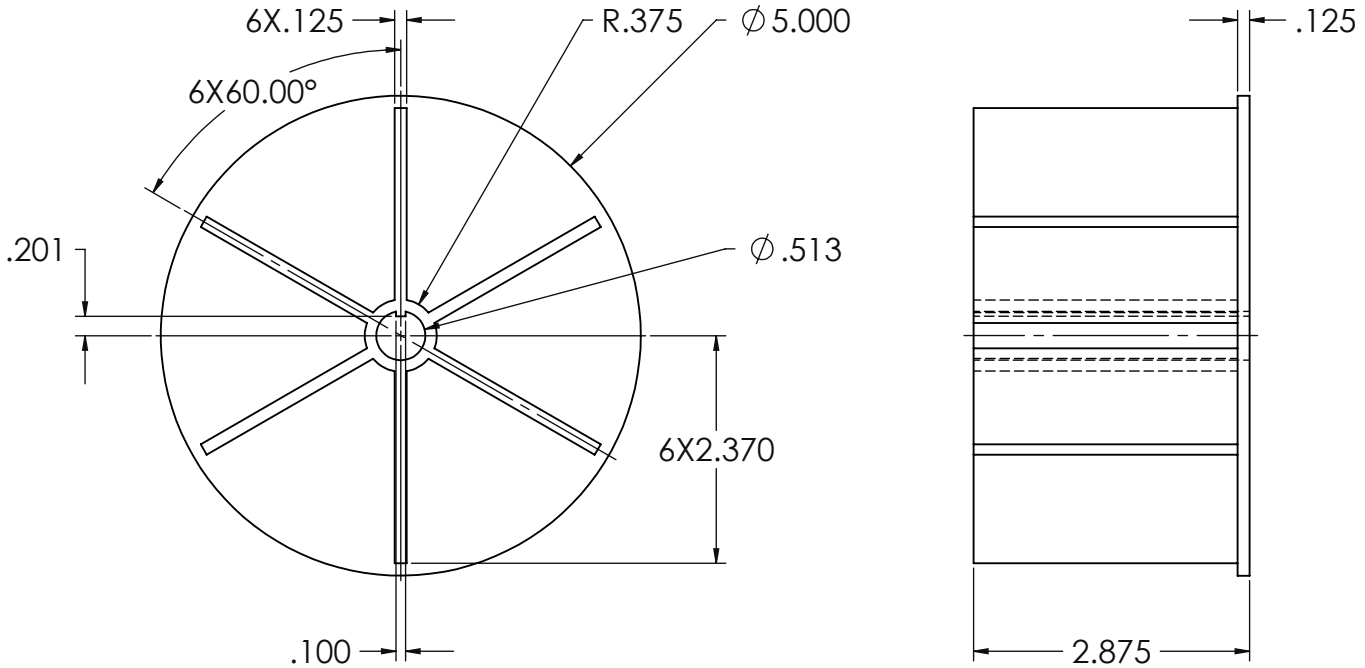
Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 10	Title: TARGET ASSEMBLY	Drwn. By: NOM
	Dwg. #: F10.A02.02	Nxt Asb: F10.A01.01	Date: 12-4-18 Scale: 1=3	Chkd. By: ME STAFF

SOLIDWORKS Educational Product. For Instructional Use Only.

NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ±.05

MANUFACTURING NOTES:
THIS PART IS INTENDED TO BE 3D PRINTED.





Cal Poly Mechanical Engineering	Lab Section: 03	Feature 10	Title: WATERWHEEL		Drwn. By: NOM
WATER FUN 2018	Dwg. #: F10.A02.02.01	Nxt Asb: F10.A02.02	Date: 4-25-18	Scale: 1=2	Chkd. By:

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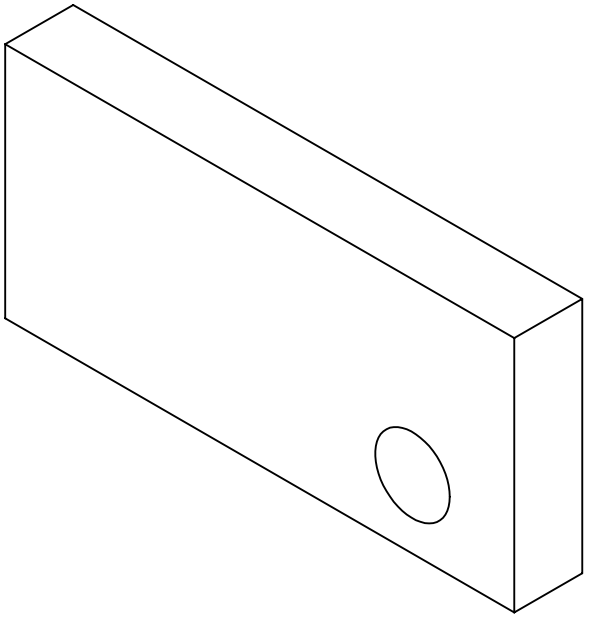
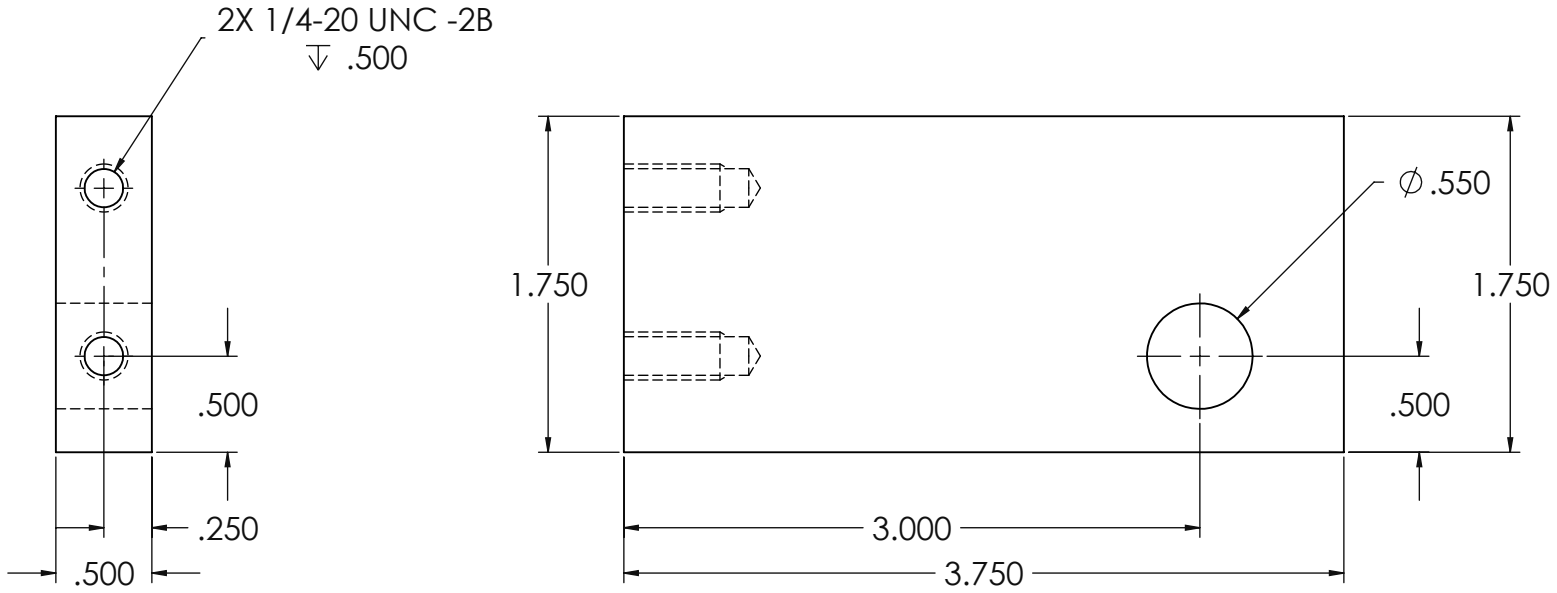
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ±.005





Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 10	Title: WALL BRACE 01		Drwn. By: NOM
	Dwg. #: F10.A02.02.02	Nxt Asb: F10.A02.02	Date: 4-25-18	Scale: 1=1	Chkd. By:

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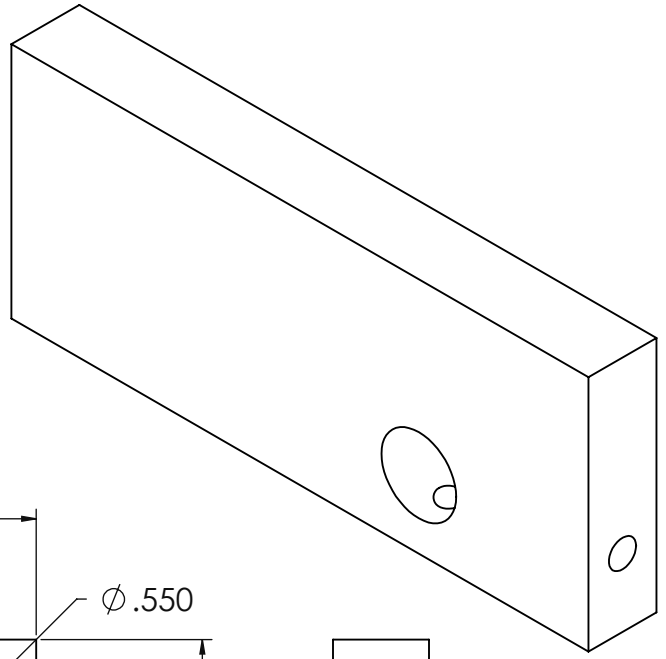
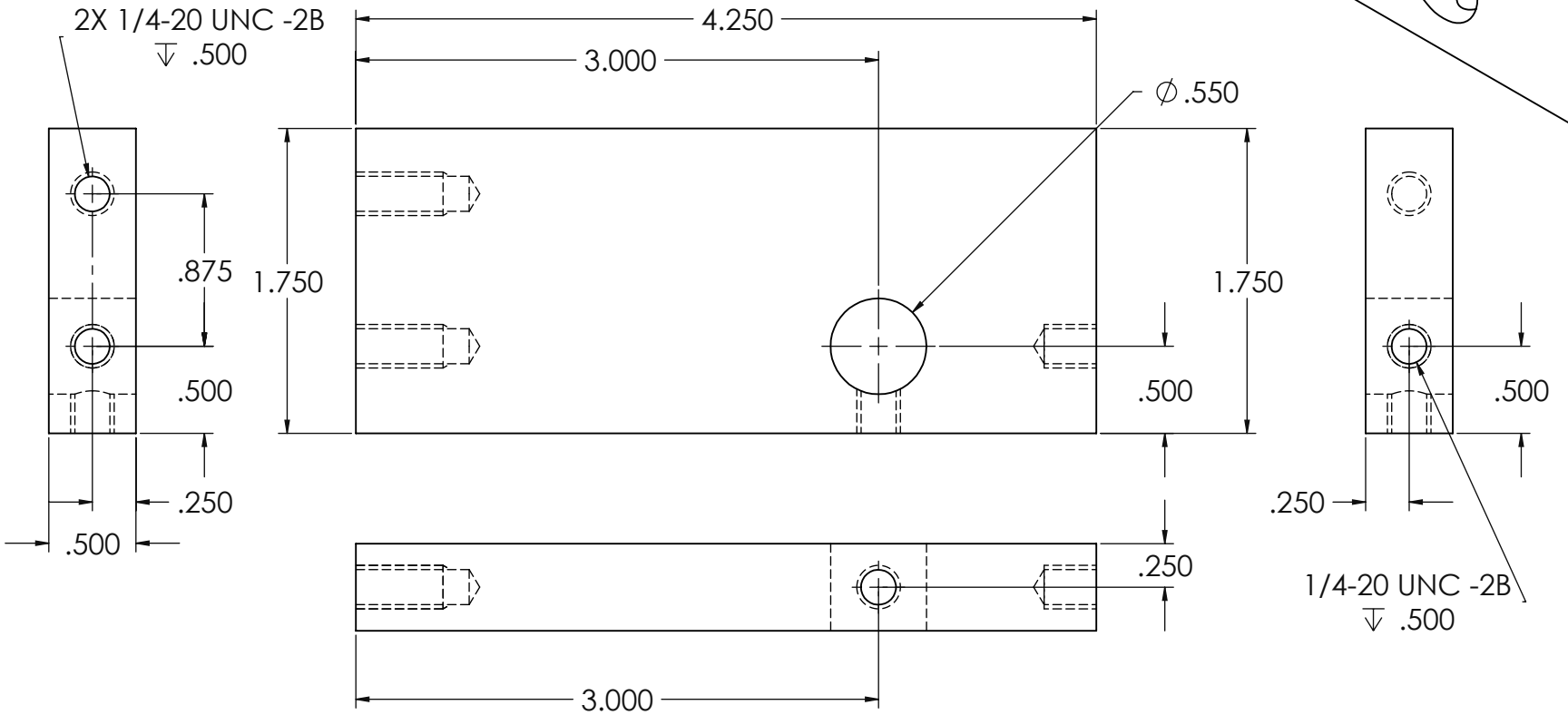
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ±.005





Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 10	Title: WALL BRACE 02		Drwn. By: NOM
	Dwg. #: F10.A02.02.03	Nxt Asb: F10.A02.02	Date: 4-25-18	Scale: 1=1	Chkd. By:

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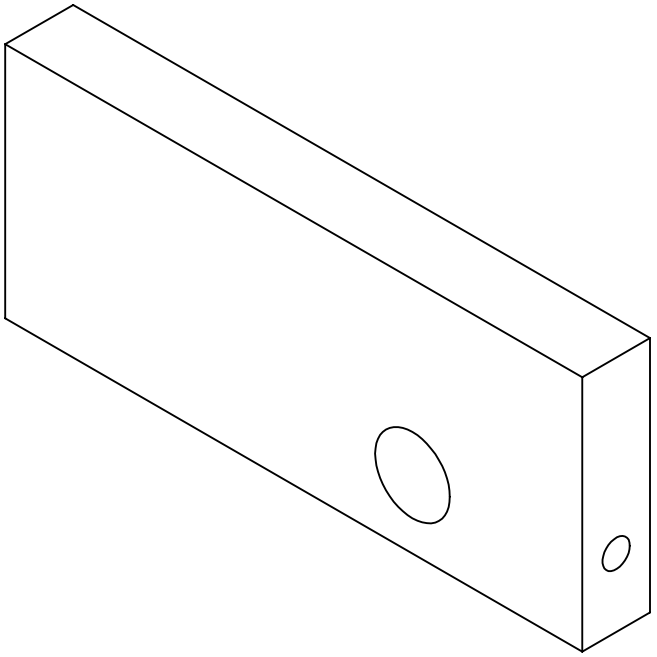
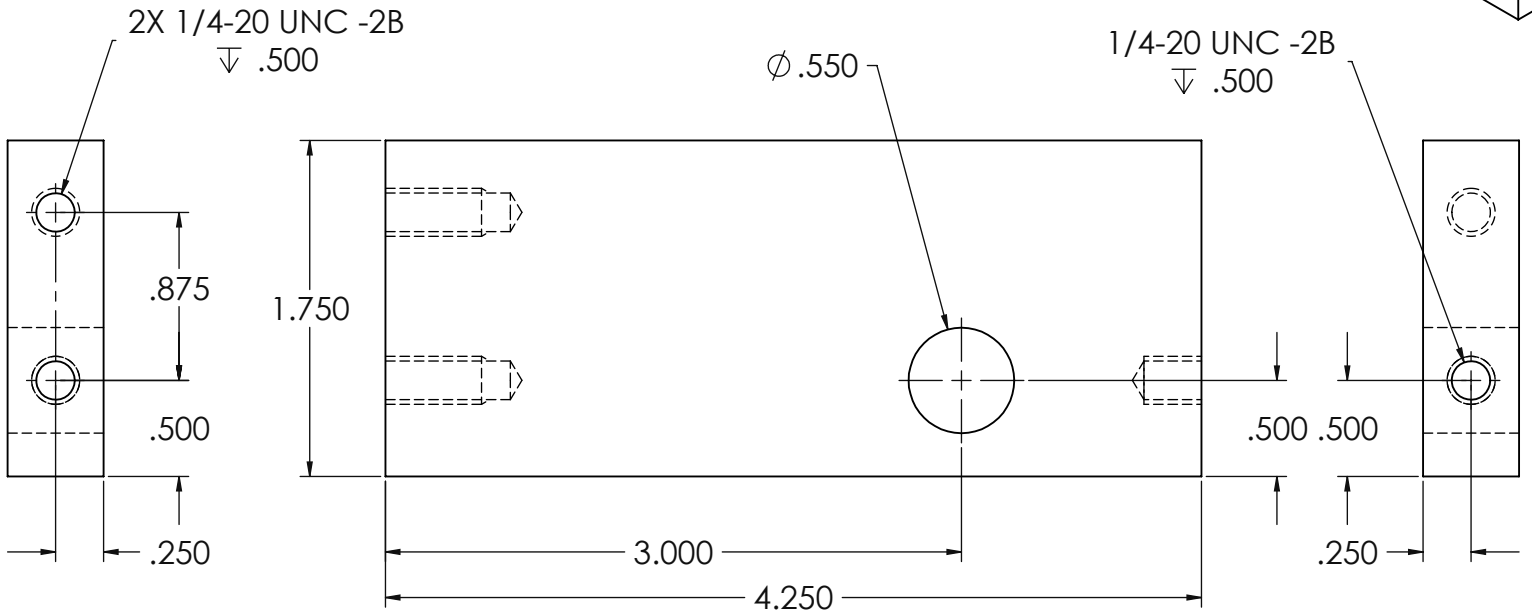
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ±.005





Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 10	Title: WALL BRACE 03		Drwn. By: NOM
	Dwg. #: F10.A02.02.04	Nxt Asb: F10.A02.02	Date: 4-25-18	Scale: 1=1	Chkd. By:

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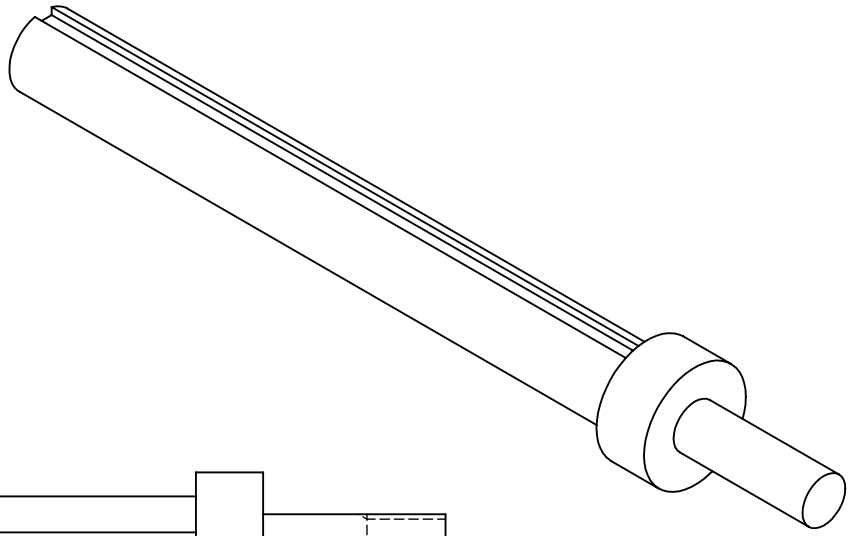
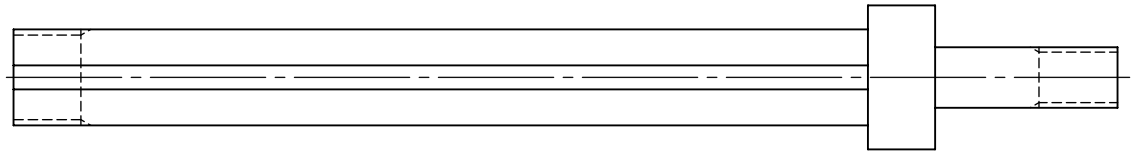
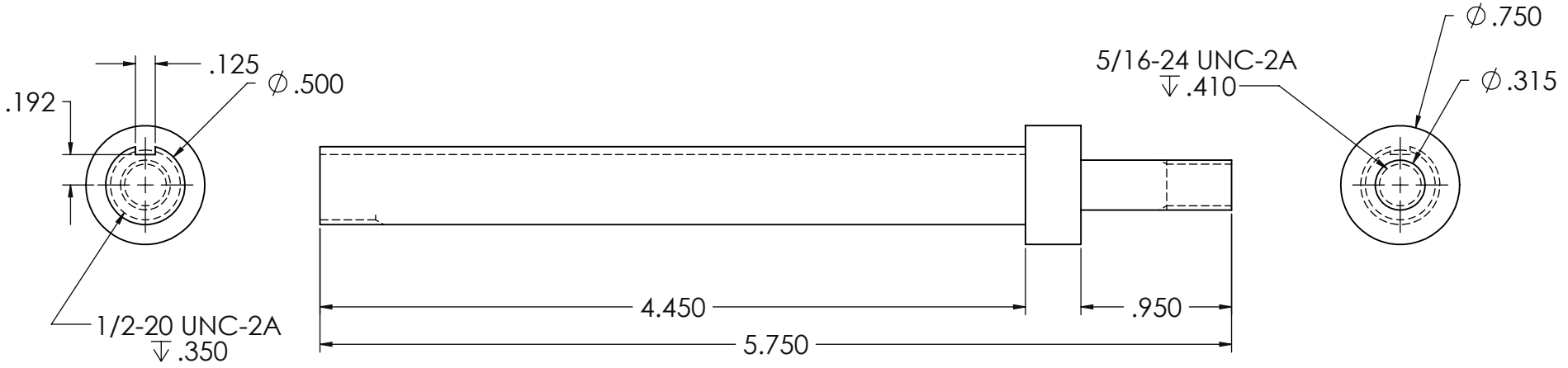
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ±.005







Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 10	Title: WATERWHEEL SHAFT		Drwn. By: NOM
	Dwg. #: F10.A02.02.05	Nxt Asb: F10.A02.02	Date: 4-25-18	Scale: 1=1	Chkd. By:

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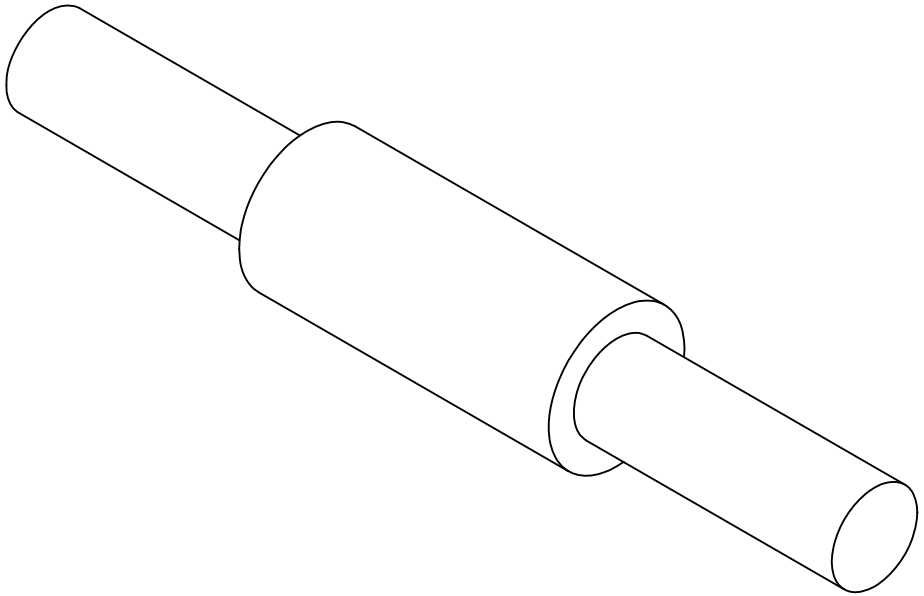
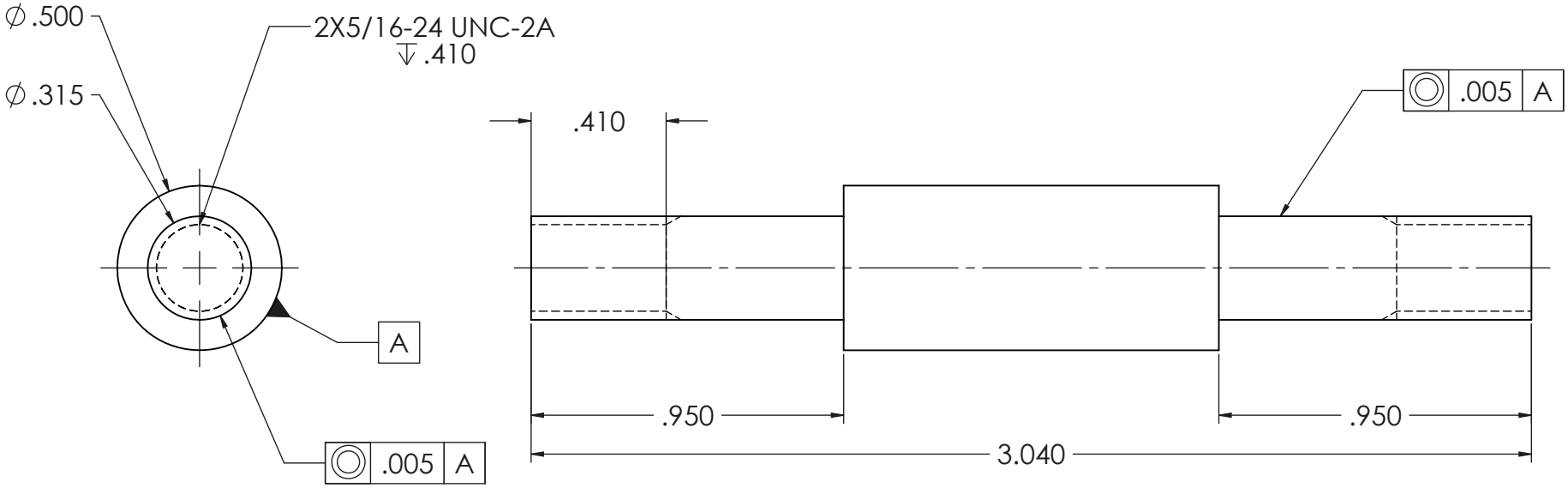
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
X.XXX= ±.005





Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 10	Title: PULLEY SHAFT		Drwn. By: NOM
	Dwg. #: F10.A02.02.08	Nxt Asb: F10.A02.02	Date: 4-25-18	Scale: 1=1	Chkd. By:

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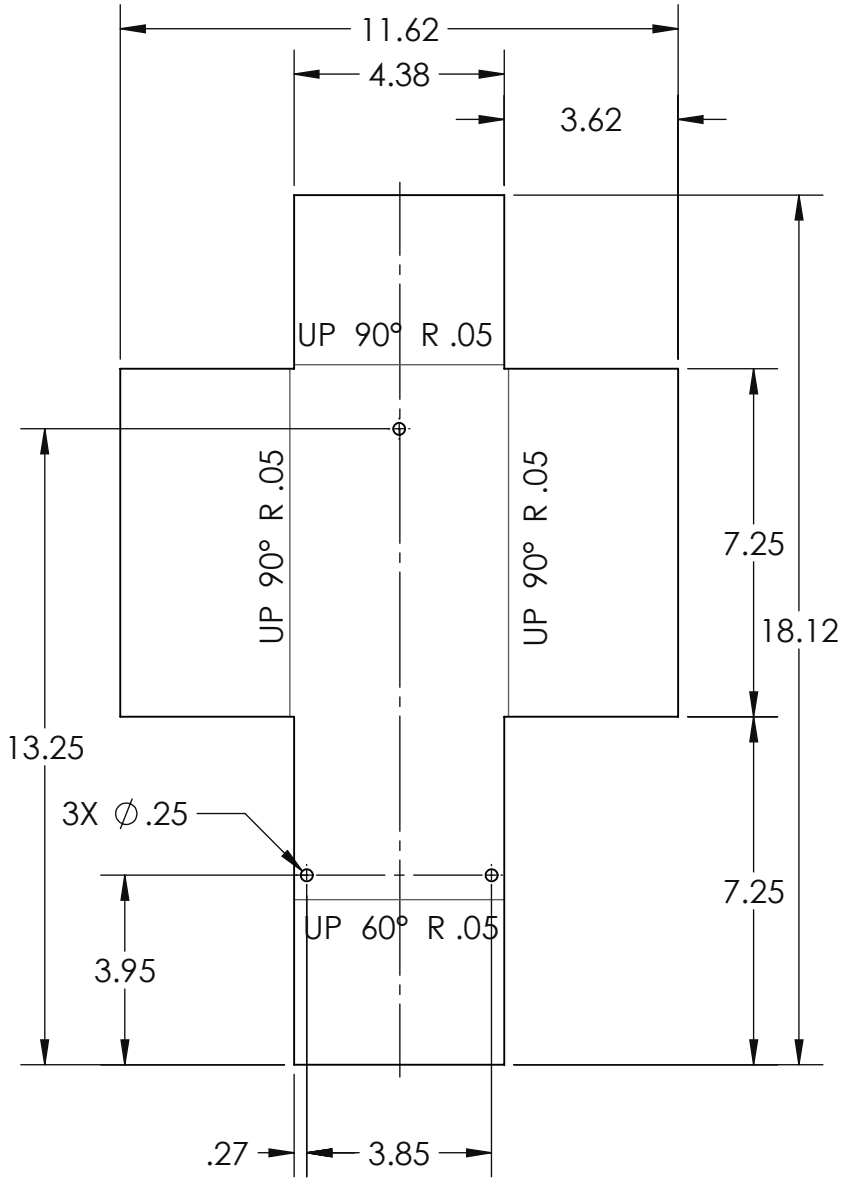

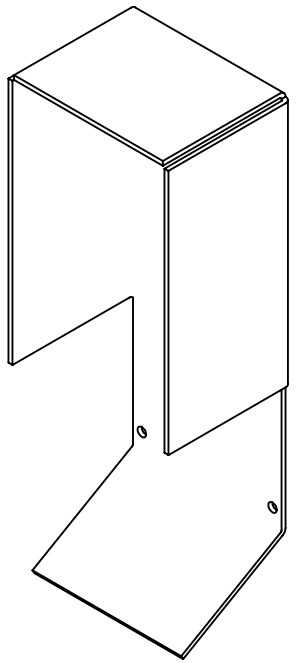

NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XXX= ±.005
   X° = ±1°

Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature # 10	Title: SAFETY COVER		Drwn. By: NOM
	Dwg. #: F10.A02.02.16	Nxt Asb: F10.A02.02	Date: 10/6/18	Scale: 1=4	Chkd. By:

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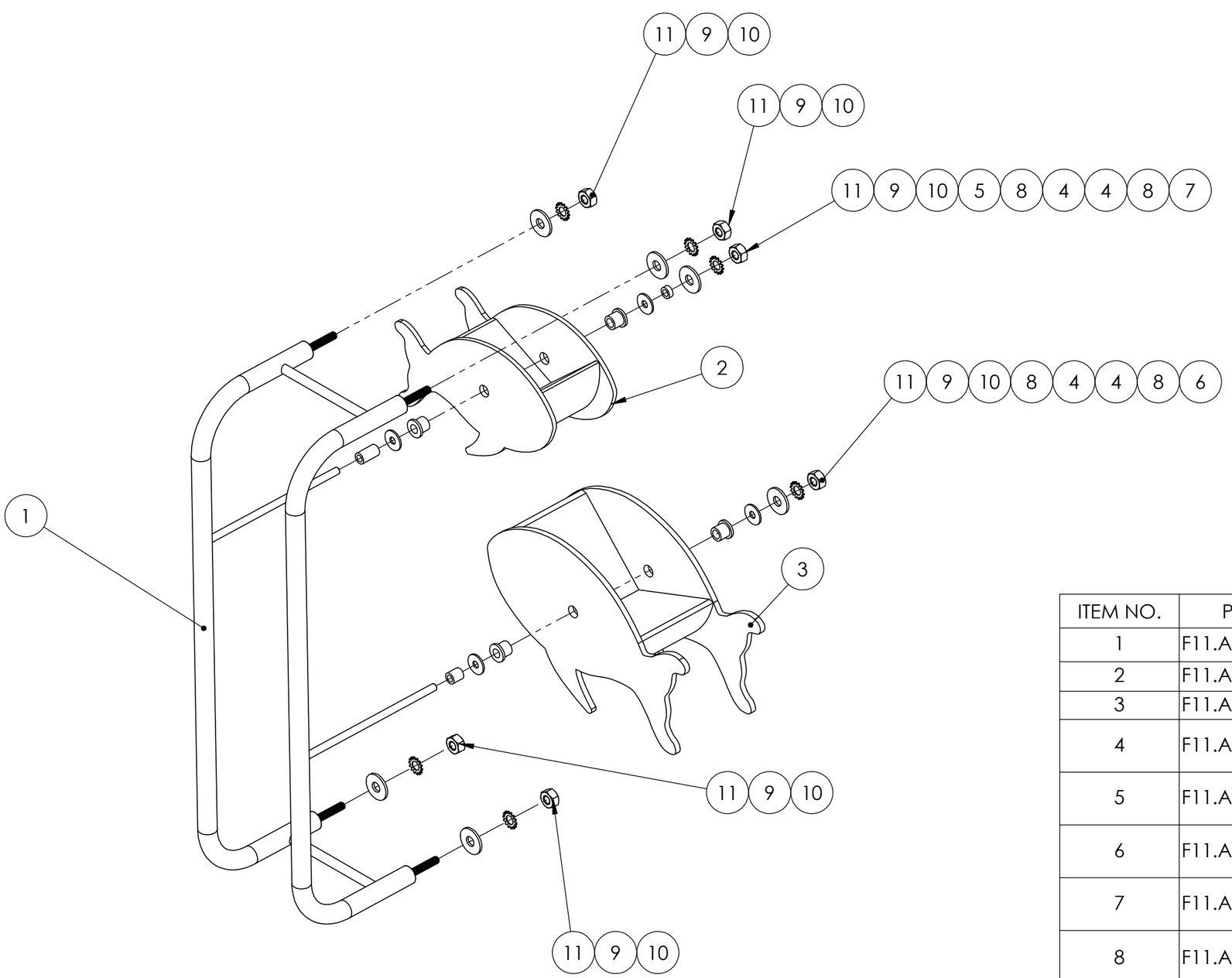

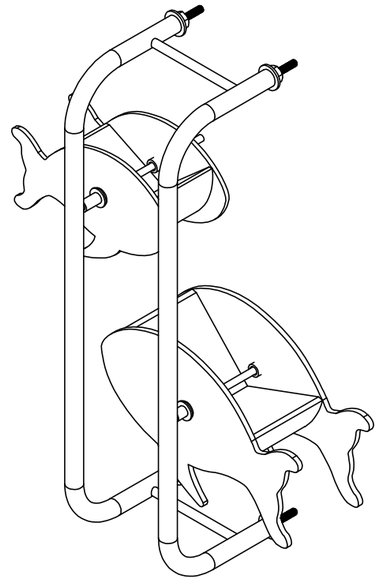

Scale: 1:4

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	F11.A03.01	New Stand Complete	1
2	F11.A02.03.01	Tipping Whale Small	1
3	F11.A02.03.02	Tipping Whale Large	1
4	F11.A02.01.09	#10 PTFE Ultra Low Friction Roller Bearing 2706T13	4
5	F11.A02.01.03	#10X 1/8" Stainless Steel Spacer 92320A460	1
6	F11.A02.01.01	#10 x 11/15" Stainless Steel Spacer 92320A757	1
7	F11.A02.01.02	#10 x 9/16" Stainless Steel Spacer 92320A772	1
8	F11.A02.01.10	#10 PTFE Ultra Low Friction Washer 95630A455	4
9	F11.A02.01.05	#10 Stainless Steel External tooth Lock Washer	6
10	F11.A02.01.04	#10 Stainless Steel Flat Washer	6
11	F11.A02.01.08	#10-32 Stainless Steel Hex Nut	6

Cal Poly Mechanical Engineering Water Fun 2018	SHEET: 1	Feature # 11	Title: Tipping Whale Assembly	Drwn. By: SM
	Dwg. #: F11.B01	Nxt Asb:	Date: 12/03/18 Scale: 1:3	Chkd. By: ME STAFF

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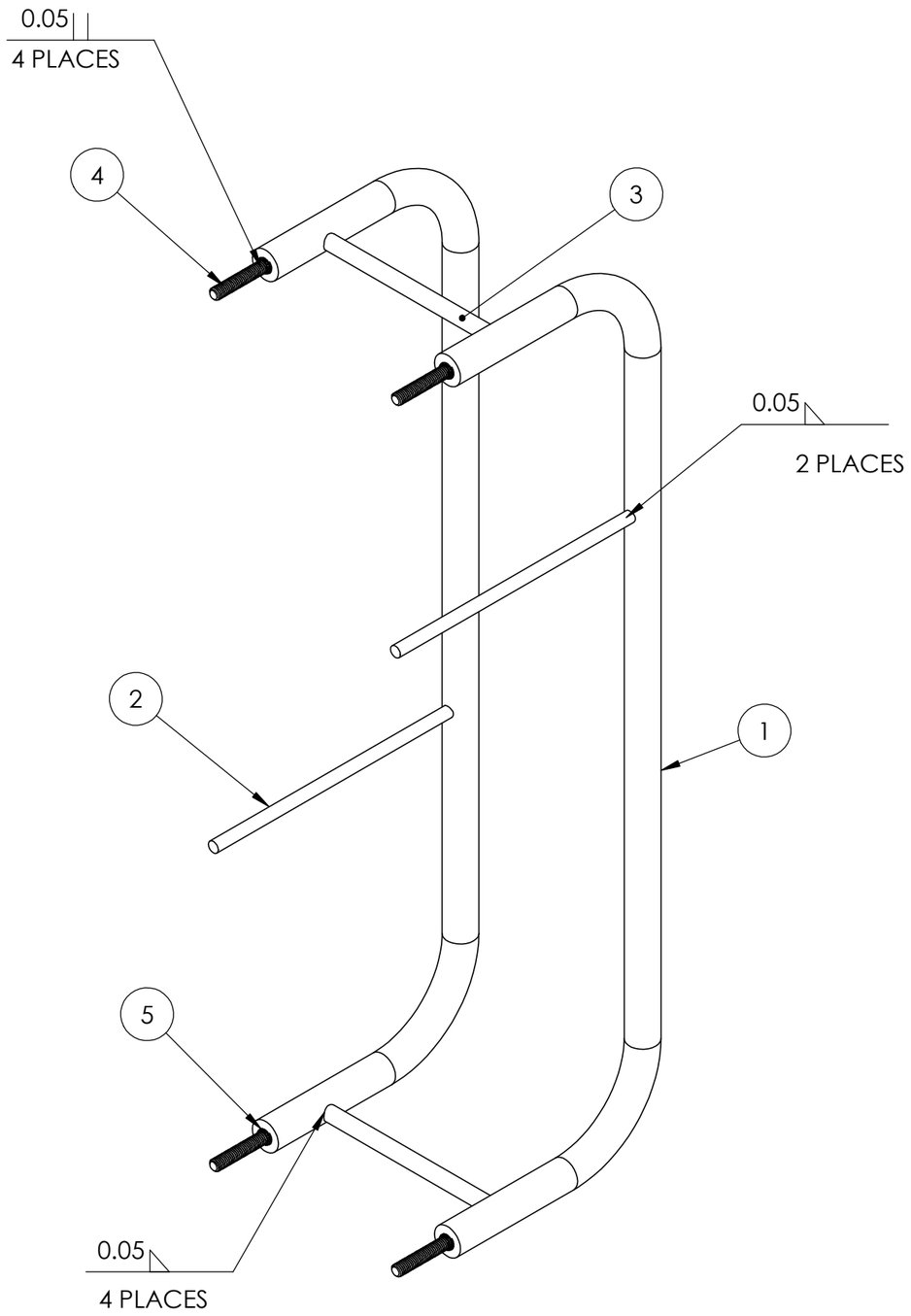

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1/2 IN BENT TUBE	Bent 1/2" SST Tube	2
2	PARTLY THREADED ROD	Partly Threaded #10-32 Pivot Rod	2
3	CONNECTING TUBE	1/4" Connecting Tube	2
4	93580A540	#10 - 32 x 1" 18-8 SST Press Fit Studs	4
5	04-0500-01	1/2" END CAP with threaded stud installed	4

NOTES:
MATERIAL IS STAINLESS STEEL, EITHER 316 OR 18-8, SEE SHEETS 3-5 FOR DETAILS

ALL DIMENTIONS IN INCHES

Cal Poly Mechanical Engineering Water Fun 2018	SHEET #: 2	Feature #11	Title: WELDED STAND		Drwn. By: SARAH MEANS
	Dwg. #: F11.A03.01	Nxt Asb: F11.B01	Date: 10/04/18	Scale: 1:2	Chkd. By: ME STAFF

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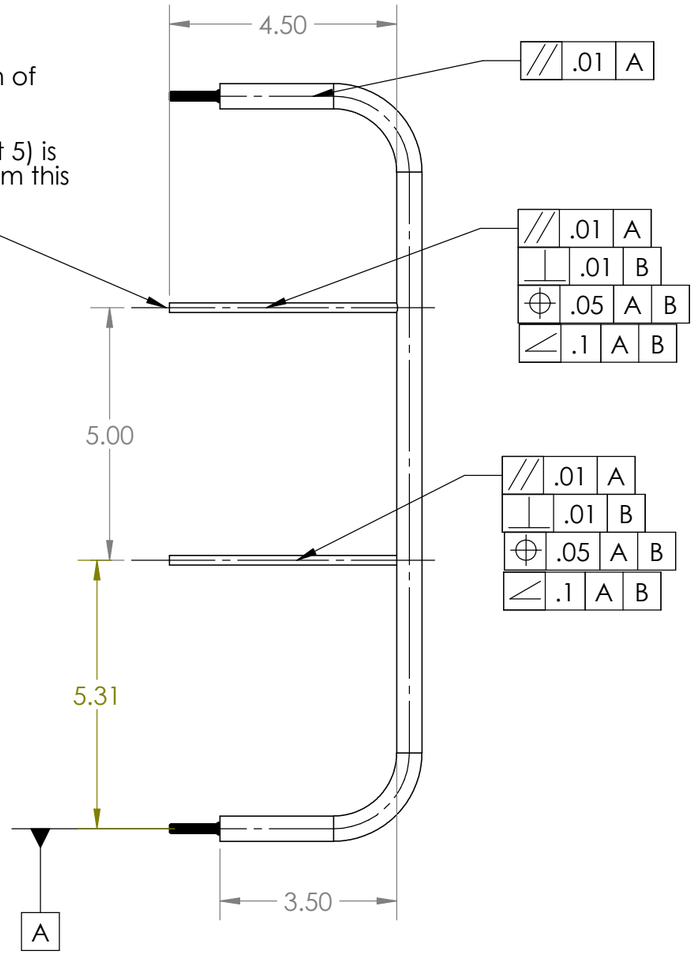
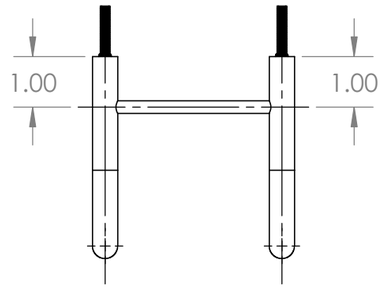
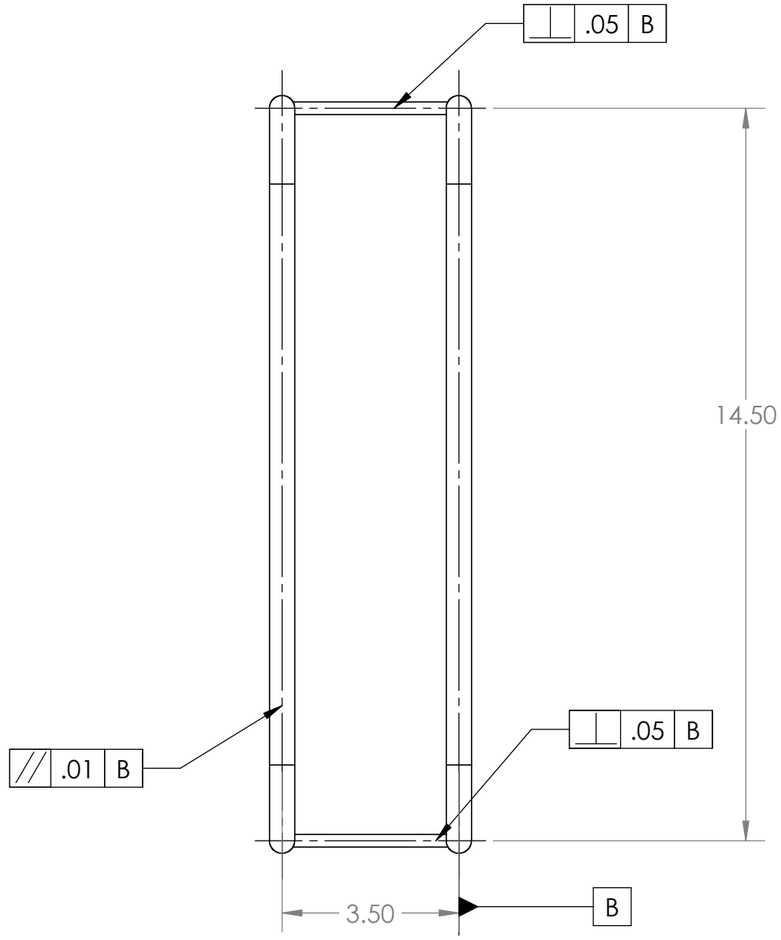
NOTE:
UNLESS OTHERWISE SPECIFIED:

ALL DIMENTIONS IN INCHES
TOLERANCES:
X.XX = ±.01

NOTE:
Threaded length of these PARTLY THREADED ROD (Shown on sheet 5) is .875", starting from this edge.







Cal Poly Mechanical Engineering Water Fun 2018	SHEET #: 3	Assignment #	Title: WELDED STAND		Drwn. By: SARAH MEANS
	Dwg. #:	Nxt Asb:	Date: 10/04/18	Scale: 1:3	Chkd. By:

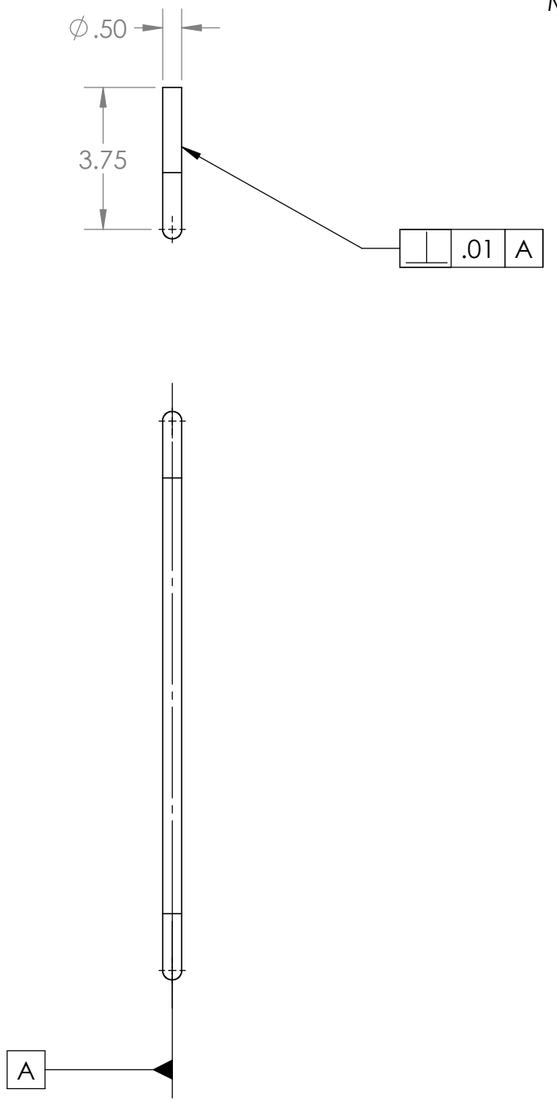
SOLIDWORKS Educational Product. For Instructional Use Only.

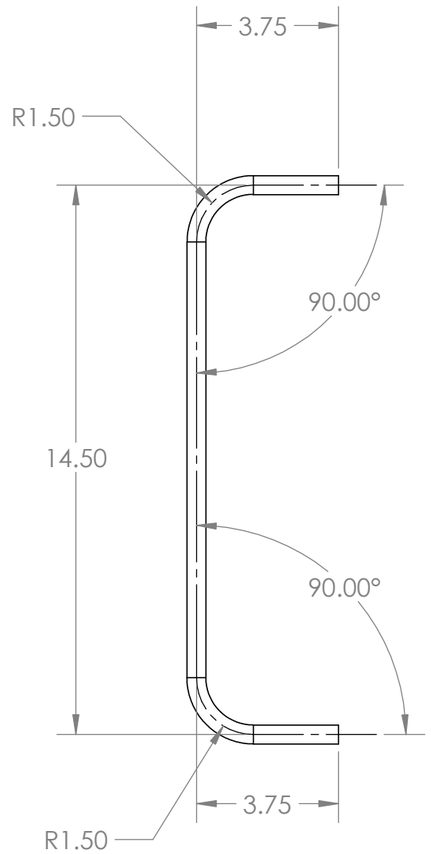
NOTES:

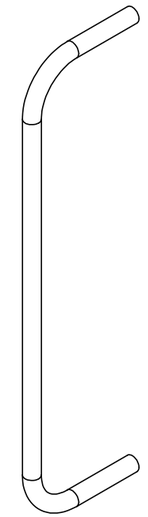
ALL DIMENTIONS IN INCHES

TOLERENCES:
X.XX = ±.05
ANGLES: ± 2°

MATERIAL: MEI PN 85-0217-01
1/2" ∅ X .065 WALL 316L SST TUBE







Cal Poly Mechanical Engineering WATER FUN 2018	SHEET #: 4	Assignment #	Title: 1/2 IN BENT TUBE		Drwn. By: SARAH MEANS
	Dwg. #:	Nxt Asb:	Date: 10/04/18	Scale: 1:4	Chkd. By:

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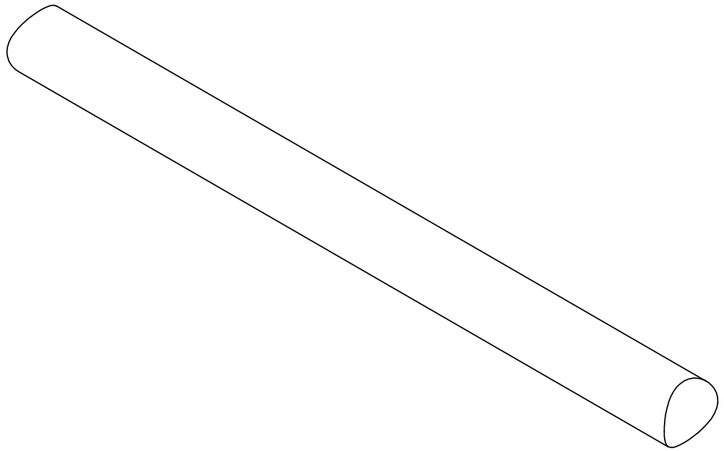
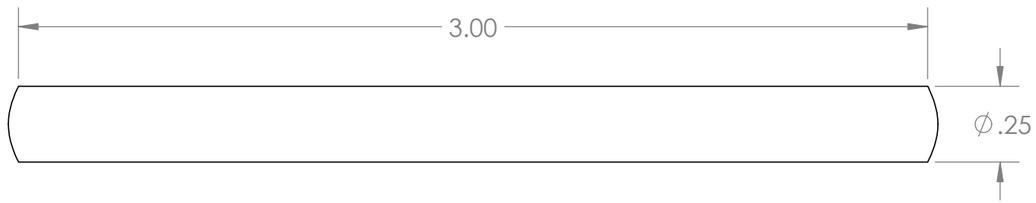
NOTES:

MATERIAL : MEI PN 85-0246-01
1/4" OD 0.35 WALL THICKNESS 316 SST TUBE

CUT OVERALL LENGTH SO THAT THE FINAL DIMENTIONS
AFTER WELDING SHOWN ON SHEET 2 CAN BE ACHEIVED





Cal Poly Mechanical Engineering WATER FUN 2018	SHEET #: 5	Assignment #	Title: CONNECTING TUBE		Drwn. By: SARAH MEANS
	Dwg. #:	Nxt Asb:	Date: 10/04/18	Scale: 2:1	Chkd. By:

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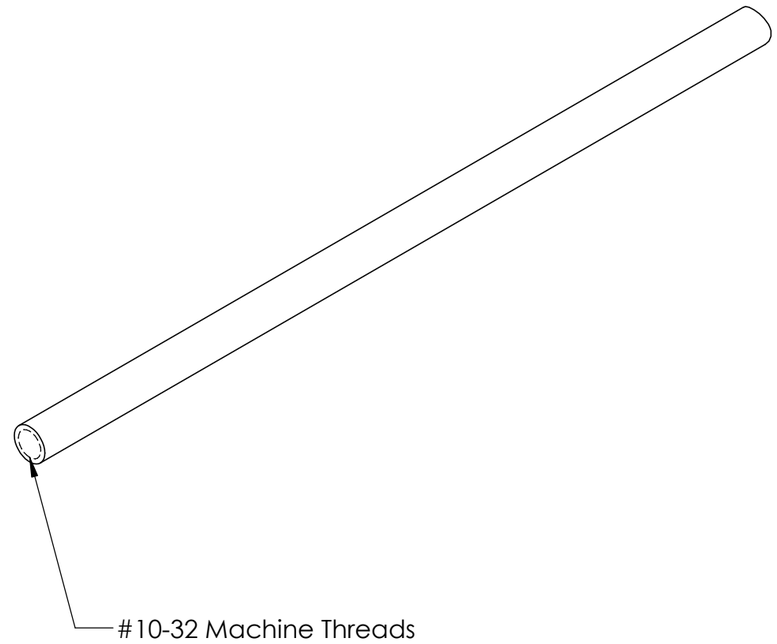
NOTES:

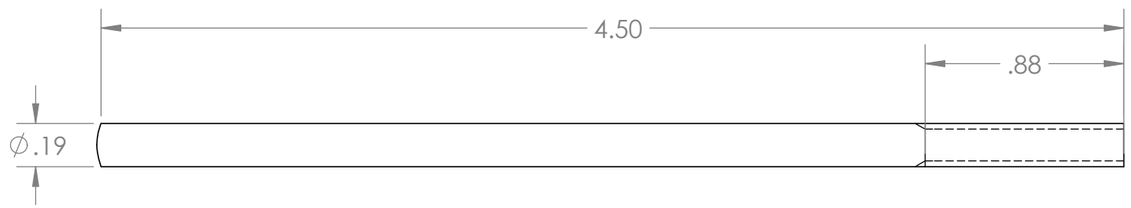
MATERIAL: McMASTER CARR PN 92196A290
10-32 x 6" SHCS 7/8" THREADED
18-8 SST

CUT HEAD OFF SCREW

LEAVE THREADS IN TACT

CUT OVERALL LENGTH SO THAT THE FINAL DIMENTIONS AFTER WELDING SHOWN ON SHEET 2 CAN BE ACHEIVED





Cal Poly Mechanical Engineering WATER FUN 2018	SHEET #: 6	Assignment #	Title: PARTLY THREADED ROD		Drwn. By: SARAH MEANS
	Dwg. #:	Nxt Asb:	Date: 10/04/18	Scale: 3:2	Chkd. By:

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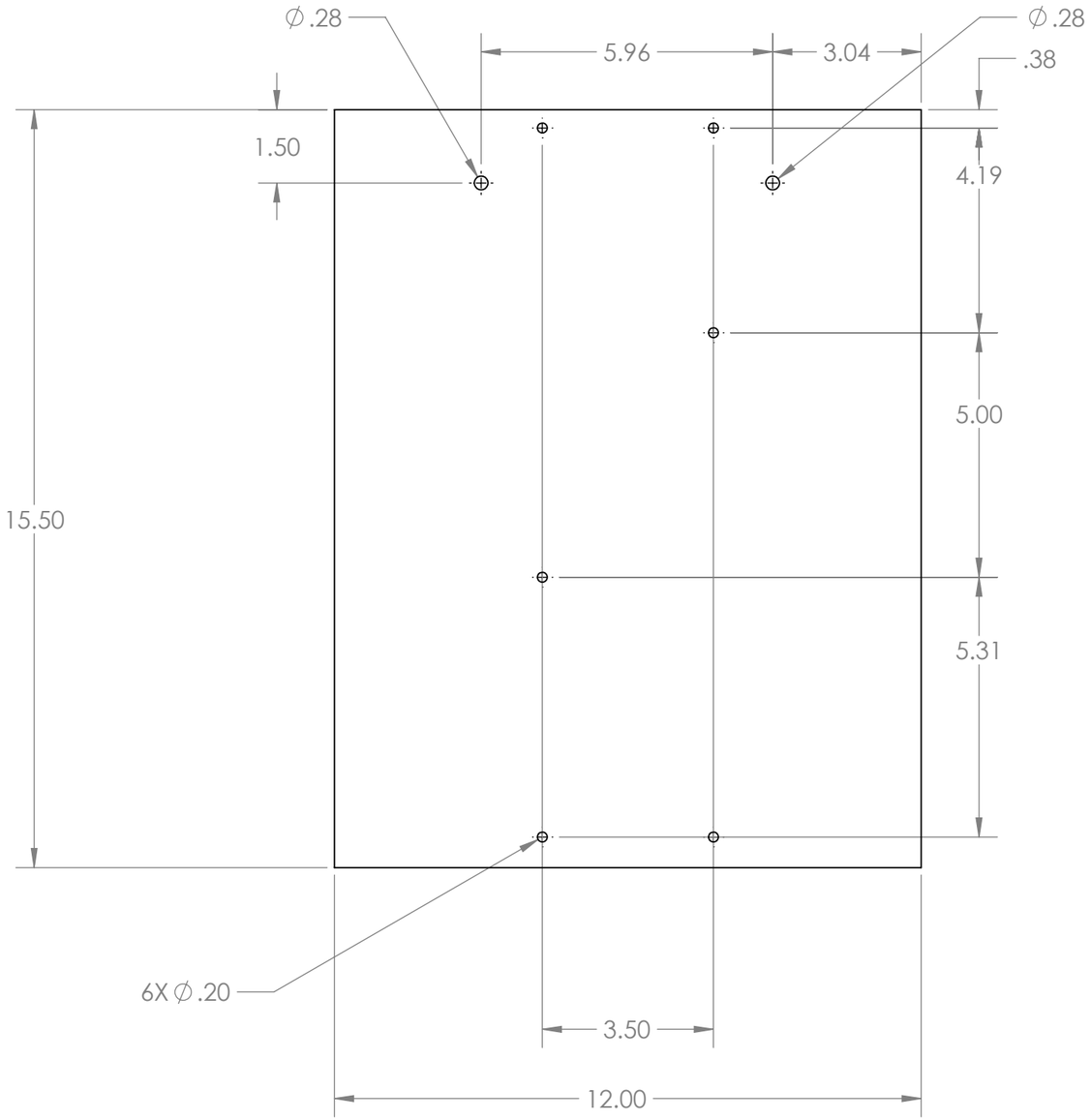
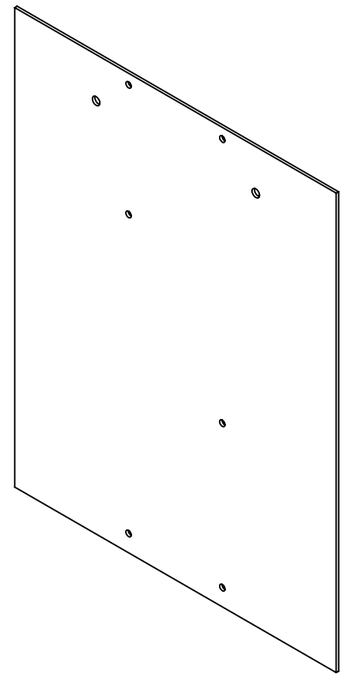
NOTES:
MATERIAL: STAINLESS STEEL SHEET 0.05" TO 0.12" THICK
ALL DIMS IN INCHES





Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature # 11	Title: WHALE STAND BACK PLATE		Drwn. By: SMEANS
	Dwg. #: F11.B01.01	Nxt Asb: F11.B01	Date: 10/30/18	Scale: 1:3	Chkd. By: ME STAFF

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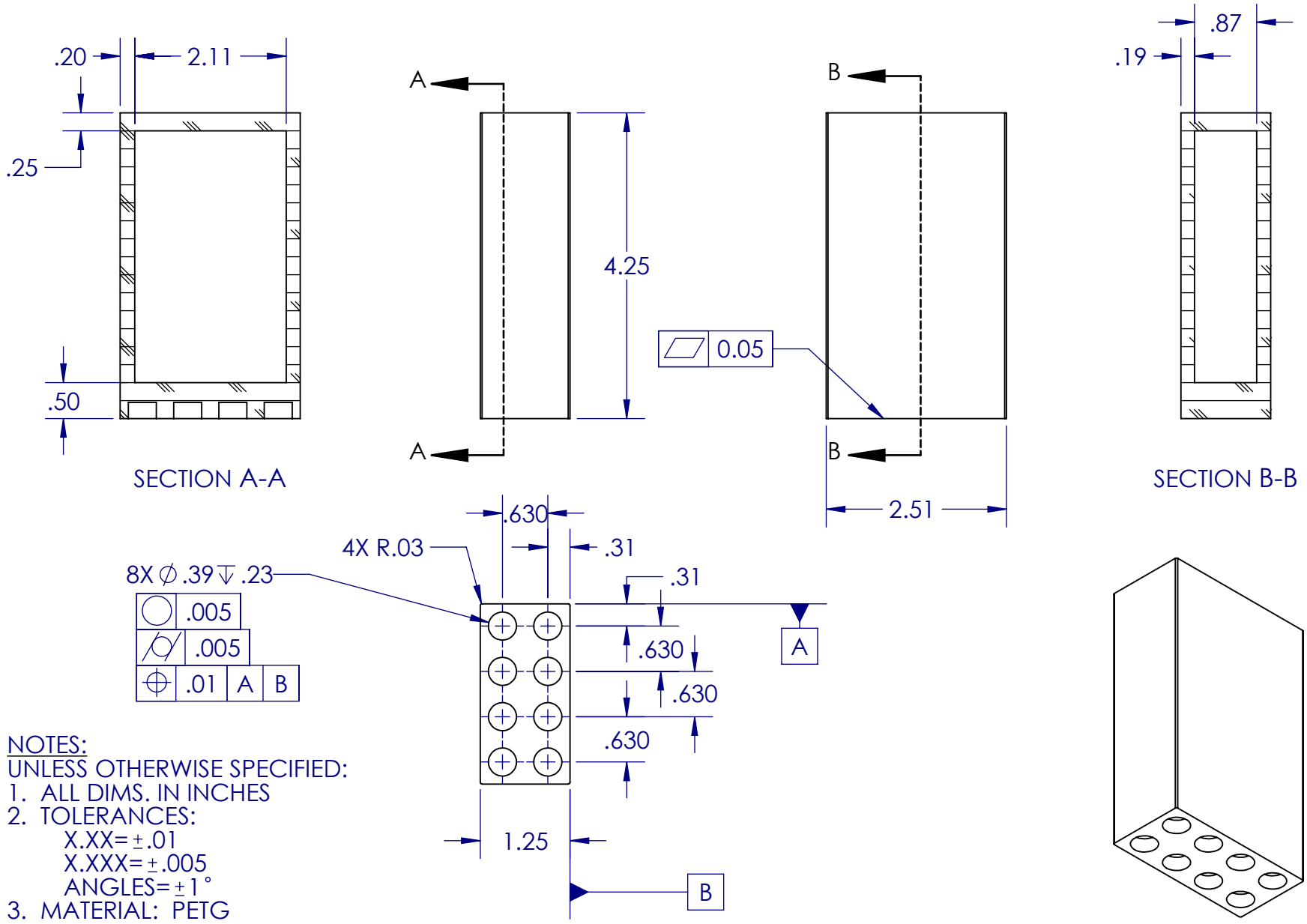
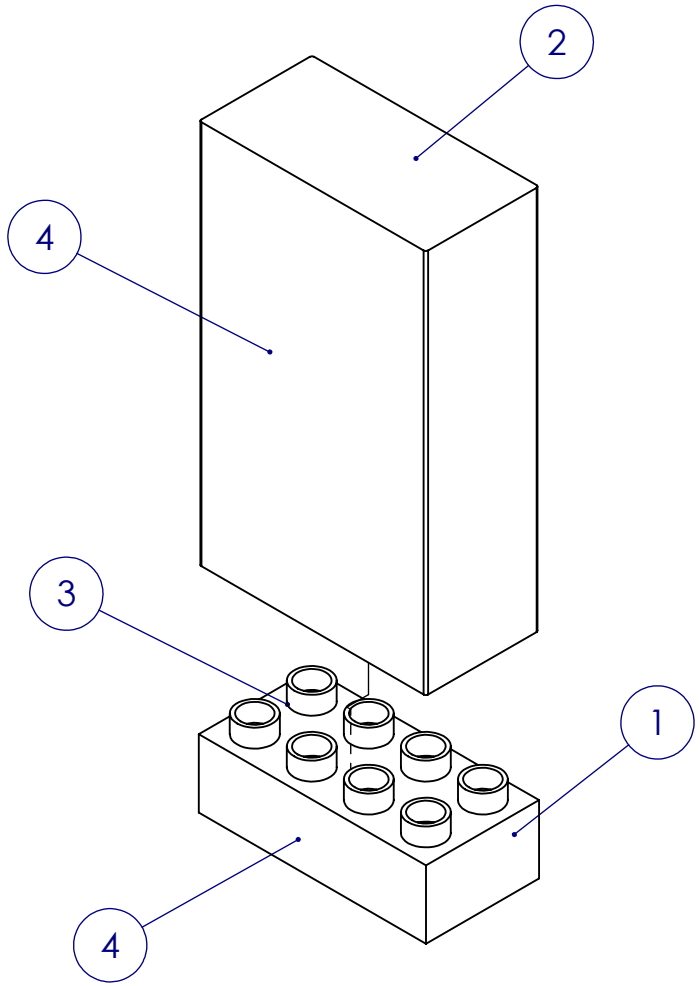


NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
   X.XX= ± .01
   X.XXX= ± .005
   ANGLES= ± 1°
3. MATERIAL: PETG

Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 22	Title: LEGO WALL 5 IN		Drwn. By: SM
	Dwg. #: 22.A02.01.01	Nxt Asb: 22.A02.01	Date: 4-25-18	Scale: 1:2	Chkd. By: ME STAFF

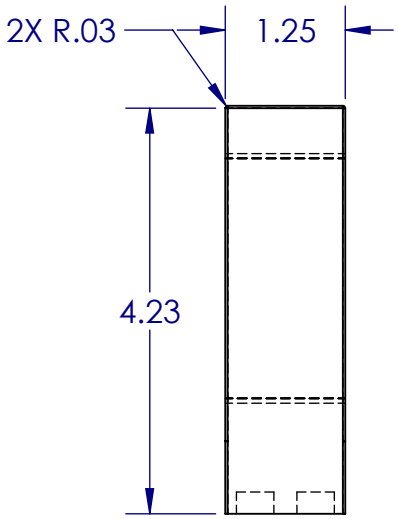
SOLIDWORKS Educational Product. For Instructional Use Only.

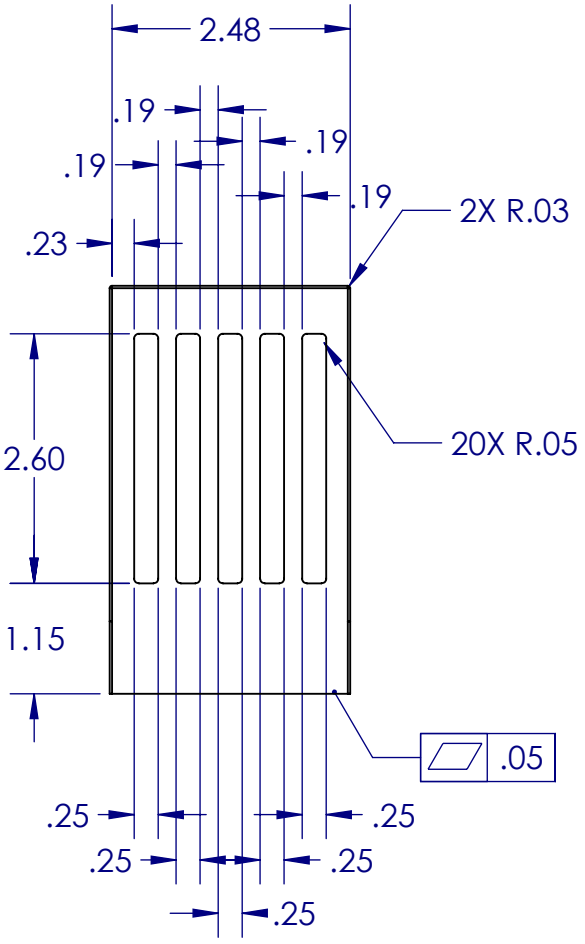
ITEM	PART NUMBER	DESCRIPTION	QTY	UOM
1	F22.A03.01.01	2X4 DUPLO LEGO	1	EA
2	F22.A02.01.01	LEGO RAMP TOPPER	1	EA
3	F22.A03.01.02	JB WELD PLASTIC BONDER	.05	OZ
4	F22.A03.01.04	UV COATING	.1	OZ



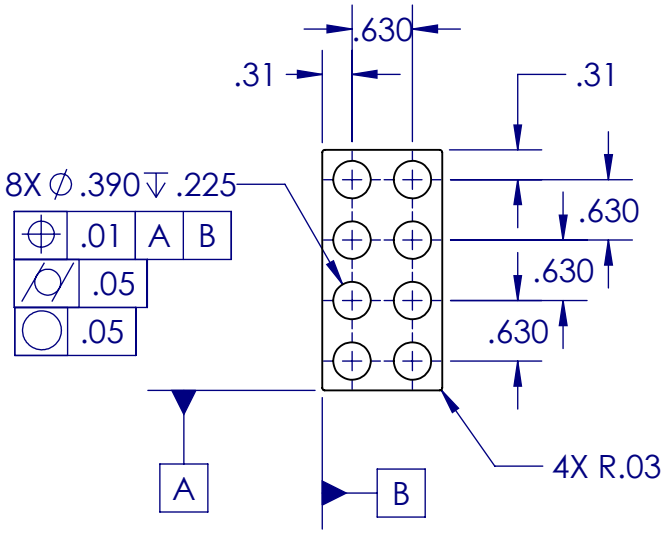
Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature #22	Title: Lego Wall Assem		Drwn. By: SM
	Dwg. #: F22.A02.01	Nxt Asb: NONE	Date: 05/02/18	Scale: 2:3	Chkd. By: ME STAFF

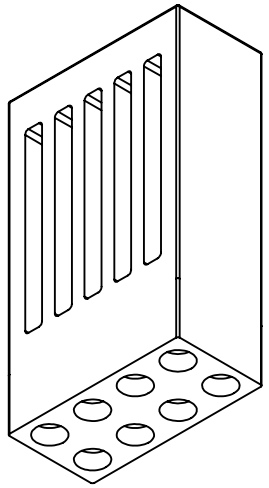
SOLIDWORKS Educational Product. For Instructional Use Only.





NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
   X.XX= ±.01
   X.XXX= ±.005
   ANGLES= ±1°
3. MATERIAL: PETG

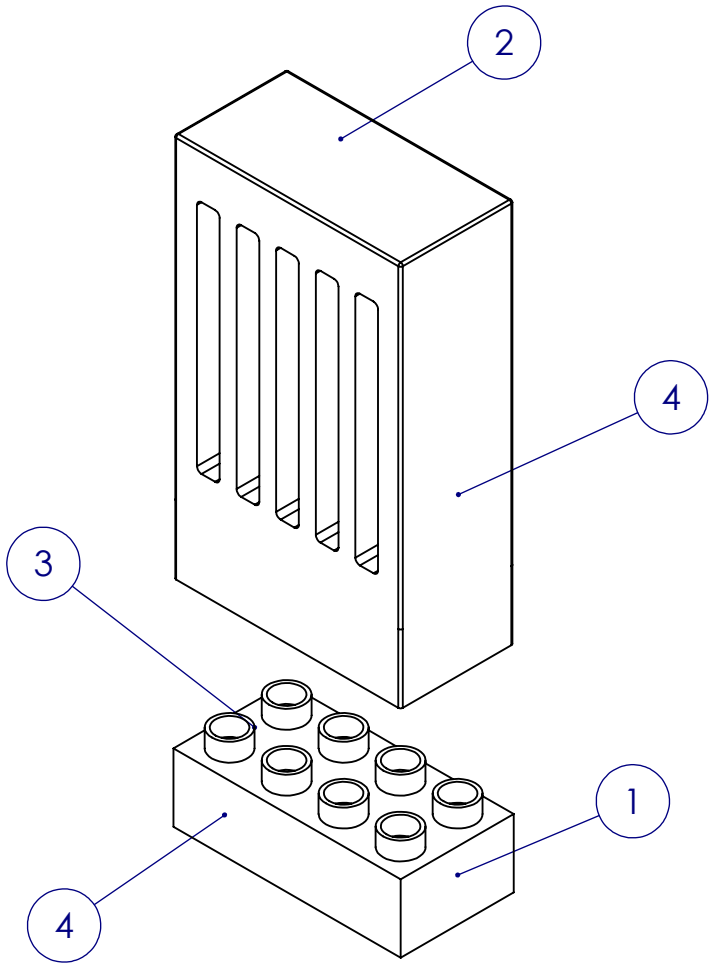




Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature 22	Title: 5 inch Weir Topper		Drwn. By: SM
	Dwg. #:22.A02.02.01	Nxt Asb: 22.A02.02	Date: 4-25-18	Scale: 1:2	Chkd. By: ME STAFF

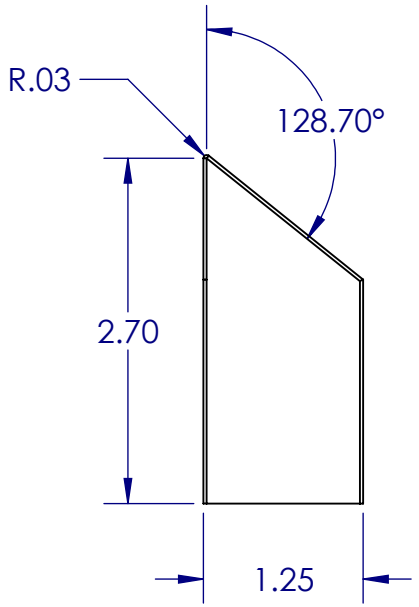
SOLIDWORKS Educational Product. For Instructional Use Only.

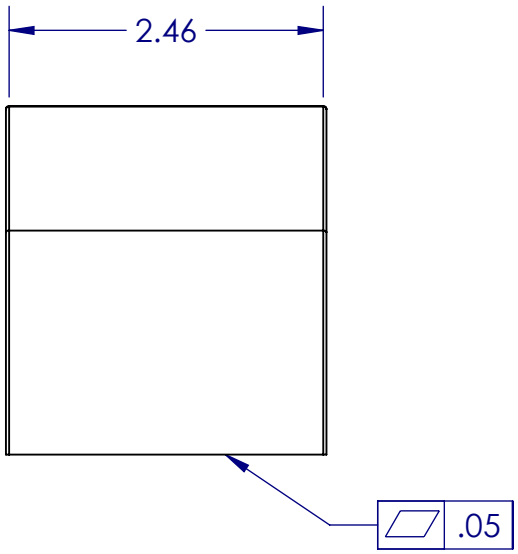
ITEM	PART NUMBER	DESCRIPTION	QTY	UOM
1	F22.A03.01.01	2X4 DUPLO LEGO	1	EA
2	F22.A02.02.01	LEGO RAMP TOPPER	1	EA
3	F22.A03.01.02	JB WELD PLASTIC BONDER	.05	OZ
4	F22.A03.01.04	UV COATING	.1	OZ

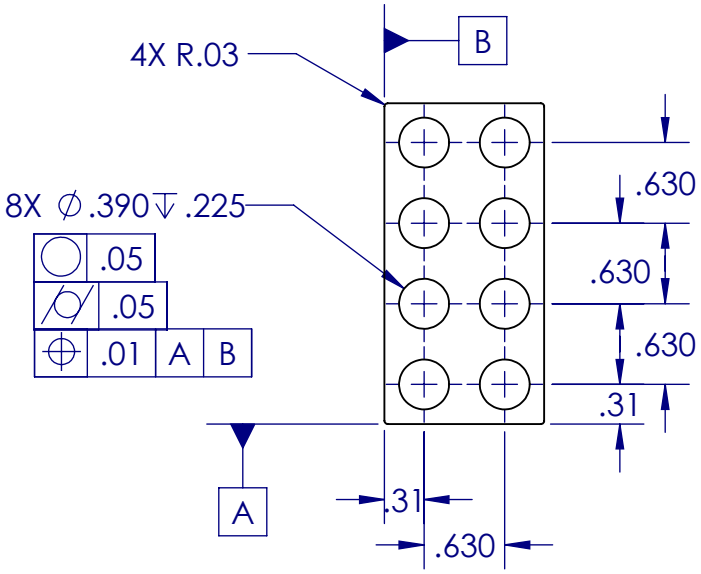


Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature # 22	Title: Lego Weir Assem		Drwn. By: SM
	Dwg. #: F22.A02.02	Nxt Asb: NONE	Date: 05/02/18	Scale: 2:3	Chkd. By: ME STAFF

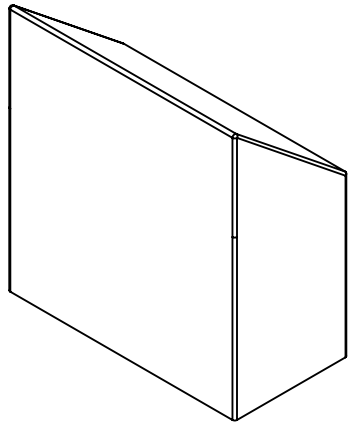
SOLIDWORKS Educational Product. For Instructional Use Only.







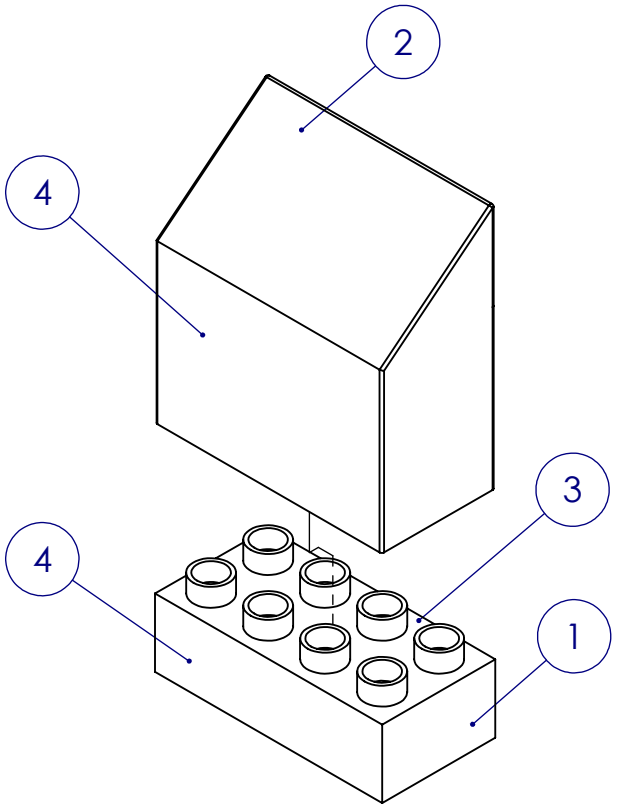
NOTES:
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMS. IN INCHES
2. TOLERANCES:
   X.XX= ± .01
   X.XXX= ± .005
   ANGLES= ± 1°
3. MATERIAL: PETG



Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature # 22	Title: Lego Ramp Topper		Drwn. By: SM
	Dwg. #: F22.A02.03.01	Nxt Asb: F22.A02.03	Date: 05/02/18	Scale: 2:3	Chkd. By: ME STAFF

SOLIDWORKS Educational Product. For Instructional Use Only.

ITEM	PART NUMBER	DESCRIPTION	QTY	UOM
1	F22.A03.01.01	2X4 DUPLO LEGO	1	EA
2	F22.A02.03.01	LEGO RAMP TOPPER	1	EA
3	F22.A03.01.02	JB WELD PLASTIC BONDER	.05	OZ
4	F22.A03.01.04	UV COATING	.05	OZ



Cal Poly Mechanical Engineering WATER FUN 2018	Lab Section: 03	Feature # 22	Title: Lego Ramp Assem		Drwn. By: SM
	Dwg. #: F22.A02.03	Nxt Asb: NONE	Date: 05/02/18	Scale: 2:3	Chkd. By: ME STAFF

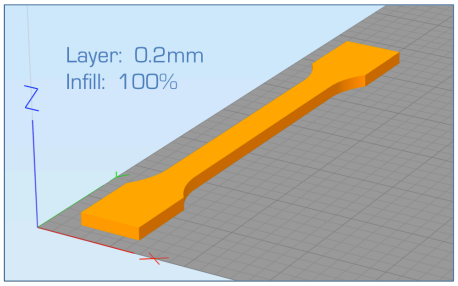
SOLIDWORKS Educational Product. For Instructional Use Only.

3DXMAX® ASA 3D Filament

3DXMAX® ASA (acrylonitrile styrene acrylate) premium UV-resistant 3D printing filament is formulated utilizing our high-flow exterior weatherable ASA resin and colorants. Our ASA has a low-gloss matte sheen with excellent layer hiding capability – making it the ideal material for demanding functional prototype and production parts that are exposed the outdoors or any application where a low-gloss technical looking matte finish is preferred. 3DXMAX® ASA is suitable for use in practically all consumer-grade FDM/FFF printers that have a heated print bed. Made by 3DXTECH® in the USA.

The reported technical data was generated from printed ISO test specimen. The general print parameters utilized are noted below.

- Desktop FDM/FFF Printer
- Nozzle: 0.4mm A2 hardened
- Layer height: 0.2mm
- Infill: 100%, +/- 45°
- Extrusion temp: 240°C
- Bed temp: 110°C
- Bed prep: ABS/Acetone Gel
- Print speed: 50 mm/sec



General Property	Unit	Standard	Typical Value
Density	g/cc	ISO 1183	1.07

Mechanical Property	Unit	Standard	Typical Value
Tensile Strength	MPa	ISO 527	43
Tensile Modulus	MPa	ISO 527	2010
Tensile Elongation, Break	%	ISO 527	10
Flexural Modulus	MPa	ISO 178	1956
Flexural Strength	MPa	ISO 178	78

Thermal Property	Unit	Standard	Typical Value
Glass Transition Temperature (Tg)	°C	DSC	104
Heat Distortion Temperature (HDT) @ 0.45MPa	°C	ISO 75	96

Electrical Property	Unit	Standard	Typical Value
Surface Resistivity	Ohm/sq	IEC 60093	$>10^{13}$

Printing Recommendation	Typical Range
Extruder Temperature	230 - 260°C
Bed Temperature	100 - 110°C
Print Speed	50 - 70 mm/sec

Disclaimer: The technical data contained on this data sheet is furnished without charge or obligation and accepted at the recipient's sole risk. This data should not be used to establish specifications limits or used alone as the basis of design. The data provided is not intended to substitute any testing that may be required to determine fitness for any specific use.

Operation Manual

ARTICEL

Pressurefilter CPF-Series

Read and follow the operating instructions and safety information before using for the first time.

Technical changes reserved!
Due to further developments, illustrations, functioning steps and technical data can differ insignificantly.

Updating the documentation
If you have suggestions for improvement or have found any irregularities please contact us.

The information contained in this document is subject to change without prior notice. No part of this document can be copied or duplicated in another form without the prior written consent of WilTec Wildanger Technik GmbH. The WilTec Wildanger Technik GmbH assumes no liability for any errors in this user manual or the connection diagram.
Although WilTec Wildanger Technik GmbH has made every effort to make sure that this user manual is complete, accurate and updated, errors cannot always be avoided. In the event of problems with this user manual please complete and send this form back to us.

FAX-notification (+++49 2403 55592-15**),**

from: _____

Name: _____

Firm:_____

Tel/Fax:_____

I would like to report the following mistakes:

Customer Service WilTec Wildanger Technik GmbH
e-mail: **service@WilTec.info**
Tel:++ +49 2403 55592-0
Introduction

Thank you for purchasing this quality product. **To minimize the risk of injury by means of fire or electric shock we urge that our clients take some basic safety precautions when using this device. Please read the operation instructions carefully and make sure you have understood its content.**
Always use a grounded power connection with the appropriate mains voltage. You can find the corresponding mains voltage on the type plate. If you have any doubts about the connection being grounded, have it checked by a qualified professional. Never use a faulty electric cable.
Do not inspect the electrical part of the pressure pond filter in a wet or damp environment or when you are wet yourself and protect it from direct sunlight. Install this device in a safe location so that nobody can step on the cable, fall over or damage it. Disconnect the power plug before cleaning it and use only a damp cloth for cleaning. Avoid using cleaning agents and make sure that no liquid enters the electrical part of the pump.
The electric part of the device contains no parts that can be inspected or serviced by the user. Leave the maintenance, adjustment and repair to qualified technical personnel. In case of unauthorised intervention the 2-year warranty is no longer valid! Keep these operation instructions safe.

Safety guideline

BEWARE:

The use of this device is allowed on standing bodies of water, garden ponds' water or swimming ponds and their surrounding areas only with fault current protection-switch with a triggering nominal current up to 30mA (according to VDE 0100 article 702 and 738).

The device is not suitable for use in swimming pools, paddling pools and other bodies of water in which during operation people or animals linger. The operation of the device during the stay of people and animals in the danger zone is not allowed. Ask your electrician.

The device is not intended for use by persons (including children) with impaired or limited physical, sensory and mental abilities or lack of experience and/or real knowledge, unless they are supervised by a person responsible for their safety or you follow the instructions made by this person how to use the device correctly.
Children should be supervised to make sure that they do not play with the device.

ATTENTION:

- Run a visual inspection of the device before every use. Do not use the device if the safety appliances are damaged or worn out. Never override safety regulations.
- Use the device exclusively according to the intended purpose stated in the instructions for use.
- You are responsible for the safety of the working environment.

- If the cable or the plug is damaged due to external influences the cable must not be repaired! It has to be replaced with a new one. This work can be carried out only by an electrician.
- The voltage indicated on the type plate of the device of 230 Volt alternating voltage has to correspond to the existent mains voltage.
- Never lift, carry or fixate the device by using the power cable.
- Make sure that the electrical plug connection is placed in a flood-proof area and is protected from moisture.
- Before working on the pond filter disconnect the appliance by taking the plug out of the socket.
- Avoid exposing the appliance to a direct water jet or rain.
- The user is responsible for the compliance with location specific safety and installing regulations. (Ask an electrician).
- Consequential damage arising from flooded rooms caused by disfunctions of the appliance must be avoided by means of the appropriate measures. (installing an alarm system, reserve pump).
- In case of malfunction the repair work can be carried out only by a qualified electricial or the WilTec-service.
- The appliance must not run dry or with a completely closed intake port. The manufacturer's warranty is no longer valid if the damage is caused by dry running.
- The appliance must not be used for swimming pools.
- The appliance must not be used for drinking water circuits.
- The device has to be installed out of water.

- The distance from device to the pond has to be at least 2m.
- You have to make sure that the filter cannot fall into the water.
- You have to make sure that the filter is not exposed directly to sunlight.
- The pond pressure filter has to be horizontally fixed with screws on a suitable mounting place.
- The universal-hose stepped tails can be shortened according to the hose diameter if necessary.
- Attach hoses and hose clamps.
- Although the ultraviolet radiation is the lowest of the ionizing radiation it can be dangerous for people and other organisms as well. Also UV-radiation with longer wavelengths can destroy the chemical bonds of the organic molecules. Therefore a responsible approach is necessary when dealing with technical UV-sources.
- Operate the tubes only if the housing is closed and not cracked.

WARNING:

Read carefully all the safety guidelines and the instructions.
Non-compliance with the safety rules and regulations can lead to an electric shock, fire and/or serious injury. Keep the instructions and the safety guidelines in a safe place in case you need them in the future.

Stability
The max. temperature of the conveyed liquid should not exceed +35°C in permanent operation.
The conveyance of flammable, gassing or explosive fluids is forbidden. This pump cannot be used for other fluids particularly not for motor fuels, cleaning agents or other chemical products.

Electrical connection

- The electrical connection takes place via an electric safety socket 230 V ~ 50 Hz. Fuse protection at least 10 Amperes.
- The appliance is turned on/off by means of the ON-/OFF-switch.

Warning

1. The UVC-Filter should be placed in such a way so that the water cannot reach it. The distance between the pond's edge and the filter should reach at least 2m. The UV lamp cannot be operated under water.
2. The power supply of the UVC-Filters must not be turned on before the water circulation has been carried out.
3. Please position the UVC-Filter on a safe and stable place because the light tube (the tube that conveys the light) of the pond filter is made of quartz glass that can burn easily.
4. Do not turn the power on before all the component parts of the device are installed.
5. If the quartz glass tube or the upper part of the UVC-Filter is damaged, the pond pressure filter cannot be used.
6. The UVC-Filter can also not be used if there are people in the pond water.
7. Make sure that the used voltage and the frequency correspond to those indicated on the filter label.
8. When the device is installed you have to pay attention to the domestic installation rules.

9. Please do not pull on the connecting cord. Keep it away from heat, grease and sharp objects.
10. Make sure the upper part of the filter is exposed to pressure lower than 0,3 bar.
11. In frosty weather please remove the UV-Filter.
12. When you install the UV-Filter do not expose it to direct sunlight.
13. Dirt influences the efficiency of the quartz glass tube; therefore it needs to be regularly cleaned.
14. To secure the proper functioning of the device the UV-quartz tube should be replaced after 8000 operating hours.
15. If the upper part is blocked by sand, the quartz tube can be destroyed. Please place the filter sponge in the inlet of the water pump.
16. UV-light is harmful for the eyes and skin. Do not look directly into the UV-light and do not expose your skin to it.
17. If you install the device or repair it, switch off the power supply of the lamp and the pump.
18. The device must be installed on a horizontal flat surface with the feet downwards. For safety reasons it not allowed to install the device otherwise.

Application area / Functioning

This UVC-device ensures clear water for healthy fish. The water is conveyed by a pump through the UVC-device. There it flows past the UV-lamp and is exposed to UVC-radiation. This way the bacteria, germs and floating algae in the water are destroyed and the water becomes clear.

To achieve an optimal result the device should be operated 24 hours in the frost-free seasons.

Commissioning

Switch on the pump and wait until the device is filled with water. Check if all connections are well sealed. By plugging in the power cable the device you put the device into operation.

Technical data

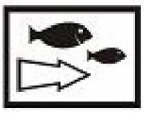
Model	Watt	Volt	Liter/h	Input/Output
CPF-180	11	230V/50Hz	6 000	38/38/40mm
CPF-250	11	230V/50Hz	11 000	38/38/50mm
CPF-15000	18	230/50Hz	30 000	38/38/73mm

Safety

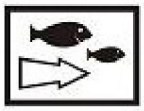
- This device dangerous radiation. Direct contact to skin and eyes may is harmful and must be avoided.
- If the pond filter is damaged it must not be operated.
- When no water is conveyed the device must be switched off.
- By frosty weather the device must be removed and kept dry in a place free of frost.

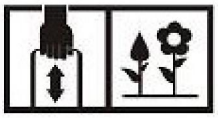
Description
CPF-180-250

Water inlet from the pump into the filter


Water flow from the filter into the pond

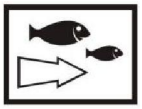
Clean water outlet from the filter to waste water or flower bed

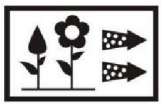

Function position "Filter"


Function position "Clean"

CPF-2500-5000-10000-15000-20000-30000

Water inlet from the pump into the filter


Water flow from the filter into the pond

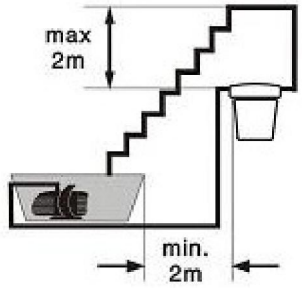

Clean water outlet from the filter to waste water or flower bed

The Wiltec pressure filter is an ideal filter system for your garden pond. The filter has more advantages
◊ high cleaning capacity
◊ combine mechanical and biological (Model dependent) filtering
◊ performant filter material
◊ Built-in UVC-unit and dirt indicator
◊ remains waterproof also by high pressure
◊ water delivery 3 m height (dependent on pump output which is connected)
◊ easy installation and maintenance of the filter

Function of the Wiltec Pond filters

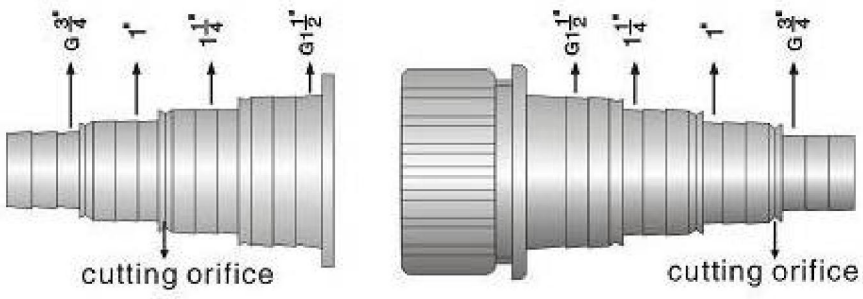
The Wiltec pond filter purifies the water in 3 phases

1. The first stage is mechanic. The visible particles of dirt, from coarse to fine are removed by means of a 3-layer filter foam
2. The second stage is biologic. With the help of the so-called bio balls (model dependent) the settling of bio-organisms is stimulated. These bio-organisms remove the organic components from the pond water. (Dependent on model)
3. The third stage comprises a UVC-water treatment. The UV-light destroys swimming algae and germs. The result is healthy water.



Commissioning

The pressure filter should be placed at least at a 2-meter distance from the pond edge. The water outlet back to pond should be placed max. 2 m over the filter cover (0,2 bar Water pressure!).
The pump must be started first. The UVC-Lamp must not be operated as long as no water flows through it. Do not use the UVC-lamp if the lamp or the connections shows damage signs. Do not use the UVC-filter, if there are people in the water. The built-in temperature sensor of the UV-Filter stops the UVC-Lamp. After the cooling, it is automatically started.
The Wiltec filter is delivered with all the necessary filter mats. Wash the filter mats with pond water carefully before using. The bio balls (dependent on model)are placed at the bottom in the filter, above comes the grating with the protective tube for the UVC unit. Put the filter foam layers on it, arranged from fine to coarse. Position the cover lid on and close the filter with the supplied cramping bracket. If properly installed the filter is waterproof up to a 0,5 bar working pressure. The power supply has to be equipped with an earth leakage circuit breaker that does not exceed 30 mA.

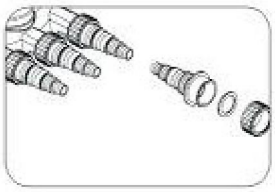


Cutting orifice = Schneidkerben
Install the stepped hose tails:

Place the coupling rings around the black hose tails, insert the flat gaskets in the coupling ring and screw it on the water inlet and outflow connection. Screw the hose tails with the flat gaskets on the device.

Connection to the water inlet
The pump is connected to the hose tail whose arrow is directed towards the filter. Use a hose diameter which is exactly the same as the diameter of the pump outlet. Saw off the diameter-hose steps that you do not need.

Connection to the water oulet:
The hose tail with the arrow showing away from filter is the outflow towards the pond. Connect a suitable hose to the large diameter step of the hose tail and saw off the other diameter- hose steps. Use hose clamps prevent the loosening of the hoses.

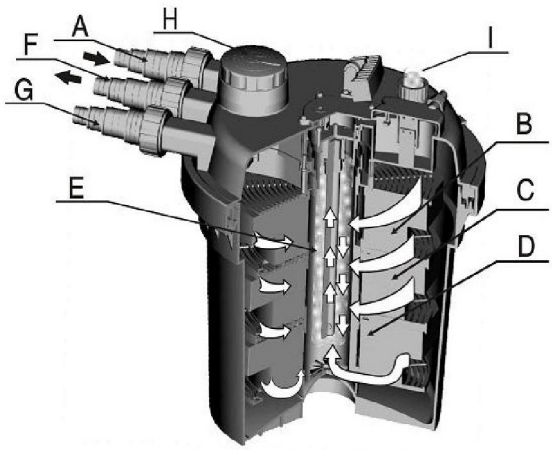


Connection to the cleaning outlet:
To install a permanent drain hose to the cleaning connection (Clean), you have to unscrew/remove the stepped tail to the cleaning connection (Clean), install the third stepped hose tail and connect a suitable hose. In the filter operation the cleaning connection or a connected drain hose must be always closed and sealed with a hose tail (closure cap) and gasket seal, as safety, in case the function switch is accidentally set on „Clean“.

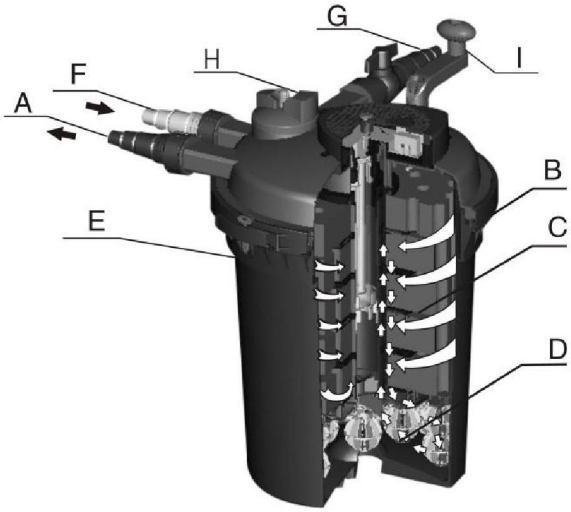
Attention! Do not operate the device without water flow or pump filter!

The operating principle of the pressure filter.
The pressure filter with the integrated UV lamp is a sealed filter system for biological and mechanical cleaning of pond water.

CPF-180-280



CPF-2500-5000-10000-15000-20000-30000



A: Water inlet
The pump is connected to the water inlet via a pressure hose.
B: Strudel-System
The water permeates through the bio -filter materials due to the centrifugal and the gravitational forces.

C: Mechanical Filter
Dirt particles are retained on the surface of the sponge filter before the water flows towards the inner of the Filter.

D: Biological cleaning
Micro organisms settle on the pores of the filter sponge. The blue and the yellow filter sponge differ in size and density. This generates zones/areas through which the water flows at different speeds. In the zones/areas with a high flow speed (blue filter) mainly micro organisms settle that convert ammonium to nitrate. In the areas in which the water flows even faster (yellow filter), mainly anaerobic micro organisms accumulate themselves that reduce the nitrate to nitrogen.

E: Pre-cleaning of the pond water.
When the water flows out, it is shortly exposed to UV radiation of the UV lamp. As a result, germs, bacteria, algae are destroyed. The water circulates when flowing through the filter from inside outwards.

F: Water discharge with flow display
The cleaned water flows back into the pond.

G: Hose tails for rinsing water when on cleaning.

H: The function-switch changes between "filtration" and "clean filter"

I: Flow indicator (For CPF-180-280)
When the dirty on the sponge is too much, the turbidimeter will be changed from green color to yellow color to warn you to clean the sponge.

J: Clean the filter sponge with handle function. (For CPF-2500-5000-10000-15000-20000-30000)
The filter sponge can be cleaned by turning around the cleaning handle. Installation guidelines with regard to the clear water guarantee, the following installation guidelines must be observed.

The filter system has to remain switched on for 24 hours a day.
The UV-lamp should be changed after 8.000 operating hours so that the device can work effectively and efficiently. The filter system must be cleaned regularly.

Connecting the pump:

On the filter cover/lid there are three connections equipped with hose tails. The pump is connected to the first hose tail. Use a hose diameter that is the same with the diameter of the pump outlet. Saw off the diameter-hose steps that you do not need.
The hose tail in the middle of the filter cover/lid is the outflow to the pump. Connect to the large diameter of the tail a suitable hose and cut away the rest of the tail diameter. To avoid the loosening of the hoses please use hose clamps.
Never use the filter with a built-in UVC-unit with a water pressure higher than 0,2 bar! The height difference between the filter lid and the pressure-free outflow point of the supply line can amount to max. 2 meter. The pressure of the water pumped to the filter cannot exceed 0,5 bar. Use the filter only with hoses that can withstand at least a pressure of 0,2 bar, the max. pressure of the pump.
Make sure that outflow /discharge in the pond is positioned on a clean place. If the outflow is blocked a higher pressure may result. Higher pressure can lead to leaking spots in the filter and therefore to a complete emptying of the pump.
When the filter is used in „filter-modes“, the user should be careful and make sure that all seals are properly installed in order to avoid the emptying of the pond. The sealing cap functions simultaneously as safety measure in „Clean“-mode. Make sure that filter always operates in the „filter-mode“ as long as the pump is running. The filter should be set on „Clean“, if the filter sponges are cleaned. Before you start the filter, check and make sure that all hoses and seals are correctly fastened. Filter only water and no other fluids. By frost the filter has to be removed. Do not expose the filter to the direct sun light.
After the filter has been placed on the right place and the pump has been connected the integrated UV-unit can be switched on.

The UV-unit:

The Wiltec Filter is delivered with all the equipment you need and an integrated UV-unit. The UV-PL lamps have ca. 8000 working hours that correspond to a season period of use from March till November. The UV-lamps can be replaced by loosening the screws from the spherical upper part of the cover lid.

It is recommended to change the UV-lamp with a new one at the beginning of the season. The UV-lamp clears as the green water and destroys germs. The Wiltec filters have a separate chamber, through which UVC-rays are not exposed to contact with the filter media. Because of this the micro organisms in the filter material are not damaged.

Maintenance / Cleaning/Adjustment Possibilities (setting options) For CPF-180-250 only

A = Pump connection
B = Return pond (backflow)
B1 = Setting – filter operation
C = Watering connection
D = Setting - cleaning
E = Switch / cleaning mechanism

Filter operation: bring the rotating switch **E** into position **B1**. With the help of a pump, the water is led to the filter through the connection **A**, here it is cleaned and via connection **B** discharged back into the pond.

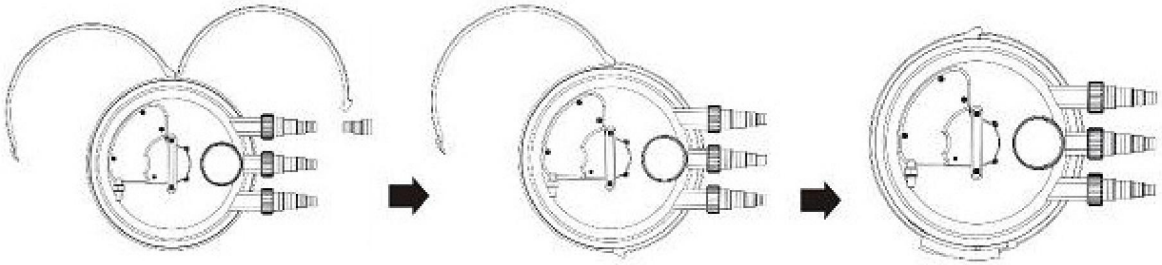
Cleaning operation: bring the switch **E** into position **D**. This setting enables the cleaning mechanism, by pressing down the setting switch **E**. By means of this pressure, the sponges inside the filter are squeezed. By using this switch setting the dirty water is not led back into the pump but it is discharged via connection **C** and it can be used for garden watering.

The pond filter of the series CPF-2500-5000-10000-15000-20000-30000 have a fast cleaning function that can be activated with the aid of the hand crank. Instead of the setting switch (press button), described above turn the crank handle so long (like by a salad spinner) until the filter sponges have lost enough dirt.

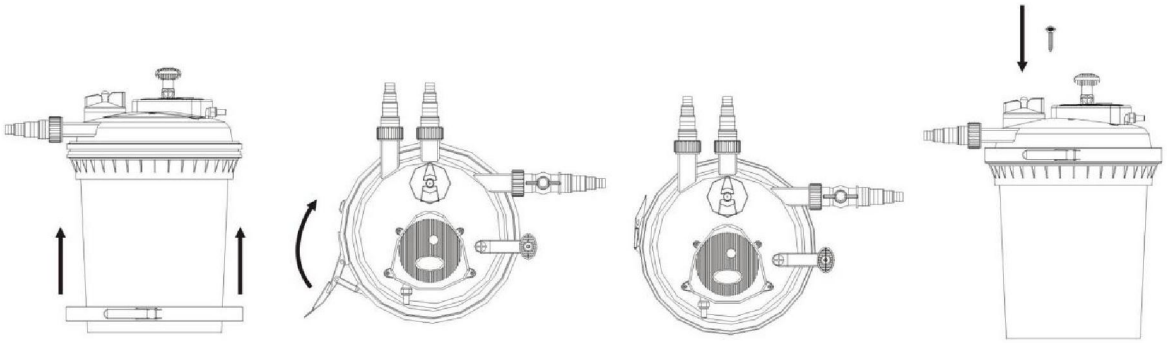
The filter materials as well as the lamp should be replaced 1 x year to ensure a problem-free operation of the filter.

When the filter is used for normal operation, "the watering- connection" (C) with the screwed ring + sealing and the viewing glass (included in the delivery) should be closed to avoid leaking. The pressure filter model of the series CPF-2500-5000-10000-15000-20000-30000 have a stepped hose tail with integrated ball valve to close the connection.
Before every commissioning of the filter the user should check if sealings and connections are fitted correctly. Pressure pond filters are exclusively designed for filtering pond water with typical impurities. Do not expose the filter to the direct sun light over a longer period.

By frost the filter has to be completely emptied, if necessary dug out and stored in a dry, frost-free place.
After work that requires the removal of the lid, please make sure when attaching the cover lid that the sealing rings are fitted correctly! Fit the clamp ring around the lid, press on the cover lid and close the sealing clam.
CPF-180-250

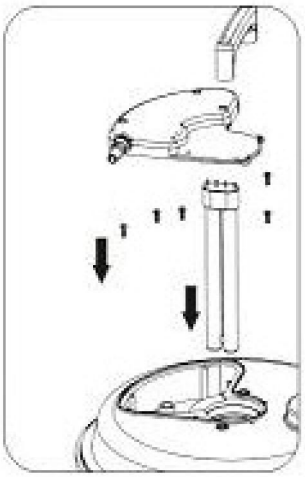


CPF-2500-5000-10000-15000-20000-30000



Changing the light tube
If the algae proliferate, it is necessary to check the correct the functioning of the UV-C lamp.
You recognise on the UV-indicator if the lamp lights at all. Change it every season.For model **CPF-2500-5000-10000-15000-20000-30000**
the four screws on the cover lid of the filter have to be loosened in order to remove / replace the UV-unit.

CPF-180-250



CPF-2500-5000-10000-15000-20000-30000

Before changing the UV-Lamp disconnect the pump. Release the 8 screws of the UV-unit from the filter lid. Carefully remove the UV-lamp. After the UV-unit has been cooled down and dried up grab the base of the light tube (not the glass!) with a soft cloth and pull it cautiously out of its socket. Grab the base of the new light tube with a soft cloth and delicately insert it in the socket. Now the quartz glass inside which the light bulb is placed must be cleaned. For this purpose the lime has to be dissolved under heating with appropriate agents (coffee machine or kettle descaler like citric acid). After this rinse the quartz glass from residues remaining from the cleaning agents. After rinsing all parts are reassembled in reverse order. The pump and the device are connected again to the power supply.

The wear parts (Filter materials, light tubes, quartz sleeves, seals) are usually by **WilTec Wildanger Technik GmbH www.wiltec.info** in stock available.

WARNING:

- For all maintenance work the UVC has to be disconnected from the power supply!
- The filter can be put into operation only if the UVC is FULLY assembled!
- Never tinker with the running UVC lamp!
- The UVC must NOT be carried by the cable!
- Always place the UVC outside the pond (not in the water)!
- Remove the UVC by frosty weather!

Warranty information

The warranty of the filter amounts to 24 months starting with the date of purchase (proof of purchase). The wearing parts (light tubes, quartz sleeves, seals) are not covered by the warranty. Damage that result from non-compliance with the operation instructions, transportation, incorrect positioning, carelessness or incorrect use are not covered by warranty. For consequential damages resulting from the use of this device, no liability is assumed.

Disposal regulations

EU guidelines regarding the disposal of scrap electric appliances (WEEE, 2002/96/EC) were implemented in the law related to electrical and electronic equipment and appliances.

All WilTec electric devices that fall under the WEEE regulations are labelled with the crossed-out wheeled waste bin logo. This logo indicates that this electric equipment must not be disposed with the domestic waste.

The company WilTec Technik GmbH has been registrated in the German registry EAR under the WEEE-registration number DE45283704.

Disposal of used electrical and electronic appliances (intended for use in the countries of the European Union and other European countries with a separate collection system for these appliances).
The logo on the article or on its packaging points out that this article must not be treated as normal household waste but must be disposed to a recycling collection point for electronic and electrical waste equipment. By contributing to the correct disposal of this article you protect the environment and the health of your fellow men. Environment and health are threatened by inappropriate disposal.

Materials' recycling helps reduce the consumption of raw materials.

Additional information on recycling this article can be provided by your local community, municipal waste disposal facilities or the store where you purchased the article.

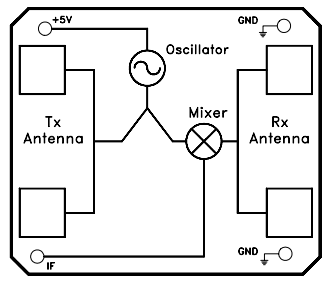
Address:
WilTec Wildanger Technik GmbH
Königsbenden 12 / 28
D-52249 Eschweiler

Important notice:

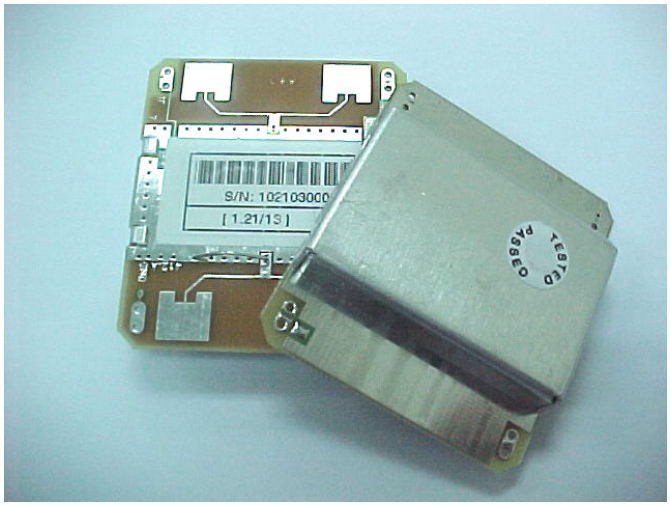
The reprint or reproduction, even of excerpts, and any commercial use, even in part of this instructions manual require the written permission of WilTec Wildanger Technik GmbH.

HB 100 Microwave Sensor Module

10.525GHz Microwave Motion Sensor Module



Block diagram and connection



Description

HB100 Miniature Microwave Motion Sensor is a X-Band Bi-Static Doppler transceiver module. Its built-in Dielectric Resonator Oscillator (DRO) and a pair of Microstrip patch antenna array, make it ideal for OEM usage in motion detection equipment.

This module is ideally suitable for false alarms reduction in intruder detectors when work together with Passive Infrared (PIR) sensor. It can also be used for auto-door opening and vehicle speed measurement.

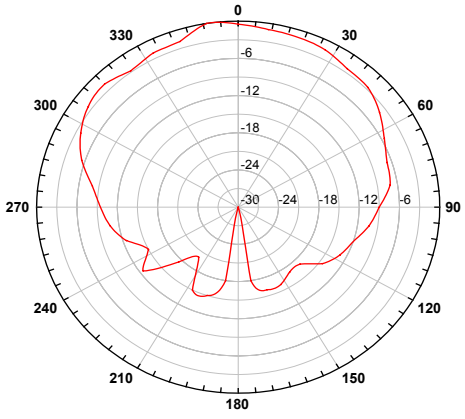
Features

- Low current consumption
- CW or Pulse operation
- Flat profile
- Long detection range

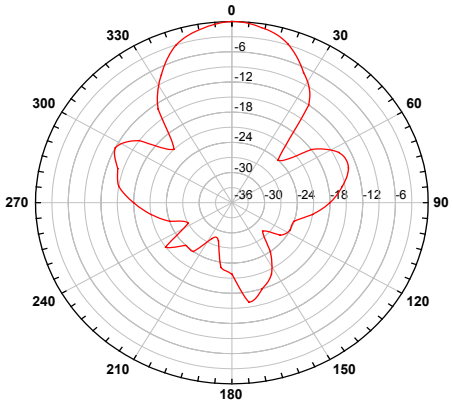
Applications

- Microwave-PIR motion detector
- Speed measurement
- Lighting control

Antenna Beam Pattern



Azimuth



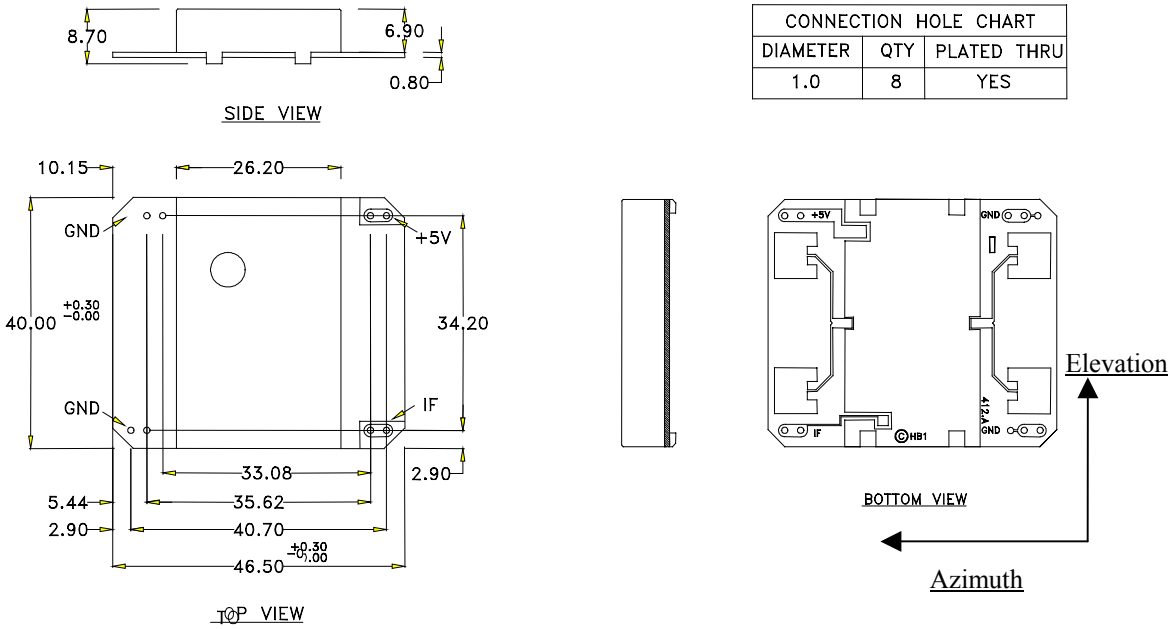
Elevation

CERT. NO. : 94-1-0033
SS ISO 9001 : 2000

AgilSense
Microwave Sensors From Agilis
www.agilsense.com

Technical Specifications

Outline diagram (All dimensions in mm)



CONNECTION HOLE CHART		
DIAMETER	QTY	PLATED THRU
1.0	8	YES

Unless noted otherwise, the specifications are measured with +5VDC, CW operation, 12 kΩ load at ambient temperature of +25°C.

Parameter	Notes	Min	Typ.	Max	Units
Frequency Setting	1	10.520	10.525	10.530	GHz
Radiated Power (EIRP)	1	12	15	20	dBm
Spurious Emission	1			-7.3	dBm
Settling Time			3	6	µSec
Received Signal Strength	2		200		µVp-p
Noise	3			5	µVrms
Antenna Beam-width (3 dB) - Azimuth			80		°
Antenna Beam-width (3 dB) - Elevation			40		°
Supply Voltage		4.75	5.00	5.25	VDC
Current Consumption			30	40	mA
Pulse Repetition Frequency	4		2		KHz
Pulse Width	4	10			µSec
Operating Temperature		-15		55	°C
Weight			8		gm

Note 1: The radiated emissions of HB100 is designed to meet the requirements of Federal Communications Commission (FCC) rules, Part 15, Section 15.245 (use within a building or to open building door)
Note 2: The Received Signal Strength (RSS) is measured at the total 2 ways path loss of 93dB.
Note 3: The noise voltages are measured from 10 Hz to 100 Hz at the output port, inside an Anechoic chamber.
Note 4: Pulse operation.
Note 5: The design, manufacturing process and specifications of this device are subjected to change without prior notice.
Note 6: **CAUTION: ELECTROSTATIC SENSITIVE DEVICE.** Observe precautions for handling and storage.

VER 1.02

Satcom & Sensor Systems
ST Electronics (Satcom & Sensor Systems) Pte Ltd
100 Jurong East Street 21, ST Electronics Jurong East Building Level 4, Singapore 609602
Tel : (65) 6567 6791 Fax : (65) 6567 6370 Email : agilsense@stee.stengg.com
Website : www.agilsense.com (*Regn: 199103901W*)

Singapore Technologies Electronics
A company of Singapore Technologies Engineering

IoT RELAY II

Safely control AC power from logic.

Build the IoT. Connect easily and safely. Control power from an Arduino, Raspberry Pi, Galileo or other micro-controller. The universal input connects to any circuit including 3.3V and 5 volt logic. No driver is requried.

Simply connect two wires. One to ground and one to your control signal, such as an output bit on a micro-controller.

The relay can also be controlled by an AC input voltage of 12 to 120VAC. No changes or jumpers are required.

The internal circuitry is very power efficient, using approximately 1/5W unswitched and 1.1W activated.

Applications include:

- IoT products, DIY gadgets, OEM test equipment
- Home and building automation
- Green power and energy conservation
- Kiosks, vending machines and signage controls

Multiple AC loads of up to 12 Amps total may be controlled. Your imagination is the limit.

The IoT control relay is rugged and reliable, with US design and QC. It ships fully assembled and tested with a 1 year warranty. This is our second design revision and over 20,000 have been built. Single units are available on Amazon.

- A single logic input signal controls one high-current SPDT AC relay. This one relay trigger signal switches three AC outlets simultaneously using a single pole-double throw relay.. One outlet normally is on. Two are normally off. A fourth outlet is unswitched. All outlets are proteced against surges and overloads..
- The universal control voltage 3-48VDC or 12-120VAC allows control from virtually any micro or AC source.
- Self-contained design eliminates dangerous high voltage wiring and safety hazards.
- Safety features include:

  3kV optical isolation -- eliminates shock hazard.
  Relay hysteresis -- prevents relay chatter.
  De-bounce protection -- extends contact life.
  LEDs -- verify input voltage and switch state.

- A large 3600W MOV clamps surges for clean power.
- The durable SPDT control relay is rated at 30/40A, 400,000 operations at 12A resistive. At no load, the estimated lifetime is 5.3 million mechanical operations.
- A 12A thermal safety circuit breaker switch prevents overloads and adds supplemental protection.
- Recommended operating range: AC input 90-120VAC. Current 0-8A with 18AWG power cords, 0-12A with 16AWG cord. Use14AWG for 12A spans over 10 feet.
- Input connector: C-13/C14. Output: 4x NEMA 5-15.
- Included cord: 12" C-13 to 5-15 16AWG. Cords up to 50' length are in-stock.
- Indoor use only: -35F to 145F, 5-95% noncondensing. Not for use on 220V.

Digital Loggers, Inc.
2695 Walsh, Santa Clara, CA 95051
Tel: (408) 330-5599 IoTrelay.com

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BILL OF MATERIALS

Feature	Part #	Description	QTY	UOM	Est. Unit Cost	Est. Total Cost	Part Name	Vendor
Racetrack	1	Race Tunnel	2	in	$ 56.94	$ 122.71	Clear Abrasion-Resistant Duct Hose for Dust, Very Flexible, 4" ID	McMaster-Carr
	2	Flange Support	20	in	$ 7.56	$ 162.92	1/2 NPT Female Thick-Wall PVC Flange for Water	McMaster-Carr
	3	10" Pipe Support	2	in	$ 3.63	$ 7.82	Thick-Wall PVC Pipe Nipple for Water, Threaded on Both Ends, 1/2 NPT, 10" Long	McMaster-Carr
	4	8" Pipe Support	2	in	$ 3.33	$ 7.18	Thick-Wall PVC Pipe Nipple for Water, Threaded on Both Ends, 1/2 NPT, 8" Long	McMaster-Carr
	5	6" Pipe Support	2	in	$ 1.26	$ 2.72	Thick-Wall PVC Pipe Nipple for Water, Threaded on Both Ends, 1/2 NPT, 6" Long	McMaster-Carr
	6	4" Pipe Support	2	in	$ 1.07	$ 2.31	Thick-Wall PVC Pipe Nipple for Water, Threaded on Both Ends, 1/2 NPT, 4" Long	McMaster-Carr
	7	3" Pipe Support	2	in	$ 0.93	$ 2.00	Thick-Wall PVC Pipe Nipple for Water, Threaded on Both Ends, 1/2 NPT, 3" Long	McMaster-Carr
	8	Zip Ties	3	in	$ 3.43	$ 11.09	Nylon Cable Tie, 24" Long, 7" Bundle Diameter, 170 lb. Break Strength, White	McMaster-Carr
	9	3D Printed start pieces	6	EA	$ 6.50	$ 42.02	3DXMAX® ASA, 3D Filament	3DXTECH
	10	Racing Ping Pong Balls (50 pack)	1	mm	$ 7.99	$ 8.61	KEVENZ 50-Pack 40mm Beer Ping-Pong Multipul Color Balls,Washable Plastic Glow in The Dark, Plastic Table Tennis Ball	Amazon
	11	12 pack Acrylic Base Epoxy	1	ml	$ 42.74	$ 46.05	Model # 50133H Internet #303710788 Store SKU #1002913059	3M
	12	Aluminum Support Bracket	0.5	2 ft	$ 46.27	$ 24.93	6061 Aluminum 90 Degree Angle, 1/4" Wall Thickness, 4" High x 4" Wide, 2 Feet Long	McMaster-Carr
	13	Hose Connector	2	in	$ 0.42	$ 0.91	1/2 in. Barb x 1/2 in. Male Pipe Thread Irrigation Swing Pipe Coupling	Home Depot
	14	Flexible Hose (10 ft)	1	in	$ 14.93	$ 16.09	Everbuilt 3/4 in. O.D. x 1/2 in. I.D. x 10 ft. PVC Braided Vinyl Tube	Home Depot
	15	Hose Clamp	10	in	$ 0.94	$ 10.13	#006 SS Clamp 3/8" x 7/8" Dia	Home Depot
	16	Plastic T Pex (Pack of 5)	1	in	$ 6.27	$ 6.76	1/2" Pex Plastic Tee	Home Depot
	17	Cup with 1 hole	8	in	$ 6.50	$ 56.03	3DXMAX® ASA, 3D Filament	3DXTECH
	18	Cup with 2 holes	8	in	$ 6.25	$ 53.88	3DXMAX® ASA, 3D Filament	3DXTECH

BILL OF MATERIALS

Cup Pyramimd	19	30 piece plastic funnels	1	in	$	6.99	$	7.53	TNT206	Amazon
	20	Neodymium magnets (6 pack)	6	in	$	12.99	$	83.98	Model: M1x14x14BR	Apex Magnets
	21	Male Adapter (5 pack)	1	in	$	6.27	$	6.76	1/2" Pex PLS Male Adpt	Home Depot
	22	PVC Ball Valve	1	in	$	2.52	$	2.72	1/2" PVC Ball Valve Slip SCH40	Home Depot
	23	PVC Elbow	2	in	$	0.46	$	0.99	1/2" PVC EL 90D SXS	Home Depot
	24	PVC Male Adapter	4	in	$	0.36	$	1.55	1/2" PVC Male Adapter SXMPT	Home Depot
	25	PVC Female Adapter	5	in	$	0.65	$	3.50	1/2" PVC Female Adapter SXFPT	Home Depot
	26	PVC Tee	3	in	$	0.45	$	1.45	1/2" PVC Tee SXSXS	Home Depot
	27	PVC Pipe 1/2" x 10'	1	in	$	2.31	$	2.49	1/2" x 10' PVC40 PE Pipe	Home Depot
	28	2' Swing Piping	1	ft	$	0.98	$	1.06	RB 2' Swing Pipe	Home Depot
	29	Swing Pipe Male Elbow	8	in	$	0.61	$	5.26	RB 1/2" Swing Pipe Elbow x 1/2" MPT	Home Depot
Magnetic Wall	30	Rod	12	EA	$	0.50	$	6.47	3DXMAX® ASA, 3D Filament	3DXTECH
	31	Rod Cap	12	EA	$	0.10	$	1.29	3DXMAX® ASA, 3D Filament	3DXTECH
	32	Water wheel	4	EA	$	2.00	$	8.62	3DXMAX® ASA, 3D Filament	3DXTECH
	33	Teeter Totter	4	EA	$	3.50	$	15.09	3DXMAX® ASA, 3D Filament	3DXTECH
	34	Slide	4	in	$	3.50	$	15.09	3DXMAX® ASA, 3D Filament	3DXTECH
	35	Neodymium magnets (6 pack)	8	pkg	$	12.99	$	111.97	Model: M1x14x14BR	Apex Magnets
	36	Metal sheets	3	EA	$	19.97	$	64.55	Zinc plated steel sheet	Metals Depot
Whale	37	1-1/2 in. Flexible Putty Knife	2	EA	$	7.47	$	16.10	1-1/2 in. Flexible Putty Knife	HomeDepot
	38	Caulk Gun for 10-13 oz. Cartridge, Half Barrel with Rubber Handle	1	EA	$	15.63	$	16.84	Caulk Gun for 10-13 oz. Cartridge, Half Barrel with Rubber Handle	Mcmaster Carr
	39	5200 10 oz. Marine Adhesive/Sealant	3	EA	$	17.97	$	58.09	5200 10 oz. Marine Adhesive/Sealant	Homedepot
	40	1/2 Polypropoline Bulkhead Passthrou with Sandoprene gasket	3	EA	$	3.95	$	12.77	1/2 Polypropoline Bulkhead Passthrou with Sandoprene gasket	usplastics
	41	1/2" Sch.40 PVC plug	1	EA	$	0.98	$	1.06	1/2" Sch.40 PVC plug	HomeDepot
	42	1/2 PVC sch. 40 male MPT x S adapter	2	EA	$	0.36	$	0.78	1/2 PVC sch. 40 male MPT x S adapter	Homedepot
	43	3/4" PVC shc. 40 FNPT x S Female Adaptor	2	EA	$	0.63	$	1.36	3/4" PVC shc. 40 FNPT x S Female Adaptor	HomeDepot
	44	1/2 in. Schedule 40 PVC Female Adapter	1	EA	$	0.65	$	0.70	1/2 in. Schedule 40 PVC Female Adapter	HomeDepot
	45	3/4 in. x 3/4 in. x 1/2 in. Schedule 40 PVC Reducing Tee	2	EA	$	1.14	$	2.46	3/4 in. x 3/4 in. x 1/2 in. Schedule 40 PVC Reducing Tee	HomeDepot
	46	1/2 - 1-1/4 in. Hose Repair Clamp	2	EA	$	0.85	$	1.83	1/2 - 1-1/4 in. Hose Repair Clamp	HomeDepot
	47	1/2 in. Barb x 1/2 in. Male Pipe Thread Irrigation Swing Pipe Coupling	2	EA	$	0.42	$	0.91	1/2 in. Barb x 1/2 in. Male Pipe Thread Irrigation Swing Pipe Coupling	HomeDepot
	48	1/2" Tube ID x 1/2" NPT Natural Kynar® Threaded Adapter	2	EA	$	2.41	$	5.19	1/2" Tube ID x 1/2" NPT Natural Kynar® Threaded Adapter	usplastics
	49	3/4" Tube ID x 3/4" NPT Natural Kynar® Threaded Adapter	2	EA	$	3.25	$	7.00	3/4" Tube ID x 3/4" NPT Natural Kynar® Threaded Adapter	usplastics
	50	Easy-to-Form 304 Stainless Steel Wire Cloth 1ftx1ft	1	EA	$	17.86	$	19.24	Easy-to-Form 304 Stainless Steel Wire Cloth 1ftx1ft	Mcmaster Carr
	51	1/2" PVC elbow 1/2 in. Schedule 40 PVC 90-Degree Elbow	3	EA	$	0.46	$	1.49	1/2" PVC elbow 1/2 in. Schedule 40 PVC 90-Degree Elbow	homedepot
	52	3/4" to 1/2" Tee barb fitting	1	EA	$	3.28	$	3.53	3/4" to 1/2" Tee barb fitting	Home Depot
	53	Everbilt 3/8 in. to 7/8 in. Hose Repair Clamp	6	EA	$	0.97	$	6.27	Everbilt 3/8 in. to 7/8 in. Hose Repair Clamp	Home Depot
	54	1/2 in. Barb x 1/2 in. Female Pipe Thread Irrigation Swing Pipe Elbow	1	EA	$	0.71	$	0.77	1/2 in. Barb x 1/2 in. Female Pipe Thread Irrigation Swing Pipe Elbow	Homedepot
	55	Charlotte Pipe 1/2 in. PVC Sch. 40 Male MPT x S Adapter	1	EA	$	0.36	$	0.39	Charlotte Pipe 1/2 in. PVC Sch. 40 Male MPT x S Adapter	Homedepot
	56	Homewerks Worldwide 1/2 in. PVC Sch. 40 Slip x Slip Ball Valve	1	EA	$	2.52	$	2.72	Homewerks Worldwide 1/2 in. PVC Sch. 40 Slip x Slip Ball Valve	Home Depot

BILL OF MATERIALS

	57	1/2 in. Furniture Grade PVC External Flat End Cap in White (10-Pack)	1	10pk	$ 11.25	$ 12.12	1/2 in. Furniture Grade PVC External Flat End Cap in White (10-Pack)	Homedepot
		Ultra-Low-Friction Dry-Running Sleeve Bearing 1/4 ID 5/16	6	EA	$ 4.86	$ 29.16	Ultra-Low-Friction Dry-Running Sleeve Bearing 1/4 ID 5/16	McMasterCarr
	58	ASA for Whales	1	1kg	$ 38.00	$ 40.95	3DXMAX® ASA, 3D Filament, 1kg Mid Blue	Amazon
Snap-in Grid	59	10x20 Duplo Baseplate	3	4 pk	$ 19.99	$ 64.62		Crystal Deals
	60	ASA for wall	1	1kg	$ 38.00	$ 40.95	3DXMAX® ASA, 3D Filament, 1kg	3DXTECH
	61	2X4 Duplo Legos	152	EA	$ 0.48	$ 77.96		Amazon, Strictly Bricks
	62	ASA for Weir	1.88	1g	$ 0.04	$ 0.08	3DXMAX® ASA, 3D Filament	3DXTECH
	63	ASA for Ramp	1.6	750g	$ 0.04	$ 0.07	3DXMAX® ASA, 3D Filament	3DXTECH
Electrical	64	Stand-Offs for Microcontroller	1	pkg	$ 7.99	$ 8.61	Anti-Vibration Fixed Screws Mounting Hardware Spacer Standoff	Amazon
	65	Step Drill Bit Set	1	EA	$ 10.85	$ 11.69		Amazon
	66	Extension Cord Plug	1	EA	$ 6.70	$ 7.22	Leviton 515CR 15 Amp	Amazon
	67	Extension Cord	1	EA	$ 68.18	$ 73.46	GFCI Power Extension Cord	Amazon
	68	Relay	1	EA	$ 27.00	$ 29.09	Iot Relay - Enclosed High-power Power Relay	Amazon
	69	Shielded Cable	1	25 FT	$ 29.00	$ 31.25	Custom Cable Connection 22 AWG 4 Conductor Stranded Shielded Plenum Cable	Amazon
	70	Microcontroller	1	EA	$ 10.86	$ 11.70	Elegoo EL-CB-001 UNO R3 Board ATmega328P ATMEGA16U2 with USB Cable for Arduino	Amazon
	71	Waterproof switch	1	2 pk	$ 8.99	$ 9.69	Podoy Heavy Duty Toggle Switch On-Off-On DPDT 6 Pin 15A 250VAC / 20A 125VAC with Waterproof Boot Cover	Amazon
	72	Water level sensor (float)	1	EA	$ 6.95	$ 7.49	uxcell Float Switch Miniature Liquid Water Level Sensor, Stainless Steel Stem, DC100V, 75mm Long, M10x1.5mm Male	Amazon
	73	Cable strain relief	1	per pk	$ 6.35	$ 6.84	IP68 Waterproof M12 PG7 Plastic Cable Gland Connector Plastic Flex Spiral Strain Relief Protector for 3.5-6mm Wire Thread	Amazon
	74	Microcontroller expansion board	1	EA	$ 7.99	$ 8.61	Aideepen Proto Screw Shield Assembled Terminal Point Prototype Expansion Board Opening Source Reset Button PCB Bareboard D13 Universal LED for Arduino	Amazon
	75	Electrical flex conduit	1	25 ft	$ 11.46	$ 12.35	1/2 x 25 ft. Non-Metallic Liquidtight Conduit	Home Depot
	76	Motion sensor junction box	4	EA	$ 7.09	$ 30.56	4 in. x 4 in. x 2 in. PVC Junction Box	Home Depot
	77	Electrical flex conduit connector	8	EA	$ 2.18	$ 18.79	1/2 in. Non-Metallic Liquid-Tight Push-On Connector	Home Depot
	78	Strain relief cord connector with cable gland	2	EA	$ 2.04	$ 4.40	1/2 in. ACC Non-Metallic Strain Relief Cord Connector	Home Depot
	79	Plug for filter and pump cords	2	EA	$ 2.79	$ 6.01	15 Amp 125-Volt Double Pole 3-Wire Grounding Plug	Home Depot
	80	Motion sensors with amplification and noise reduction circuit included	3	EA	$ 25.00	$ 80.81	HB100 Doppler Speed Sensor - Arduino Compatible	Tindie

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	81	Backboard	1	EA	$ 11.99	$ 12.92	MIFFLIN Cast Acrylic Plexiglass, Transparent Clear (12x12 Inch, 1 Piece) Plastic Sheet, 0.118" (1/8 in), Acrylic Glass for Displays, Signs, DIY Projects, Window Replacement, Greenhouses, Cabinets	Amazon
Filtration	82	Filter	1	EA	$ 109.99	$ 118.51	Grech CPF-2500 Pond Bio Pressure Filter UVC 13-watt	Amazon
	83	Swing Check Valve	1	EA	$ 11.62	$ 12.52	1-1/4" PVC Swing Check Valve - Threaded (S1520-12F)	PVC Fittings Online
	84	PVC Cement	1	EA	$ 9.17	$ 9.88	8 oz. PVC Handy Pack Purple Primer and Solvent Cement	Home Depot
	85	Flexible Vinyl Tubing	2	EA	$ 21.32	$ 45.94	Everbilt 1 in. O.D. x 3/4 in. I.D. x 10 ft. PVC Braided Vinyl Tube	Home Depot
Water Dome	86	Water dome fitting	1	EA	$ 10.99	$ 11.84	NAVA New 1/2” DN15 Interior 3/4” DN20 Exterior Thread Mushroom Fountain Nozzle Spray Head Pond	
Water Squirters	87	Wall braces	1	EA	$ 40.98	$ 44.16	Architectural 6063 Aluminum Bar Highly Corrosion-Resistant, 1/2" Thick x 2" Wide (4ft)	
	88	Aluminum Support Bracket	0.5	2 ft	$ 46.27	$ 24.93	6061 Aluminum 90 Degree Angle, 1/4" Wall Thickness, 4" High x 4" Wide, 2 Feet Long	Mcmaster Carr
	89	Fastener for safety cover	1	pkg	$ 6.97	$ 7.51	316 Stainless Steel Button Head Hex Drive Screw, Super-Corrosion-Resistant, 1/4"-20 Thread Size, 1/4" Long, packs of 25	Mcmaster Carr
	90	5/16"-24 cap nut	1	pkg	$ 12.96	$ 13.96	Nylon 6/6 Plastic Cap Nut, 5/16"-24 Thread Size, Off-White, Packs of 50	Mcmaster Carr
	91	1/2"-20 cap nut	1	pkg	$ 5.18	$ 5.58	Nylon 6/6 Plastic Cap Nut, 1/2"-20 Thread Size, Off-White, Packs of 10	Mcmaster Carr
	92	Back brace	1	EA	$ 20.30	$ 21.87	304 stainless steel sheet 12"x12", 0.06 thick	Mcmaster Carr
	93	3/4" Endmill	1	EA	$ 18.37	$ 19.79	3/4" Endmill	Amazon
	94	Timing Belt	1	EA	$ 8.99	$ 9.69	Mercurry 5 Meters GT2 timing belt width 6mm Fit	Amazon
	95	Hose	1	EA	$ 16.47	$ 17.75	5/8" X 50' Waterworks medium duty hose	Home Depot
	96	Water squirter nozzle	4	EA	$ 4.98	$ 21.46	Melnor Hi-Visibility Nozzle	Home Depot
	97	Squirter Holder	2	EA	$ 18.59	$ 40.06	Stainless SWL, 3X1-1/4" Nylon, Top Plate Mount, 350# CAP	B&C Industrial Products, Inc.
	98	Hose Connector	2	EA	$ 4.98	$ 10.73	Pro Flor Zinc Male Hose Mender	Home Depot
	99	Hose Connector	2	EA	$ 6.21	$ 13.38	5/8 X 3/4 Brass Adapter Barb X MIP LF	Home Depot
	100	Flex tubing connector	1	EA	$ 3.55	$ 3.83	3/4 X 3/4 Nylon Barb X Elbow	Home Depot

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	101	Tee Connector	1	EA	$	9.94	$	10.71	3/4 Red Brass Tee FIP LF	Home Depot
	102	Hose Clamp	6	EA	$	0.85	$	5.50	#012 SS Clamp 1/2" X 1-1/4" Dia	Home Depot
	103	Pulleys	1	EA	$	10.98	$	11.83	BIQU GT2 Synchronous Wheel 60 Teeth 8mm Bore Aluminum Timing Pulley for 3D Printer 6mm Width Belt	Amazon
	104	Shafts	1	EA	$	10.26	$	11.06	Rod, Acetal, 150, Wht, 3/4 In Dia x 1 Ft L	Amazon
	105	Safety Cover	1	EA	$	35.99	$	38.78	MIFFLIN Cast Acrylic Plexiglass, Transparent Clear (24x24 Inch, 1 Piece) Plastic Sheet, 0.118" (1/8 in), Acrylic Glass for Displays, Signs, DIY Projects, Window Replacement, Greenhouses, Cabinets	Amazon
					TOTAL:		**$**	**2,252.63**		

No. 10 Water squirter

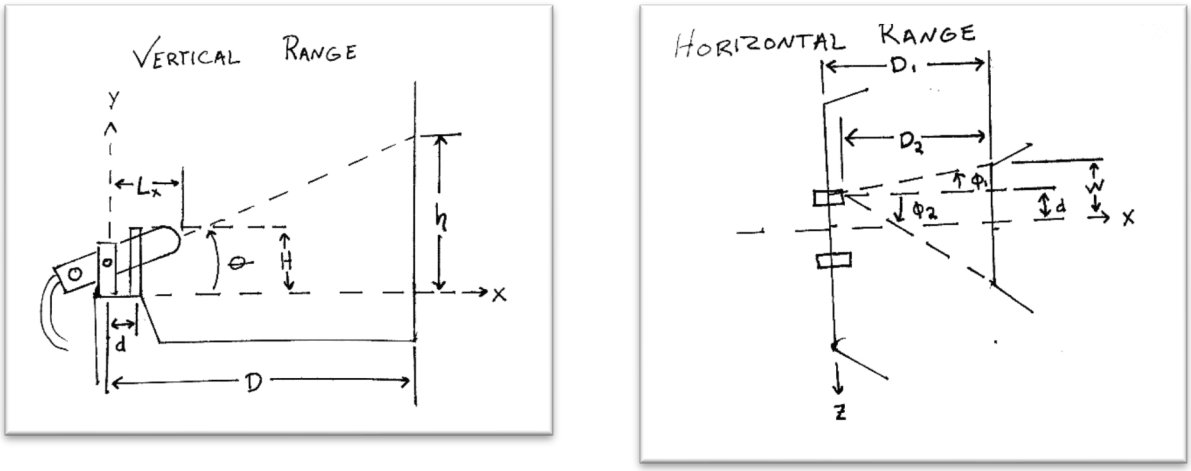


Figure L-1. Water squirter range

Table L-1. Water squirter range calculations

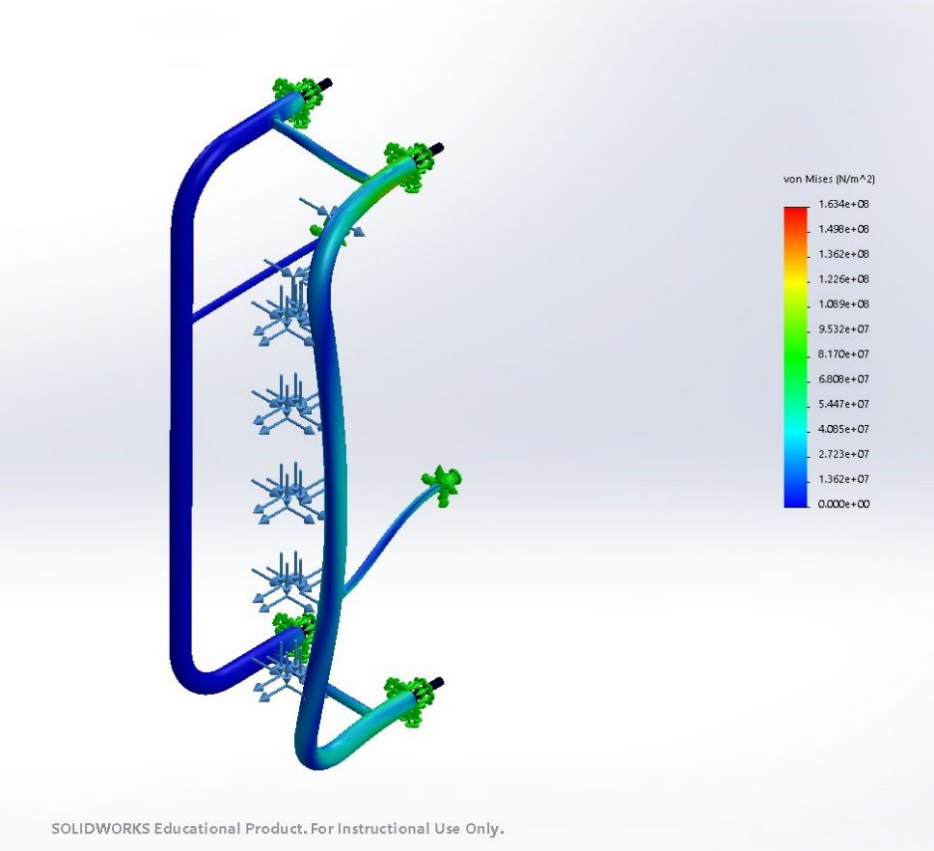
Known Dimensions		Calculated Values	
h: Desired vertical range (in)	12.0	**Θ: Maximum vertical angle**	28°
d: X-distance between pivot and limit bar (in)	1.0	**H: Height of limit bar (in)**	4.7
D: X-distance between pivot and wall (in)	23.0	**ϕ_1: Maximum outer horizontal angle**	0°
R: Outter radius of water squirter barrel (in)	1.2	**ϕ_2: Maximum inner horizontal angle**	28°
h_{pivot}: Height of pivot point (in)	3.0	**Z1: Z-distance between pivot and outer limiter**	1.2
W: Z-distance from center of wall to pivot (in)	6.0	**Z2: Z-distance between pivot and inner limiter**	1.7
d1: Z-distance from center of wall to pivot (in)	6.0	**Delta Z: Distance between Z1 and Z2**	2.8

Known Values		Calculated Values	
Horizontal distance between wall and pivot (in)	23.0	**Outlet Diameter (in)**	**Height of water jet from datum (in)**
Density of water at 70°F (slugs/ft^3)	1.94	0.25	13.1
Angle between outlet and horizontal axis	28°	0.125	14.5
		0.100	14.6

To test the water squirters we intend to build a prototype and use a garden hose to test the maximum height of the water jet. Next, we intend to build a prototype of the target and test whether the propulsive force generated by the water jet is sufficient to power the target system.

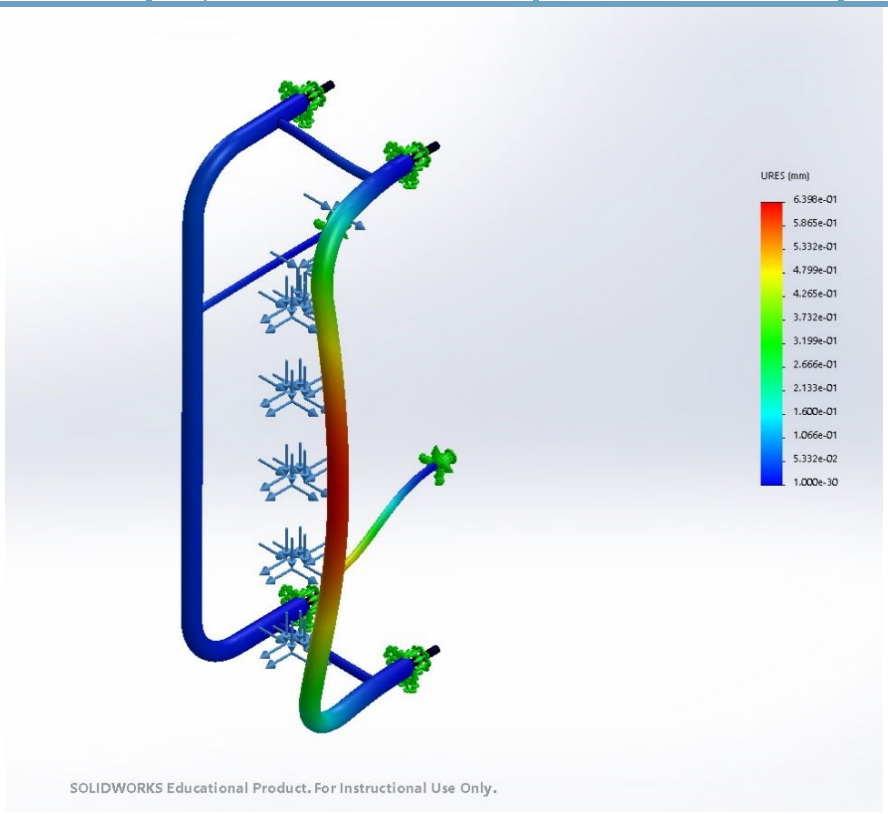
No. 11 Tipping Whales

Name	Type	Min	Max
Stress1	VON: von Mises Stress	0.000e+00 N/m^2 Node: 23072	1.634e+08 N/m^2 Node: 48741

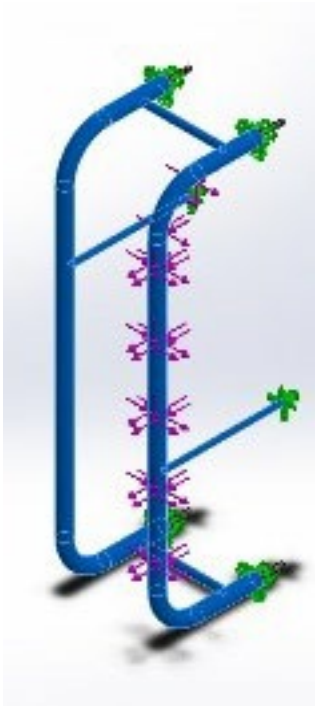


Static 1-Stress-Stress1

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00 mm Node: 1	6.398e-01 mm Node: 35200



Static 1-Displacement-Displacement1

Model Reference	Properties	Components
	Name: **AISI Type 316L stainless steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **1.7e+08 N/m^2** Tensile strength: **4.85e+08 N/m^2** Elastic modulus: **2e+11 N/m^2** Poisson's ratio: **0.265** Mass density: **8027 kg/m^3** Shear modulus: **8.2e+10 N/m^2** Thermal expansion coefficient: **1.65e-05 /Kelvin**	**SolidBody 1(Combine1)(93580A540_PEM R PRESS-IN STUD-1), SolidBody 1(Combine1)(93580A540_PEM R PRESS-IN STUD-2), SolidBody 1(Combine1)(93580A540_PEM R PRESS-IN STUD-3), SolidBody 1(Combine1)(93580A540_PEM R PRESS-IN STUD-4)**
Curve Data:N/A		

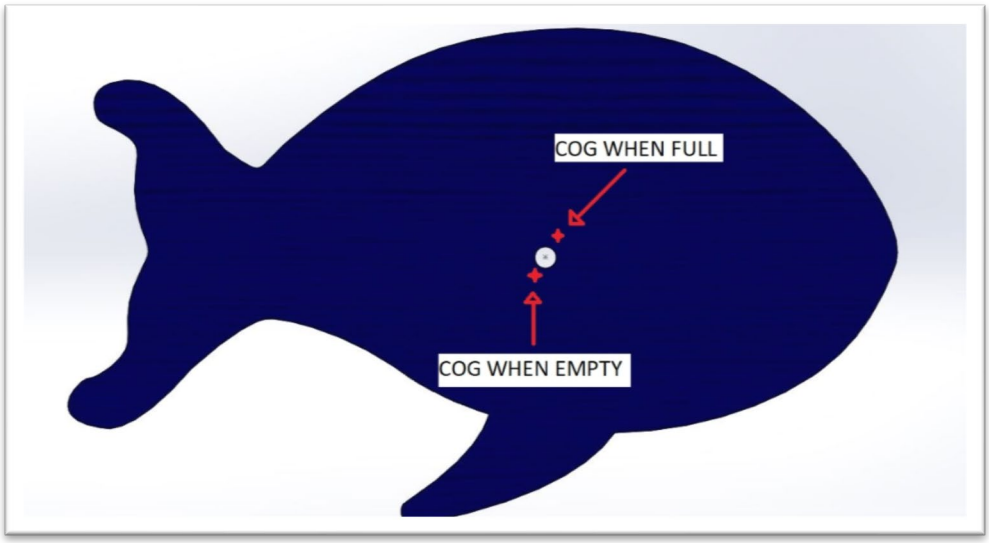


Figure L-2. Center of gravity of tipping whale when full and when empty

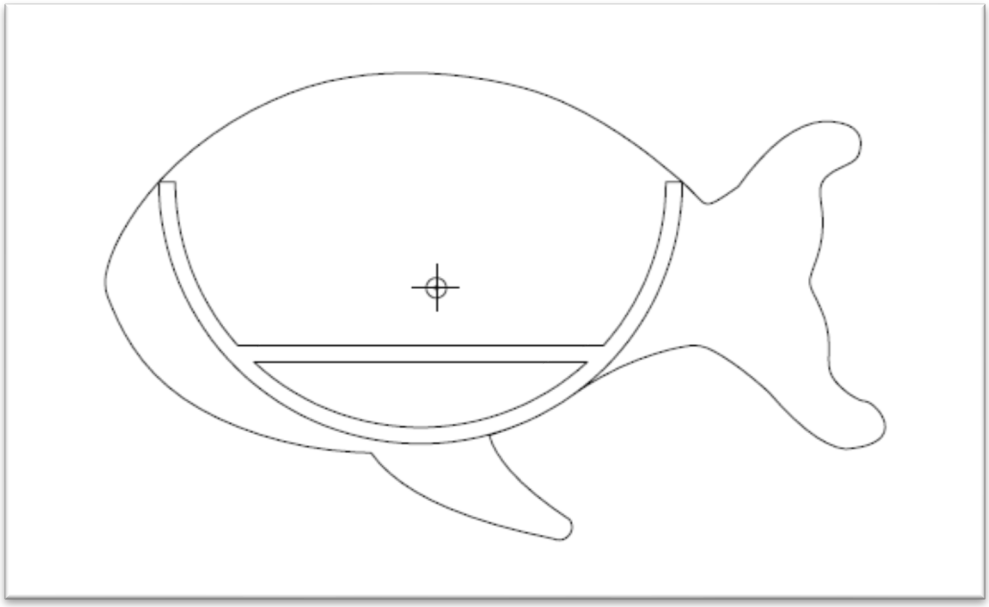


Figure L-3. Cross-sectional view of Tipping Whale design

APPENDIX M SAFETY HAZARD CHECKLIST

Y	N	
●	□	1. Will the system include hazardous revolving, running, rolling, or mixing actions?
□	●	2. Will the system include hazardous reciprocating, shearing, punching, pressing, squeezing, drawing, or cutting actions?
□	●	3. Will any part of the design undergo high accelerations/decelerations?
□	●	4. Will the system have any large (>5 kg) moving masses or large (>250 N) forces?
□	●	5. Could the system produce a projectile?
□	●	6. Could the system fall (due to gravity), creating injury?
□	●	7. Will a user be exposed to overhanging weights as part of the design?
●	□	8. Will the system have any burrs, sharp edges, shear points, or pinch points?
□	●	9. Will any part of the electrical systems not be grounded?
□	●	10. Will there be any large batteries (over 30 V)?
□	●	11. Will there be any exposed electrical connections in the system (over 40 V)?
□	●	12. Will there be any stored energy in the system such as flywheels, hanging weights or pressurized fluids/gases?
□	●	13. Will there be any explosive or flammable liquids, gases, or small particle fuel as part of the system?
□	●	14. Will the user be required to exert any abnormal effort or experience any abnormal physical posture during the use of the design?
□	●	15. Will there be any materials known to be hazardous to humans involved in either the design or its manufacturing?
□	●	16. Could the system generate high levels (>90 dBA) of noise?
●	□	17. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, or cold/high temperatures, during normal use?
□	●	18. Is it possible for the system to be used in an unsafe manner?
□	●	19. For powered systems, is there an emergency stop button?
□	□	20. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
Our table will include a water wheel that spins. A child could get hurt if it is rotating fast and the child sticks their fingers in the wheel	To reduce the risk of this occurring we will either encase the waterwheel in an acrylic housing, so no child can touch the moving parts. Or we would design the water wheel to have very little mass and keep the rotational speed low.		
Sharp edges	Some of our manufacturing methods, such as 3D printing, may produce sharp edges. We intend to round these edges. In addition, we intend to install metal plates for the magnetic wall. Since the metal will be thin, it will have sharp edges. To remove the risk of the edges we will either coat them in something so they are not sharp, or we will attach rubber lining to the metal edges.		
The water table will be used and stored outside so it will be subject to fog, rain, UV, heat and cold.	We will use only UV and weatherproof materials and coatings for the table to increase life. No other hazard will occur from the table being exposed to these conditions other than shortened life.		

APPENDIX N FAILURE MODES AND EFFECTS ANALYSIS

Feature FMEA

System / Function	Potential Failure Mode	Potential Effects of the Failure Mode	Severity	Potential Causes of the Failure Mode	Current Preventative Activities	Occurrence	Current Detection Activities	Detection	Priority	Recommended Action	Responsibility & Target Completion Date
Whale/ look nice	feature rust	a) whale wont turn b) rod breaks c) rusty metal shards	5	paint/ primer chips	properly prime and paint metal parts	4	visual inspection	3	60	research into proper primer and uv resistant, waterproof paints	Sarah 5/20/2018
Whale/ tips	whale breaks	a.) wont be educational b.) sharp edges	9	kids pull on it Kids through stuff at it	strong material will be used. the whale will be secured out of children's reach	5	visual inspection	1	45	strength analysis on materials used	Sarah 5/20/2018
	whale leaks into inner compartment	weight distribution is off	7	epoxy fails cracks	appropriate epoxy will be used. strong material will be used	3	prototype	5	105	research into UV and water resistant epoxies. strength analysis on materials used	Sarah 5/20/2018
	rod is loose	rod slides out rod hangs at angle	7	weak metal bracket is loose rod gets pulled on	securely attach all components	6	visual inspection. Stress analysis	3	126	Stress analysis then prototype and test	Sarah 5/20/2018
Grid/ looks pretty	mat warps	can't attach legos	6	a.) heat b.) UV exposure c.) Child tries to bend d.) poor epoxy	use appropriate epoxy. analysis of material properties	6	visual inspection. Stress analysis	4	144	material property analysis	Sarah 5/20/2018
	mat breaks	sharp edges cant attach Legos	9	a.) heat b.) UV exposure c.) child tries to bend d.) falling objects	use proper epoxy. stress analysis. apply coating if needed	2	visual inspection. Stress analysis	1	18	Stress analysis and material property analysis	Sarah 5/20/2018

				with sharp edges							
	mat comes loose	Mat interferes with other features cant use as racetrack	3	a.) heat b.) UV exposure c.) Child tries to bend d.) poor epoxy	use proper epoxy, material property analysis	3	visual inspection	2	18	material property analysis	Sarah 5/20/2018
	mat fades	not pretty	1	a.) UV exposure b.) chlorine in water	material property analysis. add protective coating if needed	3	visual inspection.	4	12	material property analysis	Sarah 5/20/2018
	Pieces fracture	sharp edges cant attach Legos	9	a.) heat b.) UV exposure c.) child tries to bend d.) dropping pieces	stress analysis. material property analysis. apply coating if needed	3	visual inspection stress analysis	2	54	prototype and test	Sarah 5/20/2018
	pieces come off of legos	cant divert water	7	a.) heat b.) UV exposure c.) child tries to pull them off d.) dropping pieces	stress analysis. use appropriate epoxy	7	inspection. stress analysis	2	98	prototype and test	Sarah 5/20/2018
	pieces fades	not pretty	1	a.) UV exposure b.) chlorine in water	material property analysis. add protective coating if needed	3	visual inspection	4	12	material property analysis	Sarah 5/20/2018
Racetrack/ Inspire Competition	Track is Not Competitive	a.) Track isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated	5	1.) One track is faster than the other 2.) Track is too short to excite true competition	1.) Tracks will be mirrors of each other 2.) Track will be curvy to make it longer without taking up	3	SolidWorks Design and Prototype	1	15	Prototype	Brandon 5/20/18

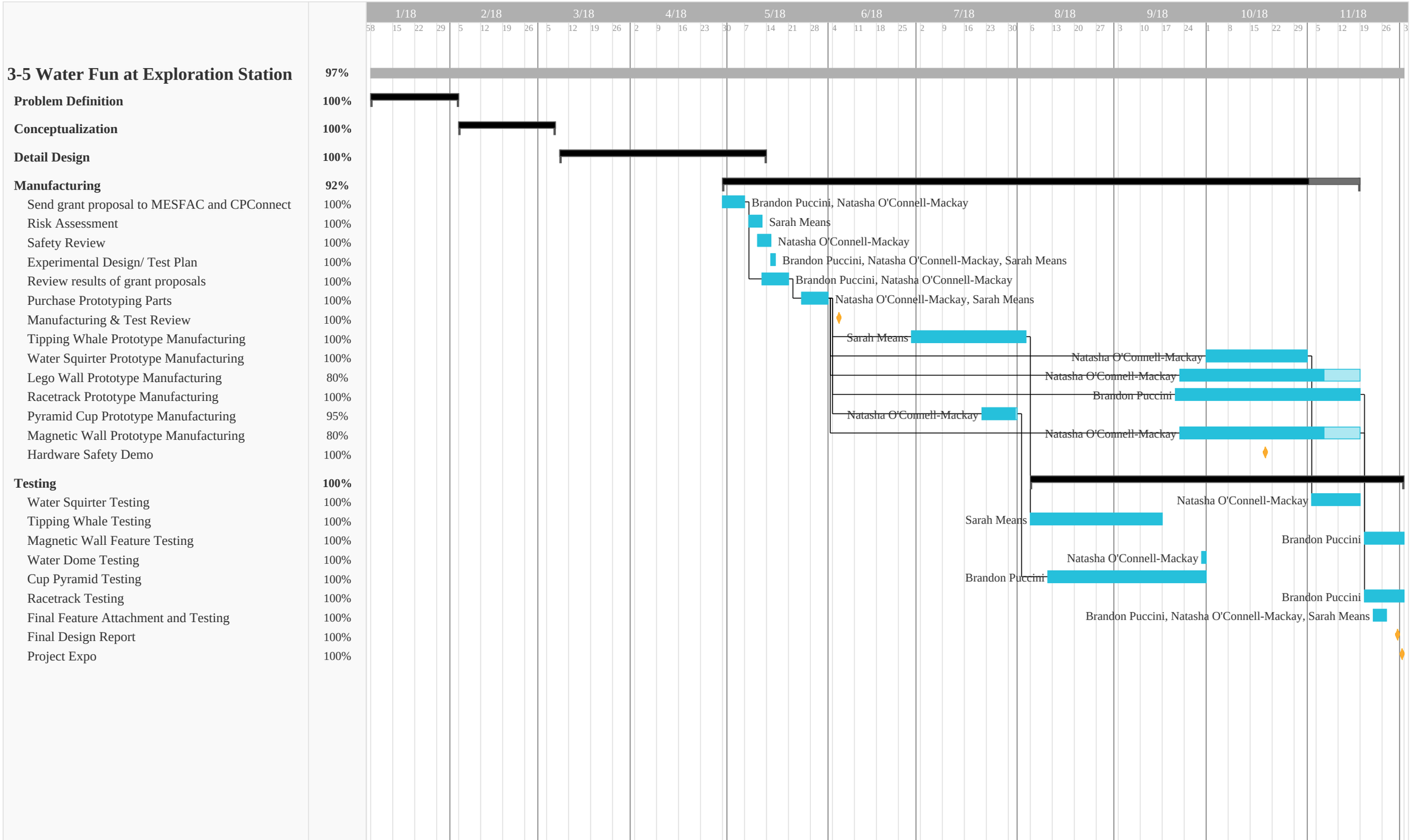
					too much space						
Racetrack/ Be Interactive	Track is Not Interactive	a.) Track isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated	6	1.) Track is hard to reach 2.) Toy boats are hard to get after they race down the track 3.)Toy boats are not readily available 4.) Other features block or interfere with the racetrack	1.) Track positioned at height suitable for all ages 2.) Install storage area for toy boats 3.) Track arranged in own section away from other interactive features	5	Verification with Anthropometric Database, Prototype and Position on 1/3 Scale Table	3	90	Research database for children, then prototype	Brandon 5/20/18
Racetrack/ Guide Toy Boats Down	Track falls down	a.) Kids get frustrated b.) Kids lose interest c.) Track isn't used and takes up space d.) Kids injure themselves e.) Repair is needed	9	1.) Support pipe isn't sturdy enough to support track 2.) Glue/epoxy at bottom of track doesn't hold 3.) Kids lean on track	1.) Design pipe to withstand weight of track and leaning weight of children 2.) Add extra support on both sides of pipe to help with vertical and horizontal displacement 3.) Install sign that says do not lean	7	Analysis on Pipe and Track and Prototype	5	315	Analysis on stress and support, then prototype	Brandon 5/20/18
	Track cracks and leaks	a.) Kids get frustrated b.) Kids lose interest c.) Track	6	1.) Glue/epoxy between track parts doesn't hold 2.) Track gets	1.) Apply UV coating to track	6	Prototype	5	180	Research UV coating, then prototype	Brandon 5/20/18

		isn't used and takes up space d.) Repair is needed		weathered							
	Piece of track breaks off	a.) Kids get frustrated b.) Kids lose interest c.) Track isn't used and takes up space d.) Repair is needed	8	1.) Glue/epoxy between track parts doesn't hold 2.) Kids lean on track 3.) Track gets weathered	1.) Apply UV coating to track 2.) Install sign that says do not lean	5	Prototype	3	120	Research UV coating, then prototype	Brandon 5/20/18
	Boats fall off track before making it all the way down	a.) Kids get frustrated b.) Track isn't used and takes up space c.) Kids lose interest d.) Kids get hit by toy boats e.) Boats fall and could break	7	1.) Track walls aren't high enough 2.) Water level is too high 3.) Track is too steep or fast	1.) Limit flow to drizzle 2.) Design track so top speed of boat does not result in tipping over edge	5	Prototype and Analysis on track and toy boats	2	70	Analysis on toy boats COG and tipping, then prototype	Brandon 5/20/18
Water Dome/Create a Water Dome	Water does not create water dome shape	a.) Feature is not visually appealing b.) Feature gets kids wet c.) Repair is needed	3	1.) Deformity in water dome piece 2.) Flow is too strong 3.) Flow is too weak	1.) Buy piece as opposed to make it ourselves	3	Analysis on flow	2	18	Buy piece and test	Brandon 5/20/18
Water Dome/Demonstrate Laminar Flow	Water demonstrates turbulent flow	a.) Feature is not as visually appealing	1	1.) Deformity in water dome piece 2.) Flow is too strong 3.) Flow is too weak	1.) Buy piece as opposed to make it ourselves	4	Analysis on flow	4	16	Buy piece and test	Brandon 5/20/18

Cup Pyramid/ Be Interactive	Cup Pyramid is not interactive	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated	6	1.) Cups are hard to reach 2.) Other features obstruct access to cups 3.) Cups get lost, broken, or stolen	1.) Cups positioned at height suitable for all ages 2.) Install storage area for extra cups 3.) Cups arranged in own section away from other interactive features	5	Verification with Anthropometric Database, Prototype and Position on 1/3 Scale Table	4	120	Research database for children, then prototype	Brandon 5/20/18
Cup Pyramid/ Inspire Competition	Feature is Not Competitive	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated	4	1.) Some cups being clearly better than others for flow 2.) Cups are not different enough to vary results	1.) Variance in cup types 2.) Decrease in cup size to allow more to be arranged in path	3	SolidWorks Design and Prototype	2	24	Prototype	Brandon 5/20/18
Cup Pyramid/ Teach Children About Outlet Flow	Cups do not flow out water	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated	9	1.) Funnels detach from cups 2.) Cups get clogged with other objects 3.) Cups leak through crack	1.) Casting parts instead of 3D printing and gluing 2.) Using UV resistant material or spray coating	4	Research into casting methods, materials, UV spray coating, and then prototype	3	108	Research then prototype	Brandon 5/20/18
Cup Pyramid/ Inspire Creativity	Feature arrangements are redundant	a.) Feature isn't used and takes up space b.) Kids lose interest	5	1.) Lack of cup variety 2.) Not enough space to arrange cups	1.) Variance in cup types 2.) Decrease in cup size to allow more to be arranged in path	2	SolidWorks Design and Prototype	2	20	Prototype	Brandon 5/20/18

Cup Pyramid/ Collect Water From Upper Basin in top cups only	Water does not flow into top cups from upper basin	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated d.) Cannot begin competition	7	1.) Flow is not directed properly from upper basin 2.) Flow is too strong and overshoots cups 3.) Flow is too weak and drizzles around cups	1.) Guide between wall and cup to direct flow into cup 2.) Flow diverters on upper basin to direct flow into cups	6	SolidWorks Design and Prototype	5	210	Prototype and Test	Brandon 5/20/18
	Water flows into secondary cups from upper basin	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated d.) Competition is affected	6	1.) Flow is not directed properly from upper basin 2.) Flow is too strong and fills secondary cups 3.) Flow is too weak and drizzles into secondary cups	1.) Space between wall and cups to ensure water flow into cups is from cups above	4	SolidWorks Design and Prototype	5	120	Prototype and Test	Brandon 5/20/18
Cup Pyramid/ Be Arranged on Upper Wall	Cups don't stick to upper wall	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated d.) Cups fall and break	7	1.) Magnets are not strong enough 2.) Magnets fall off of cups	1.) Design housing for magnets on back of cup 2.) Reinforce magnets with epoxy or glue 3.) Make sure magnets are waterproof	6	Research and analysis on magnets, SolidWorks Design and Prototype	3	126	Research, Prototype, and Test	Brandon 5/20/18

Water Squirter/ Be Interactive	Water Squirter is not interactive	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated	7	1.) Other features obstruct path of water squirter system	1.) Water squirter arranged in own section away from other interactive features	2	Prototype and Position on 1/3 Scale Table	3	42	Prototype	Natasha 5/20/18
	Water Squirter not used for intended purpose	a.) Kids can be sprayed with water b.) Other features affected by water squirter	4	1.) Water squirters hard to aim at water wheel and raise object up wall	1.) Restraints placed on range of water squirter 2.) Water wheel adjusted to proper tension	4	Measurements and analysis and prototype	3	48	Analysis, Prototype, and Test	Natasha 5/20/18
Water Squirter/ Inspire Competition	Feature is Not Competitive	a.) Feature isn't used and takes up space b.) Kids lose interest c.) Kids get frustrated	4	1.) Object is too easily moved up wall 2.) Object is too hard to move up wall 3.) One system is way better than the other	1.) Systems designed and built the same 2.) Water wheel tensioned correctly	6	Analysis on water wheel tension and prototype	5	120	Analysis, Prototype, and Test	Natasha 5/20/18
Water Squirter/ Improve Hand Eye Coordination	Feature does not improve hand eye coordination	a.) Feature is difficult to use b.) Kids lose interest c.) Kids get frustrated	3	1.) Flow is too weak to get straight stream	1.) Add extra pump if needed	3	Analysis on flow	2	18	Analysis, Prototype, and Test	Natasha 5/20/18
Water Squirter/ Teach Children About Mechanical Systems	Children do not learn about a mechanical system	a.) System does not function properly b.) Feature is not as visually appealing	1	1.) Obstruction in view of gear-pulley-belt system 2.) Defect in component interaction	1.) Water squirter arranged in own section away from other interactive features 2.) Design on SolidWorks	3	SolidWorks Design and Prototype and Position on 1/3 Scale Table			Prototype	Natasha 5/20/18


1/18
2/18
3/18
4/18
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8/18
9/18
10/18
11/18
3-5 Water Fun at Exploration Station 97%
Problem Definition 100%
Conceptualization 100%
Detail Design 100%
Manufacturing 92%
Send grant proposal to MESFAC and CPConnect 100%
Risk Assessment 100%
Safety Review 100%
Experimental Design/ Test Plan 100%
Review results of grant proposals 100%
Purchase Prototyping Parts 100%
Manufacturing & Test Review 100%
Tipping Whale Prototype Manufacturing 100%
Water Squirter Prototype Manufacturing 100%
Lego Wall Prototype Manufacturing 80%
Racetrack Prototype Manufacturing 100%
Pyramid Cup Prototype Manufacturing 95%
Magnetic Wall Prototype Manufacturing 80%
Hardware Safety Demo 100%
Testing 100%
Water Squirter Testing 100%
Tipping Whale Testing 100%
Magnetic Wall Feature Testing 100%
Water Dome Testing 100%
Cup Pyramid Testing 100%
Racetrack Testing 100%
Final Feature Attachment and Testing 100%
Final Design Report 100%
Project Expo 100%
Brandon Puccini, Natasha O'Connell-Mackay
Sarah Means
Natasha O'Connell-Mackay
Brandon Puccini, Natasha O'Connell-Mackay, Sarah Means
Brandon Puccini, Natasha O'Connell-Mackay
Natasha O'Connell-Mackay, Sarah Means
Sarah Means
Natasha O'Connell-Mackay
Natasha O'Connell-Mackay
Brandon Puccini
Natasha O'Connell-Mackay
Natasha O'Connell-Mackay
Natasha O'Connell-Mackay
Sarah Means
Brandon Puccini
Natasha O'Connell-Mackay
Brandon Puccini
Brandon Puccini
Brandon Puccini, Natasha O'Connell-Mackay, Sarah Means

Senior Project DVP&R

Date: 06/03/18	Team: Water Fun	Sponsor: Exploration Station	Description of System: Water Table Features	DVP&R Engineer: B PUCCINI, S MEANS, N OCONNEL

TEST PLAN

TEST REPORT

Item No	Specification #	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	F01.T01	Water Flow	Water flows down track without leaks and in proper shape	B PUCCINI	After Prototyping	2	Final Prototypes	11/1/2018	11/1/2018	Passed	All	None	
2	F01.T02	Object Flow	Objects float down track at proper pace	B PUCCINI	After Prototyping	2	Final Prototypes	11/1/2018	11/1/2018	Passed after many iterations of arrangements	All	None	
3	F01.T03	Structural Integrity	Track and support assembly does not fracture, bend, or lose function	B PUCCINI	After Prototyping	2	Final Prototypes	11/3/2018	11/3/2018	Passed	All	None	
4	F01.T04	UV Degradation	Part does not discolor, warp, or degrade in any other way	B PUCCINI	After Prototyping	2	Final Prototypes	10/24/2018	11/1/2018	Passed	All	None	
5	F02.T01	Magnet Test (Appendix A)	Magnet does not dislodge and part does not fracture	B PUCCINI	After Prototyping	All	Final Prototypes	10/24/2018	10/26/2018	Passed	All	None	Limited testing sample size due to lack of funding to buy magnets and print enough parts as desired
6	F02.T02	Assembly on Wall Test	Water flows into and out of cups	B PUCCINI	After Prototyping	All	Final Prototypes	10/29/2018	10/29/2018	Passed-some styles better than others	All	None	Kids are supposed to figure out why some flow better than others
7	F02.T03	Place on Metal Wall	Holds to wall	B PUCCINI	After Prototyping	All	Final Prototypes	10/24/2018	10/24/2018	Passed	All	None	
8	F02.T04	UV Degradation	Part does not discolor, warp, or degrade in any other way	B PUCCINI	After Prototyping	All	Final Prototypes	10/20/2018	10/25/2018	Passed	All	None	
9	F04.T01	Dome Size	Outer diameter of water dome fits within the confines of the basin of the upper hexagon	N OCONNEL	After Prototyping	1	Final Prototype	10/29/2018	10/29/2018	Dome was larger than the basin	0	1	Another water dome nozzle may be purchased at a later date.
10	F04.T02	Dome Quality	Water dome is clear and does not have any breaks	N OCONNEL	After Prototyping	1	Final Prototype	10/29/2018	10/29/2018	Passed	1	0	
11	F10.T01	Stream Range	Water stream has a horizontal range of at least 20 inches and a vertical range of at least 8 inches.	N OCONNEL	After Prototyping	1	Final Prototype	10/27/2018	10/27/2018	14.25" vertical range at 28" horizontally.	1	0	
12	F10.T02	Hydraulic Force	Force due to water stream impacting waterwheel target causes the waterwheel to spin.	N OCONNEL	After Prototyping	1	Final Prototype	10/29/2018	10/29/2018	Turned both waterwheels	1	0	
15	F11.T01	Tipping Forward	Whale must always tip forward	S MEANS	During Protoyping	2	First Prototype	8/13/2018	8/13/2018				
16	F11.T02	Filling whale below	Top whale must dump water in lower whale	S MEANS	During Protoyping	1	First Prototype	8/13/2018	8/13/2018				
17	F11.T03	Frame pull test	No plastic deformation	S MEANS	After Protoyping	1	Final Protoype	8/15/2018	8/15/2018				
18	F11.T04	UV test	No color degradation	S MEANS	After Protoyping	3	Final Protoype	8/6/2018	8/6/2018				
19	F23.T01	Magnet Tests (Appendix A)	Magnet does not dislodge and part does not fracture	B PUCCINI	After Prototyping	All	Final Prototypes	10/24/2018	10/26/2018	Passed	All	None	Limited testing sample size due to lack of funding to buy magnets and print enough parts as desired
20	F23.T02	Assembly on Wall Test	Water flows onto and off of parts in organized and directional way	B PUCCINI	After Prototyping	All	Final Prototypes	10/29/2018	10/29/2018	Passed-some styles better than others	All	None	Kids are supposed to figure out why some flow better than others
21	F23.T03	Place on Metal Wall	Holds to wall	B PUCCINI	After Prototyping	All	Final Prototypes	10/24/2018	10/24/2018	Passed	All	None	
22	F23.T04	Assembly on Wall Test	Part rotates to its desired degree. The waterwheel spins, the teeter totter rotates but does not capsize, and the slide does not rotate.	B PUCCINI	After Prototyping	All	Final Prototypes	10/29/2018	10/29/2018	Passed	All	None	Limited testing sample size due to lack of funding to buy magnets and print enough parts as desired
23	F23.T05	UV Degradation	Part does not discolor, warp, or degrade in any other way	B PUCCINI	After Prototyping	All	Final Prototypes	10/20/2018	10/25/2018	Passed	All	None	

Water Fun

Operators' Manual

Quick Maintenance Guide

Daily Maintenance – Perform every day water table is operated

	Task	Reference Section
1	Inspect water clarity	2.1
2	Check for dirt/sand build up in basin	2.1
3	Check chlorine concentration and reservoir water level	2.1
4	Visually inspect extension cord for wear	2.3
Yearly Maintenance – Perform once a year		
	Task	**Reference Section**
1	Replace filter medium and UV bulb	2.3

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2 General Maintenance and Troubleshooting

2.1 Cleaning and Water Quality

Before each use of the water table,

1. Visually inspect the clarity of the water in the basin. It should be easy to see the bottom of the basin and the water should not be cloudy. If the water appears cloudy, then run the pump for 30 minutes or until the water is no longer cloud following the procedure described in section 2.3.1.
2. Visually inspect the basin for dirt or sand. If the particulate in the basin is too heavy to drain from the basin in to the reservoir it will not pass through the filter and must be removed manually. Drain the basin in to the reservoir using the drain plug located on the underside of the basin and manually remove the particulate.
3. Check chlorine concentration using a test kit. Follow test kit instructions to determine concentration of free chlorine.
    a. If chlorine is **less than 1 ppm**, add the necessary amount of chlorine to increase concentration to between 1 and 10 ppm.
    b. If chlorine is **between 1 and 10 ppm**, the chlorine concentration is acceptable.
    c. Is chlorine is **greater than 10 ppm**, make sure the basin is exposed to sunlight and run the pump until the chlorine concentration is between 1 and 10 ppm. To run the pump, follow the procedure in section 2.3.1.
4. Check the water level in the reservoir beneath the basin. The pump should be at least 3 inches beneath the top of the water.

2.2 Filter and Pump

Please follow the manufacturer's instructions for maintenance of the filter and pump. These instructions have been included at the end of the operators' manual.

- Note: The cords for the filter and pump have been mechanically connected to the electrical box beneath the basin. Please disconnect the water table from the wall outlet before performing maintenance on the electrical system or attempting to remove the filter.

2.3 Electrical

Before each use of the water table visually inspect the extension cord for wear such as cracks or breaks in the protective shielding. If there is wear present, the extension cord must be replaced with an outdoor rated extension cord with GFCI.

- Before performing any maintenance on the electrical system, please make sure the extension cord is disconnected from the outlet.

2.3.1 Proximity Detection Bypass

If the operator wishes to run the water table continuously the proximity detection system may be bypassed. For convenience, a waterproof switch is located on the outside of the electrical box facing the access hatch. This switch has the following three modes,

1. UP: Proximity detection enabled.
2. MIDDLE: Off.
3. DOWN: Proximity detection bypassed. Water table will run continuously.

3 Water Feature Maintenance and Troubleshooting

3.1 Racetrack

The racetrack feature will require minimal maintenance, but troubleshooting will be necessary as time goes on.

3.1.1 Maintenance

Rinse out the racetrack tube to rid it of any debris at the end of each day. Because it is clear, it is not needed to remove the track completely. Visually inspect the track and if debris are present, run water through it to get them out.

Make sure racing objects are present on the table at the end of each day.

3.1.2 Troubleshooting

Ensure no sharp edges are visible along the racetrack. Metal wire may come loose and poke itself out of the tube, so it is important to keep an eye out for this daily. Re-apply marine grade epoxy to cover sharp edges if they appear.

If the racetrack is not working properly, it will most likely be due to the flow being interrupted. This could be due to holes along the racetrack. If this is the case, patch the holes with marine grade epoxy. If this does not work, order a new hose from McMaster-Carr (Part #: 5136K16). The flow could also be interrupted due to the water source. This may require re-attaching the tube to the start of the track. If that does not fix the problem, it is most likely stemming from underneath the table. This will require taking off the side panels and re-attaching the tube to the main pipe line.

If the racetrack is tipping over, it could be due to the zip ties securing the hose down. If this is the case, re-apply zip ties to secure the hose to the top flange through the flange holes. If this does not work, check the connection between the support rod and the top/floor flange. These may need to be screwed back together. If the floor flange de-attached from the table, the table will need to be drained, and marine grade epoxy will need to be re-applied to the floor flange and the table. If the start of the track is disrupted, marine grade epoxy may need to be re-applied to the connection 3D printed piece and the hose. If the support rod and floor flange comes undone from the support bracket, the flange will need to be re-fastened to the support bracket.

3.2 Tipping Whale

The tipping whales will mostly require cleaning ever so often.

3.2.1 Maintenance

Wipe off stand and visible surfaces of stand with rubbing alcohol if there is a buildup of dirt.

Wipe out the inside of the whales with a damp cloth if there is a buildup of debris in the whales.

If the table will not be in use for an extended period of time, tip the whales over by hand to empty out any remaining water to prevent bacteria growth or sediment build up in the whales and increase the life of the whales.

Once every year check that the rubber bumpers on the bottom of the stand are intact. if not, remove the stand from the upper hexagon, making sure to keep all hardware. Scrape off the existing damaged bumper with an exacto knife. Clean that surface with rubbing alcohol and epoxy a new bumper in the same place. Re-attach the stand with the whales to the upper hexagon.

3.2.2 Troubleshooting

If there is no water coming out of the spout on top:

Check to see if the opening is obstructed at all. If it is, try to dislodge the obstruction

If that does not work, open up the upper hexagon by removing the magnetic wall panel between the whales and the water squirters by removing the 4 visible screws. Check the tubing inside the upper hexagon to see if there are any obvious leaks, if there are leaks, either tighten the clamp around the leak or apply sealant to the leak.

Inspect the flexible tubing for any kinks

Turn the blue valve knob to see if it is open. Turn on pump to see if this fixed the problem NOTE: the valve should only be partially open so that the flow rate out of the spout is not too high.

If the whale is not tipping:

Check to see if there is nothing inside of the whale.

Inspect the pivot rod for corrosion. If there is significant corrosion remove the stand from the upper hexagon and use small grit sand paper to gently scrub off the corrosion on the rod. Wipe the surface with isopropyl alcohol and re-install the stand and whales on the upper hexagon.

With the water turned off, spin the whales on the rod, if you can hear a sloshing sound, the surface of the whale has cracked and there is water inside the whale. The whale needs to be replaced

3.3 Wall Features

The miscellaneous wall features will require minimal maintenance, but troubleshooting may be necessary in some rare instances.

3.3.1 Maintenance

It is important to make sure the wall features are still present on the table at the end of each day. There should be 3 water cups with one hole, 3 water cups with two holes, 3 water cups with one funnel, 3 water cups with two funnels, and 3 water cups with no holes. There should be 4 water wheels, 4 slides, and 4 teeter totters.

3.3.2 Troubleshooting

If flow is not reaching wall features, adjust piping on upper basin.

If features fracture, attempt to patch with marine grade epoxy. If this does not suffice, replace the part with a spare.

If funnel becomes detached from part, re-apply marine grade epoxy to set it in the hole(s) at the bottom of the water cup. If funnel is broken, replace with a spare funnel.

If rod cap comes off part, re-apply marine grade epoxy to put it back at the end of the rod. If rod cap is broken, replace with spare rod cap.

If magnet becomes dislodged, re-apply marine grade epoxy to put it back in part. If magnet is lost, order new Apex magnets (Model:M1x14x14BR) to replace lost ones.